REPORT OF THE SUPERINTENDENT

OF THE

U. S. COAST AND GEODETIC SURVEY

SHOWING

THE PROGRESS OF THE WORK

DURING THE

FISCAL YEAR ENDING WITH

JUNE, 1890.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
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National Oceanic and Atmospheric Administration

Annual Report of the Superintendent of the Coast Survey

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LETTER

FROM

THE ACTING SECRETARY OF THE TREASURY,

TRANSMITTING

The report of the Superintendent of the Coast and Geodetic Survey, showing the progress made in that work during the fiscal year ended June 30, 1890.

DECEMBER 10, 1890.—Referred to the Committee on Printing.

TREASURY DEPARTMENT, *December* 9, 1890.

SIR: In compliance with the requirements of section 4690, Revised Statutes, I have the honor to transmit herewith, for the information of Congress, a report addressed to this Department by T. C. Mendenhall, Superintendent of the Coast and Geodetic Survey, showing the progress made in that work during the fiscal year ended June 30, 1890, and accompanied by maps illustrating the general advance in the operations of the Survey up to that date.

Respectfully, yours,

A. B. NETTLETON,
Acting Secretary.

The SPEAKER OF THE HOUSE OF REPRESENTATIVES.

LETTER OF TRANSMISSION.

U. S. COAST AND GEODETIC SURVEY,
Washington, D. C., December 9, 1890.

SIR: In conformity with law, and with the regulations of the Treasury Department, I have the honor of submitting herewith, for transmission to Congress, the Annual Report of the Coast and Geodetic Survey, showing the progress of the work for the fiscal year ended June 30, 1890, and accompanied by maps illustrating the general advance in the operations of the Survey up to that date.

Very respectfully, yours,

T. C. MENDENHALL,
Superintendent.

Hon. WILLIAM WINDOM,
Secretary of the Treasury.

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COAST AND GEODETIC SURVEY REPORT FOR 1890.

Page IX, for *pages* 115–125 put *pp.* 115–117.
Page 39, line 8 from top, for *R.* put *D. B.*—Wainwright.
Page 45, line 3 from top, for *casements* put *casemates*.
Page 48, line 30 from top, for *Owen* put *Owens*.
Page 49, line 3 from bottom, for *J. M. McTiffany* put *J. McC. Tiffany.*
Page 76, line 30 from top, for *Foust* put *Faust*.
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Page 115, under head of Magnetic Work, for *observations* put *observatories*.
Page 130, line 11 from top, for *L. J.* put *L. G.*—Schultz.
Page 132, line 18 from bottom, for *Trescott* put *Trescot*.
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REPORT.

The fiscal year 1890 has been marked by a steady and systematic development of the operations of the Survey in both field and office, and by advances so notable in the closely allied work of the Office of Weights and Measures as to constitute an epoch in metrology.

Field operations involving one or more of the classes of work here named: base measurement and triangulation, the determination of latitudes, longitudes, and azimuths by astronomical observations, the determinations of heights by geodetic leveling and by vertical angles, topographical surveys, magnetic observations and determinations of the force of gravity, were in progress on the coasts or within the limits of twenty-eight States, two Territories, and in the District of Columbia. Geodetic work, intended to furnish geographical positions or determinations of heights in connection with State geological or topographical surveys, was carried on in the States of Massachusetts, New Jersey, Tennessee, Arkansas, Wisconsin, and Minnesota.

Hydrographic surveys, including inshore and offshore soundings, and observations of tides and currents, were prosecuted in the waters or off the coasts of seventeen States and one Territory. Investigations in physical hydrography were continued; these included observations of shore line changes due to tidal and wave action on the coast of Cape Cod; observations of tidal and current movements and gaugings of discharge in Long Island Sound; observations of sea-water densities near the Delaware Breakwater, and observations of currents in the Gulf Stream.

Included in the work afield and afloat were some special operations of which brief mention is here made.

While the direct benefit to the country of an accurate survey of its coasts is quite obvious, there are not unfrequently certain results of great value to the Government which are only incidentally brought out. The existence of a series of triangulation points carefully determined in position on the coasts of Long Island and Block Island made it possible for the officer commanding the Coast and Geodetic Survey steamer *Blake* to lay out a course of exactly the required length for the trial trip of the new armored cruiser *Philadelphia*. The conditions under which in June, 1890, this trial trip was made, were, it is well known, such as demanded a 40-mile course at sea with limits defined by range marks on shore, and an error of any magnitude in the determination of its length might have involved a loss of hundreds of thousands of dollars to the Government.

The measured sea-mile in the eastern passage, Narragansett Bay, laid out as a trial course for naval vessels by the officer commanding the *Blake* in the summer of 1889, depends also for its exact length between the limiting range marks upon the already existing triangulation.

One of the aims of the Survey, kept steadily in view, is co-operation with other branches of the Government service whenever such co-operation can be made available to secure results of value to both services and at a less cost than if the operations were carried on separately. An instance of this, where a single steamer did the work of two, was the detail of an officer of the Survey early in the summer of 1890 to prosecute investigations in physical hydrography in the waters of Long Island Sound in co-operation with Professor Rathbun of the Fish Commission, the commander of the steamer *Fish Hawk* furnishing transportation and other facilities for the work. Later in the season, the commander of the Coast and Geodetic Survey steamer *Blake* was instructed to co-operate with Professor Libbey of the Fish Commission in making observations of temperatures, densities, and currents to the south of Martha's Vineyard.

Such co-operation has been found to be not unfruitful of valuable suggestions relating to improvements in the methods and appliances of work.

A question having arisen between the States of Maryland and Virginia as to the interpretation of the award of the arbitrators of 1877, respecting the location of a part of the boundary line between those States, the subject was referred by their respective Governors to the Superintendent, and upon their request he detailed an officer of the Survey, who made the necessary examinations on the ground and submitted a final award.

By direction of the Secretary of the Treasury, and at the request of the president of the Fish and Game Commission of the State of Ohio, the Superintendent detailed an officer of the Survey to establish the limits of certain fishing tracts within the jurisdiction of that State on the shores of Lake Erie.

Advices have been received from the officers in charge of the parties of the Survey encamped at or near the crossings of the one hundred and forty-first meridian with the Yukon and Porcupine Rivers, Alaska, and engaged in making a preliminary determination of the boundary line between Alaska and British Columbia and the Northwest Territory.

These advices, which are to June 15, 1890, for the party on the Yukon River, and to January 24, 1890, for the party on the Porcupine River, express the intention of those officers to remain at their posts throughout the winter of 1890–1891, in the hope of being able to report satisfactory progress in their arduous duties. Almost incessant rain and fog in the autumn after their arrival, and intense cold during the following winter, the temperature frequently ranging from —30° to —59° Fahr., greatly delayed field work.

Advantage was taken of the voyage of the U. S. Eclipse Expedition to the west coast of Africa to detail an officer of the Survey to accompany it for the purpose of making observations of gravity and the magnetic elements at a number of stations where comparative observations of this character were greatly desired.

Mention more in detail of these special operations will be made later in this volume.

OFFICE OF WEIGHTS AND MEASURES.

In addition to the duties devolving upon the officer of the Survey appointed by the President to represent the United States at the Ninth Conference of the International Geodetic Association held in Paris in October last, instructions were given him to bring to Washington one of the two sets of the National Prototypes of the Metre and Kilogramme that had been allotted to the United States. This set consisted of the National Metre Prototypes Nos. 12 and 27, and the National Kilogramme Prototype No. 20. These standards were constructed under the direction of a committee appointed by the International Conference of Weights and Measures, and had been carefully compared with the standards selected to remain in Paris in charge of the International Bureau of Weights and Measures, and to serve as the international or fundamental prototypes.

The officer designated to convey these valuable standards from Paris to Washington having delivered them to the Superintendent in November, 1889, arrangement was made under his direction for their being received and opened by the President of the United States. This was done at the Executive Mansion on January 2, 1890, in the presence of the Secretary of State, the Secretary of the Treasury, and the Superintendent of the Coast and Geodetic Survey and of Weights and Measures, together with a number of other gentlemen interested officially or personally in the event. These prototypes are now in the custody of the Office of Weights and Measures.

It was but a few days later in the month that the International American Conference in session at Washington approved the report of its Committee on Weights and Measures recommending the "adoption of the metrical decimal system" of weights and measures to the nations there represented who had not already signified their acceptance of it.

This very important action, considered in connection with the fact that the use of the metric system in this country was legalized by act of the Congress in 1866, and that since that date it has been adopted by the greater number of civilized and progressive nations, leads me to recommend that steps should be taken by the Congress to insure its introduction in the customs service.

In April, 1890, at the instance of the Secretary of State and with the approval of the Secretary of the Treasury, I deputed an officer of the Survey to proceed to Paris and to convey to Washington the second of the two sets of National Prototypes which had been allotted to the United States, and deposited for safe keeping in the International Bureau of Weights and Measures. This officer, whose official position was that of an Assistant in charge of the Office of Weights and Measures, was directed to visit also London and Berlin, and to examine in these cities as well as in Paris the provisions made by the British, French, and German Governments for the safe keeping of their standards. Other subjects for incidental inquiry were suggested for his attention. This duty was in great part completed before the close of the fiscal year.

Summing up briefly the progress of metrological reform in this country during the past fiscal year, the leading events are—

(1) The publication early in the year of the results of an investigation of the relation of the yard to the metre, in which the sources of discrepancy in the values heretofore assigned were examined, and the ratio established within very narrow limits;

(2) The acquisition by the United States of metric standards of the highest accuracy, the relation of which to the International Standards is known;

(3) The action of the International American Conference in recommending the adoption of the metric system in the Three Americas; and

(4) Increased demands from all parts of the country for the comparison of weights and measures with the National Standards.

The reports of the officers of the Survey by whom the National Prototypes for the United States were brought to Washington appear in Appendix No. 18 to this volume. This Appendix includes also an historical account of United States Standards of Weights and Measures, customary and metric, with documents relating to the official opening and certification of the National Prototypes, and their deposit in the Office of Weights and Measures.

In Part I of this Report will be found general statements of progress in the Survey under the heads of Field Work, Office Work, Hydrographic Discoveries and Developments, and Bulletins, followed by notices of the more important Appendices to the Report under the heading of Special Scientific Work. An explanation of the estimates for the fiscal year 1892 and the statements of these estimates in detail conclude Part I.

Part II refers briefly at the outset to the annual reports of the Assistant in charge of Office and Topography, of the Hydrographic Inspector, of the Disbursing Agent, and of the Assistant in charge of the Office of Weights and Measures. Abstracts from the reports of field officers and from reports of special operations are then given, followed by summarized statements of progress from the annual reports just referred to, and from the reports of the Sub-offices at Philadelphia and at San Francisco.

The Appendices to the Report are contained in Part III. Appendix No. 1 shows in tabular form and in a geographical order the localities of field work, the nature of the operations, and the names of persons conducting them. Appendix No. 2 presents the statistics of field and office work of the Survey during the year and a summary of these statistics to its close. The information furnished by the Survey in response to requests, official and unofficial, is shown in Appendix No. 3. In Appendices Nos. 4 and 5, are given the annual reports of the Assistant in charge of Office and Topography and of the Hydrographic Inspector, and in Nos. 6 and 7, those of the Disbursing Agent and of the Assistant in charge of the Office of Weights and Measures. The Appendices which follow contain scientific papers of much value, relating to Terrestrial Magnetism, Physical Hydrography, Weights and Measures, and to some Special Operations of the Survey.

In order that the progress of the field work of the Survey, both ashore and afloat, throughout the entire domain of the United States may be represented graphically, this report is accompanied by two maps of general progress (Nos. 1 and 2) and by a map (No. 3) showing progress in Alaska. These maps are brought up to the close of the fiscal year.

PART I.

GENERAL STATEMENT OF PROGRESS.

I.—FIELD WORK.

ATLANTIC COAST.—*Field work during the fiscal year ended June 30, 1890, upon and off the coasts and within the borders of the States of Maine, Massachusetts, Rhode Island, and Connecticut, included the following operations:*

Reconnoissance and triangulation continued over the St. Croix River and the Boundary Lakes to a connection with the Northeastern Boundary Survey at its Initial Monument; tertiary triangulation of the Schoodic Lakes at the head waters of St. Croix River; topographical surveys on the St. Croix River with incidental hydrography from Vanceborough to the southward; topographic and hydrographic survey of the St. Croix River from Calais to Baring and above; completion of unfinished topographical work on the coast of Maine in the vicinity of Cobscook Bay, and inspection of topographical surveys in that vicinity and to the eastward and northward; examination of changes for additions of topographical details to the shore lines of the Kennebec River from Bath to Gardiner, Me.; determinations of town boundaries in the State of Massachusetts continued; continuation of physical surveys on the coast of Cape Cod; hydrographic resurveys in Nantucket Sound and vicinity; continuation of the off shore hydrography south of Nantucket and Martha's Vineyard; completion of the topographical resurvey of Wood's Holl and vicinity; topographical resurvey of the Elizabeth Islands between Buzzard's Bay and Vineyard Sound, and of the Waepecket Islands, Buzzard's Bay; establishment of a naval trial course (measured sea mile) in the eastern passage, Narragansett Bay; laying off a trial course for the new naval war vessel *Philadelphia*, off the coasts of Block Island and Long Island, and observations of tides, currents, and gaugings of discharge in Long Island Sound.

Upon and off the coasts and within the limits of the States of New York, New Jersey, Pennsylvania, and Delaware, field operations included topographic and hydrographic surveys on the south coast of Long Island; shore line examination for the determination of changes in and additions to New York City Front; hydrographic survey of Wallabout Channel, New York Harbor; hydrographic examination of the approaches to Ellis Island, New York Harbor; tidal observations continued with automatic tide-gauge at Sandy Hook, New Jersey; recovery and marking of a station of the primary triangulation in Pennsylvania; determination of the longitude of Altoona, Pa., by exchanges of telegraphic signals with Washington, D. C., and observations for latitude at Altoona; examinations for note of topographic changes on the coasts of New York and New Jersey; continuation of geodetic operations in the southwestern part of the State of New Jersey; revision of the survey of the Philadelphia City Front; hydrographic resurveys in the Delaware River in front of and below the city of Philadelphia, and observations of ice movement and water densities in Delaware River and Bay.

The following named operations were begun, completed, or in progress within the District of Columbia and the boundaries of the States of Maryland, Virginia, North and South Carolina, and Georgia, or off the coasts of those States: Determinations of gravity at the Smithsonian Institution, Washington, D. C., and of the magnetic declination, dip, and intensity at the Coast and Geodetic Survey Office station; continuation of the detailed topographical survey of the District of Columbia; definition and determination of a portion of the boundary line between

Maryland and Virginia; examination and location of a dangerous rock in the Potomac River; hydrographic examinations for the Coast Pilot in Chesapeake Bay and tributaries; examination for additions of topographical details to a chart of Norfolk Harbor and vicinity; examination and development of a shoal in Chesapeake Bay near Wolf Trap Light-House; determination of the magnetic elements at a station in Lynchburgh, Va., connection of old and new triangulations on the coast of North Carolina from Beaufort to the westward; triangulation and topography in the vicinity of Charleston, S. C.; establishment and maintenance of an automatic tidal station on Tybee Island, Savannah River Entrance; surveys and examinations of oyster bed limits for the State of Georgia, and hydrographic reconnoissance of the entrances to St. Simon's Sound.

Upon or off the east and west coasts of Florida, in the approaches to those coasts, and upon the coasts or within the limits of the States of Alabama, Mississippi, Arkansas, Louisiana, and Texas, the following operations were in progress or completed: Development of a shoal off Key Biscayne, Florida; continuation of the investigation of the currents of the Gulf Stream; hydrographic surveys in the Bay of Florida and on the west coast of Florida from Cape Romano to Shark River; triangulation, topography, and hydrography of the west coast of Florida in the vicinity of Cape Florida and to the northward; triangulation and topography of the upper branches of Escambia and East Bays, Pensacola Bay; triangulation, topography, and hydrography of Perdido Bay, Florida and Alabama; reconnoissance and occupation of stations for the extension of the primary triangulation from Atlanta to the Gulf of Mexico; occupation of stations for the determination of the magnetic elements in Alabama, Mississippi, Louisiana, and Arkansas; lines of geodetic leveling run between London, Arkansas, and Fort Smith; hydrographic surveys on the coast of Louisiana in the vicinity of Ship Shoal, Caillou Bay, and to the eastward; reconnoissance and triangulation on the coast of Louisiana between Atchafalaya and Cote Blanche Bays; establishment of a self-registering magnetic apparatus at a station in San Antonio, Tex., and determination of the magnetic elements at a number of other stations in that State.

PACIFIC COAST.—Field operations within the limits and on or off the coasts of the States of California, Oregon, and Washington, and of the Territory of Alaska, have included the completion of the topographic survey of the south coast of California, between San Diego and San Onofre; the connection of the Los Angeles primary base line with the triangulation; the completion of the magnetic record at the self-registering magnetic station at Los Angeles, Cal.; hydrographic surveys in the vicinity of Piedras Blancas, Cal.; triangulation of the coast of California in the vicinity of Monterey; topographical survey of the coast of California in the vicinity of Point Sur; general direction of land operations on the Pacific coast, and preparations for the occupation of Mount Conness; tidal record continued at the automatic tidal station at Sausalito, Bay of San Francisco; resurveys and examinations of soundings in Suisun Bay, in Karquines Strait, and the mouths of the Sacramento and San Joaquin Rivers; completion of a hydrographic survey in the vicinity of Crescent City, Cal.; hydrographic survey of the coast of Oregon, from Mack's Arch to Cape Blanco; triangulation, topography, and hydrography of Coos Bay, Oregon; hydrographic examination in the vicinity of Cape Lookout, Oregon; examination of Young's Bay and River, Oregon, with reference to the effect upon navigation of a proposed railroad bridge; triangulation of the Columbia River continued; completion of the special survey made for the Commission organized to select a site for a Navy-yard on the Pacific coast; topographical survey of the Skagit River and Delta, State of Washington; hydrographic surveys in Rosario Straits, including Thatcher and Obstruction Passes, Hale's Passage, and Lummi Bay, in Semi-ah-moo Bay and Drayton Harbor, along the east side of the Gulf of Georgia, and in Skagit Bay; extension of the triangulation of Rosario Strait into Lopez and East Sounds and through Upright Passage to its connection with San Juan Channel; topographical surveys on Orcas, Lopez, Blakely, Decatur and other islands in Washington Sound; continuation of the survey of the coast of southeastern Alaska in Frederick Sound and vicinity, and also in Lynn Canal and the neighboring waters; tidal record continued at the automatic tidal station at St. Paul, Kadiak Island, Alaska, and occupation of stations near the junction of the one hundred and forty-first meridian with the Yukon and Porcupine Rivers, in connection with a preliminary survey of the boundary line between Alaska and British Columbia.

INTERIOR STATES.—Field work in the States between the Atlantic and Pacific coasts included the following operations: Continuation of the primary triangulation near the thirty-ninth parallel to the westward from stations in Ohio, Kentucky, and Indiana; establishment of a meridian line at Toledo, Ohio; extension to the eastward in Indiana of the primary triangulation to connect with that advancing westward; re-occupation of stations to complete the connection of the triangulation of Tennessee with the primary triangulation in northern Georgia, and reconnoissance and signal building for the extension of the triangulation in eastern Tennessee; occupation of stations in Tennessee for the determinations of the magnetic elements; extension of lines of geodetic leveling from Greenfield, Tenn., to Okolona, Miss.; occupation of stations in continuation of the triangulation of the State of Wisconsin; extension of the triangulation of the State of Minnesota from the Snelling Avenue Base; establishment of a meridian line at Huron, in the State of South Dakota; occupation of stations for extending the transcontinental triangulation near the thirty-ninth parallel to the westward in Kansas; stations occupied in continuation of the primary triangulation near the thirty-ninth parallel in western and central Utah; observations for latitude and the magnetic elements, and determinations of longitude by exchanges of telegraphic signals at stations in Nevada and Utah, and occupation of stations at Salt Lake City, Utah Territory, and at Helena, State of Montana, for longitude determinations.

SPECIAL OPERATIONS during the year have been referred to in the preliminary statement, and will be mentioned more in detail towards the close of Part II of this volume.

II.—OFFICE WORK.

Demands upon the Survey for its charts and other publications have increased so largely during the past year as to tax to the utmost the capacity of the Office to supply them. So great was the demand for charts that the Office presses were found unequal to meet it fully, and this fact emphasizes the recommendation made by the Assistant in charge of Office and Topography in his annual report (Appendix No. 4) that both the plant and the personnel of the Engraving and Printing Division should be increased, and additional room be provided for their accommodation. An item for the cost of this increase was included by the Superintendent in his estimates for the fiscal year 1891 (Report for 1889), and is again made in his estimates for the fiscal year 1892, pages 10 and 15 of this volume.

Sixty-three thousand one hundred and fifty-one copies of charts were issued during the year, an increase of nearly 14,000 copies over the number issued in the fiscal year 1889, and of upwards of 20,000 over the issue of 1888. In the fiscal year 1885, 28,905 copies of charts were issued; the increase in distribution since that year has been, therefore, 118 per cent. There were sent to chart agents for sale 32,335 copies of charts. On June 30, 1890, the total number of these agencies was 79; on the Atlantic and Gulf coasts 63, and on the Pacific coast 16.

For the use of Congress 3,266 copies of charts were supplied, and to the Executive Departments 21,941 copies, including 3,048 copies for the use of the Survey. For foreign governments 1,120 copies were required.

There were received in the Chart room for issue during the year 28 new charts. Seven of these were from engraved plates, and 21 from photolithographs of drawings or tracings. The manuscript of a new Catalogue of Charts was prepared and sent to the printer.

Special mention is made of the publication and issue of Notices to Mariners and Bulletins under headings immediately following.

Tide Tables predicting for the calendar year 1891 the times and heights of every high and low water during that year at the principal ports on the Atlantic and Pacific coasts of the United States were published in May and June, 1890. These tables furnish also constants for obtaining the times and heights of the tide at 661 additional ports or anchorages on the Atlantic coast, and at 218 additional ports or anchorages on the Pacific. Within the last two years tidal data have been included for a number of stations on the coasts of British America and Lower California.

Among the publications received from the printer during the year were the Annual Report of the Superintendent for the fiscal year 1887; tables for converting customary and metric weights and measures, and extra editions of from 100 to 700 copies of ten of the Appendices to the Report for 1887. These are published to meet special requests for results of the work or descriptions of its instruments, methods, and processes, and are supplied without cost to those who apply for them.

It was but a little after the close of the fiscal year that there were received from the printer advance copies of the fourth edition of the Coast Pilot of California, Oregon, and Washington, a quarto volume of about 700 pages, illustrated by 165 plates of views of the Pacific coast.

The annual report of the Hydrographic Inspector (Appendix No. 5) gives full details respecting the progress of office work, as well as of field work, under his immediate charge.

III.—HYDROGRAPHIC DISCOVERIES AND DEVELOPMENTS.

The great value of the Notices to Mariners, issued monthly by the Survey, and oftener if occasion should require it, is shown by the fact that to supply the demand for them, 137,900 copies were printed of the fourteen notices issued during the year. During the previous year 50,000 copies were printed. Distribution was made of about 95 per cent. of the whole edition, amounting during the year to upwards of 10,000 copies for each month, excepting in August, 1889, and January, 1890, when the publication of an extra number increased the distribution in those months to 15,000 copies. All of the chart agencies of the Survey, all United States Custom-Houses, the Branch Hydrographic Offices of the Navy Department in the principal seaboard cities, foreign Hydrographic Offices and United States Consulates in foreign ports are supplied with copies of the Notices.

In the regular monthly issue is given a list of important corrections made on the charts, lists of new charts and new editions published, and of charts the issue of which has been suspended. Also lists of new publications of the Survey.

The following is an abstract of contents and dates of issue of the Notices for the fiscal year:

No. 117 (July 31, 1889). Chart corrections during the month of July, 1880. New charts. New publications. General note.

No. 118 (August 15, 1889). Information concerning Coast and Geodetic Survey Charts. Lists of catalogue numbers of charts forming complete sets for limits named on the Atlantic and Pacific coasts. Directions for using the charts. Note in regard to chart corrections. General note. List of sale agencies for Charts, Coast Pilots, and Time Tables, etc.

No. 119 (August 31, 1889). Chart corrections during the month of August, 1889. New charts. New publications. General note.

No. 120 (September 30, 1889). Chart corrections during the month of September, 1889. Charts condemned, old editions. New charts. New publications. General note.

No. 121 (October 31, 1889). Chart corrections during the month of October, 1889. Charts superseded, and old editions condemned. New charts. New publications. General note.

No. 122 (November 30, 1889). Chart corrections during the month of November, 1889. Charts suspended, condemned, and new charts. New publications. Note as to Alaska Current Floats. General note. Circular showing how to send information respecting data on charts, etc., to the Superintendent.

No. 123 (December 31, 1889). Chart corrections during the month of December, 1889. Winter buoyage. Charts condemned and charts suspended. New charts. New publications. General note. Index to notices published during 1889. List of sale agencies, and circular regarding communications.

Supplementary Notice. Index to chart corrections, January 1 to December 31, 1889.

No. 124 (January 31, 1890). Chart corrections during the month of January, 1890. New charts. Chart condemned. List of subagencies. Circular regarding communications.

No. 125 (February 28, 1890). Chart corrections during the month. New chart. Condemned charts. New publications. Circular as to communications.

No. 126 (March 31, 1890). Chart corrections during the month. New chart. New editions Canceled chart. New publications. General note. Circular as to communications.

No. 127 (April 30, 1890). Chart corrections during the month. General note. Circular as to communications.

No. 128 (May 31, 1890). Chart corrections during the month. New charts. Canceled chart. New publication. General note. Circular regarding communications.

No. 129 (June 30, 1890). Chart corrections during the month. New editions of charts. Canceled charts. New publications. General note. List of sale agencies. Circular as to communications.

IV.—BULLETINS.

In the number of Bulletins published during the year, and in the number of copies printed for distribution, there was an increase over the previous year quite noticeable, though less marked than for the charts and Notices to Mariners. The number issued was 10, and the whole number printed was 39,373.

These papers, the publication of which gives early announcement of results reached in the progress of the Survey, deemed of interest to astronomers or surveyors, navigators or scientists, are supplied without charge to applicants. Their titles, authors, dates of approval for publication, and dates of issue, are as follows:

Title.	When approved for publication.	Date of publication.
No. 9. On the Relation of the Yard to the Metre. By O. H. Tittmann, Assistant	June 15, 1889	July 8, 1889
No. 10. Report on the Sounds and Estuaries of North Carolina with reference to Oyster Culture. By Francis Winslow, lieutenant U. S. Navy, and Assistant	Jan. 30, 1889	Aug. 26, 1889
No. 11. Determinations of Latitude and Gravity for the Hawaiian Government. By Erasmus D. Preston, Assistant	Apr. 23, 1889	Sept. 21, 1889
No. 12. A Syphon Tidegauge for the Open Seacoast. By Henry L. Marindin, Assistant	Mar. 30, 1889	Aug. 19, 1889
No. 13. Telegraphic Determination of the Longitude of Mount Hamilton, California	...do	...do
Field work by C. H. Sinclair, Assistant, and R. A. Marr, Subassistant. Report by Charles A. Schott, Assistant	Oct. 7, 1889	Dec. 9, 1889
No. 14. Approximate Times of Culminations and Elongations, and of the Azimuths at Elongation of Polaris, for the Years between 1889 and 1910. Prepared for publication by Charles A. Schott, Assistant	Nov. 21, 1889	Feb. 18, 1890
No. 15. Verification of Weights and Measures. Prepared for publication by O. H. Tittmann, Assistant	Dec. 4, 1889	Mar. 1, 1890
No. 16. Description of two new transit instruments for Longitude work. By Edwin Smith, Assistant	Oct. 7, 1889	Mar. 17, 1890
No. 17. The Relation between the Metric Standards of Length of the U. S. Coast and Geodetic Survey and the U. S. Lake Survey. A report by C. A. Schott and O. H. Tittmann, Assistants	Oct. 11, 1889	Mar. 18, 1890
No. 18. Table for the Reduction of Hydrometer Observations of Salt Water Densities. Prepared for publication by O. H. Tittmann, Assistant	Feb. 18, 1890	June 25, 1890

V.—SPECIAL SCIENTIFIC WORK.

RESULTS OF MAGNETIC OBSERVATIONS AT LOS ANGELES, CALIFORNIA.

In Appendices Nos. 8 and 9 to this volume, Assistant Charles A. Schott presents a discussion and report of the results of the magnetic observations, both absolute and differential, made at the Magnetic Observatory at Los Angeles, California, between the years 1882 and 1889. Part I of the report relates to the results of the absolute measures for the magnetic declination, dip, and intensity, and appears as Appendix No. 8. In Part II (Appendix No. 9) the differential measures of the declination are discussed; those of the inclination (or dip) and intensity will be the subject of subsequent papers.

The officers in charge of the Observatory during the period referred to were Marcus Baker Acting Assistant; Carlisle Terry, jr., Sub-assistant, and R. E. Halter, Assistant.

It was in conformity with the general plan of magnetic observation and research prosecuted by the Survey and in co operation with the work of the International Polar Commission that an observatory for obtaining during a certain term of years a continuous registration of the changes of magnetic force was established at Los Angeles. This continuous registration was maintained without serious interruption from October 1, 1882, to October 1, 1889, by means of the Adie magnetographs, the changes of magnetic force being recorded photographically. A period of nearly two-thirds of a sun-spot cycle was thus covered, including the time of minimum sun-spot activity, which is supposed to have occurred early in the year 1889.

Supplementary to the differential measures were the absolute magnetic measures which were made monthly on three days about the middle of each month, and were intended to furnish the means of expressing the results of the differential measures in terms of absolute units. Examples of the forms of record and computation and full abstracts of the results of the determination of the absolute values of each element of the magnetic force are given in Mr. Schott's report, Part I.

In order to afford a means of verifying the results deduced in Part II of his report, and to give data for testing any hypothesis, method, or investigation other than that which he has adopted, Mr. Schott has accompanied this paper with the hourly record of the unifilar magnetometer during the seven years, 1882 to 1889, as read from the photographic traces. For the first year, October, 1882, to October, 1883, the period of this record coincides with the period of International Polar Research, and should therefore be regarded as an extra-polar contribution thereto.

ON A SHORT ROUGH METHOD OF DEDUCING PROBABLE ERROR.

In a paper which appears as Appendix No. 13 to this volume, Mr. Charles H. Kummell, of the Computing Division, develops a short method of deducing the probable error of an observation from a series of residuals. The rigorous method, especially where there are a great number of observations, demands, he thinks, far too much work in proportion to the value of the quantity, and by limiting the process to a few values from the largest residuals, which should be correctly combined for a final value, he shows that results are reached differing but very little from those of the longer method.

Mr. Kummell shows also that a fair value of the probable error can be obtained by one form of using his method which does not require a knowledge of the residuals.

ON THE USE OF OBSERVATIONS OF CURRENTS FOR PREDICTION PURPOSES.

In Appendix No. 14 Mr. John T. Hayford, of the Tidal Division, Coast and Geodetic Survey Office, presents the results of a preliminary investigation of a method of predicting currents based upon a reference of their times of occurrence to the predicted times of high and low water instead of to the times of moon's transit as hitherto in general use. Material for the discussion was derived from the observations of currents which have accumulated in the archives of the Survey during the past 45 years. It is thought that the systematic prediction of currents will be greatly aided by the general adoption of this method, especially if it should be found practicable to obtain long series of observations at or in the vicinity of the leading seaports of the United States.

GULF STREAM EXPLORATIONS. METHODS OF THE INVESTIGATION AND RESULTS OF THE RESEARCH.

In an elaborate report, which is published as Appendix No. 10 to this volume, Lieut. J. E. Pillsbury, U. S. N., Assistant Coast and Geodetic Survey, presents a detailed account of the methods adopted and the apparatus which he devised for the explorations of the Gulf Stream carried on by him while in command of the steamer *Blake* for several years past. He prefaces this account with an historical resumé of previous explorations, and follows it with a statement of the conclusions which he has drawn from his observations. The report is fully illustrated.

EXPLANATION OF ESTIMATES.

The estimates submitted to the Secretary of the Treasury for the fiscal year ending June 30, 1892, were accompanied by the following statement:

U. S. COAST AND GEODETIC SURVEY OFFICE,
Washington, D. C., September 30, 1890.

SIR: I have the honor to submit herewith estimates of the appropriations required for the Coast and Geodetic Survey for the fiscal year ending June 30, 1892.

The items under the head of "Party expenses" differ in some particulars from those enumerated in the act making appropriations for the year ending June 30, 1891, completed work being omitted, of course, and new localities designated. In some cases paragraphs hitherto separated have been consolidated, for the purpose of greater economy in the expenditure of the sums appropriated. The total sum estimated for "Party expenses" differs but little, however, from that appropriated for the present fiscal year. The amounts estimated for under the heads "Pay of Field Officers" and "Pay of Office Force" are identical with those provided in the act appropriating for the fiscal year ending June 30, 1891. Under the head of "Office Expenses" the amount estimated in the second paragraph is greater than the current appropriation by $4,500. It is this item which furnishes all supplies of copper-plate, chart paper, photolithographing, and all extra engraving, printing from stone, etc., and the appropriations for several years have been entirely inadequate, requiring large deficiency appropriations each year. While the output of charts has greatly increased during the past few years, the amount regularly appropriated under this item has not grown with the demand, but it is believed that the amount now asked for will, by careful expenditure, enable us to escape a deficiency.

The grand total of the regular estimates is sensibly the same as that of the current appropriation. A special estimate is submitted, however, for providing the additional facilities for chart printing which are now so imperatively demanded. During the year 1886 the number of charts issued was about 28,000; during the present year it will reach nearly 70,000. In this time there has been no increase in our facilities for chart printing, so that even with the most strenuous efforts we are now entirely unable to meet the demands made upon us. On June 30 there were on file orders for over a thousand charts of seventy different kinds, which could not be filled owing to our inadequate printing facilities. The demand for charts is constantly growing. The number supplied to sale agents has increased more than 100 per cent. during the past 5 years. The great increase in the demand for our publications is also shown in the increase of the number of notices to mariners from less than 7,000 to about 138,000 within the last 5 years, and this goes to show that the demand for charts is likely to increase considerably within the next few years. The appropriation of the comparatively small sum of $15,000 asked for to enlarge our capacity in that direction can hardly be delayed longer. With the relief which this will afford we shall doubtless be able to meet the demand for several years to come.

In addition to the estimates of expenditures on account of the Coast and Geodetic Survey, I transmit also an estimate for the expenses of the Office of Construction of Standard Weights and Measures for the fiscal year ending June 30, 1892. The items of this estimate are the same as those appropriated for the current fiscal year, with the exception of that providing for the expenses of the attendance of the American member of the International Committee on Weights and Measures at the general conference provided for in the convention signed May 20, 1875, which was estimated for but not included in the act for the present fiscal year, and of the item for salary of one messenger at $720 per annum, whose services are urgently needed.

Respectfully, yours,

T. C. MENDENHALL,
*Superintendent Coast and Geodetic Survey
and of Weights and Measures.*

The SECRETARY OF THE TREASURY.

ESTIMATES.

For every expenditure requisite for and incident to the survey of the Atlantic, Gulf, and Pacific coasts of the United States and the coast of the Territory of Alaska, including the survey of rivers to the head of tide water or ship navigation; deep sea soundings, temperature and current observations along the coasts and throughout the Gulf Stream and Japan Stream flowing off the said coasts; tidal observations; the necessary resurveys; the preparation of the Coast Pilot; continuing researches and other work relating to terrestrial magnetism and the magnetic maps of the United States and adjacent waters, and the tables of magnetic declination, dip, and intensity, usually accompanying them; and including compensation not otherwise appropriated for of persons employed on the field work, in conformity with the regulations for the government of the Coast and Geodetic Survey adopted by the Secretary of the Treasury; for special examinations that may be required by the Light-House Board or other proper authority, and including traveling expenses of officers and men of the Navy on duty; for commutation to officers of the field force while on field duty at a rate to be fixed by the Secretary of the Treasury, not exceeding $2.50 per day each; outfit, equipment, and care of vessels used in the Survey, and also the repairs and maintenance of the complement of vessels, to be expended in accordance with the regulations relating to the Coast and Geodetic Survey from time to time prescribed by the Secretary of the Treasury and under the following heads: *Provided*, That no advance of money to chiefs of field parties under this appropriation shall be made unless to a commissioned officer, or to a civilian officer who shall give bond in such sum as the Secretary of the Treasury may direct:

PARTY EXPENSES, COAST AND GEODETIC SURVEY:	
For triangulation, topography, and hydrography of the coast of Maine and to the International boundary monument, and including the Kennebec River to Augusta	$3,000
For triangulation, topography, and hydrography in the vicinity of the east end of Long Island, Nantucket shoals and approaches, and including Vineyard Sound, the coast of Massachusetts, and the Connecticut River to Hartford, Conn., and the Hudson River to Troy, N. Y., and to continue to date corrections of former surveys of the Delaware River from the vicinity of Philadelphia to Trenton	15,000
To continue the primary triangulation from the vicinity of Montgomery toward Mobile	3,500
For triangulation, topography, and hydrography of unfinished portions of the Gulf coast, including Lake Pontchartrain and the resurvey of Mobile Bay entrance	15,000
To make offshore soundings along the Atlantic coast and current and temperature observations in the Gulf Stream	8,000
For continuing the topographic survey of the coast of California, including necessary triangulation and astronomical work in connection therewith	5,000
For continuing the triangulation west of the 110th meridian and connecting the same with the transcontinental arc	10,000
For continuing the survey of the coasts of Oregon and Washington, including offshore hydrography, and to continue the survey of the Columbia River from the mouth of the Willamette towards the Cascades, triangulation, topography, and hydrography	25,000
For continuing explorations in the waters of Alaska and making hydrographic surveys in the same, and for the establishment of astronomical, longitude, and magnetic stations between Sitka and the southern end of the Territory	10,000
For continuing the researches in physical hydrography relating to harbors and bars, including computations and plottings	8,000
For examination into reported dangers on the Eastern, Gulf, and Pacific coasts	500
For continuing magnetic observations on the Atlantic, Gulf, and Pacific coasts, and at the San Antonio Magnetic Observatory	2,500

PARTY EXPENSES, COAST AND GEODETIC SURVEY—Continued.

For continuing the line of exact levels westward from the vicinity of Jefferson City, Mo.; eastward from the vicinity of Memphis, Tenn.; westward from Old Point Comfort, Va.; and eastward from San Francisco, Cal	$5,000
For continuing tidal observations on the Atlantic, Gulf, and Pacific coasts	5,000
To continue gravity experiments, at a cost not exceeding $500 per station, except for special investigations and experiments authorized by the Superintendent at one or more stations	2,500
For furnishing points for State surveys, to be applied as far as practicable in States where points have not been furnished	10,000
For determinations of geographical positions (longitude parties)	3,000
For continuing the transcontinental geodetic work on the line between the Atlantic and Pacific Oceans, including a primary base in the vicinity of Salt Lake and check bases in Ohio and Indiana	22,000
To continue the compilation of the Coast Pilot, and to make special hydrographic examinations for the same	4,500
For traveling expenses of officers and men of the Navy on duty, and for any special surveys that may be required by the Light-House Board or other proper authority, and contingent expenses incident thereto	3,500
For objects not hereinbefore named that may be deemed urgent, including the actual necessary expenses of officers of the field force temporarily ordered to the Office at Washington for consultation with the Superintendent, to be paid as directed by the Superintendent in accordance with the Treasury regulations	7,000
For contribution to the International Geodetic Association for the Measurement of the Earth, or so much thereof as may be necessary, $450, to be expended through the office of the American legation at Berlin, and for expenses of the attendance of the American delegate at the general conference of said association, or so much thereof as may be necessary, $550: *Provided*, That such contribution and expenses of attendance shall be payable out of the item "for objects not hereinbefore named." And 20 per centum of the foregoing amounts shall be available interchangeably for expenditure on the objects named.	
Total party expenses	168,000
Alaska Boundary Survey.—For expenses of carrying on a preliminary survey of the frontier line between Alaska and British Columbia and the Northwest Territory, in accordance with plans or projects approved by the Secretary of State, including expenses of drawing and publication of map or maps $10,000, said sum to continue available for expenditure until the same is exhausted	10,000
Repairs and maintenance of vessels.—For repairs and maintenance of the complement of vessels used in the Coast and Geodetic Survey	25,000

PAY OF FIELD OFFICERS:

For Superintendent	6,000
For two assistants, at $4,000 each	8,000
For one assistant	3,600
For one assistant	3,200
For four assistants, at $3,000 each	12,000
For two assistants, at $2,800 each	5,600
For two assistants, at $2,600 each	5,200
For six assistants, at $2,400 each	14,400
For four assistants, at $2,200 each	8,800
For seven assistants, at $2,000 each	14,000

PAY OF FIELD OFFICERS—Continued.	
For nine assistants, at $1,800 each	$16,200
For six assistants, at $1,600 each	9,600
For five subassistants, at $1,400 each	7,000
For two subassistants, at $1,200 each	2,400
For aids temporarily employed, at a salary not greater than $900 per annum each	3,600
Total pay of field officers	119,600
PAY OF OFFICE FORCE:	
For one disbursing agent	2,200
For one general office assistant	2,200
For one chief of division of library and archives	1,800
For one clerk to the Superintendent	1,200
For one clerk to the assistant in charge of the office and topography	1,000
For clerical force, namely:	
For two, at $1,650 each	3,300
For three, at $1,400 each	4,200
For five, at $1,200 each	6,000
For two, at $1,000 each	2,000
For chart correctors, buoy colorists, stenographers, writers, typewriters, and copyists, namely:	
For two, at $1,200 each	2,400
For three, at $900 each	2,700
For one	800
For ten, at $720 each	7,200
For one	600
For topographic and hydrographic draughtsmen, namely:	
For one	2,400
For one	2,200
For two, at $2,000 each	4,000
For three, at $1,800 each	5,400
For two, at $1,400 each	2,800
For two, at $1,200 each	2,400
For two, at $1,000 each	2,000
For three, at $900 each	2,700
For astronomical, geodetic, tidal, and miscellaneous computers, namely:	
For three, at $2,000 each	6,000
For two, at $1,600 each	3,200
For two, at $1,400 each	2,800
For three, at $1,200 each	3,600
For two, at $1,000 each	2,000
For copper plate engravers, namely:	
For three, at $2,000 each	6,000
For three, at $1,800 each	5,400
For two, at $1,600 each	3,200
For one	1,200
For one	1,000
For additional engravers, at not to exced $900 per annum each	4,000
For electrotypers, photographers, plate-printers and their helpers, instrument-makers, carpenters, engineer, janitor, and other skilled laborers, namely:	
For two, at $1,800 each	3,600
For two, at $1,600 each	3,200
For two, including a janitor, at $1,200 each	2,400

PAY OF OFFICE FORCE—Continued.	
For eight, at $1,000 each	$8,000
For two, at $900 each	1,800
For four, at $700 each	2,800
For watchmen, firemen, messengers and laborers, packers and folders, and miscellaneous work, namely:	
For three, at $880 each	2,640
For six, at $820 each	4,920
For three, at $640 each	1,920
For four, at $630 each	2,520
For four, at $550 each	2,200
For two, at $365 each	730
Total pay of office force	136,630
PUBLISHING OBSERVATIONS:	
For the discussion and publication of observations	1,000
OFFICE EXPENSES:	
For the purchase of new instruments, for materials and supplies required in the instrument shop, carpenter shop, and drawing division, and for books, maps, charts, and subscriptions	9,000
For copper plates, chart paper, printer's ink, copper, zinc, and chemicals for electrotyping and photographing; engraving, printing, photographing, and electrotyping supplies; for extra engraving and drawing; and for photolithographing charts and printing from stone and copper for immediate use	20,000
For stationary for the office and field parties; transportation of instruments and supplies when not charged to party expenses; office wagon and horses; fuel, gas, telegrams, ice and washing	6,000
For miscellaneous expenses, contingencies of all kinds, office furniture, repairs, and extra labor, and for traveling expenses of assistants and others employed in the office, sent on special duty in the service of the office	4,500
And 10 per centum of the foregoing amounts for office expenses shall be available interchangeably for expenditures on the objects named.	
Total general expenses of office	39,500
RENT OF OFFICE BUILDINGS:	
For rent of buildings for offices, work rooms, and workshops in Washington	10,500
For rent of fireproof building No. 203 New Jersey avenue, including room for standard weights and measures; for the safe-keeping and preservation of the original astronomical, magnetic, hydrographic, and other records, of the original topographical and hydrographic maps and charts, of instruments, engraved plates, and other valuable property of the Coast and Geodetic Survey	6,000

That no part of the money herein appropriated for the Coast and Geodetic Survey shall be available for allowance to civilian or other officers for subsistence while on duty at Washington (except as hereinbefore provided for officers of the field force ordered to Washington for short periods for consultation with the Superintendent), or to officers of the Navy attached to the Survey; nor shall there hereafter be made any allowance for subsistence to officers of the Navy attached to the Coast and Geodetic Survey, except that when officers are detached to do work away from their vessels under circumstances involving them in extra expenditures, the Superintendent may allow to any such officer subsistence at a rate not exceeding one dollar per day for the period actually covered by such duty away from such vessel.

PRINTING AND BINDING, COAST AND GEODETIC SURVEY:	
For printing and lithographing, photolithographing, photo-engraving, and all forms of illustration done by the Public Printer, on requisition by the Treasury Department, for the Coast and Geodetic Survey, namely:	
Tide tables, Coast Pilots, Appendices to the Superintendent's annual reports, published separately; notices to mariners, circulars, blank books, blank forms, and miscellaneous printing, including the cost of all binding and covering; the necessary stock and materials and binding for the library and archives...	$20,935
NOTE.—No engraving is done by the Public Printer for the Coast and Geodetic Survey.	
Total Coast and Geodetic Survey, exclusive of printing and binding, for the fiscal year 1892	516,230
SPECIAL ESTIMATE:	
Additional facilities for chart printing.—To provide additional facilities for chart printing rendered necessary by the greatly increased demand for charts:	
For increasing plant, including two new presses, gas engines, with necessary shafting, belting, etc	7,400
For increased force:	
Two copper-plate printers, at $1,000 per annum each	2,000
Three copper-plate printers' helpers, at $700 per annum each	2,100
One bookkeeper and clerk	1,000
Two messengers, at $700 per annum each	1,400
For rental of the whole of the brick building in rear of the "Butler Buildings".	1,200
Total	15,100
OFFICE OF CONSTRUCTION OF STANDARD WEIGHTS AND MEASURES:	
Salaries, Office of Standard Weights and Measures.—For construction and verification of standard weights and measures, including metric standards, for the custom-houses, other offices of the United States, and for the several States; and mural standards of length in Washington, District of Columbia:	
One adjuster, at $1,500; one mechanician, at $1,250; one watchman and one messenger, at $720 per annum; in all	4,190
Contingent expenses, Office of Standard Weights and Measures.—For purchase of materials and apparatus, and incidental expenses	1,000
Provided, That such necessary repairs and adjustments shall be made to the standards furnished to the several States as may be requested by the Governors thereof, and also to standard weights and measures that have been, or may hereafter be, supplied to United States Custom-houses and other offices of the United States, under act of Congress, when requested by the Secretary of the Treasury.	
For expenses of the attendance of the American member of the International Committee on Weights and Measures at the general conference provided for in the convention signed May 20, 1875, the sum of $600, or so much thereof as may be necessary	600

PART II.

Included in this part of the Report are abstracts of reports from chiefs of field parties, and from reports of special operations; summarized statements from the annual reports of the Assistant in charge of Office and Topography, the Hydrographic Inspector, the Disbursing Agent, and the Assistant in charge of the Office of Weights and Measures, and abstracts of annual reports from the Suboffices at Philadelphia and San Francisco.

The annual report of the Assistant in charge of Office and Topography, Mr. B. A. Colonna, appears in Appendix No. 4 (Part III); the annual report of the Hydrographic Inspector, Commander C. M. Thomas, U. S. N., in Appendix No. 5; the annual report of the Disbursing Agent, Mr. John W. Parsons, in Appendix No. 6, and the annual report of the Assistant in charge of the Office of Weights and Measures, Mr. O. H. Tittmann, in Appendix No. 7.

The statement in tabular form of the field operations of the Survey which is given in Appendix No. 1 shows the distribution of the field parties in a geographical order proceeding from Maine to Texas on the Atlantic coast, from San Diego to the Strait of Fuca on the Pacific, and from east to west in the interior. This order is followed in the arrangement of the abstracts of reports from chiefs of field parties.

Statistics of field and office work to the close of the fiscal year are given in Appendix No. 2, and lists of information furnished in reply to requests, official or personal, in Appendix No. 3.

SECTION I.

MAINE, NEW HAMPSHIRE, VERMONT, MASSACHUSETTS, AND RHODE ISLAND, INCLUDING COAST AND SEAPORTS, BAYS AND RIVERS. (SKETCHES NOS. 1, 4, 19, AND 20.)

Continuation of reconnaissance and triangulation over the St. Croix River and the Boundary Lakes to a connection with the Northeastern Boundary Survey at its Initial Monument.—The connection of the primary triangulation near the Bay of Fundy with the Initial Monument of the Northeastern Boundary Survey at the source of the St. Croix River was accomplished by Assistant C. H. Boyd during the summer and autumn of 1889.

Having organized his party under instructions dated towards the end of June, Mr. Boyd took up the triangulation about the 11th of July from the limits of his work of the preceding season near the south end of Grand Schoodic Lake. The signals erected on the upper St. Croix during the last season were inspected and adjusted to guard against displacements caused by the winter gales; a reconnaissance for additional stations was carried to the Boundary Monument, ten new signals were put up, and lines of sight opened preparatory to measurements of angles.

In the search for the Boundary Monument and for the stations and marks used on the Boundary Line, Mr. Boyd was compelled to rely chiefly on information derived from common report, the only map available being on a scale too small to identify the main features of the country.

The Monument was found secured to a bowlder which lies in swampy ground on the town lines of Amity, Maine, and Richmond, New Brunswick, about half a mile south from the road between the post-offices of Amity and Monument Settlement. It is of cast iron, in three sections, and owing to the sinking of the bowlder into the swamp, the Monument was seen to be out of plumb, its apex with reference to the center of its base being six-tenths of a foot too far to the south, and 1 foot too far west. Mr. Charles Trail, a resident of the neighborhood, was present when the Monument was set, and assured Mr. Boyd that it was then perfectly plumb. On its north side was the inscription "Treaty of Washington," and on its south side "Boundary, August 9, 1842;" on the east and west sides were the names of the Commissioners. Height of Monument, 9.8 feet; base, 1.2 feet square. The trees about it are from 50 to 75 feet in height.

Over the middle point of its base a signal 72 feet high was plumbed, and the Monument was thus connected with the triangulation. The line was then opened northward until it passed over the eastern side of Pole Hill, where, it was thought, the party recovered the transit station occupied by Maj. James D. Graham, U. S. Topographical Engineers, in 1842. Thence the line was cut open to Monument No. 2, and the distance measured with steel tape. Four stations were occupied on the United States side, four on the Canadian side, and two nearly upon the line, ten in all, thus completing the connection with the Initial Monument.

The points selected for stations were in most cases the summits of the highest hills and mountains. Up these elevations, which were all covered with hard-wood timber, the party cut pathways, and opened lines from the summit to the several points in the scheme of work. The signals were built of spruce and cedar trees cut in the lowlands. To mark the station points a hole was drilled in a ledge or bowlder, and a triangle cut into the stone around it. Mr. Boyd suggests that in addition to this marking it would be well to have the stone dressed down immediately about the station mark, and the name of the station and the year of its occupation cut thereon.

Heights were determined at the water line in each of the Lakes, at the head of Boundary Brook, and on the St. Croix River below the Lower Lake.

A reconnaissance along the Boundary Line for some 25 miles north of the Monument was made in October to ascertain the condition of the marks originally put down. These were iron posts, 2½ inches square at top and 4 feet long. But few of them could be found; the thick underbrush effectually hid them, and the location of many of them was unknown to the people of the vicinage. Mr. Boyd suggests that, in view of the commercial interests demanding a careful marking of this border line, the triangulation be continued northward to the St. John River, to the point where that river becomes the International Boundary, and that a strip of land ten metres (nearly 33 feet) wide for the entire length of the Line and adjacent to it in Maine should be set apart to join a similar strip in New Brunswick, and the Line marked permanently by suitable monuments.

Field work was closed November 6. Mr. Everett C. Lyle, a young civil engineer of St. Stephen, served acceptably as recorder throughout the season. Mr. Boyd reports the following statistics:

Reconnaissance:	
Area of, in square statute miles	300
Lines of intervisibility determined	40
Number of points selected for scheme	16
Triangulation:	
Area of, in square statute miles	200
Number of signal poles erected	12
Number of stations occupied for horizontal measures	10
Number of stations occupied for vertical measures	10
Geographical positions determined	20
Elevations determined trigonometrically	20

During the early part of the winter, Mr. Boyd was occupied with the records and results of his field operations, and in January, 1890, he proceeded, under instructions, to the Gulf coast to take charge of the triangulation of Atchafalaya Bay.

Reference to this duty will be made under a heading in Section VIII.

Tertiary triangulation of the Schoodic Lakes at the head waters of the St. Croix River, Me.—In pursuance of instructions issued early in June, 1890, Assistant Joseph Hergesheimer proceeded to Vanceboro, Me., about the middle of that month to organize a party for the tertiary triangulation of the Schoodic Lakes.

Between June 14 and the end of the fiscal year the time was occupied in getting together boats, working materials and signal lumber, hiring men, reconnaissance and signal building, and cutting lines of sight. Rain on 9 days during this period somewhat retarded progress. The signal at Mount Henry was rebuilt and a signal erected at Vanceboro.

Further progress will be stated in the next Annual Report.

Work executed by Mr. Hergesheimer on the Delaware River in 1889 and in Florida in 1889-'90 is referred to under headings in Sections II and VI.

Topographic and hydrographic survey of the St. Croix River from the vicinity of Vanceboro, Me., to the southward.—For the further prosecution of the survey of St. Croix River and in continuance of work begun in 1889 by the late Assistant C. M. Bache, Subassistant J. A. Flemer was instructed, under date of May 17, 1890, to proceed to Vanceboro, Me., and take up the topography of the head waters of the St. Croix and to locate as accurately as possible the thread of the stream, bearing in mind its importance as an International boundary line.

Upon arriving at Vanceboro, June 2, Mr. Flemer reconnoitered a part of the river below that town, and found it more serpentine in its course than he had expected. He decided, therefore, in accordance with suggestions contained in his instructions, to run a traverse line from station Elbow Ripps to Baring's on a scale of 1-40000, using for this purpose the unfinished sheet of Mr. C. M. Bache's survey from Vanceboro to McPhail's Rolling Tier.

As the river was found to have many characteristic features due to numerous rapids (ripps) alternating with stretches of deep and gently flowing water, to many islands with abutments and wingdams, and to ledges, numerous rocks, and bowlders, it was deemed advisable to plot the topographical survey on a scale of 1-10000, and to obtain thereby a series of detailed charts showing the thread of the St. Croix or continuous line of deepest water as obtained by soundings. The chain of plane-table stations on these detail charts forms in its continuity an independent traverse line, which, as it has some points in common with the 1-40000 traverse, gives a certain check on the later, and will also facilitate the reduction of the topography to the scale of 1-40000.

From June 3 to 15 the party was occupied in reconnaissance, procuring camp outfit, boat, and two canoes, in hiring boat and ax-men, and in moving downstream to McPhail's Rolling Tier, where the first camp was pitched. On June 28 the party moved camp to Duck Point.

Mr. Flemer will report further on the progress of his survey at the close of the season.

Messrs. Seymour P. Bradley and William B. Paca served in the party as rodmen and general assistants.

Topographic and hydrographic survey of the St. Croix River from Vanceboro to the southward.—The survey of the St. Croix River on both sides of the International boundary line from Vanceboro, Me., to the southward was taken up towards the end of July, 1889, by Assistant Charles M. Bache, under instructions dated July 15. For this work Mr. Bache was furnished with a projection on a scale of 1-40000.

Mr. Bache reports that many difficulties were encountered in executing the survey owing to the nature of the ground, the heavily wooded character of the country, and the lack of triangulation points. At Vanceboro the Maine Central Railroad crosses the St. Croix into Canada. About this town and the Canadian village of St. Croix, immediately opposite, there was an inconsiderable portion of open country, extending nearly two-fifths of a mile down the river on the Canadian side and about three-fourths of a mile on the American side. The roads were of a kind that did not favor rapid progress. On the Canadian side a trail through the woods passed on in the direction of the river; on the American side a road existed which extended a little over 3 miles to two small farms but partly cleared.

Stations were occupied on each bank of the river, using a canoe for transportation; these crossings involved in each case the taking of the sheet from the board of the plane table and the board from the legs. The river contained many rapids and jams of logs. Lines of soundings were run and soundings taken with as much care as practicable. The stage of water in the river was observed twice a day for thirty-five days.

Field operations were closed September 27.

Following are the statistics of the season:

Topography:	
Number of miles of river shore line surveyed	20
Number of miles of shore line of marshes and ponds	14
Number of miles of roads, trails, streets, and railroad surveyed	14
Area surveyed in square statute miles	7
Hydrography:	
Number of lines of soundings run	82
Number of soundings taken	413

Duty assigned to Mr. Bache later in the season on the New Jersey coast is referred to under a heading in Section II.

Topographic and hydrographic survey of the St. Croix River from Calais to Baring and above.—Instructions issued to Assistant Eugene Ellicott towards the end of June, 1889, and supplemented by more detailed instructions issued a month later, directed him to make a topographical survey of a very precise character of the St. Croix River between Calais and the great bend of the river above Baring, and to carry the survey up the River to a point above Sprague's Falls. He was also to define the axis of the stream, or the line of greatest depth, which forms the boundary between the State of Maine and the Province of New Brunswick, making soundings systematically both over the tidal area and that above the reach of the tide. All heights for topographical contours were to be referred to mean high water at Calais, and a gauge for the purpose of recording the fluctuations in river depth was to be established at or near Baring.

For the execution of this work Mr. Ellicott was provided with a projection, scale 1-10,000. He has submitted an elaborate descriptive report to accompany his topographical and hydrographical sheet, and both sheet and report have been deposited in the archives. The report discusses at some length the historic origin and significance of local names in the area under survey; gives the dates of town settlements; compares his own determinations of heights of points on the river with those given by Walter Wills, formerly in charge of the State Hydrographic Survey; describes the location of towns; states the means of communication and the facilities of travel, the general character of the geological formations and of the forest and fruit trees; gives the statistics of the work, and concludes with a statement of the need of a survey made with great elaboration to serve as a basis for establishing and marking definitely the boundary line between Maine and New Brunswick.

For the season which closed October 26 the statistics are:

Topography:	
Area surveyed in square statute miles	14
Length in miles of river and creek shore line surveyed	39
Length in miles of roads surveyed, including railroads	36
Hydrography:	
Length of river survey measured along axis in miles	13
Miles run in sounding	20
Number of soundings	8,110

During the winter Mr. Ellicott was engaged in office work, and towards the end of February, 1890, he received instructions for duty on the coast of California.

Completion of unfinished topographical work on the coast of Maine in the vicinity of Cobscook Bay, and inspection of topographical surveys in that vicinity and to the eastward and northward.—In order to complete certain unfinished areas of topography lying between the surveys executed by Assistants C. M. Bache and E. Ellicott and Aid J. H. Gray on the coast of Maine in the vicinity of Cobscook Bay and to the eastward and northward, Assistant John W. Donn was instructed, towards the end of June, 1889, to proceed to that locality and organize a party to fill the gaps then existing. In connection with this work he was directed also to make careful inspection of the topographical surveys executed by the above-named officers in the years 1885 to 1889, and to include in this inspection the topographical reconnaissance made for military purposes by Assistant W. H. Dennis in the years 1861 and 1862.

On his way to the field Mr. Donn stopped at Portland, Me., for the purpose of consultation with Assistant C. H. Boyd regarding the proposed extension of topographical work on the Boundary line between Maine and New Brunswick from the Schoodic Lakes to the Boundary Monument. This consultation was supplemented by an examination made by Mr. Donn of the topography of the country about the Boundary Line, and a special report on the subject was made by him towards the end of June.

He then took up field work on the shore of Passamaquoddy Bay, near Perry Harbor or Little River, and closed the gap lying between the work of Assistant Dennis (1865) and Assistant C. M. Bache in 1888, at the same time inspecting the work of each as to shore line and general details of inland topography. The work to the northwest was then advanced between the lines of Assistants C. M. Bache and Ellicott, the work of the former extending up the highland adjacent to the Passamaquoddy to Lewis's Cove at North Perry, and that of the latter to the Iron Mills Mountain near the foot of Pemmanaquan Lake. This area, covering about 15 square miles, contained comparatively few artificial details, and was, in part, heavily covered with timber of recent growth. Much of it was difficult of access on account of burnt and fallen trunks of trees intermingled with the new growth on the sides of ledges, and the dense mass of bushes filling the marshy ravines.

This work was finished by the 5th of August, on which date Mr. Donn transferred his party to the town of Lubec, near which were two uncompleted areas; one lying upon the eastern side of Seward's Neck (North Lubec), and the other bounded by two areas of work executed by Assistant Ellicott in 1886 and 1887. While engaged upon the survey in these localities, and during the occupancy of several stations overlooking the Lubec Narrows, Mr. Donn determined the position of the Light-house then in course of construction.

On the 5th of September, Mr. Donn found it desirable to transfer his base of operations to the towns of Dennysville and Whiting, the former being the most available point for the continuation of the work of filling gaps in topography, and the latter for the inspection of the surveys made by Assistant Ellicott and Aid Gray in 1887 and 1888.

In general the face of the country presented features of a character similar to that surveyed during the earlier part of the season. Bold, high, rocky ledges jutted out amidst dense thickets of alder, birch, spruce, and fir, which covered extensive valleys of a swampy character. The ledges were generally occupied as stations, and their heights above the adjacent valleys and the seashore determined. The western part of the work laid between Mr. Ellicott's survey of 1887 and Mr. Gray's of 1888. It was completed by the 10th of October, after which the inspection of the general field covered by the surveys of those officers occupied Mr. Donn till October 14, at which date he transferred his party to Calais. From this point the surveys of Assistant Longfellow, between Devin's Head to Robbinston, and of Assistant C. M. Bache from Robbinston to North Perry were inspected, and field operations were then closed.

Mr. Donn has communicated in much detail to the Superintendent the results of his topographical inspections, and the suggestions he makes will be given careful consideration.

For his own surveys he reports the following statistics:

Topography:

Number of miles of shore line surveyed	20
Number of miles of roads surveyed	31
Number of miles of shore line of creeks	31
Area surveyed, in square miles	32

During the early part of the winter Mr. Donn was engaged in office work, and in January, 1890, received orders for duty in the vicinity of Norfolk, Virginia, reference to which will be made under a heading in Section III.

Examination of changes for additions of topographical details to the shore lines of the Kennebec River from Bath to Gardiner.—In order to obtain data needed to publish a chart of the Kennebec River brought up to date, from Bath, Maine, to the bridge at Gardiner, it became necessary to detail an officer to make additions of topographical details to the topographic sheets of that river executed in the years 1858 to 1860 and 1869–'70. Instructions were accordingly issued to Assistant H. L. Whiting, February 15, 1890, to proceed to Bath, taking with him the original sheets, and to note on them such wharves, ice houses, etc., as had been built along the river, and also to supply any names of towns, villages, islands, etc., that might be wanting.

Upon reaching Bath, early in March, and finding the conditions there not very favorable for field work, Mr. Whiting changed his location to Gardiner, and from that town as headquarters he carried the work over the two upper sheets of the survey of 1869–'70.

In executing this work entire reliance had to be placed upon the original topography, executed by the party in charge of Assistant C. H. Boyd. The lapse of time, 20 and 21 years, since the surveys were made had obliterated all surface indications of the original triangulation stations, and the snow covering the frozen ground made it impracticable to search for underground marks. It became necessary, therefore, to use such points as the topography furnished, houses and other conspicuous objects, for fixing the stations upon which the determination of the new features could be based. There were, however, some localities near the city of Gardiner and the village of Richmond where the church spires of these places were available.

Mr. Whiting observes that it is not customary nor even practicable in ordinary topographical surveys to fix each house with enough accuracy to make it a trustworthy base point, and that it becomes necessary, therefore, in selecting such objects as will produce good results to make differential tests that tax both the time and judgment of the surveyor. He expresses his gratification at having found the original work essentially good, most of the conspicuous houses, and even barns, having been determined with care and accuracy. He was surprised at the closeness with which the positions of almost every ice house agreed with the details of the shore topography, particularly when it was considered that their details were fixed from entirely independent bases.

Below the Gardiner bridge Mr. Whiting determined in position for delineation on the topographical sheets forty-one ice houses, with an aggregate capacity of 1,076,000 tons. All of the principal wharves on the river were also added to the sheets. No personal examination of the river above Gardiner was made, but, with the present interest in the ice question, Mr. Whiting deemed it worth while to obtain an approximate statement of the resources of that part of it, as follows: On the west bank of the river between the Gardiner bridge and the dam, at Augusta, nine ice houses with a storage capacity of 202,000 tons, and on the east bank between the same limits four ice houses with a capacity of 101,000 tons.

Immediately after the completion of the work on the upper part of the river, Mr. Whiting proceeded to Bath, where he began field operations March 17, and closed them March 21. During this time he made a careful revision of the wharf line, examining each pier and dock along the city front, a distance of about 4 miles. He observes that the changes which have occurred along this line since the original survey of 1859–'60 are not considerable or important, and do not affect the navigable freedom of the river or the approaches to the city wharves. The most characteristic change is in the filling up of some of the old docks and basins; the most marked change is that of the terminal grounds of the railroad.

It was not practicable to make stations for plane table use on the water front, each pier end being occupied by large vessels loading with ice, but by careful reference and measurements to the details of the former survey, the new features were put as nearly in place as the scale would allow.

The most considerable advance of the wharf line of the city into the river channel was found to occur at the new landing pier of the Kennebec and Boston Steamboat Company. A satisfactory station was made at this point, which controlled not only that particular wharf, but the outer alignment of many of the wharves to the north and south of it.

Mr. Whiting in closing his report refers to the very close and accurate character of the original survey which was made by Assistant R. Meade Bache in the years 1858–1860, and but for which he could not have accomplished the revision he made within the time and by the methods which he found sufficient for the purpose.

The original sheets with the additions have been returned to the office.

Other service assigned to Mr. Whiting is referred to under headings in this section and in Section III.

General direction of town boundary surveys in the State of Massachusetts.—Service as a member of the Mississippi River Commission.—Assistant Henry L. Whiting has submitted a general report of the services performed by him during the fiscal year. In the earlier part of the year he made inspections of the work of topographical parties on the Massachusetts coast, and continued to supervise the town boundary work in Massachusetts as one of the Commissioners of the Topographical Survey of the State.

In October he was called to Washington and instructed to examine and make a final award respecting the portion of boundary line in dispute between the States of Maryland and Virginia. Reference to this duty will be found under the head of "Special Operations," and Mr. Whiting's report in regard to it is published as Appendix No. 11 to this volume.

Returning to Massachusetts towards the end of November, Mr. Whiting's service was almost wholly given to the State Commission in conducting the closing operations of the season's field surveys, in preparing the annual report of the Commission, and in making projects for future work on which State appropriations for the succeeding year were to be based.

In February, Mr. Whiting took up under instructions an examination of the shores of the Kennebec River between Bath and Gardiner. Details of this work are given under the preceding heading.

Towards the end of March he proceeded to Washington, having been directed to examine and report upon the condition of the topography of the Atlantic coast. The time available for this work permitted only a review of that part of the coast from the eastern boundary to Delaware Bay. Mr. Whiting submitted eight separate reports on this subject, accompanied by projects for future field surveys with estimates of their cost.

Under date of June 10, Mr. Whiting received from the President of the United States his appointment as a member of the Mississippi River Commission, and was duly qualified. At the close of the fiscal year he was occupied with the work of the Massachusetts State Survey, and with studies relating to the Mississippi River.

Determinations of town boundaries in the State of Massachusetts continued.—The work of determining in geographical position the corners of town boundaries in the State of Massachusetts was in progress at the beginning of the fiscal year in the immediate charge of Assistant C. H. Van Orden. As stated in the last annual report, he took the field in the town of Bridgewater, May 13, 1889. The general plan of the work was that followed in previous seasons: observations upon a town corner from stations of the old triangulation, making it when practicable a point in a triangle, but when not, to determine a point as near as possible to the corner and run a carefully measured traverse to it and determine its azimuth. These traverses were often measured with a rod, particularly when the surface of the ground was much broken, the angles of elevation and depression being observed, and care taken to have sufficiently short sights.

This method, Mr. Van Orden thinks, is, on rough ground, one more rapid, more accurate, and more easily checked than chaining.

From the town of Bridgewater the work was carried to the eastward to join work already completed along the coast, and westwardly to the Rhode Island line. As the season advanced one section of the party moved to the town of Whitman, and the other section to Attleborough. The towns of which the boundaries were determined were sixteen in number; namely, Hanover, Pembroke, Hanson, Halifax, Plympton, East Bridgewater, Whitman, Abington, Rockland, West Bridgewater, Bridgewater, Easton, Mansfield, Norton, North Attleborough, and Attleborough. These include all of the towns along and on the southerly side of the Old Colony Line, as it is called, which extends in substantially a straight course between Scituate and Cohasset to the Rhode Island line, between Attleborough and Wrentham.

Mr. Van Orden's work was conducted, as in previous seasons, under the general direction of the Commissioners of the Topographical Survey of the State of Massachusetts, these Commissioners being General Francis A. Walker, President of the Massachusetts Institute of Technology, Henry L. Whiting, Assistant U. S. Coast and Geodetic Survey, and Prof. N. S. Shaler, of Harvard University.

In the report of these Commissioners for 1889, made to the Governor of Massachussetts, they state that it is mainly through the aid of the Coast and Geodetic Survey that the town boundary work has been carried on; that they have received from that department the expert personal service of members of its corps, the use of costly instruments, and the advantage of carefully prepared forms for observations, computations, and records.

They acknowledge, also, the very liberal spirit which has been manifested by the various railroad officials of the State, particularly by President Choate of the Old Colony road, in giving the fullest facilities of transportation to the Commission and to the field parties of the survey, whenever their work has called them over their lines.

Mr. Van Orden expresses his obligations to the foremen in his party, Mr. Joseph B. Tolley and Mr. E. E. Peirce, for zealous and skillful service throughout the season.

Field operations were closed November 22. The statistics of the work are as follows:

Number of town corners determined	89
Number of town boundaries completed	16
Number of town boundaries partly completed	10
Number of stations occupied	103
Number of traverse and base stations occupied	99
Number of points determined	95
Area of triangulation in square miles	575

After the completion of his field work Mr. Van Orden was directed to proceed to the office of the Commission in Boston, and make such arrangements there under Mr. Whiting's general direction as would enable him to bring up to date during the winter the records and results of the season.

This work consisted in making a preliminary computation of the geographical positions of all the points determined, and in duplicating the records of observation and the descriptions of stations. As about one-third of the stations were occupied eccentrically, this added largely to the time and labor of computation.

About the middle of May, Mr. Van Orden was instructed to resume field work under the general direction of Assistant Whiting. A careful reconnaissance was taken up without delay in the towns of Lakeville, Freetown, Dighton, Rehoboth, Taunton, Raynham, Middleborough and Carver, and at the close of the fiscal year the town boundary survey was in active progress.

Messrs. Tolley and Peirce, who had aided during the winter and spring in making the computations, etc., were again attached to the party in the field.

Up to June 30, 1890, the statistics reported are:

Reconnaissance of town corners (number of)	85
Signals built	46
Stations occupied	22

Physical hydrography.—Continuation of the physical survey of the coast of Cape Cod Peninsula.— At the beginning of the fiscal year the party which had been organized by Assistant H. L. Marindin for the continuation of the physical survey of the coast of Cape Cod Peninsula was in camp at High Head in the town of Truro, that having been their headquarters since the date of beginning field operations, May 20. The part of the coast line which had been examined since that date was comprised between Cape Cod Light-House and Peaked Hill Life-Saving Station.

This work was carried on under instructions prepared in extension of the plan outlined in the memorandum of 1887 drawn up by the Chief of Physical Hydrography, and the observations included measurements of the coast line in cross-section from points far enough inland to determine the nature of the barrier to the sea, and extending seaward to a depth of 36 feet. These cross-sections will, it is believed, offer the best means of determining the waste of the shores by comparison with previous and future surveys.

The cross-sections were joined by lines of precise leveling, and tidal stations and numerous bench marks established as the work advanced. Topographical surveys were made of those parts of the coast showing marked changes since the surveys of former years; notably of that portion of the Cape situated between High Head and Provincetown, where a large area of salt-water and salt-marshes has been changed to a fresh-water pond and meadow lands by the closing of the inlet from Cape Cod Bay into this "East Harbor," as it was once called. A plane table sheet (scale 1-10000) delineating these changes will be sent to the Archives with the field-records.

The hydrographic surveys will be comprised in two sheets, each on a scale of 1-10000, which will contain the cross-sections of the shore and the water contours to 36 feet in depth.

These sheets join those completed the year before at Highland Light-house, and include the distance around the west end of Cape Cod to Long Point Light-house. Within these limits one hundred and seventy-two cross-sections were measured, averaging about 150 metres (492 feet) apart. From a preliminary comparison of the results derived from the cross-sections with the published charts, it is quite evident that some shoals exist which are not on the charts, and that others have changed position or entirely disappeared.

Information having been received from Mr. William Holden, of High Head, Truro, that owing to a break in the bluff-line made by wind and waves somewhere in the vicinity of the Peaked Hill life-saving station, the Light-house at Long Point had become visible over the land to vessels passing along the outside or north shore of the cape, a comparison was made with Assistant Whiting's survey of 1848, and the position of the break identified. A Notice to Mariners relative to this was shortly after published.

A plane-table determination was made of Highland, High Head, Peaked Hill, and Crow Hill life-saving stations. Two of these stations were found to have shifted position since the previous determination, and the charts have been corrected accordingly.

Mr. Marindin had the aid of Messrs. E. E. Haskell and Homer P. Ritter as expert observers, and he acknowledges the eminent value of the service they rendered. Messrs. George T. Bartlett and Elmer E. Snow served as recorders.

For the season which ended September 23 Mr. Marindin presents the following statistics:

Physical hydrography—	
Number of miles of cross sections laid out and measured	228
Number of cross sections sounded	231
Number of soundings on cross sections	14,288
Number of plane-table determinations of section marks	108
Number of miles of low-water line determined	10
Number of miles of shore line run	27
Number of miles run of geodetic leveling	30
Number of miles run of common levels	31
Number of miles of roads and railroads run by plane table	19
Number of points determined for plane-table work	37
Area of topographical changes surveyed in square miles	4
Number of horizontal angles measured	329
Number of tidal stations occupied	4
Number of permanent bench-marks established	7

After closing field operations Mr. Marindin proceeded under instructions to Washington, and reported for duty at the Office, where he took up the reduction and discussion of his observations.

In this work he had the assistance of Messrs. Haskell and Ritter, who reported at the Office October 1. From this date until May, 1890, with some interruptions for special duty, the party was engaged on unfinished computations of physical hydrographic work. In December, 1889, Mr. Ritter was detailed for topographical service on the New York City Front, a report of which will be found under a heading in Section II. He was again detailed for field service in February, 1890, and ordered to join the party of Assistant Welker in Florida. Towards the end of March he resumed office duty. In April, Mr. Marindin was instructed to make a hydrographic examination in the Potomac River. An abstract of his report of this service is given under a heading in Section III. In May he submitted a special report on cross-sections of the shore of Cape Cod between Chatham and the Highland Light-house; this was published as Appendix No. 13 to the Report for 1889.

Having received instructions bearing date of May 13, 1890, to organize his party for continuing physical hydrographic work on Cape Cod and on the island of Nantucket, Mr. Marindin took up preparations for field work. His departure from Washington was temporarily delayed in order to prepare for the Superintendent a report on the progress of the physical hydrographic work of the Survey, to do which it was necessary to consult the annual reports and other documents as far back as the year 1864.

Mr. Haskell was detached about this time and ordered to special service on Long Island Sound, reference to which will be found under a heading in Section II. Early in June, Mr. Marindin, accompanied by Mr. Ritter, proceeded to Provincetown, Mass., and on the 16th of the month were joined by Mr. F. A. Young as recorder.

The field work was begun June 10. It consisted in the delineation of the topographical changes within the harbor of Provincetown; in sounding out the cross-sections, the limits of which had been fixed during the previous season, and generally in such observations as were needed to complete the physical survey of this important harbor, and to furnish data for the publication of a new edition of its chart.

This survey was finished before the end of June, and arrangements were begun to transfer the party to Nantucket to continue the physical hydrography of the coast of Massachusetts.

Following are the statistics of the Provincetown work:

Examination of changes in wharf line and in marsh and beach lines:	
Number of miles of shore line surveyed	8
Number of miles of creeks surveyed	3
Area of country (approximate) in square miles	2
Hydrography:	
Number of miles of cross section sounded	15
Number of soundings on cross sections	1,074

One hydrographic sheet, scale 1-10000, on which the changes in topographical features were delineated, was sent to the Office.

Hydrographic resurveys in Nantucket Sound and vicinity.—Reference was made in the last Annual Report to the beginning of the hydrographic resurveys in Nantucket Sound and vicinity, executed during the summer and autumn of 1889 by the party in charge of Lieut. W. P. Elliott, U. S. N., Assistant Coast and Geodetic Survey, commanding the schooner *Eagre*.

Lieutenant Elliott's work was laid out upon three projections, one on a scale of 1-10000, including Chatham Roads and Stage Harbor; one on 1-20000, including that part of Nantucket Sound westward of Chatham Roads to Point Gammon, and thence southward and eastward, taking in Bishop and Clerks, Handkerchief and Shovelful Shoals, to Monomoy; and one on a scale of 1-20000 extending from Cape Poge to the west end of Nantucket Island, and including portions of Muskeget Channel and the shoals and banks in the vicinity of Muskeget and Tuckernuck Islands.

Four descriptive reports have been submitted by Lieutenant Elliott to accompany his hydrographic sheets. One of these is a general report, in which he reviews the hydrographic characteristics of the localities under resurvey, refers to the importance of a thorough development of the channels and a thorough knowledge of the dangers that beset the throngs of coasting vessels which dot the whole expanse, alludes to the changes taking place in the configuration of the shoals and to the irregular and conflicting tidal currents, and recommends as additions to or substitutes for present aids to navigation a whistling or bell buoy at the northwest corner of Handkerchief Shoal in place of black buoy No. 3, and a bell buoy in place of the small spar buoy which now marks the *slue* off Nantucket Entrance. The tidal curves at Powder Hole, Monomoy, at Stage Harbor, at Dennisport, at Bass River, and at Tuckernuck Island are represented graphically on a diagram accompanying this report.

For each projection a separate report has been filed in the archives. Between Cape Poge and the west end of Nantucket Island there remained three irregularly shaped gaps in hydrography to be filled in; these were on the various shoals to the westward of Tuckernuck Shoal and north of Muskeget Island, and the work was particularly difficult from the fact that the natural objects and signals visible were few in number and at great distances. Special care was taken to develop changes in the shoals, and it was found upon examination that Long and Shovelful Shoals had grown together at their southern ends, and had formed a continous bank. Details with regard to other changes observed are given in the report. The tidal station established on Tuckernuck Island in 1854 by Professor Mitchell was re-occupied and mean sea level determined from observations of day tides during two lunar months. A second tide gauge was set up at Cape Poge, and its indications were referred to a bench-mark fixed in 1888 by Lieut. S. C. Paine, U. S. N., Assistant Coast and Geodetic Survey. Sketches showing location of the tide guages and bench-marks are appended to the report.

The two reports relating to the work at Chatham and Stage Harbor and on the north shore of Nantucket Sound are equally full and comprehensive, and indicate the great interest taken in the work by the chief of the party and the officers under his command. In the compilation of a new edition of the Coast Pilot for the waters in this vicinity the results of these resurveys will be of special value.

On October 22, Lieutenant Elliott closed work, and proceeded under instructions with the *Eagre* to the New York Navy-Yard.

At the outset of the season, Ensign L. S. Van Duzer and E. A. Anderson, U. S. N., were attached to the party. On July 12, Ensign Anderson was detached and ordered to duty in the Office; Ensign Van Duzer was detached August 10, and ordered to duty in the Bureau of Navigation, Navy Department. Ensigns L. C. Bertelotte, E. H. Durell, F. H. Brown, C. M. Stone, and T. Washington, U. S. N., reported for duty in July and remained until the close of the work. Lieut. A. L. Hall, U. S. N., reported for duty August 21, and on October 12 was detached and ordered to command the Coast Survey steamer *Endeavor*. Pay yeomen A. R. Hasson and Irving King served as draftsmen and recorders. The general zeal and interest in the work displayed by both officers and men gave great satisfaction to their commander.

For the season the statistics are:

Number of miles run in sounding	1,616
Number of angles measured	13,762
Number of soundings	40,563

Duty assigned to Lieutenant Elliott in January and March, 1890, is referred to under headings in Section II.

Continuation of the offshore hydrography south of Nantucket and Martha's Vineyard.—Upon returning from a successful season's work on the coast of Florida towards the end of May, 1889, Lieut. J. F. Moser, U. S. N., Assistant Coast and Geodetic Survey, commanding the steamer *Bache*, was instructed to put the vessel in condition and make all needed preparations for the resumption, at the earliest date practicable, of the coast and offshore hydrography to the southward of Nantucket and Martha's Vineyard. This was an extension of the work begun by Lieutenant Moser in the summer of 1887 at Point Judith, and carried to the eastward during the summer of 1888.

The projection upon which work was begun early in July, 1889, extended from No Man's Land to Sankaty Head. Scale 1-40000. Work was also prosecuted as opportunity served, on a projection, scale, 1-20000, covering an area on the south coast of Nantucket from Surfside life-saving station to the westward. The system of lines adopted for the development of the hydrography was similar to that of preceding seasons, viz, lines normal to the coast every half mile for a distance of 6 or 7 miles, and thence normals every mile to the limit of work to seaward. This system is then crossed by lines half a mile apart for a distance of 6 or 7 miles from the shore, and thence seaward the cross lines are gradually spread, until at the seaward limit, where they are 1½ miles apart. The boat system connecting the shore line with the ship varies as the formation demands. Where the shore line was bold, a simple system of connecting traverses was deemed sufficient, but in the vicinity of shoals and inlets a more thorough development was aimed at.

Lieutenant Moser reports that the season was an exceptionally unfavorable one, and that the most unremitting effort to complete the work was of no avail under the adverse conditions that prevailed. The weather was decidedly rainy, and when it did not rain it either blew a gale of wind or the atmosphere was thick with fog or haze. Day after day the *Bache* steamed outside without getting a cast of the lead. It was found impossible to do offshore ship work successfully where the signals could not be seen at least 8 miles.

The work was at a long distance from port, about 35 miles from any shelter, and such a harbor as could be made was either through Muskeget Channel, or between Old Man and Bass Rip Shoals, neither of which could be used at night, and both are treacherous and dangerous even to those acquainted with the locality. Another drawback to progress this season was that a system of signals had to be maintained over a coast line of 40 miles, and the frequent wrecking of these signals by gales of wind caused the party great inconvenience.

Lieutenant Moser observes that this part of the coast is clear of all commerce. No vessels engaged in the carrying trade are ever found between No Man's Land and Nantucket Shoals, unless off their course. All of the coast trade passes inside and through the sounds, and the ocean track lies well outside. During the summer months many fishermen will be found between No Man's Land and Muskeget, and some few a short distance to the eastward, the sailing craft being generally engaged in swordfishing, and the steamers in seining menhaden. At one time, twenty-one menhaden steamers were counted in sight south of Martha's Vineyard.

With regard to the currents, Lieutenant Moser states that they vary greatly in force and direction, and that a thorough investigation of them is much to be desired. He calls attention to the immense number of *Physalia atlantica* (Portuguese men-of-war) which during the summer, in fine weather, fairly covered the localities of his surveys, and which, since they come to life and mature in tropical seas, must be carried northward by the Gulf Stream, but then the question constantly presented itself, how they reached the waters off the south coasts of Nantucket and Martha's Vineyard. The Gulf Stream at Hatteras trends to the eastward, and more to the eastward as a higher latitude is reached, and then the prevailing winds in summer are from the southwest.

Lieutenant Moser renews the recommendations made by him last year for the establishment of a sea buoy at Muskeget Channel and the construction of a first-order light-house on No Man's Land. His experience and observation during the season confirmed to his mind the correctness of these suggestions. While the comparatively safe inside part of Muskeget Channel is buoyed, the dangerous bar has been left unmarked. He maintained with difficulty a barrel buoy there all summer, and captains of fishing steamers would come to him for directions to enter. As many as thirty fishing vessels, steamers and sail craft, were seen within 6 miles of the shoals at one time.

With regard to No Man's Land he observes that a seacoast light there would be 5½ miles further seaward than Gay Head, and that at this latter point a third or fourth order light, as a guide to the entrance to the Sound, would serve all necessary requirements.

In addition to the regular work of the party an examination was made off Cape Poge, which resulted in the location and development of a rock with but 4 feet of water upon it, 1,000 yards southeast three quarters south from Cape Poge Light. Reference is made to this rock in Notice to Mariners for August, 1889 (No. 119).

An 8-foot uncharted bowlder having been reported to the southwest of Nobska Point, Lieutenant Moser made search in the locality and found one 8-foot bowlder and two of less depth, but according to his informant, Mr. Gifford, the one reported was farther offshore. A thorough search was then made by sounding and dragging during two days on all of the ranges given, and half a day was spent, with Mr. Gifford in the boat, without finding anything. A 15-fathom ledge known as Cox Ledge, supposed to lie about 15 miles southwest of No Man's Land, and which the lines of soundings run the preceding season did not indicate, was again looked for without success.

To obtain a plane of reference for the soundings, a tide gauge was established at No Man's Land, and referred to a well-known bench-mark on a rock near by. The height of this bench-mark above the plane of mean low water, as furnished by the Office, was used to determine the constant for the correction of the tide-gauge readings. Special care having been taken to secure this gauge in position it remained undisturbed during the entire season, notwithstanding the many violent gales. Tide gauges were located also at Wood's Holl and Uncatena Island.

The following-named officers were attached to the *Bache:* Ensigns H. A. Bispham, R. D. Tisdale, S. M. Strite, L. C. Bertolette, and W. S. Cloke, U. S. N.; Passed Assistant Surgeon J. M. Steele, U. S. N., and Passed Assistant Engineer E. H. Scribner, U. S. N.

Messrs. George R. Jones and J. L. Dunn served as recorders. Ensign Bispham, under Lieutenant Moser's direction, had charge of the tide gauges and gave careful attention to the observations.

For the season, which ended October 31, the statistics are:

Hydrography:

Area sounded in square geographical miles	500
Number of miles (geographical) run while sounding	1,015
Number of angles measured	3,929
Number of soundings	14,662
Number of tidal stations established	3
Number of specimens of bottom preserved	15

Descriptive reports giving full details relating to the work have been filed in the Archives.

Towards the end of December, Lieutenant Moser was instructed to resume his hydrographic work on the west coast of Florida from the limits of his surveys of the preceding season. Report of this service will be found under a heading in Section VI.

Completion of the topographical resurvey of Wood's Holl and vicinity.—Under instructions dated towards the end of June, 1889, Assistant W. I. Vinal was directed to resume his topographical resurveys in Wood's Holl and vicinity from the limits of his work of the previous season. Arriving at the locality July 5, Mr. Vinal immediately organized his party, put up the necessary signals, and began field operations.

The characteristic features of the area under resurvey in Wood's Holl and vicinity, and on the islands of Nonamesset, Naushon, and Uncatena, were village and county detail; cultivated, open, and densely wooded land; underbrush, salt and fresh marsh; wooded swamps and cranberry bogs; rocky shore line; contours, bluffs, and escarpments. Scale of resurvey 1-5000, contoured to every 10 feet of elevation, and showing terminal 5-feet curves.

Tracings of shore line and positions of objects on shore were furnished to Lieut. J. F. Moser, U. S. N., Assistant Coast and Geodetic Survey, in charge of the hydrographic party on the steamer *Bache.*

Field operations were closed November 5. For the season the statistics are:

Topography:

Area surveyed in square statute miles	5
Length of general coast in statute miles	6
Length of shore line of creeks and ditches, of ponds and marsh line, in statute miles	7
Length of roads in statute miles	17

For a short time after leaving the field, Mr. Vinal was engaged in office work, and towards the end of November was instructed to report for duty on the Gulf coast.

Topographical resurvey of the Elizabeth Islands, between Buzzard's Bay and Vineyard Sound, and of the Woepecket Islands, Buzzard's Bay.—The topographical resurveys assigned to the charge of Subassistant E. L. Taney by instructions dated May 30, 1889, included a resurvey of the Elizabeth Islands off the coast of Massachusetts to a junction with the work of Assistant Vinal, near Wood's Holl, and a resurvey of the three small islands of the Woepecket group in the southeastern part of Buzzard's Bay.

Reference was made in the last Annual Report to the beginning of this work on Cuttyhunk Island, June 8. The resurvey of this island was made on a scale of 1-5000 (12.67 inches to the statute mile), and contour lines were run for every 10 feet of elevation. The islands of Penikese, Nashawena, and Pasque, were resurveyed on a scale of 1-10000, and the shore line of Naushon Island delineated from the west end to the limits of Mr. Vinal's survey. Naushon Island is thickly wooded, and time was not available for a detailed survey of the interior. This, Mr. Taney recommends, should be done in the early spring before the trees and undergrowth are in leaf.

Much difficulty was experienced owing to the prevalence of fog during June and July, and from many severe storms of long duration during the rest of the season, Since not more than one station point could be recovered or any one of the islands, a plane-table triangulation was found necessary to furnish enough points to complete the work.

Field operations were closed November 9. For the season the statistics are reported as follows:

Topography:

Number of miles of shore line run	49
Area (approximate) surveyed in square miles	5

Establishment of a naval trial course by laying out a measured sea-mile in the Eastern Passage, Narragansett Bay.—An abstract of the report of Lieut. J. E. Pillsbury, U. S. N., Assistant Coast and Geodetic Survey, commanding the steamer *Blake*, who was detailed for the duty of laying out a naval trial course in Narragansett Bay, in July, 1889, will be found under the heading of "Special Operations," towards the close of Part I, of this volume.

The statistics of this service, which was finished August 12, are as follows:

Beach measurement, length of, in miles	1
Number of signal poles erected for triangulation	9
Number of stations occupied for measuring horizontal angles	11
Number of miles (geographical) run while sounding	9
Number of angles measured (sextant)	70
Number of soundings	100
Number of current stations occupied	4
Number of hours employed in observing currents	332

In October, Lieutenant Pillsbury was instructed to prepare the *Blake* for the next season's work in the Gulf Stream, and in December took command of the steamer, and, accompanied by Lieut. Charles E. Vreeland, U. S. N., as second in command, proceeded to Hampton Roads, on the way to Key West.

On December 12 he was relieved in command of the *Blake* by Lieutenant Vreeland, and instructed to continue the preparation of his general report on Gulf Stream exploration.

SECTION II.

CONNECTICUT, NEW YORK, NEW JERSEY, PENNSYLVANIA, AND DELAWARE, INCLUDING COAST BAYS, AND RIVERS. (SKETCHES Nos. 1, 4, 5, 19, and 20.)

Establishment of a trial course off the coasts of Block Island and Long Island for the speed tests of the new naval war vessel Philadelphia.—Under the heading of Special Operations, towards the close of Part II of this volume, is given an abstract of the report of Lieut. Charles E. Vreeland, U. S. N., Assistant Coast and Geodetic Survey, commanding the steamer *Blake*, to whom, in compliance with a request of the Secretary of the Navy, and with the approval of the Secretary of the Treasury, was assigned the duty of laying off a trial course for the speed tests of the new armored cruiser, Philadelphia.

Projections covering the locality finally selected, off the south coasts of Block Island and Long Island, were furnished to Lieutenant Vreeland, and by the aid of these, upon which were plotted the points of triangulation already determined on those coasts, he was enabled to locate accurately the needed range marks. For details, see the abstract of his report. The *Blake* was occupied in this service between May 17 and June 10, 1890.

Duty in the exploration of the Gulf Stream executed by Lieutenant Vreeland during the winter of 1889–'90, is referred to under a heading in Section VI.

Observations in physical hydrography on Long Island Sound in connection with the survey of the U. S. Fish Commission in those waters.—An opportunity having been afforded by the cruise of the U. S. Fish Commission steamer *Fish Hawk*, in Long Island Sound and adjacent waters, in the season of 1890, for prosecuting certain important investigations in physical hydrography, Mr. E. E. Haskell, expert observer, Coast and Geodetic Survey, was directed to report in person to Mr. Richard Rathbun, in charge of the scientific investigations of the Commission, who would assign him quarters on the *Fish Hawk*, Lieut. Robert Platt, U. S. N., commanding. Boats and crews with a number of observers were to be furnished from the steamer when required for the observations. These were to consist of:

(1) Tide observations at three points on the shores of the Sound, preferably at Willets Point, at New Haven, and at or near New London, the tidal record to be obtained by means of automatic gauges.

(2) Observations of currents, to be made on each of the dumping grounds off the coast of Connecticut, and at such grounds located on the Long Island shore. Densities and temperatures were to be noted at the same time and specimens of the bottom to be preserved.

(3) Gaugings of discharge: For this purpose transverse sections were to be occupied with as many stations for simultaneous observations as the number of current meters would allow at both ends of the Sound, one east of the mouth of the Connecticut River, and the other in the vicinity of Matinicock Point.

(4) Current observations along the axis of the Sound for the use of mariners; the stations to be located along the axial line at distances apart of about ten miles, and to be occupied for one ebb and one flood. Densities and temperatures to be noted in connection therewith.

Mr. Haskell joined the *Fish Hawk* at St. George, Staten Island, New York, on June 6, and immediately began preparations for the tidal and current work. The current meters to be employed were rated in Factory Pond, Staten Island, and by permission of Col. W. R. King, U. S. Engineers, a tide-gauge of the Coast and Geodetic Survey pattern was set up at Willets Point, East River, to replace the old gauge, which worked poorly.

On June 13, the *Fish Hawk* arrived at New Haven, Conn., and a tide-gauge was established on a wharf at Five Mile Point. At New London, where the steamer arrived on the 18th, no very satisfactory site for an automatic tide-gauge could be found; one was finally selected, however, on the wharf of the Pequot House.

From the 18th of June till the end of the fiscal year the time was occupied in obtaining supplies needed for fitting out current meters. These arrived on the 27th instant, and on June 30, 1890, the steamer was at Saybrook Point, Connecticut, waiting for weather that would permit observations.

A full abstract of work accomplished during the season will appear in the next Annual Report.

Shore-line and hydrographic resurveys of Shinnecock and Quantuck Bays, south coast of Long Island.—In continuation of the resurveys of shore-line and hydrography on the south coast of Long Island, Assistant C. T. Iardella organized his party under instructions dated towards the end of June, 1889, and early in July began topographical work from the limits of his resurveys of the preceding season at the east end of Moriches Bay.

The triangulation signals which had been erected during the summer of 1888 had all been destroyed by heavy gales of wind, and in one instance a signal (Point Inlet) which stood on a high sand hill had been entirely washed away. Some delay was caused, therefore, at the outset until the signals needful could be put up again. This having been done, a connection was made with the plane table survey of 1888, at the east end of Moriches Bay, and work carried on to Quantuck Bay through the canal which was cut some years ago between these two bays.

Quantuck Bay is about 2,200 metres (7,218 feet) long, and 1,300 metres (4,265 feet) wide, with an average depth of water of 8 feet. After finishing the shore line resurvey of Quantuck Bay, that of Shinnecock Bay was taken up, and also the resurvey of the outer beach line to the end of the bay, a distance of 12 miles.

Shinnecock Bay is 10 miles in length, and from 1 to 3 miles in width. At the time of Mr. Iardella's resurvey, its only outlet to the ocean was Fire Island Inlet, 45 miles distant. Old Inlet, abreast of Atlanticville, and three other inlets were closed by a heavy southeast storm during the month of May, 1889. The canal between Peconic and Shinnecock Bays, for opening which an appropriation was made by the State of New York, has not proved to be a success, being almost closed in some places by the falling back of sand into it from the undermining of the banks by the flow of the tide. One effect of the closing of the ocean inlets has been to lessen the depth of the main channel in the bay. But 10 feet can now be carried from the canal for the whole length of the bay.

Field operations were closed October 14. For the season, the statistics of the resurvey, which was executed on a scale of 1-10000, are as follows:

Topography:

Area surveyed in square statute miles	12
Length of general coast line in statute miles	12
Length of shore line of bay in statute miles	64
Length of shore line of creeks and ponds in statute miles	9
Length of roads in statute miles	9

After leaving the field Mr. Iardella reported for duty to the Office, and was there occupied in inking his topographical sheets until early in December, when he was ordered to join the party of Assistant Stehman Forney, on the western coast of Florida. Reference to this duty will be found under a heading in Section VII.

Upon his return from Florida, Mr. Iardella reported for duty at the Office, and between March 21 and May 14 was engaged in inking his topographical sheets.

On May 15, he left Washington under instructions to resume his resurveys on the south coast of Long Island, from the limits of his work of the preceding season, carrying them to the eastward, and taking up as soon as practicable the hydrography of the interior waters on the south shore.

After replacing four signals which had been blown down by the winter gales, he began topographical work May 21 at Indian Reservation, and continued it to South Hampton, reaching that point June 23. He then took up the hydrography, and was prosecuting that at the close of the fiscal year. Up to June 30, 1890, the statistics are:

Topography—	
Number of miles of shore line surveyed	12
Number of miles of roads surveyed	3
Number of miles of creeks and ponds surveyed	4
Area surveyed in square statute miles (approximate)	6
Hydrography—	
Number of miles of sounding lines run	25
Number of angles measured	97
Number of soundings	2,555

Shore-line examination for the determination of changes in and additions to New York City front, between West Sixty-seventh street, Hudson River and Blackwell's Island, East River, including also the shore lines on the New Jersey and Brooklyn sides of the harbor, and a shore line examination of the Raritan River from Tottenville, N. Y., to New Brunswick, N. J.—For the purpose of noting all the changes in and additions to the wharf fronts of New York Bay and Harbor that had occurred since the survey of 1885, Mr. Homer P. Ritter, expert in physical hydrography, was temporarily detached from office duty under the direction of Assistant Marindin, and under instructions dated November 11, 1889, was ordered to proceed to New York City and make a thorough examination of the shore line from West Sixty-seventh street on the North River round by the Battery to Blackwell's Island, East River, including also the shore lines on the New Jersey and Brooklyn sides of the harbor. That done, he was further instructed to make a similar examination of the Raritan River.

With the aid of a steam launch, boat's crew and instruments, furnished by Lieut. W. P. Elliott, U. S. N., Assistant Coast and Geodetic Survey, commanding the schooner *Eagre*, in compliance with a request from Lieut. Commander C. M. Thomas, Hydrographic Inspector, Mr. Ritter made a tour of the harbor front, comparing successively each portion of it with its representation on the chart No. 369–4, which was based upon the survey of 1885. Any change perceived was at once noted on the chart; measurements were taken and information in regard to it obtained, the data being entered also in a record book kept for the purpose. The corrected shore line was subsequently compared with the shore-line surveys of the New York Dock Commission, and with those of the Riparian Commission of New Jersey, permission to inspect the maps of these surveys having been kindly given.

Mr. Ritter states that his minute and rigid inspection of the shore lines showed that all the changes observed were due to alterations occurring since the survey of 1885 was made. These alterations, on the New York City front, were brought about mostly by the rebuilding of old piers, and by the gradual extension of all to an uniform pier line; and with regard to their effect on the physical status of the harbor he remarks that if a considerable portion of the reservoir capacity of the river has been encroached upon, this is balanced by the frequent dredgings which deepen the slips.

On the New Jersey shore the changes made are of a similar character and the same statement applies. The changes in the East River at the Brooklyn side were found not to have greatly altered the shore from a physical point of view, excepting, perhaps, where there has been a reduction in width in the vicinity of Blackwell's Island. But the important part which the East River plays in the regimen of New York Harbor, as pointed out so frequently by Henry Mitchell, for many years Chief of Physical Hydrography in the Survey, is now well known to both State and National authorities, and it is therefore quite improbable that any serious encroachment in the volume-carrying capacity of the stream would be permitted.

After the completion of the New York work a shore line examination was made of the Raritan River from Tottenville, N. Y., to New Brunswick, N. J. Charts embodying the changes noted on this river and on New York Bay and Harbor were forwarded to the Office.

Mr. Ritter returned to Washington December 7. He acknowledges his obligation for courtesies extended and aid afforded by the Hydrographic Inspector and by Lieutenant Elliott; also for facilities afforded by Mr. Walter G. Berg, principal assistant engineer of the Lehigh Valley Railroad Company. Permission to inspect the maps of their respective surveys was freely accorded by Lieut.-Col. W. McFarland, U. S. Engineer in charge of improvements in New York Harbor, and by Capt. Geo. McC. Derby, U. S. Engineers, in charge of the Raritan River improvements.

During the remainder of the winter Mr. Ritter was engaged in duty at the Office, and at the end of February was detached and ordered to join the party of Subassistant Welker on Pensacola Bay.

Hydrographic survey of the Wallabout Channel, New York Harbor.—In compliance with a request made by the Secretary of the Navy and by direction of the Secretary of the Treasury, instructions were given in January, 1890, to Lieut. Wm. P. Elliott, U. S. N., Assistant Coast and Geodetic Survey, commanding the schooner *Eagre*, to make a resurvey of the Wallabout Channel at the Navy Yard, East River, New York, in order to show what changes had taken place since the last survey, which was made in 1885; also what changes, if any, in the shoal near the southern entrance to the channel which was developed in 1889.

For this purpose Lieutenant Elliott was furnished with a projection, scale 1-2500, including the area of the desired resurvey, and he was directed to fill in the hydrography of the entire channel, and also that of the approaches to both entrances.

The work was taken up immediately after the receipt of instructions; a tide gauge was set up on the Cob Dock and continuous tidal observations maintained during one lunation, the zero of gauge being referred to a bench mark on the upper surface of the stone coping of the dry dock. The ends of each line of soundings run were located on the sea walls and dock walls of the Navy Yard, and having two observers on shore, the leadsman in the bow of the boat was fixed in position twice on each short line by simultaneous cross cuts at the dropping of a signal flag in the boat. Outside of the Cob Dock and Ordnance Dock the lines were generally run with one observer in the bow of the boat, who had a signal flag dropped at the instant of taking the angle, and was fixed in position by an observer on shore from a point as nearly as possible normal to the course of the boat.

A development of the shoal outside of the receiving ship *Vermont* at the western entrance to the Wallabout Channel was carefully made, and in addition to the lines plotted, many soundings were taken about the shoalest spot found. The least depth found by Lieutenant Paine in February, 1889, was 17 feet, but there is now a shoal spot having from $14\frac{3}{10}$ to $14\frac{9}{10}$ feet upon it. This spot is evidently shoaling, and the shape of the shoal was observed to have changed somewhat, being a little longer to the northward.

A systematic scheme of dredging is much to be desired, and it is understood that the present policy of the commandant is to formulate such a scheme from this resurvey.

Lieutenant Elliott reported the completion of the work February 12, and transmitted his hydrographic sheet and records to the Office. His descriptive report is filed in the Archives. He acknowledges the very acceptable service rendered by Ensign E. A. Anderson, U. S. N., who was temporarily detached from office duty to aid in the survey. Draftsman A. R. Hasson and Recorder W. S. Crosby, serving as pay yeomen on the *Eagre*, rendered efficient service as observers and recorders.

Hydrographic survey of the approaches to Ellis Island, New York Harbor.—Lieutenant William P. Elliott, U. S. N., Assistant Coast and Geodetic Survey, commanding the schooner *Eagre*, who was instructed in April, 1890, to make a hydrographic examination of the approaches to Ellis Island, New York Harbor, for the use of the Commissioners of Immigration, has reported that there is no practicable approach to the island except by the channel leading in on a range from South Brooklyn to the wharf facing southwest, and which has always been used for the handling of ammunition. Other wharves and bulkheads are inaccessible to any but small boats, and no channel can be made to them.

Lieutenant Elliott has transmitted to the Office with his report a tracing showing the corrected soundings in the channel leading to this principal wharf. He observes that it has been dredged from time to time, latterly about 4 years ago, to a depth of 10½ feet, and for a width of from 50 to 100 feet off the wharf, but it has now filled in considerably. It is contemplated to build a wharf 1,200 feet long, with a necessary turn of 30 to 45 degrees, so that boats for the transfer of immigrants can land at all tides and weathers, protection being gained against either northerly or southerly gales by using one or the other sides.

Lieutenant Elliott obtained much information respecting tides, currents, and depths from Quarterman Cook, who has lived at the magazine for 25 years. The northern and western approaches to the island are not capable of improvement, as ledges and bowlders are numerous.

In severe northerly gales, when the water is blown out of the bay, the bottom has been visible for almost the entire distance to the wharves on the north, and from southwest of the dredged channel to Bedloe's Island.

Tidal reductions were made from a gauge located at Governor's Island, where a plane of reference is marked. The tidal currents are not of great strength in the immediate vicinity of the wharf, but the projected wharf will reach out to a considerable ebb current in the ship channel. A part of the flood current comes up inside Bedloe's Island, and sweeps to the eastward on the line of the proposed wharf, and this current, Lieutenant Elliott thinks, has some scouring effect, obliterating and lessening the dredged channel.

The zeal and ability of Ensign E. A. Anderson, U. S. N., who was detailed to assist Lieutenant Elliott in this survey, are acknowledged in the report.

Tidal observations continued with automatic tide gauge at Sandy Hook, New Jersey.—At the automatic tidal station, Sandy Hook, New Jersey, the record was kept continuously throughout the year, Mr. David E. Snead having maintained it until January 31, 1890, when he was relieved by Mr. J. G. Spaulding.

The observer determined from time to time the relation of zero of tide-staff to the several bench-marks in the vicinity by running lines of level, so as to detect any change of the series in altitude.

Recovery and marking of a station of the primary triangulation in Pennsylvania.—It having been reported to the office that the tripod and observing scaffold which had been erected to mark the primary triangulation station "Governor Dick" in Lebanon County, Pennsylvania, had been removed and that there was danger of the station being lost, Assistant Stehman Forney was directed in July, 1889, to proceed to the station and take such measures as might be necessary for its preservation.

Upon his arrival he found that the underground station mark was undisturbed, but was unable to find any traces of the surface reference-stones placed in position by Prof. Mansfield Merriman, Acting Assistant, in 1883. The tripod and scaffold had also disappeared, and an observing tower was in course of construction over the site of the station by Mr. Robert Coleman.

Upon examination, Mr. Forney found that the center of the base of this observing tower was placed precisely over the center of the station, and, as the roof would soon be in place, he decided to make it available for the support of a pole to be plumbed over the station point, and to mark this point above the surface by a new stone pier. The pier was set carefully in position, its center being brought vertically over the station point. The pole, secured to the apex of the roof, was $2\frac{1}{2}$ inches in diameter and over 3 feet long.

Mr. Forney states that the observing tower vibrates too much to be used as a station from which to measure angles with a theodolite, since every movement on the platform at the top would disturb the adjustments of the instrument.

On July 29 he returned to Washington and resumed duty at the office. Towards the end of November he was instructed to organize a party for the survey of Perdido Bay, Florida. Reference to this service will be made under a heading in Section VII.

Determination of the longitude of Altoona, Pennsylvania, by exchanges of telegraphic signals with Washington, D. C. Observations for latitude at Altoona, and establishment of a meridian line.—In compliance with a request of the Pennsylvania Railroad Company, received through Mr. Theo. N. Ely, General Superintendent of Motive Power, referring to the desirability of obtaining a determination of the latitude and longitude of Altoona, and of the establishment there of a meridian line, instructions were issued towards the end of May, 1890, to Assistants C. H. Sinclair and R. A. Marr, to make the necessary arrangements for executing this work.

Mr. Sinclair having conducted the correspondence with Mr. Ely in regard to location of station, construction of instrument piers, etc., at Altoona, he was directed to occupy that station first, while Mr. Marr prepared for occupation the Coast and Geodetic Survey station in the grounds of the Naval Observatory.

The stones for the transit pier and meridian mark at Altoona having been made ready and a location for the longitude station selected by Mr. Ely, Mr. Sinclair arrived in Altoona, May 22, and put in place on a concrete foundation the sandstone pier for the transit instrument.

The station is on ground belonging to the railroad company above the small reservoir near the new shops, and is about 1 mile nearly due north from the railroad depot. The transit pier is a single block 5 feet long, 34 inches wide, and 20 inches thick. The concrete bed was 16 inches thick and about 30 by 40 inches in area. For one-half of its length the surface of the pier was below ground, and rough cut; the other half was dressed smooth and had the top cut away to allow ample space for the transit-reversing apparatus. In the center of the top and marking the station point, as well as the south point of the meridian line, is set a copper bolt, with cross-lines cut upon it, the intersection of which defines the point of reference for latitude and longitude. Four hundred feet to the north of this point was set the stone marking the north end of the meridian line, having sunk in its top a copper bolt similarly marked. Full descriptions, with drawings of the transit pier and north meridian mark, are given in the records.

At Washington, D. C., the station occupied in the grounds of the Naval Observatory was to the west and south of the meridian circle.

After some delay from cloudy and rainy weather, longitude signals were successfully exchanged between Mr. Sinclair at Altoona and Mr. Marr at Washington, on the nights of the 28th, 29th, and 31st of May; the observers then changed stations, and in their second position the longitude work was finished by exchanges of telegraphic signals on the nights of June 3, 4, and 8.

A determination of the latitude of the Altoona station was begun by Mr. Sinclair and completed by Mr. Marr, twenty-two pairs of stars being observed on six nights.

The chief cost of this work was defrayed by the Pennsylvania Railroad Company.

Other duty assigned to Messrs. Sinclair and Marr is reported under headings in Sections III, XV, XVI, and XVII.

General reconnaissance of parts of the coasts of Long Island and New Jersey with reference to the changes caused by recent storms.—Various and in some cases conflicting reports having been received at the Office of the Survey respecting changes upon the coasts of New Jersey and Long Island produced by the severe storms of the autumn of 1889, Assistant Charles M. Bache was instructed early in November of that year to make a rapid reconnaissance of the New Jersey coast to ascertain the effects of these storms, and in December he received similar instructions with reference to Coney Island and Rockaway Beaches on the coast of Long Island.

Leaving Philadelphia November 5, Mr. Bache carried his reconnaissance from Cape May to Sandy Hook, a distance of 130 miles, the coast for this entire distance consisting of sand beaches, covered more or less by sand dunes backed by either interior waters or salt marshes, with the exception of about 20 miles where the mainland reaches directly to the sea.

Much information bearing upon the subject was obtained from the superintendent of the Life-Saving Stations and from the keepers of Light-houses along the coast. Where changes were apparent, comparisons were made with the charts and measurements were taken to ascertain their extent. Mr. Bache gives full details in his report respecting the relative gain or loss on the several beaches, and says in conclusion that excepting damage to private property the beaches have been but little affected by the storms. The one of September 10 was almost unprecedented. No inlets, worthy of the name, have broken through, and all of the old inlets that were closed at the time of the storm remained closed. At the same time, Mr. Bache says that the results of these examinations and of his observation for some years while engaged in surveys upon the New Jersey coast lead him to coincide with the general belief that between the constant encroachments of the sea and the occasional gains of the shore the average effect upon the shore is a loss.

Upon the completion of his examination of the New Jersey coast, Mr. Bache returned to Philadelphia, and early in December left for Coney Island Beach, over which he drove from end to end, accompanied by a gentleman who had for some years been a resident there. Examinations confirmed the indications of constant wear upon the beach. Between the Life-Saving Station at the east end of the beach and the Oriental Hotel quite a cove had been formed close to the eastward of the hotel. West of the hotel, the beach had been wearing away for years, but the late storms had moved the high-water line back for 100 feet, forming quite a cove. Opposite the Brighton Hotel (which has been moved back 560 feet) the high-water mark has moved inland 120 feet. At Ocean Parkway where it strikes the beach, the loss is about 70 feet; beyond this the beach begins to gain, the greatest gain being at the two piers. At the western pier the beach was found to have gained 90 feet from the effects of the storm, and during the past 4 years the gain has been 200 yards. The remainder of the beach to the westward, it was noted, had been either very little or not at all affected by the storm.

Upon Rockaway Beach the east end was found to be wearing away rapidly. From the east point to the head of Far Rockaway Bay the beach had lost about 150 feet. The Life-Saving Station near the east end of the beach had been abandoned. Opposite Life-Saving Station Rockaway, the beach had lost 30 feet. There had been no change at the pier, and little or none from the west point which was found to be making slowly.

A channel had been dug, connecting Jamaica Bay with the head of Far Rockaway Bay.

Mr. Bache has transmitted with the reports of his examinations charts of the coast upon which he has marked the localities and extent of changes observed.

The duty here reported was the last field service performed by this faithful officer. Having been instructed to proceed to Washington for temporary duty at the Office early in February, he was soon after ordered to service on the coast of California, and while on his way thither he was prostrated by a paralytic attack which in the course of ten days ended his life.

He died in San Francisco, April 10, 1890. During his service of upwards of 40 years on both the Atlantic and Pacific coasts, he had become known as an active and conscientious officer, held in high esteem by his associates on the Survey, and as a man truthful and honorable in all the relations of private life.

Continuation of geodetic operations in the southwestern part of the State of New Jersey.—Geodetic operations for the extension of the triangulation of the State of New Jersey were resumed July 1, 1889, by Prof. E. A. Bowser, Acting Assistant, in accordance with instructions issued during June.

The occupation of a station at Williamstown, Gloucester County, and a reconnaissance for the extension of the triangulation to the westward of that point constituted the season's work. At Williamstown it became necessary to build an observing tripod and scaffold 64 feet high in order to see over the tall timber on the lines to stations Pine Hill and Colsons. In order that this structure should be strongly built according to the most approved plans, Assistant C. O. Boutelle was directed to go to Williamstown and give Professor Bowser the benefit of his skill and experience in putting it up. This done Mr. Boutelle returned to Washington.

Observations of horizontal angles were begun from the tripod July 29, observing signals having been erected at Pine Hill, Berlin, Hammonton, Newfield, and Colsons. While the observations were in progress, a reconnaissance was made for determining a station to the westward, which would command a good view of the country to the north, the west, and the south. Signals of 90, 100, and 110 feet in height were put up at different points, and a station was finally selected at Taylors, a point about 17 miles west northwest from Williamstown.

On August 12, a granite monument was set to mark the triangulation point. This monument is 4 feet long, dressed 6 inches square at the upper end for a length of 6 inches, and has the letters U. S. cut on each of its four sides, and a triangle on top. The monument is set in hydraulic cement to within 6 inches of the top.

On September 16, the observations at Williamstown having been completed, field operations were closed for the season. Professor Bowser has sent the records and results of his work to the Office.

Revision of the special survey of the Delaware River.—In accordance with instructions issued in June, 1889, and at the time (July 1) at which the appropriation became available, Assistant R. Meade Bache resumed the work of revising the special survey of the Delaware River in order to obtain the data needed to correct to date the charts of the river.

Between July 1 and August 31 Mr. Bache had found all of the extant stations desirable for the work immediately in hand, had supplemented them with others, and had revised the special survey from opposite the northern end of Smith's Island to below the mouth of the Schuylkill, making at the latter place a small desirable addition to the topography.

Late in the preceding autumn, as mentioned in the last annual report, the revision of topography had been completed from Bridesburg to the northern end of Smith's Island; hence on August 31, 1889, the whole of the topography of the Delaware from Bridesburg to below the mouth of the Schuylkill had been revised, the area described showing manifold and important changes.

As soon as possible after the cessation of the above work Mr. Bache placed in the field a small party for the continuation of the transit survey of the water front of the city, relating to the prospective radical changes in the harbor, and to the establishment of new port warden lines. This party consisted, including the operator, Mr. Neville B. Craig, of four persons, the city contributing the larger portion of Mr. Craig's pay.

During 1 month the transit party was occupied in supplementing the old local triangulation for the original survey of the Delaware, many points of which had been lost, and the rest of the time was devoted to final field work. During the 2 months remaining, from about October 1 to November 30, the delineation of the water front of the city from Market street to Washington avenue, $1\frac{1}{10}$ miles in an air line, was completed, and, incidentally on the route, the street corners back of the water front were fixed by angles, so as to afford data sufficiently remote from local wharf-line changes to facilitate the establishment of the port warden's line.

After the cessation of this field work at the time appointed, November 30, Mr. Craig was directed to continue the plotting of the survey on a scale of 1-1200. During the autumn, and until December 31, Mr. Bache, in addition to inking the sheets of his survey, indicated to his foreman such minor points on the river front as required examination. One important change, however, was discovered, that made by the U. S. Engineers in extending and raising in height their lately submerged jetty between Fisher's Point and Petty's Island. The amount of this change will be ascertained and incorporated in the map.

As soon as the inking of his topographical sheets is completed they will be forwarded to the office so that a new edition of the chart of Philadelphia City Water Front may be issued at the earliest date practicable.

The entire time during which the survey lasted was 83 days, of which $32\frac{1}{2}$ days were not available for work through the occurrence of bad weather and Sundays, making the whole time consumed in the field $50\frac{1}{2}$ days. During this time thirty-six subsidiary triangulation points were determined between Market street and Greenwich Point, and along the water front opposite to and on Petty's Island. By the transit work the line of the water front of the city, 3 miles in length, with an average depth of 1,100 feet, was connected with the *débouchure* of the streets upon the water front. In this work were included the wharves, all beginnings of streets, and the railroad tracks, with the addition of about eight hundred levels.

A survey of the district between Erie and Susquehanna avenue was begun but soon discontinued, the lateness of the season making it uneconomical to prosecute it farther.

By the end of the fiscal year the maps representing the transit work were finished, and a duplicate of one of them for the use of the city was ready for delivery, the duplicate of the other requiring a few days additional time to complete it. Both of the originals will then be sent to the office. These originals are on a scale of 1-1200, each over 8 feet in length.

Mr. Bache had completed, at the end of the fiscal year, the drawing and lettering of the three topographical sheets of the general survey. He observes that the ground needs inspection in a few places to settle doubtful points of junction between new and old conditions, back of the shore line, after which the maps will be sent to the office.

Hydrographic resurvey of the Philadelphia City Front and of the Delaware River from Smith's Island to Gloucester. Also of the approaches to the Schuylkill River.—The revision of hydrography on the Philadelphia City front from Bridesburg to League Island, of the hydrography of the Delaware River from the head of Smith's Island to Gloucester, and of the approaches to the Schuylkill River and the docks at the Navy-yard, was executed by Assistant Joseph Hergesheimer, in the summer and autumn of 1889.

Beginning work August 1, from the limits of the hydrography executed by Assistant R. M. Bache, in 1888, Mr. Hergesheimer was occupied until the 18th in recovering and remarking points of the triangulation, establishing tide gauges and bench-marks, and in transferring the revised shore line to his projections preparatory to sounding. Three days were then occupied in simultaneous tidal observations at Cooper's Point, Gloucester, and League Island, after which the hydrographic resurvey of the docks from Bridesburg to League Island was taken up. This was finished September 16. Some delay then occurred, due partly to bad weather and partly to the need of repairs to the working boat. On October 2 sounding was resumed, and between that date and the 22d the revision of hydrography on the Delaware River, from the head of Smith's Island to Gloucester, with that of the approaches to the Schuylkill River and of the docks at the Navy-yard, was finished.

The soundings were made with great care. Between Smith's Island and Gloucester the lines were run on ranges at or near slack water. Permanent bench-marks were established at each of the three tidal stations, and the gauges were connected by simultaneous observations at low water. Details of the marking of the benches are given by Mr. Hergesheimer in his report.

During the last week in October some rocks in the Schuylkill River above Chestnut Street Bridge were examined and located.

For the season the statistics are as follows:

Hydrography:

Survey of the docks, Philadelphia City Front, Bridesburg to Navy-yard—	
Length in miles of wharf line surveyed	38
Number of soundings	2,188
Delaware River and approaches to the Schuylkill River—	
Number of miles run in sounding	35
Number of angles measured	199
Number of soundings	2,315

Mr. George Hergesheimer served acceptably as Aid in the party during the season. Towards the middle of November Assistant Hergesheimer was instructed to organize his party for the survey of the interior waters back of Cape Romano, west coast of Florida. A report of this service will be found under a heading in Section VI.

Physical hydrography.—Observations of the movement and lodgment of ice in Delaware River and Bay, and of density and temperature of water at the Delaware Breakwater.—In pursuance of instructions issued in October, 1889, Assistant S. C. McCorkle made arrangements similar to those of the previous years for observations during the winter of 1889-'90, of the movement and lodgment of ice in the Delaware River and Bay, and of water densities and temperatures at the Delaware Breakwater. Through Commander John J. Read, U. S. N., Light-House Inspector of the Fourth District, he obtained the services of the light-keepers on the river and bay as observers, and as in previous years Henry Winsor & Co., Agents of the Boston and Philadelphia Steamship Line, Capt. W. B. Gallagher, Superintendent of the Philadelphia and Reading Steam Colliers, and the Superintendent of the City Ice Boats volunteered their aid and co-operation. The observations at the Delaware Breakwater were made by the keeper of the East End Breakwater Light.

Mr. McCorkle reports that there was no ice in the river or bay during the winter that offered any obstruction to navigation. The ice boats were not needed, though ready for service. The keeper of Horseshoe Range Light says, under date of March 3, 1890, "skim ice in cove first time this winter." At Schooner Ledge Light the first ice formed March 7, very thin, but soon melted away. At New Castle Light the keeper reported some ice on shore but none afloat. At Billingsport Light the keeper reported "no ice found in the Delaware River near this station during the winter just passed."

The lowest temperatures recorded during the winter were on March 7 and 8; on the morning of the 7th, at 7 o'clock, 10 degrees above zero (Fahrenheit) was recorded. In December, 1889, the lowest temperature noted was 32 degrees, and in January and February, 1890, the minima were 21 and 22 degrees, respectively.

Mr. McCorkle has transmitted to the Office a general report on the ice movement and lodgment in Delaware River and Bay, covering the winter of 1878-'79, and the successive winters from 1883-'84 to 1888-'90, inclusive. Also tabular statements and diagrams relating to temperatures and densities of water observed at the Delaware Breakwater, with comparisons of mean temperatures and densities at this point and at Sandy Hook.

The charge of the Suboffice at Philadelphia was continued with Mr. McCorkle during the year. A report of its operations will be found under a heading toward the close of Part II of this volume.

SECTION III.

MARYLAND, DISTRICT OF COLUMBIA, VIRGINIA, AND WEST VIRGINIA, INCLUDING BAYS, SEAPORTS, AND RIVERS (SKETCHES Nos. 1, 5, 19, AND 20).

Determinations of gravity at the Smithsonian Institution, Washington, in connection with similar determinations to be made at stations on the west coast of Africa and on islands in the Atlantic—Magnetic observations at the Coast and Geodetic Survey Office.—While under orders to join the U. S. steamer *Pensacola*, and accompany the Eclipse Expedition which she was to convey to the west coast of Africa, Assistant E. D. Preston was instructed in September, 1889, to prepare the pendulum and magnetic apparatus which he was to take with him, and to make a series of determinations of gravity at the Smithsonian Institution, and of the magnetic elements at the Coast and Geodetic Survey Office.

Since the beginning of the fiscal year, Mr. Preston had been occupied in computations supplementing the work he had done for the Hawaiian Government in 1887, the computations relating to the length and center of mass of the pendulums used; to star residuals; to a revision of temperature and pressure corrections, and to a re-reduction of the observations on the principle of the reversible pendulum.

He made also an investigation and study of the measurement of the Peruvian Arc by Bouguer, the results of which were embodied in a report submitted to the Superintendent, which was published as an appendix to the last annual report with the title "Need of a Remeasurement of the Peruvian Arc." An abstract of this paper was read by Mr. Preston before the American Association for the Advancement of Science at its meeting in Toronto, August, 1889.

Upon taking up the work preparatory to that with the Eclipse Expedition, the Peirce Pendulums, Metre No. 2 and Yard No. 3 were swung at the station in the Smithsonian Institution, and determinations of the magnetic elements made at the station in the ground south of the Coast and Geodetic Survey Office. These were made available for the annual 3-day series at this station, the days of observation being September 24, 25, and 26, 1889.

Reference to Mr. Preston's observations while with the Eclipse Expedition and later until his return to the United States will be found under the heading of Special Operations, and his report thereon appears as Appendix 12 to this volume.

Continuation of the detailed topographical survey of the District of Columbia, under Assistants J. W. Donn, R. Wainwright, and W. C. Hodgkins and Sub-assistant J. A. Flemer.—In order to obtain data for a comparison of field work executed by two of the parties engaged in the detailed topographical survey of the District of Columbia, Assistant John W. Donn was instructed towards the end of February, 1890, to make a resurvey of a small area of topography within a limit common to the surveys of Assistant Wainwright and Sub-assistant Flemer in the vicinity of Fort Stanton.

Mr. Donn observes in his report that for the objects of a critical resurvey, one of the desirable points in which was a comparison of graphic determinations of identical topographical details by several topographers working under different conditions, a more favorable selection of area as regarded variety and intricacy of features could not well have been chosen. It was unquestionable, he thinks, that the small differences shown in the positions of identical objects were caused by differences in the projections due to vicissitudes of temperature and to the influence of moisture. His own projection was fresh from the office, and therefore more susceptible to atmospheric changes. Those used by Messrs. Wainwright and Flemer had been long in the field, exposed to all variations in the weather. Under such conditions, therefore, absolute identity of determinations could not be looked for, but the close correspondence of the resurvey with the original work afforded proof that faithful work had been done.

This comparison of field work was completed during the third week in March, and a report with diagrams showing both topographical features and profiles was submitted to the Superintendent. Mr. Donn then transferred his party to the unfinished part of the District lying along the northwestern boundary, beginning the work at the junction of the Broad Branch and Chappell roads. The survey had been carried to this point in March, 1877, and closed there in order that, at the request of the Engineer Commissioner of the District, the work adjacent to the eastern branch of the Potomac might be advanced.

The original plane-table sheets had undergone so much handling during the interval that their surfaces had become softened and in parts broken and distorted; it was deemed advisable, therefore, to call for new projections, and these were furnished by the office.

Many of the bench marks established during the progress of the survey in the western section, or the country lying between Tennallytown and the north corner of the District, having disappeared, it became necessary for the accuracy as well as the convenience of the work to connect with such permanent benches as were within moderate distances. As soon as the rapidly advancing foliage rendered a continuation of operations in wooded areas uneconomical, open areas only were surveyed. Where farm roads passed through a body of woods, traverse lines were run and contours carried across and to the right and left as far as it was practicable to use the instruments effectively. In this manner the survey was advanced with considerable rapidity, and the area of unfinished country largely reduced.

All work that it was possible to do in the field profitably had been completed when further operations were discontinued for the season on June 10. Opportunity was taken during the next 10 days to have prepared and carefully established in position granite blocks of the usual size and form as permanent bench marks. These were located at points which Mr. Donn designated with reference to their future utility and convenience as data of reference for the authorities of the District. Each of these bench marks was determined in elevation by two circuits from the two nearest and most trustworthy temporary or permanent benches, the limit of error not exceeding seventy-two hundredths of an inch.

In the course of his survey, Mr. Donn had under trial a sheet of xylonite as a substitute for paper for topographical sheets. A longer time for testing it would have been desirable, but there was ample evidence of its comparative stability under varying atmospheric conditions. When prepared antiquarian paper buckled upon the table in the prevalence of excess of moisture in the air, the xylonite remained perfectly flat and unchanged. Clear and sharp definition of topographical features can be made upon its unpolished surface with a pencil which at the same time has the necessary quality and durability, the pencil mark remaining distinctly visible after repeated washing, and only disappearing under a vigorous use of India rubber.

The remaining unfinished areas in the western division of the District are, Mr. Donn states, generally of moderate character, topographically considered, and as there are no difficulties of a more serious nature than have already been met with and repeatedly overcome during the progress of the work, he thinks that no doubt need exist as to the entire completion of the survey of the District under the appropriation for the next fiscal year.

Duty previously performed by Mr. Donn is reported under a heading in Section I.

As stated in the last annual report, the party in charge of Assistant D. B. Wainwright, engaged in prosecuting the detailed topographical survey of the District of Columbia, was in the field at the close of the fiscal year, and operations were continued during the month of July, 1889. Plane-table work was carried through the open portions of the valley of Oxon Run, and a sufficient number of points were determined by triangulation for the topographical survey of the area back of Giesboro Point, several of the old points having been destroyed, and others hidden by the dense foliage.

During the month of August the party was temporarily disbanded. September 1 work was resumed, the triangulation just referred to completed, and topographical work taken up again. Subassistant Flemer was furnished with such points as he needed.

Pending the decision of a question as to the establishment of a sewer farm by the Government on the flats back of Giesboro Point, it was deemed desirable to complete that portion of the survey, as far as the 40-foot contour line, somewhat in advance. This was done during September and October, and a tracing on vellum was kept up with the work in the field, so that the commissioners of the District could be furnished with the results as early as possible.

These "flats," so called, Mr. Wainwright observes, rise abruptly from the Potomac to a height of from 20 to 25 feet, forming a bluff along the water front, and stretch back with slight undulations to the steep sides of the ridge dividing the valley of Oxon Run from the river. The general slope in any direction is so small that the numerous ditches do not drain the land effectively, and there is quite an area of wooded swamp.

After the completion of this portion of the work the pine areas on the north side of Oxon Run were taken up, then the wooded portions along the boundary on the south side of the creek, and also those adjoining Giesboro Point, until the foliage in the spring became too thick to make satisfactory progress. Work was then continued in the open fields until June 1. Between that date and June 30 the field of operations was shifted to the north corner of the District, between the Daniels and Milk House Ford roads, and the remaining open patches in that locality were completed.

Mr. J. T. Gibson and Mr. R. A. Clark rendered very acceptable service in the party until spring, when they resigned their positions. Mr. W. B. Hindmarsh took Mr. Gibson's place as levelman, and soon proved to be an exceedingly careful and painstaking assistant. Mr. William Oliver served acceptably as rodman from the time of his joining the party in May.

Following are the statistics reported by Mr. Wainwright for the fiscal year:

Topography (scale 1-1200):

Number of acres surveyed during the season	1,800
Number of triangulation stations established	7
Number of stones planted with underground marks for permanent bench-marks on standard lines of level	11
Number of bench-marks established on other permanent objects and duly described in record books	16
Number of miles of levels run on standard lines	35

On July 1, 1889, the party of Assistant W. C. Hodgkins was carrying forward the detailed topographical survey of the District of Columbia in the comparatively open country between the

Bennings and Sheriff Roads and east of the Anacostia Road. During July the weather was very unfavorable, owing to frequent rains. Work was suspended during the month of August and was resumed September 1, and prosecuted continuously till May 17, 1890.

During the season the area surveyed was in the eastern corner of the District, between the boundary lines of the District, the Anacostia Road, and the Ridge Road. In the spring a small area south of the Ridge Road which could not be finished in the preceding winter was taken up and completed. On March 4, 1890, Mr. Hodgkins began, under instructions, the determination of certain positions and distances near Poplar Point, on the Eastern Branch of the Potomac, for the District Commissioners. The base used was a side of one of the triangles of the District Survey, and a check-base was measured by steel tape on the Navy-Yard Bridge.

Mr. T. N. Badger served as levelman during the first part of the season, and upon his leaving the party, Mr. W. P. Bullock, formerly rodman, was made levelman. Mr. E. E. Storch served throughout the season as rodman.

Upon closing field work in the District Mr. Hodgkins was instructed to proceed to Beaufort, N. C., to take up the verification of the triangulation in that vicinity. He left Washington, accordingly, on May 24. A report of this service will be found under a heading in Section IV.

Subassistant J. A. Flemer, in charge of one of the topographical parties in the District of Columbia, continued work upon the unfinished plane-table sheet of the previous season in the region east of the Hamilton and Bowen Roads. This plane-table sheet, scale 1–4800, which was in hand at the beginning of the fiscal year, was completed September 26, 1889. It included an area extending to the boundary line of the District, between the third and fourth mile-stones.

Field work was suspended during the month of August in order to carry the survey on during the autumn and winter months, when the absence of foliage would admit of more rapid progress being made in the wooded sections. In September work was taken up on a new sheet embracing the area lying east of the Potomac River, from a point half a mile above Cox's down to Fox's Ferry, and taking in as much of the adjacent country as was inclosed by the 40-foot contour curve. The survey of this section was continued until November 16, after which date work was resumed on the still unfinished northern sheet, which had been laid aside temporarily in order to furnish data for the proposed plan of transforming the lowlands along the Potomac River, below Giesboro Point, into irrigation farms. By February 17, 1890, the northern sheet had been completed.

A new sheet was then taken up on the east side of the Potomac, embracing the country limited in the west by the 40-foot contour curve; on the south and southeast by the boundary line of the District, and in the north by an irregular line running southeast from a point half a mile above Cox's, on the Potomac, until it intersects the Alexandria branch of the Baltimore and Ohio Railroad, and thence east until intersected by the Giesboro Road. The limiting line follows this road and the Livingston Road until the crossing of Oxon Run, whence it takes the southern boundary of Wahler's Dairy Farm, and proceeds in a straight line to the boundary of the District.

On May 17, this sheet having been finished, the party was moved to the western part of the District, and some gaps in the topography between Fort De Russy and Swan's were filled up.

On May 24, in accordance with instructions, field operations were closed.

Mr. Flemer has transmitted with his report two sketches showing the area surveyed during the season. One of these shows also the disposition of the standard lines of levels, and the location of seven of the granite stones placed as permanent bench-marks. During the survey of the lower sheet, the party met with a line of pegs put down to mark the proposed extension of South Capitol street. These were determined in position and located upon the sheet, thus giving means of constructing the profile of that line.

The line of mean low water was located upon the plane-table sheet, developing the flats in the immediate neighborhood of Shepherd's Wharf, and also about a small island at the mouth of Oxon Run.

Mr. Flemer has transmitted to the Office all data and records relating to his survey. In the revision and preparation of the records of levelings, bench-mark determinations, and in making tracings of the original plane-table sheets, he was efficiently aided by Mr. Lewis Flemer.

The statistics of the season are:

Topography:

Number of miles of standard lines of levels run forward or backward, or checked by junctions with independent lines	23
Number of permanent bench-mark stones with underground marks established during the field season	14
Number of bench-marks established on permanent objects other than bench-mark stones	33
Total contoured area of the work in acres	2,051

In June, 1890, Mr. Flemer was instructed to take up a topographical survey on the upper St. Croix River and the Boundary Lakes. Reference to this duty will be found under a heading in Section I.

Reference to the Coast and Geodetic Survey, as arbitrator, of a question between the States of Maryland and Virginia, respecting the location of part of their boundary line.—The Superintendent having been requested by the Governors of the States of Maryland and Virginia to detail an officer of the Survey who should act as arbitrator between those States with reference to the location of a portion of their boundary line in the lower Potomac, in regard to which the proper interpretation of the award made in 1877 was in dispute, Assistant Henry L. Whiting was directed to confer with Governor Jackson, of Maryland, and Governor Lee, of Virginia, and after having placed himself in possession of all the information attainable by inspection of original charts and documents, and by examinations of the locality, to exercise his best judgment to bring the matter to a conclusion.

Mr. Whiting made a thorough study of the subject, and his methods and the conclusions finally arrived at were communicated to the Superintendent in a report which is published as Appendix No. 11 to this volume. Copies of this report were furnished to the Governors of Maryland and Virginia. See notice more in detail under the heading "Special Operations."

Examination and location of a dangerous rock in the Potomac River.—A dangerous rock not laid down on the chart having been reported to exist in the Potomac River off Easby's Point, Assistant Henry L. Marindin was directed to organize a party to examine and locate it. This work he took up under instructions dated April 19, and on the 29th he had completed the survey.

His examination showed that the rock was a dangerous obstruction to navigation for vessels drawing 9 feet and more of water. The rock was a single one, having a depth over it of 9 feet at mean low water, and 19½ feet around it. It lies very nearly in the middle of the river (taking the high-water line of each shore), but the channel proper lies to the eastward, between the rock and Easby's Point, with the deepest water, 32 feet, about 200 feet east of the rock.

To the westward, towards Analostan Island, the depths shoal from 19½ feet at the rock to 16 feet depth at a distance of 120 feet, and thence decrease to the low-water line.

The following measurements in feet give the location of the rock:

Distance to high-water line of Analostan Island	620
Distance to Littlefield's Wharf, bearing N. 17° 30′ E.	920
Distance to Government Wharf, Washington City, bearing N. 51° 50′ E.	640

Mr. Marindin was aided in his work by Expert Observers E. E. Haskell and Homer P. Ritter, and by Mr. Corcoran Thom, as recorder.

A hydrographic sheet, scale 1-5000, showing location of rock and of black buoy to the eastward of it, has been filed in the Archives.

Other duty assigned to Mr. Marindin is referred to under a heading in Section I.

Hydrographic examinations for the Coast Pilot in Chesapeake Bay and its tributaries.—Under instructions dated July 31, 1889, supplemented by detailed instructions from the Hydrographic Inspector, Ensign E. H. Tillman, U. S. N., Assistant Coast and Geodetic Survey, proceeded early in August to New York and took command of the steamer *Endeavor*, leaving port August 8 for Chesapeake Entrance. Ensign Tillman was accompanied by Mr. John Ross.

On the evening of August 9, the *Endeavor* anchored in Hampton Roads, and the next day Ensign Tillman took up the work of verifying sailing lines, descriptions of points, and collecting data from local authorities for the use of the Coast Pilot of Chesapeake Bay and tributaries. The manuscript of a volume covering these waters had been prepared from all sources available at the Office by Ensign Tillman, with the aid of Mr. Ross, and it remained only to make final verifications afloat. Between August 10 and September 13, the *Endeavor* steamed up all of the principal tributaries of Chesapeake Bay, and the work was completed with the exception of that in Chester River and at the immediate head of the Bay. When the *Endeavor* left the Chesapeake for New York September 15, it was expected that the manuscript of the Coast Pilot for the waters under examination would be ready in a few days for transmission to the printer.

On September 18, Ensign Tillman was relieved in command of the *Endeavor* by Ensign L. M. Garrett, U. S. N., and was instructed to proceed to Washington and report to the Hydrographic Inspector for duty at the Office in charge of the Coast Pilot Division.

Examination for additions of topographical details to a chart of Norfolk Harbor and vicinity.—In order to collect upon the ground all data and information practicable with regard to works of construction in Norfolk Harbor and vicinity, so as to provide for additions of topographical details to the chart of that harbor without making a detailed resurvey, Assistant John W. Donn was instructed in January, 1890, to make an examination of the water front of the city, and after consultation with Lieut. G. J. Fiebeger, U. S. Engineers, in charge of the improvements of Norfolk Harbor and the Elizabeth River, to locate the lines of new structures at the Gosport Navy-Yard, and along the water front of the town of Portsmouth.

The approximate positions of all lines not indicated upon the chart, except by compilation, had been laid down, and Mr. Donn was able therefore to proceed with the work without delay. After the completion of the work at Portsmouth, the present wharf lines of Berkley and Norfolk were located. Both at Berkley and at Atlantic City (a northern suburb of Norfolk), especially at the latter, structures of a temporary character were found to be undergoing frequent change; old wharves being altered in form and new ones in course of erection.

The work thus completed by Mr. Donn brought the record of changes up to date, and corresponded with that of the engineer in charge of harbor improvements. Lieutenant Fiebeger will keep the Office informed of such additional changes as may occur from time to time, both in structures along the water fronts and in depths of water.

Before returning to the Office Mr. Donn examined the original topographical surveys of the area to the north and east of Norfolk in order to ascertain what triangulation it would be desirable to make, should a new and more precise topographical survey of the whole area be called for. His special report upon this subject emphasizes the importance of large scale surveys of the most exact character in the vicinity of cities and harbors, and of the exercise of the utmost care in the determinations of topographical details, especially those that are likely to be permanent, with reference to their utility in such future resurveys as the development of the country may demand.

Examination of a shoal off Wolf-Trap Spit, Chesapeake Bay.—Upon being detached from duty in the Office, Lieut. Commander Seth M. Ackley, U. S. N., Assistant Coast and Geodetic Survey, was directed June 14, 1890, to take command of the steamer *Endeavor*, for the purpose of making such hydrographic examinations as would enable him to verify manuscript compiled for the Atlantic Coast Pilot for the coasts of Maine, New Hampshire, and Massachusetts.

On his way to this duty he was instructed to examine and develop a shoal reported off Wolf-Trap Spit, Chesapeake Bay. On June 20 he ran the lines of soundings required, finding rather less water on the shoal than had been reported. Records of this work have been sent to the Office. The statistics are:

Number of miles of sounding lines run	10
Number of angles measured	49
Number of soundings	528

Work executed by Lieut. Commander Ackley later in the year will be referred to in the next Annual Report.

Re-occupation of a station at Lynchburgh, Va., for magnetic determinations.—In the course of the magnetic tour of Assistant James B. Baylor, beginning in January, 1890, under instructions issued in December of the year preceding, a number of new stations were occupied for the determination of the magnetic elements, and a number of stations re-occupied to obtain data for additional knowledge respecting the secular variations of the magnetic declination, dip, and intensity.

Towards the close of the season, a station was re-occupied in Lynchburgh, Va. It had been originally occupied, under the direction of J. E. Hilgard, M. N. A. S., as one of the stations of the Bache Fund. The station was located on the bluff on the north side of the James River opposite the city; the chief of party was F. E. Hilgard, and the observations for magnetic declination, dip, and horizontal intensity were made by him and by J. M. Poole in July, 1873.

Mr. Baylor's observations were made in June, 1890; the latitude, longitude, and azimuth were determined by observing on the sun on one day, and the magnetic elements on another day. Stations occupied by Mr. Baylor earlier in the year are referred to under headings in Sections VIII, IX, and XIII.

SECTION IV.

NORTH CAROLINA, INCLUDING COAST, SOUNDS, SEAPORTS, AND RIVERS (SKETCHES NO. 1, 11, 19, AND 20).

Connection for purposes of verification of the triangulation of 1854 *in Bogue Sound with the triangulation of* 1886 *in the vicinity of Beaufort, N. C.*—A redetermination and verification of points in the triangulation of Bogue Sound, North Carolina, executed in 1854, having become desirable, Assistant W. C. Hodgkins was instructed to proceed to Beaufort, N. C., towards the end of May, 1890, and carry to the westward his triangulation made in that vicinity in 1886 to a connection with that of Bogue Sound.

Mr. Hodgkins left Washington in pursuance of these instructions May 24, and immediately upon his arrival at Beaufort began field work.

Ten tripod signals were erected, besides several ordinary signal poles; thirteen stations were occupied and twenty-three objects were observed. At three of the stations observing platforms were built, it having been found necesssary to elevate the theodolite about ten feet above the surface of the ground.

The connection of the new and old triangulations was made upon the line Jumping Run to Rocky Point, about twelve miles west of Beaufort. The old station "Shepards Point" was also recovered and occupied.

Mr. Hodgkins was furnished with one of the theodolites recently constructed in the office which are adapted to the determination of magnetic bearings, and he was enabled therefore to observe the magnetic declination at each station occupied except at two where the conditions were not favorable.

With regard to Bogue Sound, he states that the shores have been to a considerable extent washed away during heavy storms in recent years. In 1867, the topographical party found nearly all the station marks in place, while in 1890, only three were found out of ten searched for, and two of these were below high-water line.

The old stations recovered and the new ones established were marked with care, earthen cylinders being used for underground marks, and white marble blocks for center marks at the surface. Around these, for witness marks, heavy cedar posts were placed.

Mr. W. P. Bullock served in the party as recorder, and Mr. E. E. Storch as foreman. Field work was finished the last day of the fiscal year, and two days later the party was disbanded.

SECTION V.

SOUTH CAROLINA AND GEORGIA, INCLUDING COAST, SEA-WATER CHANNELS, SOUNDS, HARBORS, AND RIVERS (SKETCHES NOS. 1, 11, 19, AND 20).

Triangulation and topography in the vicinity of Charleston, South Carolina.—In order to advance towards completion the triangulation begun by Assistant Eugene Ellicott in the vicinity of Charleston, S. C., in 1889, and to check it by the measurement of a base suitably located, Assistant F. D. Granger left Washington in pursuance of instructions on March 5, 1890, and upon reaching Charleston, organized his party on board of the schooner *Ready* which was turned over to him by Ensign J. C. Drake, U. S. N., Assistant Coast Survey.

Mr. J. B. Boutelle was detailed as acting assistant in the party and Mr. V. K. Hendricks ordered to report for duty as recorder.

Work was begun by a careful examination of Fort Sumter in order to recover if possible the exact position of the triangulation station of 1857. The walls of the fort remain as before the war, except that they have been cut down one tier of casements. The station occupied in 1889 was found to be but slightly in error, being about 5 inches too far to the northeast. The measurement made in 1889 must have been taken, Mr. Granger thinks, from the outside edge of the coping instead of from the edge of the wall. The station of 1889 was connected by careful angular and linear measurements with the new position. Mr. Ellicott's signal was then removed, and an observing tripod and scaffold signal, 12 feet high, was erected over the point, this having been found necessary in order to command the entire horizon.

The reconnaissance which followed to obtain a site for a base-line resulted in the selection of a site on Morris Island. Preparations were then made to measure an astronomical azimuth at station Fort Johnson, the most convenient point for that purpose. Time was obtained by double altitudes of the sun, and for azimuth, Polaris was observed before and after western elongation. As soon as possible after the completion of the observations for azimuth, Mr. Granger visited Morris Island to prepare the base-line for measurement. Marking stakes were set upon the line for each tape-length (30 metres), the stakes being driven until their top surfaces were flush with the ground. Due precautions were taken over rough ground and over marsh to preserve an exact alignment for the tapes, both horizontally and vertically. The measurement was completed by April 3, the length measured being 1,491 metres. As soon as the connection of the base with the triangulation of 1889 had been made, Mr. Granger took up the triangulation of Ashley River from the limits of Mr. Ellicott's work of the preceding season, and carried it up that river for a distance of 9 miles. The reconnaissance, signal building, opening of lines and other operations involved in this triangulation occupied the entire party during favorable weather in the field.

At the same time, the computation of geographical positions determined by the triangulation in the lower bay was pushed ahead as rapidly as possible. Every church spire and every prominent object in the city of Charleston was determined; also all of the light-houses and other prominent objects in the harbor and bay.

A comparison of geographical positions of several of the triangulation points with a redetermination of the same points based upon St. Michael's church spire led Mr. Granger to infer that this point had been more disturbed in position by the earthquake of August 31, 1886, than either Flynn's Church or the Orphan House, two other points of the triangulation of 1857. Accordingly he sent Mr. Hendricks to Charleston to obtain information with regard to the probable changes in the positions of the various church spires due to that catastrophe. Mr. Devereux, superintendent of Government buildings, gave details respecting these changes, and stated that the spire of St. Michael's had sunk 10 inches on the Meeting street face, and was probably then leaning 2½ feet to the southwest.

On the eighth of May the triangulation of the Ashley River having been carried as far as practicable for the season, Mr. Granger, in pursuance of instructions, turned the charge of his party over to Mr. J. B. Boutelle, who took up the topographical survey of the Ashley River, carrying it up as far as station Atlantic.

Mr. Granger proceeded to Washington to prepare for other duty which will be reported under a heading in Section XV.

On May 17, Mr. Boutelle suspended field operations, and on the 21st, laid up the schooner *Ready* in the Cooper River. His services are very highly commended in the report of his chief. Mr. Hendricks rendered efficient service as recorder.

The statistics of the season are:

Base line:	
Length of, in metres	1,491.03
Triangulation:	
Area of, in square statute miles	17
Number of observing tripods erected	18
Number of stations occupied for horizontal measures	29
Number of geographical positions determined	82

Azimuth work:

Number of nights of observations for azimuth	2
Topography (scale 1-10000):	
Area surveyed in square statute miles	2
Length of shore line of river in statute miles	8
Length of roads in statute miles	10
Length of shore line of creeks in statute miles	3

Establishment and maintenance of an automatic tidal station on Tybee Island, Savannah River Entrance.—Reference was made in the last annual report to the selection of a site for an automatic tide gauge on Tybee Island at the entrance to Savannah River. A pier for the gauge was built a short distance northwest of Tybee Light. Creosoted piles were used for the foundation of the pier, and those which it was specially important to protect were also sheathed with copper below the water line. The gauge was put in operation September 28, 1889, and has been kept running since that date. This series will be of great value, not only for the prediction of the Savannah River tides but also for the study of the laws of tidal action on the South Carolina and Georgia coasts.

Mr. J. G. Spaulding established the gauge in position and kept up the record until January, 1890, when he was relieved by Mr. Eugene Veith, who had qualified himself as tidal observer under Mr. Spaulding's direction.

Special hydrography.—Examination of the sounds and estuaries of Georgia with reference to oyster culture.—In compliance with a request received from the Governor of the State of Georgia early in September, 1889, Ensign J. C. Drake, U. S. N., Assistant Coast and Geodetic Survey, commanding the schooner *Ready*, was directed by the Superintendent to proceed to Savannah and make such hydrographic surveys and examinations as might be required in connection with the investigation of oyster beds in the waters of that State.

The *Ready* having been duly fitted for the service arrived at the mouth of the Savannah River October 2. Having fully informed himself in regard to the requirements of the work by consultation with the State authorities, Ensign Drake decided to carry the investigations from the Savannah River southward to the Florida line. The experience he had already acquired in similar work during three years' service on the North Carolina coast with Lieut. Francis Winslow, U. S. N., was of great value to him. As assistants he was enabled to secure the services of Messrs. John D. Battle and W. F. Hill, who had been his associates in the North Carolina survey, and also those of Mr. W. N. King, jr., a graduate of the U. S. Naval Academy.

Great interest was manifested in the work by Dr. A. Oemler, of Savannah, an authority on the biology of the oyster, and through his efforts the survey was in many ways expedited. With the approval of the Mayor of Savannah, a naphtha launch was placed at the disposal of the party by Dr. W. F. Brunner, Health Officer of the city, and the field working force was thereby doubled.

The time for the prosecution of the surveys being limited to five months and the appropriation small, the examinations could not be made as minute and comprehensive as was desirable, but notwithstanding the limitations under which he was placed, the report submitted by Ensign Drake discusses very fully all branches of the subject, and, with the statistics gathered, points out to the State authorities what further legislation is desired in order to encourage the oyster industry.

This report, accompanied by seven charts, has been published as Bulletin No. 19, Coast and Geodetic Survey. The charts show graphically the location, limits, and areas of the natural oyster beds and the specific gravity of the water reduced to a temperature of 60° F., while the report describes the methods of work and the areas examined, states the general conclusions arrived at, and presents a tabular statement of acres for each area; acres outside of the limit of 1,000 feet from the shore at ordinary mean low tide, and acres occupied by natural oyster beds.

Ensign Drake states that of upwards of 70,000 acres examined not more than 30,000 were deemed suitable for oyster culture, but that under the present law these 30,000 acres, if leased would turn into the State school fund $30,000, and when reduced to cultivation would increase the taxable property of the State by $3,000,000.

Hydrographic investigation.—Changes on St. Simon's Bar, entrance to Brunswick Harbor, Georgia.—Certain changes on St. Simon's Bar and in the channels leading to Brunswick Harbor, Georgia, having been reported to the Office by a citizen of Brunswick, Lieut. J. F. Moser, U. S. N., Assistant Coast and Geodetic Survey, was instructed to make an investigation of these changes on his way north after the completion of his surveys on the Florida coast.

Having arrived off St. Simon's Bar in the steamer *Bache* on May 16, 1890, at 11 a. m., and finding the conditions favorable for sounding, it being low water, spring tides, and but little wind and sea, Lieutenant Moser anchored outside and sent a boat at once to sound the North and South Channels. Upon the return of the party the officer in charge reported that the best channel across the bar was between the wreck of the *Sunbeam* and No. 1 buoy. The steamer was then taken to the sea buoy and a line of soundings, using two leads, was carried from that buoy across the bar to the P. S. Channel buoy. Next morning, after passing quarantine, Lieutenant Moser sent a boat to finish the examination whilst he proceeded to Brunswick and spent some hours with two captains of tugs who daily tow vessels across the bar and with three bar pilots, all of whom gave freely the information desired.

He reports as the result of his own examinations and from information gathered as just mentioned that the North Channel has changed to such an extent that at present only 10 feet can be carried through it at mean low water, and that it is no longer used; that in the South Channel there is little more than 12 feet on the bar, probably $12\frac{3}{10}$ feet at mean low water; that the south point of the Middle Ground has made to the southward, so that buoy No. 1 is now on the south point of the shoal, and is used in entering as a starboard-hand instead of a port-hand buoy, as represented by its number and color.

Lieutenant Moser gives sailing directions for crossing the bar and entering the sound with the buoys and channels as found by his examinations, but he goes on to show that the channels are constantly shifting, and observes that the changes on this bar are similar to those that are occuring yearly on other harbor bars between New York and Key West, and which demand not extensive resurveys but a few days' soundings to furnish data for correcting charts to date. To have such work done effectively and promptly he suggests the consideration of a system previously urged, that of dividing the Atlantic coast into sections, one from Eastport to Cape Hatteras and another from that point to Key West, and the maintenance of a well-found steamer and a well-organized hydrographic party on each section to make resurveys, special examinations, locate wrecks, etc.

The advantage derived from the operation of such a system would, it is believed, amply justify the expenditure involved.

Hydrographic work executed by Lieutenant Moser in the summer and autumn of 1889 is referred to under a heading in Section I, and his surveys on the Florida coast under a heading in Section VI.

SECTION VI.

PENINSULA OF FLORIDA, FROM ST. MARY'S RIVER ON THE EAST COAST TO AND INCLUDING ANCLOTE ANCHORAGE ON THE WEST COAST, WITH THE COAST APPROACHES, REEFS, KEYS, SEAPORTS, AND RIVERS. (SKETCHES NOS. 1, 13, 14, 19, AND 20.)

Examination of a shoal reported off the northern end of Key Biscayne.—A shoal off the northern end of Key Biscayne having been reported to the Office, Lieut. A. L. Hall, U. S. N., Assistant Coast and Geodetic Survey, commanding the steamer *Endeavor*, was instructed to stop on his way north from duty on the Gulf coast and make an examination of the locality.

Under date of June 9, 1890, Lieutenant Hall reports that the shoal was found about 250 feet southwest of the present position of Cape Florida buoy; that its area was about 600 square feet, and that the least water found was $12\frac{1}{2}$ feet. The shoal had been formed by cement barrels thrown over by a steamer which grounded in that locality in June, 1889. Bundles of barbed wire had been thrown over at the same time, and in searching for and recovering these the barrels had been somewhat distributed and were no longer in piles. The least water referred to was taken on top of one of the barrels standing on its head. About the barrels the least water was 15 feet.

Due notice of this shoal was given in Notice to Mariners, No. 129, published June 30, 1890.

Gulf Stream explorations—Investigation of currents continued.—Lieut. C. E. Vreeland, U. S. N., Assistant Coast and Geodetic Survey, who succeeded Lieut. J. E. Pillsbury, U. S. N., in command of the steamer *Blake*, was instructed to continue the investigation of the currents of the Gulf Stream during the winter of 1889–'90.

He reports that the *Blake* left Hampton Roads November 18, 1889, and re-entered the roads on her return north April 10, 1890. During this interval of four months and twenty-four days, attention was directed chiefly to the two sections of the Stream, located respectively between the west end of Cuba and a point about sixty miles west of Tortugas, and between the Campeche Banks and the Mississippi Delta. There are six stations on each section, and each station was occupied at least twice during the season. Several additional anchorages were made by Lieutenant Pillsbury (who had accompanied the party southward) on the way from Hampton Roads to Key West, mainly with a view of giving Lieutenant Vreeland practice in the use of the anchoring gear and other apparatus peculiar to the *Blake's* outfit, but the points occupied were so selected as to connect all the data obtained at them with the general scheme of investigation, and to make them available either for present use or future reference.

The distances between sections, and also between the several stations on the sections, were unusually great in comparison with those made during the former seasons, and much of the time (nearly one-third) was consumed in steaming.

Lieutenant Vreeland reports the following statistics of the work:

Physical hydrography—

Number of deep-sea anchorages	33
Total number of observations of currents with the meter	1,344
Total number of observations of currents with the pole	1,350
Number of current floats put overboard	20
Number of miles steamed	7,577

A sounding was taken at each station before anchoring, and the bottom specimens brought up by the sounding rod were carefully preserved. The deepest water anchored in was 1,949 fathoms; the least depth sounded was 240 fathoms.

The accumulated data of the season were turned over to Lieutenant Pillsbury, who will embody them in a report which he has in preparation.

Lieut. H. Kimmell, U. S. N.; Ensigns C. S. Stanworth, J. E. Shindel, and P. Andrews, U. S. N.; Assistant Surgeon T. Owen, U. S. N.; and Assistant Engineer W. W. White, U. S. N., were attached to the party on the *Blake*.

Other duty assigned to Lieutenant Vreeland is referred to under a heading in Section II.

Hydrographic surveys in Barnes Sound, in the Bay of Florida, and on the west coast of Florida from Cape Romano to Shark River.—In continuation of the hydrography of the west coast of Florida, and for its completion as far as practicable, Lieut. J. F. Moser, U. S. N., Assistant Coast and Geodetic Survey, commanding the steamer *Bache*, left Baltimore for Key West January 11, 1890, and after a very rough passage arrived at the latter port January 19.

After coaling and taking on board lumber, etc., the *Bache* proceeded to the working ground, where operations were begun on the 24th instant.

During the winters of 1887–'88, and 1888–'89, Lieutenant Moser had finished the more important parts of the hydrography from Cape Romano southward to the Bay of Florida, and thence westward and southwestward along the Florida Keys, and in the unfinished portions, the waters being very shallow and no channels for commercial purposes existing, it became somewhat of a question whether any further surveys should be made. But it was finally decided that it would be desirable to have some representation hydrographically of those unfinished areas upon the charts, and in accordance with Lieutenant Moser's suggestions, the plan of work was made to include the development of the hydrography of a simple system of lines, using the topographical features, as far as possible, to locate them by. The work was divided into three sections, which, as they are differently conditioned, Lieutenant Moser considers separately in his report.

The first section embraced that portion of the work south of the main land of Florida, and included the waters of Barnes Sound and Cards Sound to Pumpkin Key, where the hydrography connected with that previously executed in Key Biscayne Bay. These waters are entered from the reefs by sloughs between all the reef-keys; from the westward by sloughs between Twin Keys, Shell Key, and Upper Matecumbe, and from the eastward by sloughs through Cards Sound. They are interspersed with many keys and are cut up into numerous lakes and ponds; the dividing lines, however, are not land, but shoals, which, in extreme low water, may be bare in places, but have usually a foot of water over them, and are covered with grass.

The ponds thus formed have from 5 to 7 feet of water, and on the reef side are connected by narrow sloughs, which, though as deep as the ponds, have bars, permitting boats having a draft of 2½ feet at ordinary water level to pass through. A westerly wind makes high water over this section, and an easterly wind low water.

There is no traffic through these inside waters. Occasionally a turtler or a sponger appears, and it is apparently quite an event when one of the dwellers on the key-reefs goes as far as the main land. There are no distinctive features to the land. The shores of the keys and the main are covered with mangrove bushes and trees, and are for the most part swampy, though generally containing sand or shell ridges, and in many places the mud is so soft as to make it almost impossible to land for signal building.

Most of the points marked in the old triangulation have been lost; two, however, were recovered, Stations West and Road; and two partially recovered, Stations Mark and Middle Plantation, and as the work progressed and expanded to the eastward four more stations were found, by means of which and by additional points determined the work was carried forward.

Lieutenant Moser notes that great changes in topographical features seemed to have occurred since the date of the earlier surveys. He observes that there is no regular tidal action in these waters, the water levels depending entirely upon the winds, except in the immediate vicinity of the inlets, where the tides slightly modify the conditions.

With regard to local names, he states that the body of water to the eastward and northeastward of the Bay of Florida, marked as Barnes Sound on the chart, is locally known as Cards Sound. At the eastern end is a point on which there is a triangulation station known as Barnes Point, and from this point extends a shoal to the northwest joining the mainland. East of Barnes Point to the Arsenicka Keys is Cards Sound, divided into Little Cards Sound, the western portion, and Big Cards Sound the eastern portion. The large landlocked pond between what is called Barnes Sound on the chart and Cards Sound is known locally as Blackwater Sound.

Having finished the eastern work, or the first section, the hydrography of the second section was taken up. Lines of soundings were run traversing the waters between the keys from Big Pine Key to Key West. These waters are generally very shallow; there are many bunches of mangroves, shoals, and bars, and the work was executed rather for the purpose of showing that there were no commercial channels than for the development of the 1 and 2 foot channels that existed.

The keys on this section are but sparingly inhabited, the soil or rocks not being so favorable for cultivation as the eastern keys. Sawyer Key, so named on the chart, is known locally as the Bay Cudjoe.

After the completion of this portion of the survey, Lieutenant Moser proceeded to Shark River, north of Cape Sable, to begin work on the inlets and river mouths between Cape Sable and Cape Romano.

The hydrography from Cape Sable to Cape Romano and thence seaward to the 10-fathom curve had been executed by his party during a preceding season, but there was then no shore-line delineated on the sheets, the hydrography having preceded the topography. Hence the inside work required a more thorough development, and the hydrography was therefore carried into the mouths of the rivers, the passes and the openings, and as far as the topography had been executed between the keys. A full account of this section, with sailing directions, etc., was given by Lieutenant Moser in his report for 1887-'88.

Field operations were closed May 17, 1890. The following named naval officers were attached to the party: Ensigns H. A. Bispham, R. D. Tisdale, S. M. Strite, C. Bertolette, and E. H. Durell, U. S. N.; Passed Assistant Surgeon John M. Steele, U. S. N., and Assistant Engineer E. H. Scribner, U. S. N. Messrs. J. L. Dunn, J. M. McTiffany, and Thos. S. Martin served as recorders.

Lieutenant Moser commends the cheerful and efficient aid rendered by his officers, and referring to the fact that during three separate tours of duty his connection with the Survey had occupied in all fifteen years, he observes that he will always look back upon this duty as the most agreeable of his naval career, and that he will hold in grateful remembrance the military and civil members of the service with whom he was associated.

Lieutenant Moser, upon his detachment from the Survey July 15, 1890, was ordered to the new armored cruiser *San Francisco.*

The statistics of his Florida work, 1890, are as follows:

Hydrography:

Area sounded in square geographical miles	830
Number of miles (geographical) run while sounding	2,361
Number of angles measured	11,218
Number of soundings	123,677
Number of tidal stations established	7
Number of hydrographic sheets finished	8

Scales of hydrographic sheets, 1–20000 and 1–40000.

Triangulation, topography, and hydrography on the west coast of Flo rida, in the vicinity of Cape Romano and to the northward.—The survey of the west coast of Florida from Cape Romano to the northward, including Caximbas Bay and Cape Marco Pass, triangulation, topography, and hydrography was taken up by Assistant Joseph Hergeshimer, January 28, 1890. Having arrived at that date at Coon Key, with his party on board the schooner *Quick*, he found it necessary to re-establish signals at Cape Romano, Caximbas, and Big Marco, and to determine a number of new points for the topographical survey.

The topography was executed on a scale of 1-10000, and included the shore line of all the navigable waters back of Cape Romano, the shore lines Coon Key to Big Marco, and Coon Key to Caximbas Pass, and those of the adjacent islands and navigable passes.

In the hydrography, on the same scale, were embraced the waters just named, and the bars at Caximbas Bay Entrance and at Big Marco Pass. These inside passes are much used by vessels of about 5 feet draft, as they afford a direct and safe passage inside of Cape Romano, avoiding the long distance outside of Cape Romano Shoal. Mr. Hergesheimer staked the passes so that strangers could go through without a pilot.

Tidal stations were established at Caximbas, Coon Key, and Big Marco, bench-marks were set at each of these stations with the level, and simultaneous observations of high and low waters made. The tide gauge at Caximbas was connected also with the granite station mark on the hill at Johnson, Caximbas Bay. The top of the station mark on this hill is 58.97 feet above zero of the tide gauge at Shell Landing. The hill is the highest on the coast for a long distance. Mr. Hergesheimer visited the tidal station at Fire Island, and erected a new gauge there, connecting it by a line of levels with the old bench-mark.

Field operations were completed April 15, and on April 26 the schooner was laid up at Fort Myers and the party disbanded, Mr. Hergesheimer proceeding under instructions to Washington. Early in June he was directed to take charge of a party for the survey of the Schoodic Lakes, at the head waters of the St. Croix River, Maine. Reference to this duty is made under a heading in Section I; and, under Section II, a report of service rendered on the Schuylkill River in 1889.

Mr. Charles H. Deetz rendered efficient ser vice in the Florida work. The statistics are:

Triangulation:	
Points detetmined with the theodolite	4
Points determined with the transit	34
Beach measurement in miles	1
Topography:	
Points determined with the plane table	92
Miles of shore line surveyed	77
Hydrography:	
Miles run in sounding	157
Number of angles measured	310
Number of soundings	20,661
Number of tidal stations established	4

SECTION VII.

PENINSULA OF FLORIDA, WEST COAST, FROM ANCLOTE ANCHORAGE TO PERDIDO BAY, INCLUDING COAST APPROACHES, BAYS, AND RIVERS. (SKETCHES NOS. 1, 14, 19, AND 20).

Triangulation, topography and hydrography of the upper branches of Escambia and East Bays, Pensacola Bay, Florida, for the use of the Gulf Coast Navy-Yard Site Commission.—In pursuance of instructions issued towards the end of November, 1889, Subassistant P. A. Welker proceeded to Pensacola, Fla, early in December of that year, and organized his party for a survey of the tributaries of Pensacola Bay, which was needed for the use of the Gulf Coast Navy-Yard Site Commision.

It was desirable to make the triangulation of Pensacola and Perdido Bays one connected scheme, and as many of the points of the old triangulation had been lost, Mr. Welker was directed to begin his work on the line Navy-Yard Wharf to Fort Pickens, and extend it to the locality of the topographical work needed. He found it necessary to lay out a new scheme from this line as a base, which was the same as had been used for carrying the triangulation into Perdido and Mobile Bays, in February and March, 1889.

With regard to the country surrounding Pensacola Bay, Mr. Welker remarks that it is very heavily timbered; that the soil consists of a drifting sand, and that in many places there are dense and almost impenetrable swamps. In order to avoid these swamps and the cutting of lines through heavy timber, it became necessary to establish the triangulation stations on the sand dunes close to the shore. The outlines of these dunes being constantly changed by the drifting sand, it was somewhat difficult to mark the stations so as to insure their preservation.

By February 6, 1890, stations had been established and signals erected as far as Lora Point on Escambia Bay, and the observations were finished as far as the line Emanuel to Hickory, about three miles above the city of Pensacola. Here it rested for the season, and the topography and hydrography in the vicinity of Pensacola was then taken up.

A number of points for this work had been determined by the triangulation, and from the stations Post-office and the cupola of the Harbor Master's Building, the geographical positions of which were known, numerous flags placed in high trees were located.

On March 18, the topography and the hydrography were finished, and on the 20th the party was disbanded.

Following are the statistics reported :

Reconnaissance:	
Area of, in square statute miles	50
Lines of intervisibility determined as per sketch	39
Number of points selected for scheme	16
Triangulation :	
Area of, in square statute miles	21
Stations occupied for horizontal measures, number of	10
Number of geographical positions determined	36
Topography :	
Area surveyed in square statute miles	16
Length of shore line of bay and of bayous in statute miles	37
Length of roads in statute miles	46

Topographic sheet completed, one on a scale of 1-10000, from a mile and a half west of the mouth of Bayou Chico to Magnolia Bluff, including both bayous and the city of Pensacola.

Hydrography :	
Area sounded in square geographical miles	1
Number of miles (geographical) run while sounding	22
Number of angles measured	78
Number of soundings	3,719

One hydrographic sheet on a scale of 1-10000, including hydrographic survey of Bayou Chico and Bayou Texas.

Mr. O. B. French served faithfully and ably in the party, as recorder and computer, until an attack of malarial fever compelled his detachment, February 12. Early in March, Mr. H. P. Ritter, expert in physical hydrography, was assigned, and aided most satisfactorily in bringing the work to a successful conclusion.

Service executed by Mr. Welker, in Ohio, later in the fiscal year, is referred to under a heading in Section XIV.

Triangulation, topography, and hydrography of Perdido Bay, Florida and Alabama.—Reference was made in the last Annual Report to the work executed by the party of Assistant A. T. Mosman on Perdido Bay, Florida and Alabama. This work involved the laying out of a scheme of triangulation requiring cutting through heavy timber, the erection of observing tripods and scaffolds from twenty to forty feet in height, the occupation of fifteen stations for observations of horizontal angles, and the measurement of an azimuth.

For the continuation of the triangulation, and for the execution of the topography and hydrography of the Bay and its approaches, Assistant Stehman Forney was instructed, towards the end of November, 1889, to organize a party to which were assigned Assistants C. T. Iardella and W. I. Vinal, with Mr. E. E. Torrey as foreman, and Mr. M. A. Coles as recorder.

Mr. Torrey having been sent on in advance of the rest of the party made all preliminary arrangements for field work, forming a camp on shore, and having the schooner *Transit* ready at her station for use in local transportation, so that upon Mr. Forney's arrival at camp, December 20, he was enabled to begin the survey next day.

Mr. Iardella was assigned to the topographical work; Mr. Vinal to the hydrography, while Mr. Forney was chiefly occupied with the triangulation, at the same time exercising a general supervision over all of the operations.

During the early part of the season the weather was favorable, and satisfactory progress was achieved, but during February and March, 1890, many delays occurred, owing to rain, to fog, and to smoke arising from the frequent forest fires in the vicinity. Nevertheless, during the season of three months, satisfactory results were obtained. The triangulation was carried to the mouth of the Perdido River, and a reconnoissance made for the connection of the triangulations of Perdido and Mobile Bays; the topography of both shores of Perdido Bay was carried to within nine miles of its head; the hydrography of the approaches was finished, and the interior waters sounded out as far up as the end of the topography. The shores thus delineated and the waters sounded embrace not only the Bay proper, but also Bay La Launch, Old River, Johnson's Bayou, Cotton Bayou, Roberts Bayou, Ingraham's Bayou, and Soldier and Palmetto Creeks.

During the last week in the field, Mr. Forney took up a reconnoissance for the connection of the triangulation of Perdido Bay with that of Mobile Bay, and found that a practicable scheme of triangles could be formed which would connect the work of Assistant Mosman with the old triangulation at the southeastern extremity of Mobile Bay. This scheme would admit of two or more quadrilaterals, the distance between the two systems of triangulation being but 9 miles, and as the timber is small and scattering not much cutting would be needed.

He examined also the country between the head of Bay La Launch and Mobile Bay, and ascertained that a simple and comparatively inexpensive scheme of triangulation could be carried over that area, should it be deemed preferable to the coast-line system.

Field operations were closed under instructions on March 26, the schooner *Transit* being laid up under charge of a ship-keeper at the Pensacola Navy-Yard, as also the tents, instruments, and camp equipage. Mr. Forney then proceeded with the members of his party to Washington.

He observes that but little commercial importance attaches to Perdido Bay. It may be described, in general terms, as a wide and irregular-shaped sound, about 15 miles long, with innumerable ramifications of creeks and bayous. At its northeastern extremity is the mouth of Perdido River, which penetrates the interior for about 40 miles, and with the bay forms the boundary on the west of Florida between that State and Alabama. Four miles above its mouth the river branches, sending off an arm to the northwestward, called the Blackwater. One mile and a half above the confluence with the Blackwater it again divides, the branch running northwesterly being known as the "Styx."

The entrance to Perdido Bay is through a very narrow inlet into a lagoon called Old River. The bar is shifting, and has upon it an average depth of 9 feet at mean low water. During the prevalence of southerly winds the cove deepens, but becomes shallow under the pressure of continued northers. The usual tidal current is about four knots, but during the prevalence of a norther there is no tidal current, the volume of water running constantly seaward.

The channel into the bay, now in general use, is not through Old River (except during north winds) but through a so-called cut-off, made some 15 years ago by persons living in the locality, through the narrow strip of lowland separating Old River from Orinoco (or Johnson's) Bay. This cut has now greatly increased in width, and has deepened to 3 fathoms of water, although it was at first but a ditch, 4 feet wide and 4 feet deep. This fact, Mr. Forney observes, is only worthy of mention because if such a scour has developed in this particular channel, and in such a time, it may have a bearing upon the future of the Bay as a commercial port. At present there is no maritime commerce, the timber (mostly yellow pine, spruce, and live oak) being conveyed to Millview, at the eastern end of the Bay, where there are two large sawmills with a manufacturing capacity of 200,000 feet a day. These mills belong to the Southern Land and Lumber Company, and their sawed lumber is transported to Pensacola by rail.

In closing his report, Mr. Forney expresses his great indebtedness to the experienced and efficient support given him by the officers of his party.

For the season the statistics are as follows:

Reconnoissance:	
Area of in square statute miles	36
Number of points selected for scheme	6
Triangulation:	
Area of in square statute miles	13
Number of stations occupied for horizontal measures	9
Number of geographical positions determined	21
Topography:	
Area surveyed in square statute miles	40
Length of general shore line in statute miles	133
Length of roads in statute miles	17
Hydrography:	
Area sounded in square geographical miles	60
Number of miles (geographical) run while sounding	300
Number of angles measured	1,250
Number of soundings	24,073

Service performed by Mr. Forney in Pennsylvania earlier in the fiscal year is referred to under a heading in Section II.

SECTION VIII.

ALABAMA, MISSISSIPPI, LOUISIANA, AND ARKANSAS, INCLUDING GULF COASTS, PORTS, AND RIVERS.

(SKETCHES NOS. 1, 12, 14, 19, AND 20.)

Reconnaissance and occupation of stations for the extension of the primary triangulation in Alabama towards the Gulf of Mexico.—Field operations in Alabama for the extension to the southward of the main triangulation were resumed by Assistant F. W. Perkins early in February, 1890, in pursuance of instructions issued in the month previous. Reconnaissance and the erection of high observing tripods and scaffolds occupied the party until the end of April.

As a result of a general examination of the topographical aspect of the country over which the reconnaissance was carried, Mr. Perkins states that it may be broadly divided into three zones.

The northern zone, drained by the Tennessee River and traversed by the southwestern extremity of the Appalachian chain, is almost mountainous.

The middle zone, lying north of the latitude of Montgomery and draining into the Coosa, Tuscaloosa, and Little Tombigbee Rivers, is traversed by ranges of high hills.

The southern zone, which drains into the Alabama, Tombigbee, Conecuh, and Chattahoochee Rivers, is best described as undulating, but may be further described as consisting of a series of broad, sandy, heavily-wooded plateaux, dividing the drainage; sloping gradually to the south and east and more abruptly to the north and west, with broad alluvial river bottoms which are in the main very flat, but with occasional knolls or clusters of hills of coarser and heavier material.

After these facts had been ascertained, it was decided to rest the eastern line of points on the Alabama–Conecuh divide, and to take advantage of the accidental elevations in the Alabama bottom for the western points, until by the narrowing of the bottoms to the southward the divides on either side of the Alabama River could be made available.

The heavy forests and the almost uniform heights of all the ridges and summit levels made it often necessary for the reconnoitering officer to be elevated from 100 to 200 feet above the ground, and to effect this most economically and expeditiously, single poles from 3 to 5 inches in diameter were set up and braced by a few sets of guys made of light wire. Upon these poles the observer with his reconnoitering telescope was hoisted to the required height.

Mr. W. B. Fairfield, extra observer, was placed in charge of the construction party engaged in erecting observing tripods and scaffolds, and accomplished excellent results with very moderate expenditure of time and money.

The reconnaissance having been extended to a point about 7 miles east of the Alabama River and about 85 miles in a southwesterly direction from Montgomery, it was there rested, and by May 3, all of the signal lights having been posted, the party was at Jamison station ready for observations. These were completed, though not without much difficulty owing to almost continuous rain and fog, by May 14, and the party was transferred on the next day to station Wilder. Owing to the withdrawal of Mr. Fairfield for other duty at this juncture, and to a series of accidents to the signal lamps, the observations at this point had not been finished at the close of the fiscal year. In the latter part of June Mr. W. B. English joined the party, and by his industry and aptness rendered very satisfactory service.

The statistics of the work will be given with an account of its progress in the next Annual Report.

At the request of Governor Seay of Alabama, and by direction of the Superintendent, Mr. Perkins established a true meridian line by suitable monuments set in the grounds of the State Capitol. This work was done between the time of closing the reconnaissance and that of beginning the regular observations, the party being then in Montgomery. The necessary astronomical observations were made May 1. All the expense of procuring, preparing, and setting the monuments was borne by the State.

Occupation of stations for the determination of the magnetic elements in Alabama, Mississippi, Louisiana, and Arkansas.—In the course of the magnetic tour of Assistant James B. Baylor, which has been already referred to under a heading in Section III, he occupied in the months of April and May, 1890, a number of stations for the determination of the magnetic declination, dip, and intensity in Alabama, Mississippi, Louisiana, and Arkansas.

At Lake Charles, Calcasieu County, La., a station was established in the grounds of the Courthouse, in the rear of the jail, and was securely marked. The latitude, longitude, and azimuth were determined by observations of the sun on one day, and the magnetic declination, dip, and intensity on another day.

At Mermenteau, Acadia County, La., a station was established in front of the Mermenteau Hotel, and securely marked, the observations made on two days being similar to those at Lake Charles.

Observations of a like character were made at La Fayette, La Fayette County, La., on two days. The station here was established in an open lot in the rear of the Railroad House, and was securely marked.

At Natchez, Adams County, Miss., a station was established on the bluff opposite the Jewish cemetery, within a few feet of the "Bache Fund" station occupied by Dr. T. C. Hilgard in 1872, and as near to it as the changed surroundings would permit. The determinations of the magnetic elements made by Mr. Baylor will be of value, therefore, when compared with Dr. Hilgard's results in ascertaining the rate of change of the declination, dip, and intensity.

The stations above named were all occupied in April, 1890; those following in the month of May.

At Vicksburg, Warren County, Miss., the Bache Fund station, occupied by Dr. Hilgard in 1872, on Castle Hill, was found to be no longer available, a tall iron tower having been built on the hill since that year. A new station was established, therefore, on the eastern edge of Castle Hill, and measurements made to connect it with the old one. Two days were occupied in making the usual observations, and the station was carefully marked.

At Greenville, Washington County, Miss., a station was established in the large open square in the center of the town, and securely marked. The magnetic elements were determined on one day, and the latitude, longitude, and azimuth by observations on the sun on one day.

Similar observations were made on two days at Helena, Phillips County, Ark., where a station was established in the Court-house grounds over the center of a small lead bolt in the north meridian stone of the County Meridian Line.

At Oxford, La Fayette County, Miss., the Bache Fund station, established by Dr. Hilgard in 1872 in the baseball grounds south of the campus of the University of Mississippi, was re-occupied, and the usual observations made on two days. The point was securely marked.

At Florence, Lauderdale County, Ala., Mr. Baylor re-occupied the station at which he had determined the magnetic elements in 1881. The point is in the grounds of the Presbyterian Female Seminary, and had been well preserved. The usual two days observations were made.

From Florence Mr. Baylor proceeded in June, 1890, to Huntsville, Madison County, Ala., where he established a magnetic station in Spring Park, and marked it securely. The usual observations were made on two days.

Other magnetic stations occupied by Mr. Baylor are referred to under headings in Sections III, IX, and XIII.

Extension of lines of geodetic leveling from London, Pope County, Ark., to Fort Smith, Sebastian County.—The lines of leveling of precision in the State of Arkansas begun in September, 1887, in compliance with a request from Prof. J. C. Branner, Director of the Geological Survey of that State, and carried westward from the Mississippi River, had reached London, Pope County, in the autumn of 1888. Towards the end of June, 1889, Assistant Isaac Winston was directed to organize a party for the extension of these lines to Fort Smith, near the western boundary of the State.

Mr. Winston reached Little Rock July 19, and was joined there by Subassistant J. H. Gray, and by Mr. F. A. Young, recorder. The party was immediately organized, and the leveling observations were begun July 24. Two new geodetic levels, Nos. 5 and 6, and four new leveling rods, L, M, N, and O, had been furnished for use in the work, and the constants of these were at once determined. The plan of operations involved the running of two separate lines of levels in opposite directions by two observers. Mr. Winston made the forward measurement, and Mr. Gray the backward one until September 11, when he was relieved from duty in the party, and Mr. Young placed in charge of the backward measure, Mr. H. D. Mitchell of Hot Springs, Ark., being made recorder in place of Mr. Young.

The route was along the Little Rock and Fort Smith Railroad, and the party was exposed at all times to the full effect of the sun's heat. During the observations the instrument was shaded with an umbrella, and while being carried from one station to another it was covered with a white cloth. The striding level of geodetic level No. 6 being the least sensitive, that instrument and rods L and M were used almost exclusively in the progress of the work. It was found that the striding level required frequent adjustment, until the wooden wedges which kept the level vial in position were removed and the vial fixed in place by plaster of Paris. The wedges after being wet during showers of rain would shrink in drying, and hence change the level adjustment.

After October 10 Mr. Winston made the measurements in both directions himself, fearing that otherwise the allotment of funds for the work would be exhausted before Fort Smith was reached. Fortunately the lines were completed October 22, without exhausting the allotment.

The record was made in ink, and the computation of the results kept up from day to day, so that the necessary comparison between the measures could be made, and assurance obtained that the limits for error were not exceeded.

Temporary bench-marks were established at intervals of 1 kilometre (about), and permanent bench-marks in all the towns and villages along the railroad. At Van Buren, Crawford County, three bench-marks were established, this being the proper point for starting the lines of precise leveling which will form a junction with the transcontinental line at Kansas City, Mo. The Arkansas River was crossed at Van Buren, the instruments and rods being placed on the stone piers of the railroad bridge outside of the superstructure. At Fort Smith, the end of the line, two bench-marks were established.

During the season the elevations of all county-road crossings, and those of the railroad stations along the line were determined by holding the rod on the ground in the center of the track at the crossings and in front of the buildings at the railroad stations, making these points *extra foresights* in the forward measure.

A bench-mark notice, printed on linen, was posted near each permanent bench-mark. Much interest was shown in the work by the people along the route, and a general desire was expressed to obtain the published results as soon as possible.

After the close of the work a complete list of all the elevations deduced by the field computation was furnished to Professor Branner, State geologist, under authority from the Superintendent.

Mr. F. A. Young, as recorder and observer, served with ability; Mr. H. D. Mitchell's services as recorder were also entirely satisfactory.

Mr. Winston transferred his party to Greenfield, Tenn., immediately after finishing the Arkansas work, and took up under instructions field duty, which will be referred to under a heading in Section XIII.

Hydrographic surveys on the coast of Louisiana, west of the Passes of the Mississippi.—The party in charge of Lieutenant A. L. Hall, U. S. N., Assistant Coast and Geodetic Survey, commanding the steamer *Endeavor*, arrived at their working ground, west of the Passes of the Mississippi, December 16, 1889. Shore signals for the hydrography were built, and a tide-gauge established, at Ship Shoal Light House, but owing to continued fog and haze, no lines of soundings were run until January 11, 1890.

The work laid out for the season was the off-shore and in-shore hydrography of the coast of Louisiana between Barataria Bay and Ship Shoal, the off-shore work being deemed the most important, and to be advanced as rapidly as possible, while the in-shore work was to be carried on at such times as would interfere least with soundings from the ship.

In running the lines to Ship Shoal, much difficulty was experienced, as the currents between it and Isle Dernière, and outside of the shoal, were so variable in strength and direction that no allowance could be made for them, besides which the swell upon the shoal was so great that Lieutenant Hall deemed it unwise to put the ship on it unless under the most favorable conditions.

But little change in the general outline of the shoal appeared to be developed by the soundings. The passage between Ship Shoal and Isle Dernière was well marked by the soundings and character of the bottom, and can be used to advantage while standing to the eastward or northward when a norther is blowing, as it gives smooth water.

From the observations of day tides at Ship Shoal Light House between January 6 and May 15, Lieutenant Hall found that the range of the tide and the times of high and low water were much influenced by the wind. The set of the current was as a rule westerly, though frequent interruptions took place, usually followed by a change of wind. Much fog and haze were experienced in the early part of the season, with but little rain; during the latter part the winds became fresh and steady, generally from the southeast. The heaviest squalls though were from north to northwest. As late as May 3 every tripod signal on the coast was blown down by one of these squalls.

Field operations were closed under instructions on May 15, and the *Endeavor* was taken north, stopping at New Orleans for slight repairs to boiler and engine, and at Cape Florida for a hydrographic examination, the result of which is reported under a heading in Section VI.

Ensigns John F. Luby, F. H. Brown, and Thomas Washington, U. S. N., were attached to the party on the *Endeavor*, the officer last named during part of the season.

The work accomplished was plotted on three hydrographic sheets, which have been sent to the Office. Their limits and scales are as follows: Terrebonne Bay to Ship Shoal, 1–20,000; Coast of Louisiana west of Isle Dernière, 1–20,000, and Barataria Bay to Atchafalaya Bay, 1–80,000.

The statistics are:

Hydrography:	
Area sounded in square geographical miles	410
Number of miles (geographical) run while sounding	762
Number of angles measured	2,501
Number of soundings	28,491
Number of specimens of bottom preserved	9

Reconnaissance and triangulation on the coast of Louisiana, between Atchafalaya and Coté Blanche Bays.—By instructions dated December 10, 1889, the reconnaissance and triangulation needed to connect the survey of the eastern part of Atchafalaya Bay with that of Coté Blanche Bay, on the south coast of Louisiana, was assigned to Assistant C. H. Boyd.

As soon as the repairs required to put the steamer *Hitchcock* in condition for service could be completed, Mr. Boyd organized his party on board that vessel, and took up the reconnaissance and triangulation in Atchafalaya Bay, from the line Deer Island–Point au Fer. The marks for these stations were found to correspond with the descriptions, and had apparently been undisturbed.

The triangulation was then carried westward over the Atchafalaya and Coté Blanche Bays by a series of quadrilaterals as well conditioned as the marshy character of the coast would allow, until a connection had been made with the work of Assistant Perkins, in 1889, in the eastern part of Vermilion Bay, upon the line Shell–Gracious. Evidences of washing shore-lines were found everywhere within the area of this work. Details of the difficulties which attended the recovery and the marking of the several points are given by Mr. Boyd in his report.

The very unstable nature of the ground along this coast made it desirable to increase the usual number of observations, and to make them at as many epochs as possible. Each angle in the main series of triangles was therefore measured by eight sets of six repetitions each; each line from a station was measured with every other line affording the greatest number of summation angles, and the circle was filled at every angle, so that at stations having six others connecting with them there were 1,440 pointings.

Mr. Boyd was indebted to Mr. John O. Scannell, proprietor of the large sugar plantation on Coté Blanche, for a list of local names which are in more common use than a number of those given on the published charts.

The work was seriously delayed and many of the observations were made under quite unfavorable conditions of haze and fog due to the overflow waters from the Mississippi crevasses.

Assistant R. A. Marr joined the party March 1, and was detached May 6. Mr. Boyd expresses himself as greatly indebted to Mr. Marr for most cordial and efficient aid.

Field operations were closed May 9. Following are the statistics reported:

Reconnaissance:	
Area of, in square statute miles	400
Lines of intervisibility determined as per sketch	40
Number of points selected for scheme	12
Triangulation:	
Area of, in square statute miles	100
Signal poles erected, number of	6
Observing tripods and scaffolds built	10
Stations occupied for horizontal measures	12
Number of geographical positions determined	16

Reference to duty performed by Mr. Boyd on the headwaters of the St. Croix River, Maine, will be found under a heading in Section I.

SECTION IX.

TEXAS, INCLUDING GULF COAST, PORTS, AND RIVERS; ALSO THE INDIAN TERRITORY.

(SKETCHES Nos. 1, 19, and 20.)

Establishment of a self-registering magnetic apparatus at a station in San Antonio, Tex.—The completion of a record of changes in the magnetic force during a period of 7 years at the magnetic observatory at Los Angeles in October, 1889, is referred to under a heading in Section X, and as there stated, Assistant R. E. Halter, who had been in charge of the observatory since February, 1877, having been directed to pack the instruments and forward them to San Antonio, Tex., had completed this duty October 23.

On the 27th he reached San Antonio, and transferred the instruments to the new magnetic observatory which had been built earlier in the year within the grounds of the United States Military Reservation. He reported his arrival to General D. S. Stanley, U. S. A., commanding the Department of Texas, and began the final arrangements needed for beginning the record with the Adie magnetographs. But owing to severe illness Mr. Halter was compelled to suspend his work, and when it became evident that some time would elapse before he could take it up again, Assistant Andrew Braid was relieved of the charge of the Instrument Division of the Office by instructions issued in December, and directed to proceed to San Antonio, and set up and adjust the magnetographs, and begin the magnetic record.

Mr. Braid arrived at San Antonio early in January, 1890, and after having made some slight alterations in and repairs to the observatory buildings, he marked the direction of the magnetic meridian on the north and south walls of the magnet room, and of the magnetic prime vertical on the east and west walls. The direction of the magnetic meridian being then marked for the unifilar and bifilar piers, and that of the prime vertical verified, threads were stretched between these various points and the suspensions of the unifilar and bifilar magnetometers were accurately placed by means of the intersections.

The slate slabs connecting the three instrument piers with the cylinder pier were leveled in the same horizontal plane, and secured in position. The marble slabs supporting the instruments proper were also carefully leveled, and the fixed mirror of each was adjusted. The lamps, lenses, slits, and condensers were adjusted without difficulty, as were also the reading telescopes and scales. For the unifilar and bifilar instruments the suspensions used at Los Angeles were again utilized. The brass torsion weight was suspended continuously for a number of days, and by means of the graduated torsion head, and after the elimination of torsion, the axis of the brass weight was accurately placed in the magnetic meridian. The magnet was then substituted for the weight and the mirror adjustment completed.

Mr. Braid made careful determinations of the weights, in grains, of the several parts of the apparatus used in obtaining values for the instrumental constants. He expresses his obligations to the steward of the Military Hospital for the loan of a very good balance and set of weights. The results of his weighings are stated in full in his report; also the values which he found for the instrumental constants, and the methods of procedure adopted.

For the vertical-force magnet no satisfactory adjustment could be effected; it was therefore taken to Washington, and at the office a thorough examination, made by Mr. Braid, discovered defects in its original construction, as well as injuries resulting from deterioration of the agate plane and knife-edge. These having been remedied and the instrument practically reconstructed, it was returned to San Antonio and has since been working satisfactorily.

On March 17 the photographic record of changes in magnetic force was begun, and has been continued without interruption to the close of the fiscal year.

Absolute determinations of the magnetic declination, dip, and intensity were made during three days of each month, and observations for time whenever needed.

The geographical position of the Observatory was determined by connecting it trigonometrically with the tower of the Military Depot, the latitude and longitude of which were known. The metal rod on the summit of this tower was made available for an azimuth mark in the determinations of the magnetic declination.

In April Mr. L. G. Schultz was assigned to duty at the Observatory, and was trained in the manipulation of the instruments, both differential and absolute, and in making the observations, with the understanding that he should act as assistant to Mr. Halter, and in case of emergency take charge of the Observatory.

On the 23d of May Mr. Braid in pursuance of instructions, turned over the direction of the work to Mr. Halter (whose health had then much improved) and proceeded to Washington, where he was occupied for a time, as already stated, in an examination and reconstruction of the vertical-force magnetometer.

On June 16 he was assigned to duty as Executive Officer in the office of the Superintendent.

In his report of the San Antonio work, Mr. Braid expresses his appreciation of the valuable assistance rendered by Mr. Halter. A report from the latter officer has been received, acknowledging the able services of Mr. Schultz, and presenting statistics of the observations made at Los Angeles and at San Antonio for the portions of the fiscal year during which the records at those stations were kept up. They are as follows:

Number of observations for time	86
Number of observations for temperature	1,536
Number of readings of scale (eye)	600
Number of unifilar hourly scale readings from traces	2,880
Number of bifilar hourly scale readings from traces	2,880
Number of vertical force hourly scale readings from traces	2,160
Number of observations for absolute declination	464
Number of observations for absolute intensity	360
Number of observations for absolute dip	1,152
Number of observations for scale values	186

Occupation of stations in Texas for the determination of the magnetic declination, dip, and intensity.—The magnetic tour, planned for Assistant James B. Baylor, by instructions dated December 13, 1889, included the occupation of a number of stations in Texas for the determination of the magnetic elements.

Early in January, 1890, Mr. Baylor proceeded to Washington for conference with the Superintendent, and thence to Corpus Christi, Nueces County, Tex., where he established a station in the open space at the foot of a main street of the town. The latitude, longitude, and azimuth were determined by observations of the sun on one day, and the declination, dip, and intensity by observations on another day. The station was securely marked.

Similar observations were made on two days at Beeville, Bee County, Tex., where a station was established in the grounds of the Court-house and carefully marked.

Also at San Diego, Duval County, Tex., the station being located in the Court-house grounds.

At Peña Station, Duval County, observations were made at a station established in the open space to the north of the railroad depot, the work occupying, as usual, two days, one for the determination of latitude, longitude, and azimuth, and one for the magnetic declination, dip, and intensity.

The stations above named were all occupied in January, 1890.

At Laredo, Webb County, Tex., in February, a station was established at Fort McIntosh, in the open space near the house of the commanding officer, and securely marked. Two days were occupied here in determinations of the magnetic elements, and one in observations on the sun for latitude, longitude, and azimuth.

At Cotulla, La Salle County, Tex., two days' observations were made at a station established in the grounds of the Court-house, and securely marked.

At Eagle Pass, Maverick County, Tex., a station was established in the open space south of the office of the commanding officer of Fort Duncan, and was carefully marked. The usual two days' observations were made.

Also at Sanderson, Pecos County, where a station was established in the open space north of the railroad hotel, and carefully marked.

Also at Langtry, Val Verde County, where a station was established and securely marked just south of Camp Langtry on the bluff near the Rio Grande River.

Also at Spofford Junction, Kinney County, the station selected being in an open lot adjoining the United States Post-office building. This was the last station, the occupation of which was completed in February, 1890.

At the end of February and at the beginning of March a station was occupied at Port Lavaca, Calhoun County, Tex., the declination, dip, and intensity being determined by observations on two days, and the latitude, longitude, and azimuth by observations on one day on the sun. A site was selected and securely marked in the Court-house grounds.

In March a station was established at Wharton, Wharton County, Tex., in the Court-house grounds. It was occupied for two days and carefully marked.

At Austin, Travis County, Tex., Mr. Baylor re-occupied the station which he had established in 1878 near the Texas Land Office. It was found to be in a good state of preservation. The latitude and longitude and the meridian line which had been established by Assistant Eimbeck were used, and the magnetic elements were determined by observations on two days.

At La Grange, Fayette County, Tex., a station was established in the Court-house grounds and securely marked. The magnetic elements were determined by observations on one day. A meridian line for the county was laid out here and securely marked by bolts set in solid stone posts which were supplied and set by the county authorities. Latitude, longitude, and azimuth were determined on one day by observations of the sun.

The last station occupied by Mr. Baylor, in March, 1890, was at Galveston, Tex. Observations were made at a point selected at the head of Fremont street, in the rear of the Beach House, —on one day for latitude, longitude, and azimuth, and on two days for declination, dip, and intensity.

At Houston, Harris County, Tex., in April, 1890, a new station was established in the Fair Grounds west of the city, and after two days occupation was carefully marked.

The usual observations for two days were made also at a station established at Columbia, Brazoria County, Tex., in an open lot in the rear of the Presbyterian church.

Also at a station established in the Court-house grounds at Beaumont, Jefferson County, Tex.

Also at a station established in the Court-house grounds at Liberty, Liberty County, Tex.

Mr. Baylor's last station in Texas was occupied in April, at Orange, Orange County. A station was established here in an open space at the intersecting streets in front of the Curry House, and, as were all other stations, was securely marked. The observations were completed in two days.

Other magnetic stations which he occupied are mentioned under headings in Sections III, VIII, and XIII.

SECTION X.

CALIFORNIA, INCLUDING THE COAST, BAYS, AND RIVERS. (SKETCHES Nos. 2, 10, 16, 16*a*, 17, 19, and 20.)

Completion of the topographic survey of the south coast of California, between San Diego and San Onofre.—Reference was made in the last Annual Report to the resumption of topographic work on the south coast of California by the party in charge of Assistant A. F. Rodgers in May, 1889. At the beginning of the fiscal year plane-table work was in progress upon a sheet projected to include the coast and vicinity to the north and south of Del Mar. Mr. Rodgers observes that the topography in this vicinity is extremely broken and complex in character, and that this is a characteristic feature of the larger part of the coast margin of San Diego County.

Work was continued upon the Del Mar sheet until July 22, and the party was then transferred to La Jolla, 10 miles to the south. Here the sheet projected to include the village and vicinity of La Jolla and Pacific Beach was taken up. This locality is marked by the hill known as Soledad Mountain. It is 812 feet in elevation above sea level and forms a prominent landmark for the mariner in approaching San Diego Bay from the northward. This summit, with its western extremity, was known to the old Spanish navigators as "Punta Falsa," or False Point, from its dangerous resemblance to Point Loma, the headland of San Diego Bay, and for which it was sometimes mistaken.

During the months of August and September the topographical survey was continued over the slopes of Soledad Mountain and to the eastward of Rose Cañon, through which the branch of the Santa Fé Railroad known as the California Central or Southern Railroad reaches the bay of San Diego from the northward. Upon the completion of the La Jolla plane-table sheet, October 2, the party was transferred on the afternoon of that day to San Diego, and was employed for a week in making additions to the original topographical sheets of San Diego Bay, chiefly new wharves, and also the line of the Coronado Belt Railroad around the shore of the bay.

The results of this work of revision were forwarded to Washington in November to be made available for publication in a new edition of the chart of San Diego Bay.

While in San Diego Mr. Rodgers visited the entrance to the bay and determined the position of the new Light-house on Point Loma, and also the road leading from that Light-house to the Government landing at Ballast Point Cove.

On October 9 the party was transferred by the coast wagon road to Oceanside, and on the 14th work was begun upon the topography in the vicinity of Las Flores, and continued until November 18. On November 20 the quarters of the party were established in a deserted cabin in the San Onofre Valley, the location of which exactly suited the requirements of the work. Soon after beginning the San Onofre sheet, the rainy season set in with vigor, and the ordinarily dry bed of the San Onofre Creek, which the party had to cross on their way to meals, became a torrent. Mr. Rodgers observes that he was not unduly impressed at such times with the improvident waste of water, millions of gallons rushing to the ocean as the result of every rainstorm, while during the dry season of summer the thirsty crops wither from lack of moisture and the only recourse of the settler, in many parts of the south-coast counties, for his daily family supply is a horse and sled and a water barrel. In former reports Mr. Rodgers has called attention to the San Onofre as one of the streams which could be readily utilized in developing the water supply of San Diego County.

The topography of the ridges of the San Onofre Mountain, the summit of which is 1,720 feet above sea level, occupied the party during the month of November. This "mountain," so called, is really a ridge about 5 miles in length, forming a prominent landmark looking north or south along the coast. Its axis is nearly parallel to the coast line; its sea-front is bordered by flat table-lands, from which long ridges flanked by deep gorges reach back to the main ridge; this breaks down abruptly on its eastern face, giving marked evidence of some displacement of mass, either from earthquake or deluge, in the remote past.

San Onofre is cut nearly down to sea level on the north by the valley of the same name, and on the south by Horno Cañon.

During November, although there had been a heavy rainfall, the precipitation had been generally at night, and field work was not seriously interfered with, but by the middle of December the rains had become almost continuous and the soil so saturated with water that the pack-animals would *bog down* on the grassy slopes of the mountain, and under such conditions progress was necessarily slow. Finally, however, the San Onofre sheet was completed, and on December 22 Mr. Rodgers began his arrangements for leaving the field.

These were not carried out without many difficulties and annoying delays, owing to the swelling of the streams, *wash-outs*, and carrying away of bridges on the railroads, and other effects of heavy rainfall, resulting in a temporary suspension of freight and passenger transportation. From the 25th to the 31st of December the party was hopelessly weather-bound at Capistrano, and it was not till January 6 that passenger-train service was resumed to the northward from Los Angeles. On that day Mr. Rodgers left for San Francisco, arriving there the next day with his aid, Mr. John Nelson. The efficient service rendered by Mr. Nelson throughout the season is acknowledged by his chief.

For the four topographical sheets which cover the coast line and vicinity from La Jolla to

San Onofre, and which were projected in 1886 and 1887 and finally completed in 1889, Mr. Rodgers presents the statistics in a tabular form as follows:

Locality of survey.	Area in square miles.	Number of miles surveyed.			
		Shore line.	Creeks.	Railroads	Wagon roads.
Del Mar	19.6	7	9	7.7	44.4
La Jolla	20	7.5	8.4	7.2	28
Las Flores	14.6	7.2	12.2	6.9	12.4
San Onofre	11.8	7	7	7.4	10
Totals	66	28.7	36.6	29.2	94.8

In addition to the above there were surveyed at San Diego Bay 3 miles of shore line and 14 miles of railroad, and in the course of the determination of the new light-house site at Point Loma, 1 mile of railroad and 3 of wagon roads.

Duty assigned to Mr. Rodgers later in the fiscal year is referred to under a subsequent heading in this section.

Connection of the Los Angeles primary base line with the main triangulation in southern California. Preparations for the occupation of Mount Conness.—The measurement of the Los Angeles primary base-line in the winter of 1888-'89 by the party in charge of Assistant George Davidson was referred to in the last Annual Report, and a full account of it by Mr. Davidson was published as Appendix No. 10 to that volume.

In the spring of 1890 he was prepared to take the field in pursuance of instructions issued in March of that year, to make the observations required at the ends of the base in order to connect it with the main triangulation. The beginning of the work was delayed by the almost impassable condition of the roads resulting from the heavy and incessant rains of the previous winter. In April Assistant J. J. Gilbert was directed to report for duty to Mr. Davidson and was assigned to the charge of the field observations at the ends of the base. Sub-assistant Isaac Winston reported for duty soon after.

Mr. Gilbert occupied first the Southeast Base station and observed all the horizontal directions. The triangulation developed from the base line by a quadrilateral on either side; the heights of the stations extend from the base line at about 100 feet to Mount Wilson at about 6,200 feet. The fogs proved to be a great hindrance to rapid work, but all of the directions needed were obtained. For this work Mr. Davidson increased the number of positions of the theodolite to 47, one observation direct and one reversed being made in each position.

Some observations for latitude and azimuth were also undertaken by Mr. Gilbert to allow of preliminary computations, but the series was badly broken by reason of fogs that came over the low country early in the night and cut off work.

Meanwhile Mr. Winston was detached to make a series of levelings between Northwest Base station and the tidal bench-mark at San Pedro Harbor. This he did both ways and then established two permanent bench-marks at San Pedro for future reference.

Towards the end of May, the observations at Southeast Base, which included also vertical angles and the determination of the magnetic elements, were completed, and the party was transferred to Northwest Base. Here the weather proved more favorable; the horizontal directions were soon finished; vertical angles and the magnetic elements were observed, and upon two or three nights observations for latitude were made. The time and azimuth observations were not completed, the advance of the season making it necessary to push forward the preparations for the occupation of the primary triangulation station, Mount Conness. On the 17th of June Assistant Gilbert moved the party from Northwest Base station to Oakdale, beyond Stockton, the end of rail towards Conness, and after conference with Mr. Davidson he moved to the front.

Assistant J. S. Lawson and Subassistant Fremont Morse forwarded from the Suboffice all the necessary camp equipage and extra instruments for the Mount Conness work. Mr. Morse then moved to the front.

In approaching Conness, Messrs. Gilbert, Winston, and Morse encountered snow and bad roads at a point 43 miles west of Soda Springs in the Tuolumne Meadows.

An account of the occupation of this important primary station is necessarily deferred to the next fiscal year.

Completion of the record of changes of magnetic force at the self-registering station, Los Angeles, Cal.—A continuous record, without any serious interruption, of the changes of magnetic force having been obtained by means of the Adie magnetographs at Los Angeles, Cal., from October 1, 1882, to October 1, 1889, Assistant R. E. Halter, who had been in charge of the Magnetic Observatory since February, 1887, was directed to pack the instruments and forward them to San Antonio, Tex., proceeding there himself to set them up again and adjust them at the station which had been previously selected there.

The period of 7 years during which the magnetic changes had been recorded at Los Angeles, covering nearly two-thirds of a sun-spot cycle, included the time of minimum sun-spot activity supposed to have occurred early in the year 1889. In Appendices Nos. 8 and 9 to this volume, the results of an elaborate discussion of both absolute and differential measures of the magnetic force as derived from the observations at Los Angeles are presented by Assistant Schott.

Before disturbing the instruments, Assistant Halter redetermined the scale values, and remeasured the astronomical azimuth of the mark.

By the 23d of October he had completed and forwarded to the Office all of the records of the Los Angeles work, original and duplicate, and had sent to San Antonio all of the instruments and apparatus pertaining to the Observatory.

Reference to the establishment of the instruments at the San Antonio Observatory is made under a heading in Section IX.

Completion of a hydrographic survey in the vicinity of Piedras Blancas, coast of California, including the development of rocks in Twin Peak Bay.—Under the date of May 22, 1890, Lieut. D. Delehanty, U.S. N., Assistant Coast and Geodetic Survey, commanding the steamer *Hassler*, reports the completion of the hydrography in the vicinity of Piedras Blancas, coast of California, assigned to him by instructions dated October 17, 1889.

From the northern end, near San Simeon Harbor, the character of this part of the coast is irregular for a distance of 6¾ miles to the signal White, the shore being low and thickly wooded. Thence for 6 miles to the signal Kan, at the limit of the hydrographic sheet, it is a range of barren hills terminating in low land, the shore line throughout consisting of low clay bluffs.

The general set of the current, Lieutenant Delehanty observes, is southerly, ranging from one-fourth of a knot inside of the 10-fathom curve to a half knot outside of this curve. No dangers exist inside of the kelp line, which extends from half mile to three-quarters of a mile from the shore, and the least water on this line is 8 fathoms. Inside of the kelp line the bottom is mostly rocky. From this line, or the 10-fathom curve, to the 100-fathom curve the depth of water is marked by a regular increase. Between the 10-fathom and the 30-fathom curves, the character of the bottom is variable, consisting of mud, sand, broken shells, and hard bottom. Where specimens were not obtained with the cup, an armed lead generally indicated a layer of fine sand. Between the 30-fathom and the 100-fathom curves, the bottom is principally green mud and sand.

There are no possible harbors within the limits of this survey; landings might be constructed, but it is highly improbable that they will be, owing to the proximity of San Simeon to the north and Cayucos to the south, both of which are very fair summer harbors, but are dangerous anchorages during the winter in the southerly gales.

Soundings were taken for the development of a rock and a rock awash in Twin Peak Bay (or Cove) about half way between Piedras Blancas and the Sur.

The officers attached to the party were Lieut. C. A. Gove, U. S. N., executive officer; Ensign Guy W. Brown, U. S. N. (part of the season), Ensigns J. P. McGuinness and W. L. Dodd, U. S. N., Ensign E. Moale, jr., U. S. N. (part of the season), and Ensign S. R. Hurlbut, U. S. N.

For the work in the vicinity of Piedras Blancas the statistics are as follows:

Hydrography:	
Number of miles run in sounding	176
Number of angles measured	1,299
Number of soundings	2,590

Hydrographic surveys executed by Lieutenant Delehanty in the vicinity of Crescent City, Cal., are referred to under a subsequent heading in this section, and a hydrographic examination off the coast of Oregon near Cape Lookout under a heading in Section XI.

Connection of the coast triangulation south of Monterey Bay with the main series.—Acting under general instructions to take up at as early a date as was expedient the connection of the coast triangulation south of Monterey Bay with the main series, Assistant A. F. Rodgers made all preparations needed for the organization and equipment of his party in the field, and left San Francisco April 17 for Toro Station, one of the points in the main series.

Mr. Rodgers, with his aid, Mr. John Nelson, had been continuously employed from January till early in March in the inking of his topographic sheets of the south coast of California, and in making the outline tracings of these objects needed for file in the suboffice. He found it necessary then to occupy part of his time with the details of preparation for the field, and on the 20th of March to go to Jolon and thence to Pacific Valley to inform himself personally respecting the requirements of the work. Soon after returning to San Francisco he was summoned by telegram to meet Assistant Charles M. Bache at Benicia, under the painful conditions attendant upon the serious illness of that officer, resulting, on the 10th of April, in his death.

Hence it was not till April 17 that he could reach Toro Station. After erecting a signal there he proceeded to station Pico Blanco, 30 miles south of Monterey. The building of signals was continued during the month of May, and two stations, Pico Blanco, 3,700 feet in height, and Manuel, 3,300 feet, both near the coast, were occupied. Directions to stations of the coast triangulation of 1875 and to those of the revised scheme were observed.

While Mr. Rodgers was occupying stations, Mr. Nelson was frequently detached to build new signals. Cooper, Sur River, and Pfeiffer's Point were occupied in succession. This, Mr. Rodgers observes, may be called a climatic point or local barrier to the northwest winds and fogs which are so characteristic of the coast from San Francisco southward.

North of Pfeiffer's Point, along the coast line, a clear day in summer is the exception, and in the vicinity of Point Sur the fog horn of the Light-House Establishment is a reminder night and day to the coasting mariner that he must depend on sound, rather than sight, in keeping a close offing from the shore. South of Pfeiffer's Point, and on the bight between that and Cape San Martin, the coast line and hills are as a rule bathed in sunshine, and the temperatures are frequently as high as 90° to 100° F., while between Pfeiffer's Point and the Sur the coast is covered with a dense mantle of fog.

This feature Mr. Rodgers noted specially, not alone as causing delay in his work, but in watching the coasting steamers bound north, hugging the shore south of Pfeiffer's Point in order to avoid the heavy northwest wind and sea 2 or 3 miles off shore, and coasting so close as to suggest the need of a very careful hydrographic examination of this locality when the hydrography is in hand in order to develop any dangers not now known to exist.

Work was not closed at Pfeiffer's Point until June 16, as it was often necessary to dismount the theodolite, drop the observing tent upon the ground and weight it down to prevent its being blown away. The wind frequently reached a velocity of from 30 to 35 miles per hour.

The stations next occupied were Rico (which took the place of Blank Ridge on the old scheme), Timber Ridge, Castro, Anderson Station, Anderson Point, and Little River Hill. With the occupation of this last named station, a satisfactory connection was completed between the triangulation of 1875 and that now in progress.

Up to June 21, 1890, eleven stations had been occupied, at which 1,617 pointings had been made. After that date and to the close of the fiscal year, the party was engaged in traveling and building signals. Supplies for the men and forage for the pack animals had to be carried and long detours often made to reach points near each other, but separated by impassable cañons.

The progress of the work will be again adverted to in the next annual report.

Topographical survey of the coast of California in the vicinity of Point Sur.—Report is made under a heading in Section XI of the surveys executed by Assistant Cleveland Rockwell in Young's Bay and on the Columbia River, Oregon and Washington. After finishing this work and completing and forwarding to the office the records and results relating to it, he took up in the spring a reduction of topography for a new edition of the chart of the approaches to New York

Harbor. This having been completed and sent to the Office, he left Portland, April 3, under instructions to report to Assistant George Davidson for duty in his party organized for the connection of the primary base line at Los Angeles, Cal., with the main triangulation.

Mr. Rockwell had forwarded the camp outfit, got the party into camp at Southeast Base, and aided in the erection of an observing pier and tower at that station, when he received instructions to return to San Francisco and take charge of the topographical party left without a chief by the sudden demise of Assistant Charles M. Bache. Mr. Rockwell thereupon took up the preparations needed for the work of this party, which was to co-operate with that of Assistant Rodgers on the coast of Monterey County, Cal.

Leaving San Francisco May 1, he arrived the same day at Jolon, and proceeded thence to Pacific Valley, his field of work, reaching there on the 6th. Camp was immediately pitched and the topographical survey begun. It was carried on under the general direction of Assistant Rodgers, with whom Mr. Rockwell frequently conferred by letter. Owing to the almost constant prevalence of foggy weather during the month of May, but small progress could be made. To supplement the want of geographical positions for the control of the topography, a plane-table triangulation was laid out, but the exceedingly rough and mountainous character of the country and the necessity of moving the instruments on mule back between every two plane-table stations made it impracticable to accomplish more than the survey of about 3½ miles of ocean shore line, and an area of 6 square statute miles. The last camp of the season was at an elevation of 3,300 feet above sea level and barely two miles from shore. At one place a height of 2,000 feet in the slope of the mountain gave an angle of elevation of 32½ degrees or 2½ degrees more than the graduated arc on the alidade.

Field operations were closed June 16, and after disposing of the property and the animals, Mr. Rockwell proceeded to San Francisco.

General direction of land operations upon the Pacific coast—Observations of moon culminations at San Francisco in connection with similar observations by the Alaska Boundary parties—Main triangulation, etc.—Assistant George Davidson continued in general charge of the land operations of the Survey upon the Pacific coast. He submitted to the Superintendent general plans for the prosecution of the work; examined all estimates and referred them to the Superintendent; conferred with the officers on duty on that coast, and received and transmitted all official correspondence between them and the Superintendent.

Following is an abstract of his annual report, which gives a résumé of the several classes of work carried on by him or under his direction during the fiscal year.

Having been appointed by the President as a Delegate on the part of the United States to the Ninth Conference of the International Geodetic Association held at Paris, October 3 to 12, 1889, Mr. Davidson was instructed early in August of that year to make all preparations needful for the temporary assignment of an officer to the charge of the Suboffice at San Francisco, and to proceed to Washington for conference with the Superintendent, and thence to Paris. After receiving from the Superintendent special instructions under date of September 7, governing his action as Delegate, he left New York September 10, and returned to Washington November 15.

The full report made by Mr. Davidson relating to the subjects considered by the Association and with regard to his own action as the Delegate from the United States was published as Appendix No. 18 to the Report of the Superintendent for 1889. In Appendix No. 17 to this volume will be found the paper which he presented to the Association respecting the objects, methods, processes, results, and scope of the work of the Coast and Geodetic Survey.

Reference has already been made in Part I of this volume to the duty specially assigned to Mr. Davidson of bringing from Paris to Washington one of the two sets of the National Prototypes of the Metre and Kilogramme that had been allotted to the United States. His report of the performance of this service appears in Appendix No. 18, and an abstract of it under the heading "Special Operations."

Observations of moon culminations at the Lafayette Park telegraphic longitude station in connection with the longitude work of the Alaska boundary parties.—Upon returning to San Francisco and resuming his duties upon the Pacific coast, Mr. Davidson assigned to Sub-assistant Fremont Morse the observation of all possible meridian transits of the moon at the Lafayette Park telegraphic longitude station in connection with the longitude work of Assistant McGrath and Subassistant Turner in charge of the Alaska Boundary Survey parties on the Yukon and Porcupine Rivers. This series of moon culminations extended from December 23, 1889, to April 10, 1890. In addition to making these observations, Mr. Morse attended to his regular office duties. He reduced all of the work, and transmitted the results with the original and duplicate records to the Office.

Main triangulation, southern California, and preparations for the occupation of Mount Conness.—Reference to this work, which involved the occupation of the ends of the Los Angeles Base, and the advance towards Mount Conness, has been made under the second heading in this section.

Tidal record continued at the automatic tidal station, Sausalito, Bay of San Francisco—Temporary automatic tidal station established at Mission Street Wharf, city of San Francisco.—The tidal record at the automatic tidal station Sausalito, San Francisco Bay, was continued under the direction of Mr. Davidson, except during his absence, from August 25 till December 12, 1889, when Assistant Lawson was in charge. Mr. Emmet Gray remained as observer. Each month's tidal roll and the tabulations of the observer are examined before being forwarded to the Office.

On September 17, 1889, and January 30, 1890, Subassistant Morse made the levelings between the two bench-marks and the zero of the gauge to guard against any possible change in the sinking of the piling. He visited the tide-gauge also to examine the condition of the pier and observing hut. The transit observations for determining the error and rate of the tidal chronometer were made by Mr. F. W. Edmonds, at the astronomical station, Lafayette Park, San Francisco.

In order to obtain the times and heights of the tides at the city front, and also to establish a zero for the reduction of soundings in that part of the bay, Mr. Davidson made all the preparations for putting up an automatic tide-gauge at Mission Street Wharf. On his departure for Europe, Mr. Lawson took charge of the execution of the work. A temporary observing hut was erected on the wharf by permission of the State Harbor Commissioners, and a bench-mark established for reference. Subassistant Morse connected this bench-mark by levelings each way with the three old tidal bench-marks of Fort Point. The record was kept up from September 28 to December 15, during which time the climatic conditions happened to be somewhat abnormal, so that it is not improbable that a more extended series will have to be observed. Andrew Wikman had charge of the gauge under the immediate eye of Mr. Morse, by whom all the work was tabulated. Mr. Davidson acknowledges the facilities kindly afforded for the occupation of the wharf by Mr. Marsden Manson, chief engineer of the State Harbor Commissioners.

Reference to the automatic tidal station on Kadiak Island, Alaska, under Mr. Davidson's direction, is made in one of the abstracts of field operations in Section XII.

Sub-office, San Francisco.—For a notice of the operations of the Suboffice, San Francisco, see that heading towards the close of Part II, of this volume.

Pacific Coast Pilot.—Since the publication of the fourth edition of the Pacific Coast Pilot, California, Oregon, and Washington, Mr. Davidson has continued the collection of material relating to new discoveries, additional aids to navigation, etc., and has now about ninety pages on hand.

Special reports and examinations, etc.—Among the various subjects which have engaged Mr. Davidson's attention during the year, and reports of which he has communicated to the Superintendent, may be mentioned the following: A report upon Mount San Bernardino, 11,725 feet in elevation, to indicate its importance in the scheme of main triangulation governing southern California; a letter of April 15, 1890, proposing a new form of tide-tables with illustrations; a letter transmitting a copy of a map drawn by the Chilkat Chief, Koh-klux, illustrating the connection of the waters of the Chilkat and Tah-heena Rivers, Alaska; a conference with Mr. Wells, of the Frank Leslie Exploration Expedition to Alaska, and advice given him, which he followed, to enter by the Chilkat; a conference also with Mr. Mark B. Kerr, of the U. S. Geological Survey, and advice given him in his preparations to make a survey for the National Geographic Society of the Elias Range near Yakutat Bay, and to make the ascent of Mount St. Elias, if practicable; a special report in January, 1890, on the triangulation, topography, and hydrography of the Pacific coast, and a communication with regard to an apparent error in the determination of the eastern boundary line of California, where it reaches Lake Tahoe at the north shore and leaves it at the southeast shore.

Mississippi River Commission.—As the representative of the Coast and Geodetic Survey on the Mississippi River Commission, Mr. Davidson had served since October, 1888. Recognizing the demand made by the exceptional floods of the spring of 1890 for his active co-operation and conference with the Board, and finding that his field duties on the Pacific coast at that time necessarily precluded his leaving them, he deemed that the only course for him to take was to transmit to the President of the United States through the Superintendent his resignation as a member of the Commission. This was accepted, and took effect April 19, 1890.

Resurveys and examinations of soundings in Suisun Bay, Karquines Strait and vicinity.—Certain additional lines of soundings and verifications of hydrography executed in 1886–'87 in Suisun Bay, Karquines Strait and vicinity having become desirable in order to obtain data for chart corrections, Lieut. D. H. Mahan, U. S. N., Assistant Coast and Geodetic Survey, commanding the steamer *McArthur*, was instructed to take up that work at as early a date as practicable.

The *McArthur* was detained at the Mare Island Navy-yard by needed repairs until the end of March, 1890, so that it was not till early in April that Lieutenant Mahan could begin field operations. He reports under date of July 7, 1890, that the required resurveys as outlined in his original instructions were completed May 28, and that in obedience to supplementary instructions of that date a resurvey of the mouth of the Sacramento River was taken up and on June 25 completed.

The statistics of the season are:

Number of miles of sounding run	210
Number of soundings	11,830

The officers attached to the *McArthur* were Lieut. J. H. L. Holcombe, U. S. N., Lieut. A. G. Rogers, U. S. N., Ensigns W. H. G. Bullard and M. L. Bristol, U. S. N., and Assistant Engineer J. C. Leonard, U. S. N.

Completion of a hydrographic survey in the vicinity of Crescent City, Cal.—Under the date of October 31, 1889, Lieut. D. Delehanty, U. S. N., Assistant Coast and Geodetic Survey, commanding the steamer *Hassler*, reports the completion of a hydrographic survey on the northern coast of California in the vicinity of Crescent City, and extending 27¼ miles to the southward from False Klamath Rock.

Reference to the beginning of this work by the party of Lieutenant Delehanty early in June was made in the last Annual Report. He observes, with regard to the tidal currents in the locality of his survey, that they are irregular, and noticeably affected by moderate winds, the inshore and offshore currents differing at times in force and set to a marked degree. This he attributed largely to the influence of the Klamath River. For several miles off the mouth of this river the water is much discolored, giving it the appearance of shoal water, but from the soundings taken in the course of the work and from information given by the fishermen and coasting captains in the vicinity he came to the conclusion that no dangers to navigation existed within the limits of the survey beyond 1 mile from the shore line, where the depth of water varies from 7 fathoms gradually increasing to the northward 15 fathoms. Within 1 mile of the shore line there are numerous low and sunken rocks, as indicated on the projections.

Lieutenant Delehanty reports that there are no possible harbors within the limits of the hydrography. The Klamath River is shoal and its mouth narrow, with a shifting bar. The small vessels trading there are not infrequently bar-bound for a month or two during the winter months. The current in this river runs out continually, except during the highest tides in the autumn, when the water in the river is lowest. Throughout the length of coast surveyed, the soundings were marked by great regularity from the 10-fathom to the 100-fathom curve, this curve ranging in distance from 18 to 20 miles off the coast on the northern sheet, and gradually drawing in on the southern sheet to 8½ miles off Patrick's Point, the southern end.

The general character of the bottom is green mud and fine sand between the 30-fathom and 100 fathom curves. Inside the 30-fathom curve it was fine gray sand over hard bottom, the cups frequently failing to bring up specimens which were afterwards obtained by using an armed lead.

After finishing the hydrography to the southward of Crescent City, Lieutenant Delehanty made a careful searchfor shoals in the vicinity of Point Lookout and Haystack Rock, coast of Oregon, but found no evidence of their existence.

The officers attached to the party were: Lieut. C. A. Gove, U. S. N., executive officer; Ensigns Guy W. Brown, J. P. McGuinness, W. L. Dodd, and S. R. Hurlbut, U. S. N.

For the season the statistics are:

Miles run in sounding	640
Angles measured	1,897
Number of soundings	4,656

About the middle of October Lieutenant Delehanty was instructed to make preparations for, taking up the inshore hydrography of the coast of California between Monterey Bay and Point Buchon.

SECTION XI.

OREGON AND WASHINGTON, INCLUDING COAST, INTERIOR BAYS, PORTS, AND RIVERS.

(SKETCHES NOS. 2, 10, 17, 18, 19, AND 20.)

Hydrographic survey of the coast of Oregon from Mack's Arch to Cape Blanco.—Lieut. J. M. Helm, U. S. N., Assistant Coast and Geodetic Survey, commanding the steamer *Gedney*, has transmitted to the Office full descriptive reports, accompanying the hydrographic sheets of his survey on the coast of Oregon from Mack's Arch to Cape Blanco. This work, executed between May 28 and September 11, 1889, was laid out on two projections, scale of each 1–20000, the first sheet comprised within the limits, Mack's Arch to Rogue River Reef, and the second, Rogue River Reef to Cape Blanco.*

Only an abstract of these reports can be given here; the hydrographic details contained in them, and the sailing directions by which they are accompanied, will be of value as embodying results of the most recent surveys for the fourth edition of the Pacific Coast Pilot.

Three channels are embraced in the limits of the two hydrographic sheets just referred to; one inside of Rogue River Reef; one, the channel to Rogue River; and one, a channel between Orford Rocks and the mainland. In Rogue River Reef Channel the depth of water was from 7 to 15 fathoms, and the shoalest water, 7 fathoms, was found three-fifths of a mile northeast (magnetic) from Pyramid Rock in the reef. A pilot would not be necessary with the use of a chart and the lead. Lieutenant Helm has recommended that this channel should be buoyed.

The channel into Rogue River is of the kind so frequently met with on this coast, subject to the changing conditions of a bar. At high tide from 1 to 1½ fathoms water was found. Ranges have been established as guides to the channel approach, but they are shifted from time to time, and strangers should not attempt to enter without a pilot.

A survey had been formerly made of the channel between Orford Rocks and the mainland. Search, however, was made for a reported shoal spot, but no material change was found from the former survey. This channel is used by vessels of all sizes, nor is a pilot necessary.

The best anchorage in this locality is at Port Orford, in from 6 to 8 fathoms, hard sandy bottom, the end of the wharf bearing NNW. one-half west (true), distant one-quarter of a mile. A few small steamers and sailing vessels, probably twenty-five per year, enter this harbor, which is mostly used during the summer, when the northwesterly winds prevail, it being open, unprotected and unsafe in winter, or with southerly gales.

Notes are made in Lieutenant Helm's report of other anchorages which were sometimes resorted to by the *Gedney*, and which coasters may use occasionally in a heavy northwest blow, while waiting for the wind to go down; it is to be said, however, with regard to them, that frequently at night local southerly winds spring up, which cause vessels to ride broadside to a northerly swell and roll heavily.

The aspect of the coast in approaching from seaward is that of high foothills backed by successive broken ranges of mountains, well timbered, except between Port Orford and Cape Blanco, where there is a long range of sand hills, backed by timbered ranges. Orford Rocks, off Cape Blanco; the Redfish Rocks, 3 miles to the southward of Port Orford; Island Rock, the Sisters Rocks, Rogue River Reef, and Mack's Arch are prominent and well-recognized groups of rocks along the coast. In approaching Port Orford or this part of the coast from

* The local name Blanco has been adopted, instead of Orford, by the U. S. Board on Geographic Names.

seaward, Humbug Mountain, 4½ miles to the southward of that port, is a prominent landmark. From seaward this mountain presents a symmetrical shape; broad at its base, it rises gradually from northward and southward to a peak upwards of 1,900 feet in height, and in color of a reddish brown. This same landmark will be seen in approaching the coast from the southward. Coasting along the shore from the northward, Cape Blanco Light-house is the most prominent object; it stands on a high base bluff, about 7 miles north of Port Orford, and can not be mistaken for anything else.

The following-named officers were attached to the *Gedney* during the season: Ensigns R. O. Bitler, Joseph Strauss, W. H. Bullard, F. W. Jenkins, and M. L. Bristol, U. S. N. Mr. William Joynes served as pay yeoman, and Mr. P. M. Christiansen as ship's writer.

Lieutenant Helm reports the following statistics of his survey:

Hydrography:

Area sounded, in square geographical miles	402
Number of miles, geographical, run while sounding	1,126
Number of angles measured	7,328
Number of soundings	12,270
Number of tidal stations established	2
Number of specimens of bottom preserved	19

Triangulation and topography of Coos Bay, Oregon.—At the beginning of the fiscal year, the party of Assistant E. F. Dickins had been in the field since May 20, 1889, engaged in the resurvey of Coos Bay, Oregon. As stated in the last Annual Report, a scheme of triangulation had been laid out and signals erected, but, on account of the strong northwest winds then prevailing, the measurement of angles was temporarily postponed and the topographical survey of the lower bay was taken up. The first plane-table sheet, which included the area of this bay, was finished July 13, and two days later Mr. Dickins moved his quarters to Marshfield, on the upper bay, and began the erection of signals.

Finding that the northwest winds did not blow home with the same force in the upper as in the lower bay, the triangulation was taken up. Two theodolites being available for this work, Mr. Dickins took one and put the other in the hands of his assistant, Mr. Ferdinand Westdahl. With two observers, the observations made rapid progress, and by August 22 the triangulation of the upper bay was finished, the computations were made, and the work plotted. The second plane-table sheet was then taken up; this included the whole upper part of the bay and a good portion of its tributaries. The topography of this area presented a large amount of detail; owing to this and to unfavorable weather, the sheet was not completed until November 2. Returning then to Empire City, the party took up the triangulation of the lower bay, including the connection with Cape Arago Light-House. This done, field work was closed for the season, November 23.

Mr. Dickins had hoped to complete the hydrography of Coos Bay also, but, owing to the strong northwest winds which prevailed during the summer, the dense smoke from forest fires which obscures signals in the greater part of the autumn, and the early beginning of the rainy season, he found it impracticable.

Both the reports submitted by Mr. Dickins—annual and descriptive—contain details of interest relative to the development of the Coos Bay country. He observes that it is being rapidly settled and improved. There were at the time of his survey seven sawmills on the bay, with a total cutting capacity of about 430,000 feet of lumber per day. The Newport coal mine employs three steam colliers to transport its coal to San Francisco. The two principal towns are Empire City, on the lower bay, population about 500, and Marshfield, about 1,500 inhabitants, on the upper bay. Shipbuilding is carried on at North Bend, the vessels built ranging in size from small schooners to full-rigged ships. There are two salmon canneries on the bay.

At the head of navigation for sea-going vessels on Isthmus Slough, seven or eight miles above Marshfield, there is a valuable coal mine, and there was expressed a general desire to have the survey extended to this point. Isthmus Slough is also the main channel of communication with the Coquille Valley. The other principal tributaries of Coos Bay are Coos River, which is navigated by small steamers up both the north and south forks for about 10 miles, and Catching Slough, navigable for small steamboats to the town of Sumner, about 8 miles from its mouth.

Mr. Dickins acknowledges the capable and trained assistance rendered throughout the season by Mr. Ferdinand Westdahl.

The statistics of the survey are as follows:

Triangulation:	
Area of, in square statute miles	36
Number of signals erected	64
Number of stations occupied	37
Number of geographical positions determined	62
Topography:	
Area surveyed, in square statute miles	36
Number of miles of shore line surveyed (coast and bay)	51
Number of miles of shore line, rivers and sloughs	67
Number of miles of shore line of creeks and ponds	15
Number of miles of wagon road surveyed	29
Number of miles of dikes	7
Number of miles of railroad	5

In March, 1890, Messrs. Dickins and Westdahl were instructed to take up the hydrographic resurvey of Coos Bay as soon as the weather would permit.

The party was re-organized for this purpose on May 1, and on its arrival in Coos Bay, on the 3d, the hydrography of the lower bay was taken up, and at the end of the fiscal year this had been finished and work was in progress on the upper bay.

For the hydrography, up to June 30, 1890, Mr. Dickins reports the following statistics:

Area sounded in square geographical miles	10
Number of miles (geographical) run while sounding	226
Number of angles measured	3,203
Number of soundings	15,176

Further account of the progress of this survey will be given in the next annual report.

Hydrographic examination off the coast of Oregon, in the vicinity of Cape Lookout.—A shoal having been reported to this office as a danger to navigation off Cape Lookout, coast of Oregon, and also a rock off Haystack Rock to the southwestward of that cape, Lieutenant D. Delehanty, U. S. N., Assistant Coast and Geodetic Survey, commanding the steamer *Hassler*, was instructed to make careful search in the locality. This service was executed in August, 1889, but the dangers reported were not found, and Lieutenant Delehanty states that he is satisfied that they do not exist.

The statistics of the work are:

Number of miles run in sounding	67
Number of angles measured	215
Number of soundings	838

Hydrographic surveys on the coast of California, made by Lieutenant Delehanty during the fiscal year, are referred to under headings in section X.

Examination of Young's Bay and River, Oregon, with reference to the effect upon navigation of a proposed railroad bridge—Triangulation of the Columbia River continued.—The Astoria and South Coast Railroad Company having proposed to construct a bridge for the crossing of their road over Young's Bay, Assistant Cleveland Rockwell was directed, under instructions dated April 27, 1889, to make a hydrographic examination of that bay and of Young's River, with special reference to its probable effect upon navigation.

Mr. Rockwell obtained from the chief engineer of the road the following details of construction of the bridge. Bents of four piles each to be 15 feet 6 inches between centers. Piles 16 to 20 inches diameter at large end. Total length of trestle and bridge 8,400 feet. The draw span across the channel will be 254 feet over all. The opening or clear span will be 110 feet. The pivot pier will be 26 feet wide, and the abutment piers will be each 6 feet wide.

In considering the effect this bridge will have upon the navigation of the Columbia, Young's, and Lewis and Clarke Rivers, Mr. Rockwell observes that the future interests and importance of the port of Astoria demand recognition and protection far more than the present. While for the present the great transcontinental railroads have made such combinations that Puget Sound, as an ocean outlet and terminus, is their objective point, he thinks it improbable that the Columbia River will long remain unnoticed. The completion of the stone jetty now in course of construction will probably greatly improve the entrance to the Columbia River, so that in the near future vessels of the largest class may enter and find a secure harbor within but 10 or 12 miles from the sea. A large city may therefore be reasonably expected to be located at or near Astoria, and Young's Bay, in that event, would afford the best facilities for wharf room and mooring ground.

Young's River is mainly a tidal estuary, extending 6 or 7 miles to the head of tide water. A short distance above that point the river falls from a height of 60 or 70 feet, affording a good water power.

The river is navigable to nearly the head of tide water. The tide lands along the shore are partly reclaimed by diking, and being very productive are valuable.

Lewis and Clarke River is navigable to about the same distance as Young's River. Valuable deposits of fire and pottery clay are found on the shores of this stream, and the material is loaded on barges and towed to the works at Portland.

The bottom in Young's Bay is generally very soft, and, though the sounding lead indicates hard bottom in places, Mr. Rockwell deems it probable that boring or driving piles would develop a soft silt bottom, and he thinks that without doubt the obstruction presented by this long trestle bridge would have the effect of shoaling the water in the bay to a very considerable extent, and that the pivot and abutment piers would have a similar effect in the channel. The section opposed to the flow of the currents would be represented by 542 *bents*, or say 2,000 piles from 16 to 20 inches in diameter, besides the sections of the piers and the abutments. He observes that, in the advanced practice of building bridges with long spans, 110 feet is an inadequate width of span and that the draw should be at least 150 feet in the clear.

The Astoria and South Coast Railroad could easily be built around the head of Young's Bay, and would then be able to cross both rivers by a very moderate draw span in each bridge.

After the completion of the survey near Astoria, Mr. Rockwell took up, under instructions, the triangulation of the Columbia River, above the mouth of the Willamette. This work was begun August 27 by the occupation of the secondary stations Balch and Harney, already established. From this time forward the erection of signals and the marking and occupation of stations were carried on steadily, interrupted only by smoke from burning clearings or from forest fires. This smoke was sometimes so dense as to make doubtful the intervisibility of points on even the shortest lines.

Field operations were closed October 22. It was not deemed judicious to begin topographical work after this date, owing to the near approach of the rainy season. Enough points had been determined to carry the topography over 10 miles of the river.

For the season the statistics are as follows:

Triangulation:

Number of signals erected	15
Number of stations occupied	15
Number of geographical positions determined	35

During the winter Mr. Rockwell was engaged in the reduction of his observations and in preparing his records for transmission to the Archives. In April, 1890, he was ordered to duty in southern California, reference to which is made under a heading in Section X.

Completion of the special survey made for the Commission organized to select a site for a Navy-Yard on the Pacific Coast. Topographical survey of the Skagit River and Delta, State of Washington.—Under the heading of "Special Operations" in the last Annual Report, an abstract was given of the labors of Assistant J. F. Pratt in making a special survey of the site for a Navy-Yard, selected at Port Orchard, Puget Sound, by the Pacific Coast Naval Commission.

At the close of the fiscal year, the triangulation, topography, and hydrography had been nearly completed, there remaining only the interior topography in the rear of the site. On July 15 this was finished, and a month later a tracing for the Commission covering both of the original sheets of the survey was forwarded to Washington. Included in the very full report made by Mr. Pratt are letters addressed to the President of the Commission, giving details in regard to the borings made, the areas inside of high-water mark, the anchorage room directly in front of the yard, etc.

Instructions having reached Mr. Pratt to resume field work from the limits of his survey of 1888 on Skagit River and Delta at as early a date as practicable after leaving Port Orchard, he proceeded to Utsalady, and from thence on the schooner *Yukon* to Skagit River.

Owing to the smoky weather it was impossible to begin the topographic survey at the mouth of the river where the lines were long, so work was commenced at the head of ordinary navigation just above Mount Vernon, and carried downstream in the main river to the junction of Steamboat Slough and Old River, and about 2 miles down the North Fork. The atmosphere having then sufficiently cleared, work was carried up the various mouths of the river to a junction with that brought down the stream. On November 6 the topography of the Delta was finished, and unfavorable winter weather being indicated, preparations for closing field operations were begun. On November 16 the *Yukon* was laid up in Eagle Harbor.

In view of the development of this exceedingly fertile valley, which is rapidly becoming a very important factor in the agricultural interests of the Puget Sound Basin, Mr. Pratt calls attention to the necessity of framing and enforcing systematic and comprehensive regulations respecting the driving of piles in channel ways, the placing of sheer booms and pocket booms and the driving of logs down the navigable outlets of the river. Steamboat Slough is now the only outlet that has not been injured by the operations of the loggers, and should this be closed the whole of this important valley would be deprived of the facilities of navigation.

For the season beginning July 26 and ending November 6, the statistics are:

Topography (scale 1–20000):	
Area surveyed in square statute miles	29
Length of general coast line in statute miles	14
Length of shore line of rivers in statute miles	95
Length of shore line of creeks in statute miles	25
Length of roads in statute miles	33

During the remainder of the fiscal year Mr. Pratt, at his own request, was relieved from field duty, and allowed to complete at home the records and computations which had to some extent accumulated on his hands.

Hydrographic surveys in Rosario Straits, including Thatcher and Obstruction Passes, Hale's Passage and Lummi Bay; in Semi-ah-moo Bay and Drayton Harbor, and along the east side of the Gulf of Georgia; also in Skagit Bay.—At the beginning of the fiscal year the party in charge of Lieut. J. N. Jordan, U. S. N., Assistant Coast and Geodetic Survey, commanding the schooner *Earnest*, was making a hydrographic survey of the Obstruction Passes between Orcas, Blakeley, and Cypress Islands, Washington Sound. A tide gauge had been erected and tidal levels taken from Eagle Harbor, Cypress Island. The positions of triangulation points having been obtained from Assistant J. J. Gilbert, signals were erected and work carried through the Passes on each side of Obstruction Island and through Thatcher Pass.

On July 23 the vessel was moved to Inati Bay, Lummi Island, where a tide gauge was put up, and tidal levels taken from Eagle Harbor. Thick smoke from forest fires prevented work for many days, but the projection having been extended so as to take in Hale's Passage and Lummi Bay, work was carried on when possible, and the sheet completed September 10.

The work on this sheet made but slow progress, not only because of smoke, but also by reason of the strong tidal currents that sweep back and forth from the Gulf of Georgia, Bellingham Bay, and the Straits of Fuca. The steam launch belonging to the party was unable at times to make headway enough to work, and when there was any wind it was dangerous to attempt work in the more exposed portions of the waters under survey.

In Rosario Strait and in Hale's Passage, the currents run nearly north and south, and through Thatcher and Obstruction Passes east and west. Tide-rips and whirls dangerous to small boats make between Blakeley and Cypress Islands, especially around Black Rock, around the Pea Pod Rocks, off Lawrence Point, Orcas Island, and between Clark and Lummi Islands.

Lieutenant Jordan names as the principal dangers to be avoided, Lawson's Rock in Thatcher Pass, bare at low spring tides; a rock near the beach off the east end of Obstruction Island; two rocks under water off the southeast shore of Orcas Island, and the ledge extending from the north end of Clark Island. All of these are well marked with kelp when it is not swept under by the current. There is a rock, half a mile northwest of Lummi Island, and a ledge or bar extending from the northeast side of Lummi Island to the mud flats in Lummi Bay, both of which are entirely free from kelp.

There is a good anchorage in the bight on the south side of Orcas Island, also in Obstruction Pass, and for small vessels in a cove protected by a small island on the south side of Blakeley Island. Shelter can be found on the south side of Clark Island, in the pass between that island and the Sisters, but there is very little swinging room and a strong current. The other anchorages are open to southeast and southwest or northwest winds, and should be avoided except in emergencies.

The carrying trade, he observes, is done almost entirely by steamers, the Straits being the general passage way of steamers bound from the upper Sound ports to Vancouver. A stern-wheel steamer made regular trips twice a week through Thatcher Pass, and a propeller three times a week through Obstruction Pass. Five steamers made regular passages through Hale's Passage, bound from Whatcom to the northward (Semi-ah-moo and Blaine), and to the westward (Roche Harbor and Victoria). These steamers varied in size from forty to a thousand tons.

On September 4 the *Earnest* was moved to Drayton Harbor, near the town of Semi-ah-moo. A tide gauge was put up and tides observed day and night for a lunar month. Signals were erected and soundings begun for the hydrography of Semi-ah-moo Bay. Advantage was taken also of favorable weather, while the vessel was at this anchorage, to do the boat work along the east shores of the Gulf of Georgia and Boundary Bay.

There is very little tidal current in Semi-ah-moo Bay and Drayton Harbor. There are no dangers except the mud flats and a shoal extending out from the north side of Semi-ah-moo spit, marked by a spar buoy. The flats on the east side, south of the boundary line, and in front of the town of Blaine, have been piled around by tide-flat jumpers, and in some cases these piles are under water at high tide.

There is a good anchorage for large vessels in Semi-ah-moo Bay, and an excellent one, though rather limited, for vessels of all kinds in Drayton Harbor. Three steamers make weekly trips to Semi-ah-moo and Blaine.

On October 26 the vessel was moved to a temporary anchorage on the northeast side of Lummi Island, a tide gauge put up and tide levels taken from Drayton Harbor and Eagle Harbor, Cypress Island. The boat work along the east side of the Gulf of Georgia was finished November 2, and field operations were then closed.

Ensigns Edward Moale, jr., and F. K. Hill, U. S. N., were attached to the party on board the *Earnest*.

The statistics of the season are as follows:

Hydrography:	
Area sounded in square geographical miles	123
Number of miles (geographical) run while sounding	850
Number of angles measured	5,564
Number of soundings	20,260
Number of tidal stations established	5

Two hydrographic sheets were finished, one of 1–20000 scale, the other of 1–10000.

Soon after the return of the party to their winter quarters at Port Townsend, office work was begun, and early in January, 1890, the completed sheets and records were forwarded to the Office.

Lieutenant Jordan has sent with his report general sailing directions for Rosario Straits and vicinity, Semi-ah-moo Bay and Drayton Harbor, and for Washington Sound and vicinity. These will be of much value as a supplement to the forthcoming new edition of the Pacific Coast Pilot.

Ensign Moale was detached November 4 and ordered to the steamer *Hassler*.

Towards the end of March and the beginning of April preparations were made under instructions issued in March for resuming field operations. Ensign Moale was again ordered to join the party, and on April 14 a hydrographic survey of Skagit Bay was taken up and carried on till the end of the fiscal year. Ensign Harry George, U. S. N., reported for duty May 2. On June 11 the *Earnest* was moved from Utsalady to near Deception, Fidalgo Island. The further progress of hydrographic surveys in this locality will be stated in the next Annual Report.

For the fiscal year Lieutenant Jordan reports the following statistics:

Hydrography:	
Number of miles run in sounding	1,124
Number of angles measured	6,599
Number of soundings	29,806
Area in square miles covered by soundings (approximate)	170

Extension of the triangulation of Rosario Strait into Lopez and East Sounds and through Upright Passage to its connection with San Juan Channel. Topographical surveys on Orcas, Lopez, Blakely, Decatur, and other islands in Washington Sound.—During the summer and autumn of 1889 the work executed by Assistant J. J. Gilbert included a reconnaissance for the extension of the triangulation of Rosario Strait into Lopez and East Sounds, Washington Sound, in the State of Washington, and the completion of four topographical sheets.

The triangulation was finished to the northward to the head of East Sound, and southward to the head of Lopez Sound and through Upright Channel to its connection with San Juan Channel. The topography was extended from the point on Orcas Island reached in 1888 to the south of Lawrence Point around the southeast point of Orcas Island, and thence including East Sound to a point halfway between East and West Sounds. On Lopez Island the topography was completed from near station Boulder at the southeast point of the island, by way of Lopez Sound, Shoal Bay, etc., to include all of Fisherman's Bay. All of the smaller islands included within these limits were also surveyed, among them Blakely, Decatur, and James Islands. The shore line surveyed was mostly rocky, and over a large portion of it the telemeter rods had to be carried in boats.

The weather was exceptionally favorable; the smoke, though dense at times, never was so thick as to interrupt the work.

Lopez Island, Mr. Gilbert observes, is quite generally settled; the surface has easy slopes and is well cut up with roads. Orcas Island is characterized by hills, the valleys between which are in course of settlement. Blakely Island is all hilly, with but little land fit for cultivation.

The hydrographic party in charge of Lieutenant Jordan, U. S. Navy, at work in the vicinity, was furnished with tracings of the shore line of Obstruction, Peavine, and Thatcher Passes and portions of the shore lines of Orcas and Blakely Islands.

Field operations were closed October 21.

The statistics of the season for the five months beginning May 20 are as follows:

Triangulation:	
Number of signals erected	93
Number of stations occupied	69
Number of angles measured	443
Number of geographical positions determined	100
Topography:	
Area of topography in square miles	49
Number of miles of shore line surveyed	119
Number of miles of roads surveyed	60

SECTION XII.

ALASKA, INCLUDING THE COAST, INLETS, SOUNDS, BAYS, RIVERS, AND THE ALEUTIAN ISLANDS.

(SKETCH No. 3.)

Continuation of the survey of the coast of southeastern Alaska, in Frederick Sound and vicinity. Triangulation, topography, and hydrography; determinations of latitude, longitude, and azimuth and of the magnetic elements.—At the beginning of the fiscal year, the party in charge of Lieut. (now Lieut. Commander) H. B. Mansfield, U. S. N., Assistant Coast and Geodetic Survey, commanding the steamer *Patterson*, had been actively engaged since April 27, 1889, in prosecuting a general survey of Frederick Sound, and connecting it with the survey made during the preceding season by Lieut. Commander (now Commander) C. M. Thomas, U. S. N., since then assigned to duty as Hydrographic Inspector, Coast and Geodetic Survey.

The part of Frederick Sound included in the survey of 1889 lies between Point Napean and Point Hugh, Point Windham and Point Fort. Previous to July 1 four tidal stations had been established, astronomical observations made at four stations, a base line measured, and signals for the triangulation erected. Nearly 900 miles had been run in sounding; in this part of the work and for transportation, the steam launch *Cosmos*, which had been brought from Port Simpson, was of great service.

The first tidal station established during the season was in Cleveland Passage, near the anchorage of the Patterson. Tidal observations were taken day and night for a lunar month. Tide staffs were subsequently erected as follows: At Eliza Harbor to connect with Cleveland Passage; at Snug Cove, Gambier Bay, to connect with Eliza Harbor; at Mole Harbor, Seymour Canal, to connect with Snug Cove; at Windfall Harbor to connect with Mole Harbor, and at Holkham Bay to connect with Taku Harbor. These gauges were connected by the methods indicated in the "General Instructions for Hydrographic Work." This last named gauge was destroyed by floating ice before the full series of observations had been taken.

Planes of reference were thus obtained for the soundings upon the following harbor and inlet hydrographic sheets, upon which the work of the season was represented, viz: Cleveland Passage and Steamboat Bay, scale 1-10000; Eliza Harbor, scale 10000; Gambier Bay, scale 1-20000; Mole Harbor, scale 1-20000; Windfall Harbor, scale 1-20000; Holkham Bay, scale 1-80000. Those just named are harbor sheets; the inlet sheets are: N. E. Inlet from Port Houghton, scale 1-80000; N. E. Inlet from Hobart Bay, scale 1-80000; Tracy Arm, Holkham Bay, scale 1-80000; Ford's Terror, Endicott Arm, scale 1-80000.

The flood tide enters through Frederick Sound, and sets to the northward and southward from Cape Fanshaw. In the open sound the tidal stream is weak.

Determinations of latitude and longitude by astronomical observations were made at stations in Cleveland Passage, Eliza Harbor, Gambier Bay, Seymour Canal, and Holkham Bay. All of the longitudes were referred to Port Simpson, British Columbia, as a standard station. One hundred and five pairs of stars were observed for latitude, and six stations were occupied for determinations of azimuth. Observations for the magnetic declination, dip, and intensity were made at four of the astronomical stations.

Lieutenant Mansfield devotes much space in his report to full descriptions of the several harbors, bays, sounds, and anchorages included within the limits of his survey. During the season the *Patterson* occupied the following-named anchorages: Cleveland Passage, Eliza Harbor, Gambier Bay, Mole Harbor, Windfall Harbor, Holkham Bay, Taku Harbor, Holkham Bay, and Juneau Harbor.

He observes with regard to the character of the country surveyed in 1889 that it is similar to that surveyed in 1887 and 1888. The timber is chiefly hemlock, with a few scattered trees of spruce and cedar; the latter very poor. The trees are rooted in decomposed vegetable matter, with a covering of thick spongy moss. The country is mountainous, densely wooded, and deeply indented.

The wild flowers in summer are numerous, and the salmon berry grows in profusion in sheltered spots.

Deer are plentiful and a number were shot; many black bears were seen during the salmon season, and one was killed. The inlets and bays were full of sea ducks, and a few edible ducks were killed. Grouse are numerous, and in the berry season are in fine condition for the table. The spring run of the salmon was very poor, but later the streams and inlets were full of the dog-nosed and hump-backed varieties.

Within the limits of the survey there was but one Indian village, a small settlement of the Sumdum Indians, and this was deserted in the summer.

Lieutenant Mansfield states that he could find no evidence of general glacial action; all the glaciers seen were evidently local and were receding.

Referring to Holkham Bay and to its glaciers, he observes:

"Holkham Bay consists of two arms. The Tracy, or North Arm, is 22½ miles long with an average width of three-quarters of a mile. The Endicott, or South Arm is 25 miles long with an average width of 1 mile.

"There are five glaciers in this bay, which terminate at the water. Two at the head of Endicott Arm, called the Dawes Glaciers, have a width at the water's edge of seven-eighths and one-quarter of a mile respectively. Two at the head of Tracy Arm, called the Sawyer Glaciers, have a width at the water's edge of seven-eighths and three-eighths of a mile respectively. The fifth glacier is in Ford's Terror, and has a width of one-quarter of a mile.

"There are, in addition, a great number of glaciers with terminal moraines between the mountain peaks. The largest of these is nearly opposite the entrance to the bay, and is called the Sumdum Glacier.

"The highest peak measured this season lies back of the Sumdum Glacier, and I have named it Mount Harrison.

"The scenery in the upper arm is grand, the rocks running up almost perpendicularly, and showing the marks of glaciers which have receded."

On September 29, 1889, field operations were closed for the season, and the *Patterson* left for San Francisco, arriving at that port October 15.

The following named officers were attached to the party: Lieut. E. J. Dorn, U. S. N., executive officer; Ensign A. N. Wood, U. S. N., navigator; Ensigns A. C. Almy, A. M. Beecher, J. D. McDonald, G. R. Slocum, and W. H. Foust, U. S. N. Messrs. H. L. Ford, J. G. Smith, and L. Sandford served as draftsmen and recorders.

Lieutenant Mansfield observes that owing to the thorough organization of the party which had been effected by his predecessor in command, Lieut. Commander Chas. M. Thomas, U. S. N., all of the work was carried on as easily the first day of the season as on the last. To the officers associated with him, as above named, he expresses his acknowledgments for their faithful and hearty service.

Following is an abstract of the statistics reported:

Signal construction:	
Number of triangulation signals built	162
Number of plane table signals built	586
Triangulation:	
Number of stations occupied with the theodolite	250
Topography:	
Number of miles of shore line run	740
Approximate area of the country surveyed in square miles	1,500
Hydrography:	
Number of miles run in sounding	2,324
Number of angles measured	15,810
Number of soundings	14,776
Number of specimens of bottom obtained	63
Number of occasions when velocity of current was noted	28

Latitude, longitude, and azimuth observations:	
Number of latitude stations occupied	5
Number of pairs of stars observed for latitude	105
Number of longitude stations occupied	7
Number of azimuth stations occupied	6
Magnetic observations:	
Number of magnetic stations occupied	4
Number of sets of magnetic observations	24

In the spring of 1890, under instructions dated March 4, Lieutenant Commander Mansfield began preparations needful for an early resumption of field work in Alaska. During the winter his party had been engaged in San Francisco in the completion for the archives of the records and results of the surveying season of 1889. These have all been forwarded to the office.

The *Patterson* left San Francisco April 10, 1890, Lieutenant Commander Mansfield commanding, and the following named officers attached to his party at that date: Lieut. E. J. Dorn, U. S. N., executive officer; Ensign H. C. Poundstone, U. S. N., navigator and astronomer; Ensigns G. R. Slocum, Joseph Strauss, W. H. Faust, and F. W. Jenkins, U. S. N.; T. L. Carter, assistant engineer, U. S. N. H. L. Ford, master-at-arms, served as draughtsman, and J. G. Smith and J. C. Dornin as pay yeomen. Passed Assistant Surgeon H. T. Percy, U. S. N., was attached as medical officer.

By direction of the Superintendent, a party organized for explorations in Alaska under the direction of Mr. E. H. Wells, of Cincinnati, was taken on board the *Patterson* for transportation to Pyramid Harbor.

The steamer arrived April 18 at Port Townsend after a long and rough passage. Time signals were exchanged with Mare Island, and 20,000 feet of signal lumber taken aboard. At this port Mr. Wells left the *Patterson* and proceeded by mail steamer to make arrangements for the transportation of himself and party beyond Pyramid Harbor. After leaving Port Townsend, the *Patterson* coaled at Departure Bay, and on April 28 anchored off Port Simpson, where observations were made at the astronomical station. The steam launch *Cosmos* was overhauled and made ready for service, and on the night of May 2 the *Patterson* with the *Cosmos* in tow anchored off Cape Fanshaw at the head of Frederick Sound.

Next morning, observations having been obtained during the night, the steamer got under way and landed the astronomical officer, his assistant, and camp outfit at Point Lena, Lynn Canal. The *Cosmos* was then sent on detached service and the *Patterson* proceeded to Pyramid Harbor where the Wells exploring expedition was landed May 4.

The next afternoon Lieutenant Commander Mansfield anchored in Barlow Cove, Admiralty Island, and on the morning of May 6 began work laid out for the season. This included the triangulation, topography, and hydrography of Saginaw Channel, Gastineau Channel, and Taku Inlet.

At the date at which this report closes all of the operations of the Survey were in active progress. Full details with regard to it and statistics will appear in the next annual report.

Tidal record continued at the automatic tidal station at St. Paul, Kadiak Island, Alaska.—Assistant George Davidson has continued to direct the tidal observations at the automatic gauge station, St. Paul, Kadiak Island, Alaska. He has examined the monthly tidal rolls and forwarded these and the tabulations to the office. During his absence from San Francisco, from August 25 to December 12, 1889, Assistant James S. Lawson was in charge. Mr. Fred Sargent continued to serve as observer. Connection by leveling is made between the two bench-marks and the zero of the staff, and this duty is ordered to be regularly performed.

The Survey is indebted to the Alaska Commercial Company for the use of its wharf for the tide-house and gauge, and also for the facilities kindly afforded for the transmission each way of letters and records. During the winter there is no communication with the Island.

Whenever practicable, Mr. Davidson has asked the services of officers of the Navy and Revenue Marine to examine the condition of the clock and apparatus, and he reports that these examinations have been cheerfully made.

In August, 1889, and again in October, Mr. Ivan Petroff, U. S. Census Agent for Alaska, examined the condition of the tide-gauge and the reference to bench-mark and personally reported that everything was in good condition.

Tidal observations at Iliuliuk, Unalaska Island, Alaska.—Reference was made in the last Annual Report to the establishment of a tidal station on Unalaska Island under the direction of Lieut. Commander H. E. Nichols, U. S. N., Assistant Coast and Geodetic Survey. By permission of the Alaska Commercial Company the fixed wooden staff by means of which the observations were taken was secured to the Company's wharf at Iliuliuk, Unalaska. With the exception of a few hours lost, mostly at night, the observations were made every hour from June 1 to September 2, 1889, and the records have been received at the Office.

On the 30th of June, 1889, Assistant McGrath and Subassistant Turner, just before leaving Unalaska for their duties on the Yukon and Porcupine Rivers, established two bench-marks as references for this gauge. They have forwarded to the Office descriptions and sketches of these benches.

Occupation of stations near the junction of the one hundred and forty-first meridian with the Yukon and Porcupine Rivers, Alaska, in connection with a preliminary survey of the boundary line between Alaska and the Northwest Territory.—Reference was made in the last annual report to the organization of parties to make a preliminary determination of the boundary line between Alaska and British Columbia and the Northwest Territory in accordance with plans or projects approved by the Secretary of State, and to the arrival of those parties on the 27th of June, 1889, at Iliuliuk, Unalaska Island, and their transfer to the steamer *St. Paul*, bound for St. Michael's, Norton Sound.

Reports and journals of progress of great interest have been received from the chiefs of these parties, Assistant J. E. McGrath and Subassistant J. H. Turner; from the former, encamped on the Yukon River near the eastern boundary of Alaska, as late as June 15, 1890, and from the latter, in camp near the eastern boundary of Alaska, on the Porcupine River up to January 24, 1890.

Abstracts of results reached by these officers, as derived from their reports, will be found under the heading of "Special Operations" towards the close of Part II of this volume. They will remain at their stations to continue work during the winter of 1890-'91.*

SECTION XIII.

KENTUCKY AND TENNESSEE. (SKETCHES NOS. 1, 6, 19, AND 20.)

Geodetic operations.—Re-occupation of stations to complete the connection of the triangulation of Tennessee with the primary triangulation extending to the westward in northern Georgia.—Extension of the triangulation in eastern Tennessee.—The re-occupation of two stations of the triangulation of the State of Tennessee, and one station in northern Georgia, having been found necessary to perfect the connection between the two systems of triangulation, Prof. A. H. Buchanan, Acting Assistant, was instructed to take up this work at the beginning of the fiscal year.

Station John's Mount, Georgia, was re-occupied to observe High Point and Cohutta; station Roy, Tennessee, to observe Luper and Melton, and station Cockspur, Tennessee, to observe Bean and Roy. The re-occupation of John's Mount completed the connection of the triangulation of the State of Tennessee with the primary triangulation extending from the Atlanta base-line over the northern part of the State of Georgia. It had been intended also to obtain a more perfect connection of the station Roy with the points north of it by the re-occupation of stations Luper and Melton, but the atmosphere was so continuously hazy that even heliotropes were at times invisible. Progress was slow therefore, and the re-occupation of these stations had to be postponed.

Field operations, begun July 1, 1889, were closed September 20. Assistant C. O. Boutelle, in immediate charge of State surveys, was kept advised by Professor Buchanan of the progress of this work, and consulted in regard to the plans for its advancement.

* At the date at which this report is transmitted to Congress letters have been received from Mr. McGrath dated August 23, 1890, and from Mr. Turner dated September 6. Mr. McGrath was at his camp on the Upper Yukon and would continue his observations there during the winter of 1890-'91; Mr. Turner had finished his work July 14, and had arrived at St. Michael's August 30. He would winter there if unable to obtain transportation southward for himself and party.

A small unexpended balance of appropriation being available before the expiration of the fiscal year, it was deemed advisable to employ it in a reconnaissance and erection of signals for the extension of the main scheme of triangulation in east Tennessee to connect with the triangulation of the State of Kentucky. Instructions were accordingly issued to Professor Buchanan under which he took the field June 10, 1890, and began this work from the lines Cockspur-Melton and Melton-Luper. The re-occupation of these last-named stations was included in his instructions.

Reference to the progress of this reconnaissance will be made in the next Annual Report.

Occupation of stations in Tennessee for the determination of the magnetic declination, dip, and intensity.—Having determined the magnetic elements at a number of stations in Alabama, Mississippi, Louisiana, Arkansas, and Texas, as stated in previous parts of this report, Assistant James B. Baylor, in May, 1890, had arrived at Memphis, Tenn. Here he established a new station in the Marine Hospital Grounds, marked it securely, and on one day observed for values of the magnetic declination, dip, and intensity, and on one day for latitude, longitude, and azimuth on the sun.

In June, 1890, Mr. Baylor re-occupied the station which he had established in 1881 in the grounds of the Staunton House at Chattanooga, Hamilton County, Tenn. The point was well preserved. The usual two days' observations were made.

He observed also at Knoxville, Knox County, Tenn., where a new station was established in the grounds of the University of Tennessee.

Also at Bristol, Sullivan County, Tenn., in June, 1890, the last station occupied in the State during the present magnetic tour. Mr. Baylor had occupied a station here in 1881 on the hill on which observations had been made in August, 1869, of the total solar eclipse. This station had to be shifted in position a few yards on account of the proximity of some electric wires. The new point was well marked, and was connected with the old one. Longitude and azimuth were determined by observations for one day on the sun, and the magnetic declination, dip, and intensity on one day.

In Tennessee, and in the other States in which magnetic stations were occupied, topographical sketches of each station were preserved, and linear measures made to adjacent objects.

Upon the expenditure of his entire allotment for party expenses, June 18, Mr. Baylor closed field work, and proceeded to his home to complete the computation of his results.

He acknowledges the facilities afforded by the officers of the U. S. Army at the stations along the Rio Grande River, and the encouragement received from county officials at the several county towns in which magnetic stations were established.

Extension of lines of geodetic leveling from Greenfield, Tenn., to Okolona, Miss.—Report was made, under a heading in Section VIII, of the geodetic leveling operations in Arkansas, executed in the summer and autumn of 1889 by the party in charge of Assistant Isaac Winston. Upon the completion of that work, October 23, Mr. Winston transferred his party from Van Buren, Ark., to Greenfield, Tenn., under instructions to fill the gap in the lines of geodetic leveling thence to Okolona, Miss.

The bench-mark at Greenfield, established the preceding season, was found to be undisturbed, and the leveling observations were begun on the 25th, the forward measure throughout the whole distance being made by Mr. Winston with geodetic level No. 5, and the backward measure by Mr. F. A. Young with level No. 6. The line follows the Illinois Central Railroad from Greenfield, Tenn., to Jackson, Madison County, Tenn., and thence the Mobile and Ohio Railroad to Okolona, Miss. On arriving at Jackson, Mr. Winston deemed it advisable to transfer his party to Okolona, and work from that point towards Jackson, as he was informed that the roads in the vicinity of Okolona became almost impassable when the spring rains began.

The two bench-marks which had been established by Assistant J. B. Weir at Okolona in 1884 were found in good condition, and a remeasurement of their difference of elevation agreed with his result, thus giving a satisfactory starting point for the work. Progress was delayed to some extent by wet weather and bad wagon roads, the line of the Mobile and Ohio Railroad in this region running through numerous swamps, and along the banks of creeks and rivers.

Precautions were taken as usual to protect the levels from the effect of the direct rays of the sun. Temporary bench-marks were established at intervals of 1 kilometre, and permanent ones in all the towns and villages along the route. Two bench-marks were established at Corinth, Miss., which may be the point of starting for a check line of geodetic leveling to Memphis, Tenn.

Great care was observed not to allow the discrepancies between the two independent lines of level to exceed the limit of error; when this occurred remeasurements were always made.

The elevations of the county road crossings, of the railroad crossings, and of the railroad stations along the line were determined by holding the leveling rod on the ground in the center of track at the crossings, and in front of the buildings at the railroad stations.

Mr. Winston completed his work at Jackson, Tenn., on March 14, and immediately afterwards the party was disbanded. The circuit of geodetic levels—Cairo, New Orleans, Mobile, Cairo—is now closed, the lines run by the Coast and Geodetic Survey extending from Greenville, Miss., to New Orleans, and thence to Mobile and to Cairo, while the work between Cairo and Greenville, Miss., was executed under the direction of the Mississippi River Commission.

Mr. F. A. Young, as observer, and Mr. H. D. Mitchell, as recorder, served very satisfactorily throughout the season.

After redetermining the constants of his instruments, Mr. Winston proceeded, under instructions, to Washington, D. C., where he took up preparations for duty on the Pacific coast. The records and computations of his leveling work were placed in Mr. Young's hands for completion and transmission to the archives.

SECTION XIV.

OHIO, INDIANA, ILLINOIS, MICHIGAN, AND WISCONSIN. (SKETCHES Nos. 1, 6, 15, 19, AND 20.)

Continuation of the primary triangulation near the 39th parallel to the westward from stations in Ohio, Kentucky, and Indiana.—At the beginning of the fiscal year there remained to close the gap between the scheme of primary triangulation along or near the 39th parallel, advancing to the westward in Ohio, Kentucky, and Indiana, and the like scheme advancing to the eastward in Indiana, the erection of three tripod and scaffold signals, and the occupation of eleven primary stations.

The prosecution of the work in the main triangulation in Kentucky, Ohio, and Indiana was assigned to Assistant A. T. Mosman. In addition to this it was necessary to connect the main series with the Cincinnati Observatory, which had been occupied as a telegraphic longitude station in July, 1881, and also with the old observatory on Mount Adams which had been occupied in 1848 as a telegraphic longitude station. Incidentally it was desirable to determine as many prominent objects in Cincinnati and its vicinity as could be located during the occupation of one of the main stations.

On July 11 preparations had been completed for observations at station Tanner, 1 mile west of the town of Florence, Kentucky, and about 11 miles south of Cincinnati. A tripod and scaffold signal 135 feet in height had been built here in 1887. To avoid as far as possible the movement of the signal that would have been caused by its exposure to the sun, the sides of the scaffold were covered with canvas. It was necesssary to open the line Tanner-Dry Ridge, which was partially obstructed by the tops of trees, and for this purpose, and for posting heliotropers at stations Dry Ridge, Stow, Reizin, and Tate, Mr. Mosman detailed Extra Observer W. B. Fairfield and Recorder C. T. Mosman, who had been assigned to duty in his party. While away from the station on this service Mr. Fairfield made a reconnaissance for the connection of the station with the Cincinnati Observatory. He selected also a site for the signal station Mud Lick, and opened lines of sight from station Stevens to Cold Spring Church and to Lookout House, Covington.

The weather was very rainy during the whole of July, and the progress of the observations at Tanner was thereby delayed, but Mr. Mosman completed them August 16, and while the instruments were being moved to the next station, Dry Ridge, he went to station Reizin, Indiana, to examine the locality with reference to occupying it as an astronomical station.

Upon reaching Dry Ridge, August 21, he found that Messrs. Fairfield and C. T. Mosman had completed all the preparations for its occupation. This station is in Grant County, Kentucky, 4 miles north of Williamstown, the county seat. The observing tripod and scaffold are 90 feet high.

From Dry Ridge, the lines of sight, with one exception, that of the line to Culbertson, presented no difficulty in observing in favorable weather. This line, 36 miles long, passes just clear above the tops of several intervening ridges, and considerable difficulty was found in seeing the heliotrope at Culbertson, but it was successfully overcome by substituting a mirror 4 inches in diameter, instead of the usual one of $2\frac{1}{4}$ inches.

Very hazy weather prevailed during the first 10 days after arriving at Dry Ridge, but all of the necessary observations were finished on September 9. At this date, Mr. E. E. Torrey, Foreman, having finished signal building, joined the party, and Mr. C. T. Mosman, Recorder, was detached from it.

Station Reizin, about 1 mile east of Elrod, Ripley County, Indiana, was then occupied. While the observations for horizontal directions were in progress, an astronomical observatory was built, and a meridian telescope mounted for observations of time and latitude, and a 20-inch theodolite for determinations of azimuth. Observations for horizontal directions were begun at Reizin on September 21. Mr. Fairfield had been sent to re-occupy station Stevens, connecting with the secondary stations Lookout House, Price's Hill, Convent, and Cincinnati Observatory. These stations he subsequently occupied, and thus completed the connection of the telegraphic longitude station of 1881 with the main triangulation. Many prominent objects in the city of Cincinnati, such as spires of churches, public buildings, flagstaffs on the Custom-house, Post-office, Court-house, etc., were also determined in position.

Observations for time were begun at station Tanner September 28, and for azimuth October 4. These were made by Mr. Mosman. On Mr. Fairfield's return to Reizin, October 9, he began observations for latitude, and finished them on the 17th. During this time, the stations at Correct, Glasgow, Culbertson, and Stow were marked temporarily to preserve them in the event of their destruction during the winter.

Extremely smoky weather and the peculiarly difficult nature of the work in the city delayed very much the completion of the work in and about Cincinnati. Nearly all of the objects to be determined were situated in the heart of the city and were obscured by smoke, except in very clear weather and when the wind was favorable. The final observations were made, however, on November 11, and the instruments forwarded to Washington that night.

Between October 29 and November 9, Mr. Mosman was temporarily detached from his party for special duty, reference to which is made under the heading "Special Operations" towards the end of Part II of this volume.

Soon after his arrival in Washington, he was assigned to duty under the immediate direction of the Superintendent.

In his report of the season's work he refers particularly to the very satisfactory service rendered by Mr. W. B. Fairfield, all of whose duties were performed with energy, intelligence, and accuracy. Mr. Torrey rendered efficient service in posting heliotropers, reading one of the microscopes of the theodolite, and marking stations.

The statistics of the season are as follows:

Reconnaissance:	
Lines of intervisibility determined as per sketch	50
Number of points selected for scheme	8
Triangulation:	
Primary. Area of, in square statute miles	559
Secondary. Area of, in square statute miles	275
Days occupied in opening and verifying lines of sight	12
Number of stations occupied for horizontal measures	7
Number of geographical positions determined	50
Latitude and Azimuth work:	
Number of latitude and azimuth stations	1
Number of pairs of stars observed for latitude	18
Average number of observations upon a pair	6
Number of nights of observations for azimuth	5

Early in May, 1890, in anticipation of his relief from office duty, Mr. Mosman was instructed to make preparations for resuming the field work of the transcontinental triangulation advancing to the westward in Indiana. Until he could take the field in person, Subassistant W. B. Fairfield was assigned to his party to make the necessary observations under his direction, while his foreman, E. E. Torrey, went to Indiana and visited the several stations to verify their adjustments. The observing tripod and scaffold at station Glasgow was found to have been struck by lightning in March and badly injured. Having put it in repair Mr. Torrey went to station Stow on May 27 and joined Mr. Fairfield, who had arrived from Washington with the instruments. Observations of horizontal directions were begun at Stow May 28, and, with Mr. Torrey's assistance, were finished June 5, after which the party was transferred to station Culbertson, Indiana. At this point an observing tripod and scaffold 116 feet high was occupied. The weather continuing very favorable for observations, work at Culbertson was completed June 19, and the party moved to Glasgow, Indiana, on June 21.

Mr. Mosman, having been formally relieved from duty in the office of the Superintendent on June 16, and directed to proceed as soon as practicable to Indiana, joined his party at this station. The theodolite was mounted on the tripod, 116 feet high, over Glasgow station on June 23, and a pole adjusted on the 150 feet signal at station Green, ready for observing the next day. Frequent showers with very hot weather delayed progress somewhat at Glasgow, but the station was finished July 1, and the party moved on the 2d to station Correct.

Statements of further progress will appear in the next Annual Report.

Up to the close of the fiscal year the statistics are:

Triangulation:

Area of, in square statute miles	260
Number of signal poles erected	5
Number of stations occupied	3
Number of geographical positions determined	3

Extension to the eastward in Indiana of the transcontinental triangulation near the thirty-ninth parallel.—Under instructions issued towards the end of June, 1889, Assistant George A. Fairfield resumed work on the transcontinental triangulation in Indiana, carrying it to the eastward by the occupation of stations and by the building of signals with a view to connecting it with the similar work advancing westward in the State of Ohio, under the direction of Assistant A. T. Mosman.

Mr. Fairfield organized his party on the 12th of July at North Vernon, Indiana, and began field operations for the season. He dispatched Mr. E. E. Torrey, chief of the signal building party, to Holman station, one of the points of the State Survey, to put up a tripod and scaffold signal 75 feet high. Included in the scheme of work were observations on all of the State Survey points visible, so that a thorough connection might eventually be established between the transcontinental and the State triangulations.

Mr. Torrey and his carpenters were employed until the middle of September in signal building, having erected at that date, in addition to the signal at Holman, three tripod and scaffold signals, each 116 feet high, at the primary stations Glasgow, Correct, and Mud Lick. As this completed the building of all the signals needed to connect the work of Mr. Fairfield with that of Mr. Mosman, the carpenters were discharged, and Mr. Torrey was directed to report for duty to Mr. Mosman.

Mr. Fairfield makes special mention in his report of the admirable manner in which Mr. Torrey has conducted the signal building during several years for both of the primary triangulation parties, his own and Mr. Mosman's. Among the signals he has built are the highest ones ever erected for the Survey, and in no instance has one of them ever been blown down or rendered unsuitable for the work through any defect in construction.

The first station occupied was Weed Patch, about 4 miles south of Nashville, the county seat of Brown County, Indiana. This station is said to be located on the highest land in the State, about 1,150 feet above mean sea level. Observations were begun August 3 and completed September 29; they included determinations of time, latitude, and azimuth, and observations of horizontal directions on ten stations, five of which were points of the State Survey. Some delay occurred owing to the necessity of opening the line to Green station, a distance of nearly 40 miles, and one of the longest lines in the triangulation between the Ohio and the Mississippi. The trees obstructing the view were 25 miles from Weed Patch.

Miller station, situated on the bluffs, about 3 miles south of Brownstown, the county seat of Jackson County was next occupied. Observations of horizontal directions were made upon nine stations, and had been nearly completed by the 14th of October, when a dense smoke began to fill the atmosphere, making it difficult to see objects at a distance of but 2 miles. This smoke lasted till November 2 with but few intervals of clearing, so that while it prevailed observations could be obtained on only three nights.

Both at Weed Patch and Miller stations the observations of horizontal directions were made, as for some seasons previous, at night, upon signal lights obtained by means of student lamps and metallic reflectors.

Upon the completion of work at Miller station, the allotment of funds for the party having been exhausted, field operations were closed for the season, and Mr. Fairfield returned to Washington, reporting for duty at the Office November 8.

Assistant James B. Baylor was assigned to duty in the party at the outset of the season, and served until October 5.

Mr. Fairfield reports the following statistics:

Triangulation:	
Area of in square statute miles	573
Days occupied in opening and verifying lines of sight, number of	16
Geographical positions determined, number of	5
Latitude and azimuth work:	
Number of latitude and azimuth stations occupied	1
Number of pairs of stars observed for latitude	20
Average number of observations upon a pair	5
Number of nights of observations for azimuth	6

During the winter Mr. Fairfield was engaged on office work, and on April 22, 1890, was directed to take charge of the Office of Weights and Measures, relieving Assistant O. H. Tittmann, who had been temporarily detached for special service.

He was relieved from this duty May 14, having received instructions to resume the field work of the transcontinental triangulation and carry it eastward in Indiana to a junction with the triangulation coming westward in charge of Assistant Mosman.

The first station to be occupied was Tripp, about one mile north of North Vernon, Jennings County, Indiana. Mr. Fairfield arrived here May 21, and by the end of the month had his men in camp and all preliminary arrangements made for beginning work. On June 2 Mr. J. B. Boutelle, acting aid, reported for duty and was at once sent to post signal lights at the several stations to which horizontal directions were to be observed. Mr. R. L. McCormick reported for duty as recorder June 21.

On that day also the Superintendent made a short visit of inspection to the party.

Observations at station Tripp were completed June 26; the light was then posted for the next station, and teams hired to move the party with the camp equipage and instruments to station Stout. Before a start could be made, however, a violent thunderstorm came up, torrents of rain flooded the camp ground, and the wind blew almost a hurricane. Next day a telegram was received from the light-keeper at Stout station informing Mr. Fairfield that the signal there had been blown over and badly wrecked, the storm at that point having developed into a tornado. He decided, therefore, to go at once to Green station, about 12 miles northeast of North Vernon, and occupy that while the signal at Stout was being rebuilt. On June 30 camp was established at station Green, and Mr. E. E. Torrey, foreman in Mr. Mosman's party, was detailed by him, as desired by Mr. Fairfield, to rebuild the signal at Stout. This signal, 136 feet in height, was with one exception the highest ever built in the Survey, and its destruction caused much delay in the season's work, the line Green-Stout being the one on which the triangulation advancing to the eastward in charge of Assistant Fairfield was eventually to join with that in charge of Assistant Mosman, advancing to the westward.

This junction was effected later in the season.

While at Tripp station Mr. Boutelle was directed to connect that point with a bench-mark of the transcontinental line of levels. The original mark was established by Assistant Braid in 1879 on the stone abutment of a railroad bridge near North Vernon. Some years ago the top stone of this abutment had been broken by a wreck on the bridge, and it was replaced by another stone, but as the grade of the road has not been changed, Mr. Fairfield states that he is confident that the mark occupies relatively the same place as the one first made, the change, if any, not exceeding a few inches.

Up to June 30, 1890, the triangulation had covered an area of 206 square miles. Its progress after that date will be stated in the next Annual Report.

Progress of geodetic operations in the State of Wisconsin.—During the summer and autumn of 1889 geodetic operations were resumed in the State of Wisconsin by Prof. J. E. Davies, Acting Assistant. He occupied two stations of the Lake Survey, Lebanon and Minnesota Junction, thus effecting a connection of the Lake Survey work with that of the Wisconsin State Survey. This connection will be strengthened when the astronomical station Fitzsimmons is fully connected with the triangulation of Professor Davies by its occupation and that of Arlington as geodetic stations.

The work of Professor Davies was carried on in accordance with a scheme of triangulation decided upon after a reconnaissance made the year before by Assistant Charles O. Boutelle, in immediate charge of State surveys. Mr. Boutelle had occupied Fitzsimmons station in 1887 for the determination of latitude and azimuth, and in this, as in other State surveys, he continued the correspondence with Acting Assistants and the immediate supervision of their work up to the spring of 1890, when his health, which had been gradually failing, compelled him to ask relief from duty.

He was at this time in his seventy-seventh year, and the oldest officer but one in his term of 46 years' service upon the work. Having gone to Hampton, Virginia, for medical care and rest, he died there at the home of his son on June 22.

Mr. Boutelle's unremitting efforts to advance the interests of the Survey during his long connection with it, and the ability he manifested in the discharge of the various and responsible duties assigned to him were the subjects of a commemorative notice issued by the Superintendent.

Establishment of a meridian line in Toledo, Ohio.—In compliance with a request made by the commissioners of Lucas County, Ohio, Subassistant P. A. Welker was instructed to lay out and mark a meridian line at Toledo, in that State, the Commissioners offering to bear all incidental expenses of furnishing and setting the stone monuments.

A site having been selected upon public ground known as Washington and Lincoln Parks, on Forest avenue, determinations of the direction of the true meridian were made by Mr. Welker on two nights by observations on α Ursæ Minoris, the work being begun May 14. These observations were made at the south end of the line near the corner of Prospect and Forest avenues. The latitude and longitude of this point were obtained by referring its position to the stone longitude post established in 1881 by the U. S. Engineers near the corner of Monroe and Michigan streets. The meridian line is 923.375 feet in length. Each end of it was marked by a heavy granite post 12 by 12 inches square on the top surface and 3½ feet long. These posts were set in concrete made of Portland cement, broken stone, and sand. Into the top of each stone was firmly set a ¾-inch copper bolt, 3½-inches long, and having cut upon its upper surface a cross with a small hole in the center to mark the ends of the line.

Full records of the observations and measurements made, with descriptions and sketches, have been forwarded to the Office by Mr. Walker.

Duty assigned to him earlier and later in the fiscal year is referred to under headings in Sections VII and XVI.

SECTION XV.

MISSOURI, KANSAS, IOWA, NEBRASKA, MINNESOTA, AND NORTH AND SOUTH DAKOTA.

(SKETCHES NOS. 1, 7, 8, 15, 19, AND 20.)

Extension of the triangulation of the State of Minnesota from the Snelling Avenue Base.—Under instructions issued early in June, 1889, Prof. W. R. Hoag, Acting Assistant, had in that month organized his party for the extension of the triangulation of the State of Minnesota from the base which had been measured on Snelling avenue, in the city of St. Paul, in the autumn of 1888, by Assistant C. O. Boutelle.

During June he was occupied mostly in building signals and observing angles at stations in the immediate vicinity of the cities of St. Paul and Minneapolis, and in making a short reconnaissance for the extension of the triangulation to the northward and northwestward from the latter city. During the first part of July, he continued measurements of horizontal angles at Washburn Home and at other stations west of Minneapolis; to the east and northeast of St. Paul, and to the south and southeast towards Prescott, Wisconsin, and when the weather was unfavorable for observations of angles, he pushed forward his reconnaissance.

The latter part of July was spent in conducting a general reconnaissance to the southeast along the Mississippi River, and in building signals as selections for stations were made. In the early part of August, the same kind of work was carried back from the river in Wabasha and Goodhue Counties. The weather becoming then almost continuously smoky, an extended reconnoitering trip was undertaken during the latter part of the month, the reconnaissance being carried south through Goodhue and Olmsted Counties as far as Rochester, and thence through the tier of counties bordering on the Mississippi River from Winona to Hennepin.

In September, station Woodbury, about 10 miles southeastwardly from St. Paul, was occupied; also stations South Base and Washburn Home, and the line North Base Woodbury was opened. Field operations were then closed for the season.

Professor Hoag reports the following statistics:

Triangulation:

Number of signals built	12
Number of stations occupied	14
Number of underground marks made	10
Number of surface monuments fixed in place	6

In December, Professor Hoag, in accordance with instructions, reported at the Office for conference and consultation with the Superintendent and with Assistant C. O. Boutelle, in immediate charge of the State surveys.

Towards the end of May, 1890, he was instructed to organize his party for continuing the work of the preceding season, with special reference to a reconnaissance for the extension of his scheme of triangulation to the next tier or range of stations beyond those connecting with the Snelling Avenue Base.

Taking the field June 17, he occupied stations South Base and Wallace to get a few needed measures of horizontal directions. At Wallace station, lines were opened to Buck Hill, Marcotta, and Woodbury stations. Horizontal and vertical angles were measured at stations Ramsey, Mound View, Marcotta, and Buck Hill. At the two stations last named, the value of the observations was somewhat impaired by the intensely heated state of the atmosphere.

Professor Hoag's progress after the close of the fiscal year will be adverted to in the next Annual Report.

Establishment of a meridian line at Huron, South Dakota.—In compliance with a request received from the Surveyor-General of the State of South Dakota, arrangements were made towards the end of February, 1890, for the detail of an officer of the Survey to lay out and mark permanently a meridian line at Huron, in that State.

A description and drawing of the stones needed for the marking having been sent to the Surveyor-General, it was arranged that he should fix the south stone in position, informing the

Superintendent when this had been done, so that Assistant C. H. Sinclair, who had been instructed to lay out the line, could start at once for Huron.

A telegram having been received stating that all of the preliminary arrangements would be completed April 14, Mr. Sinclair left Washington April 10 and arrived at Huron on the 14th.

The location that had been selected was in the grounds of the Court-house, on the west side of the building. Observations for azimuth were made on the first favorable night, using Polaris at any hour angle, twenty-four pointings being taken on the star and mark with 8-inch theodolite No. 148.

The direction of the line having been established, and the south stone in place, the north stone was fixed in position at a point 375 feet distant. Each of these stones is 5 feet long, dressed down at top to the form of a truncated pyramid, with a base 2 feet square and sloping to 1 foot square on the upper surface. The north stone has in its top a copper bolt, three-fourths of an inch in diameter and 3½ inches long, with a slot and expansion brass wedge in the bottom to hold the bolt fast when driven down. A drill hole half an inch deep and one-sixteenth of an inch in diameter, at the intersection of two cross lines cut on the bolt, marks its center and the north point. On the south stone, its center and the south point are marked by the intersection of two cross-lines, each 3 inches long, three-quarters of an inch deep, and three-quarters of an inch wide. These stones marking the ends of the meridian line are of pink-tinted limestone, weighing about 3,100 pounds each. They project something over a foot above ground, and are set in a concrete foundation 2½ feet deep and 3 feet square, so that the bottom of each stone is practically 6½ feet below the surface of the ground.

On April 17 Mr. Sinclair observed the magnetic declination with the needle belonging to the theodolite, and on the same day left for Washington.

The record of his observations has been deposited in the Archives. Other duty performed by him is referred to under headings in Sections II and XVI.

Occupation of stations for extending to the westward in Kansas the transcontinental triangulation near the thirty-ninth parallel.—On July 5, 1889, Assistant F. D. Granger arrived at Junction City, Kans., under instructions to organize his party for extending to the westward in Kansas the transcontinental triangulation near the thirty-ninth parallel.

The first work undertaken was the erection of signals in advance of the occupation of stations, so that the measures of horizontal directions could be carried forward uninterruptedly during the season. By July 19 signals had been put up at stations Wilmer, Frey, Vine Creek, and Iron Mound west of the ninety-seventh meridian, and on the 26th observations were begun at station Robbins, 4 miles southeast of Junction City.

At this point the theodolite was elevated nearly 20 feet above the ground. Six primary and ten tertiary objects were observed, and the station was finished August 9. The party and instruments were then transferred to station Humboldt, 15 miles east of Junction City. Observations were begun here August 17 and finished August 30, four primary and five tertiary points having been observed. At this point the theodolite was mounted upon an observing tripod, at an elevation of 40.7 feet above the ground. This elevation was required to render visible one station only, Zean Dale, all of the other stations being in sight from a height of 5 feet.

Between September 5 and 13 Mr. Granger occupied station Erricssen, situated about 10 miles to the northwest of Manhattan, Riley County. For one of the points observed from Erricssen the theodolite had to be mounted upon an observing tripod 50 feet high. Directions to five primary and seven tertiary objects were observed. Wilmer station, about 23 miles to the westward, was then occupied, the theodolite being elevated 40 feet and five primary and four tertiary objects being observed.

Upon the completion of the work at Wilmer, October 3, the party was transferred to station Taylor, 7 miles south of Chapman, Dickinson County. The weather became very unfavorable for observations just as the work was begun at Taylor, and it was not till October 27 that the atmosphere cleared sufficiently to enable the measurements to proceed. The theodolite was elevated 41 feet above the ground, and six primary and fourteen tertiary objects were observed, the work being finished November 5.

During the season of 1888 some observations had been made at station White, near White City, Morris County, for vertical angles, but under unfavorable conditions, snow having fallen to a depth of 20 inches before the work had been begun, and the moisture from this melting snow having produced abnormal refraction. Mr. Granger decided, therefore, to re-occupy station White before disbanding his party for the season, and obtained there a satisfactory set of vertical measures by the end of November, 1889.

Field operations were then closed, and Mr. Granger proceeded to Washington, and was occupied in office work during the winter until instructed to proceed to Charleston, S. C., for duty, a report of which is given under a heading in Section V.

Having returned to Washington May 9, 1890, he found instructions awaiting him to resume the work of the transcontinental triangulation in Kansas as soon as practicable, and in pursuance thereof he proceeded to Junction City, and on May 20 took up field operations, beginning by a reconnaissance for the selection of points one figure to the westward of the limits of triangulation reached during the preceding season.

Two points, Heath and Thompson, forming a quadrilateral with Vine Creek and Iron Mound, were selected, and a tripod signal was erected at each. Heath is situated about 14 miles west-northwest of Brookville, Saline County, and Thompson, 11 miles west-southwest of Minneapolis, Ottawa County.

The progress of the work was somewhat retarded and its cost slightly increased by the difficulty of getting the consent of the owner of the land at Thompson station to have the signal put up on his property. Mr. Granger takes occasion, in view of this and similar delays encountered, to suggest the advisability of obtaining from the legislature of the State of Kansas the enactment of laws of like purport to those now in force in a number of eastern States and in some of those in the Mississippi Valley, providing for the occupation of points in such localities as the progress of the Survey demands.

Arrangements having been finally made which were entirely satisfactory to the owner of the land at station Thompson, Mr. Granger began the occupation of station Frey on June 14. Four primary and nine tertiary objects were observed, and on the completion of the work here the party was transferred, June 24, to station Vine Creek, four miles west of the town of Manchester, Dickinson County. Observations were in progress at this station at the close of the fiscal year.

Mr. Granger refers in very commendatory terms to the services of Mr. M. A. Coles, recorder in his party.

The statistics for the fiscal year of the work in Kansas are:

Reconnaissance:	
Area of, in square statute miles	475
Lines of intervisibility determined as per sketch	6
Triangulation:	
Area of, in square statute miles	726
Stations occupied for horizontal measures, number of	6
Stations occupied for vertical measures, number of	7
Geographical positions determined, number of	17
Elevations determined trigonometrically, number of	11

SECTION XVI.

NEVADA, UTAH, COLORADO, ARIZONA, AND NEW MEXICO. (SKETCHES Nos. 2, 8, 9, 10, 19, AND 20.)

Determination of longitude by exchanges of telegraphic signals between stations in California, Utah, and Nevada.—The parties organized for the determination of longitudes by exchanges of telegraphic signals were in the field in California and Nevada at the beginning of the fiscal year. As stated in the last Annual Report, Assistant C. H. Sinclair was then occupying a station at Verdi, Nevada, and Subassistant R. A. Marr, in charge of the co-operating party, was at Sacramento, California, and the observers having already exchanged places, a second series of exchanges, completing the line Sacramento–Verdi, was obtained July 1, 2, 3, and 4.

A triangulation having been made by Assistant George Davidson in 1872 in the vicinity of Verdi to determine the one hundred and twentieth meridian, Mr. Sinclair connected his station with that triangulation, and found that the two results for the position of that meridian were almost identical, differing but 0.002 of a second of time.

On July 6, Mr. Marr reached Carson City, Nevada, with his instruments. He had previously written to Mr. Charles W. Friend, who had a private observatory there and who very kindly placed it at the disposal of the longitude parties, dismounting his own transit for their accommodation and making the necessary telegraphic connection.

Mr. Marr exchanged signals with Mr. Sinclair at Verdi on the nights of July 6, 7, 9, and 10; the observers then changed stations, and a second set of exchanges was obtained on five nights between July 11 afid 16. The magnetic elements at Verdi were determined by Mr. Marr on July 13, 14, and 15. The latitude of the station at Carson City was determined by Mr. Sinclair on July 17, 18, 19, and 20, with meridian telescope No. 2, seventy-one observations having been made on eighteen pairs of stars.

Mr. Friend had obtained an approximate difference of longitude, Carson City, and Lafayette Park station, San Francisco, by making one trip with a chronometer, and so carefully had the work been done that his result agreed with that given by the field computation of the longitude party within 0.076 of a second of time.

The next line taken up was Carson City–Virginia City. Mr. Marr on arriving at Virginia City examined the pier which had been left there by Lieutenant Wheeler, U. S. Engineers, in 1873, but found that it would not be advisable to occupy it. His station was above the Imperial Mine and just above the town of Gold Hill and from the crack in the ground nearly midway between the town and the top of Mount Davidson, it is generally thought that all of the ground east of Mount Davidson below this point has moved and is now moving—a movement, due without doubt, as Mr. Marr observes, to the underground workings, compelling re-adjustments of the timbering of the mine-shafts every few weeks.

Through the kindness of Mr. D. B. Lyman, superintendent of the California and Virginia Mines, Mr. Marr was enabled to establish the longitude station within the office grounds of the Company. Exchanges of signals for longitude between Carson City and Virginia City were made on eight consecutive nights from July 19 to 26, inclusive, the observers having changed stations between the night of the 22d and the night of the 23d.

Mr. Sinclair then moved the Virginia City outfit to Genoa, Nevada, and the line Carson City–Genoa was taken up. Longitude signals were exchanged July 30, 31, and August 1, 2, and again, after change of stations by the observers, on five nights between August 3 and 11. At Genoa, the magnetic elements were determined by Mr. Marr from observations made August 4, 5, and 6.

The line Carson City–Austin was next taken up, and exchanges obtained on four consecutive nights, August 18, to 21, inclusive, after which Mr. Sinclair went to Austin and Mr. Marr to Carson City, and three more nights, August 24, 25, 26, completed the determination of that line. While at Austin, Mr. Marr availed himself of a delay caused by unfavorable weather to connect his station with that occupied by Lieutenant Wheeler, U. S. Engineers.

Austin–Eureka was then determined, the nights of exchange of longitude signals being August 30, September 1, 2, and 3, in the first position of the observers, and September 5, 6, 7, and 8 in the second position. Mr. Marr then went to Salt Lake City, and occupied the station in Temple Block. He found the observatory which had been built there by Assistant Dean in 1869 in good condition, and secured his transit instrument upon the sandstone pier. Signals were exchanged with Mr. Sinclair at Eureka September 10, 11, 12, and 14. Owing to the burning of snow sheds and a bridge on the Southern Pacific Railroad, the trains from the west were delayed, and Mr. Marr returned to Eureka before Mr. Sinclair had left. Advantage was taken of this to make direct observations for personal equation, September 17. The results differed only 0.011 of a second from those derived from the exchanges of observers on the lines.

After Mr. Sinclair reached Salt Lake, signals were exchanged on the nights of September 21, 23, 24, and 25, completing the determination of the line Eureka–Salt Lake.

By the field computation, the sum of the differences of longitude for the the six lines, San-Francisco–Sacramento, Sacramento–Verdi, Verdi–Carson City, Carson City–Austin, Austin, Eureka, and Eureka–Salt Lake, differed but 0.068 of a second of time from the direct measurement Salt Lake City–San Francisco.

Before leaving Eureka, Mr. Marr made a geodetic connection with Prospect Park station, Nevada.

During the three months that the longitude parties had been in the field since July 1, 1889, fifty-two exchanges of longitude signals were made, six and a half lines of longitude determined, four stations were prepared, and two others already prepared were occupied. These results, which are much greater than the average, were due, Mr. Sinclair remarks, primarily to favorable weather, and also to the location of some of the stations near Carson City and to the hearty co-operation of the two parties.

Mr. Frank Jaynes, superintendent of the Western Union Telegraph Company at San Francisco, and his officers afforded every facility for the use of the telegraph circuits and are entitled to the thanks of the Survey for their kindness.

Other duty assigned to Messrs. Sinclair and Marr is referrrd to under headings in Sections VIII, X, XV, and XVII.

Occupation of stations in continuation of the primary triangulation near the thirty-ninth parallel in western central Utah.—Reference was made in the last annual report to the operations carried on by the party in charge of Assistant William Eimbeck preparatory to the occupation of the stations Pilot Peak and Ibapah in western central Utah, these stations forming points in the great quadrilateral, Ogden–Mount Nebo–Ibapah–Pilot Peak.

Having organized his party before the beginning of the fiscal year and made all arrangements needed for the occupation of Pilot Peak, the 1st of July, 1889, found Mr. Eimbeck on the summit of the peak, establishing camp and mounting the instruments.

Observations of horizontal directions and double zenith distances were begun July 3. The number of primary points observed upon was six, counting the reference mark as one. Two of of the longest lines of the Utah work were included, Pilot–Nebo, and Pilot–Jeff. Davis, both approximately 148 miles long. Work upon the secondary points was also made as complete as possible, including several of the points connecting with the Terrace and Lucin base-line, 37 kilometres in length, which had been measured along the Central Pacific Railroad by Lieutenant Wheeler when he was in charge of surveying parties in this region. All of these points are marked by substantial rock monuments or cairns. In connection with the determination of the principal mountain peaks throughout the round of the horizon, and of the tertiary points, an exhaustive study of the country lying to the north and northeast from Pilot Peak was made in order to decide upon a plan for the extension of the Salt Lake meridional chain of triangles to the northward. Of this chain, the great quadrilateral already referred to forms the first link. The best figure for this extension is shown upon the sketch accompanying Mr. Eimbeck's report.

Three well-preserved boundary stakes upon the boundary between the State of Nevada and the Territory of Utah were identified and connected by a local triangulation with the main chain of the geodetic work. The boundary, a meridian line, passes about two miles east of the station on Pilot Peak. A comprehensive scheme of observations of secondary and tertiary points was planned and carried out.

For latitude of the station, twenty-three pairs of stars were observed on five nights with the zenith telescope; and for azimuth of the reference mark, observations were made on Polaris at eastern and western elongation on five nights.

As an aid to describing the station of observation, a somewhat extensive and fairly accurate topographical survey of the mountain was made.

Upon the completion of the work at Pilot Peak, July 25, preparations were made for the occupation of Ibapah, a station of an altitude of about 12,300 feet, located upon the King Peak of the Deep Creek Mountains, Utah. From Willow Springs, near the eastern base of Pilot Peak, the party was transferred by freight teams to Deep Creek Settlement and Ibapah station. Food and water for both men and animals had to be carried as usual. The transfer from Willow Springs to Camp Aspen, in Granite Cañon of the Deep Creek Mountains, a distance of about 120 miles, was effected in 5 days. The journey was a laborious and exhausting one, the days being scorchingly hot. To escape the burning heat of the sun and the desert sands, travel was limited to the early morning and late afternoon.

Although the most practicable route for a pack trail had been explored and located and the trail partly opened in advance to the top of the mountain, much remained to be done to finish it. This work, and the preparation of the summit of the peak and the station for occupation, consumed the whole time of the party from its arrival in Granite Cañon, August 5 until August 24, on which day all was in readiness, and observations for horizontal directions were begun. These were prosecuted vigorously until September 1, when there came a sudden change in the weather; a period of thunder storms set in, and when the storm clouds were dissipated, the atmosphere was left in a condition unfavorable for observations. It was not, therefore, till the 28th of September that work at the station could be completed.

Eight primary directions were determined at Ibapah, and also the numerous secondary points visible from the summit by measures of both horizontal and vertical angles. Quite an extensive local triangulation was executed for the purpose of connecting two boundary stakes, seemingly well authenticated, upon the western boundary of Utah, with the main series of triangles. Incidentally, this work has brought the United States Land Surveys of that locality into a connection with the Coast and Geodetic Survey main triangulation.

It had been intended to include the astronomical longitude station of Lieutenant Wheeler, near the relay station of the old Overland Pony Express, at Deep Creek, in the local triangulation, but a search for the station monument or other mark of the point was unsuccessful.

The latitude of Ibapah was determined by observation with the zenith telescope on twenty-three pairs of stars on five nights, and the azimuth of the reference direction by observing Polaris five nights at eastern and western elongations.

To obtain data needful for descriptions of the station and for other purposes, such as the study of the deflection of the plumb-line on the summit of mountain peaks, a topographical survey was made at Ibapah, similar to that at Pilot Peak.

Immediately upon the conclusion of the observations at Ibapah the instruments were dismounted and camp struck and packed down to Camp Aspen, preparatory to the return of the party to Salt Lake. The advance of the party left Deep Creek on the morning of October 2, and arrived at Salt Lake City on the evening of the 7th, after a journey of 195 miles through a country as desolate as can well be conceived. Mr. Eimbeck states that three of the old pony express stations are maintained on the route to this day, and greatly facilitate travel through this extensive desert.

Subassistant P. A. Welker joined the party July 31, and left it at Salt Lake, October 21, proceeding east under instructions to complete the records and computations of his field work. During his stay with the party Mr. Welker rendered valuable and efficient service, the especial duty assigned to him having been the observations of double zenith distances and astronomical azimuth at Ibapah.

The observations for local time and for latitude at both stations were made by Mr. E. P. Austin, of Salt Lake City, who served as extra observer from July 1 to October 25. He assisted also in the local triangulations connecting points on the State boundary.

Messrs. C. L. Brackett and J. C. Meem were employed as recorders.

At the close of the season Mr. Eimbeck reported for duty, under instructions, at the Office in Washington, D. C., and until about the middle of June was engaged in the computations and discussions relating to his field work. He will resume charge of the transcontinental triangulation advancing to the eastward in Utah near the thirty-ninth parallel at an early date.

SECTION XVII.

IDAHO, WYOMING, AND MONTANA. (SKETCHES NOS. 2, 19 AND 20.)

Determination of the longitude of Helena, Montana, by exchanges of telegraphic signals with Salt Lake City.—It having become desirable to obtain certain additional longitude determinations from Salt Lake City and Chicago that should furnish a northern connection with the longitudes of the Pacific coast, instructions were issued in June, 1890, to Assistants C. H. Sinclair and R. A.

Marr to take up at as early a date as practicable exchanges of signals for longitude between Salt Lake City, Utah, and Helena, Mont.; between Helena and Bismarck, N. Dak.; between Bismarck and Minneapolis, Minn., and between Minneapolis and Chicago.

Messrs. Sinclair and Marr were not able to leave Washington before the 23d of June, but at the end of that month they had completed arrangements for exchanges of longitude signals, Mr. Sinclair at Salt Lake City and Mr. Marr at Helena.

Their progress will be further stated in the next Annual Report.

SPECIAL OPERATIONS.

Establishment of a Naval Trial Course by laying off a measured sea-mile in the Eastern Passage, Narragansett Bay.—At the request of the Secretary of the Navy, and with the approval of the Secretary of the Treasury, arrangements were made in July, 1889, for the establishment of a Naval Trial Course in Narragansett Bay. Lieut. J. E. Pillsbury, U. S. N., Assistant Coast and Geodetic Survey, was detailed for this duty, and having availed himself of the stations which had been already determined in position by the triangulation of the Survey on the shores of the bay, he made the measurements and established the shore ranges needed to lay off a nautical mile in the Eastern Passage.

Currents were observed at two stations near the trial course, and at two stations at right angles to it and in the vicinity of the turning and maneuvering grounds at the end of the course. Successive anchorages were made at the same points, and the currents were observed at both spring and neap tides. Tabular statements of velocities of currents at the several stations occupied accompany Lieutenant Pillsbury's report. Neap tide flood, he observes, is decidedly the most favorable time for any trial of speed on the course where a current is to be taken into account. At the southern end of the measured mile, at the strength of the tide, the current runs nearly fair with the course. In changing direction, it turns to the westward as it diminishes in velocity; the tendency, therefore, will be to make to the westward of the proper line. The ebb is stronger than the flood, and at about neap tides there may be no flood current on the surface while below the flood is running. For the ebb current, the maximum at greatest strength of tide was found to be $1\frac{2}{10}$ knots, and the average of maxima was eighty-five hundredths of a knot. For the flood current the maximum was nine-tenths of a knot, and the average velocity half a knot.

The work was finished August 12. Lieutenant Pillsbury has transmitted to the Office, with his report, diagrams showing velocities and directions of currents, and a projection, scale 1-10000, on which he has marked the location of the measured mile, of the ranges at each end of it, and of the steering range. Of the latter he has sent a photograph so that it may be engraved on the charts.

Establishment of a Trial Course for the speed tests of the new naval war vessel, Philadelphia, off the coasts of Block Island and Long Island.—In compliance with a request from the Secretary of the Navy for the laying off an accurately measured trial course to test the speed of the new naval cruiser, *Philadelphia*, the locality finally selected being to the southward of Block Island and the eastern end of Long Island, instructions were issued by the Superintendent to Lieut. C. E. Vreeland, U. S. N., assistant Coast and Geodetic Survey, commanding the steamer *Blake*, to execute this work so as to obtain a course of 40 miles in length as nearly as practicable, and having its extremities capable of ready identification by range marks.

Having been furnished with the projections necessary from the Office, and having taken on board signal lumber at the Navy-Yard, New York, Lieutenant Vreeland left that port May 17, 1890, and having established the locality of the course outside of the 20-fathom curve off the coasts of Block Island and Long Island he proceeded to make a reconnaissance for the proper location of range marks.

Block Island back range signal was located on Beacon Hill, the highest point on the island. It was a vertical extension of a small building which is used as an observation point by summer visitors. Above the building rises a 20-foot flagstaff, on which slides a wooden diamond, measuring 6 feet vertically by 5 feet laterally. This diamond was hoisted a few feet above the roof and was kept in that position till after the trial.

Block Island front range signal is a tripod structure, reaching to a height above ground of 40 feet, this height being increased to 49 feet by a small pyramid mounted on top. At the intersection of the range and course when viewed from a point 20 feet above sea-level, the top of the front range is clearly outlined against the back one.

For the Long Island front range, it had been intended to erect a signal on the beach at the western terminus of the course, but as permission to do this was refused by property owners, it became necessary to select some permanent and prominent object on shore to serve as a front range signal. Upon viewing the locality from seaward, the tower of the Presbyterian church at once presented itself as suitable by reason of its size and proportions. The body of the church is a high-roofed structure standing on an elevation of about 30 feet above sea level, and the tower attains a height of 70 feet above the ground. To enable the observer on board ship to pick up this object more readily, a 40-foot flagstaff was planted on the beach, and a large American ensign hoisted on it. With a powerful glass, the flag is visible 7 miles off shore.

In the hills that extend in an almost unbroken line for some distance, rising to the right and left of the tower, there was fortunately a slight depression nearly on a range, making an almost right-angled cut, and this was seized upon as a site for the back range, being in fact the only point available. The signal erected here stands on an elevation of 55 feet amidst a clump of pines, and resembles in general appearance the front range on Block Island, but its dimensions are considerably larger. Its total height above the ground is 78 feet.

Passing in either direction, the church tower is lost against the back hills within a quarter of a mile after crossing the range, but when it comes out against the sky there is no mistaking it. The back signal has been carried $1\frac{1}{2}$ miles to the east, and 2.3 miles to the west of the range, and from the lofty decks of the *Philadelphia* can probably be carried much farther. When on the course both signals are projected against the sky background.

The working party on shore numbered from 8 to 17 men according to the necessities of the case. During their absence the *Blake* frequently put to sea in order that the ranges might be examined, as they approached completion, from different points on the course.

From the time of leaving Hampton Roads, April 21, to the conclusion of the trial the ship was under way in all 14 days and steamed a distance of 2,505 miles.

The work of establishing the course was finished June 10, and the *Blake* was at once headed for New York. Upon his arrival, Lieutenant Vreeland received telegraphic instructions to place the steamer at the disposal of the Board of officers appointed to test the performance of the *Philadelphia*, of which Captain Henry Erben, U. S. N., was president. This was done; the Board was taken over the course June 16, and Lieutenant Vreeland was then verbally instructed to erect such signals and locate such prominent objects on the south shore of Long Island as would enable the second and third vessels from the west end of the course to establish themselves upon it at about 10-mile intervals.

Having completed this work and returned to New York, the *Blake* left on June 23 to take up a position on the trial course, but, owing to fog, was unable to get into position until the afternoon of June 25, when the trial was nearly finished.

The steamer then returned to New York, and Lieutenant Vreeland began preparations for a cruise in the waters south of Martha's Vineyard to obtain serial temperatures and density observations.

The officers attached to the *Blake* were Lieut. Harry Kimmell, U. S. N.; Ensigns C. S. Stanworth, J. E. Shindel, and Philip Andrews, U. S. N.; Assistant Surgeon Thomas Owens, U. S. N., and Assistant Engineer Wm. W. White, U. S. N.

Lieutenant Vreeland makes cordial acknowledgment to Mr. Frank Littlefield, Block Island, for the gracious manner in which he accorded permission for the erection of a signal on his property on Beacon Hill; also to Messrs. William L. Peckham and Edmund B. Peckham, jr., joint owners of the land on which was erected the south range signal on the island.

Definition and determination of a portion of boundary line in dispute between the States of Maryland and Virginia.—A question having arisen between the States of Maryland and Virginia as to the interpretation of the award of the arbitrators of 1877 respecting the location of that part of the boundary line between those States which lies near Hog Island in the Potomac River, the Superintendent of the Coast and Geodetic Survey was requested by Governor Jackson of Maryland and by Governor Lee of Virginia, in letters bearing date of October 8 and October 10, 1889, to detail an officer of the Survey to examine and locate that portion of the boundary line in the lower Potomac.

In pursuance of this request, Assistant Henry L. Whiting was directed to proceed to Baltimore, and hold a preliminary conference with the Commissioners appointed by the Governors of Maryland and Virginia to represent the views held by those States respectively in regard to the location of the disputed boundary. Having done this, and placed himself in possession of all the information attainable by the inspection of original charts and documents, and having met the Commissioners again early in November, and had also a personal conference with Governor Jackson at his home in Maryland, and with Governor Lee at Richmond, Virginia, Mr. Whiting was further instructed to exercise his best judgment to bring the matter to a conclusion.

The report, which he submitted to the Superintendent under date of November 18, states the conclusions which he arrived at after basing his study on the declaration of the award of the arbitrators of 1877. The question turned upon the technical interpretation of the data given in the award as applied to the projection of a line representing the thread of a stream, and to that of a line along the shore which should conform as nearly as might be to the physical system of a river as characterized by its area and figure.

Mr. Whiting observes that, in the first case, the same rule would be applied as that laid down for the course of the boundary line in the Pocomoke River, viz:

"*The middle thread* is equidistant as nearly as may be between the two shores without considering arms, inlets, creeks or affluents, as parts of a river, but *measuring the shore lines from* headland to headland.

"No other measurements would mathematically determine the *middle thread*, which must be a mean direction between the course of the two shores.

"Measuring *straight* lines from headland to headland would not determine the middle thread of a stream, because, in the bends of a river, straight lines giving equivalent results can not be measured on corresponding or opposite concave and convex shores."

"Again, in the second case" (to quote from Mr. Whiting's report), "the same rule would be applied as that laid down for the boundary line on the Potomac River, viz:

"*The low-water mark is to be measured* from headland to headland, without following indentations, bays, creeks, inlets or affluent rivers; for the reason that such lateral features are incidental to the general system of the river, and can not properly be made factors in determining its true physical limits."

"Referring again to the boundary line between Maryland and Virginia, refixed by the arbitrators of 1877 on the right bank of that river to coincide with low-water mark; the descriptive text used and the conventional sign adopted can only be regarded as an intentional avoidance of more specific mention and definition of points and features which time and natural causes might so change as to render their future identification doubtful. Whereas the right bank of the Potomac, in its general features, will always be the right bank so long as the river itself remains.

"The only deviation made by the arbitrators of 1877 from the ruling of the original charter is in adopting the *low-water mark*, instead of the high-water mark, as the true line of boundary. Physically, the lines are substantially the same as features of the river bank, while low-water mark is more in accord with modern regulations pertaining to riparian rights."

Finally, Mr. Whiting says that, for the reasons assigned in his report, he is prepared to state, on the part of the Coast and Geodetic Survey, that according to the text of the award of the arbitrators of 1877, as descriptive of the boundary line between Maryland and Virginia, no mathematical or physical construction can be put upon the meaning of said description which will locate and define the cognate boundary line and low-water mark in any other place, or make it conform to any other course of the river than that which they have ascertained and determined to be the low-water mark on the south shore (right bank) of the Potomac River as marked and shaded in red upon the coast chart No. 33 of the United States Coast Survey which is filed as part of the said award and explanatory thereof. This clearly illustrates the intended location of the boundary line, and conforms to the terms and meaning of the award.

Copies of Mr. Whiting's report, duly verified, were sent by direction of the Superintendent to the Governors of Maryland and Virginia. It is published in full as Appendix No. 11 to this volume.

Special survey made at the request of the Fish and Game Commission of the State of Ohio.—In compliance with a request made to the Secretary of the Treasury by the Governor of the State of Ohio and referred by the Secretary to the Superintendent of the Coast and Geodetic Survey, Assistant A. T. Mosman was directed to proceed to Toledo, Ohio, and confer with the Hon. C. V. Osborn, President of the Ohio State Fish and Game Commission, with regard to the establishment of the limits of certain fishing tracts on the shore of Lake Erie.

On his arrival in Toledo, October 29, 1889, Mr. Mosman was met by Mr. Osborn and after conferring with him that afternoon a conference was held in the evening, at which were present also the other members of the Commission and the representatives of the large fishing interests near Toledo. It was then decided to select as the location for survey a fishing tract on the south shore of Lake Erie, southeast of Cedar Point, and known locally as Sandy Point. This tract was selected as being without dispute owned by one of the large fishing firms present at the conference.

Mr. Osborn having then left for his home in Dayton, Judge E. D. Potter, of Toledo, remained to represent the Commission, and he made arrangements to furnish Mr. Mosman with transportation from Toledo to Sandy Point, and also with the men and tools needed for the survey.

Subassistant P. A. Welker, being at his home in Toledo, was instructed to assist Mr. Mosman, and rendered valuable aid in the work that followed, taking part in the tests of the measuring wire and in the measurement of the base line.

Sandy Point was so located on the open shore of the Lake as to be inaccessible by land, being but a narrow strip of sand beach from 16 to 20 yards wide, backed by an impassable marsh of from three to four miles in width. It had therefore to be reached by water from Toledo, a distance of 17 miles, and no landing could be made on the beach except when the wind was from the south, or off-shore. These conditions made the work comparatively slow and added to its cost.

From October 30 to November 3 the weather was very stormy and all that could be done was to complete the preparations for the survey. On November 4, a steamer having been chartered and the party landed at Sandy Point, the measuring wire was tested, and had been stretched at a tension of 50 pounds on the beach, when the party was signaled to come at once on board the steamer, as the wind had hauled to the northwest and the vessel was dragging her anchor.

On November 6 and 7, landings were again effected. It had been intended to measure a line a mile long, but, this being found impracticable on account of the ends falling in marshy ground, a base of 1,200 metres (3,937 feet) was measured and angles observed on Cedar Point station of the Lake Survey, on Turtle Island Light-House, and on West Sisters Island Light-House. These angles, with others measured from Cedar Point Station by Mr. Mosman and data published by the Lake Survey, enabled him to determine the geographical positions of station No. 1 and Back Range No. 1 on Sandy Point, and these stations were permanently marked.

On November 9 Mr. Welker finished the marking of station No. 2 and of Back Range No. 2, and made a sketch of the line measured.

Mr. Mosman was enabled to occupy Cedar Point through the courtesy of Mr. W. T. Blunt, U. S. Assistant Engineer, in charge of the improvements of Toledo Harbor, who took him upon his steamer to the station.

Mr. Blunt also ran out to the end of Mr. Howell's string of nets extending six miles in one line from Cedar Point, and located the extreme end by sextant angles. The location of this string of nets had been the subject of dispute between Mr. Howell and other fishermen, so that its accurate determination by a disinterested person was very desirable.

Before leaving Toledo, Mr. Mosman arranged the field notes of his survey, and upon arriving in Washington took up the computation of the results. He had made a copy of the sketch of the line, and also, on an enlarged scale, a sketch of the general location of the tract surveyed, taken from a chart of the Lake Survey. These sketches, together with his descriptions of the survey made and of the marks at the stations and back ranges, were transmitted by the Superintendent to the President of the Ohio Fish and Game Commission.

Other duty assigned to Mr. Mosman is referred to under a heading in Section XIV and at the conclusion of Part II of this volume.

Surveys for a preliminary determination of the Boundary Line between Alaska and British Columbia and the Northwest Territory.—That portion of the plan for a preliminary determination of the eastern boundary line of Alaska which involved the location in latitude and longitude of points on the Yukon and Porcupine Rivers at or near the one hundred and forty-first meridian of west longitude having been assigned to the parties in charge of Assistant J. E. McGrath and Subassistant J. H. Turner, these officers with their assistants reached their respective camps in August, 1889, Mr. McGrath establishing himself on the Yukon River and Mr. Turner on the Porcupine River at localities as near as practicable to the crossings of those rivers by the one hundred and forty-first meridian.

The voyage up the Yukon River was made without special difficulty, both parties having been transported up the river from St. Michael's, Norton Sound, by the Alaska Commercial Company's steamer *Yukon* and having reached Fort Yukon August 2.

Here the parties separated, Mr. Turner proceeding up the Porcupine River in the steamer with his party, while Mr. McGrath remained at Fort Yukon, awaiting the steamer's return to convey him up the Yukon to the boundary line or a point near it. While thus waiting he made observations for the magnetic elements, determined time, azimuth, latitude, and longitude, and measured a base line and connected it by triangulation with points around Fort Yukon. On August 12 he started up the river in the steamer for the boundary line and on the 19th he was landed at the site of an abandoned camp near the boundary, and began at once the building of quarters for officers and men, the erection of an observatory, and all the preparations needed for the winter's work.

The reports which have been received from Mr. McGrath bear dates of September 30 and October 31, 1889, and June 15, 1890. These reports with his daily journals and monthly reports give detailed accounts of the employment of the party and cover the time between its establishment in camp and the end of May, 1890.

During this entire period, the weather was most unfavorable for astronomical work. The summer had been an unusually wet one, high water and constant floods had stopped mining operations on the branch of the Yukon known as Forty Mile Creek, and this humid condition persisted through the autumn. The winter was milder than any known except the previous one, and the sky constantly covered with clouds except on the few days when the thermometer fell to temperatures which made out-of-door observations impracticable. Not a single occultation was visible, and the only lunation that could be observed was that beginning at the end of March and lasting through the early part of April. The days were beginning to get long then, and it became difficult to take any almanac stars with the moon, except those of the second magnitude. This set being the only one that Mr. McGrath could get for his longitude determination and the range of the several values being too large, he decided to remain at his station another winter in the hope of having more favorable weather. Observations for latitude had been made in November on four nights by Talcott's method.

The magnetic declination, dip, and intensity were determined every month beginning in September, and the meteorological instruments were read three times a day. The lowest temperatures noted were —54° and —59°.3 Fahr. on January 28 and 29, and —55°.3, —53°.9, and —51°.3 Fahr. on February 5, 6, and 7, 1890. During these three days in February, the highest temperatures were —32°, —41°.5, and —39°.9 Fahr.

During the autumn the Yukon River was gauged; lines of soundings were run and floats were sent down to determine the velocity of the current.

The natural resources of this section of the country being few, much apprehension of a scarcity of provisions was felt for a time when news came on the 11th of October of the loss of the steamer *Arctic* between St. Michaels and the mouth of the Yukon. This steamer was carrying supplies for Mr. McGrath's party, and she was expected to arrive about the 20th of September. Ultimately she was raised and repaired, and the supplies saved from the wreck were forwarded up the Yukon by the steamer *St. Michaels* and landed September 23 about 150 miles below Fort Yukon. There being a scarcity of flour for the party, but five pounds a month to each man, and many of the staple articles of food being either wholly wanting or to be had only in exceedingly small quantities, Mr. McGrath deemed it advisable to send two of his men to the point of storage of the supplies with orders to take what care they could of them, and if possible get some up to the party during the winter. These men started on their return journey in February with a hand sled and a toboggan drawn by three dogs, and after traveling 70 days reached camp May 2, bringing 200 pounds of flour. They had to cut off the tops of their boots to feed the dogs and gave them also deer-skin sinew and line from the toboggan; their own clothes they *cached* on the road, being able to carry besides the flour but one pair of blankets, and having on their arrival only the clothes on their backs. The chief privation that had been felt by Mr. McGrath's party during the winter, next to the lack of flour, was the want of illuminating material, the supply of oil having been only enough to allow lights for a few hours each day.

Mr. McGrath expresses his thanks to his assistants Mr. Davis and Mr. Kingsbury for the aid they afforded him. The men of the party worked cheerfully and diligently throughout the season.

From Mr. Turner, in charge of the Porcupine River party, reports have been received bearing dates of January 1 and 24, 1890. These reached Washington on the 30th of June. After leaving Mr. McGrath at Fort Yukon, the steamer *Yukon* with Mr. Turner and his party on board proceeded up the Porcupine River until the morning of August 6, when Captain Petersen stated that he had sounded the channel ahead and found it impossible to proceed further. He represented also that the rapidly falling water made his safe return to Fort Yukon problematical were he to delay longer. He therefore landed Mr. Turner and party with its stores and equipments at a point on the river 37 miles west of the boundary.

Mr. Turner expresses his conviction that this action was due to ignorance of the river, as within two days after the steamer's departure the river rose at least 2 feet, rendering navigation to the boundary perfectly practicable, and with short periods of rise and fall, the low water of August 6 was not reached for two weeks or more.

It was necessary, therefore, to track the supplies up the river, and for this purpose the whale-boat *Lottie* brought from San Francisco, and one of the Alaska Commercial Company's lighters, placed at Mr. Turner's disposal by Captain Petersen, were used. On August 8, the lighter with the whaleboat in tow started on its way up the river. The surgeon, Dr. Kierulff, and one man were left at the lower camp, and Mr. Turner hired four Indians to assist in pulling the boats upstream. Difficulties were encountered at the outset, owing to the rapid current and the frequent grounding of the lighter, which finally grounded so heavily that the combined exertions of the whole force failed to start her. The whaleboat was therefore loaded, and the lighter left with one man and an Indian boy to remain until the lighter could be sufficiently relieved of her load to be got off. On August 11 the Rampart House was reached during a thunder storm.

Observations made at the Rampart House placed it in latitude 67° 08′ north, longitude 9^h 27.1^m west of Greenwich, or in arc 141° 46′.5, nearly 20 miles west of the boundary line.

On August 12, having obtained the loan of a boat, Mr. Turner started up the river, accompanied by Assistant Astronomer Edmonds and three men, for the purpose of locating the boundary and selecting a site for a camp. On August 18, a point having been reached at which observations with the sextant gave the longitude as 9^h 23^m 58^s, or in arc 140° 59′ 30″ (the latitude having been assumed as 67° 25′ from observations made a few miles higher up), a site for a house was finally selected at the mouth of Sunaghun Hun (Old Wife's River). The Assistant Astronomer and two men were left here, while Mr. Turner with one man returned to Rampart House, where he found the lighter and the whaleboat.

By the 17th of September the whole party outfit (except some flour and meat stored at Rampart House) had been transported fully 50 miles upstream in the face of a rapid current and despite numerous mishaps; a space had been cleared in the forest and a house put up 50 feet long and 15 wide, with a projecting wing 15 by 20. By the 4th of October the house was ready for occupation; the astronomical observatory, a log structure 10 feet square, was finished and the meridian telescope in position. The magnetic observatory was completed October 15. Mr. Turner noted great daily fluctuations in the magnetic declination, and these induced him to observe once a week the declination through twenty-four hours. This was begun November 4, and was continued without intermission up to the date of his last report.

The most formidable obstacle he has had to contend with has been cloudy weather and fog. Solely from this cause he had been unable up to January 24 to secure more than one occultation, that of η Geminorum, on November 11, 1889, and eleven moon culminations. He states that, although the temperature had fallen as low as—45° F., he did not find cold weather an insurmountable obstacle to observing.

Mr. Turner had made arrangements at the date of his last report to undertake in March a sledge journey from his camp to the shores of the Arctic Ocean, a distance overland of about 150 miles. On his return from this expedition, if successful, he proposed to send Assistant Astronomer Edmonds to try and push across the country to the Yukon. Minor exploring trips into the surrounding country were also projected. He will continue his surveys throughout the winter of 1890–1891.

The impression made by the reports of Mr. McGrath and Mr. Turner is that both of these officers have brought to the conduct of their work a spirit that will overcome all obstacles, and an enthusiasm for its success which has been infused into all connected with their parties.

Determinations of gravity and the magnetic elements at stations on the west coast of Africa, and at St. Helena, Ascension Island, Barbados, and Bermuda.—Magnetic observations at stations on the Cape Verde Islands and the Azores.—The voyage of the U. S. Eclipse Expedition to the west coast of Africa in the autumn and winter of 1889, under the direction of Professor Todd, of Amherst College, and under the auspices of the Navy Department, afforded an opportunity for the detail of an officer of the Survey to join the expedition under instructions to occupy certain stations, not readily accessible, for determinations of gravity and the magnetic elements. These stations included localities which had been occupied by Foster, Sabine, and other earlier observers, and which, therefore, it was desirable to connect with home stations, and with the work of later observers.

Authority having been duly granted by the Navy Department, and the sanction of the Secretary of the Treasury obtained, Assistant E. D. Preston was instructed to join the U. S. S. *Pensacola* and proceed to the west coast of Africa, occupying stations in the vicinity of St. Paul de Loanda, and also at the Cape of Good Hope, for determinations of gravity and the magnetic elements, and on the return voyage to make similar determinations on the islands of St. Helena and Ascension, should time enough be afforded by the landing of the steamer at these points.

Mr. Preston's report (Appendix No. 12) shows that he secured a valuable series of observations at the localities above named, and at others where he was enabled to stop through the courtesy of Capt. A. R. Yates, U. S. N., commanding the *Pensacola*.

Transportation of the National Prototypes of the Metre and Kilogramme from Paris to Washington.—In September, 1889, the Superintendent of Weights and Measures was officially informed that the standards intended to serve as International Prototypes of the Metre and Kilogramme had been formally adopted by the International Conference of Weights and Measures; that the construction of the standards intended for distribution as National Prototypes among the several countries represented in the Conference had also been completed, and that three metre standards and two kilogramme standards had been assigned to the United States.

Instructions were accordingly given to Assistant George Davidson, who was then in Paris as a delegate from the United States to the International Geodetic Association to obtain from the Hon. Whitelaw Reid, Minister of the United States, one of the sets of National Prototypes and bring them to Washington for delivery to the Office of Weights and Measures. This set consisted of Prototypes Nos. 12 and 27 of the Standard Metre and Prototype No. 20 of the Standard Kilogramme. It had been deemed advisable, in view of the risks of transportation and for other reasons, that the United States should possess two copies of the National Prototype Metres and two of the National Prototype Kilogrammes, and also an additional metre bar made of the "alloy of 1874." This was No. 12 in the set just referred to. Both sets of standards allotted to this country had been carefully compared by a committee of the International Conference with the International or Fundamental Prototypes deposited in the care of the International Bureau of Weights and Measures at Breteuil, near Paris.

It is needless to say that the instructions given to Mr. Davidson were most carefully carried out, and that he gave the closest personal supervision to the boxes containing the standards during the successive stages of their transfer to the United States. His report of their reception, transportation, and delivery to the Superintendent of Weights and Measures on the 27th of November, 1889, forms a part of Appendix No. 18 to this volume.

This appendix contains also the report of Assistant O. H. Tittmann, Assistant in charge of the Office of Weights and Measures, of the duty assigned to him by instructions issued in April, 1890. In pursuance of these instructions he visited London, Paris, and Berlin, to examine in those cities the plans adopted for the safe-keeping of governmental standards, and obtained from the International Bureau of Weights and Measures the second set of National Prototypes which had been allotted to the United States. This set, consisting of the National Prototype Metre No. 21 and the National Prototype Kilogramme No. 4, he conveyed safely to Washington, and on July 18 delivered them to the Superintendent of Weights and Measures.

ABSTRACTS OF ANNUAL REPORTS FROM THE ASSISTANT IN CHARGE OF OFFICE AND TOPOGRAPHY, THE HYDROGRAPHIC INSPECTOR, THE DISBURSING AGENT, AND THE ASSISTANT IN CHARGE OF THE OFFICE OF WEIGHTS AND MEASURES.

ABSTRACT OF THE ANNUAL REPORT OF THE ASSISTANT IN CHARGE OF OFFICE AND TOPOGRAPHY.

The annual report of Mr. B. A. Colonna, Assistant in charge of Office and Topography, accompanied by the annual reports of the chiefs of the several Office Divisions, is published as Appendix No. 4 to this volume.

Mr. Colonna calls attention to the fact that, in accordance with instructions recently given, the Disbursing Officer of the Survey and the Assistant in charge of the Office of Weights and Measures have submitted their annual reports directly to the Superintendent.

He expresses his gratification at the continued able support that he has received from the chiefs of the several Divisions of the Office and states that no efforts have been overlooked during the past year that would promote the efficiency of the service by improving the proficiency of its personnel and by complying strictly with the letter and spirit of the Civil Service laws.

He calls attention to the urgent need of more room for certain of the operations incidental to the printing of charts from copper plates which require the use of much inflammable matter and a constant fire. These operations, for want of space in the press room, have now to be carried on in the basement of the building intended solely for the preservation of the Archives of the Survey.

Between July 2, 1889, and July 8, when the President made the appointment of the Superintendent of the Survey, Mr. Colonna performed the duties of Superintendent, so far as necessary for the proper conduct of the work, under the direction of the Secretary of the Treasury.

The Computing Division of the Office has remained as heretofore in charge of Assistant Charles A. Schott. Details of the work of the several computers, with the names of officers of the Survey and other persons temporarily assigned to duty in the Division, are given in his annual report.

Mr. Schott has directed and supervised the work of the computers, furnished from time to time the results of the computations, supplied information in connection with the scientific correspondence of the Survey, and completed the discussion of much accumulated material relating to terrestrial magnetism. Among the scientific papers which he has submitted for publication was one in which are presented the results of the absolute measures of the magnetic declination, dip, and intensity at Los Angeles, California, during a period of seven years, and one in which are given the results of the differential observations of the declination at the same place and for the same time. In the latter paper more than 61,000 hourly readings have been subjected to an analysis and discussion which includes an exposition of the lunar and solar rotation effect on the horizontal magnet. These papers are published as Appendices Nos. 8 and 9 to this volume.

Mr. Schott continued to act by appointment of the Civil Service Commission as a member of the Board of Examiners for computing and astronomy.

Assistant W. H. Dennis continued in charge of the Drawing Division during the fiscal year. His annual report is accompanied by lists of drawings completed of charts which were published by photolithography during the year and of drawings revised and corrected for reprints of photolithographed charts; also lists of drawings completed for new charts to be engraved on copper and of drawings revised and corrected for new editions of charts printed from engraved plates. Drawings were furnished to the Engraving Division for 216 corrections or changes required to be made on engraved plates of charts.

The loss of the services of three experienced draughtsmen by resignation was seriously felt during the year. Notwithstanding this reduction in force, Mr. Dennis reports that the amount of work accomplished will compare favorably with that of previous years, especially when the size and character of the drawings for new charts are considered.

Assistant Herbert G. Ogden submits the annual report of the Engraving Division, of which he continued in charge during the year. Included in this duty there is also the direction of the work of electrotyping and photographing and of the chart-printing.

Thirteen new engraved plates of charts were completed and 14 engraved plates of new editions of charts; 11 new engraved chart plates were begun, and fourteen plates for new editions of charts. Impressions for the chart room were taken from 862 plates, and 627 chart plates were corrected for printing. There were in hand at the close of the year engraved plates of 28 new charts and of 11 new editions of charts.

Thirty-three alto and 45 basso plates were made in the electrotyping room. For the use of the draughtsmen and engravers in reductions and for other purposes 277 negatives were made in the photographic laboratory, and 702 prints taken from negatives.

In the printing rooms the total number of impressions taken from engraved plates was 53,091; of this number 47,008 were for the chart room.

Mr. Ogden observes that the number of plates finished during the year is larger than for any year during his charge of the Division, and that the year's work has shown material progress towards completing the series of coast charts (scale 1–80000) and general coast charts (scale 1–400000 on the Atlantic and Gulf coasts. Of the coast charts, but two are required to finish the series of 195 from the northeastern boundary to the Mississippi River, and of the general coast charts two will complete the whole series of 21 from the NE. boundary to the Rio Grande. On the Pacific coast the recent publication of the general coast chart (scale 1–200000) from San Diego to Santa Monica has completed the series of those charts from the southern boundary to Cape Mendocino, with the exception of a gap between Point Buchon and Point Pinos, where the surveys are as yet unfinished.

Mr. D. C. Chapman, aided by Mr. L. P. Keyser, continued in charge of the electrotype and photograph rooms. Mr. F. Moore served throughout the year as foreman of printing, with the usual force of assistant printers and helpers. Seven thousand two hundred and fifty-four more impressions were furnished to the chart room than during the preceding year. A still larger number was needed to meet the demand for charts, but the appropriation for printing was not enough to permit the employment of printers for the small press during the last four months of the year.

Mr. Ogden commends the zeal and fidelity to duty of Mr. John H. Smoot, clerk in the Division.

A list by title of engraved plates of charts begun, completed, and in progress during the year accompanies his report.

From the beginning of the fiscal year till December 18, Assistant Andrew Braid had charge of the Instrument Division, and upon his assignment to field service Assistant Edwin Smith was directed to take charge of it and has submitted the annual report of its work. Mr. E. G. Fischer continued to serve as chief mechanician. Some changes in the personnel of the force of mechanicians were made with a view to obtain greater efficiency.

Mr. Smith observes that the construction of new instruments has been confined to such as can not be purchased or made to order except at very much greater cost, but quite a number of instruments were so thoroughly remodeled or repaired that they became practically new; among these were 12 plane tables, 1 meridian telescope, two 45-inch astronomical transits, and 3 theodolites, 1 of which was regraduated.

Among the new instruments completed were six 8-inch repeating theodolites (begun the year preceding) and 1 tracing apparatus and 1 set of 16 metric weights for the Office of Weights and

Measures. The facilities of the instrument shop were increased by the purchase of a new lathe and of one of Brown & Sharpe's tool-grinding machines.

Mr. H. O. French continued to serve as head carpenter and Mr. R. C. Glascock as clerk to the division.

The report of Mr. A. S. Christie, computer, in charge of the Tidal Division, indicates that a large amount of valuable work has been done during the year. The manuscripts of the tide tables for the Atlantic and Pacific coasts for the calendar year 1891 were prepared and the proofs read; tidal notes were furnished for 131 stations on 38 charts and for 62 stations for publication in the Coast Pilots. The usual information was supplied to field parties and tidal data were prepared in response to requests from persons not connected with the Survey.

Series of tidal observations at the following-named ports were under discussion by the method of harmonic analysis: Eastport, Me., 1862; Boston, Mass., 1869; Sandy Hook, N. J., 1887–1888; and Sausalito, Cal., 1889. All data and records relating to observations of currents were examined in detail and memoranda preserved in the form of a card catalogue, so that all material for the reduction of current observations could be readily referred to and plans of reduction laid out to the best advantage. A paper on the Use of Observations of Currents for Prediction Purposes was prepared by Mr. John T. Hayford, computer, and is published as Appendix No. 14 to this volume. He has also submitted a paper on the Relation between the Harmonic Components of a Tidal Curve and its Mean Amplitude, and a paper on A Modification of the Ferrel Tide-Predicting Machine to adapt it to the Prediction of Hourly Ordinates.

A special report has been made on the results of an elaborate comparison between prediction with the machine and observation by means of automatic gauges. (See Appendix No. 15 to this volume.) Mr. Christie has submitted a paper on a new method for the analysis of periodical phenomena. The acquisition of an 8-keyed comptometer facilitated in a remarkable degree the numerical work of the Division.

Mr. M. W. Wines, general office assistant, reports a considerable increase in the business of the Miscellaneous Division, of which he has continued in charge. Four thousand six hundred and fifty-nine more charts were sent to sale agents than during the fiscal year preceding. The annual report of the Superintendent for the fiscal year 1887 was received from the printer and that for the fiscal year 1888 was sent to the press. Of these reports, from the year 1851 to the year 1887, a home distribution was made of 2,928 copies and a foreign distribution of 463 copies, making a total distribution during the year of 3,391 copies. Lists of the publications of the Survey received during the year from the Public Printer, with the number of copies of each publication printed, are included in Mr. Wines's report. Among these were for free distribution to applicants the extra copies of Appendices to the Annual reports and the Bulletins. Of the Notices to Mariners issued monthly, or oftener should occasion demand, upwards of 10,000 copies were distributed each month.

Mr. Freeman R. Green kept the accounts of sale agents for charts and attended faithfully to the other clerical duties of the division. Mr. Wines commends the chief messenger, William H. Butler, who had served many years in that capacity, for his faithful performance of duty; also the assistant messengers.

Assistant Gershom Bradford, in charge of the Chart Division, reports that a number of improvements have been made in the routine of chart receipts, corrections, and issues, thereby facilitating the work. A large increase in the labors of those employed grew out of the constantly growing demand for charts. The issue of charts to vessels of the Navy was about twice as large as during the preceding year.

Mr. Bradford presents a comparative statement of the net issues of charts during the fiscal years 1889 and 1890, showing for 1890 an increase of net issue of 30 per cent. A similar statement of the issues to sale agents shows a net increase of 19 per cent. For the fiscal year 1890 the numbers of these issues are 61,882 and 31,146 respectively.

The titles of 7 charts printed from engraved plates, and of 21 charts published by photolithography were added to the catalogue. The text of a new catalogue of charts was prepared and it is now in the hands of the Public Printer.

The annual report of the Archives and Library Division, submitted by Mr. Artemas Martin, who remained in charge during the year, shows in detail the number and kind of records, original and duplicate, and of the computations received and registered in the archives; also the numbers and titles of topographic and hydrographic sheets received for registry, and the number of specimens of sea-bottom. The number of books and pamphlets received in the library is stated, and attention is called to the mass of valuable records and computations which need binding.

In the Office Division under the immediate direction of the Assistant in charge of Office and Topography the following persons were employed:

Dr. William B. French served as executive officer and accountant; Mr. R. M. Harvey, until December 7, as file clerk; Miss F. B. Bailey, as stenographer and type-writer; Miss F. Cadel and Miss K. Lawn, as type-writers; Miss C. B. Turnbull, as miscellaneous copyist until May 27, when her resignation took effect; Mrs. J. Waddill, as copyist until her transfer to the Treasury Department, August 10; Mr. E. B. Wills, as clerk, and Miss I. M. Peck, as clerk and copyist.

In the office of the Superintendent Mr. W. B. Chilton continued to serve as clerk.

ABSTRACT OF THE ANNUAL REPORT OF THE HYDROGRAPHIC INSPECTOR.

Commander C. M. Thomas, U. S. Navy, Hydrographic Inspector Coast and Geodetic Survey, submits in Appendix No. 5 to this volume his annual report of the hydrographic work executed in the field and in the office, with tables appended showing the number of naval officers and of enlisted men attached to the several vessels of the Survey during the fiscal year 1890.

Commander Thomas entered upon his duties as Hydrographic Inspector at the beginning of the fiscal year, relieving Lieut. Commander W. H. Brownson, U. S. Navy. Referring to the work of this officer he observes that he found the parties in the field so thoroughly organized and the routine of the office so admirably arranged and systematized that no changes of moment in administration were found necessary.

In his general summary of hydrographic operations on the Atlantic, Gulf, and Pacific coasts Commander Thomas takes occasion to say with regard to the completion of the hydrography of the Florida Keys that the survey is to be congratulated that this important and intricate piece of work was wholly executed under the immediate supervision of Lieut. J. F. Moser, U. S. Navy, an officer whose surveys have never been surpassed and seldom equaled. Lieutenant Moser was detached soon after the close of the fiscal year. It may be added that the reports which he has submitted during three separate terms of duty on the Survey, occupying in all a period of fifteen years, have been models in their clearness and completeness of statement, have contained many valuable suggestions, and could have emanated only from an officer deeply interested in his work and of exceptional ability as a hydrographer.

For the use of the Gulf Coast Navy Yard Site Commission, Commander William P. McCann, U. S. Navy, president, a hydrographic survey was made of the tributaries of Pensacola Bay by Sub-assistant P. A. Welker, and for the Pacific Coast Navy Yard Site Commission Capt. A. T. Mahan, U. S. Navy, president, the special survey (begun during the preceding fiscal year) of Port Orchard by Assistant J. F. Pratt was completed.

In his notices of special work, after referring to the trial courses for naval vessels laid out on the Atlantic Coast,* Commander Thomas states that for the 40-mile course on the Pacific coast the vicinity of Santa Barbara, Cal., was determined upon, and that the work would be begun by Lieut. D. Delehanty, U. S. Navy, Assistant Coast Survey, commanding the steamer *Hassler*, as soon as his preparations at San Francisco could be finished. He expresses the pleasure it gives him to report that the Navy Department has given its official approval to the Atlantic Coast trial courses.

Coast Pilot Division.—The report of Commander Thomas is accompanied by a report from the Coast Pilot division of his office. Ensign E. H. Tillman, U. S. Navy, Assistant Coast Survey, had charge of this Division from July 1 till October 31, 1889, with the exception of a period of about seven weeks field duty, during which he was in command of the steamer *Endeavor* on Coast Pilot service in Chesapeake Bay. On October 31 he was relieved by Lieut. Commander Seth M. Ackley, U. S. Navy, who was specially selected for this responsible position on account of his high standing as a seaman, and his former service of more than three years on the Survey.

A new volume of the Atlantic Coast Pilot is in preparation to include the coast from Eastport to Cape Ann. Proof has been read of Part VI, Atlantic Coast Pilot, Chesapeake Bay and tribu-

* See "Special Operations."

taries, and Subdivision No. 22, Atlantic Local Coast Pilot, Jupiter Inlet to Dry Tortugas, was published in December, 1889.

The fourth edition of the Pacific Coast Pilot, California, Oregon, and Washington, prepared by Assistant George Davidson, was nearly ready for issue at the close of the year, and the manuscript of a third edition of the Alaska Coast Pilot was completed by Lieut. Commander H. E. Nichols, on duty on the Pacific Coast.

Lieutenant-Commander Ackley had the efficient assistance of Ensign E. A. Anderson, U. S. Navy, and of Mr. John Ross. Miss Alice F. Carlisle rendered very efficient service as copyist.

Hydrographic Division.—On January 14, 1890, Lieut. M. L. Wood, U. S. Navy, Assistant Coast Survey, who had been in charge of the Hydrographic Division since the beginning of the fiscal year, was relieved by Lieut. R. T. Jasper, U. S. Navy. Commander Thomas refers in terms of commendation to the untiring industry exhibited by Lieutenant Wood, and to the improvements introduced by him in the details of chart corrections. Under Lieutenant Jasper the efficiency of the Division has been kept up and important advances made. His annual report of work accomplished accompanies the report of the Hydrographic Inspector, and presents in a tabular form lists of hydrographic sheets plotted, verified, and inked during the year, of reduced drawings of hydrography verified, revised, and corrected, and of miscellaneous draughting done.

Messrs. E. Willenbucher, W. C. Willenbucher, and F. C. Donn continued to serve as hydrographic draughtsmen, their many years' experience and tried ability making their services of great value. Mr. E. H. Wyvill as chart corrector, and Mr. J. H. Roeth as clerk, rendered efficient service.

In the course of the fiscal year there were in all seventy-seven officers of the Navy assigned to duty on the Survey, and of these fifty-four were on duty at its close.

ABSTRACT OF THE ANNUAL REPORT OF THE DISBURSING AGENT, U. S. COAST AND GEODETIC SURVEY.

On December 3, 1889, Mr. George A. Bartlett, Disbursing Clerk of the Treasury Department, who had made the disbursements for the Coast and Geodetic Survey since the close of July, 1885, was relieved of the duties devolving upon him in connection therewith by Mr. John W. Parsons, who had qualified as Disbursing Agent of the Survey by appointment of the Secretary of the Treasury under date of November 7, 1889.

The annual report of the Disbursing Office for the fiscal year ended June 30, 1890, which is submitted by Mr. Parsons, is published as Appendix No. 6 to this volume. Accompanying it will be found the statement of the expenditures of the Survey for the fiscal year, which, by Section 264 of the Revised Statutes, is required to be submitted annually to Congress.

Mr. Parsons observes that some little time will yet be required before such changes in methods of keeping accounts for both the field and the office as have been demanded by the appointment of a Disbursing Agent for the Survey can be thoroughly systematized, and made to result, as ultimately they will, in economy of time and money. But the great advantage of the Survey's having its own disbursing officer has already become apparent.

The accounts rendered to the Department during the past fiscal year have almost uniformly been passed by the accounting officers of the Treasury, but few items having been objected to, and the explanations with regard to these having been satisfactory.

From the statistics submitted by Mr. Parsons showing the details of work in his office, it is evident that unremitting and intelligent labor has been needed on the part of himself and coadjutors to keep his books up to date. He acknowledges faithful and capable service rendered by Mr. William H. Lanman, clerk, and by Miss Paula E. Smith, writer.

ABSTRACT OF THE ANNUAL REPORT OF THE ASSISTANT IN CHARGE OF THE OFFICE OF WEIGHTS AND MEASURES.

The annual report of the Office of Weights and Measures, submitted by Assistant O. H. Tittmann, in charge of its operations under the direction of the Superintendent, is published as Appendix No. 7 to this volume.

Mr. Tittmann states that the demands upon this Office have much increased, largely owing to the necessity of preparing standards of weight and measure for the newly admitted States, but also to the increased demand from all parts of the country for the comparison of weights and measures with the National Standards. In this connection he calls attention to the need of Congressional legislation for fixing definitely the ultimate standards of weight and measure, and making obligatory a verification by this Office of all measures intended for use in interstate as well as international commerce.

A fitting occasion for such legislation is afforded by the receipt at Washington of the National Prototypes of the Metre and Kilogramme, which, having been formally opened by the President of the United States, are now deposited for safe-keeping in a fire-proof building in this Office. Full accounts of the transfer of these standards from the International Bureau of Weights and Measures near Paris, to Washington, under the personal charge of Assistants Davidson and Tittmann, appear in Appendix No. 18 to this volume. In this appendix will be found a copy of the certificate, recording the circumstances under which the standards were received and opened, signed by the President and by the Secretaries of State and of the Treasury; also a copy of a separate attestation signed by the Superintendent of Weights and Measures and by other gentlemen present. It contains also an historical account of U. S. Standards of Weights and Measures, customary and metric.

The work of the office during the year included a collection of the latest State laws relating to weights and measures, and of information from United States consuls abroad respecting weights and measures in the countries to which they are accredited, the preparation and distribution of a table for converting U. S. weights and measures—customary to metric, and the preparation and publication of Bulletin No. 15 on the Verification of Weights and Measures, and of Bulletin No. 18 on the Reduction of Salinometer observations.

During Mr. Tittmann's absence in Europe on business relating to weights and measures, the Office was in charge of Assistant George A. Fairfield from April 22 to May 14, and then under the charge of Assistant F. H. Parsons to the close of the fiscal year. The vacancy caused December 31, 1889, by the resignation of Dr. J. J. Clark, who had served with ability for many years as Adjuster, was filled February 19, 1890, by the appointment of Mr. L. A. Fischer, who has shown much capacity for the duties devolved upon him.

Mr. Tittmann has appended to his report a tabular statement of information furnished, and of comparisons and weighings made in compliance with requests both official and personal.

SUBOFFICES, U. S. COAST AND GEODETIC SURVEY.

Suboffice at Philadelphia.—Assistant S. C. McCorkle, in charge of the Suboffice of the Survey at Philadelphia, reports that information has been requested by and furnished to the following named branches of the Government Service in that city: The U. S. Corps of Engineers, the Light-House Inspector and Engineer of the Fourth Light-House District; the Branch Hydrographic Office of the Navy; the U. S. Civil Engineer of League Island Navy-Yard, and the United States District Courts of eastern Pennsylvania and New Jersey.

The following-named local organizations or municipal officers asked and received information: The Philadelphia Maritime Exchange; the Board of Port Wardens; the Harbor Commission; the Pilots Association; the Chief Engineer and Surveyor of the City; the Engineers' Club, and the Historical Society of Pennsylvania. Inquiries from a number of citizens of Pennsylvania and New Jersey were answered. All questions of a specially important nature were referred to the Office at Washington.

Upwards of 650 persons visited the Suboffice during the year.

Occasional use was made of the facilities of the Suboffice by Assistants C. O. Boutelle, R. Meade Bache, C. M. Bache, and Joseph Hergesheimer.

Two visits of inspection were made by the Superintendent.

By special invitation from the Maritime Exchange, Mr. McCorkle accompanied a committee to Delaware Breakwater, in the interests of the commerce of the city; and later, by invitation, accompanied a committee of all the maritime associations in Philadelphia to League Island Navy-Yard as a representative of the Coast and Geodetic Survey.

Other duty assigned to Mr. McCorkle in connection with the physical hydrography of Delaware River and Bay is referred to under a heading in Section II.

Suboffice at San Francisco.—In addition to the general direction of the land operations on the Pacific Coast, and other duties referred to under headings in Sections X and XII, Assistant George Davidson continued in charge of the Suboffice at San Francisco. During Mr. Davidson's absence in Europe and in the field this duty was assigned to Assistant James S. Lawson.

All calls for information, whether from field officers or from persons not connected with the Survey, have been either answered directly or referred to the Superintendent. Mr. Frank W. Edmonds served as clerk, and as observer at the Lafayette Park station in determining time for the tidal station at Sausalito. Vicente Denis continued to serve as messenger and porter, and had charge of the instruments and camp equipage in the storage room.

Special examinations were made of all the instruments and camp equipage during Mr. Davidson's absence in Europe by Assistant Lawson and Subassistant Morse. All instruments not in use were forwarded to Washington, and all condemned camp material was sold at public auction.

CONCLUSION.

The development of the resources of Alaska, and its increasing importance as a valuable possession of the United States, has induced the Superintendent to advance as rapidly as possible the surveys of its coasts and waters, and to issue preliminary charts based on these surveys as soon as their results can be made available.

By his direction Mr. Charles Junken has been employed as a civilian expert in the reduction and adjustment of the triangulation made in the course of the hydrographic reconnaissance of southeastern Alaska. One result of this reduction was the determination of upwards of 250 stations in geographical position. During the year Mr. Junken has submitted a new scheme for the publication of the coast charts of Alaska; has made the drawings of two of these charts, and has arranged for the printer the manuscript of a new edition of the Alaska Coast Pilot, prepared by Lieut. Commander H. E. Nichols, U. S. N., Assistant, Coast and Geodetic Survey.

Under the direction of the Superintendent the following-named officers were specially employed: Assistant Charles S. Peirce in gravity research; Assistant Charles O. Boutelle, in the immediate supervision of State Surveys until the failure of his health; Assistant E. D. Preston, in reductions and discussions supplementary to work done by him for the Hawaiian Government, and in studies and investigations relating to arc measurements and determinations of gravity; and Assistant Edward Goodfellow, in the preparation for publication and the editing of the Annual Reports and Bulletins of the Survey.

PART III.

APPENDICES.

APPENDIX No. 1—1890.

DISTRIBUTION OF THE FIELD PARTIES OF THE COAST AND GEODETIC SURVEY UPON THE ATLANTIC, GULF OF MEXICO, AND PACIFIC COASTS, AND IN THE INTERIOR OF THE UNITED STATES, DURING THE FISCAL YEAR ENDING JUNE 30, 1890.

Sections.	Parties.	Operations.	Persons conducting operations.	Localities of work.
SECTION I.				
Maine, New Hampshire, Vermont, Massachusetts, and Rhode Island, including coast and seaports, bays and rivers.	No. 1	Reconnaissance and triangulation.	C. H. Boyd, assistant; Everett C. Lyle, recorder.	Reconnaissance and triangulation continued over the St. Croix River and the Boundary Lakes to a connection with the Northeastern Boundary Survey at its initial monument. (See also Section VIII.)
	2	Triangulation	Joseph Hergesheimer, assistant ..	Tertiary triangulation of the Schoodic Lakes at the headwaters of the St. Croix River. (See also Section VI.)
	3	Topography and hydrography.	J. A. Flemer, subassistant; S. P. Bradley, recorder; W. B. Paca, recorder.	Topographical surveys on the St. Croix River, with incidental hydrography from Vanceboro' to the southward. (See also Section III.)
	4	Topography and hydrography.	Charles M. Bache, assistant.......	Topographic and hydrographic surveys on the St. Croix River from Vanceboro' to the southward. (See also Section II.)
	5	Topography and hydrography.	Eugene Ellicott, assistant.........	Topographic and hydrographic survey of the St. Croix River from Calais to Baring and above.
	6	Topography and inspection of topographical surveys.	John W. Donn, assistant..........	Completion of unfinished topographical work on the coast of Maine in the vicinity of Cobscook Bay, and inspection of topographical surveys in that vicinity and to the eastward and northward. (See also Section III.)
	7	Topographical examinations.	Henry L. Whiting, assistant	Examination of changes for additions of topographical details to the shore lines of the Kennebec River from Bath to Gardiner, Me. (See also "Special Operations.")
	8	Town boundary surveys.	Henry L. Whiting, assistant, and Commissioner Massachusetts State Survey; C. H. Van Orden, assistant; Joseph B. Tolley and E. E. Peirce, foremen.	General direction of town boundary surveys in the State of Massachusetts continued. Service as a member of the Mississippi River Commission. (See also Section III.)
	9	Physical hydrography.	Henry L. Marindin, assistant; E. E. Haskell and Homer P. Ritter, expert observers; G. T. Bartlett and E. S. Snow, recorders.	Physical hydrography. Continuation of physical surveys on the coast of Cape Cod. (See also Section III.)
	10	Hydrography.....	Lieut. W. P. Elliott, U. S. N., assistant; Lieut. A. L. Hall, U. S. N. (part of season); Ensigns L. S. Van Duzer and E. A. Anderson, U. S. N. (part of season); Ensigns L. C Bertolette, E. H. Duvall, F. H. Brown, C. M. Stone, and T. Washington, U. S. N.	Hydrographic resurveys in Nantucket Sound and vicinity. (See also Section II.)

APPENDIX No. 1—Continued.

Sections.	Parties.	Operations.	Persons conducting operations.	Localities of work.
SECTION I—Continued.	No. 11	Hydrography	Lieut. J. F. Moser, U. S. N., assistant; Ensigns H. A. Bispham, R. D. Tisdale, S. M. Strite, L. C. Bertolette, and W. S. Cloke, U. S. N.; Passed Assistant Surgeon J. M. Steele, U. S. N.; Passed Assistant Engineer E. H. Scribner, U. S. N.	Continuation of off-shore hydrography south of Nantucket and Martha's Vineyard. (See also Section VI.)
	12	Topography	W. I. Vinal, assistant	Completion of the topographical resurvey of Woods Hole and vicinity.
	13	Topography	E. L. Taney, subassistant	Topographical resurvey of the Elizabeth Islands between Buzzards Bay and Vineyard Sound, and of the Waepecket Islands, Buzzards Bay.
	14	Special hydrography.	Lieut. J. E. Pillsbury, U. S. N., assistant.	Establishment of a naval trial-course in the eastern passage, Narragansett Bay.
SECTION II. Connecticut, New York, New Jersey, Pennsylvania, and Delaware, including coasts, bays and rivers.	1	Special hydrography.	Lieut. C. E. Vreeland, U. S. N., assistant.	Laying off a trial-course for the new naval war vessel Philadelphia off the coasts of Block Island and Long Island. (See also Section VI.)
	2	Physical hydrography.	E. E. Haskell, expert in physical hydrography.	Observations of tides, currents, and gaugings of discharge in Long Island Sound. (See also Section I.)
	3	Topography and hydrography.	C. T. Iardella, assistant	Topographic and hydrographic surveys on the south coast of Long Island.
	4	Examination of changes in water front.	H. P. Ritter, expert in physical hydrography.	Shore line examination for the determination of changes in and additions to New York City Front.
	5	Hydrographic examination.	Lieut. W. P. Elliott, U. S. N., assistant; Ensign E. A. Anderson, U. S. N.	Hydrographic survey of Wallabout Channel, New York Harbor. (See also Section I.)
	6	Hydrographic examinations.	Lieut. W. P. Elliott, U. S. N., assistant; Ensign E. A. Anderson, U. S. N.	Hydrographic examination of the approaches to Ellis Island, New York Harbor.
	7	Tidal observations.	David E. Snead and J. G. Spaulding, observers.	Tidal observations continued with automatic tide gauge at Sandy Hook, N. J.
	8	Recovery and marking of station.	Stehman Forney, assistant	Recovery and marking of a station of the primary triangulation in Pennsylvania. (See also Section VII.)
	9	Latitude and longitude.	C. H. Sinclair, assistant; R. A. Marr, assistant.	Determination of the longitude of Altoona, Pa., by exchanges of telegraphic signals with Washington. Observations for latitude at Altoona. (See also Sections III, XV, XVI, XVII.)
	10	Topographic examinations.	C. M. Bache, assistant	Examinations for note of topographic changes on the coasts of New Jersey and New York. (See also Section I.)
	11	Geodetic operations.	Charles O. Boutelle, assistant; Prof. E. A. Bowser, acting assistant.	Continuation of geodetic operations in the southwestern part of the State of New Jersey.
	12	Topographical additions and changes.	R. Meade Bache, assistant	Revision of the survey of Philadelphia City Front.
	13	Hydrography	J. Hergesheimer, assistant	Hydrographic resurvey in the Delaware River, in front of Philadelphia and to the southward. (See also Sections I and VI.)
	14	Physical hydrography.	S. C. McCorkle, assistant	Observations of ice-movement in Delaware River and Bay.
SECTION III. Maryland, District of Columbia, Virginia, and West Virginia, including bays, seaports, and rivers.	1	Determinations of gravity and magnetic observations.	E. D. Preston, assistant	Determinations of gravity at the Smithsonian Institution, Washington, D. C. Also determinations of the magnetic declination, dip, and intensity at the Coast and Geodetic Survey Office station, Washington, D. C. (See also "Special Operations.")

APPENDIX No. 1—Continued.

Sections.	Parties.	Operations.	Persons conducting operations.	Localities of work.
SECTION III—Continued.	No. 2	Topography	John W. Donn, assistant	Continuation of the detailed topographical survey of the District of Columbia. (See also Section I.)
	3	Topography	D. B. Wainwright, assistant	Continuation of the detailed topographical survey of the District of Columbia.
	4	Topography	W. C. Hodgkins, assistant	Continuation of the detailed topographical survey of the District of Columbia. (See also Section IV.)
	5	Topography	J. A. Flemer, subassistant	Continuation of the detailed topographical survey of the District of Columbia. (See also Section I.)
	6	Definition and determination of boundary line.	Henry L. Whiting, assistant	Definition and determination of a portion of boundary line in dispute between States of Maryland and Virginia. (See also Section I and "Special Operations.")
	7	Hydrographic examination.	Henry L. Marindin, assistant; E. E. Haskell and Homer P. Ritter, expert observers; Corcoran Thom, recorder.	Examination and location of a dangerous rock in the Potomac River. (See also Section I.)
	8	Hydrographic examinations.	Ensign E. H. Tillman, U. S. N., assistant; John Ross, recorder.	Hydrographic examinations for the Coast Pilot in Chesapeake Bay and tributaries.
	9	Topographical additions.	John W. Donn, assistant	Examination for additions of topographical details to a chart of Norfolk Harbor and vicinity. (See also Section I.)
	10	Hydrographic examination.	Lieut. S. M. Ackley, U. S. N., assistant.	Examination and development of a shoal in Chesapeake Bay, near Wolf Trap Light-house.
	11	Magnetic observations.	Jas. B. Baylor, assistant	Determination of the magnetic elements at a station in Lynchburg, Va. (See also Sections VIII, IX, and XIII.)
SECTION IV. North Carolina, including coast, sounds, seaports, and rivers.	1	Triangulation	W. C. Hodgkins, assistant	Connection of old and new triangulations on the coast of North Carolina, from Beaufort to the westward. (See also Section III.)
SECTION V. South Carolina and Georgia, including coasts, sea-water channels, sounds, harbors, and rivers.	1	Triangulation and topography.	F. D. Granger, assistant; J. B. Boutelle, extra observer; V. K. Hendricks, recorder.	Triangulation and topography in the vicinity of Charleston, S. C. (See also Section XV.)
	2	Tidal observations.	J. G. Spaulding, observer; Eugene Veith, observer.	Establishment and maintenance of an automatic tidal station on Tybee Island, Savannah River entrance. (See also Section II.)
	3	Special hydrography.	Ensign J. C. Drake, U. S. N., assistant.	Surveys and examinations of oyster beds for the State of Georgia.
	4	Hydrography	Lieut. J. F. Moser, U. S. N., assistant.	Hydrographic examination of the entrances to St. Simon's Sound. (See also Sections I and VI.)
SECTION VI. Peninsula of Florida, from St. Mary's River on the east coast to and including Anclote Anchorage on the west coast, with the coast approaches reefs, keys, seaports, and rivers.	1	Hydrographic examination.	Lieut. A. L. Hall, U. S. N., assistant.	Development of shoal off Key Biscayne, Florida. (See also Section VIII.)
	No. 2	Physical hydrography.	Lieut. C. E. Vreeland, U. S. N., assistant; Lieut. H. Kimmell, U. S. N.; Ensigns C. S. Stanworth, James E. Shindel, P. Andrews, and C. M. Stone, U. S. N.; Assistant Surgeon Thomas Owens, U. S. N., and Assistant Engineer W. W. White, U. S. N.	Continuation of the investigation of the currents of the Gulf Stream. (See also Section II.)

APPENDIX No. 1—Continued.

Sections.	Parties.	Operations.	Persons conducting operations.	Localities of work.
SECTION VI—Continued.	No. 3	Hydrography	Lieut. J. F. Moser, U. S. N., assistant; Ensigns H. A. Bispham, R. D. Tisdale, S. M. Strite, L. C. Bertolette, and E. H. Durell, U. S. N.; Passed Assistant Surgeon J. M. Steele, U. S. N., and Assistant Engineer E. H. Scribner, U. S. N.	Hydrographic surveys in Barnes Sound, in the Bay of Florida, and on the west coast of Florida from Cape Romano to Shark River. (See also Section I.)
	4	Triangulation, topography, and hydrography.	Joseph Hergesheimer, assistant; Charles H. Deetz.	Triangulation, topography, and hydrography on the west coast of Florida in the vicinity of Cape Romano and to the northward. (See also Sections I and II.)
SECTION VII.				
Peninsula of Florida, west coast, from Anclote Anchorage to Perdido Bay, including coast approaches, bays, and rivers.	1	Triangulation, topography, and hydrography.	P. A. Welker, subassistant, Homer P. Ritter, expert observer; O. B. French, aid.	Triangulation, topography, and hydrography of the upper branches of Escambia and East Bays, Pensacola Bay. (See also Section XIV.)
	2	Triangulation, topography, and hydrography.	Stehman Forney, assistant; C. T. Iardella and W. I. Vinal, assistants; E. E. Torrey, foreman; M. A. Coles, recorder.	Triangulation, topography, and hydrography of Perdido Bay, Florida and Alabama. (See also Section II.)
SECTION VIII.				
Alabama, Mississippi, Louisiana, and Arkansas, including Gulf coasts, ports, and rivers.	1	Reconnaissance and triangulation.	F. W. Perkins, assistant, W. B. Fairfield, extra observer.	Reconnaissance and occupation of stations for the extension of the primary triangulation in Alabama to the Gulf of Mexico.
	2	Magnetic observations.	James B. Baylor, assistant	Occupation of stations for the determination of the magnetic elements in Alabama, Mississippi, Louisiana, and Arkansas. (See also Sections III, IX, and XIII.)
	3	Geodetic leveling.	Isaac Winston, assistant; J. H. Gray, subassistant (part of the season); F. A. Young, observer and recorder; H. D. Mitchell, recorder.	Lines of geodetic leveling run between London, Arkansas, and Fort Smith. (See also Sections X and XIII.)
	4	Hydrography	Lieut. A. L. Hall, U. S. N., assistant; Ensigns John F. Luby, F. H. Brown, and (part of the season) Thomas Washington, U. S. N.	Hydrographic surveys on the coast of Louisiana in the vicinity of Ship Shoal, Caillou Bay, and to the eastward. (See also Section VI.)
	5	Reconnaissance and triangulation.	C. H. Boyd, assistant; R. A. Marr, assistant.	Reconnaissance and triangulation on the coast of Louisiana between Atchafalaya and Coté Blanche Bays. (See also Section I.)
SECTION IX.				
Texas, including Gulf coast, ports, and rivers; also the Indian Territory.	1	Magnetic station	Andrew Braid, assistant; R. E. Halter, assistant; L. G. Schultz.	Establishment of a self-registering magnetic apparatus at a station in San Antonio, Tex. (See also Section X.)
	2	Magnetic observations.	James B. Baylor, assistant	Determination of the magnetic elements at stations in Texas. (See also Sections III, VIII, and XIII.)
SECTION X.				
California, including the coast, bays, harbors, and rivers.	1	Topography	A. F. Rodgers, assistant; John Nelson, subassistant.	Completion of the topographic survey of the south coast of California between San Diego and San Onofre.
	2	Triangulation	George Davidson, assistant; J. J. Gilbert, assistant; Isaac Winston, subassistant; Fremont Morse, subassistant.	Connection of the Los Angeles primary base-line with the triangulation; preparations for the occupation of Mount Conness. (See also Section XII and Special Operations.)
	3	Magnetic observations.	R. E. Halter, assistant	Completion of magnetic record at the self-registering magnetic station, Los Angeles, Cal. (See also Section IX.)

APPENDIX No. 1—Continued.

Sections.	Parties.	Operations.	Persons conducting operations.	Localities of work.
SECTION X—Continued.	No. 4	Hydrography	Lieut. D. Delehanty, U. S. N., assistant; Lieut. Charles A. Gove, U. S. N.; Ensigns J. P. McGuinness, W. L. Dodd, and S. R. Hurlbut, U. S. N.	Hydrographic surveys in the vicinity of Piedras Blancas, Cal., including the development of rocks in Twin Peak Bay. (See also Section XI.)
	5	Triangulation.....	A. F. Rodgers, assistant; John Nelson, subassistant.	Triangulation of the coast of California in the vicinity of Monterey.
	6	Topography	Cleveland Rockwell, assistant	Topographical survey of the coast of California in the vicinity of Point Sur. (See also Section XI).
	7	Primary triangulation and general charge of land operations.	George Davidson, assistant; Jas. S. Lawson, assistant; J. J. Gilbert, assistant; Isaac Winston, subassistant; Fremont Morse, subassistant.	General direction of land operations on the Pacific coast; observations of lunar transits at Lafayette Park observatory; main triangulation, etc. (See also Section XII and "Special Operations.")
	8	Tidal observations	George Davidson, assistant; Emmet Gray, observer; Andrew Wickman, observer.	Tidal record continued at the automatic tidal station at Sausalito, Bay of San Francisco; also at a temporary automatic station at the foot of Mission Street, San Francisco. (See also Section XII.)
	9	Hydrographic examinations.	Lieut. D. H. Mahan, U. S. N., assistant; Lieut. J. H. L. Holcombe, U. S. N., and Lieut. A. G. Rogers, U. S. N.; Ensigns W. H. G. Bullard, and M. L. Bristol, U. S. N.	Resurveys and examinations of soundings in Suisun Bay, in Karquines Strait, and at the mouths of the Sacramento and San Joaquin Rivers.
	10	Hydrography.....	Lieut. D. Delehanty, U. S. N., assistant; Lieut. C. A. Gove, U. S. N.; Ensigns G. W. Brown, J. P. McGuinness, W. L. Dodd, E. Moale, jr., and S. R. Hurlbut, U. S. N.	Completion of a hydrographic survey in the vicinity of Crescent City, Cal. (See also Section XI.)
SECTION XI.				
Oregon and Washington, including coast, interior sounds and bays, ports and rivers.	1	Hydrography.....	Lieut. J. M. Helm, U. S. N., assistant; Ensigns R. O. Bitler, Jos. Strauss, W. H. G. Bullard, F. W. Jenkins, and M. L. Bristol, U. S. N.	Hydrographic survey of the coast of Oregon from Mack's Arch to Cape Blanco.
	2	Triangulation, topography, and hydrography.	E. F. Dickins, assistant; F. Westdahl.	Triangulation, topography, and hydrography of Coos Bay, Oregon.
	3	Hydrographic examination	Lieut. D. Delehanty, U. S. N., assistant; Lieut. C. A. Gove, U. S. N.; Ensigns G. W. Brown, J. P. McGuinness, W. L. Dodd, E. Moale, jr., and S. R. Hurlbut, U. S. N.	Hydrographic examination in the vicinity of Cape Lookout, Oregon. (See also Section X.)
	4	Hydrographic examination and triangulation.	Cleveland Rockwell, assistant	Examination of Young's Bay and River, Oregon, with reference to the effect upon navigation of a proposed railroad bridge. Triangulation of the Columbia River continued. (See also Section X.)
	5	Completion of special survey for Navy yard site; topographical surveys.	J. F. Pratt, assistant	Completion of the special survey made for the Commission organized to select a site for a Navy-yard on the Pacific Coast. Topographical survey of the Skagit River and Delta, State of Washington.
	6	Hydrography.....	Lieut. J. N. Jordan, U. S. N., assistant; Ensigns Harry George, F. K. Hill, and Edward Moale, jr.	Hydrographic surveys in Rosario Straits, including Thatcher and Obstruction Passes, Hale's Passage and Lummi Bay; in Semi-ah-moo Bay and Drayton Harbor, and along the east side of the Gulf of Georgia. Also in Skagit Bay.

APPENDIX No. 1—Continued.

Sections.	Parties.	Operations.	Persons conducting operations.	Localities of work.
SECTION XI—Continued.	No. 7	Triangulation and topography.	J. J. Gilbert, assistant	Extension of the triangulation of Rosario Strait into Lopez and East Sounds and through Upright Passage to its connection with San Juan Channel. Topographical surveys on Orcas, Lopez, Blakely, Decatur, and other islands in Washington Sound. (See also Section X.)
SECTION XII.				
Alaska, including the coast, inlets, sounds, bays, rivers, and the Aleutian Islands.	No. 1	Hydrographic work involving a general survey.	Lieut.-Commander H. B. Mansfield, U. S. N., assistant. Officers attached to party in season of 1889: Lieut. E. J. Dorn, U. S. N.; Ensigns A. N. Wood, A. C. Almy, A. M. Beecher, J. D. McDonald, G. R. Slocum, and W. H. Faust, U. S. N. Season of 1890: Lieut. E. J. Dorn, U. S. N.; Ensigns H. C. Poundstone, G. R. Slocum, Jos. Strauss, W. H. Faust, and F. W. Jenkins, U. S. N.	Continuation of the survey of the coast of southeastern Alaska in Frederick Sound and vicinity. Triangulation, topography, and hydrography; determinations of latitude, longitude, azimuth, and the magnetic elements. Similar surveys in Lynn Canal and other waters in the vicinity of Douglas Island.
	2	Tidal observations.	George Davidson, assistant; F. Sargent, observer.	Tidal record continued at the automatic tidal station at St. Paul, Kadiak Island, Alaska. Tidal observations at Iliuliuk, Alaska. (See also Section X.)
	3	Preliminary determination of boundary line.	J. E. McGrath, assistant; J. Henry Turner, subassistant.	Occupation of stations near the junction of the one hundred and forty-first meridian with the Yukon and Porcupine Rivers, Alaska, in connection with a preliminary survey of the boundary line between Alaska and the Northwest Territory. (See also "Special operations.")
SECTION XIII.				
Kentucky and Tennessee.	No. 1	Geodetic operations.	Prof. A. H. Buchanan, acting assistant; C. O. Boutelle, assistant in immediate charge of State surveys.	Re-occupation of stations to complete the connection of the triangulation of Tennessee with the primary triangulation in northern Georgia. Reconnaissance and signal building for the extension of the triangulation in eastern Tennessee.
	2	Magnetic observations.	James B. Baylor, assistant	Occupation of stations in Tennessee for determinations of the magnetic elements. (See also Sections III, VIII, and IX.)
	3	Geodetic leveling.	Isaac Winston, subassistant; F. A. Young, observer; H. D. Mitchell, recorder.	Extension of lines of geodetic leveling from Greenfield, Tenn., to Okolona, Miss. (See also Sections VIII and X.)
SECTION XIV.				
Ohio, Indiana, Illinois, Michigan, and Wisconsin	No. 1	Triangulation	A. T. Mosman, assistant; W. B. Fairfield, extra observer; C. T. Mosman, recorder; E. E. Torrey, foreman.	Continuation of the primary triangulation near the 39th parallel to the westward from stations in Ohio, Kentucky, and Indiana.
	2	Special survey	A. T. Mosman, assistant	Special survey on Lake Erie near Toledo, Ohio. (See also "Special operations.")
	3	Triangulation	George A. Fairfield, assistant; James B. Baylor, assistant; E. E. Torrey, foreman; J. B. Boutelle, acting aid.	Extension to the eastward in Indiana of the primary triangulation near the thirty-ninth parallel.
	4	Geodetic operations.	C. O. Boutelle, assistant in immediate charge of State surveys; Prof. J. E. Davies, acting assistant.	Occupation of stations in continuation of the triangulation of the State of Wisconsin.
	5	Meridian line	P. A. Welker, subassistant	Establishment of a meridian line at Toledo, Ohio. (See also Section VII.)

APPENDIX No. 1—Continued.

Sections.	Parties.	Operations.	Persons conducting operations.	Localities of work.
SECTION XV.				
Missouri, Kansas, Iowa, Nebraska, Minnesota, and North and South Dakota.	No. 1	Geodetic operations.	C. O. Boutelle, assistant in immediate charge of State surveys; Prof. W. R. Hoag, acting assistant.	Extension of the triangulation of the State of Minnesota from the Snelling avenue base.
	2	Meridian line.....	C. H. Sinclair, assistant	Establishment of a meridian line at Huron S. Dak. (See also Sections VIII, X, XVI, and, XVII.)
	3	Triangulation	F. D. Granger, assistant; M. A. Coles, recorder.	Occupation of stations for extending the trans-continental triangulation near the thirty-ninth parellel to the westward in Kansas. (See also Section V.)
SECTION XVI.				
Nevada, Utah, Colorado, Arizona, and New Mexico.	No. 1	Longitude determinations.	C. H. Sinclair, assistant; R. A. Marr, assistant.	Determinations of longitude by exchanges of telegraphic signals at stations in Nevada and Utah. Observations for latitude and the magnetic elements. (See also Sections VIII, X, XV, and XVII.)
	2	Triangulation	William Eimbeck, assistant; P. A. Welker, subassistant; E. P. Austin, observer; C. L. Brackett and J. C. Meem, recorders.	Occupation of stations in continuation of the primary triangulation near the thirty-ninth parallel in western and central Utah.
SECTION XVII.				
Idaho, Wyoming, and Montana.	No. 1	Determinations of longitude.	C. H. Sinclair, assistant; R. A. Marr, assistant.	Determination of the longitude of Helena, Mont., by exchanges of telegraphic signals with Salt Lake City. (See also Sections VIII, X, XV, and XVI.)
SPECIAL OPERATIONS	No. 1	....	Lieut. J. E. Pillsbury, U. S. N., assistant.	Establishment of a naval trial course in Narragansett Bay.
	2	....	Lieut. C. E. Vreeland, U. S. N., assistant.	Establishment of a trial course for the speed tests of the new naval war vessel *Philadelphia* off the coasts of Block Island and Long Island.
	3	....	Henry L. Whiting, assistant......	Definition and determination of a portion of boundary line in dispute between the States of Maryland and Virginia.
	4	....	A. T. Mosman, assistant; P. A. Welker, subassistant.	Special survey made for the Fish and Game Commission of the State of Ohio.
	5	....	J. E. McGrath, assistant; J. H. Turner, subassistant.	Surveys for a preliminary determination of the boundary line between Alaska and British Columbia and the Northwest Territory.
	6	....	E. D. Preston, assistant..........	Determinations of gravity and the magnetic elements in connection with the Eclipse Expedition to the west coast of Africa.
	7	....	George Davidson, assistant; O. H. Tittmann, assistant.	Transportation of the National Prototypes of the Metre and Kilogramme from Paris to Washington.

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APPENDIX No. 2.—1890.

STATISTICS OF FIELD AND OFFICE WORK OF THE COAST AND GEODETIC SURVEY FOR THE YEAR ENDING JUNE 30, 1890.

	Total to June 30, 1889.	During fiscal year 1890.	Total to June 30, 1890.
RECONNAISSANCE.			
Area in square statute miles	383,561	4,960	388,521
Parties, number of	----------	3	----------
BASE LINES.			
Primary, number of	15	0	15
Primary, length of, in statute miles	101	0	101
Subordinate, number of	136	2	138
Subordinate and beach measures, length of	527	1	528
TRIANGULATION.			
Area in square statute miles	232,282	24,159	256,441
Stations occupied for horizontal measures, number of	12,578	305	12,883
Geographical positions determined, number of	24,046	693	24,739
Stations occupied for vertical measures, number of	898	23	921
Elevations determined trigonometrically, number of	2,229	76	2,305
Heights of permanent bench-marks by spirit-leveling, number of	756	47	803
Lines of spirit-leveling, length of, in statute miles	3,965	150	4,115
Triangulation and leveling parties, number of	----------	26	----------
ASTRONOMICAL WORK.			
Azimuth stations, number of	221	7	228
Latitude stations, number of	349	6	355
Longitude stations, telegraphic, number of	148	*6	154
Longitude stations, chronometric or lunar, number of	110	†2	112
Astronomical parties, number of	----------	10	----------
MAGNETIC WORK.			
Stations occupied, number of	786	‡52	838
Magnetic observations in operation	4	1	5
Magnetic parties, number of	----------	7	----------
GRAVITY MEASURES.			
Home stations occupied, number of	19	0	19
Foreign stations occupied, number of	15	8	23
Parties, number of	----------	1	----------

* In addition to these six new stations one old station was re-occupied.

† In addition to these two new stations one old station was re-occupied.

‡ In addition to these fifty-two new stations eight old stations were re-occupied.

APPENDIX No. 2—Continued.

	Total to June 30, 1889.	During fiscal year 1890.	Total to June 30, 1890.
TOPOGRAPHY.			
Area surveyed, in square statute miles	33,071	839	33,910
Length of general coast, in statute miles	8,770	62	8,832
Length of shore-line, in statute miles, including rivers, creeks, and ponds	95,183	1,224	96,407
Length of roads, in statute miles	47,024	437	47,461
Topographical parties, number of	----------	24	----------
HYDROGRAPHY.			
Parties, number of, in charge of naval officers	----------	13	----------
Parties, number of, in charge of civilian officers	----------	14	----------
Number of miles (geographical) run while sounding	449,413	12,120	461,533
Area sounded, in square geographical miles	146,870	4,013	150,883
Miles run additional of outside or deep sea soundings	85,418	7,577	92,995
Number of soundings	19,445,890	461,275	19,907,165
Deep-sea soundings	13,214	33	13,247
Deep-sea temperature observations	15,455	----------	15,455
Current stations, number of, occupied by hydrographic parties	----------	28	----------
Deep-sea current stations, number of	----------	33	----------
Deep-sea subcurrent observations, number of	----------	1,344	----------
Deep-sea surface current observations, number of	----------	1,350	----------
Specimens of bottom, number of	13,420	113	13,533
Automatic tide gauges established	89	7	96
Automatic tide gauges discontinued	84	3	87
Parties doing tidal work exclusively	----------	7	----------
Parties doing tidal work in connection with hydrographic work	----------	20	----------
Staff and box gauges established	2,019	62	2,081
Staff and box gauges discontinued	2,009	70	2,078
RECORDS.			
Triangulation, originals, number of volumes	5,609	265	5,874
Triangulation, originals, number of cahiers	----------	4	----------
Astronomical observations, originals, number of volumes	1,922	29	1,951
Astronomical observations, originals, number of cahiers	----------	2	----------
Magnetic observations, originals, number of volumes	674	2	676
Magnetic observations, originals, number of cahiers	----------	20	----------
Pendulum observations, originals, number of volumes	----------	2	----------
Duplicates of above, number of volumes	6,038	297	6,335
Duplicates of above, number of cahiers	----------	15	----------
Computations, number of volumes	4,194	11	4,205
Computations, number of cahiers	----------	245	----------
Hydrographic soundings and angles, originals, number of vols	11,242	322	11,564
Hydrographic soundings and angles, duplicates, number of vols	3,264	200	3,464
Tidal and current observations, originals, number of volumes	4,354	116	4,470
Tidal and current observations, duplicates, number of volumes	2,849	105	2,954

APPENDIX No. 2—Continued.

	Total to June 30, 1889.	During fiscal year 1890.	Total to June 30, 1890.
RECORDS—continued.			
Aggregate years of record from automatic tide gauges	$266\frac{4}{12}$	$4\frac{3}{12}$	$270\frac{7}{12}$
Tidal stations for which reductions have been made	1, 405	71	1, 476
Aggregate years of record reduced	262	18	280
MAPS AND CHARTS.			
Topographic maps, originals	1, 898	72	1, 970
Hydrographic charts, originals	2, 116	79	2, 195
ENGRAVING AND PRINTING.			
Finished charts published from engraved plates, total number of	462	13	475
Engraved charts withdrawn from circulation	160	4	164
Engraved plates of preliminary charts and diagrams for the Coast and Geodetic Survey reports, number of	668	54	722
Electrotype plates made	2, 104	78	2, 182
Charts published by photolithography, number of	----------	28	----------
Charts published by photolithography withdrawn from circulation	----------	15	----------
Engraved plates of Coast Pilot charts	80	0	80
Engraved plates of Coast Pilot views	98	0	98
Printed sheets of maps and charts distributed	719, 466	63, 152	782, 618
Printed sheets of maps and charts deposited with sale agents	337, 398	32, 335	369, 733

APPENDIX No. 3—1890.

INFORMATION FURNISHED TO DEPARTMENTS OF THE GOVERNMENT IN REPLY TO SPECIAL REQUESTS, AND TO INDIVIDUALS UPON APPLICATION, DURING THE FISCAL YEAR ENDING JUNE 30, 1890.

Date.		Name.	Data furnished.
1889.			
July	3	Albert M. Ford, Salem, N. J.	Description of five bench-marks at and near Philadelphia.
	5	N. B. Craig, Philadelphia, Pa	Geographical positions and geodetic data of 272 trigonometrical points, vicinity of Philadelphia.
	8	Director U. S. Geological Survey	Descriptions of eight trigonometrical stations in the vicinity of New Haven, Conn.
	8	A. D. Blackinston, Dunmore, Pa	Times of elongations and of lower culminations of Polaris during August, 1889.
	10	Jno. P. Rasbach, Eatonville, N. Y	Annual change of the magnetic declination in Herkimer County, N. Y.
	10	Commander C. M. Chester, U. S. N., Peekskill, N. Y	Tidal data for six stations in Puget Sound, Oregon.
	11	Capt. Alfred T. Mahan, U. S. N., Bar Harbor, Me	Do.
	11	Jno. P. Rasback, Eatonville, N. Y	Magnetic chart for the epoch 1885.
	12	Reuel Keith, Washington, D. C	Copy of tidal predictions for Philadelphia, Pa., 1890.
	12	Kiggins & Tooker, New York City	Copy of tidal predictions for San Francisco, Cal., 1890.
	16	Wm. F. Smith, Wilmington, Del	Descriptions of five bench-marks, eastern shore of Virginia.
	16	Henry C. Lee	Tracing of topographical sheets Nos. 148-149. Cold Spring Inlet round to Cape May light-house wharf. Same locality from sheet No. 1470.
	17	Director U. S. Geological Survey	Geographical descriptions and positions of five stations, vicinity of Hartford, Conn.
	20	A. D. Blackinston, resident engineer, Dunmore, Pa	Time interval between Polaris on the meridian and Polaris in the same vertical with ε Ursæ Majoris for 1850 and 1890 and for latitude 30° and 40° N.
	23	F. E. Stewart, Cape May Point, N. J	Tidal constants for the coast of New Jersey.
	23	J. C. Stabler, Cape May Point, N. J	Do.
	23	New York and New Jersey Joint Boundary Commission, Cape May Point, N. J.	Projection scale 1-20000. Hudson River with shore-lines of 1837, 1840, and 1855-56 and triangulation.
	24	Simon Stevens, No. 61 Broadway, New York City	Relative weight of surface of sea in Back River Harbor and in Leusset River, Massachusetts, for a lunar day.
	25	Assistant Professor Signal Office	Remarks about station marks on Mount Washington, and height of the same.
	26	F. M. Smith, San Francisco, Cal	Tracing of hydrography mouth of Chetko River and vicinity from original sheet No. 1239.
	27	James F. Gregory, U. S. Engineers	Tracing of topographical sheets Nos. 1757 and 1759. Umpquah River southerly and No. 1811, same northerly.
Aug.	5	Capt. W. M. Black, U. S. Engineer's Office, St. Augustine, Fla.	Descriptions of four bench-marks. Coast of Florida.
	5	Phil. Atkinson, Chicago, Ill	Position of the line of no declination at various times; rate of change of the same; magnetic declination and dip at Washington at present time, and suggestions as to magnetic maps in general.
	5	A. White, Cazenovia Seminary, New York	Adjustment of the compass.
	6	Capt. W. M. Black, U. S. Engineer, St. Augustine, Fla	Geographical position and description of stations Little Sarasota to Casey's Pass, Florida.
	12	Lieut. Col. Jared A. Smith, U. S. Engineer's Office, Portland, Me.	Description of bench-marks near Ellsworth, Me.
	13	R. A. Brown, Portersville, Tulare County, Cal	Position and law of change of the band of no annual change of the magnetic declination in Southern California.
	13	Chief Signal Officer	Height above the Gulf of Mexico of two bench-marks at Meridian, Miss.

APPENDIX No. 3—Continued.

Date.		Name.	Data furnished.
1889.			
Aug.	17	Captain Ritch, Provincetown, Mass	Tracing of original topographical sheet No. 616, vicinity of Provincetown, Mass.
	17	Captain Willard, U. S. Engineers, Vicksburg, Miss	Height of bench-marks at Meridian, Miss., and at Delta, La., and description of marks.
	20	U. S. Commissioner Fish and Fisheries	Magnetic declination at the Fishing Battery, Md., for the years 1836, 1852, 1879, 1889.
	24	J. E. Savage, U. S. Assistant Engineer, Bar Harbor, Me	Description o' two bench-marks, coast of Maine.
	26	Thos. Monroe, C. E., Coteau Landing, Province of Quebec	Height of Lake Champlain and of bench-marks at Chapman's Block, Rouse's Point.
	27	S. Garwood, Camden, N. J	Description of bench-marks at Camden and Gloucester.
	28	J. J. Lee, Bucksport, Me	Geodetic date for 30 trigonometrical positions in the vicinity of Bucksport.
	28	S. Garwood, Supt. Atlantic City R. R., N. J	Description of bench-marks, Gloucester, N. J.
	30	R. S. Blakeman, Danville, Boyle County, Ky	Annual rate of change of magnetic declination in Boyle County.
Sept.	2	F. A. Lietze, Carlyle, Ill	Height of bench-mark at Carlyle.
	3	A. S. Wadsworth, Henrietta, N. Y	Table of times of elongation of Polaris for 1889 and subsequent years, and the azimuth of the star when at elongation for 1890.
	9	J. C. Pilling, U. S. Geological Survey	Geographical position of station, Salem, Pa.
	12	Prof. A. R. Nelson, Danville, Ky	Annual change of the magnetic declination at Danville and Stanford.
	13	T. Roberts, County Surveyor, Wartburgh, Tenn	Geographical positions and geodetic data of 7 trigonometrical points in or near Morgan County, Tenn.
	12	A. E. Burton, Boston, Mass	Approximate height of Mount Stinson and Cube Mountain, in New Hampshire.
	14	J. J. Lee, Bucksport, Me	At request of Hon. E. E. Burleigh, Governor of Maine, tracing of original topographical survey of Bucksport, Me.
	16	J. C. Pilling, Acting Director, U. S. Geological Survey	Geographical positions and descriptions of stations Haystack, Halifax, and White Hill, Vt.
	19	Col. G. L. Gillespie, U. S. Engineers	Tracing of New York Upper Bay including Kill van Kull; Hydrographic sheet, No. 1667.
	19	U. S. Life Saving Service, Treasury Department	Two charts of the magnetic declination (variation of the compass) of the United States for 1885, and two pamphlets showing the annual change for 1890.
	23	George W. Simonds, Secretary Kansas City and La. Gulf R. R.	Hydrographic tracing Southwest Pass, Vermillion Bay (sheet No. 1717).
	25	C. F. Hayden, Bath, Me	Geographical positions of 9 trigonometrical points in Bath.
	27	E. L. Meyer, City Surveyor, Elizabeth, N. J	Change of magnetic declination at Elizabeth since 1802 and present annual change.
	29	Captain Bixby, U. S. Engineers	Tracing of topography, Shallotte Inlet and River—topograpical sheet No. 725.
Oct.	1	C. C. Vermeule and J. R. Bien, Civil and Mining Engineers, New York City.	Thirty-seven geographical positions on Staten Island.
	4	Captain Black, U. S. Engineers	Tracing of topography from Casey's Pass to Tampa Bay.
	4	U. S. Light-House Board	Length in statute miles of Atlantic, Gulf, Pacific, and Alaska coast, including islands, bays, and rivers.
	4	Navy-Yard Site Commission (Southern)	Tracing of Assistant Welker's work; hydrography and topography of Escambia Bay, Florida.
	6	Navy-Yard Site Commission (Pacific coast)	Tracing of Assistant Pratt's surveys for Navy-Yard site, Washington.
	10	Henry Cope, Lincoln University, Chester County, Pa	Magnetic declination at Lincoln University in October, 1889, and in 1794.
	10	Chas. F. Warren, Attorney and Counselor at Law, Washington, N. C.	Magnetic declination at the mouth of Pungo River, N. C., in 1779, 1787, 1819, and the present time.
	11	For R. G. Hazzard, at the request of the Secretary of the Treasury.	Tracings from topographical survey, Boston Neck, Narragansett Bay.
	15	H. K. Hibbets, Electrician, Los Angeles, Cal	Appendix 6, Report 1885. Magnetic dip and intensity.
	15	Capt. S. S. Leach, U. S. Engineers	Angles and sides of base quadrilateral at Memphis, Tenn.
	23	J. Baker Kearfolt, Martinsburgh, W. Va	Magnetic declination at Washington, D. C., for 1885–'86–'87–'88–'89.
	24	S. M. Mylin, Herrville, Pa	Three papers on terrestrial magnetism and magnetic chart for 1885.
	26	Ensign Geo. P. Blow, U. S. N., in charge of branch hydrographic office, New York City.	Highest tide observed by the Coast Survey at Governor's Island, N. Y., and Sandy Hook, N. J.
	28	Thompson & Slater, Washington, D. C	Distance from Tampa Bay and New Orleans to various South American ports.
	29	K. King, Norfolk, Va	Distance from Edenton, N. C., to several points in the south.
	30	Capt. Edwin Maguire, U. S. Engineers	Tracing of topography of part of Delaware Bay, old and new surveys.

APPENDIX No. 3—Continued.

Date.		Name.	Data furnished.
1889.			
Nov.	1	Wm. D. Gillette, San Francisco, Cal	Tracing of part of San Francisco Bay, vicinity of Oakland.
	2	Hon. B. Butterworth	Triangulation sketch of region of junction of North Carolina, Tennessee, and Georgia, with remarks on boundary survey.
	4	Capt. J. H. Willard, U. S. Engineers	Height and description of bench-marks at Arkansas City, Pine Bluffs, and Little Rock.
	4	Edward P. Doyle, Boundary Commission, New York and New Jersey.	Geographical positions and geodetic data of triangulation points on and near the Hudson River from New York City to New Jersey boundary line.
	4	Albert W. Bee, Boston, Mass	Tracing of Great Wass Island and vicinity, Maine.
	8	S. S. Gannett, U. S. Geological Survey	Abstract of angle at station, Penobscot, Pa.
		M. G. Farmer, Topsfield, Mass	Horizontal magnetic force at Washington, Baltimore, Philadelphia, New York, New Haven, Sandy Hook, Boston, and Cambridge for 1890, with annual change.
	11	W. F. Shunk, Civil Engineer, Harrisburg, Pa	Tables of the times of culminations and elongations and of the azimuths at elongation of Polaris for any time between 1890 and 1910 and any latitude between 25° and 50° north.
	12	Geo. W. Wheeler, Washington, D. C	Area of water-shed which feeds Eagle Lake, Mount Desert, Me.
	12	The Mather Electric Co., Manchester, Conn	Horizontal components of earth's magnetic force at Washington, Baltimore, Philadelphia, New York, and Boston.
	13	H. Carpenter, Engineer and Surveyor White Plains, N.Y.	Magnetic declination for Westchester County, N. Y., in 1890, and annual change.
	14	Vermeule & Bien, Civil and Mining Engineers, New York City.	Descriptions of six bench-marks on Staten Island, N. Y.
	14	Navy-Yard Site Commission (Southern)	Tracing of Bohemia, Pensacola Bay, Fla.
	15	Joint Boundary Commission, Maryland and Virginia	Copy of Chart No. 376, with boundary line drawn between Maryland and Virginia; also salt-water area in both States inside the capes of Virginia.
	21	G. W. Fernald, Farmington, N. H	Geographical position of Farmington and information about magnetic declination.
	21	Edward Conant, State Normal School, Randolph, Vt	Approximate elevation of a number of trigonometrical stations in Vermont.
	21	J. G. Kelley, Civil Engineer, Bar Harbor, Me	Magnetic declination between 1800 and 1900 at Mount Desert, Me., and geographical positions of two trigonometrical stations.
	22	International Marine Conference	Enlarged copies of sections from charts Nos. 111, 112, 120, and 337.
	23	Thomas V. Smith, Town Clerk, Hempstead, L. I	Copies of plane-table sheets Nos. 1471 a and b and 1482 b, south shore of Long Island.
	27	E. Taussig, Lieutenant, U. S. N	Geographical positions of twenty-eight trigonometrical stations, coast of Long Island and Connecticut, with descriptions of stations.
	29	M. C. Paret, Assistant Engineer, U. S. A., Savannah, Ga	Tidal data at Old Fernandina, Fla.
Dec.	2	Robert Ransom, Canaveral, Fla	Interpolation of stations in Tide Tables.
	4	Major W. S. Stanton, U. S. Engineers	Magnetic declination at Narraguagus Bay, Me., in January, 1890, and November, 1851, with present annual change.
	7	Ira E. Hine, President Shalersville Board of Education, Mantua Station, Ohio.	Specimen of computation of triangle sides and of geographical positions.
	9	H. H. Cline, Chief Engineer, U. S. N	Table of reduction of salinometer readings.
	13	Director U. S. Geological Survey	Heights and descriptions of bench-marks between New Orleans and Donaldsonville, La.
	14	N. King, Assistant State Engineer, Sacramento, Cal	Geographical position of the initial boundary monument on the Pacific coast south of San Diego, as determined by United States and Mexico Boundary Commission and by the U. S. Coast Survey.
	14	W. T. Shunk, Civil Engineer, Harrisburg, Pa	Method adapted to the use of surveyors of establishing a meridian line for the measure of the magnetic declination or for other purposes, with data for use between 1890 and 1900.
	14	H. A. D. Crocker, Surveyor, Falls Church, Va	Magnetic declination at Washington, D. C., in 1890 and 1826.
	14	Director U. S. Geological Survey	Description and geographical position of Gauley Bridge, W. Va.
	16	John L. Kenyon, Wyoming post-office, R. I	Description of station in Rhode Island.
	16	Mr. Baughman, Norfolk, Va	Copy of plane-table sheet No. 1499 a, vicinity of Norfolk, Va.
	17	Prof. J. J. Wolfe, West Millville, Clarion County, Pa	Magnetic declination chart for 1885 and annual change of declination at West Millville.
	20	H. J. Lewis, Brunswick, Ga	Tracing of topography between Buttermilk Sound and Brunswick, Ga.
	21	U. S. Geological Survey	Tracing of topographical sheets, north shore, Long Island Sound.
	21	Washington Gas Light Company	Estimate of cost of making copy of their large map of Washington, D. C., including suburbs.

APPENDIX No. 3—Continued.

Date.	Name.	Data furnished.
1889.		
Dec. 22	J. J. Rutledge, Blaine, Wash	Estimate of cost of tracing hydrography and topography, vicinity of Drayton Harbor, Wash.
23	J. J. Henderson, Attorney at Law, San Diego, Cal	The meaning of the expression, "Ordinary high-water mark."
23	John C. Clark, Pine Ridge, S. Dak	One copy of magnetic chart for 1885 and copy of Appendix 12, Report of 1886.
26	Joint Boundary Commission, New York and New Jersey	Geographical positions of twenty-four trigonometrical points, vicinity of New York Bay and Harbor, and description of stations.
28	H. J. Lewis, Brunswick, Ga	Tracing of topography of Ogeeche River and Altamaha and Doboy Sounds, Georgia.
30	Henry P. Curtis, Boston, Mass	Tidal data, Sandy Hook, N. J., September, 1889.
1890.		
Jan. 6	Director U. S. Geological Survey	The geodetic position of station Wilder, Ala.
6	....do	The geodetic position of station Roslyn, Va.
6	Dr. John N. Tilden, Principal Peekskill Military Academy.	Description of bench-marks at Verplanck's Point, N. Y.
7	William Minto, Surveyor, San Francisco, Cal	Azimuth of a line from a point in Lake Tahoe to a point on Colorado River.
8	G. O. Eaton, Surveyor-General of Montana	Telegraphic longitude of Helena, Mont.
9	Capt. Thomas Turtle, U. S. Engineers	Tracing of topography vicinity of Forts Foote and Washington, Potomac River.
10	J. J. Lee, Bucksport, Me	Magnetic declination at Bucksport in 1762, 1790, 1805, 1890.
10	Cronise & Conklin, Rochester, N. Y	Magnetic declination at Rochester in 1821 and 1890.
11	E. P. Doyle	Description of a number of trigonometrical stations vicinity of New York and along the Hudson River to the New Jersey State line.
15	W. W. Snow, Hilburn, Rockland County, N. Y	Magnetic bearing of a line in 1890, the bearing of which was given for 1813.
15	Director U. S. Geological Survey	Geodetic data of primary triangulation stations Fulton, Hutton Mound, Baker, and Thornton, Mo.
15	A. F. Sherwick, Wood's Holl, Mass	Tracing of topographical survey of Wood's Holl, Mass.
15	E. J. Harkness, Chicago, Ill	Tracing of a diagram on map of final attack on Fort Fisher, N. C.
16	Rev. Father Seatle, Brookland, D. C	Geodetic data of ten triangulation points, District of Columbia.
16	Prof. J. K. Rees, Columbia College, New York City	Relation of size of heliotrope mirror to distances in California, Nevada, Utah, the Alleghany Mountains, and Ohio River Valley.
17	C. F. Powell, Captain U. S. Engineers, Mississippi River Commission.	Geographical positions of five primary triangulation stations, vicinity of St. Louis, Mo.
17	L. Y. Schermerhorn	Explanation of tidal data on charts.
17	E. A. Geisder, Assistant U. S. Engineer, Savannah, Ga.	Tidal data Tybee Island, Ga.
17	W. Evan Preston, Civil Engineer, Newark, N. J	Explanation of diurnal inequality, tides at Governor's Island, N. Y.
20	W. W. Olney, Blunt, Hughes County, S. Dak	Magnetic declination at Pierre, S. Dak., in 1860 and 1890.
21	A. N. Davidson, City Engineer, Augusta, Ga	Magnetic declination observed at and referred to Augusta between 1837 and 1890.
21	J. C. Branner, State Geologist of Arkansas	Elevation above the Gulf of Mexico of the bench-mark at St. Louis known as the city directrix.
23	Director U. S. Geological Survey	Heights of twelve primary stations in Alabama.
23	Vermule & Bien, Engineers to Joint Boundary Commission, New York and New Jersey.	Geodetic positions of thirty-seven stations in the vicinity of the Hudson River.
24	Dr. G. B. Lartegill, Blackville, Barnwell County, S. C	Magnetic declination at Blackville, S. C., in September, 1849, and in January, 1890.
28	St. Thomas's College, Brookland, D. C	Information about magnetic declination at Washington, D. C. Appendix 12, Report of 1886, and four magnetic charts (1835 and 1890).
Feb. 3	John Carmichael, Waynesborough, Va	Magnetic declination at Waynesborough.
6	Director U. S. Geological Survey	Height of twelve trigonometrical stations in West Virginia.
10	Prof. H. F. Reid, School of Applied Science, Cleveland, Ohio.	Table of papers published by the Survey on pendulum researches, four magnetic charts of the United States for the year 1890, and explanatory pamphlets.
11	William C. Langfitt, First Lieutenant U. S. Engineers, Galveston, Tex.	Explanation of the method of Pourtales for separating diurnal from semi-diurnal wave.
12	W. Fears, Iowa Point, Cecil County, Md	Magnetic declination at Town Point in 1715, and at present; also annual change.
14	Gardner G. Hubbard, Washington, D. C	Enlarged maps of Central Africa, before and after Stanley.
5	Lieut. O. M. Carter, U. S. Engineers, Savannah, Ga	Tidal observations Tybee Island, Ga., September 29, 1889, to January 1, 1890.

APPENDIX No. 3—Continued.

Date.	Name.	Data furnished.
1890.		
Feb. 17	George N. Stetson, New York City	Tidal data from Hempstead Harbor, N. Y.
	F. Trevor Spencer, Engineer, Florida Coast Line Canal Company, St. Augustine, Fla.	Description of eleven tidal bench-marks on Indian River, Fla.
19	U. S. Engineers	Tracing of hydrography, Karquines Strait, Cal.
21	E. E. Peirce, Boston	Geographical position of Powow (Borden).
24	J. J. Henderson, Attorney at Law, San Diego, Cal	Discussion and definition of "line of ordinary high-water mark" for the Pacific coast.
25	Director U. S. Geological Survey	Position of Gainesville, Fla.
26	J. L. Kenyon, Surveyor and Civil Engineer, Wyoming, R. I.	Description of two trigonometrical stations.
27	Maj. Thomas L. Handbury, U. S. Engineers	Tracing of hydrographic survey of part of Columbia River, Oregon. Hydrographic sheets 1930–1931.
27	J. R. Soley, Superintendent Naval War Records	Tracing of diagram on map of final attack on Fort Fisher, N. C.
28	J. F. Flagg, Engineer Department, Washington, D. C	Geodetic position of Buzzard Point and Giesboro Point.
March 4	G. E. Hyde, Washington, D. C	The elevations of stations Halifax, Haystack, and White Hill, Vt.
5	E. E. Peirce, Boston	Geographical positions of the corners of Wareham Township, Mass.
6	Engineer's Office, Washington, D. C	Positions of the corners of the District boundary, length and azimuth of sides.
10	H. J. Lewis, Brunswick, Ga	Tracing of topography of part of coast of Georgia, original sheets Nos. 721, 750, and 778.
14	Senate Committee on Printing	Drawing of map of each State reduced to size of Congressional Directory, and showing Congressional districts.
	Hon. Samuel G. Snyder, M. C	Tracing of hydrography and topography, mouth of Klamath River to False Klamath Head.
15	G. M. Donham, Portland, Me	Copy of predicted tides Eastport and Portland, Me., for January, February, March, 1891.
20	P. N. Coombs, City Engineer, Bangor	Description of two tidal bench-marks, Bangor, Me.
22	Maj. N. H. Hutton, Engineer Baltimore Harbor Board	Tracing of Isle of Wight Bay, Md.
22	J. H. Manzy, Rockingham County, Va	Present magnetic bearing of an old line run by compass in 1799.
24	Hon. G. F. Hoar, U. S. Senate	Geographical position of Hasnebumskit, Mass.
27	Lieut. O. M. Carter, U. S. Engineers	Tracing of several hydrographic surveys of Fernandina Bar, Fla
27	U. S. Senate Printing Committee	Redrawing and correcting Congressional districts on State maps.
28	John Cowie, jr., Navy Yard, Brooklyn, N. Y	Length of the seconds pendulum at various places.
28	Clarence M. Clarke, Surveyor, Washington, D. C	Two copies of magnetic charts for 1885, and Appendix No. 12, Report for 1886.
29	U. S. Senate Printing Committee	Measurement and sketch of boundary between United States and Mexico.
April 3	Henry W. Putnam, Boston, Mass	High and low waters for two months, Boston, Mass.
3	J. W. Fox, New York	Geographical position of Big Stone Gap, Va., and standard time of the place.
6	William Smith, Deputy Minister of Marine, Ottawa, Canada.	Suggestions as to the best means of promoting tidal observations in Canadian waters.
7	Thomas Burke, Seattle, Wash	Tracing of Duwamish Bay, Wash.
14	William G. Wheelock, jr., East Greenwich, R. I	Description of bench-mark, East Greenwich, R. I.
14	N. G. Herreshoff, Bristol, R. I	Explanation of tidal predictions, Bristol, R. I.
15	Hon. William Elliott, M. C	Map on small scale of eastern part of United States, showing distances from principal cities to Port Royal.
April 16	Commandant of the U. S. Naval Academy	Tracing of hydrographic sheet No. 167, Annapolis Harbor.
16	Hydrographic Inspector	Geographical positions and angles vicinity of Annapolis, Md.
16	Director Geological Survey	Geographical position of station Roslyn, Petersburg, Va.
18	Lieut. Commander Samuel W. Very, U. S. N., Annapolis, Md.	Description of 14 bench-marks, Annapolis, Md.
19	J. F. Dodds, Deputy Surveyor, Hickman, Fulton County, Ky.	Magnetic declination at Hickman in 1858, 1881, and 1890.
19	J. K. Wilson, Surveyor, Maryville, Tenn	Magnetic declination at this time and annual change.
19	J. F. Johnson, Olean	Bulletin No. 14, App. 12, Report for 1886, and magnetic chart for 1885.
21	F. Trevor Spencer, St. Augustine, Fla	Explanation of tidal data, Indian River, Fla.
21	F. J. Havens, Central School District, Wallingford, Conn	Position of a church in Wallingford.
22	J. W. Bachman, Santa Aña, Texas	General information on terrestrial magnetism.
24	J. N. McClintock, Civil Engineer	Geographical positions of Bean Hill and Rattlesnake Hill, vicinity of Concord, N. H.
25	Dr. J. G. Michael, Citronelle, Ala	Height of bench-marks at Citronelle.
26	C. A. Howes, Hoquiam, Wash	Explanation of diurnal inequality in Gulf of Mexico.

APPENDIX No. 3—Continued.

Date.		Name.	Data furnished.
1890.			
May	1	Hayton, Kleberg & Dabney, Victoria, Texas	Magnetic declination at Victoria in 1834, 1885, and 1890, two charts and pamphlet.
	2	N. Roberts, Civil Engineer, Anacostia, D. C	Distance and azimuth of Capitol and Washington Monument.
	2	U. S. Geological Survey	Tracing of topographical sheets of the north shore Long Island Sound.
	2	Earle & Hanson, Philadelphia, Pa	Three tracings of topography of Gloucester Point, Delaware Bay, Surveys of 1840-'41, 1870-'71, and 1878-'79.
	3	E. E. Howell, Rochester, N. Y	Tracing of deep sea arms, Atlantic coast.
	6	Dr. H. Schenck, County Surveyor, York County, Va	Magnetic declination at Williamsburg, Old Point Comfort, and Cape Henry, with annual change in 1690, and 1895, and three magnetic charts.
	7-8	U. S. Geological Survey	Tracings of topographical sheets, coast of Maine.
	8	Do	Tracings from topographical sheets Long Island.
	9	J. P. Bogart, Bridgeport, Conn	Geographical positions of Stratford Hill and Black Rock light-house.
	10	E. W. Harrison, Jersey City, N. J	Magnetic declination at Philadelphia in 1890 and geographical position of Fish Club flagstaff at Gloucester, N. J.
	10	Mr. Atkinson, Topographical and Geological Survey	Descriptions of stations on Connecticut River.
	10	E. B. Clark, Topographical and Geological Survey	Geographical positions and descriptions of stations east end of Long Island and in Connecticut.
	10	M. D. Merriweather, Sec'y Board of Trade, Jackson, Tenn	Height of bench-mark at Post-office, Jackson, above the Gulf of Mexico.
	15	G. A. Karweise, Civil Engineer, 200 Gray street, Louisville, Ky.	Tidal data for Colon, Isthmus of Panama.
	17	Lieut. Col. G. L. Gillespie, U. S. Engineers, New York City	Description of bench-marks, Randall's Island and Spuyten Duyvil, N. Y.
	17	J. P. Wharton, Cherokee County, Ala	Magnetic declination in Cherokee County, Ala., at the present time.
	17	U. S. Geological Survey	Copies from the Survey Records of geographical positions of stations on the Kennebec River, Me., on the Hudson River, N. Y., and on the Connecticut River, Conn.
	19	O. M. Carter, First Lieut. U. S. Engineers, Savannah, Ga	Tabulated high and low waters Tybee Island, Ga., November 20, 1889, to February 28, 1890.
	19	Dr. F. E. Stewart, 1204 Del. ave., Wilmington, Del	Tidal constants for Cape May Point, N. J.
	19	C. F. Powell, Capt. U. S. Engineers., Mississippi River Commission.	Descriptions of bench-marks along the river between Carrollton and stations beyond Fort Adams.
	19	H. Scougall, Steamboat Springs, Colo	Magnetic declination in Routt County, Colo., and annual change.
	21	F. S. Beardsley, Brunswick, Ga	Tracings of shore line of creeks, rivers, and sounds, Savannah River to Little Ogeechee River.
May	23	H. C. Crowell, Boston, Mass	Tracing of Hope and Bogue Islands and vicinity of Casco Bay.
	23	Director U. S. Geological Survey	Geographical positions of Louisa Court-House, Ky., and of South Point, Ohio; also positions and descriptions of stations and heights of a number of trigonometrical points in West Virginia.
	28	S. H. Frank & Co., San Francisco, Cal	Tracing of topography and hydrography one mile north to one mile south of the Sisters, Oregon.
	28	Mr. Hall, Brooklyn, N. Y	Information on the subject of magnetic storms.
	28	S. L. Smedley, Engineer and Surveyor, Philadelphia	Description and position of primary station Willow Grove.
	28	T. N. Taylor, University of Texas, Austin	Latitude and longitude astronomical station at Austin, Texas.
	31	A. J. Bartlett, Kendaia, Seneca County, N. Y	Height of source of Mississippi River above ocean and difference of distance of source and mouth from the earth's center.
	31	J. B. Rawls, Deer Park, Ala	Height of bench-mark at Deer Park, Ala., above the Gulf.
	31	F. V. Abbot, Captain U. S. Engineers	Nine geographical positions, azimuths, and distances of the recent triangulation of Charleston Harbor.
June	1	B. C. Hodgkins, Assistant Postmaster, Upper Stillwater, Me.	Bulletin No. 14.
	1	L. H. Jacoby, Columbia College, N. Y	Values of line intervals of diaphragm, of pivot inequality, and of one turn of eye-piece micrometer Transit No. 6.
	6	W. B. Wilson, Conway, Ark	Height of bench-mark at Court-house above the level of the Gulf.
	7	G. B. Nicholson, Chief Engineer, Cincinnati, Ohio	Isogonic charts for 1885 and 1890 and pamphlet on secular variation of the magnetic declination.
	13	Director U. S. Geological Survey	Descriptions and positions of astronomical stations Richmond and Lexington, Ky.
	14	Bureau of Statistics	Length of shore line of Pacific coast and of Alaska.
	16	...do	Length of shore line of Pacific coast and of Alaska, including indentations.

APPENDIX No. 3—Continued.

Date.	Name.	Data furnished.
1890.		
June 16	W. R. Dunston, Ocean Park, N. J.	Magnetic declination at Ocean Park and annual change.
18	M. P. Jackson, Greensborough, N. C	Approximate geographical position of Greensborough, N. C.
18	Bureau of Statistics	Length of Atlantic and Gulf coasts.
20	Mississippi River Commission	Tracing of hydrographic sheets 1442 a, b, and c.
21	C. A. Benjamin, New York	Geodetic positions of two primary stations in Connecticut and Appendix 8, Report of 1885.
24	Director U. S. Geological Survey	Geographical positions of five points in Tennessee, vicinity of Nashville.
28	W. A. Burr, Los Angeles, Cal	Magnetic declination at Los Angeles and at San Pedro, Cal., at various dates since 1853; also magnetic pamphlets and charts for 1885 and 1890.
28	Mississippi River Commission	Tracing of hydrographic sheet 1408.
29	B. M. Harrod, Civil Engineer, New Orleans	Tracing of topography and hydrography of island in Lake Pontchartrain; of the Rigolets, etc.

APPENDIX No. 4—1890.

REPORT OF ASSISTANT IN CHARGE OF OFFICE AND TOPOGRAPHY FOR THE YEAR ENDING JUNE 30, 1890.

U. S. COAST AND GEODETIC SURVEY OFFICE,
Washington, D. C., October 18, 1890.

SIR: I have the honor to submit my annual report for the Office for the fiscal year ending June 30, 1890, and along with it the reports of the various Divisions thereof submitted by their respective chiefs, as follows:

The Computing Division by Assistant Charles A. Schott.
The Drawing Division by Assistant W. H. Dennis.
The Engraving Division by Assistant H. G. Ogden.
The Instrument Division by Assistant E. Smith.
The Tidal Division by Mr. A. S. Christie, Computer.
The Miscellaneous Division by M. W. Wines, General Office Assistant.
The Chart Division by Assistant Gershom Bradford.
The Library and Archives by Mr. A. Martin, Librarian.

It will be noted that the Accounting Division no longer appears as a Division of the Office. This change was made when on the recommendation of the Superintendent the Honorable Secretary of the Treasury appointed a Disbursing Agent for the Survey. This officer being entirely under control of the Superintendent and dealing with all the accounts of the Survey, it was deemed best to place the Disbursing Office in the immediate office of the Superintendent. No written direction concerning this change has been given; it was made on the verbal direction of the Superintendent, after a full understanding as to its desirability on the part of all concerned.

The Office of Weights and Measures being distinct from the Coast and Geodetic Survey Office, and by direction of the honorable Secretary of the Treasury placed under the Superintendent of the Coast and Geodetic Survey, he has decided not to continue it under the form of a Division of the Coast and Geodetic Survey Office, either in form or in fact, but to have it under his especial care, the Assistant in charge of the details of Weights and Measures work being attached to the Superintendent's immediate office and reporting directly to him. No written instructions have been issued concerning the matter, but the change was made in accordance with the Superintendent's verbal instructions given after a thorough understanding of the matter on the part of all concerned.

The Computing Division has produced the usual amount of valuable scientific matter and has kept up with the demands for routine work during the year.

The Drawing Division presents the usual statistics. Great difficulty is experienced in securing the services of suitable draughtsmen; all have to be trained, and salaries are so small in the lower grades that after the young men become proficient they often find more lucrative employment and leave us. There has been 292 days' work upon tracing, etc., from our original sheets to supply demands of persons not connected with the Survey. Taking into consideration the time lost by interruptions occasioned in filling these demands there is consumed about all the time of one draughtsman during the year. If the Drawing Division could be relieved of this it would help much.

The Engraving Division has put out a larger number of charts than during any previous year. It has reached the limit of its capacity to produce with the present facilities and I respectfully urge that both the plant and personnel be increased and that additional room be provided.

The Instrument Division could not be brought to any satisfactory state of efficiency with the old force. Assistant Andrew Braid had displayed both energy and skill in the administration of the affairs of the Division, but some of the older employés could not reconcile themselves to new methods and various changes had to be made in the force. The new men give new life to the work and perform their duties cheerfully and satisfactorily. Some alterations in the rooms occupied are necessary, but only such as are absolutely required will be undertaken pending the action of Congress in providing more space.

The Tidal Division has progressed satisfactorily with its work and is improving gradually in efficiency. Some transfers and appointments made in its force have tended much to strengthen it. This Division presents to-day the broadest and most advantageous field for research and investigation of any in the Survey.

The Miscellaneous Division is well conducted and it is largely due to its good management that we have such gratifying increases in the sale of our publications. The number of agencies needs to be increased, but in order to do this an additional clerk is absolutely necessary.

The Chart Division while proficient within itself is much crippled and the efficiency of the service seriously impaired by our inability to supply charts as fast as called for. At the end of the fiscal year its books showed 1,000 charts called for that we could not supply. No one can be held responsible for this. The public begins to know of and to appreciate the charts; as they are more widely known they are more in demand and this demand has finally outgrown our ability to supply. More facilities for printing must be furnished if we are to meet the demands of the public.

The Library and Archives submits the usual statistical information. This Division ranks second in importance to no other Division in the Office. It needs thorough re-organization, more help, and a better utilization of the space at its disposal. The fact that our necessities compel us to carry on certain of the operations incidental to the printing of the charts from the copper plates in the basement of the Archives building, that this requires the use of much inflammable material and a constant fire, thus endangering much valuable property, has been called to the attention of the proper authorities and they have made repeated recommendations to Congress looking to an abatement if not entire eradication of this evil, but as yet no relief has been obtained. It is a serious matter and should be promptly attended to.

During the fiscal year ending June 30, 1890, the following-named persons have been employed under my immediate direction:

Dr. Wm. B. French has continued to assist me in matters of executive detail, to receive and account to me for all moneys from sales of charts, publications, old property, etc.; has aided in the office correspondence, received all office bills, adjusted and arranged them on vouchers in proper form for my approval, and filed a copy of each bill. He has prepared quarterly statements of moneys received, and they have been rendered to the Treasury Department and the money deposited with the Treasurer of the United States.

Mr. R. M. Harvey receipted for and received express packages, registered a large percentage of the mail, forwarded and incoming, and filed correspondence until December 7, when his connection with the Survey ceased.

Miss F. B. Bailey acted as stenographer and typewriter during the year and kept the leave-of absence account. Her services have been satisfactory.

Miss F. Cadel has used her typewriter in a variety of miscellaneous copying during the year, in preparing stencils for the "neostyle," and in tabular statements from the various Divisions of the Office. Her work shows increased care and has been highly satisfactory.

Miss K. Lawn also has used her typewriter during the year in copying for the annual report under the direction of its editor and in miscellaneous copying, and has been efficient and diligent as usual.

Miss C. B. Turnbull has been occupied in miscellaneous copying, addressing envelopes for monthly Notices to Mariners and for occasional Bulletins, also in copying instructions. On May 27 her resignation was accepted.

Mrs. J. Waddill copied field records until August 10, when she was transferred to the Treasury Department.

Mr. E. B. Wills has remained on duty during the year registering the mail and attending to express matter received and forwarded, and has assisted in the miscellaneous work of the Division.

Miss I. M. Peck reported for duty May 10 and has addressed wrappers for Notices to Mariners, copied instructions, and assisted in the Office correspondence.

The following-named persons whose salaries are provided for under the head of "Pay of Office force" have been detailed for special duty, as follows:

John W. Parsons, Accountant in the Disbursing Office, under the immediate control of the Superintendent. He qualified as Disbursing Agent of the Survey under authority given by the Secretary of the Treasury November 7, 1889.

William B. Chilton, Clerk in the Office of the Superintendent, under his special direction.

Ferdinand Westdahl, Draughtsman, Frank W. Edmonds, Clerk, and Vicente Denis, Messenger, with Assistant George Davidson, in charge of the Sub-Office at San Francisco, Cal.

E. Willenbucher, William C. Willenbucher, F. C. Donn, and E. H. Wyvill, Draughtsmen, and J. H. Roeth, Clerk, in the Office of the Hydrographic Inspector.

In my report for the fiscal year 1889 I said:

"Along with increased proficiency and business comes increased labor of all kinds, and the Office has now about reached the limit of its capacity with the present force."

Concerning this statement, I think that there has been no difference of opinion among those aware of all of the circumstances, and effort to meet absolute requirements for work, to promote the efficiency of the service by improving the proficiency of its personnel, and to comply strictly with the letter and spirit of the Civil Service laws, has not been overlooked during the past year. Not a removal has been made in any case that has not been solely and absolutely for the purpose of promoting the efficiency of the public service, and not an appointment has been recommended or made except with this object in view. It has been hoped that by proceeding very slowly and deliberately any persons not performing their work satisfactorily would take warning and improve. In some instances this has been the case and the disagreeable duty of making an adverse report has been avoided. In other instances the parties concerned have not profited by advice or warning.

There have been no deaths in the office force during the year.

The duties of Mr. F. M. Thorn as Superintendent of the U. S. Coast and Geodetic Survey ceased with June 30, 1889. His resignation, at the request of friends, was withheld for a time at the beginning of President Harrison's administration, and when tendered later was not acted upon. Mr. Thorn called the attention of the President and of the Secretary to the fact that in his opinion the Office of Superintendent would be vacant on July 1, on account of a clause in the appropriation bill providing for the position and salary, in which it was required that the Superintendent of the U. S. Coast and Geodetic Survey be "appointed by the President by and with the advice and consent of the Senate." On July 1, 1889, Mr. Thorn, without any formal action on the part of the President or the Secretary, ceased to perform duty as Superintendent, being uncertain in his own mind whether under the circumstances his official acts would be considered legal. On July 2 the Secretary instructed me to perform the duties of Superintendent so far as necessary for the proper conduct of the work. I performed these duties under the Secretary's direction until July 8, when you were appointed Superintendent by the President. I subsequently looked after the work for about 30 days under your direction and pending the time when you could arrange your affairs so as to admit of your taking charge of the work in detail.

In conclusion, I beg to express my gratification at the continued able support that I have received from the Chiefs of the several Divisions of the Office, and to thank you for the courtesy which you have shown me personally and the consideration which you have extended to me in the performance of my various duties.

Respectfully, yours,

B. A. COLONNA,
Assistant in charge of Office and Topography.

Dr. T. C. MENDENHALL,
Superintendent U. S. Coast and Geodetic Survey.

REPORT OF THE COMPUTING DIVISION, U. S. COAST AND GEODETIC SURVEY OFFICE, FOR THE FISCAL YEAR ENDING JUNE 30, 1890.

COMPUTING DIVISION, *June* 30, 1890.

SIR: In conformity with regulations, I have the honor to submit herewith the usual annual report of work done in the Computing Division during the fiscal year ending with June 30, 1890.

The charge of the Computing Division was continued with the undersigned; the personnel remained the same as last year. Temporary assistance was given by assigning to duty as computers Assistant E. Smith from July 1 to December 9, 1889; Sub-Assistant R. A. Marr from October 26, 1889, to the close of January, 1890; Assistant C. H. Sinclair from November 27, 1889, to February 25, 1890. Mr. J. B. Boutelle was relieved from duty in the Computing Division February 28, 1890; Mr. L. J. Schultz, magnetic observer, received instructions in observing and computing between March 6 and 28, 1890; Mr. F. A. Young was engaged in the Computing Division from April 2 to June 15, 1890; Mr. D. L. Hazard was connected with this Division on the part of the State of Massachusetts on December 13, 1889, and was engaged on computations connecting the triangulation during the years 1885–'89 of the Coast and Geodetic Survey with the State town-boundary survey. It is only with this temporary assistance given that the regular computing force is able to keep pace with the demands of the Survey for results.

The duty of directing and supervising the work of the computers and of reporting the results, as well as the furnishing of information in connection with the scientific correspondence of the Survey referred to me, has been promptly discharged. During the time I could spare from these duties I completed the discussion (seventh edition) of the accumulated material for the secular variation of the magnetic declination; this paper forms Appendix No. 7, Report for 1887–'88; I also brought out a second edition, for publication in the Report for 1888–'89 of the distribution of the magnetic declination in the United States and adjacent parts for the epoch 1890; this paper is based upon the results at 3,237 observing stations and is accompanied by three charts. With the assistance of Mr. Bauer, I was able to bring out the results of the absolute measures of the declination, inclination, and intensity taken at the magnetic observatory at Los Angeles during the seven years, 1882–'89, also to submit the differential observations of the declination, made at the same place, to analysis and discussion, the latter paper comprising more than 61,000 hourly readings. It includes the exposition of the lunar and solar rotation effect on the horizontal magnet. These papers form Parts I and II of the results from the Los Angeles observatory, and are designed to appear in the Report for 1889–'90. I also brought out Bulletin No. 13 (Telegraphic determination of the longitude of Mount Hamilton, Cal.), and Bulletin No. 14 (Approximate times of culminations and elongations and of the azimuths at elongation of Polaris for the years between 1889 and 1910); also, in connection with Assistant Tittmann, Bulletin No. 17 (Relations between certain metric standards of length). The duties demanded as Civil Service examiner were attended to, as well as proof-reading of certain appendices in the 1887–'88 Report.

An account of the work performed by each computer during the fiscal year is herewith presented in detail; it is made up from the daily and monthly reports.

Edward H. Courtenay continued the adjustment by least squares of the secondary and tertiary triangulations, vicinity of New York City; made satisfactory progress with the least square adjustment of the supplementary (since the publication of results in Report for 1885) triangulation in Massachusetts in connection with the State survey, omitting, however, all computations of positions in which the Coast and Geodetic Survey is not directly interested; these latter are in the hands of Mr. Hazard. Mr. Courtenay has charge of the geographical registers and supplies the field parties with geodetic data required by them; he has also charge of the duplicate records of the Survey pertaining to geodesy, astronomy, and magnetism, and supervises the work of Mr. J. B. Boutelle and Mr. D. L. Hazard.

Myrick H. Doolittle completed the local adjustment of angular measures at primary stations in Ohio and Kentucky, 1883–'87; computed the base lines Point au Chevreuil and Atchafalaya River, Louisiana, 1889, and the triangulation of 1888–'89 of Atchafalaya Bay and River and adjusted the coast triangulation between Barataria Bay and Atchafalaya Bay, Louisiana. Mr.

Doolittle made the figure adjustment of the triangulation along the thirty-ninth parallel between longitudes 82° and 84° in West Virginia, Ohio, and Kentucky, involving 35 equations; attended to the station and figure adjustments of the triangulation between St Louis and Jefferson City, Mo., involving 49 equations for the conditions of figure; attended to the same adjustments for the triangulation between Jefferson City and Kansas City, Mo., involving 50 conditions of figure, and continued the abstracts of directions and station adjustments of this triangulation in eastern Kansas, 1885-'87.

Henry Farquhar completed the computation for latitude of Station Piney, W. Va., 1883, computed the latitudes of Stations Needles and Mount Hamilton, Cal., 1888-'89, of Portland, Oregon, 1887, of Carson City, Nev., 1889, of Yaquina, Oregon, 1888, of Seattle, Wash., 1888, of Walla Walla, Wash., 1887, and of Station Balch (Portland), Oregon, 1886, commenced the computation for latitude of Howlett, N. Y., 1883, and made progress with the latitude computation for Altoona, Pa., 1890. Mr. Farquhar also supplied the mean places of stars required by field parties, a labor of some magnitude, involving the use of all available star catalogues (the latest being the Greenwich 10-year catalogue, 1877 to 1886); the proper motion and the probable error in declination are worked out for each star, excepting fundamental stars.

Louis A. Bauer completed the computation of the magnetic declinations, dips, and intensities observed by Assistant Baylor, in 1888, and by Sub Assistant Marr, in 1889; revised office computations for telegraphic difference of longitude observations of 1885-'87, assisted me in the preparation of the papers on the distribution of magnetic declination in the United States by reducing the observed values to the epoch 1890 and platting the same (about 3,000 stations); computed the observations for declination, dip, and intensity made monthly (on three days), at Los Angeles, Cal., between 1882 and 1889, and assisted me in the preparation of Parts I and II of the magnetic results at that observatory, and in particular marked and tabulated the magnetic disturbances in the hourly record, and made the necessary tabulation of the differential readings according to lunar hours and phase of the moon. Mr. Bauer also supervised the work done by Mr. Young, and attended to proof-reading and other miscellaneous work.

Charles H. Kummell was engaged on geodetic computations, abstracts of angles, triangle side, and position computations and miscellaneous revisions; checked and solved normal equations prepared by Mr. Courtenay in connection with the adjustment of the secondary triangulations in Massachusetts and in New York. Mr. Kummell also computed the triangulation of Duwamish Bay, Washington, 1886, and revised the conditional and normal equations of the triangulation in Missouri (St. Louis and Kansas City), before they were solved by Mr. Doolittle.

John B. Boutelle was principally engaged in revising abstracts of angles, computing triangle sides, and making position and miscellaneous computations under the direction of Mr. Courtenay. He also collected geodetic data for field parties, and attended to the copying of scientific reports, and assisted in duplicating the hourly differential readings of the magnetic declination at Los Angeles.

James Page made miscellaneous revisions of magnetic computations, and plotted positions; tabulated angles and computed triangle sides of the supplementary triangulation about Charleston, S. C., 1889; established the coefficients of a set of ten normal equations relating to distribution of magnetic declination in Alaskan waters; computed the position of the Jefferson pier, District of Columbia; aided Mr. Courtenay in verifying or revising abstracts of angles and other computations of the triangulations of New York and of Massachusetts, and Mr. Doolittle in revising his abstracts of directions, triangulations of Missouri and Kansas.

William C. Maupin was engaged in supplying the descriptions of stations and sketches of trigonometrical stations required by field and hydrographic parties, inserted resulting positions in the geographical registers, and attended to miscellaneous clerical duty.

Temporary assistance to the Computing Division was rendered as follows:

Assistant E. Smith computed the following telegraphic differences of longitude: Salt Lake City, Utah, and San Francisco, La Fayette Park, Cal., 1887; San Francisco, La Fayette Park, and Washington Square, 1887; San Francisco, La Fayette Park, and Portland, Oregon, 1887; Portland, Oregon, and Walla Walla, Wash., 1887; Walla Walla, Wash., and Salt Lake, Utah, 1887; Portland, Oregon, and Yaquina, Oregon, 1888; Portland, Oregon, and Seattle, Wash., 1888.

Sub-Assistant R. A. Marr prepared abstracts of horizontal angles of the triangulation in the vicinity of New York.

Assistant C. H. Sinclair was engaged on computations of the triangulations in Massachusetts, 1885 to 1888, and computed his supplementary triangulation in the District of Columbia, 1890, locating Meridian monument and Jefferson pier.

F. A. Young reduced observations of spirit levels, Villa Ridge, Ill., to Greenfield, Tenn., 1888-'89, under the direction of Mr. Bauer.

Respectfully yours,

CHAS. A. SCHOTT,
Assistant U. S. Coast and Geodetic Survey,
In charge of the Computing Division.

Mr. B. A. COLONNA,
Assistant in charge of Office and Topography.

REPORT OF THE DRAWING DIVISION, U. S. COAST AND GEODETIC SURVEY OFFICE, FOR THE FISCAL YEAR ENDING JUNE 30, 1890.

DRAWING DIVISION, *September* 5, 1890.

SIR: I respectfully submit the report of the Drawing Division, which has remained under my direction, for the fiscal year ending June 30, 1890.

The general assignment of work has been similar to that of previous years.

Mr. A. Lindenkohl has been employed on hydrographic reductions and corrections for the published charts, in obtaining information and tracings of surveys and improvements from the U. S. Engineers, and in the preparation of the progress sketches for the Annual Report. Mr. H. Lindenkohl on drawings for charts to be engraved and charts published by photolithography, projections on copper and for field use, and has also done the usual amount of lithographing for the Annual Report.

Mr. E. H. Fowler and Mr. E. J. Sommer have made drawings for charts published by photolithography, and by copper-plate printing, projections for field work, and miscellaneous high-class drawings.

Mr. Paul Erichsen made tracings of the District of Columbia survey, drawings of instruments, fac-simile copies of valuable maps, and the measurements of engraved work.

Mr. Emil Mólkow was employed in inking topographical field sheets, triangulation sketches, and measurement of engraved work. Mr. C. Mahon on topographic and hydrographic reductions for publication. Mr. E. A. Trescott was employed in numbering and registering original field sheets, copying triangulation sketches, etc., until the 28th of July, 1889, when he resigned.

Mr. W. H. Benton and Mr. D. M. Hildreth made drawings of charts for publication, tracings in answer to calls from private parties, and projections for field work. Mr. Benton resigned March 25, 1890.

Marshall P. Jackson and Edwin Rose were principally employed in making tracings of original sheets in answer to demands from other departments and private parties.

Mr. Rose resigned on the 15th of January and Mr. Jackson on the 7th of June, 1890.

Mr. Charles H. Dietz was also employed on tracings in answer to outside calls, and in clerical work from July 1 to January 14, when he was sent to the field, returning on the 7th of May, when he resumed his work.

Mr. G. F. Pohlers was appointed as draughtsman on the 27th of March. He has been engaged in making diagrams illustrating the Gulf Stream currents, and for the Annual Report of the Superintendent.

The Division has been considerably crippled by the resignations mentioned above; it is difficult to find draughtsmen skilled in the work called for by the Survey. Of the four who have left the service, three were valuable assistants, and the fourth, Mr. Rose, gave promise, with practice, of being so, and thus far we have only been able to find one, Mr. Pohlers, to replace them. Notwithstanding the reduced force, the amount of work accomplished will compare favorably with that of previous years, especially when the size and character of the new charts are considered, and that 292 days work of a good draughtsman, as well as much of the time of the Chief of the Division, was consumed in making tracings and furnishing information in answer to requests from the other Departments and private parties.

The work of the Division during the year may be summarized as follows: Seventeen drawings of charts for publication by photolithography were completed, and the charts published; the drawings of thirteen charts and five maps were revised and corrected for photolithographic reprints; sixty sketches and illustrations were drawn or revised for the Report of the Superintendent for the fiscal year 1888; three drawings were finished of charts for publication by photolithography which could not be published for want of funds; the drawings of twenty-four charts for publication from engraved plates were completed, and the drawings of twenty charts were revised and corrected for new editions from engraved plates.

Drawings were furnished to the Engraving Division for two hundred and sixteen corrections or changes on engraved plates. Forty-nine topographical sheets were inked, and ninety-five field projections made. The list of tracings, drawings, or information furnished in answer to requests, official or personal, from persons not connected with the Survey, has been included in Appendix No. 2.

I am indebted to all the employés of the Division for their cordial co-operation and assistance.

Respectfully, yours,

W. H. DENNIS,
Assistant U. S. Coast and Geodetic Survey,
In charge of the Drawing Division.

Mr. B. A. COLONNA,
Assistant in charge of Office and Topography.

NOTE.—Accompanying the report of Assistant Dennis are lists by title of drawings completed for publication as charts, and of drawings revised and corrected for new editions of charts. These lists have been filed as office records in the Archives.

REPORT OF THE ENGRAVING DIVISION, U. S. COAST AND GEODETIC SURVEY OFFICE, FOR THE FISCAL YEAR ENDING JUNE 30, 1890.

ENGRAVING DIVISION, *August* 22, 1890.

SIR: I respectfully submit the following report on the operations of the Engraving Division during the fiscal year ending with June 30, 1890.

The statistics are as follows:

ENGRAVING.

Number of new chart plates completed		13
Number of new editions of charts completed		14
Number of sketches and illustrations completed		54
Number of new chart plates commenced		11
Number of new editions of charts commenced		14
Number of sketches and illustrations commenced		49
Number of plates of charts corrected for printing		627
Number of plates printed for chart room		862
Number of plates of sketches and illustrations corrected for printing		29
Number of plates in progress during the year but not completed		13
Number of unfinished plates on hand at the close of the year:		
New charts	28	
New editions of charts	11	
Sketches and illustrations	19	
		58

ELECTROTYPING.

Number of pounds of copper deposited		1,983
Number of square inches on which deposit was made		79,724
Number of basso plates made	33	
Number of alto plates made	45	
		78

PHOTOGRAPHING.

Number of negatives made	277
Number of prints made	702

PRINTING.

Number of impressions for chart room	47,008
Number of impressions for Assistant in charge	2,384
Number of impressions for Engraving Division	1,838
Number of impressions for Hydographic Inspector	1,710
Number of transfer impressions for lithographers	151
Total number of impressions	53,091

The engravers were employed during the year principally as follows: H. M. Knight, A. Petersen, J. G. Thompson, R. F. Bartle, jr., and H. L. Thompson on lettering; W. A. Thompson on topography and sanding; J. Enthoffer, R. F. Bartle, and E. J. Enthoffer on topography; H. C. Evans on sanding; E. H. Sipe on miscellaneous corrections and lettering; T. Wasserbach and W. H. Davis on miscellaneous corrections and additions; W. A. Van Doren, A. H. Sefton, and E. A. Kubel on outlines and lettering. All of the engravers except those employed on contract work have been engaged at different times on the miscellaneous corrections and additions to the printing plates arising from resurveys and changes in aids to navigation. This class of work consumed time equivalent to that of three and a half men, a slight reduction over the preceding year, when the time of four men was required. The average time required to correct a plate and the percentage of printing plates requiring correction were also less than for the preceding year.

The number of plates completed during the year is greater than for any year in my experience; a result, it is true, that was anticipated from the larger force employed in the office, but is nevertheless gratifying as demonstrating the practicability of increasing the product of the Division without incurring too great expense.

The year's work has shown material progress towards completing the "Coast Charts" and "General Coast Charts" on the Atlantic and Gulf coasts; of the former we now require only Nos. 101 on the coast of Maine and No. 146 on the coast of North Carolina, to finish the series from the northeastern boundary to the Mississippi River; and of the latter No. 6[a] on the coast of Maine and No. 19 on the coast of Louisiana to complete the whole series from the northeastern boundary to the Rio Grande. We have also published Chart No. 671, San Diego to Santa Monica, completing the series of $\frac{1}{200000}$ charts on the Pacific coast from the southern boundary to Cape Mendocino, with the exception of a gap between Pt. Buchon and Pt. Pinos, where the surveys are as yet incomplete. The revision of a number of important charts has been completed during the year and new editions published showing the latest hydrographic surveys; among the number Boston Harbor, New York Harbor, Approaches to Delaware Bay, St. Simon's Sound, and Brunswick Harbor, Florida Bay, Atchafalaya Bay and River, and the Approaches to San Francisco.

Mr. D. C. Chapman has continued in charge of the Electrotype and Photograph rooms, assisted by Mr. L. P. Keyser. The requirements in both branches run about the same as during the preceding year. Three alto plates were made for the Hydrographic Office, Navy Department.

Mr. F. Moore has remained in charge of the Printing Office during the year, assisted by Messrs. Hoover, Beck, and Craufurd, printers, and the usual number of helpers. Seven thousand two hundred and fifty-four more prints were furnished to the Chart Division than during the preceding year; but this number was not sufficient to meet the demand for charts, and would have been increased by several thousand had the appropriation for printing permitted the employment of printers for the small press during the last four months of the year. Under these circumstances I cannot urge too strongly the necessity for the increased facilities I have brought to your attention in successive years past as greatly needed, and that were included in the Superintendent's estimates for the current year.

Mr. John H. Smoot has continued to perform the clerical duties of the Division with great satisfaction as heretofore, and I cannot too earnestly commend to your attention his zeal and fidelity. The clerical work has so largely increased that it greatly interferes with the important function of proof-reading, now, also, largely increased through the more frequent necessity of making new printing plates; and I must therefore urge upon you again the assignment of an additional bookkeeper.

The customary list of chart-plates completed, commenced, and in progress during the year is submitted herewith for file in the Archives.

Respectfully, yours,

HERBERT G. OGDEN,
Assistant U. S. Coast and Geodetic Survey,
In charge of the Engraving Division.

Mr. B. A. COLONNA,
Assistant in charge of Office and Topography.

REPORT OF THE INSTRUMENT DIVISION, UNITED STATES COAST AND GEODETIC SURVEY, FOR THE FISCAL YEAR ENDING JUNE 30, 1890.

INSTRUMENT DIVISION, *September* 18, 1890.

SIR: I have the honor to submit the following report of the work of the Instrument Division for the fiscal year ending June 30, 1890:

Assistant Andrew Braid was in charge of the Division till December 18, 1889, at which date he was relieved to take up certain other duties and the undersigned was placed in charge of the Division.

This Division has to send out, receive, and account for all instruments and general property used in the field and the various divisions of the office, make the needed repairs to instruments, plan and construct new instruments, determine their constants so far as practicable to do so at the office, and purchase new instruments and all material used in the instrument and carpenter shops.

The instrument shop is essentially a repair and experimental shop, and the construction of new instruments is incidental to this work, being mostly confined to such instruments as can not be purchased or made to order except at very much greater cost. The new work of this year has been as follows:

Letter gauges for Engraving Division	66
Eight-inch repeating theodolites completed (begun last year)	6
Three-armed protractors	12
Box heliotropes	12
Six by eight inch Steinheil heliotropes	4
One-quarter metre scales	6
Tracing apparatus for Weights and Measures Division	1
Set of sixteen metric weights for Weights and Measures Division	1

The following instruments have been so thoroughly remodeled or repaired that they are practically new instruments:

Heliotropes Nos. 300, 303, 304, 306, and 17	5
Plane tables Nos. 12, 22, 25, 26, 29, 42, 47, 51, 55, 59, 62, and 84	12
Meridian telescope No. 9	1
Forty-five inch astronomical transits Nos. 4 and 5	2
Theodolites Nos. 15, 32, and 74, the latter regraduated	3

A large number of other instruments have been repaired and a great amount of work done incidental to fitting out the field parties, the details of which are given in the monthly reports of this Division and are too voluminous to give in this report.

The supply of instruments has been further increased by purchase as follows:

Burkhordt reckoning machine	1
Eight-column comptometer	1
Stierle self-registering tide gauges	2
Buff and Berger plane table alidade	1
Aneroid barometers	12
Townshend double reflecting and repeating circle	1
Austrian double reflecting circle and protractor	1
Tagliabue hydrometers	36
Green centigrade thermometers	48
Portable testing and resistance set	1
Universal rheometer	1
D'Arsonval galvanometer	1
Portable reflecting galvanometer	1

A large supply of fine level vials.

A number of small drawing instruments, etc.

The facilities of the instrument shop have been increased by the purchase of a No. 2 tool-grinding machine by Brown and Sharpe, a large supply of small tools, and a new lathe by Francis Hill, which latter will not become available till September next.

Several changes in the force of the instrument shop have been made during the year, and it is safe to state that at this date the shop has reached a very satisfactory degree of efficiency, and by keeping up the present standard a greater amount of first-class work will be turned out in the future.

The carpenter shop is part of this Division and is really an essential part of the instrument shop. It has done a large amount of construction and repairs for instruments having wooden parts, made all wooden patterns for castings, and all packing boxes for instruments to be sent to the field, etc. This shop has also during this last year done a large amount of general carpentry work for the office, the details of which are given in the monthly reports.

The force of this Division during this past year has been as follows:

Assistant Andrew Braid, Chief of Division, July 1 to December 18, 1889; Assistant Edwin Smith, Chief of Division, December 19, 1889, to June 30, 1890; R. C. Glascock, clerk; William West, messenger; E. G. Fischer, chief mechanician; E. M. Eshelman, mechanician, July 1, 1889, to April 12, 1890; L. A. Fisher, mechanician, July 1 to October 10, 1889, at which latter date he was assigned to duty in the Office of Weights and Measures, and on February 18, 1890, he was permanently transferred to that office; P. Vierbuchen, mechanician, July 1, 1889, to April 30, 1890; S. A. Kearney, mechanician; O. Storm, mechanician; M. Lauxman, mechanician; W. R. Whitman, mechanician, February 20 to June 30, 1890; C. E. Regennas, mechanician, June 23 to June 30, 1890; W. Gaertner, mechanician, June 23 to June 30, 1890; T. Gerhards, mechanician for the Office of Weights and Measures, but assigned to work in the Instrument Division; H. O. French, head carpenter; G. W. Clarvoe, carpenter; C. N. Darnall, carpenter.

Messrs. Whitman, Regennas, and Gaertner were appointed in the places of Messrs. Eshelman, Fisher, and Vierbuchen. Mr. Gerhards resigned June 30, 1890, and his place has yet to be filled.

Respectfully yours,

EDWIN SMITH,
Assistant U. S. Coast and Geodetic Survey,
In charge of the Instrument Division.

Mr. B. A. COLONNA,
Assistant in charge of Office and Topography.

REPORT OF THE TIDAL DIVISION, U. S. COAST AND GEODETIC SURVEY OFFICE, FOR THE FISCAL YEAR ENDING JUNE 30, 1890.

TIDAL DIVISION, *July* 10, 1890.

SIR: I have the honor to submit in duplicate this my report of the Tidal Division for the fiscal year ending June 30, 1890.

The work done during the year may be summarized as follows:

1. An aggregate of 3 years 9 months of record from automatic tide gauges with accompanying tabulated half-hourly heights of the sea, high and low waters, temperature and density of the sea and meteorological data, 103 original and 102 duplicate volumes of observations from staff and box gauges, have been received, examined, and registered, and 282 letters prepared.

2. The Tide Tables for the Pacific coast for the year 1890, an octavo of 105 pages, have been read and differenced in proof. The Tide Tables for the Atlantic and Pacific coasts for the year 1891, two octavos of 250 and 111 pages, respectively, have been prepared and read and differenced in proof. In the volume for the Atlantic coast, the current tables have been extended to include 12 stations in New York Harbor and approaches and 3 stations in Delaware Bay and River. In the volume for the Pacific coast, type curves with accompanying explanatory text have been introduced to aid the mariner in an intelligent use of the tables.

3. Tide notes have been prepared and furnished for 131 stations for publication on 38 charts, and for 62 stations for publication in the Coast Pilot.

4. Thirty-nine requisitions from field parties have been filled. This included the preparation of descriptions of 151 tidal bench marks and the computation of half-monthly mean sea level at stations in the Gulf—Key West, Fort Morgan, and Biloxi—for an aggregate of 3½ years.

5. Tidal information, including 12 tide notes and descriptions of 56 tidal bench marks, has been prepared and furnished in reply to 42 calls from persons not connected with the Survey.

6. Harmonic analyses of tides have been made as follows: Eastport, Me., 1862, has been two-thirds finished; Boston, Mass., 1869, one-sixth; Sandy Hook, N. J., 1887, and 1888, each one-half, and Sausalito, Cal., 1889, one-half finished—that is, the equivalent of two and one-third years completed.

7. Non-harmonic "1st reductions" have been made of 63 series, the equivalent of about 9 years of continuous observations, and "2d reductions" of 4 series, the equivalent of about 5 years of continuous observations.

8. The Superintendent's Annual Reports, the Coast Pilots, the charts, and the records in the archives have been examined in detail and memoranda preserved in the form of a card catalogue, by means of which everything hitherto done by the Survey in observation, reduction, and publication of currents may be readily found. This places us in position to collect rapidly and present everything of value already attained, and to push forward the work of observation and reduction intelligently along the best lines. Reductions for fifteen stations have been made and the results introduced into the tide tables for 1891.

9. An elaborate comparison of prediction by means of Prof. Ferrel's tide predicting machine with observation by means of automatic gauges, has been made for the year 1889 for Sandy Hook, N. J. The results, which are very satisfactory, will be made the subject of a special report.

The following is a statement of the general character of the work of each computer or clerk:

Mr. L. P. Shidy has been engaged in the responsible work of revising and differencing the tide tables in manuscript and in proof, contributing to their completeness and accuracy; in preparing and revising data to fill requisitions, and in inspection, interpretation, and reduction of defective records.

Mr. J. W. Whitaker made the major part of the predictions with the machine for the year 1891, summed the harmonic components for Sandy Hook, 1887, made some non-harmonic reductions and assisted in preparing data, reading proof, etc. Mr. Whitaker was transferred from this Division May 20.

Miss A. G. Reville examined and registered the records received, copied reports, sketches, and descriptions of bench-marks and other data, and tabulated tides. Miss Reville does a large amount of work of good quality.

Mrs. Virginia Harrison made non-harmonic reductions, summed harmonic components, tabulated tides, copied sketches and descriptions of bench-marks, copied and differenced predictions, and assisted in reading proof.

Mrs. M. E. Nesbitt predicted for Philadelphia and Baltimore from curves for 1891, computed mean predicted range of tide for both coasts for 1891, summed the harmonic components for Eastport, 1862, and several for Sansalito, 1889, computed mean sea level at Key West, Fort Morgan, and Biloxi, and made a large number of non-harmonic reductions. Mrs. Nesbitt produces a large quantity of computation reasonably free from error.

Mr. F. M. Little predicted with the machine for New York and San Francisco, 1891, made non-harmonic reductions, summed the harmonic components for Sandy Hook, 1888, and several for Eastport, 1862, computed corrections to staff, and assisted in the preparation of data. Mr. Little submitted a paper on March 20, on the "Determination of the True Scale of a Maregram, etc."

Mr. John F. Hayford computed the amplitudes and epochs for machine prediction, 1891, predicted for Newport and Port Townsend, 1891, with the machine, compared machine prediction with observation at Sandy Hook, 1889, selected and drew type curves for the Pacific coast tide tables, compared the Mission Street, San Francisco, series with the simultaneous observations at Sausalito, prepared data to fill requisitions, investigated the subject of observation, reduction, and publication of currents by the Survey, and reduced fifteen series of current observations. Mr. Hayford has submitted a paper on "The Relation between the Harmonic Components of a Tidal Curve and its Mean Amplitude;" a paper "On a Modification of the Ferrel Tide Predicting Machine to adapt it to the Prediction of Hourly Ordinates;" a "Report on the Records of Current Observations, etc., and the Use of the Observations for Prediction Purposes;" and a report which I am about to submit on the comparison of prediction with observation at Sandy Hook, 1889, is essentially his also. Mr. Hayford has exhibited throughout the year a remarkable power for doing work, and improving our methods.

Mr. Eugene Veith was attached to this Division November 19 to 30, preparatory to taking charge of the tidal station on Tybee Island, Georgia.

The charge of this Division, involving the distribution, supervision, and revision of work, preparation of the tide tables and other data, has continued with the undersigned throughout the year. I have given much attention to the improvement of the tide tables, to the correction and extension of tidal data on charts and in the Pacific Coast Pilot, to the preparation of tidal results for publication, and the improvement of methods of reduction. I submitted in March a paper on a new method for the analysis of periodical phenomena. The introduction of a Fell & Tarrant eight-keyed comptometer has facilitated our numerical work in a marked degree.

Respectfully, yours,

ALEX. S. CHRISTIE,
Computer in charge of the Tidal Division.

Mr. B. A. COLONNA,
Assistant in charge of Office and Topography.

REPORT OF THE MISCELLANEOUS DIVISION OF THE U. S. COAST AND GEODETIC SURVEY OFFICE FOR THE FISCAL YEAR ENDING JUNE 30, 1890.

MISCELLANEOUS DIVISION, *October 1, 1890.*

SIR: I have the honor to submit herewith the report of the Miscellaneous Division for the fiscal year ending June 30, 1890.

With the exception of the transfer of Mr. R. T. Bassett, map mounter, to the Chart Division, the organization of this Division has remained the same as in the preceding year. There has, however, been a considerable increase in the volume of business transacted, as is shown by records accompanying this report which are for file in the Archives.

The following table gives the general issue of some of the important publications of the Survey during the year:

Publications of the Coast and Geodetic Survey issued during the fiscal year 1890.

	No. of copies.
Annual Reports of the Superintendent, distribution of	3,391
Tide Tables	4,874
Atlantic Coast Pilots	24
Subdivisions of the Atlantic Local Coast Pilot	457
U. S. Coast Pilot, Atlantic Coast, Part IV	272
Pacific Coast Pilot, Alaska, Part I	2
Charts sent to sale agents	32,335

Four thousand six hundred and fifty-nine more charts were sent to sale agents during the year than in the preceding year, being an increase of nearly 17 per cent.

	Sheets.
Charts supplied to agencies, 1889–'90	32,335
Charts supplied to agencies, 1888–'89	27,676
Increase	4,659

Could we have filled all orders received, this increase would have been eleven hundred and eighty-five larger, there having been orders on hand at the close of the year for that number of sheets that we were unable to supply.

Twelve agencies for the sale of publications—eight on the Atlantic and Gulf coasts and four on the Pacific coast—were established during the year, and seven were discontinued—all on the Atlantic and Gulf coasts. The total number of agencies on June 30, 1890, was seventy-nine, viz: sixty-three on the Atlantic and Gulf coasts and sixteen on the Pacific coast.

The aggregate of business done through the agencies from July 1, 1889, to June 30, 1890, is shown by a table which has been prepared for file in the Archives. From this table it appears that the total value of the publications of the Survey in the hands of sale agents on June 30, 1890, was $8,846.16, and that the net amounts received from sale agents on the Atlantic and Pacific coasts during the fiscal year from the sales of the publications of the Survey were $5,667.57 and $1,212.45, respectively.

The following publications were sent to press: Annual Report of the Superintendent for the year ended June 30, 1888; U. S. Coast Pilot, Atlantic Coast, Part VI; Chesapeake Bay and Tributaries; Catalogue of Charts and other Publications, 1890; Tide Tables for the Atlantic Coast of the United States for the year 1891; Tide Tables for the Pacific Coast of the United States for the year 1890; Tide Tables for the Pacific Coast of the United States for the year 1891, and Appendices to the Annual Report of the Superintendent for the fiscal year ended June 30, 1888, which are to be printed separately in pamphlet form, as follows:

No. 7.—The secular variation of the magnetic declination in the United States and at some foreign stations.

No. 8.—Geographical positions of trigonometrical points in the State of Connecticut, determined by the U. S. Coast and Geodetic Survey, between the years 1833 and 1886.

No. 9.—Tidal levels and flow of currents in New York Bay and Harbor.

No. 10.—Heights from spirit-leveling of precision between Mobile, Ala., and Okolona, Miss.

No. 11.—Heights from spirit-leveling of precision between New Orleans, La., and Wilkerson's Landing, Miss., opposite Arkansas City, Ark.

No. 12.—Heights from spirit-leveling of precision between Arkansas City, on the Mississippi River, and Little Rock, Ark.

No. 13.—Differential method of computing the apparent places of stars for determinations of latitude.

No. 14.—Determinations of latitude and gravity for the Hawaiian Government.

The usual distribution was made of the Annual Reports of the Superintendent, the Appendices to the same printed separately in pamphlet form, the Bulletins, and the Notices to Mariners, and they were also furnished in large numbers in response to numerous special applications. The distribution in detail of Annual Reports was as follows:

Date of report.	Domestic distribution.		Foreign distribution.		Total.
	To institutions.	To individuals.	To institutions.	To individuals.	
1851	3	....	1	....	4
1852	3	3	1	....	7
1853	2	3	1	....	6
1854	2	1	1	1	5
1855	2	....	1	....	3
1856	2	2	1	1	6
1857	2	....	1	....	3
1858	2	....	1	1	4
1859	2	....	1	....	3
1860	2	2	2	....	6
1861	4	3	1	....	8
1862	2	....	1	....	3
1863	4	....	1	1	6
1864	1	....	1	....	2
1865	9	5	2	2	18
1866	8	9	2	2	21
1867	9	8	3	2	22
1868	10	9	3	2	24
1869	9	5	3	2	19
1870	9	6	2	2	19
1871	10	7	2	2	21
1872	15	11	5	2	33
1873	16	19	4	2	41
1874	16	25	5	2	48
1875	17	20	5	2	44
1876	20	23	5	2	50
1877	18	22	5	3	48
1878	24	82	5	5	116
1879	82	137	5	6	230
1880	23	104	5	8	140
1881	25	89	5	7	126
1882	26	98	5	7	136
1883	27	96	5	7	135
1884	29	104	6	7	146
1885	38	119	9	7	173
1886	30	150	10	8	198
1887	615	648	222	32	1,517
Totals	1,116	1,810	338	125	3,391

Following is a list of the publications of the Survey, with the number of copies of each received during the year from the Public Printer, and issued, as has been customary, for the use of the people and the Government:

Name of publication.	No. of copies.
Annual Report of the Superintendent for the year ended June 30, 1887	2, 000
Atlantic Local Coast Pilot, Subdivision 22—"Straits of Florida, Jupiter Inlet to Dry Tortugas"	500
Tide Tables for the Atlantic Coast of the United States for the year 1890	2, 025
Tide Tables for the Atlantic Coast of the United States for the year 1891	2, 025
Tide Tables for the Pacific Coast of the United States for the year 1890	2, 960
Tide Tables for the Pacific Coast of the United States for the year 1891	3, 525
Correction slip for insertion in Tide Tables for the Atlantic Coast of the United States for the year 1890	2, 000
Additional information for insertion in Subdivision 6–7, Atlantic Local Coast Pilot, sheet 1	500
Additional information for insertion in Subdivision 13, Atlantic Local Coast Pilot, sheet 3	500
Additional information for insertion in United States Coast Pilot, Atlantic Coast, Part IV	500
Tables for converting Customary and Metric Weights and Measures	5, 000
Appendix No. 6, Report for 1887—"On the Movements of the Sands at the Eastern Entrance to Vineyard Sound"	300
Appendix No. 7, Report for 1887—"Fluctuations in the Level of Lake Champlain and Mean Height of its Surface above the Sea"	300
Appendix No. 8, Report for 1887—"Gulf Stream Explorations. Observations of Currents, 1887"	500
Appendix No. 9, Report for 1887—"Heights from Geodesic Leveling between Mobile and New Orleans. 1885-1886"	300
Appendix No. 10, Report for 1887—"Terrestrial Magnetism. The Magnetic Work of the Greely Arctic Expedition, 1881-1884"	100
Appendix No. 12, Report for 1887—"General Index of Illustrations contained in the Annual Reports of the United States Coast and Geodetic Survey from 1844 to 1885, inclusive"	100
Appendix No. 13, Report for 1887—"Addendum to Appendix No. 8, Report for 1883, The Estuary of the Delaware"	100
Appendix No. 14, Report for 1887—"Heights from Geodesic Leveling. New York Bay and Vicinity, 1886 and 1887"	500
Appendix No. 15, Report for 1887—"On the Results of the Physical Surveys of New York Harbor"	500
Appendix No. 16, Report for 1887—"A Bibliography of Geodesy"	711
BULLETINS.	
No. 9—On the relation of the yard to the metre	5, 000
No. 10—Report on the Sounds and Estuaries of North Carolina with reference to Oyster Culture	3, 014
No. 11—Determinations of Latitude and Gravity for the Hawaiian Government	3, 000
No. 12—A Siphon Tide-gauge for the open Seacoast	3, 139
No. 13—Telegraphic Determination of the Longitude of Mount Hamilton, California	3, 000
No. 14—Approximate Times of Culminations and Elongations and of the Azimuths at Elongation of Polaris for the years between 1889 and 1910	3, 000
No. 15—Verifications of Weights and Measures	10, 000
No. 16—Description of Two new Transit Instruments for Longitude Work	3, 170
No. 17—The relation between the Metric Standards of Length of the United States Coast and Geodetic Survey and the United States Lake Survey	3, 000
No. 18—Table for the Reduction of Hydrometer Observations of Salt Water Densities	3, 050
NOTICES TO MARINERS.	
No. 116—Chart Corrections during month of June, 1889	9, 600
No. 117—Chart Corrections during month of July, 1889	9, 500
No. 118—Information concerning United States Coast and Geodetic Survey Charts	9, 800
No. 119—Chart Corrections during month of August, 1889	10, 000
No. 120—Chart Corrections during month of September, '89	10, 000
No. 121—Chart Corrections during month of October, 1889	10, 000
No. 122—Chart Corrections during month of November, '89	10, 000
No. 123—Chart Corrections during month of December, 1889, including Index to Chart Corrections, 1889	11, 500
No. 124—Chart Corrections during month of January, 1890	11, 500
No. 125—February, 1890, Chart Corrections during the month	11, 500
No. 126—March, 1890, Chart Corrections during the month	11, 500
No. 127—April, 1890, Chart Corrections during the month	11, 500
No. 128—May, 1890, Chart Corrections during the month	11, 500

Mr. Freeman R. Green has performed clerical duties, in addition to keeping the accounts of Sale Agents, throughout the year; and it affords me much pleasure to testify to the zeal, ntelligence and fidelity with which he has discharged the duties assigned to him.

The duties of janitor were performed by Mr. W. M. Long, and those of watchmen by Messrs. David Parker, W. H. Keith, and A. B. Simons in a satisfactory manner.

Credit is due to Messrs. W. H. Butler, chief messenger; C. H. T. Over, Sandy Bruce, William Savoy, Peter Page, and William West, messengers; Charles H. Jones and Attrell Richardson, packers and folders; William R. McLane, driver; Horace Dyer and Harrison Murray, firemen; Mrs. S. E. Flynn, William P. Young, John H. Brown, and Hans Bowdwin, laborers, for the faithful performance of their respective duties.

Respectfully, yours,

M. W. Wines,
General Office Assistant,
In charge of the Miscellaneous Division.

Mr. B. A. Colonna,
Assistant in charge of Office and Topography.

REPORT OF THE CHART DIVISION OF THE U. S. COAST AND GEODETIC SURVEY OFFICE, FOR THE FISCAL YEAR ENDING JUNE 30, 1890.

CHART DIVISION, *August* 13, 1890.

SIR: I have the honor to submit the following report of the Chart Division for the fiscal year ending June 30, 1890.

The Division has been under my charge during the year, and I have been assisted by the following named persons, whose duties and time of service have been as follows:

Name.	Duties.	Time of service.
Mr. J. H. Barker	Chart correcting	The whole year.
Miss L. A. Mapes	Book keeping, etc	Do.
Miss Sophie Hein	Coloring and correcting charts, etc	Do.
Mrs. Jennie Fitch	Coloring charts, correcting catalogues, etc	Do.
Mr. Neil Bryant	Receiving charts, correcting catalogues, etc	Do.
Mr. R. T. Bassett	Map mounting	Do.
Mr. A. Upperman	Chart correcting	July 1 to May 13.
Mr. J. L. Smith	Receiving charts, etc	July 1 to Mar. 20.
Miss Mary Thomas	Coloring charts	July 1 to Apr. 30.
Mr. H. R. Garland	Issuing and correcting charts, etc	Aug. 20 to June 30.
Mrs. M. H. Bailey	Coloring charts	Apr. 10 to Apr. 17.
Miss Libbie Ludgate	Coloring charts	Apr. 18 to June 30.
Mr. J. W. Whitaker	Correcting charts	May 20 to June 30.
Miss M. L. Handlan	Coloring charts	May 21 to June 30.
Mr. C. W. Childs	Correcting charts, etc	May 22 to June 30.

It gives me pleasure to testify to the general efficiency of the Division, and to the marked individual interest of those employed in the work, evidenced by their earnestness in promoting the rapidity and accuracy of the various operations in which they take part. As a result of more experience, various improvements have been made in the routine of chart receipts, corrections, and issues, which have facilitated the work. A notable one is the use of a system of cards for a record of back orders (back order is a term used to designate those charts of any requisition which for some cause can not be supplied at the time of the receipt of the requisition). The card system supplants the ordinary book method, which had failed to meet our wants. This accumulation of back orders arises almost exclusively from the want of facilities for printing our charts, and adds largely to the work of the Chart Division, but the work is absolutely necessary for the service of the public. However much to be regretted, the back-order list will continue to increase as the demand for charts increases, unless the demand be met by increased facilities for chart supply. As the demand for charts is much greater during the summer months, it would be well if extra facilities for printing charts could be provided as early as March. There were on our back-order list at the end of the fiscal year more than a thousand copies of charts.

The following table shows that the charts are gaining in favor notwithstanding the vexatious and prolonged delays on account of our lack of printing facilities. This year's issue shows an increase over last year's, of 30 per cent., and an increase of circulation through sale agents of 19 per cent. The former shows the gross increase of the work of the Division as well as the demand for charts from all sources, but the latter is the direct measure of the increased popularity of the charts. The issue of charts to vessels of the Navy was about double this year as compared with the last. This was largely due to the fitting out of a number of new vessels.

Percentage of increase of chart issues.—Comparison of the present year with the preceding.

Total:		
Gross issue, July 1, 1888, to June 30, 1889	49,312	
Returned, July 1, 1888, to June 30, 1889	1,573	
Net issue, preceding year		47,739
Gross issue, July 1, 1889, to June 30, 1890	63,151	
Returned, July 1, 1889, to June 30, 1890	1,269	
Net issue, present year		61,882
Increase (30 per cent.)		14,143
Sale agents:		
Gross issue, July 1, 1888, to June 30, 1889	27,677	
Returned, July 1, 1888, to June 30, 1889	1,520	
Net issue, preceding year		26,157
Gross issue, July 1, 1889, to June 30, 1890	32,334	
Returned, July 1, 1889, to June 30, 1890	1,188	
Net issue, present year		31,146
Increase (19 per cent.)		4,989

Seven new charts from copper plates and twenty-one lithographic charts, twenty-eight in all, have been added to the list for issue during the year, as follows:

Title.	Date.	Catalogue No.
ENGRAVED.	1889.	
Core Sound to Bogue Inlet, including Cape Lookout, North Carolina	July 3	147
Montauk Point to New York and Long Island Sound	Nov. 13	52
Bogue Inlet to Old Topsail Inlet, North Carolina	Dec. 16	148
	1890.	
Old Topsail Inlet to Cape Fear, North Carolina	Jan. 28	149
Wall Creek to Cedar Keys, Florida	Feb. 3	179
San Diego to Santa Monica, California, including the Gulf of San Catalina	Mar. 31	671
Delaware River, Cross Ledge to Penn's Neck, New Jersey and Delaware	May 27	125
PHOTOLITHOGRAPHED.	1889.	
Calcasieu Pass, Louisiana	July 9	518
Mobile River, Alabama	July 19	491[4]
Mobile River, Alabama	July 19	491[5]
Mobile River, Alabama	July 19	491[7]
Norfolk Harbor, Virginia	Aug. 19	404
Thomas, Farragut, and Portage Bays, Frederick Sound, Alaska	Aug. 20	733
Nantucket Harbor, Massachusetts	Oct. 11	343
New York Entrance, New York	Oct. 11	120a
Eastern Passage, Narragansett Bay, Rhode Island	Oct. 31	353[4]
Vineyard Haven, Massachusetts	Nov. 9	347
Big Marco Pass to San Carlos Bay, Florida	Dec. 2	174
Cape Mendocino and vicinity, California	Dec. 3	695
Cape Flattery, Washington	Dec. 4	645
Seminole Point to Big Marco Pass, Florida	Dec. 7	173
Key West to Tampa Bay, Florida	Dec. 27	16
Harbors of Southport, Black Rock, and Bridgeport, Connecticut	Dec. 30	363
Point Arena, California	Dec. 30	661
	1890.	
Manursing Island to Stamford Light, New York and Connecticut	Jan. 21	361[7]
Cape Sable to Seminole Point, Florida	Jan. 24	172
General chart of Alaska	Mar. 7	900
Raritan River, from Raritan Bay to New Brunswick, New Jersey	May 24	375

During the winter and early spring the text of a new catalogue was prepared. It is now in the hands of the Public Printer. It is to be hoped that it will soon be published, as the last edition is overburdened with corrections and the supply is low.

The following table will show the receipts, issues, and general distribution of charts during the year:

Issues.	July 1, 1889, to June 30, 1890.	
	Number.	Value.
Sales agents	32, 335	$13, 777. 70
Sales by Office and Chart Division	705	279. 30
Congressional account	3, 266	1, 476. 80
Hydrographic Office, Navy	12, 584	5, 010. 15
Light House Board	2, 563	977. 65
Coast and Geodetic Survey Office	3, 048	1, 260. 45
Executive Departments	3, 746	1, 439. 00
Foreign Governments	1, 120	439. 70
Miscellaneous	3, 785	1, 517. 35
Totals	63, 152	26, 178. 10
Condemned	1, 717	665. 80
Total issue, including the number condemned	64, 869	26, 843. 90

Charts on hand and received from July 1, 1889, *to June* 30, 1890.

	Number.	Value.
On hand by inventory July 1, 1889	45, 067	$15, 049. 35
Received July 1, 1889, to June 30, 1890 (plate)	45, 440	19, 248. 55
Received July 1, 1889, to June 30, 1890 (stone)	18, 287	8, 032. 95
Returned	1, 269	501. 35
Total on hand and received to June 30, 1890	110, 063	42, 832. 20
Total issued and condemned June 30, 1890	64, 869	26, 843. 90
On hand by book July 1, 1890	45, 194	15, 988. 30
Difference between book and count	38	22. 30
On hand by count July 1, 1890	45, 156	15, 966. 00

Respectfully yours,

GERSHOM BRADFORD,
Assistant, U. S. Coast and Geodetic Survey,
In charge of the Chart Division.

Mr. B. A. COLONNA,
Assistant in charge of Office and Topography

REPORT OF THE ARCHIVES AND LIBRARY DIVISION, U. S. COAST AND GEODETIC SURVEY OFFICE, FOR THE FISCAL YEAR ENDING JUNE 30, 1890.

LIBRARY AND ARCHIVES DIVISION,
September 30, 1890.

SIR: I submit herewith a report of the receipt and registry in the Archives of the original and duplicate records, computations, and specimens of sea bottom during the fiscal year ending June 30, 1890, as enumerated in detail in tables prepared for file with the Office records, and also of the books and pamphlets received in the Library during the same time. A tabular statement by register number and title of the topographic and hydrographic sheets registered during the year accompanies this report.

Topographic and hydrographic sheets registered in the Archives of the Coast and Geodetic Survey during the fiscal year ending June 30, 1890.

TOPOGRAPHIC WORK.

Register No.	Titles of topographic sheets.	Descriptive reports.	No. of sheets.
1545	New Jersey shore of Delaware River from Old Man's Creek to the outskirts of Penngrove, N. J.		1
1566	Country between Milford and West Haven, Conn.		1
1570	Shore line of the western part of Gardiner's Bay between Acobomack Harbor and Cedar Island Point, Long Island, New York		1
1571	Shore line of the southern part of Shelter Island, New York		1
1572	Shore line of Shelter Island, New York		1
1579	Kill van Kull and east shore of Bergen Neck, New Jersey		1
1595	From Shuman's Cañon to Santa Maria River and vicinity, including Point Sal, north of Point Conception, California		1
1607	Vicinity of Barataria Bay, Louisiana		1
1610	East side of Mississippi River, vicinity of Baton Rouge, La.		1
1612	Vicinity of West Baton Rouge, La.		1
1613	Mississippi River below Baton Rouge, La		1
1614	San Francisco Bay and Approaches. Sheet No. 4: Ballenas southward to Rocky Point, roads, improvements, life saving station, etc., California		1
1616	San Francisco Bay and Approaches. Sheet No. 2: Interior of Tamalpais Peninsula, head of Richardson's Bay, toward San Rafael, etc., California		1
1617	San Francisco Bay and Approaches. Sheet No. 3: Interior of Tamalpais Peninsula, Ballenas, Sausalito, and Point Bonita Roads, etc., California		1
1618	San Francisco Bay and Approaches. Sheet No. 1: Point Bonita to Sausalito, including part of Richardson Bay and Angel Island, California		1
1620	San Francisco Bay and Approaches. Sheet No. 5: San Rafael and San Quentin, including landings, roads, and railroads, California		1
1621	San Francisco Bay and Approaches. Sheet No. 7: Contra Costa shore, including wharves, roads, and railroads, California		1
1625	San Francisco Bay and Approaches. Sheet No. 8: Oakland and Alameda, Cal		1
1629	San Francisco Bay and Approaches. Sheet No. 9: Point San José to Point Avisadero, San Francisco Peninsula California		1
1650	Indian River from the Inlet southward, east coast of Florida, Florida		1
1664	Coast of Maine from Schooner Brook to Moose River, Maine		1
1684	Southwest Pass and Entrance to Vermilion Bay, Louisiana		1
1685	Entrance from Vermilion Bay to Vermilion River, Louisiana		1
1687	Wicke's Bay and east shore of Vermilion Bay, Louisiana		1
1694	Continuation of Petite Anse Bayou, Louisiana		1
1704	Shore line from Nauset Harbor southward, Massachusetts		1
1706	Shore line of the northern part of Monomoy Island, Massachusetts		1
1712	Head of Raritan Bay, including the mouths of Raritan River and Arthur Kill, New York		1
1726	North shore of Long Island, from Mount Misery to Rocky Point Landing, New York		1
1732	Eaton's Neck and adjacent shores, Long Island, New York		1
1734	North shore of Fisher's Island Sound, Connecticut		1
1736	North shore of Long Island Sound, Westerly and vicinity, Rhode Island		1
1755	Port Susan and Stillaguamish River, Washington		1
1765	From Grand Pass Timballier to Bayou Moreau, Louisiana	1	1
1766	From Bayou Moreau to Caminada Bay, Louisiana	1	1
1779	Country between Milford and New Haven, Conn		1
1805	South shore of Cobscook Bay, Maine	1	1
1833	Plan showing the boundary lines in tide-water of the cities and towns bordering on the sea in Bristol, Dukes, Nantucket, and part of Barnstable and Plymouth Counties, Massachusetts		1
1837	West coast of Florida, Rabbit Key to Pavilion Key, Florida	1	1
1849	South shore of Long Island, Breslau to Ridgewood, N. Y.		1
1850	South shore of Long Island, Ridgewood to Baldwin, N. Y.		1
1852	Schuylkill River, from Gray's Ferry Bridge to Fairmount Dam, Pennsylvania		1
1865	Subplan No. 6, showing the boundary lines in tide-water of a portion of the cities and towns in Essex County, Mass		1
1866	Plan No. 7 and subplan No. 5, showing the boundary lines in tide-water of a portion of the cities and towns in Barnstable, Plymouth, Norfolk, Suffolk, and Essex Counties, Mass		1
1867	Plan No. 8, showing the boundary lines in tide-water of a portion of the cities and towns in Suffolk and Essex Counties, Mass		1
1868	Plan No. 10, showing the boundary lines in tide-water of a portion of the cities and towns in Essex County, Mass		1
1892	Resurvey of Suisun Bay, Sheet No. 4, California		1

Topographic and hydrographic sheets registered in the Archives of the Coast and Geodetic Survey during the fiscal year ending June 30, 1890—Continued.

TOPOGRAPHIC WORK.

Register No.	Titles of topographic sheets.	Descriptive reports.	No. of sheets.
1893	Resurvey of Suisun Bay, including parts of Montezuma Creek, California	....	1
1894	Scarborough Hill and the hill crests near Point Ellice, Washington	....	1
1895	Bayou Grande, a tributary of Pensacola Bay, Florida	1	1
1896	South coast of California, from Faucher Ranch to Prewett Creek, California	1	1
1903	West coast of Florida, from Northwest Cape △n Point to Shark Point, Florida	....	1
1904	West coast of Florida, from Shark Point to Porpoise Point, Florida	....	1
1927	Schuylkill River, from League Island to Gray's Ferry Bridge, Pennsylvania	....	1
1933	North Lubec: part of Seward's Neck, south side of Entrance to Cobscook Bay, Maine	....	1
1934	Water Front of the city of Philadelphia from Bridge street to Erie avenue, Pennsylvania	....	1
1935	Porcupine Hills, West Lubec to Lilly Lake and Trescott's Rock, Maine	....	1
1936	Norfolk Harbor: Addition to wharf line and part of line of Norfolk and Western Railroad, Virginia	....	1
1941	Proposed site for a Navy-yard at Port Orchard, Wash	....	1
1948	Topographical map of the District of Columbia	....	1
1950	Illiouliouk Harbor, Unalaska Island, Alaska	....	1
1951	Proposed site for a Navy yard at Port Orchard, Wash	....	1
1952	Washington Sound, part of Orcas and Blakeley Islands, Washington	1	1
1953	Washington Sound, Thatcher Pass to Watmough Bight, Washington	1	1
1954	Washington Sound, part of Orcas Island, Washington	1	1
1955	Washington Sound, northeast of Lopez Island, Washington	1	1
1956	Delaware River, near Philadelphia, Cooper's Point to Petty's Island, Pennsylvania	....	1
1957	Water Front of Philadelphia, Dickinson street to Poplar street, Pennsylvania	....	1
1958	Norfolk Harbor: New wharves and changes in old wharves, Virginia	....	1
1959	Tubbs Inlet, North Carolina	....	1
1970	Coos Bay, Sheet No. 2, Oregon	1	1
1971	Coos Bay, Sheet No. 1, Oregon	1	1
	Total	12	72

HYDROGRAPHIC WORK.

Register No.	Titles of hydrographic sheets.	Descriptive reports.	No. of sheets.
1831	Coast of Louisiana, Ship Shoal Light to Marsh Island, Louisiana	1	1
1874	Chesapeake Entrance, Old Plantation Shoal to Cape Henry, Virginia	1	1
1877	Nantucket Harbor, Massachusetts	....	1
1879	Muskeget Channel, Massachusetts	....	1
1884	Saratoga Passage, Washington	1	1
1885	Saratoga Passage to Skagit Bay, Washington	1	1
1886	Northwest coast of Whidbey Island, Washington	1	1
1887	Bellingham Bay, Washington	1	1
1891	Portland Canal and vicinity, southeast Alaska	....	1
1892	Harbors, Portland Canal and vicinity, southeast Alaska	....	1
1893	Head of Portland Canal, Bear and Salmon River Flats, southeast Alaska	....	1
1894	Willard Inlet, southeast Alaska	....	1
1895	Harbors in Portland Canal and vicinity, southeast Alaska	....	1
1896	Willard Inlet, southeast Alaska	....	1
1897	Northern part of Stephens Passage, southeast Alaska	....	1
1898	Harbors of northern part of Stephens Passage, southeast Alaska	....	1
1899	Portland Inlet and vicinity, southeast Alaska	....	1
1900	Portland Canal, southeast Alaska	....	1
1905	Coast of California, from Sand Ridge △ to Leucadia △, California	....	1
1906	Coast of California, from Leucadia △ to Barranca Bluff △, California	....	1
1907	Coast of California, from Barranca Bluff △ to Dana △, California	....	1
1919	Northern part of Stephens Passage, southeast Alaska	....	1
1920	Northern part of Stephens Passage, southeast Alaska	....	1
1921	Port Snettisham, southeast Alaska	....	1
1922	Taku Harbor, southeast Alaska	....	1
1923	Limestone Inlet, southeast Alaska	....	1

Topographic and hydrographic sheets registered in the Archives of the Coast and Geodetic Survey during the fiscal year ending June 30, 1890—Continued.

HYDROGRAPHIC WORK—Continued.

Register No.	Titles of hydrographic sheets.	Descriptive reports.	No. of sheets.
1924	Oliver Inlet, southeast Alaska		1
1925	Examination of bar of Northwest Channel, Key West Harbor, Florida	1	1
1926	Big Spanish and Knight Key Channels and approaches, Florida Reefs, Florida	1	1
1927	Florida Bay, from Upper Matecumbe Key to Vaca Keys and Cape Sable, Florida	1	1
1928	From Cedar Keys to Steinhatchee River, Florida	1	1
1929	From Steinhatchee River to Dog Island, Florida	1	1
1930	Columbia River from Tansy Point to Tongue Point, Oregon		1
1931	Parts of Young's River and Lewis and Clark River, Oregon		1
1932	Escambia Bay, Florida, proposed site of Navy-yard, Florida	1	1
1933	Approaches to Atchafalaya Bay, Louisiana		1
1934	Coast of California, Rocky Point to Upper Bluff, California		1
1935	Extension of above sheet, California		1
1936	Coast of California, Upper Bluff to False Klamath Rock, California		1
1937	Coast of California, extension of sheet No. 1936, California		1
1938	Eastern Passage, Narragansett Bay, showing measured mile for Naval Trial Course, Rhode Island		1
1939	Mouth of Schuylkill River and docks of Delaware River from Gloucester to Cooper's Point		1
1940	Docks of Delaware River from Cooper's Point to east end of Petty's Island		1
1941	Hydrography off Martha's Vineyard and Nantucket, Massachusetts	1	1
1942	Southern coast of Nantucket, Tuckernuck Island to Miacomet Rip, Massachusetts	1	1
1943	Schuylkill River, Pennsylvania, from League Island to Gray's Ferry Bridge		1
1944	Schuylkill River, Pennsylvania, from Gray's Ferry Bridge to Fairmount Dam		1
1945	Pacific Coast from Cook's Point to Euchre Creek, Oregon	1	1
1946	Pacific Coast from Euchre Creek to Cape Orford, Oregon	1	1
1947	Nantucket Sound, Maddequet Harbor, and Tuckernuck, Edwards, Shovelful, Long, and Hawe's Shoals, Massachusetts	1	1
1948	Nantucket Sound from Monomoy Island to Point Gammon, Massachusetts	1	1
1949	Chatham Roads and Stage Harbor, Massachusetts	1	1
1951	Cross-sections north and east shore of Cape Cod, Highland Light to Peaked Hill Life-Saving Station, Massachusetts		1
1952	Cross-sections, north and west shore, Cape Cod, Peaked Hill Life-Saving station to Long Point Lights, Massachusetts		1
1953	Rosario Strait, Washington		1
1954	Semi-ah-moo Bay, Washington		1
1956	Soundings between Key West, Florida, and Havana, Cuba		1
1957	Cross-sections of lines across the Gulf Stream		1
1958	Cross-sections of lines across the Gulf Stream		1
1959	Cross-sections of lines across the Gulf Stream		1
1960	Comparative map of Boston Harbor, Massachusetts		1
1961	Boston Harbor, reduced from the survey of Lieut. A. S. Wadsworth, U. S. Navy, in 1817, to scale of 1-20000		1
1962	Comparative chart of dumping ground and bulkhead of west bank channel, New York Lower Bay, New York		1
1963	Investigations of the oyster beds off Onancock Creek, and in the neighboring creeks, Virginia		1
1964	Investigations of the oyster beds off Pungoteague Creek, Virginia		1
1965	Inshore soundings off the Delta of the Mississippi		1
1966	Examination of Tartar Shoal, Mexico, west coast		1
1982	Physical Hydrography, Delaware River, Pennsylvania		1
1983	Physical Hydrography, Delaware River, Pennsylvania		1
1984	Physical Hydrography, Delaware River, Pennsylvania		1
1985	Dynamic chart of the Delaware River, No. 1, Pennsylvania		1
1986	Dynamic chart of the Delaware River, No. 2, Pennsylvania		1
1987	Dynamic chart of the Delaware River, No. 3, Pennsylvania		1
1988	Dynamic chart of the Delaware River, No. 4, Pennsylvania		1
1994	Wallabout Bay, East River, New York	1	1
1995	Pacific Coast, examination for reported rocks off Haystack Rock and Cape Lookout, Oregon		1
2004	Examination of reported dangerous rock off Easby's Point, Potomac River, District of Columbia		1
2005	Vicinity of Ellis Island, New York Harbor, New York		1
		20	79

It appears from the tabular statements preceding, and those filed with the office records, that there have been registered in the Archives during the fiscal year ending June 30, 1890:

Geodetic observations	volumes	515
Geodetic observations	cahiers	6
Geodetic computations	cahiers	157
Astronomical observations	volumes	74
Astronomical observations	cahiers	2
Astronomical computations	volumes	4
Astronomical computations	cahiers	78
Chronograph sheets		191
Magnetic observations	volumes	4
Magnetic observations	cahiers	33
Magnetic observations	sheets	10
Magnetic computations	volumes	7
Magnetic traces	sheets	527
Pendulum observations	volumes	2
Pendulum computations	cahiers	10
Chronograph sheets		13
Meteorological observations	cahiers	2
Hydrographic observations	volumes	747
Hydrographic observations	cahiers	3
Hydrographic observations	rolls	4
Hydrographic observations	packages	2
Hydrographic observations	sheets	13
Maregrams	rolls	63
Specimens of sea-bottom	bottles	183
Log-books	volumes	45
Completed hydrographic sheets		79
Descriptive reports on hydrographic sheets		20
Completed topographic sheets		72
Descriptive reports on topographic sheets		12

Twenty-six volumes of computations were bound during the fiscal year. A great mass of valuable records and computations still remain unbound which ought to have been bound long ago for their preservation and for convenience of reference and use. I have repeatedly in my annual reports called attention to their condition, and I would once more urge the importance of prompt action, so that these records and computations may be bound, re-arranged by States, and catalogued.

During the fiscal year ending June 30, 1890, there were received in the library 334 volumes of bound books, and 115 volumes of unbound books, besides pamphlets and the usual periodicals and publications of scientific societies. These figures include duplicates and the various Nautical Almanacs.

Two hundred and eighty volumes have been bound at the Government bindery for the library during the fiscal year.

Mr. J. M. Duesberry has been employed in this Division as clerk throughout the fiscal year.

Mr. Archie Upperman was assigned temporarily to this Division June 12, 1890, and assisted in clerical work during the remainder of the fiscal year.

Respectfully, yours,

ARTEMAS MARTIN,
Librarian, in charge of Library and Archives Division.

Mr. B. A. COLONNA,
Assistant in charge of Office and Topography.

APPENDIX No. 5.—1890.

REPORT OF THE HYDROGRAPHIC INSPECTOR FOR THE FISCAL YEAR ENDING JUNE 30, 1890.

U. S. COAST AND GEODETIC SURVEY,
OFFICE OF THE HYDROGRAPHIC INSPECTOR,
Washington, D. C., July 1, 1890.

SIR: I have the honor to submit the following report of the hydrographic work executed in the field, the routine office duties, repairs of vessels, and tables showing the number of naval officers and enlisted men attached to the several vessels of the Survey during the fiscal year ending June 30, 1890.

July 1, 1889, I relieved Lieut. Commander W. H. Brownson, U. S. N., as Hydrographic Inspector to the U. S. Coast and Geodetic Survey, and it gives me pleasure to state that I found the vessels of the Survey in as good condition as could be possibly expected, taking into consideration the limited appropriation for repairs, the parties in the field thoroughly organized, and the routine of the office so admirably arranged and systematized that it was a comparatively easy matter for me to continue the work as mapped out by my able predecessor; consequently no radical changes in the method of conducting the business of this office have been found necessary.

The following is a general summary of the hydrography carried on during the fiscal year just closed:

ATLANTIC COAST.

Approaches to Nantucket Sound.—This work was commenced July 11, 1889, by the steamer *Bache* and party, under the command of Lieut. J. F. Moser, U. S. N., and the season ended October 31, 1889, when the *Bache* proceeded to Baltimore, Md., for the purpose of having some slight repairs made previous to the winter's work in the vicinity of the Florida Keys.

Nantucket Sound.—The continuation of this survey was in progress at the beginning of the fiscal year by the schooner *Eagre*, the steamer *Daisy*, and three steam launches, and party, under the command of Lieut. William P. Elliott, U. S. N. The season closed October 19, when the vessels, launches, and party returned to the U. S. Navy Yard Brooklyn, N. Y. Upon the conclusion of the office work in preparing the several projection sheets and records for transmission to the Superintendent, it became necessary to break up the party under the command of Lieutenant Elliott, and distribute the officers among other vessels in order to fill vacancies and keep the field parties up to their full strength.

Coast of Massachusetts.—Vicinity of Cape Cod. Inshore hydrography by Assistant H. L. Marindin, Coast and Geodetic Survey.

Pennsylvania.—Water front of the city of Philadelphia, Schuylkill River. Hydrography by Assistant J. Hergesheimer, Coast and Geodetic Survey.

GULF COAST.

West coast of Florida.—The *Bache*, after receiving slight repairs, left Baltimore, Md., January 1, 1890, under command of Lieut. J. F. Moser, U. S. N., and commenced work January 24 on the west coast from Punta Rasa to Cape Sable, in Florida Bay, Barnes' Sound, and Card's Sound; also Florida Keys from Big Pine Key to Key West. The season closed May 17, 1890, and the hydrography of the Florida Keys was completed.

The Survey is to be congratulated that this important and intricate piece of work was wholly executed under the immediate supervision of Lieutenant Moser during the four consecutive seasons of 1887 to 1890 inclusive, and I do not hesitate to say that this hydrography, like all the rest performed by Lieutenant Moser, has never been surpassed and seldom equaled by any other hydrographic party.

West coast of Florida.—Cape Romano to Shark River. Inshore hydrography by Assistant J. Hergesheimer, Coast and Geodetic Survey.

Florida—Pensacola Bay.—The hydrography of Bayous Grande, Chico, and Texar was finished by Subassistant P. A. Welker, Coast and Geodetic Survey, for the use of the Gulf Coast Navy Yard Site Commission, Commodore William P. McCann, U. S. N., president.

West coast of Florida and Alabama.—Perdido Bay.—Hydrography by Assistant Stehman Forney, Coast and Geodetic Survey.

Coast of Louisiana.—The continuation of the hydrography between Terre Bonne Bay and Ship Shoal was commenced December 16, 1889, by the steamer *Endeavor*, and party, under the command of Lieut. A. L. Hall, U. S. N., and the season ended May 15, 1890. Owing to unfavorable weather the quantity of work accomplished was much less than anticipated, but I am happy to state that the quality of the work proved to be excellent when plotted and verified.

PACIFIC COAST.

Coast of California.—The beginning of the fiscal year found the steamer *Hassler* and party, under the command of Lieut. D. Delehanty, U. S. N., at work off the coast in the vicinity of Crescent City. The projections furnished to this party were completed to the 100-fathoms curve in accordance with instructions, and the season ended July 30, 1889. Then the party proceeded to the vicinity of Cape Lookout to search for reported rocks, returning to San Francisco August 19, and then commencing the preparation of the projection sheets and records for transmission to you.

November 25, 1889, the *Hassler* left San Francisco, sailing to the southward, and on the 27th began work off the coast in the vicinity of Cox's Hole and Cambria. Work was suspended December 19, 1889, on account of continuous bad weather, and the *Hassler* returned to San Francisco. She left port again February 12, 1890, for the field, and resumed the survey on the 14th. The season closed March 27, when Lieutenant Delehanty returned to San Francisco with the vessel and party under his command for the completion of the office work and records. The two seasons were highly successful, and the results, both in quantity and quality, were consistent with the reputation of the competent and energetic chief of party.

San Francisco Bay and tributaries.—Owing to the long and unexpected delay in the completion of the new boiler for the steamer *McArthur* at the U. S. Navy Yard, Mare Island, Cal., that vessel, under the command of Lieut. Dennis H. Mahan, U. S. N., was unable to commence the resurvey of Suisun Bay and vicinity until April 1 of the present year. The work assigned to the party under Lieutenant Mahan was somewhat in the nature of patchwork, being a resurvey of portions of the work done during the winter of 1886–1887 in the vicinity of Suisun Bay and near the mouth of the Sacramento River, much of the previous hydrography being found erroneous and impossible to plot. This duty was completed on the last day of the fiscal year, as announced by telegram.

Coast of Oregon.—The opening of the fiscal year found the steamer *Gedney* and party, under the command of Lieut. J. M. Helm, U. S. N., at work off the coast from Cape Blanco to Crook's Point, the season having commenced May 28, 1889, of the previous fiscal year, and ended September 11, 1889. The results of this survey are thoroughly satisfactory in every respect.

Lieutenant Helm had served a tour of duty under the Coast Survey previous to his present detail, and it gives me pleasure to add that he ranks among the very best of hydrographers.

Owing to the exhaustion of party funds it was impossible to employ the *Gedney* during the remainder of the past fiscal year, so advantage was taken of this opportunity by docking the vessel, thoroughly overhauling the hull fastening, and making other repairs much needed.

Interior waters of Washington.—Lieut. J. N. Jordan, U. S. N., assumed command of the schooner *Earnest* June 15, 1889, relieving Lieut. H. T. Mayo, U. S. N., who had commenced field work in the vicinity of Rosario Strait, on May 20, 1889, so that the beginning of the fiscal year 1889-1890 found the season well advanced, and the hydrography was most satisfactorily continued into

Semiahmoo Bay and Gulf of Georgia, under Lieutenant Jordan, until November 2, 1889, when the *Earnest* and party returned to Port Townsend, Wash., and commenced the preparation of records for transmission to the Superintendent. The results as plotted and verified in the office are all that could be desired.

April 19, 1890, Lieutenant Jordan and party in the *Earnest* commenced their second season in Skagit Bay, Puget Sound, and are so employed at the present time.

Washington—Puget Sound.—The hydrography in the vicinity of Port Orchard was executed by Assistant J. F. Pratt, Coast and Geodetic Survey, for the use of the Pacific Coast Navy Yard Site Commission, Capt. A. T. Mahan, U. S. N., president.

Southeast Alaska.—The long season in Alaska is continuous, covering portions of two fiscal years, generally beginning early in May and closing the latter part of September; so July 1, 1889, found the *Patterson* and party, under the command of Lieut. H. B. Mansfield, U. S. N., with the small steamer *Cosmos* as tender, at work in the vicinity of Stephens Passage and Frederick Sound. The season closed September 29, 1889, and the *Patterson* returned to San Francisco on October 16 following. The preparation of the phenomenal amount of work accomplished by the party under Lieutenant Mansfield occupied the time from the date of his return to San Francisco until April 10, 1890, the date of his again sailing for Alaska. His sheets and data have already been submitted to you, and from them it will be seen that the quality of the results is only equalled by the quantity, and I am satisfied that the record of general work done has never been exceeded by any party, at any time, under the Coast Survey.

It gives me pleasure to state that Lieutenant Mansfield received his well-deserved promotion to the grade of Lieutenant-Commander on January 3, 1890, so that when the *Patterson* left San Francisco, April 10, 1890, her commanding officer held the higher rank. The working ground was reached May 6, and covers the vicinity of Lynn Canal, Chatham Strait, Saginaw and Gastineau Channels, and Taku Inlet, thus completing the survey of the extreme northern and interior waters of southeast Alaska. The *Patterson's* party was still engaged on this work at the close of the fiscal year just ended.

By your permission, Lieutenant-Commander Mansfield gave passage from San Francisco, Cal., to Juneau, Alaska, to an exploring party of five persons, under the charge of Mr. E. H. Wells, for the purpose of making a reconnoissance of the interior of Alaska in the vicinity of the Copper River, with the intention of following it from its source to its mouth. This party will rejoin the *Patterson* at Juneau about the middle of next September, for transportation to San Francisco.

INVESTIGATION OF THE GULF STREAM.

Lieut. J. E. Pillsbury, U. S. N., commanding the steamer *Blake*, left Hampton Roads November 18, 1889, with Lieut. C. E. Vreeland, U. S. N., as his prospective relief, for the continuation of the investigation of the Gulf Stream in the Gulf of Mexico, and in order that Lieutenant Vreeland might have the benefit of his predecessor's personal experience and instruction in the method of conducting this important work. On December 12, 1889, Lieutenant Vreeland relieved Lieutenant Pillsbury of the command of the *Blake*, the latter officer returning to the Washington Office for the purpose of obtaining data from the archives, and for the preparation and compiling of his exhaustive report upon the Gulf Stream, derived from his five years' experience on this work, the results of which will surely be of immense benefit to navigation, and of great interest to the scientific world. At the end of the fiscal year Lieutenant Pillsbury is still engaged upon his report, which he hopes to conclude by the latter part of next October.

Lieutenant Vreeland occupied about thirty stations in the Gulf of Mexico, successfully continuing the investigation so ingeniously inaugurated by his predecessor, closing the season in time to reach Hampton Roads by April 9, 1890.

SPECIAL EXAMINATIONS AND SEARCH FOR REPORTED DANGERS.

The following is a summary of the work executed by the several vessels of the Survey under the above heading:

Steamer Bache, Lieut. J. F. Moser, U. S. N., commanding.—On returning from the completion of the survey of the Florida Keys to Baltimore, Md., this officer was directed to stop at St.

Simon's Sound, Georgia, and make an examination of the bar near the entrance to Brunswick, Ga., for a reported increase in the depth of water. He was engaged upon this work May 16 and 17, and found a very slight increase over that previously indicated on Coast Survey charts, which have since been corrected in accordance with this examination.

Schooner Eagre, Lieut. Wm. P. Elliott, U. S. N., commanding.—After the conclusion of the season's work in Nantucket Sound, and while lying at the U. S. Navy Yard, Brooklyn, N. Y., Lieutenant Elliott, with one of the steam launches belonging to the *Eagre*, assisted by Ensign E. A. Anderson, U. S. N., temporarily detached from the Coast Pilot Division of this office, made a close hydrogragraphic survey of Wallabout Channel. This work was done by your instructions between January 15 and February 7, 1890, in response to a request from the Honorable Secretary of the Navy, for the purpose of accurately developing the channel previous to commencing much needed dredging.

A shoal spot, with only 17 feet of water over it, having been reported to exist outside of the 4-fathom curve to the southward of the Battery, New York City, by a witness before an admiralty court in a collision case, Lieutenant Elliott, under instructions from yourself, was directed to make a thorough examination of the locality specified; and, between the dates March 20 and April 2, whenever the weather would permit, a minute search was made; the lines of soundings were run as close together as possible, crossed and recrossed, the result being that the reported shoal or ledge was proved to be a myth. This examination, however, showed that the 4-fathom curve had extended out slightly from the Battery since the last survey was made, and Lieutenant Elliott was therefore directed by you to develop the changes in this curve from Pier No. 1, North River, to Coenties Slip, East River. This work was executed between May 22–27, and the charts of New York Harbor have been corrected accordingly.

Ellis Island having been designated as the new immigrant landing station, the Honorable Secretary of the Treasury made a request to you for a resurvey of the waters immediately surrounding the island in order that the bottom might be accurately developed previous to building wharves out to deep water. This work was executed by Lieutenant Elliott between April 16–21, and in its prosecution he was assisted by Ensign Anderson, who was again temporarily detached from the Office for this duty.

Steamer Endeavor, Lieut. Commander S. M. Ackley, U. S. N., commanding.—June 20, 1890, made an examination for a reported shoal off Wolf Trap Spit, Chesapeake Bay; found and developed shoal, and correction on charts will be made when next printed.

A sunken rock, not charted, having been reported off Easby Point, Potomac River, opposite the city of Washington, Assistant H. L. Marindin, Coast and Geodetic Survey, was detailed by the Superintendent to make an examination for the reported danger. The rock was found with 9 feet of water over it, and the charts affected have been corrected accordingly.

Steamer Endeavor, Lieut. A. L. Hall, U. S. N., commanding.—A 9-foot shoal having been reported off the northern end of Key Biscayne, east coast of Florida, caused by the grounding of a vessel laden with barrels of cement, many of which were thrown overboard in order to lighten her, Lieutenant Hall was directed to examine the shoal while making passage from the coast of Louisiana to Washington, D. C. This investigation was made May 31 and June 1, and the result showed the least depth of water to be 12 feet. The correction has been made upon the charts affected.

Steamer Hassler, Lieut. D. Delehanty U. S. N., commanding.—August 14–16, 1889, inclusive, searched for reported rocks off Cape Lookout, Oregon, without success. This examination having been very thorough, carried on both by sounding and sweeping, Lieutenant Delehanty came to the conclusion that the reported dangers do not exist in the locality designated.

SPECIAL WORK.

The Honorable Secretary of the Navy having requested the Superintendent of the Coast and Geodetic Survey to lay off a measured mile course in Narragansett Bay, also a 40-mile course to the southward of Long Island in not less than 20 fathoms of water, and a similar course on the Pacific coast for the speed trials of United States vessels of war, this important work was successfully accomplished as follows, viz:

Steamer Blake, Lieut. J. E. Pillsbury, U. S. N. commanding.—July 2–24, 1889, a course of one nautical mile was laid off in Narragansett Bay, between Conanicut Island and Rose Island, with range signals, the northern range being on the former island, the southern range on the latter, and the course range on the land in the vicinity of Fort Adams. Valuable current observations were also made by Lieutenant Pillsbury.

Chart No. 353[4], showing this course, has been published by the U. S. Coast and Geodetic Survey for the benefit of naval vessels.

Steamer Blake, Lieut. C. E. Vreeland, U. S. N. commanding.—May 17 to June 10, 1890, a course of 40 nautical miles was laid off in not less than 20 fathoms of water to the southward of Long Island, N. Y., and Block Island, R. I., with large range signals, the western range being on Long Island in the vicinity of Shinnecock Light-House and the eastern range on Block Island.

For the 40-mile course on the Pacific Coast the vicinity of Santa Barbara, Cal., has been determined upon, and Lieut. D. Delehanty, U. S. N., commanding steamer *Hassler*, has been selected by you to perform this responsible duty. He will commence operations in about two weeks, when his preparations are completed at San Francisco, Cal.

It gives me pleasure to state that the Navy Department has officially expressed its satisfaction with the two courses measured on the Atlantic Coast, both having been satisfactorily tested, and when the one on the Pacific Coast is completed I am confident it will give equal satisfaction.

The Hon. John B. Gordon, Governor of Georgia, having requested that an examination be made of the oyster beds of that State, this important work was delegated to Ensign J. C. Drake, U. S. N., commanding the schooner *Ready*. From October 1, 1889, to February 28, 1890, Ensign Drake was engaged upon this examination, and his exhaustive report is now being prepared for publication in the form of a special bulletin. This officer's long experience in the examination of the oyster beds of North Carolina rendered him peculiarly well fitted for the supervision of the duty assigned him.

THE COAST PILOT DIVISION.

August 5, 1889, Ensign E. H. Tillman, U. S. N., Chief of the Coast Pilot Division, was detached from duty in the office and ordered to assume command of the steamer *Endeavor* for the purpose of verifying the sailing directions of Chesapeake Bay and tributaries, Part VI. of the Atlantic Coast Pilot. He completed this work September 21, 1889, and resumed his duties in the office. October 31, following, Ensign Tillman, who had been temporarily in charge of the Coast Pilot Division since the detachment of Lieut. George H. Peters, U. S. N., November 25, 1888, was relieved by Lieut. Commander S. M. Ackley, U. S. N., who was specially selected for this responsible position on account of his high standing as a seaman and navigator and his previous experience of more than three years' service under the Coast and Geodetic Survey.

Lieutenant-Commander Ackley has been most efficiently assisted in the labor of compiling the Coast Pilot by Ensign E. A. Anderson, U. S. N., and Mr. John Ross, on permanent duty under this Division.

June 14, 1890, Lieutenant-Commander Ackley was ordered to assume command of the steamer *Endeavor* at the U. S. Navy Yard, Washington, D. C., then to proceed to New Bedford, Mass., for the purpose of making some slight repairs to the boiler and engine of the vessel previous to commencing the verification of the Coast Pilot MSS. of the coast of Maine. In a few days he will leave New Bedford to prosecute the active field work.

The detailed report of the Chief of the Coast Pilot Division will be found annexed to this report.

The Coast Pilot volume of the Atlantic Coast will be subdivided into seven parts, and the following shows the limits embraced in each, with the condition of progress at the end of the fiscal year just closed, viz: Parts I and II.—One volume—Eastport, Me., to Cape Ann, Mass.

The MSS. is completed and is now being verified in the field by Lieut. Commander S. M. Ackley, U. S. N., commanding steamer *Endeavor*. It will be ready for the printer about the last part of next October.

Part III—One volume—Cape Ann, Mass., to Point Judith, R. I. MSS. commenced.

Part IV—One volume—Point Judith, R. I., to New York City, N. Y. [Long Island Sound.] Published June 22, 1889.

Part V—One volume—New York City, N. Y., to Cape Henry, Va. MSS. commenced.

Part VI—One volume—Chesapeake Bay. In the hands of the printer, and it is expected that it will be ready for issue next December.

Part VII—One volume—Cape Henry, Va., to Key West, Fla. Not yet commenced.

Gulf Coast Pilot.—The present intention is to publish this in one volume. Its compilation has not yet been commenced.

Pacific Coast Pilot.—A most exhaustive work under this heading has been prepared by Prof. George Davidson, Assistant Coast and Geodetic Survey, and is now in the hands of the printer. This Coast Pilot will be published in one large volume, and it is expected that it will be ready for issue to the public about the latter part of this month.

Alaska Coast Pilot.—Lieut. Commander H. E. Nichols, U. S. N., was directed, November 14, 1887, by your predecessor, to rewrite the Alaska Coast Pilot, and he has been continuously engaged on this work ever since. I am happy to announce that it is now completed and the MSS. will be received at this office in a few weeks' time. That part of the coast covered by the compilation of Lieutenant Commander Nichols is commonly known as Southeast Alaska, and extends from Dixon Entrance, marking the boundary line between British Columbia and Alaska, northward to Yakutat Bay, embracing all of the interior waters and outside coast line of this remarkable country, far famed for its grand scenery and rugged beauty.

The rapidly increasing commercial importance of Alaska renders it imperative that this volume of the Alaska Coast Pilot should be published at the earliest possible moment for the benefit of navigation.

Lieutenant Commander Nichols having had five years' personal experience in Alaskan waters, commanding the U. S. Coast and Geodetic Survey steamer *Hassler* and the U. S. S. *Pinta*, he was peculiarly adapted and equipped for the work assigned him.

The work covering that portion of Alaska to the northward and westward of Yakutat Bay, including the Aleutian Islands, will be compiled as rapidly as reliable data is obtained, and will be known as Part II. The volume covering southeast Alaska will be Part I.

THE HYDROGRAPHIC DIVISION.

At the beginning of the fiscal year Lieut. M. L. Wood, U. S. N., was in charge of this Division, and it gives me pleasure to call your attention to the untiring industry exhibited by this zealous officer, and to state that he was the originator of many improvements in the details of chart corrections and in preparing for publication the monthly Notices to Mariners. January 14, 1890, Lieutenant Wood was relieved by Lieut. R. T. Jasper, U. S. N., and I am happy to state that the efficiency of the Division has not only been kept up under his able supervision, but has made important advances, its duties being rendered more exacting than ever, owing to the rapidly increasing sale of Coast Survey charts necessitating new editions at short intervals, each proof sheet of a fresh edition requiring close inspection for the verification of hydrography and changes in aids to navigation.

Mr. E. H. Wyvill, the chart corrector, has given thorough satisfaction, and his close attention to duty merits the highest approbation.

It gives me pleasure to follow the example of my predecessors in bringing to your notice the long and faithful services of Messrs. E. Willenbacher, Wm. C. Willenbucher, and F. C. Donn, hydrographic draughtsmen, all of whom are thoroughly efficient, and whose many years' experience in this division has rendered their services simply invaluable.

The detailed report of the Chief of the Hydrographic Division, giving a synopsis from the records of the work done upon the hydrographic sheets, will be found appended.

REPAIRS OF VESSELS.

The following is a general summary of the repairs made upon the several vessels of the Survey during the past fiscal year, viz :

ATLANTIC COAST.

Steamer Blake.—New coupling and bushing for shaft; engines lined up; floor plates renewed; new blow valves, bunker plates, and asbestos covering for boilers; incidental repairs on bridge walls, steam pipe, water gauges, bearing bars, and distiller; windlass engine and galley repaired; spar deck recanvased; new suit of sails; new cutter; vessel docked and bottom cleaned. Amount allowed for repairs, $3,368.

Steamer Bache.—General repairs on main boilers and engines, rudder and steering gear; galley repaired; new chain cable, 45 fathoms; water-closets overhauled; skylights repaired; new planking on spar deck, and same recovered with canvas; new ash chute and fire-room floor plates; new boat falls; new boiler and general repairs on steam launch; vessel docked and bottom cleaned. Amount allowed for repairs, $4,207.16.

Steamer Endeavor.—Vessel docked and bottom re-coppered and new propeller put on; galley repaired; new awnings; incidental repairs to deck, boiler, and engine. Amount allowed for repairs, $1,860.15.

Schooner Eagre.—New mainmast; hull planking repaired; water-closets overhauled; galley, deck pumps, and boats repaired. Amount allowed for repairs, $1,393.55.

Light repairs and painting for the preservation of the following small vessels and boats, viz:

Steamer *Hitchcock*, $44.19; steam launch No. 4, $35.60; schooners *Ready*, $150.00; *Transit*, $272.00; *Spy*, $86.20; *Quick*, $132.79; barge *Beauty*, $30.47; and boats at the U. S. Navy Yard, Brooklyn, N. Y., $44.34. Total, $795.59.

PACIFIC COAST.

Steamer Patterson.—Crank-pin brasses; pillow blocks; lining up engine; calking seams in boiler; check valves; new furnace frames; new covering for steam pipe and cylinders; anchor engine and connecting-rods and new drain pipes; incidental repairs to auxiliary boiler; general repairs on three steam launches; brass steam-heating piping; steam pump and fittings; new galley; water-closets overhauled; boat davits; boats repaired; new flatboat and canoe; gearing to wire sounding reels; vessel docked and bottom cleaned. Amount allowed for repairs, $2,200.

Steamer Hassler.—Piston-rod; shaft; flanges; valves; calking boilers; rudder; calking forecastle and berth decks; windlass and steam capstan; water-closets overhauled; painting hull; vessel docked and bottom cleaned. Amount allowed for repairs, $2,700.

Steamer Gedney.—Calked boiler seams; new injector; repaired condenser; piston and facing rings and main exhaust pipe; new ash-pit doors; brass valve-seats and eccentric straps; bunkers refloored; new smokestack and boat falls for steam launch; steam windlass repaired; hull fastenings renewed; bow strengthened with three iron braces; chain locker and shaft alley cemented; new rudder chains and preventer chains; chain bobstays for bowsprit; jibboom; water-tight bulkhead; water-closets overhauled; new flatboat and boats repaired; vessel docked, bottom re-coppered, and new rudder shoe put on. Amount allowed for repairs, $4,500.

Steamer McArthur.—New boiler; general repairs on main engine; pilot house enlarged; new anchor shields, spars, boat davits, awning stanchions, rigging, and boat falls; steering gear repaired; wardroom bathtub and wash sinks for crew added; water-closets overhauled; galley repaired; new fire hose; ship painted inside and out; three new boats; vessel docked and bottom re-coppered. Amount allowed for repairs, $10,344.12.

Schooner Earnest.—Sheathing main deck; new gig davits and lanyards for lower rigging; new dingey; boats repaired; water-closets overhauled. Amount allowed for repairs, $385.

From the above summary it will be seen that all the vessels of the Survey on active service have been under repairs during the fiscal year, and many of the alterations and improvements and the renewal of worn-out material have been quite extensive. The large amount of work accomplished with a limited appropriation has been rendered possible by utilizing the enlisted force of the ships' mechanics as far as possible, thus economizing greatly on the cost of labor.

New boilers are required for the *Endeavor* and *Daisy* to replace those now in use and which are worn out from the wear and tear of long service. It is hoped that new boilers may be constructed for these vessels during the fiscal year 1890–'91.

NEW VESSELS AND STEAM LAUNCHES NEEDED.

I respectfully call your attention to the necessity of a special appropriation for the construction of a vessel of 1,500 tons displacement, costing about $200,000, for use in northwest Alaska. A vessel for this purpose should be composite built, of the strongest construction, sheathed bow as a protection against ice, great coal endurance, triple expansion engines, and a maximum speed of 12 knots.

With a steamer properly designed for this service an excellent reconnoissance of northwest Alaska could be made in a period of three or four years, locating the principal shoals and dangers and establishing astronomical stations at the most important points, thus adding greatly to our very meagre knowledge of that immense portion of our country, which is rapidly growing in importance, on account of the whaling and sealing industry and mineral discoveries, in an increasing ratio from year to year.

Such a steamer would be available for running lines of deep-sea soundings preparatory to laying submarine cables in the Pacific. If the Coast Survey should be called upon for the work here suggested, there is not a single vessel at its command fitted for such service, of which the greatest requirement would be coal endurance.

A small steamer of 250 tons, costing about $75,000, is necessary for work on the Atlantic coast. A vessel of this size would be economical, and is needed to fill the place of the *Gedney*, which was transferred to the Pacific coast in 1888. As the *Blake* is continuously engaged upon the investigation of the Gulf Stream, the only two steamers available for hydrographic work on the Atlantic and Gulf coasts are the *Bache* and *Endeavor*. A third steamer is undoubtedly required.

A large steam launch of 25 tons, costing about $12,000, is needed for work in Puget and Washington Sounds, in conjunction with the schooner *Earnest*. The launch *Tarry Not*, which has been in use with the *Earnest* for many years past, is completely worn out, is not worth repairing, and is known to be unseaworthy. During the present season, in the northern waters of Washington, the launch *Fuca* has been substituted for the *Tarry Not*, but is unsuitable for the work, and will probably be required in a short time by the topographical party working in Washington.

Five new steam launches are necessary for the following vessels, viz:

	Estimated cost.
One for the *Blake*	$2,500
Two for the *Hassler* (each)	2,500
One for the *Bache*	2,000
One for the *Endeavor*	1,800

HYDROGRAPHIC INSPECTOR'S OFFICE.

The clerical work has been most satisfactorily performed by Mr. J. H. Roeth, and it gives me pleasure to state that I have found his thorough knowledge of the routine duties in connection with the forms of the Coast Survey Office and of the Navy Department invaluable, relieving the Hydrographic Inspector entirely of the drudgery of details.

I have the honor to be yours respectfully,

CHAS. M. THOMAS,
Commander, U. S. N.,
Hydrographic Inspector Coast and Geodetic Survey.

Dr. T. C. MENDENHALL,
Superintendent U. S. Coast and Geodetic Survey.

REPORT OF THE COAST PILOT DIVISION FOR THE FISCAL YEAR ENDING JUNE 30, 1890.

U. S. COAST AND GEODETIC SURVEY STEAMER ENDEAVOR,
New Bedford, Mass., July 1, 1890.

SIR: I have the honor to submit the following report covering the work of the Coast Pilot Division during the fiscal year ending June 30, 1890.

At the beginning of the year the first edition of subdivision 22 of the Atlantic Coast Pilot was in the hands of the printer; it was ready for issue December 19, 1889. The manuscript for U. S. Coast Pilot, Atlantic Coast, Part VI, Chesapeake Bay and tributaries, was sent to the printer September 30, 1889, and the proofs are now being received at long intervals. The manuscript for a new Coast Pilot volume covering the coasts of Maine, New Hampshire, and Massachusetts, from the eastern boundary to Cape Ann, is practically completed; the sailing directions are to be tested and descriptive matter verified as soon as practicable, after which it will be ready for the printer. This volume will include Parts I and II, of the U. S. Coast Pilot, Atlantic Coast; Part I covering the coast from the eastern boundary to Whitehead, and Part II from Whitehead to Cape Ann. It is to be issued separately to meet the demand for a Coast Pilot publication covering the section of the coast included therein, and forms part of the large volume now in preparation, which is designed to embrace the Atlantic coast of the United States.

Much work has been done in the preparation of the volume to cover the Atlantic coast. The data for the coast from the eastern boundary to New York have been collected and the field work completed, excepting the verification of sailing lines on the coast of Maine, and a few special examinations necessitated by the changes which are constantly occurring along the coast. Very little has been done between New York and Chesapeake Bay; some data have been collected, but the field work is still to be done. Some of the data for the coast between Chesapeake Bay and Key West have been collected and put in form, but the field work is yet to be taken up.

Over 2,000 miles were run to verify sailing lines in Chesapeake Bay and descriptions which are incorporated in the Coast Pilot volume in the hands of the printer. See the report of Ensign E. H. Tillman, U. S. N., Assistant Coast and Geodetic Survey, dated September 21, 1889.

I will here call your attention to the very slow progress of the Government Printing Office in getting out Part VI, Atlantic Coast Pilot, Chesapeake Bay and tributaries. The first pages of proofs were received on November 11, 1889; since that date only about one-half of the proof has been received, and at the present rate of progress this work will be more than a year in the printer's hands, which for a small volume of about one hundred and eighty pages seems ridiculous.

Under your instructions dated June 14, 1890, the Coast Pilot party was transferred from the Office to the steamer *Endeavor* for work in the field. On our way thither a shoal near Wolf Trap Spit, in Chesapeake Bay, was developed; the data for this work consist of 9½ miles of sounding lines, 528 soundings, 49 angles, 1 signal built and located.

The party then proceeded to New York and to New Bedford, Mass., stopping at New Haven, Conn., to inquire about the casualty to the schooner *Robert Morgan.* At the end of the fiscal year the *Endeavor* is undergoing repairs at New Bedford, Mass., preparatory to continuing the season's work as directed in your instructions.

Previous to October 1, 1889, the date of his detachment from the Survey, Ensign E. H. Tillman, U. S. N., had charge of the Coast Pilot work; since that date the Division has been under my charge.

Ensign E. A. Anderson, U. S. N, reported for duty in the Division on July, 1889, and has been engaged in general Coast Pilot work, excepting from January 13 to 23, both inclusive, and April 14 to 23, both inclusive, when he was detailed for hydrographic work in New York Harbor under your instructions. Since June 14 he has been engaged in the field work of the party on board the steamer *Endeavor.* He is a most intelligent and conscientious officer in the performance of his duty, and his services are of the greatest value to the Coast Survey.

Mr. John Ross has been employed in the Division, at the Office and in the field, during the entire fiscal year; he has been engaged in revising and compiling data for Coast Pilot volumes and in the routine office work of the Division. His experience in this class of work, combined with a general knowledge of the Atlantic coast of the United States, and his intelligent and willing attention to duty, make his services valuable.

Miss Alice F. Carlisle has been employed during the entire fiscal year as a copyist for the Division at the Office. I can not speak too highly of her industry and the satisfactory manner of doing her work.

I would most urgently call your attention to the necessity of some more systematic and thorough arrangement with the Light-House Department by which this Office can be informed of changes in the aids to navigation. They are constantly being made, and sometimes for months afterwards we have no knowledge of them and consequently our publications and charts on which they should appear are for the time incorrect.

Very respectfully,

S. M. ACKLEY,
Lieutenant-Commander, U. S. N.,
Assistant Coast and Geodetic Survey,
In charge Coast Pilot Division.

Commander C. M. THOMAS, U. S. N.,
Hydrographic Inspector Coast and Geodetic Survey.

REPORT OF HYDROGRAPHIC DIVISION FOR THE FISCAL YEAR ENDING JUNE 30, 1890.

U. S. COAST AND GEODETIC SURVEY OFFICE,
Washington, July 1, 1890.

SIR: I have the honor to submit herewith the report of the work done in the Hydrographic Division during the year ending June 30, 1890.

The Division was in charge of Lieut. M. L. Wood, U. S. N., until January 14, 1890, on which date he was relieved by myself.

The force of draughtsmen in the Division has been the same throughout the year as at the date of the last annual report, viz, Mr. E. Willenbucher, Mr. W. C. Willenbucher, Mr. F. C. Donn, and E. H. Wyvill, the three first named being engaged on the work hereinafter stated, and Mr. Wyvill performing the varied duties pertaining to the office of the Chief of Division. It gives me great pleasure to testify to the zeal, industry, and ability of these draughtsmen, to whom is due, in a great measure, whatever of credit belongs to this Division.

A tabular statement of the work performed during the year in plotting, verifying, and inking original hydrographic sheets, in the verification, revision, and correction of reduced drawings of hydrography,* and in miscellaneous draughting, has been prepared for file with the Office reports in the archives.

A summary of the work upon the original hydrographic sheets is presented in the following table:

Synopsis from the records of the hydrographic sheets plotted and drawn during the fiscal year ending June 30, 1890.

Names of draughtsmen.	Number of—					
	Sheets.	Volumes.	Angles.	Soundings.	Miles.	Deep sea soundings.
E. Willenbucher	16	438	41, 229	221, 986	7, 771½	931
W. C. Willenbucher	25	126	43, 413	168, 278	6, 072¾	....
F. C. Donn	13	88	27, 567	137, 178	4, 045	....
Grand total	54	652	112, 209	527, 442	17, 889¼	931

Very respectfully,

ROBT. T. JASPER,
Lieutenant, U. S. N.,
Assistant U. S. Coast and Geodetic Survey,
Chief of Hydrographic Division.

Commander C. M. THOMAS, U. S. N.,
Hydrographic Inspector U. S. Coast and Geodetic Survey.

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* The number of these drawings verified, revised, or corrected was seventy-nine.

List of Naval Officers attached to the Coast and Geodetic Survey during the fiscal year ending June 30, 1890.

Name.	Date attached.	Date detached.	Remarks.
COMMANDER.			
Charles M. Thomas	*Jan. 10, 1887		Still in service.
LIEUTENANT-COMMANDERS.			
W. H. Brownson	Jan. 29, 1885	July 1, 1889	
H. E. Nichols	Nov. 11, 1887		Still in service.
S. M. Ackley	Oct. 2, 1889		Do.
H. B. Mansfield	May 15, 1888		Do.
LIEUTENANTS.			
J. E. Pillsbury	July 13, 1882		Still in service.
D. Delehanty	Mar. 20, 1889		Do.
J. F. Moser	Jan. 29, 1884		Do.
Robert T. Jasper	Dec. 9, 1889		Do.
D. H. Mahan	Nov. 15, 1888		Do.
E. M. Hughes	June 25, 1890		Do.
Charles E. Vreeland	Oct. 25, 1889		Do.
William P. Elliott	Mar. 19, 1889		Do.
E. J. Dorn	Apr. 1, 1889		Do.
J. M. Helm	Sept. 4, 1888		Do.
M. L. Wood	Apr. 21, 1887	Jan. 14, 1890	
LIEUTENANTS—JUNIOR GRADE.			
Charles A. Gove	Apr. 9, 1888		Still in service.
J. N. Jordan	June 13, 1889		Do.
A. L. Hall	Aug. 21, 1889		Do.
A. N. Wood	Mar. 17, 1887	Apr. 7, 1890	
R. M. Hughes	Jan. 13, 1886	July 17, 1889	
J. H. L. Holcombe	Aug. 4, 1889		Do.
Harry Kimmell	Dec. 18, 1888		Do.
A. G. Rogers	Mar. 7, 1890		Do.
ENSIGNS.			
A. C. Almy	Sept. 16, 1887	Jan. 31, 1890	
L. M. Garrett	May 16, 1888	Oct. 24, 1889	
E. H. Tillman	Dec. 28, 1886	Oct. 31, 1889	
R. O. Bitler	Apr. 29, 1883	Feb. 7, 1890	
H. C. Poundstone	Feb. 5, 1890		Still in service.
J. C. Drake	Apr. 16, 1886	Mar. 13, 1890	
L. S. Van Duzer	July 10, 1888	Aug. 10, 1889	
Franklin Swift	Oct. 20, 1886	July 1, 1889	
John F. Luby	Dec. 14, 1888		Do.
G. W. Brown	July 13, 1888	Sept. 10, 1889	
	Apr. 29, 1890		Do.
E. A. Anderson	Apr. 24, 1888		Do.
F. A. Huntoon	Jan. 14, 1890	Apr. 14, 1890	Deserted.
Harry George	May 2, 1890		Still in service.
A. M. Beecher	Aug. 16, 1886	Jan. 31, 1890	
F. K. Hill	Mar. 31, 1888	Jan. 10, 1890	
J. D. McDonald	Aug. 10, 1886	Jan. 9, 1890	
ENSIGNS—continued.			
G. R. Slocum	Aug. 7, 1887		Still in service.
J. P. McGuinness	Aug. 9, 1887		Do.
Jos. Strauss	July 16, 1887		Do.
C. S. Stanworth	July 15, 1887		Do.
H. A. Bispham	July 13, 1887		Do.
G. R. Evans	July 12, 1887	July 1, 1889	
J. E. Shindel	July 13, 1887		Do.
W. H. G. Bullard	July 8, 1888		Do.
P. Andrews	July 4, 1888		Do.
W. H. Faust	Aug. 1, 1888		Do.
W. L. Dodd	July 14, 1888		Do.
R. D. Tisdale	July 8, 1888		Do.
S. M. Strite	July 11, 1888		Do.
F. W. Jenkins	Feb. 8, 1889		Do.
M. L. Bristol	July 15, 1889	Mar. 7, 1890	
L. C. Bertolette	July 2, 1889		Do.
W. S. Clarke	July 11, 1889	Nov. 15, 1889	
E. Moale, jr	Aug. 9, 1889		Do.
S. R. Hurlbut	July 25, 1889		Do.
E. H. Durell	July 11, 1889		Do.
F. H. Brown	July 1, 1889		Do.
C. M. Stone	July 11, 1889	Apr. 17, 1890	
Thos. Washington	July 15, 1889	Jan. 25, 1890	
PASSED ASSISTANT SURGEONS.			
N. H. Drake	Dec. 26, 1888		Still in service.
John M. Steele	Mar. 30, 1888		Do.
H. T. Percy	Mar. 10, 1889		Do.
ASSISTANT SURGEONS.			
J. F. Urie	Nov. 5, 1888	Dec. 4, 1889	
P. H. Bryant	Dec. 3, 1889		Still in service.
Thos. Owens	July 23, 1888		Do.
PAYMASTER.			
Geo. A. Deering	Oct. 15, 1889		Still in service.
PASSED ASSISTANT PAYMASTER.			
J. N. Speel	Dec. 20, 1886	Oct. 30, 1889	
PASSED ASSISTANT ENGINEERS.			
Geo. D. Strickland	Sept. 17, 1886	Apr. 10, 1890	
ASSISTANT ENGINEERS.			
E. H. Scribner	July 9, 1889		Still in service.
Thos. F. Carter	Mar. 25, 1890		Do.
W. W. White	Dec. 19, 1888		Do.
J. C. Leonard	Jan. 21, 1889		Do.
CARPENTER.			
W. W. Richardson	Oct. 27, 1888		Still in service.

* Re-attached July 1, 1889.

RECAPITULATION.

Commander	1
Lieutenant-commanders	4
Lieutenants	11
Lieutenants (junior grade)	8
Ensigns	39
Passed assistant surgeons	3
Assistant surgeons	3
Paymaster	1
Passed assistant paymaster	1
Passed assistant engineer	1
Assistant engineers	4
Carpenter	1
	77

NOTE.—From the statement immediately following it appears that of the 77 officers above named, 54 were on duty in the Survey at the close of the fiscal year.

List of Naval Officers attached to the Coast and Geodetic Survey June 30, 1890.

COAST AND GEODETIC SURVEY OFFICE.

Commander Chas. M. Thomas, Hydrographic Inspector.
Lieut. Commander H. E. Nichols, Alaska Coast Pilot.
Lieut. J. E. Pillsbury, special duty.
Lieut. Robert T. Jasper, Hydrographic Division.
Paymaster Geo. A. Deering, in charge naval pay accounts.

ATLANTIC AND GULF COASTS.

Steamer Blake (Atlantic Coast).—Lieut. Charles E. Vreeland, commanding; Lieut. Harry Kimmell, Ensign C. S. Stanworth, Ensign J. E. Shindel, Ensign P. Andrews, Assistant Surgeon Thos. Owens, Assistant Engineer W. W. White.

Steamer Bache (Atlantic Coast).—Lieut. J. F. Moser, commanding; Lieut. E. M. Hughes, Ensign H. A. Bispham, Ensign R. D. Tisdale, Ensign S. M. Strite, Ensign L. C. Bertolette, Ensign E. H. Durell, Passed Assistant Surgeon John M. Steele, Assistant Engineer E. H. Scribner.

Schooner Eagre (Atlantic Coast).—Lieut. Wm. P. Elliott, commanding; Carpenter W. W. Richardson.

Steamer Endeavor (Atlantic Coast).—Lieut. Commander S. M. Ackley, commanding; Lieut. A. L. Hall, Ensign J. F. Luby, Ensign E. A. Anderson, Ensign F. H. Brown.

PACIFIC COAST.

Steamer Patterson (Coast of Alaska).—Lieut. Commander H. B. Mansfield, commanding; Lieut. E. J. Dorn, Ensign H. C. Poundstone, Ensign G. R. Slocum, Ensign Jos. Strauss, Ensign W. H. Faust, Ensign F. W. Jenkins, Passed Assistant Surgeon H. T. Percy, Assistant Engineer Thos. F. Carter.

Steamer Hassler (Coast of California).—Lieut. D. Delehanty, commanding; Lieut. Chas. A. Gove, Ensign J. P. McGuinness, Ensign W. L. Dodd, Ensign S. R. Hurlbut, Passed Assistant Surgeon N. H. Drake.

Steamer Gedney (Coast of Oregon).—Lieut. J. M. Helm, commanding; Assistant Surgeon P. H. Bryant.

Steamer McArthur (Coast of California).—Lieut. D. H. Mahan, commanding; Lieut. J. H. L. Holcombe, Lieut. A. G. Rogers, Ensign G. W. Brown, Ensign W. H. G. Bullard, Assistant Engineer J. C. Leonard.

Schooner Earnest (Coast of Washington).—Lieut. J. N. Jordan, commanding; Ensign Harry George, Ensign E. Moale, jr.

Number of naval officers attached to the Coast and Geodetic Survey vessels during the fiscal year ending June 30, 1890.

Name of vessel.	Dec. 31, 1889.	June 30, 1890.	Name of vessel.	Dec. 31, 1889.	June 30, 1890.
Steamer Bache	8	9	Steamer Hassler	6	6
Steamer Blake	8	7	Steamer McArthur	5	6
Schooner Eagre	2	2	Steamer Patterson	9	9
Schooner Earnest	3	3	Schooner Ready	1	....
Steamer Endeavor	4	5	Coast Survey Office	8	5
Steamer Gedney	6	2	Total	60	54

Average number, 57.

Number of men attached to the Coast and Geodetic Survey vessels during the fiscal year ending June 30, 1890.

Name of vessel.	Sept. 30, 1889.	Dec. 31, 1889.	Mar. 31, 1890.	June 30, 1890.
Steamer Arago	1	1	....	....
Steamer Bache	37	37	35	34
Steamer Blake	39	37	38	37
Barge Beauty	1	1	1	1
Steamer Daisy	13	5	6	9
Schooner Drift	1	1	1	1
Schooner Eagre	24	21	16	20
Schooner Earnest	14	11	16	18
Steamer Endeavor	24	24	25	24
Steamer Gedney	29	30	27	29
Steamer Hassler	33	34	32	33
Steamer Hitchcock	2	2	....	1
Schooner Matchless	1	2	2	2
Steamer McArthur	25	28	30	30
Steamer Patterson	51	43	38	51
Schooner Palinurus	1	1	....	....
Schooner Quick	1	1	....	1
Schooner Ready	12	14	1	2
Schooner Scoresby	1	1	1	1
Schooner Spy	1	2	9	1
Schooner Transit	....	....	....	....
Schooner Yukon	1	1	1	1
Launch No. 4	1	1	1	1
Launch Fuca	1	1	1	....
Launch Tarry Not	....	....	....	1
Total	314	299	281	298

Average number of men, 298.

RECAPITULATION.

Number of vessels in active service	17
Average number of naval officers for the year	57
Average number of men for the year	298

The complements above given do not represent the actual number of officers or men in the Survey during the year, owing to the fact that some vessels were employed only a part of the time.

Names of vessels, their tonnage, etc., in the service of the Coast and Geodetic Survey during the fiscal year ending June 30, 1890.

No.	Name of vessel.	Tonnage.	Complement of— Officers.	Men.
1	Steamer Patterson	453	12	46
2	Steamer Hassler	243	10	34
3	Steamer Blake	218	10	38
4	Steamer Bache	186	10	38
5	Steamer Gedney	133	8	29
6	Steamer McArthur	112	7	30
7	Steamer Endeavor	105	7	23
8	Steamer Hitchcock	83	5	14
9	Steamer Cosmos	25	3	6
10	Steamer Daisy	44	3	14
1	Schooner Eagre	202	6	26
2	Schooner Drift	87	5	14
3	Schooner Earnest	80	5	18
4	Schooner Ready	80	5	14
5	Schooner Yukon	76	6	14
6	Schooner Scoresby	72	5	14
7	Schooner Matchless	....	5	14
8	Schooner Quick	38	4	12
9	Schooner Transit	43	3	9
10	Schooner Spy	35	3	9
1	Barge Beauty	28	....	1

RECAPITULATION.

Whole number of vessels:

Steamers	10
Schooners	10
Barge	1
Total	21

NOTE.—Steamer Arago and schooner Palinurus were sold January 6, 1890; also 4 steam launches and 14 boats, worn out in the service and not worth repairing.

Appendix No. 6.—1890.

REPORT OF THE DISBURSING AGENT FOR THE FISCAL YEAR ENDED JUNE 30, 1890.

U. S. Coast and Geodetic Survey, Disbursing Office,
Washington, D. C., October 31, 1890.

Sir: I have the honor to submit herewith the report of the Disbursing Office for the fiscal year ending June 30, 1890.

On December 3, 1889, I relieved Mr. George A. Bartlett, Disbursing Clerk of the Treasury Department, of the duties devolving upon him in making disbursements for the Coast and Geodetic Survey, having previously qualified as Disbursing Agent for the Survey under authority of Department letter dated November 7, 1889.

Immediately upon taking charge of the Disbursing Office I found it was necessary that Mr. Bartlett's accounts should be closed out and the available balances in his hands deposited in the Treasury so as to be subject to my own requisitions. This work was at once entered on, and by the close of the fiscal year Mr. Bartlett's accounts had all been rendered to the Department and the necessary transfers of funds accomplished. These accounts are yet in process of adjustment by the Accounting Officers, and in the usual routine of settlement will require more or less explanation in relation to differences before they are finally closed on the books of the Treasury Department. The books of this Office, however, as far as Mr. Bartlett's accounts are concerned, were closed on June 30, 1890.

The attention given to the adjustment and closing of Mr. Bartlett's accounts naturally delayed the progress of my own work. Practically, I was compelled during the period from December 1, 1889, to June 30, 1890, to run two sets of disbursing accounts, and for the time being the work of the Office may be considered to have been doubled. This condition was somewhat embarrassing, and that it should have finally resulted in a large accumulation of arrearages in my own accounts was but a natural sequence. Moreover, the force in my office was, and had been for some time prior, entirely too small to cope with the amount of work required to be done, and hence it was that at the close of the fiscal year the unadjusted accounts were several months in arrears. I refer to this merely to show the causes which were operating to retard the work and as a response to various complaints which have been made from time to time as to tardiness in the adjustment and settlement of accounts. In the near future, with an increased force, and a more equitable distribution of the work of the Office, I hope to be able to make a more prompt settlement of accounts than has been possible heretofore.

The annual report of expenditures of the Survey, required by the act approved March 3, 1853, for the fiscal year ending June 30, 1890, was transmitted to Congress, through the Treasury Department, on December 18, 1889. The preparation of these reports in their present detailed form is a work of some magnitude, but their advantages as a means of reference, apart from their usefulness as a complete financial record of the Survey for each fiscal year, will no doubt more than compensate for the labor expended in compiling them.

It will be necessary for some little time to elapse before the changed condition of affairs in the Disbursing Office, produced by the Survey having its own Disbursing Officer, can be harmonized and a new system adopted to meet the exigencies of the case. Experience is necessary to enable such changes to be made in the methods of work, records, accounting, etc., as may be of advantage, both to the officer in the field and this Office, without detracting from or materially changing the methods and customs with which both have become familiar. The ultimate result of such changes and reforms will, in my opinion, result in a saving of both time and money.

The accounts of the Survey rendered to the Department during the past fiscal year have almost uniformly received the sanction and approval of the Accounting Officers of the Treasury. Objections have been made to but few items, and in nearly every instance the explanations submitted by this Office have proved satisfactory.

The statistics of work accomplished during the year, as nearly as they can be stated, are given below. It is apparent that many of the duties performed by this Office can not be accounted for in any manner which would be intelligible. Hence, the figures which follow, while giving some idea of the volume of work, afford but little conception of the time and labor expended in disposing of it:

Statistics.

Abstracts, quarterly and monthly, of disbursements, pages of	231
Accounts, with United States, opened, number of	30
Accounts, allotments, opened, number of	149
Accounts, sub-appropriations opened, number of	47
Accounts, entered on abstracts, number of	2, 266
Accounts current with United States, prepared, number of	94
Accounts posted to allotments, number of	846
Accounts posted to statement book, number of	4, 219
Accounts posted to voucher book, number of	1, 724
Accounts posted to sub-appropriations, number of	1, 734
Advances to field officers, amount of	$141, 655.43
Allotments to field officers, received, number of	149
Authorities, number posted	477
Balance sheets, number of	50
Cashbook entries, number of	1, 988
Certificates of deposit, received, acted on, and filed	49
Check lists, for drawing checks, number of	120
Checks drawn and issued	2, 201
Circulars issued	386
Copying, miscellaneous, pages of	790
Disbursements on adjusted accounts	$493, 018.78
Drafts, Treasury, received, number of	28
Estimates, approved, received, and filed	187
Letters received, acted on, and filed	2, 818
Letters written and press-copied	2, 079
Letters indexed	2, 338
Letters written, rough drafts	608
Pay envelopes, prepared, number of	1, 743
Pay rolls, office, pages of	246
Pay rolls, field officers, pages of	55
Property lists, checked and returned	147
Receipts of funds from Treasury, amount of	$522, 930.00
Reports of Division, monthly, pages of	86
Report for calendar year, pages of	17
Report for fiscal year, pages of	157
Requisitions on Treasury for funds, number of	19
Requisitions from field officers, for advances, number of	169
Statements of condition of appropriations, pages of	42
Trial balances of receipts and disbursements, number of	23
Vouchers, bills, etc., settled	17, 020

During the year I have had the assistance of Mr. Wm. H. Lanman, clerk, and Miss Paula E. Smith, writer. Both have rendered intelligent and capable service in the execution of the work assigned them. Mr. Lanman's qualifications as a stenographer and typewriter have made his services of exceptional value to the Office.

The annual report of expenditures for the fiscal year just ended will be submitted at an early date. The details necessary for its formulation are now being compiled, and its completion will be hastened as rapidly as the other work of the Office will permit. I beg to ask that it may be considered as forming a part of this report.*

Respectfully yours,

JOHN W. PARSONS,
Disbursing Agent, U. S. Coast and Geodetic Survey.

The SUPERINTENDENT,
U. S. Coast and Geodetic Survey.

[House Ex. Doc. No. 278, Fifty-first Congress, second session.]

EXPENDITURES COAST AND GEODETIC SURVEY, 1890.

Letter from the Acting Secretary of the Treasury, transmitting a statement of expenditures on account of the Coast and Geodetic Survey for the fiscal year ended June 30, 1890.

TREASURY DEPARTMENT, *Washington, D. C., February 26,* 1891.

SIR: In compliance with section 264 of the Revised Statutes, I have the honor to transmit herewith a statement of expenditures made on account of the Coast and Geodetic Survey for the fiscal year ended June 30, 1890.

Respectfully yours,

A. B. NETTLETON,
Acting Secretary.

The SPEAKER OF THE HOUSE OF REPRESENTATIVES.

STATEMENT OF THE EXPENDITURES OF THE UNITED STATES COAST AND GEODETIC SURVEY FOR THE FISCAL YEAR ENDING JUNE 30, 1890.

[Prepared pursuant to act approved March 3, 1853.]

Salaries—Pay of field officers.

To whom paid.	Time employed.	Amount.
SUPERINTENDENT.		
Thomas C. Mendenhall	Eleven months twenty-three days	$5,869.60
ASSISTANTS.		
George Davidson	One year	4,000.00
Charles A. Schott	do	4,000.00
Benjamin A. Colonna	do	3,600.00
Aug. F. Rodgers	do	3,200.00
Charles S. Peirce	do	3,000.00
George A. Fairfield	do	3,000.00
Alonzo T. Mosman	do	2,800.00
James S. Lawson	do	2,400.00
William H. Dennis	do	2,400.00
Cleveland Rockwell	One year (waiting instructions ten days)	2,383.52
John W. Donn	One year	2,400.00
William Eimbeck	do	2,300.00
Edward Goodfellow	do	2,300.00
Charles M. Bache	Nine months ten days (waiting instructions one month seventeen days).	1,711.97
Henry L. Whiting	One year	2,046.98
Richard M. Bache	do	2,200.00
Charles H. Boyd	do	2,200.00

*Copy appended.

STATEMENT OF THE EXPENDITURES OF THE UNITED STATES COAST AND GEODETIC SURVEY FOR THE FISCAL YEAR ENDING JUNE 30, 1890—Continued.

Salaries—Pay of field officers—Continued.

To whom paid.	Time employed.	Amount.
ASSISTANTS—continued.		
Herbert G. Ogden	One year	$2,200.00
Otto H. Tittmann	...do	2,200.00
John J. Gilbert	...do	2,200.00
Henry L. Marindin	...do	2,031.27
Spencer C. McCorkle	...do	2,000.00
Gershom Bradford	...do	2,000.00
Charles O. Boutelle	Eleven months twenty-two days	1,956.08
Andrew Braid	One year	2,000.00
Frank Walley Perkins	...do	1,831.23
Frank D. Granger	...do	1,831.23
Richard E. Halter	...do	1,800.00
Edwin Smith	...do	1,800.00
Stehman Forney	...do	1,800.00
Edmund F. Dickins	...do	1,800.00
Joseph Hergesheimer	...do	1,800.00
John F. Pratt	One year (waiting instructions three months)	1,687.49
Cephas H. Sinclair	One year	1,800.00
Dallas B. Wainwright	...do	1,800.00
William C. Hodgkins	...do	1,546.90
Erasmus D. Preston	...do	1,546.90
Eugene Ellicott	Nine months	1,125.00
Charles T. Iardella	One year	1,500.00
Washington Irving Vinal	...do	1,500.00
James B. Baylor	...do	1,500.00
Charles H. Van Orden	...do	1,500.00
Francis H. Parsons	One month twenty-six days	230.74
Robert A. Marr	One month nineteen days	201.90
George W. Dean	Furlough without pay	....
A. W. Longfellow	...do	....
SUB-ASSISTANTS.		
Francis H. Parsons	Ten months five days	1,184.63
Robert A. Marr	Ten months twelve days	1,211.55
John E. McGrath*	One year	....
Isaac Winston	...do	1,315.36
Philip A. Welker	...do	1,140.44
John Henry Turner*	...do	....
Fremont Morse	...do	1,130.77
Edmund L. Taney	Six months (waiting instructions nineteen days)	535.80
James H. Gray	Four months	367.70
John A. Flemer	Seven months twenty-four days	714.37
John Nelson	One month five days	105.81
AIDS.		
John A. Flemer	Four months six days	315.47
John Nelson	Ten months twenty-six days	813.49
Expenditures		105,836.20
Appropriation		119,500.00
Expenditures		105,836.20
Unexpended balance		13,663.80

Salaries—Pay of office force.

To whom paid.	Time employed.	Amount.
ACCOUNTANTS.		
John W. Parsons	One year	$1,800.00
Eugene B. Wills	...do	1,800.00
Roger C. Glascock	...do	1,400.00

* Absent in Alaska.

STATEMENT OF THE EXPENDITURES OF THE UNITED STATES COAST AND GEODETIC SURVEY FOR THE FISCAL YEAR ENDING JUNE 30, 1890—Continued.

Salaries—Pay of office force—Continued.

To whom paid.	Time employed.	Amount.
GENERAL OFFICE ASSISTANT.		
Marshall W. Wines	One year	$2,200.00
DRAUGHTSMEN.		
A. Lindenkohl	One year	2,350.00
H. Lindenkohl	do	2,100.00
Eugene Willenbucher	do	2,000.00
Edwin H. Fowler	do	2,000.00
Ferdinand Westdahl	do	1,800.00
Ernest J. Sommer	do	1,800.00
William C. Willenbucher	do	1,600.00
Paul Erichsen	do	1,400.00
Emil Molkow	do	1,400.00
F. C. Donn	do	1,400.00
James H. Barker	do	1,330.00
Charles Mahon	do	1,260.00
E. A. Trescot	Twenty-eight days	91.30
Edward H. Wyvill	One year	1,200.00
William H. Benton	Eight months twenty-five days	850.12
David M. Hildreth	One year	1,032.63
Charles H. Deetz	do	838.72
Marshall P. Jackson	Eleven months seven days	867.01
Archie Upperman	One year	900.00
George F. Pohlers	Three months eleven days	252.50
COMPUTERS.		
E. H. Courtenay	One year	1,850.00
M. H. Doolittle	do	1,850.00
Henry Farquhar	do	1,420.00
Louis A. Bauer	do	1,300.00
Charles H. Kummell	do	1,260.00
F. M. Little	do	1,100.00
James Page	do	900.00
John F. Hayford	do	874.20
TIDAL COMPUTERS.		
Alexander S. Christie	One year	2,000.00
L. P. Shidy	do	1,500.00
John W. Whitaker	Eleven months two days	1,153.86
ENGRAVERS.		
Henry M. Knight	One year	2,060.00
William A. Thompson	do	2,000.00
John G. Thompson	do	1,960.00
August Petersen	do	1,800.00
Theodore Wasserbach	do	1,800.00
Edward H. Sipe	do	1,565.00
William H. Davis	do	1,500.00
Rudolph F. Bartle, jr	do	1,200.00
Henry L. Thompson	do	875.00
A. H. Sefton	do	480.00
William A. Van Doren	do	480.00
E. A. Kubel	do	480.00
John S. Carman	Two months	80.00
Harry R. McCabe	Seven months twenty-five days	78.25
George Hergesheimer	Six months thirteen days	193.32
CONTRACT ENGRAVERS.		
Joseph Enthoffer	One year	2,399.93
Henry C. Evans	do	2,099.98
Rudolph F. Bartle	do	1,790.64
E. J. Enthoffer	Six months	799.90
ELECTROTYPIST AND PHOTOGRAPHER.		
D. C. Chapman	One year	1,800.00

STATEMENT OF THE EXPENDITURES OF THE UNITED STATES COAST AND GEODETIC SURVEY FOR THE FISCAL YEAR ENDING JUNE 30, 1890—Continued.

Salaries—Pay of office force—Continued.

To whom paid.	Time employed.	Amount.
ELECTROTYPIST'S HELPER.		
Charles N. Darnall	One year	$500.00
APPRENTICE TO ELECTROTYPIST AND PHOTOGRAPHER.		
L. P. Keyser	One year	500.00
COPPER-PLATE PRINTERS.		
Frank Moore	One year	1,700.00
Dickerson N. Hoover	...do	1,330.00
James Beck	...do	1,330.00
George B. Craufurd	...do	1,250.00
PLATE-PRINTER'S HELPERS.		
Lynn H. Troutman	One year	675.00
James F. Dickson	Three months fourteen days	172.83
John M. Williams	Eight months thirteen days	420.70
CHIEF MECHANICIAN.		
Ernst G. Fischer	One year	1,800.00
MECHANICIANS.		
Edwin M. Eshleman	Nine months twelve days	1,225.34
Louis A. Fischer	Seven months eighteen days	846.10
Peter Vierbuchen	Ten months	1,040.50
Stephen A. Kearney	One year	1,175.00
Otto Storm	...do	1,056.40
W. R. Whitman	Four months nine days	325.00
Clarence E. Regennas	Eight days	21.98
William Gaertner	...do	21.98
Michael Lauxmann, jr	One year	545.00
CARPENTERS.		
H. O. French	One year	1,565.00
George W. Clarvoe	...do	800.00
CARPENTER AND FIREMAN.		
Horace Dyer	One year	570.00
NIGHT FIREMEN.		
William Young	Three months twenty-two days	170.38
Harrison Murray	Eight months nine days	379.62
MAP MOUNTER.		
R. T. Bassett	One year	1,020.00
LIBRARIAN.		
Artemas Martin	One year	1,800.00
CLERKS.		
William B. French	One year	1,650.00
William B. Chilton	...do	1,500.00
John H. Smoot	...do	1,400.00
James L. Smith	Eight months twenty days	863.37
William H. Lanman	One month twenty-nine days	194.50
William C. Maupin	Nine months twenty-four days	979.12
John W. Whitaker	Twenty-eight days	92.31
J. M. Duesberry	One year	1,000.00
J. Henry Roeth	...do	1,000.00
Frank W. Edmonds	...do	843.28
Freeman R. Green	Eleven months twenty-two days	1,146.24
RECEIVING AND FORWARDING CLERKS.		
Richard M. Harvey	Five months seven days	586.98
William C. Maupin	Two monthsxsixdays	248.45

STATEMENT OF THE EXPENDITURES OF THE UNITED STATES COAST AND GEODETIC SURVEY FOR THE FISCAL YEAR ENDING JUNE 30, 1890—Continued.

Salaries—Pay of office force—Continued.

To whom paid.	Time employed.	Amount.
MAP COLORISTS.		
Mary Thomas	Seven months sixteen days	$451.51
Creed W. Childs	One month ten days	79.08
WRITERS.		
Freeman R. Green	Nine days	22.01
William H. Lanman	Nine months twenty-eight and a half days	741.69
Fannie B. Bailey	One year	747.08
M. E. Nesbitt	Eleven months twenty-two days	798.87
Virginia Harrison	One year	720.00
Fannie Cadel	Eleven months twenty-three days	704.35
Kate Lawn	One year	720.00
Paula E. Smith	Eleven months twenty-nine days	716.00
Jennie H. Fitch	One year	720.00
Sophie S. Hein	Eleven months fifteen days	592.41
Lily A. Mapes	Sixteen days	26.03
Ida M. Peck	One month twenty-two days	85.76
MESSENGERS.		
William H. Butler	One year	875.00
Vicente Denis	...do	840.00
Charles Over	...do	820.00
Neil Bryant	...do	820.00
Sandy Bruce	...do	820.00
William Savoy	...do	640.00
Peter Page	...do	640.40
William West	...do	640.00
DRIVER.		
W. R. McLane	One year	730.00
PACKERS AND FOLDERS.		
Charles H. Jones	One year	820.00
Attrell Richardson	...do	630.00
LABORERS.		
John W. Reed	One year	630.00
George Newman	...do	630.00
John H. Brown	...do	550.00
Harrison Murray	Three months twenty-two days	170.38
William Young	Eight months nine days	379.62
S. E. Flynn	One year	315.00
Robert Brady	Eight months thirteen days	255.89
JANITOR.		
William M. Long	One year	1,200.00
WATCHMEN.		
David Parker	One year	880.00
William H. Keith	...do	880.00
Expenditures		129,660.01
Appropriation		132,705.00
Expenditures		129,660.01
Unexpended balance		3,044.99

SUMMARY.

Pay of field officers	$105,836.20
Pay of office force	129,660.01
Total expenditures	235,496.21
Total sum appropriated for salaries	252,205.00
Total sum expended for salaries	235,496.21
Unexpended balance	16,708.79

STATEMENT OF THE EXPENDITURES OF THE UNITED STATES COAST AND GEODETIC SURVEY FOR THE FISCAL YEAR ENDING JUNE 30, 1890—Continued.

Party Expenses, 1890.

COAST OF MAINE.

To whom paid.	On what account.		Amount.
Fred S. Allan	Storage		$0.30
Charles M. Bache	Topography		719.31
C. H. Boyd	Triangulation		1,143.66
John W. Donn	Topography		1,478.09
Eugene Ellicott	do		1,522.26
J. A. Flemer	Topography and hydrography		479.23
W. F. Grant	Storage		60.00
Joseph Hergesheimer	Combined operations		219.20
Expenditures			5,622.05
Appropriation			6,000.00
Less 6 per cent. transferred to Resurveys—Vineyard Sound, etc		$360.00	
Expenditures		5,622.05	
			5,982.05
Unexpended balance			17.95

RESURVEYS—VINEYARD SOUND, ETC.

To whom paid.	On what account.	Amount.
William P. Elliott, U. S. Navy	Hydrography, schooner *Eagre*	$1,968.92
C. T. Iardella	Topography	1,436.86
Walter R. Luscombe	Storage	13.34
P. F. Meschutt	do	16.50
J. F. Moser, U. S. Navy	Hydrography, steamer *Bache*	2,461.00
Philadelphia and Reading Coal and Iron Company.	Coal, schooner *Eagre* and steamer *Bache*	590.45
E. L. Taney	Topography	1,471.18
W. Irving Vinal	do	1,446.99
Henry L. Whiting	Traveling expenses and subsistence	257.50
Expenditures		9,662.74
Appropriation		7,000.00
Add 6 per cent. from Coast of Maine		360.00
Add 10 per cent. from Delaware Bay, etc		200.00
Add 10 per cent. from Physical Survey—Cape Cod, etc		270.00
Add 10 per cent. from Charleston Entrance		200.00
Add 10 per cent. from Florida—West Coast		700.00
Add 10 per cent. from Pensacola Bay, etc		200.00
Add 10 per cent. from Coast of Louisiana		700.00
Add 10 per cent. from Reported Dangers		50.00
		9,680.00
Expenditures		9,662.74
Unexpended balance		17.26

DELAWARE BAY, ETC.

To whom paid.	On what account.		Amount.
Henry L. Marindin	Physical surveys		$1,628.27
Spencer C. McCarkle	Ice movements		9.66
Expenditures			1,637.93
Appropriation			2,000.00
Less 10 per cent. transferrd to Resurveys—Vineyard Sound, etc		$200.00	
Expenditures		1,637.93	
			1,837.93
Unexpended balance			162.07

STATEMENT OF THE EXPENDITURES OF THE UNITED STATES COAST AND GEODETIC SURVEY FOR THE FISCAL YEAR ENDING JUNE 30, 1890—Continued.

Party Expenses, 1890—Continued.

PHILADELPHIA WATER-FRONT, ETC.

To whom paid	On what account.		Amount.
R. M. Bache	Topography		$1,670.23
John J. Beckett	Storage		28.00
Joseph Hergesheimer	Topography and hydrography		1,199.28
Expenditures			2,897.51
Appropriation			1,000.00
Add 10 per cent. from Offshore Soundings, etc			800.00
Add 9 per cent. from San Francisco Bay, etc			810.00
Add 10 per cent. from Geographical Positions			300.00
			2,910.00
Expenditures			2,897.51
Unexpended balance			12.49

PHYSICAL SURVEY—CAPE COD, ETC.

To whom paid.	On what account.		Amount.
Henry L. Marindin	Physical surveys		$2,429.53
Appropriation			2,700.00
Less 10 per cent. transferred to Resurveys—Vineyard Sound, etc		$270.00	
Expenditures		2,429.53	
			2,699.53
Unexpended balance			.47

CHARLESTON ENTRANCE.

To whom paid.	On what account.		Amount.
F. D. Granger	Triangulation		$1,735.65
Appropriation			2,000.00
Less 10 per cent. transferred to Resurveys—Vineyard Sound, etc		$200.00	
Expenditures		1,735.65	
			1,935.65
Unexpended balance			64.35

TRIANGULATION—ATLANTA-MOBILE.

To whom paid.	On what account.	Amount.
F. Walley Perkins	Triangulation and storage	$3,062.04
Appropriation		3,000.00
Add 6 per cent. from Magnetics—Atlantic and Gulf		72.00
		3,072.00
Expenditures		3,062.04
Unexpended balance		9.96

STATEMENT OF THE EXPENDITURES OF THE UNITED STATES COAST AND GEODETIC SURVEY FOR THE FISCAL YEAR ENDING JUNE 30, 1890—Continued.

Party Expenses, 1890—Continued.

FLORIDA—WEST COAST.

To whom paid.	On what account.		Amount.
Bureau of Equipment and Recruiting, Navy Department.	Coal, steamer *Bache*		$830.29
Joseph Hergesheimer	Combined operations		2,872.69
J. F. Moser, U. S. Navy	Hydrography, steamer *Bache*		2,438.18
Expenditures			6,141.16
Appropriation			7,000.00
Less 10 per cent. transferred to Resurveys—Vineyard Sound, etc		$700.00	
Expenditures		6,141.16	
			6,841.16
Unexpended balance			158.84

PENSACOLA BAY, ETC.

To whom paid.	On what account.		Amount.
P. A. Welker	Topography and triangulation		$1,794.69
Appropriation			2,000.00
Less 10 per cent. transferred to Resurveys—Vineyard Sound, etc		$200.00	
Expenditures		1,794.69	
			1,994.69
Unexpended balance			5.31

PERDIDO BAY, ETC.

To whom paid.	On what account.	Amount.
Stehman Forney	Combined operations	$3,585.07
Amos Ross	Storage	30.00
Expenditures		3,615.07
Appropriation		3,000.00
Add 6.50 per cent. from Triangulation—California		617.50
		3,617.50
Expenditures		3,615.07
Unexpended balance		2.43

COAST OF LOUISIANA.

To whom paid.	On what account.		Amount.
M. W. Bateman	Storage, etc		$7.50
C. H. Boyd	Triangulation		2,517.26
Bureau of Equipment and Recruiting, Navy Department.	Coal, steamer *Endeavor*		82.69
A. L. Hall, U. S. Navy	Hydrography, steamer *Endeavor*		2,507.60
Daniel L. Hazard	Services and traveling expenses		43.22
F. Walley Perkins	Ship-keeping		2.50
Revenue Marine Bureau	Coal, steamer *Endeavor*		89.08
Expenditures			5,249.85
Appropriation			7,000.00
Less 10 per cent. transferred to Resurveys—Vineyard Sound, etc		$700.00	
Expenditures		5,249.85	
			5,949.85
Unexpended balance			1,050.15

STATEMENT OF THE EXPENDITURES OF THE UNITED STATES COAST AND GEODETIC SURVEY FOR THE FISCAL YEAR ENDING JUNE 30, 1890—Continued.

Party Expenses, 1890—Continued.

OFFSHORE SOUNDINGS, ETC.

To whom paid.	On what account.		Amount.
Bureau of Provisions and Clothing, Navy Department.	Soap, steamer *Blake*		$23.25
J. E. Pillsbury, U. S. Navy	Hydrography, steamer *Blake*		3,984.85
Revenue Marine Bureau	Coal, steamer *Blake*		76.35
C. E. Vreeland, U. S. Navy	Hydrography, steamer *Blake*		3,111.98
Expenditures			7,196.43
Appropriation			8,000.00
Less 10 per cent. transferred to Philadelphia Water-front, etc		$800.00	
Expenditures		7,196.43	
			7,996.43
Unexpended balance			3.57

SAN FRANCISCO BAY, ETC.

To whom paid.	On what account.		Amount.
Bureau of Equipment and Recruiting, Navy Department	Outfit, steamer *McArthur*		$67.90
D. Delehanty, U. S. Navy	Hydrography, steamer *Hassler*		5,619.20
D. H. Mahan, U. S. Navy	Hydrography, steamer *McArthur*		2,397.32
Amount disbursed			8,084.42
Railroad accounts referred for settlement			67.70
Expenditures			8,152.12
Appropriation			9,000.00
Less 9 per cent. transferred to Philadelphia Water-front, etc		$810.00	
Expenditures		8,152.12	
			8,962.12
Unexpended balance			37.88

TOPOGRAPHY—CALIFORNIA.

To whom paid.	On what account.		Amount.
Charles M. Bache, deceased	Transportation and embalming remains		$223.15
Stehman Forney	Pasturage, storage, and repairs		109.85
Cleveland Rockwell	Topography		649.32
Aug. F. Rodgers	...do		5,921.68
Amount disbursed			6,904.00
Railroad accounts referred for settlement			551.06
Expenditures			7,455.06
Appropriation			10,000.00
Less 2 per cent. transferred to Physical Hydrography		$200.00	
Less 2 per cent. transferred to Transcontinental Work		200.00	
Expenditures		7,455.06	
			7,855.06
Unexpended balance			2,144.94

STATEMENT OF THE EXPENDITURES OF THE UNITED STATES COAST AND GEODETIC SURVEY FOR THE FISCAL YEAR ENDING JUNE 30, 1890—Continued.

Party Expenses, 1890—Continued.

TRIANGULATION—CALIFORNIA.

To whom paid.	On what account.		Amount.
George Davidson	Triangulation		$5,302.05
Jas. S. Lawson	Repairing tents, etc		138.01
Amount disbursed			5,440.06
Railroad accounts referred for settlement			535.58
Expenditures			5,975.64
Appropriation			9,500.00
Less 6.50 per cent. transferred to Perdido Bay, etc		$617.50	
Less 3.50 per cent. transferred to Tides—Atlantic		332.50	
Expenditures		5,975.64	
			6,925.64
Unexpended balance			2,574.36

COAST OF OREGON.

To whom paid.	On what account.		Amount.
D. Ballauf	Sounding reel, steamer *Gedney*		$151.00
Fred. Bickel	Storage		22.50
E. F. Dickins	Triangulation, topography, etc		3,506.61
J. M. Helm, U. S. Navy	Hydrography, steamer *Gedney*		4,349.09
Cleveland Rockwell	Triangulation, hydrography, etc		803.78
G. W. Shaver	Storage		1.50
Amount disbursed			8,833.79
Railroad accounts referred for settlement			3.67
Expenditures			8,837.46
Appropriation			10,000.00
Less 10 per cent. transferred to Magnetics—Pacific, etc		$1,000.00	
Expenditures		8,837.46	
			9,837.46
Unexpended balance			162.54

WASHINGTON TERRITORY.

To whom paid.	On what account.	Amount.
D. Ballauf	Sounding reel, schooner *Earnest*	$151.00
J. J. Gilbert	Triangulation, topography, etc	1,866.34
J. N. Jordan, U. S. Navy	Hydrography, schooner *Earnest*	2,345.53
J. F. Pratt	Triangulation and topography	1,868.48
Amount disbursed		6,231.35
Railroad accounts referred for settlement		22.92
Expenditures		6,254.27
Appropriation		5,000.00
Add 10 per cent. from State Surveys		800.00
Add 10 per cent. from Coast Pilot		500.00
		6,300.00
Expenditures		6,254.27
Unexpended balance		45.73

STATEMENT OF THE EXPENDITURES OF THE UNITED STATES COAST AND GEODETIC SURVEY FOR THE FISCAL YEAR ENDING JUNE 30, 1890—Continued.

Party Expenses, 1890—Continued.

ALASKA EXPLORATIONS.

To whom paid.	On what account.		Amount.
Bureau of Equipment and Recruiting, Navy Department.	Outfit, steamer *Patterson*		$127.06
H. B. Mansfield, U. S. Navy	Hydrography, steamer *Patterson*		8,872.88
Expenditures			8,999.94
Appropriation			10,000.00
Less 6.50 per cent. transferred to Magnetics—Pacific, etc.		$650.00	
Less 3 per cent. transferred to Transcontinental Work		300.00	
Expenditures		8,999.94	
			9,949.94
Unexpended balance			50.06

PHYSICAL HYDROGRAPHY.

To whom paid.	On what account.	Amount.
Henry L. Marindin	Physical surveys	$2,002.16
Mount Holly Paper Company	Tide-gauge paper	84.30
Homer P. Ritter	Physical surveys	90.98
Expenditures		2,186.44
Appropriation		2,000.00
Add 2 per cent. from Topography—California		200.00
		2,200.00
Expenditures		2,186.44
Unexpended balance		13.56

REPORTED DANGERS.

To whom paid.	On what account.		Amount.
Wm. P. Elliott, U. S. Navy	Hydrography, schooner *Eagre*		$51.26
Henry L. Marindin	Hydrography, Potomac River		150.89
Expenditures			202.15
Appropriation			500.00
Less 10 per cent. transferred to Resurveys—Vineyard Sound, etc		$50.00	
Expenditures		202.15	
			252.15
Unexpended balance			247.85

MAGNETICS—ATLANTIC AND GULF.

To whom paid.	On what account.		Amount.
Jas. B. Baylor	Magnetics		$1,071.94
Appropriation			1,200.00
Less 6 per cent. transferred to Triangulation—Atlanta—Mobile		$72.00	
Less 4 per cent. transferred to Exact Leveling		48.00	
Expenditures		1,071.94	
			1,191.94
Unexpended balance			8.06

STATEMENT OF THE EXPENDITURES OF THE UNITED STATES COAST AND GEODETIC SURVEY FOR THE FISCAL YEAR ENDING JUNE 30, 1890—Continued.

Party Expenses, 1890—Continued.

MAGNETICS—PACIFIC, ETC.

To whom paid.	On what account.	Amount.
E. and H. T. Anthony & Co	Bromide paper	$61.88
Andrew Braid	Magnetics	464.02
The Eastman Company	Copy paper	3.75
R. E. Halter	Magnetics	2,102.26
L. G. Shultz	Services	78.30
Amount disbursed		2,710.21
Railroad accounts referred for settlement		118.16
Expenditures		2,828.37
Appropriation		1,200.00
Add 10 per cent. from Coast of Oregon		1,000.00
Add 6.50 per cent. from Alaska Explorations		650.00
		2,850.00
Expenditures		2,828.37
Unexpended balance		21.63

EXACT LEVELING.

To whom paid.	On what account.	Amount.
Isaac Winston	Leveling	$3,040.05
Appropriation		3,000.00
Add 4 per cent. from Magnetics—Atlantic and Gulf		48.00
		3,048.00
Expenditures		3,040.05
Unexpended balance		7.95

TIDES—PACIFIC.

To whom paid.	On what account.		Amount.
George Davidson	Alaska and Saucelito tidal		$1,362.10
Jas. S. Lawson	do		651.85
Mount Holly Paper Company	Tide-gauge paper		175.20
Expenditures			2,189.15
Appropriation			2,500.00
Less 10 per cent. transferred to Transcontinental Work		$250.00	
Expenditures		2,189.15	
			2,439.15
Unexpended balance			60.85

TIDES—ATLANTIC.

To whom paid.	On what account.	Amount.
Martin Cooley	Contingencies, Tybee gauge	$200.00
Mount Holly Paper Company	Tide-gauge paper	175.50
David E. Snead	Services and contingencies	379.35
J. G. Spaulding	do	1,230.65
Eugene Veith	do	400.10
Expenditures		2,385.60
Appropriation		2,100.00
Add 3.50 per cent. from Triangulation—California		332.50
		2,432.50
Expenditures		2,385.60
Unexpended balance		46.90

STATEMENT OF THE EXPENDITURES OF THE UNITED STATES COAST AND GEODETIC SURVEY FOR THE FISCAL YEAR ENDING JUNE 30, 1890—Continued.

Party Expenses, 1890—Continued.

GRAVITY EXPERIMENTS.

To whom paid.	On what account.	Amount.
E. S. & J. D. Negus	Chronometers	$800.00
E. D. Preston	Pendulum observations	791.20
U. S. Eclipse Expedition	Transportation	108.38
Expenditures		1,699.58
Unexpended balance June 30, 1883		1,725.94
Expenditures		1,699.58
Unexpended balance		26.36

STATE SURVEYS.

To whom paid.	On what account.	Where expended.	Amount.
C. O. Boutelle	Triangulation	Wisconsin	$162.10
E. A. Bowser	do	New Jersey	1,031.52
A. H. Buchanan	do	Tennessee	1,352.46
Wm. Conkle	Storage	Wisconsin	6.00
John E. Davies	Triangulation	do	982.26
George A. Fairfield	Building signals	Indiana	350.62
W. R. Hoag	Triangulation	Minnesota	1,198.86
Isaac Winston	Leveling	Arkansas	2,090.90
Expenditures			7,174.72
Appropriation			8,000.00
Received from George A. Fairfield, rebate on overcharges for freight on lumber			14.40
			8,014.40
Less 10 per cent. transferred to Washington Territory		$800.00	
Expenditures		7,174.72	
			7,974.72
Unexpended balance			39.68

GEOGRAPHICAL POSITIONS.

To whom paid.	On what account.		Amount.
R. A. Marr	Longitudes		$962.74
C. H. Sinclair	do		1,412.29
Amount disbursed			2,375.03
Railroad accounts referred for settlement			270.65
Expenditures			2,645.68
Appropriation			3,000.00
Less 10 per cent. transferred to Philadelphia Water-front, etc		$300.00	
Expenditures		2,645.68	
			2,945.68
Unexpended balance			54.32

STATEMENT OF THE EXPENDITURES OF THE UNITED STATES COAST AND GEODETIC SURVEY FOR THE FISCAL YEAR ENDING JUNE 30, 1890—Continued.

Party Expenses, 1890—Continued.

TRANSCONTINENTAL WORK.

To whom paid.	On what account.	Where expended.	Amount.
William Eimbeck	Triangulation	Utah and Nevada	$8,389.96
George A. Fairfield	...do	Indiana	5,438.11
F. D. Granger	...do	Kansas	3,224.70
A. T. Mosman	...do	Indiana	3,696.87
Amount disbursed			20,749.64
Railroad accounts referred for settlement			282.38
Expenditures			21,032.02
Appropriation			20,000.00
Add 3 per cent. from Alaska Explorations			300.00
Add 10 per cent. from Tides—Pacific			250.00
Add 9.50 per cent. from Transportation (Navy), etc			285.00
Add 2 per cent. from Topography—California			200.00
Received from George A. Fairfield, rebate on overcharges for freight on lumber			28.90
			21,063.90
Expenditures			21,032.02
Unexpended balance			31.88

COAST PILOT.

To whom paid.	On what account.		Amount.
S. M. Ackley, U. S. Navy	Hydrography, steamer *Endeavor*		$1,232.31
John P. Agnew & Co	Coal, steamer *Endeavor*		75.60
Alice F. Carlisle	Services		520.00
L. M. Garrett, U. S. Navy	Hydrography, steamer *Endeavor*		375.02
J. H. Gore	Services		500.00
Lehigh Valley Coal Co	Coal, steamer *Endeavor*		75.20
Maryland Union Coal Co	...do		92.80
John Ross	Services		1,500.00
E. H. Tillman, U. S. Navy	Hydrography, steamer *Endeavor*		129.05
Expenditures			4,499.98
Appropriation			5,000.00
Less 10 per cent. transferred to Washington Territory		$500.00	
Expenditures		4,499.98	
			4,999.98
Unexpended balance			.02

TRANSPORTATION (NAVY), ETC.

To whom paid.	On what account.	Amount.
S. M. Ackley, U. S. Navy	Mileage	$128.72
E. A. Anderson, U. S. Navy	...do	112.28
L. C. Bertolette, U. S. Navy	...do	35.92
M. L. Bristol, U. S. Navy	...do	279.84
F. H. Brown, U. S. Navy	...do	40.68
P. H. Bryant, U. S. Navy	...do	262.08
W. H. G. Bullard, U. S. Navy	...do	2.00
Thomas F. Carter, U. S. Navy	...do	270.32
W. S. Clarke, U. S. Navy	...do	21.12
George A. Deering, U. S. Navy	...do	20.00
J. C. Drake, U. S. Navy	...do	109.76
E. H. Durell, U. S. Navy	...do	21.84
Wm. Du Wors, U. S. Navy	Traveling expenses	7.55
Wm. P. Elliott, U. S. Navy	Mileage, etc	59.85
Harry George, U. S. Navy	...do	281.12
A. L. Hall, U. S. Navy	...do	137.36

STATEMENT OF THE EXPENDITURES OF THE UNITED STATES COAST AND GEODETIC SURVEY FOR THE FISCAL YEAR ENDING JUNE 30, 1890—Continued.

Party Expenses, 1890—Continued.

TRANSPORTATION (NAVY), ETC.—Continued.

To whom paid.	On what account.	Amount.
J. M. Helm, U. S. Navy	Mileage, etc	$19.84
J. H. Lee Holcombe, U. S. Navy	...do	250.88
Edward M. Hughes, U. S. Navy	...do	28.24
F. A. Huntoon, U. S. Navy	...do	159.84
S. R. Hurlburt, U. S. Navy	...do	283.76
F. W. Jenkins, U. S. Navy	...do	2.00
J. N. Jordan, U. S. Navy	...do	5.76
Edward Moale, jr., U. S. Navy	...do	223.68
J. F. Moser, U. S. Navy	...do	19.20
Jens Petersen, U. S. Navy	Traveling expenses	5.83
J. E. Pillsbury, U. S. Navy	Mileage	181.20
H. C. Poundstone, U. S. Navy	...do	250.88
E. H. Scribner, U. S. Navy	...do	35.04
C. M. Stone, U. S. Navy	...do	110.88
Joseph Strauss, U. S. Navy	...do	2.00
Charles M. Thomas, U. S. Navy	...do	164.16
E. H. Tillman, U. S. Navy	...do	36.48
C. E. Vreeland, U. S. Navy	...do	50.24
Thomas Washington, U. S. Navy	...do	81.12
Expenditures		3,701.47
Appropriation—Sundry Civil Act, March 2, 1889		3,000.00
Appropriation—Deficiency Act, April 4, 1890		1,000.00
		4,000.00
Less 9.50 per cent. transferred to Transcontinental Work	$285.00	
Expenditures	3,701.47	
		3,986.47
Unexpended balance		13.53

OBJECTS NOT NAMED.

To whom paid.	On what account.	Amount.
Chas. M. Bache	Reconnoissance, New Jersey coast	$181.24
Wm. Curry	Supplies, schooner *Spy*	6.00
George Davidson	San Francisco Tidal and International Geodetic Association.	761.65
John W. Donn	Topography, Norfolk Harbor	82.88
J. C. Drake, U. S. Navy	Hydrography, schooner *Ready*	293.01
Stehman Forney	Remarking triangulation point	57.68
W. C. Hodgkins	Triangulation, North Carolina coast	400.00
Jas. S. Lawson	San Francisco tidal	302.96
D. H. Mahan, U. S. Navy	Outfit, steamer *McArthur*	397.96
Spencer C. McCorkle	Observing tides	18.50
McKenzie, Oerting & Co	Supplies, schooner *Transit*	1.30
T. C. Mendenhall	Traveling expenses	271.64
F. Walley Perkins	Storage	24.00
J. E. Pillsbury, U. S. Navy	Measuring sea-mile	77.02
J. F. Pratt	Survey, Navy-yard site	305.50
Saml. N. Prince	Tent flies	115.00
C. H. Sinclair	Meridian line, Huron, S. Dak	128.35
Chas. M. Thomas, U. S. Navy	Supplies, schooner *Ready*	9.70
Henry L. Whiting	Topography, Kennebec River	469.70
F. A. Young	Services	187.50
Amount disbursed		4,094.59
Railroad accounts referred for settlement		433.50
Annual contribution to the International Geodetic Association		385.56
Expenditures		4,913.65
Appropriation		5,000.00
Expenditures		4,913.65
Unexpended balance		86.35

STATEMENT OF THE EXPENDITURES OF THE UNITED STATES COAST AND GEODETIC SURVEY FOR THE FISCAL YEAR ENDING JUNE 30, 1890—Continued.

Party Expenses, 1890—Continued.

RECAPITULATION.

[Showing expenditures in gross (by sub-items) on account of the appropriation for Party Expenses, 1890.]

Coast of Maine		$5,622.05
Resurveys—Vineyard Sound, etc		9,662.74
Delaware Bay, etc		1,637.93
Philadelphia Water-front, etc		2,897.51
Physical Survey—Cape Cod, etc		2,429.53
Charleston Entrance		1,735.65
Triangulation—Atlanta—Mobile		3,062.04
Florida—West Coast		6,141.16
Pensacola Bay, etc		1,791.69
Perdido Bay, etc		3,615.07
Coast of Louisiana		5,249.85
Off-shore Soundings, etc		7,196.43
San Francisco Bay, etc		8,084.42
Topography—California		6,904.00
Triangulation—California		5,440.06
Coast of Oregon		8,833.79
Washington Territory		6,231.35
Alaska *Explorations*		8,999.94
Physical Hydrography		2,186.44
Reported Dangers		202.15
Magnetics—Atlantic and Gulf		1,071.94
Magnetics—Pacific, etc		2,710.21
Exact Leveling		3,040.05
Tides—Pacific		2,189.15
Tides—Atlantic		2,385.60
Gravity Experiments		1,699.58
State Surveys		7,174.72
Geographical Positions		2,375.03
Transcontinental Work		20,749.64
Coast Pilot		4,499.98
Transportation (Navy), etc		3,701.47
Objects not named		4,094.59
Amount disbursed		153,618.76
Railroad accounts referred to accounting officers for settlement		2,285.62
Annual contribution to the International Geodetic Association		385.56
Total expenditures		156,289.94
Total amount appropriated for Party Expenses, 1890:		
Sundry Civil Act, March 2, 1889	$160,700.00	
Deficiency Act, April 4, 1890	1,000.00	
		161,700.00
Additional amount as authorized by Sundry Civil Act of March 2, 1889, being the unexpended balance remaining on June 30, 1888, of the sub-item for gravity experiments (Party Expenses, 1888)		1,725.94
Received from George A. Fairfield, being rebates on original overcharges for freight on lumber		43.30
		163,469.24
Total amount expended for Party Expenses, 1890		156,289.94
Unexpended balance		7,179.30

CLASSIFICATION OF EXPENDITURES FOR PARTY EXPENSES, 1890.

On what account.	Amount.
Triangulation	$23,757.04
Topography	25,032.18
Hydrography	51,877.73
Transcontinental Geodetic Work	21,032.02
Points for State Surveys	7,174.72
Coast Pilot	4,499.98
Leveling	3,040.05
Magnetics	3,900.31
Physical Hydrography	6,510.13
Geographical Positions (longitudes)	2,645.68
Tidal Operations	5,110.86
Ice Movements	9.66
Gravity Experiments	1,699.58
Total	156,289.94

STATEMENT OF THE EXPENDITURES OF THE UNITED STATES COAST AND GEODETIC SURVEY FOR THE FISCAL YEAR ENDING JUNE 30, 1890—Continued.

Alaska Boundary Survey.

To whom paid.	On what account.	Amount.
George Davidson	Moon culminations	$19.30
Charles Junken	Services	1,800.00
John E. McGrath	Boundary survey	1,426.30
Expenditures		3,245.60
Unexpended balance on July 1, 1889		3,180.55
Appropriation		20,000.00
		23,180.55
Expenditures		3,245.60
Unexpended balance		19,934.95

Publishing Observations, 1890.

To whom paid.	Time employed.	Amount.
COMPUTER.		
John B. Boutelle	One year	$1,600.00
COPYISTS.		
C. B. Turnbull	Ten months twenty-two days	642.82
M. E. Nesbitt	Sixteen days	31.28
Lily A. Mapes	Eleven months fifteen days	688.72
Alice G. Reville	One year	720.00
Expenditures		3,682.82
Appropriation		3,760.00
Expenditures		3,682.82
Unexpended balance		77.18

Repairs of Vessels, 1890.

To whom paid.	On what account.	Amount.
James S. Bartlum	Schooner *Spy*	$57.00
Bureau Equipment and Recruiting, Navy Department.	Steamer *Blake*	88.80
Cross, Austin & Co	Whaleboat and cutter No. 88	17.93
William Curry	Schooner *Spy*	29.20
John Dalton	Steamer *Hitchcock*	10.65
D. Delehanty, U. S. Navy	Steamer *Hassler*	2,878.65
J. C. Drake, U. S. Navy	Schooner *Ready*	78.95
William P. Elliott, U. S. Navy	Schooner *Eagre* and launches	1,458.26
Stehman Forney	Schooner *Transit*	63.38
L. M. Garrett, U. S. Navy	Steamer *Endeavor*	1,595.50
A. L. Hall, U. S. Navy	... do	224.02
J. M. Helm, U. S. Navy	Steamer *Gedney*	4,411.24
C. J. Hendry	... do	66.00
Joseph Hergesheimer	Schooner *Quick*	132.79
Herreshoff Manufacturing Co	Steamer *Gedney*	22.70
J. N. Jordan, U. S. Navy	Schooner *Earnest*	354.21
Robert H. Langford	Schooner *Transit*	197.00
D. H. Mahan, U. S. Navy	Steamer *McArthur*	6,561.12
H. B. Mansfield, U. S. Navy	Steamer *Patterson*	2,174.79
A. Melville	Use of floating derrick	6.76
J. F. Moser, U. S. Navy	Steamer *Bache*	3,260.88
B. G. Neff	Whaleboat and cutter No. 88	19.65
J. E. Pillsbury, U. S. Navy	Steamer *Blake*	3,110 22

STATEMENT OF THE EXPENDITURES OF THE UNITED STATES COAST AND GEODETIC SURVEY FOR THE FISCAL YEAR ENDING JUNE 30, 1890—Continued.

Repairs of Vessels, 1890—Continued.

To whom paid.	On what account.	Amount.
J. F. Pratt	Launch No. 26	$35.60
Samuel R. Risley	Barge *Beauty*	30.47
Thomas Shannon	Steamer *Hitchcock*	20.25
E. H. Tillman, U. S. Navy	Steamer *Endeavor*	20.15
C. E. Vreeland, U. S. Navy	Steamer *Blake*	39.55
William E. Woodall & Co	Steamer *Bache*	919.58
Woodward, Wright & Co	Steamer *Hitchcock*	13.20
Expenditures		27,898.56
Appropriation		25,000.00
Deficiency Act April 4, 1890		3,000.00
		28,000.00
Expenditures		27,898.56
Unexpended balance		101.44

CLASSIFICATION OF EXPENDITURES FOR REPAIRS OF VESSELS

Name of vessel.	Amount.	Name of vessel.	Amount.
Steamer *Bache*	$4,180.46	Schooner *Quick*	$132.79
Steamer *Blake*	3,238.63	Schooner *Ready*	78.95
Steamer *Endeavor*	1,839.67	Schooner *Spy*	86.20
Steamer *Gedney*	4,499.94	Schooner *Transit*	260.38
Steamer *Hassler*	2,878.65	Launch No. 26	35.60
Steamer *Hitchcock*	44.10	Launch No. 88	15.73
Steamer *McArthur*	6,561.12	Small whale boat	21.85
Steamer *Patterson*	2,174.79	Barge *Beauty*	30.47
Steam launches	6.76	Total	27,898.56
Schooner *Eagre* and launches	1,458.26		
Schooner *Earnest*	354.21		

General Expenses, 1890.

INSTRUMENTS, INSTRUMENT SHOP, CARPENTER SHOP, DRAWING DIVISION, BOOKS, MAPS, CHARTS, AND SUBSCRIPTIONS.

To whom paid.	On what account.	Amount.
Theodore Altender	Instrument shop	$53.46
American Geologist	Subscriptions	3.50
American Journal Mathematics	Books and subscriptions	10.00
Astronomical Journal	Books	5.00
William Ballantyne & Son	...do	86.21
D. Ballauf	Instrument shop	323.50
R. F. Bartle	Drawing division	6.00
J. Baumgarten & Son	Instrument shop	86.62
Robert Beall	Books	72.00
Charles Becker	Carpenter shop	5.03
Benedict & Burnham Manufacturing Co	Instrument shop	125.29
Hugo Bilgram	Instruments	222.60
John Bliss & Co	Instrument shop and charts	49.00
Arthur Bob	Instrument shop	2.50
Gustave Bossange	Drawing division	169.89
W. Andrew Boyd	Books	15.00
John A. Brashear	Instrument shop	20.00

STATEMENT OF THE EXPENDITURES OF THE UNITED STATES COAST AND GEODETIC SURVEY FOR THE FISCAL YEAR ENDING JUNE 30, 1890—Continued.

General Expenses, 1890—Continued.

INSTRUMENTS, INSTRUMENT SHOP, CARPENTER SHOP, DRAWING DIVISION, BOOKS, MAPS, CHARTS, AND SUBSCRIPTIONS—Continued.

To whom paid.	On what account.	Amount
George W. Brown	Books	$5.50
W. L. Brown & Co	Instrument shop	11.17
Brown & Sharpe Manufacturing Co	...do	125.00
Buff & Berger	Instruments	590.11
E. W. Bullinger	Subscriptions	6.00
Arthur Burkhardt	Instruments	122.33
Casino Art Co	Books	2.07
Chamberlain & Smith	Instrument shop	132.00
J. J. Chapman	Books	115.61
G. N. Colby	...do	11.00
Charles L. Condit	...do	35.00
Edward Corbett	Instrument shop	34.80
James D. and E. S. Dana	Subscriptions	6.00
Darling, Brown & Sharpe	Instrument shop	43.52
George Davidson	Instrument shop, books, maps, and subscriptions	57.25
J. M. Day	Instrument shop	2.25
D. Delehanty, U. S. Navy	Instruments and instrument shop	88.50
W. D. Doremus	Instrument shop	6.40
Electrical Review	Subscriptions	3.00
William P. Elliott, U. S. Navy	Instrument shop	.25
Engineering News Publishing Co	Subscriptions	5.00
Felt and Tarrant Manufacturing Co	Instrument shop	125.00
Fredk. Crane Chemical Co	Instrument and carpenter shops	19.25
T. H. Gardner	Books	12.00
Z. D. Gilman	Instrument shop	31.51
August Grass	Carpenter shop	4.50
Henry J. Green	Instrument shop	246.25
H. & L. E. Gurley	Instruments	20.00
R. E. Halter	Instrument shop and maps	21.00
Harris & Shearer	Instrument shop	122.45
Francis J. Hill	...do	352.50
H. Hoffa	...do	10.40
Hooe, Bro. & Co	Instrument and carpenter shops	53.57
L. H. Hopkins	Carpenter shop	28.85
Houghton, Mifflin & Co	Books	1.25
R. E. Jackson & Co	Carpenter shop	5.00
Jones & Laughlins, Limited	Instrument shop	11.80
Edwd. Kahler	...do	27.75
J. Karr	...do	281.50
Keuffel & Esser Co	Instruments and instrument shop	1,182.75
Julius Lansburgh	Carpenter shop	8.65
Jas. S. Lawson	Instrument shop, books, maps, and subscriptions	158.29
Libbey, Bittinger & Miller	Carpenter shop	527.15
C. F. Libbie & Co	Books	76.45
A. Lietz & Co	Instrument shop	15.70
Melville Lindsay	...do	8.21
M. Lukanitsch, jr	...do	149.50
Lutz & Bro	...do	4.50
Manhattan Brass Co	...do	50.00
H. B. Mansfield, U. S. Navy	...do	7.25
Chas. A. Martin	...do	.75
F. P. May & Co	Instrument and carpenter shops	171.26
McFadden Co	Instrument shop	245.31
W. H. Mehler	...do	.72
W. W. Mildrum	...do	9.00
Edward Miller	Subscriptions	4.57
Francis Miller	Instrument shop	62.56
Howard Miller	Subscriptions	6.00
W. H. Morrison	Maps	1.75

STATEMENT OF THE EXPENDITURES OF THE UNITED STATES COAST AND GEODETIC SURVEY FOR THE FISCAL YEAR ENDING JUNE 30, 1890—Continued.

General Expenses, 1890—Continued.

INSTRUMENTS, INSTRUMENT SHOP, CARPENTER SHOP, DRAWING DIVISION, BOOKS, MAPS, CHARTS, AND SUBSCRIPTIONS—Continued.

To whom paid.	On what account.	Amount.
W. B. Moses & Son	Instrument shop	$9.35
Mount, Orr & Co	.. do	3.00
H. & F. Müller	Instruments	63.61
New York Herald	Subscriptions	1.35
John C. Parker	Books, maps, and subscriptions	55.25
Seaton Perry	Carpenter shop	7.50
J. E. Pillsbury, U. S. Navy	Instrument shop	138.00
Pittsburgh Reduction Co	...do	2.06
Chas. H. Pleasants	...do	5.90
James W. Queen & Co	...do	779.24
Railroad and Engineering Journal	Subscriptions	3.00
Thos. D. Reed	Books	42.00
E. S. Ritchie & Sons	Instrument shop	167.00
Aug. F. Rodgers	...do	13.50
Rollstone Machine Co	Carpenter shop	2.65
Royce & Marean	Instrument shop	6.00
Geo. Ryneal, jr	Instrument and carpenter shops	67.81
Fred A. Schmidt	Drawing division	13.28
L. H. Schneider's Son	Instrument and carpenter shop	45.72
Science, N. D. C. Hodges, Pub	Subscriptions	3.50
Seaboard	do	2.00
Seth Thomas Clock Co	Instrument shop	62.40
Sidereal Messenger	Subscriptions	1.80
C. H. Sinclair	Maps	.75
Thos. W. Smith	Carpenter shop	4.00
L. S. Starrett	Instrument shop	8.80
B. F. Stevens	Maps and subscriptions	36.82
Giuseppe Tagliabue	Instrument shop	268.00
M. A. Tappan	.. do	12.00
S. Thaxter & Son	Charts	6.33
Chas. Henry Townshend	Instruments	150.00
U. S. Naval Institute	Subscriptions	3.50
W. H. Veerhoff	Carpenter shop	25.00
Chas. H. Walker	Instrument shop	12.00
Chas. L. Ward	.. do	10.00
Washington Gas Light Co	Carpenter shop	3.40
C. West & Sons	Instrument shop	78.03
B. Westermann & Co	Books and subscriptions	57.86
Richard H. Willet	Carpenter shop	192.80
Isaac Winston	Instrument shop	1.50
W. D. Wyvill	... do	30.00
Expenditures		9,111.62
Appropriation		9,000.00
Received from U. S. Fish Commission in payment for instruments furnished		115.00
		9,115.00
Expenditures		9,111.62
Unexpended balance		3.38

STATEMENT OF THE EXPENDITURES OF THE UNITED STATES COAST AND GEODETIC SURVEY FOR THE FISCAL YEAR ENDING JUNE 30, 1890—Continued.

General Expenses, 1890—Continued.

COPPER PLATES, CHART PAPER, PRINTING INK; COPPER, ZINC, AND CHEMICALS FOR ELECTROTYPING AND PHOTOGRAPHING; ENGRAVING, PRINTING, PHOTOGRAPHING, AND ELECTOTYPING SUPPLIES; EXTRA ENGRAVING AND DRAWING; PHOTOLITHOGRAPHING AND PRINTING FOR IMMEDIATE USE.

To whom paid.	On what account.	Amount.
James L. Barbour & Son	Engraving and photographing supplies	$9.35
Chas. Becker	Printing and electrotyping supplies	34.13
M. W. Beveridge	Electrotyping supplies	1.50
Julius Bien & Co	Photolithographing	4,973.70
A. Brown	Printing from stone	49.00
Bureau of Engraving and Printing	Printing ink and supplies	709.83
Bureau of Ordnance, Navy Department	Engraving supplies	53.02
E. F. Campbell	Printing for immediate use	172.90
Chas. F. Carter & Co	Electrotyping supplies	1.25
J. B. Chamberlain	Photographing supplies	5.60
Chamberlain & Smith	Engraving and photographing supplies	1.10
Clendenin Bros	Electrotyping supplies	637.40
George Davidson	Photographing supplies	54.08
E. J. Enthofler	Extra engraving	326.94
Isaac Friedenwald	Photolithographing	282.45
Henry E. Garland	Extra drawing	563.50
Z. D. Gilman	Engraving, printing, photographing and electrotyping supplies.	237.35
C. D. Gildersleeve	Printing supplies	70.00
Andrew B. Graham	Photolithographing, etc	198.00
E. N. Gray & Co	Printing supplies	61.92
Chas. J. Harlow	Printing for immediate use	105.14
Heliotype Printing Co	Photolithographing	21.00
Sophie S. Hein	Extra drawing	25.80
George Hergesheimer	Extra engraving	30.00
A. Hoen & Co	Photolithographing, etc	145.00
Hoe, Bro. & Co	Engraving and printing supplies	97.87
Geo. C. Howard	Printing supplies	75.00
H. Hoffa	Engraving supplies	19.80
Harry T. Knight	Extra engraving	783.70
Ernest Kubel	Engraving supplies	760.40
S. J. Kubel	Copper plates	74.20
Jas. S. Lawson	Photographing supplies	.50
Melville Lindsay	Electrotyping supplies	1.00
F. P. May & Co	Engraving and photographing supplies	10.92
J. P. Madigan	Printing for immediate use	334.55
Matthiessen & Hegeler Zinc Co	Electrotyping supplies	283.11
Robert Mayer & Co	Printing ink	4.50
W. H. Mehler	Printing supplies	19.20
Francis Miller	Engraving and electrotyping supplies	32.32
E. Morrison	Printing supplies	60.50
Mount Holly Paper Co	Chart paper	30.00
Wm. C. Peake	Photographing supplies	22.75
Norris Peters, deceased, by R. F. Crowell and Henry V. Parsell, administrators.	Photolithographing	191.25
Peter Adams Co	Chart paper	5,956.17
Charles H. Pleasants	Printing, photographing, and electrotyping supplies	183.95
Edwin Rose	Extra drawing	199.13
A. Rowland Robbins	Photolithographing	50.00
Geo. Ryneal, jr	Printing and electrotyping supplies	17.50
Fenner B. Satchwell	Extra drawing	10.72
Fred. A. Schmidt	Photographing supplies	35.22
L. H. Schneider's Son	Printing supplies	1.35
John Sellars & Sons	Copper plates	20.16
Augustine Smith & Co	Printing supplies	15.00
J. M. Williams	Printing for immediate use	65.55
Wilmarth & Edmonston	Printing supplies	.75
Expenditures		18,127.03
Appropriation—Sundry Civil Act March 2, 1889		12,000.00
Appropriation—Deficiency Act April 4, 1890		6,000.00
Received for electrotyping done for the Hydrographic Office, Navy Department		158.34
		18,158.34
Expenditures		18,127.03
Unexpended balance		31.31

STATEMENT OF THE EXPENDITURES OF THE UNITED STATES COAST AND GEODETIC SURVEY FOR THE FISCAL YEAR ENDING JUNE 30, 1890—Continued.

General Expenses, 1890—Continued.

STATIONERY, TRANSPORTATION OF INSTRUMENTS AND SUPPLIES, OFFICE WAGON AND HORSES, FUEL, GAS TELEGRAMS, ICE, AND WASHING.

To whom paid.	On what account.	Amount.
Adams Express Company	Transportation	$299.20
Theodore Alteneder	Stationery	18.00
William Ballantyne & Son	...do	8.30
J. Baumgarten & Son	...do	32.25
Herman Baumgarten	...do	6.00
Robert Beall	...do	2.00
Brentanos	Transportation	.40
James J. Chapman	Stationery	1.50
James Connor	Office horses	28.00
George Davidson	Telegrams, transportation, etc	28.89
Z. D. Gilman	Office horses	1.20
Ira Godfrey	Washing	9.00
Great Falls Ice Company	Ice	308.63
R. E. Halter	Stationery	1.75
Harriet E. Harrod	Washing	121.45
Inland and Seaboard Coasting Company	Transportation	5.57
C. K. Judson	Stationery, etc	11.52
Kennedy Bros	Fuel	1,063.30
Kueffel & Esser Company	Stationery	172.00
George W. Knox	Transportation	45.18
James S. Lawson	Transportation, stationery, etc	19.80
Lutz & Bro	Office wagon and horses	9.75
Walter H. Marlow	Fuel	105.93
E. Morrison	Stationery	159.92
Office Specialty Manufacturing Company	...do	2.40
John F. Paret	...do	17.25
John C. Parker	...do	75.90
Aug. F. Rodgers	...do	.80
Fred. A. Schmidt	...do	347.02
B. F. Shaw	Office horses and wagon	248.25
Smithsonian Institution	Transportation	30.45
J. N. Speel, U. S. Navy	Telegrams	.76
Stationery Division, Treasury Department	Stationery	1,676.62
John F. Stephenson	Transportation	6.33
Stephenson's Express	...do	30.67
B. F. Stevens	Stationery	553.34
William H. Teepe	...do	3.30
United States Express Company	Transportation	92.35
J. A. Walker	Stationery	2.25
Washington Gas Light Company	Gas	1,090.02
William Walters' Sons	Office wagon	35.00
Joseph Z. Williams	Fuel	11.00
Wyckoff, Seamans & Benedict	Stationery	63.00
Amount disbursed		6,766.25
Railroad accounts referred for settlement		148.28
Expenditures		6,914.53
Appropriation—Sundry Civil Act March 2, 1889		6,000.00
Appropriation—Deficiency Act April 4, 1890		1,000.00
		7,000.00
Expenditures		6,914.53
Unexpended balance		85.47

STATEMENT OF THE EXPENDITURES OF THE UNITED STATES COAST AND GEODETIC SURVEY FOR THE FISCAL YEAR ENDING JUNE 30, 1890—Continued.

General Expenses, 1890—Continued.

MISCELLANEOUS EXPENSES, CONTINGENCIES OF ALL KINDS, OFFICE FURNITURE, REPAIRS, EXTRA LABOR, AND TRAVELING EXPENSES (OFFICE).

To whom paid.	On what account.	Amount.
American Machinist Publishing Co	Advertising	$1.80
James F. Anderson	Repairs	66.92
Albert A. Asho	Extra labor	156.23
Margaret A. Bailey	...do	14.00
William Ballantyne & Son	Binder	.75
D. Ballauf	Oil cups	2.25
Barber & Ross	Brass letters	1.35
James L. Barbour & Son	General office supplies	71.60
G. W. Bates	Window protectors	8.00
James Bates	Graphite grease	12.00
J. Baumgarten & Son	Rubber stamps, etc	61.40
Charles Becker	General office supplies	14.00
Hans Bowdwin	Extra labor	39.37
C. T. Bride	Repairs	50.67
Burdett & Dennis	Auctioneer's commission	66.94
E. F. Campbell	Extra labor	24.70
Chesapeake and Potomac Telephone Co	Exchange rental	100.00
Henry A. Clark & Son	Repairing caligraph	3.00
Wm. Cogan's Sons	Repairs	2.00
Columbia Phonograph Co	Use of phonograph, etc	56.09
Commercial Weekly	Advertising	3.88
M. G. Copeland & Co	Awnings and ensign	31.50
Daily Critic	Advertising	11.20
Daily Press Co	...do	11.10
George Davidson	Suboffice expenses	122.39
Owen Donnelly	Case ladder	5.00
Evans & Rupertus	Office furniture	12.00
Evening Star Newspaper Co	Advertising	31.06
E. G. Fischer	Traveling expenses	15.96
James Fitzpatrick	Making archway	20.00
Forsberg & Murray	Repairs	195.00
Henry R. Garland	Extra labor	57.50
Z. D. Gilman	General office supplies	19.25
E. N. Gray & Co	Repairs	16.72
Henry J. Green	Packing and boxing	2.50
Israel Green	Extra labor	5.75
Mary L. Handlan	...do	81.29
Thomas Hensen	...do	13.00
Hooe, Bro. & Co	General office supplies	168.38
Edmund Hudson Publishing Co	Advertising	5.40
Chas. E. Hutchinson	Extra labor	4.50
W. S. Jenks & Co	General office supplies	230.25
Philip Kropp	Extra labor	110.00
Jas. S. Lawson	Suboffice expenses	143.80
Julius Lansburgh	General office supplies and office furniture	835.98
Library Bureau	Book supports	23.04
Robert P. Luckett, jr	Extra labor	9.50
Libbie Ludgate	...do	144.07
Lutz & Bro	Wallet	2.50
J. P. Madigan	Extra labor	1.90
Mail and Express, New York	Advertising	51.30
Marine Journal, New York	...do	10.50
Maritime Journal and Seaboard	...do	15.00
F. P. May & Co	General office supplies	31.92
W. H. Mehler	Repairs	41.35
B. P. Meyers	Post-office box rent	2.00
Francis Miller	General office supplies	5.17
I. H. Mills & Co	Type	5.76
E. Morrison	General office supplies	91.05
W. B. Moses & Son	Office furniture	72.60

STATEMENT OF THE EXPENDITURES OF THE UNITED STATES COAST AND GEODETIC SURVEY FOR THE FISCAL YEAR ENDING JUNE 30, 1890—Continued.

General Expenses, 1890—Continued.

MISCELLANEOUS EXPENSES, CONTINGENCIES OF ALL KINDS, OFFICE FURNITURE, REPAIRS, EXTRA LABOR, AND TRAVELING EXPENSES (OFFICE).

To whom paid.	On what account.	Amount.
Munn & Co	Advertising	$4.50
National Republican	....do	5.25
National View	....do	3.30
George Neal	Extra labor	8.00
New York Herald	Advertising	2.40
New York Press Co. (limited)	....do	42.75
J. N. Oden	Office sign	25.00
John C. Parker	Mimeograph	12.00
William C. Peake	Repairs	66.80
Charles H. Pleasants	General office supplies	9.96
The Republic	Advertising	3.48
Royce & Marean	Signal bells	125.00
George Ryneal, jr	General office supplies	9.75
F. A. Schneider	....do	2.55
L. H. Schneider's Son	....do	6.75
William E. Sietz	Extra labor	115.32
Edwin Smith	Traveling expenses	67.05
J. N. Speel, U. S. Navy	Post-office box rent	2.00
Sunday Herald	Advertising	7.65
William H. Teepe	Cyclostyle and supplies	26.95
William Thomas	Extra labor	65.00
H. O. Towles	Office furniture	47.00
Tribune Association	Advertising	7.20
William Wagner	Pass keys	.75
Washington City Post-office	Post-office box rent	16.00
Washington Critic Co	Advertising	3.75
Washington Post Co	....do	24.34
Washington Press	....do	5.52
John H. Wilkinson	Inspecting boilers	10.00
Wilmarth & Edmonston	General office supplies	42.85
Wykoff, Seamans & Benedict	Type-writers and supplies	276.00
F. H. Youngs	Cleaning carpets	14.85
Expenditures		4,493.83
Appropriation—*Sundry Civil Act March 2, 1889*		3,500.00
Appropriation—Deficiency Act April 4, 1890		1,000.00
		4,500.00
Expenditures		4,493.83
Unexpended balance		6.17

RENT OF BUILDINGS FOR OFFICES, WORKROOMS, AND WORKSHOPS.

To whom paid.	On what account.	Amount.
Alfred and Sarah A. Richards	Rent of buildings	$10,500.00
Appropriation		10,500.00
Expenditures		10,500.00

RENT OF FIRE-PROOF BUILDING.

To whom paid.	On what account.	Amount.
Benjamin F. Butler	Rent of fire-proof building	$6,000.00
Appropriation		6,000.00
Expenditures		6,000.00

STATEMENT OF THE EXPENDITURES OF THE UNITED STATES COAST AND GEODETIC SURVEY FOR THE FISCAL YEAR ENDING JUNE 30, 1890—Continued.

General Expenses, 1890—Continued.

RECAPITULATION.

(Showing expenditures in gross (by sub-items) on account of the appropriation for General Expenses, 1890.)

Instruments, instrument shop, carpenter shop, drawing division, books, maps, charts, and subscriptions		$9, 111. 62
Copper plates, chart paper, printing ink, copper, zinc, and chemicals for electrotyping and photographing; engraving, printing, photographing, and electrotyping supplies; extra engraving and drawing; photolithographing and printing for immediate use		18, 127. 03
Stationery, transportation of instruments and supplies, office wagon and horses, fuel, gas, telegrams, ice, and washing		6, 766. 25
Miscellaneous expenses, contingencies of all kinds, office furniture, repairs, extra labor and traveling expenses (office)		4, 493. 83
Rent of building for offices, workrooms, and workshops		10, 500. 00
Rent of fire-proof building		6, 000. 00
Amount disbursed		54, 998. 73
Railroad accounts referred to accounting officers for settlement		148. 28
Total expenditures		55, 147. 01
Total amount appropriated for General Expenses, 1890:		
Sundry Civil Act March 2, 1889	$47, 000. 00	
Deficiency Act, April 4, 1890	8, 000. 00	
		55, 000. 00
Received for electrotyping done for the Hydrographic Office, Navy Department		158. 34
Received for instruments furnished the U. S. Fish Commission		115. 00
		55, 273. 34
Total amount expended for General Expenses, 1890		55, 147. 01
Unexpended balance		126. 33

CLASSIFICATION OF EXPENDITURES FOR GENERAL EXPENSES, 1890.

On what account.	Amount.	On what account.	Amount.
Instruments	$2, 248. 65	Fuel	$1, 200. 23
Instrument shop	4, 933. 84	Gas	1, 090. 02
Carpenter shop	1, 007. 35	Telegrams	5. 76
Drawing division	189. 17	Ice	308. 63
Books, maps, and charts	625. 85	Washing	134. 14
Subscriptions	106. 76	Miscellaneous expenses and contingencies of all kinds	2, 689. 63
Copper plates	94. 36	Office furniture	431. 60
Chart paper	5, 986. 17	Repairs	439. 46
Engraving, printing, photographing, and electrotyping supplies	3, 518. 17	Extra labor	850. 13
Extra engraving	1, 140. 64	Traveling expenses (office)	83. 01
Extra drawing	799. 15	Rent of buildings for offices, workrooms, and workshops	10, 500. 00
Photolithographing	5, 910. 40	Rent of fire-proof building	6, 000. 00
Printing for immediate use	678. 14	Total	55, 147. 01
Stationery	3, 060. 12		
Transportation of instruments and supplies	693. 43		
Office wagon and horses	322. 20		

Salaries—Standard Weights and Measures, 1890.

To whom paid.	Time employed.	Amount.
Adjusters.		
James J. Clark	Six months	$750. 00
L. A. Fischer	Four months ten days	545. 87
Mechanician.		
Theodore Gerhards	One year	1, 250. 00
Watchman.		
A. B. Simons	One year	720. 00
Expenditures		3, 265. 87
Appropriation		3, 470. 00
Expenditures		3, 265. 87
Unexpended balance		204. 13

STATEMENT OF THE EXPENDITURES OF THE UNITED STATES COAST AND GEODETIC SURVEY FOR THE FISCAL YEAR ENDING JUNE 30, 1890—Continued.

Contingent Expenses—Standard Weights and Measures, 1890.

MATERIALS AND INCIDENTAL EXPENSES.

To whom paid.	On what account.	Amount.
Aluminum Brass and Bronze Co	Materials	$18.75
J. Baumgarten & Son	Stamps and stencils	9.50
Benedict & Burnham Manufacturing Co	Materials	4.07
George Davidson	Traveling expenses	78.27
Z. D. Gilman	Materials	5.50
Harris & Shearer	Brass castings	2.80
Hooe, Bro. & Co	Materials	10.65
Edward Kahler	Materials and instruments	53.00
E. J. Lewis	Materials	10.55
Libbey, Bittinger & Miller	...do	3.10
John C. Parker	Post-office guide	.80
Charles S. Platt	Materials	1.10
Charles H. Pleasants	...do	5.00
The Pratt and Whitney Co	...do	60.00
James W. Queen & Co	...do	87.42
Royce & Marean	Materials	4.60
Geo. Ryneal, jr	Gas screen, lamp chimneys, etc	1.05
L. H. Schneider's Son	Sheet lead and demijohns	11.99
B. F. Stevens	Reports	.99
O. H. Tittmann	Traveling expenses	17.50
Henry Troemner	Materials	112.50
Expenditures		499.11
Appropriation		500.00
Expenditures		499.11
Unexpended balance		.89

EXPENSES AMERICAN MEMBER—INTERNATIONAL COMMITTEE.

To whom paid.	On what account.	Amount.
B. A. Gould	Traveling expenses	$467.64
Appropriation		600.00
Expenditures		467.64
Unexpended balance		132.36

RECAPITULATION.

[Showing expenditures in gross (by sub-items) on account of the appropriation for Contingent Expenses—Standard Weights and Measures, 1890.]

Materials and incidental expenses	$499.11
Expenses American member—International Committee	467.64
Total expenditures	966.75
Total amount appropriated for Contingent Expenses—Standard Weights and Measures, 1890	1,100.00
Total amount expended for Contingent Expenses—Standard Weights and Measures, 1890	966.75
Unexpended balance	133.25

STATEMENT OF THE EXPENDITURES OF THE UNITED STATES COAST AND GEODETIC SURVEY FOR THE FISCAL YEAR ENDING JUNE 30, 1890—Continued.

RECAPITULATION.

[Showing appropriations, expenditures, and balances for the fiscal year ending June 30, 1890.]

Name of appropriation.		Appropriated.	Expended.	Balances.
Salaries, pay of Field Officers		$119, 500. 00	$105, 836. 20	$13, 663. 80
Salaries, pay of Office Force		132, 705. 00	129, 660. 01	3, 044. 99
Party Expenses:				
Sundry Civil Act March 2, 1889	$160, 700. 00			
Unexpended balance on Gravity Experiments, 1888	1, 725. 94	163, 469. 24	156, 289. 94	7, 179. 30
Deficiency Act April 4, 1890	1, 000. 00			
Repayment by George A. Fairfield	43. 30			
Alaska Boundary Survey:				
Sundry Civil Act March 2, 1889	20, 000. 00	23, 180. 55	3, 245. 60	19, 934. 95
Unexpended balance of appropriation on June 30, 1889	3, 180. 55			
Publishing Observations		3, 760. 00	3, 682. 82	77. 18
Repairs of Vessels:				
Sundry Civil Act March 2, 1889	25, 000. 00	28, 000. 00	27, 898. 56	101. 44
Deficiency Act April 4, 1890	3, 000. 00			
General Expenses:				
Sundry Civil Act March 2, 1889	47, 000. 00			
Deficiency Act April 4, 1890	8, 000. 00	55, 273. 34	55, 147. 01	126. 33
Repayment from Hydrographic Office, Navy Department	158. 34			
Repayment from U. S. Fish Commission	115. 00			
Salaries, Weights and Measures		3, 470. 00	3, 265. 87	204. 13
Contingent Expenses, Weights and Measures		1, 100. 00	966. 75	133. 25
Total		530, 458. 13	485, 902. 76	44, 465. 37
Total amount appropriated				530, 458. 13
Total amount expended				485, 992. 76
Total unexpended balance				44, 465. 37

EXPENDITURES SINCE LAST REPORT ON ACCOUNT OF THE APPROPRIATIONS FOR THE FISCAL YEAR ENDING JUNE 30, 1888.

Party Expenses, 1888.

OBJECTS NOT NAMED.

To whom paid.	On what account.	Amount.
Oregon Railway and Navigation Co	Transportation	$3. 19
Balance on hand—report for 1888		53. 88
Expended since, as above		3. 19
Present unexpended balance		50. 69

RECAPITULATION.

(Showing expenditures in gross by sub-items.)

Coast of Maine—report for 1889	$9. 00
Triangulation—Atlanta—Mobile—report for 1889	89. 99
Topography—California—report for 1889	72. 32
Triangulation—California—report for 1889	31. 70
Coast of Oregon—report for 1889	5. 74
Coast of Alaska—report for 1889	464. 20
Objects not named—report for 1890	3. 19
Expenditures during years 1889 and 1890	676. 14
Balance on hand—report for 1888	5, 786. 32
Expended since, as above	676. 14
Present unexpended balance	5, 110. 18

EXPENDITURES SINCE LAST REPORT ON ACCOUNT OF THE APPROPRIATIONS FOR THE FISCAL YEAR ENDING JUNE 30, 1889.

Party Expenses, 1889.

RESURVEY—SAN FRANCISCO BAY, ETC.

To whom paid.	On what account.	Amount.
Southern Pacific Company—Pacific system	Transportation	$310.98
Balance on hand—report for 1889		1,271.53
Expended since, as above		310.98
Present unexpended balance		960.55

TIDES—ALEUTIAN ISLANDS.

To whom paid.	On what account.	Amount.
M. C. Erskine	Observing tides	$150.00
Richard Finnegan	do	90.00
Expenditures		240.00
Balance on hand—report for 1889		433.25
Expended since, as above		240.00
Present unexpended balance		193.25

COAST PILOT.

To whom paid.	On what account.	Amount.
H. E. Nichols, U. S. Navy	Examinations	$397.00
Balance on hand—report for 1889		544.69
Expended since, as above		397.00
Present unexpended balance		147.69

OBJECTS NOT NAMED.

To whom paid.	On what account.	Amount.
Atchison, Topeka and Santa Fé R. R. Co	Transportation	$2.55
Balance on hand—report for 1889		3.56
Expended since, as above		2.55
Present unexpended balance		1.01

RECAPITULATION.

(*Showing expenditures in gross by sub-items.*)

Resurvey—San Francisco Bay, etc	$310.98
Tides—Aleutian Islands	240.00
Coast Pilot	397.00
Objects not named	2.55
Expenditures during year 1890	950.53
Balance on hand—report for 1889	6,763.60
Balance on hand—Transfer, steamer *Gedney*—report for 1889	15.30
	6,778.90
Expended since, as above	950.53
Present unexpended balance	5,828.37

EXPENDITURES SINCE LAST REPORT ON ACCOUNT OF THE APPROPRIATIONS FOR THE FISCAL YEAR ENDING JUNE 30, 1889—Continued.

General Expenses, 1889.

INSTRUMENTS, INSTRUMENT SHOP, CARPENTER SHOP, DRAWING DIVISION, BOOKS, MAPS, CHARTS, AND SUBSCRIPTIONS.

To whom paid.	On what account.	Amount.
Jas. D. and E. S. Dana	Subscriptions	$6.00
Railroad and Engineering Journal	do	3.00
Expenditures		9.00
Balance on hand—report for 1889		101.28
Expended since, as above		9.00
Present unexpended balance		92.28

MISCELLANEOUS EXPENSES, CONTINGENCIES OF ALL KINDS, OFFICE FURNITURE, REPAIRS, EXTRA LABOR, AND TRAVELING EXPENSES (OFFICE).

To whom paid.	On what account.	Amount.
D. Ballauf	Gas-engine fittings	$3.25
Lutz & Bro	Thread	1.50
Expenditures		4.75
Balance on hand—report for 1889		9.25
Expended since, as above		4.75
Present unexpended balance		4.50

RECAPITULATION.

(Showing expenditures in gross by sub-items.)

Instruments, instrument shop, carpenter shop, drawing division, books, maps, charts, and subscriptions	$9.00
Miscellaneous expenses, contingencies of all kinds, office furniture, repairs, extra labor, and traveling expenses (office)	4.75
Expenditures during year 1890	13.75
Balance on hand—report for 1889	127.50
Balance on hand—Deficiency Act March 2, 1889—report for 1889	59.70
	187.20
Expended since, as above	13.75
Present unexpended balance	173.45

U. S. COAST AND GEODETIC SURVEY,
OFFICE OF THE DISBURSING AGENT,
Washington, D. C., February 25, 1891.

I certify that the foregoing statement is a complete exhibit, in detail, of the expenditures of the U. S. Coast and Geodetic Survey (under the appropriations made by Congress) for the fiscal year ending June 30, 1890, and prior years, as shown by the books, records, and accounts now on file in this office.

JOHN W. PARSONS,
Disbursing Agent, U. S. Coast and Geodetic Survey.

Approved:
T. C. MENDENHALL,
Superintendent, U. S. Coast and Geodetic Survey.

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APPENDIX No. 7—1890.

REPORT OF THE ASSISTANT IN CHARGE OF THE OFFICE OF WEIGHTS AND MEASURES FOR THE FISCAL YEAR ENDED JUNE 30, 1890.

UNITED STATES COAST AND GEODETIC SURVEY,
OFFICE OF WEIGHTS AND MEASURES,
Washington, D. C., September 2, 1890.

SIR: Herewith I beg leave to submit a report on the operations of the Weights and Measures Office, in my charge, under your direction, during the fiscal year ending June 30, 1890.

The work of the office has been carried on with the usual force, although the demands upon it have greatly increased. This was largely owing to the necessity of preparing standards for the newly admitted States, but also to the increased demand from all part of the country for the comparison of weights and measures with the National Standards. Legislation relating to the sealing of weights and measures has been left to the several States, but it is evident that for interstate as well as for international commerce, and for other purposes, an official verification by this office of the measures involved is a necessary voucher for their correctness. These facts and considerations and the absence of legislation regarding the material representatives of national standards of weights and measures call for a comprehensive legislative enactment in regard to them. The receipt by this Government of the Prototype Metric Standards constructed by virtue of an international agreement, and now in the custody of this office, affords a fitting occasion to recommend such legislation as will insure their safe keeping and define their standing as ultimate standards of length and mass.

One set of these standards, namely, National Prototype Metre No. 27 and National Prototype Kilogramme No. 20, was brought from the International Bureau of Weights and Measures near Paris by Assistant George Davidson, and was deposited in this office on November 15, 1889. They remained under seal in the standards room in the Butler Building, whence they were taken to the Executive Mansion on January 2, 1890, and opened by the President of the United States in the presence of the Secretaries of State and of the Treasury, and others who had been invited to be present at the ceremony.

A certificate recording the circumstances under which the standards were received and opened was signed by the President and by the Secretaries of State and of the Treasury, and a separate attestation by the other gentlemen present.

When the International Committee undertook the construction of the standards, this Government, in view of the risks of transportation and for other reasons, ordered for its own use two sets of these standards and an additional metre bar of similar cross-section and material, but made of the alloy of 1874.

It was intended that after these should have been safely transported to this country one set should remain here permanently, while the other could be taken back to the International Bureau, whenever it might be deemed desirable, for comparison with the International Prototypes.

The first set and the metre of the alloy of 1874 (Metre No. 12) having been safely brought to this country by Assistant Davidson, I was directed to bring the second set from Paris. In accordance with instructions from the Honorable Secretary of State and yourself, I sailed for Europe on April 23, and after visiting the weights and measures offices of London, Paris, and Berlin, I received the standards in question (National Prototype Metre No. 21 and National Prototype Kilogramme No. 4) from the International Bureau, and brought them to this country, depositing them in the standards room on July 14. A more detailed statement in regard to these standards and the certificates accompanying them will be published in Appendix No. 18, to this volume.

A collection of the latest State laws relating to weights and measures was made during the year, and a circular was issued through the Department of State to the United States Consuls asking for information on the weights and measures of the different countries to which they are accredited. Replies from about forty-five countries have been received.

The necessity of furnishing reliable information to the public on the relation of metric to customary weights and measures of the United States led to the preparation of a convenient table for the interconversion of the units of these two systems. The publication of this has been followed by a great demand, and the distribution of several thousand copies to meet it.

Bulletin No. 15, on the verification of weights and measures, was prepared and issued. Bulletin No. 18, for the reduction of salinometer observations, was prepared for the use of the Coast and Geodetic Survey and the U. S. Fish Commission.

During my absence in Europe on business relating to weights and measures, the office was in charge of Assistant George A. Fairfield from April 22 to May 14, and under the charge of Assistant F. H. Parsons from the latter date to the end of the fiscal year.

On December 31, 1889, Dr. J. J. Clark, for many years adjuster of weights and measures, a position the duties of which he discharged honorably and with ability, resigned; and this vacancy was filled by the appointment of Mr. L. A. Fischer, who was transferred from the Instrument Division to this one on October 9, 1889, and who was appointed to the position of adjuster on February 19, 1890.

Mr. Fischer has shown much aptitude for the work devolved on him, and has performed his duties with earnest zeal. He constructed an experimental hydraulic lift for the comparator, and made drawings for certain parts of the latter, while his principal work has been to make adjustment weighings and length comparisons.

Mr. Parsons attended to the clerical work of the office, made and assisted in thermometer and scale comparisons, and determined the irregularities of the screws of the micrometers of microscopes 3 and 4 of the comparator.

The services of Mr. Gerhards, mechanician, and those of Mr. Simons, watchman, are accounted for in the reports of the Instrument and Miscellaneous Divisions, respectively.

A detailed statement of information furnished and work done is appended.

Yours, respectfully,

O. H. TITTMANN,
Assistant in charge of Office of Weights and Measures.

Dr. T. C. MENDENHALL,
Superintendent U. S. Coast and Geodetic Survey and of Weights and Measures.

Table containing list of work done and information furnished during the fiscal year 1890.

No.	Date.	Name.	Service.
	1889.		
1	July 13	Columbia College, New York	4^m base rod, compared
2	July 25	University of Virginia	5^m bar, compared.
3	July 31	Becker Bros., for city of Boston	1 set grain and 1 set metric weights; compared (22 grain) (22 metric), 44 weights.
4	July	Coast and Geodetic Survey	4^m bars No. 7 and 8, compared.
5	Aug. 6	Mint Bureau, Treasury Department	4 coin weights, furnished.
6	Aug. 6	Agricultural Department	4 polariscope tubes, compared.
7	Aug. 8	... do	6 polariscope tubes, compared.
8	Sept. 28	U. S. Geological Survey	300 feet tape, compared.
9	Oct. 8	Richards & Co., New York	1 set metric and 1 set karat weights, compared (23 metric) (16 karat), 39 weights.
10	Nov. 23	U. S. Geological Survey	100 feet tape, compared.
11	Nov. 25	J. H. Allen, Rome, Ga	1 set weights, compared, 13 weights.
12	Nov.	Coast and Geodetic Survey	Bulletin No. 15, prepared for publication.
13	Dec. 4	J. W. Queen & Co. for H. H. Jackman, civil engineer, Wichita, Kans.	1 50-foot tape, compared.
14	Dec. 5	Prof. M. A. Howe	1 200-foot tape, compared.
15	Dec. 12	International Marine Conference	Information furnished.
16	Dec. 14	State of Nebraska	1 set weights, measures, and balances furnished.
17	Dec. 17	State of New Jersey	1 set weights, measures, and balances repaired and partially replaced.
18	Dec. 20	Coast and Geodetic Survey	2 thermometers, compared.
	1890.		
19	Jan. 15	C. C. Covey, Farmer City, Ill	Information furnished.
20	Jan. 20	U. S. Coast and Geodetic Survey	Scale, compared.
21	Jan. 23	Governor of Kentucky	Information furnished.
22	Feb. 4	U. S. Geological Survey	1 300 foot tape, compared.
23	Feb. 8	Mint Bureau, Treasury Department	15 coin weights, furnished.
24	Feb. 14	E. S. Holden, Lick Observatory	1 scale, compared.
25	Mar. 6	U. S. Coast and Geodetic Survey	2 tapes, compared.
26	Mar. 6	....do	3 thermometers, compared.
27	Mar. 8	....do	1 tape, compared.
28	Mar. 11	J. P. Walton, civil engineer, Lincoln, Nebr.	1 100-foot tape, compared.
29	Mar. 12	Report prepared for publication on	Schuckburg scale and Kater pendulum
30	Mar. 12	L. W. Matthewson, Cincinnati, Ohio	Tape, compared.
31	Mar. 13	Agricultural Department	2 6-litre flasks, compared.
32	Mar. 18	E. A. Vance, Kinsman, Ohio	1 tape, compared.
33	Mar. 18	E. D. Stockwell, Cleveland, Ohio	Do.
34	Mar. 18	C. H. Burgess, Cleveland, Ohio	Do.
35	Mar. 20	Internal Revenue Bureau	1 thermometer, compared.
36	Mar. 27	Geo. L. Wilson, civil engineer, St. Paul, Minn.	1 tape, compared.
37	Mar. 27	Justus Roe & Son, New York	Do.
38	Mar. 28	Eimer & Amend, New York	1 set metric weights, compared, 24 weights.
39	Mar. 29	Wyatt & Weingaerten, New York	1 set metric weights, compared, 22 weights.
40	Apr. 3	Mayor of Boston	Information furnished.
41	Apr. 12	U. S. Coast and Geodetic Survey	1 tape, compared.
42	Apr. 28	Keuffel & Esser, New York	1 Y and M bar, compared.
43	May 10	G. W. Osborne, Washington	1 set of weights, compared, 4 weights.
44	May 13	Geo. F. Lucas, Castile, N. Y	1 tape, compared.
45	May 15	Internal Revenue Bureau	1-gallon and ½-gallon standards, loaned.
46	May 15	... do	4 thermometers, compared.
47	May 16	Greeley Carlson Co., Chicago, Ill	2 tapes, compared.
48	May 29	U. S. Coast and Geodetic Survey	1 tape, 200 feet, compared.
49	June 3	....do	Do.
50	June 11	G. Tagliabue, New York	2 thermometers, compared.
51	June 12	Internal Revenue Bureau	1 set capacity measures, compared.
52	June 14	M. D. Ewell	Metric weights, compared, 2 weights.
53	June 14	Oscar Oldberg, Chicago	Information furnished.
54	June 23	M. Fargusson, North Carolina	1 tape, compared.
55	June 26	U. S. Geological Survey	Do.

APPENDIX No. 8—1890.

RESULTS OF THE OBSERVATIONS MADE AT THE U. S. COAST AND GEODETIC SURVEY MAGNETIC OBSERVATORY, AT LOS ANGELES, CALIFORNIA, IN CHARGE SUCCESSIVELY OF MARCUS BAKER, ACTING ASSISTANT, CARLISLE TERRY, JR., SUBASSISTANT, AND RICHARD E. HALTER, ASSISTANT, BETWEEN THE YEARS 1882 AND 1889.

PART I.—RESULTS OF THE ABSOLUTE MEASURES OF THE DIRECTION AND INTENSITY OF THE EARTH'S MAGNETIC FORCE.

Discussion and report by CHARLES A. SCHOTT, Assistant.

[Submitted for publication January 27, 1890.]

TABLE OF CONTENTS.

INTRODUCTION.

In conformity with the general plan pursued for the prosecution of the work of the Coast and Geodetic Survey in terrestrial magnetism, and in coöperation with the work proposed by the International Polar Commission, and supported on the part of the United States by the participation of the U. S. Signal Service, the Superintendent of the Survey, Mr. J. E. Hilgard, decided to reëstablish at the most suitable place a magnetic observatory for continuous registration of the changes of the magnetic force.

Before this similar records had been made at Key West, Florida, between the years 1860 and 1866, and at Madison, Wisconsin, between the years 1876 and 1881, and it became, therefore, desirable to select the new station as far remote from these places as practicable and in a region where the laws of magnetism were as yet but little understood or only imperfectly developed. At the same time, the part which the United States took in connection with the International Polar Researches, by fitting out two expeditions, one under Lieut. P. H. Ray, U. S. A., to Point Barrow, the other under Lieut. A. W. Greely, U. S. A., to Lady Franklin Bay,* demanded assistance nearer home in the form of continuous registry of the changes of the magnetic force in order to furnish the means for the comparison of the magnetic results at all stations taking part in the undertaking of the International Commission.

LOCATION AND POSITION OF OBSERVATORY.

Under instructions issued to him May 26, 1882, Assistant James S. Lawson was directed to examine certain localities in southern California, and he finally selected as the most favorable site for the observatory the grounds of the Branch Normal School in Los Angeles as meeting fully the essential requirements respecting permanency of occupation for several years, freedom from local disturbances, supply of pure water, economy of construction of building, and convenience of living for the observer. Mr. Lawson constructed the observatory according to plans furnished by the Office with such needful modifications as suggested themselves to him. The maintenance of as uniform a temperature as could be secured being a desideratum for the proper performance of self-registering magnetometers, the building was a double one, the inner and the outer walls being separated by an air space of about 2½ feet, which extended also over the double roof. The walls are formed of planking and the space between them is filled with dry earth well tamped in; the inner and outer walls of the structure are of rough boards and battened, the ceiling of the inner shell is composed of tongued-and-grooved boards, and on the top of the joists is a rough board floor covered with a layer of earth. The roof is shingle-covered. The outer door is on the south face and, after entering, a narrow passage on the west side leads to the dark room attached to the north side, whence the instrument room proper is reached. Ventilation is provided for by pipes running through the roof. The dimensions of the building are as follows: Length, 28 feet; width, 21 feet; dark room, 10 by 12 feet; height, about 8 feet to the eaves. The instrument room measures 19 by 12 feet, height about 8 feet, just sufficient to accommodate the Adie magnetograph. The three instrument piers, the clock and lamp piers, were of brick and rested on the same foundation, and the central clock pier was connected with the tops of the magnet piers by the stone slabs originally furnished with the instruments. The wooden floor of the room was disconnected from the piers.

The observatory was placed on the sloping ground about 200 feet (61 metres) from the nearest wall of the school building and almost directly west of it; at the foot of the slope and about 210 feet, or 64 metres, to the southward and westward (S. 37° W. true) a small wooden structure was put up for the accommodation of a magnetometer and dip circle used for the monthly absolute

* For the part the Survey took in the magnetic work of these two expeditions see, for Point Barrow, Appendix No. 13, annual report for 1883, and part VI of Lieutenant Ray's official publication, Washington, 1885, and for Lady Franklin Bay, Lieutenant Greely's official report, vol. 2, Appendix No. 139, Washington, 1888. An abstract of the results will be found in Appendix No. 10, annual report for 1887.

measures. The elevation of the observatory is nearly 312 feet (95 metres) above the sea level, and its geographical position as determined by triangulation* is as follows:

Observatory north of flag-pole of normal school 135 feet (41.1 metres), and west of the same 275 feet (83.9 metres); it is also 47.0—41.1, or 5.9 metres south of the astronomical telegraphic longitude station established here temporarily in the western grounds in March, 1889, and 83.9—56.8, or 27.1 metres, west of the same.

Present geodetic latitude of normal school flag-pole, 34° 02′ 55″.9, with probable correction of + 0″.8

Difference of latitude, 1″.3

Latitude of magnetic observatory (center), 34° 02′ 57″.2, and corrected 34° 02′ 58″.0

Present astronomical longitude of 1889 station, 118° 15′ 22″.6

Difference of longitude 1″.0

Longitude of magnetic observatory, 118° 15′ 23″.6, or 7^h 53^m $01^s.57$ west from Greenwich; also 8^h 32^m $47^s.81$ west from Göttingen.†

The elevation of the brick pier for absolute measures is 279 feet, or 85 metres, above the average sea level.

The magnetic instruments.—As early as 1861 the Survey had procured from Kew one of the newly devised Adie magnetographs, but owing to the then disturbed state of the country, and later on from lack of funds, the instrument remained in the storeroom until it was decided in the spring of 1882 to bring it into permanent use. In order to test its completeness and the proper conditions of the magnets the instrument was set up at the Office in Washington in October, 1878, with the aid of Mr. Werner Suess, mechanician to the Office; the scale values were then roughly determined by the writer and the magnets were found to be in a satisfactory condition.

Organization of the observatory.—Under instructions to Mr. Suess, dated July 7, 1882, the instrument was mounted by him at the Los Angeles observatory and roughly adjusted, and the photographic process was brought into a good working condition. On the arrival of Mr. Marcus Baker, acting assistant, who was placed in charge of the observatory by instructions from the Superintendent, dated July 19, 1882, the final adjustments were made and the scale values of the three magnetometers were determined. The regular work of the observatory commenced with October 1, 1882, and was continued without any serious interruption to October 1, 1889, thus covering a period of nearly two-thirds of a sun-spot cycle and including the time of the minimum sun-spot activity, supposed to have occurred early in the year 1889. Mr. Baker remained in charge of the observatory until August 1, 1884, when Mr. Carlisle Terry, jr., aid in the Survey, assumed charge under instructions dated June 16, 1884. In consequence of failing health‡ Mr. Terry was relieved from this duty (at his own request) and Assistant R. E. Halter, who had been aiding him since November, 1886, was appointed to the observatory January 17, 1887, and on February 1 took charge of the same. Mr. Halter conducted the work to its close in October, 1889, when it became necessary to discontinue the service in consequence of the encroachments caused by the necessity of enlarging the building accommodations of the public school.

Besides the chiefs in charge there was but one employé who assisted in the manual labor. The duty of duplicating the records§ and making a first computation of the observations, inclusive of the reading off of hourly coördinates of the traces, devolved upon the chief of the observatory.

The absolute magnetic measures.—They are supplementary to the differential measures and were made monthly on three days about the middle of each month, in order to furnish the means of expressing the results of the differential measures in terms of absolute units. The portable instruments provided for these observations were magnetometer No. 8 and Kew dip circle No. 21. The magnetometer is of a pattern shown on plate No. 35, Coast and Geodetic Survey report for 1881; it is an old instrument originally made by Jones, of London, but actually

* The trigonometrical connection with the main triangulation was made by Assistant A. F. Rodgers in 1883.

† Taking longitude of Göttingen 0^h 39^m $46^s.24$ east from Greenwich.

‡ Subassistant Terry died at his home, Columbus, Georgia, March 10, 1887.

§ The photographic traces were duplicated by the blue-print process.

composed of various pieces from condemned instruments. The declination magnet (L_8) is mounted over the center of the horizontal circle and is about $3\frac{1}{2}$ inches (8.9 centimetres) long. The shorter magne (S_8), suspended during deflections, is about 3 inches (7.6 centimetres) long; both are collimators. The determination of the astronomical azimuth is more conveniently done with a separate instrument for which purpose a small theodolite was provided. The construction of the dip circle is shown on plate No. 37, report for 1881.

Determination of the instrumental constants.—The constants of magnetometer No. 8 are as follows:

Scale values of magnets.—The scale of L_8 consists of 20 vertical lines on glass, every fifth being longer; the scale is considered "erect" when the long lines project upwards or the figures 0, 5, 10, 15, 20 appear above. Observations for scale value were made by Mr. Baker February 13, 1883, whence one division of scale, 2′.72 and 2′.70, and by Subassistant R. A. Marr June 11, 1886, who got from 3 sets 2′.72; value adopted, 2′.71. Increasing scale readings correspond to decreasing horizontal circle readings. The scale of S_8 is similar to that of L_8, the two longer lines projecting upwards on one side of the middle and downwards on the other; scale considered erect when two large scratches point downwards. Observations made by Mr. Baker September 13, 1882, gave the value at 2′.91. Increasing scale readings correspond to decreasing circle readings.

The deflecting bar is of brass graduated to feet and tenths; the graduation was tested by means of a steel standard bar, and Mr. Baker concludes from his comparisons of November 3, 4, and 5, 1883, that the deflecting bar is a little too long and the correction constant throughout the scale. This correction for each foot is — 0.00018 feet (or — 0.0055 centimetres) at 62°.2 F., and supposing r_0 = the apparent distance between centers of magnets and r = the true distance, then

$$r = r_0\,[1 + 0.000019\,(T - 16^\circ.8\ C) - 0.00018]$$

Ordinarily the value of r_0 was taken 1.2 feet, or 36.58 centimetres.

Mass or inertia-ring Z, weight	648.8 grains, weight probably by maker .... January 4, 1874 648.7 grains, by J. J. Clark .... December, 27, 1878	$w = 42.038$ gm.
Outer diameter	2.3289 inches, at 60°.5 F., measure probably by maker ..... 1874 2.3285 inches, at 62°.0 F., by C. A. Schott, December 27, 1878	$2r_1 = 5.9149$ cn
Inner diameter...........	1.8400 inches, at 60°.5 F., measure probably by maker .... 1874 1.8425 inches, at 62°.0 F., by C. A. Schott, December 27, 1878	$2r = 4.6767$ cm.

Moment of mass or of inertia, $M_1 = \frac{1}{2}\,(r^2 + r_1^2)\,w$; $M_1 = 298.773$ at 16°.5 C and putting e, the coefficient of expansion for bronze = 0.000019, we have for any temperature τ on the centigrade scale, log. $M_1 = 2.47534 + 0.0000165\,(\tau - 16^\circ.7)$.

Numerous observations were made for the *moment of mass or inertia* (M) of magnet L_8 between 1874 and 1886, but I propose to use only the observations which were made by Mr. Baker and Mr. Marr at Los Angeles when the small *balancing* rings remained in the same position as during the measures of intensity.

We have $M = M_1 \frac{T^2}{T_1^2 - T^2}$, where T, the time of one oscillation, refers to the magnet (with stirrup) and T_1 to the magnet (and stirrup) loaded with mass-ring Z.

Results from successive observations of oscillations with and without the mass ring.

SET No. I. DECEMBER 19, 1882. M. BAKER, OBSERVER.

No.	Temp. Fah.	T^2 at $\begin{cases} 66.0° \text{ F.} \\ 18.9 \text{ C.} \end{cases}$	T_1^2 at $\begin{cases} 66.0° \text{ F.} \\ 18.9 \text{ C.} \end{cases}$	$T_1^2 - T^2$	$M_1 \frac{T^2}{T_1^2 - T^2}$
1	60.1°	25.309			
2	62.1	(25.323)*	83.838	58.515	129.31
3	64.1	25.337	(83.893)*	58.556	.29
4	65.8	(25.336)	83.948	58.612	.16
5	65.6	25.336	(83.922)	58.586	.22
6	67.8	(25.338)	83.896	58.558	.29
7	68.4	25.341	(83.900)	58.559	.30
8	68.1	(25.332)	83.903	58.571	.23
9	67.1	25.322		Mean.	129.257 ±.014

* Numbers within parentheses are means of the preceding and following values respectively, the combination by *alternate* means correcting for effect of progressive change of the horizontal force.

SET No. II. SEPTEMBER 22, 1883. M. BAKER, OBSERVER.

No.	Temp. Fah.	T^2 at $\begin{cases} 104.1° \text{ F.} \\ 40.1 \text{ C.} \end{cases}$	T_1^2 at $\begin{cases} 104.1° \text{ F.} \\ 40.1 \text{ C.} \end{cases}$	$T_1^2 - T^2$	$M_1 \frac{T^2}{T_1^2 - T^2}$
1	108.8°	26.011			
2	104.1	(26.043)	86.284	60.241	129.28
3	101.8	26.076			

SET No. III. APRIL 22, 1886. R. A. MARR, OBSERVER.

No.	Temp. Fah.	T^2 at $\begin{cases} 68.2° \text{ F.} \\ 20.1 \text{ C.} \end{cases}$	T_1^2 at $\begin{cases} 68.2° \text{ F.} \\ 20.1 \text{ C.} \end{cases}$	$T_1^2 - T^2$	$M_1 \frac{T^2}{T_1^2 - T^2}$
1	59.8°	25.456			
2	62.4	(25.455)	84.219	58.764	129.44
3	64.2	25.454	(84.236)	.782	.40
4	65.7	(25.452)	84.252	.800	.34
5	67.9	25.449	(84.296)	.847	.23
6	70.9	(25.453)	84.341	.888	.16
7	72.7	25.457	(84.318)	.861	.24
8	74.0	(25.465)	84.295	.830	.34
9	75.2	25.472		Mean.	129.307 ±.026

Results from successive observations of oscillations with and without the mass ring—Continued.

SET No. IV. APRIL 23, 1886. R. A. MARR, OBSERVER.

No.	Temp. Fah.	T^2 at $\begin{cases} 66^\circ.0 \text{ F.} \\ 18.9 \text{ C.} \end{cases}$	T_1^2 at $\begin{cases} 66^\circ.0 \text{ F.} \\ 18.9 \text{ C.} \end{cases}$	$T_1^2 - T^2$	$M_1 \frac{T^2}{T_1^2 - T^2}$
1	64°.4		84.078		
2	66.7	25.405	(84.089)	58.684	129.35
3	67.5	(25.410)	84.099	.689	.37
4	68.2	25.416		Mean.	129.360

SET No. V. APRIL 30, 1886. R. A. MARR, OBSERVER.

No.	Temp. Fah.	T^2 at $\begin{cases} 71^\circ.6 \text{ F.} \\ 22.0 \text{ C.} \end{cases}$	T_1^2 at $\begin{cases} 71^\circ.6 \text{ F.} \\ 22.0 \text{ C.} \end{cases}$	$T_1^2 - T^2$	$M_1 \frac{T^2}{T_1^2 - T}$
1	66°.7	25.530			
2	69.6	(25.532)	84.445	58.913	129.51
3	70.8	25.534	(84.511)	58.977	.38
4	70.2	(25.541)	84.577	59.036	.28
5	70.1	25.548	(84.524)	58.976	.45
6	71.0	(25.538)	84.471	58.933	.50
7	72.2	25.528	(84.478)	58.950	.41
8	72.3	(25.523)	84.485	58.962	.36
9	73.0	25.517	(84.505)	58.988	.27
10	73.8	(25.524)	84.524	59.000	.28
11	73.8	25.531	(84.547)	59.016	.28
12	72.6	(25.534)	84.569	59.035	.25
13	72.0	25.538		Mean.	129.361 ±.019

RECAPITULATION OF RESULTS FOR M, ALL REDUCED TO TEMPERATURE 62°.0 F. OR 16.7 C.

Set.	Date.	Observer.	M.	No. of values.
1	1882, Dec. 19	M. B.	129.250	7
2	1883, Sept. 22	M. B.	.210	1
3	1886, Apr. 22	R. A. M.	.290	7
4	1886, Apr. 23	R. A. M.	.355	2
5	1886, Apr. 30	R. A. M.	.350	11
		Weighted* mean.	129.305 ±.015	

*According to number of values.

The coefficient of expansion for hard-tempered steel may be taken as 0.0000122 for the centigrade scale, hence, for any temperature τ we have

$$M = \underset{\pm .015}{129.305}\,[1 + 0.0000244\ (\tau - 16^\circ.7)]$$

and logarithmically; $\log M = \underset{\pm\ \ \ 5}{2.11162} + 0.0000106\,(\tau - 16^\circ.7\ \text{C}).$

For the purpose of determining the coefficient q or the change of magnetic moment of magnet L_0 for a change of temperature of 1°, an elaborate series of observations was made at Lafayette Park Observatory, San Francisco, by Assistant J. S. Lawson, by alternately heating and cooling the magnet and observing the changes in the angle of deflection of the suspended magnet S_8. The results are as follows:

	Date.	Operation.	Range of temperature.		Relative weight.
	1881.		° °		
1	Apr. 7	Alternate heating and cooling	40.2 to 106.4 F.	$q=$ .00054	10
2	Apr. 8	Alternate heating and cooling	34.5 to 109.3	.00057	16
3	Apr. 12	Alternate heating and cooling	37.9 to 103.0	.00053	18
4	Apr. 15	Gradually heating and cooling	38.8 to 107.5	.00059	8
5	Apr. 16	Gradually heating and cooling	34.4 to 107.9	.00063	11
6	Apr. 26	Alternate heating and cooling	37.4 to 105.8	.00058	18
7	Apr. 27	Alternate heating and cooling	36.9 to 107.3	.00058	18
			Weighted mean	$q=0.00057$ ± 1	

It would seem that the value of q is decreasing with time; thus we have

1874, April to November, C. O. Boutelle, observer . . . . $q=.00103$ for Fah. scale [from rough observations of oscillations].
1879, January to November, W. Eimbeck and J. B. Baylor, observers. $q=.00074$ for Fah. scale.
1881, April, J. S. Lawson, observer . . . . $q=.00057$ for Fah. scale.

Where $q=\frac{a\ n\ \text{cosec.}\ u}{t-t_0}$, u being the angle of deflection at the lower temperature, n the differences of scale-readings, and a the arc value of one division of the suspended magnet in radians; for the centigrade scale we have $q=0.00103 \atop \pm\ 2$

Determination of the coefficient P depending on the distribution of magnetism in the deflecting and deflected magnets L_8 and S_8. The ratio of length of these magnets is $\frac{3.37}{3.04}$ or 1.11 nearly, but as 1.224 is the most advantageous value, we may expect a somewhat large negative value for P.

Let u, u_1 be the angles of deflection and let $A=\frac{1}{2}r^3\sin u$ for the shorter deflecting distance r, and $A_1=\frac{1}{2}r_1^3\sin u_1$ the same for the longer distance r_1, corrected for change of temperature, error of scale, and effect of induction, then $P=\frac{A-A_1}{\frac{A}{r^2}-\frac{A_1}{r_1^2}}$ which may be put in the forms

$\frac{r_1^2\,r^2}{r_1^2-r^2}\left(1-\frac{A_1}{A}\right)$ or $P=\frac{r_1^2\,r^2}{r_1^2-r^2}\left\{\frac{\log A-\log A_1}{\text{modulus}}\right\}$, which formulæ will give P with a sufficient degree of approximation.

We have the following results deduced from observations made by Mr. Baker: February 17, 1883, between 9¾ a. m. and 5 p. m., L_8 deflecting, S_8 suspended; the 6 values of r range from 1.08 to 1.13 feet and those of r_1 from 1.525 to 1.59 feet, and the values of u and u_1 range from 40′ to 2° 08′. Combining 1.08 with 1.525, 1.09 with 1.535, etc., the following six values of P_1 were found expressed in F. G. S. units:*

$$\left.\begin{array}{r}-.0179\\-.0121\\-.0137\\-.0137\\-.0208\\-.0002\end{array}\right\}\text{Mean, } P_1=-.0131$$

By combining each (short) r with every (long) r_1 the observer deduces the value $P_1=-0.0134\pm0.0006$, but this value is more incumbered by the effect of changes in the horizontal force during the time of observation. From a number (25) of observations made by Assistant Lawson at

*For C. G. S. units the subscript to the coefficient is omitted.

various places between June and December, 1881, we deduce the value $P_1=-0.0117\pm0.0012$. Further, Mr. R. A. Marr made a series of observations for the value of P_1 between April 24 and May 1, 1886, from which the following values were deduced:

April 24	$P_1=-.0121$	$n=4$
26	$-.0083$	3
27	$-.0120$	2
28	$-.0095$	1
May 1	$-.0084$	5
Weighted mean	$-.0099$	
	$\pm.0006$	

Combining these three values the weighted mean becomes $P_1=0.0113\pm.0008$; hence for C. G. S. units $P=-10.5\pm0.7$, which value has been adopted in the reduction of the deflections. The effect of the next coefficient Q is supposed to be insensible.

Determination of the induction coefficient (μ).—A series of elaborate observations for determining the value of the induction factor (h) was made by Mr. Baker on October 27, November 27 and 28, 1883, by means of a simple contrivance of his own for placing the induced magnet into the various positions required. For the method followed the reader may be referred to Lamont's Handbuch des Erdmagnetismus, Berlin, 1849, and to Coast Survey Report for 1869, Appendix No. 9, pp. 200, 201. Magnet L_8 was mounted vertically by the side and at a short distance from the suspended magnet S_8, and in the plane of the magnetic prime vertical passing through the center of S_8; deflections are observed with magnet L_8, north end *down*, magnet up and down, and again with L_8, north end *up*, magnet up and down. Let φ and φ_1 = the angles of deflection respectively and let θ = the magnetic dip and H = the horizontal component of the earth's magnetic intensity, then

$$h=\frac{\tan\frac{1}{2}(\varphi-\varphi_1)}{H\tan\theta\tan\frac{1}{2}(\varphi+\varphi_1)}$$

Observations were made on both sides of the suspended magnet and at various distances from it, as may be seen from the following table computed by the observer and revised at the Office. The values used in the computation were $\theta=59°\ 30'$ and $H=5.914$ in units of the F. G. S. system, or 0.2727 in units of the C. G. S. system.

Set.	Time, 1883.	Temp. C.	Deflector, E. or W.	Distance cm.	φ			φ_1			h F. G. S. system.	h C. G. S. system.
	h. m.	°			°	′	″	°	′	″		
1	Oct. 27, 10 45 a. m.	20.5	W.	11.61	25	31	50.0	24	44	42.5	0.00146	0.0317
2	1 59 p. m.	22.0	W.	11.18	25	26	12.5	24	38	02.5	149	323
3	2 40 p. m.	21.9	W.	11.99	24	47	20.0	23	56	45.0	162	352
4	3 29 p. m.	21.1	E.	11.99	25	18	40.0	24	28	42.5	156	339
5	4 01 p. m.	20.6	E.	11.61	25	54	16.2	25	04	58.7	150	325
6	4 34 p. m.	19.7	E.	11.18	25	57	42.5	25	07	40.0	152	330
7	Nov. 27, 11 26 a. m.	22.7	E.	11.18	27	49	20.0	26	52	30.0	159	345
8	1 38 p. m.	25.4	E.	11.61	27	31	47.5	26	39	00.0	149	323
9	2 20 p. m.	24.5	E.	11.40	27	59	30.0	27	01	15.0	162	352
10	3 04 p. m.	23.2	E.	11.07	28	10	35.0	27	16	55.0	148	321
11	3 52 p. m.	21.8	W.	11.07	26	56	25.0	25	59	55.0	165	358
12	Nov. 28, 9 33 a. m.	16.2	W.	11.40	26	52	20.0	26	06	25.0	133	289
13	10 12 a. m.	22.0	W.	11.61	25	05	47.5	24	18	25.0	149	323
14	10 46 a. m.	25.0	W.	11.18	25	03	00.0	24	17	15.0	0.00144	0.0312
	Mean	21.9									0.00152	0.0329

Hence by combination:

Sets.		h (F. G. S.).	h (C. G. S.).
1 and 6		0.00149	0.0323
2	5	150	324
3	4	159	345
7	14	152	329
8	13	149	323
9	12	148	321
10	11	156	339
Mean		0.00152	0.0329
		±.00001	±.0002

Let μ=the increase in the magnetic moment m of the magnet (L_3), as produced by the inducing action of the earth's magnetic force, then $\mu=hm$.

For the case L_8 the value of m (at 16.7 C) equals 183.2 . Hence the average value of μ becomes 6.03 . To apply the correction for induction we have to substitute for the value of T^2, resulting from the oscillations, the value $T^2\left(1+\mu\frac{H}{m}\right)$ or $T^2(1+hH)$, and in the case of the deflections* we have to substitute for $\frac{m}{H}$ the value $\frac{m}{H}\left(1+\frac{2\mu}{r^3}\right)$.

On November 28 and December 4, 1883, Mr. Baker made similar observations for the short magnet (S_8), and found:

Set.	Time.	Temp. C.	Deflector.	φ			φ_1			h F. G. S. system.	h C. G. S. system.
	h. m.	°		°	′	″	°	′	″		
1	Nov. 28, 11 30 a. m.	27.7	W.	22	52	00	22	29	12	0.00079	0.0171
2	Dec. 4, 2 08 p. m.	19.3	W.	23	50	48	23	27	08	78	169
3	4, 2 47 p. m.	19.1	E.	24	13	05	23	49	35	76	164
4	4, 3 23 p. m.	18.6	E.	24	13	15	23	55	00	61	132
	Mean	21.2								0.00074	0.0159
										±0.00002	±0.0004

DETERMINATION OF THE MAGNETIC DECLINATION.

Observations for local time.—The observations for time were generally made once a month and at other times when specially needed. The method was that of equal altitudes of the sun, observed with sextant No. 145 and mercurial horizon; mean time chronometer Parkinson and Frodsham No. 2701 was used throughout the series. It was deemed unnecessary to give here a table of daily chronometer corrections and rates, since in all cases where time is recorded or referred to in this report it is specially stated whether it is chronometer time (in which case the correction is given) or the corrected mean local time.

*To correct the angle of deflection u_1 for the effects of change of temperature and of induction we have

$$\sin u=\frac{\sin u_1}{\left[1-(t^1-t)q\right]\left[1-\mu\frac{H}{m}\sin u_1\right]}.$$

See also "Supplement to Magnetic Instructions," by Capt. C. J. B. Riddell, London, 1846, p. 11.

Determination of the azimuth of the declination mark.—This mark was established by Mr. Baker; it consists of a black cross painted on a chimney (about 130 metres distant) with a copper nail at the intersection of the cross; its direction from the pier for absolute measures is about 40° west of true south, and about 5 metres higher than the instrument pier. On July 13, 1887, Mr. Halter established a new mark on another chimney of the same house in consequence of an obstruction in the line of sight occasioned by the erection of a building; the azimuth of this mark was about 43° west of south.* On January 9, 1888, in order to avoid overflow in heavy rains, Mr. Halter raised the observing hut and the brick pier 3 feet; the foundation of the pier, which had been threatening to give way, was better secured and the cap stone re-plumbed. On July 10, 1889, Mr. Halter virtually re-established the first or old mark by marking a new one 45.7 centimetres (18 inches) above it and verifying their line of verticality by means of a plummet.

Numerous observations were made by Mr. Baker to determine the azimuth of his mark by means of the sun and of Polaris. About one-half of these observations were made with the telescope and horizontal circle of the declinometer No. 8, an instrument very ill adapted and not intended for such work;† the other half were made with a 10-centimetre (4 inch) Casella theodolite No. 3416. The observations on the sun are less satisfactory than those on Polaris, besides they involve a more exact knowledge of time; I gave these results therefore but half the weight assigned to those from Polaris. The following table contains the results from 26 sets of observations by Mr. Baker:

No. of sets.	Date.	Instrument.	Object sighted.	Azimuth of B. mark W. of S.
	1882.			° ′
1	Oct. 18, a. m.	C. 3416	⊙	40 01.6
2	Oct. 18, a. m.	C. 3416	⊙	6.6
3	Oct. 18, a. m.	C. 3416	⊙	6.5
4	Oct. 18, p. m.	C. 3416	⊙	3.4
5	Oct. 18, p. m.	C. 3416	⊙	4.6
6	Oct. 18, p. m.	C. 3416	⊙	5.4
	1883.			
7	Jan. 8, near noon	Dec. No. 8	⊙	4.0
8	Jan. 8, near noon	Dec. No. 8	⊙	3.6
9	Jan. 8, near noon	Dec. No. 8	⊙	4.2
10	Apr. 16, p. m.	Dec. No. 8	*	2.9
	1884.			
11	Jan. 4, p. m.	Dec. No. 8	*	5.9
12	Jan. 4, p. m.	Dec. No. 8	*	5.3
13	Jan. 16, p. m.	Dec. No. 8	*	2.4
	1884.			° ′
14	Jan. 16, p. m.	Dec. No. 8	*	40 02.4
15	Jan. 16, p. m.	Dec. No. 8	*	2.6
16	Jan. 17, near noon	Dec. No. 8	⊙	4.6
17	Jan. 17, near noon	Dec. No. 8	⊙	4.3
18	Jan. 17, near noon	Dec. No. 8	⊙	4.7
19	Jan. 17, near noon	Dec. No. 8	⊙	4.7
20	Jan. 18, near noon	Dec. No. 8	⊙	6.1
21	Jan. 18, near noon	Dec. No. 8	⊙	6.0
22	Jan. 18, near noon	Dec. No. 8	⊙	6.1
23	Jan. 18, near noon	Dec. No. 8	⊙	5.9
24	Jan. 18, p. m.	Dec. No. 8	*	2.4
25	Jan. 18, p. m.	Dec. No. 8	*	1.8
26	Jan. 18, p. m.	Dec. No. 8	*	1.9
	Weighted mean from 26 sets			40 03.9
				± 0.3

* Its altitude is about 3 metres higher than the instrument pier, and distant about 125 metres.

† The telescope can not be reversed in order to correct for error in horizontality of axis and for error of collimation.

Table of results for azimuth of the Halter mark and of the above Baker mark from observations by Mr. Halter after strengthening and elevating the observatory pier. These observations are all on Polaris, and the H. mark could be referred to the B. mark by the angle between them measured by Mr. Halter July 10, 1889, viz, 2° 58′ 36″. Second or check computation by Mr. L. A. Bauer.

No. of set.	Date.	Instrument.	H. mark.	B. mark.	No. of set.	Date.	Instrument.	B. mark.
	1888.		° ′	° ′		1889.		° ′
1	Feb. 1	Dec. No. 8	43 00.9	40 02.3	13	Sept. 21	C. 3416	40 04.4
2	Feb. 1	Dec. No. 8	1.0	2.4	14	Sept. 21	C. 3416	3.7
3	Feb. 1	Dec. No. 8	1.5	2.9	15	Sept. 21	C. 3416	3.3
4	Feb. 1	Dec. No. 8	1.9	3.3	16	Sept. 21	C. 3416	3.4
5	Feb. 1	Dec. No. 8	1.9	3.3	17	Sept. 21	C. 3416	2.2
6	Feb. 1	Dec. No. 8	1.6	3.0	18	Sept. 21	C. 3416	2.1
	1888.				19	Sept. 22	C. 3416	3.7
7	Apr. 24	C. 3416	0.4	1.8	20	Sept. 22	C. 3416	4.0
8	Apr. 24	C. 3416	0.3	1.7	21	Sept. 22	C. 3416	2.5
9	Apr. 24	C. 3416	0.8	2.2	22	Sept. 22	C. 3416	2.8
10	Apr. 24	C. 3416	1.2	2.6	23	Sept. 22	C. 3416	2.2
11	Apr. 24	C. 3416	0.2	1.6	24	Sept. 22	C. 3416	2.3
12	Apr. 24	C. 3416	0.2	1.6				
	H. mark W. of S.		43 01.0			Mean of 24 sets		40 02.7 ± 0.1

To combine these measures for azimuth of the (B.) mark we have:

	° ′
Angle between the B. and H. marks, July 14, 1887 (before the pier was raised)	2 58.50
Angle between the B. and H. marks, July 10, 1889 (after the pier was raised)	2 58.60
Adopted mean value, weight 6	2 58.55 $+v_1$
Astronomical azimuth of (B.) mark, October, 1882, to January, 1884, from 18 (star) sets	40 03.9
Astronomical azimuth of (B.) mark, September, 1889, from 12 (star) sets	40 03.05
Weighted mean value, from 30 (star) sets	40 03.56 $+v_2$
Astronomical azimuth of (H.) mark, February, 1888, to April, 1888, from 12 (star) sets	43 01.0 $+v_3$

Hence the conditional equation $0=+1.11+v_1+v_2-v_3$, the weights being 1, 5, and 2 respectively; the normal equation becomes $0=17\,C+1.11$ and the corrections are:

$$v_1=-0.65,\ v_2=-0.13,\ \text{and}\ v_3=+0.33$$

and the final azimuths of the marks are:

	° ′ ′
Baker's mark	40 03.4 ± 0.2
Halter's mark	43 01.3 ± 0.2

which values were used in the reduction of the observations for declination.

Before presenting the table of results for declination a specimen of the record and of the computation for one day is here inserted.

Specimen of record and of computation of the magnetic declination.

[U. S. Coast and Geodetic Survey. Form 1.]

Magnetic observations for declination: Date, September 15, 1883. Station, Los Angeles; pier for absolute measures, grounds of the magnetic observatory. Instrument, magnetometer No. 8. Magnet L_8 suspended, with scale erect.

Line of detorsion, 216°. Observer, Marcus Baker.

Local mean time.	Scale readings. Left.	Scale readings. Right.	Mean.	
a. m.				Azimuth circle, A 27° 54′ 40″
				B 207 55 20
				Mean, 27 55 00
h. m.	*d.*	*d.*	*d.*	
6 45	5.2	5.5	5.35	
7 00	5.4	5.6	5.50	
15	5.4	5.6	5.50	
30	5.4	5.8	5.60	*d.*
45	5.6	5.6	5.60	Maximum, 5.60
8 00	5.5	5.7	5.60	
15	5.1	6.0	5.55	
30	4.9	5.7	5.30	
45	5.0	5.2	5.10	
9 00	4.7	4.9	4.80	
p. m.	Line of detorsion, 218°			Azimuth circle A 27° 54′ 40″
				B 207 55 20
				Mean, 27 55 00
− 15	2.0	2.2	2.10	
12 00	2.0	2.1	2.05	
15	2.0	2.1	2.05	
30	1.3	2.7	2.00	*d.*
45	1.7	2.2	1.95	Minimum, 1.95
1 00	1.7	2.4	2.05	

A correction to local mean time of chronometer P. and F. No. 2701, at noon, − 3m 35s was applied.

Mean scale reading of extremes 3.78

Reading of the mark.

		° ′ ″
At beginning of a. m. observations	A	53 26 10
	B	233 26 20
At end of p. m. observations	A	53 26 40
	B	233 26 20
Mean,		53 26 22

Determination of scale value of magnet. L_8, Feb. 13, 1883, p. m.

Scale erect.	Circle readings, mean of verniers.	Sum Value of 110 divisions.
	° ′ ″	′ ″
20	239 22 05	26 45
19	24 40	24 10
18	27 30	21 20
17	30 00	18 50
16	32 45	16 05
15	34 50	14 00
14	37 55	10 55
13	40 20	8 30
12	43 00	5 50
11	45 55	2 55
10	48 50	
9	51 05	2 15
8	54 00	5 10
7	57 00	8 10
6	59 45	10 55
5	240 02 10	13 20
4	04 55	16 05
3	07 50	19 00
2	10 10	21 20
1	12 55	24 05
0	16 00	27 10
	Sum	296 50

Value of one division of scale = 2′.70
Mean value adopted = 2′.71

Determination of axis of magnet.*

Scale.	Scale readings.		Mean.	Alternate mean.	Axis.
					d.
E	3.4	4.8	4.10		
I	4.3	3.5	3.90	4.08	3.99
E	3.5	4.6	4.05	3.95	4.00
I	4.8	3.2	4.00	4.00	4.00
E	3.2	4.7	3.95	4.05	4.00
I	5.2	3.0	4.10	3.93	4.01
E	3.0	4.8	3.90		

Scale reading of axis 4.00

	° ′		
Mean scale reading of east and west magnetic elongation			3.78
Reduction to axis	− 0.6	= diff. = −	0.22
Azimuth circle reads	27 55.0		
Magnetic south meridian reads	27 54.4		
Mean reading of mark	53 26.4		
Azimuth of mark W. of S.	40 03.4		
True meridian reads	13 23.0		
Magnetic declination	14 31.4	E. of N.	

* Began at 10h 39m; ended at 10h 52m.

The magnetic declination at Los Angeles, Cal., 1882–1889.

Abstract of results* of the monthly determinations of the magnetic declination, on pier for absolute measures. Inrstument used, the magnetometer No. 8.

Date.	Approximate local mean time of—		Scale readings.		Magnetic axis reads.	Magnetic declination east.	Remarks.
	Morning or eastern elongation.	Afternoon or western elongation.	a. m.	p. m.			
1882.	*h. m.*	*h. m.*	*d.*	*d.*	*d.*	° ′	
Sept. 14	8 40	0 50	7.45	3.65	5.26	14 35.0	M. Baker, observer.
15	7 53	1 00	10.70	7.95	5.10	33.9	Short magnet (S_8) sus-
16	7 30	1 30	6.50	4.05	5.02	33.6	pended, erect; one
Oct. 14	7 45	1 00	6.50	2.82	5.14	14 32.4	division of scale =
15	8 15	0 30	6.00	3.25	5.02	31.2	2′.91
16	8 30	1 15	6.70	3.85	5.14	32.5	
Nov. 14	8 17	1 15	8.30	2.30	5.07	14 37.2	
15	9 00	1 30	7.75	3.80	5.28	31.8	
16	9 00	1 08	6.80	1.75	5.04	31.0	
Dec. 14	9 51	1 30	6.60	4.35	4.97	14 34.0	
15	8 45	1 45	6.05	3.15	4.74	31.0	
16	7 45	1 30	5.60	3.50	4.75	29.1	
1883.							
Jan. 14	9 38	1 30	14.60	12.15	4.09	14 33.8	M. Baker, observer.
15	8 52	1 00	5.05	1.35	4.09	32.6	Long magnet (L_8) sus-
16	10 07	2 00	5.78	2.85	4.10	33.9	pended, erect; one
Feb. 14	9 15	2 00	6.10	1.70	4.04	14 28.4	division of scale
15	9 00	1 30	5.60	3.90	4.03	31.6	2′.71
16	9 30	1 30	5.35	4.15	4.05	31.6	
Mar. 14	8 30	0 52	5.05	2.40	4.01	14 32.2	
15	9 15	2 30	5.00	2.15	4.07	31.1	
16	8 30	2 00	4.25	1.65	4.07	31.8	
April 14	8 30	3 15	4.95	0.10	4.05	14 32.3	
15	8 00	2 38	5.50	2.10	4.01	30.2	
16	8 00	1 45	5.35	1.30	4.05	31.0	
17	8 15	2 30	5.25	—0.30	3.97	32.1	Lucius Baker, observer.
May 14	7 22	1 55	5.65	1.10	4.03	14 32.3	M. Baker, observer.
15	6 52	1 25	5.25	2.60	4.06	30.6	
16	7 15	1 25	5.60	2.50	4.10	31.9	
June 14	7 30	—0 05	5.75	2.10	4.07	14 30.7	
15	7 45	1 30	5.95	1.95	4.06	30.5	
16	8 08	—0 15	6.55	1.60	4.07	30.8	
July 14	7 23	2 05	5.00	2.95	4.07	14 30.8	
15	7 45	0 00	5.85	2.85	4.04	31.8	
16	7 30	0 15	5.80	2.20	4.07	30.6	
Aug. 14	7 30	0 00	7.00	2.40	3.98	14 32.8	
15	7 30	—0 15	6.45	1.95	4.01	32.2	
16	7 30	1 15	5.90	2.75	4.03	32.3	
Sept. 14	7 15	0 15	6.05	2.90	3.97	14 32.5	
15	7 45	0 45	5.60	1.95	4.00	31.4	
16	8 00	—0 12	6.95	2.10	4.06	32.3	

* These results were all revised by Mr. L. A. Bauer, of the Computing Division of the Office.

The magnetic declination at Los Angeles, Cal., 1882–1889—Continued.

Date.	Approximate local mean time of— Morning or eastern elongation.	Afternoon or western elongation.	Scale readings. a. m.	p. m.	Magnetic axis reads.	Magnetic declination east.	Remarks.
1883.	*h. m.*	*h. m.*	*d.*	*d.*	*d.*	° ′	
Oct. 14	7 45	0 45	5.60	2.40	4.11	14 30.8	
15	8 00	—0 30	6.65	1.50	4.04	31.5	
16	8 18	2 03	7.50	—0.10	4.09	30.1	
Nov. 14	7 15	—0 15	4.50	2.80	4.11	14 29.6	
15	8 30	0 30	4.85	2.55	4.07	30.4	
16	8 15	0 30	5.40	2.85	4.07	31.0	
Dec. 14	8 38	80 0—	4.80	3.00	3.98	14 30.6	
15	9 15	1 15	4.80	2.70	3.96	30.3	
16	8 30	1 30	4.30	2.05	3.95	29.0	
1884.							
Jan. 14	9 22	0 45	5.05	1.60	4.02	14 29.2	M. Baker, observer.
15	9 00	1 08	5.40	2.30	3.95	30.8	
16	9 30	1 22	5.55	2.05	4.02	30.6	
Feb. 14	9 22	3 18	5.15	2.65	4.01	14 30.1	
15	10 00	2 30	5.20	2.05	3.99	28.5	
16	10 00	3 00	5.25	2.65	3.91	30.0	
Mar. 14	8 45	1 :	6.35	2.00	4.01	14 30.8	
15	8 52	1 38	6.25	1.55	3.95	31.6	
16	9 21	1 08	6.75	2.75	3.93	32.8	
April 14	8 08	2 00	6.00	2.20	3.96	14 31.0	
15	8 15	1 22	5.55	2.80	3.94	30.8	
16	7 30	1 52	5.85	2.20	3.96	30.7	
May 14	7 15	1 00	5.85	2.00	3.97	14 30.4	
15	7 30	0 30	5.05	1.20	3.97	28.5	
16	7 15	0 45	4.80	2.15	3.97	29.5	
June 14	7 30	0 30	4.80	1.50	3.98	14 28.6	
15	7 38	0 15	5.20	2.45	3.99	30.2	
16	7 45	1 15	5.65	2.65	3.98	30.6	
July 14	8 15	1 38	4.95	1.85	3.98	14 30.7	
15	8 15	2 08	5.05	2.00	3.99	29.1	
16	8 00	0 22	5.05	1.90	4.00	30.4	
Aug. 14	7 58	1 22	5.65	1.30	3.95	14 29.6	C. Terry, observer.
15	7 52	0 10	5.45	2.10	3.96	30.8	
16	7 22	—0 45	5.30	2.25	3.96	30.3	
Sept. 14	6 45	0 15	4.80	2.15	3.97	14 29.6	
15	7 30	—0 15	4.95	2.55	4.03	30.0	
16	6 45	0 30	5.00	2.40	3.95	30.2	
Oct. 14	6 45	0 30	4.45	0.90	3.95	14 28.0	
15	7 30	—0 45	3.90	1.50	3.90	27.9	
16	8 30	1 30	5.05	2.70	3.94	30.9	
Nov. 14	10 15	1 45	4.70	2.45	3.97	14 30.0	
15	9 00	2 22	4.45	1.75	3.94	30.0	
16	8 30	2 15	4.40	1.95	3.97	29.3	
Dec. 14	9 45	0 15	4.75	2.65	3.97	14 29.3	
15	8 00	0 08	4.20	2.60	3.93	29.0	
16	9 15	1 30	4.85	2.65	3.93	29.9	

The magnetic declination at Los Angeles, Cal., 1882-1889—Continued.

Date.	Approximate local mean time of— Morning or eastern elongation.	Afternoon or western elongation.	Scale readings. a. m.	p. m.	Magnetic axis reads.	Magnetic declination east.	Remarks.
1885.	h. m.	h. m.	d.	d.	d.	° ′	
Jan. 14	10 00	2 00	4.95	2.95	3.91	14 30.6	
15	10 00	2 00	5.15	2.25	3.96	29.5	
16	10 15	1 30	4.30	2.65	3.97	29.6	
Feb. 14	8 30	0 52	4.05	2.35	3.90	14 29.4	
15	8 45	1 30	4.90	1.60	3.92	29.4	
16	9 15	1 45	4.35	2.05	3.97	29.0	
Mar. 14	10 30	1 45	5.40	3.45	4.02	14 30.4	
15	9 15?	0 00	(?) 2.95	1.95	3.93	25.6	
16	10 30	2 45	5.15	3.15	3.94	30.3	
Apr. 14	8 45	2 45	5.30	2.20	3.97	14 30.0	
15	7 15	1 45	5.85	1.75	3.95	29.5	
16	7 45	1 00	6.00	2.25	3.96	30.1	
May 14	7 45	0 30	6.20	2.90	3.94	14 31.2	
15	7 30	1 22	6.15	2.75	3.96	31.0	
16	7 00	— 0 30	5.70	2.40	4.02	29.5	
June 14	7 45	0 45	6.05	1.40	3.96	14 28.8	
15	8 45	2 30	6.95	1.90	4.06	30.6	
16	9 00	0 45	5.95	2.70	4.06	30.1	
July 14	7 52	0 45	5.80	1.50	4.07	14 28.4	
15	8 22	2 22	6.60	2.65		31.0	
16	7 30	1 30	6.30	2.35		30.2	
Aug. 14	8 00	1 00	6.55	1.85	4.05	14 30.1	
15	7 45	0 30	6.75	2.30		31.0	
16	7 52	1 00	6.95	2.20		31.4	
Sept. 14	8 22	0 30	6.00	1.85	4.10	14 29.3	
15	7 15	0 45	5.30	2.25		28.7	
16	7 45	0 30	5.40	2.65		29.6	
Oct. 14	8 15	1 22	5.10	2.95	4.07	14 30.0	
15	8 30	0 00	4.70	2.40		28.7	
16	9 15	0 30	5.10	3.05		30.2	
Nov. 14	8 15	1 15	4.55	2.65	4.05	14 28.9	
15	8 52	1 38	4.85	2.70		29.5	
16	8 45	1 30	4.75	2.85		29.4	
Dec. 14	10 15	1 30	4.80	2.55	4.07	14 29.5	
15	10 00	2 45	5.55	3.35		30.3	
16	10 15	2 00	4.65	3.15		29.7	
1886.							
Jan. 14	10 30	2 45	5.00	3.00	4.04	14 30.1	
15	10 15	1 45	5.00	3.20		30.4	
16	10 22	2 15	5.55	3.30		31.1	
Feb. 14	10 30	2 00	4.65	2.85	4.04	14 29.3	
15	8 45	1 30	4.40	2.75		28.6	
16	8 15	1 00	4.85	2.35		28.3	
Mar. 14	9 38	2 15	5.35	2.55	4.06	14 28.3	
15	8 52	1 18	5.75	2.90		29.0	
16	9 38	2 30	5.60	2.15		27.9	

The magnetic declination at Los Angeles, Cal., 1882–1889—Continued.

Date.	Approximate local mean time of— Morning or eastern elongation.	Afternoon or western elongation.	Scale readings. a. m.	p. m.	Magnetic axis reads.	Magnetic declination east.	Remarks.
1886.	*h. m.*	*h. m.*	*d.*	*d.*	*d.*	° ′	
Apr. 14	8 30	0 00	5.20	2.85	4.11	14 27.8	
15	7 08	1 15	5.60	3.35		29.1	
16	7 30	0 08	5.30	3.60		29.0	
May 14	7 15	0 15	5.95	3.30	4.05	14 30.3	
15	7 15	2 00	5.45	2.50		29.1	
16	7 30	1 00	6.15	2.10		29.5	
June 14	7 15	0 45	5.35	1.85	4.13	14 28.2	
15	7 08	1 45	5.35	3.05		28.6	
16	7 45	1 15	5.75	2.30		28.2	
July 14	7 30	—0 02	5.80	1.85	4.12	14 28.5	
15	7 30	1 08	5.65	3.10		29.8	
16	7 45	0 00	5.65	2.25		28.6	
Aug. 14*	8 15	0 15	6.25	2.50	4.09	14 30.1	
15	8 15	0 15	6.45	1.40		28.9	
16	6 55	—0 15	5.60	2.10		28.7	
Sept. 14	7 45	0 38	6.25	2.80	4.05	14 30.1	
15	7 45	0 15	5.65	2.60		29.4	
16	7 45	0 08	5.60	2.35		29.2	
Oct. 14	7 30	0 08	5.30	3.15	4.08	14 29.8	
15	8 00	0 15	4.90	2.45		28.5	
16	7 52	0 15	5.15	2.70		28.9	
Nov. 14	8 15	1 30	5.25	2.75	4.04	14 29.1	
15	7 45	1 30	5.05	2.95		29.2	
16	8 15	0 45	5.20	2.90		29.3	
17	8 15	0 38	5.05	1.90	4.03	27.4	R. E. Halter, observer.
18	8 15	1 00	5.35	3.00		29.3	
19	8 30	1 15	5.00	3.15		29.2	
Dec. 14	9 30	0 45	4.55	2.50	4.02	14 28.0	
15	9 00	1 45	5.40	2.95		29.7	
16	10 08	2 30	5.05	2.95		29.2	
1887.							
Jan. 14	9 45	1 15	5.50	1.95	4.02	14 28.0	
15	9 30	0 52	5.20	2.55		28.9	
16	10 00	0 30	5.35	2.40		28.9	
Feb. 14	9 30	2 15	4.40	2.60		14 27.6	
15	9 52	2 00	4.55	3.00	4.01	28.6	
16	8 45	1 45	4.55	3.10		28.7	
Mar. 14	9 15	2 15	3.50	3.15	4.04	14 27.7	
15	8 15	1 30	5.10	2.15		28.0	
16	8 30	1 22	5.15	2.55		28.7	
Apr. 14	7 45	1 38	5.40	2.15		14 28.8	
15	7 45	1 00	4.95	2.55	4.07	28.5	
16	7 45	1 45	5.35	2.40		28.9	
May 14	7 45	0 00	4.95	2.55		14 28.6	
15	7 15	2 00	4.90	2.50		28.4	

* One-inch iron water pipe running NNW. and SSE. laid 19 metres NNE. of pier for absolute measures, August 11, 1886; no effect felt apparently.

The magnetic declination at Los Angeles, Cal., 1882-1889—Continued.

Date.	Approximate local mean time of— Morning or eastern elongation.	Afternoon or western elongation.	Scale readings. a. m.	p. m.	Magnetic axis reads.	Magnetic declination east.	Remarks.
1887.	h. m.	h. m.	d.	d.	d.	° ′	
May 16	7 30	0 22	4.85	2.40	4.10	14 28.2	
June 14	8 30	1 45	4.60	2.85	4.15	14 28.3	
15	7 45	1 00	5.05	2.85		28.9	
16	7 22	1 08	4.90	2.65		28.5	
July *14	8 00	0 30	5.70	2.10	4.15	14 28.1	
15	8 08	1 15	5.85	2.70		29.1	
16	7 30	0 15	5.05	1.60		26.7	
Aug. 14	7 15	1 00	6.15	2.00	4.06	14 29.0	
15	7 30	0 45	5.70	2.15		28.6	
16	7 15	0 15	5.50	2.45		29.1	
Sept. 14	7 52	0 38	6.05	2.95	4.11	14 29.7	
15	7 15	0 00	6.05	2.55		29.2	
16	7 15	0 00	5.45	2.65		28.9	
Oct. 14	8 00	0 30	4.85	2.45	4.17	14 27.4	
15	9 00	0 00	4.60	2.55		27.6	
16	9 30	0 15	5.00	2.85		28.4	
Nov. 14	7 30	0 22	5.00	2.85	4.16	14 28.4	
15	8 15	0 15	4.60	2.85		27.9	
16	8 08	0 38	5.00	2.70		28.3	
Dec. 14	9 30	1 15	4.65	3.30	4.19	14 28.4	
15	9 00	1 15	4.50	3.40		28.4	
16	9 00	1 30	5.00	2.20		27.5	
1888.							
Jan. †14	9 00	1 00	6.60	4.00	4.08	14 19.4	New suspension put in.
15	9 45	1 45	4.40	2.50		22.4	
16	10 00	1 52	4.15	1.60		21.3	
Feb. 14	7 30	1 30	3.10	1.95	4.10	14 22.6	
15	7 30	0 52	3.60	2.65		23.4	
16	7 30	0 52	5.15	2.90		23.7	
Mar. 14	9 30	2 38	5.50	2.50	4.12	14 27.7	New suspension put in.
15	8 45	2 15	5.60	2.15		27.3	
16	9 30	0 00	5.45	3.55		27.0	
Apr. 14	7 30	1 15	5.40	1.55	4.22	14 24.5	New suspension put in.
15	9 21	1 30	4.45	3.00		25.0	
16	8 00	2 15	4.60	2.55		24.5	
May 14	7 52	2 30	4.00	1.85	4.21	14 23.1	
15	8 00	0 45	5.40	2.45		23.4	
16	8 30	2 30	5.35	3.00		24.1	
June 14	8 00	1 45	5.00	1.60	4.21	14 25.9	
15	7 45	2 00	5.20	2.45		23.0	
16	7 15	0 08	5.05	3.05		22.9	
July 14	8 00	1 52	5.25	2.65	4.21	14 23.7	
15	7 30	0 00	5.15	2.55		24.0	
16	7 08	0 15	4.95	2.10		23.2	
Aug. 14	7 34	0 30	4.90	1.35	4.13	14 22.1	

*On July 13 a new azimuth mark was established.

† Pier and hut raised 3 feet on January 9, 1888. The observer can not account for the apparent jump in the declination.

The magnetic declination at Los Angeles, Cal., 1882–1889—Continued.

Date.	Approximate local mean time of— Morning or eastern elongation.	Afternoon or western elongation.	Scale readings. a. m.	p. m.	Magnetic axis reads.	Magnetic declination east.	Remarks.
1888.	*h. m.*	*h. m.*	*d.*	*d.*	*d.*	° ′	
Aug. 15	7 45	0 00	5.05	1.55		14 22.6	
16	8 15	0 45	4.90	1.95		23.3	
Sept. 14	7 45	0 30	4.35	2.60	4.12	14 23.6	
15	7 00	0 08	4.85	3.15		22.9	
16	7 15	0 22	5.00	3.45		23.7	
Oct. 14	8 15	0 00	5.50	4.10	4.13	14 23.2	
15	8 08	0 15	5.10	3.60		22.0	
16	7 30	0 30	4.85	2.90		23.2	
Nov. 14	8 30	0 45	4.90	3.70	4.23	14 22.9	
15	7 30	0 30	4.65	3.15		22.3	
16	8 00	0 15	4.85	2.60		21.7	
Dec. 14	7 38	0 30	5.05	4.50	4.21	14 22.7	
15	8 15	1 00	5.15	3.90		22.4	
16	8 45	0 30	5.15	4.40		23.1	
1889.							
Jan. 14	9 30	1 22	6.00	4.40	4.20	14 24.1	
15	9 00	0 15	4.70	3.90		23.1	
16	9 28	0 38	5.90	3.50		22.8	
Feb. 14	7 15	1 15	4.50	3.55	4.22	14 20.8	
15	9 27	1 22	4.95	2.85		21.6	
16	9 30	1 38	5.05	3.50		21.9	
Mar. 14	8 00	2 30	4.90	3.05	4.13	14 22.3	
15	7 45	0 38	5.45	3.00		23.2	
16	8 38	1 30	5.05	2.70		23.7	
Apr. 14	8 15	0 15	5.30	1.60	4.21	14 22.5	
15	8 30	0 15	5.65	2.90		22.8	
16	8 00	1 52	5.90	1.95		23.1	
May 14	7 45	0 08	4.95	1.90	4.20	14 23.1	
15	7 45	0 30	5.45	2.40		22.6	
16	8 00	0 30	5.70	2.55		23.3	
June 14	7 08	0 52	5.95	2.60	4.23	14 22.1	
15	7 30	0 45	4.70	1.55		22.2	
16	7 45	1 00	5.50	0.75		22.2	
July *14	8 08	0 30	5.30	1.35	4.18	14 23.8	
15	8 00	1 15	5.00	2.90		23.1	
16	7 08	1 30	5.10	2.45		23.5	
Aug. 14	8 00	0 15	5.00	2.55	4.17	14 23.4	
15	8 22	0 15	5.30	2.40		23.7	
16	7 22	0 52	4.90	2.60		23.4	
Sept. 14	7 38	0 15	4.60	2.05	4.19	14 22.9	
15	8 00	1 22	4.65	2.60		23.7	
16	8 00	1 45	4.95	2.80		24.4	
Oct. 3	7 15	0 30	5.05	3.00	4.17	14 23.8	
4	8 15	0 00	4.95	3.15		23.9	
5	8 00	0 00	5.35	2.95		24.2	

*On July 10 Baker's original mark was restored.

Recapitulation of resulting monthly and annual values of the magnetic declination at Los Angeles, 1882–1889.

14° east + tabular quantity.

Month (middle).	1882–'83.	1883–'84.	1884–'85.	1885–'86.	1886–'87.	1887–'88.	1888–'89.	Monthly means.
	′	′	′	′	′	′	′	′
October.	32.0	30.8	28.9	29.6	29.1	27.8	22.8	28.7
November.	33.3	30.3	29.8	29.3	28.9	28.2	22.3	28.9
December.	31.4	30.0	29.4	29.8	29.0	28.1	22.7	28.6
January.	33.4	30.2	29.9	30.5	28.6	21.0	23.3	28.1
February.	30.5	29.5	29.3	28.7	28.3	23.2	21.4	27.3
March.	31.7	31.7	28.8	28.4	28.1	27.3	23.1	28.4
April.	31.4	30.8	29.9	28.6	28.7	24.7	22.8	28.1
May.	31.6	29.5	30.6	29.6	28.4	23.5	23.0	28.0
June.	30.7	29.8	29.8	28.3	28.6	23.9	22.2	27.6
July.	31.1	30.1	29.9	29.0	28.0	23.6	23.5	27.9
August.	32.4	30.2	30.8	29.2	28.9	22.7	23.5	28.2
September.	32.1	29.9	29.2	29.6	29.3	23.4	23.7	28.2
Annual means	31.8	30.2	29.7	29.2	28.7	24.8	22.9	28.2

A scrutiny of the tabular values would seem to reveal the cause of the sudden diminution in the observed values of the declination in December, 1887, and January, 1888, this defect in the series being most likely referable to imperfect elimination of the torsion in the suspension. If this view be correct, the values of the declination during 1887 seem all too great, as is also manifest by an examination of the annual means. The difference between any two consecutive years should gradually change from 0′.5 at the middle of the series to 1′.9 at the end of it, conformably to the differential measures. The latter show only a difference of 0′.6 between the December, 1887, and the January, 1888, readings.

The annual variation as well as the annual change due to secular variation must be derived from the differential series.

The probable error of a single determination of the declination can be derived from the differences of each of the three daily values from the mean of the values; the labor of squaring these differences may be saved by using the formula

$$r=0.845\frac{[v}{\sqrt{n\,(n-\nu)}}$$

where $[v$ stands for the sum of all differences, abstracting from their sign, n is the total number of observations and ν the number of means or monthly values. We have

$$r=0.845\frac{136.5}{\sqrt{262\,(262-86)}}=\pm 0'.54$$

hence the probable error of any tabular monthly mean $\frac{0.54}{\sqrt{3}}=\pm 0'.31$

DETERMINATION OF THE MAGNETIC INCLINATION.

The magnetic inclination or dip as determined monthly on three days each is tabulated separately for needle 1 and needle 2 and for each position of the needle with respect to polarity. A specimen of record and of computation is herewith given in order to exhibit the process gone through on each day of observation.

Specimen of record and of computation of the magnetic dip.

[U. S. Coast and Geodetic Survey. Form 5.]

Magnetic observations for dip: Date, September 15, 1883. Station, Los Angeles, grounds of Magnetic Observatory, about 15 paces NW. from pier for absolute measure.

Kew Dip Circle No. 21.—Needle No. 1.

Mean by polarities: 59° 31′.1

Mean by polarities: 59° 33′.1

Polarity of marked end B, south.							
Circle east.				Circle west.			
Face east.		Face west.		Face east.		Face west.	
S.	N.	S.	N.	S.	N.	S.	N.
° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
59 53	59 53	59 40	59 34	59 43	59 54	59 35	59 33
58	53	32	31	47	45	28	33
58	51	33	29	49	52	27	41
59 56.3	59 52.3	59 35.0	59 31.3	59 46.3	59 50.3	59 30.0	59 35.7
59° 54′.3		59° 33′.1		59° 48′.3		59° 32′.9	
59° 43′.7				59° 40′.6			
Mean, 59° 42′.2							

Polarity of marked end A, south.							
Circle west.				Circle east.			
Face west.		Face east.		Face west.		Face east.	
S.	N.	S.	N.	S.	N.	S.	N.
° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
59 31	59 28	59 10	59 11	59 33	59 34	59 17	59 17
30	24	5	14	38	24	21	23
21	33	4	12	35	37	17	12
59 27.3	59 28.3	59 06.3	59 12.3	59 35.3	59 31.7	59 18.3	59 17.3
59° 27′.8		59° 09′.3		59° 33′.5		59° 17′.8	
59° 18′.5				59° 25′.7			
Mean, 59° 22′.1							

Resulting dip, 59° 32′.1

Local mean time of beginning,	8:12 a. m.
Local mean time of ending,	8:45 a. m.
Magnetic meridian reads	87° 50′

Circle in Mag. prime vertical.

		° ′
Circle N.	Needle N.	88 07
"	" S.	87 39
Circle S.	" N.	88 17
	" S.	87 19
	Mean,	87 50

Observer, Marcus Baker.

Dip Circle No. 21.—Needle No. 2.

Mean by polarities: 59° 29'.4

Mean by polarities: 59° 32'.9

Polarity of marked end B, south.							
Circle east.				Circle west.			
Face east.		Face west.		Face east.		Face west.	
S.	N.	S.	N.	S.	N.	S.	N.
° '	° '	° '	° '	° '	° '	° '	° '
59 30	59 31	59 24	59 21	59 30	59 44	59 19	59 24
30	33	22	24	27	38	26	30
34	40	25	29	34	38	24	25
59 31.3	59 34.7	59 23.7	59 24.7	59 30.3	59 40.0	59 23.0	59 26.3
59° 33'.0		59° 24'.2		59° 35'.1		59° 24'.7	
59° 28'.6				59° 29'.9			
Mean: 59° 29'.3							

Polarity of marked end A, south.							
Circle west.				Circle east.			
Face west.		Face east.		Face west.		Face east.	
S.	N.	S.	N.	S.	N.	S.	N.
° '	° '	° '	° '	° '	° '	° '	° '
59 32	59 32	59 28	59 29	59 39	59 35	59 35	59 32
29	38	25	34	42	42	33	35
23	37	27	27	34	40	36	29
59 28.0	59 35.7	59 26.7	59 30.0	59 38.3	59 39.0	59 34.7	59 32.0
59° 31'.8		59° 28'.4		59° 38'.6		59° 33'.4	
59° 30'.1				59° 36'.0			
Mean: 59° 33'.1							

Resulting dip, 59° 31'.2

Local mean time of beginning,	8:48 a. m.	Circle in Mag. prime vertical.		
Local mean time of ending,	9:12 a. m.	Circle N.	Needle N.	Not determined.
Magnetic meridian reads	87° 50'		" S.	
		Circle S.	" N.	
			" S.	
			Mean, as before.	

Observer, Marcus Baker.

The magnetic inclination at Los Angeles, Cal., 1882–1889.

Abstract of results* of the magnetic dip determined in the grounds of the magnetic observatory, about 60 metres SW. by W. (true) of the observatory and close to the pier for absolute measures. Instrument used, the Kew Dip Circle No. 21.

Date.	Los Angeles local mean time.	Dip by needle No. 1. Polarity of marked end south or up. A 59° +	B 59° +	Diff. A—B	Dip ½ (A + B) I.	Dip by needle No. 2. Polarity of marked end south or up. A 59° +	B 59° +	Diff. A—B	Dip ½ (A + B) II.	Diff. dip I — II.	Dip by 2 needles. 59° +
1882.	h. m.	′	′	′	° ′	′	′	′	° ′	′	′
Sept. 14	2 16 p.m.	26.3	37.9	—11.6	59 32.1	25.4	25.6	—0.2	59 25.5	+6.6	28.8
15	7 45 a.m.	17.4	42.2	—24.8	29.8	31.7	30.6	+1.1	31.2	—1.4	30.5
16	8 00 a.m.	18.4	45.9	—27.5	32.1	32.1	27.8	+4.3	29.9	+2.2	31.0
Oct. 14	7 57 a.m.	22.5	41.3	—18.8	31.9	36.9	28.3	+8.6	32.6	—0.7	32.3
15	7 23 a.m.	18.5	36.2	—17.7	27.4	34.0	26.6	+7.4	30.3	—2.9	28.8
16	8 04 a.m.	16.3	40.2	—23.9	28.3	33.3	29.6	+3.7	31.5	—3.2	29.9
Nov. 14	{ 8 38 a.m. / 0 50 p.m.	18.3	35.9	—17.6	27.1	31.7	33.5	—1.8	32.6	—5.5	29.8
15	8 18 a.m.	17.5	40.2	—22.7	28.9	33.4	30.9	+2.5	32.2	—3.3	30.5
16	8 08 a.m.	16.9	39.9	—23.0	28.4	29.8	29.2	+0.6	29.5	—1.1	28.9
Dec. 14	{ 8 49 a.m. / 0 35 p.m.	21.9	43.7	—21.8	32.8	31.3	28.7	+2.6	30.0	+2.8	31.4
15	{ 0 19 p.m. / 8 36 a.m.	24.7	47.4	—22.7	36.1	28.6	27.2	+1.4	27.9	+8.2	32.0
16	{ 0 26 p.m. / 8 32 a.m.	22.8	44.5	—21.7	33.7	27.4	31.9	—4.5	29.6	+4.1	31.6
1883.											
Jan. 14	{ 9 10 a.m. / 0 55 p.m.	24.7	37.3	—12.6	59 31.0	30.7	28.6	+2.1	59 29.6	+1.4	30.3
15	1 46 p.m.	19.1	40.9	—21.8	30.0	31.4	29.5	+1.9	30.5	—0.5	30.3
16	1 16 p.m.	21.8	39.9	—18.1	30.9	34.3	31.4	+2.9	32.9	—2.0	31.9
Feb. 14	3 48 p.m.	16.0	40.0	—24.0	28.0	30.5	26.1	+4.4	28.3	—0.3	28.2
15	3 24 p.m.	20.8	37.8	—17.0	29.3	28.3	25.5	+2.8	26.9	+2.4	28.1
16	9 54 a.m.	18.8	40.2	—21.4	29.5	30.0	27.6	+2.4	28.8	+0.7	29.2
Mar. 14	{ 8 47 a.m. / 0 59 p.m.	24.0	41.5	—17.5	32.8	31.6	31.1	+0.5	31.3	+1.5	32.0
15	{ 0 51 p.m. / 11 42 a.m.	25.7	39.5	—13.8	32.6	32.1	33.2	—1.1	32.6	0.0	32.6
16	2 38 p.m.	17.9	40.0	—22.1	29.0	35.6	28.0	+7.6	31.8	—2.8	30.4
Apr. 14	10 56 a.m.	18.2	32.6	—14.4	25.4	28.0	24.9	+ 3.1	26.4	—1.0	25.9
15	{ 9 42 a.m. / 4 16 p.m.	22.4	40.1	—17.7	31.2	33.1	27.6	+ 5.5	30.3	+0.9	30.8
16	8 08 a.m.	22.5	39.9	—17.4	31.2	33.6	27.6	+ 6.0	30.6	+0.6	30.9
17	3 48 p.m.	19.9	33.2	—13.3	26.5	29.5	29.2	+ 0.3	29.4	—2.9	27.9
May 14	2 52 p.m.	20.9	37.7	—16.8	29.3	30.8	27.0	+ 3.8	28.9	+0.4	29.1
15	10 14 a.m.	21.3	42.1	—20.8	31.7	29.2	30.0	— 0.8	29.6	+2.1	30.6
16	3 20 p.m.	19.5	40.2	—20.7	29.8	29.2	28.7	+ 0.5	29.0	+0.8	29.4
June 14	0 22 p.m.	24.8	39.0	—14.2	31.9	33.3	26.3	+ 7.0	29.8	+2.1	30.8
15	10 50 a.m.	27.2	39.6	—12.4	33.4	35.9	26.0	+ 9.9	30.9	+2.5	32.1
16	11 20 a.m.	20.4	39.3	—18.9	29.9	28.3	29.1	— 0.8	28.7	+1.2	29.3

* These results were all revised by Mr. L. A. Bauer, of the Computing Division.

The magnetic inclination at Los Angeles, Cal., 1882-1889—Continued.

Date.	Los Angeles local mean time.	Dip by needle No. 1. Polarity of marked end south or up. A 59°+	B 59°+	Diff. A—B	Dip ½ (A+B) I.	Dip by needle No. 2. Polarity of marked end south or up. A 59°+	B 59°+	Diff. A—B	Dip ½ (A+B) II.	Diff. dip I—II.	Dip by 2 needles. 59°+
1883.	h. m.	′	′	′	° ′	′	′	′	° ′	′	′
July 14	10 56 a. m.	24.8	37.3	—12.5	59 31.0	31.6	28.0	+ 3.6	59 29.8	+1.2	30.4
15	8 45 a. m.	26.0	40.5	—14.5	33.3	33.2	33.1	+ 0.1	33.1	+0.2	33.2
16	7 56 a. m.	25.6	41.4	—15.8	33.5	31.7	27.7	+ 4.0	29.7	+3.8	31.6
Aug. 14	8 27 a. m.	23.4	38.5	—15.1	30.9	29.2	30.1	— 0.9	29.7	+1.2	30.3
15	8 26 a. m.	23.2	34.6	—11.4	28.9	33.4	26.5	+ 6.9	29.9	—1.0	29.4
16	9 50 a. m.	26.3	38.3	—12.0	32.3	31.0	31.4	— 0.4	31.2	+1.1	31.7
Sept. 14	8 34 a. m.	24.4	40.1	—15.7	32.3	32.1	29.7	+ 2.4	30.9	+1.4	31.6
15	8 44 a. m.	22.1	42.2	—20.1	32.1	33.1	29.3	+ 3.8	31.2	+0.9	31.7
16	8 42 a. m.	32.2	45.8	—13.6	39.0	38.1	30.8	+ 7.3	34.4	+4.6	36.7
Oct. 14	{ 1 34 p. m. 8 48 a. m.	}25.6	38.5	—12.9	32.0	34.0	28.8	+ 5.2	31.4	+0.6	31.7
15	8 52 a. m.	27.2	41.3	—14.1	34.3	33.9	31.2	+ 2.7	32.6	+1.7	33.4
16	8 32 a. m.	25.5	41.8	—16.3	33.6	30.8	27.5	+ 3.3	29.2	+4.4	31.4
Nov. 14	8 54 a. m.	22.1	41.3	—19.2	31.7	28.7	24.5	+ 4.2	26.6	+5.1	29.1
15	8 18 a. m.	22.8	38.0	—15.2	30.4	31.7	28.3	+ 3.4	30.0	+0.4	30.2
16	8 39 a. m.	24.8	39.7	—14.9	32.2	32.0	28.0	+ 4.0	30.0	+2.2	31.1
Dec. 14	{ 1 50 p. m. 8 50 a. m.	}23.0	43.0	—20.0	33.0	30.7	28.6	+ 2.1	29.6	+3.4	31.3
15	8 50 a. m.	22.3	39.9	—17.6	31.1	30.7	26.8	+ 3.9	28.8	+2.3	29.9
16	8 47 a. m.	22.3	38.8	—16.5	30.5	27.8	27.6	+ 0.2	27.7	+2.8	29.1
1884.											
Jan. 14	2 42 p. m.	19.5	39.0	—19.5	59 29.3	28.6	20.9	+ 7.7	59 24.7	+4.6	27.0
15	11 30 a. m.	26.7	42.8	—16.1	34.8	29.9	29.0	+ 0.9	29.5	+5.3	32.1
16	9 00 a. m.	26.0	39.9	—13.9	32.9	32.6	29.1	+ 3.5	30.9	+2.0	31.9
Feb. 14	0 34 p. m.	22.7	36.8	—14.1	29.7	31.8	26.0	+ 5.8	28.9	+0.8	29.3
15	1 59 p. m.	20.4	36.9	—16.5	28.6	31.9	27.3	+ 4.6	29.6	—1.0	29.1
16	2 29 p. m.	22.7	34.8	—12.1	28.8	29.4	29.1	+ 0.3	29.3	—0.5	29.0
Mar. 14	3 24 p. m.	22.5	34.7	—12.2	28.6	28.0	23.3	+ 4.7	25.6	+3.0	27.1
15	3 41 p. m.	28.1	39.9	—11.8	34.0	31.2	22.4	+ 8.8	26.8	+7.2	30.4
16	3 13 p. m.	20.1	37.7	—17.6	28.9	27.5	26.5	+ 1.0	27.0	+1.9	28.0
Apr. 14	3 19 p. m.	22.0	37.7	—15.7	29.9	32.4	30.6	+ 1.8	31.5	—1.6	30.7
15	2 56 p. m.	18.8	40.9	—22.1	29.9	31.5	26.3	+ 5.2	28.9	+1.0	29.4
16	3 01 p. m.	24.9	41.4	—16.5	33.2	29.2	24.8	+ 4.4	27.0	+6.2	30.1
May 14	8 24 a. m.	24.4	39.9	—15.5	32.1	29.9	27.1	+ 2.8	28.5	+3.6	30.3
15	8 00 a. m.	21.7	36.6	—14.9	29.2	28.1	26.8	+ 1.3	27.5	+1.7	28.3
16	8 08 a. m.	25.0	27.8	— 2.8	26.4	33.9	26.0	+ 7.9	30.0	—3.6	28.2
June 14	2 45 p. m.	22.1	41.1	—19.0	31.6	30.3	23.6	+ 6.7	26.9	+4.7	29.3
15	8 26 a. m.	23.2	37.0	—13.8	30.1	29.3	28.4	+ 0.9	28.9	+1.2	29.5
16	8 34 a. m.	24.1	43.5	—19.4	33.8	32.3	27.1	+ 5.2	29.7	+4.1	31.7
July 14	8 34 a. m.	23.5	41.2	—17.7	32.3	30.1	27.8	+ 2.3	28.9	+3.4	30.6
15	8 10 a. m.	25.0	40.4	—15.4	32.7	31.0	28.3	+ 2.7	29.6	+3.1	31.2
16	7 57 a. m.	22.0	41.3	—19.3	31.6	32.3	28.2	+ 4.1	30.2	+1.4	30.9

The magnetic inclination at Los Angeles, Cal., 1882–1889—Continued.

Date.	Los Angeles local mean time.	Dip by needle No. 1. Polarity of marked end south or up. A 59° +	B 59° +	Diff. A — B	Dip ½ (A + B) I.	Dip by needle No. 2. Polarity of marked end south or up. A 59° +	B 59° +	Diff. A — B	Dip ½ (A + B) II.	Diff. dip I — II.	Dip by 2 needles. 59° +
1884.	h. m.	′	′	′	° ′	′	′	′	° ′	′	′
Aug. 14	8 59 a. m.	22.3	40.9	—18.6	59 31.6	24.0	29.4	— 5.4	59 26.7	+4.9	29.2
15	8 49 a. m.	19.5	32.5	—13.0	26.0	34.0	20.5	+13.5	27.3	—1.3	26.6
16	8 20 a. m.	21.7	29.4	— 7.7	25.5	29.8	33.9	— 4.1	31.8	—6.3	28.7
Sept. 14	8 11 a. m.	26.3	33.2	— 6.9	29.8	33.7	26.1	+ 7.6	29.9	—0.1	29.9
15	8 02 a. m.	18.1	36.1	—18.0	27.1	24.8	26.8	— 2.0	25.8	+1.3	26.5
16	7 29 a. m.	24.8	32.5	— 7.7	28.6	30.6	25.2	+ 5.4	27.9	+0.7	28.3
Oct. 14	7 56 a. m.	21.5	38.0	—16.5	29.7	28.6	29.5	— 0.9	29.1	+0.6	29.4
15	8 01 a. m.	19.8	39.4	—19.6	29.6	36.6	28.2	+ 8.4	32.4	—2.8	31.0
16	7 58 a. m.	22.8	42.0	—19.2	32.4	34.6	25.6	+ 9.0	30.1	+2.3	31.2
Nov. 14	8 04 a. m.	20.6	36.3	—15.7	28.5	28.6	29.8	— 1.2	29.2	—0.7	28.8
15	10 49 a. m.	21.5	38.7	—17.2	30.1	29.6	28.8	+ 0.8	29.2	+0.9	29.6
16	10 26 a. m.	23.4	40.4	—17.0	31.9	30.6	20.7	+ 9.9	25.7	+6.2	28.8
Dec. 14	11 12 a. m.	23.1	37.9	—14.8	30.5	29.6	28.4	+ 1.2	29.0	+1.5	29.7
15	0 50 p. m.	21.6	36.2	—14.6	28.9	35.0	25.7	+ 9.3	30.4	—1.5	29.7
16	10 17 a. m.	15.0	40.1	—25.1	27.5	36.4	29.0	+ 7.4	32.7	—5.2	30.1
1885.											
Jan. 14	10 34 a. m.	26.9	32.4	— 5.5	59 29.7	32.4	29.7	+ 2.7	59 31.0	—1.3	30.3
15	9 38 a. m.	19.2	39.1	—19.9	29.1	35.7	27.9	+ 7.8	31.8	—2.7	30.5
16	9 04 a. m.	18.9	35.9	—17.9	27.0	33.2	26.8	+ 6.4	30.0	—3.0	28.5
Feb. 14	10 20 a. m.	15.7	39.1	—23.4	27.4	30.8	24.8	+ 6.0	27.8	—0.4	27.6
15	8 38 a. m.	21.0	38.0	—17.0	29.5	33.3	25.0	+ 8.3	29.1	+0.4	29.3
16	8 30 a. m.	24.1	42.5	—18.4	33.3	31.4	28.6	+ 2.8	30.0	+3.3	31.6
Mar. 14	8 44 a. m.	23.2	35.8	—12.6	29.5	33.3	24.8	+ 8.5	29.0	+0.5	29.3
15	8 20 a. m.	22.6	39.4	—16.8	31.0	34.4	29.7	+ 4.7	32.1	—1.1	31.5
16	10 44 a. m.	19.5	45.7	—26.2	32.6	31.3	31.0	+ 0.3	31.2	+1.4	31.9
Apr. 14	8 44 a. m.	22.4	38.5	—16.1	30.5	31.4	26.9	+ 4.5	29.2	+1.3	29.8
15	8 48 a. m.	18.8	40.8	—22.0	29.8	35.3	27.1	+ 8.2	31.2	—1.4	30.5
16	8 28 a. m.	18.0	41.9	—23.9	29.9	30.9	25.3	+ 5.6	28.1	+1.8	29.0
May 14	8 01 a. m.	18.5	42.6	—24.1	30.5	34.0	25.2	+ 8.8	29.6	+0.9	30.1
15	7 58 a. m.	16.4	36.6	—20.2	26.5	32.7	26.7	+ 6.0	29.7	—3.2	28.1
16	8 00 a. m.	22.2	40.2	—18.0	31.2	34.2	25.4	+ 8.8	29.8	+1.4	30.5
June 14	8 00 a. m.	20.9	34.9	—14.0	27.9	32.2	26.1	+ 6.1	29.2	—1.3	28.5
15	8 08 a. m.	23.6	39.4	—15.8	31.5	33.6	26.9	+ 6.7	30.2	+1.3	30.9
16	7 52 a. m.	18.1	37.1	—19.0	27.6	31.6	28.4	+ 3.2	30.0	—2.4	28.8
July 14	7 56 a. m.	18.7	41.2	—22.5	30.0	32.8	29.4	+ 3.4	31.1	—1.1	30.5
15	7 52 a. m.	19.1	37.3	—18.2	28.2	36.3	23.8	+12.5	30.1	—1.9	29.1
16	7 48 a. m.	18.1	38.1	—20.0	28.1	33.5	23.8	+ 9.7	28.6	—0.5	28.4
Aug. 14	7 44 a. m.	21.9	39.0	—17.1	30.4	34.7	24.6	+10.1	29.6	+0.8	30.0
15	7 38 a. m.	19.8	44.1	—24.3	32.0	32.2	28.9	+ 3.3	30.6	+1.4	31.3
16	7 38 a. m.	17.2	43.2	—26.0	30.2	34.0	27.3	+ 6.7	30.7	—0.5	30.4
Sept. 14	7 44 a. m.	23.1	38.0	—14.9	30.6	28.1	25.1	+ 3.0	26.6	+4.0	28.6
15	7 32 a. m.	16.4	39.1	—22.7	27.7	27.9	23.6	+ 4.3	25.8	+1.9	26.7
16	7 48 a. m.	26.5	38.0	—11.5	32.2	31.9	28.9	+ 3.0	30.4	+1.8	31.3

The magnetic inclination at Los Angeles, Cal., 1882–1889—Continued.

Date.	Los Angeles local mean time.	Dip by needle No. 1. Polarity of marked end south or up. A 59° +	B 59° +	Diff. A — B	Dip ½(A + B) I.	Dip by needle No. 2. Polarity of marked end south or up. A 59° +	B 59° +	Diff. A — B	Dip ½(A + B) II.	Diff. dip I — II.	Dip by 2 needles. 59° +
1885.	h. m.	′	′	′	° ′	′	′	′	° ′	′	′
Oct. 14	7 44 a. m.	17.8	38.5	—20.7	59 28.2	33.7	23.9	+ 9.8	59 28.8	—0.6	28.5
15	7 38 a. m.	19.7	35.8	—16.1	27.8	34.0	26.3	+ 7.7	30.1	—2.3	29.0
16	7 38 a. m.	20.1	40.4	—20.3	30.2	32.8	26.3	+ 6.5	29.5	+0.7	29.9
Nov. 14	7 52 a. m.	18.6	41.7	—23.1	30.1	34.8	27.3	+ 7.5	31.0	—0.9	30.6
15	7 50 a. m.	19.2	39.7	—20.5	29.4	35.4	26.6	+ 8.8	31.0	—1.6	30.2
16	7 58 a. m.	24.6	34.2	— 9.6	29.4	32.4	24.1	+ 8.3	28.3	+1.1	28.8
Dec. 14	7 54 a. m.	22.6	38.1	—15.5	30.3	32.3	23.5	+ 8.8	27.9	+2.4	29.1
15	8 08 a. m.	15.2	37.0	—21.8	26.1	30.0	25.8	+ 4.2	27.9	—1.8	27.0
16	7 59 a. m.	23.8	39.4	—15.6	31.6	30.5	23.4	+ 7.1	27.0	+4.6	29.3
1886.											
Jan. 14	1 18 p. m.	19.9	45.5	—25.6	59 32.7	31.6	28.2	+ 3.4	59 29.9	+2.8	31.3
15	1 12 p. m.	28.0	42.7	—14.7	35.4	36.3	27.3	+ 9.0	31.8	+3.6	33.6
16	1 08 p. m.	20.6	36.8	—16.2	28.7	33.6	28.2	+ 5.4	30.9	—2.2	29.8
Feb. 14	8 40 a. m.	22.6	43.5	—20.9	33.1	35.2	28.1	+ 7.1	31.6	+1.5	32.4
15	11 00 a. m.	20.7	35.0	—14.3	27.9	32.2	29.0	+ 3.2	30.6	—2.7	29.2
16	10 15 a. m.	20.8	38.6	—17.8	29.7	28.2	30.5	— 2.3	29.4	+0.3	29.6
Mar. 14	10 30 a. m.	20.9	37.8	—16.9	29.3	34.3	31.8	+ 2.5	33.0	—3.7	31.2
15	10 59 a. m.	21.2	44.2	—23.0	32.7	31.9	24.7	+ 7.2	28.3	+4.4	30.5
16	10 48 a. m.	18.9	39.5	—20.6	29.2	37.4	27.8	+ 9.6	32.6	—3.4	30.9
Apr. 14	11 02 a. m.	28.3	40.9	—12.6	34.6	36.9	29.4	+ 7.5	33.1	+1.5	33.9
15	10 28 a. m.	23.5	45.6	—22.1	34.5	38.4	25.1	+13.3	31.8	+2.7	33.2
16	10 19 a. m.	32.7	45.0	—12.3	38.8	34.4	32.2	+ 2.2	33.3	+5.5	36.1
May 14	10 13 a. m.	21.0	42.5	—21.5	31.8	33.8	29.3	+ 4.5	31.6	+0.2	31.7
15	10 14 a. m.	24.3	44.4	—20.1	34.4	35.3	29.5	+ 5.8	32.4	+2.0	33.4
16	10 34 a. m.	23.2	42.2	—19.0	32.7	34.4	32.4	+ 2.0	33.4	—0.7	33.1
June 14	10 06 a. m.	22.1	46.3	—24.2	34.2	32.7	34.2	— 1.5	33.4	+0.8	33.8
15	9 55 a. m.	24.4	44.5	—20.1	34.4	33.8	32.2	+ 1.6	33.0	+1.4	33.7
16	10 32 a. m.	24.0	45.5	—21.5	34.7	34.8	32.8	+ 2.0	33.8	+0.9	34.3
July *14	8 10 a. m.	24.0	45.9	—21.9	35.0	36.9	32.5	+ 4.4	34.7	+0.3	34.8
15	8 30 a. m.	25.4	46.7	—21.3	36.1	36.7	33.8	+ 2.9	35.3	+0.8	35.7
16	8 37 a. m.	26.2	47.7	—21.5	36.9	37.5	33.6	+ 3.9	35.6	+1.3	36.3
Aug. 14	10 04 a. m.	23.8	48.6	—24.8	36.2	37.5	33.5	+ 4.0	35.5	+0.7	35.9
15	9 07 a. m.	24.3	48.1	—23.8	36.2	38.1	33.3	+ 4.8	35.7	+0.5	35.9
16	9 14 a. m.	24.7	47.1	—22.4	35.9	37.2	33.4	+ 3.8	35.3	+0.6	35.6
Sept. 14	7 55 a. m.	27.6	37.9	—10.3	32.7	36.5	32.7	+ 3.8	34.6	—1.9	33.7
15	7 52 a. m.	28.0	39.8	—11.8	33.9	29.0	28.3	+ 0.7	28.6	+5.3	31.3
16	0 54 p. m.	19.2	40.5	—21.3	29.9	32.6	28.6	+ 4.0	30.6	—0.7	30.2
Oct. 14	7 56 a. m.	22.3	37.1	—14.8	29.7	33.5	28.8	+ 4.7	31.2	—1.5	30.4
15	8 11 a. m.	22.7	45.0	—22.3	33.8	30.3	31.8	— 1.5	31.1	+2.7	32.5
16	0 30 p. m.	25.2	37.5	—12.3	31.3	31.0	27.9	+ 3.1	29.4	+1.9	30.4

*Supposed local disturbance by an iron pipe. See also remarks further on respecting observations from April to August, 1886, inclusive.

The magnetic inclination at Los Angeles, Cal., 1882–1889—**Continued.**

Date.	Los Angeles local mean time.	Dip by needle No. 1.				Dip by needle No. 2.				Diff. dip I — II.	Dip by 2 needles.
		Polarity of marked end south or up.		Diff. A — B	Dip ½ (A + B)	Polarity of marked end south or up.		Diff. A — B	Dip ½ (A + B)		
		A 59° +	B 59° +		I.	A 59° +	B 59° +		II.		59° +
1886.	h. m.	′	′	′	° ′	′	′	′	° ′	′	′
Nov. 14	0 52 p. m.	21.9	37.7	—15.8	59 29.8	31.2	26.2	+ 5.0	59 28.7	+1.1	29.2
15	0 48 p. m.	22.8	45.1	—22.3	34.0	34.8	30.6	+ 4.2	32.7	+1.3	33.3
16	0 30 p. m.	18.2	35.6	—17.4	26.9	32.9	24.3	+ 8.6	28.6	—1.7	27.7
17	8 04 a. m.	16.0	37.4	—18.0	28.8	32.7	31.4	— 3.2	31.0	—2.2	29.9
	1 14 p. m.	23.6	38.3			26.1	33.7				
18	8 00 a. m.	24.6	39.2	—14.6	31.9	30.6	29.6	+ 1.0	30.1	+1.8	31.0
19	7 45 a. m.	20.7	38.7	—17.9	30.5	29.4	29.2	+ 2.4	31.5	—1.0	31.0
	0 56 p. m.	22.4	40.1			35.9	31.3				
Dec. 14	8 08 a. m.	17.7	36.0	—18.3	26.9	32.7	31.4	+ 1.3	32.0	—5.1	29.5
15	7 50 a. m.	19.3	33.8	—14.5	26.6	32.7	25.8	+ 6.9	29.2	—2.6	27.9
16	7 47 a. m.	27.4	39.1	—11.7	33.3	33.6	25.0	+ 8.6	29.3	+4.0	31.3
1887.											
Jan. 14	7 39 a. m.	20.5	46.3	—25.8	59 33.4	27.9	29.9	— 2.0	59 28.9	+4.5	31.2
15	7 43 a. m.	22.0	38.5	—16.5	30.3	31.5	23.8	+ 7.7	27.7	+2.6	29.0
16	7 34 a. m.	21.9	35.2	—13.3	28.5	34.5	31.7	+ 2.8	33.1	—4.6	30.8
Feb. 14	3 42 p. m.	20.1	41.0	—20.9	30.5	32.1	27.1	+ 5.0	29.6	+0.9	30.1
15	3 16 p. m.	20.8	40.8	—20.0	30.8	34.6	27.4	+ 7.2	31.0	—0.2	30.9
16	3 14 p. m.	23.1	37.7	—14.6	30.4	27.2	33.4	— 6.2	30.3	+0.1	30.3
Mar. 14	7 36 a. m.	22.6	37.9	—15.3	30.2	33.8	27.3	+ 6.5	30.6	—0.4	30.4
15	7 26 a. m.	18.9	35.7	—16.8	27.3	36.7	30.0	+ 6.7	33.3	—6.0	30.3
16	7 18 a. m.	17.8	39.4	—21.6	28.6	39.3	31.1	+ 8.2	35.2	—6.6	31.9
Apr. 14	3 00 p. m.	21.7	30.3	— 8.6	26.0	36.3	25.3	+11.0	30.8	—4.8	28.4
15	3 03 p. m.	26.1	35.8	— 9.7	31.0	37.4	29.8	+ 7.6	33.6	—2.6	32.3
16	7 24 a. m.	17.9	42.8	—24.9	30.4	29.6	26.4	+ 3.2	28.0	+2.4	29.2
May 14	7 30 a. m.	24.3	39.0	—14.7	31.6	36.3	27.8	+ 8.5	32.1	—0.5	31.9
15	7 21 a. m.	19.6	41.0	—21.4	30.3	32.4	28.0	+ 4.4	30.2	+0.1	30.2
16	7 16 a. m.	16.1	39.6	—23.5	27.9	30.2	32.0	— 1.8	31.1	— 3.2	29.5
June 14	7 24 a. m.	21.8	33.7	—11.9	27.7	31.0	26.4	+ 4.6	28.7	—1.0	28.2
15	7 21 a. m.	22.9	34.5	—11.6	28.7	35.7	35.0	+ 0.7	35.4	—6.7	32.0
16	7 18 a. m.	17.1	34.3	—17.2	25.7	39.4	30.9	+ 8.5	35.2	—9.5	30.5
July 14	7 24 a. m.	19.4	34.4	—15.0	26.9	33.5	30.3	+ 3.2	31.9	—5.0	29.4
15	7 22 a. m.	17.3	39.8	—22.5	28.5	28.4	24.3	+ 4.1	26.3	+2.2	27.4
16	7 16 a. m.	19.4	43.3	—23.9	31.4	37.8	32.2	+ 5.6	35.0	—3.6	33.2
Aug. 14	7 32 a. m.	16.5	35.7	—19.2	26.1	36.9	28.4	+ 8.5	32.6	—6.5	29.4
15	7 22 a. m.	23.4	36.8	—13.4	30.1	30.9	31.7	— 0.8	31.3	—1.2	30.7
16	7 26 a. m.	23.0	37.7	—14.7	30.4	33.0	26.2	+ 6.8	29.6	+0.8	30.0
Sept. 14	7 24 a. m.	24.8	34.0	— 9.2	29.4	31.4	28.2	+ 3.2	29.8	—0.4	29.6
15	6 52 a. m.	21.6	38.7	—17.1	30.2	34.4	26.7	+ 7.7	30.5	—0.3	30.3
16	6 52 a. m.	24.6	34.9	—10.3	29.7	31.8	29.8	+ 2.0	30.8	—1.1	30.3
Oct. 14	7 01 a. m.	23.9	36.5	—12.6	30.2	36.2	29.1	+ 7.1	32.7	—2.5	31.4
15	7 03 a. m.	20.2	33.8	—13.6	27.0	32.0	28.1	+ 3.9	30.0	—3.0	28.5
16	7 08 a. m.	23.0	38.3	—15.3	30.6	28.4	35.4	— 7.0	31.9	—1.3	31.3

The magnetic inclination at Los Angeles, Cal., 1882–1889—Continued.

Date.	Los Angeles local mean time.	Dip by needle No. 1.				Dip by needle No. 2.				Diff. dip I − II.	Dip by 2 needles.
		Polarity of marked end south or up.		Diff. A − B	Dip ½ (A + B)	Polarity of marked end south or up.		Diff. A − B	Dip ½ (A + B)		
		A 59° +	B 59° +		I.	A 59° +	B 59° +		II.		59° +
1887.	h. m.	′	′	′	° ′	′	′	′	° ′	′	′
Nov. 14	7 26 a. m.	19.9	29.9	−10.0	59 24.9	32.5	32.9	− 0.4	59 32.7	−7.8	28.8
15	7 31 a. m.	24.3	31.0	− 6.7	27.7	34.7	25.9	+ 8.8	30.3	−2.6	29.0
16	7 26 a. m.	21.6	40.1	−18.5	30.9	28.8	27.2	+ 1.6	28.0	+2.9	29.4
Dec. 14	0 30 p. m.	22.8	37.8	−15.0	30.3	34.7	23.2	+11.5	28.9	+1.4	29.6
15	7 24 a. m.	19.2	34.1	−14.9	26.6	34.4	32.3	+ 2.1	33.4	−6.8	30.0
16	7 21 a. m.	23.6	35.7	−12.1	29.7	30.7	24.5	+ 6.2	27.6	+2.1	28.6
1888.											
Jan. 14	1 36 p. m.	21.5	32.7	−11.2	59 27.1	29.1	39.6	−10.5	59 34.4	−7.3	30.7
15	7 32 a. m.	23.2	35.1	−11.9	29.1	27.0	30.4	− 3.4	28.7	+0.4	28.9
16	7 39 a. m.	27.4	40.6	−13.2	34.0	25.6	30.8	− 5.2	28.2	+5.8	31.1
Feb. 14	7 45 a. m.	24.6	40.5	−15.9	32.5	38.0	26.8	+11.2	32.4	+0.1	32.5
15	7 28 a. m.	18.6	41.0	−22.4	29.8	37.9	33.3	+ 4.6	35.6	−5.8	32.7
16	7 24 a. m.	25.6	37.7	−12.1	31.6	29.1	22.5	+ 6.6	25.8	+5.8	28.7
Mar. 14	7 31 a. m.	17.4	40.3	−22.9	28.8	34.9	33.9	+ 1.0	34.4	−5.6	31.6
15	7 28 a. m.	20.8	37.2	−16.4	29.0	35.4	29.8	+ 5.6	32.6	−3.6	30.8
16	7 30 a. m.	20.9	42.4	−21.5	31.6	36.2	24.4	+11.8	30.3	+1.3	30.9
Apr. 14	7 26 a. m.	22.1	38.1	−16.0	30.1	32.6	29.9	+ 2.7	31.2	−1.1	30.6
15	7 25 a. m.	30.4	35.9	− 5.5	33.2	32.0	25.4	+ 6.6	28.7	+4.5	30.9
16	7 22 a. m.	23.2	40.2	−17.0	31.7	33.3	25.7	+ 7.6	29.5	+2.2	30.6
May 14	7 25 a. m.	23.7	37.7	−14.0	30.7	31.2	33.6	− 2.4	32.4	−1.7	31.6
15	7 28 a. m.	19.8	36.2	−16.4	28.0	27.3	27.2	+ 0.1	27.3	+0.7	27.7
16	7 25 a. m.	19.7	39.8	−20.1	29.8	28.2	28.1	+ 0.1	28.1	+1.7	29.0
June 14	7 30 a. m.	25.5	42.9	−17.4	34.2	31.1	20.3	+10.8	25.7	+8.5	30.0
15	7 32 a. m.	21.3	40.4	−19.1	30.9	33.3	24.7	+ 8.6	29.0	+1.9	29.9
16	1 06 p. m.	16.9	41.7	−24.8	29.3	41.2	18.9	+22.3	30.0	−0.7	29.7
July 14	1 06 p. m.	21.3	35.7	−14.4	28.5	34.6	32.6	+ 2.0	33.6	−5.1	31.1
15	7 36 a. m.	21.4	42.5	−21.1	31.9	24.1	32.4	− 8.3	28.3	+3.6	30.1
16	7 31 a. m.	28.0	33.8	− 5.8	30.9	24.7	33.7	− 9.0	29.2	+1.7	30.0
Aug. 14	7 28 a. m.	22.5	32.0	− 9.5	27.3	39.2	21.9	+17.3	30.5	−3.2	28.9
15	7 24 a. m.	23.7	38.1	−14.4	30.9	33.1	26.8	+ 6.3	30.0	+0.9	30.4
16	7 30 a. m.	19.8	36.4	16.6	28.1	36.9	27.6	+ 9.3	32.3	−4.2	30.2
Sept. 14	7 30 a. m.	21.7	31.5	− 9.8	26.6	26.9	28.7	− 1.8	27.8	−1.2	27.2
15	7 32 a. m.	24.7	35.9	−11.2	30.3	32.3	31.2	+ 1.1	31.7	−1.4	31.0
16	7 22 a. m.	27.1	37.3	−10.2	32.2	29.9	35.4	− 5.5	32.6	− 0.4	32.4
Oct. 14	7 31 a. m.	26.9	31.6	− 4.7	29.3	29.9	28.6	+ 1.3	29.2	+0.1	29.3
15	7 20 a. m.	20.0	33.8	−13.8	26.9	30.9	28.3	+ 2.6	29.6	−2.7	28.2
16	7 46 a. m.	23.0	41.2	−18.2	32.1	28.7	24.2	+ 4.5	26.5	+5.6	29.3
Nov. 14	7 30 a. m.	23.8	36.0	−12.2	29.9	35.3	20.9	+14.4	28.1	+1.8	29.0
15	7 28 a. m.	16.5	35.5	−19.0	26.0	35.2	18.4	+16.8	26.8	−0.8	26.4
16	7 28 a. m.	23.6	29.7	− 6.1	26.6	37.0	20.5	+16.5	28.7	−2.1	27.7
Dec. 14	7 38 a. m.	34.9	30.4	− 4.5	32.6	27.4	25.9	+ 1.5	26.7	+5.9	29.7
15	7 30 a. m.	21.4	29.5	− 8.1	25.5	34.1	28.2	+ 5.9	31.2	−5.7	28.3
16	7 30 a. m.	20.2	39.6	−19.4	29.9	30.2	23.5	+ 6.7	26.8	+3.1	28.4

The magnetic inclination at Los Angeles, Cal., 1882-1889—Continued.

Date.	Los Angeles local mean time.	Dip by needle No. 1. Polarity of marked end south or up. A 59°+	B 59°+	Diff. A—B	Dip ½ (A+B) I.	Dip by needle No. 2. Polarity of marked end south or up. A 59°+	B 59°+	Diff.	Dip ½ (A+B) II.	Diff. dip I—II.	Dip by 2 needles. 59°+
1889.	*h. m.*	′	′	′	° ′	′	′	′	° ′	′	′
Jan. 14	7 38 a. m.	22.4	35.0	—12.6	59 28.7	31.6	22.1	+ 9.5	59 26.8	+1.9	27.8
15	7 34 a. m.	22.8	37.4	—14.6	30.1	32.0	24.0	+ 8.0	28.0	+2.1	29.1
16	7 28 a. m.	23.2	31.8	— 8.6	27.5	34.9	28.9	+ 6.0	31.9	—4.4	29.7
Feb. 14	7 32 a. m.	22.3	33.7	—11.4	28.0	31.3	27.9	+ 3.4	29.6	—1.6	28.8
15	7 33 a. m.	21.1	29.1	— 8.0	25.1	35.4	21.5	+13.9	28.4	—3.3	26.8
16	7 31 a. m.	25.3	35.0	— 9.7	30.1	34.6	24.8	+ 9.8	29.7	+0.4	29.9
Mar. 14	7 32 a. m.	21.7	29.9	— 8.2	25.8	32.9	27.4	+ 5.5	30.2	—4.4	28.0
15	0 30 p. m.	22.4	29.4	— 7.0	25.9	33.7	29.5	+ 4.2	31.6	—5.7	28.8
16	1 57 p. m.	29.8	37.4	— 7.6	33.6	26.6	27.2	— 0.6	26.9	+6.7	30.2
Apr. 14	7 33 a. m.	25.8	36.6	—10.8	31.2	28.0	25.2	+ 2.8	26.6	+4.6	28.9
15	7 24 a. m.	15.6	37.4	—21.8	26.5	39.6	27.4	+12.2	33.5	—7.0	30.0
16	7 26 a. m.	19.0	29.4	—10.4	24.2	35.1	25.4	+ 9.7	30.3	—6.1	27.2
May 14	7 32 a. m.	22.1	31.9	— 9.8	27.0	30.1	24.0	+ 6.1	27.0	0.0	27.0
15	7 26 a. m.	24.3	32.0	— 7.7	28.2	33.4	28.8	+ 4.6	31.1	—2.9	29.6
16	7 22 a. m.	18.6	39.0	—20.4	28.8	29.9	25.0	+ 4.9	27.4	+1.4	28.1
June 14	7 38 a. m.	26.1	29.7	— 3.6	27.9	29.7	28.1	+ 1.6	28.9	—1.0	28.4
15	7 28 a. m.	26.2	36.3	—10.1	31.2	33.4	27.9	+ 5.5	30.7	+0.5	31.0
16	7 28 a. m.	26.1	35.4	— 9.3	30.8	32.9	28.9	+ 4.0	30.9	—0.1	30.8
July 14	7 32 a. m.	20.3	38.0	—17.7	29.1	30.4	25.2	+ 5.2	27.8	+1.3	28.5
15	7 40 a. m.	30.1	37.2	— 7.1	33.7	35.6	34.9	+ 0.7	35.2	—1.5	34.4
16	7 32 a. m.	30.0	30.3	— 0.3	30.1	26.8	29.8	— 3.0	28.3	+1.8	29.2
Aug. 14	7 36 a. m.	20.5	40.8	—20.3	30.7	28.8	28.9	— 0.1	28.9	+1.8	29.8
15	7 20 a. m.	21.0	37.0	—16.0	29.0	32.6	31.5	+ 1.1	32.0	—3.0	30.5
16	7 20 a. m.	22.1	37.8	—15.7	30.0	34.9	30.0	+ 4.9	32.5	—2.5	31.7
Sept. 14	7 34 a. m.	21.9	34.2	—12.3	28.1	35.4	24.0	+11.4	29.7	—1.6	28.9
15	7 24 a. m.	19.2	39.7	—20.5	29.5	27.6	26.5	+ 1.1	27.0	+2.5	28.2
16	7 25 a. m.	17.8	36.6	—18.8	27.2	32.6	25.3	+ 7.3	28.9	—1.7	28.1
Oct. 3	7 34 a. m.	17.8	43.8	—26.0	30.8	35.0	22.0	+13.0	28.5	+2.3	29.7
4	7 12 a. m. 8 04 a. m.	22.4 29.3	22.7 29.4	— 0.2	25.9	. . 30.4	. . 30.9	— 0.5	30.7	—4.8	28.3
5	7 36 a. m.	24.9	37.7	—12.8	31.3	34.6	25.6	+ 9.0	30.1	+1.2	30.7

Difference in dip as determined by needles 1 and 2.—By taking the mean of the 262 tabular differences I-II, we find the value $=\frac{40.7}{262}=+0'.16$, which small constant difference makes it highly probable that the dip is well ascertained.

The probable error of observation for dip.—This probable error may be ascertained by means of the above differences I-II, which should all be $+0'.16$ if there was no observing error. It suffices to disregard this small difference, and also to use the differences themselves in the place of their squares.

We have consequently the mean error of an observation for dip by one needle

$$\sqrt{\frac{[\triangle^2]}{2n}} = 1.253 \frac{[\triangle}{n \sqrt{2}}$$

where $[\triangle =$ sum of the 262 values *disregarding* their differences of *sign;** hence mean error $\frac{1.253 \times 632}{262 \times 1.414} = \pm 2'.13$ and the probable error of an observation for dip, by one needle, $\frac{2}{3}$ times ± 2.13 or $\pm 1'.4$, also the probable error of an observation for dip from two needles, $\pm 1'.0$

The probable error of a dip determination may also be arrived at by comparing each monthly mean value with each of the three daily values in the last column of the table. We then have the probable error of a dip from two needles equal

$$0.675 \sqrt{\frac{[vv]}{n(n-\nu)}} = 0.845 \frac{[v}{\sqrt{n(n-\nu)}} = 0.845 \times \frac{234}{\sqrt{262(262-86)}} = \pm 0'.9$$

which is practically the same as the preceding result, though we might have expected a slightly greater result, since the effect of variation in time enters to some extent in the latter method.

If the needles have any constant correction for dip at $59\frac{1}{2}°$, this would have to be combined with the preceding probable error, as affecting all measures.

Recapitulation of resulting monthly and annual values for dip from observations with two needles and on three days each month.

Dip = 59° + tabular quantity.

Month (middle).	1882–'83.	1883–'84.	1884–'85.	1885–'86.	1886–'87.	1887–'88.	1888–'89.	Monthly means.
	′	′	′	′	′	′	′	′
October.	30.3	32.2	30.5	29.1	31.1	30.4	28.9	30.4
November.	29.7	30.1	29.1	29.9	30.4	29.1	27.7	29.4
December.	31.7	30.1	29.8	28.5	29.6	29.4	28.8	29.7
January.	30.8	30.3	29.8	31.6	30.3	30.2	28.9	30.3
February.	28.5	29.1	29.5	30.4	30.4	31.3	28.5	29.7
March.	31.7	28.5	30.9	30.9	30.9	31.1	29.0	30.4
April.	28.9	30.1	29.8	34.4	30.0	30.7	28.7	[29.8]
May.	29.7	28.9	29.6	32.7	30.5	29.4	28.2	[29.5]
June.	30.7	30.2	29.4	33.9	30.2	29.9	30.1	[30.1]
July.	31.7	30.9	29.3	35.6	30.0	30.4	30.7	[30.4]
August.	30.5	28.2	30.6	35.8	30.0	29.8	30.7	[30.0]
September.	33.3	28.2	28.9	31.7	30.1	30.2	28.4	30.1
Annual means.	30.6	29.7	29.8	[30.2]	30.3	30.2	29.0	29.98

It is evident that between April and September, 1886, there must have been some disturbance which produced an increase of 4′.5 of the dip over its otherwise normal amount; the nature of this disturbance can only be surmised since the observer makes no other allusion to it than in notes of August 11 and 14, when he refers to the presence of an iron water pipe 15 or 19 metres east and north of the station.† In order to get an improved annual mean I substitute for each of the 5

*Wright's notation. See Art. 22 of his "Treatise on the Adjustment of Observations," New York, 1884.

†I learn from Assistant R. A. Marr that the surroundings of the station for absolute measures were unfavorable, due to the vicinity of premises in which wagons were kept, but the cause of the discrepant results appears to me to be instrumental, probably defective adjustment, since *neither the declination nor the horizontal intensity measures,* which are more sensitive to outside disturbances than the dip, *are in the least affected during these five months.*—SCH.

monthly dips the respective mean of the dips of the preceding and following years, viz, 29.9, 30.0, 29.8, 29.6, and 30.3, corrected by $+0'.2$, which is the average difference for the other months of the year (1885–1886) between the observed value and the mean deduced from the preceding and following year; these figures were also used when taking the monthly means in the last column. These last figures show the insufficiency of the absolute measures to bring out the *annual inequality*, for which we have to refer to the combined differential measures.

With respect to the *annual change* it must be noted as an accidental circumstance that the secular variations both for the declination and the dip were in one of their extreme phases during the occupation of the Los Angeles observatory, and for the dip this was shown on the chart accompanying Appendix No. 6, Coast and Geodetic Survey Report for 1885. On this chart the belt of stationary dip or of no annual change passes through Los Angeles in 1885. Our annual means are insufficient to fix the precise year and they barely indicate that a decrease has set in; this would make it probable that the belt is now moving to the westward.

The mean dip for the middle period or for April 1, 1886, is $59° 30'.0 \pm 0'.2$

The annual inequality of the dip will be derived from the differential measures.

DETERMINATION OF THE HORIZONTAL COMPONENT OF THE EARTH'S MAGNETIC FORCE.

The form of record and the arrangement for computing the horizontal force from the combination of results of deflections and oscillations is shown in the following example: Let

r=deflecting distance of magnets corrected for error of graduation and for difference from standard temperature; it was originally expressed in feet and decimals, but is converted into centimetres.

u=observed angle of deflection.

$\frac{m}{H}$=ratio of magnetic moment of the deflecting and oscillating magnet to the horizontal component of the earth's magnetic force, corrected for the particular distribution of magnetism in the deflecting and deflected magnets; corrected for the earth's inducing action on the magnetic moment of the magnet and for difference of temperature from adopted standard value t_0 and the observed temperature t, then

$$\frac{m}{H}=\frac{r^3}{2}\sin u\left[1-\frac{P}{r^2}+\frac{2u}{r^3}+q\,(t-t_0)\right] \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

T_1=observed mean time T_0, of one oscillation of the horiontal magnet, corrected for rate of chronometer (s=daily rate, + when losing, − when gaining) and reduced to an infinitesimal arc of oscillation (α and α^1 being the semi-arcs of oscillation at beginning and end expressed in radians).

T=the time of one oscillation after T_1 is further corrected (1) for torsion in the suspension ($\frac{h}{f}$ being the ratio of the horizontal force to the force of torsion), and (2) corrected for difference of temperature t^1 of magnet while oscillating and an adopted standard temperature t_0 (in the example we have reduced to t, but $t_0=62°$ F. or 16.7 C. is adopted for the general reduction*), and (3) corrected for effect of the earth's inductive force (μ being the increase of the magnetic moment m of the magnet under the influence of induction), then

$$T_1=T_0\left\{1+\frac{s}{86400}-\frac{\alpha\,\alpha^1}{16}\right\} \quad \text{and} \quad T^2=T_1^2\left\{1+\frac{h}{f}-q\,(t^1-t_0)+\frac{\mu H}{m}\right\} \quad \text{and} \quad mH=\frac{\pi^2 M}{T^2} \quad . \quad (2)$$

* In the example, the temperature of the deflection observations was adopted and the oscillation-observations were referred to it; in the body of the work, however, both deflections and oscillations were referred to 16°.7 C. as standard temperature; the values of m, therefore, also referred to this. We have $m_0=m\,[1+q\,(t-t_0)]$.

Whence by combining (1) with (2) we get m and H separately.*

Before the results for $\frac{m}{H}$ and m H can be combined it is necessary to correct one of the expressions for any change in the value of H that may have taken place during the interval of the observations of deflections and oscillations, and it is most convenient to apply the correction to the result of the former.

Let f_d = the scale reading (divisions) of the bifilar instrument at the average time of the deflections.

Let f_v = the scale reading (divisions) of the bifilar instrument at the average time of the oscillations.

k = value of one division of scale in terms of H, then

$$1+\frac{\triangle H}{H}=1+(f_d-f_v)\,k \quad \text{and} \quad \log\left(1+\frac{\Delta H}{H}\right)=\text{Mod.}\times k\,(f_d-f_v)$$

we have $k=0.000109$; hence we add algebraically to $\log\frac{m}{H}$ the correction:

$$0.0000473\,(f_d-f_v)$$

as tabulated below.†

f_d-f_v	$\log\left(1+\frac{\triangle H}{H}\right)$	f_d-f_v	$\log\left(1+\frac{\triangle H}{H}\right)$	f_d-f_v	$\log\left(1+\frac{\triangle H}{H}\right)$	f_d-f_v	$\log\left(1+\frac{\triangle H}{H}\right)$
±7.8	±0.00037	±5.7	±0.00027	±3.6	±0.00017	±1.5	±0.00007
7.6	36	5.5	26	3.4	16	1.3	6
7.4	35	5.3	25	3.2	15	1.1	5
7.2	34	5.1	24	3.0	14	0.9	4
7.0	33	4.9	23	2.7	13	0.6	3
6.8	32	4.7	22	2.5	12	0.4	2
6.6	31	4.4	21	2.3	11	0.2	1
6.3	30	4.2	20	2.1	10	0.0	0
6.1	29	4.0	19	1.9	09		
5.9	28	3.8	18	1.7	08		

*For the numerical expressions of magnetic intensity the C. and G. S. units[1] will be employed in the place of the F. G. S. units formerly used on the Survey. We therefore note the dimensions and multipliers of m and H for the conversion of one system into the other.

In the electro-magnetic system the dimensions of the magnetic moment m or of the product of the strength of either pole and the length of the magnet are:

$$[M^{\frac{1}{2}}\,L^{\frac{3}{2}}\,T^{-1}]\times[L]=[M^{\frac{1}{2}}\,L^{\frac{5}{2}}\,T^{-1}]$$

and the dimensions of the magnetic field intensity or of the force which a unit pole will experience when placed in it:

$$[M^{\frac{1}{2}}\,L^{-\frac{1}{2}}\,T^{-1}]$$

Adopting the relations:

1 grain = 0.064799 gramme

1 foot = 30.48006 centimetres

we have, for the multiplier to convert values of m from F. G. S. units into C. G. S. units

$$\sqrt{.064799}\times\sqrt{(30.48006)^5}=1305.64$$

and its logarithm, 3.115824, and the multiplier to convert values of H from F. G. S. units into C. G. S. units becomes

$$\sqrt{\frac{.064799}{30.480}}=0.0461080 \quad \text{and its logarithm} \quad 8.663776-10.$$

[1] In this system the magnetic pole of unit strength will repel an equal pole at the distance of one centimetre with a force of one dyne.

†The temperature correction to (f_d-f_v) can generally be neglected. The daily range of temperature of the magnets was on the average about 1.3° C., and supposing a tolerably uniform change, the difference for an hour would generally be less than 0.15° C.; hence with the value $\frac{q}{k}=\frac{0.00025}{0.00011}=2.3$ nearly, the logarithmic correction would be less than 2 units in the fifth place. The difference in time was generally three-quarters of an hour.

The table of results given below has been drawn up by Mr. L. A. Bauer, of the Computing Division, who made an independent reduction of the observed intensities. This table is preceded by a specimen of the record and computation for one date.

Specimen record and computation of the horizontal intensity.

[U. S. Coast and Geodetic Survey. Form 3.]

U. S. Coast Survey. Magnetic observations. Horizontal intensity. Deflections with magnetometer. Date, September 15, 1883. Station, Los Angeles, Cal. Pier for absolute measures, grounds of the magnetic observatory. Instrument, magnetometer No. 8. Magnet, L_8 deflecting at right angles to magnet S_8 suspended (scale up). Observer, Marcus Baker.

Distance $r = 36.5757$ cm log. $r = 1.56319$
Corrected $r = 36.5753$

Magnet.	North end.	No.	A.	B.	Mean.	No.	A.	B.	Mean.
			° ′ ″	′ ″	′		° ′ ″	′ ″	′
East.	E.	1	29 11 50	12 20	12.08				
	W.					2	26 05 10	5 30	05.33
	E.	3	11 40	12 00	11.83				
	W.					4	04 50	5 20	05.08
	E.	5	11 10	11 40	11.42				
	Mean.		29		11.78		26		05.20
West.	W.					6	26 05 20	5 40	05.50
	E.	7	29 09 40	10 00	9.83				
	W.					8	05 30	5 50	05 67
	E.	9	09 40	10 00	9.83				
	W.					10	05 10	5 30	05.33
	Mean.		29		09.83		26		05.50

Computation. $\frac{m}{H} = \frac{1}{2} r^3 \sin. u \left(1 - \frac{P}{r^2} \ldots\right)$

					Logarithms.
	° ′				
Magnet east, $2u =$	3 06.58			$\frac{1}{2}$	9.69897
Magnet west, $2u =$	3 04.33			r^3	4.68956
Mean	3 05.455			Sin. u	8.43089
$u =$	1 32.73			$1 - \frac{P}{r^2}$	0.00340
	h m		°		
Chronometer time of beginning.	9 59	Temp.	24.7 C	$1 + \frac{2\mu}{r^3}$	0.00011
Chronometer time of ending.	10 25	Temp.	26.7	$*1 + q(t - t_0)$	0.00000
				$\frac{m}{H}$	2.82293
Mean	10 12		$t = 25.7$		
		Index corr'n	— 0.6		
			25.1		

*Here this factor is zero; the oscillations being reduced to the temperature of the deflections or $t_0 = t$.

Specimen of record of oscillations and of computation of the horizontal intensity.

[U. S. Coast and Geodetic Survey. Form 4.]

Magnetic observations for horizontal intensity. Oscillations: Date, September 15, 1883. Station, Los Angeles, Cal. Pier for absolute measures, grounds of magnetic observatory.
Instrument, Magnetometer No. 8. Magnet, L_8 suspended; scale erect. Mass ring, not used. (M. T.) Chronometer, P. & F. No. 2701, daily rate* gaining on mean time $3.^s15$

Number of oscillations.		Chronometer time.	Temp. t'	Extreme scale readings.		Time of 100 oscillations.
		h. m. s.	°			
Right	0	9 28 05.0	22.8C	0.0	20.0	
	6	28 35.3				
	12	29 05.6				
	18	29 35.8				
	24	30 06.2				
Left	31	30 41.5				
	37	31 11.8				
	43	31 42.0				
	49	32 12.3				
	53	32 42.5	23.2	2.7	17.1	m. s. 8 24.4
Right	100	36 29.4				24.4
	106	36 59.7				24.3
	112	37 29.9				24.3
	118	38 00.2				24.4
	124	38 30.5				24.3
Left	131	39 06.0				24.5
	137	39 36.3				24.5
	143	40 06.5				24.5
	149	40 36.7				24.4
	153	41 06.9	23.6	4.7	15.0	24.4
		Mean {Index corr'n t'}	23.2 — 0.6 22.6		Mean	8 24.41

Coefficient of torsion. Value of one scale div'n = 2.71

Tors. circle.	Scale.		Means.	Diff's.		Logarithms.
216	8.9	11.0	9.95	1.45	$v' = 4.0$	
306	11.0	11.8	11.40	2.95	$5400' + v' = 5404.0$	3.73272
126	8.1	8.8	8.45	1.50	5400 (ar. co.)	6.26761
216	9.1	10.8	9.95			
	Mean v =			1.475	$1+\frac{h}{f}$	0.00033

*State whether gaining or losing.

Observer, Marcus Baker.

$$T^2 = T_1^2\left(1+\frac{h}{f}\right)\left(1-(t'-t_0)\,q\right)$$

		s.
Observed time of 100 oscillations	=	504.41
Time of one oscillation	=	5.0441
Correction for rate	=	—.0002
Correction for arc	=	—.0000
		$T_1 = 5.0439$

			Logarithms.
q	0.00103	T_1	0.70277
* $t'-t_0$	—2.5	T_1^2	1.40553
$(t'-t_0)\,q$	—0.00258	$1+\frac{h}{f}$	0.00033
$1-(t'-t_0)\,q$	1.00258	$1-(t'-t_0)\,q$	0.00112
		$1+\mu\frac{H}{m}$	0.00388
$mH = \frac{\pi^2 M}{T^2}$		T^2	1.41086
		(ar. co.) T^2	8.58914
		π^2	0.99430
		M at t_0 C.	2.11171
		m H	1.69515
m = 181.57 at t_0C.†		m	2.25904
H = 0.27297.		H	9.43611

Obs'ns of defl'ns {Date: September 15. Hour: $10^h\ 12^m$ by chronometer. Temp. $t = 25°.1$C.}

Remarks.		
Chronometer correction at noon to local mean time $-3^m\ 35^s$.	m H	2.82293
	m H	1.69515
	m^2	4.51808
	m	2.25904

*Here $t_0 = t$.

†For standard temperature 16.7 C, we have $m_0 = 183.14$

The magnetic horizontal intensity at Los Angeles, Cal., 1882–1889.

Abstract of results of the monthly determinations of the horizontal component of the earth's magnetic intensity, on pier for absolute measures. Instrument used, the magnetometer No. 8.

Date.	Observations of deflections.				Observations of oscillations.			L_8	Horizontal
	Los Angeles local mean time.	Corrected t C.	Corrected distance r.	Observed angle of deflection u.	Los Angeles local mean time.	Corrected t' C.	Time of one oscillation T_1.	Magnetic moment m at 16°.7 C.	component of magnetic force H.
1882.	*h. m.*	°	*cm.*	° ′	*h. m.*	°	*s.*		*dyne.*
Sept. 14	9 34 a.m.	+31.1	36.579	1 31.60	10 21 a.m.	34.0	5.0831	182.1	0.2730
	11 12 a.m.	36.7	83	1 31.09					
15	9 22 a.m.	20.8	72	1 32.80	10 27 a.m.	22.7	5.0445	2.7	31
	11 24 a.m.	25.4	75	1 32.55					
16	9 56 a.m.	25.3	75	1 32.38	10 45 a.m.	26.4	5.0522	2.7	28
	11 50 a.m.	29.3	78	1 32.28	11 22 a.m.	29.0	5.0672		
Oct. 14	10 16 a.m.	28.1	77	1 32.62	10 54 a.m.	28.3	5.0528	3.4	27
	0 13 p.m.	26.4	76	1 32.78	11 20 a.m.	28.4	5.0522		
15	10 19 a.m.	32.8	80	1 32.08	10 58 a.m.	33.8	5.0711	3.2	27
	0 00	32.5	80	1 32.07	11 27 a.m.	33.9	5.0695		
16	9 40 a.m.	32.8	80	1 31.88	10 25 a.m.	34.6	5.0763	3.0	26
	0 04 p.m.	35.4	82	1 31.94	11 13 a.m.	35.4	5.0758		
Nov. 14	10 56 a.m.	19.8	71	1 33.62	11 37 a.m.	21.0	5.0340	3.5	25
15	10 46 a.m.	19.4	71	1 33.70	11 24 a.m.	20.3	5.0305	3.6	26
16	10 50 a.m.	18.1	70	1 33.49	11 25 a.m.	18.5	5.0255	3.4	31
Dec. 14	11 04 a.m.	19.7	71	1 33.35	11 43 a.m.	21.2	5.0332	3.3	30
15	10 43 a.m.	20.1	71	1 33.20	11 23 a.m.	22.1	5.0352	3.3	31
16	10 35 a.m.	21.9	36.573	1 33.25	11 16 a.m.	23.3	5.0414	183.4	0.2726
1883.									
Jan. 14	11 55 a.m.	+16.8	32.303	2 16.09	11 06 a.m.	14.6	5.0197	183.6	0.2724
15	11 04 a.m.	15.4	32.302	2 15.65	10 06 a.m.	12.2	5.0092	3.1	35
	11 35 a.m.	15.6	48.453	0 40.22	0 09 p.m.	16.1	5.0195		
16	11 42 a.m.	14.9	36.568	1 34.11	10 53 a.m.	14.1	5.0123	3.6	28
Feb. 14	11 00 a.m.	11.9	36.566	1 34.31	10 05 a.m.	11.1	5.0013	3.7	32
15	11 03 a.m.	15.2	36.568	1 33.67	9 53 a.m.	12.1	5.0062	3.3	34
					10 13 a.m.	13.8	5.0126		
16	11 44 a.m.	17.4	36.569	1 33.76	10 59 a.m.	16.8	5.0172	3.7	31
Mar. 14	10 25 a.m.	18.1	30.475	2 41.07	9 36 a.m.	16.1	5.0173		
	10 57 a.m.	18.4	36.570	1 33.57				3.5	30
	11 27 a.m.	18.7	42.665	0 59.04	11 58 a.m.	19.9	5.0313		
15	10 28 a.m.	16.0	36.568	1 33.82	9 42 a.m.	14.3	5.0133	3.5	31
16	10 10 a.m.	15.9	30.474	2 41.17	9 20 a.m.	14.7	5.0170		
	10 44 a.m.	16.4	36.569	1 33.59				3.3	31
	11 17 a.m.	16.8	42.664	0 59.11	11 53 a.m.	17.2	5.0230		
Apr. 14	6 29 a.m.	4.6	36.561	1 34.54	7 14 a.m.	7.3	4.9950	3.1	37
15	6 47 a.m.	7.8	63	1 34.38	7 25 a.m.	11.2	5.0060	3.2	31
					3 25 p.m.	31.7	5.0666		
16	10 29 a.m.	30.1	78	1 32.12	9 28 a.m.	26.7	5.0498	3.1	32
17*	11 19 a.m.	27.9	77	1 32.29	9 38 a.m.	23.5	5.0427	3.0	32
May 14	10 15 a.m.	20.2	71	1 33.27	9 25 a.m.	17.9	5.0235	3.4	32
15	9 03 a.m.	17.8	70	1 33.57	8 03 a.m.	13.7	5.0116	3.5	31
16	9 12 a.m.	19.4	71	1 33.21	8 12 a.m.	15.4	5.0152	183.3	0.2734

* By Lucius Baker.

The magnetic horizontal intensity at Los Angeles, Cal., 1882–1889—Continued.

Date.	Observations of deflections.				Observations of oscillations.			L_8	Horizontal component of magnetic force H.
	Los Angeles local mean time.	Corrected t C.	Corrected distance r.	Observed angle of deflection u.	Los Angeles local mean time.	Corrected t' C.	Time of one oscillation. T_1.	Magnetic moment m at 16°.7 C.	
1883.	*h. m.*	°	*cm.*	° ′	*h. m.*	°	*s.*		*dyne.*
June 14	9 42 a. m.	+24.3	36.574	1 32.75	8 51 a. m.	22.3	5.0403	183.2	0.2732
15	9 41 a. m.	25.4	75	1 32.60	8 49 a. m.	23.8	5.0442	3.2	32
16	9 42 a. m.	25.1	75	1 32.70	8 54 a. m.	22.9	5.0427	3.2	31
July 14	6 10 a. m.	19.3	71	1 33.21	6 50 a. m.	19.8	5.0324	3.2	34
15	10 40 a. m.	27.1	76	1 32.26	9 59 a. m.	24.0	5.0438	3.0	36
16	9 38 a. m.	22.6	73	1 33.13	9 01 a. m.	20.4	5.0353	3.4	29
Aug. 14	10 02 a. m.	29.2	78	1 32.35	9 19 a. m.	26.9	5.0544	3.2	30
15	10 01 a. m.	28.8	77	1 32.17	9 18 a. m.	27.6	5.0547	3.0	33
16	10 54 a. m.	30.7	79	1 32.03	10 17 a. m.	28.3	5.0500	3.3	37
Sept. 14	10 20 a. m.	22.8	73	1 33.21	9 29 a. m.	19.8	5.0359	3.4	26
15	10 12 a. m.	25.1	75	1 32.73	9 31 a. m.	22.6	5.0439	3.1	30
16	10 18 a. m.	22.6	73	1 33.53	9 34 a. m.	20.4	5.0444	3.4	19
Oct. 14	10 16 a. m.	17.9	70	1 33.79	9 26 a. m.	16.8	5.0275	3.5	25
15	10 27 a. m.	20.3	71	1 33.46	9 43 a. m.	18.6	5.0318	3.4	27
16	10 14 a. m.	24.4	74	1 32.72	9 30 a. m.	22.2	5.0391	3.2	33
Nov. 14	10 41 a. m.	26.1	75	1 32.74	9 53 a. m.	23.1	5.0411	3.4	30
15	10 10 a. m.	20.9	72	1 33.23	9 24 a. m.	17.9	5.0258	3.4	32
16	10 30 a. m.	26.6	76	1 32.58	9 39 a. m.	23.4	5.0417	3.3	32
Dec. 14	10 18 a. m.	18.8	70	1 33.32	9 27 a. m.	14.2	5.0161	3.3	34
15	10 46 a. m.	25.2	75	1 32.50	10 00 a. m.	21.2	5.0365	3.0	35
16	10 28 a. m.	23.6	36.574	1 32.96	9 44 a. m.	20.3	5.0338	183.3	0.2731
1884.									
Jan. 14	11 01 a. m.	+15.7	36.568	1 33.92	9 58 a. m.	13.9	5.0177	183.4	0.2728
					10 17 a. m.	14.6	5.0207		
15	10 12 a. m.	13.1	66	1 34.07	9 30 a. m.	8.2	5.0044	3.3	29
16	10 58 a. m.	17.8	70	1 33.56	10 02 a. m.	8.2	5.0177	2.8	22
Feb. 14	11 05 a. m.	9.2	64	1 34.52	10 15 a. m.	7.8	5.0012	3.5	30
15	11 21 a. m.	11.8	66	1 34.19	10 28 a. m.	8.2	5.0067	3.3	29
16	11 11 a. m.	15.7	68	1 33.80	10 30 a. m.	15.3	5.0206	3.7	28
Mar. 14	10 36 a. m.	14.7	68	1 33.95	9 47 a. m.	13.3	5.0184	3.4	29
15	10 35 a. m.	16.8	69	1 33.86	9 50 a. m.	16.0	5.0237	3.6	28
16	10 55 a. m.	17.9	70	1 33.76	10 11 a. m.	17.4	5.0298	3.5	26
Apr. 14	10 05 a. m.	19.6	71	1 33.45	9 20 a. m.	18.6	5.0293	3.5	30
15	10 12 a. m.	19.6	71	1 33.23	9 27 a. m.	18.2	5.0285	3.3	33
16	9 24 a. m.	20.0	71	1 33.39	8 33 a. m.	16.9	5.0266	3.4	30
May 14	10 17 a. m.	21.9	73	1 33.11	9 33 a. m.	22.0	5.0411	3.3	30
15	10 31 a. m.	23.3	74	1 32.71	9 44 a. m.	20.4	5.0351	3.1	35
16	9 16 a. m.	23.1	73	1 32.76	8 33 a. m.	20.7	5.0372	3.1	34
June 14	9 27 a. m.	23.0	73	1 32.76	8 16 a. m.	19.2	5.0319	3.2	36
					8 54 a. m.	21.5	5.0392		
15	10 06 a. m.	26.2	76	1 32.89	9 22 a. m.	24.5	5.0485	3.4	26
16	10 44 a. m.	29.2	36.578	1 32.33	9 35 a. m.	25.6	5.0525	183.2	0.2730
					10 09 a. m.	27.7	5.0567		

The magnetic horizontal intensity at Los Angeles, Cal., 1882–1889—**Continued.**

Date.	Observations of deflections. Los Angeles local mean time.	Corrected t C.	Corrected distance r	Observed angle of deflection u	Observations of oscillations. Los Angeles mean local time.	Corrected t' C.	Time of one oscillation T_1.	L_{8} Magnetic moment m at 16°.7 C.	Horizontal component of magnetic force H.
1884.	*h. m.*	°	*cm.*	° ′	*h. m.*	°	*s.*		*dyne.*
July 14	10 25 a. m.	+29. 8	36. 578	1 32. 26	9 40 a. m.	27. 8	5. 0612	183. 0	0. 2728
15	9 50 a. m.	27. 4	76	1 32. 36	9 04 a. m.	24. 9	5. 0501	3. 0	32
16	9 41 a. m.	26. 7	76	1 32. 46	8 57 a. m.	24. 6	5. 0506	3. 0	31
Aug. 14	11 56 a. m.	33. 4	81	1 31. 96	11 02 a. m.	33. 4	5. 0818	3. 1	21
15	11 51 a. m.	34. 1	81	1 31. 86	11 06 a. m.	32. 9	5. 0824	2. 8	24
16	10 52 a. m.	33. 7	81	1 31. 51	10 08 a. m.	31. 8	5. 0743	2. 6	32
Sept. 14	11 33 a. m.	30. 4	78	1 32. 16	10 40 a. m.	28. 9	5. 0650	2. 9	29
15	10 19 a. m.	30. 3	78	1 32. 12	9 40 a. m.	27. 3	5. 0591	3. 0	30
16	10 24 a. m.	31. 2	79	1 31. 98	9 41 a. m.	28. 5	5. 0635	2. 9	30
Oct. 14	10 20 a. m.	22. 1	73	1 33. 06	9 41 a. m.	19. 4	5. 0328	3. 3	32
15	10 27 a. m.	24. 7	74	1 32. 68	9 43 a. m.	23. 3	5. 0498	3. 0	29
16	10 26 a. m.	21. 4	72	1 33. 11	9 49 a. m.	19. 1	5. 0348	3. 2	30
Nov. 14	11 25 a. m.	19. 9	71	1 33. 16	10 43 a. m.	18. 4	5. 0331	3. 1	31
15	10 20 a. m.	18. 2	70	1 33. 39	9 44 a. m.	16. 4	5. 0282	3. 1	30
16	10 20 a. m.	17. 4	69	1 33 51	9 42 a. m.	15. 7	5. 0232	3. 3	32
Dec. 14	11 03 a. m.	12. 2	66	1 34 06	9 12 a. m.	9. 9	5. 0095	3. 2	31
15	11 03 a. m.	14. 2	67	1 34. 02	10 25 a. m.	11. 9	5. 0149	3. 4	28
16	10 27 a. m.	13. 4	36. 567	1 33. 91	9 54 a. m.	11. 5	5. 0146	183. 2	0. 2731
1885.									
Jan. 14	11 07 a. m.	+15. 1	36. 568	1 33. 80	10 27 a. m.	13. 2	5. 0164	183. 3	0. 2732
15	11 11 a. m.	15. 4	68	1 33. 96	10 29 a. m.	13. 1	5. 0190	3. 4	27
16	11 16 a. m.	16. 2	69	1 33. 68	10 40 a. m.	14. 4	5. 0214	3. 3	30
Feb. 14	10 07 a. m.	16. 9	69	1 33. 66	9 27 a. m.	14. 1	5. 0214	3. 3	29
15	10 16 a. m.	19. 3	71	1 33. 46	9 40 a. m.	17. 2	5. 0282	3. 4	29
16	10 34 a. m.	20. 4	72	1 33. 29	9 58 a. m.	18. 7	5. 0327	3. 3	30
Mar. 14	11 28 a. m.	25. 8	75	1 32. 83	10 56 a. m.	24. 2	5. 0450	3. 4	30
15	10 40 a. m.	26. 8	76	1 33. 00	10 10 a. m.	24. 7	5. 0574	3. 3	20
16	11 41 a. m.	20. 7	72	1 33. 56	11 09 a. m.	18. 9	5. 0374	3. 4	23
Apr. 14	10 30 a. m.	19. 1	71	1 33. 43	9 55 a. m.	18. 3	5. 0340	3. 2	28
15	10 28 a. m.	21. 3	72	1 33. 26	9 54 a. m.	18. 6	5. 0333	3. 3	28
16	10 00 a. m.	21. 0	72	1 33. 28	9 27 a. m.	19. 5	5. 0386	3. 2	26
May 14	10 47 a. m.	27. 2	76	1 32. 91	10 14 a. m.	27. 6	5. 0616	3. 4	22
15	10 14 a. m.	26. 4	76	1 32. 77	9 40 a. m.	25. 1	5. 0533	3. 2	26
16	10 50 a. m.	24. 5	74	1 32. 92	10 18 a. m.	23. 6	5. 0480	3. 2	27
June 14	10 02 a. m.	28. 6	77	1 32. 42	9 27 a. m.	27. 2	5. 0582	3. 1	29
15	10 10 a. m.	28. 7	77	1 32. 74	9 39 a. m.	27. 6	5. 0615	3. 4	22
16	10 11 a. m.	30. 6	79	1 32. 32	9 40 a. m.	29. 3	5. 0613	3. 3	28
July 14	10 11 a. m.	34. 7	81	1 31. 82	9 37 a. m.	33. 2	5. 0754	3. 0	28
15	10 12 a. m.	32. 4	80	1 32. 07	9 41 a. m.	31. 1	5. 0712	3. 0	26
16	10 08 a. m.	30. 4	78	1 32. 15	9 36 a. m.	28. 5	5. 0598	3. 1	31
Aug. 14	10 13 a. m.	34. 8	81	1 31. 90	9 43 a. m.	33. 9	5. 0807	3. 0	24
15	10 11 a. m.	33. 3	80	1 31. 90	9 35 a. m.	31. 3	5. 0731	2. 9	27
16	10 12 a. m.	34. 4	36. 581	1 31. 51	9 42 a. m.	33. 7	5. 0795	182. 7	0. 2731

The magnetic horizontal intensity at Los Angeles, Cal., 1882–1889—Continued.

Date.	Observations of deflections.				Observations of oscillations.			L.	Horizontal component of magnetic force H.
	Los Angeles local mean time.	Corrected t C.	Corrected distance r.	Observed angle of deflection u.	Los Angeles local mean time.	Corrected t' C.	Time of one oscillation T_1	Magnetic moment m at 16°.7 C.	
1885.	*h. m.*	°	*cm.*	° ′	*h. m.*	°	*s.*		*dyne.*
Sept. 14	10 05 a. m.	+28.6	36.577	1 32.40	9 35 a. m.	26.7	5.0565	183.1	0.2729
15	10 13 a. m.	29.1	78	1 32 38	9 44 a. m.	27.9	5.0629	3.0	27
16	10 10 a. m.	30.0	78	1 31.88	9 40 a. m.	28.8	5.0688	2.5	31
Oct. 14	10 41 a. m.	24.2	74	1 32.66	10 09 a. m.	23.5	5.0554	2.7	27
15	10 15 a. m.	23.9	74	1 32.84	9 43 a. m.	23.3	5.0541	2.8	26
16	10 29 a. m.	23.4	74	1 33.04	9 56 a. m.	23.7	5.0562	3.0	23
Nov. 14	10 21 a. m.	18.4	70	1 33.30	9 46 a. m.	16.6	5.0322	2.9	29
15	10 06 a. m.	16.4	69	1 33.66	9 36 a. m.	14.6	5.0262	3.1	28
16	10 17 a. m.	17.8	70	1 33.46	9 45 a. m.	16.7	5.0338	3.0	28
Dec. 14	11 15 a. m.	19.3	71	1 33.42	10 41 a. m.	18.3	5.0369	3.1	26
15	11 00 a. m.	15.3	68	1 33.70	10 26 a. m.	13.8	5.0247	3.0	29
16	11 12 a. m.	16.7	36.569	1 33.57	10 40 a. m.	15.7	5.0284	183.1	0.2729
1886.									
Jan. 14	11 44 a. m.	+16.0	36.568	1 33.85	11 09 a. m.	15.3	5.0295	183.2	0.2725
15	11 26 a. m.	14.9	68	1 34.01	10 54 a. m.	13.9	5.0260	3.2	24
16	11 27 a. m.	13.0	66	1 34.23	10 55 a. m.	12.6	5.0244	3.2	23
Feb. 14	11 26 a. m.	22.6	73	1 32.90	10 58 a. m.	21.6	5.0465	2.9	29
15	10 17 a. m.	20.2	71	1 32.96	9 41 a. m.	18.3	5.0347	2.8	33
16	10 27 a. m.	18.6	70	1 33.32	9 35 a. m.	17.7	5.0325	3.0	30
Mar. 14	10 43 a. m.	21.5	72	1 33.14	10 10 a. m.	20.7	5.0444	3.0	26
15	10 50 a. m.	22.3	73	1 33.06	10 17 a. m.	21.4	5.0441	3.1	28
16	10 42 a. m.	20.0	71	1 33.47	10 10 a. m.	18.7	5.0379	3.2	25
Apr. 14	10 12 a. m.	20.6	72	1 33.41	9 40 a. m.	19.9	5.0419	3.2	24
15	10 13 a. m.	22.2	73	1 33.30	9 41 a. m.	21.3	5.0482	3.2	22
16	10 08 a. m.	23.3	74	1 33.07	9 35 a. m.	22.2	5.0493	2.9	28
May 14	10 10 a. m.	26.9	76	1 32.55	9 37 a. m.	25.8	5.0596	2.9	26
15	10 15 a. m.	28.1	77	1 32.48	9 43 a. m.	27.1	5.0638	2.9	25
16	10 12 a. m.	31.1	79	1 32.25	9 37 a. m.	30.2	5.0735	2.9	23
June 14	10 16 a. m.	25.7	75	1 32.56	9 42 a. m.	23.5	5.0525	2.8	28
15	10 05 a. m.	21.4	72	1 33.16	9 35 a. m.	20.2	5.0427	3.0	27
16	10 16 a. m.	22.7	73	1 32.92	9 43 a. m.	20.7	5.0424	3.0	28
July 14	10 12 a. m.	33.4	80	1 31.90	9 40 a. m.	33.2	5.0794	2.8	27
15	10 04 a. m.	32.3	80	1 31.98	9 33 a. m.	31.1	5.0747	2.8	26
16	10 08 a. m.	32.7	80	1 31.84	9 35 a. m.	31.4	5.0791	2.6	25
Aug. 14	10 07 a. m.	28.8	77	1 32.37	9 35 a. m.	27.1	5.0632	2.9	26
15	10 08 a. m.	31.1	79	1 32.33	9 37 a. m.	30.2	5.0760	2.9	21
16	10 07 a. m.	24.6	74	1 32.73	9 36 a. m.	23.1	5.0517	2.9	27
Sept. 14	10 12 a. m.	27.2	76	1 32.70	9 41 a. m.	25.5	5.0607	3.0	22
15	10 26 a. m.	24.3	74	1 32.84	9 53 a. m.	22.3	5.0505	2.9	25
16	10 20 a. m.	21.3	72	1 33.29	9 43 a. m.	19.8	5.0455	3.0	22
Oct. 14	10 18 a. m.	24.2	74	1 32.90	9 42 a. m.	23.8	5.0537	3.0	25
15	10 10 a. m.	23.9	74	1 32.83	9 35 a. m.	23.3	5.0530	2.9	26
16	10 22 a. m.	19.7	36.571	1 33.42	9 47 a. m.	18.3	5.0374	183.1	0.2725

The magnetic horizontal intensity at Los Angeles, Cal., 1882–1889—Continued.

Date.	Observations of deflections.				Observations of oscillations.			L_8	Horizontal component of magnetic force H.
	Los Angeles local mean time.	Corrected t C.	Corrected distance r.	Observed angle of deflection u.	Los Angeles local mean time.	Corrected t' C.	Time of one oscillation T_1.	Magnetic moment m at 16°.7 C.	
1886.	*h. m.*	°	*cm.*	° ′	*h. m.*	°	*s.*		*dyne.*
Nov. 14	10 21 a. m.	+18.3	36.570	1 33.54	9 40 a. m.	16.3	5.0302	183.1	0.2727
15	10 23 a. m.	15.6	68	1 33.88	9 44 a. m.	13.3	5.0240	3.2	25
16	10 13 a. m.	13.6	67	1 33.92	9 38 a. m.	11.1	5.0156	3.1	29
17	10 33 a. m.	15.0	68	1 33.78	9 48 a. m.	12.8	5.0197	3.0	28
18	10 47 a. m.	15.0	68	1 34.01	10 01 a. m.	12.8	5.0207	3.3	25
19	10 52 a. m.	15.2	68	1 33.79	10 10 a. m.	13.0	5.0204	3.1	28
Dec. 14	11 17 a. m.	24.4	74	1 32.72	10 10 a. m.	20.2	5.0442	2.8	28
15	10 30 a. m.	21.6	72	1 33.14	9 43 a. m.	18.6	5.0370	3.0	28
16	11 19 a. m.	20.5	36.572	1 33.04	10 40 a. m.	18.8	5.0376	182.8	0.2731
1887.									
Jan. 14	11 00 a. m.	+16.0	36.568	1 33.98	10 10 a. m.	13.5	5.0240	183.2	0.2724
15	10 40 a. m.	14.4	67	1 34.14	10 00 a. m.	12.6	5.0266	3.1	20
16	11 05 a. m.	16.7	69	1 33.68	10 32 a. m.	15.6	5.0292	3.1	26
Feb. 14	10 50 a. m.	12.5	66	1 34.41	10 10 a. m.	12.1	5.0199	3.3	24
15	11 24 a. m.	11.3	65	1 34.70	10 46 a. m.	9.9	5.0118	3.7	22
16	11 39 a. m.	13.6	67	1 34.12	10 59 a. m.	12.7	5.0167	3.4	28
Mar. 14	10 43 a. m.	21.0	72	1 33.43	9 58 a. m.	19.3	5.0318	3.6	28
15	10 41 a. m.	23.8	74	1 33.14	9 57 a. m.	22.6	5.0434	3.4	26
16	10 12 a. m.	17.9	70	1 33.69	9 34 a. m.	15.3	5.0235	3.5	27
Apr. 14	10 58 a. m.	16.3	69	1 33.87	10 01 a. m.	16.5	5.0270	3.5	26
15	10 10 a. m.	13.9	67	1 34.03	9 40 a. m.	12.1	5.0156	3.4	28
16	10 19 a. m.	20.6	72	1 33.45	9 42 a. m.	18.9	5.0366	3.3	25
May 14	10 24 a. m.	32.9	80	1 31.93	9 43 a. m.	31.1	5.0705	2.9	28
15	10 10 a. m.	28.3	77	1 32.44	9 36 a. m.	26.5	5.0554	3.1	29
16	10 21 a. m.	27.2	76	1 32.63	9 44 a. m.	25.2	5.0533	3.2	27
June 14	10 20 a. m.	27.8	77	1 32.50	9 39 a. m.	26.3	5.0565	3.1	28
15	10 12 a. m.	29.3	78	1 32.17	9 37 a. m.	28.3	5.0639	2.8	29
16	10 09 a. m.	34.8	81	1 31.64	9 32 a. m.	33.3	5.0801	2.7	28
July 14	10 12 a. m.	24.5	74	1 32.87	9 33 a. m.	22.1	5.0456	3.1	27
15	10 17 a. m.	23.6	74	1 33.12	9 41 a. m.	22.2	5.0463	3.3	25
16	10 19 a. m.	23.3	74	1 33.06	9 46 a. m.	22.6	5.0462	3.2	26
Aug. 14	10 23 a. m.	29.7	78	1 32.28	9 39 a. m.	27.7	5.0594	3.1	29
15	10 08 a. m.	27.6	76	1 32.56	9 32 a. m.	24.5	5.0523	3.1	27
16	10 13 a. m.	29.2	78	1 32.37	9 38 a. m.	27.8	5.0611	3.1	27
Sept. 14	10 12 a. m.	29.5	78	1 32.37	9 37 a. m.	28.3	5.0634	3.1	26
15	10 36 a. m.	29.6	78	1 32.28	9 59 a. m.	27.3	5.0626	2.9	27
16	10 20 a. m.	29.4	78	1 32.42	9 38 a. m.	26.6	5.0614	3.0	24
Oct. 14	10 17 a. m.	26.4	76	1 32.86	9 35 a. m.	24.8	5.0532	3.3	24
15	10 24 a. m.	21.1	72	1 33.32	9 40 a. m.	18.2	5.0350	3.3	26
16	10 41 a. m.	19.8	71	1 33.50	9 59 a. m.	19.1	5.0367	3.3	25
Nov. 14	10 12 a. m.	26.8	76	1 32.58	9 37 a. m.	23.7	5.0484	3.1	29
15	10 08 a. m.	22.3	73	1 33.20	9 30 a. m.	18.8	5.0348	3.3	27
16	10 15 a. m.	18.4	36.570	1 33.71	9 37 a. m.	15.6	5.0253	183.5	0.2726

The magnetic horizontal intensity at Los Angeles, Cal., 1882–1889—Continued.

Date.	Observations of deflections.				Observations of oscillations.			Lg	Horizontal component of magnetic force H.
	Los Angeles local mean time.	Corrected *t* C.	Corrected distance *r*.	Observed angle of deflection *u*.	Los Angeles local mean time.	Corrected *t′* C.	Time of one oscillation T_1.	Magnetic moment *m* at 16°.7 C.	
1887.	*h. m.*	°	*cm.*	° ′	*h. m.*	°	*s.*		*dyne.*
Dec. 14	10 32 a.m.	18.8	36.570	1 33.60	9 56 a.m.	16.1	5.0269	183.4	0.2726
15	10 07 a.m.	15.8	68	1 33.74	9 30 a.m.	12.2	5.0153	3.3	30
16	10 11 a.m.	16.7	69	1 33.64	9 37 a.m.	11.9	5.0156	3.2	30
1888.									
Jan. 14	10 11 a.m.	11.4	36.565	1 34.48	9 33 a.m.	8.1	5.0061	183.5	0.2726
15	10 52 a.m.	10.6	65	1 34.38	10 10 a.m.	7.9	5.0096	3.2	26
16	11 01 a.m.	12.7	66	1 34.39	10 26 a.m.	10.0	5.0136	3.4	24
Feb. 14	10 38 a.m.	14.8	68	1 33.88	9 55 a.m.	13.4	5.0204	3.3	28
15	10 13 a.m.	16.1	69	1 33.74	9 39 a.m.	13.7	5.0201	3.3	29
16	10 17 a.m.	14.1	67	1 34.21	9 38 a.m.	13.1	5.0206	3.4	24
Mar. 14	10 52 a.m.	18.6	70	1 33.94	10 11 a.m.	17.2	5.0322	3.6	21
15	10 15 a.m.	19.5	71	1 33.47	9 35 a.m.	17.3	5.0322	3.3	26
16	10 28 a.m.	23.4	74	1 33.17	9 54 a.m.	21.7	5.0439	3.2	26
Apr. 14	10 14 a.m.	28.2	77	1 32.49	9 36 a.m.	26.5	5.0601	3.0	26
15	10 31 a.m.	20.6	72	1 33.25	10 00 a.m.	20.2	5.0398	3.1	28
16	10 16 a.m.	19.6	71	1 33.52	9 36 a.m.	18.4	5.0349	3.3	26
May 14	10 17 a.m.	27.2	76	1 32.64	9 37 a.m.	26.4	5.0557	3.2	27
15	10 13 a.m.	21.4	72	1 33.25	9 35 a.m.	19.6	5.0333	3.4	28
16	10 15 a.m.	24.2	74	1 33.05	9 35 a.m.	22.9	5.0465	3.3	25
June 14	10 26 a.m.	31.1	79	1 32.18	9 53 a.m.	30.2	5.0645	3.1	28
15	10 10 a.m.	29.8	78	1 32.24	9 36 a.m.	28.8	5.0610	3.0	30
16	10 05 a.m.	29.7	78	1 32.48	9 30 a.m.	28.9	5.0641	3.2	24
July 14	3 02 p.m.	32.1	80	1 32.31	2 27 p.m.	32.7	5.0801	3.0	20
15	10 09 a.m.	32.8	80	1 31.96	9 35 a.m.	31.2	5.0700	3.0	27
16	10 03 a.m.	30.0	78	1 32.70	9 31 a.m.	28.0	5.0623	3.4	20
Aug. 14	10 18 a.m.	31.9	80	1 32.11	9 40 a.m.	30.3	5.0716	2.9	24
15	10 03 a.m.	28.5	77	1 32.59	9 29 a.m.	27.0	5.0608	3.1	23
16	10 10 a.m.	27.3	76	1 32.84	9 34 a.m.	24.9	5.0593	3.0	21
Sept. 14	10 10 a.m.	31.2	79	1 32.17	9 31 a.m.	29.4	5.0710	2.8	24
15	10 12 a.m.	32.7	80	1 32.01	9 34 a.m.	30.7	5.0743	2.8	24
16	10 03 a.m.	34.9	82	1 31.82	9 31 a.m.	33.8	5.0864	2.7	21
Oct. 14	10 05 a.m.	19.6	71	1 33.56	9 32 a.m.	17.8	5.0337	3.3	24
15	10 10 a.m.	24.8	75	1 32.96	9 33 a.m.	23.1	5.0347	3.7	32
16	10 06 a.m.	22.1	73	1 33.05	9 32 a.m.	20.2	5.0421	3.0	27
Nov. 14	10 16 a.m.	17.8	70	1 33.38	9 40 a.m.	15.5	5.0257	3.0	30
15	10 04 a.m.	18.1	70	1 33.33	9 31 a.m.	16.1	5.0270	3.0	30
16	10 08 a.m.	14.8	68	1 33.97	9 39 a.m.	13.9	5.0206	3.3	27
Dec. 14	10 12 a.m.	12.9	66	1 34.00	9 36 a.m.	11.5	5.0159	3.2	28
15	10 08 a.m.	15.7	68	1 33.89	9 34 a.m.	14.3	5.0256	3.2	25
16	10 10 a.m.	17.4	36.569	1 33.50	9 36 a.m.	16.1	5.0295	3.0	28
1889.									
Jan. 14	10 30 a.m.	11.9	36.566	1 34.38	9 56 a.m.	11.0	5.0188	183.2	0.2722
15	10 05 a.m.	9.9	64	1 34.47	9 30 a.m.	8.0	5.0055	3.3	27
16	10 25 a.m.	13.4	67	1 34.33	9 55 a.m.	11.7	5.0173	183.5	0.2723

The magnetic horizontal intensity at Los Angeles, Cal., 1882–1889—Continued.

Date.	Observations of deflections.				Observations of oscillations.			L.s	Horizontal component of magnetic force H.
	Los Angeles local mean time.	Corrected t C.	Corrected distance r.	Observed angle of deflection u.	Los Angeles local mean time.	Corrected t' C.	Time of one oscillation T_1.	Magnetic moment m at 16°.7 C.	
1889.	*h. m.*	°	*cm.*	° ′	*h. m.*	°	*s.*		*dyne.*
Feb. 14	10 19 a. m.	16.9	36.569	1 33.98	9 46 a. m.	15.8	5.0248	183.6	0.2724
15	10 35 a. m.	15.6	68	1 34.26	9 59 a. m.	14.4	5.0211	3.7	22
16	10 25 a. m.	15.6	68	1 34.21	9 54 a. m.	14.2	5.0205	3.6	22
Mar. 14	10 07 a. m.	20.2	71	1 33.64	9 33 a. m.	18.6	5.0344	3.5	23
15	10 11 a. m.	17.4	69	1 33.89	9 38 a. m.	16.1	5.0283	3.5	23
16	10 06 a. m.	13.6	67	1 34.14	9 31 a. m.	11.4	5.0170	3.3	25
Apr. 14	10 10 a. m.	21.7	72	1 33.10	9 34 a. m.	19.9	5.0364	3.2	29
15	10 02 a. m.	24.1	74	1 32.75	9 29 a. m.	23.1	5.0457	3.0	30
16	10 08 a. m.	25.7	75	1 33.18	9 33 a. m.	24.3	5.0493	3.6	21
May 14	10 08 a. m.	25.6	75	1 32.77	9 32 a. m.	23.8	5.0467	3.2	28
15	10 09 a. m.	26.3	76	1 32.86	9 30 a. m.	25.6	5.0540	3.3	24
16	10 10 a. m.	27.7	77	1 32.82	9 36 a. m.	27.2	5.0564	3.4	23
June 14	10 03 a. m.	21.9	73	1 33.30	9 31 a. m.	20.8	5.0420	3.3	24
15	10 07 a. m.	23.2	73	1 33.12	9 34 a. m.	22.4	5.0467	3.2	24
16	10 00 a. m.	22.3	73	1 33.15	9 29 a. m.	21.9	5.0442	3.2	26
July 14	10 07 a. m.	26.9	76	1 32.77	9 29 a. m.	26.6	5.0554	3.3	25
15	10 07 a. m.	24.6	74	1 32.94	9 34 a. m.	22.2	5.0446	3.2	26
16	10 07 a. m.	28.3	77	1 32.52	9 30 a. m.	26.1	5.0534	3.2	27
Aug. 14	10 06 a. m.	32.8	80	1 32.22	9 34 a. m.	31.8	5.0760	3.0	21
15	10 02 a. m.	32.8	80	1 32.05	9 29 a. m.	32.7	5.0785	2.9	23
16	10 06 a. m.	34.2	81	1 31.86	9 32 a. m.	33.4	5.0815	2.8	24
Sept. 14	10 05 a. m.	22.9	73	1 33.18	9 29 a. m.	21.1	5.0420	3.3	25
15	10 05 a. m.	29.6	78	1 32.45	9 34 a. m.	28.1	5.0619	3.1	25
16	10 13 a. m.	35.6	82	1 31.78	9 33 a. m.	34.2	5.0805	2.9	25
Oct. 3	9 10 a. m.	25.3	75	1 32.88	9 29 a. m.	23.1	5.0469	3.2	26
4	9 43 a. m.	22.1	73	1 33.10	9 11 a. m.	20.6	5.0414	3.1	27
5	8 59 a. m.	20.9	36.572	1 33.56	8 25 a. m.	19.9	5.0383	183.5	0.2722

Recapitulation of the values for magnetic moment of the intensity magnet.

Annual mean values of *m*:

Between September, 1882 and September, 1883, from 36 observations,	183.25	First 3½ years, 183.197
Between September, 1883 and September, 1884, from 36 observations,	3.27	
Between September, 1884 and September, 1885, from 36 observations,	3.19	
Between September, 1885 and September, 1886, from 36 observations,	2.96	
Between September, 1886 and September, 1887, from 36 observations,	3.15	Last 3½ years, 183.160
Between September, 1887 and September, 1888, from 36 observations,	3.22	
Between September, 1888 and September, 1889, from 36 observations,	3.21	

Apparent loss in 3½ years, 0.037

which is only about $\frac{1}{5000}$ part of the whole value, indicating a well-seasoned magnet.

Comparing the mean, or 183.18 with each individual value, we get the probable error of a single determination $=\pm 0.25$, or about $\frac{1}{730}$ part of the whole.

For the probable error of the mean of three observations we get ± 0.0001, which shows that the observations were very carefully made.

The probable error of an observation for horizontal intensity.—This is most readily arrived at by comparing each of the three daily values with their monthly mean and summing the differences. We then have

$$r = 0.845 \frac{[v}{\sqrt{n\,(n-\nu)}} = 0.845 \frac{.0406}{\sqrt{262\,(262-86)}} = \pm\, 0.00016$$

which is about $\frac{1}{1740}$ of the force.

The preceding probable error is relative only as shown by its derivation, as no account has been taken of the uncertainty in the measures of the weight of the mass-ring and of the diameters of the same. Making a liberal estimate of the former as $\pm$ 0.1 grain, and of the latter as $\pm$ 0.001 inch, the corresponding probable errors in H would be $\pm$ 0.00002 and $\pm$ 0.00004 dyne, or together $\pm$ 0.00005 dyne, which would seem to show that with portable instruments of this kind observations can be made the results of which can be trusted within $\frac{1}{1500}$ part of H. This would include also the effects of uncertainty in coefficients q, P and h.

Recapitulation of resulting monthly values for the horizontal component of the magnetic intensity.

Month (middle).	1882–'83.	1883–'84.	1884–'85.	1885–'86.	1886–'87.	1887–'88.	1888–'89.	Monthly means.
October.	0.2727	0.2728	0.2730	0.2725	0.2725	0.2725	0.2728	0.2727
November.	27	31	31	28	27	27	29	29
December.	29	33	30	28	29	29	27	29
January.	29	26	30	24	23	25	24	26
February.	32	29	29	31	25	27	23	28
March.	31	28	24	26	27	24	24	26
April.	33	31	27	25	26	27	27	28
May.	32	33	25	25	28	27	25	28
June.	32	31	26	28	28	27	25	28
July.	33	30	28	26	26	22	26	27
August.	33	26	27	25	28	23	23	26
September.	25	30	29	23	26	23	25	26
Annual means.	0.2730	0.2730	0.2728	0.2726	0.2726	0.2726	0.2725	0.2727

The mean of all the values answers to the middle epoch, April 1, 1886, for which we have H = 0.27273 dyne; this result is for 10 o'clock a. m., and consequently may be reduced to the daily mean, or to the mean of observations from 24 hours by means of the differential series of observations.

The annual change, or the effect of the secular variation in one year, is plainly indicated in the last row of the table. The horizontal force is diminishing slowly (as was indicated in 1885 on the chart showing the isodynamic curves for that epoch, Coast and Geodetic Survey Report 1885, Appendix No. 6).

Let a = annual change (in absolute measure and C. G. S. units).

H_o=mean horizontal force at middle epoch t_o; we have H_o=.27273 for t_o or for April 1, 1886.

H =horizontal force for April 1 of any other year t; then

$$H = H_o + a\,(t - t_o)$$

whence we get 7 observation-equations and find $a = -0.00009$ dyne

$$H = 0.27273 - 0.00009\,(t - t_o) \text{ where } t_o = 1886.25$$

Expressed in parts of the horizontal force we have $a_1 = -0.00033$, a value considerably smaller than the values (a_1) given for San Diego, Santa Barbara, Monterey, or San Francisco, in the report just referred to. For neither of these places, however, do the observations possess an accuracy comparable with our present series.

Further discussion of the horizontal force variations must be deferred till we treat of the differential observations, and we conclude this part of the discussion by tabulating the resulting values for V and F derived from the preceding tables of monthly results for H and θ, viz:

$$V = H \tan\theta \qquad \text{and} \qquad F = H \sec\theta$$

Monthly and annual values of the vertical component of the magnetic intensity of Los Angeles, Cal.

Month (middle).	1882–'83.	1883–'84.	1884–'85.	1885–'86.	1886–'87.	1887–'88.	1888–'89.	Monthly means.
October.	0.4630	0.4638	0.4636	0.4623	0.4630	0.4627	0.4628	0.4631
November.	29	37	34	31	31	27	26	31
December.	38	40	34	27	32	31	26	32
January.	35	29	34	29	24	27	21	29
February.	34	30	31	37	27	34	18	30
March.	42	27	27	31	32	28	21	29
April.	36	37	29	27	28	32	26	31
May.	37	36	25	27	33	28	21	30
June.	40	37	26	31	32	29	27	32
July.	45	37	29	27	28	22	30	31
August.	41	22	31	28	31	22	25	28
September.	36	29	30	28	28	23	21	28
Annual means.	0.4637	0.4634	0.4631	0.4629	0.4629	0.4629	0.4623	0.4630

The probable error of any single tabular value is found by $dV = \tan\theta dH + H\sec^2\theta d\theta$

Putting $\theta = 59° 30'$, $H = 0.2727$, $d\theta = \pm 0'.6 \left(\text{or } \frac{1}{5730}\right)$, and, $dH = \pm 0.0001$, we get

$$dV = \sqrt{(0.00017)^2 + (0.00018)^2} = \pm 0.0003$$

The annual change becomes $a = -0.00019$ dyne and $a_1 = -0.00041$ in parts of V, and $V = 0.4630 - 0.00019\,(t - t_0)$, where $t_0 = 1886.25$

Monthly and annual values of the total magnetic intensity at Los Angeles, Cal.

Month (middle).	1882–'83.	1883–'84.	1884–'85.	1885–'86.	1886–'87.	1887–'88.	1888–'89.	Monthly means.
October.	0.5374	0.5381	0.5380	0.5367	0.5372	0.5370	0.5372	0.5374
November.	72	81	78	75	74	71	71	75
December.	81	85	78	71	76	75	70	76
January.	79	72	78	71	66	70	64	72
February.	79	75	76	82	70	76	61	74
March.	85	71	69	73	75	70	64	72
April.	82	81	72	69	71	75	70	74
May.	82	82	68	70	76	71	64	74
June.	85	81	69	75	75	73	69	75
July.	89	81	73	70	71	64	73	74
August.	86	66	75	70	75	65	67	71
September.	78	74	74	70	71	66	65	71
Annual means.	0.5380	0.5378	0.5374	0.5372	0.5372	0.5372	0.5366	0.5373

The probable error of any single tabular value is found by $dF = \sec\theta dH + H\tan\theta\sec\theta d\theta$ and putting $dH = \pm 0.0001$ and $d\theta = \pm 0'.6$ (or $\frac{1}{5730}$), then

$$dF = \sqrt{(0.00020)^2 + (0.00014)^2} = \pm 0.0002$$

The annual change becomes $a=-0.00020$ dyne and $a_1=-0.00037$ in parts of F, and

$$F=0.5373-0.00020\,(t-t_0),\ \text{where}\ t_0=1886.25$$

In conclusion of Part I of the magnetic work of the Los Angeles observatory I may be permitted to remark that whatever merit it may possess is largely due to the scrupulous care and minute attention to detail on the part of its first observer, nor have his two successors shown less devotion to duty in order to render their laborious task as effective as possible.

The second part of this paper will contain the record and discussion of the differential observations.

APPENDIX No. 9.—1890.

RESULTS OF THE OBSERVATIONS RECORDED AT THE U. S. COAST AND GEODETIC SURVEY MAGNETIC OBSERVATORY AT LOS ANGELES, CAL., IN CHARGE SUCCESSIVELY OF MARCUS BAKER, ACTING ASSISTANT, CARLISLE TERRY, JR., SUB-ASSISTANT, AND RICHARD E. HALTER, ASSISTANT, BETWEEN THE YEARS 1882 AND 1889.

PART II.—RESULTS OF THE DIFFERENTIAL MEASURES OF THE MAGNETIC DECLINATION.

Discussion and report by CHARLES A. SCHOTT, Assistant.

[Submitted for publication July 5, 1890.]

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ILLUSTRATIONS.

In the preceding part of the account of the magnetic work done at the Los Angeles Observatory by the Coast and Geodetic Survey (Appendix No. 8, 1890), the plan and object of these observations have been described and the instruments and methods for obtaining the declination, the inclination and the horizontal magnetic force in absolute measure have been explained. The results there obtained will be utilized in this, the second part, which is chiefly devoted to the presentation and the discussion of the differential measures as secured by continuous photographic registration.

The differential magnetic instruments.—The Adie magnetograph belonging to the Survey came into use for the first time at Los Angeles in 1882, as has been stated. No detailed description of these instruments is here demanded, as this can be found in "Account of the construction of the self-recording magnetographs at present in operation at the Kew Observatory of the British Association, by Balfour Stewart, M. A., taken from the report of the British Association for the Advancement of Science for 1859, London, 1860, 4to, pp. 200–228." We have there given a full description of each of the three magnetographs, their adjustment, as well as an exposition of the photographic process, accompanied by two plates showing construction (to scale) of instruments and specimens of traces. The apparatus is also described and well illustrated on Plates XVII (full view) and XVIII (detail of magnetometers and recording cylinders) in Vol. I of "A Physical Treatise on Electricity and Magnetism, by J. E. H. Gordon, B. A., New York, 1880." The apparatus was originally constructed for the use of gas, but at Los Angeles it was found more suitable to burn coal oil, for which purpose each lamp was provided with a large copper tank containing fluid enough to last a day and a half. The photographic process was that followed at the preceding station, Madison, Wis., but about July, 1886, the gelatino-bromide paper was introduced with the most complete satisfaction. As mounted in the Observatory, the horizontal force and declination magnetometers stood on a magnetically west and east line, with the vertical force magnetometer centrally to the north of it and nearly in the magnetic meridian. The air in the vacuum chambers was not exhausted, but the magnets were allowed to move under the variations of the ordinary atmospheric pressure.

DETERMINATION OF THE INSTRUMENTAL CONSTANTS OF THE ADIE MAGNETOGRAPH, AS MOUNTED AT LOS ANGELES, CAL.

The Unifilar Magnetometer.—As far as known, the relation between the fixed semicircular mirror on the pier and the scale on the reading telescope was not disturbed from the time of the first adjustment after the instrument was set up to the close of the series; nor was there any change in the suspension of the magnet and its attached semicircular mirror; hence the scale value remained the same. The magnet and appendages were suspended by a thread composed of twelve single silk fibers. The *scale* is mounted on the reading telescope, with the zero division towards the south and the 500th or last division towards the north. The scale appears erect and the numbers increase from left to right as seen through the telescope. *Increasing* numbers indicate a movement of the north (seeking) end of the magnet towards the *east* or increasing east declination. The torsion head is graduated from 0° to 360°, from left to right as seen from above the center, and into degree divisions, and can be read by means of a vernier to 5′.

Let l = length of one division of scale, = 0.0197 inch or 0.05 centimetres.

r = distance from surface of mirror to face of scale plus two-thirds of thickness of glass mirror = 42.55 inch (to rim of scale) + 0.085 inch (to its surface), + $\frac{2}{3} \times 0.102$ inch = 108.465 centimetres, and when corrected for slant measure (see note to scale value for the bifilar) it becomes 108.348

a_1 = angular value of one division of scale $= 3437'.75 \times \frac{0.05}{2 \times 108.348} = 0'.7932$, uncorrected for torsion.

a = angular value of one division $= 3437.75 \frac{l}{2r}\left(1 + \frac{h}{f}\right)$, where $\frac{h}{f} = \frac{\alpha}{\beta - \alpha}$ and α = the angle through which the magnet turns when the torsion head is turned through the angle β.

The following observations for amount of torsion were made by Mr. Baker, September 4, a. m., 1882, the angle β being 90°.

Torsion head.	Mean scale readings.	Difference.	
° ′			
89 20	325.3		hence $a = 7.35 \times 0.793 = 5'.83 = 0°.097$
359 20	318.0	7.3	and $\frac{h}{f} = \frac{0.097}{89.903} = 0.00108$
179 20	332.7	14.7	
89 20	325.3	7.4	
	Mean	7.35	

hence, $a = 0'.7941$ or $47''.65$

To determine the corresponding space on the recording cylinder or trace through which the luminous dot will move, we have given: Distance from surface of paper to surface of mirror + $\frac{2}{3}$ thickness of mirror = 57.57 inch + 0.068 inch = 146.40 centimetres, hence the corresponding space on the cylinder or on the paper $= \frac{00.5 \times 146.40}{108.348} = 0.06756$ centimetre, or 100 scale divisions; or 79′.41 correspond to 6.76 centimetres measured perpendicularly to the base of the unifilar trace. Also, 1 millimetre of the ordinate represents 1′.176

The time-scale or abscissa averages 14.75 inches or 37.465 centimetres for 24 hours, hence linear value representing *one hour* = 1.561 centimetre, and length representing one minute = .026 centimetre, or nearly one-fourth of a millimetre; the length of the trace, however, varies slightly with irregularities in expansion and contraction of the paper and some lost motion in the gearing with the clock.* *Increasing* ordinates from the base denote increasing *east* declination.

For reading off the unifilar traces, the observer had provided himself with a triangular piece of cardboard with the straight edge of its right angle graduated, 100 parts corresponding to 6.76 centimeters. To place its edge on the time scale, a ruler had been made with white paper pasted firmly to it; upon this the length of 37.465 centimetres had been subdivided into twenty-four equal parts and numbered from 9 hours a. m. (the time approximately of the beginning of the trace) to 9 a. m. of the next day; the hour spaces were subdivided into 5-minute spaces.

After the magnetometers had been regularly at work for about a fortnight it became desirable to change the adjustment of the unifilar and of the vertical force instruments. The fixed mirror of the unifilar was originally set to read on the scale 250; on October 13, 1882, it was changed to 300. This, together with a turning of the other half of the mirror, produced a change of 32.2 divisions,

* This was taken into account by means of additional subdivisions of the scale.

as found by taking the mean reading ($338^d.2$) of ten days before and comparing the same with the mean reading (370.4) of ten days after October 13. To render the tabulation uniform, this constant was added to all readings before that date.

The hourly readings of the traces and the corresponding tabulation of the differential angular movements of the declination magnet expressed in scale divisions are due to the respective observers.

Occasional short breaks in the series, of one or more hours, had their values supplied by interpolation. This I effected as follows: For the missing hourly ordinates were substituted the corresponding monthly mean values, but *corrected* for difference of readings from the monthly mean at the last recorded hour and again at the first recorded hour after the break, and this difference was distributed equally over the intervening monthly means. All interpolated values are distinguished by being inclosed in brackets. All recognized disturbances (above a certain limit) are indicated by an asterisk. These tables are appended.

Effect of the vertical force magnet upon the unifilar and bifilar magnets.—In order to determine the effect produced by the vertical force magnet upon the two other magnets of the magnetograph, Mr. Baker made a number of observations on September 25, 1882, alternately removing and replacing the balance magnet and noting the difference in scale readings of the other two magnets. He found the effect to be: Upon the unifilar, to attract its north (seeking) end to the westward 1.8 scale divisions, or $1'.4$; and upon the bifilar, to attract its west (north seeking) end to the north 2.3 scale divisions, $1'.9$, or 0.00025 parts of the horizontal component of the magnetic force.

Connection of the differential with the absolute measures of the declination.—For this purpose the traces were read off for the times near the daily extremes when the absolute observations were recorded. For each monthly mean of absolute measures on 3 days we have, therefore, corresponding to it, the mean of six trace or scale-readings. This connection is shown in the following table, the resulting absolute declinations being taken from Part I.

Recapitulation of unifilar scale readings corresponding to times of absolute determination of declination.

[300 divisions — tabular quantity].

Month (middle).	1882–'83.	1883–'84.	1884–'85.	1885–'86.	1886–'87.	1887–'88.	1888–'89.	Monthly means.
	d.	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*
October.	70.7	69.8	67.7	73.2	71.1	68.8	66.3	69.7
November.	71.9	69.3	70.0	73.5	71.4	69.0	65.5	70.1
December.	70.6	70.0	69.9	73.2	71.2	69.0	65.7	69.9
January.	72.0	70.7	71.4	74.2	71.8	67.8	66.0	70.6
February.	71.7	69.9	70.8	70.4	70.3	67.2	65.1	69.3
March.	71.4	68.1	70.5	70.4	68.7	66.7	65.0	68.7
April.	70.4	67.9	72.1	70.7	69.7	66.6	66.2	69.1
May.	71.3	66.4	73.2	71.3	70.7	67.6	66.0	69.5
June.	70.4	66.9	72.2	69.6	69.9	67.7	64.6	68.8
July.	70.4	67.4	73.0	70.9	69.4	67.7	65.0	69.1
August.	70.8	68.6	74.3	71.6	70.1	66.4	65.1	69.6
September.	71.0	69.3	72.0	72.0	69.9	66.7	66.4	69.6
Annual mean.	71.0	68.7	71.4	71.8	70.4	67.6	65.6	69.50
Corresponding absolute measure. } 14°+	31'.8	30'.2	29'.7	29'.2	28'.7	24'.8	22'.9	14° 28'.2

Hence for any scale reading s we have the corresponding declination D_s

$$D_s = 14^\circ\ 28'.2 + 0'.794\ (s - 69.5) \quad \textit{East,}$$
$$\pm 0.3 \qquad\qquad \pm 0.6$$

where the first-named probable error refers principally to that of the azimuth mark, and the second to the want of correspondence throughout the series between absolute and differential measures.

The yearly averages taken from the *monthly mean* readings, as they will be needed when discussing the secular variation, are therefore as follows:

Year.	Declination.	Year.	Declination.
	° ′		° ′
1882.87	14 29.2 E	1886.50	14 29.2 E
83.50	28.6	87.50	28.2
84.50	26.7	88.50	26.1
85.50	30.2	89.37	24.7

The annual change of the magnetic declination.—This is simply the effect of the secular variation during one year, and since the unifilar declinometer remained in the same adjustment during the whole time, it is best made out from the monthly mean readings of the unifilar traces, viz:

Monthly means of hourly readings of the declination traces during seven years.

[300 divisions ÷ tabular quantity.]

Month (middle).	1882–'83.	1883–'84.	1884–'85.	1885–'86.	1886–'87.	1887–'88.	1888–'89.	Monthly means.
	d.	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*
October.	70.3	69.9	68.5	72.7	70.9	69.3	66.3	69.7
November.	70.7	69.4	69.2	72.7	71.3	69.1	66.2	69.8
December.	71.1	69.5	69.8	72.7	71.4	68.9	65.8	69.9
January.	71.1	70.1	70.4	72.1	71.3	68.2	65.3	69.8
February.	71.1	69.2	70.9	70.5	70.5	67.1	65.5	69.2
March.	70.6	66.6	71.0	70.3	69.3	67.0	65.2	68.6
April.	70.3	65.3	71.5	70.2	69.7	67.3	65.0	68.5
May.	69.9	65.0	72.2	70.0	69.8	67.2	65.2	68.5
June.	69.5	65.4	71.8	70.2	69.8	66.9	64.7	68.3
July.	69.2	66.5	72.2	70.3	68.7	66.6	64.7	68.3
August.	69.5	67.3	72.7	70.8	68.8	66.2	64.9	68.6
September.	69.8	68.2	72.9	71.2	69.0	66.5	65.3	69.0
Annual mean.	70.3	67.7	71.1	71.1	70.0	67.5	65.3	69.0

With the exception of the first year, the annual means consistently exhibit at first an annual increase, next a stationary value, and last a decrease of declination; our series thus includes the epoch of maximum east declination. When the observatory was established it was not known how soon the secular variation would change its direction from increasing to diminishing values. In my latest discussion* of secular variation, I found the year 1880 to be the epoch of eastern maximum for Santa Barbara, Cal., and 1883 the epoch for San Diego, Cal., both stations being near Los Angeles. By the year 1890 the region of stationary direction or of no annual change, accompanying the maximum east declination, had moved considerably out to sea, as shown on the chart of annual change illustrating the discussion.

It is known that the secular variation is made up of a principal and a number of minor fluctuations, and it is these last which especially obtrude themselves about those years immediately preceding and following extreme values, and thus render it difficult to seize the exact year and

* Secular variation of the magnetic declination, etc. Seventh edition, Appendix No. 7, C. and G. S. Report for 1888.

month of the maximum and minimum. In our series, the large value for the first year is supposed to be due to a short subordinate fluctuation. We may represent the annual means by

$$D = d_0 + y\,(t - t_0) + z\,(t - t_0)^2$$

where t_0 answers to the middle of the years (or April 1, 1886). Putting $d_0 = 71.1 + x$ we get the following observation equations:

$$\begin{cases} 0 = +0.8 + x - 3\,y + 9z \\ 0 = +3.4 + x - 2\,y + 4z \\ 0 = 0.0 + x - y + z \\ 0 = 0.0 + x \\ 0 = +1.1 + x + y + z \\ 0 = +3.6 + x + 2\,y + 4\,z \\ 0 = +5.8 + x + 3\,y + 9\,z \end{cases}$$

Normal equations,

$$\begin{cases} 0 = +14.7 \quad + \ 7\,x \qquad\qquad + \ 28\,z \\ 0 = +16.5 \qquad\qquad + 28\,y \\ 0 = +88.5 \quad + 28\,x \qquad\qquad + 196\,z \end{cases}$$

$$\begin{cases} x = -0.70 \\ y = -0.59 \\ z = -0.354 \end{cases}$$

hence $D = 70.40 - 0.59\,(t-t_0) - 0.354\,(t-t_0)^2$ which gives the annual means as follows: 69.0, 70.2, 70.6, 70.4, 69.5, 67.8, and 65.4, and leaves the residuals +1.3, −2.5, +0.5, +0.7, +0.5, −0.3, −0.1

For the time of the maximum east declination T_0, we have $T_0 = t_0 - \frac{y}{2z} = 1886.25 - 0.83$ or June, 1885, with the maximum value 70.59, or in absolute measure

$$14^\circ\,28'.2 + 0'.794\,(70.59 - 69.50) = 14^\circ\,29'.1 \text{ East.}$$

Our earliest information respecting the direction of the magnetic needle on this coast dates from 1714, when the declination was about $7\frac{1}{4}^\circ$ East, and it has been steadily increasing since, though with various rates.

The annual variation of the declination.—The numerical exhibition of this inequality, which apparently depends on the sun's declination, is difficult to give, on account of the length of the period and the smallness of the phenomenon; it demands very firmly mounted and unchangeable instruments, operated for a series of years.

With the Adie magnetograph, the fixity of the zero direction is assured, but the possible development of torsion in the suspension skein must be guarded against, since such an effect would probably have the same period as the magnetic inequality under consideration. The annual variation is directly deduced from the preceding table by taking the difference of each monthly mean (scale-reading) and its corresponding annual mean and correcting the same for effect of secular change.

Annual variation of the magnetic declination.

[In scale divisions; 1 div. = 0.'79].

Month (middle.)	1882–'83.	1883–'84.	1884–'85.	1885–'86.	1886–'87.	1887–'88.	1888–'89.	Mean.	Mean.
	d.	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	'
October.	+0.8	+2.[illegible]	−2.5	+1.4	+0.4	+0.9	−0.2	+0.5	+0.4
November.	+1.0	+2.1	−1.8	+1.5	+0.9	+0.9	−0.1	+0.6	+0.5
December.	+1.2	+2.1	−1.2	+1.5	+1.1	+0.9	−0.3	+0.8	+0.6
January.	+1.1	+2.6	−0.6	+0.9	+1.1	+0.3	−0.6	+0.7	+0.6
February.	+1.0	+1.6	−0.2	−0.7	+0.4	−0.6	−0.2	+0.2	+0.2
March.	+0.4	−1.1	−0.1	−0.8	−0.7	−0.6	−0.3	−0.5	−0.4
April.	−0.1	−2.4	+0.4	−0.9	−0.2	−0.1	−0.2	−0.5	−0.4
May.	−0.6	−2.8	+1.1	−1.1	+0.1	−0.1	+0.2	−0.5	−0.4
June.	−1.1	−2.4	+0.7	−0.8	+0.2	−0.2	−0.1	−0.5	−0.4
July.	−1.5	−1.4	+1.1	−0.6	−0.8	−0.3	+0.2	−0.5	−0.4
August.	−1.3	−0.6	+1.6	0.0	−0.6	−0.5	+0.6	−0.1	−0.1
September.	−1.1	+0.2	+1.8	+0.4	−0.3	0.0	+1.3	+0.3	+0.3

A + sign indicates *easterly* deflection of the north end of the magnet or *increased* east declination, a — sign signifies the reverse motion. The numbers of the last column exhibit a regular progression with a maximum *easterly* deflection in December, or about the winter solstice, and a maximum *westerly* deflection in June, or about the summer solstice—the total range of the variation being one minute of arc. Of the above seven years of observation, in one only (1884–'85) is the above conclusion reversed and the last year's work seems feebly to support this.

It can not be said that our knowledge of the annual variation is satisfactory in view of the, as yet unexplained, fact of the greater or less discord or even contradiction of the results obtained at various places located even in the same magnetic hemisphere, as for instance may be seen from the following table.

Comparative values of the annual variation of the magnetic declination at several places in the northern (magnetic) hemisphere.

[A + sign indicates a deflection of the north end of the magnet to the *eastward*, a — sign the contrary direction.]

Month.	Los Angeles, Cal., 1882–'89.	Key West, Fla., 1862–'65.*	Washington, D. C., 1840–'42, 1867–'68.*	Philadelphia, Pa., 1840–'45.*	Toronto, Canada, 1845–'51, 1856–'64, 1865–71.†	Dublin, Ireland, 1841–'50‡.	Kew, England, 1858–'62§.
	′	′	′	′	′	′	′
January.	+0.6	—0.6	+0.6	—0.5	0.0	+0.4	0.0
February.	+0.2	—0.6	+0.3	—0.4	+0.2	+1.6	—0.6
March.	—0.4	+0.1	+0.2	+0.1	+0.1	+1.7	—0.5
April.	—0.4	+0.3	—0.1	+0.1	0.0	+1.9	0.0
May.	—0.4	+0.3	—0.4	—0.2	+0.3	+1.3	+0.7
June.	—0.4	+0.2	—0.1	+0.6	+0.5	0.0	+0.8
July.	—0.4	+0.3	+0.2	+1.0	+0.4	—1.2	+1.2
August.	—0.1	+0.8	+0.7	+0.9	0.0	—2.2	+0.3
September.	+0.3	+0.7	—0.4	0.0	—0.4	—2.1	—0.2
October.	+0.4	—0.5	—0.2	+0.2	—0.6	—1.4	—0.8
November.	+0.5	—0.5	—0.2	—0.9	—0.4	—0.3	—0.6
December.	+0.6	—0.3	—0.3	—0.7	—0.1	+0.2	—0.7

*U. S. Coast Survey Report for 1874, Washington, D. C., 1877, p. 112.

†Abstracts and results of magnetical and meteorological observations at the magnetic observatory, Toronto, Canada, Toronto, 1875, Table IV. (G. T. Kingston, director.)

‡A Treatise on Magnetism, General and Terrestrial, by H. Lloyd, London, 1874, p. 162.

§Terrestrial and Cosmical Magnetism, by E. Walker, Cambridge, England, 1866, p. 76.

The only feature of agreement is in the range of the annual variation, which for the North American stations does not differ much from 1′.

It does not appear that the plane of detorsion of the unifilar suspension at Los Angeles was examined after the first mounting of the instrument.

The total daily variation of the declination.—The daily variation in the direction of the magnet is directly shown by a comparison of the hourly trace-readings with the corresponding mean value of the day. In the following table we give the monthly mean values of scale-readings for *each hour* of the day, taken directly from the general collection of trace-readings, and arranged for each month separately. To these have been added the resulting mean hourly values from the 7-year series.

DIFFERENTIAL OBSERVATIONS

Recapitulation of mean hourly values of

[300 divisions + tabular quantity; 1 div. = 0′.794

[Local mean time.]

Month.	Year.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
Oct.	1882	70.8	69.9	70.4	71.3	70.7	71.6	73.0	73.7	73.5	71.8	69.1	67.2
	1883	69.8	69.9	70.2	70.1	70.9	71.9	74.2	75.4	73.6	70.9	68.0	66.6
	1884	68.7	69.0	68.9	68.6	69.1	69.8	71.2	72.7	71.8	69.7	67.4	65.7
	1885	73.2	73.3	73.3	73.3	73.4	74.0	75.4	76.5	75.9	73.7	70.9	69.2
	1886	70.6	71.2	71.4	70.9	71.4	72.1	73.3	74.5	73.1	71.2	68.9	67.6
	1887	69.8	69.7	69.3	69.4	69.5	69.8	70.9	72.2	72.3	70.1	67.9	66.3
	1888	66.4	66.4	66.6	66.9	66.9	67.4	68.2	69.3	68.6	66.3	64.1	63.1
	Mean .	69.90	69.91	70.01	70.07	70.27	70.94	72.31	73.47	72.69	70.53	68.04	66.53
Nov.	1882	70.5	70.0	69.5	70.2	69.4	70.4	72.4	73.6	74.4	72.8	69.9	68.1
	1883	70.0	70.2	70.0	69.4	70.0	70.1	71.3	72.9	72.4	70.8	68.7	66.9
	1884	69.4	69.0	68.4	68.6	68.3	68.5	69.9	71.6	72.8	72.2	70.2	67.7
	1885	72.5	72.3	72.6	72.1	72.7	73.1	73.8	75.5	75.7	74.6	72.8	70.9
	1886	71.0	71.0	71.4	71.4	71.3	71.2	72.2	72.9	72.8	71.5	70.5	69.2
	1887	69.2	68.9	69.5	69.4	69.8	69.5	70.1	71.2	70.8	69.6	68.1	66.6
	1888	66.6	66.0	66.0	66.4	66.4	66.5	67.0	67.5	67.5	66.6	65.3	64.2
	Mean .	69.89	69.63	69.63	69.64	69.70	69.90	70.96	72.17	72.34	71.16	69.36	67.66
Dec.	1882	71.3	71.1	70.8	70.9	70.7	70.8	71.5	72.5	73.7	73.6	72.2	70.4
	1883	69.1	69.2	69.3	69.4	69.4	69.7	70.3	72.2	73.4	72.9	70.0	67.6
	1884	69.7	69.6	69.3	69.2	69.1	69.4	70.1	71.4	73.0	73.4	71.4	68.4
	1885	72.4	72.2	72.2	72.4	72.4	72.4	72.7	74.1	75.2	75.1	74.0	72.1
	1886	70.9	71.2	70.6	70.8	70.6	71.1	70.7	71.6	72.8	73.4	72.6	70.7
	1887	68.6	69.0	68.8	68.5	68.4	68.1	68.4	69.4	70.6	70.9	70.2	68.5
	1888	65.6	65.5	65.3	65.7	65.7	65.6	65.8	66.5	67.3	67.0	66.2	64.7
	Mean .	69.66	69.69	69.47	69.56	69.47	69.59	69.93	71.10	72.29	72.33	70.94	68.91
Jan.	1883	70.6	70.7	70.6	71.0	71.2	70.6	71.6	73.1	74.9	75.5	72.9	69.8
	1884	70.0	69.8	69.9	69.9	69.9	70.0	70.7	73.0	75.3	75.6	72.2	68.4
	1885	70.4	70.6	70.2	69.7	69.8	70.2	70.6	72.0	73.2	74.0	72.0	69.6
	1886	71.9	72.3	72.1	71.7	71.7	71.6	71.8	72.7	74.7	75.7	74.7	72.4
	1887	70.8	70.9	70.9	70.4	70.4	70.6	71.0	72.5	74.7	75.8	73.7	70.8
	1888	68.3	68.9	68.8	68.5	67.7	67.3	67.4	68.4	69.8	70.1	69.0	66.6
	1889	65.0	65.0	65.1	65.0	65.1	65.2	65.6	66.6	67.9	67.7	66.0	63.5
	Mean .	69.57	69.74	69.66	69.46	69.40	69.36	69.81	71.19	72.93	73.49	71.50	68.73

OF THE DECLINATION.

scale-readings for each month and year.

Increasing scale-readings denote increasing east declination.]

[Local mean time.]

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily means.
66.6	67.1	68.0	69.1	69.6	70.1	70.4	71.1	70.7	71.1	70.7	70.6	70.34
66.8	67.2	68.5	68.7	68.5	68.8	69.1	69.5	69.4	69.3	69.6	69.6	69.86
65.2	65.5	66.5	67.4	68.0	68.0	68.2	68.2	68.8	68.8	69.0	68.6	68.52
69.0	69.9	70.8	71.8	72.0	72.3	72.7	72.7	72.8	72.9	72.6	72.7	72.68
67.6	68.6	69.8	70.4	70.6	70.8	71.1	71.2	71.5	71.0	70.9	71.0	70.87
66.0	66.9	67.8	68.5	68.9	69.2	69.8	69.5	69.5	69.6	69.8	69.8	69.26
63.2	64.4	65.4	66.0	66.1	66.4	66.4	67.0	66.6	66.6	66.2	66.2	66.28
66.34	67.09	68.11	68.84	69.10	69.37	69.67	69.89	69.90	69.90	69.83	69.79	69.69
67.6	68.1	68.7	69.7	70.2	71.6	72.2	71.7	72.6	71.8	71.0	70.8	70.72
66.6	67.2	67.6	68.3	68.5	69.1	69.6	69.5	69.5	69.3	69.0	69.8	69.45
66.6	66.5	67.2	67.8	68.7	69.3	69.6	69.6	69.7	69.9	69.6	69.4	69.19
70.0	70.3	71.0	71.8	72.4	72.8	73.2	73.2	73.1	73.8	72.9	72.7	72.74
68.9	69.5	70.4	70.7	71.4	71.9	72.2	72.9	72.1	72.0	71.8	71.3	71.31
66.4	67.0	67.6	68.4	69.0	69.6	69.8	69.6	69.7	69.4	69.3	69.3	69.07
64.2	64.3	65.0	65.7	66.3	67.0	66.8	67.4	67.0	66.7	66.5	66.5	66.22
67.19	67.56	68.21	68.91	69.50	70.19	70.49	70.56	70.53	70.41	70.01	69.97	69.81
69.2	68.6	69.1	69.6	70.6	71.2	71.4	71.8	72.0	71.4	71.2	71.2	71.12
66.8	67.0	67.6	68.4	69.1	69.6	69.7	69.8	69.8	69.7	69.6	69.2	69.53
66.9	66.6	67.4	68.5	69.5	70.0	70.1	70.3	70.4	70.1	70.1	69.8	69.75
71.0	70.7	71.9	71.9	72.8	73.0	73.3	73.2	73.2	73.0	72.8	72.4	72.73
69.7	69.6	70.1	70.7	71.6	72.4	72.3	73.0	72.3	72.1	71.9	71.4	71.42
67.2	67.0	67.2	68.1	69.0	69.3	69.7	69.9	69.7	69.6	69.2	68.9	68.91
63.9	64.2	64.5	65.3	66.1	66.4	66.6	66.9	66.7	66.4	66.0	65.5	65.81
67.81	67.67	68.13	68.93	69.81	70.27	70.44	70.70	70.59	70.33	70.11	69.77	69.90
68.3	68.3	68.9	70.0	70.7	71.0	71.2	71.3	71.5	71.2	70.8	70.8	71.10
66.4	66.3	66.9	68.3	69.4	69.7	70.0	70.1	70.2	70.1	69.9	69.7	70.06
68.2	67.9	68.5	69.5	70.1	70.4	70.8	70.8	70.6	70.6	70.7	70.4	70.44
70.5	69.8	69.8	70.5	71.6	72.2	72.3	72.3	72.7	72.4	72.2	71.8	72.13
68.9	68.4	69.0	70.1	71.4	71.7	71.7	71.8	72.2	71.9	71.4	71.4	71.34
65.9	66.2	66.6	67.6	68.1	68.4	68.8	68.8	69.0	68.5	68.5	68.4	68.15
62.4	62.9	63.9	65.0	65.7	65.9	66.0	65.9	66.0	65.6	65.4	64.9	65.29
67.23	67.11	67.66	68.71	69.57	69.90	70.11	70.14	70.31	70.04	69.84	69.63	69.79

DIFFERENTIAL OBSERVATIONS

Recapitulation of mean hourly values of

[300 divisions + tabular quantity; 1 div. = 0′.794

[Local mean time.]

Month.	Year.	1ʰ	2ʰ	3ʰ	4ʰ	5ʰ	6ʰ	7ʰ	8ʰ	9ʰ	10ʰ	11ʰ	Noon.
Feb.	1883	70.9	71.1	70.9	71.2	70.9	71.2	71.3	72.7	73.5	73.6	71.8	70.0
	1884	69.6	69.9	69.5	69.4	69.4	69.2	69.2	70.5	72.2	73.4	72.9	70.4
	1885	70.9	70.9	71.0	71.1	71.6	71.9	72.3	73.2	73.3	72.4	71.0	69.0
	1886	70.8	70.9	70.4	70.6	70.3	70.2	70.6	71.4	72.5	72.9	72.1	70.4
	1887	70.7	70.5	70.7	70.2	70.3	70.2	70.3	71.3	72.4	72.8	71.5	69.6
	1888	67.3	67.5	67.2	67.6	68.0	68.2	69.0	69.4	68.8	67.6	65.9	64.6
	1889	65.5	65.4	65.6	65.7	65.6	65.8	66.0	66.7	67.5	67.4	66.2	64.5
	Mean .	69.39	69.46	69.33	69.40	69.44	69.53	69.81	70.74	71.46	71.44	70.20	68.36
Mar.	1883	71.1	71.7	71.4	70.9	70.8	71.5	73.0	74.3	74.8	73.2	70.5	68.3
	1884	67.2	67.1	67.4	67.2	67.7	68.5	70.4	72.5	72.8	70.1	66.6	63.5
	1885	71.0	71.3	71.4	71.2	71.3	71.8	73.1	75.2	75.7	75.0	72.8	70.2
	1886	69.9	70.0	71.2	70.8	71.1	71.6	72.6	74.3	75.4	73.7	71.0	68.1
	1887	69.7	69.4	69.4	70.0	69.7	70.5	71.3	72.2	72.1	71.0	68.8	67.3
	1888	67.4	67.3	67.3	67.6	67.4	67.7	69.2	70.6	70.7	68.7	66.4	64.3
	1889	65.6	65.6	65.4	65.7	65.7	66.1	66.9	68.3	68.1	66.6	64.8	62.8
	Mean .	68.84	68.91	69.07	69.06	69.10	69.67	70.93	72.49	72.80	71.19	68.70	66.36
Apr.	1883	70.2	70.8	70.8	71.1	71.4	72.1	74.4	75.9	75.7	73.4	70.5	68.5
	1884	65.6	65.6	65.9	66.3	66.8	68.2	70.4	71.3	70.1	66.5	64.4	62.5
	1885	71.8	72.2	72.2	72.4	72.6	73.6	75.2	76.4	75.8	73.0	70.3	69.2
	1886	70.4	70.4	71.3	71.3	71.8	72.8	74.3	74.8	73.7	71.0	68.5	67.5
	1887	69.4	69.9	69.6	69.9	70.8	71.2	73.0	73.9	73.3	71.0	68.6	67.3
	1888	67.7	67.6	67.7	68.3	68.1	69.3	71.0	72.0	70.8	68.3	65.8	64.4
	1889	65.4	65.5	65.6	65.8	66.3	67.3	68.5	69.6	68.5	65.7	63.2	62.0
	Mean .	68.64	68.86	69.01	69.30	69.66	70.64	72.40	73.41	72.56	69.84	67.33	65.91
May	1883	69.8	70.3	70.4	71.0	71.7	73.5	75.6	75.6	73.6	69.9	67.2	66.0
	1884	65.1	65.2	65.6	65.9	66.8	68.6	70.2	70.3	68.3	65.6	62.8	61.5
	1885	71.7	71.6	72.2	73.0	73.8	75.7	77.7	78.1	76.4	72.9	69.8	68.6
	1886	70.3	70.2	70.6	71.2	71.7	73.8	75.6	75.6	73.1	70.0	67.3	66.0
	1887	69.8	69.9	70.2	70.6	71.1	72.7	74.4	74.5	73.0	70.4	67.8	66.5
	1888	66.9	66.7	67.2	68.1	68.6	69.8	71.4	71.6	70.2	67.8	65.5	64.3
	1889	65.3	65.5	65.9	66.0	66.7	68.2	69.8	70.2	68.0	65.1	62.8	61.8
	Mean .	68.41	68.49	68.87	69.40	70.04	71.76	73.53	73.70	71.80	68.81	66.17	64.94

OF THE DECLINATION.

***scale-readings for each month and year*—Continued.**

Increasing scale-readings denote increasing east declination.]

[Local mean time.]

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily means.
68.6	67.7	68.5	69.8	70.6	71.2	71.9	71.5	71.8	71.7	71.6	71.4	71.11
68.0	66.6	65.3	66.0	67.3	68.4	68.6	68.8	69.4	69.5	69.3	69.2	69.24
68.0	68.4	68.9	69.6	70.1	70.3	70.8	70.9	71.0	70.8	70.6	70.8	70.88
69.2	68.7	68.7	69.1	69.6	70.2	70.7	70.4	70.6	70.6	70.8	71.2	70.54
68.8	67.9	68.6	69.3	70.1	70.7	71.2	71.1	71.1	71.1	70.8	70.9	70.50
63.9	64.7	65.8	66.6	67.1	67.2	67.4	67.5	67.4	67.6	67.6	67.2	67.13
63.1	62.8	63.2	64.4	65.0	65.8	65.9	66.0	66.2	66.2	66.2	65.7	65.52
67.09	66.69	67.00	67.83	68.54	69.11	69.50	69.46	69.64	69.64	69.56	69.49	69.27
66.9	66.6	67.1	68.2	69.2	70.2	70.6	70.4	70.9	71.1	70.8	71.1	70.61
61.8	61.5	62.1	63.8	65.0	65.6	65.9	66.4	66.2	66.6	66.7	66.7	66.64
68.0	66.9	67.0	68.2	69.2	70.1	70.6	70.6	70.6	71.2	71.1	70.9	71.01
66.4	66.1	66.7	68.1	68.9	69.3	69.8	70.5	70.4	70.7	70.4	70.4	70.30
66.4	66.4	67.1	68.4	68.8	68.8	68.9	69.3	69.3	69.4	69.7	69.7	69.31
63.3	62.9	64.0	65.3	66.5	66.9	67.1	67.2	67.6	67.6	67.6	67.0	66.98
61.9	61.8	62.7	63.8	64.5	64.7	65.1	65.4	65.4	65.8	65.8	65.8	65.17
64.96	64.60	65.24	66.54	67.44	67.94	68.29	68.54	68.63	68.91	68.87	68.80	68.57
66.6	65.3	65.3	66.3	68.0	69.5	69.8	70.2	70.3	70.3	70.3	70.5	70.30
61.5	60.8	61.2	62.8	63.9	64.4	65.0	64.6	64.8	65.3	65.3	65.2	65.34
68.3	67.8	67.9	69.0	70.0	70.7	71.1	71.0	71.1	71.2	71.3	71.7	71.48
67.0	66.8	67.3	68.2	69.1	69.5	69.4	70.1	70.3	69.9	70.1	70.6	70.25
66.4	66.0	66.8	68.0	69.0	69.6	69.2	69.8	70.1	69.9	70.0	70.0	69.69
63.4	63.1	64.0	65.3	66.0	66.9	67.0	67.1	67.3	67.4	67.7	67.8	67.27
61.4	61.3	62.0	63.1	64.1	64.8	65.0	64.9	65.1	65.0	65.2	65.3	65.02
64.94	64.44	64.93	66.10	67.19	67.91	68.07	68.24	68.43	68.43	68.56	68.73	68.48
65.8	66.0	66.9	67.9	69.0	69.5	69.7	69.5	70.1	69.8	69.8	69.9	69.94
60.8	60.7	61.6	63.0	64.0	64.7	65.1	64.6	64.9	65.0	65.2	64.9	65.02
68.4	68.4	69.0	69.7	70.8	71.7	71.8	71.8	72.5	72.1	72.5	71.5	72.15
65.9	66.4	67.1	68.2	69.0	69.5	69.6	69.7	70.0	69.7	69.9	70.0	70.02
66.1	66.1	66.9	67.7	68.8	69.1	69.6	69.4	69.6	69.9	69.9	69.8	69.75
63.9	64.0	64.6	65.4	66.0	66.7	66.9	67.2	67.3	67.3	67.2	67.0	67.15
61.7	62.1	62.9	63.8	64.4	64.6	64.8	65.0	65.2	65.2	65.5	65.3	65.24
64.66	64.81	65.57	66.53	67.43	67.97	68.21	68.17	68.51	68.43	68.57	68.34	68.47

DIFFERENTIAL OBSERVATIONS

Recapitulation of mean hourly values of

[300 divisions + tabular quantity; 1 div. = 0′.794

[Local mean time.]

Month.	Year.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
June	1883	69.6	69.7	70.2	70.4	71.1	72.5	74.8	75.3	73.9	70.0	67.2	65.3
	1884	65.7	65.7	65.9	66.2	67.3	69.2	71.1	71.3	69.6	65.8	62.4	60.8
	1885	71.8	71.8	72.3	72.6	73.7	75.3	77.3	78.0	76.6	73.8	70.3	68.2
	1886	70.4	70.2	70.6	71.2	72.1	74.0	75.2	74.9	73.2	70.7	68.1	66.6
	1887	69.7	69.7	70.4	70.7	71.3	72.8	74.7	75.1	73.4	70.2	67.3	65.6
	1888	66.8	67.0	67.2	67.6	68.4	69.8	71.5	71.5	70.1	67.1	64.7	63.4
	1889	65.3	65.2	65.3	65.7	66.4	67.6	68.6	68.8	67.3	65.0	63.0	61.8
	Mean.	68.47	68.47	68.84	69.20	70.04	71.60	73.31	73.56	72.01	68.94	66.01	64.53
July	1883	69.4	69.4	69.8	70.1	71.2	73.0	74.8	75.1	73.2	69.6	66.6	64.6
	1884	66.7	66.7	66.9	67.3	68.0	70.1	71.7	73.0	71.2	67.0	64.0	62.1
	1885	72.0	72.3	72.5	73.0	74.1	76.1	78.8	79.9	78.0	73.8	69.9	67.7
	1886	70.0	70.2	70.8	71.5	72.2	74.0	75.9	76.4	74.8	71.2	68.4	66.5
	1887	68.7	69.0	69.0	69.4	70.3	71.8	74.1	74.7	73.2	69.5	66.2	64.2
	1888	66.2	66.8	66.8	67.4	68.1	69.7	71.5	72.0	70.6	67.3	64.2	62.5
	1889	65.0	64.8	65.1	65.6	66.0	67.5	68.8	69.4	68.1	65.5	63.1	61.4
	Mean.	68.29	68.46	68.70	69.19	69.99	71.74	73.66	74.36	72.73	69.13	66.06	64.14
Aug.	1883	69.4	69.5	69.9	70.4	71.0	73.2	75.4	75.6	73.1	69.5	67.0	65.7
	1884	67.0	67.4	67.5	68.2	69.0	70.8	73.5	74.2	71.6	67.4	64.6	63.2
	1885	72.8	72.6	72.9	73.0	74.4	76.6	79.1	80.2	77.6	72.7	69.0	67.5
	1886	70.5	70.6	71.1	71.7	72.1	74.3	76.2	77.0	74.4	70.8	68.1	66.8
	1887	68.8	68.8	68.8	69.2	70.1	71.9	74.0	74.4	72.8	68.9	65.9	64.6
	1888	66.5	66.3	66.8	66.8	67.1	69.0	71.6	72.5	70.2	66.3	63.0	61.4
	1889	65.0	64.8	65.1	65.4	66.1	67.5	69.8	70.4	68.2	64.6	62.0	60.8
	Mean.	68.57	68.57	68.87	69.24	69.97	71.90	74.23	74.90	72.56	68.60	65.66	64.29
Sept.	1883	69.5	70.3	70.4	70.6	70.9	72.6	74.6	74.9	73.0	70.1	67.5	66.0
	1884	68.3	69.0	68.6	68.7	69.4	71.1	73.4	73.2	71.6	68.2	65.5	64.0
	1885	73.2	73.3	73.8	73.8	74.2	76.2	78.0	78.0	76.7	73.1	70.5	68.6
	1886	71.3	71.2	71.7	71.9	72.4	74.2	76.0	75.9	74.0	70.8	68.7	67.5
	1887	68.9	69.5	69.3	69.9	70.3	71.1	72.3	72.6	71.2	68.3	66.5	65.5
	1888	66.7	67.4	67.0	67.5	67.8	68.9	70.2	70.0	68.3	65.3	63.7	62.8
	1889	65.2	65.5	65.7	66.2	66.4	67.6	69.5	69.4	67.9	65.3	63.1	61.9
	Mean.	69.01	69.46	69.50	69.80	70.06	71.67	73.43	73.43	71.81	68.73	66.50	65.19

OF THE DECLINATION.

***scale-readings for each month and year*—Continued.**

Increasing scale-readings denote increasing east declination.]

[Local mean time.]

13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily Mean.
64.9	64.8	65.8	67.3	68.6	69.3	69.6	69.2	69.6	70.0	69.6	69.5	69.51
60.4	60.7	61.7	63.1	64.4	65.2	65.2	65.0	65.1	65.6	65.2	65.7	65.35
67.0	67.1	67.7	69.0	70.4	71.6	71.6	71.1	71.1	71.6	71.7	71.8	71.82
66.0	66.3	67.3	68.1	68.9	69.5	70.0	70.0	69.9	70.1	70.6	70.2	70.18
65.4	65.8	66.8	68.2	69.2	69.9	70.0	69.5	69.6	69.5	69.3	69.5	69.75
63.2	63.6	64.2	65.2	65.9	66.5	66.7	67.0	67.0	66.6	66.9	66.9	66.86
61.5	61.8	62.3	63.0	63.6	64.2	64.1	64.3	64.1	64.3	64.5	64.8	64.68
64.06	64.30	65.11	66.27	67.29	68.03	68.17	68.01	68.06	68.24	68.26	68.34	68.31
64.4	64.8	66.2	67.3	68.2	69.0	69.5	68.8	69.2	69.0	69.5	69.2	69.25
61.4	61.9	63.1	64.5	65.5	66.1	66.1	66.6	66.3	66.2	66.4	66.9	66.49
66.9	67.9	68.5	70.0	71.2	72.0	71.8	71.7	71.4	71.6	71.8	72.0	72.25
65.9	66.1	67.1	68.2	69.2	69.3	69.4	69.4	70.0	70.2	70.4	70.4	70.31
63.8	64.6	65.6	66.9	67.7	68.2	68.4	68.4	68.4	68.3	68.7	68.6	68.66
62.2	62.6	63.6	64.9	65.9	66.4	66.2	66.2	66.7	66.5	66.9	66.6	66.57
60.7	60.9	61.8	62.9	63.7	64.5	64.4	64.8	64.7	64.8	64.8	65.0	64.72
63.61	64.00	65.13	66.39	67.34	67.93	67.97	67.99	68.10	68.09	68.36	68.39	68.32
65.2	65.8	67.2	68.4	68.9	68.8	68.9	68.6	68.9	69.0	69.1	69.0	69.48
62.8	63.4	64.8	66.2	66.8	66.5	66.4	66.6	67.1	67.2	67.3	67.2	67.33
67.4	68.3	69.8	71.3	72.2	72.6	72.6	72.3	72.2	72.6	72.6	72.6	72.72
66.5	67.2	68.5	69.7	70.2	70.3	70.5	71.0	70.9	70.6	70.7	70.5	70.84
64.2	65.0	66.2	67.4	68.0	68.8	68.6	69.0	69.1	69.4	69.5	68.8	68.85
61.2	62.0	63.5	65.0	65.9	66.2	66.1	66.0	66.4	66.3	66.8	66.3	66.22
60.6	61.5	63.0	64.0	64.5	64.7	64.4	64.5	64.8	65.5	65.0	64.8	64.87
63.99	64.74	66.14	67.43	68.07	68.27	68.21	68.29	68.49	68.66	68.71	68.46	68.62
65.8	66.7	68.0	68.8	69.0	69.1	69.8	69.4	69.3	69.3	69.3	69.3	69.76
64.0	65.0	66.6	67.8	67.7	67.0	67.7	68.0	68.0	68.0	67.9	68.2	68.20
68.2	69.4	70.6	72.1	72.4	72.2	72.4	72.3	72.5	72.9	73.1	73.0	72.93
67.6	68.2	69.5	70.6	70.7	70.9	70.8	70.9	71.4	71.2	71.1	70.9	71.23
65.5	66.5	67.6	68.3	69.3	69.0	69.0	69.4	68.7	69.0	69.3	69.1	69.00
63.1	64.2	65.4	66.3	66.5	66.5	66.2	66.4	66.4	66.7	66.3	66.6	66.51
61.9	62.8	63.8	65.1	65.3	65.2	64.9	65.4	65.1	65.0	65.2	64.9	65.34
65.16	66.11	67.36	68.43	68.70	68.56	68.69	68.83	68.77	68.87	68.89	68.86	69.00

If we subtract, for each month, the daily mean from each hourly mean, and convert these hourly differences from scale divisions into minutes of arc, we get the following table of the total daily variation:

Total solar-diurnal variation of the magnetic declination at Los Angeles between October, 1882, *and October,* 1889.

[A + sign signifies a deflection of the north end of the magnet to the *east*, a — sign, the contrary direction.]

[Local mean time.]

1882–'89.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
	′	′	′	′	′	′	′	′	′	′	′	′
Jan.	−0.17	−0.04	−0.10	−0.26	−0.31	−0.34	+0.02	+1.11	+2.49	+2.94	+1.36	−0.84
Feb.	+0.10	+0.16	+0.06	+0.11	+0.14	+0.20	+0.44	+1.18	+1.75	+1.73	+0.75	−0.71
Mar.	+0.21	+0.27	+0.40	+0.39	+0.42	+0.87	+1.87	+3.11	+3.36	+2.08	+0.10	−1.75
Apr.	+0.13	+0.30	+0.42	+0.65	+0.94	+1.72	+3.11	+3.91	+3.24	+1.08	−0.91	−2.04
May	−0.05	+0.02	+0.32	+0.74	+1.25	+2.61	+4.02	+4.15	+2.64	+0.27	−1.83	−2.80
June	+0.13	+0.13	+0.42	+0.71	+1.37	+2.61	+4.00	+4.17	+2.94	+0.50	−1.83	−3.00
July	−0.02	+0.11	+0.30	+0.69	+1.33	+2.72	+4.24	+4.80	+3.50	+0.64	−1.79	−3.32
Aug.	−0.04	−0.04	+0.20	+0.49	+1.07	+2.60	+4.45	+4.99	+3.13	−0.02	−2.35	−3.44
Sept.	+0.01	+0.37	+0.40	+0.64	+0.84	+2.12	+3.52	+3.52	+2.23	−0.21	−1.98	−3.03
Oct.	+0.17	+0.17	+0.25	+0.30	+0.46	+0.99	+2.08	+3.00	+2.40	+0.67	−1.31	−2.51
Nov.	+0.06	−0.14	−0.14	−0.13	−0.09	+0.08	+0.91	+1.87	+2.01	+1.07	−0.36	−1.71
Dec.	−0.19	−0.17	−0.34	−0.27	−0.34	−0.25	+0.02	+0.95	+1.90	+1.93	+0.83	−0.79

1882–'89.	13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.
	′	′	′	′	′	′	′	′	′	′	′	′
Jan.	−2.03	−2.13	−1.69	−0.86	−0.17	+0.09	+0.25	+0.28	+0.41	+0.20	+0.04	−0.13
Feb.	−1.72	−2.04	−1.79	−1.14	−0.57	−0.12	+0.19	+0.16	+0.30	+0.38	+0.24	+0.18
Mar.	−2.87	−3.15	−2.64	−1.61	−0.90	−0.50	−0.22	−0.02	+0.05	+0.27	+0.24	+0.18
Apr.	−2.81	−3.21	−2.82	−1.89	−1.02	−0.45	−0.32	−0.19	−0.04	−0.04	+0.06	+0.20
May	−3.03	−2.91	−2.30	−1.54	−0.83	−0.40	−0.21	−0.24	+0.03	−0.03	+0.08	−0.10
June	−3.37	−3.18	−2.54	−1.62	−0.81	−0.22	−0.11	−0.24	−0.20	−0.06	−0.04	+0.02
July	−3.74	−3.43	−2.53	−1.53	−0.78	−0.31	−0.28	−0.26	−0.17	−0.18	+0.03	+0.06
Aug.	−3.68	−3.08	−1.97	−0.94	−0.44	−0.28	−0.33	−0.26	−0.10	+0.03	+0.07	−0.13
Sept.	−3.05	−2.29	−1.30	−0.45	−0.24	−0.35	−0.25	−0.13	−0.18	−0.10	−0.09	−0.11
Oct.	−2.66	−2.06	−1.25	−0.67	−0.47	−0.25	−0.02	+0.16	+0.17	+0.17	+0.11	+0.08
Nov.	−2.08	−1.79	−1.27	−0.72	−0.25	+0.30	+0.54	+0.60	+0.57	+0.48	+0.16	+0.13
Dec.	−1.60	−1.70	−1.33	−0.70	0.00	+0.37	+0.50	+0.71	+0.62	+0.41	+0.24	−0.03

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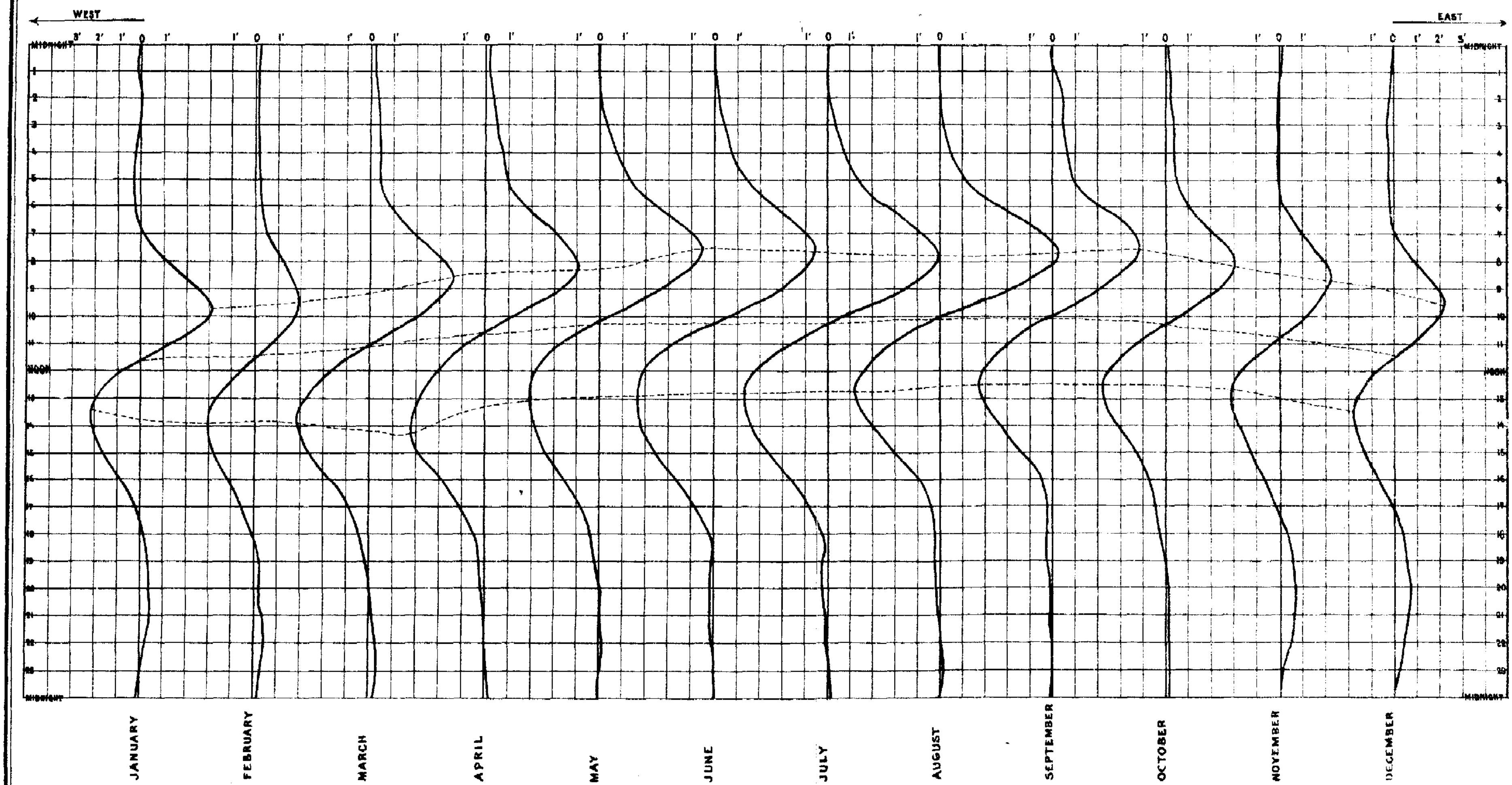
MONTHLY VALUES OF THE

TOTAL SOLAR-DIURNAL VARIATION OF THE MAGNETIC DECLINATION, AT LOS ANGELES, CALIFORNIA.

FROM SEVEN YEARS OF OBSERVATIONS BETWEEN OCT. 1882 & OCT. '88



A graphical representation of the tabular values is given on accompanying diagram (Illustration No. 21). It will be seen at a glance that the character of the daily variation is in general the same throughout the year, viz, a single prominent wave with its two extreme values at an interval of less than one-fourth of the whole period between them, followed by an indication of a very small secondary wave, which in some months can only be made out with difficulty. To render the systematic monthly changes of the daily motion clearer suitable combinations were made by quarters and by half years, as is evidently allowable; thus the curves for June, July, and August are almost identical, also those of December, January, and February. Further, there is a most marked contrast between the curves for the summer half year (sun in north declination) and the curves of the winter half (sun in south declination).

Total solar-diurnal variation of the declination for different seasons, 1882–'89 (*local mean time*).

Seasons.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
	′	′	′	′	′	′	′	′	′	′	′	′
Dec., Jan., Feb.	−0.09	−0.02	−0.13	−0.14	−0.17	−0.13	+0.16	+1.08	+2.05	+2.20	+0.98	−0.78
Mar., Apr., May.	+0.10	+0.20	+0.38	+0.59	+0.87	+1.73	+3.00	+3.72	+3.08	+1.14	−0.88	−2.20
June, July, Aug.	+0.02	+0.07	+0.31	+0.63	+1.26	+2.64	+4.23	+4.65	+3.19	+0.37	−1.99	−3.25
Sept., Oct., Nov.	+0.08	+0.13	+0.17	+0.27	+0.40	+1.06	+2.17	+2.80	+2.21	+0.51	−1.22	−2.42
(S.) 6 months, Apr. to Sept., inclusive.	+0.03	+0.15	+0.34	+0.65	+1.13	+2.40	+3.89	+4.26	+2.95	+0.38	−1.78	−2.94
(W.) 6 months, Oct. to Mar., inclusive.	+0.03	+0.04	+0.02	+0.02	+0.05	+0.26	+0.89	+1.87	+2.32	+1.74	+0.23	−1.38
Whole year.	+0.03	+0.10	+0.18	+0.34	+0.59	+1.33	+2.39	+3.06	+2.63	+1.06	−0.78	−2.16
Seasons.	**13h**	**14h**	**15h**	**16h**	**17h**	**18h**	**19h**	**20h**	**21h**	**22h**	**23h**	**Mid-night.**
	′	′	′	′	′	′	′	′	′	′	′	′
Dec., Jan., Feb.	−1.78	−1.96	−1.60	−0.90	−0.25	+0.11	+0.31	+0.38	+0.44	+0.33	+0.17	+0.01
Mar., Apr., May.	−2.90	−3.09	−2.59	−1.68	−0.92	−0.45	−0.25	−0.15	+0.01	+0.07	+0.13	+0.09
June, July, Aug.	−3.60	−3.23	−2.35	−1.36	−0.68	−0.27	−0.24	−0.25	−0.16	−0.07	+0.02	−0.02
Sept., Oct., Nov.	−2.60	−2.05	−1.27	−0.61	−0.32	−0.10	+0.09	+0.21	+0.19	+0.18	+0.06	+0.03
(S.) 6 months, Apr. to Sept., inclusive.	−3.28	−3.02	−2.24	−1.33	−0.69	−0.33	−0.25	−0.22	−0.11	−0.06	+0.02	−0.01
(W.) 6 months, Oct. to Mar., inclusive.	−2.16	−2.14	−1.66	−0.95	−0.39	−0.02	+0.21	+0.32	+0.35	+0.32	+0.17	+0.08
Whole year.	+2.72	−2.58	−1.95	−1.14	−0.54	−0.18	−0.02	+0.05	+0.12	+0.13	+0.09	+0.03

Referring to the hourly means for the whole year, it will be seen that the total diurnal variation of the declination at Los Angeles, Cal., is of the ordinary type met with in the northern temperate zone, exhibiting generally two principal and two subordinate extreme values each day, with the principal turning hours shortly after 8 o'clock a. m. and shortly after 1 o'clock p. m.; the average position of the magnet or the mean of the day is reached shortly after half past ten a. m. A small easterly extreme is reached about two hours before midnight, followed by a small westerly extreme soon after midnight. On the yearly average, the daily range of the principal wave is less than 6′, but that of the secondary is sixty times less, or only 0′.1

For convenience of comparison with the daily variation at other stations, and for a more strict expression of its features, we have thrown the hourly numbers for the whole year into an analytical form,* and get—

$$d=+1'.294 \sin(\theta+22^\circ\,03')+1'.387 \sin(2\theta+217^\circ\,20')$$
$$+0.712 \sin(3\theta+60\ 34)+0.249 \sin(4\theta+279\ 32)+\text{smaller terms of no importance.}$$

where the angle θ counts from midnight and at the rate of 15° an hour.

We may compare this expression with a similar one for a station where the dip and horizontal intensity are not very different from the Los Angeles values. At Key West the Survey secured a 6-year series of magnetic observations, absolute and differential, for which certain results are given in the Coast Survey Report for 1874, Appendix No. 9.

The position of the magnetic observatory at Key West was in $\varphi=+24^\circ\ 33'.1$, and in $\lambda=81^\circ\ 48'.5$ W. from Gr., and the instrument, a Brooke magnetograph, was mounted barely four metres

*A Bessel periodic function.—Bessel's first publication of this function is contained in the Literary Gazette of Jena, in 1814; see, also, his paper in the Astronomische Nachrichten, No. 136, May, 1828. A further contribution to the subject is given in a memoir by A. Bravais in "Voyages en Scandinavie, au Laponie, au Spitzberg et aux Faroe pendant les années, 1838, 1839, et 1840, Météorologie." An extract is given by J. Haeghens in the "Annuaire Météorologique de la France, pour 1850," p. 93. See also Sir John Herschel's article, "Meteorology," in the Encyclopædia Britannica, 8th edition; Reprint, p. 144.

The coefficients in the general formulæ $\Psi=A+B_1 \sin(\theta+C_1)+B_2 \sin(2\theta+C_2)+B_3 \sin(3\theta+C_3)+$ etc., when applied to the case of 24 equidistant observations $y_1\ y_2\ y_3\ y_4\ \ldots\ y_{24}$ in the cycle, change into the following simple expressions and are applicable directly for numerical computation:

$$A=\tfrac{1}{24}(y_1+y_2+y_3+\ldots\ldots+y_{24})$$

$$12a_1=0.966\,(y_1-y_{11}-y_{13}+y_{23})+0.866\,(y_2-y_{10}-y_{14}+y_{22})+0.707\,(y_3-y_9-y_{15}+y_{21})$$
$$+0.500\,(y_4-y_8-y_{16}+y_{20})+0.259\,(y_5-y_7-y_{17}+y_{19})-y_{12}+y_{24}$$
$$12b_1=0.259\,(y_1+y_{11}-y_{13}-y_{23})+0.500\,(y_2+y_{10}-y_{14}-y_{22})+0.707\,(y_3+y_9-y_{15}-y_{21})$$
$$+0.866\,(y_4+y_8-y_{16}-y_{20})+0.966\,(y_5+y_7-y_{17}-y_{19})+y_6-y_{18}$$
$$12a_2=0.866\,(y_1-y_5-y_7+y_{11}+y_{13}-y_{17}-y_{19}+y_{23})+0.500\,(y_2-y_4-y_8+y_{10}+y_{14}-y_{16}-y_{20}+y_{22})$$
$$-y_6+y_{12}-y_{18}+y_{24}$$
$$12b_2=0.500\,(y_1+y_5-y_7-y_{11}+y_{13}+y_{17}-y_{19}-y_{23})+0.866\,(y_2+y_4-y_8-y_{10}+y_{14}+y_{16}-y_{20}-y_{22})$$
$$+y_3-y_9+y_{15}-y_{21}$$

$$12a_3=0.707\,(y_1-y_3-y_5+y_7+y_9-y_{11}-y_{13}+y_{15}+y_{17}-y_{19}-y_{21}+y_{23})-y_4+y_8-y_{12}+y_{16}-y_{20}+y_{24}$$
$$12b_3=0.707\,(y_1+y_3-y_5-y_7+y_9+y_{11}-y_{13}-y_{15}+y_{17}+y_{19}-y_{21}-y_{23})+y_2-y_6+y_{10}-y_{14}+y_{18}-y_{22}$$

$$12a_4=0.500\,(y_1-y_2-y_4+y_5+y_7-y_8-y_{10}+y_{11}+y_{13}-y_{14}-y_{16}+y_{17}+y_{19}-y_{20}-y_{22}+y_{23})$$
$$-y_3+y_6-y_9+y_{12}-y_{15}+y_{18}-y_{21}+y_{24}$$
$$12b_4=0.866\,(y_1+y_2-y_4-y_5+y_7+y_8-y_{10}-y_{11}+y_{13}+y_{14}-y_{16}-y_{17}+y_{19}+y_{20}-y_{22}-y_{23})$$

etc.

$$B_1=(a_1^2+b_1^2)^{\frac{1}{2}} \qquad \tan C_1=a_1/b_1$$
$$B_2=(a_2^2+b_2^2)^{\frac{1}{2}} \qquad \tan C_2=a_2/b_2$$
$$B_3=(a_3^2+b_3^2)^{\frac{1}{2}} \qquad \tan C_3=a_3/b_3$$
$$B_4=(a_4^2+b_4^2)^{\frac{1}{2}} \qquad \tan C_4=a_4/b_4$$

etc.

For 12 equidistant ordinates in a cycle the formulæ become:

$$A=\tfrac{1}{12}(y_1+y_2+y_3+\ \ldots\ldots\ +y_{12})$$

$$6a_1=0.866\,(y_1-y_5-y_7+y_{11})+0.500\,(y_2-y_4-y_8+y_{10})-y_6+y_{12}$$
$$6b_1=0.500\,(y_1+y_5-y_7-y_{11})+0.866\,(y_2+y_4-y_8-y_{10})+y_3-y_9$$

$$6a_2=0.500\,(y_1-y_2-y_4+y_5+y_7-y_8-y_{10}+y_{11})-y_3+y_6-y_9+y_{12}$$
$$6b_2=0.866\,(y_1+y_2-y_4-y_5+y_7+y_8-y_{10}-y_{11})$$

$$6a_3=-y_2+y_4-y_6+y_8-y_{10}+y_{12}$$
$$6b_3=+y_1-y_3+y_5-y_7+y_9-y_{11}$$

$$6a_4=0.500\,(-y_1-y_2-y_4-y_5-y_7-y_8-y_{10}-y_{11})+y_3+y_6+y_9+y_{12}$$
$$6b_4=0.866\,(+y_1-y_2+y_4-y_5+y_7-y_8+y_{10}-y_{11})$$

etc.

$B_1\ B_2\ B_3\ B_4\ \ldots$ and $C_1\ C_2\ C_3\ C_4\ \ldots$ are formed as before. The above expressions, together with others, are given in the Coast Survey Report for 1862, appendix No. 22, with erratum in Report for 1866, p. 141.

In certain applications of Bessel's periodic function to cases demanding great precision, two corrections are needed, viz, one for inequality in the *length* of the calendar months, and another for *curvature* or difference in the mean monthly value of the observed quantity, and the observed quantity for the *middle* of the month. The first correction, for unequal length, affects principally the mean annual value and but slightly the epochs of the periodic above the sea level. At the middle epoch of the observations, 1863.5, the dip was 54° 31′.9 and the horizontal intensity, 0.3107 dyne. The declination was 4° 37′.6 east at that epoch, with an annual decrease of 3′.1

In order to make the comparison of the Los Angeles and Key West results for the diurnal variation as close as possible, I have thrown the tabular hourly scale readings of the declination, as given on pp. 116 and 117, report of 1874, into the same shape as those given for Los Angeles.

Total solar-diurnal variation of the magnetic declination at Key West, Florida, between March, 1860, and March, 1866.

[A + sign signifies a deflection of the north end of the magnet to the *east*, a — sign, the contrary direction.]

[Local mean time.]

1860–'66.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
	′	′	′	′	′	′	′	′	′	′	′	′
Jan.	—0.25	—0.38	—0.43	—0.33	—0.32	—0.17	0.00	+1.10	+2.43	+2.75	+1.48	—0.37
Feb.	—0.02	—0.12	—0.08	—0.08	—0.03	+0.02	+0.18	+1.07	+1.83	+1.87	+1.05	—0.23
Mar.	+0.04	—0.03	+0.09	+0.21	+0.39	+0.67	+1.77	+2.50	+2.31	+1.50	+0.31	—1.00
April	+0.32	+0.42	+0.57	+0.68	+0.77	+1.45	+2.75	+2.97	+2.10	+0.90	—0.47	—1.63
May	+0.32	+0.35	+0.47	+0.60	+0.92	+2.02	+3.37	+3.40	+2.23	+0.48	—0.95	—2.07
June	+0.20	+0.13	+0.30	+0.48	+0.98	+2.15	+3.48	+3.65	+2.45	+0.85	—0.83	—2.10
July	+0.07	+0.08	+0.17	+0.32	+0.80	+2.22	+3.55	+3.52	+2.42	+0.72	—0.88	—1.98
Aug.	+0.17	+0.12	+0.07	+0.43	+0.83	+2.27	+4.50	+4.22	+2.78	+0.32	—1.68	—2.83
Sept.	—0.12	+0.18	+0.47	+0.58	+0.70	+1.80	+3.55	+3.62	+2.32	+0.22	—1.47	—2.60
Oct.	+0.15	+0.05	—0.02	+0.05	—0.05	+0.47	+1.77	+2.17	+1.75	+0.52	—0.73	—1.57
Nov.	—0.32	—0.42	—0.45	—0.38	—0.12	—0.02	+0.53	+1.38	+1.72	+1.27	+0.20	—0.78
Dec.	—0.37	—0.57	—0.55	—0.48	—0.35	—0.33	—0.22	+0.62	+1.83	+2.13	+1.33	—0.02

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terms; the second correction, for curvature, affects only the amplitude of the fluctuations. These corrections may be applied separately and for each month before applying the periodic function, especially in cases where the observed daily quantity is given. Thus for normal months:

January	ends with 0.44	of the 31st	of the calendar month.
February	0.62	2d	of March.
March	0.06	2d	of April.
April	0.50	2d	of May.
May	0.94	1st	of June.
June	0.37	2d	of July.
July	0.81	1st	of August.
August	0.25	1st	of September.
September	0.69	1st	of October.
October	0.13	1st	of November.
November	0.56	1st	of December.
December	midnight of the 31st.		

This table answers for complete quadriennia, for which the average or normal month comprises 30.44 days.

The correction for curvature can be effected by multiplying the parameters, or the values B_1 B_2 B_3 . . . ., respectively, by the factors $\frac{\frac{\pi}{n}}{\sin\frac{\pi}{n}}$, $\frac{2\frac{\pi}{n}}{\sin 2\frac{\pi}{n}}$, $\frac{3\frac{\pi}{n}}{\sin 3\frac{\pi}{n}}$ . . . . . . or the ratio of arc and sine, n being the number of subdivisions in the cycle. Further information respecting these two corrections will be found in Silliman's Journal of Science and Arts, May numbers of 1866 and 1867, by E. L. DeForest, and in Voyages en Scandinavie, etc. Meteorology, vol. II, chapter V, pp. 291–325. Here are also given a number of interpolation formulæ in cases of certain missing ordinates or incomplete observations.

Total solar-diurnal variation of the magnetic declination at Key West, Florida, between March, 1860, *and March,* 1866—Continued.

[A + sign signifies a deflection of the north end of the magnet to the *east*, a — sign, the contrary direction.]

[Local mean time.]

1860–'66.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.
	′	′	′	′	′	′	′	′	′	′	′	′
Jan.	−1.53	−1.92	−1.80	−1.20	−0.62	−0.28	+0.15	+0.48	+0.60	+0.42	+0.23	+0.03
Feb.	−1.15	−1.52	−1.55	−1.17	−0.87	−0.60	−0.20	+0.28	+0.32	+0.28	+0.23	+0.12
Mar.	−2.00	−2.27	−2.03	−1.11	−0.91	−0.64	−0.53	−0.19	+0.24	+0.19	+0.11	+0.09
April	−2.62	−2.88	−2.58	−1.87	−0.92	−0.52	−0.18	−0.08	+0.05	+0.28	+0.40	+0.37
May	−2.58	−2.62	−2.30	−1.68	−0.80	−0.45	−0.43	−0.22	−0.07	+0.02	+0.20	+0.25
June	−2.68	−2.85	−2.67	−1.78	−1.07	−0.53	−0.40	−0.27	−0.02	+0.08	+0.23	+0.18
July	−2.47	−2.65	−2.40	−1.68	−1.00	−0.52	−0.42	−0.27	−0.07	+0.25	+0.23	+0.23
Aug.	−3.32	−3.30	−2.52	−1.53	−0.82	−0.43	−0.23	−0.03	−0.02	+0.30	+0.17	+0.13
Sept.	−2.95	−2.57	−1.72	−0.87	−0.57	−0.37	−0.23	+0.02	+0.07	0.00	−0.12	−0.13
Oct.	−1.62	−1.28	−1.03	−0.77	−0.67	−0.42	+0.02	+0.22	+0.35	+0.28	+0.33	+0.30
Nov.	−1.20	−1.13	−0.90	−0.62	−0.27	0.00	+0.22	+0.43	+0.48	+0.33	+0.15	−0.15
Dec.	−0.95	−1.42	−1.40	−1.02	−0.45	−0.02	+0.23	+0.47	+0.55	+0.40	+0.10	−0.08

Total solar-diurnal variation of the declination for different seasons, 1860–'66.

[Local mean time.]

Seasons.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
	′	′	′	′	′	′	′	′	′	′	′	′
Dec., Jan., Feb.	−0.21	−0.36	−0.35	−0.30	−0.23	−0.16	−0.01	+0.93	+2.03	+2.25	+1.29	−0.21
Mar., Apr., May	+0.23	+0.25	+0.38	+0.50	+0.69	+1.38	+2.63	+2.96	+2.21	+0.96	−0.37	−1.57
June, July, Aug.	+0.15	+0.11	+0.18	+0.41	+0.87	+2.21	+3.84	+3.80	+2.55	+0.63	−1.13	−2.30
Sept., Oct., Nov.	−0.10	−0.06	0.00	+0.08	+0.18	+0.75	+1.95	+2.39	+1.93	+0.67	−0.67	−1.65
(S) 6 months, Apr. to Sept., inclusive.	+0.16	+0.21	+0.34	+0.52	+0.83	+1.98	+3.53	+3.56	+2.38	+0.58	−1.05	−2.20
(W) 6 months, Oct. to Mar., inclusive.	−0.13	−0.24	−0.24	−0.17	−0.08	+0.11	+0.67	+1.47	+1.98	+1.67	+0.61	−0.66
Whole year.	+0.02	−0.02	+0.05	+0.17	+0.38	+1.04	+2.10	+2.52	+2.18	+1.13	−0.22	−1.43
Seasons.	**13h**	**14h**	**15h**	**16h**	**17h**	**18h**	**19h**	**20h**	**21h**	**22h**	**23h**	**Mid-night.**
	′	′	′	′	′	′	′	′	′	′	′	′
Dec., Jan., Feb.	−1.21	−1.62	−1.58	−1.13	−0.65	−0.30	+0.06	+0.41	+0.49	+0.37	+0.19	+0.02
Mar., Apr., May	−2.40	−2.59	−2.30	−1.55	−0.88	−0.54	−0.38	−0.16	+0.07	+0.16	+0.24	+0.24
June, July, Aug.	−2.82	−2.93	−2.53	−1.66	−0.96	−0.49	−0.35	−0.19	−0.04	+0.21	+0.21	+0.18
Sept., Oct., Nov.	−1.92	−1.66	−1.22	−0.75	−0.50	−0.26	0.00	+.022	+0.30	+0.20	+0.12	+0.01
(S) 6 months, Apr. to Sept., inclusive.	−2.77	−2.81	−2.36	−1.57	−0.86	−0.47	−0.32	−0.14	−0.01	+0.16	+0.18	+0.17
(W) 6 months, Oct. to Mar., inclusive	−1.41	−1.59	−1.45	−0.98	−0.63	−0.33	−0.02	+0.28	+0.42	+0.32	+0.19	+0.05
Whole year.	−2.09	−2.20	−1.91	−1.27	−0.75	−0.40	−0.17	+0.07	+0.20	+0.24	+0.19	+0.11

A comparison of the monthly curves of the diurnal variation shows them to be of the same shape even in some minute detail, although with relation to the distribution of land and ocean the two stations are located very dissimilarly.

On the yearly average, the diurnal variation of the declination at Key West for the epoch 1864.5 is given by the expression:

$$\begin{aligned} d = &+1'.129 \sin(\theta + 18^\circ 24') + 1'.182 \sin(2\theta + 206^\circ 22') \\ &+0.506 \sin(3\theta + 58\ 03) + 0.151 \sin(4\theta + 279\ 53) \\ &+ \cdots\cdots \end{aligned}$$

How closely these expressions for Los Angeles and Key West represent the observed values of the diurnal variation may be seen from the following differences, or observed minus computed (O—C) values, viz:

Hour.	Los Angeles.	Key West.	Hour.	Los Angeles.	Key West.	Hour.	Los Angeles.	Key West.	Hour.	Los Angeles.	Key West.
	′	′		′	′		′	′		′	′
Midnight	+0.01	—0.01	6^h	—0.11	—0.13	Noon	+0.03	+0.03	18^h	+0.07	+0.03
1^h	— .06	— .06	7^h	— .03	+ .12	13^h	+ .12	+ .05	19^h	.00	— .05
2^h	— .05	— .06	8^h	+ .11	+ .06	14^h	+ .01	.00	20^h	— .07	— .03
3^h	+ .04	+ .06	9^h	+ .09	— .03	15^h	— .09	.00	21^h	— .04	— .01
4^h	+ .13	+ .09	10^h	— .09	— .07	16^h	— .04	— .05	22^h	+ .04	+ .04
5^h	— .12	— .08	11^h	— .09	— .02	17^h	+ .04	+ .07	23^h	+ .08	+ .03

Hence we have the probable error of any single hourly representation for Los Angeles $\pm 0'.06$ and for Key West $\pm 0'.04$ The systematic concurrence of the signs of (O—C) shows that the given expressions are not exhaustive.

The formulæ give the times when in the morning the average declination of the day (mean of 24 hourly readings) is reached, also the times of the daily extreme phases with their amount of deflections, as follows:

		h. m.
At Los Angeles: Time of average declination	. . . .	10 38
At Key West: Time of average declination	. . . .	10 51

		h. m.		′
At Los Angeles:	Time of extreme *easterly* deflection,	8 07;	amount	2.96
	Time of extreme *westerly* deflection,	13 12;	amount	2.86
At Key West:	Time of extreme *easterly* deflection,	8 11;	amount	2.47
	Time of extreme *westerly* deflection,	13 33;	amount	2.24

COMPARISON OF TOTAL SOLAR-DIURNAL VARIATION OF THE MAGNETIC DECLINATION FROM A NUMBER OF PROMINENT STATIONS IN NORTH AMERICA.

The following comparative table of the diurnal variation has been prepared in order to exhibit the changes which the total solar-diurnal variation undergoes with a change of geographical position within the region of North America. The series of observations admitted extend over one or more years, and in no instance have any so-called disturbances been excluded. Had the normal or simply the solar-diurnal variation been tabulated the values would not compare perfectly on account of the more or less arbitrary way in which the disturbances were treated. The year or years of each series is added to admit of a correction for position in the sun-spot period.

The particulars for each station are as follows:

Name.	Latitude.	Longitude (west from Greenwich).		Extent of series.
	° ′	° ′	h. m.	
Key West, Fla.	24 33.1	81 48.5 or	5 27.2	Mar., 1860, to Mar., 1866, exclusive.
Los Angeles, Cal.	34 03.0	118 15.4	7 53.0	Oct., 1882, to Oct., 1889, exclusive.
Washington, D. C.	38 53.6	77 00.6	5 08.0	July, 1840, to June, 1882, inclusive.
Philadelphia, Pa.	39 58.4	75 10.2	5 00.7	Jan., 1840, to June, 1845, inclusive.
Madison, Wis.	43 04.5	89 24.2	5 57.6	Mar., 1877, to Mar., 1878, exclusive.
Toronto, Canada.	43 39.4	79 23.5	5 17.6	July, 1842, to June, 1848, inclusive.
Sitka, Alaska.	57 02.9	135 19.7	9 01.3	Irregular series, 1848 to 1862.
Uglaamie, Point Barrow.	71 17.7	156 39.8	10 26.6	Sept., 1882, to Aug., 1883, inclusive.
Plover Point, Point Barrow.	71 21.4	156 16.1	10 25.1	17 months, 1852–'53–'54.
Fort Rae, Great Slave Lake.	62 38.9	115 13.8	7 40.9	Oct., 1882, to Sept., 1883, inclusive.
Kingua Fjord, Cumberland Sound.	66 35.7	67 19.2	4 29.3	Do.
Fort Conger, Grinnell Land.	81 44.0	64 43.8	4 18.9	Sept., 1881, to Aug., 1882, inclusive.

The order of the stations is that of increasing magnetic inclination, as given at the bottom of the next table.

References to preceding stations.

(1) *Key West, Fla.*—The present discussion, Part II. See also Coast Survey Report for 1874, App. 9.

(2) *Los Angeles, Cal.*—The present discussion, Parts I and II.

(3) *Washington, D. C.*—Pub. Doc. (Senate) 28th Cong., 2nd sess., Dec. 1844, Magnetical and Meteorological Observations made at Washington, D. C., Lieut. J. M. Gilliss, Washington, 1845—Table X, p. 344. [The series is bi-hourly and tabulated for Göttingen mean time; by plotting the results, the values for the whole (even) hours at Washington as well as those for the odd hours were secured.]

(4) *Philadelphia, Pa.*—Coast Survey Report for 1859, p. 294, for diurnal-disturbance variation and Report for 1860, p. 301, for normal solar-diurnal variation; the former was added (algebraically) to the latter, and the 24 values resulting for the whole or total solar-diurnal variation were further reduced to the local whole hours to correct for the observations having been made 19½ minutes later.

(5) *Madison, Wis.*—From my reduction of part of the observations made here; MS. of 1878, Coast and Geodetic Survey archives.

(6) *Toronto, Canada.*—Magnetical and Meteorological Observations, Vol. II, London, 1852, p. xv, Col. E. Sabine.

(7) *Sitka, Alaska.*—Coast and Geodetic Survey Report for 1883, App. 13, p. 347.

(8) *Uglaamie, Alaska.*—Coast and Geodetic Survey Report for 1883, App. 13, p. 346.

(9) *Plover Point, Alaska.*—Philosophical Transactions Royal Society for 1857, Vol. 147, Part II. Table V, p. 509.

(10) *Fort Rae, B. N. A.*—Observations of the International Polar Expeditions, 1882–'83, Fort Rae, London, 1886, pp. 130–141.

(11) *Kingua Fjord.*—Die Internationale Polarforschung, 1882–'83, Kingua Fjord, Berlin, 1886.

(12) *Fort Conger, Grinnell Land.*—International Polar Expedition to Lady Franklin Bay, Grinnell Land, Lieut. A. W. Greely, 2 vol's, Washington, 1888.

Total solar-diurnal variation of the magnetic declination, on the yearly average, at prominent places in North America.

[A + sign indicates a deflection of the north-seeking end of the magnet towards the *east*, a — sign the contrary direction.]

Local mean time.	1. Key West, Fla.	2. Los Angeles, Cal.	3. Washington, D. C.	4. Philadelphia, Pa.	5. Madison, Wis.	6. Toronto, Canada.	7. Sitka, Alaska.	8. Uglaamie, Point Barrow.	9. Plover Point, Point Barrow.	10. Fort Rae, Great Slave Lake.	11. Kingua Fjord, Cumberland Sound.	12. Fort Conger, Grinnell Land.	Average values stations 1 to 6, inclusive.
	′	′	′	′	′	′	′	′	′	′	′	′	′
Midnight.	+0.1	+0.0	+1.0	+0.6	+0.1	+0.8	−0.6	−13.4	−10.8	−12.0	+ 9.2	+32.6	+0.45
1	+0.0	+0.0	+0.7	+0.6	+0.1	+0.6	+0.2	−12.8	− 8.0	−11.0	+11.7	+43.2	+0.35
2	−0.0	+0.1	+0.7	+0.5	0.0	+0.5	+1.0	− 4.9	− 1.9	− 6.6	+15.8	+45.1	+0.05
3	+0.1	+0.2	+0.9	+0.6	+0.2	+0.8	+1.4	+ 3.3	+ 3.6	+ 0.8	+18.0	+41.2	+0.07
4	+0.2	+0.3	+1.2	+1.0	+0.5	+1.2	+2.0	+ 6.2	+10.9	+ 7.4	+19.1	+25.7	+0.75
5	+0.4	+0.6	+1.7	+1.5	+1.0	+1.8	+2.9	+14.3	+16.6	+13.6	+19.3	+31.6	+1.19
6	+1.0	+1.3	+2.1	+2.1	+1.4	+2.7	+4.2	+21.6	+19.3	+21.0	+20.1*	+19.7	+1.79
7	+2.1	+2.4	+2.8	+3.3	+2.6	+3.5	+5.3	+26.1	+27.1*	+26.2	+19.9	+26.6	+2.80
8	+2.5*	+3.1*	+3.2*	+3.5*	+3.2*	+3.8*	+6.0*	+26.7*	+27.0	+29.4*	+17.4	+18.7	+3.24*
9	+2.2	+2.6	+2.3	+2.8	+3.0	+3.0	+5.3	+26.1	+19.9	+25.5	+10.8	+ 1.2	+2.67
10	+1.1	+1.1	+0.9	+0.8	+1.7	−0.8	+3.0	+ 9.9	+ 9.3	+16.8	+ 3.7	−12.7	+1.09
11	−0.2	−0.8	−1.3	−1.6	−0.7	−2.0	+0.6	+ 1.4	− 0.4	+ 8.0	+ 1.3	−21.4	−1.08
Noon.	−1.4	−2.2	−3.2	−3.4	−2.5	−4.2	−2.1	− 5.9	− 8.2	− 0.9	− 9.0	−40.7	−2.80
13	−2.1	−2.7*	−4.3*	−4.3*	−3.5*	−5.0*	−3.2	− 7.3	−10.7	− 4.0	−15.1	−45.6	−3.63*
14	−2.2*	−2.6	−4.3*	−4.1	−3.5*	−4.8	−4.2	− 7.7	− 9.8	− 8.1	−21.2	−49.2	−3.56
15	−1.9	−2.0	−3.5	−3.1	−2.6	−3.8	−4.6*	− 7.3	− 9.9	−10.6	−20.4	−45.8	−2.80
16	−1.3	−1.1	−2.5	−2.2	−1.6	−2.5	−4.6	− 9.1	− 9.8	−11.3	−20.6	−53.7	−1.85
17	−0.8	−0.5	−1.5	−1.0	−0.7	−1.3	−3.8	− 9.9	−10.2	−12.1	−23.6	−23.7	−0.95
18	−0.4	−0.2	−0.8	−0.4	−0.2	−0.3	−3.2	− 9.9	− 9.7	−12.9	−19.4	−17.3	−0.36
19	−0.2	−0.0	0.0	+0.0	+0.2	+0.2	−2.4	− 8.4	− 8.4	−12.5	−16.1	−27.2	+0.05
20	+0.1	+0.1	+0.6	+0.8	+0.2	+0.7	−1.4	− 6.0	− 9.0	−11.0	−15.5	− 3.5	+0.44
21	+0.2	+0.1	+1.0	+0.6	+0.6	+1.2	−0.8	− 8.1	− 7.5	−12.0	− 8.8	+ 3.5	+0.64
22	+0.2	+0.1	+1.1	+1.2	+0.7	+1.3	−0.4	−10.9	− 7.9	−11.9	− 0.6	+22.4	+0.79
23	+0.2	+0.1	+1.1	+0.7	+0.2	+1.2	−0.6	− 9.1	−11.5	−11.9	+ 3.9	+30.0	+0.60
Midnight.	+0.1	+0.0	+1.0	+0.6	+0.1	+0.8	−0.6	−13.4	−10.8	−12.0	+ 9.2	+32.6	+0.45
Magnetic inclination at epoch (mean date of series).													
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	
$\theta =$	54 32	59 30	71 19	71 58	73 56	75 15	75 55	81 24	81 36	82 54	83 51	85 01	

N. B.—Certain extreme tabular values are marked by an asterisk.

A perusal of the tabular values for the localities marked 1 to 6, and which represent all that part of the United States and Canada which lies south of the forty-ninth parallel, shows a very close accord of the diurnal variation, having an average maximum easterly deflection of 3′.2 at about 7ʰ.9 in the morning and an average maximum westerly deflection of 3′.6 at about 1ʰ.4 in the afternoon, although the dip varies 20¾° between these geographical limits. At Sitka the range reaches already 10′.6 and beyond, with a dip of 80° and more, the diurnal range rapidly rises, attaining 1° 40′ nearly at Fort Conger. At the higher (magnetic) latitude stations there is a tendency to shift the morning extreme to an *earlier* hour and the afternoon opposite extreme to a later hour than the corresponding epochs as given above. A remarkable feature in the diurnal variation (yearly average) is the close correspondence in the local times when the magnet passes the average magnetic meridian (tabular values passing from + to — sign); these epochs are:

	h. m.
For Key West	10 51
Los Angeles	10 35
Washington	10 25
Philadelphia	10 20
Madison	10 43
Toronto	10 17
Average	10 32

and we have seen that this time is subject to an annual inequality which at Los Angeles in the summer months displaces it to about $10^h\ 00^m$ and in the winter months to about $11^h\ 30^m$.

The tabular values are exhibited on accompanying diagram (illustration No. 22).

The annual inequalities of the diurnal variation.—These inequalities consist in a systematic change in the form and the magnitude of the solar-diurnal variation, as is clearly exhibited in the accompanying illustration (No. 23) by lines of dashes connecting the corresponding phases from month to month. The magnitude of the change at the several hours is best shown by the contrast of the diurnal variation in the half year when the sun is in north declination and the half year when in south declination. Thus by subtracting the annual mean for any hour from the six-monthly mean April to September, inclusive, and again from the sixth-monthly mean October to March, inclusive, for the same hour, we get the following table of the semiannual inequality at the several hours:

Semiannual inequality in the daily variation during the six months when the sun is north of the equator (or with the signs reversed when south of the equator).

[A + sign indicates deflection to the *east*.]

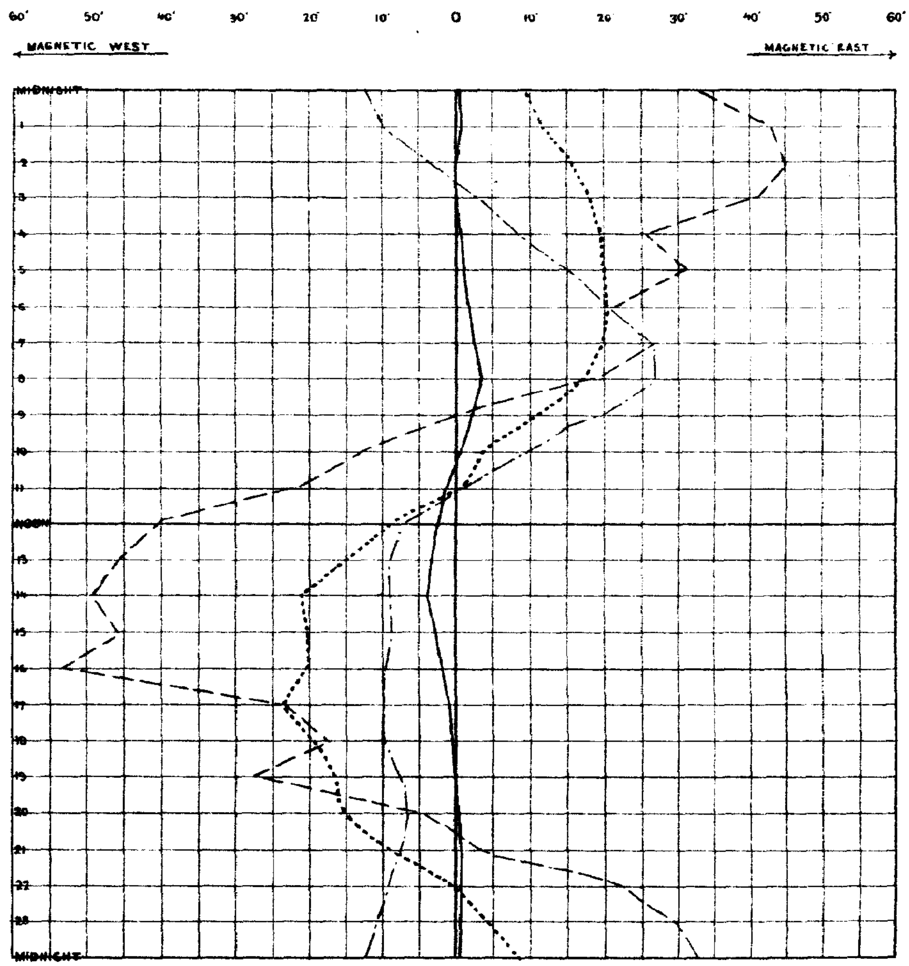
	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
	′	′	′	′	′	′	′	′	′	′	′	′
Los Angeles.	0.00	+0.05	+0.16	+0.31	+0.54	+1.07	+1.50	+1.20	+0.32	—0.68	—1.00	—0.78
Key West.	+0.14	+0.23	+0.29	+0.35	+0.45	+0.94	+1.43	+1.04	+0.20	—0.55	—0.83	—0.77
	13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.
	′	′	′	′	′	′	′	′	′	′	′	′
Los Angeles.	—0.56	—0.44	—0.29	—0.19	—0.15	—0.15	—0.23	—0.27	—0.23	—0.19	—0.07	—0.04
Key West.	—0.68	—0.61	—0.45	—0.30	—0.11	—0.07	—0.15	—0.21	—0.21	—0.08	—0.01	+0.06

Illustration No. 23 gives the graphical representation of this inequality for Los Angeles. The diagram for Key West would differ but slightly from this. We have for both places the hour 7 showing the maximum change of 3′ nearly, and the hour 11 as the one of the next greatest change of 2¾′ about. The direction of the magnet is most nearly constant throughout the year about $9^h\ 20^m$, and again near 1^h, also near 18^h. In Coast Survey Report for 1860, Appendix No. 23, being Part II of the discussion of the magnetic observations at Girard College, Philadelphia (1840-'45), by Dr. A. D. Bache, we have given on Plate VII several similar diagrams, all of which have a close family resemblance.

The following table shows the annual inequality in the phases of the diurnal variation of the

B

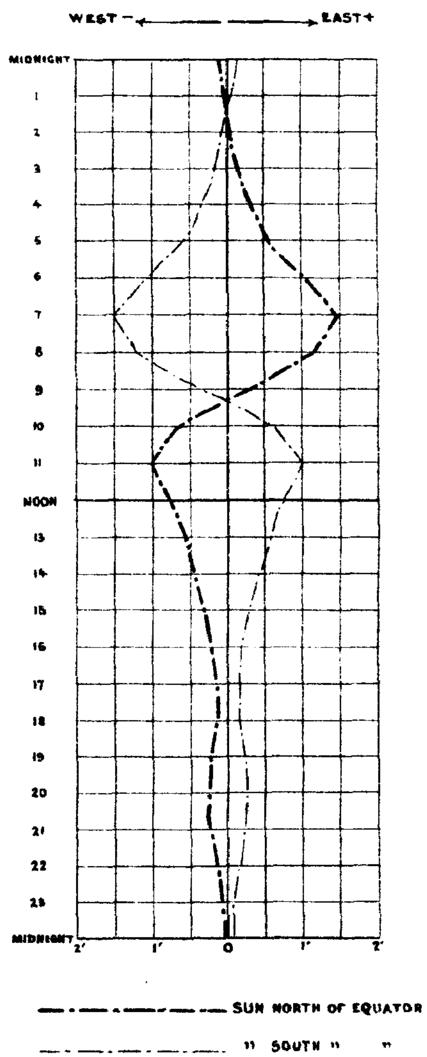
COMPARATIVE DIAGRAM OF THE
TOTAL SOLAR-DIURNAL VARIATION OF THE MAGNETIC DECLINATION
FROM YEARLY AVERAGES.



MEAN OF 6 STATIONS, DIP LESS THAN 75½°
UGLAAMIE & PLOVER PT., PT. BARROW
KINGUA FJORD, CUMBERLAND SOUND
FORT CONGER, GRINNELL LAND

C

SEMI-ANNUAL INEQUALITY IN THE DIURNAL VARIATION OF THE DECLINATION.



declination for the three places, Los Angeles, Key West (Report for 1874, p. 127), and Philadelphia (Report for 1860, pp. 308, 309).

Month.	Epoch of greatest eastern deflection at—			Epoch of greatest western deflection at—			Duration of westerly motion at—			Average daily range.		
	L. A.	K. W.	P.	L. A.	K. W.	P.	L. A.	K. W.	P.	L. A.	K. W.	P.
	h m	*h m*	*h m*	*h m*	*h m*	*h m*	*h m*	*h m*	*h m*	′	′	′
January.	9 40	9 40	8 58	13 25	14 20	13 27	3 45	4 40	4 29	5. 2	5. 0	6. 0
February.	9 30	9 30	8 34	13 50	14 10	13 32	4 20	4 40	4 58	3. 9	3. 8	5. 8
March.	8 40	8 10	8 07	13 50	13 40	13 34	5 10	5 30	5 27	6. 6	4. 7	7. 8
April.	8 05	8 00	8 12	14 00	14 00	13 27	5 55	6 00	5 15	7. 1	6. 0	9. 3
May.	7 40	7 30	7 29	13 05	13 30	13 21	5 25	6 00	5 52	7. 3	6. 4	10. 0
June.	7 40	7 30	7 33	13 05	13 40	13 20	5 25	6 10	5 47	7. 6	6. 8	10. 3
July.	7 40	7 30	7 36	13 00	14 00	13 28	5 20	6 30	5 52	8. 5	6. 4	11. 0
August.	7 45	7 20	7 18	12 45	13 40	13 05	5 00	6 20	5 47	8. 7	8. 1	12. 2
September.	7 30	7 30	7 30	12 35	12 40	12 45	5 05	5 10	5 15	6. 7	6. 8	10. 3
October.	8 05	8 00	8 00	12 40	13 10	13 17	4 35	5 10	5 17	5. 7	3. 9	5. 4
November.	8 40	9 00	7 54	12 50	13 00	13 08	4 10	4 00	5 14	4. 2	2. 9	4. 8
December.	9 30	9 40	8 54	13 25	14 30	13 40	3 55	4 50	4 46	3. 8	3. 7	4. 8
Yearly average.	8 22	8 17	8 00	13 12	13 42	13 20	4 50	5 25	5 20	6. 3	5. 4	8. 1

The Los Angeles tabular times and ranges were derived from a graphical process; the times are subject to an uncertainty of a quarter of an hour. It appears that the morning easterly extreme is reached earliest in September ($7\frac{1}{2}^h$) and latest in January ($9\frac{3}{4}^h$) and the afternoon opposite extreme earliest in September ($12\frac{1}{2}^h$) and latest in March (14^h); these extremes lying farthest apart in April (6^h) and closest together in January ($3\frac{3}{4}^h$); the daily range seems to be a minimum about January (5′) and a maximum about August (11′).

The following table shows, for each month, the annual inequality in the times when the average declination of the day is reached:

Month.	Epoch of average daily value of the declination.					
	Motion westward.			Motion eastward.		
	L. A.	K. W.	P.	L. A.	K. W.	P.
	h m	*h m*	*h m*	*h*	*h*	*h*
January.	11 37	11 48	10 52	17. 7	18. 8	19. 1
February.	11 31	11 49	10 52	18. 4	19. 8	19. 4
March.	11 03	11 14	10 46	20. 3	20. 7	19. 5
April.	10 33	10 39	10 34	22. 4	21. 1	19. 7
May.	10 08	10 20	10 19	22. 3(?)	22. 2	19. 0
June.	10 13	10 31	10 25	23. 7	21. 7	20. 4
July.	1[illegible] 16	10 27	10 30	22. 9(?)	21. 9	21. 5
August.	10 00	10 10	10 10	21. 8(?)	21. 3	20. 7
September.	9 55	10 08	9 58	24. 9	19. 9(?)	18. 7
October.	10 20	10 25	10 30	19. 1	19. 4	17. 4
November.	10 45	11 12	10 16	17. 4	18. 0	18. 1
December.	11 31	11 59	10 50	17. 0	18. 2	18. 3
Yearly average.	10 39	10 53	10 30	20. 7	20. 2	19. 3

Observations for declination are frequently made about the times of the two principal extremes of the diurnal variation, and the mean of the two directions at these times is then taken to represent the daily mean (from 24 hourly readings). How near this assumption approaches the truth may be judged from the following comparisons:

Month.	Los Angeles, Cal.						Key West, Fla.			Philadelphia, Pa.
	Extreme readings from curve.		Mean.	Monthly mean from 24 hours.	Difference from true monthly mean.		Extremes from mean of day.		Mean or difference from 24 hours.	Mean of extremes or difference from 24 hours.*
	a. m.	p. m.					a. m.	p. m.		
	d	d	d	d	d	′	′	′	′	′
January.	73.5	67.0	70.2	69.8	+0.4	+0.3	+2.8	−2.0	+0.4	+0.5
February.	71.6	66.7	69.2	69.3	−0.1	−0.1	+2.0	−1.6	+0.2	+0.2
March.	72.9	64.6	68.8	68.6	+0.2	+0.2	+2.6	−2.3	+0.1	+0.2
April.	73.4	64.4	68.9	68.5	+0.4	+0.3	+3.0	−2.9	0.0	+0.6
May.	73.7	64.6	69.2	68.5	+0.7	+0.6	+3.6	−2.7	+0.4	+0.1
June.	73.6	64.0	68.8	68.3	+0.5	+0.4	+3.7	−2.9	+0.4	−0.1
July.	74.4	63.6	69.0	68.3	+0.7	+0.6	+3.7	−2.7	+0.5	0.0
August.	74.9	64.0	69.4	68.6	+0.8	+0.6	+3.7	−3.0	+0.4	+0.3
September.	73.5	65.1	69.3	69.0	+0.3	+0.2	+3.8	−3.0	+0.4	+0.4
October.	73.5	66.3	69.9	69.7	+0.2	+0.2	+2.2	−1.7	+0.3	+0.5
November.	72.5	67.2	69.8	69.8	0.0	0.0	+1.8	−1.2	+0.3	+0.5
December.	72.5	67.6	70.0	69.9	+0.1	+0.1	+2.2	−1.5	+0.3	+0.7
Year.						+0.3			+0.3	+0.3

* C. S. Rep., 1860, p. 309.

Both at Los Angeles and at Key West the morning or eastern elongation exceeds in magnitude the afternoon or western elongation, the mean of the two elongations, therefore, is too great compared with the mean of the day, hence *east* declination when deduced from the mean of the two daily extremes must be *diminished* by 0′.3. On the other hand, at Philadelphia, the morning or eastern elongation is the smaller, hence the *west* declination (deduced from the extremes) at that place needs to be diminished; the amount, however, is the same. Generally, therefore, this correction to results from ordinary field work may be neglected.

Long-period inequalities in the total solar-diurnal variation of the declination.—The fact that the annual mean of the diurnal range follows closely the periodic changes in the frequency of the sun-spots was noted as early as 1852, *i. e.*, a large declination range was found to correspond to the time of great activity of the sun in the production of spots and *vice versa.* It remains to show this dependence or relation in the case of the observations at Los Angeles. In consequence of the annual inequality in the solar-diurnal range, the yearly average values of the diurnal range are alone directly available for comparison with Dr. R. Wolf's relative numbers of spot frequency and extent. The latter numbers were taken from his latest publication in the "Vierteljahrschrift der Naturforschenden Gesellschaft," in Zürich; Erstes Heft, 1888, Table III, viz:

Table of monthly values of adjusted relative numbers of sun-spot activity.

Year.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	Annual mean.
1876	. .	. .	. .	. .	. .	. .	11.7	11.9	10.8	10.6	11.8	13.0	11.7
1877	13.1	12.6	12.7	12.7	12.6	12.5	11.4	10.4	10.1	9.8	8.0	7.1	11.1
1878	6.5	6.0	5.3	4.6	4.0	3.4	3.3	3.0	2.4	2.3	2.4	2.2	3.8
1879	2.5	3.2	3.7	4.2	5.0	5.7	6.9	9.0	10.9	12.3	13.7	15.8	7.7
1880	17.7	19.8	23.9	26.8	29.7	31.3	32.8	34.4	36.5	39.5	41.6	43.6	31.5
1881	46.9	49.7	49.6	49.9	51.8	54.2	54.6	55.6	57.0	59.5	62.2	62.4	54.4
1882	60.4	58.4	57.9	57.8	58.9	59.9	60.4	60.1	58.1	56.5	54.6	54.5	58.1
1883	57.3	59.0	59.0	59.8	60.8	62.3	65.0	67.9	71.4	73.0	74.2	74.6	65.3
1884	72.4	71.7	72.4	71.3	67.8	64.6	61.4	58.8	56.6	54.2	53.6	55.2	63.3
1885	57.1	57.4	56.2	54.9	54.4	53.2	51.6	49.2	47.6	47.4	45.2	41.1	51.3
1886	37.2	34.3	32.2	30.2	27.5	25.8	24.6	23.2	20.5	16.7	15.0	13.8	25.1
1887	13.1	13.0	12.6	11.9	12.1	12.7	. .	. .	. .	. .	. .	. .	(13.1)
The remainder for the year 1887 was taken from the same publication, the numbers being the mean of 3 series. Those for July, August, and December were reduced by 1.2 in order that the annual mean should be preserved as given by Dr. Wolf. The series of numbers for 1888 was copied from Astr. Nachrichten No. 2887 and the numbers for 1889 from No. 2959. These relative numbers are still subject to corrections.													
1887	. .	. .	. .	. .	. .	. .	23.1	20.0	7.4	6.5	5.7	19.4	(13.1)
1888	13.0	7.0	6.3	3.9	7.8	6.5	1.9	1.9	7.8	2.0	12.9	9.9	(6.7)
1889	1.0	7.9	6.3	4.9	2.4	7.0	8.0	20.6	6.3	0.0	0.0	5.7	(5.8)

These numbers will answer for our purpose as well as more refined measures, which depend on the amount of spotted area depicted on the daily photographs of the sun.*

From these numbers it will be seen that the Los Angeles magnetic observations commenced shortly *before* the last maximum sun-spot development and extend beyond the minimum recently attained, either in the last quarter of 1888 or more probably in 1889. In the column below headed R the annual mean values of the relative numbers are given for the several observing years, October to October.

The declination range was obtained by collating the monthly means of scale-readings for each of the hours 6 to 15, also, for mean of day, and forming average values for each of the 7 years of observation. The deflection (+ to the east) for each hour is found by subtracting the mean of the day from that of each hour. The scale-divisions were converted into minutes of arc and the hourly results were plotted on a suitable scale in order to find the intermediate extreme values as given in the table below.

Annual mean values of differences of declination from the daily mean for the hours 6 to 15 inclusive, showing dependence of the diurnal variation of the declination on the sun-spot cycle.

[A + sign indicates deflection to the *east*.]

Year Oct. to Oct.	6^h	7^h	8^h	9^h	10^h	11^h	Noon.	13^h	14^h	15^h	Maximum morning deflection.	Maximum afternoon deflection.	Daily range.	R.
	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	′	
1882–'83	+1.6	+3.2	+4.1	+3.6	+1.6	−0.9	−2.8	−3.6	−3.6	−2.8	+4.3	−3.8	6.5	60.7
1883–'84	+2.1	+3.7	+4.8	+4.1	+1.8	−0.9	−2.9	−3.8	−3.7	−2.9	+5.0	−3.9	7.1	68.2
1884–'85	+1.8	+3.3	+4.5	+4.0	+1.9	−0.7	−2.7	−3.7	−3.6	−2.9	+4.8	−3.8	6.9	53.7
1885–'86	+1.8	+3.0	+3.7	+3.2	+1.3	−0.8	−2.5	−3.3	−3.2	−2.5	+3.8	−3.4	5.8	32.4
1886–'87	+1.4	+2.6	+3.4	+2.9	+1.2	−1.0	−2.6	−3.2	−3.0	−2.1	+3.5	−3.3	5.4	14.3
1887–'88	+1.4	+2.7	+3.4	+2.8	+0.8	−1.3	−2.9	−3.4	−3.0	−2.1	+3.4	−3.4	5.4	7.3
1888–'89	+1.5	+2.5	+3.2	+2.5	+0.7	−1.2	−2.7	−3.2	−2.8	−2.0	+3.2	−3.2	5.1	7.4

* In this connection it may be stated that late researches indicate that the periodic changes of the sun-spots are accompanied by characteristic changes in the solar corona.

The diurnal range, as well as its component parts, the morning easterly extreme and the afternoon westerly extreme, are thus seen to follow the variations in the sun-spot activity. This relation may be expressed in the form:

$$r = a + b\,R = 5'.12 + 0.027\ R,$$

which represents the observed range as follows:

Year Oct. to Oct.	Computed range.	Observed less computed range.
	′	′
1882–'83	6.8	−0.3
1883–'84	7.0	+0.1
1884–'85	6.6	+0.3
1885–'86	6.0	−0.2
1886–'87	5.5	−0.1
1887–'88	5.3	+0.1
1888–'89	5.3	−0.2

For the sake of comparison I give here also similar expressions between the variations in the sun-spot cycle and the declination ranges of the magnetic observations at ***Philadelphia*** by Dr. A. D. Bache, which series includes a year of *minimum* solar activity and the magnetic observations at *Key West*, which begin with a year of *maximum* activity. The observed declination ranges are taken from Coast Survey Reports for 1859, p. 286, and for 1874, p. 130.

For Philadelphia, 1840–'45, inclusive.

$r = 6'.89 + 0.037\ R.$

Year.	R.	Observed daily range.	Computed range.	O.–C.
		′	′	′
1840	61.8	9.08	9.18	−0.10
1841	38.5	8.06	8.31	−0.25
1842	23.0	7.83	7.74	+0.09
1843	13.1	7.46	7.38	+0.08
1844	19.3	7.51	7.60	−0.09
1845	38.3	8.53	8.31	+0.22

For Key West, 1860–'65, inclusive.

$r = 2'.39 + 0.042\ R.$

Year.	R.	Observed daily range.	Computed range.	O.–C.
		′	′	′
1860	94.8	6.4	6.37	+0.03
1861	77.7	5.6	5.65	−0.05
1862	61.0	5.2	4.95	+0.25
1863	45.4	4.2	4.30	−0.10
1864	45.2	4.0	4.29	−0.29
1865	31.4	3.9	3.71	+0.19

The adjacent diagram (illustration No. 24) further illustrates the relation existing between sun-spots and diurnal range of declination. The diagram shows plainly that the morning or easterly deflection is subject to a greater extent to the influence of the sun-spots than the afternoon or opposite deflection, and the same is true, though less marked, for Key West (Coast Survey Report for 1874, App. 9, p. 129.)*

Ratio of declination ranges in years of extremes of sun-spot activity.—This ratio of the maximum to the minimum declination range is for Los Angeles, 1.37; for Key West, 1.64; and for Toronto, Canada, 1.51 (Younghusband and Lefroy). Our series is too short to investigate the lagging behind of the magnetic ranges as noted elsewhere.

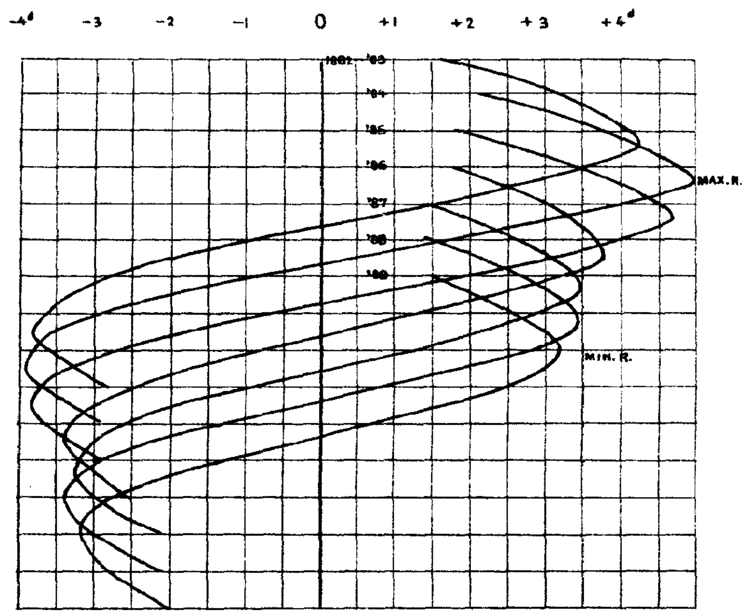
So far as known there are at least two dominant inequalities of long period in the observed productivity of sun-spots, of which the shorter one, or the eleven-and-one-third-year period, is the best determined and the only one available for comparison with our series of magnetic observations. This period is subject to considerable fluctuations as to length and development to which

*It may be noted here that during the period 1883–'88, the spots as well as the prominences were more numerous in the sun's southern hemisphere than in the northern one.—E. B. Frost in "Sid. Mess.," March, 1890.

D

INEQUALITY IN RANGE OF DIURNAL VARIATION

DEPENDING ON THE SUN-SPOT CYCLE.



the motion of the magnet apparently conforms, and since there can be no doubt of the complex composition of the sun-spot curve we must, likewise, consider the observed daily motion of the magnet as governed by a number of laws, each cause contributing its effect to the resultant direction.

Separation and analysis of the disturbances; diurnal disturbance-variation and solar-diurnal variation of the declination.—Any observation deviating from what is taken as the normal solar-diurnal variation may be considered a disturbance; more frequently, however, we designate by a disturbance a large deviation from the daily normal motion of the magnet and, in particular, those sudden deflections which simultaneously affect large areas of the earth's surface. We may also distinguish at any one station isolated disturbances and perturbed motions persisting for one or several days.

For the analysis of the disturbances there is as yet no general agreement as to treatment, and it is largely a matter of individual experience what process would for any location be most advantageous. A method applicable for continuous registered data may fail for eye-observations made at certain hours, and another may apply to an equatorial or middle-latitude station, but fail in the higher latitudes, where the horizontal component of the magnetic force is very weak and consequently the diurnal variation is much exaggerated and apparently irregular.

Of the several methods proposed by Sabine, Lloyd, and Broun, and later on by Dr. Wild and J. P. Van der Stok, we give the preference to the practical and hitherto successful method of Sabine, at least as far as it refers to the elucidation of the laws of the disturbances, but it is proposed here to compare his values of the normal diurnal variation with the values which can be derived, according to Dr. Wild's proposition, by a selection of all the magnetically quiet days, as exhibited by the photographic traces and by comparing their results. Van der Stok's method is regarded as too laborious to be profitably employed in the present case. There is necessarily some arbitrary step in every method, either as to the limit of what should be regarded a disturbance or what degree of smoothness or shape should constitute a normal curve, since we can not know how far disturbances, not recognizable by their size, may affect this shape.

Separation and analysis of the larger disturbances of the declination.—In accordance with the method proposed for discussion,* the first step is to settle upon the inferior limit of deviation beyond which an observed value will be marked a disturbance and will be excluded from the mean of the month; for this we need the *mean* error, m, of an observation found by comparing each hourly value with its monthly mean from n values and noting the difference v; we then have

$$m=\sqrt{\frac{[vv]}{n-1}}$$

or more simply,

$$m=\frac{1.253[v}{\sqrt{n^2-n}}$$

for which we can also write, approximately,

$$m=\frac{1.253[v}{n-0.5}$$

since n equals either 28, 29, 30, or 31.

For a preliminary estimate † we may put $m=\frac{1}{5}$ of the extreme range of the values for any one hour, for that hour. In determining m it is requisite to include 24 hours, or at least symmetrically arranged hours, in order to eliminate the effect of the diurnal variation of the disturbances, and

* See also remarks on the method in "Report upon magnetic observations made at the U. S. Polar station, Ooglaamie, Point Barrow, Alaska, 1881–'82–'83," Appendix 13, Coast and Geodetic Survey Report for 1883, pp. 348–349, and "Contributions to terrestrial magnetism, Appendix No. 139, pp. 539–548, Vol. 2 of Report on the Proceedings of the U. S. Expedition to Lady Franklin Bay, Grinnell Land," by Lieut. A. W. Greely, Washington, 1888. [N. B.—On page 610 of that report the numbers in column headed "Magnetic moment in C. G. S. units" should be canceled as erroneous.]

† Taking the probable error approximately equal to one-seventh of the greatest range of the errors of observation.

likewise to use the middle year of the series (in our case) to eliminate the sun-spot inequality, and for that year to use every month to eliminate the annual inequality in the disturbances.

For Los Angeles, 24 values were obtained, viz, one value each for October, 1885, at 1^h and 13^h, for November, at 2^h and 14^h, for December, at 3^h and 15^h, for January, 1886, 4^h and 16^h, and so on to September, 1886, at noon and midnight; whence average value,

$$m = \pm 1.3 \text{ scale-divisions.}$$

[The rough method above indicated gave ± 1.5]

A first trial was made with the limit $1\frac{1}{2}\,m$ or $\pm$ 2 divisions (according to Lloyd), but this was found to separate rather more values than was desirable, in other words it cut too deep into the diurnal curve, and it was decided to adopt $\pm$ 2.5 divisions, or $\pm 2'.0$, for our limit; hence all observations differing more than that amount from their respective monthly means were marked as (large) disturbances; on the average every fifteenth was so marked.

The limit adopted by me for Key West series was $\pm 2'.6$; this separated 1 in every 34 observations. At Philadelphia Dr. Bache adopted the limit $\pm 3'.6$, which separated 1 in 10 observations. At Toronto at first $\pm 3'.6$, afterwards $\pm 5'.0$ was taken as the limit, the latter separating 1 in 17 observations.

In the hourly record of scale-readings all values differing more than 2.5 scale-divisions from their respective monthly means for that hour were considered (large) disturbances and were marked with an asterisk. The bottom line of that record contains the resulting monthly normals for each hour after these disturbed values had been separated.* The whole of this work was performed by Mr. L. A. Bauer of the Computing Division. The total number of disturbed hourly values thus separated was 4 070, and, since the total number of observations is 61 344, we have the ratio 1 to 15 very nearly.

In the following analysis of the (larger) disturbances we shall consider them in reference to number and to (relative) magnitude, and shall also distinguish between eastern and western disturbances.

Long-period inequality of disturbances in declination.—In the following tables of the number and magnitude of the (larger) disturbances for each of the 7 years the observing year begins with October.

Year.	Number of disturbances.				Aggregate amount of disturbances.				Average magnitude of disturbances.		
	West.	East.	Total.	Ratio to mean.	West.	East.	Total.	Ratio to mean.	West.	East.	Total.
					d.	d.	d.		′	′	′
1882–'83.	386	386	772	1.33	1671	1765	3436	1.46	3.46	3.66	3.56
1883–'84.	346	365	711	1.22	1319	1486	2805	1.19	3.05	3.26	3.16
1884–'85.	292	332	624	1.07	1163	1408	2571	1.10	3.18	3.39	3.30
1885–'86.	289	309	598	1.03	1093	1263	2356	1.00	3.02	3.27	3.15
1886–'87.	269	281	550	0.95	1000	1127	2127	0.90	2.98	3.21	3.10
1887–'88.	220	289	509	0.87	845	1160	2005	0.85	3.07	3.22	3.16
1888–'89.	152	154	306	0.53	536	634	1170	0.50	2.82	3.30	3.06
Sum.	1954	2116	4070		7627	8843	16470		3.12	3.34	

These tables lead to the following conclusions: (*a*) The number of disturbances, whether westerly or easterly, as also their magnitudes follow the law of the sun-spot cycle. This is well shown by the ratios, less so by the average magnitude of the deflection when compared with the

* Not unfrequently the monthly means, for any hour, had to be slightly changed more than once in consequence of the exclusion of the disturbed value or values for that hour. They became normals only after the above final condition was reached.

values of R previously given. (*b*) The number of disturbances as well as their aggregate amount is nearly three times as great in the year of maximum sun-spots as in the year of minimum sun-spots. (*c*) The number of disturbances which deflect the north-seeking end of the magnet to the eastward is greater than those which deflect it to the westward in the proportion of 1.08 to 1. The same superiority in number of the easterly deflections was found at Toronto, Canada (1841–'48), ratio 1.17 to 1, and at Key West, Fla. (1860–'66),* ratio 1.33 to 1, and at Lady Franklin Bay (Lieutenant Greely's expedition), 1882–'83, the ratio was 1.30 to 1. (*d*) The aggregate magnitude of the easterly deflections is greater than that of the westerly, in the following proportions:

Los Angeles, Cal.,	1.16 to 1
Key West, Fla.,	1.43 to 1
Toronto, Can.,	1.40 to 1
Point Barrow, Alaska,	1.63 to 1 (Maguire's series of 1852–'53–'54.)
Port Kennedy, Arctic regions,	1.85 to 1
Carlton Fort, Brit. Poss., N. A.,	1.74 to 1
Lady Franklin Bay, Arctic regions,	1.06 to 1

The preponderance of the easterly over the westerly disturbances, both in number and magnitude, thus appears to be characteristic of North America.

The annual inequality of disturbances in declination.—Number and aggregate amount of disturbances in each month and ratios to average annual values, from the seven-year series.

Month.	Number of disturbances.					Aggregate amount of disturbances.					Average magnitude of all.
	West.	East.	Ratio.		Mean ratio.	West.	East.	Ratio.		Mean ratio.	
			W.	E.				W.	E.		
						d.	d.				′
Oct.	137	162	0.84	0.92	0.88	606	686	0.95	0.93	0.94	3.46
Nov.	185	188	1.14	1.07	1.10	902	990	1.42	1.34	1.38	4.06
Dec. (W. S.).	86	89	0.53	0.50	0.52	343	356	0.54	0.48	0.51	3.19
Jan.	180	120	1.11	0.68	0.89	684	508	1.08	0.69	0.88	3.18
Feb.	143	123	0.88	0.70	0.79	548	504	0.86	0.68	0.77	3.17
Mar. (V. E.).	203	201	1.24	1.14	1.19	761	818	1.20	1.11	1.16	3.13
Apr.	186	205	1.14	1.16	1.15	692	812	1.09	1.10	1.10	3.08
May	154	207	0.95	1.18	1.06	606	884	0.95	1.20	1.08	3.30
June (S. S.).	161	205	0.99	1.16	1.07	589	786	0.93	1.07	1.00	3.01
July	165	190	1.01	1.08	1.05	594	739	0.93	1.01	0.97	3.01
Aug.	157	200	0.96	1.13	1.05	570	819	0.90	1.11	1.00	3.11
Sept. (A. E.).	197	226	1.21	1.28	1.25	732	941	1.15	1.28	1.22	3.17

From these tables we can draw the following conclusions: (*a*) The distribution of the westerly and easterly disturbances over the several months of the year is the same whether we regard their number or their magnitude. This is plainly shown by the mean ratios. (*b*) The law of the distribution of the disturbances in the yearly cycle shows maxima in the equinoctial months (marked V. E. and A. E.), with September preponderating over March, and minima in the solstitial months (marked W. S. and S. S.), with the most decided minimum in December, but an indifferent value in June. This would indicate a semiannual variation, rendering the December value lower and the June value higher than they otherwise would be. The same law of number of disturbances as depending on the season of the year holds for Philadelphia, Key West, and Toronto, and any

*C. S. Report for 1874, p. 121; at Philadelphia (1840–'45), the result was indecisive.

apparent displacement of one month earlier or later than that indicated by the position of the sun could easily be accounted for by an insufficient number of observations. (*c*) It would also appear that the December minimum for stations in the northern hemisphere corresponds to the June minimum at stations in the southern hemisphere.* In other words, these minima occur in the cold season of the year. Likewise there is reason to believe that the superior and inferior maxima for the northern hemisphere exchange places in the southern hemisphere. (*d*) The excess of the easterly over the westerly disturbances is *greater* in the summer months (April to September inclusive) than in the winter months (October to March inclusive). In the former season the excess is 213, in the latter season −51; *i. e.*, in winter the westerly disturbances prevail. This is also the case for Toronto and for Key West. The respective num bers for Key West are 172 and 32, there being but one month (March) in which westerly disturbances exceed in number those of opposite direction, while at Los Angeles there were three such months (J anuary, February, and March).

The diurnal inequality of the disturbances in declination.

Local hours.	Number of disturbances.						Aggregate amount of disturbances.					
	West.	East.	Excess of easterly disturb-ances.	Ratios to mean value.			West.	East.	Excess of easterly disturb-ances.	Ratios to mean value.		
				W.	E.	All.				W.	E.	All.
	d.	*d.*	*d.*				*d.*	*d.*	*d.*			
1	48	127	+ 79	0.59	1.44	1.03	181	566	+385	0.57	1.54	1.09
2	55	102	+ 47	0.68	1.16	0.93	239	507	+268	0.75	1.38	1.09
3	52	99	+ 47	0.64	1.12	0.89	244	459	+215	0.77	1.25	1.03
4	66	65	− 1	0.81	0.74	0.77	278	277	− 1	0.87	0.75	0.81
5	81	64	− 17	0.99	0.73	0.86	342	242	−100	1.07	0.66	0.85
6	86	37	− 49	1.06	0.42	0.73	376	126	−250	1.18	0.34	0.73
7	119	76	− 43	1.46	0.86	1.15	487	260	−227	1.53	0.70	1.09
8	156	97	− 59	1.92	1.10	1.50	654	338	−316	2.06	0.92	1.45
9	169	121	− 48	2.08	1.37	1.71	686	429	−257	2.16	1.17	1.63
10	201	123	− 78	2.47	1.39	1.91	779	420	−359	2.45	1.14	1.75
11	197	110	− 87	2.42	1.25	1.81	728	367	−361	2.29	1.00	1.59
Noon.	154	86	− 68	1.89	0.97	1.41	578	315	−263	1.82	0.86	1.30
13	132	79	− 53	1.62	0.90	1.24	460	277	−183	1.45	0.75	1.07
14	115	69	− 46	1.41	0.78	1.08	414	231	−183	1.30	0.63	0.94
15	89	41	− 48	1.09	0.46	0.77	322	131	−191	1.02	0.35	0.66
16	65	29	− 36	0.80	0.33	0.55	243	96	−147	0.77	0.26	0.49
17	50	30	− 20	0.62	0.34	0.48	188	116	− 72	0.59	0.31	0.44
18	32	65	+ 33	0.39	0.74	0.57	115	300	+185	0.36	0.81	0.61
19	21	87	+ 66	0.26	0.99	0.64	59	438	+379	0.19	1.19	0.73
20	9	117	+108	0.11	1.33	0.74	39	576	+537	0.12	1.56	0.89
21	5	128	+123	0.06	1.45	0.78	17	650	+633	0.05	1.76	0.97
22	6	126	+120	0.07	1.43	0.78	21	614	+593	0.07	1.67	0.92
23	17	129	+112	0.21	1.46	0.86	60	580	+520	0.19	1.57	0.93
Midnight.	29	109	+ 80	0.35	1.24	0.81	117	528	+411	0.37	1.43	0.94
Σ	1954	2116	+162				7627	8843	+1216			

*The same end of magnet is of course referred to.

From these tables we gather the following information:

(*a*) The most remarkable feature is the fact of the easterly disturbances presenting a *double* progression in a day, whereas the westerly disturbances show but one. This is also found to be the case for Key West, Philadelphia, and Toronto, and is supposed also true at other stations; yet for certain places in the southern hemisphere the *reverse* law seems to obtain. This diversity in the law for eastern and western disturbances would point to their having a different origin. With respect to number of disturbances, the following comparative table will best show the accord between the extreme values at different stations.

	Los Angeles.	Key West.*	Philadelphia.†	Toronto‡
Easterly disturbances:	*h.*	*h.*	*h.*	*h.*
Time of principal maximum	23	21	21	21
Time of secondary maximum	10	9	10	11
Time of principal minimum	16	16	14	15
Time of secondary minimum	6	6	8	8
Westerly disturbances:				
Time of maximum	10	10	10	10
Time of minimum	21	21	21	22

*Coast Survey Report for 1874, p. 122. †Coast Survey Report for 1859, p. 290. ‡Walker's Terrestrial and Cosmical Magnetism, 1866, p. 86.

(*b*) The table shows the simultaneous occurrence at about 21^h of the greatest number of easterly disturbances and of the least number of westerly disturbances.

(*c*) Irrespective of direction, the most disturbed time of the day is between 9^h, 10^h, and 11^h, and the least disturbed about 17^h; less pronounced times are 1^h, 2^h, and 6^h; the former hours greater, the latter less disturbed than the average. If we divide the day into two equal parts, say from 7^h to 18^h inclusive, and from 19^h to 6^h, we find in the first half day, or that of day hours, 2405 disturbances, while there are but 1665 disturbances in the second half or that of night hours.

(*d*) While the *easterly* disturbances upon the whole predominate over the western ones, we find them most active about 3 hours before midnight, whereas the excess of the *westerly* over the easterly disturbances is most marked about 1 hour before noon, the respective aggregate excess being $+633$ divisions and -361 divisions. From 4 o'clock in the morning to 5 in the afternoon the *westerly* disturbances are in excess in number and magnitude; in the remaining hours of the day the *easterly* disturbances greatly exceed the westerly ones.

The normal solar-diurnal variation of the declination.—In the following table will be found collected the hourly normals as given at the foot of each monthly tabulation, but condensed into a single table; each value is therefore the mean of seven undisturbed ordinates.

DIFFERENTIAL OBSERVATIONS

Recapitulation of hourly normals of the solar-diurnal

[Local mean time. 300 divisions + tabular

Month.	1h	2h	3h	4	5h	6h	7h	8h	9h	10h	11h	Noon.
	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.
October.	69.61	69.66	69.91	70.14	70.36	71.11	72.50	73.56	73.00	70.66	68.20	66.63
November.	69.53	69.61	69.69	69.86	70.02	70.34	71.04	72.53	72.54	71.46	69.56	67.70
December.	69.47	69.54	69.46	69.59	69.56	69.63	70.13	71.21	72.34	72.47	71.01	68.91
January.	69.43	69.47	69.47	69.39	69.41	69.61	69.84	71.31	73.07	73.76	71.91	68.74
February.	69.19	69.39	69.36	69.49	69.51	69.54	69.99	70.89	71.64	71.43	70.37	68.57
March.	68.74	68.86	68.90	69.07	69.20	69.80	70.99	72.73	73.01	71.31	68.73	66.29
April.	68.53	68.80	68.83	69.19	69.56	70.71	72.43	73.50	72.64	69.83	67.44	66.16
May.	68.31	68.43	68.74	69.26	70.04	71.69	73.53	73.76	71.83	68.87	66.20	65.05
June.	68.29	68.40	68.67	69.11	70.00	71.54	73.36	73.50	71.70	68.90	66.33	64.84
July.	68.20	68.39	68.74	69.24	69.96	71.70	73.61	74.39	72.77	69.27	66.17	64.29
August.	68.57	68.51	68.86	69.23	69.91	71.97	74.36	75.06	72.60	68.81	65.70	64.30
September.	68.86	69.31	69.40	69.73	70.20	71.79	73.54	73.53	71.96	68.97	66.69	65.30

Normal solar-diurnal variation of the declination at Los

[A + sign signifies a deflection of the north end of the

Month.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
	′	′	′	′	′	′	′	′	′	′	′	′
January.	−.31	−.28	−.28	−.34	−.33	−.17	+.02	+1.19	+2.60	+3.15	+1.67	−.86
February.	−.06	+.10	+.08	+.18	+.20	+.22	+.58	+1.30	+1.90	+1.74	+.89	−.55
March.	+.14	+.24	+.27	+.41	+.51	+.99	+1.94	+3.34	+3.56	+2.20	+.14	−1.82
April.	+.06	+.27	+.30	+.58	+.88	+1.80	+3.18	+4.03	+3.34	+1.10	−.82	−1.84
May.	−.08	+.02	+.26	+.68	+1.30	+2.62	+4.10	+4.28	+2.74	+.37	−1.77	−2.69
June.	+.02	+.11	+.33	+.68	+1.39	+2.62	+4.08	+4.19	+2.75	+.51	−1.54	−2.74
July.	−.08	+.07	+.35	+.75	+1.33	+2.72	+4.25	+4.87	+3.58	+.78	−1.70	−3.21
August.	.00	−.05	+.23	+.53	+1.07	+2.72	+4.63	+5.19	+3.22	+.19	−2.30	−3.42
September.	−.07	+.29	+.36	+.62	+1.00	+2.27	+3.67	+3.66	+2.41	+.02	−1.81	−2.92
October.	−.05	−.01	+.19	+.38	+.55	+1.15	+2.26	+3.11	+2.66	+.79	−1.18	−2.43
November.	−.21	−.14	−.08	+.06	+.18	+.44	+1.00	+2.19	+2.20	+1.34	−.18	−1.67
December.	−.34	−.29	−.35	−.25	−.27	−.22	+.18	+1.05	+1.95	+2.06	+.89	−.79
6 mths., Apr. to Sept.	−.02	+.12	+.30	+.64	+1.16	+2.46	+3.98	+4.37	+3.01	+0.50	−1.66	−2.80
6 mths., Oct. to Mar.	−.14	−.06	−.03	+.07	+0.14	+0.40	+1.00	+2.03	+2.48	+1.88	+0.37	−1.35
Whole year,	−.08	+.03	+.14	+.36	+0.65	+1.43	+2.49	+3.20	+2.74	+1.19	−0.64	−2.08

OF THE DECLINATION.

variation for each month of the seven-year series, 1882–'89.

quantity. One division of scale = 0. '794]

13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.
66.40	67.14	68.19	68.83	69.00	69.33	69.60	69.69	69.81	69.69	69.61	69.51	69.67
67.24	67.57	68.17	68.86	69.47	70.01	70.26	70.14	70.03	69.99	69.79	69.57	69.79
67.99	67.70	68.14	68.97	69.80	70.21	70.40	70.51	70.46	70.23	70.04	69.69	69.90
67.37	67.17	67.76	68.80	69.57	69.90	70.13	70.10	70.07	69.99	69.86	69.59	69.82
67.14	66.79	67.11	67.84	68.57	69.07	69.36	69.41	69.47	69.44	69.40	69.30	69.26
64.93	64.60	65.29	66.61	67.57	67.96	68.23	68.36	68.43	68.59	68.64	68.70	68.56
65.03	64.57	65.06	66.14	67.26	67.83	68.00	68.00	68.23	68.27	68.34	68.59	68.46
64.76	65.01	65.67	66.60	67.49	67.91	67.97	67.97	68.00	68.11	68.24	68.29	68.41
64.24	64.44	65.21	66.40	67.37	67.96	67.93	67.84	67.93	68.04	68.13	68.16	68.26
63.69	64.14	65.23	66.51	67.43	67.91	67.83	67.76	67.83	67.91	68.06	68.10	68.30
63.96	64.76	66.17	67.50	68.13	68.16	67.93	67.99	68.14	68.27	68.40	68.31	68.57
65.07	66.09	67.43	68.44	68.67	68.30	68.43	68.53	68.57	68.67	68.59	68.77	68.95

Angeles, Cal., between October, 1882, *and October,* 1889.

magnet towards the east, a — sign, the contrary direction.]

13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.
'	'	'	'	'	'	'	'	'	'	'	'
−1.96	−2.12	−1.65	−.82	−.20	+.06	+.25	+.22	+.20	+.14	+.03	−.18
−1.70	−1.98	−1.72	−1.14	−.55	−.15	+.08	+.12	+.17	+.14	+.11	+.03
−2.90	−3.17	−2.62	−1.56	−.79	−.48	−.26	−.16	−.10	+.02	+.06	+.11
−2.74	−3.11	−2.72	−1.86	−.96	−.50	−.37	−.37	−.18	−.15	−.10	+.10
−2.92	−2.72	−2.19	−1.45	−.74	−.40	−.35	−.35	−.33	−.24	−.14	−.10
−3.22	−3.06	−2.44	−1.49	−.71	−.24	−.26	−.34	−.26	−.18	−.10	−.08
−3.69	−3.33	−2.46	−1.43	−.70	−.31	−.38	−.43	−.38	−.31	−.19	−.16
−3.69	−3.05	−1.92	−.86	−.35	−.33	−.51	−.46	−.34	−.24	−.14	−.21
−3.10	−2.29	−1.22	−.41	−.22	−.52	−.42	−.34	−.30	−.22	−.29	−.14
−2.62	−2.02	−1.18	−.67	−.54	−.27	−.06	+.10	+.11	+.02	−.05	−.13
−2.04	−1.78	−1.30	−.74	−.26	+.18	+.38	+.28	+.19	+.16	.00	−.18
−1.53	−1.76	−1.41	−.74	−.08	+.25	+.40	+.49	+.45	+.26	+.11	−.17
−3.23	−2.93	−2.16	−1.25	−.61	−.38	−.38	−.38	−.30	−.22	−.16	−.10
−2.13	−2.14	−1.65	−0.94	−.40	−.07	+.13	+.18	+.17	+.12	+.04	−.09
−2.68	−2.54	−1.90	−1.10	−.50	−.22	−.12	−.10	−.06	−.05	−.06	−.10

Comparing the tabular values of the normal solar-diurnal with the total solar-diurnal variation, as previously given, no change is noticeable in the general character of the variation, and this is true whether we make the comparison for the whole year or for the half-years when the sun has north and when it has south declination. The change from one season to the other is plainly brought out in the diagram (illustration No. 25), which also shows that the small secondary undulation during the night hours (persisting for about 6 hours preceding midnight) is only noticeable in the winter half-year, and entirely disappears during the summer half year.

The greater disturbances having been removed, the diurnal range is increased thereby 0′.1 very nearly, but at no hour does the difference between the disturbed and the normal ordinates rise to 0′.2 . It would therefore be a waste of labor to rediscuss the hourly normals, and the various laws already brought out for the total solar-diurnal variation apply equally to the normal variation. We have the average daily range during the half-year, sun north of the equator, 7′.8, and during the half-year, sun south of the equator, 4′.8; average for the year, 6′.3

Days of large range of disturbances in declination.—In the preceding investigation we have made exclusive use of the *hourly* trace readings; thus no account was taken of the disturbances, however large, that may have occurred between these hours. For a more complete understanding of the disturbances of large amount, we give below, in tabular form, the dates (days) at which the range exceeded 19 scale-divisions, or nearly 15′ of arc, together with the time of occurrence (as near as it could be read off) the amount of angular deflection in scale-divisions, and whether to the east or west.

Table of disturbances largely affecting the daily range at Los Angeles, Cal., 1882 to 1889.

Date.	Local mean time* of extremes.				Amount of deflection 300 divisions +		Daily range.	Magnitude of disturbance or difference from normal.		Remarks.
	Deflection east.		Deflection west.					East.	West	
1882.	h.	m.	h.	m.	d.	d.	′	′	′	
Oct. 2	2	40	2	00	82.2	57.2	19.8	9.5	10.2	
Oct. 5	19	55	13	50	86.2	62.7	18.7	12.6	3.4	
Oct. 6	0	55	5	22	82.2	58.4	18.9	9.5	10.3	
Nov. 12	18	17	23	58	80.5	58.0	17.9	7.4	9.8	
Nov. 13	2	55	0	03	79.0	58.5	16.3	7.0	9.2	
Nov. 17	†20	52	2	55	104.5	20.0	67.1	26.8	40.2	See appended tracing of the photographic curves (illustration No. 26).
Nov. 18	† 0	50	3	20	88.5	58.5	23.8	14.6	9.5	
Nov. 19	†20	45	5	30	100.0	46.0	42.9	23.3	20.0	
Nov. 20	† 0	35	4	00	98.5	40.5	46.1	22.6	24.1	
Dec. 20	21	00	6	00	82.0	60.5	17.9	8.3	8.2	
1883.										
Feb. 2	22	45	2	10	84.0	65.0	15.1	10.2	4.8	
Feb. 24	18	55	13	25	89.5	58.0	25.0	14.6	8.4	
Apr. 3	6	30	8	42	89.5	60.5	23.0	13.1	12.2	
Apr. 24	10	02	13	47	82.5	56.0	21.0	6.9	7.8	
June 17	7	10	15	42	82.3	63.0	15.3	6.1	3.1	
July 20	7	25	13	40	78.3	60.0	14.9	2.9	4.2	
Aug. 17	7	38	11	30	80.0	59.5	16.3	3.2	5.5	
Sept. 15	22	32	12	10	87.5	64.5	18.3	14.6	1.6	
Sept. 16	3	12	11	00	89.5	63.0	21.0	15.4	4.0	

* From midnight to midnight, 0 to 24 hours.

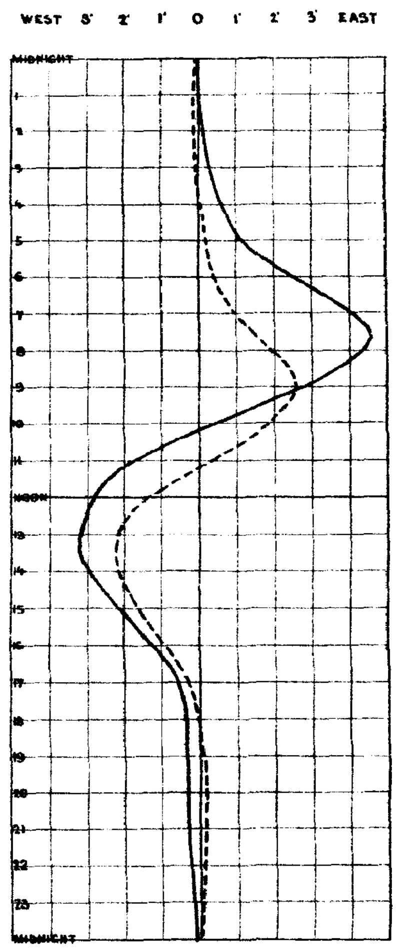
† "The southern hemisphere [of the sun] has still [1890] preserved that predominance [in productiveness of sun-spots] which it has shown, almost without a break, ever since the closing up of the *great northern spot of November, 1882.*" E. W. Maunder in Monthly Notices of the Royal Astronomical Society, April, 1890.

E

NORMAL SOLAR DIURNAL VARIATION

OF THE DECLINATION.

FROM 7 YEARS OF OBSERVATIONS



FOR 6 MONTHS, SUN NORTH OF EQUATOR ————

" " " , " SOUTH " " - - - - - -

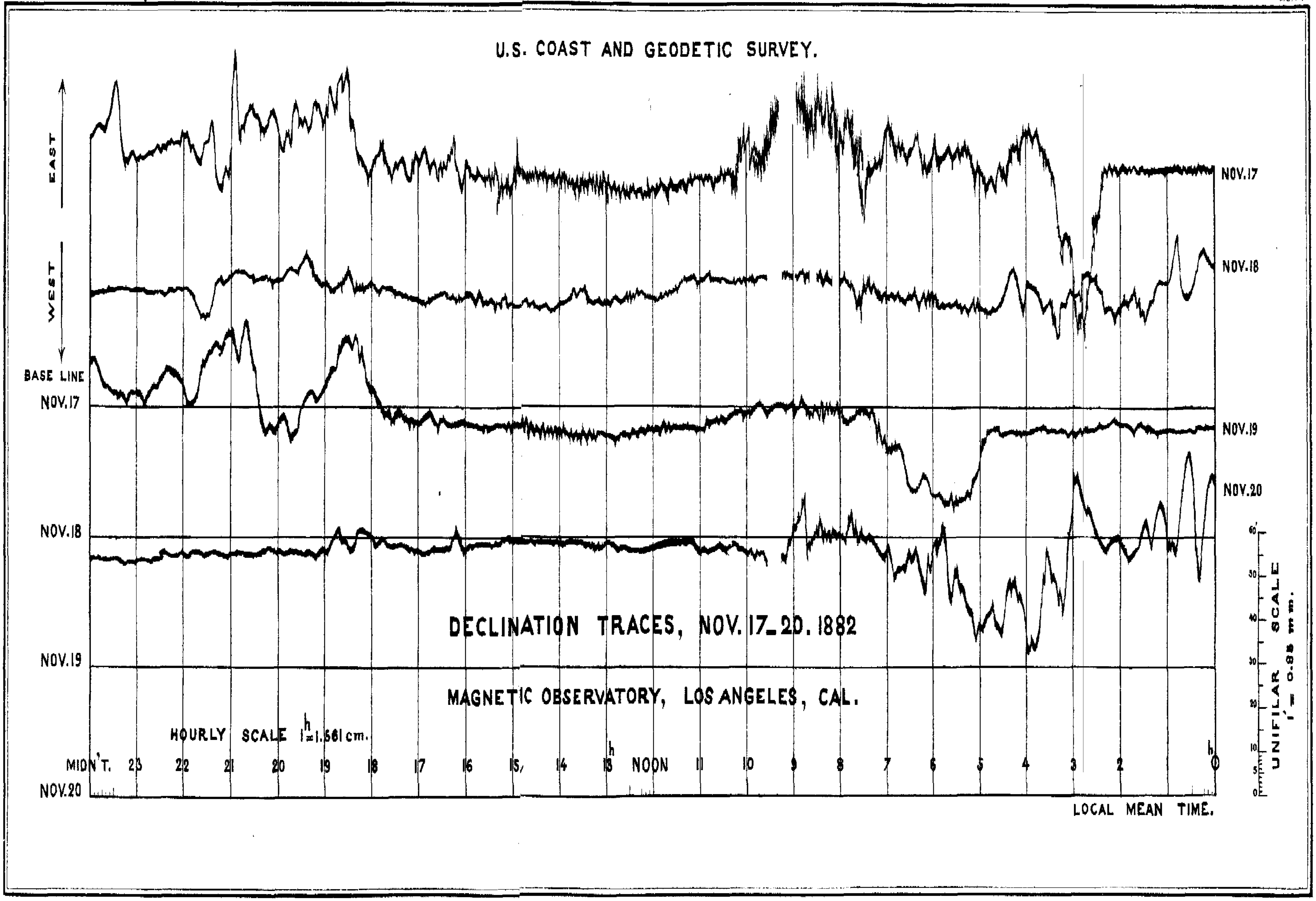

U.S. COAST AND GEODETIC SURVEY.
EAST
WEST
BASE LINE
NOV. 17
NOV. 18
NOV. 19
NOV. 20
DECLINATION TRACES, NOV. 17-20. 1882
MAGNETIC OBSERVATORY, LOS ANGELES, CAL.
HOURLY SCALE 1h = 1.561 cm.
MIDN'T. 23 22 21 20 19 18 17 16 15 14 13h NOON 11 10 9 8 7 6 5 4 3 2 0h
LOCAL MEAN TIME.
UNIFILAR SCALE 1' = 0.85 mm.
60' 50 40 30 20 10 5 0

Table of disturbances largely affecting the daily range, etc.—Continued.

Date.	Local mean time* of extremes. Deflection east.		Deflection west.		Amount of deflection 300 divisions +		Daily range.	Magnitude of disturbance or difference from normal. East.	West.	Remarks.
1883.	*h.*	*m.*	*h.*	*m.*	*d.*	*d.*	′	′	′	
Oct. 16	20	15	13	55	80.8	56.5	19.3	9.2	8.8	
Nov. 22	0	14	{ 4 22	10 48 }	86.5	64.2	17.7	13.7	4.2	
1884.										
Apr. 24	7	25	14	52	75.7	52.5	18.4	3.9	7.3	
Oct. 1	21	02	20	02	81.5	56.5	19.8	10.4	9.6	
Nov. 3	2	28	5	12	83.2	55.2	22.2	11.4	11.1	
Nov. 28	0	53	5	00	79.0	59.8	15.2	8.2	7.4	
1885.										
Mar. 15	2	55	15	02	84.0	62.0	17.5	10.3	4.0	
May 13	18	25	15	16	78.8	57.2	17.2	6.1	9.6	
May 25	22	41	23	55	85.8	63.2	17.9	11.6	6.6	
May 26	19	22	12	45	88.3	68.0	16.1	13.7	0.6	
May 27	20	50	3	05	86.3	63.2	16.0	12.2	7.0	
May 28	8	43	5	22	84.0	65.0	15.1	5.7	7.4	
July 25	7	25	13	06	85.0	66.2	14.9	4.6	0.7	
Aug. 1	8	12	13	50	86.5	66.5	15.9	5.5	1.5	
Sept. 15	21	36	13	10	89.8	67.2	17.9	13.9	1.0	
Nov. 10	22	00	5	08	86.9	67.0	15.8	11.2	4.5	
Nov. 18	21	30	{ 3 13	37 28 }	87.0	67.3	15.6	11.3	3.3	
1886.										
Jan. 9	2	00	0	12	87.5	67.5	15.9	12.5	3.8	
Mar. 30	3	52	{ 0 13	56 36 }	83.7	59.2	19.5	10.5	7.4	
Apr. 4	20	22	23	06	82.8	63.2	15.6	10.6	5.4	
May 8	20	37	14	57	80.6	58.0	17.9	8.8	7.6	
July 27	20	16	17	32	88.0	57.2	16.5	14.9	9.9	
Aug. 15	20	00	12	00	84.5	63.5	16.7	11.6	2.6	
Aug. 23	20	42	{ 14 16	25 11 }	90.3	64.2	20.7	16.2	3.8	
Sept. 9	23	47	11	48	83.5	63.2	16.1	10.1	3.8	
Oct. 8	1	22	4	05	81.9	63.0	15.0	9.0	6.6	
Nov. 2	20	43	11	23	83.9	64.0	15.8	9.7	5.0	
1887.										
Apr. 6	17	50	12	06	83.7	64.0	15.6	11.8	2.9	
Sept. 25	19	22	13	11	89.1	61.6	21.8	16.2	3.2	
1888.										
Jan. 8	2	15	5	16	78.1	51.1	21.4	7.9	13.4	
Jan. 13	2	42	6	58	76.3	56.3	15.9	6.6	9.4	
Nov. 16	20	03	12	06	84.0	61.0	18.3	13.7	2.6	
1889.										
July 17	0	05	6	40	83.0	62.0	16.7	14.6	5.3	
Aug. 12	22	02	12	56	79.2	59.6	15.6	11.7	0.7	

*From midnight to midnight, 0 to 24 hours.

The diurnal range of the declination is about 6′; this was exceeded two and a half times on the 53 disturbed days in a total of 2 557 days, or in the proportion of 1 day in 48. On 4 days only was the disturbed range equal to four times the average range. The maximum range on any one day during 7 years was 1° 07′.1, and the maximum deflection from the normal was 40′.2 (November 17, 1882).

INVESTIGATION OF THE LUNAR INFLUENCE ON THE MAGNETIC DECLINATION AS OBSERVED AT LOS ANGELES, 1882-1889.

The most efficient process to prepare the basis for this investigation would be to tabulate anew the ordinates of the traces according to lunar hours; but, on account of the great labor involved, the values already tabulated according to solar hours* may be utilized by marking each with the corresponding hour angle of the moon, and by collecting all the values belonging to a given lunar hour and deducing a mean value for each of the twenty-four lunar hours. Since a solar hour will as often precede as follow a lunar hour, the difference in any case can not exceed half an hour.

To find the local mean (astronomical) time of the moon's upper transit over the meridian, we take the mean time of the upper transit over the meridian of Greenwich from the American Ephemeris and Nautical Almanac, and refer the same to the Los Angeles meridian by adding the product of the longitude (7^h 53.0^m west) and of the lunar-hourly difference. The nearest solar hour thereto was marked in the table U. T., or 0^h; similarly the time of the moon's lower transit was found and marked L. T., or 12^h. The intermediate tabular ordinates were thus marked with their nearest lunar hour, and in case the latter fell midway between two solar hours the mean of the two solar ordinates was substituted for the single ordinate. In order to eliminate the effect of the solar-diurnal variation of the annual change and of the annual variation, the *difference* of each ordinate from the monthly normal corresponding to it was tabulated and entered under its proper lunar hour. From this tabulation all differences previously marked as disturbances were excluded.

Lunar-diurnal variation from observations of the magnetic declination at Los Angeles, Cal.—Kreil in 1841, and soon after Broun and Sabine, also Bache in 1860, have shown that the moon has a minute effect on the declination needle, causing in each lunar day a double oscillation of small amplitude; these investigations were soon extended to other magnetic elements, and later on applied to cases depending on position in the lunar orbit.

In consequence of the great labor involved in using a 7-year hourly series, the lunar-diurnal variation was brought out for a period of 3 years only, viz, for the years October, 1882, to October, 1883, October, 1885, to October, 1886, and October, 1888, to October, 1889. The first year is one which includes the time about a sun-spot maximum and the last year probably includes a sun-spot minimum. These years, as will be seen, cover a sufficient length of time to clearly bring out the variation. The number of observations or hourly ordinates involved were:

7 725 in 1882-'83	Which give respectively an average number of values for each lunar hour of	322
7 913 in 1885-'86		329
8 169 in 1888-'89		340

The increase in these numbers is due to decreasing frequency in the number of disturbed ordinates. The average number of ordinates for any one hour covering the period of half a year would be 165, which is about the lower limit for which a satisfactory result of the variation may be expected.

Lunar-diurnal variation derived from 3 years of observation of the magnetic declination at Los Angeles, Cal.—A + sign indicates that the direction of the north end of the magnet is *east* of its normal or undeflected position, a — sign, that it is to the *west*. Value of one scale-division, 0′.794, or 47″.6. The consistency of the results for a variation of which the amplitude (half range) is below 10″ of angular deflection is the best evidence of the accuracy of the instrumental record, as well

*There are more than 61 000 ordinates available, comprising 2 557 days; the total length of the declination traces when put together, end to end, would be nearly one kilometre, or six-tenths of a statute mile; for the study of the lunar effect (diurnal variation) but one-fourth of a mile of this ribbon was used.

as of the care taken by the observers.* For comparison, I have added to the table the results obtained from the Philadelphia record by Bache,† those for Toronto, Canada, by Sabine,‡ those for Kew, England,§ and for Pekin, China, || all stations in the northern hemisphere.

Lunar hours or ☽'s hour-angle.	Los Angeles, Cal.					Philadelphia.	Toronto, Canada.	Kew, England.	Pekin, China.
	Oct., 1882, to Oct., 1883.	Oct., 1885, to Oct., 1886.	Oct., 1888, to Oct., 1889.	Mean of 3 years.	Mean of 3 years, from 23807 observations.	1840–1845, from 21644 observations.	1843–1848, 6 years, from 40543 observations.	1858–1862, 5 years of observations.	1852–1855, $3\frac{3}{8}$ years of observations.
	d.	*d.*	*d.*	*d.*	"	"	"	"	"
U. T., 0	−0.15	−0.09	−0.20	−0.15	−7.1	−11.4	−16.5	−6.2	−4.1
1	−0.06	−0.03	−0.07	−0.05	−2.4	−10.2	−13.9	−9.6	−2.9
2	+0.05	−0.01	0.00	+0.01	+0.5	−3.0	−9.5	−8.4	−1.4
3	+0.01	+0.08	+0.10	+0.06	+2.9	−2.4	−5.2	−2.0	+0.7
4	+0.14	+0.13	+0.17	+0.15	+7.1	+6.0	+8.2	+0.6	+2.3
5	+0.17	+0.21	+0.17	+0.18	+8.6	+8.4	+15.2	+4.0	+2.5
6	+0.16	+0.18	+0.19	+0.18	+8.6	+11.4	+19.5	+9.0	+4.2
7	+0.13	+0.06	+0.13	+0.11	+5.2	+8.4	+17.3	+11.3	+2.7
8	−0.03	−0.06	+0.07	−0.01	−0.5	+9.0	+8.7	+9.6	+2.9
9	−0.15	−0.06	−0.04	−0.08	−3.9	−0.6	+1.3	+4.7	−0.9
10	−0.19	−0.20	−0.11	−0.17	−8.1	−6.0	−12.6	−0.1	−1.1
11	−0.18	−0.12	−0.24	−0.18	−8.6	−11.4	−19.9	−5.5	−4.2
L. T., 12	−0.09	−0.10	−0.20	−0.13	−6.2	−17.4	−20.3	−9.6	−4.3
13	−0.11	−0.07	−0.21	−0.13	−6.2	−11.4	−15.6	−11.3	−2.1
14	0.00	+0.03	−0.06	−0.01	−0.5	−7.8	−8.2	−9.5	+1.9
15	+0.12	+0.06	+0.08	+0.09	+4.3	−3.6	+1.7	−5.4	+1.9
16	+0.14	+0.09	+0.17	+0.13	+6.2	+6.0	+10.4	−0.6	+4.3
17	+0.22	+0.14	+0.20	+0.19	+9.0	+10.8	+18.2	+5.1	+5.4
18	+0.24	+0.05	+0.20	+0.16	+7.6	+15.6	+23.4	+8.5	+3.9
19	+0.21	−0.01	+0.08	+0.09	+4.3	+11.4	+15.6	+9.8	+3.9
20	+0.03	−0.01	−0.01	0.00	0.0	+7.2	+9.1	+8.8	+2.1
21	−0.18	−0.14	−0.09	−0.14	−6.7	−0.6	−2.6	+7.4	−2.4
22	−0.27	−0.08	−0.17	−0.17	−8.1	−2.4	−10.4	+2.4	−2.9
23	−0.23	−0.03	−0.20	−0.15	−7.1	−7.2	−13.8	−1.6	−3.3

In the first place we notice that the effect of the moon on the declination is to produce at all the stations a double oscillation in each lunar day, *i. e.*, two deflections to the east and two intermediate deflections to the west, these extremes lying about 6 lunar hours apart; with a half range varying between 5″ and 20″ at different stations.

Secondly, it appears that at Los Angeles the lunar-diurnal variation comes out the same for the years of maximum, of average, and of minimum sun-spot activity, and is thus shown to be independent of the sun-spot cycle; the same conclusion was reached by Sabine from his discussion of the Toronto and Hobarton observations, viz: that there is no systematic influence in the lunar-diurnal variation such as we know to be present in the solar-diurnal variation and depending on the sun-spot cycle. Stewart,¶ from a preliminary discussion of the Trevandrum (India) observa-

*We may note here that the width of the photographic trace is nearly 1mm (one twenty-fifth of an inch), which in angular measure corresponds to 70″.6, so that the whole lunar range or effect is confined within a width of one-quarter of that of the trace; yet in spite of this minuteness, the hourly changes of this variation are plainly exhibited.

† Coast Survey Report for 1860, App. No. 24, p. 320. These Girard College observations, made by direct scale readings, were partly hourly, partly bi-hourly; they comprise the period from June, 1840, to June, 1845.

‡ Toronto Observations, Vol. III.

§ Phil. Trans., 1863.

|| Magnetical and Meteorological Observations. St. Helena, Vol. II, p. CXLV. Maj. Gen. E. Sabine, London, 1860.

¶ Encyc. Brit., 9th Ed., Vol. XVI; Art., Meteorology.

tions, thought there was as yet not sufficient evidence to finally decide this point. We next notice the close accord in the ranges, with the greatest effect at Toronto and with the least at Pekin; we also observe a variability of 1 or 2 hours in the local times of the extreme phases (see the underlined tabular values). The characteristic form of the lunar-diurnal variation is shown in the accompanying diagram (illustration No. 27) for each of the 3 years submitted to analysis from the Los Angeles Record.

The analogy apparently suggested by such curves between the magnetic and tidal actions has long since been remarked, but the manner of action, whether mechanical or otherwise inductively influencing electric earth currents, is still in a state of mere conjecture. That the moon, like the earth, should be a magnetic body and possess a magnetic axis and poles would seem a reasonable hypothesis, from which it would follow that mutual magnetic influence might here be observable as well as a reflex action of the sun spot inequality. The double oscillation which is characteristic of the lunar-diurnal variation may in part be due to the dynamical stress set up in the earth's body through tidal action, which changes sign every 6 lunar hours, and thus may affect the magnetic conditions.

A comparison of the lunar-diurnal variation, as observed at various places, is best thrown into an analytical expression, viz:

Los Angeles, Cal	$d_{\text{☾}} = -0''.05 + 0''.31 \sin(15n + 42^\circ.4) + 8''.53 \sin(30n + 300^\circ.1)$ $+ 0.48 \sin(45n + 67.1)$
Philadelphia, Pa*	$d_{\text{☾}} = 0.0 + 1.7 \sin(15n + 115) + 12.4 \sin(30n + 265.0)$
Toronto, Can†	$d_{\text{☾}} = -1.05 + 1.05 \sin(15n + 168.9) + 19.19 \sin(30n + 271.4)$
Kew, England‡	$d_{\text{☾}} = +0.48 + 1.32 \sin(15n + 83.8) + 10.03 \sin(30n + 236.8)$ $+ 0.43 \sin(45n + 119.6)$
Pekin China†	$d_{\text{☾}} = +0.38 + 0.81 \sin(15n + 234.2) + 4.1 \sin(30n + 285.4)$

where n = number of lunar hours elapsed since the upper culmination and the terms in $B_2 \sin(2\theta + C_2)$ are the important ones or comparison.

The following table shows the computed hourly values by above formula for Los Angeles and the difference of the observed and computed values, from which it follows that the probable error $\left(0.675\sqrt{\frac{\Sigma\Delta^2}{24-7}}\right)$ of the representation of a single value is but $\pm 0''.7$; for Philadelphia the same was $\pm 1''.3$ and for Toronto $\pm 1''.4$

Representation of the Los Angeles hourly values.

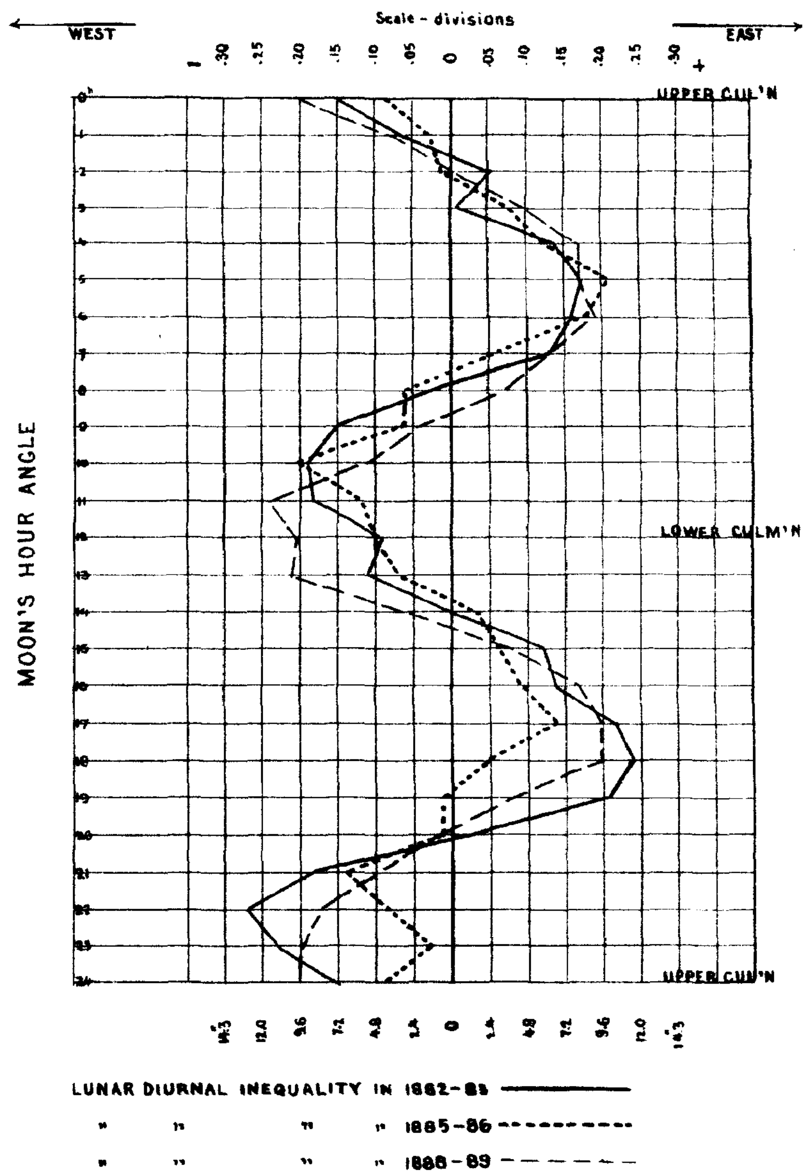
[C. stands for computed and O—C. for observed—computed.]

	C.	O—C.		C.	O—C.		C.	O—C.		C.	O—C.
h	"	"	*h*	"	"	*h*	"	"	*h*	"	"
0	—6.8	—0.3	6	+7.4	+1.2	12	—8.1	+1.9	18	+7.3	+0.3
1	—3.6	+1.2	7	+4.6	+0.6	13	—5.0	—1.2	19	+3.8	+0.5
2	+0.5	0.0	8	+0.5	0.0	14	—0.5	0.0	20	—0.6	+0.6
3	+4.4	—1.5	9	—3.9	0.0	15	+4.1	+0.2	21	—4.8	—1.9
4	+7.2	—0.1	10	—7.3	—0.8	16	+7.5	—1.3	22	—7.6	—0.5
5	+8.3	+0.3	11	—8.9	+0.3	17	+8.6	+0.4	23	—8.3	+1.2

* From Coast Survey Report for 1860, p. 320, with sign changed to conform with + for east deflection.
† From the Mag'l and Met'l Obs'n's at St. Helena, Vol. II, p. cxlvi.
‡ Directly computed from the tabular values.

F

LUNAR-DIURNAL VARIATION OF THE DECLINATION, OBSERVED AT LOS ANGELES, CAL.



The epochs or the lunar hour-angles of the four extreme deflections and the amounts as deduced for Los Angeles and for Philadelphia compare as follows:

After moon's U. C.				After moon's U. C.			
First easterly extreme.		Second easterly extreme.		First westerly extreme		Second westerly extreme.	
Los Angeles.	Philadelphia.	Los Angeles.	Philadelphia.	Los Angeles.	Philadelphia.	Los Angeles.	Philadelphia.
h m	h m	h m	h m	h m	h m	h m	h m
5 03	6 03	16 57	18 17	11 10	12 06	22 48	24 18
"	"	"	"	"	"	"	"
8.3	11.4	8.6	13.2	8.9	13.8	8.3	10.8

On the average, therefore, the extremes occur, locally, 1^h 12^m (lunar) later at Philadelphia than at Los Angeles.*

Annual inequality in the lunar-diurnal variation.—There is a marked difference in the lunar-diurnal variation during that time of the year when the sun is north of the equator when contrasted with the time when south of the equator, as shown in the following table:

Lunar hour angle.	Sun south of equator (mean of 6 months.)			Mean for 3 winter half years, ☉'s decl.—	Sun north of equator (mean of 6 months).			Mean for 3 summer half years, ☉'s decl.+
	Oct., 1882, to Mar., 1883.	Oct., 1885, to Mar., 1886.	Oct., 1888, to Mar., 1889.		April to Sept., 1883.	April to Sept., 1886.	April to Sept., 1889.	
h	d	d	d	"	d	d	d	"
0	—0.11	—0.01	—0.08	— 3.1	—0.19	—0.18	—0.32	—10.9
1	— .04	+ .11	+ .08	+ 2.4	— .07	— .17	— .22	— 7.3
2	— .03	+ .10	+ .07	+ 2.2	+ .13	— .12	— .07	— 1.0
3	— .03	+ .18	+ .12	+ 4.3	+ .05	— .03	+ .08	+ 4.8
4	+ .14	+ .27	+ .12	+ 8.4	+ .15	— .02	+ .22	+ 5.6
5	+ .11	+ .27	+ .07	+ 7.1	+ .24	+ .14	+ .26	+10.1
6	+ .07	+ .22	+ .06	+ 5.6	+ .24	+ .15	+ .33	+11.4
7	+ .11	+ .06	— .01	+ 2.5	+ .16	+ .06	+ .27	+ 7.8
8	— .14	— .15	— .01	— 4.8	+ .08	+ .03	+ .15	+ 4.1
9	— .25	— .25	— .15	—10.3	— .04	+ .13	+ .07	+ 2.5
10	— .30	— .32	— .18	—12.7	— .09	— .07	— .05	— 3.3
11	— .26	— .17	— .28	—11.3	— .11	— .08	— .19	— 6.0
12	— .06	— .15	— .17	— 6.0	— .12	— .05	— .24	— 6.5
13	+ .04	— .15	— .16	— 4.3	— .26	+ .01	— .26	— 8.1
14	+ .14	— .01	+ .01	+ 2.2	— .15	+ .06	— .12	— 3.3
15	+ .24	+ .13	+ .21	+ 9.2	— .01	— .01	— .06	— 1.3
16	+ .24	+ .06	+ .23	+ 8.4	+ .05	+ .12	+ .11	+ 4.4
17	+ .28	+ .06	+ .26	+ 9.5	+ .16	+ .21	+ .14	+ 8.1
18	+ .24	+ .04	+ .25	+ 8.4	+ .25	+ .05	+ .14	+ 7.0
19	+ .29	— .05	+ .01	+ 4.0	+ .13	+ .02	+ .15	+ 4.8
20	— .04	+ .04	— .05	— 0.8	+ .09	— .07	+ .03	+ 0.8
21	— .13	— .10	— .11	— 5.4	— .24	— .17	— .08	— 7.8
22	— .25	— .10	— .21	— 8.9	— .28	— .05	— .13	— 7.3
23	— .21	— .01	— .14	— 5.7	— .24	— .05	— .27	— 8.9

*The difference of longitude between these places is 2^h $52\frac{1}{2}^m$.

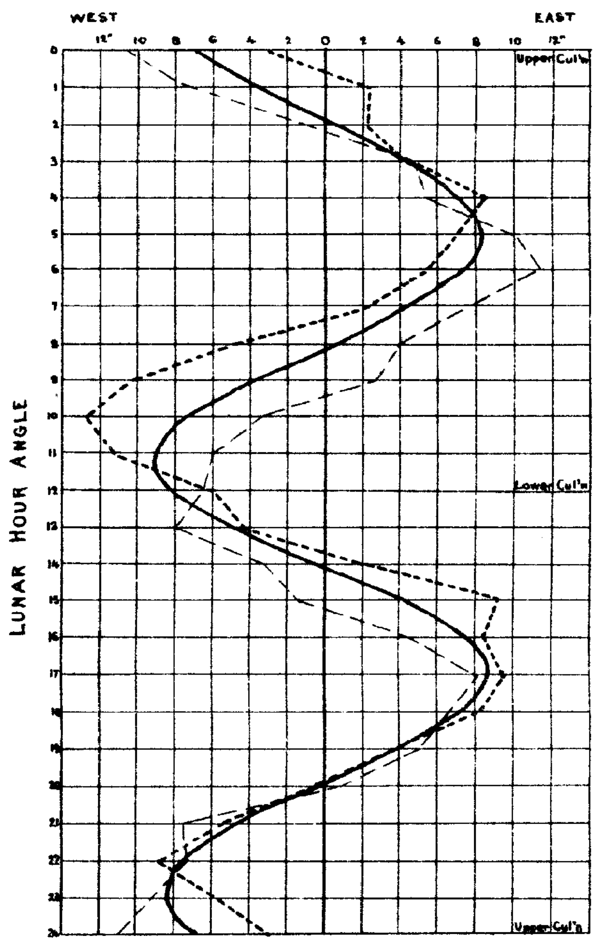
By reference to annexed diagram (illustration No. 28), which exhibits the lunar-diurnal variation during the winter half-year and the summer half-year as observed, as well as the computed variation on the yearly average by the heavy smooth curve which was derived from the preceding formula, it will be seen that the extreme positions are reached nearly two hours *later* in summer than in winter; also that the amplitude for extremes occurring just before the upper culmination and about five hours later is increased in summer as compared with the winter amplitude, the contrary being the case at the lower culmination. The same law was brought out at Philadelphia, the summer extremes occurring later and the amplitudes being larger in summer than in winter.

Lunar effect on the magnetic declination depending on the moon's position in its orbit.—There is still much uncertainty respecting the effect of the moon as depending on its position in its orbit relative to the sun, *i. e.*, on the lunar phases or age of the moon, and the same unsatisfactory state of our knowledge exists as to the supposed dependence of changes of the earth's magnetism with respect to the moon's variations in declination and in distance. Different investigators found either negative results or effects of no great reliability, owing no doubt mainly to the smallness of the influence when its existence could be made out at all. The results obtained from the Los Angeles record necessarily partake of this character; nevertheless, they are supposed to assist in the general elucidation of facts.

Lunar effect depending on the moon's varying phases.—For this investigation the days of occurrence of new moon, of first quarter, of full moon, and of last quarter were marked in the table of hourly and daily mean readings of the declination; the mean for $29\frac{1}{2}$ days, *i. e*, for the synodic month (from new moon to new moon), was then taken and subtracted from the daily means for 3 days before to three days after each phase; the same was done for each lunation, and the respective means for the whole series were united with the following results, derived from the whole series, 1882–1889, or from 86 lunations. See illustration No. 29.

G

LUNAR-DIURNAL VARIATION OF THE DECLINATION

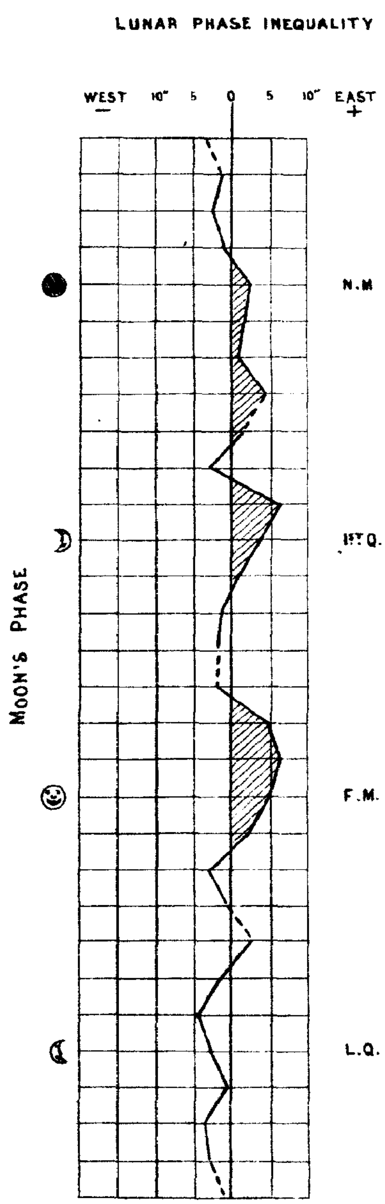


DURING HALF YEAR, SUN BELOW THE EQUATOR (WINTER) - - - - - -

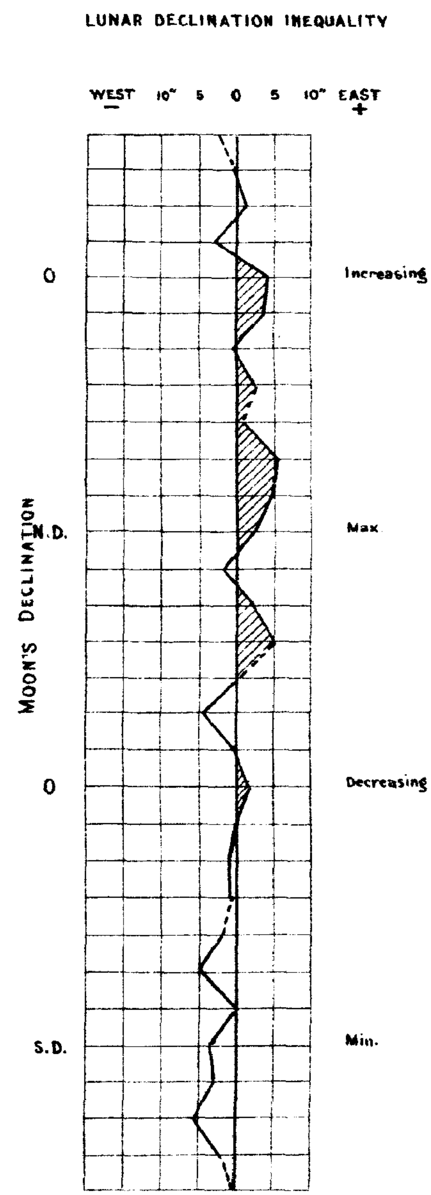
" " " , " ABOVE " " (SUMMER) — — —

" WHOLE " ————

H


LUNAR PHASE INEQUALITY
WEST − 10" 5 0 5 10" EAST +
N.M.
IST Q.
F.M.
L.Q.
MOON'S PHASE

I


LUNAR DECLINATION INEQUALITY
WEST − 10" 5 0 5 10" EAST +
0
N.D.
0
S.D.
Increasing
Max.
Decreasing
Min.
MOON'S DECLINATION

Lunar phase-inequality in the magnetic declination (from 86 lunations).

Phase.	Deflection.	Remarks.
	″	
3 days before.	−1.1	A + sign indicates deflection to the east, a — sign to the west of the normal direction.
2 days before.	−2.3	Referring to the accompanying diagram it will be seen that there is a preponderance of easterly deflections ($\Sigma = +23''.3$) over westerly deflections between new moon and full moon and a preponderance of westerly deflections ($\Sigma = -17''.2$) between full and new moon.
1 day before.	−1.0	The extreme deflections appear to occur as follows:
New moon ●	+2.4	Greatest *east* deflections, 1 day before first quarter and full moon, amount $5''.7$
1 day after.	+1.3	Greatest *west* deflections, 2 days before new moon and 1 day before last quarter, amount $3''.3$
2 days after.	+1.1	Whole range of phase-inequality $9''$ nearly.
3 days after.	+4.3	The above results are strengthened by the first 43 lunations giving the same characteristic curve as the last 43 lunations; hence we may also infer that the sun-spot cycle is not reflected in this lunar effect.
3 days before.	+1.5	
2 days before.	−3.0	
1 day before.	+5.7	
First quarter ☽	+3.5	
1 day after.	+0.2	
2 days after.	−1.5	
3 days after.	−1.7	
3 days before.	−1.9	
2 days before.	+4.5	
1 day before.	+5.7	
Full moon ○	+4.8	
1 day after.	+2.0	
2 days after.	−3.1	
3 days after.	−1.1	
3 days before.	+2.3	
2 days before.	−1.3	
1 day before.	−4.3	
Last quarter ☾	−3.0	
1 day after.	−1.0	
2 days after.	−3.8	
3 days after.	−3.1	

Lunar effect depending on the moon's declination.—This investigation is conducted as in the preceding case.

Lunar declination-inequality (from 86 revolutions), 1882–1889.

Declination.	Deflection.	Remarks.
	″	
3 days before.	−0.2	A + sign indicates deflection to the east, a — sign to the west of the normal direction. Referring to the diagram, we notice a preponderance of easterly deflections ($\Sigma = +23''.7$) during the period of moon's zero, maximum *north* and zero declination, and a preponderance of westerly deflections ($\Sigma = -20''.9$) during the period of moon's zero, maximum *south*, and zero declination. Extreme east deflections occur on the day of zero declination (increasing north) and 2 days before the maximum *north* declination, amount 4″.9; extreme west deflections occur 2 days before zero declination (decreasing north) and 2 days before maximum *south* declination, amount 4″.7; hence range of declination inequality, 9″.6 about. The phase and declination ranges are therefore nearly equal and do not quite reach 10″. A disturbing force (acting in the horizontal plane and at right angles to the magnetic meridian) corresponding to a deflection of 10″, equals $\frac{10}{206265} \times 0.2727$ dyne $= 0.00001322$ dyne.
2 days before.	+1.0	
1 day before.	−2.9	
Zero declination.	+4.5	
1 day after.	+3.7	
2 days after.	−0.4	
3 days after.	+2.7	
3 days before.	+1.0	
2 days before.	+5.3	
1 day before.	+4.7	
Extreme N. declination.	+2.5	
1 day after.	−1.6	
2 days after.	+2.1	
3 days after.	+5.0	
3 days before.	+0.7	
2 days before.	−4.5	
1 day before.	−0.6	
Zero declination.	+1.8	
1 day after.	0.0	
2 days after.	−1.0	
3 days after.	−0.5	
3 days before.	−1.7	
2 days before.	−4.9	
1 day before.	+0.1	
Extreme S. declination.	−3.3	
1 day after.	−3.0	
2 days after.	−5.6	
3 days after.	−2.0	

Lunar effect depending on the moon's parallax.

Lunar parallactic-inequality (from 86 revolutions), 1882–1889.

	″			″	
3 days before	−1.2		3 days before	−2.8	
2 days before	+0.1		2 days before	+2.4	
1 day before	−0.5	″	1 day before	+0.7	″
Perigee	−1.2	Mean −1.9	Apogee	+1.0	Mean +1.3
1 day after	+0.6		1 day after	−0.7	
2 days after	−0.6		2 days after	+1.0	
3 days after	+0.9		3 days after	−0.3	

Apparently the declination magnet is deflected about 2″ to the westward about the time of the perigee and about 1″.3 to the eastward about the time of the apogee—quantities so small that not much reliance can be placed upon them.

SOLAR ROTATION PERIOD DEDUCED FROM OBSERVED VARIATIONS OF TERRESTRIAL MAGNETISM.

If we conceive the sun, like the earth, to possess magnetic property and to have its magnetic poles not coincident with its poles of axial rotation, the alternate presentation towards the earth of these magnetic poles during the synodic rotation of the sun might be supposed to exert a measurable inductive influence on terrestrial magnetism and in particular on the horizontal component which admits of very refined measures. The first steps towards a recognition of a connection between the solar rotation period and variations in the horizontal component of terrestrial magnetism are due to John Allan Broun, who, in the year 1858, noticed a tendency, in the Trevandrum (Southern India) observations, of certain changes to recur at intervals of about 26 days; the same tendency and relation were rediscovered in 1871 by Dr. Hornstein, of the Prague observatory, and the research was extended by him to the declination and inclination for several localities, and his method has since been generally followed. The investigations were also made to embrace the vertical force, daily ranges and disturbances; these latest results are chiefly due to Dr. P. A. Müller and J. Liznar.

The method involves the formation of hourly differences from the monthly mean and the respective daily readings. These monthly tables of hourly differences have frequently served as the basis of general discussions, especially for the elucidation of the laws of disturbances, by some investigators the plain monthly mean for any hour being replaced by the normal or by a mean value depending on certain selected days of supposed tranquil and regular character. This last method was especially advocated by Dr. H. Wild for use by the late International Polar Research parties.

The process of reduction was as follows: The monthly undisturbed mean or the normal value corresponding to any of the hourly differential declination readings was subtracted from the daily readings at that hour and the remainders were tabulated. All largely disturbed values or those differing more than 2.5 scale divisions from their respective normals were excluded from the process. The twenty-four (or less) tabular differences were then summed up for each day, separately for the positive and for the negative values, and the respective sums were divided by the number of occurrence. The daily averages so obtained, one answering to the average eastern, the other to the average western deflection, formed the basis of the tabulation. The process was extended over the first and over the last year of the series, *i. e.*, for years of greatest (about) and least (about) sun-spot activity, each comprising 14 solar rotation periods. These daily averages were arranged for periods of 24, 25, 26, 27, and 28 days, and the means were taken of the 14 entries for each day of every period, viz:

Solar rotation, 14 periods, October 1, 1882 to October, 1883.

Days.	Means of westerly deflections in declination.					Means of easterly deflections in declination.				
	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.
1	0.83	0.79	0.73	0.72	0.81	0.81	0.88	0.74	0.84	0.61
2	.73	.76	.71	.79	.78	.79	.93	.76	.84	.70
3	.75	.70	.77	.66	.75	.87	.92	.90	.78	.74
4	.86	.79	.73	.79	.77	.80	.76	.74	.72	.77
5	.74	.75	.83	.55	.75	.74	.84	.73	.78	.84
6	.84	.64	.67	.66	.76	.84	.66	.62	.69	.83
7	.71	.75	.64	.65	.72	.87	.70	.78	.69	.77
8	.66	.65	.71	.76	.71	.83	.84	.74	.69	.65
9	.96	.79	.67	.74	.76	.80	.69	.61	.72	.84
10	.73	.65	.60	.79	.69	.78	.80	.87	.84	.79
11	.66	.59	.56	.76	.73	.76	.73	.70	.74	.84
12	.62	.68	.71	.84	.70	.84	.69	.78	.77	.86
13	.69	.67	.81	.75	.71	.69	.77	.79	.86	.73
14	.64	.77	.69	.61	.75	.75	.79	.77	.68	.68
15	.72	.70	.77	.72	.78	.77	.73	.74	.88	.90
16	.73	.71	.76	.76	.78	.78	.74	.77	.86	.86
17	.71	.71	.74	.81	.86	.78	.57	.78	.93	.76
18	.56	.77	.71	.84	.68	.76	.81	.76	.89	.79
19	.68	.71	.82	.72	.66	.74	.74	.78	.70	.76
20	.67	.67	.64	.78	.66	.76	.73	.81	.72	.77
21	.74	.66	.79	.77	.76	.74	.93	.86	.82	.71
22	.68	.81	.78	.72	.69	.75	.70	.94	.79	.81
23	.74	.76	.79	.68	.65	.64	.81	.82	.69	.73
24	.67	.78	.75	.68	.68	.64	.80	.87	.77	.71
25	. .	.79	.87	.66	.82	. .	.83	.82	.76	.81
26	. .	. .	.60	.62	.57	. .	. .	.79	.73	.79
27	. .	. .	. .	.74	.79	. .	. .	. .	.84	.82
28	. .	. .	. .	. .	.60	. .	. .	. .	. .	.81
Mean d	0.72	0.72	0.73	0.73	0.73	0.77	0.77	0.78	0.78	0.77

Solar rotation, 14 periods, September, 1888 to September, 1889.

Days.	Means of westerly deflections in declination.					Means of easterly deflections in declination.				
	d.	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*
1	0.56	0.62	0.62	0.65	0.57	0.60	0.68	0.60	0.68	0.57
2	.56	.55	.57	.60	.66	.66	.63	.64	.61	.69
3	.52	.61	.59	.53	.63	.66	.60	.79	.63	.67
4	.61	.56	.60	.70	.66	.55	.65	.79	.54	.65
5	.60	.51	.56	.64	.66	.61	.75	.59	.65	.57
6	.59	.64	.62	.69	.73	.70	.66	.71	.84	.71
7	.60	.56	.66	.72	.65	.57	.58	.65	.81	.61
8	.64	.64	.65	.68	.61	.74	.59	.54	.74	.71
9	.62	.71	.64	.59	.70	.62	.64	.66	.64	.70
10	.70	.56	.63	.54	.62	.76	.63	.66	.50	.69
11	.61	.51	.67	.49	.60	.71	.57	.59	.56	.75
12	.63	.54	.56	.61	.66	.73	.67	.64	.61	.63
13	.67	.58	.56	.46	.53	.79	.60	.64	.68	.73
14	.58	.54	.49	.51	.52	.61	.63	.70	.60	.66
15	.61	.61	.47	.56	.57	.62	.69	.72	.67	.64
16	.63	.59	.59	.67	.59	.61	.75	.66	.76	.63
17	.56	.72	.57	.49	.58	.59	.71	.56	.61	.59
18	.54	.65	.56	.61	.65	.70	.76	.65	.76	.72
19	.60	.74	.66	.75	.56	.76	.69	.65	.72	.67
20	.54	.61	.64	.64	.57	.64	.59	.72	.64	.77
21	.64	.65	.66	.62	.58	.56	.61	.68	.58	.66
22	.71	.56	.75	.57	.58	.68	.73	.71	.64	.71
23	.64	.61	.55	.68	.60	.56	.63	.59	.64	.60
24	.53	.70	.59	.61	.56	.65	.63	.64	.57	.67
25	. .	.59	.59	.62	.59	. .	.71	.59	.64	.63
26	. .	. .	.66	.62	.56	. .	. .	.66	.70	.59
27	. .	. .	. .	.57	.59	. .	. .	. .	.61	.69
28	. .	. .	. .	. .	.67	. .	. .	. .	. .	.59
Mean *d*	0.60	0.60	0.60	0.61	0.61	0.65	0.65	0.65	0.65	0.66

Comparing the mean values d at the bottom of the preceding tabulation we notice the same fact, as already brought out for the "larger disturbances," namely the greater magnitude of the *easterly* in comparison with the *westerly* deflections from the normal values—this law holds consequently for all disturbances, large or small. The tabular difference amounts to $0d.05$ during the first year and last years.

The next step is to represent the variation of the numbers in each vertical column, *i. e.*, for every selected period as a simple harmonic function of the time.

The tabular numbers corresponding to any period p may be expressed by

$$d + a \sin \left(\frac{360}{p} n + c\right) \quad \text{or by}$$

$a \sin \frac{360}{p} n \cos c + a \cos \frac{360}{p} n \sin c$, where n = number of days of the period.

$$\text{Putting} \begin{cases} a \cos c = x \\ a \sin c = y \\ \dfrac{360}{p} = \theta \text{ we get } \dfrac{y}{x} = \tan c, \quad \text{and} \end{cases}$$

$D = d + \sin n\theta.x + \cos n\theta.y$, hence the observation equations are of the form
$0 = d - D + \sin n\theta.x + \cos n\theta.y$

The following numerical expressions were obtained by the use of Cauchy's method:

		From western deflections, 1882–'83.	From eastern deflections, 1882–'83.
p = 24 days	$15^\circ.00$	$D = 0.72 + 0.0476 \sin (n\theta + 45^\circ)$*	$D = 0.77 + 0.0645 \sin (n\theta - 22^\circ)$
25	14.40	$0.72 + 0.0306 \sin (n\theta + 112)$	$0.77 + 0.0412 \sin (n\theta + 84)$†
26	13.85	$0.73 + 0.0553 \sin (n\theta + 149)$	$0.78 + 0.0320 \sin (n\theta + 93)$
27	13.33	$0.73 + 0.0446 \sin (n\theta - 83)$	$0.78 + 0.0172 \sin (n\theta - 152)$
28	12.86	$0.73 + 0.0150 \sin (n\theta - 11)$	$0.77 + 0.0286 \sin (n\theta - 120)$
		From western deflections, 1888–'89.	From eastern deflections, 1888–'89.
p = 24 days	$15^\circ.00$	$D = 0.60 + 0.0234 \sin (n\theta - 108^\circ)$	$D = 0.65 + 0.0279 \sin (n\theta - 82^\circ)$
25	14.40	$0.60 + 0.0358 \sin (n\theta + 166)$	$0.65 + 0.0241 \sin (n\theta + 167)$
26	13.85	$0.60 + 0.0232 \sin (n\theta + 49)$	$0.65 + 0.0235 \sin (n\theta + 92)$
27	13.33	$0.61 + 0.0229 \sin (n\theta + 97)$	$0.65 + 0.0188 \sin (n\theta - 98)$
28	12.86	$0.60 + 0.0428 \sin (n\theta - 24)$	$0.66 + 0.0317 \sin (n\theta - 79)$

We have next to find the particular value of p, which makes the amplitude a maximum, for this purpose we express the amplitude A as a function of the period, viz:

$$A = \alpha + \beta\,(p - 26) + \gamma\,(p - 26)^2$$

where 26 is a conveniently assumed approximate value for the period. For the maximum we put

$$\frac{dA}{dp} = 0.$$

It is plain that the amplitudes of the above expressions from the *eastern* deflections do not follow any systematic law, and no value for p can therefore be deduced from them; this failure is evidently caused by the excessive smallness of the solar rotational effect on the direction of the horizontal declination magnet, its angular deflection on one side and the other of the undisturbed direction being only about $2\frac{1}{4}$ seconds of arc.

*Weight half, since two of the twenty-four daily values had to be excluded as excessive in amount.

†One of the twenty-five values excluded.

From the western deflection ranges we get the following conditional equations:

First year series.

$$^{*}\begin{cases} 0.0476 = \alpha - 2\beta + 4\gamma \\ 0.0306 = \alpha - \beta + \gamma \\ 0.0553 = \alpha \\ 0.0446 = \alpha + \beta + \gamma \\ 0.0150 = \alpha + 2\beta + 4\gamma \end{cases}$$

whence the normal equations:

$$\begin{cases} 0 = -.1693 + 4.5\alpha + \beta + 8\gamma \\ 0 = +.0036 + \alpha + 8\beta + 4\gamma \\ 0 = +.2304 + 8\alpha + 4\beta + 26\gamma \end{cases}$$

hence:

$$A = +.0478 - .0038\,(p - 26) - .0053\,(p - 26)^2$$

Last year series.

$$\begin{cases} 0.0234 = \alpha - 2\beta + 4\gamma \\ 0.0358 = \alpha - \beta + \gamma \\ 0.0232 = \alpha \\ 0.0229 = \alpha + \beta + \gamma \\ 0.0428 = \alpha + 2\beta + 4\gamma \end{cases}$$

$$\begin{cases} 0 = -.1481 + 5\alpha + 10\gamma \\ 0 = -.0259 + 10\beta \\ 0 = -.3235 + 10\alpha + 34\gamma \end{cases}$$

$$A = +.0336 + .0026\,(p - 26) - .0020\,(p - 26)^2$$

and the maximum for

$$P = 26 - 0.36 = 25.64 \text{ days and } A = .0486 = 2''.3 \qquad P = 26 + 0.65 = 26.65 \text{ days and } A = .0345 = 1''.6$$

But omitting the last of the above equations (for rotation of 28 days) as anomalous, we get

$$\begin{cases} 0 = -.1053 + 4\alpha - 2\beta + 6\gamma \\ 0 = +.0597 - 2\alpha + 6\beta - 8\gamma \\ 0 = -.1523 + 6\alpha - 8\beta + 18\gamma \end{cases}$$

$^{*}w = \frac{1}{2}$

and,

$$A = +.0415 - .0173\,(p - 26) - .0159\,(p - 26)^2$$

with maximum for

$$P = 26 - 0.54 = 25.46 \text{ and } A = .0468 = 2''.2$$

According to this last result the synodic rotation period would be between 25½ and 26½ days, but from the first year's discussion it would be 25½ days. The minuteness of the effect precludes any closer or more precise statement.

The values of the synodic rotation of the sun as deduced from observed magnetic phenomena at a number of stations, as given by the several investigators mentioned above, are included between the limits 25.47 and 26.69 days, and their average is very nearly 26 days. There is but one other American station where the method has been applied, namely, Fort Rae,* one of the Hudson Bay Company's posts, situated in latitude 62° 38′.9 and in longitude 115° 13″.8, on an arm of the Great Slave Lake. For this place and for Jan-Mayen, also in a high latitude, Mr. Liznar † deduces the mean period 25.85 days, depending on variations of declinations, of horizontal and of vertical forces, during 13 rotations. At Fort Rae the amplitude amounted to 55′, presenting a strong contrast to the smallness of the corresponding value for the comparatively low (magnetic) latitude of Los Angeles. [At Fort Rae the dip was 82° 55′.3; at Los Angeles, 59° 30′.6.] ‡

* Observations of the International Polar Expeditions, 1882–'83; Fort Rae. London, 1886. H. P. Dawson, captain, R. A., in charge.

† Ueber die 26-tägige Periode der magnetischen Elemente in höheren magnetischen Breiten; Wiener Ber., Band 95.

‡ At Vienna, with a dip of about 63°, Liznar found the amplitude of the 26-day period equal to 24″.

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at the magnetic

Local mean time. 300 divisions + tabular quantity.

OCTOBER, 1882.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	69.2	69.2	70.2	70.2	70.7	72.2	73.7	74.7	75.2	73.2	69.2	66.2
2	68.7	59.2*	74.2*	79.2*	69.2	69.2*	65.2*	66.2*	73.2	72.2	61.2*	59.2*
3	70.2	71.2	71.2	71.2	71.7	73.2	75.2	74.7	74.4	73.2	70.2	67.2
4	70.2	71.2	67.2*	69.2	70.9	71.6	73.0	72.3	71.9	69.2*	67.4	67.2
5	69.2	70.7	70.2	71.2	71.7	71.7	72.7	72.2	72.2	70.2	69.7	67.7
6	83.7*	72.7*	71.2*	74.2*	67.2*	67.7*	66.2*	64.7*	67.9*	70.2	69.2	69.7
7	70.4	71.0	71.5	72.2	72.4	73.4	74.2	74.7	72.7	70.7	69.4	67.4
8	71.2	71.2	71.4	71.2	71.3	72.2	72.2	72.4	70.6*	70.0	68.4	66.4
9	70.2	70.2	70.7	70.7	71.2	72.7	73.5	74.2	73.2	72.2	70.2	68.4
10	70.7	69.7	70.2	69.2	72.7	72.7	75.2	75.2	73.2	71.2	68.2	67.2
11	70.2	70.7	70.2	71.7	72.4	72.7	72.7	73.2	73.2	72.2	68.2	67.7
12	70.2	69.7	71.2	71.2	71.7	72.7	73.7	74.2	73.2	71.7	70.2	68.2
13†	70.7	71.2	71.2	71.7	72.2	73.2	74.9	75.2	75.2	[73.1]	[70.2]	68.0
14	70.4	71.0	67.5*	71.5	71.5	73.3	75.0	[75.4]	[74.9]	[72.8]	[69.9]	[67.7]
15	71.0	72.2	71.4	70.2	70.0	70.5	71.7	74.2	[74.0]	72.3	70.2	68.0
16	70.2	70.5	69.0	72.0	72.0	72.5	75.0	75.5	76.0	72.5	69.3	66.2
17	70.0	70.0	71.0	71.0	71.0	71.0	74.0	75.0	75.0	74.0	71.0	68.0
18	71.2	68.3	70.0	70.6	71.5	72.5	73.7	75.2	75.1	72.0	70.0	68.0
19	71.0	71.2	70.5	71.8	72.0	72.5	75.0	77.4*	77.0*	74.0	71.0	68.2
20	69.0	69.0	69.0	70.0	70.0	71.0	73.0	74.8	74.0	71.5	70.0	68.5
21	70.0	69.8	70.0	70.0	70.5	72.0	74.2	75.0	74.0	70.0	67.0	66.0
22	69.8	70.0	69.0	72.0	71.0	71.5	73.5	72.0	73.0	72.0	69.0	67.0
23	69.8	66.0*	70.2	71.0	71.2	71.5	74.0	75.0	73.0	73.0	71.0	67.0
24	74.5*	70.2	71.0	69.2	69.2	67.0*	70.0*	73.5	74.0	72.0	68.0	66.5
25	73.5*	71.0	71.0	72.0	70.5	73.0	73.2	73.5	72.0	69.5	68.0	67.0
26	70.0	70.0	70.5	71.0	71.0	72.0	74.0	75.0	74.5	72.3	71.0	69.8
27	70.5	70.4	69.5	71.0	70.5	71.2	73.5	75.8	73.0	71.0	69.0	67.8
28	72.0	71.0	70.5	70.5	65.5*	69.0*	70.8*	72.2	71.5	70.0	68.8	64.4*
29	68.8	70.5	70.8	72.8	69.3	72.0	[73.0]	[73.2]	[72.5]	70.2	69.0	68.2
30	68.0	70.0	70.8	70.0	70.3	72.0	74.0	75.2	76.0	74.8*	71.8	68.0
31‡	69.2	69.0	69.2	69.4	70.2	71.0	72.5	73.8	74.0	[72.2]	[69.6]	[67.7]
Monthly mean	70.8	69.9	70.4	71.3	70.7	71.6	73.0	73.7	73.5	71.8	69.1	67.2
Normal	70.3	69.9	70.5	70.9	70.9	72.1	73.7	74.2	73.7	71.8	69.4	67.6

† October 13, 10h a. m. to 11h a. m., changed adjustment.

DECLINATION.*

observatory of the Coast and Geodetic Survey, Los Angeles, Cal., October, 1882, *to October,* 1889.

One division of scale = 0′.794

Increasing scale readings correspond to increasing east declination.

OCTOBER, 1882.

Day.	13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.	Daily range.
1	65.2	64.2*	66.2	68.2	68.2	69.2	69.7	69.2	69.2	71.2	72.7	70.7	69.9	11
2	62.2*	61.2*	64.2*	[70.8]	76.7*	68.7	71.2	71.2	65.2*	70.2	70.7	70.7	[68.3]	25
3	66.2	67.7	68.2	68.5	68.3	68.7	69.7	70.0	71.2	72.2	70.8	67.7	70.5	10
4	67.0	68.2	68.2	68.7	68.2	70.2	70.2	70.2	70.2	71.7	70.7	69.2	69.8	7
5	65.7	65.7	67.2	67.7	69.2	75.2*	72.2	86.2*	70.2	77.2*	73.2	72.2	71.3	23
6	70.2*	70.2	70.7	70.2	70.0	70.2	70.2	70.2	70.4	70.4	70.2	70.7	70.3	24
7	67.5	68.2	69.2	69.2	68.7	69.4	70.2	70.0	71.0	71.0	71.2	71.0	70.7	8
8	66.5	67.2	68.0	68.7	68.7	69.2	69.2	69.2	70.2	69.7	70.2	70.2	69.8	6
9	66.2	68.4	69.2	69.2	68.2	68.7	69.4	68.7	69.2	68.7	69.4	69.2	70.1	10
10	66.7	66.9	[68.1]	[69.6]	[70.4]	71.2	70.4	71.7	70.7	70.2	70.7	70.2	[70.5]	12
11	67.2	68.2	68.2	70.2	70.2	71.5	71.7	70.7	70.7	70.7	70.2	70.5	70.6	6
12	68.2	68.2	68.2	70.2	70.2	70.4	71.4	71.2	71.2	70.7	71.0	68.2	70.7	7
13†	65.0	65.0	65.5*	67.5	67.5	69.4	69.8	70.0	71.0	70.0	69.8	70.7	[70.3]	10
14	[66.8]	[66.9]	[67.5]	[68.3]	[68.5]	68.7	69.0	72.5	70.8	70.0	70.0	68.7	[70.4]	[8]
15	65.6	65.4	66.8	68.7	69.5	70.0	70.0	70.0	70.0	70.0	69.8	69.5	[70.0]	[11]
16	66.0	66.0	65.0*	70.0	67.0	70.0	72.5	73.8*	71.0	70.0	71.0	74.0*	70.7	14
17	67.0	67.0	68.0	68.0	68.0	69.8	69.5	70.0	70.2	70.5	71.3	71.8	70.5	10
18	67.0	66.5	67.0	68.5	69.0	69.6	69.9	70.3	70.4	70.1	70.0	70.6	70.3	10
19	66.4	66.5	67.0	68.8	69.5	69.5	70.0	70.2	70.0	69.8	69.5	69.5	70.8	8
20	68.0	68.0	68.7	69.0	69.0	69.5	70.0	70.0	69.5	70.0	70.0	69.8	70.0	7
21	66.0	67.3	68.0	68.5	68.5	69.2	69.8	70.0	70.0	71.5	71.0	71.0	70.0	9
22	66.0	67.5	66.0	69.2	68.5	67.5	69.0	72.0	71.0	71.0	69.8	69.0	69.8	14
23	66.0	66.0	67.0	69.0	69.0	68.5	69.5	70.2	71.0	74.0*	71.0	74.0*	70.3	17
24	65.0	67.0	69.0	69.0	70.0	70.0	70.0	70.2	70.0	75.8*	76.0*	77.5*	70.6	14
25	67.5	70.0*	70.5	70.0	70.0	73.0*	74.0*	70.8	71.2	70.0	67.5*	70.0	70.8	12
26	69.0	70.4*	70.5	70.5	70.5	70.5	71.0	70.2	70.2	70.8	71.5	73.5*	71.2	7
27	67.4	67.4	68.7	69.0	67.0	72.0	70.2	71.2	81.5*	75.7*	73.8	69.6	71.2	16
28	65.1	63.8*	69.1	70.0	74.5*	71.5	70.0	74.2*	73.0	70.2	70.0	69.1	69.9	16
29	69.0	70.0*	69.8	70.5	70.0	70.0	71.0	71.0	72.2	71.3	70.0	69.8	[70.6]	[6]
30	66.9	67.8	68.6	69.2	69.8	69.7	69.8	70.0	69.3	68.1	68.5	69.1	70.3	9
31‡	[67.0]	[67.5]	[68.4]	69.5	70.0	70.8	73.0*	70.5	71.0	71.0	71.0	71.0	[70.4]	[7]
Monthly mean	66.6	67.1	68.0	69.1	69.6	70.1	70.4	71.1	70.7	71.1	70.7	70.6	70.34	
Normal	66.6	67.1	68.3	69.1	69.2	69.8	70.2	70.4	70.7	70.3	70.4	70.0		

‡ October 31, 10^h a.m. and subsequent hours, redetermined constants.

*For explanation of this table see in particular pp. 245, 246 and 270.

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

NOVEMBER, 1882.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	70.5	69.5	70.0	70.5	71.0	69.3	71.0	74.5	75.2	73.0	70.3	68.2
2	70.5	70.2	70.5	72.0	71.3	72.0	74.5	75.0	74.5	73.0	70.3	67.8
3	70.5	71.0	70.8	71.0	71.5	66.2*	71.8	74.0	72.8	71.0	69.5	67.2
4	70.2	70.5	70.2	70.5	71.0	71.0	73.0	75.0	73.5	71.0	70.0	69.5
5	71.8	72.0	72.0	72.0	72.0	72.0	73.8	75.8	76.2	73.8	71.2	69.0
6	71.6	72.3	73.0*	71.6	71.7	71.8	73.5	76.0	77.0	72.2	69.0	67.0
7	71.2	67.5*	70.8	71.8	71.0	72.0	74.8*	76.0	75.6	73.3	71.5	69.3
8	70.5	70.3	70.0	71.5	71.0	69.5	72.8	74.0	72.0*	70.2*	68.0	66.8
9	71.0	70.8	71.0	71.0	67.0*	71.0	72.8	75.2	73.0	69.5*	66.0*	64.8*
10	69.8	69.8	70.0	70.2	70.8	71.0	72.0	74.0	73.5	71.8	70.0	68.0
11	70.0	70.2	70.2	70.3	70.8	71.2	73.0	73.8	72.5	71.0	68.8	66.0
12	75.0*	63.0*	71.8	68.5	69.7	70.0	69.5*	70.5*	65.0*	68.0*	65.2*	67.5
13	65.0*	71.0	77.0*	69.5	64.2*	68.0*	70.8	63.5*	65.0*	65.5*	67.0*	68.2
14	69.0	70.2	66.0*	70.0	72.0	72.8	71.0	73.2	75.3	74.0	70.0	67.0
15	69.5	71.2	71.0	71.5	70.2	72.0	75.0*	77.5*	79.5*	74.7	72.2	70.2
16	70.5	70.5	64.5*	70.2	72.8	71.8	73.0	74.0	76.0	73.0	70.4	66.7
17	69.8	70.0	27.0*	81.0*	67.5*	78.0*	83.5*	76.0	84.0*	79.0*	67.0*	64.5*
18	75.0*	67.7*	70.0	73.5*	67.0*	69.5	70.2	74.0	75.5	74.5	75.0*	70.0
19	70.5	71.2	68.7	68.5	65.0*	50.5*	66.0*	75.5	74.5	74.0	70.0	69.2
20	73.0*	72.0	91.5*	42.0*	48.0*	72.0	71.0	75.0	78.0*	70.8	71.0	72.0*
21	70.5	70.8	71.0	71.0	70.0	69.5	72.0	63.5*	69.8*	77.0*	69.3	67.0
22	69.4	69.6	70.2	70.1	70.8	71.4	72.7	75.0	75.0	73.2	71.0	69.0
23	70.7	70.2	69.0	71.8	71.0	70.0	69.4*	72.2	74.8	73.8	71.5	69.0
24	70.0	69.8	70.3	70.8	70.2	70.5	71.2	72.2	73.8	72.9	70.8	68.9
25	69.2	69.8	70.1	69.6	70.2	71.6	72.4	71.2*	76.0	77.0*	67.8	67.0
26	70.2	70.8	70.8	71.0	71.0	71.0	70.5	74.0	73.0	72.0	70.5	68.8
27	70.0	69.0	69.0	71.0	71.8	72.0	72.7	74.0	74.3	72.0	70.0	67.5
28	68.0	70.3	69.0	70.0	70.3	70.9	71.8	74.0	74.8	74.0	72.0	70.5
29	[70.6]	[70.2]	[69.9]	[70.7]	[70.2]	[71.4]	[73.6]	[75.0]	[75.9]	74.5	71.8	68.5
30	71.5	69.5	70.0	71.0	70.8	72.0	72.8	74.5	75.5	74.5	70.0	68.0
Monthly mean	70.5	70.0	69.5	70.2	69.4	70.4	72.4	73.6	74.4	72.8	69.9	68.1
Normal	70.3	70.4	70.3	70.6	71.0	71.1	72.2	74.4	74.7	72.9	70.3	68.2

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794

Increasing scale readings correspond to increasing east declination.

NOVEMBER, 1882.

Day.	13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.	Daily range.
1	67.8	68.8	68.0	69.5	70.2	70.5	71.0	70.5	71.2	71.0	71.5	70.5	70.6	9
2	67.8	67.5	67.5	69.0	67.0*	67.0*	67.5*	68.8	69.0	70.0	70.3	70.2	70.1	11
3	66.8	66.5	68.0	68.5	68.8	69.0	69.5	70.0	70.0	70.0	70.2	70.5	69.8	10
4	69.2	70.0	69.5	70.0	70.3	70.8	71.0	71.2	71.5	71.2	71.5	71.2	71.0	6
5	67.5	68.0	69.0	70.0	69.5	70.1	71.5	70.8	71.9	72.1	71.5	71.1	71.4	9
6	67.0	67.2	69.0	68.5	69.8	70.0	70.3	70.5	70.5	71.0	70.5	70.0	70.9	10
7	68.0	67.5	68.8	69.5	70.0	71.0	70.3	70.2	70.4	71.0	70.7	70.3	70.9	10
8	66.8	67.0	67.2	68.0	69.0	70.0	70.0	70.0	70.0	70.0	70.0	69.8	69.8	12
9	63.4*	67.0	67.5	68.3	69.2	69.8	69.8	69.5	69.8	69.5	69.5	69.5	69.4	8
10	67.8	68.7	69.4	69.5	69.9	70.0	70.8	70.5	70.0	70.0	70.0	70.0	70.3	8
11	64.7*	66.5*	67.2	67.8	67.8	72.0	71.7	70.8	69.9	70.2	70.0	75.0*	70.1	14
12	70.0	69.8	69.5	69.5	69.0	79.8*	72.5	75.0*	75.8*	82.0*	76.5*	58.0*	70.5	22
13	69.8	70.5	67.0	71.0	70.8	71.0	72.0	75.0*	73.5	70.5	69.0	68.8	69.3	20
14	67.0	67.2	69.3	70.0	71.8	72.8	74.5*	70.0	71.5	71.0	70.0	71.2	70.7	11
15	69.0	69.0	69.0	70.0	70.2	71.8	72.0	72.0	72.0	70.9	71.0	71.5	71.8	12
16	65.0*	67.5	67.0	70.0	73.8*	71.3	72.8	74.8*	72.0	70.5	70.2	70.2	70.8	14
17	67.0	67.0	66.0*	70.5	71.0	70.0	84.5*	81.0*	86.0*	80.0*	72.5	79.0*	72.6	84
18	69.0	67.5	69.2	70.0	69.8	74.0*	74.0*	74.5*	76.0*	72.7	72.2	71.0	71.7	30
19	67.2	68.0	70.5	71.0	71.0	81.0*	84.0*	72.0	95.0*	80.0*	80.0*	89.0*	73.0	54
20	73.0*	73.3*	75.2*	72.8*	71.0	74.8*	71.0	70.8	70.5	71.0	69.0	69.8	70.8	58
21	66.7	65.5*	69.0	70.0	70.8	71.5	71.0	70.8	70.2	70.6	69.2	68.8	69.8	15
22	68.5	68.8	69.4	70.0	70.7	72.2	71.5	71.0	71.0	70.2	69.0	70.0	70.8	7
23	69.0	69.2	70.0	71.0	72.8*	72.0	72.8	72.0	72.9	72.0	70.6	69.7	71.1	9
24	67.9	68.9	69.6	70.2	72.5	71.5	72.0	71.9	71.8	72.0	70.8	69.5	70.8	5
25	66.0	69.0	69.0	69.0	70.0	72.0	74.0*	72.2	72.7	71.0	69.5	70.8	70.7	18
26	67.5	69.0	69.0	71.0	71.0	71.3	71.2	69.0	70.8	70.2	70.4	67.0*	70.5	9
27	66.8	66.8	68.0	69.5	70.0	70.5	71.5	71.3	70.8	71.0	71.0	69.5	70.4	7
28	67.5	68.0	69.0	69.5	70.5	71.5	71.5	72.0	72.0	71.3	[70.7]	[70.7]	[70.8]	8
29	65.5	65.8	66.5	68.2	69.7	70.2	70.5	70.2	70.5	71.0	72.5	70.5	[70.6]	[10]
30	67.5	67.5	68.5	68.3	69.0	69.5	70.3	71.5	70.2	71.0	70.8	70.0	70.6	10
Monthly mean	67.6	68.1	68.7	69.7	70.2	71.6	72.2	71.7	72.6	71.8	71.0	70.8	70.72	
Normal	67.7	68.0	68.6	69.6	70.1	70.9	71.2	70.8	71.0	70.8	70.2	70.2		

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

DECEMBER, 1882.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	70.0	69.7	70.2	69.4	70.5	72.5	72.0	72.5	74.5	74.0	72.0	70.0
2	70.5	70.0	70.0	70.2	69.5	70.5	71.0	71.0	72.5	73.0	72.0	70.0
3	70.0	70.0	70.5	70.8	71.0	71.0	72.0	74.0	76.0	75.0	73.0	70.7
4	72.0	71.5	71.0	71.0	70.3	68.0*	70.0	72.0	70.0*	70.0*	70.0	68.2
5	70.5	70.5	71.0	72.0	70.3	71.5	72.2	73.7	75.0	75.0	73.7	70.5
6	70.5	70.5	70.8	71.0	71.0	71.0	72.0	72.8	74.8	73.0	72.0	71.0
7	71.0	71.0	70.8	71.0	71.0	71.0	71.0	73.0	73.0	72.8	72.2	70.0
8	71.0	71.0	71.0	71.0	71.5	71.0	71.5	73.0	73.2	[73.7]	[72.0]	71.0
9	71.0	71.5	71.0	71.5	71.0	71.0	72.0	72.5	73.0	71.0*	70.0	69.5
10	71.0	71.0	71.0	72.0	71.5	71.0	72.0	72.0	72.8	72.0	71.5	70.5
11	70.8	71.0	71.2	73.0	71.5	71.5	73.0	73.2	73.7	73.0	71.0	70.5
12	70.7	71.0	67.0*	71.2	71.0	71.0	72.5	73.1	74.0	72.2	71.0	69.5
13	71.0	71.0	71.0	71.5	71.2	71.5	72.7	75.0	76.0	75.2	72.2	69.7
14	70.2	70.2	70.5	71.0	71.0	71.2	71.5	73.0	74.8	75.0	72.8	69.3
15	70.4	70.5	71.2	71.8	72.0	73.0	73.2	74.0	76.5*	73.5	71.5	69.5
16	74.0*	76.5*	78.0*	74.5*	71.5	72.5	73.2	74.0	73.0	73.0	70.5	71.0
17	70.2	70.0	70.0	70.0	69.0	70.5	72.0	72.8	74.0	75.0	74.0	71.0
18	70.8	71.0	70.7	70.5	70.5	71.0	71.2	73.0	74.0	76.2	75.5*	72.0
19	76.7*	72.2	71.5	71.0	71.0	71.0	71.5	72.2	74.0	75.0	74.8*	72.5
20	70.5	70.2	71.0	66.5*	69.3	62.0*	63.0*	66.0*	68.0*	72.1	69.0*	68.8
21	75.5*	81.0*	66.0*	72.0	68.5	69.0	70.0	72.5	73.5	73.2	73.0	70.0
22	73.0	69.0	69.5	72.0	68.0*	69.8	71.8	71.5	73.0	73.8	72.6	71.0
23	71.0	71.0	71.0	68.0*	71.0	72.0	72.0	72.0	75.0	75.0	73.3	70.2
24	70.0	70.0	71.2	71.3	71.5	70.0	68.5*	71.2	72.8	74.0	72.7	69.8
25	70.0	70.0	71.0	69.0	70.0	71.8	72.0	72.0	73.2	73.2	71.8	70.3
26	70.2	70.2	70.6	71.1	70.0	72.0	71.8	72.3	73.8	73.0	72.0	70.5
27	71.2	72.0	72.0	72.0	72.2	72.3	72.7	73.0	75.0	75.0	74.0	71.5
28	71.5	70.5	71.5	70.3	[70.4]	[70.8]	[71.6]	[72.8]	[74.3]	74.5	73.0	70.5
29	72.5	71.0	71.3	70.5	73.0	74.2*	72.5	73.0	73.2	73.0	71.5	70.8
30	70.8	70.2	71.0	71.5	73.0	69.8	71.5	72.3	74.0	75.5	71.2	70.7
31	70.7	70.0	70.8	69.0	69.0	70.7	72.5	72.5	73.5	74.0	72.8	70.5
Monthly mean.	71.3	71.1	70.8	70.9	70.7	70.8	71.5	72.5	73.7	73.6	72.2	70.4
Normal.	70.8	70.6	70.9	71.0	70.8	70.8	71.9	72.7	73.9	73.9	72.1	70.4

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale=0′.794 Increasing scale readings correspond to increasing east declination.

DECEMBER, 1882.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.	Daily range.
1	68.8	67.8	67.8	67.0*	69.0	69.0	70.8	71.0	71.6	71.5	70.5	70.0	70.5	9
2	69.0	69.0	69.0	69.5	70.0	71.0	71.5	71.0	71.0	71.5	70.3	70.3	70.6	5
3	69.8	69.2	69.0	69.0	69.0	69.5	69.5	70.2	70.0	70.0	70.0	70.0	70.8	7
4	69.0	69.5	68.8	69.8	71.0	71.0	71.0	71.2	71.0	71.0	71.5	71.0	70.4	8
5	70.0	69.5	70.0	70.2	70.8	71.0	71.0	71.5	71.2	71.2	71.0	70.4	71.4	7
6	69.8	69.0	69.5	70.0	70.3	71.2	71.2	72.0	71.0	71.0	71.0	71.0	71.1	5
7	69.8	70.0	70.5	70.3	70.2	71.3	71.3	71.5	71.0	71.0	71.0	71.0	71.1	5
8	70.2	69.8	70.0	70.0	71.0	71.5	71.2	70.9	71.0	71.0	74.0*	70.5	71.3	6
9	69.0	70.0	68.5	70.0	70.5	71.0	72.0	71.8	71.8	71.5	71.2	71.0	71.0	8
10	69.7	69.0	69.7	70.6	71.0	72.0	71.5	72.0	70.7	71.0	71.5	71.0	71.2	5
11	67.0	67.0	69.0	70.8	70.0	70.2	71.0	70.5	71.0	71.0	70.3	70.3	70.9	8
12	67.0	68.0	69.5	70.0	71.2	71.0	72.0	71.5	71.0	71.0	71.0	71.0	70.8	8
13	67.0	67.0	67.5	69.7	70.0	71.0	71.2	71.5	71.0	70.8	70.8	70.8	71.1	9
14	68.0	68.0	69.0	70.2	71.0	71.5	72.0	71.8	72.0	71.5	71.0	70.8	71.1	8
15	67.2	65.3*	67.0	65.0*	70.0	71.5	70.0	74.5*	73.5	72.5	72.5	72.0	71.2	12
16	65.5*	67.0	68.0	70.0	70.5	71.5	71.0	71.5	71.5	71.2	70.8	70.2	71.7	15
17	69.0	68.0	68.8	69.6	70.8	71.0	71.2	70.5	71.8	71.0	71.0	71.0	70.9	7
18	69.2	69.0	68.0	69.7	71.0	70.0	71.3	74.8*	72.2	71.5	76.0*	75.5*	71.9	9
19	70.0	69.0	69.0	70.0	70.7	71.0	71.2	72.0	72.0	71.4	71.5	74.0*	71.9	9
20	69.9	66.6	70.5	67.0*	69.7	71.0	73.0	72.3	81.8*	74.5*	64.0*	75.0*	69.6	22
21	69.5	69.7	69.2	70.0	73.8*	71.8	72.0	72.2	72.5	71.9	71.7	70.0	71.6	15
22	71.0	70.0	69.5	70.2	71.0	72.5	72.0	74.0	72.0	71.2	72.0	70.0	71.3	6
23	69.5	69.0	70.0	70.0	71.0	71.5	71.2	71.2	71.3	71.5	70.9	70.5	71.2	8
24	69.8	69.0	69.8	69.4	71.2	71.8	71.5	72.0	71.3	70.5	70.5	68.0*	70.7	6
25	69.8	70.0	70.0	70.4	71.0	71.5	71.5	71.5	71.5	71.0	71.0	71.0	71.0	6
26	69.8	69.0	69.8	70.0	71.0	72.0	72.8	71.0	73.0	71.0	72.0	72.0	71.3	4
27	70.0	68.5	69.2	70.8	71.0	72.0	72.0	71.5	72.8	72.5	71.7	71.8	72.0	8
28	69.2	69.2	69.5	70.2	70.8	71.0	71.3	71.7	74.0	72.0	72.0	73.5*	71.6	6
29	71.0	69.5	69.0	70.5	71.0	71.5	71.5	71.8	72.0	72.0	71.0	71.2	71.6	5
30	70.5	70.0	68.8	71.0	69.6	71.5	71.0	71.0	71.2	71.8	73.0	71.5	71.4	8
31	69.0	67.0	67.5	68.3	70.0	70.3	71.3	73.5	71.0	71.5	71.0	71.0	70.7	8
Monthly mean.	69.2	68.6	69.1	69.6	70.6	71.2	71.4	71.8	72.0	71.4	71.2	71.2	71.12	
Normal.	69.3	68.8	69.1	70.0	70.5	71.2	71.4	71.6	71.6	71.3	71.2	70.8		

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

JANUARY, 1883.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	69.8	70.0	70.0	72.0	71.5	67.0*	71.2	73.0	75.3	77.0	74.0	70.0
2	71.0	71.3	71.0	71.0	70.0	70.8	71.0	73.5	75.8	77.0	75.0	72.0
3	70.0	70.5	70.3	70.0	70.5	69.0	70.5	72.0	74.0	75.2	74.8	72.0
4	70.8	70.8	71.5	70.0	70.7	71.0	71.0	72.7	75.5	76.0	74.5	71.0
5	71.8	71.3	71.0	70.8	70.8	70.5	71.0	73.2	76.0	75.7	72.3	69.0
6	70.8	69.5	71.0	71.0	71.7	68.0*	67.4*	71.5	73.5	73.3	70.0*	68.0
7	71.5	69.5	68.0*	70.5	73.0	70.0	71.5	72.0	75.0	74.0	71.0	69.5
8	72.5	71.5	70.5	72.0	72.5	69.8	71.5	73.0	74.0	73.8	71.2	69.0
9	69.0	70.0	70.7	71.5	72.2	72.0	72.0	74.0	74.0	72.8*	70.0*	69.0
10	71.0	71.0	71.0	71.0	71.2	71.8	72.8	74.0	75.0	73.0	71.0	69.5
11	70.3	70.7	70.5	71.0	71.3	71.5	72.0	74.2	76.0	75.3	71.0	68.5
12	70.5	70.8	71.0	71.0	71.5	72.0	72.2	75.0	76.0	73.0	70.0*	69.0
13	70.2	70.2	70.5	71.0	71.8	72.5	72.0	73.3	74.5	73.0	69.0*	67.5
14	71.0	71.0	70.5	70.5	70.0	71.0	71.5	73.5	76.5	76.0	72.0	70.0
15	71.2	71.5	71.0	71.0	71.8	73.0	72.0	74.0	76.0	76.0	72.5	67.5
16	70.0	70.0	70.3	70.3	70.8	71.2	72.0	74.0	76.0	77.5	75.0	72.0
17	70.0	71.2	71.5	71.0	71.0	70.0	72.0	72.0	73.5	77.0	74.0	70.0
18	70.5	71.0	70.5	70.7	70.7	70.0	71.0	73.5	75.0	76.5	75.5	70.5
19	70.8	70.5	70.5	69.8	69.9	70.3	71.0	72.7	76.2	77.0	74.0	70.0
20	69.5	69.8	68.0*	67.5*	69.0	71.0	71.0	72.2	72.4	75.7	73.7	70.3
21	71.0	73.0	74.0*	73.5	71.0	72.0	72.0	73.2	73.0	74.5	73.5	70.2
22	71.2	71.3	71.0	70.4	71.0	71.7	72.5	74.0	76.0	76.0	74.0	71.0
23	70.0	70.9	71.2	71.0	71.0	70.2	71.0	72.3	74.0	76.2	73.2	69.5
24	[70.8]	[70.7]	[71.1]	[71.6]	[71.9]	[71.5]	[72.6]	[74.3]	[76.2]	77.0	74.0	69.9
25	70.8	71.0	70.0	74.0*	74.0*	71.0	73.0	73.5	74.0	77.0	72.0	68.0
26	70.2	70.1	70.5	73.0	72.0	66.0*	73.5	74.2	75.3	75.3	73.0	67.5
27	69.2	68.5	70.5	70.5	70.5	71.0	71.0	70.5*	73.0	74.0	71.3	68.3
28	70.5	70.2	70.8	71.0	71.2	71.2	72.5	73.0	74.8	76.5	73.0	69.8
29	70.0	70.4	71.0	70.5	71.2	71.2	72.0	74.0	77.0	77.0	75.0	71.7
30	71.0	71.0	71.0	71.2	71.0	71.7	72.0	73.5	75.6	75.9	74.0	70.8
31	72.0	72.0	70.0	70.8	70.2	70.8	70.5	72.0	74.0	75.0	75.2	73.0*
Monthly mean	70.6	70.7	70.6	71.0	71.2	70.6	71.6	73.1	74.9	75.5	72.9	69.8
Normal	70.6	70.7	70.7	71.0	71.1	71.1	71.7	73.2	74.9	75.5	73.3	69.7

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0.′794

Increasing scale readings correspond to increasing east declination.

JANUARY, 1883.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Midnight.	Daily mean.	Daily range.
1	67.5	67.0	68.0	69.0	70.0	70.0	70.0	71.0	71.3	71.0	71.0	70.5	70.7	11
2	70.5	69.5	68.0	69.0	70.0	71.0	71.0	70.5	70.8	71.0	70.5	70.0	71.3	7
3	69.0	68.5	68.5	69.2	70.8	71.0	71.0	71.2	71.0	71.0	71.0	71.0	70.9	8
4	70.0	69.5	70.0	71.0	71.0	71.0	71.5	70.8	71.0	71.8	71.5	71.3	71.5	7
5	68.5	67.5	68.0	67.8	68.8	68.3*	68.8	71.0	70.5	71.0	71.8	71.0	70.7	10
6	67.7	69.0	69.3	70.0	70.2	71.0	71.0	71.0	71.0	71.0	72.0	71.0	70.4	11
7	69.8	71.0*	72.0*	74.0*	73.5*	71.5	72.7	72.5	72.8	72.8	71.0	72.0	71.7	7
8	69.3	70.5	71.0	71.2	71.0	71.0	72.0	71.3	71.3	71.0	70.8	70.8	71.4	6
9	69.0	68.8	69.3	71.0	71.2	71.5	71.2	71.5	71.5	70.5	70.8	70.7	71.0	6
10	69.0	68.3	69.1	69.8	71.0	71.5	71.5	71.5	71.0	70.3	70.2	70.0	71.1	8
11	68.0	70.0	70.8	71.8	72.0	72.0	72.0	72.0	72.0	71.8	71.0	70.0	71.5	8
12	68.5	69.2	70.0	70.3	70.6	70.8	71.2	71.0	71.0	71.2	70.8	70.5	71.1	9
13	67.0	69.0	69.5	70.0	70.8	71.0	71.2	71.0	70.0	70.8	70.8	71.0	70.8	8
14	68.0	69.0	68.8	69.8	70.2	71.0	71.0	71.0	71.0	71.0	71.0	70.5	71.1	9
15	65.0*	66.0	70.5	70.5	71.0	71.0	71.2	71.0	71.0	70.8	70.8	70.0	71.1	12
16	69.5	69.5	69.8	70.2	71.0	71.0	71.5	71.5	72.0	72.0	71.0	71.5	71.6	10
17	68.0	67.5	68.0	70.5	71.2	71.3	71.7	72.0	73.0	73.0	71.2	72.0	71.4	11
18	68.0	68.0	67.5	70.0	70.8	71.0	71.0	70.5	71.0	70.7	70.8	71.0	71.1	12
19	68.5	67.8	68.3	69.8	70.0	70.5	70.2	70.2	70.3	70.2	70.0	70.0	70.8	10
20	69.8	69.0	68.0	69.2	70.5	70.7	70.7	71.0	71.2	72.0	72.0	72.0	70.7	5
21	68.5	69.0	69.5	71.0	72.0	72.0	72.2	72.0	71.8	71.5	71.0	71.2	71.8	7
22	68.8	68.2	69.0	70.0	71.0	71.8	71.8	71.5	71.0	71.0	70.5	70.5	71.5	8
23	68.0	68.0	69.0	70.0	71.0	72.0	71.8	71.5	71.0	70.8	[70.6]	[70.7]	[71.0]	9
24	66.5	66.0	68.0	69.3	71.0	71.3	71.0	71.5	71.5	71.0	71.0	71.0	[71.3]	13
25	65.3*	65.3*	68.3	70.0	71.2	71.5	72.0	71.5	80.0*	72.0	70.0	72.0	71.6	16
26	65.0*	64.0*	66.7	69.0	69.5	70.0	70.3	73.0	70.0	70.7	69.8	69.5	70.3	13
27	67.0	67.0	68.0	70.0	70.7	71.0	72.0	71.8	71.5	72.4	71.7	71.0	70.5	11
28	68.0	69.0	68.5	71.0	70.5	70.8	71.0	71.3	71.2	70.8	70.3	70.5	71.1	9
29	69.0	67.5	67.0	69.0	70.5	71.0	71.0	71.3	71.5	72.0	70.8	71.0	71.4	10
30	69.6	69.0	68.0	66.7*	69.2	70.0	71.0	71.0	71.0	71.0	70.0	70.5	71.1	7
31	70.0	69.0	69.5	68.3	69.3	70.0	70.8	70.5	71.0	70.8	70.4	70.1	71.0	6
Monthly mean	68.3	68.3	68.9	70.0	70.7	71.0	71.2	71.3	71.5	71.2	70.8	70.8	71.10	
Normal	68.6	68.4	68.8	69.9	70.6	71.0	71.2	71.3	71.2	71.2	70.8	70.8		

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

FEBRUARY, 1883.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	70.2	71.0	71.0	72.0	71.0	70.8	71.3	72.7	76.5*	74.3	70.6	68.8
2	70.0	65.5*	70.0	78.0*	68.0*	72.3	70.0	75.0	73.5	76.0*	74.2	71.5
3	74.5*	72.3	72.0	69.8	70.0	70.3	70.2	71.0	71.8	72.2	71.0	70.0
4	69.0	71.2	72.2	72.0	70.0	71.0	66.5*	69.5*	72.8	73.0	72.8	71.0
5	69.5	73.0	68.0*	73.0	72.5	72.0	72.2	74.2	73.3	72.2	73.5	71.3
6	70.0	70.8	70.7	70.2	70.0	70.0	70.0	71.0	70.0*	72.0	71.8	69.0
7	70.7	71.0	71.0	71.3	71.0	71.0	71.0	72.5	75.0	75.0	72.8	70.2
8	70.5	70.9	71.0	71.0	71.0	71.0	72.0	74.0	74.5	74.7	72.5	70.3
9	71.2	71.3	71.7	71.5	71.5	72.0	72.3	75.0	76.0	76.0*	74.0	70.0
10	71.3	71.5	71.1	72.2	72.5	72.8	71.0	74.0	76.0	77.0*	74.0	70.8
11	70.3	70.0	70.7	70.8	71.0	71.2	72.3	75.0	76.5*	74.5	71.8	69.0
12	70.5	70.5	70.4	71.0	71.2	72.0	73.8	76.5*	77.0*	75.5	72.8	69.8
13	71.0	71.0	71.0	71.0	71.5	72.0	73.8	76.8*	77.2*	77.0*	74.0	69.5
14	71.5	70.5	70.5	71.0	71.0	68.0*	72.0	74.5	75.0	73.0	73.0	70.7
15	70.2	70.5	70.0	70.3	70.7	70.7	71.0	73.2	76.0	75.5	74.0	71.5
16	70.8	70.2	70.5	71.0	71.0	71.0	70.2	71.0	72.0	73.0	72.0	70.5
17	72.8	71.0	71.0	71.2	69.0	72.0	71.8	74.5	73.8	73.0	73.5	72.5
18	70.5	70.5	70.3	70.2	70.2	70.5	70.5	72.0	73.0	73.0	72.0	70.5
19	71.0	71.3	71.2	71.0	71.2	71.0	70.7	71.0	72.0	72.8	72.0	71.0
20	69.5	68.5*	68.7	69.6	71.2	70.0	71.2	73.0	73.3	72.7	71.5	70.0
21	70.0	70.5	70.5	71.0	71.2	71.0	72.0	72.0	74.0	73.7	73.0	70.0
22	71.5	66.0*	72.7	73.0	71.5	71.0	70.0	69.5*	69.5*	71.0	66.0*	67.5
23	73.0	77.0*	71.7	71.0	73.0	70.0	72.0	74.0	74.0	74.0	71.7	70.0
24	70.3	71.2	69.3	71.0	71.2	72.0	71.0	67.7*	71.0*	73.0	70.7	68.5
25	75.5*	79.0*	71.5	72.5	70.0	70.5	72.0	73.0	73.0	72.5	71.5	70.0
26	71.0	71.0	70.5	71.0	71.0	71.0	72.8	73.0	74.5	71.0	69.5*	68.0
27	69.0	71.0	70.5	71.0	71.7	72.0	70.0	72.8	73.7	76.0*	66.0*	69.0
28	70.0	73.0	76.0*	65.0*	69.0	74.0*	72.5	66.0*	64.0*	68.5*	69.5*	68.5
Monthly mean	70.9	71.1	70.9	71.2	70.9	71.2	71.3	72.7	73.5	73.6	71.8	70.0
Normal	70.6	71.1	70.8	71.2	71.0	71.2	71.5	73.1	73.9	73.3	72.5	70.0

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794 Increasing scale readings correspond to increasing **east declination.**

FEBRUARY, 1883.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.	Daily range.
1	67.8	61.0*	64.2*	67.0*	67.0*	65.0*	71.7	69.2	71.0	72.0	72.0	74.3*	70.1	14
2	71.8*	68.0	69.0	69.0	74.0*	71.8	71.5	72.2	72.2	74.0*	76.0*	75.0*	72.0	19
3	68.0	69.7	70.3	69.8	70.2	71.0	72.6	75.3*	72.5	71.7	72.0	69.0	71.1	10
4	70.4	68.5	68.7	70.0	71.0	71.5	71.7	72.5	73.0	72.0	71.0	71.7	71.0	7
5	69.4	68.2	69.5	70.0	70.0	72.4	70.4	70.8	71.2	70.7	71.2	72.0	71.3	6
6	69.5	69.5	70.0	70.3	71.0	71.3	71.3	71.0	71.7	71.3	70.8	71.0	70.6	4
7	69.0	68.0	68.0	69.2	70.4	71.0	70.8	71.0	71.0	70.8	70.5	70.5	71.0	7
8	68.5	68.0	69.0	70.2	71.0	71.5	71.8	72.0	71.8	71.5	71.3	70.9	71.3	7
9	68.0	67.0	69.0	70.0	71.3	72.2	71.0	72.0	72.5	71.0	71.2	71.5	71.6	9
10	69.0	68.0	69.5	70.5	71.8	71.5	71.2	71.2	71.2	71.2	70.5	71.0	71.7	9
11	66.3	66.0	68.0	70.0	71.0	71.8	71.8	71.5	71.5	71.2	71.0	70.8	71.0	11
12	67.5	67.0	68.0	70.0	71.0	71.0	71.5	72.0	72.0	72.0	71.5	71.0	71.5	12
13	68.0	68.0	69.2	69.8	70.0	71.0	71.0	71.0	71.0	70.5	70.5	74.5*	71.7	9
14	66.8	65.4*	68.0	68.0	71.0	71.0	71.2	71.8	71.2	71.0	71.0	70.7	70.8	12
15	69.8	69.2	68.5	71.0	70.8	70.8	71.5	74.0*	70.0	71.0	71.0	71.0	71.3	7
16	70.0	69.2	69.8	70.2	70.0	70.5	70.8	71.0	71.0	71.0	71.5	72.5	70.9	5
17	70.0	69.0	68.0	69.0	70.0	70.8	71.0	71.0	71.0	70.7	70.5	70.3	71.1	6
18	69.7	69.7	68.5	69.7	70.5	71.2	71.0	71.3	72.0	71.4	71.5	71.2	70.9	7
19	69.7	69.0	69.3	70.0	70.5	71.2	72.0	71.0	70.8	70.4	71.0	71.0	70.9	5
20	69.5	69.0	69.3	70.0	70.2	71.0	70.8	70.8	70.5	70.2	70.0	70.5	70.5	5
21	69.0	69.0	66.8	69.2	69.7	69.0	70.5	70.4	76.0*	71.0	71.0	71.5	70.9	10
22	65.0*	65.5*	65.5*	67.7	67.0*	70.0	69.8	71.0	71.0	71.5	78.5*	71.5	69.7	15
23	69.5	67.0	67.7	69.0	70.0	70.8	71.0	73.0	71.5	70.5	70.0	69.7	71.3	14
24	65.0*	64.5*	69.5	71.0	74.5*	81.0*	90.5*	74.0*	74.0	83.0*	75.0*	71.5	72.5	31
25	69.3	69.0	69.5	70.5	71.0	70.5	70.8	71.0	71.3	71.0	71.3	69.5	71.5	14
26	67.5	67.5	68.0	70.5	70.5	70.7	71.0	71.0	71.0	71.0	71.0	71.7	70.6	8
27	67.5	68.8	67.3	70.3	69.8	69.5	70.5	69.2	74.0	73.0	69.5	73.0	70.6	15
28	68.0	68.8	69.2	70.0	70.7	72.0	72.5	71.0	71.0	71.0	73.5	70.3	70.1	16
Monthly mean	68.6	67.7	68.5	69.8	70.6	71.2	71.9	71.5	71.8	71.7	71.6	71.4	71.11	
Normal	68.7	68.3	68.8	69.8	70.6	71.0	71.2	71.2	71.6	71.2	71.2	71.0		

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

MARCH, 1883.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	74.0*	73.0	73.0	73.0	71.0	74.0	72.2	70.5*	72.0*	72.0	69.8	68.0
2	71.5	73.5	73.2	69.0	66.2*	67.7*	70.0*	71.0*	72.0*	73.0	71.7	71.0
3	67.5*	70.8	71.5	71.8	71.5	71.5	71.0	72.0	73.0	73.5	[70.7]	[68.0]
4	69.0	70.3	71.0	70.0	70.2	70.8	73.0	75.0	76.0	75.5	72.0	69.2
5	71.0	71.0	70.3	69.5	71.8	71.3	72.0	73.0	74.5	74.0	71.0	69.5
6	71.0	71.0	71.0	71.2	71.8	72.0	72.5	74.5	73.0	72.0	69.5	66.5
7	71.5	72.2	72.5	73.0	73.2	74.0	73.5	74.0	75.0	69.0*	69.0	68.5
8	73.0	76.0*	73.5	71.5	71.0	72.0	69.3*	72.0	72.2*	69.8*	67.3*	65.2*
9	71.0	72.0	73.0	71.0	73.0	73.0	75.7*	76.5	74.5	71.5	70.0	69.2
10	71.0	71.5	71.8	71.8	72.0	72.5	74.5	75.7	75.0	74.0	70.8	68.0
11	71.0	70.0	71.5	71.0	70.0	71.0	73.5	75.0	75.0	73.5	71.0	68.0
12	70.0	70.5	70.3	70.8	71.5	71.5	72.5	74.0	75.0	73.0	70.2	69.0
13	73.0	74.0*	69.0	72.5	67.3*	69.3	75.5	74.0	74.9	73.5	71.0	69.0
14	70.5	70.8	69.8	67.0*	68.0*	70.0	72.0	74.0	73.0	73.0	70.0	68.5
15	70.0	69.3	69.5	70.0	70.0	71.0	73.0	74.8	75.5	75.7	73.0	70.0
16	70.5	70.5	70.3	70.3	70.3	71.0	72.3	75.0	74.0	74.5	72.0	70.0
17	71.0	71.0	71.0	70.0	70.0	70.5	72.7	74.8	74.8	74.5	73.0	71.0
18	70.0	70.5	70.5	70.3	68.0*	70.0	73.2	75.2	75.3	73.5	70.5	68.0
19	70.0	70.0	70.2	70.5	70.8	71.0	72.8	75.0	76.5	73.0	70.0	67.5
20	70.0	70.0	70.0	70.5	70.5	71.2	74.0	75.7	75.5	72.0	69.0	67.0
21	72.8	73.0	72.0	72.0	71.3	73.5	75.0	75.0	76.5	75.5	72.0	66.3
22	75.5*	80.0*	70.0	71.0	71.0	73.0	74.0	74.5	76.0	75.0	71.0	68.0
23	71.5	71.5	71.2	71.5	70.0	70.0	72.5	75.3	77.0	73.9	69.3	67.0
24	70.0	69.8	70.0	70.0	70.3	71.0	72.7	76.0	77.2	75.5	73.0	69.3
25	70.5	70.5	70.5	70.8	71.0	71.8	73.2	75.0	76.2	74.5	70.3	67.8
26	72.3	73.0	74.5*	72.8	74.5*	72.9	73.0	76.0	76.5	75.5	71.5	67.2
27	74.0*	75.5*	76.5*	73.0	75.0*	72.0	73.0	74.5	75.0	69.8*	69.0	68.0
28	71.0	71.0	72.0	72.8	71.0	72.5	73.8	72.0	73.2	72.0	68.0*	66.7
29	69.0	69.4	69.6	69.8	71.0	71.0	73.0	73.0	74.8	71.4	71.0	68.5
30	70.5	70.5	70.5	69.0	70.0	71.0	72.5	74.5	74.5	72.4	70.0	68.0
31	70.7	71.0	72.0	71.0	71.5	72.8	74.2	75.0	75.5	72.5	70.0	68.5
Monthly mean	71.1	71.7	71.4	70.9	70.8	71.5	73.0	74.3	74.8	73.2	70.5	68.3
Normal	70.9	71.0	71.1	71.0	71.0	71.6	73.1	74.5	75.1	73.6	70.7	68.7

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794

Increasing scale readings correspond to increasing east declination.

MARCH, 1883.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.	Daily range.
1	69.3	69.5*	71.0*	71.0*	71.0	72.5	74.2*	73.0*	73.0	69.0	70.0	70.0	71.5	8
2	71.0*	70.5*	71.0*	71.0*	71.0	71.5	72.0	71.5	72.5	71.5	73.0	70.8	71.1	5
3	[66.8]	[66.4]	[66.7]	[67.6]	[68.5]	[69.3]	69.5	70.0	71.0	72.5	71.5	71.5	[70.2]	[8]
4	68.0	68.0	69.0	69.4	70.2	72.5	72.0	72.0	71.3	72.0	69.5	71.5	71.1	10
5	69.0	69.3*	69.5	70.5	70.0	70.3	71.0	71.0	72.0	70.2	70.2	70.5	70.9	6
6	65.8	66.2	68.0	68.0	70.0	70.5	70.0	70.7	71.0	76.0*	72.0	72.0	70.7	11
7	67.8	68.0	70.0*	71.0*	71.0	71.0	71.0	71.0	71.5	72.5	71.5	70.3	71.3	9
8	64.0*	64.8	66.0	68.5	69.0	76.5*	70.8	70.5	72.0	71.5	71.0	71.0	70.4	13
9	69.0	69.5*	69.5	70.0	71.0	70.2	70.5	71.0	70.5	70.5	70.8	70.8	71.4	8
10	67.0	66.3	66.8	67.0	69.0	69.8	70.5	70.5	71.0	70.8	70.7	70.8	70.8	8
11	66.3	66.3	67.0	69.0	70.0	70.2	70.2	70.5	70.5	70.2	70.0	70.0	70.4	10
12	66.5	68.5	67.2	68.5	69.0	70.0	70.5	71.0	73.0	82.0*	74.0*	78.5*	71.5	17
13	67.7	67.8	68.0	69.5	69.5	69.8	70.2	70.5	70.0	70.2	71.0	71.5	70.8	15
14	67.8	68.7	68.5	68.5	69.0	69.2	69.8	70.2	71.0	71.0	70.0	69.0	70.0	5
15	68.3	67.0	67.0	67.8	69.0	69.5	70.0	70.0	70.0	70.5	70.5	71.0	70.5	9
16	68.0	66.5	67.0	68.3	69.7	70.3	70.5	71.2	70.5	70.5	70.8	71.0	70.6	10
17	68.0	66.0	66.5	67.8	69.0	69.5	69.8	69.8	71.0	70.0	70.0	70.3	70.5	8
18	67.0	66.0	67.0	68.0	69.0	69.3	69.7	69.8	69.8	69.5	69.8	69.8	70.0	10
19	66.5	66.3	66.3	68.3	69.2	69.5	69.8	70.0	69.8	70.0	69.8	69.7	70.1	11
20	65.5	65.0	66.0	67.4	68.7	69.0	69.0	69.0	69.5	72.5	74.0*	72.7	70.2	12
21	63.5*	62.5*	61.5*	63.5*	66.5*	67.2*	76.0*	69.0	71.3	71.0	71.5	72.5	70.4	18
22	66.0	66.0	66.5	68.0	68.5	69.8	71.0	71.2	71.0	70.0	71.5	72.0	71.3	15
23	66.0	66.0	67.3	67.8	69.0	70.8	69.2	69.0	71.0	70.0	68.0*	70.5	70.2	12
24	67.0	66.0	65.4	66.0	68.0	69.0	69.5	69.5	69.9	70.2	70.3	70.7	70.3	14
25	66.0	66.2	66.0	68.0	69.5	70.0	70.2	69.8	70.0	70.2	70.5	70.5	70.4	11
26	65.0	63.5*	61.5*	64.5*	65.2*	66.0*	67.8*	69.2	69.7	69.8	70.0	73.0	70.2	16
27	65.3	65.7	66.7	68.5	69.0	69.5	72.5	71.0	72.5	70.0	71.2	70.0	71.1	14
28	65.8	63.0*	67.0	67.3	67.2	71.5	71.5	69.5	71.5	70.5	71.0	70.3	70.1	12
29	67.8	67.4	67.0	67.0	71.5	72.5	69.3	72.0	70.0	70.0	70.0	70.2	70.3	13
30	66.0	66.5	67.0	68.0	68.8	69.4	69.8	69.8	70.0	70.0	70.0	70.0	70.0	[9]
31	67.0	66.5	67.0	68.0	69.0	71.0	71.0	70.0	70.0	70.0	70.0	71.0	70.6	10
Monthly mean	66.9	66.6	67.1	68.2	69.2	70.2	70.6	70.4	70.9	71.1	70.8	71.1	70.61	
Normal	67.0	66.6	67.2	68.2	69.4	70.3	70.4	70.3	70.9	70.6	70.6	70.8		

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

APRIL, 1883.

Day.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
1	71.7	71.0	70.5	69.8	70.4	72.3	74.0	75.0	75.0	74.5	72.5	70.3
2	70.5	71.2	71.1	71.2	71.8	72.0	74.0	75.8	74.5	69.4*	67.5*	65.5*
3	73.3*	77.0*	74.7*	73.0	77.5*	71.0	73.0	73.0*	70.0*	68.0*	67.5*	68.5
4	70.0	72.5	72.4	73.0	72.5	72.0	75.5	76.0	76.0	73.8	70.0	69.8
5	72.0	69.0	71.0	70.4	71.0	71.0	73.8	76.2	76.0	74.0	71.0	69.0
6	69.5	70.0	70.2	71.0	71.0	71.0	74.0	77.5	78.5*	73.8	70.0	66.2
7	70.0	70.0	70.0	70.0	70.2	71.0	73.8	77.0	79.2*	77.0*	72.8	69.8
8	70.2	70.5	71.0	70.8	70.4	72.0	74.0	76.0	77.0	75.7	71.0	68.2
9	70.7	71.0	71.0	71.0	68.0*	71.8	74.7	77.5	79.5*	76.8*	74.0*	70.0
10	70.3	70.5	70.0	70.3	70.2	71.8	74.0	76.8	79.0*	77.0*	72.0	69.0
11	71.0	68.5	69.3	70.0	70.5	72.8	75.0	76.0	75.5	72.7	70.5	69.5
12	71.0	71.0	71.0	70.4	70.5	72.2	74.5	78.0	78.0	74.0	70.0	67.8
13	69.0	70.8	71.0	71.0	71.0	72.0	73.8	75.2	74.5	70.5*	69.0	68.5
14	70.0	70.0	70.2	70.0	70.5	71.5	74.0	76.0	75.0	73.5	72.0	70.5
15	70.5	70.7	70.8	71.0	71.0	71.5	73.0	75.5	75.0	74.0	71.0	69.7
16	70.2	71.0	71.3	72.0	72.0	73.5	75.0	77.0	77.0	73.5	70.0	67.0
17	70.5	70.8	71.5	71.2	71.3	73.0	76.0	78.0	77.0	73.3	70.2	67.0
18	73.0*	72.0	72.5	73.0	73.0	71.2	75.5	76.5	77.0	74.2	70.0	67.2
19	65.5*	72.0	71.0	72.5	73.7	74.8*	77.0*	75.2	73.5	71.0*	68.5	67.0
20	65.5*	70.5	70.0	70.5	70.5	71.8	73.2	74.2	74.0	70.3*	68.0*	68.0
21	70.0	70.0	70.7	70.5	71.0	72.8	74.8	76.5	76.5	74.5	72.0	70.0
22	70.2	70.4	70.0	71.0	71.5	73.0	75.5	77.3	76.5	75.0	71.0	69.0
23	69.7	70.0	70.2	70.5	71.0	72.5	75.0	76.5	76.5	75.0	72.5	70.3
24	70.3	71.0	71.5	72.0	72.9	75.2*	78.5*	79.5*	79.0*	81.5*	72.0	67.0
25	70.0	70.0	70.2	71.5	71.5	71.2	75.5	76.0	76.0	73.0	70.5	69.4
26	69.0	70.0	70.5	71.0	71.3	73.0	74.0	76.0	75.0	71.3*	70.7	69.2
27	70.0	70.5	69.3	72.0	72.0	72.0	73.5	74.0	73.0*	70.5*	68.7	67.0
28	71.0	71.0	70.8	70.5	71.0	71.2	71.2*	72.0*	71.5*	70.0*	69.2	69.5
29	70.0	70.0	70.2	70.5	71.0	70.7	71.0*	71.0*	71.0*	70.5*	70.0	69.0
30	70.0	70.5	71.0	71.0	70.5	71.5	73.7	75.0	74.0	72.5	70.5	67.0
Monthly mean	70.2	70.8	70.8	71.1	71.4	72.1	74.4	75.9	75.7	73.4	70.5	68.5
Normal	70.3	70.6	70.7	71.1	71.3	71.9	74.3	76.0	75.7	73.9	70.7	68.6

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794 Increasing scale readings correspond to increasing east declination.

APRIL, 1883.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.	Daily range.
1	68.8	67.8	67.0	67.5	69.0	70.0	70.2	70.5	72.0	71.2	72.0	72.0	71.0	9
2	65.5	65.0	66.0	67.2	68.8	69.9	70.0	70.2	70.0	70.0	71.0	71.0	70.0	11
3	66.3	66.5	68.6*	65.1	69.0	70.0	69.1	71.3	70.5	70.1	73.6*	71.4	70.8	29
4	68.0	66.0	66.0	69.0*	69.0	70.5	70.3	70.0	70.0	71.5	71.0	71.0	71.1	13
5	65.0	64.0	65.0	66.5	68.0	69.2	70.0	71.5	71.8	69.8	68.0	69.7	70.1	12
6	64.3	64.5	65.5	66.7	69.0	70.0	70.0	69.5	69.7	69.5	69.5	70.0	70.0	15
7	67.0	65.2	65.0	67.0	68.0	69.0	69.2	70.0	70.0	69.7	70.0	70.0	70.4	16
8	66.0	64.8	64.5	66.8	69.0	69.8	70.0	70.0	69.8	69.8	70.0	70.2	70.3	14
9	67.0	65.5	64.7	66.0	67.5	69.5	70.5	71.2	70.4	70.0	69.8	70.0	70.8	15
10	66.5	65.5	65.7	66.8	69.0	71.0	70.2	70.0	69.7	70.3	70.4	71.0	70.7	14
11	68.0	67.0	66.8	67.5	69.0	70.2	70.0	70.5	70.3	70.8	71.0	71.0	70.6	10
12	66.0	65.0	65.0	66.2	68.0	69.5	70.0	70.0	70.0	70.2	70.5	71.7	70.4	13
13	68.0	66.5	66.0	67.0	68.0	70.0	69.8	70.5	70.0	70.5	70.3	70.0	70.1	9
14	69.0	67.8	66.5	66.5	69.0	70.3	69.8	70.0	70.0	70.0	70.0	70.5	70.5	10
15	67.8	65.0	64.3	66.0	69.0	70.5	69.4	70.0	70.0	70.0	70.0	70.2	70.2	11
16	65.0	64.2	64.0	65.0	67.0	68.5	69.0	68.0	69.5	70.8	70.3	70.0	70.0	13
17	65.0	64.3	64.5	65.8	67.5	69.0	68.8	69.2	70.0	70.0	70.3	70.5	70.2	15
18	66.0	64.0	62.8*	64.0	66.5	68.0	70.5	69.5	75.5*	73.0*	72.3	71.5	70.8	18
19	65.7	64.0	62.8*	63.0*	64.0*	65.0*	67.8	77.0*	70.0	70.0	70.0	70.8	69.7	16
20	67.2	67.0	67.0	68.0	69.5	70.3	70.7	70.8	70.0	69.5	69.8	69.5	69.8	12
21	67.0	65.5	65.8	67.8	69.0	70.3	70.1	69.8	69.7	69.7	69.8	69.7	70.5	11
22	66.0	64.0	64.0	65.5	68.0	70.5	69.7	69.5	69.5	69.3	69.5	69.3	70.2	15
23	66.5	63.7	64.0	65.2	67.2	69.4	69.5	69.2	69.3	69.5	69.7	70.0	70.1	15
24	62.3*	58.0*	60.8*	63.0*	64.0*	69.0	69.5	69.0	69.8	70.5	70.0	69.8	70.2	27
25	65.7	63.0	65.0	66.0	66.8	69.3	69.7	70.0	72.0	69.2	71.3	72.0	70.2	13
26	69.0	68.5*	67.5	67.0	69.3	68.5	69.5	69.5	69.8	70.5	70.0	70.0	70.4	10
27	66.0	66.0	66.0	66.5	69.0	70.0	70.8	71.0	70.2	71.0	71.0	70.8	70.0	9
28	69.0	67.0	66.0	66.0	67.5	69.3	69.5	69.3	69.5	69.8	69.8	70.0	69.6	5
29	68.0	67.2	66.3	67.0	67.3	68.5	69.8	70.4	70.0	69.8	70.0	70.0	69.6	6
30	66.0	66.0	67.0	66.5	67.0	69.3	69.8	70.0	70.7	71.8	69.0	72.0	70.1	12
Monthly mean	66.6	65.3	65.3	66.3	68.0	69.5	69.8	70.2	70.3	70.3	70.3	70.5	70.30	
Normal	66.7	65.4	65.6	66.4	68.2	69.6	69.8	70.0	70.1	70.2	70.2	70.5		

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

MAY, 1883.

Day.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
1	70.5	71.5	71.3	71.2	72.0	72.0	74.0	75.3	75.0	71.5	69.8*	69.2*
2	70.2	70.8	71.0	70.2	70.0	72.5	74.0	74.0	73.5	71.5	69.8*	68.5
3	70.8	69.5	70.8	71.3	71.2	72.7	74.0	74.4	74.0	72.7	70.3*	69.5*
4	70.2	70.6	70.0	71.3	71.3	72.0	73.3	73.8	73.2	69.8	66.5	65.8
5	69.9	70.4	70.5	71.0	71.8	71.8	73.0	73.7	73.0	70.2	67.2	65.0
6	70.2	70.0	70.3	70.8	68.0*	71.4	75.0	77.0	75.0	69.2	68.0	67.0
7	70.3	70.2	70.8	70.8	71.0	74.0	77.0	77.5	75.5	70.0	67.0	66.4
8	69.5	70.0	70.2	71.0	72.0	74.0	76.7	76.5	74.0	68.8	65.4	65.0
9	69.4	70.3	69.3	70.5	71.5	73.2	75.5	76.0	74.9	72.0	70.0*	68.5
10	69.8	69.9	70.4	71.0	72.4	74.0	75.9	76.5	74.2	70.0	66.5	65.4
11	69.5	69.5	70.4	71.5	73.0	75.0	77.0	76.9	75.0	71.0	69.0	67.4
12	69.5	69.7	70.0	70.5	71.2	73.4	76.0	75.2	73.0	69.0	65.8	65.0
13	70.0	70.1	70.6	71.0	71.5	74.9	78.2*	79.2*	74.0	68.0	65.2	65.0
14	69.5	69.5	70.0	70.9	72.2	74.5	78.4*	78.0*	75.5	71.5	67.6	66.4
15	69.4	69.5	71.0	71.9	72.0	73.6	75.2	73.4	70.0*	66.0*	64.2*	64.2
16	72.0	74.0*	72.6	73.6*	71.0	74.5	76.4	73.0	68.6*	65.2*	64.4*	65.0
17	70.3	72.8*	73.0*	72.4	74.5*	76.4*	79.2*	74.5	71.0*	70.0	68.5	67.0
18	69.5	70.0	70.0	69.5	71.6	74.6	77.5	75.4	71.2	67.5*	67.2	68.0
19	69.3	69.6	70.4	71.5	70.5	72.5	74.5	74.5	73.6	71.5	68.0	67.0
20	70.5	69.0	70.5	70.8	73.0	73.0	74.0	74.9	72.8	70.3	67.0	64.0
21	70.0	71.2	68.0	73.0	73.3	73.0	71.8*	74.2	74.0	72.0	69.4	67.0
22	68.6	70.5	69.4	70.5	72.4	71.5	74.8	74.0	72.4	71.0	68.0	67.0
23	69.5	70.6	70.8	71.0	72.5	74.5	77.0	76.3	74.0	67.4*	64.5*	63.6
24	68.0	70.2	70.6	71.4	72.0	73.5	75.2	76.4	74.0	69.8	66.0	63.0*
25	69.9	70.3	70.6	71.4	72.2	74.3	76.8	76.2	72.5	68.0	65.0*	63.0*
26	70.1	70.5	70.4	70.5	72.0	75.5	76.4	76.5	77.4*	70.0	67.0	65.9
27	69.0	69.0	69.5	70.0	71.5	74.6	76.5	76.2	74.0	69.5	67.4	64.3
28	69.6	70.0	70.5	70.0	70.6	72.0	73.2	73.9	72.5	70.0	67.5	65.6
29	67.4	69.4	69.5	70.2	70.6	72.8	76.1	76.5	74.0	72.0	69.4	67.5
30	70.4	69.6	69.0	70.5	71.5	73.5	74.5	76.4	73.4	70.8	67.0	65.9
31	69.5	70.0	70.2	70.5	71.5	73.6	76.0	76.4	75.0	69.6	66.0	64.5
Monthly mean	69.8	70.3	70.4	71.0	71.7	73.5	75.6	75.6	73.6	69.9	67.2	66.0
Normal	69.8	70.0	70.3	70.9	71.7	73.4	75.4	75.4	73.7	70.4	67.1	66.0

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′. 794

Increasing scale readings correspond to increasing east declination.

MAY, 1883.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.	Daily range.
1	69.1*	68.0	67.2	67.3	67.3	69.0	71.0	71.0	70.0	69.5	69.8	69.0	70.5	8
2	66.8	67.0	67.0	69.4	69.4	69.9	71.0	70.0	70.0	70.0	70.3	71.0	70.3	7
3	67.5	66.5	66.0	67.0	67.8	69.0	69.5	70.0	69.8	69.9	69.7	69.9	70.2	8
4	66.3	65.0	66.2	67.8	68.2	69.5	69.7	69.8	69.3	69.3	70.0	70.0	69.5	10
5	64.8	65.0	66.3	68.5	70.0	70.3	69.8	69.0	70.8	70.7	71.8	69.5	69.8	10
6	66.5	66.8	69.0	70.5	71.0	71.0	71.0	70.8	70.2	69.8	68.4	72.0	70.4	11
7	65.5	66.0	65.5	67.0	69.0	70.0	70.0	70.0	69.5	69.3	69.7	69.5	70.1	12
8	64.0	62.8*	64.0*	66.3	68.0	69.0	69.5	69.2	69.0	68.7	69.0	69.8	69.3	15
9	68.0	67.4	68.5	69.0	69.2	69.3	69.4	69.9	69.5	69.5	69.5	69.6	70.4	9
10	65.5	65.6	67.0	68.5	69.5	69.9	69.8	69.2	69.4	69.3	69.4	69.4	69.9	11
11	66.0	65.4	65.5	66.5	68.0	69.4	69.5	68.5	69.6	69.5	69.6	69.8	70.1	12
12	65.2	65.8	67.5	68.0	68.0	68.0	69.5	69.4	69.5	69.6	69.9	69.6	69.5	11
13	66.0	66.5	66.5	67.2	67.0	68.0	68.5	68.4	69.4	69.3	69.3	69.5	69.7	13
14	64.5	64.9	66.0	67.6	69.0	69.4	69.3	69.0	69.3	69.4	69.5	69.5	70.1	14
15	65.5	67.0	67.6	68.3	69.0	69.0	69.0	68.0	68.4	68.5	69.1	71.5	69.2	11
16	66.3	67.6	68.8	69.4	70.2	69.5	69.0	68.9	69.5	69.5	69.6	70.0	69.9	12
17	66.8	67.4	68.5	68.9	71.0	69.5	67.5	69.5	69.6	68.5	70.0	70.0	70.7	14
18	69.0*	69.9*	70.5*	70.3	69.5	69.6	69.4	69.1	69.9	72.0	70.5	69.5	70.5	10
19	67.0	67.0	67.0	68.2	68.5	69.3	69.5	69.4	70.0	71.0	69.0	69.9	70.0	9
20	64.5	65.4	65.3	66.0	66.0*	68.0	71.0	70.8	75.0*	71.2	71.0	73.0*	69.9	17
21	65.5	65.0	67.4	67.2	72.3*	70.5	69.4	68.6	72.0	68.6	70.0	65.0*	69.9	11
22	67.0	67.0	68.2	69.4	70.0	70.6	71.0	72.0	73.2*	70.5	69.5	70.8	70.4	8
23	64.0	65.0	65.6	68.0	69.5	69.5	69.4	69.2	70.0	70.1	69.8	70.0	69.7	13
24	63.3	63.5*	65.4	62.9*	69.4	69.8	70.0	70.0	70.0	70.1	70.0	69.8	69.4	14
25	62.5*	63.0*	65.0	68.0	69.0	68.5	69.0	69.0	69.4	69.6	69.5	71.4	69.3	15
26	65.5	66.6	67.4	69.4	69.9	70.6	70.6	69.5	70.5	70.4	69.4	69.3	70.5	12
27	63.2	64.0	65.4	68.4	70.0	69.9	69.4	69.0	69.8	69.0	69.6	70.1	69.6	14
28	65.5	66.6	67.5	67.8	68.2	69.1	69.0	69.2	69.8	70.2	69.7	69.5	69.5	8
29	66.5	66.0	67.6	68.0	69.5	70.0	70.5	70.0	70.0	70.0	69.5	69.6	70.1	12
30	65.9	66.0	66.2	66.7	66.8	68.5	69.5	69.6	70.0	72.0	73.1*	70.4	69.9	12
31	64.6	65.6	67.4	68.5	70.1	70.0	69.5	69.6	69.5	69.4	69.3	69.3	69.8	11
Monthly mean	65.8	66.0	66.9	67.9	69.0	69.5	69.7	69.5	70.1	69.8	69.8	69.9	69.94	
Normal	65.6	66.2	66.8	68.1	69.0	69.5	69.7	69.5	69.8	69.8	69.7	70.0		

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

JUNE, 1883.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	69.4	69.6	70.5	70.3	71.6	72.7	75.5	76.0	74.6	71.0	67.0	65.2
2	70.5	71.0	69.0	72.0	72.3	95.5*	74.0	73.0	73.5	70.0	65.0	66.0
3	74.7*	70.8	71.8	71.5	73.2	75.0	76.0	74.2	69.3*	66.8*	65.2	65.0
4	69.8	70.0	70.0	71.0	71.0	72.0	74.0	73.0	72.0	70.2	69.0	67.0
5	70.0	69.8	70.0	70.5	71.8	74.5	76.5	75.8	73.0	70.2	67.3	66.0
6	70.3	64.8*	73.5*	76.0*	74.5*	75.8*	75.8	75.0	72.0	68.3	65.5	63.0
7	69.5	69.8	70.5	71.0	72.2	74.0	75.0	74.8	71.5	68.0	67.0	66.0
8	69.0	69.8	70.2	69.5	72.0	73.5	74.2	76.3	75.3	[70.1]	66.0	64.5
9	70.0	69.8	70.0	70.5	70.8	71.0	74.7	76.3	74.2	70.8	68.3	66.0
10	69.5	69.5	70.0	70.0	71.0	72.2	74.0	74.2	72.2	69.5	67.0	66.0
11	70.0	70.5	70.5	70.2	71.0	72.0	74.0	73.0	70.5*	66.0*	65.3	65.1
12	69.7	70.6	70.3	71.0	70.5	72.0	74.0	75.2	73.0	68.7	66.5	67.7
13	69.3	70.0	70.0	70.3	70.5	72.8	74.0	75.0	74.0	68.5	67.1	67.0
14	70.0	69.8	69.8	70.2	71.5	73.0	75.5	76.5	72.8	67.5	64.8	64.2
15	70.4	70.3	70.3	70.5	71.0	73.0	75.0	76.0	74.5	71.0	68.0	65.0
16	70.7	70.5	70.5	70.2	72.0	74.0	78.0*	79.0*	76.8*	67.5	65.0	64.0
17	69.5	75.5*	70.5	70.0	71.3	67.0*	78.0*	78.0*	[76.2]	72.0	68.0	65.5
18	68.0	69.0	71.0	69.5	71.5	73.0	73.7	74.0	74.0	71.4	68.0	65.5
19	69.0	69.4	69.0	69.5	71.0	72.4	74.5	74.6	73.4	69.5	67.0	65.4
20	68.5	68.6	69.6	69.5	70.7	71.5	74.5	75.2	74.4	69.5	66.4	63.5
21	68.0	68.5	69.0	70.1	70.5	73.0	75.0	76.0	74.9	70.5	64.5*	61.7*
22	67.6	69.2	70.2	70.9	70.1	73.0	75.0	76.9	76.5*	74.4*	69.6	65.0
23	69.2	65.5*	67.6	69.5	69.5	72.4	74.9	79.0*	78.0*	74.5*	68.4	65.0
24	68.2	68.8	69.5	69.6	70.6	72.0	73.6	74.8	74.5	72.0	67.5	65.0
25	69.0	69.4	69.5	69.6	70.2	70.5	71.5*	72.5	74.5	69.4	66.2	63.5
26	69.4	70.4	70.0	70.5	70.6	73.2	75.9	75.4	74.0	69.5	67.6	64.3
27	68.5	71.5	73.0*	73.0*	70.5	71.6	74.6	76.4	75.2	75.0*	72.4*	67.0
28	69.5	69.2	68.6	67.5*	70.5	71.4	74.6	74.5	74.0	70.5	68.2	67.0
29	70.4	70.5	70.5	70.4	71.0	72.4	75.0	74.5	72.3	69.6	69.5	67.0
30	72.0	70.2	71.0	67.8	69.0	69.0*	73.0	73.0	75.0	69.0	68.0	66.2
Monthly mean	69.6	69.7	70.2	70.4	71.1	72.5	74.8	75.3	73.9	70.0	67.2	65.3
Normal	69.5	69.9	70.0	70.2	71.0	72.6	74.7	74.9	73.8	69.8	67.1	65.4

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794 Increasing scale readings correspond to increasing east declination.

JUNE, 1883.

Day.	13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.	Daily range.
1	63.8	64.2	66.7	67.0	67.0	67.2	69.5	67.0	69.0	75.0*	70.2	69.5	69.6	13
2	65.5	64.5	66.0	68.2	68.8	69.7	70.8	69.0	67.8	68.5	69.0	74.2*	69.7	10
3	66.0	67.0	68.5*	69.2	69.0	69.3	68.4	69.0	69.3	70.0	69.5	68.8	69.9	11
4	66.5	67.5	68.2	69.5	70.0	70.0	69.7	69.4	69.3	69.2	69.0	69.5	69.9	8
5	66.0	67.0	68.0	69.4	69.3	69.2	69.5	69.0	69.0	69.0	69.5	70.5	70.0	11
6	63.0	63.0	65.3	68.0	70.8	70.0	69.0	69.0	68.5	69.5	69.0	68.0	69.5	13
7	66.0	66.0	67.0	67.5	68.8	69.2	69.2	69.0	69.0	69.0	69.0	69.0	69.5	9
8	65.0	64.8	65.0	66.0	67.0	68.0	68.0	69.0	71.0	70.0	69.3	67.5	[69.2]	13
9	66.0	66.7	68.0	69.0	70.2	70.5	69.5	69.0	69.0	69.2	69.2	69.3	69.9	11
10	65.7	64.5	65.5	66.3	67.0	68.0	68.5	68.0	68.5	70.0	70.0	69.5	69.0	9
11	66.3	66.0	66.5	67.2	69.0	69.8	69.9	69.6	69.5	69.3	69.5	69.3	69.2	11
12	68.0*	68.0*	68.8*	69.3	69.6	70.1	69.3	69.7	70.2	70.8	71.0	69.5	70.2	9
13	66.5	66.0	66.3	68.0	69.0	70.0	69.5	69.5	69.3	69.5	70.0	70.0	69.7	9
14	64.7	66.2	68.5*	69.5	70.0	70.5	70.7	70.0	70.0	70.0	70.3	70.2	69.8	13
15	64.0	64.7	66.8	69.0	70.4	70.5	70.5	70.3	70.5	70.8	70.5	70.7	70.2	14
16	64.8	64.0	66.0	67.0	68.5	70.2	[72.3*]	74.0*	73.0*	70.0	70.0	68.0	[70.2]	17
17	65.3	64.2	62.8*	68.0	68.0	64.2*	68.5	68.5	[70.6]	73.0*	69.6	70.7	[69.8]	19
18	64.0	65.0	65.5	67.5	70.4	69.6	72.0*	70.5	70.3	71.5	72.0	70.0	69.9	11
19	65.4	66.5	66.6	67.0	69.5	69.6	68.9	69.4	69.7	70.2	70.1	68.6	69.4	9
20	61.5*	61.4*	63.6	67.9	70.0	71.4	70.2	69.0	69.0	68.4	69.5	68.5	68.8	15
21	61.9*	61.9*	64.4	66.5	69.5	70.0	69.0	68.0	68.1	68.0	68.2	68.4	68.6	16
22	64.3	62.1*	62.4*	63.4*	66.2*	67.7	69.5	73.0*	70.5	72.0	69.4	70.0	69.5	15
23	62.5	63.0	64.2	66.0	67.5	69.6	68.2	67.6	68.0	68.0	69.4	68.1	69.0	15
24	64.0	64.5	65.1	66.9	68.5	69.5	70.0	69.8	68.5	68.5	68.5	68.5	69.1	12
25	63.4	64.4	65.6	66.2	67.9	69.0	68.0	68.0	68.0	68.5	68.6	70.6	68.5	11
26	64.0	63.0	63.5	65.2	66.5	68.0	68.5	66.6	67.8	72.8*	69.5	70.5	69.0	14
27	66.0	64.5	65.0	65.2	69.3	70.6	70.5	68.2	72.0*	70.7	69.4	69.0	70.4	13
28	66.9	66.5	66.3	67.0	68.6	69.9	69.5	69.6	69.7	69.6	69.5	70.2	69.5	9
29	64.2	62.8	64.3	66.2	67.9	68.4	69.2	68.5	68.2	68.0	71.0	68.5	69.2	12
30	66.3	65.4	64.5	65.5	64.0*	69.0	69.5	69.0	73.4*	71.0	67.5	71.0	69.1	13
Monthly mean	64.9	64.8	65.8	67.3	68.6	69.3	69.6	69.2	69.6	70.0	69.6	69.5	69.51	
Normal	65.0	65.1	65.7	67.4	68.8	69.5	69.3	68.9	69.2	69.6	69.6	69.4		

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

JULY, 1883.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	72.5*	68.0	69.0	68.6	73.0	76.0*	77.0	74.0	73.5	71.3	69.5*	67.0
2	68.5	68.5	69.0	69.0	70.5	73.0	75.0	75.0	71.9	65.5*	64.0*	64.0
3	69.5	69.8	70.2	70.8	71.5	74.0	75.5	76.2	74.3	70.8	67.0	62.8
4	68.5	69.0	69.3	70.4	71.0	72-8	74.2	74.2	71.0	67.7	66.0	65.0
5	70.5	70.3	70.0	70.8	70.0	72.3	74.4	76.8	73.0	68.3	65.5	64.8
6	68.5	69.0	69.7	69.4	70.7	73.0	74.8	74.5	72.5	70.2	66.5	64.9
7	68.8	69.3	70.0	70.3	70.7	73.0	73.2	77.0	72.0	69.5	68.0	64.0
8	72.5*	72.0*	71.0	71.2	70.3	69.0*	70.0*	75.0	72.5	70.5	67.0	64.5
9	68.2	69.5	69.5	70.4	70.8	72.0	73.5	73.9	71.2	66.5*	64.5	63.8
10	74.0*	67.0	69.0	70.2	70.7	74.0	74.7	74.8	73.0	70.5	65.6	62.0*
11	70.0	70.0	70.2	71.0	72.0	73.5	74.9	76.0	74.4	70.3	67.5	66.0
12	69.4	69.2	69.0	70.1	70.9	72.0	74.0	75.2	74.5	70.5	68.0	66.8
13	69.5	69.4	70.5	70.6	71.2	73.0	74.0	73.5	73.0	71.0	69.0	66.5
14	68.0	70.1	69.0	69.5	70.5	74.6	70.6*	69.9*	74.6	70.5	68.0	66.4
15	69.5	69.5	70.0	70.4	71.5	73.4	76.0	75.5	74.0	68.0	66.2	66.3
16	68.5	67.4	69.6	70.0	71.9	74.2	75.1	75.0	72.9	68.9	65.5	63.5
17	69.2	70.0	70.4	70.5	72.0	73.5	75.0	74.5	74.5	69.6	66.0	63.5
18	66.5	70.2	72.1	71.0	72.7	70.5	75.0	74.5	72.0	72.0	67.3	61.2*
19	68.0	69.3	70.0	70.0	70.5	73.6	76.2	78.0*	74.3	71.0	67.2	64.5
20	69.0	69.0	69.5	70.4	70.5	73.5	76.7	77.0	76.0*	71.3	65.9	63.0
21	68.6	69.3	69.5	70.0	70.3	72.4	75.0	76.8	74.5	69.0	64.5	60.6*
22	69.0	69.3	69.9	70.0	71.0	73.5	75.6	76.0	73.5	70.4	66.5	63.4
23	69.0	68.9	69.4	69.5	70.0	72.0	75.0	76.1	74.4	71.5	69.0	66.2
24	70.5	70.9	70.5	71.4	72.0	74.5	76.0	74.2	70.5*	67.0*	63.0*	61.0*
25	68.4	68.3	67.2*	67.5*	68.2*	70.8	74.5	77.0	75.0	70.2	66.9	64.0
26	68.6	69.0	70.0	69.0	71.0	73.2	77.0	74.6	72.6	70.0	69.0	65.5
27	69.9	69.0	69.5	70.5	70.8	72.7	75.0	75.5	70.2*	67.0*	64.0*	64.0
28	69.0	69.0	69.8	69.7	70.8	73.0	75.4	75.0	73.2	70.5	69.0	68.5*
29	69.3	69.7	69.8	69.8	70.2	71.5	74.3	75.8	72.5	71.8	69.0	67.5*
30	69.0	70.0	72.3	70.3	76.0*	73.0	77.0	75.0	76.8*	68.7	68.0	65.0
31	70.0	70.0	70.0	70.5	74.0*	75.2	74.5	72.5*	69.5*	66.5*	63.0*	65.2
Monthly mean	69.4	69.4	69.8	70.1	71.2	73.0	74.8	75.1	73.2	69.6	66.6	64.6
Normal	69.0	69.3	69.9	70.2	71.0	73.0	75.1	75.3	73.2	70.1	67.0	64.8

DECLINATIONS—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794

Increasing scale readings correspond to increasing east declination.

JULY, 1883.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.	Daily range.
1	68.0*	68.5*	69.0*	69.0	70.0	73.5*	72.0*	70.0	70.0	70.5	70.5	69.0	70.8	11
2	64.5	64.7	65.8	67.6	68.0	69.7	69.2	67.5	68.0	68.0	69.0	68.0	68.5	11
3	61.5*	62.2*	64.2	67.0	69.0	70.1	68.5	67.0	67.5	69.0	68.0	68.5	69.0	16
4	65.4	66.8	67.3	67.3	67.3	68.0	70.2	68.7	68.2	69.5	69.5	70.3	69.1	10
5	65.0	65.0	67.7	69.0	69.2	69.3	68.0	67.0	67.8	68.0	68.0	68.3	69.1	12
6	65.5	66.0	66.7	67.0	67.0	66.8	68.0	66.7	66.8	67.2	67.0	68.3	68.6	10
7	64.2	65.0	65.5	65.2	65.5*	67.0	68.0	67.8	69.0	69.0	76.5*	75.3*	69.3	14
8	63.8	65.0	65.5	66.0	65.5*	66.0*	67.5	66.8	67.3	68.0	68.0	68.5	68.5	15
9	63.3	64.0	64.0	66.0	67.5	67.7	69.0	72.8*	70.5	67.2	70.0	66.0*	68.4	16
10	64.2	65.5	67.0	68.1	69.6	73.5*	69.2	68.0	68.0	69.0	69.5	69.6	69.4	17
11	66.1	66.0	66.2	68.9	71.6*	71.0	74.2*	74.5*	72.0*	69.1	69.4	70.0	70.6	12
12	65.5	66.4	67.0	66.8	68.2	68.3	68.5	68.8	68.5	68.5	68.6	69.0	69.3	9
13	64.9	65.0	66.5	68.4	70.4	69.9	68.5	68.3	68.0	69.0	69.3	67.6	69.5	10
14	66.6	66.8	66.5	66.5	67.6	68.0	68.5	68.7	69.0	69.0	69.0	69.5	69.1	14
15	67.0	66.5	66.4	68.0	67.2	66.5	68.2	69.5	74.0*	73.0*	69.9	68.2	69.8	10
16	64.6	63.5	68.0	68.4	67.5	67.5	68.0	70.0	68.5	68.3	68.6	68.6	68.9	12
17	63.0	65.0	66.9	69.4	70.4	69.5	67.6	67.5	70.0	68.0	68.5	68.5	69.3	12
18	63.2	64.5	67.4	67.3	65.8	68.3	70.5	65.4*	68.0	68.2	68.6	68.5	68.8	17
19	64.0	64.3	66.5	69.4	69.5	70.0	69.5	69.0	68.0	67.9	68.6	68.5	69.5	14
20	60.5*	60.0*	62.5*	65.4	69.0	69.5	69.0	68.5	69.0	68.5	68.4	68.5	68.8	19
21	59.2*	61.0*	64.5	67.5	69.6	69.5	68.5	68.2	68.5	68.5	68.5	68.6	68.4	17
22	61.3*	61.5*	63.0*	65.2	67.1	68.8	68.5	67.6	68.0	68.5	69.4	69.1	68.6	15
23	64.5	64.0	65.0	65.6	67.0	68.4	68.3	71.5*	70.6	69.0	70.5	71.0	69.4	13
24	61.5*	62.5*	64.0	66.4	66.6	68.0	73.6*	68.5	68.5	67.9	68.3	68.0	68.6	17
25	62.3	63.4	64.5	65.8	68.0	68.4	67.9	68.3	68.0	68.2	68.9	69.0	68.4	15
26	65.9	65.8	67.2	68.7	69.0	69.0	69.3	69.5	69.8	71.0	70.5	70.7	69.8	11
27	65.0	65.5	66.9	68.0	68.5	68.3	68.0	68.0	68.5	68.8	69.0	69.0	68.8	11
28	68.0*	68.0*	68.5	68.0	68.5	69.0	68.8	68.5	69.5	68.5	69.0	69.0	69.8	8
29	66.5	66.5	67.5	66.5	67.8	69.0	80.0*	72.5*	74.0*	73.5*	77.0*	73.5*	71.1	15
30	67.0	66.0	69.0*	68.0	70.4	70.7	70.5	69.0	70.0	71.8*	70.9	70.0	70.6	14
31	63.5	65.3	66.3	65.5	66.0	70.0	69.0	70.0	70.0	69.0	68.3	67.2	68.8	13
Monthly mean	64.4	64.8	66.2	67.3	68.2	69.0	69.5	68.8	69.2	69.0	69.5	69.2	69.25	
Normal	64.8	65.3	66.3	67.3	68.3	68.8	68.7	68.4	68.7	68.6	69.0	68.9		

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

AUGUST, 1883.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	71.5	69.5	71.0	72.5	72.2	74.0	74.0	73.8	73.8	67.0*	65.8	65.3
2	70.0	70.5	70.3	71.2	72.3	75.0	77.0	77.0	75.2	70.8	69.8*	67.5
3	69.0	69.4	69.8	71.3	72.0	74.5	76.7	77.0	73.3	67.5	64.8	65.0
4	68.3	69.0	69.2	70.0	71.0	73.5	76.0	77.0	75.8	72.0	70.5*	69.0*
5	69.9	70.0	70.0	70.5	71.6	75.7	76.5	74.4	72.0	70.5	66.5	63.6
6	70.5	71.0	70.5	74.5*	72.4	73.0	75.7	77.4	74.4	70.9	67.1	65.4
7	69.4	70.0	70.0	70.3	70.5	73.2	74.8	75.0	73.0	69.0	66.0	65.0
8	69.4	68.9	69.4	70.0	70.3	73.0	76.0	77.5	74.2	70.5	69.0	67.5
9	69.6	69.5	69.4	70.4	70.3	72.1	75.3	75.0	72.0	69.5	67.6	67.2
10	69.5	70.0	70.0	70.2	71.0	73.2	74.0	74.8	72.0	69.5	68.0	67.0
11	69.2	69.0	70.0	72.0	71.8	73.0	75.2	72.7*	72.5	69.3	69.4	67.5
12	69.0	69.0	69.1	69.5	70.5	72.5	75.8	76.0	73.5	69.0	66.5	65.4
13	68.7	69.2	69.2	69.2	70.6	72.5	74.0	74.2	72.0	68.0	66.0	65.0
14	70.0	70.3	70.0	69.2	70.8	74.0	77.3	77.0	73.0	68.5	65.5	63.7
15	68.5	66.2*	69.7	69.5	71.5	75.0	77.3	75.5	69.3*	65.9*	64.0*	63.8
16	69.3	69.4	[70.2]	[71.0]	[71.9]	[74.3]	[76.9]	[77.3]	[75.1]	72.0	68.0	66.7
17	69.3	69.5	70.0	70.2	70.8	74.0	77.5	77.0	72.5	64.8*	60.0*	58.8*
18	69.8	70.5	71.2	69.5	72.2	74.5	77.0	77.0	69.5*	66.2*	64.2*	63.0*
19	69.2	69.5	69.8	70.5	72.0	74.0	75.5	75.8	73.2	70.5	67.0	65.0
20	70.0	70.5	71.0	71.0	71.5	73.0	75.0	77.0	75.0	70.8	67.0	63.5
21	69.2	69.3	70.0	70.0	70.8	73.0	76.3	78.2	78.0*	73.2*	69.8*	67.0
22	69.4	70.8	70.0	70.5	71.0	73.0	75.9	78.5	76.5*	71.0	69.0	65.3
23	69.3	70.0	69.8	69.5	70.0	72.8	73.9	75.0	74.8	72.8*	69.7*	66.7
24	69.5	68.2	70.0	70.5	70.0	72.3	75.0	76.4	74.0	71.5	68.0	66.0
25	69.5	69.2	69.2	69.5	69.5	72.3	76.5	78.0	74.2	70.0	67.0	65.0
26	68.5	69.0	69.2	69.5	70.2	72.0	75.0	76.0	73.5	70.9	68.0	66.4
27	68.7	69.0	69.0	69.0	69.3	69.0*	69.5*	65.0*	62.5*	67.0*	66.0	70.0*
28	69.2	69.2	69.5	70.0	71.0	71.0	73.0*	71.0*	69.8*	70.0	69.5	70.5*
29	70.0	69.8	70.2	70.5	72.0	73.2	76.4	77.0	75.5	69.4	65.3	65.0
30	69.0	69.5	70.0	70.2	70.8	74.0	75.5	75.0	73.0	69.0	67.5	67.0
31	69.2	69.8	69.8	70.0	70.8	71.0	74.0	75.0	71.0	67.0*	64.0*	63.0*
Monthly mean	69.4	69.5	69.9	70.4	71.0	73.2	75.4	75.6	73.1	69.5	67.0	65.7
Normal	69.4	69.6	69.9	70.2	71.0	73.3	75.7	76.2	73.5	70.0	67.1	65.7

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794 — Increasing scale readings correspond to increasing east declination.

AUGUST, 1883.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.	Daily range.
1	65.3	66.5	69.7	71.5*	71.2	70.4	77.0*	74.0*	73.8*	72.0*	72.0*	70.0	71.0	16
2	66.0	67.0	68.0	70.0	70.0	70.3	72.4	69.5	69.3	69.3	69.3	69.5	70.7	10
3	65.0	65.5	66.5	68.0	68.8	69.0	69.5	69.0	68.0	68.0	68.3	68.5	69.4	11
4	67.4	67.0	67.3	68.0	69.0	68.9	68.5	68.0	68.4	68.3	68.6	69.2	70.0	11
5	63.2	64.9	65.0	67.6	67.5	67.5	69.0	68.1	67.9	68.0	68.6	66.3*	69.0	16
6	64.5	63.5	66.5	69.0	70.2	70.0	69.4	68.5	69.0	70.6	67.2	68.0	70.0	17
7	65.4	66.0	68.5	69.2	69.0	74.5*	70.0	69.0	68.2	69.0	71.0	69.5	69.8	11
8	66.8	67.0	67.1	68.5	69.3	69.0	68.8	68.5	69.0	69.0	69.5	69.4	69.9	11
9	66.0	67.4	69.0	68.0	68.0	67.6	68.2	68.5	68.5	69.0	68.6	69.5	69.4	10
10	65.2	65.6	67.0	68.3	67.9	69.3	69.6	69.5	70.0	71.5*	71.0	70.5	69.8	7
11	66.1	66.0	66.2	66.2	66.7	67.5	68.0	69.3	69.0	68.0	68.5	68.8	69.2	10
12	65.5	65.8	66.0	66.4	66.5	67.0	67.2	67.8	68.0	68.0	68.0	68.5	68.8	12
13	65.5	64.4	63.0*	64.3*	65.7*	67.0	67.0	67.5	68.0	68.0	68.5	69.0	68.2	11
14	64.2	63.1*	69.2	68.3	69.8	67.8	66.3	67.0	67.5	67.5	67.7	68.0	69.0	16
15	64.3	66.0	66.5	67.4	68.0	68.0	67.5	67.5	67.5	68.5	69.0	69.0	68.6	14
16	66.0	67.0	68.0	69.6	69.5	68.5	68.0	68.0	68.5	68.5	69.0	69.2	[70.1]	[11]
17	60.5*	64.5	67.5	69.0	69.4	69.0	69.0	69.2	69.1	69.0	69.1	70.0	68.8	20
18	62.8	63.0*	67.0	69.0	69.0	69.2	71.8*	67.9	69.3	69.0	68.5	68.8	69.2	15
19	64.5	64.0	65.3	68.0	68.2	68.0	68.0	67.8	68.2	68.7	69.8	69.8	69.3	16
20	62.3*	64.0	66.0	68.5	70.0	70.0	69.8	69.5	69.5	69.4	68.9	69.0	69.7	15
21	65.0	64.0	64.4*	66.0	67.3	68.5	69.0	69.2	69.5	68.5	68.5	69.0	69.7	14
22	63.3	64.8	65.0	67.7	69.3	69.5	68.5	68.8	69.5	72.8*	71.0	69.4	70.0	16
23	64.2	64.8	66.5	68.0	70.0	70.8	69.7	69.2	71.2	70.0	69.3	69.0	69.9	12
24	64.5	65.5	68.0	69.5	70.2	69.8	69.2	69.4	69.5	70.0	69.5	69.0	69.8	12
25	65.0	67.0	69.0	70.0	70.0	69.0	68.0	68.3	68.0	68.5	68.2	68.0	69.5	13
26	66.0	66.9	68.7	69.4	69.2	68.5	68.0	68.0	69.0	68.0	68.3	68.5	69.4	11
27	69.0*	68.5*	70.4*	69.0	68.2	67.4	68.0	68.0	69.0	68.5	69.2	69.5	68.3	9
28	72.0*	70.2*	70.5*	72.2*	70.5	67.5	67.7	68.0	68.0	68.5	69.5	69.3	69.9	6
29	64.5	65.7	65.0	66.0	67.8	67.7	68.0	68.0	68.5	69.4	69.8	69.0	69.3	14
30	67.0	66.4	67.2	68.2	68.5	68.3	68.2	68.4	68.4	68.5	68.5	68.8	69.4	10
31	64.5	66.8	68.8	69.7	70.2	69.0	67.8	67.8	67.5	68.2	69.3	68.8	68.9	13
Monthly mean	65.2	65.8	67.2	68.4	68.9	68.8	68.9	68.6	68.9	69.0	69.1	69.0	69.48	
Normal	65.1	65.7	67.2	68.3	69.0	68.7	68.4	68.4	68.7	68.7	69.0	69.1		

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

SEPTEMBER, 1883.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	68.5	69.4	69.7	70.3	70.4	73.3	76.2	76.5	74.0	70.6	67.0	62.6*
2	69.7	70.2	70.5	72.8	74.2*	75.5*	77.5*	78.6*	74.5	69.0	65.5	64.5
3	67.5	69.0	70.0	69.6	69.7	73.0	77.6*	79.2*	75.7	70.0	65.0*	64.2
4	69.5	69.8	70.2	70.5	71.0	73.6	76.2	77.5	74.5	69.5	65.8	65.8
5	70.0	69.4	69.0	69.8	70.1	72.5	76.0	72.0*	66.9*	65.5*	64.0*	61.5*
6	71.5	71.0	69.5	69.5	68.0*	75.0	77.5*	76.6	73.0	66.5*	64.3*	61.4*
7	69.5	70.0	70.2	70.5	70.8	72.5	75.6	76.0	72.0	70.0	67.0	65.5
8	69.4	69.3	69.6	70.2	70.6	73.5	75.3	76.5	73.0	70.5	68.0	65.5
9	69.4	69.6	69.9	70.0	70.5	74.1	79.0*	77.0	74.5	71.0	68.9	65.2
10	67.5	71.5	70.8	71.0	70.4	71.5	74.3	74.0	73.4	71.3	69.5	66.5
11	69.2	69.5	69.6	69.8	70.5	73.2	77.0	76.5	73.3	69.3	65.8	65.6
12	69.4	69.5	69.5	69.8	70.4	72.5	74.5	74.0	74.3	70.6	68.1	66.9
13	69.7	70.2	69.0	71.5	72.3	73.6	74.5	77.5	69.0*	66.5*	65.0*	64.8
14	69.8	69.7	70.0	70.0	71.0	73.0	77.3*	75.0	74.0	70.8	67.5	66.9
15	70.0	70.2	70.0	70.1	70.5	73.3	76.0	76.0	74.0	69.4	66.0	64.5
16	77.0*	80.0*	82.5*	79.5*	76.0*	76.0*	70.0*	78.0*	74.0	67.5*	63.0*	63.5*
17	65.5*	70.8	72.0	72.3	67.5*	70.0*	73.0	74.5	74.0	71.5	70.0	69.4*
18	68.9	69.1	69.3	69.5	70.2	71.2	74.5	73.0	72.0	71.8	68.0	63.2*
19	69.2	69.2	69.8	69.7	72.0	73.0	74.4	75.5	74.5	73.0	71.0*	68.2
20	68.0	68.0	69.8	70.2	70.6	71.8	74.6	74.2	74.5	71.0	68.5	66.8
21	69.3	69.5	69.8	70.2	70.9	72.6	74.8	75.0	75.8	72.5	70.0	67.7
22	67.7	70.0	69.8	69.8	70.4	71.2	72.5	72.5*	72.5	71.3	67.8	66.0
23	69.2	69.3	69.9	70.2	71.5	72.2	74.0	72.0*	73.0	72.5	70.5*	69.0
24	70.2	70.4	70.8	70.5	73.3	72.2	73.0	25.0	73.3	69.5	68.5	67.3
25	72.0*	72.3	71.5	80.8	71.8	72.0	71.7*	69.3*	69.2*	68.0*	65.3*	68.2
26	69.8	70.0	70.3	70.7	70.8	72.8	74.0	74.0	74.0	72.0	69.8	68.3
27	69.2	69.5	70.0	70.2	70.2	71.8	72.7	72.2*	71.5	70.1	69.3	68.8
28	71.0	74.0*	72.5	71.0	71.2	68.0*	72.3	73.0	72.0	71.0	68.7	67.4
29	69.0	69.3	70.0	70.3	69.0	70.0*	69.0*	69.8*	69.3*	69.5	68.7	67.7
30	68.5	70.0	67.0*	67.7*	70.0	72.0	74.2	74.5	73.5	70.8	68.0	66.3
Monthly mean	69.5	70.3	70.4	70.6	70.9	72.6	74.6	74.9	73.0	70.1	67.5	66.0
Normal	69.3	69.8	70.1	70.4	70.8	72.7	74.5	75.4	74.0	70.7	68.0	66.6

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794

Increasing scale readings correspond to increasing east declination.

SEPTEMBER, 1883.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.	Daily range.
1	62.0*	63.1*	65.5	68.2	69.0	69.0	68.0	68.5	68.0	68.5	69.0	69.0	69.0	17
2	65.0	65.5	67.7	67.5	68.0	67.5	71.5	69.0	69.0	68.4	67.0	68.0	69.9	16
3	63.5	65.0	67.2	69.3	70.0	70.0	69.4	68.7	68.8	69.0	70.6	60.0	69.7	16
4	66.5	68.0	69.4	70.3	70.5	70.5	70.1	70.0	70.2	71.2	72.0*	71.1	70.6	12
5	62.0*	66.5	68.5	70.4	72.0*	69.4	69.2	68.5	69.5	70.5	70.6	73.9*	69.1	16
6	62.5*	65.0	67.5	69.4	70.0	69.5	69.0	68.6	69.0	69.0	69.0	69.0	69.2	16
7	64.5	65.6	67.5	67.7	68.2	68.0	68.6	68.6	68.9	68.8	68.7	69.2	69.3	12
8	64.5	64.6	66.8	68.5	69.5	69.0	68.9	69.2	69.2	69.1	69.0	69.4	69.6	13
9	64.8	66.2	66.5	68.0	68.5	67.4	67.9	68.3	68.6	68.5	69.0	69.5	69.7	15
10	65.5	67.2	69.0	70.1	69.7	68.5	68.5	68.6	69.0	69.0	69.0	69.2	69.8	9
11	66.1	66.5	68.4	69.3	69.5	68.9	69.0	69.5	70.5	69.9	67.5	70.5	69.8	11
12	66.0	66.5	67.5	68.0	67.5	67.4	67.5	74.5*	68.0	68.8	68.5	69.3	69.6	10
13	65.5	68.0	70.6*	70.4	70.0	69.9	70.0	60.5	69.3	69.3	69.2	69.4	69.8	14
14	67.4	68.0	70.4	70.3	69.5	68.6	69.0	68.9	69.1	69.0	69.1	69.5	70.2	10
15	65.0	66.0	67.0	68.5	69.2	69.0	69.0	70.3	72.2*	71.5	74.5*	71.0	70.1	23
16	64.0	68.0	67.5	67.0	67.0	71.5	83.5*	71.0	74.0*	70.5	71.5	63.5*	71.9	26
17	69.4*	69.3*	69.0	69.6	70.0	69.8	69.2	69.1	69.1	68.5	69.0	69.0	70.1	16
18	64.0	65.0	65.8	67.0	68.7	70.8	74.0*	70.0	70.0	70.0	68.5	69.0	69.3	15
19	66.0	66.0	66.9	68.0	69.0	69.4	69.0	69.2	69.1	71.5	70.0	69.0	70.1	10
20	65.4	65.5	67.0	68.0	69.0	68.8	69.5	69.3	69.1	69.0	69.0	69.0	69.4	11
21	66.0	66.3	66.7	68.5	68.0	68.9	69.8	69.0	69.0	69.2	69.0	68.8	69.9	10
22	65.7	67.0	67.5	68.2	67.5	68.5	68.2	69.5	69.3	69.0	69.0	69.4	69.2	7
23	67.5	66.5	68.0	69.0	69.0	68.5	68.5	70.0	68.8	69.0	69.3	69.8	69.9	7
24	66.4	65.8	66.3	66.3	67.0	66.7	68.3	68.7	69.8	68.8	69.8	69.5	69.5	8
25	69.0*	68.5	69.2	69.4	68.0	68.5	69.8	69.8	67.0	70.4	70.0	72.0*	69.7	10
26	68.0	68.5	69.5	69.0	68.5	68.2	68.7	68.8	69.0	69.0	69.2	69.0	70.1	8
27	69.0*	69.5*	69.5	69.2	68.0	68.2	68.5	69.2	67.8	67.8	68.7	69.5	69.6	6
28	67.8	68.5	69.0	69.5	69.0	71.5	71.0	71.0	69.8	68.5	68.0	65.7*	70.1	9
29	67.7	68.0	69.0	69.8	71.2	72.3*	69.7	68.5	68.5	68.2	68.5	69.0	69.2	6
30	66.8	67.7	68.3	69.5	69.2	68.8	69.2	68.7	68.5	68.5	68.0	68.0	69.3	10
Monthly mean	65.8	66.7	68.0	68.8	69.0	69.1	69.8	69.4	69.3	69.3	69.3	69.3	69.76	
Normal	65.8	66.6	67.9	68.8	68.9	69.0	69.1	69.1	69.1	69.3	69.1	69.4		

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

OCTOBER, 1883.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	68.3	68.0	68.7	66.0*	69.2	71.0	74.0	74.5	72.7	70.8	68.1	67.0
2	69.5	69.2	69.8	70.0	70.7	71.5	74.5	76.0	75.3	71.3	68.4	66.8
3	70.0	70.2	70.2	70.8	71.0	72.3	74.0	75.2	72.5	69.0	66.5	66.3
4	70.0	70.2	70.1	70.2	71.0	72.0	74.2	75.0	75.5	71.7	69.0	68.0
5	76.5*	72.8*	73.2*	71.7	74.5*	74.0	75.0	79.5*	69.0*	69.5*	64.0*	64.6
6	67.0*	69.0	70.0	69.8	69.3	70.4	72.0	70.8*	70.0*	68.1	66.0	66.4
7	69.7	68.5	70.5	66.5*	71.5	71.8	73.0	73.5	73.7	72.0	69.5	68.1
8	69.9	70.3	70.0	68.3	70.3	70.7	72.5	74.0	74.0	72.2	69.3	66.5
9	69.5	70.0	69.8	70.2	70.5	71.7	74.0	74.0	73.0	[70.5]	[68.1]	67.0
10	69.2	70.0	70.0	70.0	70.7	73.5	76.2	76.2	75.3	[72.8]	[70.2]	69.0
11	[71.6]	[71.6]	[71.9]	[71.8]	[72.4]	[73.5]	[75.7]	[76.8]	[75.0]	72.2	68.5	67.2
12	70.0	70.9	71.0	71.5	71.0	72.5	76.0	78.8*	75.7	74.0*	69.2	66.0
13	69.8	69.5	69.7	69.7	70.6	72.8	76.8*	79.2*	74.7	70.0	67.0	64.0*
14	69.2	69.2	70.0	70.2	70.2	73.0	75.5	75.5	74.5	71.0	67.8	66.1
15	68.0	69.5	70.0	70.8	70.7	72.5	74.0	79.7*	73.7	69.0	64.0*	64.4
16	69.0	67.9	69.0	70.3	71.0	72.8	75.7	76.1	73.9	72.4	67.8	65.0
17	69.4	70.3	71.3	71.6	72.0	73.2	75.0	75.0	73.5	70.2	65.5*	64.8
18	69.3	68.5	69.0	71.5	72.2	73.5	75.5	76.0	74.4	72.5	69.4	67.0
19	69.5	69.9	69.5	70.5	70.5	71.4	75.5	75.5	74.0	70.5	68.6	65.7
20	70.1	70.5	70.5	70.5	69.3	69.0*	72.0	72.8	73.5	70.0	64.3*	62.5*
21	69.6	69.7	70.2	69.9	70.5	72.0	75.0	75.3	73.0	69.4	67.0	65.6
22	69.	71.3	72.0	70.8	73.0	73.4	72.5	74.5	74.3	71.3	70.2	69.3
23	70.0	69.6	70.0	70.4	70.6	71.3	74.0	74.0	71.5	69.4	68.0	67.6
24	69.8	70.3	70.3	70.0	71.0	71.5	72.7	73.0	72.4	70.5	69.4	68.0
25	70.3	70.2	70.3	70.5	71.0	71.5	73.0	73.4	72.5	71.0	69.4	68.0
26	71.5	69.6	69.8	69.6	70.6	70.5	73.5	73.6	72.6	70.4	69.0	68.0
27	70.3	70.4	70.3	70.3	70.6	71.4	73.5	74.5	74.4	70.5	68.0	67.4
28	69.4	70.0	70.1	70.0	70.9	71.3	73.4	74.5	73.5	70.5	68.5	68.0
29	69.5	70.0	70.0	70.2	70.5	71.5	74.4	75.5	74.5	70.2	66.4	65.0
30	69.9	70.0	70.0	70.0	70.3	71.5	74.6	76.5	75.5	73.0	70.5	68.5
31	69.5	69.9	70.2	70.0	70.3	70.5	74.0	77.0	75.0	72.5	70.0	68.0
Monthly mean	69.8	69.9	70.2	70.1	70.9	71.9	74.2	75.4	73.6	70.9	68.0	66.6
Normal	69.7	69.8	70.1	70.4	70.8	72.0	74.2	74.9	73.9	71.1	68.5	66.9

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0.′794

Increasing scale readings correspond to increasing **east declination.**

OCTOBER, 1883.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.	Daily range.
1	67.2	67.2	69.3	70.8	70.0	69.3	69.2	69.2	69.3	69.0	68.8	68.8	69.4	9
2	66.7	67.8	69.3	69.8	69.0	69.1	69.8	69.5	71.3	69.5	70.0	70.2	70.2	9
3	67.7	68.8	70.0	69.8	69.5	69.1	69.3	69.5	69.5	69.4	69.4	69.3	70.0	10
4	68.0	67.7	68.0	67.7	66.8	68.0	69.0	69.5	69.0	69.4	69.6	72.0	70.1	8
5	66.0	65.7	68.0	67.5	68.0	69.0	67.5	74.0*	71.0	69.0	69.0	67.8	70.3	18
6	68.2	69.4	68.0	67.8	68.3	69.0	69.5	70.0	71.0	69.0	69.5	69.6	69.1	7
7	68.0	68.0	69.0	69.5	69.0	69.0	69.0	69.3	69.2	69.4	69.5	69.8	69.9	7
8	65.4	65.0	65.7	67.2	68.0	69.4	69.6	69.4	69.2	69.3	69.3	69.2	69.4	9
9	[67.0]	67.0	67.5	68.0	67.5	[67.4]	[67.1]	67.0	67.5	68.0	67.2	69.0	[69.1]	8
10	69.2	[69.5]	[70.7]	[70.9]	[70.6]	[71.0]	[71.2]	[71.5]	[71.5]	[71.2]	[71.4]	[71.4]	[71.4]	9
11	65.8	66.4	68.5	69.0	68.0	68.0	68.7	68.7	69.0	68.8	69.2	69.3	[70.3]	[10]
12	66.0	68.2	69.5	69.8	68.0	68.0	69.4	68.8	69.0	69.0	69.2	69.1	70.4	14
13	65.7	67.0	69.0	69.0	68.5	68.5	68.7	68.7	69.0	69.0	69.3	69.0	69.8	17
14	65.9	67.0	68.0	68.5	67.9	68.5	69.0	69.0	68.8	68.9	70.2	69.5	69.7	11
15	65.3	65.6	66.8	67.7	67.0	66.0*	68.0	69.0	67.7	69.8	70.0	69.0	69.1	16
16	65.0	57.5*	68.0	64.5*	67.3	66.5	67.0	71.0	70.0	70.5	70.0	67.0	69.0	24
17	65.4	67.0	68.6	68.3	69.0	69.0	69.2	68.2	68.5	69.4	70.0	69.5	69.8	10
18	65.6	66.9	68.3	69.2	69.5	69.8	69.5	71.5	70.0	68.2	68.6	68.6	70.2	10
19	67.0	66.0	66.8	69.2	69.0	69.5	70.6	68.8	69.0	69.8	70.2	70.0	69.9	12
20	63.3*	67.0	68.0	69.0	69.4	69.4	69.0	70.0	69.8	70.0	70.0	69.5	69.1	12
21	65.7	67.1	67.8	69.0	69.0	69.5	69.4	69.0	69.2	69.0	71.5	70.5	69.8	10
22	68.5	68.5	69.0	68.5	68.6	69.4	69.0	69.3	69.3	69.5	69.6	69.5	70.5	7
23	68.5	69.2	69.0	68.5	68.5	69.0	69.5	69.5	69.4	70.3	70.0	70.2	69.9	7
24	68.0	68.9	68.5	68.8	68.5	70.0	70.0	69.8	70.4	70.0	69.5	70.0	70.0	5
25	67.6	67.4	69.5	69.2	69.0	69.5	69.3	70.2	69.1	68.5	70.0	73.5*	70.2	5
26	68.0	68.9	69.5	68.5	68.0	68.5	68.3	69.0	69.0	69.2	69.3	69.6	69.8	7
27	[67.6]	68.0	69.0	69.0	68.0	68.4	68.6	69.2	69.0	69.1	69.2	69.4	[69.8]	10
28	67.5	68.4	69.4	69.0	68.5	69.0	69,4	69.3	69.0	69.0	69.2	69.3	69.9	7
29	65.0	67.0	68.5	69.0	68.5	69.2	69.6	69.5	69.4	69.0	69.2	69.3	69.6	12
30	67.6	68.3	69.0	68.4	68.0	69.1	69.0	69.2	69.5	69.4	69.1	69.0	70.2	10
31	67.3	67.3	67.5	68.2	68.3	69.0	69.0	69.5	69.6	69.4	69.5	69.3	70.2	11
Monthly mean	66.8	67.2	68.5	68.7	68.5	68.8	69.1	69.5	69.4	69.3	69.6	69.6	69.86	
Normal	66.9	67.5	68.5	68.7	68.5	68.9	69.1	69.3	69.4	69.3	69.6	69.5		

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

NOVEMBER, 1883.

Day.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
1	69.3	69.6	70.0	70.0	70.4	71.0	75.0*	78.2*	77.5*	71.0	67.0	65.9
2	74.0*	75.5*	68.0	69.0	70.3	72.0	75.0*	76.0*	74.5	71.8	68.5	66.2
3	70.0	68.5	69.2	69.5	71.0	73.5*	72.2	73.8	73.5	70.7	68.9	67.0
4	68.5	69.0	70.2	70.0	69.0	70.3	73.3	75.0	70.4	70.3	68.3	66.4
5	69.2	69.2	69.5	70.0	69.8	70.3	72.2	73.9	73.2	72.2	68.2	66.8
6	69.0	69.0	69.4	69.0	69.8	70.0	71.3	73.5	72.5	70.7	69.5	68.4
7	69.5	69.5	69.3	69.8	70.2	70.8	72.0	73.7	74.0	72.0	70.8	68.8
8	68.0	69.0	69.0	69.0	69.7	70.3	72.0	73.5	71.0	68.4	66.2*	65.0
9	68.3	68.5	68.5	68.8	69.0	70.0	72.0	73.5	72.8	70.2	67.7	66.5
10	69.0	69.0	69.0	69.0	69.3	69.8	71.0	73.0	72.2	71.2	68.5	66.7
11	68.5	70.0	69.4	69.8	69.5	70.0	71.3	72.0	71.0	70.0	68.0	66.8
12	70.0	71.0	70.5	71.5	71.0	71.8	72.3	72.3	73.0	71.0	68.0	67.6
13	70.0	70.7	70.0	70.5	70.6	68.5	72.5	72.8	72.4	71.0	70.0	69.3
14	71.0	71.0	71.0	71.4	70.5	70.9	71.5	71.0	70.0	68.0*	65.9*	65.0
15	69.0	69.0	70.2	70.0	69.8	70.3	70.8	72.4	72.6	70.5	68.0	66.2
16	69.4	69.8	70.1	70.0	70.0	70.5	72.0	74.1	73.6	71.5	69.0	66.8
17	69.0	70.5	71.0	70.5	70.5	71.0	71.5	74.5	74.0	71.0	69.2	66.5
18	69.4	69.3	69.0	69.4	70.0	70.2	71.8	73.5	75.1*	73.3	71.0	68.5
19	69.4	69.8	69.2	69.5	70.0	70.5	72.1	75.3	73.5	72.5	69.5	65.0
20	74.5*	69.5	69.3	66.4*	74.6*	74.5*	66.9*	67.5*	66.5*	67.5*	69.0	67.0
21	70.0	69.0	68.8	69.5	69.4	70.0	70.8	74.0	72.0	70.8	67.6	65.2
22	79.5*	81.6*	81.6*	65.4*	70.0	67.0*	69.2	74.0	73.5	70.1	68.5	66.0
23	72.3*	74.5*	74.5*	68.6	65.5*	64.5*	70.0	71.0	71.3	71.0	69.4	67.0
24	69.4	69.3	69.3	69.4	69.6	69.5	70.0	71.5	73.0	73.5*	72.0*	69.5*
25	68.6	68.8	69.0	69.5	69.4	69.3	70.0	71.5	72.5	71.5	69.5	67.4
26	68.5	68.9	68.4	69.0	69.5	69.5	71.0	72.6	72.7	70.5	68.0	66.0
27	69.0	70.3	69.5	67.5	70.0	67.0*	67.0*	66.5*	70.0	70.0	68.5	67.5
28	69.3	69.8	69.0	68.0	70.0	70.5	70.6	71.5	71.4	70.0	69.6	67.3
29	68.0	68.0	70.0	70.4	70.1	69.3	70.6	71.2	71.0	70.4	65.5*	67.3
30	69.0	69.1	69.5	70.0	70.2	70.4	71.0	72.6	72.5	70.5	68.0	66.5
Monthly mean	70.0	70.2	70.0	69.4	70.0	70.1	71.3	72.9	72.4	70.8	68.7	66.9
Normal	69.1	69.5	69.5	69.6	70.0	70.3	71.3	73.0	72.4	70.9	68.9	66.8

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.904

Increasing scale readings correspond to increasing east declination.

NOVEMBER, 1883.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.	Daily range.
1	66.5	67.0	64.5*	67.0	68.0	68.5	71.0	70.3	70.0	69.6	70.5	76.7*	70.2	16
2	66.7	66.8	68.0	69.2	68.0	76.2*	71.5	72.0	72.0*	73.5*	68.0	70.3	71.0	11
3	66.8	67.7	68.8	69.3	69.0	69.2	69.0	69.0	69.0	68.8	68.5	68.3	69.6	10
4	66.0	67.0	67.8	68.5	68.7	69.2	69.2	69.3	69.0	69.0	69.0	69.1	69.3	10
5	66.0	67.0	67.0	69.0	69.0	68.8	69.2	69.0	69.0	68.8	68.5	68.5	69.4	10
6	69.0	70.0*	69.5	68.0	68.5	69.2	69.2	69.2	69.0	69.0	68.5	68.2	69.6	5
7	66.3	68.0	68.2	68.4	68.0	68.0	68.3	68.5	68.3	68.5	69.0	67.2	69.5	6
8	65.3	66.0	67.2	67.5	67.5	68.0	68.2	68.7	68.5	68.7	68.2	68.2	68.5	9
9	65.0	66.0	67.0	67.8	68.0	68.3	68.8	69.0	69.0	69.0	69.0	69.0	68.8	8
10	67.0	67.8	67.0	67.5	67.5	68.3	68.0	69.0	69.0	69.0	68.5	69.2	69.0	7
11	66.0	67.5	66.8	67.3	67.3	68.7	68.5	68.8	68.3	69.0	70.0	70.0	68.9	5
12	67.5	68.0	67.9	69.4	69.3	69.5	70.0	70.5	73.4*	70.6	69.8	69.5	70.2	6
13	69.2*	69.4	69.5	69.0	69.2	70.0	70.5	69.6	69.5	69.1	69.3	69.5	70.1	4
14	65.5	66.5	67.3	68.0	68.4	69.0	70.0	70.0	68.9	68.6	70.0	68.0	69.1	6
15	66.4	68.0	68.3	69.0	69.5	69.2	69.5	70.0	69.4	69.3	68.6	69.0	69.4	7
16	67.0	67.0	68.0	68.9	68.5	69.3	70.0	69.5	69.3	69.2	69.0	69.0	69.6	8
17	66.5	67.1	67.2	67.7	68.3	69.2	69.0	69.5	69.6	69.8	69.3	69.2	69.6	8
18	67.4	66.5	66.4	67.0	67.5	69.2	69.5	69.6	69.3	69.4	68.9	68.9	69.6	9
19	63.2*	63.0*	64.2*	66.4	66.5	69.2	69.0	69.9	70.0	69.6	69.8	67.6	69.0	14
20	67.0	67.1	67.2	67.8	68.5	67.5	69.0	70.8	69.5	69.7	69.4	69.5	69.0	15
21	64.6	65.5	65.0*	67.7	68.0	67.5	69.0	68.5	69.4	69.5	70.5	80.5*	69.3	18
22	67.5	68.5	68.0	69.0	69.8	67.0	74.5*	70.5	70.8	71.8*	65.5*	75.5*	71.0	22
23	66.5	67.3	69.5	71.0*	69.6	69.7	69.7	69.8	69.8	69.5	69.4	69.5	69.6	10
24	68.0	67.0	67.4	67.3	67.8	68.5	69.4	69.5	69.0	69.4	69.2	68.5	69.5	6
25	66.5	67.0	67.5	67.5	68.2	68.5	69.0	69.0	69.0	68.9	69.0	68.4	69.0	6
26	66.3	67.0	67.9	69.0	69.3	69.0	69.5	69.2	69.8	69.0	68.5	69.1	69.1	6
27	67.6	67.6	69.0	69.5	69.4	69.4	69.5	69.5	69.5	68.6	69.2	69.6	68.8	6
28	67.0	68.1	68.8	68.5	68.5	69.3	69.5	69.0	69.2	67.5	69.0	68.4	69.2	6
29	67.5	67.4	68.2	68.9	69.9	69.5	69.5	69.5	69.3	69.0	69.0	68.9	69.2	4
30	66.5	66.5	68.3	68.9	69.0	69.2	69.8	69.5	69.3	68.9	68.5	69.4	69.3	7
Monthly mean	66.6	67.2	67.6	68.3	68.5	69.1	69.6	69.5	69.5	69.3	69.0	69.8	69.45	
Normal	66.6	67.2	67.9	68.2	68.5	68.8	69.4	69.5	69.3	69.1	69.1	68.9		

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

DECEMBER, 1883.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	69.5	67.8	69.0	69.0	68.3	69.5	71.6	73.8	73.0	70.2*	65.5*	64.3*
2	67.5	68.5	70.0	70.0	70.4	71.2	72.0	72.5	72.4	71.5	68.6	65.7
3	69.0	69.0	69.1	69.5	69.6	70.0	70.9	72.4	73.0	72.6	69.9	67.0
4	69.3	69.3	69.1	69.2	69.5	70.0	70.5	72.0	73.0	72.0	69.0	66.0
5	68.5	68.6	68.5	68.8	69.2	70.0	71.5	73.0	73.6	72.5	69.0	66.0
6	68.6	68.8	69.0	69.0	69.1	69.4	70.5	72.5	73.5	71.8	69.5	67.0
7	69.0	68.9	68.9	68.5	69.0	69.5	70.3	72.0	74.0	72.3	68.5	66.2
8	68.5	68.5	68.5	68.8	69.0	69.2	70.7	73.8	73.5	72.2	70.0	66.0
9	69.8	67.0	70.8	69.0	66.3*	69.5	66.8*	71.5	74.7	71.0	68.7	67.5
10	69.2	70.0	68.0	69.3	69.0	69.5	70.7	72.5	74.5	74.8	71.5	69.0
11	68.0	71.0	71.3	71.6	70.5	70.0	70.5	72.1	72.4	71.5	69.8	69.2
12	70.0	68.5	70.0	71.2	70.5	72.0	72.0	72.0	72.0	70.0*	67.5	66.4
13	68.9	69.5	68.5	69.0	69.5	69.3	69.5	70.4	71.0	70.4	68.6	67.4
14	69.1	69.4	67.5	70.5	71.2	70.4	70.1	72.0	72.5	70.2*	68.5	67.5
15	69.2	69.2	70.0	69.5	70.0	70.1	70.5	72.4	73.2	72.3	70.0	67.6
16	69.0	69.0	69.3	69.2	69.5	69.6	70.1	71.2	72.2	72.0	69.8	67.4
17	69.5	69.5	69.3	69.6	70.0	70.1	71.0	72.4	74.3	75.0	71.3	68.1
18	70.0	70.0	70.0	70.3	70.0	71.6	73.0	13.4	74.2	74.0	71.6	68.5
19	69.1	69.2	69.3	69.5	69.6	70.3	70.1	72.0	74.5	75.2	73.0*	68.5
20	69.5	69.4	69.3	69.5	70.0	69.8	71.0	74.5	75.0	74.8	72.4	69.8
21	70.0	69.4	69.0	69.3	70.0	69.6	70.3	73.0	74.6	75.5*	72.2	69.1
22	68.6	68.5	68.5	68.4	68.5	69.2	69.6	72.8	75.5	76.6*	72.6*	69.3
23	69.2	68.5	68.8	68.9	69.0	68.8	70.0	71.6	74.0	73.9	70.5	68.0
24	68.5	69.0	69.0	69.1	68.2	68.4	68.2	70.5	74.3	75.5*	71.8	69.0
25	70.6	70.0	67.7	69.4	69.0	68.0	67.5*	70.2	71.8	72.0	70.1	68.2
26	68.0	71.5	71.1	68.4	69.4	69.5	69.6	70.7	72.3	73.0	69.9	67.5
27	69.0	68.9	68.5	68.0	68.2	69.0	69.2	71.0	72.7	73.0	70.1	68.6
28	69.4	70.1	69.8	68.8	67.5	69.4	70.0	71.5	71.0	73.5	70.5	67.6
29	69.1	70.8	71.5	69.9	70.9	68.5	70.5	72.0	74.0	73.8	71.5	70.1
30	69.2	69.2	69.9	69.8	70.0	70.3	70.8	72.2	73.1	72.8	69.0	66.2
31	69.0	69.3	69.4	69.5	69.6	70.2	71.2	73.3	74.8	73.5	69.1	66.0
Monthly mean	69.1	69.2	69.3	69.4	69.4	69.7	70.3	72.2	73.4	72.9	70.0	67.6
Normal	69.1	69.2	69.3	69.4	69.5	69.7	70.5	72.2	73.4	72.9	70.0	67.8

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794 — Increasing scale readings correspond to increasing east declination.

DECEMBER, 1883.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.	Daily range.
1	64.4	66.0	67.4	68.0	69.0	69.3	70.0	71.5	71.5	70.5	71.0	70.0	69.2	10
2	64.2*	65.0	66.5	67.5	68.3	69.5	70.0	70.0	69.8	70.0	69.5	69.5	69.2	7
3	65.8	65.5	67.0	68.0	68.5	69.0	69.0	69.5	69.0	69.5	69.5	69.2	69.2	10
4	65.5	65.5	66.8	68.0	69.0	69.5	69.4	69.5	69.6	69.3	68.9	68.5	69.1	7
5	65.2	66.1	66.5	68.3	68.9	69.8	69.9	69.9	69.8	69.6	69.0	68.8	69.2	8
6	66.2	67.0	67.0	67.8	69.0	69.4	69.3	69.8	69.5	69.3	69.5	69.0	69.2	7
7	65.8	66.0	66.4	67.5	68.0	69.0	69.2	69.3	69.3	69.0	69.0	68.8	68.9	8
8	65.5	66.8	68.0	68.5	69.3	69.7	69.7	69.9	69.5	69.2	73.0*	68.5	69.4	9
9	67.0	67.3	67.9	68.7	69.3	70.0	70.0	70.0	70.0	69.5	70.0	69.9	69.3	8
10	69.0	69.0	69.3	69.3	69.4	70.3	69.8	69.9	70.2	70.4	70.4	70.0	70.2	9
11	68.5	68.5	69.1	68.9	69.1	69.0	69.5	69.5	70.0	72.5*	68.2	69.1	70.0	6
12	65.2	66.8	66.0	66.5	68.0	67.9	67.9	67.5	69.6	69.3	69.6	69.4	69.0	7
13	67.3	69.0	69.0	69.0	69.4	70.0	69.6	69.6	69.6	70.2	69.2	69.2	69.3	4
14	67.6	67.4	68.0	69.4	70.2	70.5	71.0	70.5	70.1	69.5	69.4	69.3	69.7	6
15	67.0	66.9	66.9	68.4	69.2	69.5	69.6	69.6	69.5	69.1	69.3	68.9	69.5	5
16	65.5	66.2	66.5	68.0	69.5	69.4	70.0	70.0	69.8	69.5	69.3	69.3	69.2	6
17	66.0	64.0*	66.3	68.5	69.0	70.0	69.5	70.0	70.2	69.6	70.3	68.2	69.6	12
18	67.5	67.2	67.6	69.8	69.8	70.0	70.0	70.0	70.2	69.6	69.4	69.0	70.3	8
19	66.0	65.2	66.5	67.5	68.3	69.6	69.7	70.0	70.0	70.0	70.2	70.4	69.7	10
20	68.5	67.0	67.3	68.0	70.0	70.0	70.2	70.3	70.5	69.5	70.0	69.5	70.2	8
21	68.2	67.4	67.0	67.3	69.0	69.4	69.8	69.6	69.6	69.6	69.4	69.1	69.9	8
22	67.4	67.0	66.9	67.6	69.0	69.0	68.6	69.1	69.0	69.0	69.0	69.0	69.5	9
23	66.3	66.5	66.5	67.4	68.2	69.0	68.6	69.0	68.5	68.3	68.5	68.5	69.0	8
24	67.6	67.6	68.4	69.6	70.0	69.8	69.9	69.5	69.0	71.5	70.5	69.6	69.8	8
25	69.3	70.0*	69.5	69.8	70.3	70.0	70.6	70.3	70.5	69.4	69.8	70.0	69.8	5
26	68.5	69.0	69.6	69.7	69.6	70.2	70.1	69.5	69.7	70.4	69.8	68.6	69.8	6
27	68.1	67.8	68.5	68.2	68.0	69.8	70.2	71.0	70.5	68.0	68.5	69.0	69.3	5
28	67.3	68.3	68.5	69.0	69.4	70.0	69.8	69.6	69.4	71.0	69.4	70.0	69.6	5
29	69.0	68.6	68.7	69.5	69.5	70.0	70.8	70.0	70.1	69.4	69.1	69.3	70.3	5
30	66.1	67.0	68.6	69.2	69.2	70.0	70.0	69.6	69.5	69.3	69.0	69.0	69.5	7
31	65.6	66.2	67.1	68.5	69.0	69.5	69.4	69.3	69.3	69.2	68.5	68.3	69.4	10
Monthly mean	66.8	67.0	67.6	68.4	69.1	69.6	69.7	69.8	69.8	69.7	69.6	69.2	69.53	
Normal	66.9	67.0	67.6	68.4	69.1	69.6	69.7	69.8	69.8	69.6	69.4	69.2		

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

JANUARY, 1884.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	68.0	68.4	68.6	68.9	69.2	69.9	70.5	73.8	75.5	73.2	69.3*	66.5
2	69.8	70.3	70.8	70.5	70.6	70.5	72.0	73.4	75.0	73.8	69.4*	67.4
3	69.0	69.0	69.0	69.4	69.8	70.1	71.0	73.5	76.5	75.2	70.3	67.0
4	68.5	69.0	68.9	68.9	68.9	69.2	70.0	72.0	73.8	73.6	69.5*	67.3
5	69.8	71.3	71.0	70.5	70.0	70.0	70.6	73.0	76.0	77.0	74.0	68.6
6	70.2	69.5	69.4	69.5	69.6	70.0	70.5	73.5	75.5	75.5	73.0	69.6
7	69.3	69.0	69.0	68.9	69.3	69.3	70.4	74.0	76.8	77.2	72.3	66.8
8	69.5	70.0	70.0	70.4	70.6	70.5	70.5	72.8	77.0	76.9	72.6	70.0
9	70.0	69.9	69.8	70.0	70.1	70.0	71.0	73.0	75.5	76.0	72.8	68.4
10	70.5	70.5	70.4	69.6	70.3	70.3	71.0	74.2	78.0*	76.3	72.4	68.0
11	70.5	69.5	69.4	69.5	70.0	69.4	70.3	73.0	75.5	75.0	70.4	67.5
12	71.0	71.2	73.0*	72.0	67.5	70.0	69.9	72.2	74.3	73.0*	69.0*	65.5
13	69.9	70.5	72.0	70.5	70.4	70.3	70.8	73.0	75.1	74.9	70.5	69.0
14	70.0	70.0	69.9	69.9	69.9	69.5	69.8	72.4	74.5	74.9	70.9	66.5
15	72.0	71.5	71.6	69.2	70.6	71.0	72.0	74.0	76.3	75.5	70.8	68.0
16	70.0	69.7	69.6	70.6	71.0	71.5	72.5	73.8	77.0	76.5	70.5	65.5
17	69.4	69.6	69.9	69.3	70.0	70.0	70.6	72.3	74.5	76.0	73.5	70.3
18	69.3	69.4	69.3	69.5	70.0	70.3	71.5	74.5	75.2	74.8	70.2	66.0
19	70.6	70.0	69.2	69.6	70.5	70.0	71.0	73.2	75.0	76.0	73.0	69.7
20	69.5	69.8	70.1	69.5	69.5	70.3	71.2	74.0	76.3	77.9	74.0	67.6
21	70.1	69.8	69.5	69.5	67.3*	69.5	70.5	73.4	75.2	77.3	75.2*	70.9*
22	69.6	69.5	69.8	69.5	69.9	69.4	70.0	72.1	74.6	77.0	73.1	69.0
23	70.0	68.5	70.0	70.3	69.5	69.4	70.2	72.7	75.8	78.4*	76.3*	72.1*
24	69.4	69.4	69.6	69.8	69.6	69.3	70.2	72.8	75.3	76.6	73.0	68.5
25	69.3	69.2	69.1	69.3	69.9	69.5	69.8	71.0	75.0	75.6	73.2	68.0
26	78.6*	74.3*	68.0	73.0*	72.0	70.9	70.5	72.5	74.9	74.0	71.2	67.0
27	70.0	69.3	70.5	70.3	70.0	70.0	70.6	72.7	73.4	73.5	72.0	68.3
28	68.0	68.3	69.8	69.8	70.1	70.3	70.3	72.2	74.5	76.2	74.0	73.5*
29	69.3	69.5	69.6	70.0	70.0	70.3	70.8	72.4	74.5	75.3	72.8	68.0
30	69.3	69.3	69.7	69.8	70.0	70.2	70.6	72.2	73.3	75.0	73.0	67.1
31	69.6	70.0	70.2	70.4	70.6	70.6	70.6	72.0	74.5	76.0	75.8*	72.0*
Monthly mean	70.0	69.8	69.9	69.9	69.9	70.0	70.7	73.0	75.3	75.6	72.2	68.4
Normal	69.7	69.5	69.7	69.7	69.9	70.0	70.7	73.0	75.2	75.6	72.2	67.8

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794 Increasing scale readings correspond to increasing east declination.

JANUARY, 1884.

Day.	13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
1	66.0	66.4	67.4	68.5	69.6	70.0	70.1	70.0	70.0	69.5	69.3	69.3	69.5
2	67.0	66.5	67.0	68.5	70.1	69.8	69.9	69.3	69.5	69.0	68.5	68.5	69.9
3	64.5	64.5	66.0	68.0	69.3	69.4	69.6	69.8	69.5	69.3	69.0	68.6	69.5
4	65.0	64.1	65.5	68.3	68.5	69.0	69.5	69.2	70.0	70.3	70.4	70.8	69.2
5	64.8	63.6*	64.9	67.6	69.2	69.8	69.9	70.3	70.4	70.6	71.9	70.1	70.2
6	67.0	66.1	67.0	69.0	69.5	70.2	70.3	70.4	70.3	70.3	70.0	69.9	70.2
7	64.5	65.0	66.2	67.5	69.4	69.5	69.5	71.6	70.4	70.4	70.3	69.9	69.8
8	66.8	66.5	67.0	68.2	69.0	70.0	70.3	70.2	70.4	70.2	70.4	69.6	70.4
9	67.0	67.0	67.5	69.0	69.9	69.9	70.8	70.0	70.2	69.5	70.2	70.1	70.3
10	65.4	65.5	65.5	66.5	70.0	69.2	69.8	69.5	71.2	70.8	70.8	70.2	70.2
11	66.4	67.0	68.2	69.6	70.3	70.5	69.9	70.5	70.2	70.3	69.3	70.0	70.1
12	64.8	65.0	66.6	68.9	69.5	68.0	68.8	69.6	69.5	69.5	69.8	69.9	69.5
13	68.2	68.9*	69.4	70.0	70.0	70.0	70.0	70.0	70.1	69.8	69.5	69.5	70.5
14	64.0	65.1	67.2	69.5	69.6	70.0	70.2	70.2	70.6	69.5	70.0	70.6	69.8
15	66.5	67.3	68.2	70.0	70.4	70.5	70.2	70.5	70.4	70.0	69.5	69.6	70.6
16	65.0	65.1	66.0	68.4	70.0	70.2	70.3	70.0	70.0	69.4	69.4	69.4	70.1
17	68.6	67.7	67.3	69.5	70.3	70.1	70.4	70.0	69.8	70.0	69.4	69.5	70.3
18	64.6	65.2	66.3	68.5	69.4	69.2	69.5	70.3	70.6	72.1	70.5	69.5	69.8
19	68.0	67.5	67.2	67.6	69.0	69.5	70.1	70.2	70.0	70.0	69.6	69.8	70.3
20	65.2	65.3	66.2	67.5	69.0	69.5	70.0	70.5	70.5	72.0	70.2	70.8	70.3
21	68.2	67.1	67.0	68.0	69.0	69.7	70.0	70.0	70.2	70.0	70.2	70.0	70.3
22	67.0	67.3	67.3	69.0	69.8	70.0	70.4	70.6	70.5	70.1	70.0	70.0	70.2
23	69.9*	67.3	67.5	68.5	69.3	69.5	69.7	70.0	70.0	69.8	70.0	69.5	70.6
24	67.3	68.3	68.5	69.0	69.8	69.8	70.0	70.2	70.0	70.0	69.6	69.6	70.2
25	67.6	67.4	67.5	67.3	66.5*	70.0	70.5	70.6	72.5	70.5	70.5	67.5	69.9
26	66.3	67.3	67.6	67.7	69.0	69.8	70.0	70.0	69.3	70.2	70.0	70.2	70.6
27	67.0	67.5	67.6	69.0	69.4	69.9	70.0	70.0	69.9	69.3	69.6	69.4	70.0
28	66.0	66.2	67.0	68.0	69.3	69.5	69.7	69.8	69.5	69.5	69.4	69.3	70.0
29	66.5	65.5	65.3	67.0	69.0	68.5	69.4	70.0	70.0	70.0	69.6	69.3	69.7
30	64.6	65.0	65.5	67.4	68.5	70.0	70.0	70.0	70.0	70.0	69.9	69.8	69.6
31	70.0*	68.0	66.2	66.8	68.5	69.6	69.6	69.3	70.0	70.0	69.4	69.3	70.4
Monthly mean	66.4	66.3	66.9	68.3	69.4	69.7	70.0	70.1	70.2	70.1	69.9	69.7	70.06
Normal	66.2	66.3	66.9	68.3	69.5	69.7	70.0	70.1	70.2	70.1	69.9	69.7	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

FEBRUARY, 1884.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	69.3	69.5	70.6	70.4	70.5	70.5	71.0	72.3	73.5	74.5	73.2	71.2
2	73.9*	73.8*	72.8*	69.9	70.2	70.8	65.5*	70.0	72.2	73.2	73.3	71.1
3	68.5	69.1	69.0	69.2	69.2	69.3	70.0	70.9	72.3	74.4	74.1	69.6
4	70.3	69.4	69.2	69.1	69.0	68.6	71.2	68.7	71.5	74.1	75.2	72.3
5	69.2	69.3	68.7	68.7	68.6	68.9	68.7	69.2	70.6	73.8	73.9	71.2
6	69.9	69.6	70.2	69.4	69.4	69.0	68.6	71.2	74.4	75.0	75.0	73.2
7	70.3	70.5	70.3	70.1	71.0	69.4	69.8	70.4	72.3	74.1	74.4	72.9
8	73.0*	71.8	71.3	70.9	69.8	69.2	69.0	70.7	73.6	74.1	74.8	72.9
9	71.2	72.4*	71.1	70.4	71.4	69.7	69.4	70.5	73.4	75.0	75.2	73.3
10	69.7	69.6	69.4	69.0	68.9	68.4	67.6	69.2	71.9	75.4	75.1	73.3
11	69.4	69.3	70.0	69.3	70.3	70.0	69.3	70.4	72.7	74.2	73.3	71.4
12	69.4	69.3	69.0	69.5	69.3	69.1	70.0	71.3	73.0	73.3	72.1	71.2
13	69.0	69.6	69.8	69.6	69.4	70.0	69.6	71.0	73.4	73.6	73.4	71.0
14	69.4	69.6	69.5	69.5	69.5	69.7	70.1	71.6	73.3	73.6	71.7	69.6
15	69.3	69.4	69.4	69.2	69.4	69.2	69.4	72.0	73.3	74.4	72.7	70.4
16	70.0	69.4	69.4	69.3	69.4	69.3	69.5	70.9	72.0	74.3	71.6	70.8
17	68.7	69.3	69.5	69.0	69.0	68.5	69.4	69.8	70.0	72.3	72.0	70.8
18	69.0	69.0	68.8	70.0	69.2	69.2	68.7	71.2	70.5	72.5	73.0	71.5
19	70.0	70.5	70.2	68.3	68.6	68.7	68.0	70.7	72.3	73.5	72.1	70.0
20	69.8	69.0	69.0	69.4	69.0	69.0	69.2	70.0	73.2	73.0	72.2	70.8
21	68.5	69.0	68.8	68.3	68.5	68.7	68.3	70.0	71.3	72.3	72.3	69.9
22	68.3	68.8	68.0	68.0	68.5	68.4	68.5	70.0	72.0	73.5	73.2	71.5
23	69.0	70.8	69.0	69.2	69.0	69.5	70.5	68.5	69.0*	71.0*	72.0	68.0*
24	71.0	72.0	71.5	70.3	69.3	70.0	69.1	69.9	69.3*	67.0*	70.0*	67.7*
25	68.0	71.0	65.5	69.0	69.9	69.2	68.5	70.0	73.5	74.8	72.5	69.0
26	68.5	69.0	69.0	68.7	68.0	68.7	69.0	71.8	72.3	72.0	71.0	68.0*
27	67.4	67.7	68.1	68.2	68.0	68.3	69.0	70.8	72.0	72.0	70.3*	67.7*
28	68.3	69.0	69.0	69.5	68.2	68.4	69.7	72.0	73.8	75.3	73.7	68.8
29	69.4	69.2	68.9	70.4	70.6	70.0	71.0	70.0	71.0	72.0	71.0	61.0*
Monthly mean	69.6	69.9	69.5	69.4	69.4	69.2	69.2	70.5	72.2	73.4	72.9	70.4
Normal	69.3	69.6	69.3	69.4	69.4	69.2	69.3	70.5	72.4	73.7	73.1	71.2

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794 Increasing scale readings correspond to increasing **east declination.**

FEBRUARY, 1884.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
1	68.0	65.5	64.5	65.0	67.3	69.4	69.8	69.8	73.8*	71.0	71.5	72.2*	70.2
2	68.2	65.3	65.1	66.1	67.3	68.9	69.0	69.1	69.2	69.2	69.0	68.9	69.7
3	65.1*	62.8*	62.5*	65.0	67.2	67.7	67.4	68.5	69.5	70.1	70.1	70.3	68.8
4	69.0	67.2	64.5	63.2*	65.6	66.3	66.6	69.1	69.8	70.0	70.1	70.4	69.2
5	68.5	68.4	64.4	66.5	67.3	68.5	69.3	69.7	69.5	69.8	69.6	69.1	69.2
6	70.1	67.9	66.5	66.7	67.1	68.2	68.9	69.4	70.0	70.0	70.1	70.0	70.0
7	71.0*	68.1	65.5	65.7	67.2	68.1	68.3	68.5	69.0	69.4	69.3	70.5	69.8
8	69.3	67.3	65.1	66.2	68.1	69.1	69.1	69.2	69.9	69.5	70.3	70.7	70.2
9	71.5*	74.4*	66.5	66.4	67.7	68.8	68.6	68.9	69.2	68.4	68.3	69.0	70.4
10	71.4*	69.0	66.5	66.5	67.6	69.5	69.5	69.4	69.2	69.3	69.3	69.4	69.8
11	69.8	68.5	67.8	68.7*	69.4	70.2	70.2	70.1	69.9	69.8	69.9	69.7	70.2
12	70.2	69.0	67.7	67.4	68.5	69.5	70.0	69.7	69.3	69.1	69.0	69.2	69.8
13	69.4	66.9	66.0	66.6	68.6	69.4	69.5	69.4	69.1	69.4	69.2	69.4	69.7
14	67.5	66.3	65.4	66.0	67.9	69.0	69.4	69.3	69.4	69.4	69.3	69.3	69.4
15	66.4	65.0	64.8	65.5	67.3	69.3	69.3	69.3	69.5	69.2	69.0	69.4	69.2
16	67.7	66.0	66.0	66.7	68.0	69.2	69.2	69.0	69.0	68.7	68.7	68.7	69.3
17	68.6	66.2	64.0	66.4	66.4	68.2	68.7	69.2	70.2	69.0	69.0	69.0	68.9
18	68.3	66.7	66.0	66.4	67.9	69.0	68.8	69.0	69.2	69.4	69.6	69.5	69.3
19	68.0	67.1	67.2	67.5	68.5	69.3	69.6	69.2	69.5	69.0	69.3	69.1	69.4
20	69.0	67.0	66.9	67.0	67.0	68.0	68.5	68.2	68.2	68.6	69.5	68.7	69.2
21	67.0	66.0	65.8	66.4	67.5	68.0	68.0	68.0	68.0	68.0	69.0	68.0	68.6
22	69.5	68.0	66.3	66.0	66.8	67.3	68.0	67.8	68.0	68.0	69.0	68.4	68.8
23	67.3	65.8	64.7	65.0	68.3	68.5	69.0	69.3	69.5	79.0*	72.0*	69.0	69.3
24	65.5*	64.7	65.0	66.0	67.9	68.0	68.5	68.5	68.3	69.0	69.2	68.0	68.6
25	66.3	65.5	63.8	65.3	66.8	67.2	67.8	68.0	67.5	67.7	67.8	68.0	68.4
26	66.5	65.3	65.5	66.0	67.0	67.3	67.2	67.0	68.5	67.0	67.2	67.3	68.2
27	65.5*	63.0*	64.0	65.0	64.8*	66.9	66.4	66.5	66.8	67.3	67.3	67.8	67.5
28	65.4*	65.5	65.0	66.0	67.2	68.0	67.7	68.0	69.0	67.5	67.0	69.3	68.8
29	61.0*	61.5*	61.5*	63.0*	63.5*	68.0	68.6	68.8	74.0*	72.5*	70.5	69.8	68.2
Monthly mean	68.0	66.6	65.3	66.0	67.3	68.4	68.6	68.8	69.4	69.5	69.3	69.2	69.24
Normal	68.3	66.7	65.6	66.1	67.5	68.4	68.6	68.8	69.0	69.0	69.2	69.1	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

MARCH, 1884.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	70.5*	66.3	67.4	69.0	68.0	69.7	69.0	70.8	70.0*	68.0*	69.9*	68.2*
2	73.2*	73.0*	72.0*	73.0*	70.2	67.2	65.0*	68.5*	70.5*	71.5	70.8*	69.2*
3	70.0*	69.8*	75.0*	64.0*	69.2	70.2	70.0	69.8*	70.8*	73.8*	72.5*	71.5*
4	68.5	68.0	69.0	68.5	68.7	69.0	68.0	69.0*	70.0*	72.0	70.3*	68.0*
5	68.2	68.3	68.5	68.5	68.8	69.5	69.5	72.0	73.0	73.0	71.7*	68.2*
6	67.8	68.0	67.8	68.0	68.0	68.5	70.0	73.0	74.0	71.0	68.0	65.0
7	67.3	67.8	67.2	68.0	68.5	66.4	70.0	74.5	75.0	69.5	65.8	62.0
8	66.0	67.0	67.0	67.0	67.0	65.8*	69.0	69.5*	72.8	73.7*	70.0*	66.3*
9	71.0*	68.0	68.2	68.0	68.0	68.5	70.0	73.8	75.7	72.0	67.0	62.8
10	67.0	67.8	67.0	63.5*	68.2	69.3	71.0	74.0	74.0	71.0	67.0	63.0
11	65.9	65.0	66.2	67.2	67.3	68.8	71.7	75.5	76.2	71.8	66.2	63.0
12	67.0	67.3	68.0	67.8	68.0	69.0	71.2	74.5	73.8	66.5*	61.0*	59.8*
13	67.0	67.2	68.0	68.0	68.0	68.8	72.0	74.0	73.0	69.0	63.0*	60.7
14	66.5	67.0	67.5	67.5	68.5	69.3	70.8	74.0	74.8	71.0	66.2	62.5
15	66.0	66.5	66.8	67.7	68.0	69.2	72.0	74.0	75.0	72.8	68.0	63.0
16	66.7	66.5	66.5	67.0	67.0	69.0	72.0	73.0	75.0	72.0	68.0	65.0
17	66.0	66.0	66.0	64.5*	64.8*	66.7	70.3	74.5	75.7	72.3	66.0	61.3
18	65.3	65.0	64.8	64.0*	64.8*	65.8*	69.2	72.0	72.3	70.8	67.0	63.0
19	65.7	66.0	66.2	66.0	66.7	67.7	70.5	72.3	73.7	72.2	66.0	62.0
20	66.0	66.2	66.0	66.5	66.9	67.2	69.0	71.0	71.4*	69.5	65.0	60.0*
21	66.0	66.3	65.8	66.0	65.3*	67.8	69.7	71.6	70.4*	67.3*	64.5	61.8
22	67.5	66.0	66.2	67.0	67.0	68.5	70.7	71.2	70.0*	66.0*	63.5*	62.0
23	66.0	68.0	69.5	67.5	66.9	67.0	69.2	69.4*	67.3*	64.9*	63.5*	62.0
24	65.3	65.0	67.5	67.2	69.2	69.0	69.4	71.6	72.0	69.5	66.5	64.0
25	66.0	66.0	66.2	66.4	67.5	69.2	72.5	73.0	72.2	67.5*	63.5*	60.5
26	65.7	66.2	67.0	67.5	68.0	69.5	73.8*	75.3	73.2	67.3*	62.5*	58.5*
27	66.8	66.2	64.0*	70.0*	69.8	69.8	74.0*	75.3	75.2	69.7	66.5	62.0
28	66.7	68.0	67.5	67.0	67.5	69.0	71.7	74.0	74.3	72.0	69.0	64.0
29	71.0*	67.8	68.2	68.0	69.0	70.3	69.0	69.3*	71.0*	67.0*	64.0*	62.0
30	65.5	66.0	67.0	67.0	68.0	69.5	71.5	76.0*	74.0	70.0	67.5	64.2
31	64.7	66.7	66.0	66.3	67.0	68.2	70.5	71.0	70.5*	68.0*	64.3	61.8
Monthly mean	67.2	67.1	67.4	67.2	67.7	68.5	70.4	72.5	72.8	70.1	66.6	63.5
Normal	66.4	66.8	67.1	67.4	68.0	68.7	70.3	73.2	74.0	71.1	66.6	62.6

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794 Increasing scale readings correspond to increasing east declination.

MARCH, 1884.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
1	65.2*	65.2*	62.2	61.8	62.0*	65.5	68.0	68.1	71.8*	70.0*	70.8*	71.0*	67.8
2	66.3*	65.0*	65.0*	63.5	64.0	66.0	68.5*	70.8*	70.0*	69.0*	71.7*	70.0*	68.9
3	68.0*	66.0*	65.4*	66.5	66.8	68.2*	70.0*	68.5*	69.3*	69.3*	70.4*	68.0	69.3
4	65.5*	65.0*	65.0*	66.0	67.0	68.0	68.0	68.0	68.5*	68.8*	68.3	68.6	68.2
5	64.8*	64.0*	63.8	63.0	65.0	65.5	66.7	67.0	67.0	67.2	67.8	67.4	67.8
6	62.5	62.5	63.5	65.2	66.3	66.6	67.7	68.0	70.5*	69.2*	68.0	68.3	67.8
7	59.5	59.0	59.0*	63.0	65.5	66.0	65.8	66.0	65.5	65.0	66.0	66.3	66.2
8	63.0	62.0	63.0	65.8	65.5	67.5	66.0	66.0	67.2	68.0	69.0*	70.3*	67.3
9	61.7	61.7	63.8	65.3	66.0	66.3	66.0	66.0	65.5	65.8	65.8	66.0	67.2
10	61.7	61.0	62.7	64.7	65.3	65.0	64.8	65.0	65.2	65.0	65.5	65.5	66.4
11	63.0	64.0*	65.0	66.5	67.0	65.8	66.0	66.5	66.5	66.5	66.8	67.0	67.3
12	60.8	62.0	64.5	66.0	67.0	66.3	66.8	66.7	66.5	66.2	66.3	66.8	66.7
13	61.0	62.0	62.7	64.3	66.0	66.0	66.8	66.5	66.6	66.3	66.3	66.5	66.6
14	60.5	60.3	60.7	63.5	65.7	66.2	66.0	66.0	66.0	66.2	66.0	66.0	66.6
15	60.8	60.4	62.0	64.5	66.0	66.0	66.0	70.5*	65.3	65.8	66.0	67.5	67.1
16	63.0	63.0	61.5	64.8	66.0	66.0	65.8	66.0	66.0	65.8	66.0	66.0	67.0
17	60.0	59.0	60.7	63.0	64.2	64.8	65.2	65.7	65.5	65.0	65.0	65.0	65.7
18	60.7	60.0	61.0	62.0	64.1	65.0	65.2	65.2	65.3	65.3	65.3	65.2	65.4
19	60.0	59.0	57.5*	62.0	63.2	64.0	71.0*	65.3	66.0	68.0	65.8	66.0	66.0
20	57.8*	59.0	59.5*	60.5*	63.0	63.2	62.2*	65.0	65.0	65.0	65.0	65.3	64.8
21	60.2	61.0	61.5	64.5	64.8	64.0	63.2*	64.3	63.0*	64.7	64.7	66.0	65.2
22	61.0	62.0	63.3	65.0	64.3	64.2	65.2	65.7	64.2	66.5	66.2	65.0	65.8
23	62.0	61.5	63.5	64.8	65.0	64.8	63.0*	63.5	64.5	65.0	65.0	65.3	65.4
24	63.0	60.8	62.0	63.0	64.5	64.5	64.3	65.0	65.3	65.5	66.0	65.7	66.1
25	60.2	61.0	63.2	65.0	65.8	67.7	66.0	66.3	65.2	65.7	65.2	65.0	66.1
26	58.0*	59.0	61.3	64.8	67.0	66.0	65.0	65.5	65.8	65.7	66.0	65.8	66.0
27	60.8	62.0	63.0	65.8	66.7	65.0	64.8	64.8	64.8	67.0	67.0	66.5	67.0
28	60.0	58.5	57.5*	59.0*	62.0*	66.0	64.5	71.0*	66.5	70.0*	70.5*	69.5*	66.9
29	61.3	61.8	61.7	62.0	63.0	64.5	66.0	65.0	64.5	64.8	65.3	65.0	65.9
30	61.5	60.3	60.5	61.8	63.0	64.3	64.5	64.7	65.0	66.0	66.0	65.3	66.2
31	61.0	59.0	60.0	60.5*	62.2*	64.7	65.2	65.0	64.3	66.0	65.0	66.0	65.2
Monthly mean	61.8	61.5	62.1	63.8	65.0	65.6	65.9	66.4	66.2	66.6	66.7	66.7	66.64
Normal	61.0	61.0	62.3	64.2	65.3	65.5	65.9	65.8	65.6	65.9	66.0	66.2	. .

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time.

300 divisions + tabular quantity.

APRIL, 1884.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	66.7	67.3	66.8	67.0	67.3	68.0	70.5	71.4	71.0	69.2*	67.8*	63.0
2	66.0	66.2	66.2	66.7	68.0	69.2	70.5	72.8	73.8*	70.9*	67.0*	64.6
3	65.2	66.1	66.1	66.1	66.7	68.2	70.3	71.2	72.2	69.8*	67.8*	64.2
4	65.7	65.4	64.8	62.7*	66.4	68.8	73.0*	73.5	71.0	67.0	65.9	64.3
5	65.9	65.9	65.5	67.1	66.3	67.8	70.8	73.5	72.6	67.8	64.8	63.4
6	66.0	65.0	65.0	65.8	65.3	67.3	70.9	73.9	72.2	67.4	64.8	62.0
7	65.0	65.2	65.3	65.6	66.0	67.5	70.0	70.6	69.5	66.5	64.3	62.0
8	66.5	66.0	66.3	66.4	66.8	68.8	71.5	73.4	70.8	68.8	64.8	62.0
9	65.4	67.0	67.0	[66.9]	[67.0]	[67.9]	[69.6]	[70.1]	[68.4]	63.9	62.5	61.5
10	57.8	70.7*	70.5*	69.3*	70.8*	71.0*	71.0	[71.1]	[69.0]	64.0	62.5	59.0*
11	69.6*	70.7*	68.7*	69.2*	66.6	67.8	71.7	72.0	72.0	68.0	66.0	64.5
12	66.0	66.5	66.5	65.8	67.0	68.0	69.1	71.5	70.0	66.8	64.0	62.5
13	65.2	65.2	65.0	66.0	67.5	69.0	71.0	73.2	72.0	68.0	65.2	63.8
14	64.8	65.0	65.8	66.0	66.5	68.5	70.5	72.5	69.5	66.1	64.3	63.2
15	66.9	65.3	66.0	66.0	68.2	68.0	69.5	69.6	69.2*	64.5	63.8	62.1
16	66.2	67.0	65.5	66.1	66.0	67.7	68.7	70.0	67.5*	64.8	62.0	63.0
17	66.2	64.0	66.0	69.2*	67.8	71.0*	76.0*	72.0	71.5	63.5*	63.5	63.0
18	64.5	60.0*	64.0	66.0	62.8*	63.5*	65.5*	66.8*	67.2*	66.2	66.8*	64.2
19	66.8	66.2	66.0	65.0	66.1	67.3	69.8	70.5	69.9	68.8	64.8	63.9
20	66.3	65.8	65.5	66.3	66.8	68.8	70.3	70.8	69.4	67.5	66.2	65.8*
21	63.8	65.0	65.0	65.8	66.0	69.0	70.0	69.3	67.0*	64.8	63.5	63.5
22	65.5	66.0	66.0	66.8	68.0	69.3	72.0	72.8	70.5	[66.2]	[63.9]	[61.8]
23	[62.5*]	[62.3*]	[62.3*]	[62.5*]	[62.8*]	[64.0*]	[66.0*]	[66.8*]	[65.4*]	61.2*	58.9*	58.7*
24	66.0	66.7	67.2	69.0*	68.8	69.8	74.4*	73.5	71.0	66.2	62.8	57.2*
25	64.8	64.8	69.0*	69.0*	69.7*	70.3	70.0	69.2	67.8*	64.3	62.1	60.9
26	65.3	65.7	64.3	64.9	67.8	68.9	71.6	72.0	72.0	68.0	66.2	60.3
27	63.9	64.7	64.3	64.3	65.5	67.2	69.3	70.8	70.5	67.8	65.0	63.0
28	65.3	65.5	65.5	66.2	66.3	67.3	69.3	72.0	70.5	66.8	64.0	61.0
29	64.7	65.0	65.1	65.3	66.2	67.8	69.7	71.0	70.0	65.2	63.1	61.2
30	64.8	65.0	65.1	65.0	66.1	67.3	70.0	70.9	69.7	65.8	63.7	63.8
Monthly mean	65.6	65.6	65.9	66.3	66.8	68.2	70.4	71.3	70.1	66.5	64.4	62.5
Normal	65.6	65.7	65.6	66.0	66.8	68.3	70.3	71.6	70.6	66.3	64.1	62.8

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794

Increasing scale readings correspond to increasing east declination.

APRIL, 1884.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily means.
1	60.2	59.7	60.2	62.0	63.7	64.2	64.5	65.0	65.3	65.2	65.8	66.0	65.7
2	62.3	61.9	61.2	62.8	63.1	63.9	64.0	65.0	65.0	66.1	66.0	65.0	66.2
3	61.2	59.7	60.8	62.6	64.4	64.8	65.4	65.4	66.0	64.8	65.2	65.2	65.8
4	62.2	60.7	60.8	61.1	62.7	64.0	64.2	64.7	64.2	64.3	64.2	64.4	65.2
5	62.8	63.0	63.8	64.0	64.4	64.3	64.1	64.0	64.0	64.0	64.0	64.8	65.8
6	64.8*	64.8*	61.0	64.0	65.2	65.4	64.4	64.2	64.0	64.2	64.5	64.6	65.7
7	60.8	59.8	61.5	64.3	66.0	65.5	64.6	64.4	64.5	64.3	64.4	65.0	65.1
8	60.0	60.0	61.5	64.2	65.7	66.0	64.8	64.8	64.5	64.7	64.7	65.2	65.8
9	62.7	63.2	64.8*	65.3	65.3	64.8	65.0	65.1	65.1	65.2	65.5	66.5	[65.6]
10	59.3	61.3	61.5	66.5*	66.7*	65.2	66.3	66.0	66.0	67.8*	69.8*	72.0*	[66.9]
11	62.5	61.5	63.2	64.5	64.3	66.0	65.0	64.0	64.0	65.8	63.0	63.0	66.4
12	61.3	59.5	61.7	64.0	65.0	65.0	64.5	64.3	94.3	64.2	64.7	65.5	65.3
13	62.7	62.7	63.0	64.2	65.0	64.7	64.2	64.0	64.2	64.2	64.8	65.0	65.8
14	63.7	61.2	61.3	61.0	61.9	64.0	67.0	64.7	64.3	65.3	64.7	64.2	65.2
15	62.2	62.2	63.0	64.2	64.4	64.8	64.3	62.8	63.2	63.8	64.2	65.8	65.2
16	62.0	60.8	61.5	62.5	63.5	63.3	65.0	68.0*	65.0	64.2	64.2	66.0	65.0
17	61.5	59.5	62.2	61.0	59.2*	64.0	64.9	63.5	65.0	65.8	66.0	64.5	65.4
18	64.0	61.1	61.0	62.6	65.0	64.3	64.5	67.1*	64.0	65.0	65.6	61.3*	64.3
19	62.0	61.0	61.2	62.5	64.0	63.6	69.3*	64.3	66.2	65.0	67.7*	65.8	65.7
20	65.2*	63.0	62.0	63.5	64.8	67.0	68.0*	65.0	67.7*	66.3	65.0	64.7	66.3
21	63.0	62.5	62.5	64.0	63.8	64.4	64.8	64.7	64.7	65.0	65.0	65.0	65.1
22	[60.7]	[59.8]	[60.1]	[61.5]	[62.3]	[62.7]	[63.0]	[62.5]	[62.5]	[62.7]	[62.6]	[62.3*]	[64.6]
23	58.8*	60.3	62.8	63.8	64.3	64.5	64.7	64.8	66.2	65.5	64.8	66.3	[63.3]
24	55.8*	55.5*	51.2*	57.0*	60.0*	60.3*	66.0	62.3	65.8	65.2	66.8	67.0	64.4
25	59.9	60.0	61.0	62.9	64.3	64.9	64.7	64.3	64.7	65.0	65.0	65.0	65.2
26	58.2*	57.2*	57.2*	60.5*	63.2	62.0*	62.0*	64.0	63.9	64.5	65.5	65.0	64.6
27	61.0	61.0	62.0	63.0	63.8	64.0	64.2	64.3	64.3	64.5	64.5	64.7	64.9
28	59.7	57.5*	58.8*	59.5*	62.6	64.7	65.0	65.0	64.8	64.8	64.9	64.5	64.6
29	60.2	60.2	60.8	61.6	63.2	64.7	64.8	64.9	64.7	64.8	64.9	64.9	64.8
30	64.0	62.9	63.2	[64.2]	64.5	65.4	65.5	65.5	65.5	75.2*	70.8*	67.5	[66.3]
Monthly mean	61.5	60.8	61.2	62.8	63.9	64.4	65.0	64.6	64.8	65.3	65.3	65.2	65.34
Normal	61.7	61.1	61.7	63.2	64.1	64.6	64.8	64.4	64.8	64.8	64.9	65.2	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time.

300 divisions + tabular quantity.

MAY, 1884.

Day.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
1	68.1*	66.2	68.0	66.0	66.0	68.2	70.0	69.8	71.2*	69.0*	66.0*	64.2
2	64.8	65.2	65.3	65.7	66.5	68.0	70.3	71.2	70.0	66.5	64.5	63.5
3	64.8	64.5	66.0	65.8	66.3	67.8	69.8	70.0	68.3	66.0	63.0	63.0
4	64.5	65.0	64.8	64.8	66.0	67.7	71.0	72.2	70.0	66.0	63.0	62.0
5	64.8	64.0	64.8	64.8	66.0	67.5	[69.6]	[70.2]	[68.7]	66.5	63.0	62.8
6	66.5	66.5	66.0	66.7	67.5	69.0	71.0	70.0	68.0	65.0	64.0	64.0
7	65.3	66.0	65.5	67.5	68.5	69.0	70.0	70.0	67.2	64.0	61.2	61.5
8	65.3	65.5	66.0	66.2	67.0	68.5	71.3	72.0	69.8	66.0	62.0	61.5
9	66.0	66.0	66.0	66.0	66.8	69.3	71.5	71.5	69.5	66.0	63.3	62.0
10	66.2	67.3	67.7	67.0	67.6	71.2*	70.8	68.2	66.0	64.0	62.0	60.2
11	65.5	66.0	66.5	66.3	68.0	69.7	70.0	72.5	67.1	63.0*	61.5	59.3*
12	66.0	66.0	64.8	64.5	65.8	68.0	68.3	68.5	68.0	66.5	63.5	61.7
13	64.4	64.8	65.0	64.5	66.8	69.8	71.7	71.5	70.2	69.0*	64.8	62.8
14	64.8	64.3	65.3	66.3	67.5	68.3	70.5	70.8	69.3	66.0	62.5	60.0
15	64.8	65.0	65.3	66.5	65.0	69.0	69.2	69.0	65.0*	60.2*	57.5*	57.0*
16	63.5	66.0	65.5	66.0	66.5	67.5	69.0	68.5	67.0	64.7	62.0	61.8
17	64.8	65.0	65.5	66.0	66.3	67.8	69.0	69.5	67.5	65.0	63.0	62.0
18	65.0	65.7	65.2	65.4	66.2	67.5	69.0	68.0	66.0	63.8	62.5	62.5
19	65.0	63.5	65.2	65.5	67.5	69.0	68.5	65.5*	63.8*	62.2*	60.5	58.5*
20	64.5	64.9	65.2	66.0	66.0	67.0	68.0	68.0	65.5*	62.5*	61.5	61.3
21	64.9	65.0	65.2	65.3	65.6	66.3	67.2*	68.8	68.5	68.0	67.0*	66.3*
22	63.5	64.0	64.8	64.8	66.3	67.0	66.0*	66.0*	63.5*	63.5	64.8	61.0
23	66.2	65.7	66.2	66.8	68.5	70.0	71.0	71.0	69.0	67.0	62.0	59.8
24	67.0	64.5	66.0	66.7	67.0	70.0	72.5	71.2	69.0	64.3	60.8	59.0*
25	64.8	65.7	65.8	66.5	67.2	70.0	73.0*	72.3	67.6	63.0*	58.0*	56.0*
26	64.5	64.5	65.0	65.3	67.0	69.5	70.5	72.5	70.0	65.2	60.8	58.4*
27	64.2	64.5	65.0	65.5	66.5	68.5	72.5	75.2*	74.5*	70.8*	64.0	60.7
28	64.5	64.3	64.2	65.3	65.3	67.7	71.0	72.0	70.8	67.8	64.1	62.0
29	64.8	65.0	65.0	66.0	67.0	70.2	72.0	72.7	70.0	67.8	65.2	64.0
30	64.8	65.0	65.2	66.0	67.3	69.3	70.5	69.8	67.0	67.0	64.3	62.8
31	65.2	65.2	66.0	68.2	69.2	69.9	71.2	70.3	69.5	67.0	64.5	64.1
Monthly mean	65.1	65.2	65.6	65.9	66.8	68.6	70.2	70.3	68.3	65.6	62.8	61.5
Normal	65.0	65.2	65.6	65.9	66.8	68.6	70.3	70.4	68.5	65.8	62.9	62.1

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794

Increasing scale readings correspond to increasing east declination.

MAY, 1884.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
1	62.8	61.5	61.5	62.3	64.2	64.8	64.2	64.8	66.3	66.0	65.0	65.5	65.9
2	62.0	61.8	61.5	61.5	62.0	63.0	64.0	64.3	65.5	64.4	64.3	64.8	65.0
3*	63.5*	63.3	63.3	64.0	64.4	64.0	64.3	64.3	64.2	64.3	64.5	64.5	65.2
4	61.3	62.0	62.0	63.0	63.0	63.5	63.3	62.8	62.8	63.5	64.0	64.5	64.7
5	62.5	62.0	62.5	63.0	64.0	64.5	65.0	64.7	64.7	65.0	65.0	65.0	[65.0]
6	64.8*	63.5	64.0	63.8	63.5	64.3	63.2	63.8	63.5	65.5	68.0*	65.5	65.7
7	61.5	61.5	62.5	64.0	65.2	66.0	70.0*	64.5	64.5	65.2	65.5	66.0	65.5
8	59.0	60.2	61.5	64.2	65.3	67.2	65.3	65.3	65.3	65.3	66.0	66.0	65.5
9	59.7	58.5	60.9	62.4	64.3	65.1	65.0	64.2	64.8	64.3	64.2	65.0	65.1
10	59.0	56.5*	58.0*	62.8	62.0	61.8*	66.5	64.8	64.9	63.8	66.1	66.3	64.6
11	61.2	59.2	60.7	62.0	64.2	63.8	70.2*	65.0	70.0*	66.0	64.5	61.0*	65.1
12	61.0	60.5	61.0	62.5	64.0	65.0	65.0	64.5	64.3	64.5	67.5	64.8	64.8
13	61.0	59.3	60.0	61.5	63.5	65.5	65.3	64.7	65.0	67.2	65.5	65.8	65.4
14	59.2	60.5	62.0	63.2	63.0	64.0	64.2	65.0	67.0	65.5	65.0	67.3	65.1
15	59.0	60.0	62.0	63.0	64.0	64.3	65.5	64.5	64.5	65.0	65.0	64.3	63.9
16	61.3	62.0	63.0	64.1	65.0	65.3	64.5	65.0	65.0	65.3	66.0	65.0	65.0
17	61.3	61.0	61.3	62.0	63.0	64.4	65.3	65.2	64.8	64.5	65.0	65.0	64.8
18	61.5	60.5	60.0	61.0	61.5	62.0*	63.0	63.2	63.2	64.0	64.2	64.3	64.0
19	58.8	59.2	61.2	64.0	64.2	63.8	63.0	63.0	64.2	64.0	64.3	64.2	63.7
20	61.5	61.8	61.7	62.2	63.0	63.0	63.5	63.8	64.0	64.2	64.4	64.7	64.1
21	63.0	61.7	61.5	62.0	63.0	64.0	64.5	63.5	63.5	63.0	63.5	63.5	64.8
22	60.5	61.0	62.0	63.0	63.5	66.3	68.0*	65.5	64.7	64.0	65.5	64.7	64.3
23	59.5	61.0	62.0	65.0	66.0	65.8	65.3	64.3	64.8	66.5	67.0	65.5	65.7
24	58.5	60.0	62.5	64.3	65.5	65.5	65.0	64.8	64.7	64.5	64.5	64.7	65.1
25	55.0*	56.5*	60.0	63.0	64.5	64.5	64.5	64.5	64.5	65.0	65.2	64.3	64.2
26	58.0*	59.3	61.2	64.0	65.7	66.0	65.8	65.2	65.0	65.2	65.0	64.5	64.9
27	59.5	59.0	60.5	63.0	65.0	66.0	64.0	64.7	65.3	65.0	64.3	64.2	65.5
28	60.7	61.3	62.0	63.5	64.7	65.7	64.8	64.2	64.8	64.3	64.7	64.5	65.2
29	63.0	63.2	63.0	64.0	64.3	66.0	66.9	67.0	66.0	65.8	64.9	64.8	66.2
30	62.2	62.3	63.0	64.0	65.0	66.0	65.9	65.1	65.2	66.0	65.3	65.2	65.6
31	63.2	62.9	62.2	62.0	63.2	64.0	64.0	64.9	65.2	66.5	66.2	66.3	65.9
Monthly mean	60.8	60.7	61.6	63.0	64.0	64.7	65.1	64.6	64.9	65.0	65.2	64.9	65.02
Normal	60.9	61.0	61.7	63.0	64.0	64.9	64.7	64.6	64.7	65.0	65.0	65.0	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

JUNE, 1884.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	69.1*	70.8*	70.0*	69.0*	70.2*	72.0*	71.2	71.0	67.5	66.0	65.0	64.7
2	67.0	65.0	66.2	66.5	67.2	67.0	66.5*	62.5*	64.0*	64.8	61.0	64.0
3	66.0	65.5	65.5	66.0	68.5	69.0	71.8	71.3	[69.5]	65.5	64.2	64.2
4	65.2	65.2	65.3	66.0	65.5	68.0	69.0	68.0*	66.5*	62.0*	59.0*	58.3*
5	65.2	65.8	65.0	66.5	67.8	69.5	72.0	73.8	72.0	68.0	64.0	62.0
6	65.5	65.2	65.0	66.0	68.0	70.3	72.8	73.0	72.1	68.5*	64.5	61.0
7	65.3	65.5	65.8	66.0	67.0	69.0	70.8	70.2	68.0	64.7	60.7	58.0*
8	65.0	65.3	65.5	65.8	66.0	68.5	71.0	74.0	73.0*	69.0*	66.2*	63.8
9	65.3	64.7	65.0	65.0	67.5	69.2	70.8	72.0	71.0	67.0	62.3	59.3*
10	65.5	66.0	66.0	66.0	67.3	68.5	71.0	72.9	72.0	67.5	62.2	61.0
11	65.0	65.5	65.8	65.2	66.8	69.2	72.5	72.2	69.3	64.0	59.0*	57.3*
12	65.5	65.8	66.0	67.2	68.0	70.5	73.0	73.8	70.3	64.0	59.2*	57.0*
13	65.0	65.3	66.0	67.0	67.2	68.0	70.5	72.0	70.5	65.7	61.5	59.0*
14	65.0	65.7	65.2	65.5	66.2	67.0	68.0*	66.8*	68.0	64.7	61.2	59.2*
15	65.0	65.0	65.0	65.0	66.2	68.0	70.0	70.5	70.0	66.5	63.0	61.8
16	65.0	65.2	65.2	66.0	66.7	69.7	71.8	71.0	69.0	66.3	64.3	62.5
17	64.3	65.0	67.0	66.8	68.5	69.8	73.0	71.5	70.8	64.3	60.0*	57.5*
18	64.8	64.3	65.0	65.5	67.0	69.3	71.5	72.0	68.5	64.0	59.5*	58.2*
19	67.5	64.3	64.5	65.8	66.8	69.2	72.0	71.5	67.2	62.2*	61.3	59.8*
20	63.2	66.0	66.7	67.0	67.5	69.2	70.3	70.9	68.8	64.5	60.8	59.2*
21	65.5	66.5	66.5	67.2	68.0	70.5	72.0	72.0	69.0	65.0	62.8	62.7
22	66.5	67.8	68.0	68.5	69.0	70.0	72.3	70.8	67.2	66.2	64.8	61.0
23	69.5*	66.8	69.0*	68.2	66.2	69.0	71.0	70.5	70.7	68.0	64.8	63.5
24	68.0*	67.0	65.8	63.0*	67.3	69.0	70.1	70.0	69.3	67.2	62.4	61.4
25	65.6	65.0	65.3	66.3	67.8	68.8	71.0	72.5	71.3	68.6*	64.4	62.5
26	65.6	66.0	66.2	65.5	66.5	68.8	70.6	71.8	70.2	65.8	63.0	62.5
27	65.8	65.4	65.4	66.5	66.8	69.0	72.7	72.4	70.3	64.4	60.5	56.4*
28	65.0	65.3	64.6	64.4	66.6	68.7	72.0	74.8*	72.5*	66.5	63.0	60.3
29	65.0	66.6	66.5	68.8*	69.2	70.3	71.1	72.0	70.7	67.8	63.5	63.0
30	64.5	64.5	64.7	65.3	65.8	69.7	71.5	71.7	68.0	65.8	64.1	63.6
Monthly mean	65.7	65.7	65.9	66.2	67.3	69.2	71.1	71.3	69.6	65.8	62.4	60.8
Normal	65.3	65.6	65.7	66.0	67.2	69.1	71.4	71.8	69.7	65.8	62.9	62.5

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794 — Increasing scale readings correspond to increasing **east declination.**

JUNE, 1884.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
1	63.5*	63.9	63.8	63.3	64.2	64.2	64.0	64.3	65.0	66.8	65.7	67.9	66.8
2	65.0*	64.8*	65.2*	66.0*	64.5	65.0	64.5	66.2	66.5	71.0*	65.5	65.3	65.4
3	62.0	62.0	62.5	63.7	64.3	65.0	65.0	64.8	64.3	65.0	65.5	64.8	[65.7]
4	60.0	61.0	62.2	63.8	65.0	65.0	64.8	64.3	66.0	65.0	64.8	65.7	64.4
5	61.2	61.3	60.8	60.8	63.2	64.8	65.2	65.0	65.0	65.3	65.0	65.0	65.6
6	58.8	57.8*	59.2*	61.7	63.5	65.5	65.2	64.8	65.2	65.0	65.5	66.0	65.4
7	58.0*	58.0*	60.7	63.2	65.0	65.2	66.0	65.5	64.8	64.8	65.0	64.8	64.7
8	62.3	61.3	62.7	63.7	65.0	65.5	66.0	64.5	64.3	64.8	65.0	65.0	66.0
9	60.5	61.6	63.2	64.0	66.2	66.0	65.5	64.0	64.3	64.5	65.2	65.5	65.4
10	59.5	60.5	61.3	62.2	64.5	66.2	66.0	64.7	64.8	65.2	65.2	65.8	65.5
11	58.5	59.5	61.2	63.5	64.5	65.7	65.5	65.3	65.3	65.0	65.3	65.3	64.8
12	57.5*	58.5*	59.5*	60.5*	62.0	64.5	64.0	64.0	65.3	65.0	64.3	64.5	64.6
13	58.5	58.2*	58.8*	61.0	63.5	63.5	63.0	63.5	64.3	64.0	64.2	64.3	64.4
14	59.5	61.0	61.8	63.0	64.0	64.5	64.8	65.0	64.8	65.0	65.0	65.0	64.4
15	62.3	62.1	63.7	65.0	66.0	66.5	65.2	64.8	64.8	64.8	65.0	64.9	65.5
16	62.5	62.3	63.2	65.0	66.0	66.5	65.5	64.3	64.2	64.0	64.0	64.5	65.6
17	56.8*	56.0*	58.5*	60.7	62.5	63.5	63.0	63.0	63.3	64.0	64.1	64.3	64.1
18	55.2*	56.8*	59.0*	61.0	62.0	64.7	64.2	63.3	64.6	69.5*	69.0*	67.0	64.4
19	60.7	62.0	63.0	64.5	65.3	65.8	65.0	65.0	66.5	66.2	66.0	65.8	65.3
20	59.0	60.8	62.0	64.2	65.8	68.0*	68.0*	65.0	64.5	65.2	61.5*	65.0	65.1
21	63.0	63.2	64.5	65.2	65.3	64.5	65.2	63.5	64.0	65.0	65.5	66.5	66.0
22	60.5	60.8	61.5	61.0	61.8*	64.0	65.5	69.0*	64.0	63.0	62.2*	73.7*	65.8
23	61.9	60.8	60.5	62.0	64.2	65.2	64.8	65.8	65.2	68.8*	66.9	66.0	66.2
24	61.5	62.3	63.4	64.4	65.0	65.0	65.4	65.6	68.0*	66.7	65.3	65.3	65.8
25	62.0	60.8	61.3	62.3	64.0	65.5	66.4	65.7	65.5	65.4	65.7	66.8	65.8
26	62.5	61.4	61.4	63.5	64.4	65.4	64.9	66.0	65.5	66.0	64.8	65.2	65.6
27	56.0*	58.0*	58.7*	61.7	64.3	65.7	67.2	65.7	65.4	65.4	65.0	64.4	64.7
28	59.4	60.3	62.5	63.5	64.0	64.2	64.2	65.0	65.8	66.0	66.2	65.6	65.4
29	61.4	61.8	62.3	64.5	65.3	65.3	65.0	65.0	65.0	65.0	67.5	64.0	66.1
30	62.4	62.4	63.6	64.6	65.4	65.6	66.0	67.3	66.3	66.3	66.0	66.8	65.9
Monthly mean	60.4	60.7	61.7	63.1	64.4	65.2	65.2	65.0	65.1	65.6	65.2	65.7	65.35
Normal	60.9	61.5	62.3	63.1	64.4	65.1	65.1	64.8	65.0	65.1	65.3	65.4	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

JULY, 1884.

Day.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
1	68.3	67.0	67.0	67.0	67.2	68.8	69.8	73.8	71.1	67.6	63.5	60.8
2	65.5	65.5	65.9	65.9	66.1	68.0	70.0	71.2	70.3	[66.1]	[63.1]	[61.2]
3	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
4	[68.0]	[67.9]	[68.2]	[68.6]	[69.3]	[71.4]	[73.0]	[74.2]	[72.5]	[68.3]	65.3	63.5
5	66.0	66.3	66.3	66.5	67.3	69.0	69.0	72.0	69.5	65.5	63.0	60.7
6	66.1	66.5	66.3	66.5	66.5	68.0	70.3	71.5	71.5	68.5	63.5	61.0
7	65.5	65.5	65.7	67.0	67.3	69.0	71.8	72.7	69.0	62.0*	58.5*	56.4*
8	68.6	69.0	66.0	67.0	67.0	72.0	74.7*	77.0*	73.0	67.3	63.0	59.4*
9	66.0	66.3	67.3	67.7	68.7	70.0	74.0*	74.5	73.8*	68.3	64.0	60.7
10	66.6	67.3	68.0	68.0	68.5	70.3	71.3	71.0	70.5	66.0	63.2	61.2
11	66.1	66.3	67.0	68.0	68.7	69.7	70.7	72.2	72.2	69.2	65.0	61.0
12	67.1	66.3	66.5	67.2	69.3	71.6	73.6	76.0*	73.5	68.3	65.1	63.0
13	66.0	66.1	66.0	68.1	69.9	72.9*	73.1	74.1	73.0	68.0	61.2*	61.9
14	68.2	65.3	67.3	65.5	67.8	70.0	71.8	73.3	73.0	70.7*	68.5*	66.3*
15	65.5	66.0	67.0	67.7	68.0	68.3	70.8	71.8	70.0	67.3	65.8	64.0
16	66.6	66.3	67.0	67.4	68.1	68.7	69.8	73.3	72.5	67.0	64.0	62.3
17	66.8	66.4	67.0	67.2	68.4	70.1	72.3	74.0	72.0	67.3	64.8	62.8
18	66.3	66.8	67.2	67.2	67.5	68.8	70.3	70.0*	69.3	65.5	63.7	62.0
19	66.3	66.5	67.3	68.0	68.5	69.7	71.3	72.3	71.0	67.3	64.3	62.5
20	66.3	66.3	66.6	66.5	67.0	69.0	70.7	71.5	70.0	64.8	62.2	60.3
21	65.5	65.7	66.3	66.5	67.7	69.7	72.0	72.5	69.0	65.3	62.5	60.0
22	66.3	66.5	66.5	67.2	67.7	69.2	71.5	72.7	70.3	65.7	63.7	63.9
23	67.8	67.8	68.3	69.3	69.7	72.3	72.7	73.7	70.3	64.3*	61.7	61.0
24	66.6	67.5	67.5	68.5	70.0	72.7*	75.0*	75.0	72.3	68.0	65.0	62.7
25	68.5	68.0	70.3*	69.0	69.5	71.7	70.3	74.0	72.8	68.5	65.5	64.3
26	66.7	67.3	64.7	66.3	66.7	70.0	71.7	73.0	72.3	70.0*	67.0*	65.3*
27	66.7	66.3	66.5	67.0	66.5	69.8	72.7	73.0	70.9	66.7	64.3	62.7
28	67.8	66.3	67.7	67.5	69.5	71.8	73.5	73.0	71.0	67.5	66.3	65.5*
29	67.3	66.8	65.7	68.0	67.3	74.0*	72.3	73.5	70.7	66.5	63.7	62.0
30	66.7	66.8	67.3	67.3	67.8	69.2	70.0	70.3*	69.7	68.0	66.7*	65.0*
31	66.5	67.5	67.0	67.0	67.5	69.0	72.4	72.0	70.3	65.0	61.3*	59.0*
Monthly mean	66.7	66.7	66.9	67.3	68.0	70.1	71.7	73.0	71.2	67.0	64.0	62.1
Normal	66.7	66.7	66.9	67.3	68.0	69.8	71.1	72.9	71.2	67.1	64.0	62.0

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794

Increasing scale readings correspond to increasing east declination.

JULY, 1884.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
1	60.5	61.1	62.0	64.0	64.7	67.0	66.1	64.9	65.8	66.9	66.0	66.2	66.1
2	[61.4]	[61.9]	[63.1]	[64.5]	[65.5]	[66.1]	[66.1]	[66.6]	[66.3]	[66.2]	[66.4]	[66.9]	[65.8]
3	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	[. .]
4	63.3	63.3	64.5	65.5	66.0	67.5	65.0	64.5	66.0	66.0	66.0	66.0	[67.2]
5	61.0	62.0	62.7	63.5	65.0	65.3	66.3	68.8*	67.0	65.5	65.0	66.1	65.8
6	60.3	61.0	63.5	64.3	66.8	67.0	66.4	65.7	65.5	65.5	65.5	65.5	66.0
7	57.3*	59.5	63.8	65.7	66.3	66.7	68.0	64.5	66.0	66.0	66.7	69.2*	65.4
8	59.3	61.0	63.8	65.8	66.8	66.8	66.0	65.5	65.3	65.3	65.8	65.8	66.7
9	58.8	60.5	63.3	65.3	66.0	66.8	65.3	65.0	65.3	65.7	66.0	66.0	66.5
10	59.5	58.5*	60.2*	63.0	65.7	65.1	65.1	64.9	64.9	67.0	67.9	70.1*	66.0
11	59.3	60.9	63.1	64.0	64.8	65.0	66.1	67.1	67.1	66.9	66.0	66.5	66.4
12	60.2	61.4	63.0	64.1	65.1	66.1	66.3	66.0	68.6	67.1	66.8	66.1	67.0
13	61.8	59.5	56.9*	59.5*	61.6*	64.9	64.3	74.3*	70.6*	72.0*	67.0	68.9*	66.7
14	63.5	63.0	63.3	64.5	66.0	66.0	66.0	67.3	66.5	65.8	66.2	66.0	67.2
15	62.3	61.3	61.0	62.5	64.3	64.8	65.2	69.8*	66.0	65.5	65.5	66.0	66.1
16	63.3	63.3	61.7	64.0	64.3	65.4	65.7	65.5	65.4	65.7	66.5	66.5	66.3
17	62.6	62.6	63.5	65.1	66.2	66.8	66.2	65.8	65.7	65.7	66.2	66.0	66.7
18	61.0	61.0	61.4	62.0*	63.0*	64.2	64.4	64.7	64.7	64.7	65.3	65.7	65.3
19	60.5	62.0	63.0	64.7	64.3	64.0	66.5	68.3	66.3	64.7	65.7	66.0	66.3
20	60.7	62.3	63.3	65.3	66.7	67.7	68.7*	65.0	65.0	65.0	65.3	65.5	65.9
21	59.8	61.3	64.0	66.5	67.3	66.7	66.3	65.7	65.5	65.5	65.7	66.0	66.0
22	64.0*	64.3	65.0	65.8	66.3	66.7	66.7	65.7	65.3	65.7	66.0	66.3	66.6
23	61.7	64.3	65.3	66.5	66.7	67.2	66.8	66.3	66.3	66.6	66.6	66.4	67.1
24	62.0	62.5	64.5	65.5	66.3	66.7	66.3	66.0	67.5	68.3	71.5*	76.0*	68.1
25	61.7	61.7	63.3	64.7	66.0	67.3	66.8	74.0*	66.5	65.0	65.5	65.0	67.5
26	64.0*	64.0	64.3	64.5	65.5	66.5	66.5	66.5	67.7	66.8	66.5	67.8	67.2
27	62.0	62.5	63.5	64.7	65.7	66.3	66.0	66.8	67.8	67.3	67.3	67.7	66.7
28	64.3*	64.3	64.0	64.3	65.7	66.0	66.3	65.8	66.3	66.0	66.0	66.8	67.2
29	62.0	63.0	64.5	65.5	67.7	65.8	65.5	66.3	66.3	67.0	66.8	66.3	66.8
30	62.7	61.3	62.3	63.7	64.5	65.7	65.7	65.8	66.0	66.3	66.3	66.0	66.3
31	59.7	61.5	65.0	65.7	65.3	65.5	65.5	65.7	65.3	65.5	66.5	67.0	66.0
Monthly mean	61.4	61.9	63.1	64.5	65.5	66.1	66.1	66.6	66.3	66.2	66.4	66.9	66.49
Normal	61.3	62.0	63.4	64.8	65.8	66.1	66.0	65.9	66.1	66.0	66.2	66.2	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

AUGUST, 1884.

Day.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
1	67.3	66.5	67.2	67.5	68.0	68.7	70.8*	72.7	69.3	65.5	64.8	64.0
2	66.1	66.7	66.8	67.0	67.1	70.1	72.3	74.0	71.1	68.9	65.6	63.2
3	66.7	67.7	67.7	68.4	67.7	70.8	73.0	72.3	71.7	68.9	66.7	65.1
4	66.2	66.1	67.0	67.0	68.7	69.6	72.0	73.0	69.8	64.9	61.2*	61.1
5	67.1	67.9	68.2	68.7	70.0	72.9	76.0	76.0	71.6	67.0	63.0	61.0
6	68.0	68.2	69.0	69.3	70.0	71.8	75.0	76.1	73.1	67.8	64.0	62.7
7	67.7	67.9	68.0	68.8	69.8	71.0	77.1*	74.0	72.5	65.4	64.1	60.5*
8	66.1	66.9	61.9*	71.0*	69.2	70.0	73.1	72.2	68.9*	64.0*	62.1	60.0*
9	66.4	71.2*	70.4*	69.0	71.9*	73.3	73.5	76.9*	72.4	68.1	65.0	62.6
10	65.0	67.2	67.2	67.5	68.0	70.0	72.8	73.7	70.6	66.0	63.0	63.0
11	65.8	67.3	68.2	69.4	69.7	72.6	75.1	74.0	71.0	66.9	63.4	62.0
12	67.2	67.0	67.8	67.8	68.5	70.3	73.0	73.9	72.7	68.9	66.8	65.1
13	67.3	67.7	67.8	68.9	67.0	72.0	72.2	73.6	71.3	66.8	63.0	61.8
14	66.3	67.8	68.3	67.8	69.7	71.2	73.6	74.8	70.0	65.2	63.2	61.3
15	66.0	66.5	66.1	67.8	68.1	70.7	73.0	74.0	71.6	66.7	64.0	64.0
16	66.4	66.7	67.1	67.1	67.8	70.0	72.6	71.0*	67.0*	64.8	63.4	64.1
17	67.0	67.6	67.0	68.0	68.4	70.4	72.7	72.5	70.0	65.9	63.1	62.0
18	68.2	67.9	69.0	69.0	69.1	71.2	74.1	76.5	72.0	66.9	64.5	64.6
19	68.4	69.2	68.7	69.3	70.0	71.0	73.0	73.9	72.1	69.0	66.5	65.0
20	67.0	67.0	67.7	68.2	69.2	71.2	72.7	71.0*	67.0*	63.1*	60.9*	60.4*
21	67.9	67.7	66.7	68.8	71.6*	72.0	75.0	72.9	69.8	65.0	64.0	64.5
22	67.7	66.0	65.0*	64.0*	67.4	69.1	70.8*	73.0	72.5	70.0*	68.1*	65.3
23	68.8	63.8*	66.0	68.9	70.1	72.8	76.0	78.8*	76.0*	71.4*	69.4*	67.3*
24	67.6	68.0	68.1	67.2	69.0	70.5	72.9	74.8	73.9	71.7*	69.0*	66.3*
25	68.0	67.7	67.7	68.1	68.1	69.5	73.0	75.1	73.3	68.9	65.6	63.9
26	66.8	67.2	67.3	68.5	69.0	69.9	72.5	74.7	72.7	69.3	64.0	62.0
27	66.4	67.0	67.6	67.8	68.8	70.9	73.5	74.4	73.1	69.2	65.1	64.3
28	67.0	67.4	68.0	67.9	68.9	71.0	76.0	76.2	73.0	67.1	64.5	62.0
29	67.2	68.4	68.1	68.0	68.9	70.5	73.8	74.3	71.5	66.9	62.8	60.9
30	66.2	67.1	67.9	67.9	69.0	71.0	74.0	75.1	73.0	69.1	66.1	63.9
31	67.0	68.0	68.5	68.1	68.6	69.9	73.1	74.0	73.5	70.1*	66.8	64.8
Monthly mean	67.0	67.4	67.5	68.2	69.0	70.8	73.5	74.2	71.6	67.4	64.6	63.2
Normal	67.0	67.4	67.7	68.2	68.8	70.8	73.6	74.1	71.8	67.2	64.4	63.2

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794

Increasing scale readings correspond to increasing east declination.

AUGUST, 1884.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
1	63.2	63.0	62.3	64.2	66.1	65.2	65.8	66.0	68.2	66.0	65.0	66.0	66.4
2	63.2	63.2	64.0	65.9	66.7	66.0	65.3	65.3	66.0	65.8	66.0	66.5	66.8
3	64.0	64.0	64.0	65.0	66.0	66.5	65.8	65.0	65.0	65.1	66.1	66.0	67.0
4	61.2	62.0	63.0	65.2	66.9	66.2	65.9	66.0	65.0	65.5	67.0	66.5	66.1
5	60.0*	61.3	64.0	66.2	67.8	66.7	66.0	66.0	66.0	66.6	67.1	67.2	67.3
6	62.5	63.0	64.0	65.8	66.1	66.2	66.0	66.0	66.1	66.3	68.8	67.8	67.6
7	61.0	62.2	65.0	67.5	67.3	66.7	64.2	65.6	65.7	67.1	69.8*	67.0	67.3
8	61.3	62.9	63.9	65.8	67.2	65.0	64.0	64.0	64.7	64.8	65.0	65.9	65.8
9	61.0	60.4*	63.2	66.1	68.0	68.0	67.0	65.0	66.8	65.9	66.1	66.0	67.7
10	65.0	64.2	64.8	65.1	66.1	66.5	66.3	67.0	68.1	68.5	66.9	66.7	67.0
11	60.9	62.7	65.0	66.7	67.7	67.0	67.0	66.6	66.2	66.9	66.7	67.0	67.3
12	64.8	64.7	63.9	63.5*	65.0	64.8	65.7	66.0	66.7	67.1	67.1	68.0	67.4
13	61.8	62.0	63.4	65.2	66.3	66.0	66.2	66.2	67.0	68.0	66.3	66.5	66.8
14	59.0*	59.9*	61.1*	62.9*	64.6	65.2	67.2	66.6	67.8	67.0	67.3	66.3	66.4
15	65.1	66.2*	67.7*	68.0	67.6	67.3	67.0	67.5	68.1	67.6	66.9	66.9	67.7
16	65.6*	66.1*	66.8	67.8	66.5	67.4	67.0	67.0	66.9	66.5	68.1	67.6	67.1
17	62.8	64.0	66.0	67.9	68.1	67.2	67.3	67.8	68.0	68.2	67.9	68.2	67.4
18	64.0	65.8	66.7	67.1	68.5	68.0	67.8	67.1	67.7	67.1	68.2	68.1	68.3
19	65.0	65.0	66.8	65.6	65.8	65.6	66.2	66.6	66.2	66.1	66.6	66.4	67.8
20	62.0	64.8	65.7	68.8*	68.0	67.5	67.8	71.5*	71.7*	72.1*	67.0	66.6	67.4
21	63.2	64.0	66.0	66.1	65.4	64.7	66.2	66.0	67.6	72.0*	73.0*	70.8*	68.0
22	65.3	65.2	66.6	67.7	68.9	68.1	67.1	67.3	68.0	68.9	67.7	68.1	67.8
23	65.5*	65.5	66.0	66.5	66.5	67.7	68.2	68.5	68.1	67.2	67.2	67.2	68.9
24	65.0	64.3	65.0	66.1	66.0	66.6	66.9	67.0	70.0*	68.5	69.0	69.0	68.4
25	61.6	62.4	63.4	66.0	66.3	66.0	68.2	66.3	66.6	66.7	66.5	66.7	67.3
26	61.6	62.1	64.3	65.6	66.3	66.0	65.6	66.0	66.0	66.2	67.1	67.2	67.0
27	63.1	62.8	64.0	67.1	68.0	67.2	67.5	67.7	67.2	67.2	67.2	67.2	67.7
28	61.6	61.8	64.0	66.1	67.7	66.7	66.1	66.2	66.4	66.4	67.9	67.2	67.4
29	61.1	62.4	65.8	66.5	66.7	65.1	65.0	65.3	66.7	66.1	66.1	66.1	66.8
30	62.0	62.7	64.6	65.6	65.4	66.1	66.0	66.1	66.9	67.0	67.0	66.5	67.3
31	64.0	64.1	66.1	67.8	68.0	67.8	67.6	67.7	68.0	68.0	68.5	68.5	68.3
Monthly mean	62.8	63.4	64.8	66.2	66.8	66.5	66.4	66.6	67.1	67.2	67.3	67.2	67.33
Normal	62.9	63.4	64.8	66.3	66.8	66.5	66.4	66.4	66.9	67.1	67.0	67.0	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

SEPTEMBER, 1884.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	67.7	67.8	68.6	69.0	69.0	71.2	74.0	74.1	70.9	67.0	62.0*	60.1*
2	67.7	68.0	68.3	68.1	69.3	70.8	72.9	71.2	70.0	64.3*	61.8*	62.1
3	68.3	69.3	69.1	68.8	69.7	71.7	73.3	72.5	69.8	65.3*	64.0	63.6
4	67.6	68.2	68.5	68.5	69.1	72.0	75.0	74.5	71.2	66.0*	62.4*	62.2
5	67.5	67.6	67.9	68.1	68.1	70.5	72.9	72.0	69.4	65.0*	62.0*	61.8
6	67.7	67.0	68.7	69.8	70.2	71.6	73.9	74.2	71.1	65.2*	62.0*	61.2*
7	67.2	67.2	68.0	68.8	69.1	72.0	74.7	74.5	73.0	67.6	63.2*	61.1*
8	67.5	67.7	68.1	68.5	69.2	71.5	75.0	75.7	73.1	69.9	66.0	62.5
9	67.7	67.8	68.5	68.9	69.5	70.7	73.6	75.4	74.2*	71.5*	66.7	63.1
10	67.0	71.7*	66.2	67.8	69.8	72.5	74.7	74.1	70.0	69.0	65.5	62.8
11	71.0*	73.9*	70.1	68.4	69.7	68.7	71.0*	72.2	70.7	68.7	66.8	65.6
12	69.8	68.3	68.5	69.7	70.2	71.8	73.0	72.1	71.4	68.7	66.9	65.6
13	63.9*	69.9	69.9	66.4	68.1	70.8	71.7	70.5*	69.8	64.4*	64.0	64.5
14	70.9*	72.1*	69.5	70.5	71.0	72.2	72.3	70.3*	66.0*	64.7*	63.0*	64.5
15	68.5	69.0	67.5	68.5	68.5	71.0	72.3	71.8	69.3	67.0	66.3	66.2
16	68.3	69.2	69.3	69.7	70.0	71.7	73.7	71.8	68.7	66.3*	65.8	65.9
17	69.9	72.0*	69.4	70.3	70.3	73.6	75.9	73.8	70.9	64.1*	64.1	63.0
18	69.2	70.1	69.0	65.8	69.3	73.1	76.1	75.3	72.3	68.0	65.0	61.4
19	69.1	69.1	68.7	69.3	70.0	72.0	74.0	73.0	70.0	68.0	65.0	62.9
20	67.8	68.2	69.0	69.8	70.6	72.3	76.0	77.0*	74.9*	69.6	66.1	63.2
21	68.1	67.5	68.3	69.2	68.2	70.9	73.0	74.4	73.6	70.6	67.6	63.6
22	67.8	69.0	68.3	68.6	69.5	71.0	73.7	76.0*	76.1*	74.0*	71.1*	68.0*
23	68.9	68.9	68.7	68.8	69.3	70.9	74.8	76.2*	75.1*	71.0	67.2	64.6
24	68.7	68.6	69.7	69.3	69.8	71.0	73.8	75.6	74.0*	70.0	66.1	64.1
25	67.7	67.9	68.1	68.1	68.8	70.2	72.1	73.9	72.9	70.3	67.4	64.8
26	70.2	68.9	68.1	68.6	69.7	70.3	72.6	73.2	71.7	68.7	64.9	63.6
27	67.2	67.5	67.2	67.7	68.0	69.1	70.6*	72.2	72.9	70.2	66.2	64.6
28	68.1	69.0	69.1	69.2	68.7	68.0*	70.1*	72.6	72.3	69.5	67.1	65.1
29	68.1	68.1	68.2	67.9	68.0	69.4	70.4*	70.9	71.1	70.6	69.4*	68.2*
30	68.6	69.1	69.3	68.8	69.7	69.4	74.0	66.3*	70.1	70.3	70.1*	70.2*
Monthly mean	68.3	69.0	68.6	68.7	69.4	71.1	73.4	73.2	71.6	68.2	65.5	64.0
Normal	68.2	68.4	68.6	68.7	69.4	71.2	73.8	73.4	71.1	68.9	65.9	63.8

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794

Increasing scale readings correspond to increasing east declination.

SEPTEMBER, 1884.

Day.	13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
1	62.0	63.5	65.3	67.2	67.9	67.6	67.2	67.3	68.1	67.0	67.4	67.9	67.5
2	61.5	64.4	67.0	67.8	66.4	66.0	66.8	67.4	68.0	66.5	67.5	68.5	67.2
3	64.3	65.3	67.3	68.3	67.8	67.0	68.3	68.0	67.8	67.3	67.5	67.5	68.0
4	63.0	65.3	67.4	69.2	68.5	67.0	66.8	66.6	67.2	67.2	67.2	67.2	67.8
5	61.9	64.3	66.7	67.8	67.8	66.8	67.3	66.6	66.9	67.0	66.0	67.7	67.1
6	61.8	63.3	66.3	68.2	68.7	67.0	66.8	67.0	67.5	68.0	67.0	66.3	67.5
7	61.5	62.8	64.8	66.6	67.4	67.0	66.8	67.0	67.2?	68.0	66.5	67.0	67.5
8	61.8	62.5	64.2	66.7	67.8	67.5	66.9	67.6	67.8	67.8	67.7	67.6	67.9
9	60.5*	61.7*	63.9*	66.3	67.2	67.4	69.6	68.3	66.0	67.0	72.1*	70.0	68.2
10	61.7	62.7	65.3	66.2	67.3	68.3	67.6	68.9	68.5	71.4*	68.6	67.3	68.1
11	66.2*	67.8*	68.0	68.3	67.5	67.0	69.0	68.0	67.8	68.0	68.0	70.2	68.9
12	65.0	64.8	66.7	67.8	67.9	68.5	67.0	67.6	67.0	70.5*	69.6	70.1	68.7
13	64.6	65.8	66.9	66.9	67.9	66.4	66.6	75.0*	70.0	70.0	70.2*	70.6*	68.1
14	65.0	67.3*	68.3	69.4	67.8	65.5	66.2	66.3	68.8	66.6	67.2	67.7	68.0
15	67.3*	68.3*	69.7*	69.1	67.3	66.7	66.8	66.8	67.0	67.5	67.5	68.0	68.2
16	66.7*	67.9*	69.2*	69.0	67.0	66.0	66.8	66.8	66.4	67.1	67.3	67.9	68.3
17	62.6	63.9	64.1	68.2	68.8	66.8	77.0*	74.0*	77.0*	71.1*	73.1*	74.0*	69.9
18	62.0	63.0	69.0	69.8	69.0	66.6	66.8	69.2	69.3	72.0*	66.0	65.3	68.4
19	63.9	65.0	67.7	69.2	69.3	68.0	68.0	68.0	68.3	67.2	67.7	67.8	68.4
20	62.5	64.2	67.1	69.7	69.2	67.8	67.3	67.8	67.5	67.9	67.7	67.9	68.8
21	62.1	62.8	65.2	68.2	69.2	67.5	67.7	68.2	68.1	67.4	67.1	67.5	68.2
22	66.1*	65.3	66.1	68.0	68.3	68.0	67.9	68.0	67.8	68.0	68.0	68.3	69.3
23	63.8	63.7	65.2	68.7	68.7	67.8	68.0	68.6	68.5	68.2	68.3	68.3	68.8
24	64.8	65.3	66.9	67.4	66.8	66.7	66.8	67.0	67.1	67.3	67.1	67.2	68.4
25	65.1	65.5	66.1	66.8	67.0	67.0	67.4	67.5	67.8	67.8	67.6	69.0	68.2
26	63.8	65.1	66.7	68.3	67.8	66.8	67.4	67.3	67.3	67.3	66.7	66.6	68.0
27	64.8	65.9	67.1	66.9	66.1	66.9	67.1	67.0	67.1	67.1	67.3	67.9	67.7
28	63.7	65.0	65.0	65.2*	66.1	66.8	67.8	67.3	67.2	67.7	68.1	68.1	67.8
29	68.7*	68.0*	66.9	65.3*	65.7	66.6	66.9	67.4	67.5	67.3	67.6	68.2	68.2
30	69.8*	69.2*	68.0	67.5	66.5	66.3	67.3	67.0	67.3	67.3	67.4	67.6	68.6
Monthly mean	64.0	65.0	66.6	67.8	67.7	67.0	67.7	68.0	68.0	68.0	67.9	68.2	68.20
Normal	63.2	64.3	66.5	68.0	67.7	67.0	67.3	67.6	67.7	67.5	67.5	68.0	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

OCTOBER, 1884.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	67.6	68.2	67.9	68.2	68.2	68.9	70.2	70.6	69.5*	66.5*	65.0	64.4
2	72.0*	70.4	72.4*	67.8	69.2	70.8	70.4	71.6	59.9*	62.5*	67.7	66.1
3	69.7	69.4	69.3	68.8	68.9	70.2	71.4	72.0	71.5	70.0	68.0	66.8
4	68.0	69.2	69.3	69.2	69.3	70.3	72.1	73.5	72.6	71.0	68.1	66.0
5	68.4	65.7*	69.4	69.8	68.8	69.7	70.7	72.8	73.3	71.8	67.9	64.7
6	68.8	69.4	69.2	66.8	69.3	69.8	70.7	72.3	73.8	70.8	67.9	65.2
7	66.6	69.3	67.0	62.8*	67.7	70.0	71.4	73.3	73.8	70.3	68.2	66.0
8	68.5	68.5	68.0	68.5	69.0	69.7	72.0	74.0	75.9*	75.2*	71.8*	67.3
9	68.3	68.1	68.2	69.0	68.8	69.4	70.0	73.8	75.0	73.0*	68.2	65.8
10	68.5	68.4	68.4	68.9	69.3	69.7	71.3	72.2	72.7	70.1	67.1	64.4
11	67.7	67.9	68.2	68.2	68.9	69.3	70.5	71.8	72.9	71.9	69.8	67.7
12	68.1	68.1	68.2	68.2	69.2	69.6	70.6	72.9	71.9	68.8	66.0	64.1
13	67.9	68.0	67.9	68.1	69.2	69.9	71.2	72.9	71.9	69.6	67.0	65.0
14	72.7*	73.7*	69.7	68.9	68.4	69.6	70.0	68.2*	65.6*	64.1*	62.5*	63.7
15	67.5	69.5	70.5	70.8	69.4	69.1	69.7	67.0*	68.0*	65.1*	63.3*	64.3
16	69.7	69.7	69.2	69.0	68.2	69.3	71.9	72.9	71.9	69.9	68.9	67.9
17	71.6*	70.0	68.1	67.0	67.7	70.0	69.4	70.7	71.6	70.1	67.3	64.8
18	68.5	69.0	69.5	69.7	69.8	70.7	73.9*	75.2	73.4	69.6	67.0	65.8
19	68.6	67.8	69.0	68.9	69.7	70.7	70.4	75.3	71.5	68.7	65.2	64.2
20	68.1	68.8	68.9	69.2	69.1	69.7	72.1	72.9	72.1	68.3	66.1	65.9
21	67.8	69.7	69.7	68.4	69.5	69.4	69.7	72.0	69.8*	68.9	66.8	66.0
22	68.2	68.8	67.3	68.0	68.5	70.2	72.8	74.5	74.9	73.8*	70.7*	68.9*
23	68.1	68.4	68.2	69.0	69.1	70.0	71.8	73.3	72.0	71.1	69.2	67.5
24	67.7	68.0	68.4	68.4	69.0	70.0	72.7	75.6*	75.0	72.0	69.7	66.1
25	69.1	70.1	68.9	70.2	69.0	71.1	71.7	74.0	74.4	70.6	66.4	63.5
26	68.5	68.7	69.7	70.9	71.6	67.2*	72.2	72.3	72.7	70.1	68.0	67.0
27	69.2	68.2	68.5	69.1	69.1	69.8	71.0	72.0	71.4	69.5	67.1	65.1
28	67.1	68.1	68.5	69.0	69.5	69.2	71.9	72.1	70.6	67.2*	65.6	64.3
29	69.1	70.3	69.1	67.2	68.3	69.4	71.6	72.6	68.7*	66.6*	64.7*	64.0
30	68.4	69.0	68.8	68.9	69.1	70.0	72.3	74.7	74.8	72.1	69.3	67.3
31	69.6	69.0	69.2	69.4	70.0	69.8	71.0	74.1	74.1	71.0	68.4	66.1
Monthly mean	68.7	69.0	68.9	68.6	69.1	69.8	71.2	72.7	71.8	69.7	67.4	65.7
Normal	68.3	68.7	68.7	68.8	69.1	69.8	71.2	73.0	72.9	70.3	67.5	65.6

DECLINATION—Continued

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794

Increasing scale readings correspond to increasing east declination.

OCTOBER, 1884.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
1	65.0	59.0*	64.2	64.2*	64.5*	64.7*	67.1	60.0*	77.4*	73.5*	73.6*	73.3*	67.6
2	66.1	64.9	66.1	69.1	73.9*	69.1	69.1	70.8	67.0	67.9	68.0	68.7	68.4
3	65.6	66.9	67.9	68.2	67.5	68.3	68.6	67.6	68.0	68.0	68.4	68.1	68.7
4	65.3	65.8	67.1	67.7	68.8	68.8	67.7	67.6	67.7	67.8	67.9	68.0	68.7
5	63.7	64.3	65.7	67.1	68.0	68.0	67.2	69.0	67.1	68.0	68.0	69.0	68.2
6	64.7	64.4	65.2	66.8	70.1	70.2	68.0	69.3	69.6	71.2	71.9*	66.6	68.8
7	65.7	65.7	66.7	68.1	69.0	68.7	68.2	68.2	68.2	68.3	68.7	68.3	68.3
8	64.7	64.3	65.0	66.0	67.2	68.0	68.1	69.1	69.0	68.8	68.0	68.0	68.9
9	64.8	64.1	64.8	66.1	67.7	68.0	68.3	68.7	69.3	69.3	68.1	68.4	68.6
10	64.0	64.3	64.7	65.3	66.8	67.0	67.1	67.6	68.1	68.1	68.0	68.1	67.9
11	66.0	64.9	66.0	67.1	67.1	67.5	67.9	68.0	68.0	68.2	68.1	68.1	68.4
12	64.3	65.8	66.8	67.1	66.9	67.1	68.0	68.0	68.1	67.9	67.7	67.8	68.0
13	64.6	65.2	66.7	67.1	67.7	66.1	67.1	67.1	66.9	68.2	72.9*	70.3	68.3
14	63.0	66.4	67.7	69.1	69.6	68.0	68.7	68.9	68.9	69.1	69.0	68.3	68.1
15	65.6	66.6	68.7	69.2	67.7	69.0	68.8	69.2	68.4	70.5	69.2	69.7	68.2
16	66.7	67.7	67.8	67.1	67.0	67.1	68.0	67.8	67.7	67.8	68.0	68.7	68.8
17	64.1	64.9	66.6	67.8	68.1	68.0	68.8	68.6	68.4	68.2	68.2	68.0	68.2
18	65.0	66.0	66.8	67.2	67.7	67.7	67.6	67.2	67.9	67.2	68.3	68.0	68.7
19	64.2	65.0	66.0	67.7	67.7	67.1	67.9	67.5	67.8	67.9	67.9	67.9	68.1
20	65.7	66.2	67.1	67.3	68.1	69.0	69.2	68.1	68.1	68.2	69.2	65.9	68.5
21	66.0	66.9	68.2	69.0	69.0	68.0	68.7	68.1	68.3	68.3	67.9	68.0	68.5
22	66.9	66.2	66.1	67.0	67.4	67.9	68.0	68.8	68.0	68.8	68.0	67.9	69.1
23	66.3	67.0	67.4	67.5	67.5	68.1	68.4	68.0	68.0	67.9	67.8	67.8	68.7
24	65.1	65.2	66.4	67.2	68.0	68.9	69.3	69.7	70.9	70.0	72.7*	71.7*	69.5
25	65.0	66.4	67.1	67.9	68.1	68.0	68.1	68.6	69.0	68.2	68.6	68.1	68.8
26	66.0	67.0	67.6	68.0	68.4	68.3	68.9	69.0	70.1	69.0	69.0	68.0	69.1
27	64.8	65.4	66.3	67.0	67.3	68.0	68.4	69.5	69.0	70.0	68.5	68.5	68.4
28	64.3	64.8	65.9	66.0	66.6	67.8	64.9*	67.1	68.7	68.0	71.1*	70.2	67.8
29	64.9	65.7	66.1	68.9	68.0	69.0	69.2	69.3	69.9	69.5	68.1	69.3	68.3
30	67.0	67.0	66.6	67.7	68.0	68.5	69.0	68.5	69.8	69.6	69.6	69.0	69.4
31	65.7	66.0	67.1	67.2	68.0	69.0	69.1	69.3	69.7	69.7	69.3	69.1	69.2
Monthly mean	65.2	65.5	66.5	67.4	68.0	68.0	68.2	68.2	68.8	68.8	69.0	68.6	68.52
Normal	65.2	65.7	66.5	67.5	67.9	68.1	68.3	68.5	68.5	68.7	68.4	68.3	. .

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

NOVEMBER, 1884.

Days.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
1	69.6	69.6	69.0	69.2	69.7	69.9	70.5	73.0	76.1*	69.1*	69.0	66.2
2	68.0	69.2	69.0	69.9	71.2	68.1	68.0	65.9*	69.9*	68.0*	67.0*	66.6
3	79.0*	78.5*	65.2*	64.2*	56.0*	60.4*	63.7*	65.0*	64.9*	67.7*	67.7*	66.9
4 *	68.2	61.0*	68.7	69.7	69.3	68.1	70.1	71.8	72.1	71.0	67.7*	65.6
5	69.2	68.6	67.9	67.3	68.9	69.9	71.2	73.6	74.7	73.2	70.8	67.2
6	68.3	68.2	68.8	68.9	68.8	69.7	70.4	73.1	74.9	73.0	69.1	64.8*
7	68.6	68.2	69.1	69.1	68.0	69.6	71.1	73.1	73.8	72.8	70.9	67.9
8	67 9	68.9	68.7	69.2	69.2	67.8	69.0	71.1	73.0	73.8	71.4	67.8
9	70.3	69.4	69.0	70.9	69.4	65.3*	68.3	71.1	72.1	71.6	70.0	67.3
10	67.9	68.1	68.2	69.2	69.7	69.9	72.1	72.9	73.1	73.0	70.0	67.7
11	70.7	70.2	63.0*	69.3	69.3	70.1	71.9	74.3	74.8	73.0	70.0	67.5
12	68.9	68.9	69.7	68.8	69.3	69.8	70.0	72.0	72.8	72.3	70.1	67.2
13	68.4	68.0	67.5	67.9	69.0	69.1	70.1	73.0	73.9	73.0	70.8	67.5
14	69.3	70.2	70.6	69.2	69.4	70.1	71.9	73.1	73.9	72.6	70.5	68.1
15	68.4	68.8	69.0	69.1	69.2	69.3	70.7	73.0	74.4	73.6	70.3	67.8
16	68.7	69.1	68.9	69.2	69.4	69.4	70.9	73.8	73.2	72.6	70.2	67.8
17	68.3	68.8	66.7	69.0	69.0	70.2	71.6	72.9	72.7	70.1	69.0	65.7
18	69.1	70.1	69.1	69.2	68.9	69.1	71.0	72.1	72.7	71.3	68.6	67.0
19	68.3	68.7	68.7	68.8	67.4	67.9	70.2	71.9	73.9	72.9	71.7	68.9
20	68.8	68.2	68.0	69.1	69.2	67.2	69.8	71.0	73.0	73.2	72.0	69.0
21	68.3	66.0	68.0	69.1	68.9	69.1	70.2	71.1	73.2	73.4	71.6	68.0
22	68.0	68.1	68.2	68.1	68.1	67.9	70.0	72.2	74.8	74.1	72.0	69.0
23	69.7	69.1	68.9	68.9	69.6	69.5	69.4	70.7	72.4	74.3	68.3	67.4
24	68.4	68.8	69.3	69.6	69.6	69.9	70.6	72.4	71.4	71.0	69.5	66.8
25	69.4	69.0	68.0	67.9	68.4	69.0	67.5*	69.1*	71.8	72.1	70.3	68.2
26	69.1	69.1	69.5	69.4	69.4	69.6	70.1	72.1	72.8	73.2	72.0	69.0
27	69.0	69.0	69.0	69.3	69.1	69.5	70.0	71.2	72.9	73.1	72.1	69.6
28	77.9*	71.0	70.5	65.5*	58.8*	62.7*	69.4	72.1	72.9	72.6	72.1	70.3*
29	68.1	68.9	68.9	66.0*	69.3	69.3	69.3	69.5*	71.0	72.2	71.0	69.0
30	69.2	69.2	68.5	67.6	67.8	68.9	69.2	69.2*	70.0*	70.7	69.7	67.9
Monthly mean	69.4	69.0	68.4	68.6	68.3	68.5	69.9	71.6	72.8	72.2	70.2	67.7
Normal	68.8	69.0	68.8	69.0	69.1	69.2	70.2	72.3	73.2	72.6	70.5	67.7

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794

Increasing scale readings correspond to increasing east declination.

NOVEMBER, 1884.

Days.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
1	66.1	67.5	67.1	67.8	68.5	70.5	69.0	68.6	70.6	77.8*	72.0*	69.8	69.8
2	66.8	67.8	71.2*	72.3*	69.3	70.0	73.2*	72.2*	76.1*	76.7*	75.7*	77.0*	70.4
3	67.1	69.6*	70.3*	70.8*	68.0	71.1	70.1	72.3*	71.0	70.2	70.2	71.0	68.4
4	65.9	66.8	68.0	69.0	69.3	69.1	69.1	69.1	68.8	68.9	69.0	67.8	68.5
5	66.0	66.0	67.0	67.3	68.1	68.3	68.7	69.0	68.9	69.2	69.1	68.4	69.1
6	64.0*	64.0	65.0	66.0	66.7	69.0	69.3	69.0	69.1	68.9	68.4	68.1	68.6
7	65.5	65.7	66.0	66.9	68.2	69.3	69.0	69.2	69.0	69.0	67.9	68.2	69.0
8	66.3	65.3	65.4	65.8	68.4	69.1	70.0	69.0	68.7	70.1	67.9	68.2	68.8
9	66.0	66.7	67.4	67.4	68.4	69.8	68.9	69.8	69.8	69.2	69.4	69.2	69.0
10	66.2	66.3	65.3	65.3	68.8	69.0	69.3	69.8	71.7	70.4	70.6	69.5	69.3
11	66.7	67.0	67.6	67.7	68.0	68.8	69.0	69.0	68.3	68.4	68.8	68.3	69.2
12	66.1	66.0	66.7	67.2	68.1	69.0	69.0	69.1	68.7	68.5	68.7	69.0	69.1
13	66.0	65.4	66.3	67.6	68.7	68.8	69.7	69.8	69.8	69.8	70.2	70.0	69.2
14	67.1	66.2	66.8	67.0	67.9	68.0	69.1	68.8	68.9	69.1	68.7	68.7	69.4
15	66.7	66.7	66.7	67.0	68.8	69.0	69.4	69.6	69.0	69.3	69.3	68.9	69.3
16	66.2	66.1	66.3	67.9	69.2	69.4	69.8	69.6	69.1	69.0	69.0	68.1	69.3
17	64.6	65.8	67.3	68.3	69.3	70.1	70.8	69.7	69.7	69.6	70.8	69.8	69.2
18	66.0	66.0	67.2	68.0	69.2	69.2	70.8	69.8	69.6	69.3	68.7	68.3	69.2
19	67.3	66.7	66.8	68.1	69.1	69.6	69.6	69.9	69.7	69.5	68.9	68.9	69.3
20	67.1	67.0	67.8	68.2	69.7	69.5	69.7	69.7	69.6	69.5	69.1	68.2	69.3
21	66.9	66.0	67.0	68.0	69.0	69.8	69.5	69.0	68.6	68.5	68.8	68.8	69.0
22	66.8	65.2	67.0	66.9	68.6	68.8	69.2	70.0	70.0	69.9	69.8	68.9	69.2
23	65.7	65.7	65.0	66.5	69.2	69.8	69.7	69.7	72.5*	70.4	69.3	68.5	69.2
24	66.9	66.3	67.0	67.0	68.0	68.2	68.9	69.0	69.2	69.8	70.8	68.9	69.0
25	67.6	68.0	67.8	68.4	69.0	69.2	69.5	69.4	69.3	69.3	69.2	69.2	69.0
26	66.4	66.0	67.0	68.0	69.1	69.2	69.3	69.6	69.4	69.3	69.0	69.0	69.4
27	67.6	66.3	67.0	67.8	69.5	69.8	70.0	71.0	70.6	72.7*	73.8*	74.0*	70.2
28	69.7*	69.0*	68.5	68.8	69.4	69.7	69.4	69.4	69.3	69.0	69.3	72.4*	69.6
29	67.8	67.1	68.4	68.3	68.8	69.0	69.2	68.5	68.3	68.6	68.5	69.1	68.9
30	67.2	67.4	68.2	69.0	69.2	69.3	69.3	69.0	69.0	68.0	68.1	66.6	68.7
Monthly mean	66.6	66.5	67.2	67.8	68.7	69.3	69.6	69.6	69.7	69.9	69.6	69.4	69.19
Normal	66.6	66.3	66.9	67.5	68.7	69.3	69.5	69.4	69.4	69.3	69.2	68.8	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

DECEMBER, 1884.

Day.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
1	67.8	68.9	68.8	67.7	69.3	67.0	68.6	70.9	71.1	71.1	70.1	68.2
2	69.0	69.2	69.4	69.2	69.3	69.7	70.1	71.0	71.9	71.7	70.5	68.7
3	69.1	69.2	68.3	69.0	69.7	69.8	70.3	72.0	72.2	72.1	70.6	68.7
4	[69.4]	[69.2]	[68.7]	[68.5]	[68.2]	[68.3]	[68.9]	[70.0]	71.5	71.0	69.7	67.8
5	67.8	78.1	68.5	69.5	69.3	69.8	70.2	71.6	72.9	72.0	70.1	67.0
6	67.7	67.7	67.9	68.0	68.0	68.3	69.4	71.1	72.2	72.0	70.7	68.9
7	67.7	68.0	68.0	68.7	68.4	68.6	69.3	70.4	72.2	73.3	70.8	67.7
8	69.2	69.8	69.0	69.8	70.0	68.1	69.9	69.8	72.1	72.1	71.0	68.1
9	69.8	69.0	69.1	68.9	68.9	68.2	70.2	71.2	73.0	72.3	70.5	67.8
10	68.8	68.9	68.8	69.1	69.3	69.4	70.5	72.0	73.2	73.9	72.3	69.6
11	72.0*	70.5	70.4	70.7	70.3	71.2	72.4	71.7	72.8	73.0	69.8	66.2
12	69.3	70.0	70.0	69.2	69.3	69.8	69.8	71.0	73.0	73.7	72.1	69.3
13	69.3	69.4	69.5	69.7	69.7	70.0	70.4	71.6	72.5	72.7	68.7*	66.3
14	68.3	70.0	69.8	74.7*	70.6	70.3	70.8	69.4	71.7	73.3	70.3	66.5
15	76.0*	78.8*	72.8*	67.0	71.5	70.6	72.0	71.8	69.8*	70.3*	67.9*	66.9
16	71.3	69.2	70.2	69.8	65.9*	70.0	69.2	70.3	73.9	72.7	70.6	68.5
17	69.2	69.3	69.7	69.7	69.7	70.3	70.5	72.3	73.5	72.8	71.8	69.3
18	68.3	69.1	69.5	69.8	69.7	70.2	70.2	71.1	73.8	74.0	71.0	69.1
19	68.6	68.8	69.1	69.2	69.4	69.7	70.6	72.2	73.9	73.7	71.4	66.4
20	71.8*	70.3	70.7	70.2	70.2	70.0	70.6	72.0	73.8	74.1	72.7	68.3
21	69.1	68.4	69.1	69.0	66.4*	69.8	70.4	72.7	74.2	74.8	72.2	69.7
22	69.4	69.0	69.0	69.2	69.2	69.6	69.9	70.7	74.2	75.3	72.9	67.6
23*	75.0*	72.7*	68.0	66.8	68.5	68.6	69.7	70.9	72.9	73.8	72.0	69.5
24	69.2	68.7	68.7	68.4	68.5	68.5	69.5	70.9	74.1	75.9	74.2*	69.1
25	70.2	69.7	69.3	69.0	69.1	67.0	69.3	71.2	73.1	75.0	74.0*	70.6
26	69.3	69.1	69.1	69.0	69.1	68.7	69.9	71.3	74.0	75.3	71.3	66.6
27	68.1	69.7	68.9	68.9	69.0	69.0	69.8	72.4	74.1	74.0	72.2	69.7
28	72.2*	69.0	68.3	69.7	69.1	69.4	69.7	73.0	72.2	74.1	73.1	69.9
29	69.5	69.6	70.2	68.9	68.1	69.7	70.9	73.0	76.0*	77.0*	74.9*	70.8
30	69.7	69.0	69.7	69.1	69.1	70.2	69.4	71.0	73.8	74.3	72.0	68.0
31	70.3	68.9	70.3	69.8	69.9	69.9	70.1	72.2	74.3	74.0	72.0	68.6
Monthly mean	69.7	69.6	69.3	69.2	69.1	69.4	70.1	71.4	73.0	73.4	71.4	68.4
Normal	69.0	69.2	69.2	69.1	69.4	69.4	70.1	71.4	73.1	73.4	71.3	68.4

DECLINATION—Continued.

magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794 — Increasing scale readings correspond to increasing east declination.

DECEMBER, 1884.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
1	67.2	66.3	68.6	68.4	69.4	70.2	70.2	70.1	69.5	69.3	70.0	69.2	69.1
2	67.6	67.6	68.2	68.3	69.2	70.3	70.2	70.2	69.7	70.0	69.7	69.1	69.6
3	67.2	68.0	68.7	69.0	70.1	70.9	70.8	70.8	70.7	[70.3]	[70.2]	[69.7]	[69.9]
4	66.3	66.6	67.3	67.3	69.3	69.1	69.1	69.6	69.6	69.0	68.1	67.9	[68.8]
5	66.2	66.2	67.0	67.9	69.0	69.0	68.7	68.9	69.1	68.1	67.6	67.7	68.8
6	66.4	66.7	67.0	68.2	69.0	69.3	69.3	69.6	68.9	68.1	67.8	67.7	68.8
7	66.4	66.6	67.4	69.2	70.3	70.4	70.6	70.4	70.3	69.7	70.3	70.2	69.4
8	66.8	66.4	66.3	67.8	67.8	69.5	70.1	70.8	71.1	70.4	69.8	69.2	69.4
9	66.7	67.3	68.0	69.0	69.8	70.7	70.3	70.2	70.1	70.2	69.6	69.3	69.6
10	68.0	67.9	68.7	69.7	70.2	70.2	70.7	70.8	71.1	72.0	71.1	70.7	70.3
11	66.3	65.7	66.0	68.9	69.7	70.7	70.5	70.6	70.3	69.7	70.3	70.2	70.0
12	68.4	67.4	67.7	68.3	69.4	70.2	70.3	70.3	70.3	69.7	69.5	69.3	69.9
13	65.3	66.7	67.7	68.6	69.3	69.6	69.5	69.3	69.3	69.5	69.5	68.4	69.3
14	67.9	64.5	66.3	67.5	68.4	70.3	69.7	72.9*	70.9	70.7	70.5	73.9*	70.0
15	67.5	67.2	68.4	69.0	68.9	71.0	70.0	70.3	71.2	74.2*	73.7*	72.0	70.8
16	67.7	67.9	68.9	70.1	70.5	70.7	70.7	70.6	71.9	70.3	69.4	69.2	70.0
17	68.5	68.3	68.6	69.6	69.8	70.2	70.2	69.6	69.3	69.0	68.2	68.3	69.9
18	67.3	66.8	67.6	68.6	69.8	70.0	70.0	69.7	69.6	69.4	69.0	68.4	69.7
19	65.0	66.0	67.1	68.5	70.0	70.1	71.8	70.9	71.3	70.5	73.0*	71.5	70.0
20	65.4	64.8	66.5	67.5	68.9	69.0	69.5	69.8	70.0	69.7	69.3	69.4	69.8
21	68.0	67.3	67.5	69.3	69.1	70.2	70.7	70.7	70.5	70.0	69.8	69.8	70.0
22	64.2*	64.3	66.4	66.6	68.5	69.1	70.2	70.2	73.1*	71.3	72.4*	74.3*	69.9
23	67.0	66.3	67.1	69.0	70.2	70.5	70.5	70.5	70.3	70.3	70.2	69.3	70.0
24	66.1	65.6	67.1	69.4	71.0	70.2	70.2	70.5	70.4	70.3	70.3	68.5	69.8
25	68.2	67.3	67.6	69.0	69.9	70.2	69.9	70.2	70.7	70.6	70.2	70.0	70.0
26	65.1	64.9	66.4	68.6	69.3	69.8	70.1	70.3	70.5	70.3	70.0	69.9	69.5
27	67.1	66.4	66.0	67.0	69.7	69.9	70.0	71.0	72.3	71.5	75.0*	72.0	70.2
28	67.3	66.2	66.0	68.0	68.2	69.0	69.9	70.0	70.0	69.6	69.9	69.8	69.7
29	68.9	68.0	67.8	69.0	69.6	69.6	69.9	70.1	69.8	69.9	69.7	69.7	70.4
30	66.8	67.2	67.8	68.1	69.2	69.0	69.2	69.9	70.1	70.2	69.9	70.2	69.7
31	66.0	66.2	68.2	69.3	69.7	70.1	70.1	69.9	69.7	69.8	70.7	69.8	70.0
Monthly mean	66.9	66.6	67.4	68.5	69.5	70.0	70.1	70.3	70.4	70.1	70.1	69.8	69.75
Normal	67.0	66.6	67.4	68.5	69.5	70.0	70.1	70.2	70.3	70.0	69.6	69.5	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

JANUARY, 1885.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	69.4	69.7	69.4	69.6	69.7	69.8	69.7	71.7	73.0	72.2	70.0	66.5*
2	69.8	70.8	69.7	57.8*	68.2	70.8	72.1	74.3	72.7	72.1	70.5	66.3*
3	69.8	69.8	69.7	69.4	68.8	70.1	70.8	72.3	74.0	74.1	69.0*	67.3*
4	69.2	69.2	69.7	69.2	69.6	70.3	69.8	72.0	73.8	74.0	71.1	68.7
5	69.2	69.1	69.0	69.3	68.9	69.9	70.3	72.9	74.9	74.9	72.0	69.7
6	69.7	70.1	70.1	70.2	70.2	70.9	71.2	72.1	74.7	74.2	69.7*	67.6*
7	70.2	69.8	70.4	70.4	70.4	70.7	70.9	73.9	76.1	75.4	71.9	68.1
8	70.3	70.2	69.7	69.5	69.3	70.3	70.2	71.8	74.4	75.9	71.2	67.2*
9	69.6	69.7	70.1	69.5	69.4	69.9	71.0	73.0	74.7	74.6	71.6	68.1
10	69.9	67.4*	71.9	69.6	69.8	69.1	69.0	70.7	72.3	73.9	72.2	70.3
11	70.8	69.6	68.0	68.8	69.6	69.5	69.9	70.4	72.1	74.1	73.0	71.1
12	69.7	69.8	70.0	69.3	70.0	70.1	70.4	70.9	72.3	73.5	73.0	72.0
13	70.8	69.7	68.1	68.8	69.1	69.3	69.6	70.8	73.1	75.8	74.4	71.3
14	69.7	69.9	70.1	70.0	70.1	70.0	70.2	71.8	73.8	74.9	73.8	70.9
15	70.0	70.2	70.3	70.7	70.2	70.1	70.8	72.0	73.9	75.8	74.1	70.0
16	72.0	74.0*	71.1	70.2	69.9	69.9	70.2	71.7	72.9	73.3	72.2	70.3
17	71.1	71.0	71.0	69.6	69.9	69.8	69.8	70.5	72.9	74.6	75.0	72.6
18	70.8	70.4	70.5	70.2	70.8	70.3	70.6	72.3	74.1	75.3	73.6	70.9
19	70.6	70.0	70.8	70.4	68.2	70.0	70.6	72.1	74.2	75.2	72.3	66.1*
20	69.6	69.9	69.7	69.7	69.9	69.9	70.4	72.0	74.0	76.1	74.6	71.6
21	69.7	69.4	69.4	69.6	70.1	70.2	70.3	71.1	74.0	76.0	72.2	66.8*
22	70.7	69.3	71.5	70.8	69.0	67.0*	68.6	72.6	65.2*	69.2*	66.9*	70.6
23	71.6	73.0*	68.9	72.2	70.9	71.4	70.0	72.7	73.9	75.2	73.1	71.0
24	70.6	70.8	70.8	70.6	70.8	70.8	71.0	73.8	75.8	75.8	73.7	71.0
25	71.2	71.6	71.7	70.5	70.7	69.7	70.9	71.1	72.2	73.1	71.8	69.1
26	69.8	69.8	70.0	70.3	70.3	70.4	70.6	72.0	73.2	74.0	73.8	72.1
27	70.4	70.7	70.0	70.7	71.2	70.8	70.9	71.5	73.0	73.8	73.7	70.6
28	70.7	70.8	70.8	71.4	70.5	72.0	72.9	72.8	73.3	73.0	72.4	70.2
29	70.9	71.2	70.7	70.7	70.5	70.5	70.8	71.0	72.7	72.3	70.9	69.7
30	74.1*	81.5*	72.3	71.2	69.5	71.5	74.0*	74.0	72.1	72.6	71.4	71.0
31	69.9	69.9	70.0	69.6	69.9	70.0	69.5	69.0*	68.9*	69.3*	68.5*	68.1
Monthly mean	70.4	70.6	70.2	69.7	69.8	70.2	70.6	72.0	73.2	74.0	72.0	69.6
Normal	70.3	70.1	70.2	70.1	69.8	70.3	70.5	72.1	73.6	74.3	72.7	70.4

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0.′794

Increasing scale readings correspond to increasing east declination.

JANUARY, 1885.

Day.	13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
1	66.2	67.3	68.5	69.7	70.3	70.6	70.6	70.7	70.7	70.3	72.1	69.8	69.9
2	67.0	66.6	68.0	70.9	70.5	71.3	75.2*	71.0	71.0	71.0	70.2	69.7	69.9
3	68.1	69.0	69.9	70.5	70.5	70.7	70.7	70.8	70.3	69.7	69.5	69.1	70.2
4	66.8	66.7	67.1	69.1	69.9	70.1	70.1	70.1	69.9	70.1	70.1	69.3	69.8
5	68.7	68.8	69.4	70.3	71.0	70.9	70.8	70.6	70.1	70.3	70.0	68.8	70.4
6	65.8*	65.7	68.2	70.0	70.1	70.4	70.6	70.7	70.4	70.4	70.6	70.6	70.2
7	67.0	67.6	68.0	68.3	68.7	70.1	70.8	70.3	70.2	70.4	70.2	70.4	70.4
8	67.0	65.3*	66.0*	67.7	67.8	68.0	72.9	69.6	70.2	71.0	70.7	71.2	69.9
9	66.9	67.1	69.5	70.0	70.5	71.0	72.0	72.4	71.0	71.6	72.4	69.9	70.6
10	68.8	68.7	67.8	69.7	70.3	71.0	70.9	71.0	69.9	70.9	71.0	71.0	70.3
11	69.1	68.0	68.1	69.2	69.3	71.1	70.1	70.2	70.6	70.2	70.3	70.0	70.1
12	69.9	67.8	67.2	68.7	70.3	70.5	70.6	72.0	70.6	70.1	70.3	70.6	70.4
13	69.7	69.2	69.0	69.3	70.1	70.2	70.4	70.6	70.5	70.6	70.2	69.8	70.4
14	69.3	68.7	68.7	69.1	70.5	70.6	70.7	70.9	70.7	70.3	70.2	70.3	70.6
15	67.3	66.7	68.0	68.9	69.6	69.3	70.7	70.9	70.4	70.3	70.8	70.9	70.5
16	69.1	69.0	68.0	69.0	70.0	70.0	69.8	70.3	69.9	70.7	70.7	70.3	70.6
17	69.4	67.9	69.4	69.8	70.6	70.6	69.8	72.0	70.7	71.0	70.6	70.8	70.8
18	69.8	68.3	68.7	69.2	70.2	70.3	70.8	70.7	71.0	70.6	70.5	70.2	70.8
19	65.0*	66.6	66.0*	68.0	68.5	69.1	69.4	70.3	70.7	70.1	70.3	70.0	69.8
20	69.9	68.2	67.5	68.3	70.1	70.3	70.6	70.6	70.6	70.3	70.2	70.1	70.6
21	65.2*	65.3*	65.5*	68.3	69.9	70.4	70.3	70.5	70.3	70.3	70.4	70.6	69.8
22	64.0*	66.3	69.0	70.3	71.1	71.9	72.3	72.1	72.0	72.0	72.3	71.7	69.8
23	69.3	67.2	69.7	69.8	70.0	70.9	70.9	70.9	71.7	71.9	71.4	71.2	71.2
24	68.0	66.9	67.1	68.2	69.7	70.1	70.2	71.0	71.1	71.0	70.7	71.2	70.9
25	68.5	68.9	69.8	70.2	70.2	70.1	70.3	70.5	70.4	70.3	70.3	70.1	70.6
26	70.0	69.0	69.7	70.1	70.2	70.5	70.9	71.0	71.0	71.0	71.0	70.2	70.9
27	68.1	68.1	67.8	70.1	70.1	70.3	70.2	70.7	70.9	71.1	70.6	70.3	70.6
28	69.1	69.8	70.3	71.1	71.4	71.0	71.0	70.3	70.2	70.4	70.7	70.7	71.1
29	70.0	70.0	69.8	70.3	70.9	70.8	70.9	71.3	70.8	70.3	73.0	74.5*	71.0
30	71.0	70.9*	70.6	70.5	70.6	70.3	70.2	70.2	70.3	70.3	69.7	70.0	71.7
31	68.5	70.0	70.2	70.0	70.3	70.6	70.4	70.5	70.5	70.2	70.3	70.1	69.8
Monthly mean	68.2	67.9	68.5	69.5	70.1	70.4	70.8	70.8	70.6	70.6	70.7	70.4	70.44
Normal	68.6	68.0	68.7	69.5	70.1	70.4	70.7	70.8	70.6	70.6	70.7	70.3	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

FEBRUARY, 1885.

Day.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
1	70.2	70.5	70.5	70.5	70.6	70.7	70.6	70.4*	70.1*	69.3*	67.3*	66.4*
2	70.0	70.2	70.7	71.5	71.2	71.5	71.9	72.0	72.0	71.9	70.7	68.5
3	70.6	70.7	71.6	70.3	73.3	73.2	73.7	74.4	73.7	71.9	70.3	68.0
4	70.1	70.4	71.0	71.4	72.2	73.2	74.1	75.2	72.3	72.0	69.0	68.1
5	70.8	70.3	71.4	70.8	71.5	72.0	74.0	78.0*	76.0	72.0	71.0	69.6
6	69.7	70.0	70.5	71.0	71.0	71.7	72.1	74.0	75.2	73.0	70.8	68.5
7	70.0	70.0	70.1	70.0	70.3	70.2	71.6	72.2	73.6	75.0*	74.6*	72.9*
8	70.7	70.5	71.0	71.0	71.2	71.9	70.4	71.1	72.0	70.0	70.3	68.9
9	70.1	70.6	71.0	70.9	70.8	69.6	69.1*	70.7	72.0	74.0	73.3	72.0*
10	70.3	70.6	67.5*	72.9	81.1*	75.3*	75.1*	71.2	70.3*	70.4	70.5	70.4
11	70.7	70.3	70.3	70.7	71.0	71.2	71.5	72.0	71.9	72.2	71.0	69.2
12	71.7	72.6	72.1	70.3	65.0*	71.7	73.0	73.0	75.7	69.9	69.8	63.6*
13	70.5	71.1	71.7	71.5	72.1	74.1	72.3	71.8	70.9	70.3	70.3	69.6
14	70.9	70.8	71.0	71.2	71.9	71.4	72.5	72.9	72.9	72.0	70.2	68.9
15	70.7	70.9	71.3	71.2	71.8	72.2	74.0	75.8*	75.8	74.1	72.0	69.1
16	71.0	70.7	70.9	70.9	70.8	71.5	72.4	72.3	73.9	73.3	71.4	69.1
17	70.2	72.2	70.9	71.4	73.7	72.1	73.0	74.4	75.0	73.0	70.5	68.0
18	72.3	72.4	70.3	70.6	71.8	72.3	71.5	73.9	75.5	74.5	70.6	67.5
19	70.8	70.8	71.4	70.0	72.0	72.2	73.0	73.3	73.9	73.5	72.2	70.0
20	70.5	70.4	70.5	70.5	70.8	71.0	72.3	73.5	75.6	76.0*	73.3	70.0
21	70.8	70.8	70.6	70.6	70.9	71.1	72.4	73.9	72.0	72.6	72.3	70.4
22	72.4	70.0	72.3	72.5	72.0	72.4	74.2	75.0	74.4	70.5	70.3	69.3
23	[70.6]	[70.5]	[70.6]	[70.8]	[71.3]	[71.7]	[72.2]	73.1	74.6	75.0*	73.1	70.6
24	71.2	70.9	71.2	71.2	71.1	71.1	72.0	72.2	72.2	71.6	70.7	69.0
25†	[71.5]	[71.6]	[71.8]	[72.1]	[72.7]	[73.1]	[73.8]	74.8	75.0	73.3	[71.6]	69.3
26	71.0	71.0	71.0	71.3	71.6	71.8	72.4	74.3	74.8	73.3	72.0	70.2
27	75.7*	72.5	71.9	72.5	70.0	71.5	69.4*	69.8*	71.7	73.1	72.0	70.3
28	70.9	71.5	72.0	71.4	71.6	71.5	72.0	73.9	70.2*	68.0*	67.8*	65.7*
Monthly mean	70.9	70.9	71.0	71.1	71.6	71.9	72.3	73.2	73.3	72.4	71.0	69.0
Normal	70.8	70.9	71.1	71.1	71.5	71.8	72.5	73.1	73.6	72.3	71.1	69.3

† February 25, 10 a. m., trace faded.

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794 Increasing scale readings correspond to increasing east declination.

FEBRUARY, 1885.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
1	66.6	68.4	70.7	71.6	71.6	71.3	70.8	70.7	71.6	70.6	70.3	69.9	70.0
2	68.4	69.8	71.3	71.9	71.2	70.6	70.7	71.0	70.8	70.8	70.4	70.5	70.8
3	67.7	68.4	70.0	70.4	70.6	71.0	71.0	71.0	71.1	70.5	70.5	69.3	71.0
4	68.2	68.3	69.0	70.1	70.3	70.4	70.8	70.9	70.7	70.8	70.5	70.4	70.8
5	66.2	66.3	69.1	68.6	67.7	68.1	70.0	71.0	70.7	70.8	70.0	71.0	70.7
6	67.2	66.9	66.9	67.3	69.0	69.7	70.2	71.0	71.0	70.9	70.3	69.9	70.3
7	71.6*	70.1	69.2	69.0	69.9	70.8	70.4	70.8	71.8	70.7	70.0	70.6	71.1
8	68.6	68.4	68.2	68.3	69.5	70.2	70.2	70.7	70.6	70.5	70.4	70.3	70.2
9	71.3*	71.0*	70.3	70.8	70.8	70.9	71.2	70.7	70.7	70.6	70.6	70.5	71.0
10	70.7*	70.6	71.3	71.0	70.5	70.7	71.1	71.0	70.5	70.6	70.5	70.7	71.4
11	69.5	70.0	69.5	70.1	70.1	70.3	69.4	72.0	73.8*	70.5	69.8	72.0	70.8
12	64.3*	68.2	68.7	70.7	70.2	70.0	70.8	71.1	70.7	70.7	70.7	70.7	70.2
13	69.8	70.1	70.7	71.1	70.0	70.3	70.5	71.0	70.7	70.7	70.8	70.7	70.9
14	68.1	68.9	69.5	70.6	70.8	70.4	71.0	70.8	70.2	70.7	70.6	70.2	70.8
15	66.6	67.7	68.0	69.7	70.1	70.2	70.4	70.5	70.5	70.4	70.6	70.5	71.0
16	66.9	67.3	68.5	68.5	70.1	70.5	70.5	70.9	70.7	70.5	70.5	70.5	70.6
17	67.3	68.0	67.3	69.7	70.3	71.2	70.0	70.5	70.7	70.3	70.0	69.0	70.8
18	67.0	66.9	68.3	70.0	70.8	71.4	71.5	71.6	71.0	71.6	70.6	70.8	71.0
19	68.8	68.7	69.0	70.0	70.6	71.0	71.0	71.4	71.0	71.0	70.8	70.6	71.1
20	67.7	67.0	67.2	68.6	70.0	70.7	70.3	70.7	70.5	70.4	70.2	71.2	70.8
21	69.2	67.5	67.1	68.2	68.2	68.4	70.3	71.2	71.7	74.5*	72.1	73.6*	70.8
22	67.3	67.0	67.8	68.2	70.0	70.2	70.1	[70.2]	[70.3]	[70.2]	[70.1]	[70.3]	[70.7]
23	69.1	69.0	69.2	69.6	70.1	70.6	71.1	71.2	71.2	71.4	71.1	71.2	[71.2]
24	66.5	68.1	[68.9]	[69.8]	70.6	70.2	70.3	70.9	70.6	[70.7]	[70.7]	[71.1]	[70.5]
25	68.2	68.8	69.3	69.8	70.0	70.2	70.4	70.7	70.7	70.7	70.8	70.7	[71.3]
26	68.4	68.1	68.7	69.2	70.0	70.5	70.8	70.3	70.0	69.5	71.3	74.5*	71.1
27	68.0	68.0	68.4	69.1	70.3	70.6	70.9	70.7	70.7	70.6	70.5	70.9	70.8
28	66.0	66.4	67.0	67.9	70.0	68.8	77.0*	70.3	70.5	70.1	72.0	70.5	70.1
Monthly mean	68.0	68.4	68.9	69.6	70.1	70.3	70.8	70.9	71.0	70.8	70.6	70.8	70.88
Normal	67.8	68.3	68.9	69.6	70.1	70.3	70.6	70.9	70.9	70.6	70.6	70.5	. .

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

MARCH, 1885.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	68.5	73.6	72.1	72.3	70.5	72.0	73.1	74.6	75.1	73.8	72.0	69.2
2	74.0*	70.6	72.9	71.6	72.2	73.0	73.6	74.4	75.1	74.8	72.5	70.0
3	72.0	72.3	71.9	71.4	72.3	72.4	73.8	74.0	72.9*	74.3	71.1	69.3
4	70.6	70.9	71.5	71.7	71.4	72.3	73.3	76.0	77.6	76.5	74.7	71.6
5	70.8	70.8	70.9	71.1	71.5	71.8	72.9	76.0	76.2	76.0	73.8	70.7
6	70.9	71.1	71.2	71.6	72.0	72.2	74.3	75.7	76.0	75.4	72.7	69.5
7	70.3	70.5	70.3	69.3	71.0	71.0	72.6	74.5	78.1	77.3	74.2	71.4
8	70.7	70.7	71.6	71.2	71.2	71.8	73.1	75.8	76.6	75.4	73.8	71.7
9	70.9	70.9	70.8	70.8	70.9	71.5	72.7	74.7	77.0	77.1	74.8	70.8
10	70.3	70.5	70.8	70.8	70.7	70.6	72.7	75.2	75.1	74.3	72.4	70.0
11	70.6	70.6	70.8	71.0	71.2	71.9	74.4	76.7	77.2	74.1	70.7	68.0
12	72.3	70.8	75.0*	73.3	74.0*	73.7	74.7	75.8	75.8	73.9	72.5	70.6
13	71.7	71.8	72.5	72.3	73.4	74.3	74.3	73.5	74.1	74.5	71.7	70.4
14	71.0	70.7	70.4	70.7	70.6	71.9	72.8	74.8	71.6*	75.4	75.3	73.7*
15	70.5	74.8*	74.0*	70.7	65.2*	67.4*	66.0*	71.0*	68.3*	66.2*	68.0*	65.1*
16	72.7	73.7	72.4	72.1	72.2	72.2	74.0	73.7	73.9	74.8	74.8	72.7
17	71.4	70.7	70.7	70.6	70.9	71.4	72.5	75.4	75.1	73.6	71.4	68.6
18	70.3	70.3	70.6	70.8	71.2	72.0	72.8	74.5	75.9	75.0	71.9	69.2
19	70.2	70.3	70.6	70.6	71.4	72.1	74.4	76.6	78.2	77.4	73.6	70.1
20	71.2	72.6	71.7	70.8	72.9	72.7	75.2	76.2	80.4*	75.8	73.7	70.0
21	70.6	70.6	70.2	70.5	71.4	71.6	72.1	75.0	74.6	73.3	71.8	70.3
22	71.1	71.2	70.3	71.6	71.0	70.7	71.7	74.3	75.0	74.4	72.6	70.4
23	70.9	71.9	71.5	72.1	72.2	72.7	74.0	77.0	73.4*	73.3	72.4	70.3
24	70.6	70.6	70.7	70.6	70.8	71.7	72.8	74.6	75.8	74.7	73.3	71.3
25	70.6	70.7	70.7	70.8	70.8	71.5	72.7	75.4	76.7	76.9	74.7	71.2
26	70.8	70.8	70.7	70.6	70.4	70.7	72.3	74.8	76.5	76.6	73.4	70.5
27	70.9	70.5	70.5	70.3	70.6	70.9	73.0	75.6	75.6	76.8	74.7	71.8
28	72.0	72.4	71.7	73.0	71.9	72.1	73.9	77.2	76.2	74.4	71.6	69.2
29	70.7	70.6	70.7	70.7	71.1	71.5	72.8	76.1	78.0	77.2	73.7	70.4
30	70.5	70.5	70.6	70.7	71.0	71.3	73.4	75.5	76.7	74.2	70.6	67.8
31	71.2	71.4	72.0	71.5	72.5	73.0	74.2	76.0	78.0	76.0	72.1	69.3
Monthly mean	71.0	71.3	71.4	71.2	71.3	71.8	73.1	75.2	75.7	75.0	72.8	70.2
Normal	70.9	71.2	71.1	71.2	71.4	72.0	73.3	75.3	76.2	75.2	73.0	70.2

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794

Increasing scale readings correspond to increasing east declination.

MARCH, 1885.

Day.	13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
1	66.8	67.2	67.8	68.9	68.5	70.5	70.7	70.3	70.7	71.4	72.2	72.9	71.0
2	68.2	67.4	67.6	69.7	69.9	70.3	70.3	70.4	70.7	71.2	70.8	70.7	71.3
3	67.5	64.9	66.3	68.1	70.2	70.7	70.7	71.8	71.1	70.8	70.7	70.5	70.9
4	69.7	68.1	67.2	68.0	69.8	70.7	70.8	70.8	70.7	71.0	70.7	70.7	71.5
5	67.0	65.7	65.7	67.6	68.7	70.0	70.7	71.5	70.9	70.8	70.8	70.7	70.9
6	65.7	64.4	66.0	68.0	69.8	70.3	70.3	70.4	70.5	70.5	71.4	70.8	70.9
7	68.6	67.0	66.6	67.6	68.7	70.1	70.4	70.5	70.7	70.8	70.6	70.5	70.9
8	69.1	68.0	68.1	68.8	70.1	70.3	70.7	70.7	70.8	70.8	71.0	70.8	71.4
9	67.6	66.4	66.4	67.5	69.0	70.0	70.6	70.6	70.6	70.6	70.5	70.7	71.0
10	68.2	67.5	67.7	69.0	70.2	70.4	70.6	70.9	70.7	70.5	70.6	70.6	70.8
11	66.1	65.6	66.6	68.8	70.6	70.7	70.7	70.9	70.8	71.0	71.5	72.4	71.0
12	69.3	68.1	69.5	69.5	70.3	70.4	70.6	70.6	70.7	70.8	70.9	70.8	71.8
13	68.5	66.6	67.4	67.8	69.2	70.3	71.3	71.0	70.4	71.1	71.5	71.2	71.3
14	71.3*	70.3*	68.2	68.5	69.1	69.1	70.3	69.8	70.8	71.9	74.3*	71.6	71.4
15	66.4	66.4	65.0	69.5	66.0*	69.8	75.0*	69.0	68.5	71.8	72.0	72.3	69.1
16	70.3	69.1	68.7	69.1	70.2	70.1	70.5	71.4	70.2	71.3	71.0	68.0*	71.6
17	67.0	67.5	68.1	68.6	69.4	69.9	69.8	70.3	70.0	71.1	71.1	70.8	70.7
18	67.1	66.2	66.8	68.5	69.8	70.3	70.5	70.3	70.4	70.5	70.6	70.2	70.6
19	67.2	65.3	65.4	67.2	68.2	70.6	70.4	70.4	70.6	70.6	71.0	71.8	71.0
20	67.2	65.2	64.9	66.4	67.3	67.3*	70.0	70.1	72.1	74.3*	71.7	72.4	71.3
21	67.3	66.0	65.2	66.9	69.0	71.4	71.5	70.9	71.0	71.2	71.4	71.4	70.6
22	68.5	67.0	66.3	67.4	69.2	70.1	70.5	70.9	70.8	70.8	70.8	70.8	70.7
23	68.6	67.8	68.0	69.9	70.3	70.3	70.4	70.6	70.5	70.6	70.7	70.6	71.2
24	69.3	68.3	67.2	67.8	69.0	69.9	70.1	70.3	70.3	70.4	70.4	70.4	70.9
25	69.6	68.4	67.5	67.8	69.0	69.8	70.0	70.3	70.4	70.7	70.6	70.7	71.2
26	68.6	67.7	67.4	68.3	69.3	69.4	70.3	70.1	70.3	70.2	70.7	70.7	70.9
27	69.5	68.2	67.9	68.1	69.2	70.4	70.5	70.6	70.9	70.7	70.6	70.9	71.2
28	67.5	67.3	67.4	68.5	69.1	70.6	70.9	70.8	70.7	70.8	70.8	70.7	71.3
29	67.2	66.1	67.0	68.1	69.2	69.6	70.2	70.4	70.4	70.5	70.3	70.5	71.0
30	65.3*	64.2*	65.1	66.3	68.7	70.1	70.2	72.1	71.5	71.7	71.2	71.1	70.4
31	67.6	67.2	66.6	67.1	68.2	69.3	69.6	69.6	71.1	77.6	72.0	71.0	71.4
Monthly mean	68.0	66.9	67.0	68.2	69.2	70.1	70.6	70.6	70.6	71.2	71.1	70.9	71.01
Normal	68.0	66.9	67.0	68.2	69.3	70.2	70.5	70.6	70.6	71.1	71.0	71.0	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

APRIL, 1885.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	71.3	73.2	70.6	71.6	72.2	73.4	74.4	75.0	77.0	71.4	69.1	68.7
2	71.3	71.4	71.9	72.3	72.0	72.1	74.8	76.6	76.2	74.0	72.2	70.7
3	70.4	71.2	70.3	71.5	70.7	70.0*	71.1*	75.1	73.1	71.9	70.2	69.0
4	70.2	70.6	71.0	70.5	70.9	72.0	72.8	76.0	78.1*	77.8*	74.8*	72.0*
5	70.5	70.5	70.7	70.7	71.3	72.0	74.4	78.0	78.9*	76.1*	71.8	68.4
6	70.8	70.8	71.5	71.5	71.3	72.2	74.2	77.0	78.6*	76.5*	72.7	68.7
7	72.0	70.0	[70.2]	[70.7]	[71.2]	[72.5]	[74.3]	75.8	76.1	74.7	71.0	68.8
8	71.4	73.6	71.3	72.3	69.4*	74.4	74.5	75.3	73.5	71.5	68.8	69.7
9	73.0	72.1	71.5	72.1	72.1	72.8	75.0	76.6	76.0	72.5	69.7	69.0
10	70.7	71.0	70.9	72.2	72.0	72.7	72.9	72.8*	74.6	72.7	70.6	69.5
11	71.2	71.6	71.3	71.3	71.0	72.6	73.6	76.5	75.4	74.0	70.5	68.4
12	73.2	71.8	71.9	70.2	71.4	73.4	75.8	77.5	76.5	74.3	71.8	70.8
13	74.5*	77.7*	76.5*	76.1*	75.3*	75.0	77.9*	75.0	72.5*	68.4*	66.0*	64.9*
14	72.2	72.1	72.6	73.0	73.0	74.5	75.4	77.2	76.8	74.4	71.7	70.6
15	72.0	72.7	71.6	72.0	71.7	74.0	76.7	78.3	75.5	73.5	69.7	68.5
16	72.1	73.3	72.0	74.0	74.4	75.7	78.0*	77.5	75.0	71.8	68.7	66.8
17	70.7	71.2	71.2	71.8	72.1	73.2	74.0	75.2	75.2	72.4	71.0	70.5
18	73.0	72.2	72.0	72.1	71.0	74.0	75.3	74.5	73.3	72.2	70.7	70.0
19	70.9	71.5	72.7	74.2	72.7	74.2	73.0	75.3	74.7	71.3	68.4	70.4
20	71.1	72.2	73.3	72.0	73.2	72.5	76.3	79.1*	77.0	74.2	71.1	70.7
21	70.9	71.8	73.1	73.0	72.0	73.8	75.1	75.0	74.2	73.0	71.0	70.8
22	71.0	71.1	71.5	71.3	71.4	71.7	72.5*	75.3	76.6	76.3*	74.4*	73.4*
23	71.8	71.9	72.3	72.3	73.0	74.2	76.3	76.7	74.2	69.3*	66.5*	66.0*
24	71.5	71.8	72.0	72.1	72.9	74.7	77.0	76.0	76.4	70.6	70.3	70.5
25	71.8	72.3	72.2	72.4	73.3	75.0	77.2	79.6*	78.6*	74.9	71.3	69.8
26	71.0	71.3	72.1	72.2	73.3	75.4	77.0	75.8	75.3	72.2	69.1	69.2
27	72.2	73.2	73.9	74.3	74.8	75.2	76.0	74.7	73.0	71.7	69.4	68.4
28	79.3*	77.6*	78.3*	77.0*	79.9*	74.9	74.6	75.0	74.8	69.7*	66.3*	67.2
29	72.1	72.2	72.1	72.6	74.0	74.6	76.9	79.3*	78.3*	74.3	70.6	68.3
30	71.4	71.6	72.0	71.9	73.9	75.3	78.6*	79.0*	77.1	72.1	69.4	67.9
Monthly mean	71.8	72.2	72.2	72.4	72.6	73.6	75.2	76.4	75.8	73.0	70.3	69.2
Normal	71.5	71.8	71.8	72.1	72.3	73.7	75.1	76.0	75.3	72.8	70.4	69.3

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794

Increasing scale readings correspond to increasing east declination.

APRIL, 1885.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
1	67.1	67.4	67.8	69.2	70.9	71.1	70.8	71.2	72.0	71.4	70.9	70.9	71.2
2	69.2	68.1	67.7	68.2	69.7	72.7	73.2	70.7	70.8	70.8	70.2	69.2	71.5
3	67.9	67.8	68.2	69.4	70.3	70.7	70.8	70.8	70.6	70.6	70.4	70.3	70.5
4	69.0	67.2	66.3	67.8	69.3	70.7	70.7	70.6	70.6	70.7	70.9	70.6	71.3
5	65.3*	64.5*	65.5	68.3	70.4	70.6	71.0	70.7	70.7	70.7	70.7	70.7	70.9
6	66.0	65.0*	65.8	67.0	68.0	69.7	69.6	70.0	69.5	69.8	70.7	73.1	70.8
7	66.6	65.5	66.1	66.9	66.5*	68.9	69.9	70.7	69.0	72.5	70.6	73.5	[70.6]
8	69.0	68.3	68.5	68.5	69.7	70.0	70.6	70.3	70.4	70.6	70.6	71.7	71.0
9	68.1	67.4	67.5	67.6	68.2	70.0	70.4	70.4	70.6	72.0	70.6	70.6	71.1
10	68.0	67.0	66.8	68.3	70.7	70.4	70.6	70.7	71.0	70.7	70.8	71.0	70.8
11	66.8	66.7	66.8	68.5	70.4	71.4	71.0	70.7	70.7	70.8	70.7	73.4	71.0
12	69.3	69.1	69.4	71.0	70.8	71.2	70.8	70.7	71.4	72.4	73.7	74.8*	72.2
13	66.0	66.9	68.1	70.6	71.5	71.5	70.9	70.5	71.0	70.9	71.6	72.0	71.7
14	68.5	67.9	67.9	67.9	69.2	70.2	70.0	70.0	70.7	71.4	72.6	72.8	71.8
15	66.4	65.4	64.0*	68.4	70.4	71.0	70.9	71.6	71.4	70.9	71.0	71.7	71.2
16	66.5	67.2	68.7	70.2	71.0	71.0	70.8	70.9	74.2*	72.0	71.7	70.3	71.8
17	69.8	69.3	69.3	70.3	70.6	70.7	70.7	70.7	70.6	70.7	70.7	71.0	71.4
18	68.4	67.7	68.2	69.1	70.3	70.9	71.2	71.0	70.5	70.3	70.6	70.5	71.2
19	70.4	70.0	69.8	69.7	70.6	71.5	71.6	71.1	72.0	72.4	71.0	70.9	71.7
20	69.4	67.4	67.4	67.9	68.2	69.7	73.4	70.9	70.7	71.1	71.8	71.2	71.7
21	70.0	68.6	67.9	67.8	69.0	70.2	70.4	70.6	70.8	71.0	70.9	71.0	71.3
22	72.4*	71.4*	70.3	70.4	70.3	71.0	71.9	71.4	72.2	71.6	71.8	72.0	72.2
23	66.3	67.0	68.1	69.1	70.3	70.3	70.4	70.7	70.7	70.8	71.6	72.1	70.9
24	70.3	69.9	69.5	69.9	71.0	71.0	71.3	72.0	71.0	70.9	71.8	71.6	71.9
25	68.9	67.6	67.9	69.2	70.0	70.4	71.0	71.1	71.1	71.0	71.3	70.8	72.0
26	69.4	68.3	68.3	68.4	70.1	70.5	71.2	74.0*	74.8*	73.3	73.3	74.0	72.1
27	69.0	69.8	70.0	70.7	70.7	70.2	72.4	72.4	71.0	71.3	71.2	72.3	72.0
28	69.0	69.7	70.3	70.8	72.0	72.5	72.4	72.2	71.6	71.9	72.0	72.8	73.0
29	67.1	66.6	67.0	68.1	70.1	71.0	71.0	71.0	71.1	71.1	71.8	72.1	71.8
30	68.3	68.0	68.0	69.3	70.0	70.9	71.3	71.0	70.8	71.1	71.3	71.4	71.7
Monthly mean	68.3	67.8	67.9	69.0	70.0	70.7	71.1	71.0	71.1	71.2	71.3	71.7	71.48
Normal	68.2	67.8	68.0	69.0	70.1	70.7	71.1	70.9	70.9	71.2	71.3	71.6	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

MAY, 1885.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	71.3	71.0	72.0	72.0	72.2	74.0	76.6	77.1	76.1	72.7	68.6	68.4
2	73.0	72.0	72.5	74.2	74.3	76.7	78.0	78.9	75.5	71.0	68.3	68.1
3	71.7	71.7	72.1	72.2	73.6	76.2	79.0	79.5	76.3	71.9	70.2	69.4
4	71.0	70.9	71.6	72.7	73.5	76.4	79.8	81.5*	78.1	72.8	67.0*	64.7*
5	71.5	71.3	72.1	72.5	73.0	74.6	77.5	79.8	76.5	73.0	68.6	67.8
6	71.2	71.3	72.1	72.8	74.3	75.1	76.3	77.5	76.7	72.9	68.0	68.0
7	72.7	72.4	73.5	73.8	74.5	76.9	78.5	76.3	74.0	70.8	69.1	68.4
8	72.6	73.0	74.8*	75.2	75.0	77.0	77.4	77.0	73.9	71.1	67.9	68.0
9	70.6	70.9	72.1	71.7	72.4	73.6	75.5	75.7*	74.8	71.7	69.0	68.8
10	72.3	73.5	76.9*	76.8*	75.4	78.9*	79.9	74.1*	74.2	72.8	70.6	68.7
11	78.2*	77.0*	78.1*	78.8*	75.6	74.9	74.0*	73.9*	72.3*	70.4	67.8	68.3
12	74.1*	72.5	70.0	72.0	73.3	75.3	76.7	78.1	75.3	72.2	70.4	69.7
13	70.8	70.5	72.5	73.5	74.2	76.7	78.3	80.2	78.1	73.5	69.7	67.0
14	70.0	70.3	71.3	70.8	70.8*	74.2	76.9	78.6	76.9	72.6	69.4	68.2
15	71.3	72.0	72.2	72.9	74.3	76.5	78.4	79.0	76.5	73.5	72.0	69.9
16	71.0	68.2*	72.3	74.0	76.0	77.2	78.2	77.0	74.2	69.6*	66.4*	66.2
17	70.3	70.8	72.2	73.7	74.7	77.1	78.0	78.1	77.2	74.0	71.3	68.7
18	71.0	71.4	71.8	72.7	73.0	76.0	78.3	79.2	76.8	73.7	71.0	69.7
19	72.0	71.7	72.2	72.4	73.1	74.7	76.4	77.2	76.6	74.2	71.7	70.8
20	71.4	71.4	71.8	72.5	74.0	75.9	77.8	80.5	77.0	73.9	70.4	70.3
21	71.7	71.7	71.7	72.0	72.5	74.0	76.0	75.5*	75.0	72.2	69.4	68.1
22	71.8	72.0	71.7	72.3	73.0	75.6	78.3	79.6	78.5	74.2	70.8	68.8
23	70.7	70.8	72.2	73.2	74.7	76.8	78.9	79.2	80.0*	76.0*	70.8	68.1
24	72.2	73.0	75.0*	76.3*	77.3*	79.2*	79.3	80.3	76.9	72.3	69.6	68.2
25	71.7	72.1	72.3	72.7	73.5	75.0	77.1	81.3*	76.3	73.3	71.5	68.2
26	76.6*	74.3*	72.2	74.0	76.7*	77.5	82.0*	79.4	77.2	73.9	70.3	70.0
27	72.2	73.7	64.0*	69.4*	73.2	72.1*	78.2	80.0	78.3	75.0	73.3*	69.8
28	66.8*	66.3*	71.8	71.5	72.2	77.0	81.1*	79.9	79.3*	76.0*	70.7	69.2
29	70.1	72.1	72.4	73.3	73.1	72.8*	77.0	78.2	77.8	74.1	71.0	68.6
30	70.7	70.7	70.7	69.4*	72.3	74.3	74.9*	73.0*	74.0	70.9	69.4	68.6
31	70.7	70.7	70.5	71.2	72.5	73.2	73.8*	76.7	77.0	73.8	70.7	68.6
Monthly mean	71.7	71.6	72.2	73.0	73.8	75.7	77.7	78.1	76.4	72.9	69.8	68.6
Normal	71.4	71.7	71.9	72.8	73.7	75.6	77.8	78.6	76.3	72.8	69.9	68.7

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794

Increasing scale readings correspond to increasing east declination.

MAY, 1885.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
1	67.9	67.5	67.9	69.3	70.1	70.7	70.7	70.7	70.7	70.9	74.2*	72.4	71.5
2	68.1	67.5	69.0	70.8	70.5	70.9	71.1	71.2	70.8	70.9	71.1	71.3	71.9
3	70.2	68.7	68.4	68.7	69.8	70.2	70.5	70.2	70.2	71.0	72.3	70.9	71.9
4	65.3*	66.7	67.9	68.8	69.8	69.5	70.4	70.4	71.2	72.1	71.3	72.2	71.5
5	68.3	68.3	68.9	69.3	70.7	75.8*	73.6	71.6	71.8	71.4	71.3	71.0	72.1
6	68.3	68.4	68.5	69.2	70.6	70.8	72.0	71.6	71.5	71.7	72.2	72.3	71.8
7	68.6	68.9	68.7	69.5	70.3	70.5	70.7	70.7	70.8	71.2	71.6	72.4	71.9
8	68.2	68.8	69.7	69.8	69.9	69.9	70.2	70.2	70.3	71.1	70.8	70.7	71.8
9	70.1	70.5	71.2	71.0	70.7	70.7	70.2	69.7	69.6	70.0	70.0	70.9	71.3
10	69.1	67.7	68.9	69.3	70.1	70.7	70.2	70.3	70.8	70.7	71.6	73.4	72.4
11	70.1	70.8	71.2	71.1	71.6	70.5	71.0	74.3*	73.0	72.2	77.0*	72.3	73.1
12	69.3	69.0	69.4	69.0	70.0	70.3	70.3	70.3	70.3	70.3	70.4	70.7	71.6
13	65.3*	64.8*	64.5*	65.0*	68.3	71.4	69.8	69.2	70.8	70.8	72.2	69.7	71.1
14	68.3	69.3	70.7	71.9	72.5	72.2	71.7	71.0	71.3	70.8	70.9	71.0	71.7
15	68.8	69.3	69.4	69.3	71.4	72.9	72.3	71.5	72.1	72.1	72.1	72.0	72.6
16	67.9	69.4	70.8	71.3	74.3*	71.6	70.8	71.4	70.8	70.9	70.3	71.0	71.7
17	68.0	67.1	67.7	69.2	71.0	72.0	72.3	70.7	73.1	75.1*	72.3	72.7	72.4
18	70.3	68.8	69.2	70.1	71.0	72.0	72.3	71.8	71.3	71.6	72.4	71.5	72.4
19	69.8	69.7	69.0	69.3	70.3	71.1	71.3	71.7	72.3	72.1	71.7	71.1	72.2
20	69.7	69.7	69.2	69.6	70.7	70.8	71.7	71.2	70.7	71.0	71.3	71.8	72.3
21	67.7	66.7	67.4	68.4	70.0	71.2	71.7	71.5	71.0	70.8	71.3	71.3	71.2
22	67.3	67.7	69.0	70.4	71.6	71.6	70.5	70.3	70.1	70.2	70.1	71.0	71.9
23	69.0	69.1	69.7	70.0	71.1	72.2	71.2	70.7	71.3	71.4	72.0	72.1	72.6
24	68.1	67.8	68.1	69.2	70.3	70.7	70.9	70.3	70.7	71.0	72.2	71.3	72.5
25	66.0*	67.5	68.4	69.2	70.1	70.3	71.5	75.2*	84.9*	80.8*	82.7*	69.5	73.4
26	69.7	71.0*	71.9*	72.6*	73.2	75.4*	84.4*	84.6*	86.8*	79.5*	76.9*	73.9	76.0
27	67.5	66.0	66.8	69.9	73.2	79.0*	71.9	76.8*	85.3*	76.3*	79.4*	72.2	73.5
28	69.8	69.4	70.2	70.4	70.7	72.1	73.8	73.4	73.0	72.8	72.4	71.3	72.6
29	68.1	68.7	69.0	68.3	69.3	71.6	72.3	70.5	70.7	72.3	72.2	70.2	71.8
30	67.8	67.0	69.3	69.9	72.0	72.3	71.9	71.7	70.7	70.8	70.5	70.7	71.0
31	67.8	67.3	68.2	69.7	70.6	71.0	71.6	71.0	70.8	71.3	70.7	71.6	71.3
Monthly mean	68.4	68.4	69.0	69.7	70.8	71.7	71.8	71.8	72.5	72.1	72.5	71.5	72.15
Normal	68.7	68.4	69.0	69.7	70.7	71.1	71.3	70.9	71.1	71.2	71.4	71.5	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

JUNE, 1885.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	70.7	71.7	72.5	72.3	73.3	75.0	77.2	77.0	74.5	72.3	68.9	67.8
2	71.5	71.7	71.7	73.0	73.4	73.8	73.0*	75.4*	74.8	71.2*	66.6*	66.2
3	71.7	71.9	71.7	72.5	73.7	75.6	77.3	77.0	76.7	74.3	70.6	69.3
4	71.7	70.7	71.3	73.2	72.3	73.6	74.0*	74.0*	71.1*	68.8*	66.1*	64.8*
5	71.4	71.7	72.2	71.4	71.6	72.1*	73.6*	72.8*	72.6*	70.3*	68.9	68.1
6	71.3	71.3	71.6	71.7	72.9	75.2	77.2	78.0	76.7	73.8	72.1	70.7
7	71.7	71.5	72.1	72.3	73.2	73.7	74.7*	75.1*	73.7	72.2	70.6	68.2
8	71.9	71.7	71.3	72.2	73.1	75.0	77.3	77.3	73.9	70.3*	67.3*	66.8
9	71.1	71.5	71.3	72.7	73.4	75.1	78.3	78.0	77.8	75.0	71.4	69.4
10	71.6	72.2	73.6	72.6	73.6	76.0	79.6	81.2*	79.0*	75.7	72.2	67.8
11	71.1	70.7	71.2	71.3	75.8	75.8	78.5	78.6	76.4	74.0	71.2	70.1
12	72.2	70.6	72.6	72.0	73.5	75.6	77.3	78.0	75.3	73.0	69.9	68.7
13	72.2	72.2	73.2	72.4	75.1	76.0	78.0	77.7	75.7	[72.8]	[69.3]	[67.2]
14	[70.0]	[70.0]	[70.4]	[70.7]	[71.7]	[73.2]	[75.1*]	[75.6]	[74.2]	71.4*	66.5*	64.1*
15	71.1	71.5	72.3	72.6	73.7	77.4	79.4	81.0*	81.4*	77.2*	72.6	68.7
16	71.1	70.7	70.7	71.7	72.5	74.6	76.0	77.5	78.3	74.9	70.3	68.5*
17	72.0	71.7	72.3	72.8	73.6	75.0	76.7	79.3	79.3*	75.8	69.7	66.1
18	71.4	71.5	71.5	71.9	73.3	76.3	79.9	80.5	79.7*	75.8	71.6	67.3
19	72.0	72.0	72.6	74.0	74.1	76.8	77.0	76.8	74.9	70.8*	69.7	68.1
20	74.6*	75.2*	76.5*	76.6*	76.9*	74.0	77.0	78.0	76.0	71.3*	67.4*	65.8*
21	72.2	72.3	72.7	73.1	74.3	75.8	77.3	78.4	76.7	75.0	70.8	68.8
22	75.5*	73.9	75.8*	73.7	74.9	76.0	77.3	77.0	74.5	72.8	70.6	67.2
23	72.7	71.3	71.4	71.9	72.8	74.5	76.2	76.1	76.2	74.1	70.8	69.0
24	72.0	72.1	72.1	72.7	74.1	77.4	79.4	80.2	79.0*	75.2	71.0	68.6
25	73.8	76.5*	76.6*	74.6	77.7*	78.5*	81.0*	79.8	79.2*	78.1*	72.3	71.0
26	70.8	70.3	70.2	71.3	73.8	75.8	77.7	79.0	77.2	75.1	71.2	68.4
27	72.0	72.1	72.7	73.0	73.1	74.9	76.5	77.0	76.1	74.4	72.7	70.7
28	71.3	71.7	72.2	72.8	73.5	75.9	78.3	79.0	76.5	74.0	71.2	70.1
29	71.2	71.1	71.9	72.3	73.4	75.1	79.6	82.4*	81.9*	77.9*	73.0	70.1
30	71.6	71.8	72.3	72.7	73.7	76.3	79.7	81.1*	80.0*	76.1	72.2	69.1
Monthly mean	71.8	71.8	72.3	72.6	73.7	75.3	77.3	78.0	76.6	73.8	70.3	68.2
Normal	71.6	71.6	71.9	72.5	73.5	75.3	77.8	78.0	75.8	74.3	71.0	68.6

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794

Increasing scale readings correspond to increasing east declination.

JUNE, 1885.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
1	67.3	67.4	68.0	68.0	69.3	70.0	70.7	70.7	70.9	71.1	71.8	71.3	71.2
2	65.9	66.7	67.4	69.7	70.5	71.0	71.3	70.8	70.9	71.1	71.3	71.7	70.9
3	67.9	67.5	67.3	67.6	68.9	69.4	69.5	69.1	70.7	70.4	70.0	72.3	71.4
4	65.9	67.0	68.0	69.0	71.0	71.5	71.0	70.7	70.7	72.0	71.4	71.3	70.5
5	67.2	67.4	67.7	69.3	70.2	71.2	71.0	71.3	71.0	70.9	71.5	71.2	70.7
6	68.6	68.3	68.6	69.0	70.0	70.5	70.8	70.7	71.0	72.0	71.2	71.8	71.9
7	67.5	67.3	67.3	68.3	69.7	70.7	71.1	71.3	72.2	72.0	72.0	71.8	71.3
8	66.6	67.2	68.7	70.0	71.4	71.9	71.7	71.7	71.5	71.2	70.7	70.8	71.3
9	67.3	66.3	67.6	68.8	69.8	70.5	71.6	70.9	70.7	71.8	72.2	72.2	71.9
10	66.2	66.8	68.1	69.3	71.4	74.3*	73.3	70.9	70.6	72.0	72.3	71.5	72.6
11	69.6	69.6	70.1	70.9	70.6	71.0	71.3	72.3	73.2	74.3*	73.3	72.0	72.6
12	68.5	68.5	69.7	70.7	71.7	72.3	71.7	71.0	70.8	70.7	71.0	71.2	71.9
13	[65.9]	[65.9]	[66.5]	[67.7]	[69.1]	[70.2]	[70.1]	[69.5]	[69.6]	[70.0]	[70.0]	[70.0]	[71.1]
14	63.2*	64.5*	66.6	69.4	70.7	72.3	72.2	72.3	71.9	72.2	71.2	72.1	[70.5]
15	66.1	65.0	65.3*	69.4	72.5	73.5	74.3*	71.2	70.7	72.6	72.1	71.8	72.6
16	67.7	67.7	68.2	69.3	71.0	71.6	71.5	71.4	72.8	72.8	73.5	72.6	72.0
17	64.9	65.5	68.6	69.8	70.8	71.7	71.3	71.0	70.8	70.9	71.4	71.5	71.8
18	65.3	64.5*	65.6	66.5*	69.2	70.9	71.0	70.8	70.7	72.0	71.9	72.4	71.7
19	68.2	67.5	68.1	69.2	70.6	71.4	71.4	71.0	70.8	71.7	74.2*	75.9*	72.0
20	66.0	68.8	69.9	70.9	72.7	73.6	72.7	72.2	71.8	71.4	72.0	72.2	72.6
21	68.2	66.8	66.9	68.3	69.1	68.6*	69.2	69.8	70.2	71.7	72.5	72.5	71.7
22	64.4*	64.2*	66.0	68.0	70.0	72.1	72.3	71.4	71.4	71.6	72.0	71.7	71.8
23	67.2	66.8	67.2	68.7	70.3	71.9	72.0	71.4	71.6	71.7	72.3	72.2	71.7
24	66.6	65.7	61.5*	62.0*	66.5*	74.4*	68.7*	70.0	70.7	71.6	69.2	70.7	71.3
25	67.7	71.2*	70.8*	70.3	71.0	72.2	77.2*	72.8	72.9	74.1	74.9*	73.3	74.5
26	67.8	69.5	70.3	71.2	72.3	72.3	71.7	71.6	70.8	71.2	72.0	71.8	72.2
27	69.7	68.7	69.0	69.9	70.2	71.3	72.1	71.1	70.7	72.0	70.8	70.8	72.2
28	67.6	66.0	66.4	70.0	71.9	72.3	71.4	70.8	70.8	70.7	70.7	71.0	71.9
29	68.1	68.0	69.0	69.0	69.8	71.9	71.9	70.9	70.7	70.7	70.8	71.2	72.6
30	67.3	66.1	67.8	68.7	70.3	71.5	71.3	71.1	70.9	70.9	70.9	71.0	72.3
Monthly mean	67.0	67.1	67.7	69.0	70.4	71.6	71.6	71.1	71.1	71.6	71.7	71.8	71.82
Normal	67.2	67.2	67.9	69.4	70.6	71.5	71.4	71.1	71.1	71.6	71.5	71.7	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

JULY, 1885.

Day.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
1	71.1	71.6	73.0	75.3	77.7*	77.7	83.6*	85.5*	78.0	75.2	69.3	66.0
2	72.5	72.5	72.7	73.7	74.4	76.1	78.7	80.7	81.4*	75.2	71.6	70.7*
3	72.3	72.9	72.9	73.2	73.7	75.4	79.2	80.9	81.1*	76.5*	70.1	66.3
4	71.1	72.0	72.9	73.8	75.3	76.0	78.3	82.0	80.1	76.9*	72.3	69.3
5	72.6	72.5	72.6	72.5	74.3	76.0	78.2	77.8	74.5*	72.0	68.8	67.7
6	71.9	73.2	72.2	72.3	74.0	76.0	77.8	79.1	78.3	75.1	71.9	70.4*
7	72.5	72.5	71.8	72.5	73.9	75.3	77.5	77.6	77.3	75.3	72.5*	69.3
8	72.2	73.0	71.9	72.3	72.7	75.1	77.2	77.1	75.7	73.5	70.3	66.3
9	71.4	72.1	72.2	73.1	73.0	76.3	79.6	79.1	78.0	73.0	69.4	67.3
10	72.3	72.2	72.3	72.3	73.7	74.6	77.9	78.9	75.4*	73.7	71.2	68.0
11	71.9	71.6	69.0*	74.1	75.9	79.9*	81.2	84.8*	81.5*	74.4	68.3	64.2*
12	72.2	72.2	72.7	74.1	74.3	76.7	78.6	79.2	78.1	73.9	71.1	68.6
13	70.8	71.3	72.2	72.9	74.0	76.1	76.3	80.0	78.8	73.7	70.1	67.7
14	71.2	71.7	72.2	72.7	74.0	75.7	77.7	78.0	75.7	71.7	66.8*	64.3*
15	71.3	71.6	72.1	72.2	74.3	75.8	79.8	80.6	79.3	75.3	71.4	69.1
16	72.0	71.8	72.3	72.8	74.0	76.7	79.3	79.7	77.0	72.4	67.7	67.3
17	71.8	72.2	72.6	73.0	74.3	76.1	79.1	80.4	79.4	76.2	72.1	70.0
18	72.5	72.3	73.4	70.3*	75.0	74.7	75.7*	76.0	75.0*	73.0	69.2	66.5
19	72.3	71.7	75.4*	73.3	75.0	76.4	79.6	81.4	80.0	76.1	71.6	69.0
20	71.8	72.2	72.3	72.8	73.7	75.1	77.4	79.2	78.8	74.7	70.3	67.3
21	72.2	72.7	72.9	73.2	74.4	76.6	80.6	81.3	77.7	71.7	69.5	68.5
22	71.6	71.8	72.1	73.0	74.2	75.3	77.4	78.7	77.4	73.2	70.7	69.1
23	71.4	71.4	72.3	72.8	75.3	76.3	79.0	79.2	79.0	76.1	72.8*	70.8*
24	72.3	74.0	73.3	73.9	74.5	74.7	77.0	78.1	78.2	74.1	71.0	70.2
25	73.3	72.7	74.7	73.7	73.2	76.2	80.3	78.0	74.8*	70.2*	69.0	68.0
26	71.5	71.8	72.0	72.1	73.1	76.3	80.2	81.2	78.3	73.3	69.8	67.6
27	71.5	71.8	72.2	72.2	73.1	76.9	80.0	81.1	80.7*	74.3	69.4	68.0
28	75.2*	75.2*	73.2	73.7	70.8*	75.0	78.8	82.0	79.3	72.8	67.6	65.3
29	72.2	72.6	72.6	73.3	74.3	77.6	80.0	79.7	77.7	71.5	65.0*	62.1*
30	71.6	72.0	72.6	72.9	73.9	75.2	77.7	78.5	76.3	70.8*	67.8	67.1
31	71.3	72.0	72.2	72.6	73.9	76.2	79.9	81.5	75.2*	70.5*	67.4	65.4
Monthly mean	72.0	72.3	72.5	73.0	74.1	76.1	78.8	79.9	78.0	73.8	69.9	67.7
Normal	71.9	72.2	72.6	73.1	74.1	75.9	78.8	79.6	78.1	73.9	69.9	67.8

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794 Increasing scale readings correspond to increasing east declination.

JULY, 1885.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
1	64.7	63.2*	64.7*	67.4*	71.3	73.7	73.3	73.6	73.1	73.0	73.0	72.8	72.8
2	69.2	68.2	68.2	68.5	69.7	71.3	72.1	72.0	71.9	72.0	72.2	72.3	72.8
3	64.7	66.0	68.2	69.7	70.3	70.6	70.8	70.7	70.0	70.5	70.6	70.7	72.0
4	68.0	67.8	67.4	69.4	71.3	72.2	71.5	70.8	71.3	71.1	72.0	71.2	72.7
5	68.8	68.3	70.7	70.6	71.8	71.0	70.5	72.5	70.7	71.9	71.2	71.7	72.0
6	70.2*	70.0	70.1	70.7	72.2	72.6	72.1	73.6	71.2	71.5	72.2	71.4	72.9
7	67.6	67.2	68.1	69.3	70.5	71.3	72.6	71.5	71.7	72.4	72.3	72.2	72.3
8	64.8	64.7*	66.1	69.4	70.3	71.0	70.7	70.7	70.7	70.8	71.3	71.1	71.2
9	67.6	67.8	68.8	70.3	72.4	72.5	70.7	71.0	70.6	71.7	72.3	72.4	72.2
10	66.8	68.0	70.1	72.0	73.6	74.2	72.4	71.3	71.3	71.1	71.3	72.0	72.4
11	64.3*	65.7	67.8	70.3	72.1	72.7	72.5	71.0	70.8	71.0	71.5	71.6	72.4
12	68.2	68.0	69.8	71.0	72.2	73.0	75.1*	74.0	73.2	73.7	72.8	71.5	73.1
13	68.2	69.3	69.7	70.7	72.0	72.3	72.1	71.7	71.6	71.7	71.6	72.1	72.4
14	65.3	68.0	70.0	71.4	72.3	73.0	72.2	71.7	72.5	72.0	71.8	71.8	71.8
15	68.6	67.5	67.9	69.2	71.2	72.0	72.5	72.7	72.3	71.7	71.4	72.1	72.6
16	67.0	67.2	68.2	70.6	71.5	71.7	71.5	72.9	71.8	71.8	72.2	72.0	72.1
17	66.5	63.5*	67.8	68.0	67.2*	71.0	70.7	71.3	70.5	70.7	72.3	72.4	72.0
18	65.3	65.6	66.5	69.0	70.4	71.0	71.6	71.4	71.5	71.7	72.1	71.8	71.3
19	66.3	66.5	68.0	69.5	71.1	72.2	71.7	72.3	71.8	71.0	71.2	72.2	72.7
20	66.3	65.4	66.4	69.2	70.0	71.1	71.8	71.9	71.8	72.0	72.2	72.0	71.9
21	69.1	67.6	67.2	69.1	69.3	70.5	70.8	70.7	70.8	71.1	71.6	71.6	72.1
22	68.3	68.1	69.5	70.3	70.2	70.2	70.3	69.4	71.0	70.7	70.7	71.0	71.8
23	69.3	68.4	68.9	70.0	70.8	71.7	71.5	71.0	71.3	71.9	71.7	72.1	72.7
24	69.4	69.8	70.0	69.4	69.3	70.5	70.3	70.3	69.9	69.8	70.7	79.7*	72.5
25	66.3	67.0	69.2	71.6	74.3*	74.1	72.2	72.8	72.3	72.3	72.2	71.3	72.5
26	65.6	67.0	69.2	70.7	71.8	72.2	72.1	71.8	71.7	72.8	72.2	71.2	72.3
27	66.6	67.2	67.8	70.0	71.2	73.3	73.0	72.1	71.1	71.6	72.8	74.3	72.6
28	65.4	66.9	69.3	71.5	72.3	72.2	72.2	72.0	72.9	72.0	72.1	71.8	72.5
29	62.5*	64.0*	70.2	71.1	72.9	73.3	72.0	71.8	70.8	70.9	70.9	71.2	71.7
30	67.7	69.3	68.6	69.0	70.1	71.0	71.1	71.1	71.3	71.5	71.3	71.3	71.6
31	66.0	67.5	68.7	70.8	71.1	71.0	71.2	70.8	70.8	72.1	71.1	70.9	71.7
Monthly mean	66.9	67.1	68.5	70.0	71.2	72.0	71.8	71.7	71.4	71.6	71.8	72.0	72.25
Normal	67.1	67.6	68.6	70.1	71.2	72.0	71.7	71.7	71.4	71.6	71.8	71.8	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

AUGUST, 1885.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	71.3	72.3	72.8	73.0	78.7*	79.0	80.2	84.2*	83.6*	75.0	70.7	68.0
2	73.2	70.0	72.2	70.7	73.1	75.2	78.2	81.3	78.3	75.2	70.3	68.3
3	73.3	71.9	72.0	71.2	74.6	74.5	78.3	77.2*	77.0	71.7	69.8	69.1
4	72.7	72.3	72.1	71.6	73.2	74.8	79.9	80.5	76.1	72.2	69.2	67.2
5	69.9*	71.3	71.8	72.5	73.2	74.8	77.6	79.1	77.4	73.9	69.3	66.9
6	70.1*	72.7	71.4	72.8	74.2	76.0	78.0	80.4	78.7	73.8	68.5	66.1
7	76.7*	69.5*	72.8	74.7	75.7	75.2	77.7	76.5*	76.6	71.1	68.0	69.2
8	67.7*	71.4	70.8	71.3	73.2	75.8	79.5	79.5	78.3	73.4	71.1	69.5
9	71.7	70.8	71.8	72.2	73.7	76.3	79.0	78.7	77.0	72.8	69.2	67.0
10	68.7*	72.4	72.9	73.2	73.8	78.0	79.2	79.1	75.8	72.4	69.3	66.6
11	72.2	72.3	72.7	72.9	74.0	76.2	79.2	79.2	75.9	70.0*	66.6*	66.4
12	72.7	74.8	74.7	73.3	73.2	75.1	77.1	80.5	79.5	74.8	70.6	67.8
13	71.4	71.7	72.0	72.6	73.3	75.7	79.0	81.2	79.1	74.0	70.0	68.0
14	72.2	70.7	72.7	72.3	74.4	76.9	79.7	80.9	79.1	74.4	70.0	67.2
15	73.0	72.5	72.5	73.4	75.4	77.5	79.5	81.6	79.5	73.2	68.7	67.5
16	75.2	77.7*	78.1*	75.2	75.6	78.5	81.0	82.8*	80.2*	75.2	71.1	69.0
17	72.5	73.1	73.3	73.6	75.0	77.8	80.2	79.8	76.7	71.9	68.0	67.1
18	73.2	72.8	73.2	73.8	74.7	76.6	78.4	80.2	75.7	69.8*	64.8*	63.6*
19	72.7	73.0	73.0	73.9	74.6	77.6	80.2	80.5	76.7	71.0	66.1*	64.3*
20	74.8	73.1	73.5	74.1	75.2	76.7	79.3	77.1*	74.3*	69.4*	68.2	68.0
21	74.8	74.0	73.2	72.7	73.7	78.0	78.7	77.5*	75.9	72.7	70.3	68.9
22	72.3	72.8	72.8	73.8	73.7	77.5	79.5	80.2	77.2	73.7	69.9	68.1
23	71.7	72.1	72.2	73.2	73.8	76.8	80.5	79.5	75.1	71.1	69.1	68.1
24	71.6	72.8	73.1	73.0	74.5	76.8	81.2	82.0	74.9	68.2*	65.2*	65.3
25	72.5	74.0	73.8	72.3	74.9	77.3	80.7	81.8	75.7	70.5*	67.0	66.1
26	72.9	76.2*	75.1	75.2	78.3*	78.7	80.2	84.0*	81.3*	75.3	70.0	67.9
27	72.4	72.4	72.8	73.2	73.1	76.5	79.0	79.2	79.0	74.1	70.7	67.8
28	75.2	72.5	72.9	74.0	73.5	77.0	75.0*	81.0	77.8	75.3	70.2	68.7
29	74.5	73.0	72.8	70.8	72.7	76.2	76.8	78.1	76.9	73.5	70.1	68.0
30	72.4	72.1	73.0	73.0	73.8	76.3	80.8	83.0*	78.5	73.6	70.7	69.7
31	71.8	72.7	73.1	73.3	74.3	76.0	78.1	79.8	78.1	71.7	67.8	66.4
Monthly mean	72.8	72.6	72.9	73.0	74.4	76.6	79.1	80.2	77.6	72.7	69.0	67.5
Normal	73.2	72.4	72.8	73.0	74.1	76.6	79.2	80.2	77.3	73.3	69.5	67.7

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794

Increasing scale readings correspond to increasing east declination.

AUGUST, 1885.

Day.	13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night	Daily mean.
1	67.5	66.1	67.6	69.8	71.9*	73.0	76.3*	74.3	73.5	74.1	75.7*	75.0	73.9
2	68.0	68.4	70.0	70.6	72.0	71.9	73.7	72.0	73.2	72.8	72.3	73.1	72.7
3	68.0	67.9	68.9	70.2	71.5	72.7	75.3*	73.0	73.1	74.4	73.1	73.4	72.6
4	67.0	67.9	69.3	70.4	71.0	72.0	76.1*	73.7	72.9	72.2	72.3	71.1	72.4
5	65.9	66.0	68.2	69.9	71.8	71.8	71.7	73.1	72.1	72.5	72.6	72.2	71.9
6	66.3	68.6	69.9	69.3	71.0	72.3	71.3	73.0	72.7	81.4*	74.0	74.0	72.4
7	69.2	68.8	70.3	72.8	71.4	71.3	70.7	70.3	71.1	74.3	75.3*	73.8	72.6
8	68.2	69.2	70.4	71.3	71.6	71.9	74.2	74.5	73.5	72.3	71.0	70.8	72.5
9	67.2	68.2	70.2	70.8	72.7	72.7	71.7	71.2	72.5	71.7	71.6	71.7	72.2
10	64.7*	65.8*	67.4	70.2	72.1	73.2	72.3	71.5	72.2	73.5	73.9	73.2	72.1
11	67.8	69.3	70.1	71.1	71.7	72.7	73.8	71.7	71.3	72.0	72.1	71.8	72.2
12	66.0	65.5*	66.5*	68.3*	71.1	72.2	72.2	72.1	71.7	71.7	71.7	71.6	72.3
13	69.3	70.5	72.2	72.3	72.2	72.0	72.1	72.0	71.7	71.6	71.5	71.4	72.8
14	65.6	67.0	68.1	70.7	72.2	72.0	71.7	72.2	72.0	71.7	74.5	74.4	72.6
15	67.2	67.7	69.1	70.9	71.8	71.0	70.7	71.0	71.6	71.7	71.5	72.2	72.5
16	67.5	68.2	69.5	71.7	73.0	72.6	71.8	71.6	72.2	72.0	72.3	72.4	73.9
17	67.7	69.3	70.4	72.2	72.9	72.0	72.0	72.0	72.2	72.3	72.4	72.7	72.8
18	64.9*	68.3	70.7	72.5	73.2	72.7	72.1	72.1	72.1	72.2	72.5	72.8	72.2
19	65.8	67.7	70.1	71.7	71.8	72.1	71.7	71.6	71.6	72.0	72.1	73.2	72.3
20	69.4	70.6	72.2	72.4	73.0	74.5	71.1	71.3	72.2	73.2	72.8	73.7	72.9
21	68.7	70.2	71.8	72.4	72.9	72.3	71.9	73.7	72.0	72.3	74.4	74.0	73.2
22	67.8	69.1	71.2	73.3	73.6	71.6	71.7	72.2	73.0	71.8	71.6	71.7	72.9
23	69.3	70.3	71.0	72.3	72.5	72.1	71.5	72.0	71.5	71.0	71.8	71.1	72.5
24	67.0	69.2	71.3	74.1*	74.3	72.3	71.2	71.3	71.2	71.7	72.1	72.3	72.4
25	67.1	68.5	71.0	72.2	72.8	72.0	71.1	71.4	71.7	71.5	71.5	72.0	72.5
26	67.6	67.8	69.0	70.0	70.9	70.7	69.8	71.0	71.0	71.3	71.9	72.2	73.3
27	69.1	67.2	69.2	70.2	70.3	71.6	71.0	71.2	72.2	73.9	74.8	69.6*	72.5
28	68.0	67.1	68.1	72.9	72.8	77.8*	76.6*	77.0*	81.0*	77.5*	72.2	74.8	74.1
29	67.6	70.0	70.9	72.2	73.0	78.0*	76.1*	73.5	75.5*	77.0*	72.3	74.0	73.5
30	69.5	69.9	69.9	72.2	73.2	74.0	75.5*	72.1	71.9	71.8	71.6	72.9	73.4
31	66.2	66.1	68.6	70.7	72.0	72.6	72.9	72.5	72.1	72.1	72.2	72.2	72.2
Monthly mean	67.4	68.3	69.8	71.3	72.2	72.6	72.6	72.3	72.2	72.6	72.6	72.6	72.72
Normal	67.6	68.5	69.9	71.4	72.2	72.3	71.8	72.2	71.8	72.0	72.4	72.4	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

SEPTEMBER, 85.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	72.7	70.7	72.7	72.7	74.5	77.6	80.3	80.7*	78.5	73.9	70.0	66.8
2	72.7	70.7	75.8	75.2	75.1	76.4	79.7	80.7	77.2	70.7	67.9*	67.1
3	75.7*	73.1	76.0*	74.7	74.8	76.4	79.3	79.3	76.3	71.4	69.8	70.0
4	74.2	72.0	76.2*	77.6*	75.0	76.6	79.5	79.2	80.1*	72.2	69.2	67.9
5	70.4	73.6	72.5	73.9	74.3	76.3	78.5	77.7	75.6	71.9	70.1	69.3
6	72.2	72.0	72.9	72.0	74.0	76.2	79.1	78.2	75.8	72.7	70.7	69.8
7	72.8	73.8	73.8	73.7	74.7	77.0	81.1*	79.7	76.2	71.2	68.2	67.7
8	73.5	73.8	74.1	74.0	74.3	78.3	81.4*	78.5	75.3	69.3*	66.2*	65.0*
9	71.8	72.4	73.3	73.3	73.8	76.2	78.3	76.6	73.6*	71.0	68.6	67.3
10	73.9	74.1	73.7	73.7	74.8	76.8	79.3	79.7	78.6	74.7	70.8	67.8
11	72.3	73.4	74.0	74.2	74.2	76.1	79.3	79.1	79.2	75.3	71.1	67.7
12	72.1	72.3	72.8	73.2	73.9	78.0	81.3*	83.4*	80.0*	75.1	70.4	66.2
13	72.3	72.6	73.1	73.0	74.2	77.4	80.1	80.6*	78.9	73.6	70.6	68.4
14	72.5	72.6	73.1	73.2	73.9	76.2	78.7	78.7	77.2	73.3	69.4	67.0
15	74.1	76.9*	72.2	75.4	72.5	76.2	75.8	74.3*	75.6	74.4	72.0	69.4
16	74.8	76.9*	76.3*	72.6	71.0*	75.6	76.6	76.2	75.1	73.9	70.9	68.2
17	77.4*	75.3	73.4	73.0	74.1	74.9	76.5	75.7	76.0	75.1	73.2*	71.0
18	73.2	71.2	72.3	74.7	74.7	75.8	75.5*	76.2	75.3	74.2	70.8	69.7
19	72.2	72.8	73.0	73.3	74.0	75.9	76.8	77.0	76.2	72.4	69.2	69.0
20	72.9	73.1	73.4	73.2	73.6	75.8	77.9	78.1	76.7	74.0	71.3	69.8
21	73.5	73.8	74.1	74.4	74.7	76.2	79.0	79.3	75.9	71.2	69.7	68.6
22	73.3	73.3	73.8	75.2	76.1	77.7	76.5	76.8	79.5*	72.7	71.5	69.9
23	75.9*	70.0*	76.2*	74.0	73.7	75.8	73.5*	74.3*	73.3*	71.7	71.1	66.2
24	74.0	73.5	73.7	74.0	74.2	75.3	77.7	78.7	77.2	73.8	70.8	69.0
25	72.7	74.0	70.7*	74.2	73.5	76.2	78.2	76.3	76.8	74.3	71.8	69.6
26	72.7	74.1	74.9	70.8*	74.8	76.6	76.2	78.0	74.8	73.3	71.4	71.6*
27	72.7	77.5*	77.3*	77.5*	77.3*	74.8	72.7*	72.4*	72.8*	71.7	69.8	67.8
28	73.0	74.0	73.4	72.3	72.3	74.9	77.0	78.3	77.6	75.2	72.2	68.8
29	72.1	72.6	72.7	72.5	73.3	74.9	76.8	78.0	77.1	76.1*	74.8*	71.0
30	72.1	74.3	71.5	72.8	74.0	74.8	76.7	77.1	78.1	73.2	71.1	70.2
Monthly mean	73.2	73.3	73.8	73.8	74.2	76.2	78.0	78.0	76.7	73.1	70.5	68.6
Normal	72.8	73.0	73.3	73.6	74.2	76.2	78.1	77.9	76.7	73.1	70.5	68.6

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794 Increasing scale readings correspond to increasing east declination.

SEPTEMBER, 1885.

Day.	13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
1	67.5	68.0	70.0	72.0	72.7	71.5	71.4	71.8	76.0*	73.5	72.0	74.3	73.0
2	69.1	69.7	71.6	72.7	73.0	71.9	71.3	71.6	71.6	71.7	75.0	74.6	73.0
3	69.9	71.4	73.1	74.0	73.5	72.1	72.4	71.4	70.4	72.1	71.7	73.4	73.4
4	68.1	69.5	70.8	76.2*	68.5*	70.7	75.1*	72.2	71.2	70.8	73.1	67.8*	73.1
5	69.1	69.9	71.0	71.8	72.2	72.1	71.9	71.9	71.9	72.0	72.0	72.1	72.6
6	68.5	69.8	70.6	71.1	71.4	70.9	71.6	72.0	71.9	72.9	73.2	72.6	72.6
7	67.8	69.4	71.0	71.8	73.3	72.7	71.7	71.3	72.3	72.1	72.4	73.2	72.9
8	65.4*	67.7	70.2	72.7	72.8	71.9	72.3	72.9	71.0	71.4	73.3	71.7	72.4
9	68.3	69.2	70.7	74.5*	74.1	72.8	71.8	72.3	72.1	71.7	72.0	74.0	72.5
10	67.5	69.5	71.5	72.2	72.6	71.5	71.1	71.0	71.8	71.7	72.1	72.2	73.0
11	65.4*	67.1	69.2	71.2	73.1	72.6	72.7	71.8	72.0	71.8	72.3	72.1	72.8
12	65.8	66.6*	68.0*	70.0	73.0	72.0	72.2	72.2	72.2	72.2	72.2	72.2	72.8
13	67.5	68.9	70.5	72.3	72.8	72.5	72.5	72.6	72.4	73.6	73.6	72.3	73.2
14	67.0	68.3	70.2	71.0	72.0	73.3	72.2	72.8	72.3	72.1	72.2	73.5	72.6
15	66.4	68.1	68.0*	70.0	71.2	70.3	74.1	71.9	75.5*	83.0*	77.5*	76.2*	73.4
16	68.0	68.5	70.2	71.8	77.6*	72.1	72.2	72.6	73.3	72.2	72.5	74.2	73.0
17	69.9	69.7	69.9	70.9	71.7	72.0	72.1	73.0	72.9	72.6	72.4	69.8*	73.0
18	69.3	70.3	71.1	72.8	72.2	71.7	71.6	72.1	74.2	72.7	74.0	73.1	72.9
19	69.2	70.5	71.4	72.8	72.5	72.0	73.2	71.7	72.1	72.5	72.8	73.4	72.8
20	69.3	69.8	71.2	72.1	72.4	72.1	74.5	72.8	72.5	73.8	73.8	74.1	73.3
21	68.8	70.7	71.8	72.2	71.2	71.5	71.9	71.7	71.4	71.8	72.3	74.1	72.9
22	70.9*	70.7	71.0	71.5	72.4	71.5	71.3	75.5*	71.9	75.1	74.1	78.2*	73.8
23	68.0	69.2	69.6	71.1	72.0	72.8	72.8	72.3	72.2	72.7	73.9	74.1	72.4
24	68.5	69.2	70.0	72.1	72.2	76.7*	71.8	71.2	72.2	73.3	73.3	73.7	73.2
25	68.2	69.8	71.4	72.2	72.8	73.3	73.4	72.8	72.6	73.6	74.1	70.8	73.0
26	71.4*	72.0*	72.9	72.8	72.7	72.1	72.3	73.8	74.6	73.4	73.1	69.7*	73.3
27	67.2	69.7	70.7	70.8	71.5	72.3	73.1	72.3	72.4	72.1	72.2	73.4	72.6
28	66.3	67.9	69.3	71.1	72.1	71.8	72.3	72.2	72.1	72.2	72.0	72.2	72.5
29	68.7	69.1	70.2	71.7	71.7	72.7	73.3	72.7	73.1	74.2	74.0	73.4	73.2
30	69.0	70.2	71.7	72.8	72.2	72.3	72.4	71.3	72.4	72.7	75.0	73.2	73.0
Monthly mean	68.2	69.4	70.6	72.1	72.4	72.2	72.4	72.3	72.5	72.9	73.1	73.0	72.93
Normal	68.2	69.4	70.8	71.8	72.4	72.0	72.3	72.1	72.2	72.6	73.0	73.1	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

OCTOBER, 1885.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	73.0	72.9	72.9	72.8	73.8	74.9	76.6	76.2	75.3	72.8	70.3	67.2
2	72.2	80.2*	75.3	74.5	73.7	75.2	77.0	77.6	76.2	74.5	72.8	71.8*
3	72.2	73.6	73.5	73.2	74.0	75.7	75.7	76.6	74.3	72.3	71.5	70.3
4	72.7	73.2	73.1	73.5	73.7	74.4	75.9	75.9	74.1	73.1	70.8	68.4
5	72.6	72.5	73.0	73.3	73.9	75.0	76.0	75.7	74.5	71.7	69.0	67.1
6	72.2	72.3	72.7	73.2	73.7	75.5	76.3	77.7	76.0	72.2	69.2	66.8
7	71.9	72.3	73.3	74.1	74.8	74.7	75.6	77.0	75.2	72.5	69.3	68.7
8	72.7	74.1	75.8*	75.9*	75.0	75.7	78.0*	76.5	76.2	72.5	69.0	67.7
9	74.1	73.7	72.8	73.3	73.2	74.5	76.5	76.0	74.5	71.0	68.3	67.3
10	72.6	72.9	73.0	73.3	74.0	74.4	75.7	76.5	75.3	72.1	69.7	68.6
11	72.9	72.9	73.6	73.2	73.8	74.6	75.5	76.6	76.7	74.5	71.5	69.3
12	72.0	71.8	71.7	70.0*	72.2	73.5	75.7	76.7	77.9	74.4	73.5*	71.3
13	71.1	70.7	73.9	74.2	70.7*	72.0	73.3	75.2	77.6	77.6*	72.7	69.2
14	75.3*	71.8	73.6	74.9	69.7*	73.0	75.5	76.6	77.1	76.8*	73.8*	71.2
15	76.2*	77.5*	75.0	73.8	74.0	72.6	73.0	75.8	75.9	75.1	70.4	68.1
16	80.3*	79.1*	71.0	72.1	72.6	73.2	74.1	76.0	77.3	76.1*	72.8	70.6
17	72.8	72.7	72.8	72.8	73.0	73.4	75.3	76.9	77.3	74.4	70.5	69.1
18	72.5	72.7	72.7	73.7	73.9	72.3	75.9	75.8	74.5	71.8	70.3	69.0
19	73.0	73.4	73.8	72.9	73.1	73.3	74.7	77.0	77.2	75.8*	73.4*	70.8
20	72.9	72.8	72.8	73.3	73.3	74.2	75.1	76.3	75.3	74.4	71.0	70.3
21	72.7	72.7	72.8	73.0	73.2	74.0	76.2	78.1	77.3	73.9	69.8	67.7
22	75.2*	73.1	73.4	73.4	74.2	76.2	77.8	76.5	75.6	71.2	69.2	68.1
23	72.7	69.8*	78.7*	74.2	74.6	75.5	76.5	76.7	74.5	72.6	69.9	68.7
24	72.2	72.1	72.3	72.7	73.3	74.2	76.6	77.0	74.4	72.0	70.1	69.2
25	76.8*	76.1*	74.2	76.3*	75.0	74.7	74.3	77.7	76.2	74.2	70.9	68.5
26	73.7	73.8	73.7	72.8	73.2	74.0	75.6	76.5	75.8	72.8	70.2	69.6
27	72.9	72.7	73.5	73.5	73.4	72.2	74.6	76.2	74.7	72.7	70.0	69.2
28	72.1	72.2	72.1	72.2	72.6	73.0	73.1	75.9	77.5	76.5*	73.6*	70.8
29	71.8	73.0	71.9	71.4	71.9	72.4	73.6	75.7	76.3	74.3	71.0	69.0
30	72.7	70.7	70.3*	69.8*	72.7	72.7	73.0	76.1	77.0	75.5	73.2*	71.5
31	72.0	74.3	73.0	74.3	74.5	73.4	75.2	75.2	74.8	73.0	71.5	71.1
Monthly mean	73.2	73.3	73.3	73.3	73.4	74.0	75.4	76.5	75.9	73.7	70.9	69.2
Normal	72.6	72.7	73.1	73.3	73.6	74.0	75.3	76.5	75.9	73.1	70.5	69.1

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794

Increasing scale readings correspond to increasing east declination.

OCTOBER, 1885.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
1	67.2	67.7	69.6	69.7	70.3	71.6	71.2	71.7	71.7	72.2	72.8	74.3	72.0
2	70.8	71.0	71.5	72.5	71.6	71.2	71.0	70.9	72.2	72.8	71.8	72.6	73.4
3	69.8	70.7	71.7	72.2	71.8	71.8	72.2	72.2	72.2	72.3	72.1	72.2	72.7
4	68.9	69.8	70.5	71.7	72.1	72.1	72.5	72.6	72.5	72.6	72.3	72.5	72.4
5	67.6	69.8	71.3	72.1	71.4	71.1	71.3	71.3	71.6	71.4	71.3	72.2	72.0
6	67.5	69.3	71.3	71.7	71.5	71.3	71.3	71.4	71.3	71.3	71.4	71.7	72.0
7	70.1	70.9	71.2	72.2	72.3	72.5	72.2	72.1	72.1	72.1	72.0	72.3	72.6
8	68.0	69.2	70.8	71.9	72.8	72.2	74.4	72.4	72.7	72.6	73.5	74.7	73.1
9	68.5	69.5	69.3	71.4	72.5	72.4	72.5	72.6	72.5	72.4	72.4	72.8	72.2
10	68.6	70.3	72.1	73.2	72.6	72.7	72.6	72.6	72.7	72.5	72.4	72.7	72.6
11	68.5	69.2	69.3	71.0	71.3	72.4	72.3	72.1	72.2	72.7	73.7	72.9	72.6
12	69.6	68.9	69.6	70.7	72.2	73.4	72.4	72.2	72.2	72.2	72.6	72.1	72.4
13	67.7	68.1	70.3	71.4	72.1	72.3	72.2	72.9	72.7	73.9	73.0	75.3*	72.5
14	70.3	70.8	71.7	72.1	72.2	72.3	72.6	77.3*	73.6	73.9	74.6	71.1	73.4
15	70.2	70.0	70.0	71.3	71.2	72.7	75.2	76.4*	74.2	75.0	70.0*	72.3	73.2
16	70.7	70.8	71.7	71.8	72.0	72.7	72.3	73.1	73.2	72.8	72.8	73.0	73.4
17	69.6	70.2	70.7	71.0	71.4	72.3	72.5	72.6	72.8	72.7	72.7	73.0	72.6
18	68.3	69.8	69.4	71.8	72.0	71.6	72.9	73.0	74.1	72.7	72.4	72.6	72.3
19	70.0	70.1	70.8	71.7	72.2	72.8	73.2	74.2	72.8	73.2	72.8	72.7	73.1
20	69.7	70.2	71.1	72.2	72.3	72.8	72.8	72.7	72.7	72.6	72.7	72.7	72.8
21	67.2	69.3	70.3	71.7	71.7	72.1	72.2	72.2	72.1	72.2	72.9	73.5	72.4
22	67.9	69.3	70.8	72.3	72.6	72.9	75.0	72.9	72.7	72.7	72.1	72.2	72.8
23	68.7	69.7	71.2	72.3	72.6	73.7	72.7	72.4	71.8	72.1	71.9	72.2	72.7
24	69.2	71.1	71.6	72.6	72.6	72.9	72.8	72.8	72.7	72.4	72.6	72.8	72.6
25	68.1	69.3	71.0	72.1	72.9	72.8	73.2	72.8	72.9	73.6	73.3	73.1	73.3
26	69.5	71.1	71.6*	72.1	72.5	72.7	73.1	72.6	72.9	72.5	74.4	72.7	72.9
27	67.8	70.1	70.0	70.7	72.0	71.8	72.3	71.9	75.3	72.6	72.2	71.8	72.2
28	70.0	70.5	70.8	72.2	72.2	72.1	74.5	72.1	73.3	74.7	72.9	72.3	72.9
29	67.7	69.0	70.0	71.3	71.9	72.3	72.8	72.5	73.5	74.7	73.7	73.0	72.3
30	70.6	70.8	71.4	71.7	72.1	72.2	74.0	73.1	74.2	74.0	72.7	72.0	72.7
31	69.9	70.2	70.7	71.7	72.2	72.7	72.6	73.1	73.1	73.3	72.8	72.3	72.8
Monthly mean	69.0	69.9	70.8	71.8	72.0	72.3	72.7	72.7	72.8	72.9	72.6	72.7	72.68
Normal	69.0	69.9	70.8	71.8	72.0	72.3	72.7	72.5	72.8	72.9	72.7	72.6	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

NOVEMBER, 1885.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	72.2	72.0	71.1	71.0	71.9	71.9	73.4	74.0	72.2*	75.2	73.9	72.0
2	72.6	72.7	72.5	72.1	72.6	73.1	75.3	78.4*	79.5*	78.0*	76.2*	73.5
3	72.8	72.2	73.7	73.1	72.7	73.5	75.3	77.9	78.2	75.2	72.1	70.3
4	72.8	72.9	73.6	73.1	73.2	73.1	75.0	76.7	76.2	74.4	71.5	69.6
5	72.8	72.8	72.7	73.2	73.1	74.2	75.7	76.5	76.1	74.9	72.6	71.0
6	72.2	72.7	73.2	72.8	73.3	73.7	74.5	76.2	75.9	71.9*	68.8*	66.8*
7	72.2	72.0	72.1	72.8	73.6	74.0	75.2	76.5	75.9	72.5	70.4	68.8
8	71.0	72.2	70.2	71.5	72.7	73.4	75.0	77.0	78.7*	76.3	72.8	70.0
9	72.1	72.0	72.2	72.3	72.7	73.0	74.5	77.5	76.6	76.0	71.1	68.1*
10	77.2*	74.3	74.1	70.9	66.2*	70.3*	71.0*	74.0	74.6	74.4	73.8	71.3
11	73.8	66.7*	77.4*	68.3*	70.8	67.6*	67.1*	73.5	73.5	73.9	71.7	71.0
12	73.2	71.5	71.2	70.8	71.8	73.7	74.7	75.0	76.0	75.0	71.7	69.5
13	72.7	72.3	71.2	73.6	72.8	73.5	75.2	77.3	77.4	76.6	74.3	71.1
14	72.2	72.3	72.2	71.6	72.3	73.0	74.2	75.7	75.2	74.8	72.8	70.7
15	72.2	72.3	72.2	72.5	72.7	73.7	74.1	76.8	77.5	76.3	74.2	71.9
16	72.3	72.3	72.1	72.2	72.6	72.9	74.3	76.2	76.8	75.4	73.1	71.1
17	72.5	72.6	72.7	72.7	72.8	73.0	74.0	75.6	76.5	75.2	73.2	70.7
18	72.0	72.1	73.7	67.2*	75.3*	73.7	72.6	74.0	72.0*	71.7*	71.8	67.6*
19	71.3	71.7	69.7*	71.5	72.7	72.7	71.8	72.2*	73.2	71.0*	72.6	71.8
20	72.7	72.2	73.0	72.8	73.2	72.8	73.6	74.5	75.6	74.3	72.2	70.9
21	72.2	72.2	72.4	72.7	73.4	73.9	74.6	76.0	76.5	74.9	72.6	71.1
22	72.4	72.3	72.6	73.2	73.6	73.6	73.7	75.5	75.3	73.0	72.3	71.9
23	71.4	72.7	73.1	73.4	73.2	73.4	74.2	76.0	76.5	75.5	73.4	72.1
24	72.1	72.5	72.5	72.0	72.8	73.3	74.4	75.9	75.1	73.3	71.7	70.2
25	73.2	73.7	74.2	74.3	74.0	74.5	74.7	76.7	76.2	74.1	71.0	70.2
26	70.5	73.5	73.2	73.9	74.5	74.8	75.2	75.5	76.1	74.6	74.1	72.3
27	72.6	73.6	73.6	73.9	73.7	74.0	74.0	74.0	74.9	74.7	73.1	71.2
28	72.2	71.8	71.8	69.4*	72.1	73.0	73.3	73.8	74.8	75.1	74.3	72.4
29	72.4	72.3	72.2	72.2	72.2	72.3	72.2	72.3*	74.0	75.3	76.0*	75.0*
30	72.7	72.3	72.5	72.5	72.5	72.5	72.4	73.0*	74.1	74.5	74.3	72.4
Monthly mean	72.5	72.3	72.6	72.1	72.7	73.1	73.8	75.5	75.7	74.6	72.8	70.9
Normal	72.3	72.5	72.7	72.5	72.5	73.4	74.2	75.7	75.7	74.8	72.7	71.1

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794 Increasing scale readings correspond to increasing east declination.

NOVEMBER, 1885.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Midnight.	Daily mean.
1	71.1	71.4	71.3	71.6	72.2	72.5	72.7	72.7	72.5	72.6	72.9	72.8	72.4
2	71.4	70.8	70.3	71.1	72.2	72.4	72.7	72.7	72.5	75.2	74.1	73.2	73.6
3	70.7	71.6	71.7	71.7	72.1	72.2	72.7	72.7	72.7	72.8	72.7	72.7	73.0
4	69.4	70.4	71.1	72.0	72.2	72.4	72.6	72.5	72.4	72.1	72.2	72.6	72.7
5	69.0	70.2	70.0	72.1	72.2	72.6	72.3	73.0	72.8	72.8	73.7	73.0	72.9
6	67.2*	69.6	71.5	72.4	73.0	73.0	73.1	72.8	72.3	72.3	72.1	72.1	72.2
7	67.7	67.1*	71.0	70.4	70.2	73.0	73.4	77.2*	75.2	76.7*	75.2	75.1	72.8
8	69.1	70.2	70.8	72.1	72.9	73.2	73.2	73.0	72.8	72.7	72.1	72.1	72.7
9	66.0*	67.0*	70.5	72.3	71.9	73.3	72.2	75.7*	76.0*	76.7*	75.2	76.1*	73.0
10	68.0	69.1	70.2	71.4	71.7	71.9	72.3	73.3	72.8	84.4*	72.6	72.2	72.6
11	70.0	71.1	71.0	72.2	72.2	72.6	76.6*	72.7	73.0	71.7	73.4	70.2	71.8
12	69.2	69.6	71.0	72.2	73.0	72.9	73.0	73.3	73.5	73.8	74.2	72.7	72.6
13	69.7	70.0	71.1	72.0	72.5	72.8	72.9	72.9	73.0	72.8	72.3	72.3	73.0
14	69.8	70.1	69.9	71.1	73.3	73.0	73.3	73.0	72.8	73.4	72.7	72.2	72.6
15	70.6	70.8	70.8	71.3	72.3	72.8	73.0	73.0	73.0	72.8	72.8	72.7	73.0
16	70.1	70.2	70.7	71.7	72.3	72.8	73.0	73.1	73.0	73.0	72.9	72.6	72.8
17	70.0	69.6	70.7	71.3	72.0	72.4	72.7	72.6	72.3	72.2	72.1	72.1	72.6
18	69.2	70.3	71.0	71.5	72.3	73.0	74.2	75.0	76.8*	79.2*	74.5	72.4	72.6
19	71.3	70.5	71.7	71.8	71.8	74.3	73.4	72.8	72.7	75.1	72.3	71.8	72.2
20	70.3	70.3	72.0	72.5	73.0	73.5	74.0	74.0	72.8	72.5	72.2	72.1	72.8
21	70.2	71.9	72.5	72.3	73.0	73.1	73.2	72.7	72.7	72.4	72.7	72.2	73.0
22	71.8	72.0	72.5	73.0	73.5	73.6	73.5	73.6	73.0	73.0	73.0	72.8	73.1
23	71.0	70.2	70.8	71.8	72.7	72.9	73.0	72.8	72.4	72.4	72.2	72.0	72.9
24	70.3	70.8	70.9	71.3	72.2	73.0	73.0	72.7	73.5	72.3	70.5	73.6	72.5
25	70.2	70.5	70.9	72.2	73.0	73.0	73.6	73.1	73.0	73.1	73.0	73.6	73.2
26	71.3	70.7	70.7	71.2	72.0	72.3	73.0	72.5	72.8	72.9	72.9	72.4	73.0
27	69.8	69.6	70.2	71.4	72.4	72.7	73.0	72.9	72.8	72.8	72.6	72.5	72.8
28	71.8	71.3	71.1	71.7	72.6	72.8	73.0	73.0	72.9	73.0	72.6	72.4	72.6
29	73.5*	72.3	71.7	71.9	72.7	73.0	73.1	73.1	73.1	72.8	72.8	72.6	73.0
30	71.5	70.0	70.3	71.1	72.2	72.5	72.7	72.9	73.0	72.9	72.9	73.5	72.6
Monthly mean	70.0	70.3	71.0	71.8	72.4	72.8	73.2	73.2	73.1	73.8	72.9	72.7	72.74
Normal	70.2	70.5	71.0	71.8	72.4	72.8	73.0	73.0	72.9	72.9	72.9	72.6	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

DECEMBER, 1885.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	73.3	72.2	72.3	72.5	72.3	72.7	73.2	75.7	72.9	75.4	75.6	72.7
2	71.8	71.5	72.1	72.2	72.9	72.0	72.8	73.7	75.8	75.6	74.8	72.7
3	72.5	72.4	72.4	71.2	71.0	70.0	72.7	73.7	74.5	74.6	73.0	71.1
4	71.9	72.1	72.1	72.2	72.3	72.8	72.9	73.9	74.6	74.5	73.6	72.2
5	72.1	72.1	72.3	72.2	72.2	72.5	72.7	73.6	74.4	74.1	72.7	71.5
6	76.0*	72.2	73.0	72.5	73.2	73.0	70.6	74.2	74.2	65.6*	70.0*	71.2
7	71.8	71.3	70.0	71.7	71.0	69.2*	70.7	72.2	74.7	74.0	72.3	71.8
8	71.7	69.3*	71.1	73.0	70.8	71.6	71.1	74.3	73.2	70.6*	72.0	70.9
9	71.7	72.7	70.2	72.3	72.4	73.3	73.8	75.5	75.7	75.3	73.3	71.4
10	72.5	73.5	72.2	72.5	72.7	72.7	72.7	75.3	76.9	77.1	76.2	72.8
11	71.9	72.0	71.7	72.2	72.4	72.7	72.7	74.1	75.0	74.2	72.7	71.6
12	71.8	71.7	71.9	72.1	72.2	72.7	73.0	74.9	75.8	76.1	75.0	72.6
13	72.5	72.1	73.7	73.6	73.5	73.3	74.0	74.8	76.2	76.2	74.1	72.3
14	72.2	72.2	72.7	73.3	72.8	73.1	73.8	75.5	75.8	76.4	74.7	72.1
15	72.7	71.9	72.1	72.2	72.7	72.7	72.6	74.1	76.3	77.0	75.7	72.7
16	72.5	72.7	72.1	72.2	71.9	72.2	72.0	73.2	74.5	75.2	73.9	72.2
17	71.6	73.1	72.4	72.4	72.2	72.3	72.5	74.0	74.8	75.9	74.9	72.8
18	72.1	73.5	72.3	74.7	72.5	72.5	72.2	73.6	75.0	77.2	76.7*	74.4
19	72.4	72.7	73.5	73.0	72.7	71.7	71.7	72.9	74.6	74.2	73.8	71.7
20	73.8	73.2	73.2	71.9	72.2	73.2	72.8	74.2	75.7	76.9	76.4	73.2
21	73.0	72.7	74.0	74.3	73.3	73.3	72.9	73.8	75.1	75.5	73.4	71.2
22	73.5	73.1	73.1	72.6	72.7	72.9	73.0	73.0	74.9	75.8	74.3	71.0
23	71.9	71.3	72.3	72.2	73.2	73.2	72.8	74.9	75.7	75.7	73.7	71.7
24	70.7	71.2	71.5	71.7	72.0	71.7	72.7	74.3	76.0	75.2	72.9	70.9
25	71.7	71.6	71.7	72.1	72.2	72.6	73.0	75.4	77.1	75.8	72.7	70.7
26	72.4	72.4	72.0	72.3	73.7	72.8	72.6	73.3	74.9	75.5	73.9	72.0
27	72.6	72.6	72.7	72.2	72.7	72.7	73.0	75.0	76.8	76.9	75.2	72.7
28	72.8	72.5	72.1	72.5	71.7	73.0	74.6	75.5	76.1	75.7	76.0	73.6
29	72.1	72.6	72.0	72.4	72.3	72.7	73.5	75.0	76.5	75.4	74.4	72.7
30	72.2	72.1	71.6	71.7	71.9	71.8	71.9	72.8	74.7	75.7	74.0	72.2
31	71.8	71.8	71.7	71.0	71.9	71.8	71.9	72.0	72.9	73.7	72.8	72.1
Monthly mean	72.4	72.2	72.2	72.4	72.4	72.4	72.7	74.1	75.2	75.1	74.0	72.1
Normal	72.2	72.3	72.2	72.4	72.4	72.5	72.7	74.1	75.2	75.6	74.1	72.1

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794 Increasing scale readings correspond to increasing east declination.

DECEMBER, 1885.

Day.	13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
1	70.8	70.0	69.5	69.4	71.3	72.1	72.4	73.5	74.5	73.8	72.7	72.4	72.6
2	71.0	71.0	70.5	70.9	72.5	72.7	72.8	72.9	72.8	72.8	72.8	72.5	72.6
3	70.8	70.6	70.7	70.9	72.3	72.2	72.3	72.5	72.5	72.2	72.3	72.2	72.1
4	71.3	71.2	72.2	72.4	72.7	72.7	72.5	72.6	72.4	72.3	72.2	72.1	72.6
5	70.8	70.7	71.6	72.0	72.5	72.3	72.3	72.4	72.4	76.0*	74.0	72.9	72.6
6	70.3	70.9	71.9	72.1	73.2	73.3	78.8*	75.1	75.3	73.7	74.8	71.7	72.8
7	71.0	71.6	71.5	73.8	73.3	75.2	74.1	74.5	76.3*	74.1	74.2	72.7	72.6
8	70.5	70.2	70.8	71.8	74.8	74.2	74.8	72.6	74.6	73.3	72.4	70.8	72.1
9	69.9	70.2	71.4	71.8	73.3	74.0	73.4	73.3	73.7	73.0	72.7	72.2	72.8
10	71.0	70.3	70.9	72.0	72.7	73.3	73.3	72.7	72.6	72.9	72.2	72.2	73.0
11	70.3	70.1	71.2	72.2	72.5	72.9	72.9	72.8	72.7	72.6	72.2	72.0	72.4
12	70.9	70.5	71.1	72.2	73.0	73.3	73.2	73.5	72.9	72.8	73.5	72.5	72.9
13	71.2	71.2	71.3	72.4	73.0	73.4	73.6	73.3	73.1	73.2	72.7	72.4	73.2
14	69.6	69.7	70.4	72.1	73.0	72.8	73.7	73.7	73.2	73.3	72.6	72.4	73.0
15	70.2	69.9	69.9	71.2	72.7	73.0	72.8	73.0	72.8	72.6	72.6	72.4	72.7
16	71.0	70.6	70.7	71.7	73.0	73.2	73.1	73.0	73.0	72.7	72.4	72.3	72.6
17	71.5	70.8	71.3	72.3	73.0	72.7	73.3	72.6	72.6	72.7	72.7	72.7	72.8
18	72.8	72.3	72.0	72.3	73.0	73.5	73.5	73.6	73.7	73.3	72.8	72.7	73.4
19	71.0	71.0	71.2	72.2	72.9	74.1	73.3	73.0	72.9	74.9	72.9	73.1	72.8
20	71.7	71.3	71.0	72.3	73.5	73.7	74.0	75.4	73.9	73.3	75.2	74.1	73.6
21	71.0	71.8	72.2	73.3	74.2	72.7	74.7	74.1	73.8	73.3	73.0	73.2	73.3
22	70.5	70.3	71.1	71.8	72.4	72.7	72.6	72.3	72.0	71.6	71.4	71.3	72.5
23	71.1	70.2	70.5	71.6	72.3	72.4	72.6	72.3	72.1	71.4	71.2	70.9	72.4
24	70.8	70.6	71.0	72.3	73.0	73.5	73.1	73.1	73.7	72.9	72.2	72.1	72.5
25	69.9	69.8	70.4	72.0	72.7	73.2	73.4	73.6	73.5	73.2	73.2	72.7	72.7
26	71.4	71.1	70.9	72.2	73.0	73.1	72.7	72.9	72.7	72.7	72.7	72.7	72.8
27	71.3	70.3	70.4	71.2	72.5	72.5	72.4	72.7	72.4	72.7	73.0	73.8	72.9
28	71.7	70.0	71.8	72.2	72.5	72.7	72.7	73.7	72.3	72.5	72.5	72.3	73.0
29	71.7	70.8	70.3	71.3	72.2	71.7	72.2	72.4	72.5	72.6	72.7	72.5	72.7
30	72.2	72.3	71.0	71.1	71.7	72.2	72.3	72.3	72.3	72.1	72.1	72.1	72.4
31	71.6	71.4	71.1	71.8	72.3	72.3	72.9	73.2	72.8	73.1	72.8	73.0	72.3
Monthly mean	71.0	70.7	71.0	71.9	72.8	73.0	73.3	73.2	73.2	73.0	72.8	72.4	72.73
Normal	71.0	70.7	71.0	71.9	72.8	73.0	73.1	73.2	73.1	72.9	72.8	72.4	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

JANUARY, 1886.

Day.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
1	72.4	72.4	72.3	72.3	71.4	72.5	72.3	72.4	74.8	75.6	74.5	72.2
2	73.4	73.6	72.7	70.7	70.3	69.5*	73.5	72.7	74.0	75.0	74.8	72.6
3	72.1	73.2	70.0	71.6	70.8	71.6	71.6	72.0	75.1	76.2	75.9	74.3
4	71.3	71.7	71.1	71.5	70.3	70.0	70.6	72.5	74.8	76.8	75.1	72.7
5	71.9	72.4	72.0	70.7	71.0	73.8	73.2	74.2	74.4	76.0	75.0	72.5
6	73.2	73.7	72.7	72.8	72.8	73.2	74.3*	75.5*	76.8	76.0	72.9	70.9
7	72.2	72.2	72.1	72.1	72.2	72.8	73.5	75.1	76.7	76.8	74.5	71.7
8	72.1	72.1	72.2	72.7	73.0	73.3	74.2*	75.7*	77.0	76.7	74.5	71.3
9	70.8	83.2*	80.2*	70.1	76.0*	72.3	75.0*	74.8	73.3	75.0	71.8*	70.0
10	70.3	70.8	71.1	68.1*	71.9	73.1	70.5	76.5*	78.2*	77.5	75.2	72.7
11	70.9	70.9	71.1	71.7	71.9	72.1	71.0	73.1	74.8	77.5	76.7	73.5
12	72.3	72.3	72.3	72.1	72.2	72.9	74.5*	75.9*	78.3*	77.4	76.3	72.8
13	72.3	72.3	72.2	72.3	72.2	72.4	72.7	74.4	76.8	78.3*	77.7*	74.0
14	72.4	72.2	72.1	71.3	71.7	73.7	74.1*	76.0*	76.3	77.1	76.9	74.3
15	73.3	73.8	74.7*	73.2	73.7	69.2*	69.7	67.6*	74.4	75.8	75.7	73.3
16	73.0	73.7	68.8*	73.3	73.3	72.4	72.6	74.5	77.0	78.9*	77.7*	73.9
17	72.3	72.3	72.3	72.3	72.2	72.2	72.3	73.5	75.7	78.5*	78.2*	74.2
18	72.2	72.6	72.7	72.7	72.4	72.5	72.6	73.0	75.5	76.7	74.7	72.0
19	73.1	74.4	76.0*	78.7*	77.5*	73.9	70.0	68.3*	72.6	75.2	74.7	72.6
20	72.7	72.2	72.7	72.7	72.2	71.3	72.1	73.5	72.8	73.9	73.6	72.1
21	72.2	72.2	72.9	71.5	72.8	72.7	73.6	74.5	75.9	76.2	74.8	71.7
22	72.1	71.7	71.3	72.0	72.2	72.2	67.8*	69.0*	73.5	74.2	72.8	70.2
23	72.0	72.0	72.1	72.1	72.2	72.3	72.6	73.1	74.7	75.1	74.0	72.3
24	70.9	70.9	70.8	70.8	70.5	70.9	71.5	72.2	75.2	74.6	72.7	71.0
25	71.1	71.1	70.9	71.0	70.9	70.8	70.7	70.9	72.2*	73.7	74.2	72.2
26	70.6	70.7	70.2	71.3	69.1	70.7	70.0	71.0	72.7	74.3	74.7	73.0
27	70.7	71.0	69.2	71.7	71.0	70.9	70.8	71.5	72.6	73.3	73.0	72.0
28	70.7	70.0	69.7	68.9*	69.3	69.2*	69.2	70.4	72.2*	73.8	74.0	72.5
29	70.8	69.9	76.7*	71.6	69.0	67.8*	70.0	71.1	72.9	74.1	73.2	71.1
30	71.5	70.2	69.4	70.8	67.8*	66.7*	68.6*	69.6*	72.0*	73.6	73.7	72.7
31	71.0	69.8	70.3	69.4	69.4	69.6*	69.7	70.3	71.6*	72.3*	72.3	71.2
Monthly mean	71.9	72.3	72.1	71.7	71.7	71.6	71.8	72.7	74.7	75.7	74.7	72.4
Normal	71.9	71.9	71.5	71.7	71.5	72.2	71.5	72.6	74.8	75.5	74.5	72.4

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794 Increasing scale readings correspond to increasing east declination.

JANUARY, 1886.

Day.	13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
1	71.0	70.0	70.3	70.4	72.6	72.5	72.7	72.7	72.8	73.3	72.1	73.0	72.4
2	71.7	71.7	71.2	71.7	72.2	73.7	73.1	75.3*	72.3	72.7	72.7	72.6	72.6
3	72.7	72.6*	71.7	72.0	73.5	73.2	76.0*	72.7	72.6	72.3	73.6	70.6	72.8
4	72.2	71.3	71.6	71.6	72.6	72.7	72.8	72.8	73.0	72.3	71.7	70.0	72.2
5	71.7	72.0	72.1	72.8	74.0	74.0	73.7	73.7	73.4	74.0	73.2	73.4	73.1
6	70.8	71.4	71.7	72.3	73.2	73.3	73.7	73.3	73.7	72.3	73.0	72.1	73.2
7	69.9	70.0	70.5	72.1	73.0	72.9	72.8	72.7	72.5	72.5	72.5	72.2	72.7
8	70.3	70.7	71.7	72.0	72.6	72.9	73.6	73.8	73.0	73.6	73.9	72.1	73.1
9	66.4*	68.7	71.5	71.5	72.6	72.3	72.6	74.3	78.5*	75.0*	72.9	69.6	73.3
10	71.2	71.1	71.3	71.6	71.7	71.9	72.2	71.7	71.4	71.2	71.3	70.8	72.2
11	71.2	70.8	71.1	72.3	73.0	73.6	73.7	73.9	74.7	73.8	72.7	72.7	72.9
12	71.2	71.0	70.6	71.3	72.4	72.7	72.4	72.5	72.7	72.9	72.7	72.8	73.1
13	69.5	67.0*	67.5*	69.9	71.1	71.9	72.6	72.7	72.7	73.0	73.3	72.9	72.6
14	71.7	70.7	70.8	71.5	72.6	73.3	73.8	73.3	74.7	73.7	73.3	73.7	73.4
15	71.6	71.4	71.6	72.2	73.0	72.3	73.2	73.5	73.1	73.0	74.5	74.5*	72.8
16	71.5	70.7	70.5	71.4	72.4	72.6	72.6	72.3	72.3	72.2	72.2	72.2	73.0
17	70.2	69.0	69.9	71.1	72.6	72.9	73.0	73.1	72.7	72.7	72.6	72.5	72.8
18	71.7	71.7	72.1	72.1	72.9	73.1	73.4	73.3	74.6	72.9	72.9	72.7	73.0
19	70.2	69.2	69.1	70.6	70.1	70.2	72.0	72.1	72.5	71.9	72.3	72.2	72.5
20	70.9	70.0	69.5	70.0	71.5	72.7	72.5	72.5	72.3	72.3	72.3	72.4	72.1
21	69.8	68.4	69.5	70.8	72.0	72.2	73.1	72.6	73.4	73.9	72.2	72.2	72.6
22	68.7	69.2	68.7	70.7	71.5	72.1	72.5	72.3	72.7	72.0	71.6	71.4	71.4
23	70.0	68.8	69.7	70.3	71.2	71.9	72.2	72.4	71.7	72.0	71.6	71.1	72.0
24	69.6	68.5	68.1	67.9*	69.7	71.1	71.9	71.7	71.7	71.4	71.2	71.2	71.1
25	70.2	68.5	68.2	69.3	70.8	71.5	71.5	71.3	71.5	71.1	70.7	70.5	71.0
26	70.3	68.3	67.3*	68.5*	69.8	69.9*	70.2	70.9	71.7	71.9	71.3	71.2	70.8
27	70.2	68.2	65.9*	66.8*	68.4*	69.1*	69.8*	69.3*	70.0*	69.8*	69.4*	69.8	70.2
28	70.0	67.6	66.9*	66.8*	68.0*	69.6*	69.1*	68.6*	72.5	72.2	73.3	72.3	70.3
29	69.5	68.0	68.1	67.8*	69.8	72.7	70.1	70.3	71.4	71.0	72.3	71.0	70.8
30	69.8	69.3	69.0	70.0	69.8	73.0	69.3*	70.2	70.7	70.0	70.2	70.1	70.3
31	69.7	67.3	66.6*	67.3*	68.7*	69.7*	70.2	69.8*	69.8*	70.1	70.0	69.5	69.8
Monthly mean	70.5	69.8	69.8	70.5	71.6	72.2	72.3	72.3	72.7	72.4	72.2	71.8	72.13
Normal	70.6	69.8	70.4	71.3	71.9	72.5	72.5	72.5	72.6	72.4	72.3	71.7	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

FEBRUARY, 1886.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	69.9	69.8	69.9	69.7	70.1	69.9	69.9	71.3	72.7	73.6	72.6	71.2
2	69.3	69.3	69.1	69.8	69.2	69.0	69.2	69.2*	72.1	74.3	72.9	72.1
3	69.6	71.0	72.0	72.7	68.8	70.2	71.6	72.7	73.1	72.0	71.2	70.2
4	71.2	71.0	70.3	70.2	70.1	70.2	70.6	71.4	71.5	70.8	70.1	68.2
5	66.9*	71.5	70.7	70.5	66.2*	68.1	70.6	70.1	72.5	72.7	72.5	70.5
6	69.6	69.3	69.9	70.3	70.2	70.2	70.3	70.8	71.7	71.7	71.6	70.2
7	73.0	71.3	70.7	69.9	70.7	71.0	70.9	72.6	72.6	72.5	72.3	70.9
8	69.8	69.6	67.2*	69.7	71.2	70.8	70.3	70.7	71.6	72.3	71.9	71.3
9	69.9	70.2	70.2	70.2	70.2	70.3	70.7	71.8	72.8	73.5	72.6	71.1
10	76.5*	73.7*	70.4	69.7	68.1	68.7	70.7	72.9	73.8	73.7	72.2	70.9
11	70.2	72.3	67.0*	70.3	70.4	65.2*	64.7*	69.5	71.7	73.3	72.6	69.7
12	70.3	70.3	70.5	70.1	70.0	69.7	70.4	71.5	72.8	74.0	73.7	71.5
13	70.3	70.1	70.0	69.8	70.3	70.5	71.4	72.7	73.8	72.6	70.8	69.0
14	70.4	70.2	70.1	69.8	69.8	70.2	70.4	71.3	72.3	73.7	72.9	70.6
15	70.7	71.2	71.0	70.8	71.1	70.9	71.3	72.2	72.5	72.7	72.0	70.3
16	73.8*	72.7	70.7	72.2	71.4	71.0	72.4	72.8	71.7	71.7	70.2	67.4*
17	71.2	71.2	71.0	70.3	70.7	70.9	71.2	70.4	72.5	74.5	75.1*	72.9
18	72.3	70.6	70.3	71.0	69.5	68.7	69.8	71.5	71.6	70.7	72.2	70.9
19	69.8	70.6	70.3	71.7	69.7	70.0	68.6	68.7*	72.0	72.9	73.2	70.5
20	70.4	72.2	72.3	71.7	72.1	71.0	70.1	71.6	73.5	74.6	74.1	71.9
21	69.9	70.1	70.1	70.1	70.8	70.2	71.2	71.2	73.1	74.0	69.8	69.5
22	69.8	69.6	69.7	69.7	69.1	71.5	71.1	66.2*	67.7*	72.5	72.7	69.3
23	71.3	71.2	71.1	70.8	71.6	71.7	71.7	72.2	73.8	73.8	73.2	71.2
24	70.1	70.1	70.1	70.1	70.3	70.5	71.0	73.5	75.5*	74.0	71.7	70.7
25	72.2	72.3	72.6	71.7	71.1	71.0	71.1	72.7	74.0	74.6	72.7	70.3
26	71.7	71.1	71.2	72.3	72.7	72.1	72.7	72.8	74.1	73.9	72.7	71.3
27	70.7	72.0	73.1	71.8	71.9	71.7	71.9	72.3	72.3	71.2	71.0	70.4
28	70.1	70.2	70.3	70.3	70.7	71.4	72.0	72.2	71.0	70.3*	69.0*	67.8*
Monthly mean	70.8	70.9	70.4	70.6	70.3	70.2	70.6	71.4	72.5	72.9	72.1	70.4
Normal	70.5	70.8	70.7	70.6	70.4	70.4	70.8	71.8	72.6	73.0	72.1	70.6

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794 — Increasing scale readings correspond to increasing east declination.

FEBRUARY, 1886.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
1	69.0	67.1	67.9	69.0	69.7	70.0	69.9	69.8	69.4	70.0	70.0	70.4	70.1
2	68.7	69.1	68.1	69.2	70.5	70.9	70.9	70.9	70.7	70.3	70.7	70.7	70.3
3	69.8	69.8	70.0	70.2	70.2	70.8	71.0	70.7	70.9	70.1	69.9	72.6	70.9
4	69.0	69.7	69.2	69.2	70.2	70.8	70.7	70.1	70.0	70.1	70.2	77.3*	70.5
5	70.3	69.8	68.4	70.3	69.0	70.2	70.4	70.6	70.6	70.5	69.9	70.0	70.1
6	69.1	69.1	68.7	68.6	69.4	70.3	70.5	71.2	70.8	69.8	70.5	71.9	70.2
7	69.3	68.2	68.2	68.4	69.3	70.7	70.6	71.1	70.1	70.2	69.4	70.2	70.6
8	70.2	69.6	68.5	68.7	69.8	70.7	70.7	70.7	70.4	70.3	70.3	70.5	70.3
9	70.0	70.0	70.0	69.4	69.0	70.2	70.5	70.7	70.5	70.5	72.4	75.0*	70.9
10	70.2	69.3	69.0	69.1	69.5	69.9	75.2*	69.2	71.6	71.5	70.3	70.0	71.1
11	66.8	68.8	69.2	69.3	70.0	71.0	71.0	71.3	71.5	71.0	70.8	70.8	69.9
12	70.1	69.3	68.8	69.2	69.7	70.2	70.6	71.1	70.8	70.7	70.6	70.6	70.7
13	67.8	67.2	67.8	69.3	69.7	70.3	70.7	70.8	70.5	71.0	70.7	70.4	70.3
14	69.0	68.4	68.6	69.2	69.6	70.3	70.6	70.5	70.4	70.8	70.8	71.1	70.5
15	69.1	68.6	68.7	68.5	70.0	70.0	70.1	70.1	70.2	70.0	70.5	70.2	70.5
16	66.4*	65.4*	66.5	67.4	70.0	68.5	69.3	69.9	70.6	72.6	76.4*	73.3	70.6
17	70.7	68.7	68.7	69.1	69.3	70.0	70.8	68.7	69.7	69.7	70.3	71.1	70.8
18	69.3	69.2	69.1	69.0	68.2	69.8	71.7	68.5	69.7	69.9	69.6	69.7	70.1
19	70.3	66.9	66.1*	68.8	69.0	69.9	69.2	70.2	70.0	70.7	70.8	71.4	70.0
20	69.3	67.8	68.2	68.2	69.1	69.9	70.0	69.3	70.6	70.6	70.2	69.7	70.8
21	70.0	68.9	68.6	69.1	69.5	70.1	70.4	70.0	69.9	71.2	70.1	70.0	70.3
22	67.2	68.8	68.9	68.7	69.3	69.7	69.4	69.7	70.5	70.8	70.5	71.2	69.7
23	68.7	68.1	68.8	69.2	69.9	69.8	70.1	70.2	70.2	70.2	70.1	70.0	70.8
24	69.6	69.3	69.4	69.0	70.7	71.5	72.1	72.2	72.8	72.7	72.2	72.3	71.3
25	69.2	68.7	68.9	69.7	70.8	71.6	71.9	72.0	72.0	72.2	72.0	71.8	71.6
26	70.5	69.3	69.1	68.8	69.2	70.1	70.5	70.7	70.2	70.7	73.2*	71.7	71.4
27	70.0	70.2	70.9	70.3	69.7	70.0	70.2	70.2	70.2	70.1	70.1	70.1	70.9
28	66.9	68.1	69.1	69.2	68.8	69.8	70.3	70.2	70.7	69.9	69.9	69.8	69.9
Monthly mean	69.2	68.7	68.7	69.1	69.6	70.2	70.7	70.4	70.6	70.6	70.8	71.2	70.54
Normal	69.3	68.8	68.8	69.1	69.6	70.2	70.5	70.4	70.6	70.6	70.5	70.8	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

MARCH, 1886.

Day.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
1	70.6	70.4	70.6	70.8	70.8	71.2	71.3	73.2	74.5	73.1	70.8	67.4
2	70.2	70.9	71.0	71.1	70.9	71.0	73.0	76.3	77.8	76.5*	73.3	69.2
3	71.2	70.7	70.7	71.0	67.0*	72.5	73.5	74.2	76.9	73.7	70.5	67.5
4	70.1	68.8	69.8	70.0	70.0	70.5	72.2	74.8	75.3	75.7	72.7	69.2
5	70.0	70.0	70.1	70.1	69.9	70.2	70.8	72.6	73.9	74.7	73.1	69.7
6	70.7	70.6	70.8	70.1	71.7	71.8	71.2	72.2	77.0	73.9	70.7	67.9
7	71.0	72.3	73.1	69.2	69.3	69.7	70.5	71.3*	75.5	75.6	73.7*	70.2
8	69.3	69.9	70.3	70.5	70.7	70.7	72.4	73.7	75.5	76.6*	74.6*	71.1*
9	70.0	71.3	70.0	69.8	70.2	71.0	71.5	74.0	75.7	74.8	72.1	69.9
10	68.8	67.0*	70.7	69.3	70.9	72.3	73.6	74.7	74.1	73.3	71.0	68.3
11	70.5	71.1	71.0	70.7	71.2	72.0	72.5	74.0	75.1	74.1	71.1	68.7
12	70.3	69.9	70.2	70.2	70.7	70.8	72.1	73.0	75.5	75.8	74.0*	71.6*
13	70.3	70.1	70.0	70.7	70.2	70.3	71.9	73.1	73.3	72.5	71.0	69.4
14	70.5	69.7	70.1	70.4	70.4	70.7	71.3	73.0	74.7	74.2	72.2	69.7
15	70.3	71.0	71.0	71.0	70.7	71.1	72.5	74.5	75.8	74.3	72.1	69.7
16	71.2	71.2	73.3	71.7	72.9	71.8	70.8	70.9*	73.9	73.5	69.2	66.4
17	72.3	66.2*	71.0	71.7	68.3*	70.4	71.5	73.3	75.3	75.1	72.3	69.3
18	72.1	70.6	70.6	69.2	70.9	70.4	71.5	74.1	74.7	74.0	71.6	67.8
19	70.0	71.2	69.2	69.2	70.4	72.2	73.3	75.8	76.5	70.7*	66.3*	64.7*
20	65.2*	73.5*	71.7	71.7	73.1	73.7	76.7*	76.1	75.0	72.6	69.3	66.5
21	69.1	70.4	71.0	68.8	70.8	72.8	73.8	75.9	77.2	73.7	70.2	67.9
22	72.0	71.0	68.8	70.8	71.0	73.2	75.0*	75.9	73.9	71.9	69.1	67.2
23	69.1	70.5	71.2	72.0	74.7*	72.9	71.8	72.3	72.9	72.5	70.0	68.0
24	70.3	70.8	71.1	72.1	73.0	70.3	73.1	74.8	76.0	72.6	69.0	66.2
25	70.3	70.1	71.3	71.2	72.1	73.2	74.6	75.7	75.0	72.6	69.6	66.5
26	69.7	69.9	69.9	70.1	70.7	71.2	72.0	73.8	75.8	72.4	68.8	65.3*
27	70.9	70.2	70.8	67.7*	68.1*	71.0	73.6	74.7	74.7	73.7	70.2	66.0
28	70.0	70.2	70.9	71.2	71.1	72.8	71.8	76.1	76.0	72.9	71.9	69.7
29	72.2	71.0	73.0	71.2	71.8	73.0	75.1*	77.3*	77.2	74.1	72.0	68.6
30	60.2*	60.0*	82.1*	82.2*	80.5*	74.0	74.9*	79.6*	78.0*	70.1*	67.7*	64.2*
31	68.8	70.6	71.7	70.0	71.1	69.9	70.0	71.5*	73.6	72.5	69.7	66.8
Monthly mean	69.9	70.0	71.2	70.8	71.1	71.6	72.6	74.3	75.4	73.7	71.0	68.1
Normal	70.4	70.5	70.8	70.6	71.0	71.6	72.2	74.3	75.3	73.7	70.9	68.2

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794 Increasing scale readings correspond to increasing east declination.

MARCH, 1886.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
1	66.0	66.8	68.4	69.7	69.7	69.8	69.8	70.2	70.2	70.2	70.2	70.3	70.2
2	66.7	66.2	66.7	68.0	68.3	69.3	69.6	70.4	70.3	70.3	70.2	70.7	70.8
3	66.0	66.7	68.1	68.9	69.5	69.5	70.5	69.5	69.3	69.6	71.7	70.3	70.4
4	66.9	66.7	67.2	68.1	69.8	70.0	70.0	70.1	70.0	70.2	70.2	70.2	70.4
5	67.7	66.7	66.7	68.1	70.2	70.3	70.7	71.0	70.9	70.8	70.6	71.3	70.4
6	67.3	68.4	67.2	69.7	69.6	69.4	70.3	70.3	71.9	70.0	70.5	71.2	70.6
7	68.7	68.4	70.4*	70.3	70.4	70.6	70.5	70.3	70.3	70.5	71.6	70.6	71.0
8	69.0	68.6	68.2	68.7	68.9	69.0	69.3	69.3	69.7	69.6	69.7	69.5	70.6
9	67.8	67.2	67.7	68.7	69.2	69.3	70.2	72.5	71.0	69.0	68.2	68.8	70.4
10	67.8	67.3	68.1	69.6	70.2	70.2	70.7	71.1	70.7	70.6	70.5	70.5	70.5
11	66.8	65.8	65.8	67.0	68.8	69.8	70.2	70.2	70.0	70.0	70.3	70.1	70.3
12	69.5*	67.5	66.5	67.3	68.0	69.3	69.6	69.6	70.0	70.3	70.1	71.6	70.6
13	68.5	67.8	67.3	68.4	68.7	68.8	69.4	69.7	69.9	70.3	70.2	70.4	70.1
14	67.5	66.6	66.8	67.7	69.2	69.6	69.8	69.7	69.9	70.7	70.3	70.3	70.2
15	67.3	66.7	67.5	67.5	67.1	67.7	68.7	69.8	70.2	71.3	72.9	71.6	70.5
16	65.3	64.3	63.6*	64.3*	66.2*	66.7*	68.6	70.2	69.7	71.5	71.0	72.5	69.6
17	66.3	66.7	67.6	68.8	69.0	67.7	67.7	69.7	70.3	71.6	71.1	71.5	70.2
18	66.0	65.8	66.5	66.6	67.2	68.0	69.2	70.0	70.4	75.4*	72.0	70.4	70.2
19	64.2*	66.5	64.8	68.0	67.4	65.8*	70.3	73.2*	72.8*	71.9	72.2	65.3*	69.7
20	66.0	67.6	69.0	69.5	69.5	69.2	69.4	69.0	68.7	69.2	70.7	70.3	70.6
21	66.4	65.8	66.4	65.5*	70.7	69.4	69.2	70.0	70.3	70.2	68.7	69.5	70.2
22	65.3	63.8*	64.2*	67.9	69.2	68.4	69.8	69.2	69.0	70.9	69.5	72.0	70.0
23	67.0	66.1	67.5	69.1	70.2	70.6	70.1	70.0	70.0	72.2	69.9	70.1	70.4
24	64.8	64.8	66.4	68.0	69.7	70.1	70.0	69.0	69.2	70.2	69.4	71.1	70.1
25	64.1*	63.8*	64.7	66.6	69.0	69.0	70.1	69.8	70.7	69.3	69.6	69.6	69.9
26	62.5*	63.0*	64.8	66.5	67.2	68.7	69.2	69.2	70.6	71.6	71.2	71.2	69.4
27	63.4*	63.7*	64.8	66.1	67.1	67.9	68.5	68.9	69.0	70.1	69.8	70.2	69.2
28	67.8	67.7	67.1	67.9	68.8	71.0	70.2	70.7	70.9	71.2	71.8	72.2	70.9
29	66.2	66.1	66.4	67.9	70.1	70.2	70.9	70.6	70.2	70.8	69.8	69.1	71.0
30	64.2*	61.8*	67.1	72.5*	67.8	70.8	68.8	80.0*	70.9	70.4	70.4	69.6	71.2
31	66.0	64.1	63.8*	67.2	68.3	72.7*	72.5*	71.1	74.7*	70.7	66.4*	71.7	69.8
Monthly mean	66.4	66.1	66.7	68.1	68.9	69.3	69.8	70.5	70.4	70.7	70.4	70.4	70.30
Normal	66.8	66.6	66.8	68.1	69.0	69.4	69.7	70.0	70.1	70.5	70.5	70.6	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

APRIL, 1886.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	69.8	62.6*	70.0	70.3	70.3	71.1	72.7	73.4	74.0	72.9	69.6	68.0
2	70.2	69.2	71.9	71.0	70.7	71.5	73.6	75.5	77.1*	75.6*	72.5*	68.5
3	71.2	71.1	71.0	70.7	70.1	71.0	73.8	75.1	75.2	72.0	69.7	68.1
4	70.2	70.7	71.1	71.0	71.2	72.6	75.3	76.7	78.2*	76.3*	72.1*	69.3
5	69.6	70.2	70.5	70.6	70.9	72.6	74.6	76.2	73.9	71.2	70.3	68.4
6	70.7	71.1	71.3	71.5	72.2	72.9	75.1	76.0	75.2	71.9	69.5	67.5
7	74.2*	73.7*	73.8*	72.6	72.6	73.5	74.9	76.2	73.3	70.8	69.1	68.4
8	70.0	70.2	70.5	70.7	71.7	72.9	75.3	75.1	74.2	72.2	70.8	70.0
9	69.8	70.1	70.2	70.5	70.7	72.2	73.7	74.5	72.5	70.1	68.6	67.6
10	69.5	69.7	69.9	70.5	71.1	73.1	76.0	76.2	73.7	70.8	68.8	68.7
11	69.3	69.7	70.0	70.3	71.2	73.2	76.0	77.0	77.0*	73.4*	70.0	69.0
12	70.8	74.1*	73.6*	70.9	70.9	73.8	74.8	74.2	73.3	65.8*	65.0*	66.5
13	70.7	74.3*	74.1*	73.1	72.1	73.2	71.6*	69.0*	69.3*	68.8	67.7	67.5
14	71.2	71.7	78.0*	74.7*	74.5*	74.7	72.9	72.8	74.0	70.5	68.1	65.7
15	72.9*	70.7	72.7	73.0	74.7*	74.9	74.2	74.8	72.6	69.8	67.9	68.7
16	71.8	69.5	71.8	71.9	70.5	72.7	74.1	73.0	70.5*	69.0	67.6	67.5
17	69.2	71.0	70.9	70.7	71.6	73.5	74.9	75.1	73.8	70.7	66.2	65.3
18	71.9	70.3	71.9	71.0	74.2*	69.2*	72.6	72.2*	71.9	70.3	65.4*	64.8*
19	69.8	70.5	71.3	72.7	71.6	71.2	73.3	73.3	72.0	70.2	66.6	64.3*
20	71.0	71.6	70.9	71.5	71.9	72.7	73.8	75.0	72.7	70.2	67.6	66.3
21	69.9	69.9	70.4	70.9	72.2	72.5	74.6	73.7	73.5	71.7	68.7	65.6
22	70.4	70.2	70.5	71.8	72.3	72.9	73.8	75.2	73.6	71.2	68.6	66.6
23	70.5	70.6	71.1	71.6	72.3	73.7	74.4	74.5	72.4	69.8	68.2	68.3
24	70.4	70.2	70.7	71.0	71.7	73.3	74.6	75.5	73.7	70.1	66.9	66.2
25	69.1	69.8	70.0	71.8	71.7	74.5	76.0	77.2	75.7	72.4	69.0	67.6
26	69.7	69.7	69.9	69.6	70.0	71.7	72.2	73.1	73.5	69.5	67.2	67.8
27	69.3	69.3	70.7	70.2	72.7	72.7	73.7	74.2	72.3	69.3	68.9	68.7
28	70.0	70.1	70.1	70.8	72.0	73.8	76.0	76.3	73.1	69.7	67.5	67.3
29	69.8	69.7	70.2	71.0	71.8	74.0	75.8	76.2	74.3	71.8	70.7	69.7
30	70.0	70.0	70.3	70.3	71.5	73.4	74.5	76.0	74.0	70.7	67.2	65.9
Monthly mean	70.4	70.4	71.3	71.3	71.8	72.8	74.3	74.8	73.7	71.0	68.5	67.5
Normal	70.2	70.3	70.8	71.2	71.5	73.0	74.4	75.1	73.5	70.7	68.5	67.7

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794 Increasing scale readings correspond to increasing east declination.

APRIL, 1886.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
1	67.9	68.0	69.1	69.0	70.7	71.4	69.6	70.9	70.9	70.5	67.8	70.7	70.0
2	66.4	65.7	66.8	68.6	70.3	70.2	69.8	69.9	70.1	70.2	70.3	70.9	70.7
3	67.3	66.9	67.8	68.8	70.0	69.3	69.3	69.3	69.4	69.3	69.7	70.1	70.3
4	67.4	66.3	67.2	67.9	69.2	69.2	69.5	69.2	69.3	69.7	70.2	71.4	70.9
5	67.4	67.3	67.6	68.6	69.6	70.7	70.7	70.7	70.7	70.7	71.5	71.2	70.6
6	67.3	67.7	67.8	68.0	70.2	70.4	70.5	70.4	70.7	70.1	70.7	72.6	70.9
7	67.6	67.6	68.0	68.1	69.0	69.6	70.4	71.2	70.1	69.8	69.7	69.9	71.0
8	68.5	67.2	67.8	68.1	69.1	69.7	70.0	70.0	69.8	69.7	69.7	69.7	70.5
9	66.5	66.4	66.7	67.2	68.2	69.2	69.5	69.6	69.4	69.4	69.3	69.3	69.6
10	68.7	67.4	68.4	68.5	69.0	69.2	69.2	69.1	69.1	69.0	69.1	69.1	70.2
11	66.7	65.7	65.1	67.4	67.7	67.1	67.1	68.2	74.2*	70.1	70.0	71.8	70.3
12	67.7	66.2	66.4	67.6	67.5	69.7	67.3	74.3*	71.3	70.7	69.7	69.7	70.1
13	67.7	67.4	66.8	67.7	68.7	69.6	67.7	68.3	77.8*	75.8*	72.7*	71.6	70.6
14	66.1	68.5	67.4	71.6*	69.3	70.5	75.0*	76.7*	73.5*	70.7	65.2*	75.7*	71.6
15	68.0	67.5	68.8	67.7	69.3	70.0	71.1	70.9	68.9	68.2	70.5	71.5	70.8
16	68.6	68.3	69.6	69.7	69.3	69.8	69.7	68.7	70.1	68.1	70.6	69.6	70.1
17	64.9	64.1*	65.6	66.9	68.5	68.4	68.6	71.2	73.3*	70.2	70.2	71.2	69.8
18	63.1*	66.0	65.3	68.8	67.9	67.0	68.7	68.9	69.2	69.3	74.2*	70.7	69.4
19	62.7*	63.9*	64.9	65.7	68.7	69.3	69.2	68.9	69.1	71.7	70.2	72.2	69.3
20	66.6	64.7	64.3*	67.2	68.3	74.3*	70.5	67.8	71.7	68.7	70.3	69.8	70.0
21	64.7*	64.2*	65.5	67.6	71.1	68.9	68.9	70.5	69.5	69.1	69.5	68.9	69.7
22	66.8	66.7	67.1	68.7	69.2	69.0	69.4	69.7	69.5	69.5	69.2	70.3	70.1
23	68.7	68.1	69.3	69.6	69.0	68.3	68.5	68.8	69.2	69.6	69.6	69.8	70.2
24	66.0	66.3	67.2	66.4	68.5	68.2	67.9	68.1	68.7	71.2	72.4	69.1	69.8
25	67.2	66.8	67.7	68.3	68.7	68.5	68.7	68.6	68.7	68.8	69.2	69.7	70.2
26	69.3	69.0	68.3	68.0	68.3	68.2	68.8	69.2	68.7	69.2	69.2	69.3	69.6
27	68.2	67.6	68.2	69.2	69.5	69.5	69.9	69.3	69.6	70.0	70.7	70.7	70.2
28	68.2	67.5	67.5	67.9	69.3	69.3	69.0	68.7	69.2	69.4	71.5	70.7	70.2
29	68.9	68.4	68.4	69.3	69.3	71.6	68.6	68.6	69.5	69.5	70.2	70.9	70.8
30	66.2	66.7	67.5	68.2	68.3	69.3	70.2	76.2*	68.6	68.5	68.6	69.3	70.1
Monthly mean	67.0	66.8	67.3	68.2	69.1	69.5	69.4	70.1	70.3	69.9	70.1	70.6	70.25
Normal	67.4	67.1	67.4	68.1	69.1	69.4	69.2	69.4	69.7	69.7	70.0	70.4	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

MAY, 1886.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	71.2	73.2*	71.9	71.1	73.7	74.2	76.3	77.3	73.9	70.5	66.5	65.0
2	69.7	69.0	72.0	72.3	71.4	73.7	75.3	72.3*	74.0	70.7	65.9	65.3
3	69.1	69.2	69.0	69.7	68.1*	72.1	74.5	75.0	74.5	70.2	69.4	67.5
4	69.7	68.3	68.7	70.7	71.0	72.3	72.6*	73.3	72.0	68.7	67.2	66.4
5	69.1	68.9	69.7	70.1	71.2	72.6	74.6	75.2	72.8	71.3	68.7	65.9
6	69.7	70.1	70.2	71.0	72.7	73.6	76.2	77.3	74.6	72.1	68.6	66.5
7	69.1	69.6	70.0	70.3	70.6	72.7	74.9	74.9	72.5	69.5	67.5	67.0
8	69.7	70.0	70.2	70.3	72.1	73.5	76.5	76.8	75.0	71.0	66.9	61.9*
9	76.2*	74.0*	68.4	71.8	72.7	74.3	74.0	73.5	68.7*	66.4*	66.5	66.7
10	70.7	70.2	71.9	72.7	67.9*	72.8	73.1	71.2*	70.2*	67.8	67.1	66.7
11	69.0	66.0*	68.3	70.8	72.6	74.3	74.1	74.6	73.1	69.4	67.7	68.0
12	70.7	70.1	68.8	70.6	72.1	73.3	73.7	74.6	70.3*	68.0	66.6	65.0
13	69.9	68.0	72.5	71.0	71.0	72.2	75.2	75.2	72.6	71.4	67.6	66.0
14	69.3	71.2	72.3	73.6*	71.2	73.5	74.1	70.7*	70.5*	69.7	68.2	66.7
15	71.4	71.6	72.3	72.5	73.2	73.4	74.8	74.1	72.3	70.5	69.7	68.3
16	70.8	69.3	70.3	70.7	72.2	74.8	77.7	77.3	75.3	71.7	68.5	65.8
17	70.3	71.2	73.4*	75.6*	75.3*	76.9*	79.8*	78.2*	75.4	70.8	66.0	63.8
18	73.2*	72.2	70.6	69.8	71.6	74.7	77.1	76.4	74.8	68.4	65.4	64.7
19	68.7	69.3	69.8	69.7	71.3	73.1	75.8	76.6	73.3	71.6	67.8	64.3
20	69.7	69.3	71.2	72.2	73.5	74.9	78.0	78.9*	78.1*	73.1*	67.8	65.9
21	72.5	71.3	73.8*	72.7	74.2	75.5	77.6	79.7*	72.3	67.7	64.6*	64.2
22	69.7	70.2	70.2	70.3	70.9	73.8	75.3	78.0*	74.0	70.9	67.8	66.0
23	70.0	70.2	70.6	71.0	71.8	73.3	74.7	73.2	71.0	69.2	67.1	66.5
24	69.7	71.3	70.7	71.5	73.2	75.2	76.0	76.0	73.9	71.3	66.1	66.9
25	70.1	69.8	70.3	70.8	71.0	72.5	74.8	74.1	71.8	69.0	67.7	67.0
26	70.2	70.0	69.2	71.4	71.2	74.3	76.9	76.8	75.5	69.6	69.4	68.2
27	72.2	71.3	71.7	71.3	68.2*	75.7	76.6	79.8*	72.5	67.5	66.9	66.6
28	69.7	70.0	70.1	69.1	71.5	73.7	75.7	75.6	72.6	68.8	65.6	66.0
29	68.7	72.0	71.3	70.7	72.2	75.2	76.5	76.1	72.8	70.3	67.5	67.0
30	69.7	69.7	70.2	70.7	71.2	72.0	72.9*	73.3	72.9	71.7	67.8	65.6
31	69.7	68.7	70.2	71.5	72.1	74.5	76.7	76.2	73.1	70.2	67.2	65.3
Monthly mean	70.3	70.2	70.6	71.2	71.7	73.8	75.6	75.6	73.1	70.0	67.3	66.0
Normal	70.0	70.1	70.4	71.0	72.0	73.7	75.6	75.4	73.4	70.0	67.4	66.2

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0.′794 Increasing scale readings correspond to increasing east declination.

MAY, 1886.

Day.	13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
1	66.2	67.1	68.2	68.9	69.6	70.3	70.6	71.1	73.6*	71.7	71.3	70.1	71.0
2	66.6	67.8	68.2	69.5	70.2	70.2	70.5	70.6	70.2	70.2	71.0	70.9	70.3
3	67.1	65.9	67.2	67.7	68.2	70.7	69.7	68.1	67.6	67.9	68.7	70.6	69.5
4	66.8	66.5	67.1	67.7	68.9	69.1	69.0	68.3	68.0	68.2	68.3	69.2	69.1
5	65.4	64.9	65.7	66.6	68.3	69.0	69.2	68.0	68.1	68.2	68.5	69.1	69.2
6	65.7	65.8	67.0	68.2	69.5	69.3	69.3	69.4	69.0	68.5	69.1	68.9	70.1
7	66.7	66.7	67.5	68.7	69.7	69.7	69.3	69.2	69.2	69.3	69.4	69.6	69.7
8	61.2*	57.8*	57.2*	61.0*	57.5*	61.8*	64.0*	60.7*	73.9*	75.2*	73.1*	70.7	67.8
9	65.9	67.3	66.2	65.8*	68.1	67.6	68.3	73.4*	70.3	68.7	68.3	70.1	69.7
10	67.5	67.6	68.0	67.4	68.5	68.9	*74.2*	70.4	70.3	70.1	72.0	70.1	69.9
11	66.5	67.6	66.7	67.1	67.0	70.3	70.4	69.1	69.7	68.9	71.7	70.2	69.7
12	66.1	67.3	68.2	69.5	69.4	69.0	69.5	71.0	71.3	70.3	69.8	69.7	69.8
13	67.9	68.1	68.3	69.3	69.6	72.3*	71.6	70.3	72.2*	70.1	70.3	71.0	70.6
14	66.5	66.3	67.6	67.2	69.2	67.3	67.7	71.3	69.3	69.3	66.4*	72.3	69.6
15	67.7	66.0	68.0	68.7	70.3	69.3	69.2	71.2	69.7	69.3	70.0	70.2	70.6
16	65.3	66.3	66.2	67.2	69.2	70.0	69.6	68.9	68.7	69.9	71.0	70.1	70.3
17	61.5*	64.0*	65.3	68.9	69.3	72.3*	69.0	72.5*	68.0	69.3	69.2	67.3*	70.6
18	64.3	66.4	68.4	68.7	70.5	69.8	69.2	69.1	70.1	69.3	67.4	69.0	70.0
19	64.7	66.7	67.3	68.7	70.2	70.8	70.2	69.2	69.0	69.2	69.3	69.7	69.8
20	65.4	65.9	66.8	68.8	69.5	68.9	69.3	70.7	72.7*	71.9	71.2	70.3	71.0
21	62.9*	65.7	67.0	69.2	70.3	70.7	69.7	72.2	70.6	69.7	70.3	70.2	70.6
22	66.2	67.2	68.3	69.5	70.0	70.9	70.8	69.9	70.2	69.7	69.6	70.0	70.4
23	65.5	66.1	66.7	67.8	69.3	69.3	69.2	69.1	69.0	69.5	70.7	70.8	69.6
24	67.2	68.3	68.3	69.2	69.3	69.3	69.3	69.7	69.8	69.3	69.6	70.2	70.5
25	66.9	67.8	69.5	69.7	69.7	70.3	69.4	69.8	69.4	69.7	69.8	69.8	70.0
26	67.8	68.0	68.1	68.6	69.1	69.7	71.6	70.3	69.3	69.1	69.7	69.7	70.6
27	66.0	66.8	68.1	67.9	67.7	67.8	68.6	69.1	69.1	69.2	69.7	69.6	70.0
28	65.7	66.4	67.7	69.5	70.8	70.8	69.3	70.9	72.4*	70.6	69.7	69.9	70.1
29	67.6	67.6	67.9	68.3	69.5	70.0	70.5	69.1	69.1	69.4	73.0*	71.4	70.6
30	65.9	67.1	68.3	69.6	70.6	70.3	69.7	69.0	69.7	70.1	69.7	68.7	69.8
31	65.6	65.7	66.3	67.9	69.1	69.7	69.9	69.6	69.8	70.0	69.9	70.5	70.0
Monthly mean	65.9	66.4	67.1	68.2	69.0	69.5	69.6	69.7	70.0	69.7	69.9	70.0	70.02
Normal	66.3	66.8	67.5	68.5	69.4	69.6	69.6	69.8	69.4	69.6	69.8	70.1	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

JUNE, 1886.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	71.1	71.2	70.6	71.6	71.5	72.6	75.0	75.6	74.1	72.0	67.3	65.4
2	69.8	69.9	70.1	70.5	71.2	73.2	74.9	74.9	72.8	70.2	68.1	66.0
3	70.2	70.0	70.0	70.2	72.2	73.9	75.5	76.2	74.8	70.8	70.3	68.4
4	73.1*	72.0	72.0	73.2	74.2	74.2	76.1	74.8	72.2	69.7	67.7	65.3
5	69.3	67.8	71.8	74.8*	72.4	75.2	77.1	77.0	72.9	70.8	68.2	64.4
6	70.2	70.1	70.0	70.5	72.4	74.7	73.2	75.3	74.3	73.3	70.2	69.1*
7	69.6	69.3	67.8*	70.8	72.2	74.1	76.1	73.8	72.6	70.3	68.4	66.5
8	70.1	70.5	70.9	71.6	69.1*	74.1	74.7	75.7	74.3	72.5	69.6	67.3
9	70.1	69.9	70.2	70.7	71.7	73.1	74.2	74.2	74.3	70.7	66.8	65.0
10	70.0	70.1	69.8	70.9	72.3	73.8	75.5	76.0	74.2	70.8	66.9	65.1
11	69.7	69.7	70.1	70.7	71.7	72.8	73.5	73.1	71.6	70.7	67.8	66.8
12	72.2	71.2	71.7	71.9	74.9*	77.0*	75.7	75.3	67.8*	69.7	67.1	65.3
13	70.3	70.8	71.2	71.6	71.7	74.3	75.0	75.1	72.7	68.6	66.8	65.5
14	70.0	68.5	71.5	72.1	72.6	73.0	74.2	73.1	71.0	69.7	66.5	64.6
15	70.6	72.5	73.9*	71.7	71.2	72.7	73.7	72.8	71.2	70.1	68.1	67.2
16	70.1	70.3	70.6	70.8	71.3	72.8	74.0	74.5	72.3	70.5	67.7	65.8
17	72.0	71.5	72.3	72.5	73.2	74.7	76.0	75.2	74.1	72.3	70.1	69.2*
18	70.6	70.2	70.2	71.7	73.1	72.2	75.2	75.5	74.4	72.7	69.2	67.8
19	70.2	70.1	69.7	70.1	71.6	74.7	75.5	76.3	74.0	71.8	69.6	67.7
20	69.6	70.1	70.3	71.0	71.4	72.3	73.9	75.6	74.6	71.2	69.7	69.1*
21	70.0	69.9	70.1	70.6	72.4	73.7	74.7	73.2	72.7	70.3	67.2	65.0
22	70.0	70.5	70.9	70.6	71.0	73.7	73.8	75.8	73.7	70.7	67.8	64.4
23	69.3	69.7	70.2	71.5	72.5	74.1	74.1	70.9*	71.1	69.8	69.5	68.2
24	70.4	70.1	69.5	69.0	72.0	74.8	76.2	74.9	74.4	69.7	68.5	68.3
25	69.2	69.2	70.9	71.9	72.3	74.4	75.8	74.6	73.5	71.9	69.2	68.0
26	70.8	72.3	70.5	70.3	71.7	74.0	75.0	72.6	71.8	69.6	68.6	69.5*
27	70.8	70.3	69.7	71.1	70.3	73.8	75.1	74.3	69.6*	66.8*	64.8*	64.6
28	70.7	68.6	70.8	71.6	72.7	74.7	76.7	76.1	73.7	70.8	68.7	66.7
29	70.1	69.8	69.4	70.0	71.8	74.2	76.5	77.6*	77.5*	72.5	67.3	67.0
30	72.4	71.0	72.2	70.3	75.0*	77.6*	79.2*	76.8	76.3*	71.0	67.2	65.3
Monthly mean	70.4	70.2	70.6	71.2	72.1	74.0	75.2	74.9	73.2	70.7	68.1	66.6
Normal	70.3	70.2	70.6	71.1	72.0	73.8	75.1	74.9	73.2	70.9	68.3	66.2

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794

Increasing scale readings correspond to increasing east declination.

JUNE, 1886.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
1	64.5	63.9	65.7	68.0	69.3	70.3	70.2	69.9	72.0	70.3	70.0	69.7	70.1
2	65.1	65.8	67.0	68.8	70.1	70.2	70.2	69.9	70.1	70.9	70.5	70.1	70.0
3	68.2	67.8	68.4	69.0	69.5	69.5	68.8	68.5	68.4	69.2	70.4	72.1	70.5
4	64.2	64.7	65.7	65.8*	66.7	67.7	74.8*	67.1*	68.5	69.6	69.3	68.8	69.9
5	63.9	64.0	65.1	64.6*	68.0	69.7	69.1	67.5	68.7	69.0	69.8	70.1	69.6
6	67.3	65.3	66.9	66.7	68.2	69.8	74.8*	72.0	71.0	71.0	70.7	68.3	70.6
7	65.0	64.7	66.0	67.1	66.2*	67.7	70.3	69.3	68.5	72.2	71.5	69.2	69.6
8	66.1	65.3	65.8	66.7	67.3	70.2	69.9	68.7	70.2	70.7	69.8	70.7	70.1
9	66.0	66.5	67.6	68.9	69.6	69.7	69.6	69.3	69.8	69.7	69.5	69.8	69.9
10	64.8	65.5	66.9	67.4	68.3	68.2	69.8	72.2	69.3	68.9	68.8	69.7	69.8
11	67.8	69.3*	69.9*	69.7	69.2	68.7	68.2	67.8	68.2	68.9	72.7	75.1*	70.2
12	62.4*	64.8	66.8	67.7	68.2	69.7	69.7	70.9	70.1	69.2	69.8	68.0	69.9
13	64.3	66.9	67.8	68.0	68.2	68.7	71.1	71.8	71.2	69.6	70.6	68.7	70.0
14	64.5	66.1	67.9	69.0	69.6	69.2	70.1	69.3	69.3	69.7	71.0	72.2	69.8
15	66.3	66.6	68.2	69.0	69.7	69.9	69.5	70.5	69.6	69.5	69.6	70.1	70.2
16	64.2	65.2	66.5	68.1	68.5	69.3	68.3	69.7	69.1	72.0	71.6	70.2	69.7
17	67.6	66.6	66.6	67.5	68.8	70.4	69.5	68.7	69.5	72.2	74.2*	70.6	71.0
18	67.7	67.2	68.3	68.8	68.8	69.0	68.8	69.7	70.1	69.7	69.4	69.7	70.4
19	67.1	66.2	66.9	68.7	69.3	69.7	70.2	69.7	69.3	69.2	69.6	69.5	70.3
20	68.1	67.4	67.8	68.9	70.1	70.3	69.4	69.2	68.0	68.7	69.3	69.7	70.2
21	63.9	64.4	65.0	66.2	67.3	67.9	68.9	70.7	71.5	70.0	77.2*	71.7	69.8
22	63.2*	66.9	69.7*	70.2	71.3	71.0	71.2	69.7	70.3	70.1	69.2	69.4	70.2
23	68.0	67.7	67.7	69.5	70.7	70.9	68.1	68.1	69.5	69.7	71.0	70.7	70.1
24	67.0	66.8	68.7	69.2	69.7	70.8	71.1	74.8*	72.0	70.7	70.1	69.2	70.8
25	69.1*	69.8*	69.3	70.2	69.2	73.3*	70.3	72.0	70.7	69.3	69.1	70.1	71.0
26	69.9*	69.0*	67.9	67.9	68.9	69.9	68.9	72.2	69.7	72.1	71.8	71.2	70.7
27	65.2	66.0	67.1	68.9	69.4	69.3	69.3	68.7	69.5	72.0	71.0	71.0	69.5
28	66.7	68.0	69.2	69.3	69.7	69.5	69.1	69.2	69.9	69.3	70.2	70.1	70.5
29	68.1	65.8	65.3	66.4	69.2	67.6	72.4*	71.3	72.3	70.2	68.7	70.3	70.5
30	65.3	64.5	66.7	66.7	68.0	68.2	69.6	70.4	71.7	69.4	72.9*	70.1	70.7
Monthly mean	66.0	66.3	67.3	68.1	68.9	69.5	70.0	70.0	69.9	70.1	70.6	70.2	70.18
Normal	66.0	65.9	67.1	68.3	69.0	69.4	69.6	69.9	69.9	70.1	70.2	70.0	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

JULY, 1886.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	68.2	67.5*	70.8	72.2	72.4	74.3	78.2	77.1	76.4	71.3	68.6	65.9
2	70.6	70.6	69.8	70.0	71.8	74.5	78.8*	77.2	74.5	69.8	67.1	65.8
3	69.4	69.3	69.9	71.0	70.9	74.5	76.1	77.8	75.2	72.2	66.5	65.1
4	70.8	70.4	70.7	72.0	71.8	74.0	76.7	78.8	76.7	70.8	68.2	67.0
5	70.2	70.2	69.7	71.0	72.2	73.2	75.3	75.8	74.5	70.1	66.8	64.5
6	69.8	69.7	70.7	70.1	72.0	74.1	74.8	76.2	74.8	71.1	68.1	65.2
7	70.0	70.4	70.8	70.9	71.9	73.2	75.0	76.3	75.2	72.2	69.3	67.2
8	70.9	71.9	72.2	72.3	73.7	75.1	77.1	76.8	75.7	73.5	70.3	67.2
9	70.9	71.3	72.2	72.2	75.2*	75.2	77.0	79.4*	72.9	71.9	69.7	67.9
10	72.9*	70.0	72.8	72.2	72.8	74.7	76.2	79.0*	76.0	72.2	68.2	65.1
11	67.7	70.2	70.2	71.1	72.2	73.8	74.8	75.2	74.7	70.5	67.0	66.0
12	70.3	70.5	71.0	71.9	72.9	75.2	76.3	77.2	75.1	70.0	67.5	65.0
13	70.3	70.6	71.0	71.2	72.0	73.9	75.0	75.0	73.4	69.8	67.3	67.0
14	70.6	70.9	70.3	69.1	73.5	74.2	76.1	71.0*	70.3*	67.0*	65.7*	63.6*
15	69.6	70.5	72.4	72.2	72.1	75.0	75.3	74.1	72.1*	70.7	69.6	69.2*
16	72.5*	70.0	72.2	72.7	74.5	74.4	76.3	76.6	75.8	69.8	66.7	65.3
17	69.9	70.3	70.5	71.8	70.6	73.4	75.1	74.7	74.0	71.3	67.9	65.5
18	70.8	70.3	71.3	72.3	73.5	75.0	76.6	74.6	73.8	71.0	68.4	66.8
19	69.7	69.6	69.2	69.3	71.7	71.9	72.9*	75.5	76.2	73.8*	68.4	65.5
20	70.8	69.5	69.7	71.0	69.7	70.4*	76.8	76.3	75.4	73.2	71.5*	69.3*
21	68.2	67.8	69.3	71.8	71.0	73.0	73.4	75.4	75.5	72.0	68.8	67.5
22	69.4	68.9	69.2	70.8	70.9	73.2	75.4	78.0	76.6	74.5*	70.3	69.0*
23	68.8	70.5	72.1	72.3	71.6	73.6	75.5	76.8	75.6	72.3	70.0	67.9
24	70.0	70.4	70.2	71.0	71.8	73.3	74.2	75.5	73.2	69.1	67.2	64.9
25	70.2	70.5	68.5	70.3	71.5	72.7	75.6	77.8	76.5	71.7	68.8	66.7
26	69.9	69.8	70.2	70.5	71.3	74.2	76.6	76.6	72.9	69.1	67.8	67.2
27	71.8	71.8	70.8	72.5	72.8	75.9	78.8*	78.5	76.1	71.0	70.2	65.5
28	66.9*	71.8	72.2	73.9	72.7	74.7	76.6	76.7	76.0	72.2	69.7	68.5
29	69.8	70.4	71.2	72.0	72.3	74.9	77.3	76.4	74.3	71.0	67.7	65.6
30	68.3	70.2	71.3	72.2	72.9	73.9	74.8	76.1	73.8	70.3	68.2	66.1
31	70.2	70.7	72.3	72.5	72.8	74.5	75.4	76.7	75.9	70.7	68.9	67.7
Monthly mean	70.0	70.2	70.8	71.5	72.2	74.0	75.9	76.4	74.8	71.2	68.4	66.5
Normal	69.9	70.3	70.8	71.5	72.1	74.1	75.8	76.4	75.1	71.1	68.4	66.3

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794

Increasing scale readings correspond to increasing east declination.

JULY, 1886.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
1	64.1	65.0	67.1	68.3	70.3	70.2	69.3	69.2	69.8	69.8	70.6	75.8*	70.5
2	66.0	65.8	65.8	67.2	68.2	69.6	69.4	69.8	69.7	70.8	69.9	69.4	70.1
3	64.3	64.8	67.1	67.8	69.3	69.7	69.3	68.7	69.3	69.4	69.5	69.9	69.9
4	65.6	65.3	65.1	66.5	68.1	69.0	69.1	68.2	68.8	69.9	70.9	70.3	70.2
5	62.2*	63.2*	64.8	67.9	69.3	68.8	68.8	68.6	69.0	69.3	69.3	69.4	69.3
6	64.3	64.6	66.0	68.1	69.5	69.9	69.5	69.6	69.9	69.7	69.9	69.8	69.9
7	66.3	65.5	67.2	69.1	69.7	69.5	70.0	69.2	69.0	69.6	69.5	69.7	70.3
8	65.9	65.0	66.1	69.1	70.1	70.3	69.5	69.2	69.2	69.5	70.2	71.0	70.9
9	66.1	64.2	67.1	68.8	69.2	69.3	69.2	69.0	69.2	69.6	69.8	70.2	70.7
10	64.1	64.5	66.1	67.5	68.7	68.5	69.0	68.0	69.2	68.2	68.1	69.1	70.1
11	65.2	65.2	65.2	67.9	69.2	68.5	68.6	68.3	68.2	70.3	70.3	69.4	69.6
12	64.7	65.0	65.8	67.3	68.4	69.0	68.3	68.5	71.3	71.9	71.2	70.1	70.2
13	67.4	68.0	68.2	68.1	68.4	67.7	67.8	69.0	68.3	68.2	68.7	69.1	69.8
14	64.8	64.7	66.7	69.3	70.1	69.6	68.8	69.1	68.4	69.1	69.6	69.8	69.3
15	68.8*	69.1*	69.1	69.1	69.6	70.6	70.9	71.6	70.5	70.4	73.3*	73.7*	71.2
16	66.6	67.6	69.2	70.2	70.6	70.5	70.2	71.2	71.0	70.3	70.7	69.9	71.0
17	64.7	65.4	66.4	68.4	69.7	70.1	71.1	70.6	69.8	71.0	69.9	70.0	70.1
18	64.6	65.2	67.0	66.0	67.0	66.6*	67.0*	68.7	68.8	69.9	70.5	70.9	69.9
19	65.5	65.6	65.8	68.4	69.3	69.3	70.0	70.3	68.0	70.1	68.8	69.4	69.8
20	68.0	67.1	68.0	70.4	70.4	71.3	73.5*	72.0*	78.0*	70.2	70.4	70.0	71.4
21	66.1	67.2	68.3	70.0	71.8	72.4*	70.2	70.9	72.2*	72.3	72.8*	71.7	70.8
22	66.5	66.0	66.5	67.8	69.0	69.7	71.1	71.0	74.9*	75.3*	77.8*	72.2	71.4
23	65.6	65.4	66.4	68.0	70.8	70.4	70.0	70.3	70.5	69.8	70.2	70.0	70.6
24	64.8	65.8	67.6	67.4	68.2	69.3	69.3	68.9	69.2	69.2	69.3	69.8	69.6
25	66.2	67.1	68.0	69.4	69.8	70.1	68.8	68.5	69.2	69.7	69.7	69.8	70.3
26	68.1	68.3	68.2	68.3	69.4	69.3	69.1	68.9	69.6	69.8	70.5	72.8*	70.4
27	66.8	65.7	64.8	60.3*	61.3*	62.3*	64.4*	68.5	73.5*	70.3	71.6	70.2	69.8
28	68.2	68.3	68.7	68.3	69.3	69.3	70.2	68.2	68.1	71.2	69.7	70.6	70.9
29	65.9	67.7	69.5	70.2	71.0	69.8	70.3	70.1	69.8	70.7	69.7	68.8	70.7
30	67.5	67.9	68.1	68.2	69.2	69.3	69.3	69.6	69.2	69.6	69.3	69.8	70.2
31	67.3	68.3	69.6	70.4	70.3	69.3	70.6	69.2	69.0	69.5	70.0	70.1	70.9
Monthly mean	65.9	66.1	67.1	68.2	69.2	69.3	69.4	69.4	70.0	70.2	70.4	70.4	70.31
Normal	65.9	66.1	67.1	68.4	69.5	69.6	69.6	69.4	69.3	70.0	69.9	70.0	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

AUGUST, 1886.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	70.5	70.7	71.5	71.5	72.3	74.5	76.6	76.0	75.5	68.8	66.4	65.8
2	72.1	72.0	71.2	71.2	72.9	75.8	76.2	77.1	73.8	71.0	69.1	68.5
3	69.7	70.2	71.1	71.1	72.3	73.8	75.8	76.2	74.0	70.9	67.8	66.1
4	70.0	70.2	70.7	71.2	71.7	74.4	75.1	77.0	74.2	70.2	66.5	66.0
5	70.4	70.6	70.5	72.1	72.8	74.5	76.8	77.3	74.4	70.6	67.9	66.5
6	69.9	70.6	71.8	73.1	73.6	74.5	77.7	77.9	73.8	72.7	69.4	67.7
7	70.7	71.0	71.7	72.5	71.6	75.1	76.7	79.2	73.8	69.8	68.0	65.9
8	70.4	70.7	70.8	71.6	71.9	73.8	77.3	77.1	73.2	69.2	65.9	65.0
9	70.3	71.0	70.8	71.6	72.3	73.8	75.5	75.3	71.7*	69.2	67.3	67.2
10	70.6	70.7	71.3	70.8	70.8	73.4	76.1	76.3	75.3	72.3	69.3	68.2
11	70.5	70.2	71.4	72.9	72.5	72.3	75.9	78.7	76.2	72.2	70.7*	67.6
12	70.3	71.8	78.9*	78.1*	70.8	70.8*	71.2*	77.0	76.7	71.5	67.2	67.9
13	70.5	68.8	68.1*	71.2	71.8	74.2	74.7	76.5	75.4	73.5	71.6*	70.3*
14	76.2*	70.6	71.2	70.9	72.3	75.2	77.3	78.2	75.7	72.4	69.8	68.3
15	69.3	71.2	66.6*	71.1	72.2	74.5	74.3	78.4	76.4	71.5	66.0	63.2*
16	71.5	70.8	70.0	71.1	73.7	76.0	75.6	74.0*	71.1*	67.5*	64.5*	65.6
17	72.2	69.4	69.9	69.4	70.5	75.3	77.7	77.3	75.6	71.5	67.7	65.5
18	66.9*	69.5	70.9	69.5	72.0	73.3	75.5	76.7	75.1	72.3	69.5	66.8
19	67.5*	73.4*	72.8	68.5*	70.5	75.1	75.0	77.2	76.2	70.7	68.5	67.9
20	70.5	70.4	71.0	70.4	70.1	75.1	76.9	77.0	74.5	70.3	68.0	65.9
21	71.0	71.2	70.9	72.8	72.2	75.0	76.6	75.2	73.6	72.0	69.3	69.1
22	70.7	70.6	70.2	71.0	71.8	73.5	75.9	76.7	74.9	72.1	69.5	67.6
23	70.8	71.0	71.7	71.9	72.1	74.0	76.2	77.8	75.8	73.6	71.2*	68.1
24	69.7	70.0	72.0	72.3	73.0	74.3	75.2	75.1	74.1	71.1	69.3	68.1
25	70.4	70.4	70.9	71.2	71.9	72.8	73.7*	74.5*	73.2	70.0	67.8	67.1
26	69.4	69.1	70.7	72.1	72.2	74.1	76.8	76.2	70.3*	67.5*	65.2*	64.8
27	70.2	68.7	69.7	71.8	72.3	74.5	77.9	78.4	75.2	71.8	68.7	66.6
28	71.6	71.0	71.6	72.2	72.3	74.7	78.5	76.9	70.5*	67.7*	66.1	65.6
29	70.5	71.6	70.7	72.0	72.4	74.3	77.4	77.3	75.1	72.1	69.6	67.9
30	70.7	71.0	71.7	72.1	73.0	76.2	79.6*	81.2*	76.2	70.8	67.2	65.0
31	70.7	71.3	71.7	72.3	73.2	75.5	78.1	78.5	73.6	67.7*	65.1*	65.8
Monthly mean	70.5	70.6	71.1	71.7	72.1	74.3	76.2	77.0	74.4	70.8	68.1	66.8
Normal	70.5	70.5	71.0	71.6	72.1	74.4	76.4	77.1	74.8	71.3	68.1	66.8

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794 — Increasing scale readings correspond to increasing **east declination.**

AUGUST, 1886.

Day.	13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
1	65.0	66.1	67.0	67.8	68.7	69.0	69.6	70.5	70.0	69.4	71.7	71.1	70.2
2	68.6	69.1	69.8	70.1	70.8	69.7	68.9	68.5	69.1	69.2	69.5	69.6	71.0
3	65.8	65.9	67.3	69.1	69.9	70.1	69.7	69.7	69.7	69.8	70.2	69.9	70.2
4	66.8	67.9	69.1	69.7	69.7	70.0	69.5	69.3	72.2	70.2	70.2	70.4	70.5
5	65.8	66.5	67.4	68.5	68.8	69.2	68.7	69.0	69.0	69.6	69.0	69.4	70.2
6	67.7	66.5	67.2	68.8	69.3	69.7	69.4	69.7	70.7	69.8	70.1	70.7	70.9
7	64.5	64.1*	67.0	67.8	68.9	68.5	69.6	69.7	69.2	70.9	70.7	70.2	70.3
8	65.3	66.9	68.2	69.0	69.7	69.1	68.7	69.2	69.4	69.6	69.8	70.2	70.1
9	67.9	68.2	68.8	69.6	69.5	69.5	69.2	69.7	69.3	69.8	69.8	70.4	70.3
10	67.9	67.8	68.8	70.2	70.4	70.3	69.8	70.2	71.9	72.1	71.3	70.9	71.1
11	65.4	66.0	64.0*	67.8	68.7	69.6	68.3	69.0	76.3*	73.7*	70.3	70.1	70.8
12	66.5	67.5	67.8	69.3	69.8	70.1	71.3	70.8	69.8	70.5	69.7	69.7	71.0
13	68.8	67.7	69.8	71.3	70.4	71.9	72.3	78.9*	69.2	71.6	70.7	73.5*	71.8
14	67.9	69.2	70.0	71.2	71.7	73.2*	79.1*	73.6*	71.0	70.9	71.2	68.3	72.3
15	64.6	66.7	68.2	70.3	72.1	71.1	71.1	84.3*	71.9	71.5	71.3	72.5	71.3
16	65.6	67.0	68.2	70.2	73.5*	72.8*	71.3	71.0	70.9	69.7	71.5	71.5	70.6
17	66.4	68.1	67.0	69.4	71.1	72.1	71.0	73.9*	71.8	70.1	70.8	70.3	71.0
18	65.2	66.2	66.8	68.5	70.6	71.5	72.4	70.7	70.9	72.3	72.5	71.7	70.7
19	68.1	69.2	70.8	71.4	71.3	70.5	70.4	70.5	74.2*	71.5	70.6	70.9	71.4
20	66.0	67.3	69.2	70.4	70.7	70.3	70.9	70.4	71.1	72.4	73.5*	71.0	71.0
21	68.7	69.3	69.9	70.2	70.5	69.7	71.8	71.2	70.3	70.4	70.1	70.8	71.3
22	67.0	67.3	68.4	69.6	69.9	70.3	70.9	70.8	70.4	71.2	70.3	70.2	70.9
23	66.2	66.2	67.2	66.2*	66.3*	72.7*	69.5	70.5	82.0*	71.1	74.6*	71.6	71.6
24	67.8	68.0	69.8	70.1	69.7	69.3	72.8	70.3	69.3	69.4	70.1	69.6	70.8
25	66.7	67.0	69.4	69.4	68.8	69.1	69.7	69.7	69.4	69.3	70.9	70.2	70.2
26	65.7	67.2	69.5	70.2	70.1	70.0	69.8	69.8	69.8	71.0	69.7	69.9	70.0
27	65.3	65.8	67.8	70.8	70.9	69.8	70.3	70.0	69.7	70.0	70.2	70.7	70.7
28	66.8	68.6	70.1	70.6	70.8	70.0	69.4	69.6	69.5	70.0	70.2	70.4	70.6
29	66.9	67.6	69.0	70.3	70.7	70.3	70.0	69.7	70.2	70.2	69.8	70.2	71.1
30	65.6	67.1	69.7	70.8	71.0	70.7	70.3	70.4	70.2	70.3	70.1	70.5	71.3
31	66.0	66.9	69.8	71.2	70.9	69.7	69.5	69.9	69.8	69.9	70.2	70.3	70.7
Monthly mean	66.5	67.2	68.5	69.7	70.2	70.3	70.5	71.0	70.9	70.6	70.7	70.5	70.84
Normal	66.5	67.4	68.6	69.8	70.2	70.0	70.3	70.0	70.2	70.5	70.4	70.4	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

SEPTEMBER, 1886.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	70.7	71.0	71.6	72.5	73.5	74.5	77.2	77.3	75.0	70.4	67.3	66.3
2	71.3	71.3	71.7	72.3	73.5	75.2	77.1	79.7*	77.3*	73.2	68.0	65.1*
3	71.2	71.6	71.7	72.2	73.2	75.0	78.8*	79.1*	76.0	73.0	69.8	67.7
4	70.5	71.0	71.3	71.7	72.5	75.1	77.7	78.9*	77.8*	74.5*	71.0	69.1
5	71.1	71.7	72.3	72.2	72.2	74.2	76.2	76.[illegible]	72.4	69.3	67.6	67.1
6	70.8	70.9	71.2	71.8	72.0	73.9	75.7	76.2	74.2	71.7	69.4	68.7
7	70.8	71.1	71.4	71.5	72.2	74.2	77.3	77.2	74.5	69.5	67.1	66.0
8	71.2	71.8	71.7	71.7	73.3	75.0	76.9	76.9	74.2	69.7	68.0	66.1
9	71.9	72.3	73.8	72.5	73.8	75.4	79.2*	76.5	70.3*	64.2*	65.1*	62.8*
10	75.7*	66.6*	65.6*	76.8*	69.1*	75.3	76.8	77.4	72.7	67.7*	65.4*	65.0*
11	72.3	66.7*	71.8	69.5	73.4	75.3	78.0	76.2	71.6	69.6	68.4	67.1
12	71.3	67.3*	75.7*	72.0	71.9	73.5	74.2	75.5	71.6	69.6	68.4	67.7
13	69.1	70.7	70.2	70.3	70.9	75.2	73.7	74.0	75.2	72.0	70.3	69.2
14	70.0	72.3	69.7	68.7*	71.1	73.5	77.0	77.2	75.4	72.5	70.5	68.7
15	69.6	71.3	71.0	71.1	70.9	73.8	75.8	76.0	74.8	71.9	68.9	67.0
16	70.7	70.9	70.8	71.5	72.2	72.6	75.8	77.2	75.1	70.5	68.3	65.7
17	71.5	72.3	70.9	71.5	74.0	74.0	76.7	75.0	73.7	71.2	69.5	68.5
18	71.5	71.7	71.2	72.3	72.5	73.6	75.7	77.1	76.2	74.1*	71.9*	70.0
19	71.1	71.3	71.7	72.3	73.1	73.9	75.4	75.5	73.9	70.8	69.8	69.1
20	70.8	70.7	71.6	71.7	73.3	73.2	74.2	74.1	71.8	70.4	68.7	67.7
21	72.3	75.7*	75.5*	74.0	73.0	75.1	73.0	70.5*	72.0	71.6	70.6	69.1
22	70.9	72.0	72.0	70.7	71.2	72.7	73.4*	74.6	73.5	71.9	70.6	69.6
23	71.2	71.5	71.7	71.7	71.3	73.3	74.2	74.3	74.0	72.3	70.8	70.3
24	70.8	70.9	71.0	71.2	71.9	73.2	73.1*	73.3*	72.3	69.0	67.8	67.9
25	71.3	71.1	72.8	72.2	72.2	73.6	74.6	74.1	73.8	71.7	69.3	67.6
26	71.2	71.2	71.5	71.8	72.1	73.6	74.8	74.8	74.1	73.3	70.9	69.1
27	71.7	72.1	72.2	72.4	72.8	73.8	75.2	75.3	74.2	71.9	69.0	66.5
28	71.7	72.2	71.7	72.2	72.7	74.0	75.3	76.0	73.7	68.6	65.7*	65.5
29	71.2	72.1	72.8	72.9	72.7	73.4	75.3	75.8	74.2	69.7	67.0	66.7
30	72.6	72.8	73.6	72.6	73.2	75.7	77.0	76.1	73.3	68.8	67.2	67.8
Monthly mean	71.3	71.2	71.7	71.9	72.4	74.2	76.0	75.9	74.0	70.8	68.7	67.5
Normal	71.1	71.6	71.6	71.9	72.5	74.2	76.0	75.9	73.9	70.9	69.0	67.8

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794 Increasing scale readings correspond to increasing east declination.

SEPTEMBER, 1886.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
1	65.2	64.6*	66.6*	68.8	70.3	70.7	70.2	70.2	70.0	70.4	71.1	70.8	70.7
2	64.2*	65.0*	66.8*	68.9	70.2	70.3	70.1	70.2	70.2	70.3	70.7	71.6	71.0
3	66.1	64.7*	65.7*	66.7*	67.8*	69.8	70.1	70.2	72.3	70.3	70.7	70.8	71.0
4	67.3	66.2	66.6*	67.7*	69.2	69.7	69.7	69.7	69.8	70.6	70.6	70.8	71.2
5	67.7	69.2	69.8	69.5	69.5	69.2	69.7	69.7	69.9	70.3	70.4	70.7	70.8
6	69.2	69.6	70.1	70.6	69.9	69.3	69.7	70.0	70.2	70.3	70.5	70.5	71.1
7	66.8	68.5	69.3	70.3	70.8	70.9	71.1	70.7	72.2	72.1	70.9	71.2	71.2
8	67.1	67.8	69.2	69.7	70.6	69.8	70.3	70.3	70.8	72.4	70.3	72.2	71.1
9	66.7	67.6	68.0	71.2	71.6	70.8	69.7	72.2	77.2*	75.4*	76.3*	77.3*	71.7
10	66.1	68.3	72.8*	70.3	70.9	77.2*	70.8	71.7	72.2	71.4	73.5*	63.1*	70.9
11	69.2	70.3	70.9	76.4*	72.6	70.7	73.0	71.8	75.9*	74.1*	72.8	69.5	72.0
12	68.8	69.4	71.8	72.3	71.7	73.5*	75.4*	77.3*	73.3	72.3	71.2	71.1	72.0
13	70.0	70.4	70.5	71.7	73.5*	75.5*	75.2*	72.5	71.3	71.7	74.0*	73.6*	72.1
14	67.5	67.9	70.0	71.7	71.7	72.7	72.3	71.4	70.0	72.8	67.4*	72.2	71.4
15	67.2	68.4	69.9	71.2	71.9	70.9	70.7	71.2	71.6	70.6	70.0	70.3	71.1
16	66.8	68.2	69.8	70.7	71.0	70.6	70.2	70.2	71.5	71.4	70.7	69.2	70.9
17	67.9	68.5	69.5	69.7	70.3	70.8	72.4	70.3	70.3	70.3	70.6	71.2	71.3
18	69.0	69.7	70.2	70.7	70.7	70.6	70.9	71.2	71.2	70.8	70.8	70.9	71.8
19	69.3	69.7	70.8	71.3	71.0	70.3	70.4	70.4	70.4	70.6	71.1	71.0	71.4
20	68.2	69.1	69.8	70.4	69.0	70.4	67.2*	68.8	69.7	70.0	70.3	71.1	70.5
21	68.6	66.9	69.2	72.2	70.5	70.0	70.4	71.8	75.2*	71.5	71.2	70.6	71.9
22	68.7	69.2	68.6	70.6	69.7	70.3	70.2	70.4	70.9	70.7	70.9	70.9	71.0
23	69.6	68.3	69.7	69.9	70.0	70.0	71.2	71.4	70.7	70.5	70.6	70.6	71.2
24	67.6	69.4	70.6	70.9	70.8	70.4	70.5	70.5	70.5	70.4	70.9	70.9	70.7
25	67.2	67.7	69.0	69.7	70.3	70.2	70.2	70.1	70.2	70.3	70.5	70.7	70.8
26	68.6	69.1	69.9	70.4	70.4	71.2	70.3	70.6	70.7	70.8	70.9	71.2	71.4
27	66.0	67.4	69.2	69.9	70.8	70.3	70.7	70.3	70.3	70.4	70.7	71.1	71.0
28	66.9	68.7	69.6	70.8	70.5	70.1	70.2	70.4	70.4	70.4	70.3	70.5	70.8
29	67.7	66.2	71.2	71.6	71.1	70.4	70.0	70.3	70.3	72.5	71.7	70.7	71.2
30	67.7	69.7	70.4	72.3	73.8*	71.2	71.6	71.7	71.2	71.0	70.9	71.7	71.8
Monthly mean	67.6	68.2	69.5	70.6	70.7	70.9	70.8	70.9	71.4	71.2	71.1	70.9	71.23
Normal	67.7	68.6	69.9	70.6	70.6	70.4	70.6	70.7	70.9	71.0	70.8	70.9	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

OCTOBER, 1886.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	71.1	71.3	72.2	72.2	72.6	73.8	75.7	76.7	74.6	72.1	69.1	67.2
2	70.5	70.8	70.8	71.2	71.9	73.0	74.8	76.3	73.5	69.2	68.5	67.1
3	70.8	70.8	71.3	71.2	71.6	72.8	75.1	74.7	73.3	72.6	70.3	69.1
4	70.7	71.0	71.1	70.8	71.4	72.0	72.8	75.0	75.3	73.7	71.5	69.1
5	71.0	71.3	71.4	71.1	71.2	72.0	72.7	73.3	72.3	71.0	70.2	69.2
6	72.2	75.2*	77.0*	71.7	72.2	72.9	70.7*	70.7*	73.3	69.4	67.8	66.7
7	70.7	73.7*	71.3	67.0*	71.7	70.7	72.0	71.7*	69.7*	67.5*	63.3*	64.2*
8	74.0*	73.1	72.1	64.5*	66.7*	67.7*	71.8	68.1*	66.6*	69.4	65.9*	68.0
9	68.7	71.0	71.2	73.2	67.9*	70.7	74.5	75.5	74.2	73.0	68.8	68.2
10	66.3*	69.8	69.8	70.3	70.7	70.7	69.9*	72.5	74.1	72.2	67.1	65.8
11	68.3	68.8	71.1	67.7*	72.0	73.0	74.9	74.8	73.7	72.2	70.1	68.5
12	67.8*	72.7	75.1*	73.3	72.7	72.7	73.5	72.2	71.0*	70.8	69.2	67.8
13	71.6	69.8	71.8	72.5	71.2	72.2	73.3	73.7	71.4	67.2*	65.8*	66.1
14	70.8	71.6	70.3	71.6	73.3	73.7	74.7	74.3	70.7*	69.1	67.9	68.1
15	70.4	71.7	71.9	71.2	71.9	73.4	72.8	74.2	73.6	69.6	67.1	66.3
16	71.0	71.7	72.3	72.0	72.2	73.6	74.5	75.7	73.6	71.3	68.2	67.3
17	71.3	73.7*	72.3	73.9*	72.2	73.2	72.8	74.8	74.2	72.7	69.2	68.3
18	70.8	70.3	70.9	71.7	71.3	71.9	72.3	79.3*	72.2	70.2	69.8	66.5
19	74.8*	76.7*	71.1	71.2	71.4	72.2	72.2	72.9	73.0	72.2	70.5	68.8
20	71.1	71.1	71.3	71.4	71.4	72.1	74.0	74.6	74.6	71.3	69.7	68.6
21	72.3	70.4	71.5	71.6	71.6	72.3	72.5	76.1	74.5	71.6	69.4	67.8
22	71.7	70.7	71.2	70.3	71.2	71.7	73.9	76.1	74.5	71.1	68.7	66.7
23	70.8	70.6	70.8	69.2	71.2	72.4	73.9	74.8	73.6	71.3	69.2	67.5
24	71.0	70.8	70.9	71.2	71.6	71.8	73.1	74.9	74.4	72.5	69.4	67.4
25	70.4	70.7	70.0	70.9	70.9	71.5	72.7	73.9	72.3	70.4	68.8	67.8
26	69.9	70.0	70.2	70.6	71.3	71.9	73.7	74.8	72.8	67.6*	65.3*	64.6*
27	70.3	70.2	69.9	71.5	72.6	74.0	75.0	79.0*	73.4	72.3	69.3	67.8
28	69.7	66.5*	70.7	71.6	71.5	72.1	74.1	75.1	74.8	72.6	71.0	67.7
29	69.8	70.7	70.6	70.7	72.3	72.8	74.1	75.5	72.5	72.6	70.8	68.6
30	68.8	69.8	70.9	70.5	70.3	69.8	71.8	74.7	74.6	73.6	71.4	69.4
31	70.4	70.7	70.4	71.0	71.3	71.8	73.0	74.7	75.1	73.7	71.9	69.8
Monthly mean	70.6	71.2	71.4	70.9	71.4	72.1	73.3	74.5	73.1	71.2	68.9	67.6
Normal	70.6	70.8	71.1	71.3	71.7	72.3	73.5	74.7	73.7	71.6	69.4	67.8

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale =0′.794 Increasing scale readings correspond to increasing east declination.

OCTOBER, 1886.

Day.	13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
1	67.6	68.7	69.8	70.4	69.7	70.7	70.4	70.7	71.0	70.8	70.7	70.7	71.2
2	68.1	68.2	69.6	70.8	70.2	70.3	72.2	70.4	70.6	70.4	70.5	70.7	70.8
3	68.5	68.0	68.7	69.2	69.7	70.2	70.7	70.7	70.9	70.8	70.7	70.7	70.9
4	68.5	68.3	69.4	69.2	69.4	69.8	70.3	70.5	70.6	70.5	70.3	70.7	70.9
5	68.2	68.7	69.3	69.1	69.6	70.2	70.7	70.2	72.1	70.7	71.5	73.0	70.8
6	65.8	66.5	72.9*	67.8	71.2	70.0	71.7	70.2	73.7	78.5*	74.5*	70.2	71.4
7	67.6	66.4	70.3	69.7	70.3	71.0	73.3	75.2*	76.5*	72.2	76.2*	69.2	70.5
8	69.2	72.1*	70.9	72.5	78.3*	75.4*	71.8	72.2	72.3	68.5	66.7*	73.1	70.4
9	69.7	69.0	68.9	72.3	70.2	71.2	72.0	73.1	72.7	71.7	71.6	74.3*	71.4
10	66.8	70.9	70.9	74.0*	72.7	70.4	71.4	72.5	72.2	70.8	69.6	71.2	70.5
11	68.4	69.3	70.3	70.9	70.5	71.9	70.8	73.2	70.8	70.4	70.6	70.3	70.9
12	67.7	69.4	70.5	70.9	71.3	70.5	71.0	70.6	71.3	70.3	71.3	70.6	71.0
13	67.1	68.7	70.2	70.7	71.5	70.0	71.3	71.7	71.2	69.4	70.4	71.0	70.4
14	68.5	70.2	70.8	71.0	70.7	71.9	70.5	70.5	71.3	70.5	70.2	70.8	71.0
15	67.3	69.2	70.8	71.7	71.1	70.8	71.2	72.2	71.5	70.8	70.9	71.3	71.0
16	68.2	69.5	70.7	71.2	70.7	70.8	70.8	70.8	70.7	70.4	71.1	69.1	71.1
17	67.9	68.7	69.7	69.8	69.8	70.3	70.3	70.6	70.5	70.6	70.1	70.8	71.2
18	65.1*	68.1	67.6	70.5	69.3	70.0	71.1	73.3	71.5	71.7	77.6*	78.8*	71.3
19	68.8	70.0	71.1	71.8	71.8	71.6	71.6	71.5	71.4	71.2	71.1	71.1	71.7
20	67.8	68.8	69.5	70.2	70.6	70.7	71.1	71.2	71.1	71.2	70.9	71.0	71.0
21	67.7	67.7	69.8	69.3	70.3	71.3	71.4	71.3	72.2	71.7	71.6	70.9	71.1
22	66.0	67.7	68.9	69.8	70.2	70.0	70.7	70.2	70.3	70.3	70.2	70.7	70.5
23	67.7	69.2	69.8	70.4	70.4	70.4	70.5	70.7	70.8	71.0	70.5	70.6	70.7
24	66.8	68.3	69.6	69.7	69.3	69.7	69.6	69.5	69.5	69.7	69.9	69.7	70.4
25	67.7	69.2	70.0	70.1	70.1	69.8	69.7	69.5	69.3	69.4	69.5	69.6	70.2
26	64.5*	67.7	69.8	70.3	70.4	70.7	70.6	70.3	69.9	69.7	69.6	70.4	69.9
27	67.6	66.7	68.9	69.7	69.5	71.0	70.9	70.9	74.2*	72.9	67.2*	69.8	71.0
28	66.2	67.2	69.4	69.7	70.2	71.8	73.7*	72.1	71.6	71.2	70.2	69.8	70.8
29	67.8	68.3	68.9	69.8	70.2	71.2	71.2	71.3	71.2	70.7	70.6	70.9	71.0
30	68.5	68.1	68.9	69.4	70.3	70.7	71.3	70.9	73.0	70.7	70.8	70.7	70.8
31	69.0	69.3	68.8	69.3	70.2	70.7	70.7	70.7	71.2	70.9	70.7	70.7	71.1
Monthly mean	67.6	68.6	69.8	70.4	70.6	70.8	71.1	71.2	71.5	71.0	70.9	71.0	70.87
Normal	67.8	68.5	69.7	70.2	70.4	70.7	71.0	71.1	71.3	70.7	70.6	70.7	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

NOVEMBER, 1886.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	70.6	70.4	70.4	70.7	71.0	71.7	73.2	75.2	75.6	74.1	71.3	70.0
2	71.0	70.7	73.0	71.5	73.9	72.2	74.1	74.1	69.9*	70.9	65.9*	64.9*
3	71.0	71.1	71.2	70.1	70.4	70.6	70.3	70.2*	69.5*	69.1*	69.6	68.8
4	69.0	68.2*	70.8*	68.9*	67.9*	61.4*	69.4*	70.1*	74.3	71.9	70.0	69.8
5	70.3	69.3	69.2	71.2	68.9*	67.4*	69.9	70.4*	71.3	68.0*	68.9	69.2
6	70.9	70.2	69.8	70.4	69.1	65.8*	70.3	68.2*	67.6*	69.5*	69.4	68.4
7	68.0*	69.4	70.2	68.3*	70.4	70.3	70.8	71.3	72.9	71.6	70.9	69.5
8	70.1	72.1	71.8	71.1	72.0	72.8	73.0	74.1	73.6	71.0	69.5	67.9
9	69.2	70.0	72.0	71.5	72.4	73.0	74.1	75.0	73.9	71.1	70.6	69.9
10	70.0	71.4	70.8	71.9	71.9	72.1	72.8	74.0	74.0	71.8	69.4	68.1
11	71.1	71.1	71.7	71.2	71.4	71.0	73.2	74.0	71.9	72.2	71.0	69.8
12	73.0	72.5	71.1	72.8	72.9	72.5	73.8	74.0	74.9	71.0	70.6	68.9
13	72.9	72.0	72.4	72.5	70.9	70.3	72.8	71.2	72.1	71.0	69.7	69.4
14	70.9	71.1	71.3	71.5	72.2	72.4	73.1	75.1	75.2	73.8	70.9	69.6
15	71.6	71.8	73.8	72.2	73.4	73.0	74.0	75.2	74.9	73.8	71.1	70.0
16	71.2	71.2	71.9	71.3	72.0	72.0	72.7	74.5	74.4	73.0	71.0	69.5
17	70.9	70.6	71.6	72.6	70.2	72.7	73.8	75.0	73.8	73.2	70.6	67.8
18	71.5	71.3	71.2	71.2	71.7	72.1	72.8	74.2	74.1	73.4	72.2	71.0
19	71.8	71.3	71.5	71.5	71.2	72.0	72.8	73.9	74.1	73.8	72.3	69.6
20	74.0*	70.4	71.8	73.3	71.5	72.3	73.8	73.2	73.8	72.6	70.9	69.8
21	70.8	70.9	71.0	70.4	70.6	70.6	71.0	72.2	72.5	72.0	71.0	70.0
22	71.5	71.6	71.5	71.1	71.0	71.0	71.6	72.4	72.6	72.8	71.0	69.9
23	72.0	71.0	71.6	72.4	72.0	72.2	71.1	72.0	72.2	59.2*	70.9	69.3
24	70.3	72.6	70.3	70.9	70.9	70.9	70.0	71.0*	71.9	71.9	71.2	68.8
25	70.9	72.0	73.5	72.8	70.9	72.0	72.3	73.8	72.5	71.4	70.8	70.0
26	70.8	70.9	71.0	71.5	71.3	72.1	72.5	73.1	73.5	72.4	70.5	69.1
27	70.9	71.0	71.9	71.8	72.0	72.4	72.8	74.0	74.0	73.0	71.1	69.6
28	71.5	71.1	71.0	71.0	71.8	72.0	72.0	72.6	73.6	73.0	71.0	69.8
29	71.6	72.0	70.8	71.8	72.3	73.5	69.4*	74.0	73.0	72.0	71.0	69.4
30	70.0	71.0	71.6	73.8	71.9	71.0	73.0	69.2*	67.2*	70.9	69.4	67.8
Monthly mean	71.0	71.0	71.4	71.4	71.3	71.2	72.2	72.9	72.8	71.5	70.5	69.2
Normal	71.1	71.1	71.4	71.6	71.5	71.9	72.4	73.7	73.5	72.3	70.6	69.3

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794 Increasing scale readings correspond to increasing east declination.

NOVEMBER, 1886.

Day.	13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
1	69.2	69.2	69.5	69.7	70.5	71.4	71.8	71.8	71.7	71.9	71.0	70.6	71.4
2	66.9	70.0	69.2	67.1*	73.0	70.0	71.6	77.0*	79.2*	72.0	71.6	70.2	71.2
3	69.7	69.1	70.6	71.1	71.1	73.1	72.2	73.7	72.3	71.4	73.8	73.9*	71.0
4	68.7	69.2	74.9*	73.0	71.0	73.3	74.4	73.5	71.9	74.6*	72.5	71.0	70.8
5	69.1	70.3	71.5	71.0	70.9	73.2	73.4	72.2	71.0	74.4	71.4	69.3	70.5
6	67.2	65.1*	67.9	69.8	71.0	72.1	74.6	72.2	69.5	73.8	70.0	72.8	69.8
7	69.5	70.3	71.0	71.0	71.2	72.9	72.8	71.8	72.6	72.1	71.8	68.8	70.8
8	69.1	70.0	70.8	71.6	71.8	71.8	71.8	73.7	71.0	70.9	71.4	69.4	71.4
9	69.5	69.9	70.3	70.3	71.2	71.1	71.1	71.1	71.5	70.8	71.6	71.0	71.3
10	68.8	69.3	70.1	70.9	71.0	71.9	71.5	71.3	71.4	71.2	71.0	70.8	71.1
11	69.9	70.1	70.3	70.8	71.5	72.6	71.0	71.0	72.3	71.6	72.7	72.8	71.5
12	68.0	69.3	70.8	70.9	72.1	72.2	72.1	76.9*	71.8	72.0	71.8	70.8	72.0
13	70.2	70.0	70.0	70.9	71.8	71.8	71.8	71.8	71.8	71.4	71.0	71.0	71.3
14	69.5	68.4	69.3	70.2	71.2	71.5	71.9	72.0	72.0	72.0	72.0	71.2	71.6
15	68.0	69.0	69.0	69.9	71.5	71.5	72.0	72.0	71.8	71.7	71.2	71.1	71.8
16	69.6	70.0	71.0	71.2	71.8	71.8	72.1	72.3	72.1	72.2	72.1	71.0	71.8
17	66.3*	69.5	70.7	71.3	71.2	71.8	71.8	72.0	71.9	71.8	71.8	71.7	71.4
18	69.6	70.1	70.4	71.0	72.0	72.1	72.2	72.2	72.2	72.8	72.0	71.5	71.9
19	69.2	70.1	70.8	71.0	71.4	71.2	71.6	71.2	71.2	71.8	72.0	72.8	71.7
20	69.3	70.4	70.2	70.0	71.0	71.0	71.2	71.2	71.9	71.1	71.0	71.0	71.5
21	69.4	70.1	70.7	71.0	71.5	71.5	71.5	73.0	71.7	71.6	71.8	71.8	71.2
22	69.2	70.0	70.8	71.0	71.5	71.0	71.2	71.1	71.1	71.2	73.4	71.5	71.3
23	68.0	69.6	68.5	70.1	71.0	71.5	71.1	79.4*	72.4	70.8	71.2	74.2*	71.0
24	69.0	67.0*	70.1	70.9	71.0	72.0	71.8	71.0	71.4	71.8	71.6	71.6	70.8
25	69.5	70.5	72.0	71.8	71.8	71.5	75.0*	72.0	71.0	72.5	70.4	71.0	71.8
26	69.2	69.8	70.1	71.0	71.8	71.8	72.0	71.9	71.8	71.8	72.0	72.4	71.4
27	69.2	69.9	70.8	71.2	71.6	71.8	71.8	71.7	71.5	71.5	71.3	71.1	71.6
28	69.5	70.0	69.5	70.5	71.5	72.0	71.8	71.7	71.9	71.8	71.8	71.3	71.4
29	69.3	67.8	70.0	70.0	70.5	73.8	73.0	73.7	72.3	72.0	72.0	71.8	71.5
30	68.1	70.0	70.4	71.8	72.0	72.2	72.4	80.0*	76.5*	73.2	74.7*	68.3*	71.5
Monthly mean	68.9	69.5	70.4	70.7	71.4	71.9	72.2	72.9	72.1	72.0	71.8	71.3	71.31
Normal	69.0	69.7	70.2	70.9	71.4	71.9	72.1	72.0	71.7	72.0	71.7	71.2	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

DECEMBER, 1886.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	69.3	70.0	69.0	69.5	69.5	71.0	71.2	71.0	72.3	73.5	73.0	71.8
2	72.8	70.9	68.6	69.5	68.5	71.6	70.8	74.0	73.9	72.2	71.8	69.6
3	70.5	72.0	72.0	69.5	68.9	70.4	71.2	70.6	73.0	71.5	70.5	69.3
4	70.0	70.9	70.8	68.5	70.9	71.0	71.0	71.0	72.6	71.8	70.5	69.5
5	70.0	72.3	70.9	70.5	71.0	70.9	71.0	73.0	72.4	71.8	69.5*	68.0
6	71.8	68.8	69.8	71.9	69.4	70.1	72.0	72.8	73.2	72.4	72.1	71.1
7	70.1	70.5	70.0	72.5	71.2	71.6	71.2	71.0	72.1	71.4	69.1*	68.4
8	69.5	69.6	71.5	70.3	70.2	70.9	70.8	71.5	72.5	74.2	73.0	71.2
9	71.0	71.2	71.1	71.0	70.9	70.8	71.2	71.7	72.8	73.1	72.4	70.8
10	70.2	70.1	70.8	71.0	70.9	71.0	71.2	72.0	73.0	73.0	71.9	69.5
11	70.5	70.1	70.0	70.5	70.8	70.5	70.8	71.8	71.7	73.9	71.5	69.6
12	71.0	71.5	71.0	70.8	70.8	71.5	71.8	71.8	72.1	72.4	71.2	69.3
13	71.3	71.3	70.5	71.8	71.8	71.9	73.1	73.5	72.5	72.3	69.9*	69.4
14	70.5	69.4	69.0	70.2	71.0	71.5	70.7	72.3	72.4	75.0	71.0	68.9
15	69.5	69.5	71.0	71.0	70.0	71.5	70.9	72.6	74.5	73.8	73.4	70.4
16	71.5	71.8	71.0	71.0	70.8	71.1	72.1	71.8	72.8	75.0	73.2	71.0
17	71.0	72.0	71.2	70.8	72.0	72.0	66.0*	72.4	73.9	73.9	73.3	70.8
18	71.8	71.5	71.5	72.4	72.0	72.0	72.0	72.7	74.0	[74.6]	[73.7]	[71.7]
19	[71.3]	[71.5]	[70.9]	[71.0]	[70.8]	[71.2]	[70.8]	[71.7]	[72.7]	73.2	72.5	70.1
20	72.4	72.0	70.5	71.0	71.9	72.0	71.5	72.7	73.1	73.5	72.8	71.5
21	72.0	71.8	72.2	71.5	70.5	71.0	71.2	70.8	70.8	74.0	74.5	72.3
22	70.4	72.8	69.5	71.5	71.1	70.2	70.4	70.8	71.5	73.1	73.2	71.5
23	71.1	71.8	70.9	70.1	70.4	70.8	69.4	70.9	72.9	73.5	73.4	70.2
24	71.2	70.9	71.2	71.0	70.9	70.9	71.2	72.1	75.2	76.0*	74.2	71.0
25	71.1	71.8	70.9	71.8	71.4	72.0	71.5	72.2	73.2	75.0	74.1	71.8
26	68.2*	72.1	72.4	69.0	72.6	71.9	67.3*	72.0	73.0	72.5	72.8	71.0
27	73.2	69.5	70.1	70.2	70.9	72.8	70.9	70.5	72.3	72.3	72.8	71.0
28	71.7	72.2	71.5	71.3	70.2	70.0	72.7	69.1*	72.6	74.5	73.5	71.2
29	70.0	72.2	71.1	72.8	67.0*	67.9*	65.0*	67.8*	71.4	73.4	75.0	74.0*
30	71.4	72.8	67.5*	69.1	69.3	70.5	71.0	72.7	73.0	74.3	74.5	71.8
31	71.0	71.0	70.5	70.8	70.5	70.8	70.5	71.1	73.1	76.0*	76.0	73.4*
Monthly mean	70.9	71.2	70.6	70.8	70.6	71.1	70.7	71.6	72.8	73.4	72.6	70.7
Normal	71.0	71.2	70.7	70.8	70.7	71.2	71.2	71.9	72.8	73.2	72.9	70.4

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794 Increasing scale readings correspond to increasing east declination.

DECEMBER, 1886.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
1	70.9	70.1	71.5	71.5	72.3	78.8*	75.0*	81.5*	74.9*	74.5	73.8	69.5	72.3
2	69.0	71.0	70.9	72.3	73.0	75.0*	72.0	73.5	75.0*	72.0	72.9	69.5	71.7
3	69.2	69.1	70.0	71.0	71.8	72.0	73.7	75.5*	72.8	72.0	69.8	69.1	71.1
4	69.3	69.8	71.2	71.0	71.4	72.8	73.1	72.1	71.0	71.5	71.0	69.6	70.9
5	68.9	69.6	70.6	71.2	71.5	73.6	73.0	73.2	72.8	73.0	72.0	71.2	71.3
6	70.1	70.3	69.5	70.2	71.5	71.9	72.5	71.5	72.5	71.3	69.2*	71.1	71.1
7	68.9	69.5	70.8	70.5	74.0	71.9	73.0	74.7	75.8*	73.2	71.8	72.5	71.5
8	71.0	71.0	71.0	71.0	71.4	72.0	72.0	72.0	71.9	71.4	71.2	71.0	71.3
9	70.2	70.0	70.0	70.4	70.8	71.9	71.0	71.6	71.5	70.8	71.0	70.9	71.1
10	68.5	68.5	69.8	70.6	71.1	71.6	71.6	71.5	71.2	71.5	71.2	70.5	70.9
11	68.0	69.2	70.1	70.9	70.6	71.2	72.5	72.0	71.5	71.9	71.5	70.5	70.9
12	69.2	68.8	69.9	70.2	71.0	71.8	72.2	72.1	72.0	71.8	72.0	71.0	71.1
13	68.2	69.0	69.5	69.7	71.0	71.2	71.7	71.8	72.4	68.0*	70.9	71.0	71.0
14	66.8*	67.8	69.2	70.0	71.2	72.0	72.1	71.6	71.1	71.2	71.4	70.8	70.7
15	69.7	68.8	69.1	73.0	72.5	72.4	72.6	73.1	72.8	72.9	72.8	72.6	71.7
16	70.1	69.3	69.7	70.0	71.5	72.8	71.0	72.8	72.6	72.7	72.4	72.7	71.7
17	70.5	69.8	69.2	70.8	72.1	71.0	72.0	72.0	73.1	71.0	71.8	71.0	71.4
18	[70.7]	[70.6]	[71.0]	[71.5]	[72.3]	[73.1]	[73.0]	[73.7]	[72.9]	[72.7]	[72.4]	[71.8]	[72.3]
19	71.2	71.3	71.0	70.5	71.5	72.4	72.8	72.5	71.5	72.4	72.6	72.8	[71.7]
20	69.9	69.1	70.0	70.5	70.5	71.3	72.0	72.4	71.8	71.6	72.1	71.0	71.6
21	69.8	69.8	69.9	69.8	70.7	71.0	71.0	71.4	71.1	71.0	71.8	71.8	71.3
22	70.5	69.2	68.9	68.9	70.5	75.0*	70.0	71.8	68.9*	73.0	71.9	71.9	71.1
23	68.6	68.7	69.8	70.7	71.2	71.6	72.0	72.0	72.0	71.9	71.6	72.0	71.2
24	69.8	69.5	69.8	70.0	71.2	71.4	71.8	71.9	71.8	71.9	71.8	71.1	71.6
25	70.1	69.8	70.4	71.1	72.0	72.5	72.6	72.7	71.8	72.7	73.2	72.8	72.0
26	70.0	70.0	71.0	71.0	71.0	72.6	72.6	72.9	73.0	73.0	73.7	73.1	71.6
27	70.1	70.2	70.5	70.2	72.0	72.2	72.9	72.8	73.5	73.9	71.2	72.8	71.6
28	70.4	69.0	69.8	70.2	71.8	72.3	72.5	77.9*	72.4	73.7	74.5*	71.6	71.9
29	71.9	70.7	70.7	71.8	74.0	72.6	74.0	76.1*	73.6	74.0	71.9	73.8	71.8
30	69.8	69.1	69.0	69.8	70.5	71.0	71.0	72.0	71.5	71.0	72.0	70.6	71.0
31	70.1	69.2	69.0	70.8	71.3	71.8	72.0**	71.8	72.0	72.0	72.5	71.5	71.6
Monthly mean	69.7	69.6	70.1	70.7	71.6	72.4	72.3	73.0	72.3	72.1	71.9	71.4	71.42
Normal	69.8	69.6	70.1	70.7	71.6	72.0	72.2	72.3	72.2	72.2	71.9	71.4	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

JANUARY, 1887.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	71.7	71.5	71.0	70.8	70.5	70.9	71.1	72.0	74.1	76.1	75.2	72.8
2	71.0	70.8	70.8	70.8	70.5	70.6	70.6	71.9	74.0	75.8	75.2	72.9
3	70.5	70.8	70.0	69.8	69.3	69.8	69.8	69.8*	71.9*	73.8	72.7	71.0
4	71.0	69.8	72.1	71.9	71.5	70.9	70.0	70.8	73.9	74.9	71.8	71.0
5	71.0	71.0	71.0	70.7	70.7	70.8	71.0	72.2	74.1	74.5	72.3	70.8
6	70.8	71.0	70.8	69.4	70.2	70.5	70.5	71.8	74.5	75.8	75.3	73.1
7	72.8	71.0	71.1	70.5	70.5	71.5	70.9	71.9	74.0	74.0	72.0	69.9
8	70.2	70.3	70.5	70.4	70.3	70.2	70.0	71.6	73.8	75.5	75.2	73.0
9	72.0	71.8	71.1	71.0	70.8	71.1	70.9	72.8	74.5	75.1	73.7	69.1
10	71.0	71.2	71.3	71.5	71.2	71.5	72.2	74.1	75.7	76.5	75.3	71.1
11	71.1	70.6	72.1	71.4	71.0	70.0	70.7	73.8	75.1	76.2	72.3	70.0
12	71.1	71.8	71.8	70.9	71.8	72.0	72.2	73.8	74.9	75.8	72.5	68.0*
13	71.0	71.9	71.0	71.1	69.9	71.0	71.4	73.5	75.8	76.8	74.6	71.7
14	71.0	71.1	71.3	70.8	71.6	71.1	69.0	73.8	77.2	76.0	69.1*	67.1*
15	70.0	70.5	72.0	68.0	66.9*	69.9	71.3	73.0	74.9	75.8	72.8	69.3
16	71.4	72.1	66.8*	69.0	68.7	69.4	70.6	73.5	74.5	77.5	73.2	69.8
17	72.2	71.8	71.3	68.9	73.6*	71.8	71.8	73.5	76.1	75.7	72.7	69.2
18	73.0	71.4	70.6	70.4	70.5	71.2	72.3	72.2	73.9	75.9	73.1	71.0
19	71.0	70.4	70.5	70.9	69.4	71.2	72.8	73.8	75.8	75.8	71.6	67.8*
20	72.0	70.5	70.9	70.8	70.9	70.4	71.0	73.4	75.2	75.5	73.0	69.8
21	70.9	71.0	71.1	70.9	70.8	70.7	70.6	72.3	75.2	76.8	76.2	70.8
22	71.0	71.2	71.8	69.8	72.2	71.8	71.5	73.0	74.8	76.8	74.7	71.3
23	65.6*	71.4	72.8	69.9	71.9	67.9*	70.2	72.1	74.2	77.0	75.6	72.2
24	68.5	71.0	70.0	71.2	69.6	69.4	70.9	71.0	73.8	74.0	72.3	70.7
25	69.8	70.2	69.4	69.8	66.8*	70.0	71.2	71.8	74.8	75.9	73.0	69.2
26	71.2	70.2	70.8	70.5	68.9	69.8	71.2	73.1	75.9	75.8	74.8	71.9
27	69.0	69.9	70.5	70.2	69.1	70.8	71.3	72.5	74.3	75.5	74.0	71.2
28	69.8	70.1	70.2	70.0	70.8	71.0	71.7	72.8	74.8	76.8	75.2	73.0
29	70.2	70.8	70.5	70.9	71.0	71.0	70.8	70.9	73.0	75.8	74.5	71.3
30	70.8	70.8	71.0	70.6	70.8	70.0	69.8	72.0	74.9	76.1	76.0	74.0*
31	71.0	69.5	71.0	71.0	71.0	71.2	70.4	72.8	75.2	77.0	75.2	70.8
Monthly mean	70.8	70.9	70.9	70.4	70.4	70.6	71.0	72.5	74.7	75.8	73.7	70.8
Normal	70.9	70.9	71.0	70.4	70.6	70.7	71.0	72.6	74.8	75.8	73.9	71.0

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794 — Increasing scale readings correspond to increasing east declination.

JANUARY, 1887.

Day.	13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
1	71.3	70.0	69.7	70.1	71.0	71.5	71.8	71.5	71.6	71.5	71.8	71.4	71.7
2	70.0	69.0	68.8	69.6	70.9	71.1	71.1	71.1	71.0	71.0	70.9	70.5	71.2
3	69.0	68.5	69.5	70.5	70.9	71.1	71.2	70.5	70.9	72.0	70.8	71.0	70.6
4	[68.8]	68.0	[68.8]	70.0	70.8	71.0	71.0	71.4	71.6	71.0	71.0	71.0	[71.0]
5	70.1	69.5	70.2	70.8	71.0	71.1	71.2	71.0	71.2	71.2	71.0	70.8	71.2
6	71.8*	70.4	70.3	70.6	70.9	70.8	71.0	71.2	71.3	71.5	71.2	73.6	71.6
7	69.4	69.2	69.5	70.2	70.6	70.8	70.9	71.0	71.0	70.8	70.8	70.5	71.0
8	70.7	69.6	70.0	71.0	71.5	71.5	71.7	70.8	71.4	71.2	71.2	71.1	71.4
9	67.8	68.2	69.1	70.7	71.7	71.8	71.9	72.0	72.0	71.8	71.6	71.1	71.4
10	69.8	69.2	69.4	70.3	71.8	72.2	72.2	72.0	71.8	71.7	71.5	70.8	71.9
11	68.1	68.3	69.7	70.9	71.0	71.1	71.0	72.2	70.8	72.3	71.1	72.2	71.4
12	68.0	69.1	70.3	71.8	71.9	71.7	71.1	71.0	71.1	71.1	71.0	71.2	71.5
13	69.4	69.0	69.6	71.0	72.0	72.7	71.8	72.0	72.0	71.8	71.1	71.5	71.8
14	65.0*	68.5	68.6	69.1	71.0	74.9*	70.4	71.7	72.4	75.0*	73.8	70.1	71.2
15	66.8	66.1	67.8	69.8	70.5	70.8	71.7	71.5	73.1	72.0	72.0	70.2	70.7
16	68.8	69.1	70.2	71.8	71.5	72.9	73.9	74.1	75.0*	72.8	72.8	72.0	71.7
17	66.7	66.1	68.3	70.0	70.5	75.3*	71.5	72.3	71.8	72.8	70.5	72.2	71.5
18	70.5	69.5	69.0	69.9	71.1	71.1	72.0	72.9	71.1	71.2	69.1	71.2	71.4
19	66.4*	67.0	68.9	69.8	70.5	70.0	71.0	71.3	71.5	70.9	71.2	70.5	70.8
20	69.2	68.9	68.9	69.8	71.2	71.8	71.1	71.2	71.1	71.2	70.8	71.4	71.2
21	68.4	67.2	68.5	70.0	70.8	70.2	70.9	71.1	71.0	71.0	71.1	71.2	71.2
22	70.8	69.0	69.2	70.2	71.4	71.5	73.8	73.8	75.1*	74.3*	71.5	71.6	72.2
23	67.8	66.8	68.8	68.9	76.6*	71.6	70.8	71.0	71.2	70.9	71.0	70.8	71.1
24	70.4	69.8	69.6	69.8	72.3	71.2	72.8	72.8	72.6	70.5	72.2	71.5	71.2
25	66.0*	66.8	68.2	70.0	72.0	72.1	72.4	71.9	76.2*	72.7	72.2	70.8	71.0
26	67.5	69.1	69.0	69.2	70.9	71.1	71.9	72.0	72.0	73.4	71.9	71.2	71.4
27	68.8	67.2	67.5	69.8	71.2	72.0	72.2	72.0	72.1	72.7	71.8	71.8	71.1
28	70.1	68.4	66.1*	69.0	71.6	72.1	72.4	72.5	72.3	72.5	72.2	71.0	71.5
29	69.0	67.1	67.8	69.5	70.9	72.1	71.8	71.9	72.0	71.7	71.0	71.0	71.1
30	71.1	69.2	68.5	69.8	70.8	71.5	71.6	71.5	71.6	72.2	71.7	70.9	71.6
31	67.8	65.5*	67.4	70.1	71.1	71.1	72.0	72.1	76.8*	72.5	72.2	76.9*	71.7
Monthly mean	68.9	68.4	69.0	70.1	71.4	71.7	71.7	71.8	72.2	71.9	71.4	71.4	71.34
Normal	69.1	68.5	69.0	70.1	71.2	71.4	71.7	71.8	71.2	71.7	71.4	71.2	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

FEBRUARY, 1887.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	76.5*	72.8	70.8	71.2	69.2	69.5	71.7	73.0	73.0	75.0	74.2*	71.6
2	71.0	71.3	69.8	70.9	71.5	70.7	70.8	73.1	74.5	74.1	72.8	70.5
3	71.9	70.5	70.3	70.5	71.0	69.5	71.2	72.2	73.5	[73.6]	[71.9]	69.6
4	70.0	70.8	70.2	70.2	70.2	70.2	71.0	71.2	72.7	70.5	70.7	70.0
5	72.1	71.0	72.2	72.3	72.2	72.0	70.8	71.9	72.9	72.6	70.5	68.1
6	72.0	72.0	72.6	72.0	71.2	71.5	72.0	72.6	73.0	73.5	72.0	69.9
7	70.8	70.0	71.0	74.2*	73.4*	74.5*	71.0	71.0	73.9	72.5	70.8	69.8
8	71.0	71.0	71.1	70.8	71.0	71.0	70.8	71.0	72.4	73.1	72.0	70.0
9	71.0	70.5	70.6	72.8	71.0	70.8	72.2	72.5	71.8	71.7	69.5	68.2
10	72.1	71.0	70.9	71.2	72.3	70.5	71.2	73.8	71.3	71.8	70.9	69.2
11	70.1	70.8	70.5	70.0	71.0	71.2	68.7	70.5	71.6	72.0	71.0	70.0
12	70.8	71.8	71.0	73.0	72.0	69.8	72.5	72.6	72.8	73.0	66.8*	64.0*
13	71.0	68.0	70.0	72.0	71.8	69.2	69.0	71.0	72.0	71.7	71.0	71.0
14	68.7	70.0	70.8	72.5	66.0*	68.9	71.0	71.1	72.0	72.5	72.7	69.2
15	70.8	70.3	69.4	70.5	70.7	69.6	70.5	70.6	72.5	73.5	72.6	70.8
16	75.1*	71.6	70.8	70.7	69.0	70.2	70.7	72.0	71.8	72.8	72.4	70.8
17	69.6	69.2	70.0	69.0	69.0	70.5	71.1	72.2	73.8	73.8	72.4	69.8
18	69.7	69.8	69.5	70.0	70.4	70.5	71.0	72.8	74.0	74.0	72.0	70.0
19	70.0	70.1	70.0	70.2	70.0	70.4	71.5	73.2	74.0	74.0	70.8	69.2
20	72.3	71.8	74.5*	65.0*	71.0	71.0	66.2*	68.5*	72.1	72.0	71.0	69.0
21	67.8*	70.8	72.8	64.1*	71.0	67.8	68.0*	69.2	70.8	71.0	70.0	67.5
22	69.5	70.0	71.0	65.0*	68.0*	71.0	71.8	71.5	74.6	70.8	70.8	68.0
23	68.8	69.2	72.2	68.2*	67.0*	68.1	67.8*	69.2	69.5*	73.2	72.6	70.0
24	70.8	69.8	68.5	70.5	70.5	70.5	70.8	72.5	74.2	74.8	72.8	69.8
25	70.1	70.0	71.0	71.0	71.0	70.0	69.0	71.0	72.8	73.8	72.5	70.2
26	69.5	69.8	69.5	70.0	70.2	70.0	70.0	70.6	71.8	72.8	72.0	69.2
27	67.8*	69.8	69.6	68.0*	67.0*	68.4	67.5*	67.4*	69.5*	72.0	71.0	71.0
28	69.5	69.8	69.8	69.5	69.2	69.8	69.2	69.5	69.8*	73.2	72.8	71.0
Monthly mean	70.7	70.5	70.7	70.2	70.3	70.2	70.3	71.3	72.4	72.8	71.5	69.6
Normal	70.5	70.5	70.6	70.9	70.7	70.1	70.8	71.6	72.8	72.8	71.6	69.8

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794 Increasing scale readings correspond to increasing east declination.

FEBRUARY, 1887.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
1	70.3	68.2	67.4	69.8	71.0	72.0	71.8	72.8	72.0	72.0	72.2	71.5	71.6
2	69.4	69.0	69.2	69.8	70.9	70.8	71.0	71.8	70.8	71.0	71.8	71.9	71.2
3	69.0	68.0	68.8	69.6	70.2	72.1	73.8*	72.8	72.9	73.2	74.8*	71.2	[71.3]
4	69.9	69.9	70.0	71.0	71.1	71.5	71.9	72.0	72.0	71.8	71.8	71.8	70.9
5	68.3	67.6	68.5	69.4	70.2	70.5	71.1	71.2	71.5	71.0	71.1	71.9	70.9
6	69.2	68.0	68.5	69.5	71.0	71.0	71.0	71.0	71.0	71.0	70.8	71.0	71.1
7	69.2	70.4	71.0	71.0	72.0	71.6	71.7	71.2	71.2	71.2	71.0	71.0	71.5
8	68.0	68.8	69.6	71.0	71.1	72.5	72.0	71.9	71.0	71.0	70.8	72.5	71.1
9	68.5	69.0	69.0	70.2	69.2	70.8	72.1	72.0	71.5	70.8	71.0	69.1	70.7
10	68.5	66.6	68.1	68.2	69.5	70.4	72.0	70.8	70.6	70.8	69.8	70.2	70.5
11	69.8	69.3	69.2	68.8	69.8	69.0	70.8	71.0	71.0	70.8	70.8	71.5	70.4
12	66.0*	65.2*	69.0	68.8	70.0	74.0*	72.5	71.5	73.8*	70.8	70.0	70.8	70.5
13	71.0	68.9	69.0	69.5	70.8	70.2	72.5	72.2	72.8	71.5	69.6	69.4	70.6
14	67.6	66.5	69.0	69.8	70.0	70.8	71.0	72.4	71.8	70.0	70.5	70.8	70.2
15	70.0	68.7	69.5	69.8	69.3	72.1	70.8	70.8	71.2	71.2	71.6	74.6*	70.9
16	69.2	67.8	69.2	69.5	69.5	69.8	71.8	70.3	70.8	71.5	71.5	71.0	70.8
17	67.8	67.0	67.8	68.8	69.5	70.0	69.8	70.0	69.2	70.0	70.0	69.8	70.0
18	68.8	68.0	68.2	68.8	69.8	70.0	69.8	70.0	69.8	69.8	69.8	70.0	70.3
19	68.4	69.0	69.0	69.1	70.0	68.0*	70.5	70.5	71.2	78.4*	72.8	71.0	70.9
20	67.8	68.5	69.8	71.8	70.5	72.2	72.0	72.8	71.5	72.8	71.0	73.0	70.8
21	67.5	65.8	67.8	70.0	71.0	70.0	70.8	69.2	70.8	68.8	69.4	69.4	69.2
22	68.0	68.2	69.0	69.2	69.7	69.8	70.4	69.5	69.5	70.0	70.2	69.5	69.8
23	68.5	66.6	68.8	68.6	70.6	71.0	71.1	71.0	71.2	71.0	71.0	72.2	69.9
24	67.8	66.2	67.1	68.0	69.5	70.8	70.8	70.8	70.8	69.7	70.2	70.2	70.3
25	68.9	67.8	67.0	67.9	69.8	69.5	70.0	70.6	69.8	70.6	70.2	70.4	70.2
26	67.8	66.0	65.8*	67.2	67.8	69.1	69.3	69.6	70.3	70.5	69.8	69.8	69.5
27	70.0	69.5	68.8	68.8	69.0	69.5	69.8	70.0	70.0	69.8	69.8	69.6	69.3
28	69.8	67.8	66.5	67.4	68.5	69.5	70.1	70.3	70.5	70.2	69.8	69.5	69.7
Monthly mean	68.8	67.9	68.6	69.3	70.1	70.7	71.2	71.1	71.1	71.1	70.8	70.9	70.50
Normal	68.9	68.0	68.7	69.3	70.1	70.6	71.1	71.1	70.0	70.9	70.7	70.7	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

MARCH, 1887.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	70.8	69.1	70.1	69.9	70.0	69.8	70.0	70.5	71.0	72.0	72.6*	71.7*
2	69.2	70.8	69.8	69.8	69.8	70.2	70.2	70.5	70.0	70.0	69.5	69.0
3	70.0	70.0	70.1	70.2	70.4	70.0	71.0	71.8	72.0	71.2	70.0	69.1
4	[69.9]	[69.4]	[69.3]	[69.7]	[69.3]	[69.9]	[70.6]	[71.5]	[71.3]	70.0	69.2	67.0
5	69.2	70.3	69.8	70.8	70.0	70.5	71.0	70.8	71.2	71.8	69.2	65.4
6	69.5	70.0	68.8	72.2	65.5*	69.8	71.5	71.0	71.0	68.0	66.0*	65.0
7	69.2	69.5	69.5	70.8	67.8	69.6	70.5	70.0	69.5	68.8	68.0	67.5
8	64.8*	71.1	71.2	70.8	70.2	70.8	69.7	69.8*	70.8	69.3	66.8	67.0
9	70.8	68.0	70.6	72.0	69.2	71.8	71.2	69.0*	69.0	68.3	66.2*	65.9
10	68.4	69.0	68.5	71.8	71.0	70.1	71.3	72.8	72.8	72.2	69.2	66.8
11	70.0	69.8	69.8	69.1	70.1	70.7	72.0	72.3	70.4	69.0	66.8	66.2
12	69.3	69.5	69.7	70.1	70.5	70.7	72.3	72.2	70.8	69.1	67.0	66.8
13	69.2	69.4	69.8	70.1	70.1	70.5	70.8	72.8	71.3	70.2	68.5	67.5
14	69.2	69.3	69.5	69.5	69.6	69.5	70.0	72.1	71.8	70.2	69.2	67.4
15	71.2	70.4	68.0	70.0	70.5	69.6	71.2	73.5	72.1	71.8	69.5	66.8
16	69.8	68.8	68.0	68.8	69.9	70.4	70.8	71.6	71.2	70.3	67.8	65.4
17	70.0	68.3	69.5	69.6	69.8	69.8	71.2	72.0	71.1	69.8	68.0	66.0
18	68.8	69.0	69.0	69.0	69.3	69.8	70.8	71.4	70.5	69.4	67.7	66.0
19	69.5	69.7	69.5	69.8	70.4	70.8	72.8	73.8	72.5	69.2	66.1*	64.8
20	69.2	65.7*	67.8	69.2	69.2	69.6	68.0*	69.0*	67.8*	69.8	67.5	66.3
21	69.0	66.4*	69.3	70.0	68.8	70.6	71.8	73.8	72.8	70.9	68.2	64.8
22	68.3	68.0	70.8	67.8	67.8	71.8	72.5	74.5	74.2*	70.8	68.8	65.8
23	70.8	71.0	69.0	69.2	70.1	70.5	72.5	76.0*	76.0*	73.4*	70.0	68.0
24	75.8*	71.6	67.4	69.2	69.1	71.2	70.3	70.8	72.0	70.8	68.8	67.5
25	69.0	69.2	68.5	69.4	70.4	71.8	72.3	73.5	74.5*	72.3	69.6	68.2
26	70.2	70.1	70.0	70.0	70.8	71.0	72.2	73.0	72.8	71.3	69.3	67.7
27	70.0	70.1	70.7	69.5	70.0	70.8	71.0	73.0	74.0*	73.7*	69.7	67.2
28	70.8	69.0	69.6	70.2	70.1	70.4	73.0	74.8	76.0*	74.9*	72.0*	74.0*
29	69.4	69.0	69.0	70.0	70.4	71.6	73.1	74.0	75.2*	73.4*	71.0	58.4
30	69.3	69.5	69.5	69.5	69.9	70.6	71.8	74.1	75.8*	74.0*	71.1	68.8
31	69.2	69.5	69.8	70.0	70.5	71.3	72.8	74.5	75.2*	74.0*	70.4	67.7
Monthly mean	69.7	69.4	69.4	70.0	69.7	70.5	71.3	72.2	72.1	71.0	68.8	67.3
Normal	69.6	69.6	69.4	70.0	69.8	70.5	71.4	72.5	71.3	70.2	68.9	66.9

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794 Increasing scale readings correspond to increasing east declination.

MARCH, 1887.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
1	70.2*	69.5*	69.0	69.0	69.2	69.8	70.0	70.1	70.5	70.2	70.0	69.8	70.2
2	68.2	68.5	69.0	69.4	69.8	69.8	70.2	70.5	70.5	70.0	70.0	70.0	69.8
3	68.8	68.2	68.5	69.0	69.4	69.8	69.9	[70.1]	[70.1]	[70.0]	[70.1]	[70.0]	[70.1]
4	66.0	66.0	66.8	67.0	68.8	69.0	69.0	69.2	69.2	69.2	69.5	69.8	[69.0]
5	65.0	66.8	65.9	66.1	66.5	66.5	66.6	66.6*	70.8	68.0	68.3	68.8	68.6
6	65.5	64.6	65.0	68.5	68.0	68.0	68.0	68.0	68.0	67.6	68.0	69.2	68.2
7	67.2	67.2	68.7	69.0	69.2	68.8	68.9	68.9	69.0	69.2	70.8	69.8	69.1
8	66.2	67.2	67.8	67.8	69.7	69.8	69.9	69.0	69.2	69.6	70.2	69.1	69.1
9	67.4	67.8	69.4	69.7	69.8	69.6	69.1	69.0	68.9	70.7	69.1	69.8	69.3
10	65.8	66.5	66.9	69.2	69.6	69.5	69.8	69.9	69.5	69.0	69.1	69.7	69.5
11	66.8	67.2	69.8*	70.0	70.2	69.8	70.4	69.4	69.0	69.2	68.8	69.2	69.4
12	67.3	67.2	67.8	68.8	68.4	69.0	69.3	70.0	69.1	69.2	69.3	69.6	69.3
13	66.5	66.0	66.7	67.5	67.8	68.5	68.5	69.0	69.0	69.8	69.2	68.4	69.0
14	67.5	66.7	67.2	67.8	68.6	68.1	68.8	69.2	68.8	69.9	69.3	69.5	69.1
15	65.8	63.8*	64.6	68.0	66.8	68.4	68.4	71.5	69.5	70.5	70.3	69.0	69.2
16	65.0	65.5	66.5	68.8	68.9	68.2	68.0	67.8	68.1	70.0	69.3	69.4	68.7
17	65.4	66.0	67.0	67.8	68.6	67.8	67.8	68.0	68.2	68.5	68.9	69.0	68.7
18	65.9	66.1	66.9	68.0	68.0	67.6	67.6	67.8	68.2	69.1	68.6	68.8	68.5
19	63.2*	63.8*	65.8	66.3	67.5	67.1	67.3	69.5	68.5	68.7	71.9	69.7	68.7
20	65.5	66.0	66.2	68.0	68.5	68.7	68.9	68.6	71.5	69.2	70.2	69.8	68.3
21	64.8	65.2	67.0	69.8	70.0	69.2	69.0	69.4	68.8	69.5	69.8	70.0	69.1
22	64.7	64.2	66.2	68.4	70.0	69.5	69.2	69.2	69.2	69.3	69.8	72.8*	69.3
23	66.8	65.6	66.6	71.1*	67.8	67.7	68.4	71.3	69.2	72.0*	74.0*	73.8*	70.4
24	67.2	67.8	68.0	69.0	70.0	69.5	69.4	69.6	70.3	69.1	68.8	68.7	69.7
25	67.8	67.9	68.8	69.2	69.5	69.1	68.6	70.0	69.1	69.0	69.2	70.8	69.9
26	66.0	66.2	65.8	67.0	68.1	69.2	68.6	69.0	68.8	69.2	69.5	69.4	69.4
27	66.0	66.5	67.5	68.5	69.5	69.2	69.5	69.5	69.2	69.0	70.2	71.0	69.8
28	66.2	66.0	66.4	68.0	68.6	68.7	68.8	69.0	70.0	70.0	69.8	69.6	70.2
29	66.2	65.9	66.2	67.8	68.9	69.3	69.1	69.3	69.5	69.5	69.2	69.2	69.8
30	66.0	65.8	66.7	68.0	69.0	69.0	69.1	69.1	69.0	69.2	69.2	68.8	69.7
31	65.8	65.2	65.8	66.5	67.7	68.6	68.8	69.0	69.0	69.0	69.0	69.2	69.5
Monthly mean	66.4	66.4	67.1	68.4	68.8	68.8	68.9	69.3	69.3	69.4	69.7	69.7	69.31
Normal	66.3	66.4	67.0	68.3	68.8	68.8	68.9	69.3	69.3	69.3	69.5	69.5	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

APRIL, 1887.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	69.5	69.4	69.5	70.0	70.3	70.8	73.0	75.0	76.2	74.8*	72.4*	69.2
2	69.5	69.5	69.4	69.6	70.6	70.0	72.4	73.8	74.0	73.2	70.6	68.8
3	70.2	70.4	70.8	69.5	68.0	67.4*	74.0	72.8	70.7*	68.6	68.0	67.5
4	72.4*	71.2	71.0	71.0	70.8	71.0	73.3	75.8	74.2	70.5	65.9*	65.8
5	71.0	69.6	69.0	70.0	69.0	67.2*	70.8	72.2	71.8	69.5	67.4	67.2
6	69.0	71.5	70.2	69.0	70.4	69.5	72.8	73.9	73.0	71.5	68.0	64.6*
7	70.8	67.0*	68.2	68.0	70.3	72.0	71.3	71.0*	70.0*	69.3	66.2	66.0
8	69.8	70.2	69.6	70.5	70.6	71.1	73.2	74.0	72.8	68.8	65.9*	65.0*
9	68.0	66.0*	67.0*	70.2	70.1	71.0	73.2	75.4	76.0	72.2	67.0	64.1*
10	69.0	67.0*	69.2	69.7	70.2	71.1	73.6	76.0	74.2	71.0	68.0	66.0
11	71.5	71.2	68.0	73.0*	70.8	72.8	73.8	74.5	74.0	72.6	69.8	67.8
12	70.4	70.6	70.8	70.8	71.0	71.9	72.3	72.7	75.2	72.7	70.7	69.5
13	69.0	69.0	69.0	69.2	69.3	70.0	71.6	73.0	73.8	73.1	70.8	68.2
14	68.8	69.2	69.3	71.3	70.0	70.0	72.6	73.8	73.8	71.0	68.6	67.1
15	70.5	71.0	68.7	70.1	70.7	72.2	71.5	72.6	73.8	70.8	67.9	66.4
16	69.0	68.8	70.2	70.4	70.6	71.4	72.7	72.8	73.4	70.5	69.5	68.5
17	70.1	69.2	65.8*	66.5*	70.2	71.8	73.9	70.4*	70.8*	69.6	68.5	69.1
18	69.2	70.3	69.8	69.7	70.5	70.5	73.6	73.8	71.5	68.4	65.0*	66.1
19	69.0	69.2	69.7	69.4	70.5	71.1	72.6	74.7	74.1	70.3	68.4	67.0
20	68.1	69.9	69.4	70.5	70.4	71.1	73.1	74.9	73.4	69.8	67.2	66.7
21	65.3*	70.9	72.2*	69.8	70.2	72.1	73.0	74.1	72.6	70.5	68.0	68.0
22	70.1	70.8	68.8	69.6	74.0*	73.2	74.9	73.1	74.0	72.8	67.8	66.7
23	69.2	69.5	69.1	69.8	70.0	71.8	73.8	74.8	74.1	71.0	68.8	67.0
24	68.1	69.0	69.2	69.9	70.5	72.1	74.2	75.7	73.1	69.9	68.0	66.6
25	64.6*	74.1*	72.4*	66.0*	73.2*	72.5	73.9	75.7	74.5	72.4	70.6	69.8
26	69.0	69.4	70.0	70.7	71.0	72.4	73.8	73.9	72.7	71.0	70.2	70.0
27	69.7	69.8	70.0	70.2	71.0	72.1	74.1	75.3	75.5	73.8*	70.5	68.2
28	69.4	70.5	70.8	71.4	71.1	72.6	74.1	75.6	69.1*	69.0	66.6	64.6*
29	72.5*	72.0	70.5	70.8	71.5	72.8	72.1	74.5	74.4	72.3	70.1	68.5
30	69.8	70.4	69.2	70.2	70.4	71.2	72.0	72.3	71.7	70.6	69.2	69.1
Monthly mean	69.4	69.9	69.6	69.9	70.6	71.2	73.0	73.9	73.3	71.0	68.6	67.3
Normal	69.5	70.1	69.6	70.0	70.4	71.5	73.0	74.2	73.8	70.8	68.7	67.7

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0.′794 — Increasing scale readings correspond to increasing east declination.

APRIL, 1887.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Midnight.	Daily mean.
1	66.1	65.5	65.0	66.8	67.0	66.9	66.5	67.4	69.8	69.5	70.2	70.9	69.7
2	68.0	66.5	67.8	69.2	69.8	68.5	69.0	71.0	69.0	69.8	72.5*	71.8	70.2
3	66.2	66.5	67.8	68.8	69.9	70.0	70.1	70.1	70.4	70.6	70.8	70.8	69.6
4	66.5	65.5	65.8	66.4	66.8	67.0	68.0	68.5	68.8	69.2	72.8*	70.5	69.5
5	64.6	66.0	70.0*	69.8	70.8	69.5	69.2	69.8	70.9	69.9	73.0*	73.3*	69.6
6	65.2	65.0	68.2	70.0	70.0	81.8*	69.0	71.0	70.2	68.5	67.8	74.3*	70.2
7	65.8	67.7	68.0	70.8*	72.8*	72.3*	71.7	70.8	71.4	69.0	72.3*	68.2	69.6
8	63.8	64.8	66.0	68.1	69.2	70.7	70.8	69.8	70.7	72.1	72.8*	70.0	69.6
9	63.0*	64.0	65.9	68.0	70.0	70.0	71.0	70.0	69.2	70.5	71.0	69.1	69.2
10	65.1	64.9	64.8	67.8	69.0	69.2	68.8	68.8	69.7	69.4	69.5	71.2	69.3
11	66.5	65.8	66.7	67.0	70.0	69.6	70.0	70.8	69.8	69.8	70.0	70.2	70.2
12	66.6	65.5	66.1	66.7	69.1	69.1	68.8	68.0	68.2	68.1	68.6	68.6	69.7
13	66.4	65.2	65.5	66.6	67.8	68.0	69.0	68.1	72.2	69.8	68.6	68.5	69.2
14	65.3	64.8	66.2	66.4	67.1	69.1	68.5	69.8	70.8	73.3*	69.8	72.0	69.5
15	65.5	65.8	66.5	68.0	69.0	68.9	68.6	68.1	68.5	70.8	69.2	68.8	69.3
16	66.5	66.3	67.8	68.0	70.6	69.0	68.8	68.6	69.4	70.3	69.9	69.7	69.7
17	68.5	67.3	67.8	67.9	69.0	69.2	69.2	69.0	69.5	73.8*	71.0	71.0	69.6
18	65.8	66.0	66.0	67.2	68.9	68.8	70.6	69.5	68.8	68.5	68.8	68.8	69.0
19	65.6	66.2	66.8	67.8	68.1	68.2	68.4	68.9	73.2*	70.3	67.8	69.2	69.4
20	66.2	66.0	66.7	68.2	69.2	69.3	69.2	69.2	69.3	69.9	70.0	69.9	69.5
21	67.2	66.2	66.8	67.7	69.0	69.2	69.2	69.3	69.8	70.1	70.0	70.6	69.7
22	65.8	64.9	66.3	66.4	68.9	69.1	69.2	76.3*	70.8	68.8	68.2	69.3	70.0
23	66.2	65.6	66.0	69.1	69.0	72.3*	70.8	72.4*	72.4	70.8	69.2	68.8	70.1
24	67.1	67.4	67.8	68.8	69.4	69.5	68.7	69.3	70.2	69.7	70.2	69.9	69.8
25	69.7*	68.5*	67.8	68.2	69.1	69.9	69.4	70.0	69.4	69.0	69.0	69.2	70.4
26	69.8*	68.9*	68.9	69.0	68.8	69.0	69.1	69.0	69.1	69.2	69.3	69.5	70.2
27	66.7	65.8	66.3	67.6	68.2	68.5	68.5	68.4	68.2	68.6	68.8	68.8	69.8
28	65.6	64.8	63.8*	66.8	65.5*	69.8	68.0	70.9	73.2*	70.0	70.2	67.7	69.2
29	66.8	65.8	66.1	68.1	70.0	67.7	68.0	71.0	69.7	69.2	69.4	70.0	70.2
30	68.4	68.0	67.3	67.5	67.8	69.0	70.3	69.5	70.0	69.8	70.0	69.3	69.7
Monthly mean	66.4	66.0	66.8	68.0	69.0	69.6	69.2	69.8	70.1	69.9	70.0	70.0	69.69
Normal	66.2	65.9	66.7	67.9	69.0	69.0	69.2	69.5	69.9	69.7	69.5	69.7	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

MAY, 1887.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon
1	70.0	69.8	70.2	70.6	70.9	72.2	73.0	74.0	74.2	71.0	69.0	67.0
2	72.0	69.0	70.8	71.2	70.5	71.0	74.0	75.2	73.6	71.3	70.0	67.5
3	69.0	69.5	69.2	67.0*	69.7	72.0	74.1	74.5	72.9	70.1	68.0	67.6
4	70.2	69.5	69.7	70.6	71.5	74.0	75.0	76.1	74.4	71.7	68.5	65.5
5	69.2	69.0	69.2	70.8	67.1*	70.8	73.1	75.0	74.1	72.4	69.8	67.3
6	70.2	70.4	70.3	70.4	70.8	72.5	73.8	73.5	72.4	71.0	68.7	67.8
7	69.7	69.9	70.2	70.8	71.1	74.2	74.8	74.1	72.2	70.9	68.9	66.5
8	69.4	69.7	70.4	70.8	72.9	72.3	73.8	74.0	72.7	70.6	68.2	67.0
9	69.8	70.1	70.3	70.8	71.5	72.8	73.8	74.9	73.9	71.2	68.2	66.8
10	70.4	70.9	71.0	70.9	72.0	73.2	75.2	76.4	75.6*	73.8*	70.8*	69.9*
11	70.1	70.4	70.8	70.8	71.2	72.5	75.7	74.1	74.3	74.1*	72.1*	70.0*
12	70.0	70.0	70.8	70.1	71.2	72.8	75.5	73.2	70.8	68.0	67.1	67.0
13	67.1*	69.4	70.8	70.8	70.0	72.8	72.2	74.0	72.0	70.2	67.2	67.3
14	69.3	71.4	70.0	70.3	70.1	72.2	74.0	74.0	71.8	71.0	68.1	67.1
15	69.7	69.3	66.2*	69.7	72.0	72.5	74.5	71.8*	71.6	70.0	69.3	68.9
16	70.0	69.3	69.1	68.8	69.2	71.5	73.5	74.0	70.8	69.3	67.5	66.2
17	69.8	69.7	70.6	72.3	72.2	73.0	74.4	74.5	73.5	70.1	66.2	64.9
18	71.0	70.8	70.8	70.6	71.2	73.2	74.8	75.5	74.0	69.3	66.8	66.0
19	68.5	69.9	70.2	71.0	72.2	74.6	75.7	74.5	72.8	69.3	67.5	66.5
20	69.3	69.8	70.0	70.5	70.8	71.8	73.0	74.1	71.8	67.8	65.5	64.8
21	69.3	69.5	69.6	70.1	70.9	72.8	74.5	74.8	72.2	69.0	66.5	65.9
22	70.0	69.7	69.9	71.0	71.8	72.4	75.9	78.2*	76.1*	70.8	67.7	65.9
23	70.0	70.0	70.7	71.2	72.0	72.8	75.0	76.2	75.2	70.4	66.7	64.8
24	74.5*	75.0*	75.0*	74.3*	74.2*	74.6	78.8*	76.5	73.8	69.6	68.1	66.1
25	69.0	67.0*	69.8	69.6	72.8	72.8	73.0	72.2	72.5	70.5	66.5	65.6
26	71.0	69.2	69.1	70.3	71.0	73.2	75.0	76.5	74.8	71.6	67.8	66.0
27	69.8	70.1	71.0	71.2	72.5	73.6	74.5	72.5	70.8	67.8	64.3*	61.5*
28	66.2*	70.0	70.0	70.6	69.5	71.0	74.0	75.5	75.6*	71.0	66.8	66.0
29	69.2	69.8	70.1	70.5	70.7	73.8	76.0	75.8	74.0	71.2	69.3	67.5
30	69.2	67.8	68.8	70.0	68.9	72.2	73.0	70.0*	68.8*	68.0	66.2	65.8
31	72.0	70.7	70.5	71.0	72.2	73.6	73.8	73.1	69.8*	67.7	65.8	64.9
Monthly mean	69.8	69.9	70.2	70.6	71.1	72.7	74.4	74.5	73.0	70.4	67.8	66.5
Normal	69.9	69.8	70.1	70.4	71.1	72.7	74.3	74.6	73.0	70.1	67.7	66.4

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′. 794

Increasing scale readings correspond to increasing east declination.

MAY, 1887.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
1	67.6	67.7	67.8	67.7	68.2	68.9	69.0	68.9	68.8	75.5*	79.0*	75.8*	70.7
2	67.1	66.9	66.8	66.0	71.0	71.0	67.8	68.0	71.6	70.5	69.2	68.0	70.7
3	67.7	68.0	69.0	68.2	68.0	69.0	69.0	70.1	68.5	69.0	69.1	69.8	69.5
4	64.8	67.5	67.8	68.0	69.8	69.0	68.9	69.0	68.6	69.0	69.0	69.0	69.9
5	66.5	65.7	66.2	67.0	68.2	69.3	70.8	69.0	69.9	69.2	69.5	69.6	69.5
6	66.6	66.5	67.2	67.7	69.0	69.1	71.2	70.3	68.1	68.6	68.9	69.2	69.8
7	65.6	65.2	66.2	66.8	67.2	68.7	69.0	69.2	69.2	69.2	69.4	69.5	69.5
8	66.7	66.0	67.0	67.8	68.5	68.9	69.5	70.2	69.2	69.2	69.2	69.5	69.7
9	66.5	67.2	68.6	69.3	70.5	70.8	69.3	70.6	69.5	69.2	69.4	69.8	70.2
10	68.8*	67.5	67.6	68.5	69.0	68.8	68.9	68.5	68.2	68.9	69.0	69.8	70.6
11	69.0*	68.0	67.5	67.6	67.8	68.9	68.2	68.0	68.0	69.2	69.2	69.2	70.4
12	67.0	66.0	67.8	67.6	71.2	70.6	69.0	71.0	69.0	70.9	69.3	69.8	69.8
13	67.6	67.0	67.5	67.8	69.0	69.4	69.2	72.6*	71.0	70.0	69.5	67.6	69.7
14	67.1	67.9	68.8	69.5	69.0	69.8	72.0*	70.4	70.4	70.0	69.2	67.8	70.0
15	68.5	67.2	67.5	68.2	69.2	69.1	69.6	69.0	69.0	69.4	69.3	69.9	69.6
16	66.5	67.2	67.8	68.7	69.3	69.4	69.6	69.9	69.2	69.2	69.8	69.8	69.4
17	65.3	66.0	66.2	66.8	68.2	68.4	69.3	69.0	70.3	71.2	71.6	69.2	69.7
18	66.2	66.8	67.9	69.2	69.3	69.5	71.3	71.1	70.2	76.5*	71.4	70.5	70.6
19	65.6	65.2	66.1	68.5	70.8	70.0	69.4	69.5	70.0	70.2	69.2	69.2	69.8
20	65.5	66.2	67.4	68.8	69.8	69.5	69.4	69.2	68.9	69.0	69.2	69.2	69.2
21	66.1	66.0	66.8	69.0	69.8	69.8	69.3	68.8	68.6	68.8	69.0	69.3	69.4
22	65.0	66.2	67.6	69.3	69.8	69.8	70.0	69.6	69.5	69.4	69.9	69.9	70.2
23	64.2	63.5*	63.0*	65.4	66.5	67.4	74.8*	69.1	68.8	69.2	68.2	73.0*	69.5
24	65.5	65.5	65.5	66.0	68.2	68.1	70.0	68.9	73.8*	69.4	70.8	71.0	71.0
25	65.0	65.8	66.1	66.1	66.8	67.4	67.8	67.6	67.2	67.2	67.8	69.7	68.6
26	63.8	63.1*	65.1	66.3	67.8	68.9	67.8	67.7	68.3	69.0	69.2	69.8	69.3
27	61.1*	61.0*	63.2*	65.2	67.8	69.2	72.5*	69.4	75.0*	70.8	69.8	69.1	68.9
28	65.8	66.5	67.8	69.2	70.2	70.8	69.8	69.3	69.2	69.2	69.5	69.4	69.7
29	66.8	66.8	66.8	66.8	67.5	68.5	68.9	68.8	69.0	69.3	69.6	68.8	69.8
30	65.4	66.7	68.7	68.8	68.9	68.8	68.7	70.6	70.6	70.9	70.4	71.0	69.1
31	64.5	63.0*	63.8*	65.6	66.3	66.4*	67.2	67.8	69.0	68.8	72.1	71.3	68.8
Monthly mean	66.1	66.1	66.9	67.7	68.8	69.1	69.6	69.4	69.6	69.9	69.9	69.8	69.75
Normal	66.1	66.6	67.3	67.7	68.8	69.2	69.2	69.3	69.2	69.4	69.6	69.5	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

JUNE, 1887.

Day.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
1	71.8	69.8	71.0	70.2	71.8	73.1	73.2	74.5	72.4	70.4	68.5	66.8
2	69.5	69.2	70.2	70.4	70.8	72.7	74.5	74.0	71.3	69.8	67.6	65.7
3	68.8	68.8	69.1	69.7	70.0	71.0	74.2	74.8	72.6	69.3	67.7	67.0
4	70.4	70.8	71.0	71.4	72.0	74.3	77.4*	78.1*	73.4	68.8	65.8	66.0
5	71.0	71.0	74.5*	74.2	73.4	74.0	73.8	72.0*	72.0	68.6	64.0*	64.0
6	68.8	68.8	69.5	70.0	70.6	72.4	74.6	75.0	70.8	67.8	65.5	64.5
7	69.9	70.3	70.8	70.8	71.6	73.2	75.0	75.0	71.8	68.0	65.8	64.6
8	69.9	70.5	71.3	72.6	72.9	75.5*	74.5	77.4*	75.9*	71.5	66.3	64.2
9	69.5	69.8	70.6	71.8	72.8	74.6	75.5	74.8	72.8	70.2	67.8	66.0
10	70.2	71.7	71.8	70.4	69.0	71.8	73.8	74.5	73.2	72.0	68.0	65.8
11	70.4	69.6	70.6	72.0	72.6	74.0	75.8	75.6	75.0	70.5	68.0	66.7
12	71.0	71.0	70.8	70.3	72.4	74.0	75.0	74.8	72.2	68.8	66.3	64.8
13	71.2	70.8	70.3	71.0	70.9	73.0	75.8	75.8	74.8	70.7	66.8	64.0
14	69.4	69.0	68.8	68.9	70.3	71.2	71.8*	72.7	71.9	70.0	68.4	67.0
15	69.2	69.5	69.6	69.8	70.0	70.8	72.5	73.3	71.0	70.0	67.8	66.6
16	69.5	69.0	69.0	69.0	70.8	71.8	73.2	73.0	71.8	69.1	68.2	67.1
17	69.0	69.0	68.2	68.0*	70.3	71.4	73.5	74.6	73.2	70.8	67.8	65.7
18	68.5	69.0	69.9	70.0	71.5	73.9	75.2	75.8	73.4	69.8	67.8	66.0
19	68.8	68.8	73.8*	70.5	70.0	73.2	78.8*	75.0	74.9	72.0	68.8	67.3
20	68.7	70.0	70.6	71.0	71.6	71.5	73.0	73.3	73.3	70.3	65.6	62.6*
21	71.5	70.2	70.0	71.4	72.8	74.2	75.7	78.2*	75.3	70.8	67.8	66.0
22	70.0	70.8	71.7	71.9	71.1	71.8	76.8	79.8*	77.5*	72.0	65.7	61.8*
23	68.8	68.8	70.0	71.4	71.6	72.7	75.6	76.2	75.8*	72.8*	68.8	66.1
24	68.8	68.8	70.0	71.0	71.6	72.5	75.7	76.0	75.1	68.8	65.6	64.0
25	68.7	69.0	69.6	70.8	71.0	73.7	75.3	76.2	73.0	69.0	67.5	65.8
26	69.2	69.5	70.0	70.4	71.0	72.8	73.5	73.5	71.2	70.0	68.2	66.3
27	[70.1]	[70.1]	[70.7]	[71.0]	[71.5]	[73.0]	[74.8]	[75.2]	73.4	71.2	68.2	66.3
28	69.2	69.8	69.7	70.1	71.1	71.8	75.0	75.0	74.2	71.3	68.8	66.9
29	69.9	68.8	69.0	69.8	70.6	71.5	72.9	73.9	73.4	72.1	68.7	67.0
30	70.0	70.2	71.0	71.3	71.2	73.8	74.9	75.2	74.2	71.0	68.0	67.0
Monthly mean	69.7	69.7	70.4	70.7	71.3	72.8	74.7	75.1	73.4	70.2	67.3	65.6
Normal	69.7	69.7	70.2	70.8	71.3	72.7	74.5	74.7	73.0	70.2	67.4	65.9

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794 — Increasing scale readings correspond to increasing east declination.

JUNE, 1887.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
1	65.2	67.9	68.5	69.3	70.0	70.3	69.8	69.5	70.0	70.0	69.5	70.0	70.2
2	65.8	67.0	67.4	68.1	68.3	69.0	68.9	68.8	69.0	68.7	68.7	68.9	69.4
3	67.6	67.3	67.9	68.8	70.0	70.0	70.0	69.6	69.6	70.1	70.0	70.0	69.8
4	66.4	68.0	68.0	69.2	70.0	70.2	68.2	67.8	68.2	69.0	71.4	70.5	70.3
5	65.0	66.8	68.5	68.8	69.8	69.8	68.6	68.2	68.0	67.9	68.4	68.6	69.6
6	64.8	65.8	68.2	69.5	70.5	70.3	69.2	69.0	69.0	69.1	69.1	69.4	69.3
7	64.6	65.2	66.1	66.7	68.0	69.0	68.8	69.0	68.4	67.9	68.4	68.6	69.1
8	62.8*	63.6	65.0	66.5	68.8	70.0	69.9	68.8	70.0	73.7*	69.2	70.0	70.0
9	65.9	65.5	66.2	65.8	67.0	70.1	74.0*	69.8	69.0	68.5	69.9	71.6	70.0
10	65.2	65.6	66.5	68.1	70.1	70.6	71.0	70.9	72.0	70.5	70.6	70.4	70.2
11	67.5	67.5	68.5	69.3	70.2	70.8	70.8	70.2	70.3	70.3	70.4	70.6	70.7
12	64.6	65.2	66.8	68.8	70.8	71.5	76.0*	72.1*	71.8	71.0	71.2	72.1*	70.6
13	63.9	64.3	66.5	68.2	70.0	70.1	70.1	69.9	69.1	69.0	69.0	68.9	69.8
14	66.8	66.7	68.2	69.1	70.7	70.6	70.0	69.2	69.0	69.2	69.0	69.1	69.5
15	66.5	66.6	67.6	69.2	70.4	70.6	70.0	70.0	70.1	69.8	70.0	69.7	69.6
16	66.8	67.6	68.5	69.0	70.0	69.5	69.3	69.6	69.0	68.9	68.8	68.9	69.5
17	64.3	63.0*	66.1	66.8	68.6	70.5	70.0	69.1	68.5	67.8	68.0	68.3	68.9
18	65.3	64.5	64.9	66.8	68.8	69.8	70.8	69.5	70.1	70.2	68.4	68.2	69.5
19	66.6	66.9	67.2	68.3	69.2	69.0	69.0	69.0	69.0	68.3	68.8	68.7	70.1
20	62.0*	63.4	64.8	66.5	67.8	68.4	69.1	71.0	70.0	70.8	69.1	70.2	68.9
21	65.4	64.8	63.2*	67.5	65.2*	71.6	68.3	68.5	72.5*	70.0	68.8	68.8	69.9
22	63.1	65.0	66.8	68.8	69.2	70.2	70.5	68.4	68.7	70.8	68.6	69.5	70.0
23	66.0	67.0	68.2	68.8	70.0	70.2	70.0	71.0	70.0	69.0	70.1	69.0	70.3
24	64.0	[65.1]	66.9	68.7	68.8	69.0	69.2	70.0	69.0	68.6	68.2	68.0	[69.3]
25	64.2	65.0	67.0	69.1	69.6	70.4	70.5	68.8	70.1	70.1	68.8	69.2	69.7
26	66.5	65.2	66.5	68.2	69.0	70.7	[70.6]	[70.2]	[70.2]	[70.1]	[69.8]	[70.0]	[69.7]
27	65.2	64.7	66.8	68.8	68.6	68.8	68.8	69.5	69.0	69.0	69.2	70.1	[69.7]
28	66.2	66.8	67.4	68.5	69.8	69.2	70.3	70.3	69.0	69.5	69.2	69.1	69.9
29	67.0	65.7	64.8	65.0*	67.8	68.3	68.3	69.1	69.9	68.8	70.0	68.8	69.2
30	66.8	66.2	66.6	68.3	68.8	69.0	68.8	68.8	69.2	69.0	69.[illegible]	69.5	69.9
Monthly mean	65.4	65.8	66.8	68.2	69.2	69.9	70.0	69.5	69.6	69.5	69.3	69.5	69.75
Normal	65.6	65.9	67.0	68.3	69.3	69.9	69.6	69.4	69.5	69.4	69.3	69.4	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. | 300 divisions + tabular quantity.

JULY, 1887.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	70.3	70.3	70.4	70.6	71.2	73.2	74.3	75.8	75.1	71.7	70.0*	69.0*
2	70.8	71.2	70.6	70.6	71.1	72.4	75.1	75.9	75.8*	72.0	67.8	66.0
3	69.2	69.5	69.8	70.1	70.7	71.4	73.1	73.8	73.1	71.0	68.8*	67.5*
4	69.2	69.9	70.0	70.5	71.8	73.8	75.7	78.5*	75.0	71.4	66.4	64.8
5	70.6	70.7	70.1	72.1	71.0	73.9	75.0	75.4	74.2	[70.4]	[66.9]	64.8
6	69.2	69.5	68.4	69.0	71.8	74.0	75.9	76.0	72.5	68.8	64.5	62.6
7	70.6	75.5*	69.0	72.0	74.2*	72.7	73.6	71.8*	72.0	68.1	65.5	63.7
8	68.8	68.8	69.4	70.0	70.8	71.7	73.5	75.4	72.5	70.0	68.3	66.4
9	68.4	68.0	68.6	66.8*	68.3	71.1	73.2	74.8	73.6	69.3	64.2	62.1
10	64.4*	69.4	69.3	69.5	69.0	72.0	74.0	71.4*	72.0	69.2	68.4	66.3
11	70.4	69.5	67.6	67.5	70.8	73.0	73.0	72.6	71.4	70.2	67.2	65.0
12	69.0	68.5	69.2	64.6*	67.2*	69.9	71.8	72.8	71.4	68.0	65.5	64.2
13	67.8	67.2	67.0	67.8	69.5	69.4	73.0	74.0	73.4	70.2	65.0	63.8
14	69.1	68.5	68.2	67.8	69.0	71.7	74.8	75.8	74.0	69.8	65.8	64.0
15	68.1	68.4	68.8	69.0	70.6	72.0	74.8	75.5	74.5	71.1	68.2	66.3
16	67.9	68.2	68.5	69.2	70.2	71.6	73.5	73.1	70.7	66.8*	64.0	62.2
17	68.3	68.5	68.7	69.4	70.0	71.0	73.4	73.9	72.6	69.7	68.0	65.8
18	68.6	70.0	70.5	70.3	71.1	72.7	74.6	74.2	72.3	68.4	66.1	61.2*
19	69.0	69.0	70.1	70.1	70.4	72.6	75.3	74.7	73.1	68.5	63.8	60.9*
20	68.8	68.0	68.7	69.4	70.8	70.0	72.5	73.0	71.0	68.6	65.7	64.2
21	67.5	67.4	68.0	69.1	70.6	71.9	75.0	76.0	72.6	66.8*	63.7	62.2
22	68.0	68.5	68.8	69.1	69.5	71.3	74.0	75.0	73.9	69.9	65.1	62.8
23	68.4	68.2	68.8	69.9	70.2	70.5	72.0	74.2	73.4	66.6*	62.0*	60.0*
24	67.8	68.2	68.8	69.0	70.5	71.8	74.0	75.0	73.5	68.7	65.3	63.6
25	68.0	68.1	68.2	69.0	68.8	70.8	73.0	73.0	71.5	68.8	66.0	65.2
26	68.0	68.0	68.8	69.0	70.2	71.8	74.4	76.0	75.2	71.0	68.3	65.8
27	69.5	68.8	68.9	71.0	70.8	73.0	77.8*	75.2	73.2	70.6	68.0	65.5
28	68.8	68.6	68.8	69.2	70.0	71.3	73.8	75.0	72.2	68.2	64.8	63.8
29	68.8	68.0	69.0	70.0	70.3	71.0	74.0	75.4	74.8	70.0	66.9	65.0
30	68.5	68.6	69.0	70.2	70.5	71.8	75.0	77.1	75.4	70.3	66.0	62.8
31	68.8	69.0	69.0	69.1	69.6	70.8	73.7	75.6	74.0	69.1	66.6	64.3
Monthly mean	68.7	69.0	69.0	69.4	70.3	71.8	74.1	74.7	73.2	69.5	66.2	64.2
Normal	68.9	68.8	69.0	69.6	70.3	71.8	74.0	74.8	73.1	69.8	66.1	64.4

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794

Increasing scale readings correspond to increasing east declination.

JULY, 1887.

Day.	13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
1	68.7*	68.5*	68.0	68.3	68.7	68.8	68.7	68.5	69.2	69.0	69.0	69.9	70.3
2	65.8	65.9	66.2	67.2	68.2	68.8	68.4	68.3	68.5	68.7	69.5	69.4	69.8
3	66.7*	66.9	66.8	68.0	69.9	70.5	70.3	68.9	69.0	69.0	69.0	69.4	69.7
4	65.6	66.7	67.0	67.8	70.0	70.2	68.8	68.8	68.9	69.2	69.5	69.2	70.0
5	64.5	65.0	66.2	67.8	68.7	68.0	70.1	71.0*	72.3*	71.0*	73.0*	71.7*	[70.2]
6	60.5*	61.6*	62.5*	63.9*	65.8	66.5	66.8	68.9	66.4	69.2	70.6	73.0*	68.2
7	63.0	62.1	63.5	65.4	66.8	67.2	73.8*	66.4	66.8	65.8	67.9	67.5	68.5
8	65.5	65.3	65.0	67.8	66.3	68.7	67.8	68.3	67.4	67.8	67.7	67.9	68.8
9	62.0	63.2	64.5	65.8	67.4	68.5	68.3	67.5	70.3	68.4	68.4	67.5	67.9
10	65.6	65.5	66.4	66.8	68.0	68.9	70.3	68.0	68.5	68.0	68.8	68.3	68.7
11	64.2	63.8	64.5	65.5	66.4	68.9	68.2	69.5	68.4	68.2	68.7	68.7	68.5
12	63.2	64.0	65.3	66.1	66.8	67.4	66.8	66.6	66.7	66.8	67.0	67.1	67.3
13	63.8	65.5	67.1	68.6	69.8	69.0	70.7	68.3	68.1	68.6	71.9*	68.8	68.7
14	64.2	65.5	66.8	68.0	67.8	67.7	67.4	67.6	67.5	67.7	67.7	67.7	68.5
15	66.0	65.0	67.0	67.7	67.4	67.8	68.2	72.1*	70.0	70.2	67.5	67.5	69.3
16	63.4	64.9	66.0	67.0	67.8	67.6	67.3	67.2	67.6	67.8	67.1	68.0	67.8
17	64.0	64.0	64.9	67.7	67.8	68.0	67.9	68.0	68.0	68.0	68.7	69.2	68.6
18	61.4	62.8	65.0	66.2	66.8	67.5	68.1	67.7	70.2	69.2	68.8	68.4	68.4
19	61.6	62.5	64.8	65.8	66.7	67.5	68.8	71.6*	68.8	67.4	69.1	67.6	68.3
20	64.0	66.3	68.5*	68.8	68.8	68.8	67.7	70.2	68.7	67.4	67.3	67.7	68.5
21	62.6	63.8	65.8	67.1	67.9	68.8	68.5	68.7	68.5	68.4	68.0	67.7	68.2
22	62.6	63.6	65.8	68.0	69.0	69.0	68.6	68.8	68.5	68.2	68.2	68.0	68.5
23	59.8*	61.8*	63.7	66.2	67.4	68.0	68.0	68.0	68.0	68.0	67.8	67.6	67.4
24	62.5	64.0	65.9	66.6	67.2	67.4	67.3	67.5	67.6	67.6	67.8	67.8	68.1
25	65.4	64.6	64.8	66.0	67.4	68.2	68.3	68.2	68.5	68.8	68.4	68.8	68.2
26	64.0	64.8	65.0	65.8	66.5	68.0	68.2	67.8	68.0	68.6	70.1	70.6	68.9
27	64.5	65.5	66.2	67.0	67.6	67.5	67.5	68.0	68.2	68.6	68.8	68.7	69.2
28	64.0	65.6	66.2	67.2	68.3	68.5	67.8	68.0	68.2	68.2	68.3	68.5	68.5
29	64.0	64.2	64.8	66.4	67.0	68.0	67.8	67.7	68.5	68.3	68.8	68.8	68.6
30	62.4	63.8	64.8	66.5	67.7	68.0	67.7	67.6	67.5	67.6	68.0	68.2	68.5
31	63.6	64.2	64.8	65.6	66.9	67.8	67.6	67.6	67.8	68.0	67.8	68.2	68.3
Monthly mean	63.8	64.6	65.6	66.9	67.7	68.2	68.4	68.4	68.4	68.3	68.7	68.6	68.66
Normal	63.8	64.6	65.6	67.0	67.7	68.2	68.3	68.1	68.3	68.2	68.4	68.4	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

AUGUST, 1887.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	68.4	68.5	69.0	69.7	70.6	75.6*	77.1*	78.8*	79.3*	68.2	63.2*	61.3*
2	69.6	67.0	67.8	68.5	70.2	72.2	74.0	74.1	73.8	71.8*	67.9	67.8*
3	69.5	71.0	67.0	68.8	70.3	73.0	71.8	71.0*	74.0	68.2	66.2	64.8
4	66.2*	67.9	65.8*	70.0	68.8	70.6	74.9	76.7	72.4	66.8	63.8	61.6*
5	67.8	67.7	70.0	68.3	69.8	70.6	73.0	72.6	73.5	70.5	68.0	65.0
6	68.0	68.8	67.7	68.6	67.5*	72.0	74.2	77.0	75.5*	70.4	67.1	65.2
7	67.4	67.0	67.8	69.5	70.2	71.6	75.0	74.5	73.5	70.2	66.0	64.0
8	66.0*	66.6	68.0	68.2	69.1	71.6	73.8	74.9	74.8	70.8	67.9	64.3
9	68.1	68.8	68.8	68.5	69.8	71.4	71.8	73.0	71.2	67.7	64.8	65.0
10	68.3	67.8	68.4	69.0	68.8	71.5	73.3	74.0	73.0	70.6	68.0	66.2
11	68.8	68.5	68.6	68.8	69.6	70.7	72.7	75.0	73.9	70.7	67.0	64.8
12	68.2	68.0	68.0	68.0	68.2	70.3	73.1	75.0	74.8	72.6*	68.1	65.9
13	68.6	69.0	68.9	69.1	70.2	72.0	74.5	76.5	73.6	71.8*	68.5*	65.0
14	71.0	70.1	70.2	70.8	70.8	72.3	74.2	75.8	70.0*	68.0	66.9	65.0
15	70.5	68.0	70.2	67.8	71.6	72.4	75.6	74.4	73.4	70.0	66.9	66.0
16	68.3	69.0	68.1	67.0	70.3	73.2	75.4	74.0	70.3	66.0*	64.8	64.3
17	68.3	68.7	69.2	69.6	70.8	73.1	75.2	75.1	72.0	67.0	64.4	63.8
18	68.6	68.8	69.0	69.2	70.5	72.3	74.8	74.9	70.4	65.3*	63.7	64.3
19	69.1	69.9	69.9	70.7	71.0	72.2	75.1	76.8	73.0	67.0	64.2	62.5
20	68.9	69.2	69.0	70.2	70.5	72.0	74.2	75.8	73.8	68.7	64.4	62.5
21	67.4	67.9	68.9	68.9	69.7	72.3	75.2	75.4	71.1	68.0	63.9	63.2
22	67.9	68.2	68.7	68.8	70.0	72.2	74.1	74.6	72.9	70.1	66.0	64.8
23	69.0	69.0	69.2	68.8	69.2	70.5	72.4	73.9	73.4	70.5	67.7	66.3
24	68.8	69.0	69.0	69.5	70.5	71.7	74.0	75.0	71.9	68.2	64.2	62.6
25	69.6	70.2	70.5	70.8	70.8	73.1	74.8	74.3	72.0	69.8	68.6*	66.6
26	69.1	69.4	69.9	69.8	70.4	72.4	74.8	75.3	74.1	67.6	64.0	62.8
27	68.8	68.6	68.8	68.8	69.9	71.2	73.8	73.9	71.3	66.5	64.3	63.7
28	70.5	70.4	70.2	70.2	70.5	71.0	73.2	74.8	71.7	67.4	65.6	65.1
29	70.6	71.9*	71.8*	71.2	72.8*	72.1	74.5	69.2*	70.8	69.0	66.1	66.0
30	69.2	68.8	62.4*	69.0	70.9	71.0	70.1*	69.5*	71.3	69.4	66.2	66.2
31	71.8*	70.0	71.0	67.5	69.9	71.3	73.8	72.1*	71.2	68.0	64.8	64.8
Monthly mean	68.8	68.8	68.8	69.2	70.1	71.9	74.0	74.4	72.8	68.9	65.9	64.6
Normal	68.9	68.7	69.0	69.2	70.1	71.8	74.0	74.9	72.6	68.8	65.8	64.7

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794

Increasing scale readings correspond to increasing east declination.

AUGUST, 1887.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
1	61.8	61.6*	64.5	64.4*	65.0*	68.9	68.4	68.5	70.6	74.2*	75.6*	72.0*	69.4
2	64.0	65.3	66.0	67.9	68.5	68.7	67.3	67.7	68.8	74.5*	75.9*	67.1	69.4
3	65.0	66.8	67.1	68.8	68.8	70.3	68.5	71.5*	71.0	67.8	69.0	67.0	69.0
4	62.5	64.2	66.1	67.8	68.9	74.0*	69.5	73.8*	69.4	70.6	68.0	67.2	68.6
5	64.9	65.7	66.7	67.6	68.9	70.0	69.0	69.8	71.7*	70.1	68.8	68.8	69.1
6	63.8	64.8	66.2	67.6	70.2	68.8	68.7	67.8	69.0	68.8	68.4	67.7	68.9
7	62.0	62.7	64.8	67.7	67.3	68.9	72.5*	69.3	69.9	69.0	71.2	68.5	68.8
8	63.8	64.5	65.1	67.0	68.1	68.5	68.7	68.7	68.7	68.7	68.7	68.7	68.6
9	65.3	65.2	66.7	67.0	67.8	68.6	68.7	70.0	68.8	68.8	68.7	68.6	68.5
10	65.4	65.1	65.8	67.0	68.2	68.8	68.8	68.7	68.7	68.8	68.5	68.4	68.8
11	63.3	63.8	64.5	66.0	67.2	68.1	68.0	68.1	68.4	69.1	68.5	68.2	68.4
12	65.7	65.1	65.8	66.8	68.0	68.5	68.2	68.0	68.3	68.5	68.2	68.5	68.7
13	63.0	62.8	64.5	66.6	68.0	68.2	67.9	69.9	67.8	68.4	68.8	68.7	68.8
14	63.2	64.3	66.0	66.2	65.6*	70.4	67.6	70.4	66.8	67.4	68.2	68.7	68.8
15	64.8	65.8	66.8	68.8	68.5	71.3	69.1	73.5*	69.7	68.7	69.5	70.2	69.7
16	64.4	65.5	67.5	68.4	68.8	68.0	67.2	67.8	67.9	68.6	68.6	68.3	68.4
17	64.0	65.8	67.0	68.0	68.8	68.3	67.6	67.4	67.2	67.8	68.0	68.0	68.6
18	64.9	66.6	68.2	68.8	68.9	69.1	68.5	68.6	68.8	68.8	68.8	69.0	68.8
19	62.8	64.5	66.7	68.1	68.9	69.0	68.7	68.7	68.7	68.6	68.8	68.9	68.9
20	63.8	65.0	66.1	67.3	66.5	65.7*	65.8*	66.8	67.9	68.0	67.9	67.4	68.2
21	64.1	64.2	66.1	66.8	66.8	67.0	66.8	66.8	66.8	67.2	67.8	67.8	67.9
22	66.0	66.6	66.7	67.6	68.9	68.8	68.8	69.0	70.1	68.9	69.0	68.8	69.1
23	65.3	66.0	67.8	68.4	68.5	68.8	69.1	69.2	69.9	69.8	68.8	69.3	69.2
24	64.2	64.8	66.0	67.1	67.9	67.2	67.7	67.8	68.0	69.5	70.3	68.8	68.5
25	65.3	65.7	66.5	67.9	68.6	68.8	69.1	69.2	69.8	69.5	69.8	69.0	69.6
26	62.4	63.8	65.3	65.7	67.8	67.7	66.9	67.5	67.7	68.0	68.1	68.0	68.3
27	63.5	63.9	65.3	66.3	67.2	67.8	67.5	67.5	67.8	68.2	68.8	70.3	68.1
28	63.8	64.5	64.8	64.7*	64.2*	66.0*	68.0	69.0	72.5*	73.0*	73.5*	70.3	69.0
29	65.6	66.2	66.3	68.1	68.5	70.6	70.8	72.0*	70.0	69.7	70.1	68.6	69.7
30	67.0*	67.8*	68.0	70.0	69.1	70.7	71.8*	68.8	69.2	70.7	70.6	70.7	69.1
31	65.4	67.0	67.8	68.7	68.7	68.8	70.3	68.7	71.8*	72.6*	70.0	70.5	69.4
Monthly mean	64.2	65.0	66.2	67.4	68.0	68.8	68.6	69.0	69.1	69.4	69.5	68.8	68.85
Normal	64.1	65.0	66.2	67.6	68.3	68.9	68.4	68.5	68.7	68.8	68.9	68.7	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

SEPTEMBER, 1887.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	68.8	71.3	70.8	72.7*	73.6*	72.2	74.2	71.6	67.0*	67.0	66.6	66.9
2	69.2	68.3	67.1	67.8	70.8	73.1	72.9	72.6	71.9	67.2	66.1	65.3
3	66.8	68.8	68.8	68.7	70.0	71.7	73.8	73.8	71.7	66.8	64.8	64.3
4	67.0	68.1	68.8	68.7	69.0	71.5	73.9	74.5	72.3	69.9	67.0	65.4
5	67.8	68.8	69.6	70.5	70.9	73.0	75.6*	75.8*	72.6	66.6	64.2	65.0
6	68.8	69.0	69.0	70.0	70.9	72.4	75.1	75.1	72.3	67.0	64.2	64.2
7	68.8	68.7	69.0	69.3	70.5	72.2	74.4	74.5	73.0	68.8	66.2	65.7
8	68.8	69.1	69.6	70.3	70.8	71.9	71.2	73.5	70.5	67.8	66.3	65.0
9	68.8	68.8	69.4	70.2	71.2	73.8	75.3	74.0	70.6	66.4	63.5*	63.7
10	71.2	72.0	72.0	70.8	69.0	70.0	73.0	72.4	70.8	68.4	65.5	63.7
11	69.4	69.2	69.5	70.0	70.8	70.0	71.4	71.6	69.2	66.5	65.7	66.0
12	68.4	68.5	69.6	70.0	70.1	72.2	73.6	72.2	71.0	67.8	65.8	65.2
13	68.5	68.8	69.9	70.3	70.0	72.0	72.2	72.0	71.8	68.8	67.2	66.7
14	68.8	69.0	69.0	68.7	70.5	72.5	73.7	75.2*	71.7	68.8	66.2	65.7
15	70.2	70.0	70.2	70.5	70.7	72.2	74.8	74.2	69.7	66.8	64.8	64.2
16	68.8	70.8	71.6	72.6*	74.0*	73.5	74.4	73.5	69.2	65.9	65.5	65.0
17	69.8	71.9	70.8	70.3	70.8	71.6	73.1	73.2	72.1	70.0	66.9	65.1
18	69.6	69.6	70.2	70.5	70.8	71.4	72.0	73.2	73.0	70.5	67.8	65.9
19	68.5	68.5	69.0	70.0	70.5	71.8	74.0	72.1	70.7	68.8	65.9	64.8
20	68.5	68.8	68.9	69.2	70.0	71.2	73.5	73.0	71.5	70.3	68.0	66.0
21	68.9	70.5	69.0	72.2	71.6	71.8	73.2	74.0	73.0	70.0	67.5	65.0
22	69.0	69.0	69.4	69.8	70.0	70.6	72.0	71.5	70.1	68.8	67.5	67.5
23	68.7	68.9	69.1	69.9	70.2	70.9	71.0	71.6	72.2	70.8	67.6	65.5
24	71.0	70.1	68.8	68.6	68.4	70.6	70.4	70.6	70.2	67.2	65.8	65.7
25	68.8	70.6	68.2	69.5	69.5	70.5	70.7	70.5	72.8	67.1	67.4	62.6*
26	71.8*	74.4*	70.5	65.3*	68.2	67.3*	64.2*	69.5*	71.5	68.4	69.0*	68.3*
27	67.0	71.0	66.5*	70.6	66.6*	64.8*	66.0*	69.0*	70.6	70.0	69.2*	67.3
28	69.5	71.0	66.5*	67.8	69.5	68.0*	70.3*	71.0	70.8	70.1	69.1*	67.8
29	70.0	66.4*	71.0	71.0	70.4	68.8*	68.5*	70.5	69.4	68.3	66.0	65.5
30	65.5*	66.1*	68.5	70.4	69.8	70.4	70.8	71.7	71.5	68.8	66.6	64.9
Monthly mean	68.9	69.5	69.3	69.9	70.3	71.1	72.3	72.6	71.2	68.3	66.5	65.5
Normal	68.9	69.6	69.5	69.8	70.2	71.7	72.9	72.6	71.3	68.3	66.3	65.5

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794

Increasing scale readings correspond to increasing east declination.

SEPTEMBER, 1887.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
1	67.1	67.9	69.2	70.0	72.5*	69.2	68.6	73.0*	70.2	68.1	68.5	65.2*	69.7
2	66.5	67.2	67.9	68.8	69.5	71.5*	70.7	71.7*	70.0	68.4	68.0	68.1	69.2
3	64.8	65.8	67.1	69.0	70.0	70.2	70.3	69.5	69.3	70.0	68.5	68.6	68.9
4	64.9	66.1	67.3	68.9	70.5	70.6	70.3	68.8	69.8	69.1	69.0	68.9	69.2
5	65.1	66.0	68.0	68.9	69.2	68.8	68.6	69.2	69.0	68.8	68.8	68.7	69.2
6	65.0	66.8	67.9	69.8	70.2	68.9	68.8	68.8	68.6	68.5	68.8	68.8	69.1
7	65.4	66.6	68.3	69.5	69.9	68.7	68.5	68.8	69.0	68.1	68.3	68.7	69.2
8	65.2	65.9	66.9	68.4	69.0	68.7	68.8	68.8	68.8	68.8	68.8	68.8	68.8
9	63.4	63.5*	65.0*	66.8	68.5	68.5	68.5	67.9	67.1	67.2	67.8	69.8	68.3
10	64.4	66.3	66.7	67.0	69.0	68.0	67.9	68.8	68.5	68.8	68.9	68.8	68.8
11	65.0	65.8	66.2	66.7	68.0	67.8	68.4	68.8	68.0	68.2	68.6	68.2	68.3
12	65.0	66.0	67.1	68.1	68.1	67.1	67.5	68.0	67.9	68.0	68.5	67.5	68.5
13	66.0	66.5	66.8	67.5	68.0	67.9	68.3	68.6	68.6	68.5	68.5	68.6	68.8
14	65.2	66.6	67.7	67.5	68.1	68.7	68.0	68.7	68.5	69.0	71.0	69.6	69.1
15	65.8	67.2	68.6	68.9	71.1	71.0	70.1	70.2	69.4	70.7	68.4	69.2	69.5
16	65.7	67.8	68.8	69.0	69.0	68.6	68.3	69.0	68.2	68.8	69.1	70.8	69.5
17	65.3	66.3	67.1	68.8	69.0	68.6	68.8	68.8	68.5	68.4	68.7	68.5	69.3
18	65.7	66.8	68.3	69.1	69.5	68.9	68.9	70.2	68.2	68.2	68.2	68.2	69.4
19	65.1	66.5	68.5	69.2	69.5	68.9	69.0	68.9	68.8	68.6	68.5	68.5	68.9
20	65.2	66.0	68.0	69.0	69.1	68.5	68.8	68.8	68.9	68.5	68.9	69.0	69.1
21	64.8	66.9	68.0	67.5	67.1	67.5	67.8	67.0	69.5	71.1	72.0*	73.5*	69.6
22	67.7	67.8	68.5	69.0	68.5	69.1	68.6	68.7	68.5	68.7	68.8	68.8	69.1
23	64.6	65.4	65.0*	63.3*	67.2	67.7	68.1	68.6	68.4	71.8*	64.7*	74.0*	69.0
24	65.4	66.7	67.3	67.6	67.2	68.1	68.2	68.5	68.5	68.6	69.0	70.2	68.4
25	62.7*	64.3	66.2	65.0*	70.7	71.0	68.5	77.2*	69.5	77.0*	80.0*	73.0*	69.7
26	68.8*	68.6	68.0	68.0	70.0	71.0	71.2	69.5	68.8	68.8	68.5	69.0	69.1
27	66.8	66.6	67.3	68.0	74.0*	73.2*	73.5*	73.8*	68.7	69.6	69.0	67.5	69.0
28	67.8	68.5	70.8*	71.0	70.1	69.1	69.9	69.2	69.8	68.9	69.0	70.5	69.4
29	65.8	67.2	67.6	69.0	68.6	66.4	68.7	67.6	66.3	66.0*	66.4	66.7	68.0
30	64.0	66.0	66.8	68.5	69.0	67.5	67.0	67.0	67.5	66.8	68.2	67.3	67.9
Monthly mean	65.5	66.5	67.6	68.3	69.3	69.0	69.0	69.4	68.7	69.0	69.3	69.1	69.00
Normal	65.5	66.6	67.6	68.6	69.1	68.8	68.8	68.7	68.7	68.7	68.6	68.7	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time.

300 divisions + tabular quantity.

OCTOBER, 1887.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	67.0	65.9	68.0	68.8	68.0	69.6	71.0	72.0	71.5	70.0	[67.7]	[66.1]
2	69.1	70.0	69.5	69.5	69.0	70.7	71.8	73.0	73.1	70.8	67.3	65.7
3	69.0	69.5	69.4	68.6	69.1	69.1	70.6	71.3	72.4	71.6	69.0	66.5
4	68.8	68.8	68.9	68.8	68.8	68.5	70.8	73.0	74.8	72.6	69.0	66.0
5	69.5	70.7	67.7	69.6	69.9	70.0	70.5	72.5	71.5	[70.2]	68.7	66.8
6	71.0	71.2	71.3	71.0	71.1	71.5	72.0	73.4	73.1	69.5	66.8	65.0
7	71.0	71.2	71.1	70.8	70.9	70.8	73.0	71.8	73.0	69.2	66.8	65.0
8	68.7	69.0	69.2	69.6	69.0	69.7	70.8	72.0	71.1	69.2	67.7	66.8
9	68.5	68.8	68.5	68.8	68.7	69.4	70.2	71.7	73.5	72.1	70.7*	68.2
10	69.7	69.9	70.0	68.8	70.0	71.0	71.0	72.4	74.6	72.0	70.3	67.6
11	69.6	69.0	69.0	69.0	69.4	70.4	72.0	73.8	73.4	70.8	66.2	64.7
12	73.0*	74.0*	71.0	67.3	69.8	71.0	72.0	73.1	73.0	71.2	68.7	66.3
13	69.2	68.8	68.8	69.0	68.1	67.8	67.8*	70.3	71.5	68.9	65.8	65.8
14	71.0	70.8	69.0	70.0	68.1	70.0	71.8	72.8	72.4	68.8	66.0	65.1
15	69.0	68.8	69.2	69.6	69.1	68.6	71.2	71.8	72.3	71.3	68.5	66.0
16	71.4	71.3	70.3	69.8	71.0	71.0	71.8	72.2	71.8	71.5	67.8	65.2
17	71.8	69.5	71.6	71.0	71.0	71.3	71.6	73.2	73.5	70.5	67.0	66.2
18	68.5	68.8	68.8	69.0	70.0	70.5	71.0	72.4	72.4	70.3	67.6	66.2
19	68.2	68.8	68.8	69.0	68.7	69.0	70.5	72.4	73.3	71.6	69.0	67.0
20	69.0	69.0	69.0	69.8	70.0	70.5	71.2	72.9	72.9	71.0	68.8	67.2
21	69.0	69.1	69.5	70.1	70.3	70.8	72.5	74.0	75.5*	72.8	68.8	66.8
22	72.6*	75.7*	73.5*	68.0	70.0	66.2*	70.0	72.6	73.2	73.8*	67.4	65.0
23	68.2	68.0	68.8	70.5	69.2	70.7	70.5	71.8	71.0	69.5	68.1	67.0
24	68.6	68.5	68.5	68.4	68.5	69.0	69.5	70.3	70.0	69.5	68.4	67.5
25	69.0	68.8	68.3	68.7	69.2	70.2	70.3	71.2	71.8	71.0	70.0	69.0*
26	74.0*	72.6*	59.7*	71.2	68.7	63.0*	65.7*	72.5	70.6	67.3*	66.5	66.1
27	71.7	67.7	73.2*	68.4	69.0	70.3	69.2	69.0*	69.2*	68.8	68.2	68.0
28	68.5	68.5	68.6	68.8	69.2	69.2	70.5	70.8	70.5	68.8	67.9	66.6
29	68.7	69.0	69.0	69.0	69.5	70.0	70.8	71.5	71.5	70.4	68.8	66.0
30	72.2*	71.0	70.8	70.8	71.8	72.8*	73.5	72.3	70.8	59.0*	64.5*	63.5*
31	69.0	69.2	69.0	69.5	70.0	70.4	72.8	73.8	73.0	70.0	66.9	65.0
Monthly mean	69.8	69.7	69.3	69.4	69.5	69.8	70.9	72.2	72.3	70.1	67.9	66.3
Normal	69.4	69.3	69.3	69.4	69.5	70.0	71.2	72.3	72.3	70.4	67.9	66.3

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794

Increasing scale readings correspond to increasing **east declination.**

OCTOBER, 1887.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
1	[65.8]	[66.8]	[67.9]	[68.6]	[69.1]	69.5	69.6	68.8	68.8	68.6	69.0	68.6	[68.6]
2	65.0	66.0	67.7	68.6	68.8	68.7	69.0	69.0	69.0	68.8	68.8	68.9	69.1
3	64.8	64.8	65.8	67.2	68.2	69.0	68.8	68.9	68.7	68.4	68.8	68.2	68.7
4	64.3	64.6	65.9	66.9	67.8	68.5	68.8	68.8	68.2	68.2	68.2	68.6	68.6
5	67.0	67.9	68.8	69.2	69.5	70.5	70.5	70.8	70.7	70.8	70.8	70.8	[69.8]
6	66.8	68.2	68.8	69.6	68.6	69.1	69.1	70.0	70.8	70.5	71.2	71.4	70.0
7	65.8	66.0	67.8	67.8	67.8	69.0	68.8	68.5	68.7	68.8	68.7	68.7	69.2
8	66.5	66.4	66.8	66.8	68.0	68.0	68.3	68.5	68.6	68.7	68.8	68.6	68.6
9	66.2	66.8	67.8	68.7	69.0	69.2	69.0	69.1	69.2	69.2	69.5	69.6	69.3
10	66.5	66.8	67.7	67.5	68.0	68.6	68.6	70.6	69.5	69.2	69.0	69.0	69.5
11	65.7	66.9	68.3	68.9	69.1	68.8	69.0	68.8	69.0	70.3	70.0	71.8	69.3
12	64.2	65.8	66.8	67.2	68.7	68.5	73.8*	69.0	69.1	69.0	69.1	67.3	69.5
13	66.1	68.8	68.9	68.8	68.5	68.7	72.0	68.7	70.0	69.8	70.0	69.0	68.8
14	65.3	65.9	67.0	68.0	68.8	68.6	68.9	69.0	69.1	68.6	68.5	68.8	68.8
15	65.7	66.8	68.8	69.8	69.5	70.0	70.0	69.5	69.5	69.7	69.6	70.3	69.4
16	65.3	65.6	68.0	69.0	68.8	69.7	69.0	69.0	68.8	69.5	70.5	70.2	69.5
17	65.7	66.8	68.1	69.2	68.5	68.9	69.0	68.8	69.1	68.8	69.0	68.2	69.5
18	65.8	66.5	67.0	68.0	68.2	68.5	68.3	68.7	69.2	70.0	68.0	68.2	68.8
19	66.0	67.0	68.5	69.6	70.0	70.0	70.2	70.2	70.0	69.5	69.3	69.0	69.4
20	66.3	67.8	68.0	67.5	68.5	68.0	69.4	69.8	69.7	69.3	69.0	69.0	69.3
21	66.6	67.7	68.8	68.7	68.8	69.0	69.2	69.0	69.5	70.0	70.2	73.4*	70.0
22	66.8	67.4	64.5*	66.2	66.8	68.8	69.0	69.5	68.8	71.8	72.0	70.2	69.6
23	66.6	67.0	67.8	68.5	71.8*	71.2	72.0	69.3	70.7	70.8	72.2*	70.0	69.6
24	66.8	67.2	67.7	68.0	68.1	68.8	68.8	68.9	69.0	69.0	68.8	68.8	68.6
25	68.0	68.6	70.0	70.5	70.9	71.3	71.6	72.0	71.8	72.0	71.4	75.2*	70.4
26	66.2	66.6	68.8	70.0	69.0	71.0	73.1*	72.0	72.4*	73.6*	74.0*	71.5	69.4
27	67.8	68.5	68.5	69.5	69.5	68.8	69.5	69.8	69.0	69.3	70.2	68.8	69.2
28	66.3	67.2	68.0	68.0	68.8	69.0	69.1	69.0	69.0	68.8	68.8	68.8	68.7
29	65.8	67.0	68.0	68.8	69.2	70.0	70.4	70.5	70.0	68.8	70.0	72.1*	69.4
30	64.8	66.2	66.8	68.5	68.7	69.0	69.0	69.5	69.0	69.0	69.0	69.0	68.8
31	65.0	66.8	68.0	69.5	70.2	70.0	70.8	70.2	70.0	70.2	70.4	70.4	69.6
Monthly mean	66.0	66.9	67.8	68.5	68.9	69.2	69.8	69.5	69.5	69.6	69.8	69.8	69.26
Normal	66.0	66.9	67.9	68.5	68.8	69.2	69.5	69.5	69.4	69.5	69.5	69.3	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

NOVEMBER, 1887.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	70.3	70.4	70.5	70.4	71.0	71.0	71.8	73.0	71.5	68.5	67.3	66.0
2	69.8	70.2	70.4	70.6	70.8	71.2	73.0*	73.0	70.6	67.8	65.5*	64.0*
3	68.0	68.5	69.0	68.8	69.7	70.2	67.0*	70.9	72.8	72.2	69.0	66.4
4	67.2	67.5	68.0	68.8	68.8	69.0	70.8	72.8	72.0	71.2	70.0	68.5
5	73.4*	73.8*	73.2*	72.8*	72.5*	72.2	72.1	73.0	72.0	70.2	68.3	67.8
6	78.8*	78.6*	73.0*	72.2*	72.0	71.8	71.8	72.6	71.7	71.3	69.5	67.7
7	69.8	68.8	68.8	69.0	69.2	70.3	71.5	73.0	72.1	70.4	68.8	66.7
8	68.8	68.8	68.8	69.0	68.8	71.4	73.0*	74.8*	71.4	70.0	68.7	66.6
9	68.8	68.2	71.0	68.8	70.0	70.8	72.5	73.0	72.8	70.5	68.2	66.8
10	71.0	69.0	71.0	71.5	71.8	61.8*	68.1	70.8	70.8	70.7	69.0	68.5
11	68.9	67.3	70.1	69.6	70.0	69.0	69.5	70.6	71.0	70.3	68.7	68.0
12	69.4	69.5	70.4	70.0	70.3	68.8	70.1	70.2	70.2	68.7	67.9	66.1
13	68.7	69.0	69.2	69.5	69.5	70.0	70.8	72.2	73.6*	71.6	68.7	66.0
14	67.6	70.0	70.8	70.0	70.5	70.8	72.0	72.8	71.8	68.8	67.9	66.2
15	68.5	68.7	68.8	68.9	69.0	70.0	70.7	71.6	71.5	69.7	67.2	65.9
16	68.5	68.5	68.5	68.5	68.8	70.0	71.0	72.2	71.8	69.3	67.5	66.2
17	68.7	69.2	69.7	69.5	68.7	70.2	70.4	70.8	69.7	70.3	68.8	66.7
18	68.5	68.6	68.8	69.5	69.2	69.9	69.9	70.4	70.6	70.4	68.8	67.5
19	69.6	70.8	70.5	68.8	69.5	69.0	67.6	70.5	71.8	70.5	68.8	67.8
20	69.0	70.4	65.8*	68.8	68.8	68.8	68.8	69.8	69.7	69.2	62.8*	66.7
21	68.5	60.8*	76.0*	66.0*	72.2	68.5	68.5	70.0	68.9	67.6	70.4	64.3
22	68.8	64.4*	68.2	68.5	68.8	69.0	68.5	68.8	68.7	67.0*	66.2	65.0
23	70.0	68.2	68.8	68.0	68.2	68.7	69.2	68.8	68.1*	67.1*	67.3	66.0
24	65.0*	68.2	68.6	68.7	68.8	68.9	68.5	69.5	70.0	68.8	68.5	67.3
25	68.3	67.2	67.8	68.8	68.8	69.0	69.2	69.5	69.4	70.0	68.4	66.2
26	68.2	68.4	68.2	68.5	69.0	69.0	69.5	70.3	70.3	69.5	68.5	66.8
27	68.2	68.3	68.5	68.6	68.8	69.4	70.2	70.5	70.7	68.9	67.5	66.0
28	68.0	68.8	68.6	68.6	69.0	69.0	69.5	70.8	70.5	69.2	67.2	65.2
29	68.4	67.7	67.8	70.5	71.5	66.8*	67.8	69.0	68.0*	68.6	68.5	67.0
30	69.2	68.8	67.0	71.2	70.3	70.3	69.8	70.6	70.0	70.0	68.2	66.5
Monthly mean	69.2	68.9	69.5	69.4	69.8	69.5	70.1	71.2	70.8	69.6	68.1	66.6
Normal	68.8	68.8	69.1	69.3	69.7	69.9	70.0	71.1	70.9	69.8	68.3	66.6

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0.′794 | Increasing scale readings correspond to increasing east declination.

NOVEMBER, 1887.

Day.	13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
1	65.5	66.5	67.9	70.2	70.1	70.0	70.3	70.1	70.5	70.2	70.2	70.2	69.7
2	64.6	65.8	66.7	66.3	68.0	68.5	68.1	68.2	68.5	68.2	67.8	68.5	68.6
3	65.0	63.9*	65.0*	66.0	66.8	67.2	68.0	68.0	68.0	68.0	67.7	67.2	68.0
4	68.0	70.2*	70.6*	71.0*	70.6	71.5	72.2	72.6*	73.0*	73.0*	73.0*	73.8*	70.6
5	68.5	68.8	69.2	70.4	71.6*	72.0	72.0	72.2*	72.7*	73.0*	73.8*	74.0*	71.6
6	66.8	67.6	67.5	68.3	69.4	69.0	70.1	70.0	69.8	69.5	69.5	69.0	70.7
7	66.7	67.3	68.2	68.8	68.8	69.3	69.2	69.2	69.2	69.0	69.0	68.8	69.2
8	66.0	65.5	65.6	66.5	69.7	70.5	70.5	70.5	73.0*	70.5	69.6	69.8	69.5
9	66.0	66.2	66.8	68.0	68.6	68.8	69.8	70.5	70.2	70.5	71.0	70.2	69.5
10	68.0	68.1	68.5	69.0	69.0	69.5	69.5	69.5	69.7	69.6	69.2	68.8	69.3
11	67.5	67.5	68.4	68.5	69.0	69.5	69.5	69.5	70.0	69.4	69.3	69.0	69.2
12	66.2	66.8	68.0	68.6	68.8	68.8	68.8	69.0	68.8	68.8	68.8	68.5	68.8
13	64.5	66.2	68.1	68.8	68.8	69.6	70.2	69.0	68.8	68.8	68.7	69.0	69.1
14	66.5	66.7	67.1	68.4	69.0	69.5	69.5	69.2	69.0	70.5	68.1	68.4	69.2
15	66.0	66.5	67.3	68.2	69.0	69.0	69.2	69.0	68.8	68.8	68.6	68.5	68.7
16	66.7	67.8	68.6	68.8	69.2	70.0	70.2	70.0	69.6	69.5	69.8	69.0	69.2
17	66.1	65.8	67.4	68.0	69.1	68.8	69.7	70.1	70.0	70.2	70.2	68.8	69.0
18	67.4	68.0	67.7	68.8	69.4	70.1	70.2	70.5	69.2	69.4	69.0	68.8	69.2
19	67.8	67.5	67.8	68.8	69.0	71.0	70.4	70.3	72.3*	71.6	70.0	70.8	69.7
20	66.0	66.0	66.0	67.8	67.6	70.4	69.5	70.2	70.3	69.0	69.0	68.5	68.3
21	64.5	65.5	66.6	68.4	69.5	70.3	69.8	70.2	69.6	68.8	67.8	69.2	68.4
22	66.0	67.8	68.2	70.5	69.0	69.2	71.5	69.6	69.9	66.0*	68.7	69.4	68.2
23	66.8	67.8	68.4	68.4	68.7	68.9	70.8	68.5	68.7	68.8	68.7	68.8	68.4
24	67.2	67.8	67.8	68.0	68.1	68.5	68.6	68.6	68.5	68.5	68.2	68.4	68.3
25	66.8	67.8	68.1	68.4	68.6	68.8	69.6	68.6	68.3	68.8	68.5	68.5	68.5
26	66.7	68.0	68.8	68.9	68.6	70.4	68.8	68.6	68.8	68.3	68.7	68.0	68.7
27	66.0	65.9	66.6	66.8	68.8	69.0	69.0	69.1	68.8	68.8	69.2	68.8	68.4
28	65.6	66.5	67.8	67.8	68.6	69.8	69.0	70.1	69.4	68.8	68.0	71.0	68.6
29	66.8	66.5	67.8	68.4	68.8	69.5	69.0	68.8	68.6	68.8	69.4	68.3	68.4
30	66.7	67.4	67.0	68.3	69.0	70.0	70.0	69.7	69.2	68.6	68.8	68.6	69.0
Monthly mean	66.4	67.0	67.6	68.4	69.0	69.6	69.8	69.6	69.7	69.4	69.3	69.3	69.07
Normal	66.4	67.0	67.6	68.3	68.9	69.6	69.8	69.4	69.2	69.2	69.0	69.0	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

DECEMBER, 1887.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	68.5	69.0	68.5	68.8	68.8	68.8	69.6	70.8	70.8	69.6	68.3	65.4*
2	68.4	68.4	68.5	68.2	68.8	68.8	69.4	70.5	70.8	69.8	68.2	66.2
3	68.2	68.5	68.4	68.8	68.8	69.0	70.0	70.7	71.1	70.8	69.5	67.2
4	68.5	68.2	68.5	68.6	68.8	68.5	68.8	69.2	69.8	70.2	69.6	68.5
5	68.2	68.5	68.8	68.8	68.8	68.8	69.6	69.9	70.2	70.8	69.5	68.2
6	69.3	69.0	68.2	68.8	69.0	69.5	69.5	70.7	71.2	69.0	65.8*	67.6
7	68.2	68.5	69.2	69.0	68.5	68.8	68.8	67.4	70.2	70.0	69.9	68.2
8	68.3	68.6	68.3	68.2	68.5	68.6	69.0	69.8	71.0	71.3	70.4	68.8
9	68.6	68.5	68.5	68.5	68.4	67.7	68.1	69.0	70.4	70.4	70.5	69.9
10	68.2	68.2	68.6	68.3	68.0	68.0	68.0	69.8	71.0	71.2	71.0	68.8
11	68.0	67.8	68.2	68.0	68.0	68.4	68.3	70.2	71.4	71.8	71.0	69.0
12	68.0	68.1	68.2	68.3	68.1	68.2	68.6	70.0	70.5	71.3	71.0	69.3
13	70.3	70.2	69.8	70.0	68.2	69.0	69.8	69.2	69.8	68.8	68.5	66.8
14	69.3	69.8	69.2	69.2	67.8	68.3	68.8	70.2	71.6	71.7	71.0	68.8
15	68.4	68.4	68.8	68.8	68.8	69.0	69.0	69.4	70.5	70.8	70.4	68.3
16	66.3	71.0	72.6*	72.0*	69.8	70.3	69.0	71.8	73.1	68.1*	68.5	67.3
17	68.8	68.4	68.6	60.5*	68.7	65.9	62.0*	63.2*	67.2*	68.0*	66.8*	68.2
18	68.0	69.5	66.4	67.9	68.3	68.8	68.8	68.5	71.1	72.6	71.8	69.6
19	67.5	70.0	66.6	67.2	66.2	63.2*	67.5	67.0*	68.2	71.8	71.8	70.0
20	68.8	68.2	68.2	69.2	66.5	66.8	68.7	69.8	71.0	71.0	70.5	68.8
21	69.0	68.6	67.4	68.5	68.6	66.7	66.8	68.1	70.6	72.9	72.5	68.4
22	74.5*	74.0*	72.8*	72.0*	68.6	69.8	70.3	71.0	71.3	71.8	71.2	69.5
23	68.7	68.6	67.8	68.6	68.0	68.2	68.9	70.0	71.2	72.2	71.6	69.5
24	68.8	68.8	68.7	68.4	68.5	68.3	68.6	69.8	71.4	72.8	72.0	70.0
25	70.0	69.3	70.5	69.1	68.9	68.6	68.4	69.5	69.8	71.3	71.0	68.5
26	69.2	69.2	68.2	68.8	68.8	66.3	67.4	70.2	69.8	70.7	70.2	68.8
27	65.8*	68.2	68.4	66.1	68.0	67.2	67.8	68.5	69.7	70.1	68.8	67.2
28	68.0	67.5	68.2	68.5	67.9	66.1	64.5*	67.3	68.8	71.2	71.0	70.4
29	68.8	68.7	68.7	68.4	68.4	67.8	68.2	68.6	71.2	71.6	71.3	[69.3]
30	68.2	68.8	70.1	69.9	69.4	68.2	68.8	70.8	73.0	72.4	70.5	67.8
31	68.0	68.8	68.6	69.0	68.8	68.8	69.0	70.2	71.5	72.4	71.8	69.0
Monthly mean	68.6	69.0	68.8	68.5	68.4	68.1	68.4	69.4	70.6	70.9	70.2	68.5
Normal	68.5	68.8	68.5	68.6	68.4	68.2	68.7	69.7	70.7	71.1	70.5	68.6

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794 Increasing scale readings correspond to increasing east declination.

DECEMBER, 1887.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
1	64.5*	65.2	66.6	68.2	68.7	68.8	69.5	69.2	68.8	68.8	68.6	68.5	68.4
2	65.7	66.0	66.8	67.8	68.8	68.8	69.8	69.5	68.8	68.9	68.7	68.3	68.5
3	66.3	66.4	66.8	68.7	69.0	69.1	70.0	69.3	69.2	69.0	68.7	68.5	68.8
4	67.1	66.8	67.3	68.0	68.8	69.4	69.8	69.9	69.6	69.4	69.0	68.8	68.8
5	67.1	67.4	68.0	68.4	69.0	69.6	69.5	70.3	70.3	69.8	68.8	68.8	69.0
6	66.8	66.4	66.4	67.5	68.8	69.4	70.0	69.3	70.2	70.3	69.7	69.4	68.8
7	67.8	67.8	67.2	67.0	68.2	68.8	70.2	68.8	69.1	69.5	69.5	68.8	68.7
8	67.2	66.8	66.8	68.0	68.5	68.8	69.0	69.1	69.5	69.3	69.5	68.7	68.8
9	69.0	68.2	68.0	68.1	68.5	69.0	69.0	68.7	68.8	68.9	69.0	68.6	68.8
10	67.8	67.1	67.3	67.4	68.0	68.0	68.5	68.5	68.2	68.4	68.1	68.0	68.5
11	68.1	67.9	67.5	67.4	68.0	68.5	68.2	68.2	68.2	68.3	68.3	68.0	68.6
12	68.2	68.2	67.3	67.9	68.4	68.8	70.7	70.8	69.8	69.2	69.6	70.5	69.1
13	64.8*	66.5	68.2	68.8	70.2	69.6	69.8	69.0	69.2	69.2	69.9	70.2	69.0
14	67.2	67.5	67.9	68.6	70.0	70.2	70.2	70.0	69.6	68.9	68.5	68.4	69.3
15	67.5	67.4	67.6	68.8	70.0	70.0	70.1	69.8	69.5	70.2	70.6	70.3	69.3
16	64.8*	65.6	68.2	70.8*	71.3	70.8	70.5	70.4	69.8	73.1*	71.6	70.2	69.9
17	67.8	66.5	67.8	67.8	70.2	70.7	70.8	71.0	71.5	71.0	68.5	68.0	67.8
18	68.8	68.0	68.4	68.2	71.2	70.5	70.8	70.9	71.1	74.0*	71.0	67.4	69.6
19	68.2	67.8	67.4	68.8	68.8	69.7	70.2	71.2	71.0	69.8	69.6	66.3*	68.6
20	67.2	67.2	67.4	68.2	69.0	69.5	70.0	71.3	70.6	70.0	70.5	68.5	69.0
21	68.0	67.6	64.7	68.8	68.8	70.1	71.6	71.7	70.4	71.8	69.2	71.3	69.2
22	68.0	67.8	67.5	68.2	68.6	69.4	70.2	69.8	69.6	69.5	68.8	68.8	70.1
23	67.8	66.2	66.5	68.0	69.0	69.8	69.5	69.8	69.8	69.4	69.0	69.3	69.1
24	68.3	67.6	67.3	67.8	69.0	69.4	69.8	70.0	70.1	70.3	70.0	69.7	69.4
25	67.4	66.8	66.7	67.2	67.6	68.0	68.8	70.8	69.2	70.0	69.4	69.6	69.0
26	64.7*	66.2	66.0	67.9	67.5	67.8	68.2	68.0	70.4	68.2	68.9	68.8	68.3
27	65.8	66.8	66.9	66.7	67.6	67.7	68.0	68.2	69.0	67.5	68.2	68.8	67.8
28	69.0	68.8	67.9	68.6	70.3	71.0	69.2	70.8	70.7	68.4	66.6*	68.8	68.7
29	67.7	67.6	67.0	68.0	68.4	68.7	70.6	68.8	68.7	68.8	69.0	69.0	[68.9]
30	66.7	65.2	66.5	68.1	68.8	69.1	69.0	72.8*	69.6	69.0	68.8	68.5	69.2
31	67.4	67.4	67.0	68.0	69.0	69.0	69.7	70.0	69.5	69.0	69.0	68.8	69.2
Monthly mean	67.2	67.0	67.2	68.1	69.0	69.3	69.7	69.9	69.7	69.6	69.2	68.9	68.91
Normal	67.6	67.0	67.2	68.0	69.0	69.3	69.7	69.8	69.7	69.3	69.3	69.0	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

JANUARY, 1888.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	68.8	68.4	69.0	69.0	70.0	70.2	69.5	70.8	71.4	71.1	70.3	68.1
2	68.5	68.8	67.3	68.4	68.8	68.8	68.8	70.0	71.6	72.0	70.6	67.0
3	68.6	68.3	68.8	68.6	68.8	69.0	69.0	70.3	71.6	72.5	71.7	67.8
4	68.5	68.8	68.5	68.5	69.0	69.5	69.5	70.6	72.0	72.0	71.0	68.8
5	68.4	68.6	68.5	68.8	68.7	69.0	69.2	70.5	71.8	72.4	71.8	69.4*
6	69.1	70.2	72.0*	70.8*	70.0	67.2	68.3	69.1	70.3	72.2	72.0	70.4*
7	67.9	67.8	67.8	67.6	67.5	67.6	67.4	69.0	70.8	72.6	71.7	68.8
8	75.8*	76.6*	76.5*	66.2	56.0*	55.2*	61.8*	66.0*	69.8	70.8	72.7	71.2*
9	68.2	68.8	68.1	68.5	68.0	67.8	68.2	69.0	70.6	71.6	71.1	69.5*
10	68.0	67.9	68.1	68.0	67.0	67.0	67.8	68.5	70.2	71.5	71.8	70.2*
11	68.5	68.8	67.8	69.5	68.4	68.2	67.8	68.8	70.3	71.8	72.4	69.8*
12	70.2*	69.3	70.2	68.2	67.9	67.7	66.8	68.0	69.8	70.7	70.3	67.7
13	73.2*	74.8*	74.2*	75.5*	71.2*	70.6*	56.7*	59.4*	66.0*	67.7*	66.8*	61.8*
14	64.4*	67.8	67.3	66.0	66.4	66.5	66.8	68.7	70.7	70.2	68.8	64.2
15	67.0	67.9	68.1	67.0	67.3	66.8	68.2	68.3	70.4	71.0	68.9	67.8
16	69.2	68.2	68.2	66.7	67.2	67.0	67.7	68.2	70.8	72.8	70.8	66.6
17	68.1	67.2	67.4	67.3	66.0	66.3	68.0	69.1	71.0	73.5	70.6	67.4
18	67.2	67.6	66.2	69.0	67.0	68.0	68.1	69.0	71.2	71.0	69.8	66.2
19	67.8	68.0	68.0	67.9	67.6	67.9	68.0	68.8	70.8	71.0	69.0	66.8
20	67.4	67.5	67.8	67.8	67.6	68.0	67.8	69.0	71.3	71.2	69.1	65.8
21	67.5	67.4	67.2	67.6	67.6	66.4	67.1	70.0	71.3	71.1	69.3	66.3
22	68.0	68.7	67.1	68.4	68.6	67.5	68.1	69.2	68.8	68.8*	68.3	66.0
23	70.7*	74.2*	71.0*	77.6*	70.8*	64.0*	66.2	67.3	67.5*	65.8*	64.6*	61.8*
24	68.0	68.1	70.0	65.8	69.5	67.8	66.0	68.2	69.0	67.5*	65.6*	64.3
25	67.0	67.0	67.6	65.6	66.2	66.6	68.0	68.3	68.4	68.4*	65.8*	66.0
26	67.7	67.2	67.8	66.7	67.0	67.0	67.2	66.8	67.2*	66.8*	65.4*	62.2*
27	64.5*	68.3	68.2	68.2	65.8	67.5	68.2	67.6	68.4	67.5*	66.6*	64.3
28	66.0	69.0	67.7	68.5	66.8	67.2	67.8	67.1	66.3*	66.2*	65.6*	65.9
29	67.3	67.7	68.3	67.8	68.1	68.3	68.2	67.8	67.3*	67.6*	66.5*	65.3
30	68.1	68.0	68.3	68.6	68.7	68.2	68.4	67.8	68.0	67.7*	66.0*	64.8
31	67.5	68.0	68.4	68.4	68.5	68.8	68.5	69.0	68.2	67.1*	65.5*	64.0
Monthly mean	68.3	68.9	68.8	68.5	67.7	67.3	67.4	68.4	69.8	70.1	69.0	66.6
Normal	67.6	68.2	68.1	67.8	67.9	67.8	68.0	68.8	70.3	71.6	70.6	66.4

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794 — Increasing scale readings correspond to increasing east declination.

JANUARY, 1888.

Day.	13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
1	66.0	66.2	67.0	67.6	68.6	69.6	69.9	69.8	70.0	69.0	68.5	68.2	69.0
2	66.3	65.8	66.6	67.8	68.8	69.0	69.5	69.7	69.8	69.8	69.0	68.8	68.8
3	66.6	66.3	67.3	68.6	69.0	70.0	70.2	70.6	70.6	69.8	69.3	69.0	69.3
4	66.4	66.0	66.3	67.2	68.6	69.2	69.5	69.6	69.5	69.2	68.8	68.8	69.0
5	67.3	66.0	66.3	67.8	68.8	69.1	69.0	70.5	69.1	71.0*	70.8	70.0	69.3
6	68.8*	67.5	66.4	67.1	68.0	68.3	69.0	68.8	68.8	68.8	68.5	68.2	69.2
7	67.5	67.8	67.2	67.8	70.8*	66.6	69.4	68.8	70.8	70.4	72.3*	73.0*	69.1
8	69.1*	67.2	67.8	68.4	68.5	68.5	68.6	68.7	69.3	68.6	68.8	68.8	68.4
9	67.8	66.8	66.5	67.0	68.0	68.5	68.6	68.2	68.0	68.0	68.0	67.5	68.4
10	67.3	65.6	65.2	66.4	67.4	68.1	68.2	68.3	68.2	68.2	68.0	68.0	68.1
11	67.6	66.6	66.4	66.5	67.8	68.6	68.7	68.6	68.4	68.6	70.9	68.8	68.7
12	65.8	66.3	66.4	67.2	68.3	68.8	68.8	68.8	68.7	68.2	67.6	70.0	68.4
13	66.3	65.7	67.7	68.2	68.0	70.3	68.8	68.8	68.8	68.0	67.2	67.7	68.1
14	62.5*	64.2	67.1	68.3	68.2	68.8	68.8	73.5*	79.5*	70.2	69.5	68.1	68.2
15	66.7	66.0	66.7	67.8	68.6	68.8	68.9	68.8	68.9	68.7	68.7	69.1	68.2
16	64.3	63.9	64.5	66.6	68.2	68.7	68.7	68.6	70.2	71.3*	71.0	68.8	68.3
17	66.0	66.0	66.6	67.8	68.6	68.6	68.9	69.0	70.5	68.6	68.8	68.3	68.3
18	64.4	64.8	65.7	66.8	67.5	68.1	68.3	68.4	68.4	68.0	68.0	67.8	67.8
19	66.0	66.2	66.8	67.6	68.3	68.5	68.3	68.5	68.5	68.2	67.8	67.6	68.1
20	64.8	65.0	66.2	67.3	67.6	68.0	68.0	68.0	68.0	68.0	67.8	67.4	67.8
21	65.0	66.0	66.1	66.2	67.4	67.9	68.2	67.8	68.0	68.1	70.0	67.8	67.8
22	66.2	66.8	65.2	67.0	67.0	67.5	68.1	68.1	69.0	68.2	69.5	68.8	67.9
23	65.0	67.3	66.0	70.2*	69.0	67.5	69.6	73.4*	68.0	68.8	68.8	68.8	68.5
24	65.4	66.2	67.7	67.2	67.6	67.8	70.5	67.0	67.1	66.2	66.7	68.2	67.4
25	65.8	67.8	68.0	68.3	67.8	66.9	68.0	66.8	67.0	67.0	65.3*	67.8	67.1
26	63.8	67.8	68.4	68.5	66.7	67.0	67.6	67.7	67.6	66.9	66.9	67.3	66.9
27	64.2	66.8	66.3	67.5	67.2	68.0	69.0	66.8	67.5	67.3	67.3	67.0	67.1
28	66.8	68.2	69.0	67.8	66.8	70.0	68.2	67.4	67.5	67.5	67.4	67.1	67.4
29	65.0	66.2	67.0	68.4	68.0	68.0	68.3	68.6	68.0	67.2	67.4	67.8	67.5
30	65.3	66.0	66.8	68.0	68.2	68.0	68.0	68.0	67.8	67.5	67.2	67.5	67.5
31	63.5	64.0	65.0	66.8	68.0	67.4	67.8	67.7	67.5	67.3	67.0	66.8	67.1
Monthly mean	65.9	66.2	66.6	67.6	68.1	68.4	68.8	68.8	69.0	68.5	68.5	68.4	68.15
Normal	66.0	66.2	66.6	67.5	68.0	68.4	68.8	68.5	69.0	68.3	68.5	68.2	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

FEBRUARY, 1888.

Day.	1h.	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	66.5	66.8	67.0	67.4	67.7	67.8	68.3	70.0	70.3	68.5	66.8	64.8
2	66.8	67.2	67.5	67.2	68.4	68.8	69.7	70.2	68.4	65.1	62.6*	61.0*
3	67.0	67.0	67.5	68.0	68.5	69.0	70.8	71.4	70.7	68.8	66.6	64.5
4	66.5	66.3	66.5	66.7	67.0	67.2	68.0	70.3	71.0	69.5	67.8	64.8
5	70.3*	66.9	68.8	66.0	67.0	68.2	68.5	68.9	69.9	70.6*	68.8*	66.8
6	67.5	66.8	66.9	66.5	67.0	67.0	66.8	67.5	68.9	70.1*	70.0*	68.0*
7	66.6	67.3	67.5	67.5	66.4	67.8	66.8	66.8*	67.8	68.8	68.5*	67.8*
8	67.2	67.4	67.2	67.5	67.8	68.0	67.5	67.6	67.6	68.4	68.3	68.0*
9	68.5	71.0*	66.0	70.0	68.2	68.5	68.3	68.8	67.4	65.1	65.4	65.5
10	67.0	67.5	68.1	70.0	71.0*	67.3	71.0	69.7	68.8	68.5	66.7	64.7
11	68.0	70.0	62.0*	68.0	69.6	63.5*	68.0	67.0	67.0	65.6	64.5	65.7
12	68.5	66.3	67.8	66.0	68.5	68.5	67.0	66.6*	66.6	67.0	64.6	65.3
13	66.2	66.9	67.5	66.8	66.0	66.8	67.1	67.1	67.1	66.3	65.5	65.0
14	66.8	66.5	67.7	66.2	67.1	67.4	67.8	67.6	67.1	67.1	66.2	65.2
15	66.5	66.6	66.8	67.3	67.5	67.8	68.6	68.6	67.7	66.3	66.2	65.7
16	66.8	67.2	67.2	67.5	68.7	70.3	70.5	70.5	68.5	67.6	66.2	64.8
17	67.0	66.8	67.8	68.6	67.8	67.9	69.9	70.2	68.6	67.8	63.7	62.7
18	67.1	68.0	67.8	70.8*	68.3	69.8	69.8	69.0	68.5	67.8	66.0	64.0
19	68.0	67.2	67.6	68.2	68.0	68.6	69.2	70.8	68.8	66.2	63.4	62.2
20	68.0	69.0	64.2*	67.8	68.0	68.6	69.2	70.2	69.5	66.8	64.7	63.5
21	70.2*	68.5	68.5	66.3	64.8*	68.8	68.5	70.0	69.1	66.1	62.8*	60.8*
22	64.8	67.0	64.5*	66.5	68.8	68.5	70.0	67.5	66.3	66.8	66.0	64.2
23	67.3	67.2	67.6	68.0	70.0	70.1	70.6	71.0	70.5	68.2	66.2	63.8
24	68.1	68.0	68.3	66.2	68.8	69.1	68.5	68.5	67.5	65.8	63.0*	61.7*
25	67.6	67.5	68.0	68.1	66.5	68.0	69.3	70.6	68.9	68.1	66.3	64.8
26	67.2	68.2	67.5	67.8	68.5	67.5	70.3	71.0	70.0	68.0	65.6	64.2
27	67.1	67.8	68.0	68.4	68.3	68.7	70.5	71.4	70.0	66.7	65.0	64.0
28	67.5	67.7	68.5	67.1	69.5	69.2	71.3	72.4*	71.1	68.0	66.0	64.3
29	65.6	66.4	67.1	68.2	68.8	68.6	70.3	72.0*	71.8*	70.0*	67.8	65.7
Monthly mean	67.3	67.5	67.2	67.6	68.0	68.2	69.0	69.4	68.8	67.6	65.9	64.6
Normal	67.1	67.4	67.6	67.5	68.0	68.3	69.0	69.4	68.7	67.3	65.9	64.6

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794 Increasing scale readings correspond to increasing east declination.

FEBRUARY, 1883.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
1	64.8	65.7	66.5	67.3	67.5	67.7	67.7	67.8	67.5	67.4	67.5	66.3	67.3
2	61.2*	63.7	65.2	66.8	68.0	68.5	68.4	68.2	68.0	67.8	67.8	67.4	66.8
3	62.7	62.8	64.2	65.3	67.1	68.0	68.0	67.8	67.6	67.2	67.4	66.8	67.3
4	62.8	62.8	63.2*	64.6	66.6	66.2	67.7	67.9	68.8	68.5	68.5	69.0	67.0
5	66.0	65.1	65.5	66.0	66.8	67.1	67.5	67.5	67.5	67.5	67.2	67.0	67.6
6	66.8*	66.3	66.0	66.0	66.2	66.8	67.0	67.0	66.8	67.0	66.8	66.7	67.2
7	66.7*	66.7	66.1	66.2	66.5	66.6	67.0	67.0	67.0	67.0	67.0	67.1	67.1
8	67.6*	68.7*	67.0	67.4	66.0	66.0	64.8*	67.2	66.8	67.8	68.0	68.8	67.4
9	65.8	67.8*	68.3	68.8	68.0	67.8	69.2	67.5	67.2	66.6	66.5	66.8	67.6
10	63.2	63.8	65.7	66.7	67.6	67.5	67.5	67.7	73.0*	66.6	66.8	67.1	67.6
11	64.8	65.0	68.8*	68.0	67.8	67.7	68.6	68.7	67.3	70.0	68.6	67.5	67.2
12	65.5	66.3	67.2	68.0	67.8	68.0	68.0	67.5	68.3	66.8	66.0	66.5	67.0
13	64.8	65.7	66.2	66.8	66.5	66.8	67.3	67.4	67.5	67.5	66.8	66.4	66.6
14	65.0	65.5	66.2	67.3	67.4	67.5	67.5	67.3	67.8	66.8	66.8	66.5	66.8
15	65.8	65.8	66.2	66.8	67.0	66.8	67.5	67.3	67.2	67.5	67.0	66.6	67.0
16	63.8	65.6	64.8	66.4	65.8	67.0	67.5	67.6	68.8	67.2	67.5	67.2	67.3
17	63.8	64.2	65.8	66.8	66.1	66.5	66.7	67.3	66.4	67.3	67.5	67.0	66.8
18	61.6	62.3	64.0	66.7	65.7	65.4	67.8	68.7	68.8	68.0	68.7	69.3	67.2
19	62.0	63.8	66.1	65.0	68.8	67.2	66.0	67.8	67.5	68.0	69.0	68.0	67.0
20	63.8	64.4	66.8	66.3	66.5	67.7	66.8	67.0	67.0	67.3	66.6	64.5*	66.8
21	61.0*	63.8	66.2	66.5	67.0	68.2	66.0	66.5	67.5	67.7	67.4	66.4	66.6
22	62.8	64.0	65.8	65.8	66.5	67.0	67.0	67.3	67.4	67.4	67.6	67.3	66.5
23	62.2	62.8	64.2	66.8	67.2	67.5	67.5	67.5	67.5	67.5	68.0	67.0	67.3
24	60.8*	64.1	66.1	66.2	68.3	67.7	66.8	67.5	67.8	69.1	68.8	67.9	66.9
25	64.5	64.0	66.0	66.5	67.0	67.0	68.7	66.5	67.0	67.4	67.4	67.4	67.2
26	64.0	64.9	66.7	67.3	67.6	67.8	67.7	68.2	67.8	67.8	67.8	67.7	67.5
27	63.2	64.2	66.0	66.8	67.9	67.3	67.9	67.5	67.5	67.4	67.5	67.3	67.4
28	63.5	64.1	64.0	66.0	66.7	66.6	67.8	67.8	67.5	67.5	70.8*	67.4	67.2
29	63.7	63.4	64.6	66.0	67.1	66.8	67.1	67.6	67.5	67.3	67.2	67.2	67.4
Monthly mean	63.9	64.7	65.8	66.6	67.1	67.2	67.4	67.5	67.4	67.6	67.6	67.2	67.13
Normal	63.9	64.5	65.8	66.6	67.1	67.2	67.6	67.5	67.2	67.6	67.4	67.3	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time.

300 divisions + tabular quantity.

MARCH, 1888.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	67.6	68.0	68.0	68.4	68.2	68.7	68.7	71.3	71.6	68.7	66.8	65.0
2	66.2	67.3	67.7	68.0	68.4	68.7	70.5	71.8	72.0	70.0	67.4	64.7
3	67.1	67.4	67.5	67.6	67.7	68.0	69.0	70.8	71.1	70.7	68.9*	66.3
4	67.5	67.8	67.3	67.5	68.0	68.0	70.2	72.1	71.0	67.3	65.0	63.8
5	66.6	66.7	66.8	66.8	67.0	67.3	68.3	70.5	70.8	68.7	66.0	64.0
6	67.0	67.2	67.3	67.5	67.7	68.2	69.2	70.2	68.6	66.0*	64.2	64.0
7	67.0	67.0	67.4	67.5	68.0	68.5	70.2	72.0	73.5	67.8	65.0	62.8
8	68.0	68.2	65.8	66.8	67.5	67.8	68.8	69.0	67.5*	65.8*	65.8	65.2
9	66.5	66.0	66.2	66.2	64.8*	64.2*	66.5*	70.0	66.3*	64.5*	64.3	62.6
10	67.2	65.6	66.3	67.3	65.1	64.6*	67.0	70.8	70.5	66.8	64.3	62.8
11	65.6	66.9	67.0	67.2	67.8	68.2	69.5	71.6	71.1	68.8	66.5	64.8
12	66.8	66.8	67.0	67.5	67.3	67.1	69.0	71.0	70.5	69.1	67.0	64.8
13	67.0	66.8	67.0	67.2	67.2	67.3	69.8	71.0	70.8	69.0	66.0	64.0
14	67.0	67.0	67.1	67.0	67.0	67.3	68.8	71.0	72.5	72.0*	69.5*	66.3
15	67.9	67.0	67.1	67.4	68.0	67.5	70.2	73.0	73.2	67.8	66.0	65.0
16	68.2	68.5	67.5	69.0	66.5	65.8	65.0*	63.0*	66.9*	66.5	63.0*	61.1*
17	71.2*	68.1	65.8	68.6	66.0	69.0	70.4	71.0	70.8	68.8	67.6	62.6
18	68.8	68.2	70.8*	67.8	66.6	67.3	69.0	69.5	70.5	68.4	65.5	63.4
19	67.5	67.1	67.8	67.2	66.0	67.0	67.2	69.1	70.8	70.3	67.8	65.4
20	66.5	67.2	66.8	67.0	67.1	67.6	67.2	70.4	70.6	68.2	65.8	63.0
21	66.1	66.2	66.0	67.1	67.1	68.0	69.5	69.7	70.2	69.8	68.5	65.6
22	68.3	68.1	68.0	67.8	67.0	68.1	69.0	70.6	71.0	70.2	67.8	64.4
23	68.9	68.1	68.1	68.3	68.2	69.0	70.3	71.5	71.6	68.3	64.7	63.0
24	68.0	68.4	68.3	68.0	68.2	67.0	69.3	71.1	72.6	70.5	67.0	64.2
25	66.8	67.0	67.5	67.5	67.5	67.8	69.4	70.9	69.5	68.8	66.4	64.1
26	67.2	67.3	67.5	67.5	68.0	68.4	70.3	72.5	72.4	70.5	66.8	64.3
27	67.0	67.4	67.3	67.7	67.6	68.0	69.0	71.2	72.8	71.5*	69.2*	66.0
28	67.5	67.2	66.3	69.0	70.2	70.0	70.8	71.0	70.4	68.0	65.0	63.8
29	66.8	67.0	67.8	67.7	67.8	68.0	69.0	70.4	70.4	69.8	68.3	66.0
30	66.5	66.8	67.3	67.2	67.8	68.5	70.0	70.4	70.5	68.5	66.3	65.0
31	68.6	68.5	68.0	68.2	68.8	68.8	70.7	71.0	70.2	68.3	66.5	65.0
Monthly mean	67.4	67.3	67.3	67.6	67.4	67.7	69.2	70.6	70.7	68.7	66.4	64.3
Normal	67.3	67.3	67.2	67.6	67.4	68.0	69.4	70.9	71.1	68.8	66.2	64.4

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794 — Increasing scale readings correspond to increasing east declination.

MARCH, 1888.

Day.	13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
1	65.0	63.8	64.5	66.5	67.8	67.8	67.8	68.2	68.0	67.8	67.7	67.5	67.6
2	62.5	62.4	63.2	64.8	66.0	66.8	67.0	67.2	67.1	67.0	67.0	67.0	67.1
3	64.7	64.2	64.7	65.1	66.2	66.8	68.2	66.5	67.2	67.2	67.4	67.3	67.4
4	62.5	63.4	64.2	65.6	66.3	66.5	66.7	66.8	67.0	66.8	66.8	66.7	66.9
5	63.5	63.9	65.2	66.0	66.5	66.3	66.7	66.8	66.8	67.0	67.0	67.0	66.8
6	63.5	64.0	65.0	65.8	66.2	66.2	66.6	67.0	67.2	67.0	67.1	67.1	66.7
7	61.2	61.5	64.0	65.0	66.8	66.8	66.5	69.8*	75.8*	68.4	69.0	64.2*	67.3
8	64.8	64.8	64.6	66.3	66.7	69.0	68.0	67.8	67.2	66.8	66.4	66.2	66.9
9	64.2	64.0	64.5	65.7	66.8	67.0	67.2	67.2	69.9*	67.0	68.2	67.5	66.1
10	62.3	63.2	64.4	65.8	67.4	67.0	67.2	67.0	67.2	67.6	65.4	66.3	66.2
11	63.8	63.0	64.8	65.0	67.0	67.3	67.3	66.8	66.9	66.8	67.8	66.8	67.0
12	63.3	62.0	63.5	65.1	66.2	66.5	67.0	67.0	66.8	66.8	66.5	66.5	66.7
13	62.6	61.2	63.0	64.0	65.6	66.0	66.4	66.7	66.5	66.5	66.3	66.2	66.4
14	63.8	62.6	63.0	63.9	65.5	66.3	66.8	67.0	66.9	67.8	67.7	67.5	67.1
15	64.3	63.2	64.2	66.5	67.8	69.5*	67.8	67.6	70.2*	70.8*	69.5	68.8	67.9
16	62.1	61.0	65.3	63.6	66.0	65.5	66.0	66.7	68.0	72.0*	69.8	65.0	65.9
17	63.4	62.7	64.0	67.5	67.8	69.5*	67.1	67.0	67.0	71.2*	70.8*	67.1	67.7
18	63.3	63.6	65.0	67.0	66.8	66.5	67.0	68.0	67.1	67.3	67.4	68.2	67.2
19	64.2	62.8	64.6	65.3	67.5	66.0	69.3	67.0	66.6	67.0	67.8	67.5	67.0
20	62.0	62.0	62.5	64.7	65.1	65.8	67.1	66.0	66.2	66.2	66.2	66.0	66.2
21	64.2	63.0	64.0	65.1	66.6	67.4	67.7	68.0	68.0	68.3	68.8	68.1	67.2
22	63.0	62.5	63.8	65.2	66.6	67.3	68.0	68.0	68.0	68.1	67.8	68.7	67.4
23	62.5	63.7	64.8	65.9	66.1	67.1	66.5	67.0	68.5	68.2	67.8	67.7	67.3
24	62.8	63.4	64.2	65.3	66.3	66.8	67.0	67.0	67.0	66.9	67.5	67.1	67.2
25	63.2	63.8	65.1	66.0	67.0	67.0	67.2	67.4	67.3	67.2	67.0	67.1	67.0
26	63.5	63.5	64.0	65.1	66.5	66.7	67.0	67.0	66.9	66.8	66.8	67.0	67.2
27	63.7	62.1	62.2	64.5	66.3	66.8	68.0	67.4	66.6	66.7	66.8	67.0	67.2
28	61.7	61.5	62.8	65.1	66.8	67.0	66.8	67.0	66.9	66.9	66.8	66.8	66.9
29	63.0	61.0	61.6	62.6*	63.8*	65.8	66.1	66.8	66.1	66.6	68.0	66.0	66.5
30	63.0	63.0	64.0	65.5	66.2	66.2	65.8	66.0	66.5	67.0	67.8	67.8	66.8
31	64.1	63.8	64.1	65.3	66.4	67.0	67.5	67.5	67.0	67.3	67.2	67.3	67.4
Monthly mean	63.3	62.9	64.0	65.3	66.5	66.9	67.1	67.2	67.6	67.6	67.6	67.0	66.98
Normal	63.3	62.9	64.0	65.4	66.6	66.7	67.1	67.1	67.1	67.2	67.4	67.1	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

APRIL, 1888.

Day.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
1	66.9	67.2	67.5	68.2	68.5	69.0	71.0	71.8	71.6	70.2	68.5	66.0
2	68.6	68.5	68.8	69.2	68.8	69.8	71.9	73.4	73.2	71.0*	67.7	65.0
3	67.5	68.0	68.2	67.8	69.2	69.2	71.4	69.9	66.1*	66.5	65.3	64.8
4	64.1*	63.0*	68.5	67.5	65.1*	66.6*	68.0*	71.0	68.7	66.8	64.5	64.0
5	69.2	69.0	64.2*	70.0	68.6	68.1	70.2	72.0	69.0	66.5	65.8	65.5
6	67.5	65.4	67.2	66.0	66.4	67.9	70.8	72.7	72.0	68.8	65.8	64.4
7	67.2	67.2	67.0	67.2	67.0	67.8	69.3	71.3	71.8	68.8	65.8	64.0
8	67.1	67.2	67.4	67.5	67.2	68.0	70.5	73.3	73.5	70.0	66.1	64.2
9	67.2	67.6	67.6	68.0	68.2	69.0	71.2	73.4	72.3	69.5	66.2	64.2
10	66.8	67.2	67.2	67.6	67.8	68.6	70.3	71.6	72.5	70.7	67.6	65.1
11	73.0*	69.6	67.1	73.1*	74.3*	73.8*	72.0	68.9*	68.6	66.7	63.1*	60.8*
12	69.0	67.5	65.3	66.0	62.6*	68.3	70.4	70.7	71.0	70.2	67.2	65.5
13	70.7*	72.8*	72.0*	70.4	65.5*	67.5	70.0	71.6	71.0	66.0	64.0	63.1
14	67.2	66.9	66.5	68.0	66.2	66.6*	69.2	70.8	70.7	68.0	66.8	64.3
15	65.3	66.3	68.4	68.3	68.0	68.8	67.2*	69.0*	69.6	68.4	66.8	65.3
16	67.4	66.2	67.2	67.6	67.7	68.2	70.8	72.2	71.2	69.5	67.0	65.8
17	67.3	67.4	67.2	67.6	68.0	68.8	70.3	71.0	70.3	68.8	66.8	66.2
18	68.0	68.3	67.7	67.8	68.2	69.6	71.1	72.0	70.8	69.1	67.7	66.6
19	68.7	68.7	68.7	69.1	70.3	70.8	73.0	72.7	70.3	67.5	64.7	63.0
20	68.5	68.6	68.8	68.2	68.8	70.0	71.5	71.7	68.0*	65.7*	64.5	64.6
21	67.2	67.2	67.5	68.2	68.0	70.2	72.2	73.4	70.8	67.0	63.8	62.4
22	67.3	67.3	67.4	67.8	68.0	70.3	72.9	73.3	70.2	67.2	65.5	64.7
23	67.3	67.2	67.5	68.0	68.3	70.2	72.6	73.5	72.0	68.8	65.0	63.4
24	67.0	68.3	68.2	68.8	70.0	71.6	72.4	72.2	70.5	66.3	64.1	62.7
25	67.8	68.0	68.6	69.2	69.8	70.8	72.2	73.4	70.3	65.5*	61.7*	61.1*
26	66.9	67.2	68.0	68.0	68.2	69.6	71.2	72.2	71.6	69.0	65.4	63.5
27	67.2	67.5	67.8	68.3	68.6	70.2	72.4	74.0	72.4	68.2	64.6	63.1
28	67.5	67.8	68.4	68.3	68.7	70.1	72.5	73.8	72.8	69.0	66.6	65.5
29	68.2	68.3	67.4	67.8	68.3	69.1	71.9	72.2	72.5	70.6	68.3	66.9
30	67.6	67.7	68.4	68.8	69.5	70.1	70.6	71.5	70.3	69.0	67.5	66.6
Monthly mean	67.7	67.6	67.7	68.3	68.1	69.3	71.0	72.0	70.8	68.3	65.8	64.4
Normal	67.5	67.6	67.7	68.1	68.3	69.3	71.3	72.2	71.1	68.4	66.1	64.7

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794

Increasing scale readings correspond to increasing east declination.

APRIL, 1888.

Day.	13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
1	64.2	64.0	64.4	64.6	65.8	66.2	66.8	66.5	66.5	67.8	67.4	67.8	67.4
2	61.2	62.1	62.4	63.0	65.0	66.0	66.1	68.0	68.8	70.8*	69.8	66.7	67.7
3	64.7	64.5	65.5	65.5	66.2	67.8	69.0	67.0	68.0	65.7	66.2	67.5	67.2
4	61.0	63.8	65.8	66.8	66.7	66.7	66.7	67.1	70.0*	68.5	67.8	67.0	66.5
5	65.2	66.0*	66.2	66.5	67.4	70.1*	70.4*	66.8	67.0	67.0	68.0	68.1	67.8
6	64.2	63.5	64.5	65.8	66.5	66.8	66.8	67.0	67.1	67.2	67.0	67.0	67.0
7	62.9	62.5	63.2	65.0	65.5	66.2	66.5	66.8	66.8	66.8	66.8	67.0	66.7
8	62.3	62.4	63.3	65.2	66.8	67.3	67.2	67.3	69.0	67.7	67.3	67.2	67.3
9	63.0	62.4	63.0	64.8	66.7	67.2	67.0	66.8	66.8	66.8	66.7	66.7	67.2
10	62.6	62.4	62.8	64.2	66.0	66.2	66.8	66.3	66.8	67.8	67.5	68.6	67.1
11	60.0*	59.6*	61.2*	67.0	63.8	63.7*	66.2	69.0	66.6	66.2	66.7	66.0	67.0
12	64.2	62.2	64.0	64.0	65.6	66.5	66.7	66.6	68.0	68.7	69.6	70.0	67.1
13	62.6	61.8	63.8	64.0	65.8	72.0*	67.2	66.8	68.8	67.2	68.0	68.0	67.6
14	63.0	61.2	62.8	66.1	66.8	67.4	67.8	70.2*	68.2	68.0	67.7	68.0	67.0
15	63.2	62.5	62.0	63.0	66.5	66.2	66.2	66.6	67.9	68.0	67.3	67.0	66.6
16	64.2	62.5	62.6	64.4	66.2	66.8	66.6	67.0	68.0	67.3	67.4	67.6	67.1
17	65.8	64.0	63.9	64.0	64.8	65.8	67.5	67.3	66.2	67.1	68.2	68.0	67.2
18	65.4	64.6	64.6	65.5	66.6	66.8	67.2	67.7	67.8	68.2	68.5	68.7	67.8
19	63.2	63.4	65.4	67.0	67.8	68.0	68.3	68.2	68.3	67.8	67.8	68.2	68.0
20	64.2	63.4	64.5	65.7	66.8	66.9	66.8	66.9	67.0	67.0	67.1	67.6	67.2
21	62.7	63.7	64.5	66.3	67.5	67.2	66.8	67.0	67.0	67.1	67.4	67.2	67.2
22	64.3	64.5	65.6	66.7	67.0	67.0	66.7	66.5	66.8	67.7	67.5	67.3	67.5
23	63.1	63.1	64.1	65.6	66.9	66.8	66.7	66.7	67.3	68.0	67.4	66.8	67.4
24	61.4	62.0	61.6	65.9	67.3	67.5	67.3	66.9	67.0	67.2	67.4	67.3	67.1
25	62.0	62.8	63.3	65.2	65.9	66.5	66.4	66.7	66.5	66.9	68.0	66.7	66.9
26	63.7	64.0	65.0	65.9	66.5	67.0	66.8	66.5	66.7	66.6	66.8	67.1	67.2
27	62.0	62.0	63.8	65.2	66.8	67.4	67.0	66.7	66.8	67.1	67.2	67.5	67.2
28	64.6	64.2	64.7	65.2	66.1	66.0	66.3	66.7	66.5	66.6	66.8	67.0	67.6
29	65.0	64.8	65.7	65.2	64.9	66.5	66.5	65.6	66.1	66.6	71.7*	69.0	67.9
30	65.8	64.4	64.3	64.8	65.2	65.4	65.3	67.0	65.3	66.7	68.8	75.3*	67.8
Monthly mean	63.4	63.1	64.0	65.3	66.2	66.9	67.0	67.1	67.3	67.4	67.7	67.8	67.27
Normal	63.5	63.2	64.0	65.3	66.2	66.7	66.9	67.0	67.3	67.3	67.6	67.6	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

MAY, 1888.

Days.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	72.3*	65.4	67.0	68.8	69.2	70.6	70.8	68.7*	68.6	67.5	65.0	64.2
2	66.8	65.8	67.2	68.0	68.2	69.1	72.3	72.6	71.1	68.2	65.3	63.9
3	66.6	66.0	66.8	67.2	67.9	68.8	69.2	71.5	70.7	68.3	65.2	64.3
4	67.0	66.8	67.2	67.3	68.0	70.4	72.2	74.0	72.8*	70.1	67.4	66.2
5	67.0	67.0	67.0	67.3	67.8	69.2	71.2	72.3	70.8	68.2	66.4	65.6
6	67.3	67.4	67.3	67.8	67.8	69.2	70.7	71.2	70.5	67.9	65.6	65.0
7	69.2	68.5	70.0*	74.8*	75.4*	73.4*	72.3	69.2	67.5	65.0*	63.0	61.8
8	65.7	67.4	68.3	67.6	69.1	69.9	71.0	70.2	69.7	68.2	66.5	65.5
9	68.2	68.1	65.8	68.6	68.8	69.3	68.2*	72.1	71.7	69.0	66.8	65.2
10	67.0	67.5	67.0	66.5	68.5	69.2	71.6	71.8	72.2	70.2	67.4	65.0
11	66.7	65.8	66.8	68.0	68.0	68.8	68.5*	70.8	70.8	68.3	65.7	64.0
12	65.8	66.6	67.0	67.8	68.0	67.6	71.0	73.0	74.0*	71.2*	66.2	63.0
13	65.8	66.2	67.0	67.8	68.5	70.2	70.8	71.8	71.5	70.0	67.5	66.8*
14	67.0	67.0	67.2	67.8	68.5	69.9	71.2	71.7	71.0	69.5	68.0	66.3
15	66.0	66.5	66.7	67.8	68.0	69.5	71.6	72.9	70.6	67.0	64.1	62.0
16	67.0	66.5	66.8	67.1	68.0	68.8	71.0	71.0	70.0	68.0	66.5	66.0
17	67.0	66.8	66.8	67.2	67.5	69.9	71.2	72.0	70.3	67.8	65.8	65.4
18	66.4	66.4	66.6	67.5	68.2	70.3	71.5	71.0	67.8	65.8	64.2	63.7
19	66.0	66.5	66.8	67.6	68.4	70.8	72.4	72.5	71.0	68.8	66.2	63.9
20	66.5	66.5	67.1	68.7	68.7	70.3	73.0	73.8	70.5	69.5	68.6*	67.6*
21	67.6	66.2	65.6	70.2	67.2	67.2	71.5	73.0	71.3	69.1	66.4	65.6
22	66.7	67.2	67.5	68.2	68.6	69.2	70.8	70.3	68.8	65.8	64.8	64.0
23	66.6	66.8	67.0	67.6	68.5	70.4	70.3	69.7	66.0*	64.8*	63.2	62.5
24	67.3	67.7	66.8	66.8	68.2	69.9	71.6	71.5	68.8	65.3*	62.7*	62.4
25	66.7	66.8	67.2	67.9	68.6	70.3	72.4	72.6	70.3	67.0	63.7	62.0
26	66.5	67.1	67.0	68.8	71.0*	70.4	75.0*	70.8	70.6	67.7	65.8	64.4
27	67.4	68.2	68.7	68.8	70.2	70.0	70.8	71.1	69.1	66.4	64.3	63.1
28	67.8	68.1	68.5	67.8	67.0	68.8	71.3	71.9	69.8	67.0	65.3	63.3
29	64.0*	66.5	67.6	68.0	68.3	70.7	72.8	71.1	70.3	66.0	64.2	63.3
30	66.0	62.2*	67.0	68.0	68.7	70.4	71.2	70.6	68.7	66.3	64.2	62.8
31	66.0	66.0	67.0	67.0	68.1	70.3	72.7	72.3	70.2	67.8	65.8	65.8
Monthly mean	66.9	66.7	67.2	68.1	68.6	69.8	71.4	71.6	70.2	67.8	65.5	64.3
Normal	66.8	66.8	67.1	67.9	68.3	69.6	71.5	71.7	69.8	68.0	65.5	64.1

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794

Increasing scale readings correspond to increasing east declination.

MAY, 1888.

Day.	13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
1	64.0	64.2	65.0	65.2	66.2	67.0	66.9	69.0	69.0	68.5	67.0	67.2	67.4
2	62.8	63.1	64.0	65.6	68.3	67.5	66.9	66.6	67.3	71.4*	67.9	67.5	67.4
3	63.9	63.8	64.3	64.7	65.2	66.8	67.7	67.0	66.8	67.0	67.0	66.4	66.8
4	65.8	65.8	65.8	66.2	66.2	66.5	66.7	66.7	66.8	66.8	67.0	67.0	67.8
5	65.8	65.5	65.7	66.3	66.6	66.8	66.8	66.8	67.0	67.0	67.1	67.0	67.4
6	65.8	65.8	65.8	65.0	64.5	64.8	65.1	65.3	66.6	70.0*	72.3*	72.6*	67.6
7	64.0	62.6	63.0	64.2	65.7	65.1	67.8	68.0	69.0	68.8	67.2	66.0	67.6
8	65.1	65.7	64.5	65.5	69.2*	67.3	66.8	68.4	69.0	66.8	66.9	66.2	67.5
9	64.8	63.5	63.5	65.0	65.4	66.5	72.8*	68.8	67.5	67.0	67.1	66.8	67.5
10	62.8	62.5	63.0	64.5	65.5	67.0	67.0	70.5*	67.3	66.3	66.4	66.8	67.2
11	62.4	61.5	63.1	65.0	66.5	66.8	69.0	68.8	67.3	67.3	67.1	67.2	66.8
12	61.6	61.4*	63.0	64.5	65.8	67.2	66.3	67.8	67.0	67.2	67.1	67.0	67.0
13	66.8*	66.3	66.1	66.3	67.2	67.8	67.2	67.2	66.8	67.8	67.1	67.0	67.8
14	65.0	64.5	63.6	64.5	64.9	65.8	66.0	67.6	66.2	66.0	66.2	66.2	67.2
15	61.6	61.5	62.3	64.2	65.4	65.6	64.7	64.8	65.0	66.0	66.1	66.7	66.1
16	65.3	64.0	64.0	64.6	65.6	66.5	66.2	66.0	66.2	66.1	66.2	66.8	66.8
17	66.0	66.6*	67.6*	67.5	67.2	66.8	66.7	67.2	66.3	66.2	66.4	66.4	67.4
18	63.5	62.4	63.0	64.4	65.2	65.7	66.0	68.7	71.8*	66.6	66.7	66.4	66.7
19	63.0	63.4	64.0	65.4	65.8	66.0	66.2	66.3	66.2	66.3	66.5	66.4	66.9
20	64.7	65.8	64.3	62.7*	62.0*	74.1*	72.0*	70.6*	73.0*	71.8*	74.5*	70.8*	69.0
21	65.7	66.0	66.0	65.5	64.8	65.3	65.8	65.8	65.9	66.2	66.5	67.1	67.2
22	64.1	64.8	65.8	66.2	66.2	66.2	66.1	66.0	66.5	68.6	66.8	66.2	66.9
23	63.2	63.4	63.4	64.8	64.8	66.0	64.6	65.8	67.0	67.2	67.0	67.5	66.2
24	63.0	64.8	66.3	66.8	66.5	66.0	65.9	65.8	65.8	66.1	66.1	66.2	66.6
25	62.4	64.0	65.5	66.2	66.3	65.5	65.6	65.5	66.1	66.1	65.5	66.3	66.7
26	63.3	64.4	64.7	66.5	67.0	67.6	68.0	68.8	68.0	67.9	68.0	66.2	67.7
27	63.0	64.4	66.9	66.9	67.0	67.0	67.0	67.0	67.0	67.3	67.2	67.4	67.3
28	62.3	62.1	63.7	64.5	67.2	67.6	66.0	66.0	67.0	67.0	66.3	66.7	66.8
29	61.3*	61.9	64.3	65.4	66.3	66.3	66.7	68.8	67.4	66.1	66.5	66.2	66.7
30	63.0	63.9	65.0	66.2	66.5	67.3	67.3	66.4	66.1	67.4	66.8	66.5	66.6
31	65.8	65.1	65.2	65.5	66.0	66.7	67.0	66.7	66.7	66.3	66.6	66.5	67.2
Monthly mean	63.9	64.0	64.6	65.4	66.0	66.7	66.9	67.2	67.3	67.3	67.2	67.0	67.15
Normal	63.9	64.0	64.5	65.4	66.1	66.5	66.6	67.0	66.9	66.9	66.8	66.7	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

JUNE, 1888.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	66.5	66.8	66.8	67.8	68.4	70.0	71.3	70.8	68.5	66.2	65.5	65.0
2	66.7	66.8	66.8	67.4	68.3	69.4	71.0	71.5	69.0	65.8	64.5	64.3
3	67.8	69.8*	69.2	71.7*	70.8	73.3*	70.0	73.0	74.2*	66.2	61.3*	58.3*
4	66.8	67.0	68.3	67.1	68.5	71.0	74.0*	70.8	68.0	65.6	66.0	65.5
5	67.2	66.6	66.8	67.8	67.8	68.4	69.7	70.8	68.2	66.5	63.1	62.3
6	66.7	67.4	68.3	67.2	68.6	70.7	72.0	70.5	68.2	65.1	62.5	59.8*
7	66.6	66.2	67.8	67.8	68.8	70.4	70.4	71.5	71.3	68.8	66.3	64.4
8	66.7	65.8	65.7	67.2	68.3	69.4	71.2	71.3	68.6	64.8	62.1*	62.8
9	66.5	66.4	66.8	67.2	68.2	70.8	72.4	72.8	70.5	67.7	64.7	62.8
10	66.0	66.5	66.9	68.1	69.0	71.0	71.5	73.6	72.8*	70.8*	67.0	64.8
11	66.7	66.3	66.8	67.3	68.8	69.5	71.8	71.4	68.0	65.8	63.2	62.8
12	66.4	66.8	67.2	67.8	67.8	70.3	71.3	71.3	70.5	[67.4]	[65.0]	[63.8]
13	66.4	66.3	66.3	67.0	68.0	68.6	70.7	71.4	70.0	64.2	60.7*	60.2*
14	66.5	66.3	67.0	68.0	68.2	70.6	72.6	73.1	70.3	68.0	65.8	64.8
15	66.5	66.2	67.4	67.7	68.7	69.6	71.2	71.6	70.7	69.5*	66.9	64.8
16	66.6	67.2	67.7	68.2	68.8	68.1	70.6	70.0	70.2	68.7	65.5	64.3
17	66.1	66.6	66.8	67.6	68.4	70.7	73.2	72.2	68.8	65.6	63.5	63.7
18	66.5	66.7	67.1	67.4	68.5	69.4	70.7	70.2	68.6	66.4	64.6	64.4
19	66.7	66.7	67.0	67.6	68.8	71.7	73.5	73.0	71.8	68.8	65.8	64.8
20	66.8	67.0	67.5	67.8	68.6	70.8	71.8	70.6	68.3	64.2	61.5*	61.1*
21	66.5	66.8	67.4	67.8	68.7	70.3	71.8	69.2	67.5	65.8	62.8	61.7
22	66.4	68.3	68.0	67.5	70.0	71.2	77.0*	73.8	75.1*	64.6	63.3	61.6
23	68.4	69.1	66.6	65.6	68.8	69.8	71.4	70.8	69.0	67.9	65.7	63.6
24	67.3	67.2	66.4	67.5	65.6*	68.5	70.7	71.0	70.3	66.8	64.9	64.8
25	67.0	67.1	66.5	67.3	67.5	69.0	71.5	71.5	70.5	69.8*	67.3	65.2
26	67.8	66.8	67.0	67.5	67.3	67.8	68.7*	68.8*	68.0	66.3	64.2	64.2
27	67.7	67.2	67.5	67.7	67.3	68.6	70.3	70.7	70.2	66.7	65.0	64.1
28	66.7	67.2	67.2	67.8	68.6	67.8	70.1	71.5	70.0	66.5	65.0	63.0
29	67.0	67.3	67.2	67.7	68.0	68.4	70.6	72.5	72.5*	70.4*	68.3*	65.8
30	66.5	66.7	67.0	67.2	68.0	69.0	71.6	73.6	73.0*	71.3*	67.5*	63.3
Monthly mean	66.8	67.0	67.2	67.6	68.4	69.8	71.5	71.5	70.1	67.1	64.7	63.4
Normal	66.8	66.9	67.2	67.5	68.5	69.7	71.3	71.6	69.4	66.4	64.7	63.8

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794 Increasing scale readings correspond to increasing east declination.

JUNE, 1888.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
1	65.0	65.3	65.3	65.8	66.0	65.8	66.3	66.3	66.3	66.4	66.5	66.5	66.9
2	64.5	64.8	64.7	64.3	64.5	65.4	65.5	65.4	65.7	67.9	71.6*	71.3*	67.0
3	57.0*	59.4*	61.7	63.2	65.0	65.5	70.0*	69.0	72.6*	69.0*	68.3	65.2	67.2
4	65.4	65.7	63.6	65.2	66.0	65.4	66.7	70.8*	68.5	65.6	66.4	67.8	67.3
5	61.9	63.7	64.8	66.1	66.2	66.8	70.8*	67.6	66.2	66.5	66.0	65.5	66.6
6	59.8*	62.9	63.3	65.0	64.8	65.5	66.6	65.5	66.2	70.5*	68.0	67.2	66.4
7	64.1	63.5	64.0	64.8	66.0	66.0	66.0	66.5	66.4	66.1	68.6	67.7	67.1
8	63.9	64.5	65.8	67.1	67.4	66.4	66.3	66.1	65.8	65.5	65.8	65.8	66.4
9	62.8	63.4	64.0	65.4	67.0	67.4	66.8	66.4	66.3	66.3	66.0	66.6	66.9
10	63.4	62.8	64.2	65.8	66.9	67.5	67.2	66.9	66.4	66.4	66.8	68.0	67.5
11	62.3	62.3	63.7	64.9	65.8	66.5	67.0	68.5	67.8	66.4	65.8	66.2	66.5
12	[63.5]	[64.0]	[64.6]	[65.7]	66.4	67.3	67.3	68.0	67.0	66.8	66.4	66.1	[67.0]
13	61.6	63.0	65.1	66.0	66.8	66.4	66.3	66.2	65.8	66.0	66.3	66.5	66.1
14	64.3	64.0	64.6	64.8	64.8	65.5	65.8	65.6	65.3	66.4	68.6	66.8	67.0
15	63.2	62.6	62.7	63.6	64.5	65.2	65.1	65.6	66.3	65.7	65.8	65.8	66.5
16	64.6	64.8	65.0	65.7	66.2	66.2	66.2	66.8	65.8	66.1	66.0	66.1	66.9
17	64.0	64.5	64.7	65.6	66.1	65.9	65.8	67.8	66.8	66.2	66.5	66.7	66.8
18	64.0	64.0	63.8	64.3	65.0	65.8	65.8	65.9	66.0	66.0	66.1	66.6	66.4
19	64.4	64.5	65.4	65.6	66.3	66.5	66.6	66.4	67.0	66.3	66.3	66.6	67.4
20	62.4	63.8	64.2	65.0	65.8	66.2	66.0	66.0	66.0	66.0	66.0	66.3	66.2
21	61.3	61.8	62.5	64.0	64.8	65.8	65.5	63.5*	65.2	64.4	65.8	67.0	65.8
22	61.4	61.8	63.1	65.3	65.6	70.7*	67.8	68.3	67.9	66.0	66.1	71.2*	67.6
23	62.3	63.3	64.5	65.6	66.3	67.6	67.8	67.2	66.3	66.2	66.4	66.3	66.9
24	64.7	64.5	65.1	65.0	65.7	68.0	66.5	66.7	68.3	67.0	68.1	65.8	66.9
25	63.5	62.8	64.8	66.3	67.2	67.6	67.5	68.0	70.7*	69.8*	69.0	68.0	67.7
26	64.5	64.0	64.9	66.5	67.6	68.3	68.0	67.7	68.2	68.6	67.5	67.6	67.0
27	65.5	64.1	64.0	65.5	66.0	66.0	66.0	66.2	67.0	67.1	68.0	67.0	66.9
28	62.7	63.0	64.0	65.5	66.5	66.7	66.7	66.2	66.5	66.4	66.6	66.8	66.6
29	64.5	64.0	65.0	65.8	66.6	66.8	66.9	66.7	66.6	66.5	66.8	66.7	67.4
30	62.0	63.7	62.0	61.5*	63.7	64.0	64.5	72.6*	68.7	65.4	65.3	65.5	66.8
Monthly mean	63.2	63.6	64.2	65.2	65.9	66.5	66.7	67.0	67.0	66.6	66.9	66.9	66.86
Normal	63.5	63.7	64.2	65.3	65.9	66.3	66.4	66.8	66.7	66.3	66.8	66.6	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

JULY, 1888.

Day.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
1	66.0	68.2	67.5	66.0	68.2	71.0	70.2	71.5	70.5	67.3	64.2	63.4
2	65.8	65.5	66.0	68.0	69.0	70.9	73.0	73.5	69.9	65.5	61.5*	59.1*
3	66.3	66.8	67.2	67.8	68.7	68.0	69.7	71.4	72.0	70.0*	67.8*	63.7
4	66.8	66.0	66.5	67.5	68.2	68.8	70.5	70.8	69.5	68.1	66.2	66.5
5	67.5	67.7	67.3	67.9	67.5	69.0	70.4	70.8	70.3	70.2*	66.4	62.8
6	67.2	67.5	67.5	68.0	68.7	69.8	71.1	72.5	72.0	70.2*	67.6*	65.8*
7	66.8	67.2	67.5	68.0	69.2	70.5	72.8	75.6*	73.5*	68.1	64.4	62.8
8	65.9	66.0	67.0	67.5	68.8	70.6	72.7	73.0	73.2*	68.4	64.5	63.2
9	66.4	67.0	67.5	68.0	68.4	69.6	72.4	72.8	71.8	67.4	63.4	61.8
10	66.3	66.7	66.8	67.5	67.8	69.4	71.6	72.1	68.9	65.5	61.7	59.5
11	65.8	66.3	66.7	67.2	68.0	69.8	72.2	73.5	71.8	68.4	64.3	61.1
12	66.7	66.9	67.2	68.0	68.6	70.4	73.2	73.8	71.5	68.2	63.5	61.4
13	66.2	67.1	67.4	67.9	68.6	70.7	72.0	72.5	71.4	68.0	64.6	63.4
14	66.8	67.0	67.2	67.5	68.6	70.8	72.6	73.8	70.5	67.4	64.8	63.7
15	66.1	66.7	67.1	68.2	68.0	70.6	71.8	71.7	70.1	66.8	64.4	63.3
16	66.0	66.5	67.5	68.4	68.7	69.5	72.2	71.5	70.5	65.5	63.8	62.7
17	66.3	67.0	68.0	65.5	67.6	69.0	70.6	70.7	69.0	66.4	65.0	64.0
18	67.0	66.6	66.5	67.2	68.0	69.1	70.4	70.3	70.0	67.8	65.5	63.2
19	66.5	66.7	66.3	67.2	66.4	68.6	70.4	71.8	70.8	68.0	64.0	61.4
20	66.5	68.0	68.8	70.0*	68.7	70.8	71.3	72.1	70.3	66.8	63.8	61.2
21	66.4	69.8*	63.7*	68.0	68.4	70.3	72.1	72.0	70.3	66.8	65.1	63.7
22	62.5*	69.5*	66.2	67.0	67.7	68.5	71.2	73.2	69.0	64.9	61.6*	59.8*
23	66.0	66.2	66.6	66.8	66.0	68.1	69.0	70.1	68.5	66.4	65.5	64.3
24	67.8	67.0	66.8	65.5	67.8	70.2	72.5	73.8	71.2	67.5	64.5	63.0
25	66.3	66.0	65.9	67.3	68.6	69.7	71.2	71.5	70.2	66.0	61.8	60.0*
26	66.0	66.0	66.0	66.8	67.0	68.8	71.0	72.0	70.5	66.5	63.8	62.8
27	65.8	65.9	66.2	66.7	67.2	68.2	71.0	73.4	71.3	67.3	64.2	62.5
28	66.5	66.7	66.8	70.0*	70.0	71.0	72.6	70.2	69.8	67.8	63.0	61.2
29	65.2	64.8	67.4	64.7*	67.5	69.5	71.0	66.7*	68.2	66.0	63.5	62.3
30	66.0	66.5	66.7	67.4	67.8	68.6	70.8	72.0	71.7	67.5	62.8	61.1
31	65.5	66.5	66.7	67.0	67.8	70.0	71.7	73.0	70.9	66.3	64.0	62.5
Monthly mean	66.2	66.8	66.8	67.4	68.1	69.7	71.5	72.0	70.6	67.3	64.2	62.5
Normal	66.3	66.7	67.0	67.4	68.1	69.7	71.5	72.1	70.4	67.0	64.2	62.7

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794

Increasing scale readings correspond to increasing east declination.

JULY, 1888.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
1	62.8	62.5	63.5	64.8	66.0	65.5	66.9	67.7	66.2	65.8	67.6	65.5	66.6
2	59.2*	59.5*	60.0*	63.8	64.1	67.0	65.6	65.3	65.8	67.2	66.2	66.0	65.7
3	63.8	63.8	64.0	64.5	66.0	66.7	66.8	67.0	67.0	67.5	66.7	66.8	67.1
4	66.8*	66.0*	64.5	64.2	65.6	65.8	66.7	66.7	66.5	66.8	67.0	67.1	67.0
5	61.3	61.7	62.8	63.8	65.0	66.4	66.3	66.5	66.6	66.7	66.7	66.8	66.6
6	64.1	63.5	63.1	64.5	65.7	66.4	66.5	66.8	66.8	66.4	66.5	66.8	67.3
7	63.0	62.9	63.6	64.5	65.0	67.0	65.8	65.0	65.7	67.0	69.7*	68.0	67.2
8	62.8	62.9	63.5	65.0	66.0	66.5	66.8	67.5	69.5*	66.4	66.4	66.4	67.1
9	62.1	63.0	64.0	65.6	66.6	67.4	66.8	67.9	67.8	66.7	66.0	66.1	66.9
10	61.2	63.3	64.6	65.9	66.6	66.5	66.0	65.6	65.7	65.8	66.5	65.8	66.1
11	59.9	60.8	62.7	65.2	67.4	67.8	67.0	66.5	66.6	66.6	66.3	66.4	66.6
12	59.8	61.3	64.0	66.2	67.5	67.6	66.8	66.9	67.0	66.5	66.5	67.0	66.9
13	63.2	63.2	64.5	65.8	66.8	66.5	65.6	65.4	65.7	66.1	66.4	66.3	66.9
14	63.0	62.5	63.2	64.5	65.6	66.1	65.8	65.8	66.1	66.4	66.3	66.0	66.8
15	63.7	63.9	65.7	65.3	65.6	65.7	65.5	65.8	66.0	65.8	65.8	65.9	66.6
16	63.4	63.6	65.0	65.2	65.4	66.2	65.8	65.9	66.1	68.6	68.5	68.4	66.9
17	63.6	63.5	62.6	63.5	64.2	65.0	65.6	65.9	66.3	66.3	66.5	66.5	66.2
18	64.6	64.0	64.8	65.5	65.2	65.0	65.0	66.0	66.5	66.2	66.5	67.8	66.6
19	59.8	60.8	62.7	64.0	65.5	66.2	66.0	66.5	71.5*	67.1	66.0	65.8	66.2
20	61.2	62.6	64.5	66.6	66.4	65.8	66.6	65.8	67.3	66.2	66.4	66.7	66.8
21	62.8	62.5	62.8	64.6	66.5	68.0	68.8*	67.0	66.3	66.2	73.8*	69.0	67.3
22	60.0	61.5	64.2	66.5	68.5*	67.2	66.5	65.8	66.8	66.5	67.5	64.4	66.1
23	63.2	63.8	64.8	66.5	68.0	68.7	68.0	66.3	66.0	66.0	66.5	68.5	66.7
24	61.8	62.8	64.7	66.8	67.8	67.7	67.0	67.4	67.0	67.0	67.8	67.1	67.2
25	59.7	60.3	63.5	65.3	66.6	66.8	66.0	66.2	66.5	65.7	65.8	65.7	66.0
26	61.5	62.3	64.3	65.6	66.0	66.0	65.8	66.0	65.7	65.7	65.4	65.5	66.1
27	62.5	62.3	62.6	64.0	65.4	66.0	66.0	65.8	66.0	65.8	67.1	65.8	66.2
28	60.0	61.5	61.3	61.7*	62.4*	63.5*	64.0	64.8	68.8	68.4	67.2	67.1	66.1
29	62.2	62.2	63.0	64.1	65.6	65.8	65.7	66.0	66.0	66.7	66.2	66.1	65.6
30	61.3	62.8	63.8	64.8	65.5	65.4	65.0	65.0	66.2	65.8	65.9	66.0	66.1
31	62.4	63.7	63.7	64.3	64.4	65.8	66.2	64.5	65.4	66.2	65.8	65.8	66.2
Monthly mean	62.2	62.6	63.6	64.9	65.9	66.4	66.2	66.2	66.7	66.5	66.9	66.6	66.57
Normal	62.1	62.6	63.7	65.0	65.9	66.5	66.1	66.2	66.4	66.5	66.6	66.6	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

AUGUST, 1888.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	65.8	66.2	66.8	67.2	67.1	69.1	71.0	71.8	70.2	68.8	66.8	65.0*
2	66.3	66.5	66.7	66.2	68.8	71.0	74.8*	74.3	72.8*	66.2	62.8	61.8
3	65.8	66.3	67.0	64.2*	66.5	70.3	71.0	73.7	70.5	69.0*	65.8*	63.5
4	70.5*	70.0*	66.0	66.0	68.0	66.2*	70.0	70.0	69.5	67.0	62.4	60.5
5	65.5	66.5	66.4	67.0	67.8	68.6	70.8	71.5	69.0	64.8	62.5	61.5
6	65.8	65.3	66.4	67.2	67.2	69.0	71.8	72.4	71.3	67.1	61.7	59.5
7	65.5	66.0	66.5	66.7	67.0	68.6	71.8	73.0	70.8	67.2	63.2	60.0
8	65.6	66.0	66.4	65.8	67.7	69.5	72.0	71.6	68.5	64.1	62.1	60.8
9	65.5	65.8	66.2	67.0	67.3	69.8	73.4	75.0	71.2	66.0	62.3	61.4
10	65.5	66.3	67.0	67.5	68.0	70.2	72.0	75.0	73.2*	68.2	65.0	62.3
11	66.0	66.2	66.7	66.8	67.0	67.8	70.5	72.0	71.2	68.8	65.3	62.8
12	69.0*	69.5*	66.1	66.8	66.8	69.8	72.4	72.2	69.8	67.8	64.5	61.8
13	65.5	66.0	66.2	66.5	66.5	69.0	71.5	72.8	70.5	67.1	63.5	61.2
14	66.0	65.5	66.5	67.0	67.6	68.6	71.2	71.0	66.8*	63.5*	61.7	61.1
15	66.4	66.5	66.6	66.7	67.5	68.7	71.0	71.9	68.5	64.2	61.2	60.7
16	70.0*	71.2*	70.7*	67.7	63.0*	68.7	71.7	71.5	70.5	66.2	62.6	61.7
17	68.0	59.0*	64.5	68.4	64.5*	66.5*	69.1*	70.5	68.7	66.5	64.0	62.7
18	67.5	66.5	65.0	64.2*	65.2	70.0	72.8	73.0	69.0	65.3	61.8	60.3
19	65.3	67.0	66.5	67.6	68.4	70.2	72.0	71.3	68.2	64.9	62.8	61.4
20	67.3	62.8*	67.8	66.8	67.5	68.5	71.8	73.2	70.5	66.7	63.5	61.5
21	66.1	66.3	66.7	66.0	67.2	69.0	72.3	73.5	68.8	64.4	62.3	61.3
22	65.4	64.8	65.8	66.8	67.2	69.0	71.8	72.8	69.0	64.8	61.5	61.1
23	66.0	66.4	66.6	67.2	67.8	69.8	72.5	73.4	70.3	65.4	61.8	60.5
24	66.1	66.2	66.3	66.8	67.2	68.8	72.7	73.5	71.3	65.6	61.3	59.8
25	66.4	66.8	67.4	67.3	68.2	69.5	72.7	74.5	72.2	66.0	61.3	59.0
26	66.2	66.5	67.4	67.5	68.0	70.0	73.0	74.2	71.8	67.1	63.0	60.3
27	66.4	66.3	67.3	67.8	68.3	69.4	72.6	73.0	70.1	66.3	63.5	61.6
28	65.9	66.4	66.8	66.7	67.4	69.8	72.7	73.0	71.3	67.2	62.8	61.0
29	65.5	65.9	66.0	66.3	66.8	68.3	70.5	71.0	70.1	66.2	62.6	62.7
30	66.1	66.2	66.4	66.8	67.2	67.9	69.3	70.3	68.8	65.8	64.0	63.5
31	67.5	68.5	70.8	67.0	65.6	67.4	68.5*	70.2	70.3	68.0	64.8	62.8
Monthly mean	66.5	66.3	66.8	66.8	67.1	69.0	71.6	72.5	70.2	66.3	63.0	61.4
Normal	66.1	66.3	66.5	66.9	67.3	69.2	71.7	72.5	70.1	66.3	63.0	61.3

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794

Increasing scale readings correspond to increasing east declination.

AUGUST, 1888.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
1	64.8*	65.4*	64.8	64.8	65.0	65.3	65.7	65.5	65.6	65.6	65.7	66.0	66.7
2	60.8	60.5	61.3	65.3	66.3	65.7	65.7	65.0	65.6	66.8	68.8	67.0	66.5
3	62.6	63.1	65.7	64.5	66.2	66.8	68.8*	67.3	71.0*	70.8*	70.2*	68.6*	67.5
4	60.8	61.5	63.8	65.2	66.8	66.5	66.5	65.3	65.2	65.0	65.3	65.4	66.0
5	62.4	63.8	64.8	66.0	66.6	66.0	65.8	67.0	66.0	65.8	65.5	65.8	66.2
6	60.5	61.0	62.8	64.5	65.5	66.5	66.0	65.0	65.4	65.8	66.0	65.8	65.8
7	59.8	61.3	63.0	65.0	66.0	66.5	66.7	66.0	65.5	66.0	68.1	65.8	66.1
8	59.3	60.5	62.5	64.5	67.3	67.0	65.8	65.7	65.8	65.5	65.5	65.5	65.6
9	60.0	61.2	63.1	65.0	66.1	66.3	65.9	65.5	66.0	67.0	65.8	65.5	66.2
10	60.1	61.0	63.8	64.8	65.2	66.0	66.0	66.0	66.0	66.0	65.9	65.9	66.5
11	61.7	61.7	61.6	62.7	64.0	65.0	64.8	65.2	65.5	65.8	73.5*	71.2*	66.4
12	60.7	61.2	62.3	64.0	64.8	66.0	66.0	65.8	65.9	66.0	66.3	65.9	66.3
13	60.6	60.6	61.4	62.0*	64.5	65.0	65.1	65.0	65.8	65.7	65.6	65.7	65.6
14	60.8	62.5	64.3	65.8	66.4	66.3	65.8	65.8	65.8	65.9	66.4	66.5	65.8
15	61.5	61.9	62.5	64.0	64.2	64.3	63.8	68.5	70.5*	68.0	69.4*	70.0*	66.2
16	61.2	62.2	63.5	65.2	66.8	68.0	71.5*	66.6	71.0*	65.8	68.8	63.8	67.1
17	64.0*	64.6*	65.5	67.4	65.2	65.6	67.2	66.5	69.0*	68.8*	67.1	64.4	66.2
18	61.0	63.0	64.8	66.2	66.3	66.9	66.0	68.1	67.7	67.7	66.5	67.0	66.3
19	61.4	61.9	63.3	65.0	66.0	65.6	66.2	67.8	67.6	66.6	68.3	64.3	66.2
20	61.5	62.5	64.6	66.4	67.3	68.8*	65.6	65.5	65.3	65.5	65.5	65.8	66.3
21	62.1	63.1	64.2	65.2	65.6	66.0	65.4	66.0	65.8	66.5	65.8	65.7	66.0
22	61.7	62.9	64.4	66.1	66.8	69.0*	66.5	66.4	65.8	66.0	66.0	65.7	66.1
23	60.0	60.8	62.7	65.2	66.6	67.0	66.5	65.6	65.6	65.8	66.2	66.0	66.1
24	59.5	61.1	62.5	64.6	66.1	65.8	66.0	65.8	65.8	65.8	66.0	66.1	65.9
25	59.2	59.7	62.0	64.4	66.0	66.0	65.6	65.4	65.6	65.8	66.0	66.0	66.0
26	59.5	60.6	63.5	64.5	65.5	65.8	65.8	66.0	65.5	65.8	65.5	65.7	66.2
27	60.5	61.7	63.8	65.2	66.0	66.3	65.7	65.6	66.1	66.6	65.5	65.6	66.3
28	61.3	62.3	64.2	65.8	66.0	65.3	65.0	65.8	66.2	65.8	66.5	66.3	66.3
29	62.8	62.8	63.8	64.7	65.5	65.5	65.5	65.7	65.6	65.7	65.6	65.8	65.9
30	62.6	62.2	64.8	64.2	65.1	65.7	65.8	65.8	65.7	65.7	66.7	68.8*	66.1
31	62.8	63.5	64.5	65.7	66.4	66.3	66.6	66.0	65.8	66.2	66.8	67.5	66.6
Monthly mean	61.2	62.0	63.5	65.0	65.9	66.2	66.1	66.0	66.4	66.3	66.8	66.3	66.22
Normal	61.0	61.8	63.5	65.1	65.9	66.0	65.8	66.0	65.9	66.1	66.3	65.8	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

SEPTEMBER, 1888.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	66.5	67.7	66.8	67.5	67.6	68.3	69.2	70.5	68.8	68.0*	65.5	64.3
2	66.6	66.7	67.4	67.8	67.3	70.0	71.0	70.4	68.2	66.4	64.2	63.4
3	66.3	66.8	66.8	67.0	67.4	68.8	71.0	71.3	68.8	65.0	62.5	61.7
4	66.4	66.5	66.8	66.5	67.5	68.0	70.3	70.5	68.7	65.7	62.2	61.5
5	66.1	66.5	66.8	67.5	68.0	69.5	71.2	71.0	70.0	64.8	62.0	63.0
6	66.0	66.3	66.8	66.5	67.7	68.9	71.0	71.2	70.0	67.0	64.8	63.5
7	66.0	67.5	67.3	68.6	68.4	69.6	72.4	71.5	69.0	66.3	63.7	61.5
8	67.0	67.8	68.8	68.4	68.5	69.0	69.6	69.5	68.8	66.5	64.3	63.8
9	68.0	67.0	67.7	67.8	68.8	69.5	70.8	70.5	69.2	66.4	63.3	61.3
10	66.0	66.7	66.8	67.2	67.4	69.6	72.1	72.3	69.8	66.0	64.0	63.0
11	66.4	66.5	66.8	67.2	67.8	69.7	72.2	72.8*	70.3	65.7	62.8	62.7
12	66.3	66.7	67.0	70.3*	69.0	69.5	70.2	71.8	69.5	65.0	62.6	61.0
13	67.8	71.8*	62.8*	68.0	69.0	70.6	70.0	67.0*	69.8	65.3	63.7	62.7
14	63.3*	67.3	66.0	67.2	67.5	69.2	69.5	69.8	68.0	64.4	64.3	63.4
15	64.5	68.3	67.0	66.0	67.0	65.2*	68.8	68.2	65.6*	63.0	61.6	63.2
16	68.8	67.2	65.4	67.8	68.9	69.0	70.2	69.6	68.0	65.0	63.8	64.2
17	67.4	67.2	67.6	67.6	68.0	68.5	69.0	69.5	68.5	65.3	64.5	64.3
18	67.7	69.2	68.4	68.0	68.0	68.7	69.0	67.7	65.8*	64.0	63.0	62.7
19	66.8	67.2	68.8	65.0	68.3	69.1	69.5	69.5	67.8	65.5	64.7	64.1
20	67.0	64.7*	68.0	67.7	67.0	69.1	70.8	69.5	67.2	65.0	64.7	63.0
21	67.2	67.2	67.3	67.3	67.8	69.0	70.7	71.2	68.3	64.3	62.6	61.3
22	66.8	67.2	67.0	66.5	67.5	68.8	71.5	69.8	67.0	64.5	63.5	62.5
23	65.0	68.2	67.6	67.5	68.1	69.8	71.7	71.8	69.2	63.9	61.6	60.5
24	66.0	66.8	67.0	66.8	67.5	68.5	70.2	69.6	68.8	66.1	64.8	63.8
25	66.8	66.5	67.0	68.0	65.0*	68.0	69.6	68.3	66.4	65.0	64.6	63.5
26	66.7	69.3	64.8	68.8	68.0	68.6	68.9	68.6	68.3	65.0	64.2	62.8
27	71.2*	68.8	67.5	68.0	67.5	68.5	69.4	69.0	67.2	65.0	63.6	63.3
28	67.0	68.8	68.2	68.5	68.0	68.8	70.4	70.2	68.0	66.2	64.5	63.0
29	66.6	66.3	67.0	67.4	67.6	68.3	68.3	67.8	66.2	63.5	62.7	61.8
30	66.6	67.8	67.0	67.4	67.3	67.7	68.8	69.3	68.3	66.4	65.4	64.3
Monthly mean	66.7	67.4	67.0	67.5	67.8	68.9	70.2	70.0	68.3	65.3	63.7	62.8
Normal	66.7	67.4	67.2	67.4	67.9	69.0	70.2	70.0	68.5	65.2	63.7	62.8

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794

Increasing scale readings correspond to increasing east declination.

SEPTEMBER, 1888.

Day.	13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
1	62.4	62.7	64.0	65.2	65.7	65.7	69.0*	66.2	65.4	65.8	66.2	66.3	66.5
2	62.6	62.7	65.9	66.0	67.4	66.7	65.9	68.8	65.8	65.4	65.3	65.5	66.6
3	62.1	63.6	65.6	67.1	67.3	66.4	65.8	65.7	65.8	65.7	65.8	65.8	66.2
4	62.0	62.8	64.5	66.0	66.1	65.8	65.5	65.3	65.3	65.6	65.5	65.7	65.9
5	63.5	64.5	65.5	66.2	66.5	66.0	65.0	65.5	65.5	65.5	65.5	65.7	66.3
6	63.4	64.2	65.0	66.0	65.9	65.4	65.3	65.5	65.5	65.5	65.5	65.6	66.4
7	60.8	63.5	64.8	65.5	66.0	66.0	65.7	66.2	69.1*	69.0	65.8	66.0	66.7
8	63.8	64.0	65.3	66.2	66.3	65.9	66.1	66.7	66.2	67.7	65.9	68.0	66.8
9	61.8	63.0	64.4	65.6	66.4	66.6	67.7	66.2	66.4	65.9	66.0	66.2	66.5
10	62.4	63.6	64.8	65.9	66.3	66.4	66.2	66.0	66.4	66.3	66.3	66.3	66.6
11	63.0	64.4	65.2	66.3	66.3	66.0	65.8	66.0	66.4	66.4	66.6	66.2	66.6
12	61.0	62.6	64.5	66.2	68.2	65.5	65.8	66.5	68.8	67.6	69.0*	72.0*	66.9
13	63.8	64.0	65.2	66.2	66.0	65.2	65.5	65.8	66.0	68.5	65.5	64.0	66.4
14	64.5	65.8	66.3	66.4	69.0	73.2*	66.4	66.9	66.8	67.8	66.8	65.8	66.9
15	64.4	65.3	67.0	67.0	66.6	66.5	66.0	68.7	67.4	67.2	64.0	68.0	66.1
16	64.8	65.8	67.0	67.8	67.2	67.6	66.0	66.2	66.2	66.2	65.3	65.6	66.8
17	64.5	65.7	67.2	67.5	66.8	66.3	65.8	66.2	66.3	66.2	66.2	67.0	66.8
18	63.8	65.2	64.8	67.5	68.0	66.8	66.8	66.2	67.2	66.6	68.2	67.2	66.7
19	63.6	62.7	62.2*	62.9*	62.8*	63.8	64.7	65.2	66.5	68.5	66.0	66.3	66.9
20	62.8	63.1	64.4	66.0	66.0	65.4	65.2	65.8	66.5	65.8	66.7	66.8	66.2
21	61.9	64.0	65.8	66.7	67.0	67.1	66.5	66.5	66.4	67.0	66.2	64.4	66.4
22	63.2	64.6	66.2	67.0	66.8	66.0	66.0	67.0	65.8	65.8	65.7	66.2	66.4
23	61.8	63.5	65.4	66.6	66.5	65.8	66.2	66.3	65.8	65.7	65.5	65.8	66.2
24	63.8	64.9	65.8	66.0	66.0	65.7	66.0	65.8	66.0	65.8	66.0	65.7	66.4
25	64.2	65.8	65.8	66.5	67.1	65.7	66.2	66.2	66.2	65.8	67.2	66.8	66.3
26	63.7	65.2	65.8	65.8	66.0	71.8*	66.7	66.0	66.5	71.8*	70.2*	74.2*	67.4
27	63.4	64.1	66.9	66.2	66.3	66.2	67.0	67.2	67.2	66.5	66.6	64.8	66.7
28	62.4	64.5	65.3	66.1	66.2	66.0	66.8	66.2	66.3	67.5	66.8	65.8	66.7
29	63.2	65.0	66.2	67.7	66.4	65.8	66.2	67.3	67.4	66.2	66.5	66.1	66.2
30	64.5	65.6	66.1	66.7	66.7	66.5	66.8	66.6	65.9	66.6	66.8	67.3	66.8
Monthly mean	63.1	64.2	65.4	66.3	66.5	66.5	66.2	66.4	66.4	66.7	66.3	66.6	66.51
Normal	63.1	64.2	65.5	66.4	66.7	66.0	66.1	66.4	66.3	66.6	66.1	66.1	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

OCTOBER, 1888.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	68.0	67.2	67.8	67.5	67.2	67.6	68.4	68.7	68.5	66.8	65.0	63.4
2	66.4	66.8	67.2	67.0	67.2	67.5	68.8	70.2	68.8	66.3	64.7	63.8
3	67.0	67.0	67.3	66.8	67.0	67.6	69.4	70.5	68.5	65.1	62.6	61.8
4	66.4	67.2	67.2	67.8	68.2	68.8	70.7	71.3	69.0	65.8	62.9	62.3
5	67.8	69.4*	70.8*	69.5*	69.6*	70.0	71.2*	70.2	70.0	64.7	59.8*	61.0
6	66.9	67.5	66.4	66.8	66.5	67.8	69.6	69.5	69.0	67.7	64.5	63.4
7	65.3	66.4	66.4	66.2	67.8	68.2	70.3	70.3	68.2	64.8	62.7	62.3
8	65.8	66.2	66.5	66.8	67.2	68.2	69.6	69.8	69.4	65.8	63.0	61.7
9	65.8	66.0	66.0	66.8	67.0	68.2	70.2	70.2	70.2	66.7	63.0	61.8
10	65.3	67.1	68.0	67.2	68.0	68.6	70.2	70.5	69.0	66.8	64.5	62.8
11	66.2	65.8	65.7	66.1	66.4	66.9	67.8	70.0	68.8	66.5	63.8	63.5
12	66.8	68.0	65.5	68.4	65.0	64.8*	68.8	69.4	68.3	66.2	65.0	63.9
13	68.4	66.5	67.3	66.8	66.4	66.7	64.7*	67.9	67.0	64.8	64.0	63.9
14	67.0	65.0	68.0	67.3	67.4	67.5	67.1	68.8	67.5	65.4	64.0	64.3
15	66.0	66.4	66.3	66.4	66.3	66.8	68.2	68.8	67.5	64.9	63.0	62.7
16	66.1	66.5	67.4	66.8	67.2	67.3	69.8	69.8	67.1	64.8	63.4	63.7
17	65.2	66.2	66.5	66.8	66.8	67.7	67.0	67.7	67.9	[65.6]	[63.7]	62.8
18	66.7	66.5	67.0	68.0	67.2	67.8	67.8	69.0	67.6	65.8	64.5	63.7
19	67.8	65.5	67.6	68.2	68.0	69.6	67.7	68.8	69.5	66.8	63.0	61.5
20	68.0	66.0	64.6	66.1	65.8	66.5	62.1*	67.1	68.2	67.7	65.8	64.5
21	65.5	63.0*	61.5*	67.0	68.8	67.3	68.8	70.0	70.3	67.9	66.0	64.1
22	66.2	65.6	66.8	66.8	67.1	67.1	67.5	70.0	69.1	68.0	66.2	63.8
23	65.2	67.0	66.0	67.5	65.4	67.0	68.1	68.9	67.4	66.6	65.5	64.2
24	66.0	66.8	65.8	66.2	66.5	66.9	67.2	68.3	67.7	65.8	65.0	63.3
25	66.4	65.0	67.3	66.4	64.2*	66.3	66.6	67.8	67.8	65.7	63.5	62.1
26	66.2	66.2	66.5	65.8	65.5	64.8*	66.0	67.7	70.0	67.5	63.8	63.0
27	66.0	66.3	65.0	66.4	65.8	66.2	66.8	67.7	68.8	67.5	65.4	64.3
28	66.0	66.1	66.5	66.4	66.8	66.8	67.8	69.3	68.8	65.8	63.8	62.8
29	66.6	66.5	67.4	66.6	66.5	66.8	67.0	68.2	67.8	65.4	63.9	63.5
30	65.7	65.3	66.0	66.0	66.1	66.8	68.9	70.5	70.5	68.3	65.8	62.8
31	66.3	67.0	66.3	66.8	67.7	68.5	69.0	70.5	69.1	66.7	65.0	62.3
Monthly mean	66.4	66.4	66.6	66.9	66.9	67.4	68.2	69.3	68.6	66.3	64.1	63.1
Normal	66.4	66.4	66.6	66.9	66.9	67.6	68.4	69.3	68.6	66.3	64.2	63.1

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794

Increasing scale readings correspond to increasing east declination.

OCTOBER, 1888.

Day.	13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
1	63.5	64.7	66.1	67.0	66.4	66.5	66.5	66.3	66.8	65.9	66.2	66.4	66.6
2	64.4	65.0	65.8	66.4	65.5	65.5	65.8	65.9	66.0	66.0	66.2	66.5	66.4
3	62.1	63.9	65.2	65.8	65.4	65.6	65.5	65.8	65.9	65.9	66.2	66.5	66.0
4	62.7	63.8	65.5	66.2	66.2	66.0	66.4	66.4	66.3	66.6	67.5	67.2	66.6
5	61.5	64.2	65.4	67.0	67.3	65.5	66.5	65.8	66.0	66.5	66.0	66.5	66.8
6	63.2	63.8	65.5	67.0	66.6	66.3	66.2	66.7	66.8	65.8	65.7	65.0	66.4
7	63.0	64.8	65.9	67.0	66.8	66.3	66.4	66.4	65.8	66.0	66.0	65.8	66.2
8	62.3	64.4	65.8	66.4	66.2	66.0	65.8	66.2	65.8	65.8	65.0	65.4	66.0
9	62.1	63.2	64.5	66.4	66.0	66.0	66.0	66.0	65.8	66.8	66.0	66.3	66.1
10	62.4	63.2	64.0	64.8	65.8	67.5	66.0	67.2	66.8	67.4	64.5	65.8	66.4
11	64.1	64.8	65.5	65.5	65.3	69.0*	65.5	65.8	68.2	69.9*	67.2	66.7	66.5
12	64.3	65.5	66.0	65.7	66.1	66.6	67.8	68.8	67.4	67.2	66.3	67.0	66.6
13	64.1	66.0	66.5	66.5	66.8	65.8	66.2	66.8	66.7	66.5	66.4	66.5	66.2
14	64.8	65.8	66.4	66.2	65.9	65.8	65.9	66.0	67.1	66.0	66.1	66.2	66.3
15	63.3	64.8	65.6	65.7	65.8	65.7	65.8	66.0	66.1	66.0	66.5	66.0	65.9
16	63.5	64.6	65.5	66.0	66.4	66.0	66.1	66.2	66.3	66.2	66.7	64.8	66.2
17	63.7	65.0	66.2	66.7	66.4	66.0	66.0	66.0	66.3	66.2	65.8	65.8	[66.0]
18	63.4	65.2	65.8	66.2	66.2	66.3	66.3	66.4	66.4	66.3	66.4	65.2	66.3
19	62.2	62.3	62.8*	65.5	63.4*	65.3	66.0	66.2	66.4	66.3	65.8	67.4	66.0
20	64.0	64.0	67.8	63.8	66.8	69.1*	67.8	78.5*	69.0	68.0	66.3	66.2	66.8
21	65.0	64.9	65.9	67.9	68.1	68.2	67.8	67.5	66.2	65.5	64.0	66.0	66.6
22	63.0	63.8	65.1	66.0	66.2	66.4	67.2	66.2	66.0	65.8	65.5	65.8	66.3
23	63.8	64.5	67.1	65.2	66.0	66.5	67.5	68.0	67.5	67.5	66.7	65.7	66.4
24	62.7	64.8	65.3	65.9	66.5	67.2	68.2	67.0	66.8	70.0*	66.3	66.8	66.4
25	62.8	64.5	65.8	66.2	66.1	67.7	66.4	66.4	66.4	66.4	66.3	66.3	65.8
26	62.1	63.3	64.3	64.7	65.8	66.0	66.2	66.3	66.7	66.7	66.8	67.0	65.8
27	64.0	64.8	65.5	65.8	66.0	66.2	66.2	66.5	66.4	66.4	66.5	66.2	66.1
28	62.8	63.8	64.7	65.4	66.0	66.4	66.5	66.2	66.2	66.3	66.8	66.5	66.0
29	64.3	65.2	65.7	65.9	65.7	65.8	65.8	65.8	65.8	66.1	65.9	65.7	66.0
30	62.7	63.5	64.0	64.7	65.4	65.5	65.4	70.0*	67.5	66.9	69.1*	67.7	66.5
31	60.5*	63.3	62.5*	66.2	66.5	67.0	65.6	68.5	68.7	66.7	66.3	66.0	66.4
Monthly mean	63.2	64.4	65.4	66.0	66.1	66.4	66.4	67.0	66.6	66.6	66.2	66.2	66.28
Normal	63.3	64.4	65.6	66.0	66.2	66.3	66.4	66.5	66.6	66.4	66.1	66.2	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time.

300 divisions + tabular quantity

NOVEMBER, 1888.

Day.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
1	66.8	66.0	66.0	66.3	66.7	64.7	67.1	68.6	68.7	66.9	65.3	64.5
2	65.5	66.0	66.2	66.4	65.9	66.5	67.4	67.0	66.4	65.5	64.1	64.4
3	65.4	66.6	66.8	66.8	67.7	67.8	68.2	68.8	67.1	64.5	63.5	62.8
4	67.0	66.7	66.0	67.0	67.0	68.0	69.8*	64.3*	65.0	63.2*	61.6*	62.7
5	66.4	66.5	66.6	67.5	64.6	68.2	69.5	70.8*	68.8	67.0	65.6	64.3
6	66.0	66.9	67.0	67.2	67.0	67.6	68.8	66.2	67.0	66.8	64.5	63.5
7	66.2	65.0	66.0	66.0	67.2	67.7	69.0	69.0	67.8	66.0	64.5	63.8
8	66.6	67.0	66.1	66.8	65.8	66.0	67.5	65.5	65.0	62.2*	61.5*	62.3
9	66.2	64.8	65.0	66.0	66.5	66.8	67.2	67.4	67.5	67.3	66.4	64.8
10	66.1	66.2	66.0	66.8	66.7	67.0	68.0	69.0	69.5	68.6	67.0	65.5
11	68.8	70.0*	68.8*	68.7	67.2	67.3	68.2	68.8	68.5	68.0	67.0	65.3
12	66.4	66.3	66.6	66.6	66.4	66.5	67.8	68.8	68.8	67.8	66.7	65.7
13	66.2	65.9	65.8	65.8	66.0	66.2	67.0	67.5	67.8	66.6	64.8	63.5
14	66.2	66.2	66.4	66.4	66.6	67.2	67.2	68.2	68.0	67.4	66.0	64.4
15	66.3	66.0	66.2	66.2	66.3	66.5	67.8	67.5	67.0	66.0	64.1	62.8
16	68.3	67.0	66.8	65.4	66.7	67.2	67.4	68.5	66.8	67.4	65.8	62.3
17	75.3*	67.1	62.6*	67.5	67.0	63.8*	65.2	67.6	67.2	66.0	65.1	63.7
18	65.7	63.0*	67.4	66.5	65.6	66.5	66.8	67.8	67.5	66.2	63.3	62.2
19	65.3	65.2	64.8	66.3	65.8	66.6	64.0	68.0	69.0	68.0	66.3	64.3
20	66.2	66.1	66.0	65.9	65.9	66.3	66.7	68.5	68.5	68.4	66.7	65.0
21	65.5	65.5	64.5	66.2	66.5	66.4	66.4	67.6	67.8	67.5	66.7	64.3
22	65.5	64.8	66.5	67.3	67.0	67.4	66.5	67.5	67.4	66.8	66.5	65.4
23	65.5	65.5	65.6	65.8	66.2	66.4	66.3	66.9	67.2	66.6	66.2	65.2
24	65.5	65.6	65.5	65.7	65.8	65.8	66.5	67.4	67.7	67.2	65.8	64.9
25	65.8	65.8	65.5	65.8	65.8	65.0	65.3	66.2	67.0	68.2	66.7	64.8
26	66.7	65.8	65.3	64.8	64.5	64.7	65.1	65.6	66.6	66.7	67.0	65.7
27	66.5	66.0	66.4	66.4	66.1	66.5	65.8	66.6	66.1	66.7	66.5	65.3
28	67.0	66.8	66.6	66.7	67.5	65.0	66.0	66.8	67.2	66.3	66.4	65.5
29	66.7	65.7	65.7	66.8	66.8	66.6	66.5	66.1	67.2	66.8	65.0	63.5
30	65.1	65.6	66.0	65.8	66.0	66.2	66.2	66.6	67.8	66.8	63.6	63.0
Monthly mean	66.6	66.0	66.0	66.4	66.4	66.5	67.0	67.5	67.5	66.6	65.3	64.2
Normal	66.3	66.0	66.0	66.4	66.4	66.6	67.0	67.5	67.5	66.9	65.6	64.2

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794

Increasing scale readings correspond to increasing east declination.

NOVEMBER, 1888.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
1	64.5	64.3	64.5	66.0	65.8	65.9	66.5	66.3	66.2	66.0	65.8	65.9	66.0
2	64.8	65.7	66.2	66.5	66.5	66.8	66.8	66.7	66.5	66.4	66.4	66.3	66.1
3	63.4	64.4	65.8	66.4	66.5	66.4	66.3	66.3	65.8	65.8	65.8	65.8	66.0
4	63.0	64.2	64.5	67.6	65.8	67.0	66.7	67.6	67.4	67.0	67.0	66.7	66.0
5	64.5	64.5	64.6	66.0	66.2	67.6	67.8	68.1	67.0	67.0	67.8	66.8	66.8
6	63.7	63.8	64.6	65.4	66.0	68.4	67.2	67.4	69.5*	68.2	67.3	66.6	66.5
7	63.6	64.0	64.7	65.8	66.5	67.0	67.0	67.6	67.4	66.6	65.8	67.8	66.3
8	63.8	64.7	64.7	66.2	66.8	68.2	67.5	67.4	66.5	66.5	66.3	66.3	65.7
9	64.1	64.8	65.8	66.1	66.9	66.8	67.2	67.2	67.0	66.6	66.4	66.5	66.3
10	64.8	65.0	65.3	66.0	66.8	67.8	67.7	68.9	67.5	66.6	68.2	70.5*	67.1
11	64.8	64.7	65.8	66.3	66.2	67.0	66.8	67.4	66.8	66.6	66.7	66.3	67.2
12	65.3	65.4	64.9	65.0	65.7	66.5	66.4	66.6	66.1	66.8	66.5	66.0	66.5
13	64.2	64.5	65.4	65.8	66.4	66.5	66.5	66.5	66.4	66.3	66.2	66.2	66.0
14	64.3	64.3	64.7	65.1	66.1	66.5	66.7	66.4	66.4	66.5	66.4	65.7	66.2
15	63.2	64.0	65.0	65.5	66.2	65.8	66.7	66.4	67.8	67.8	67.8	67.8	66.1
16	62.0	63.7	64.5	66.4	67.6	67.8	68.8	80.5*	72.3*	70.6*	68.2	66.0	67.4
17	64.2	63.7	65.0	66.0	66.8	70.6*	67.5	66.8	67.3	68.6	66.8	67.9	66.6
18	62.2	63.5	64.8	66.6	67.3	68.0	69.2	67.2	66.8	66.0	65.6	65.5	65.9
19	63.7	63.1	64.5	65.7	66.5	66.8	66.8	66.9	67.6	66.3	66.0	65.8	66.0
20	64.0	63.5	63.9	65.6	66.6	66.8	67.0	66.8	66.5	66.2	65.7	65.5	66.2
21	63.8	64.8	65.5	65.8	66.9	66.9	66.9	66.8	66.0	66.0	65.9	65.7	66.1
22	65.2	65.3	65.5	65.5	66.0	66.2	66.3	66.3	66.0	66.0	65.8	65.6	66.2
23	64.7	64.4	64.5	65.5	66.2	66.6	67.0	66.7	66.3	66.3	65.9	65.8	66.0
24	64.7	64.1	64.2	65.0	66.0	66.3	66.3	66.5	66.3	66.3	66.0	66.0	65.9
25	64.0	63.5	64.6	64.1	66.0	66.2	66.4	66.6	68.2	66.8	65.3	66.8	65.8
26	64.3	64.3	64.4	65.3	65.8	65.8	66.3	66.8	66.6	66.6	70.2*	67.2	65.9
27	64.2	63.0	65.8	64.1	65.0	66.4	66.3	66.7	66.8	66.7	67.1	67.6	66.0
28	64.4	64.8	64.4	65.3	65.9	66.8	66.3	67.2	67.0	66.0	65.0	66.6	66.1
29	64.4	64.8	65.5	65.5	66.8	66.7	66.8	66.5	66.3	65.9	65.8	65.2	66.0
30	63.0	63.8	65.2	66.0	66.5	66.4	66.3	66.2	66.2	66.2	65.7	66.0	65.7
Monthly mean	64.2	64.3	65.0	65.7	66.3	67.0	66.8	67.4	67.0	66.7	66.5	66.5	66.22
Normal	64.2	64.3	65.0	65.7	66.3	66.8	66.8	66.9	66.7	66.6	66.4	66.3	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time.

300 divisions + tabular quantity.

DECEMBER, 1888.

Day.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
1	65.8	65.8	66.0	66.0	66.0	66.2	66.5	66.7	66.8	65.9	64.8	63.6
2	66.0	66.8	66.8	67.2	66.5	66.7	66.6	66.7	66.7	66.5	65.8	64.4
3	65.7	65.8	65.7	66.9	67.0	65.1	66.0	65.8	66.3	65.7	65.1	64.6
4	65.4	65.8	65.8	67.2	66.8	66.0	65.8	65.9	66.5	66.5	66.2	65.0
5	66.0	65.5	65.4	66.2	66.2	66.5	65.0	66.0	66.4	65.8	64.8	64.0
6	66.0	65.8	65.6	65.6	65.8	67.6	67.1	66.8	68.0	67.3	67.0	65.5
7	65.5	65.3	65.5	65.3	65.8	66.2	66.2	67.0	67.7	68.6	68.2	66.3
8	68.4*	67.8	69.0*	67.5	64.5	63.7	64.3	66.8	67.8	66.4	67.6	66.0
9	65.8	65.7	65.7	65.7	66.1	66.5	65.5	67.2	67.6	68.0	67.5	65.4
10	66.7	65.9	66.3	66.7	66.5	66.4	66.5	67.0	67.7	68.1	67.9	66.4
11	66.0	66.0	65.8	65.5	65.5	65.5	65.5	65.8	67.1	67.7	67.3	66.4
12	66.4	66.3	66.0	66.5	65.7	65.8	66.2	66.5	67.2	66.3	65.5	64.5
13	66.0	65.7	67.2	66.0	66.7	65.7	65.8	65.7	65.7	65.3	65.3	64.3
14	65.3	64.8	64.3	65.0	67.5	65.5	66.4	66.3	65.2	61.8*	65.8	65.3
15	63.0*	63.8	65.0	64.0	65.7	66.1	65.0	67.0	66.8	65.5	64.0	64.6
16	65.6	65.4	63.7	65.5	63.8	64.6	65.5	66.2	67.9	67.5	66.7	65.8
17	65.6	65.6	65.7	65.7	65.7	65.8	65.8	67.1	67.5	66.8	65.8	64.7
18	65.5	65.5	65.5	66.0	65.8	66.3	66.8	67.0	67.2	67.0	66.2	64.6
19	65.3	64.8	65.8	66.2	66.7	66.2	65.9	66.9	67.2	67.0	66.3	64.2
20	65.5	65.7	66.2	66.7	66.7	65.7	66.8	66.7	68.0	68.3	67.8	65.5
21	65.7	65.5	65.5	65.7	65.8	66.0	65.7	66.0	67.7	66.5	65.7	64.6
22	67.0	67.5	66.1	66.0	65.8	65.3	65.7	67.0	68.6	68.8	67.3	65.3
23	65.0	64.8	64.5	64.7	64.9	65.3	65.6	67.0	68.2	68.3	66.5	64.7
24	66.0	65.0	63.8	67.3	66.0	65.8	66.0	67.0	68.2	67.5	65.0	63.0
25	65.3	66.3	59.5*	64.8	65.2	65.3	65.8	67.2	68.2	68.5	66.7	64.8
26	64.7	65.0	65.3	65.6	64.5	66.0	66.6	67.8	68.4	68.3	64.8	62.3
27	64.8	64.5	64.3	64.5	64.2	64.5	65.0	66.5	67.7	68.1	66.1	63.2
28	65.5	65.3	64.8	65.5	65.7	64.7	64.8	66.1	66.7	66.8	66.3	63.9
29	65.5	65.4	65.3	65.0	65.0	65.0	65.0	65.8	66.9	67.3	66.2	63.4
30	65.7	64.6	65.2	62.7*	65.3	64.8	65.0	65.8	67.2	67.2	65.8	64.5
31	62.5*	64.1	64.4	63.9	63.8	64.0	64.5	65.5	66.4	67.1	66.1	65.0
Monthly mean	65.6	65.5	65.3	65.7	65.7	65.6	65.8	66.5	67.3	67.0	66.2	64.7
Normal	65.7	65.5	65.4	65.8	65.7	65.6	65.8	66.5	67.3	67.2	66.2	64.7

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale=0′.794 Increasing scale readings correspond to increasing east declination.

DECEMBER, 1888.

Day.	13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
1	63.5	64.4	65.0	65.6	66.3	66.5	66.7	66.4	67.0	66.6	66.7	66.5	65.9
2	65.2	66.0	65.8	66.4	67.0	67.5	67.5	66.7	66.4	66.0	66.0	65.9	66.4
3	64.5	65.2	65.7	65.8	66.7	67.0	67.0	67.0	68.8	67.5	66.0	64.2	66.0
4	65.3	65.6	65.7	66.6	68.3	67.0	67.7	67.7	67.0	66.3	65.8	65.8	66.3
5	64.0	64.4	65.2	66.2	66.7	68.9	68.3	67.5	67.6	69.0*	66.7	64.6	66.1
6	64.0	63.8	64.4	65.8	67.0	67.2	67.1	66.9	65.9	66.5	66.0	65.7	66.2
7	65.2	64.5	64.0	65.5	66.8	66.5	67.3	67.6	67.7	67.0	67.2	67.5	66.4
8	64.2	64.1	64.8	65.4	66.4	66.0	66.8	67.3	67.0	67.0	66.8	66.5	66.3
9	64.4	65.2	65.8	65.7	66.4	66.6	67.2	67.3	67.3	67.0	66.8	66.8	66.4
10	65.2	64.8	64.8	65.5	66.2	66.2	66.8	66.8	66.7	66.5	66.6	66.5	66.4
11	65.7	64.7	64.6	65.0	66.3	66.5	66.6	66.7	66.5	66.7	66.5	66.3	66.1
12	64.5	64.7	63.7	64.0	66.2	66.2	66.0	66.5	66.2	66.3	66.0	66.3	65.8
13	64.8	65.7	65.2	65.3	66.5	66.6	66.7	66.7	70.7*	67.7	65.5	65.3	66.1
14	64.8	64.9	65.4	65.7	66.2	66.8	66.8	67.0	68.2	67.5	67.5	63.2	65.7
15	63.0	63.8	65.3	65.3	66.0	66.4	66.3	67.0	66.5	66.0	65.5	65.5	65.3
16	65.0	64.4	64.8	65.7	66.4	66.4	67.0	66.5	66.2	66.0	63.8	65.3	65.6
17	63.7	64.3	64.6	65.2	66.1	66.5	69.1	66.6	66.8	66.6	65.7	65.8	66.0
18	64.8	65.0	65.0	65.7	66.4	66.6	67.0	68.2	66.4	66.1	65.5	65.4	66.1
19	64.5	64.8	65.2	65.5	66.2	66.8	66.8	66.8	66.8	66.6	65.8	65.5	66.0
20	64.4	63.4	64.4	65.5	66.7	66.8	66.8	66.8	66.5	66.0	65.8	65.6	66.2
21	64.5	65.4	65.5	65.5	66.2	67.0	67.2	67.2	67.2	67.0	66.8	65.5	66.1
22	64.5	65.0	65.7	66.0	66.8	67.1	67.2	67.2	66.5	65.8	65.7	65.2	66.4
23	63.8	63.4	63.8	64.8	65.5	65.7	65.6	72.5*	66.0	67.8	68.0	67.8	66.0
24	60.0*	62.2	61.8*	64.8	65.4	65.0	66.0	67.1	65.5	65.0	66.5	63.7	65.2
25	63.0	62.5	62.8	64.7	64.2	66.9	65.8	66.5	66.0	66.2	66.0	65.7	65.3
26	61.2*	62.8	63.7	64.5	65.4	65.3	65.8	66.4	65.8	65.8	65.1	65.0	65.2
27	61.5*	62.2	62.8	64.3	64.8	65.3	65.7	65.8	66.2	66.0	65.9	65.8	65.0
28	63.3	62.3	63.4	64.2	65.0	65.5	65.8	65.6	65.8	65.9	65.8	65.8	65.2
29	62.3	62.3	63.0	64.5	65.4	65.6	65.7	65.7	65.4	65.0	64.8	64.5	65.0
30	63.2	63.2	63.4	64.4	64.8	65.0	64.9	64.5	64.6	65.5	64.0	64.0	64.8
31	64.2	64.8	64.9	64.9	65.2	64.9	65.0	65.0	64.8	64.5	64.0	64.0	64.7
Monthly mean	63.9	64.2	64.5	65.3	66.1	66.4	66.6	66.9	66.7	66.4	66.0	65.5	65.81
Normal	64.3	64.2	64.6	65.3	66.1	66.4	66.6	66.7	66.5	66.3	66.0	65.5	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

JANUARY, 1889.

Day.	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Noon.
1	64.1	64.0	64.4	64.5	64.0	64.0	64.3	65.0	65.0*	64.8*	64.7	62.7
2	64.6	65.2	66.8	64.3	64.6	64.3	64.3	64.5	65.4	65.0*	64.2	63.5
3	64.3	64.3	64.6	64.7	64.7	64.8	65.2	66.0	67.6	67.9	66.6	64.6
4	64.7	64.7	65.0	65.0	65.0	65.4	65.8	66.8	67.0	66.7	65.0	62.5
5	64.8	64.8	64.8	65.0	65.0	65.4	65.7	67.8	70.0	68.6	66.2	63.3
6	63.8	64.8	65.2	64.8	64.8	65.4	65.4	66.8	67.8	67.8	65.8	63.5
7	65.5	62.8	65.7	65.6	65.5	65.5	65.7	68.0	69.0	68.8	66.5	63.3
8	65.1	65.2	65.0	65.3	65.4	65.7	66.2	67.8	68.8	68.2	65.1	62.0
9	65.0	64.8	64.6	64.5	64.8	65.1	65.6	67.4	69.9	70.0	67.4	64.3
10	64.6	64.4	63.8	64.2	65.7	65.0	65.8	66.6	68.8	69.6	67.5	63.3
11	65.5	64.2	64.0	65.0	64.8	65.0	65.0	62.8*	67.2	68.8	67.8	65.3
12	65.2	66.8	65.3	65.0	64.8	64.9	65.0	65.8	67.7	68.7	67.0	63.5
13	65.1	65.2	64.0	65.0	64.8	64.7	64.7	66.0	67.8	67.4	66.4	64.3
14	65.4	65.4	65.3	65.5	64.7	65.0	65.2	66.7	68.7	68.8	67.2	64.6
15	64.8	64.7	64.9	64.7	64.5	64.2	64.7	66.7	67.8	67.0	65.5	64.6
16	65.0	65.0	65.0	64.8	64.5	64.6	64.9	66.9	69.3	68.8	66.0	62.7
17	64.8	64.8	64.8	64.3	64.5	65.2	65.6	67.8	69.0	68.5	66.4	64.1
18	65.7	65.6	65.0	65.0	65.0	65.3	65.1	66.4	68.2	67.9	66.2	62.2
19	64.6	64.6	64.8	64.7	64.8	65.2	65.5	67.6	69.8	68.8	68.2	61.8
20	65.7	65.7	65.1	65.8	64.7	63.6	69.8*	68.2	67.8	64.5*	60.5*	60.5*
21	63.5	64.6	64.3	64.0	65.8	66.8	64.5	66.0	66.5	64.9*	63.2*	61.4
22	64.6	64.4	65.0	64.2	66.6	66.6	67.0	67.2	68.3	67.8	64.8	62.5
23	64.5	64.4	64.7	64.7	65.7	65.8	65.9	68.0	68.4	67.4	66.3	61.2
24	64.4	64.5	64.8	65.3	65.8	66.4	67.2	68.3	67.8	66.4	64.5	62.2
25	65.0	65.4	65.2	65.8	65.7	66.0	66.5	68.4	70.8*	70.8*	68.8*	66.0
26	65.4	64.8	65.4	65.5	64.9	64.8	66.3	67.8	68.6	68.5	66.3	64.0
27	65.4	65.3	65.7	66.1	65.8	66.0	66.2	66.8	67.8	68.2	68.2	67.0*
28	66.1	67.4	66.4	65.8	65.5	63.8	65.5	66.2	67.0	[68.2]	67.9	66.0
29	67.3	66.2	65.8	65.4	65.2	65.2	64.6	63.7*	65.9	67.2	66.5	65.3
30	65.5	65.7	65.8	65.8	65.5	65.3	65.3	65.3	66.0	66.0	65.6	63.5
31	66.0	66.1	66.2	66.0	65.8	65.0	65.3	66.0	66.4	66.7	65.8	63.8
Monthly mean	65.0	65.0	65.1	65.0	65.1	65.2	65.6	66.6	67.9	67.7	66.0	63.5
Normal	65.0	65.0	65.1	65.0	65.1	65.2	65.5	66.9	67.9	68.0	66.2	63.5

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′. 794

Increasing scale readings correspond to increasing east declination.

JANUARY, 1889.

Day.	13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
1	61.7	64.2	64.3	65.0	65.5	68.0	66.8	65.0	65.4	65.3	65.3	60.5*	64.5
2	63.7	63.7	64.6	64.7	65.7	65.8	65.7	65.4	65.0	64.7	64.5	64.3	64.8
3	64.0	64.0	64.0	65.0	65.8	65.9	65.8	65.8	65.3	65.4	64.8	64.7	65.2
4	62.5	63.4	64.8	65.8	66.1	66.2	66.1	66.1	65.7	65.2	65.0	64.9	65.2
5	61.6	62.3	64.0	65.5	66.0	66.2	66.0	66.1	65.8	65.5	65.4	65.0	65.4
6	62.2	62.6	64.2	64.8	65.7	66.3	66.2	65.8	65.8	65.8	65.5	65.2	65.2
7	61.2	61.2	62.0	65.6	65.8	66.0	66.4	66.3	66.7	66.5	65.8	65.8	65.5
8	60.3	60.8	62.3	64.0	64.7	65.6	66.0	65.7	65.8	65.7	65.4	65.2	65.0
9	63.5	62.8	63.7	64.7	65.4	65.7	66.4	64.3	65.3	65.5	65.0	64.9	65.4
10	61.7	61.8	62.8	64.0	65.5	65.1	65.8	65.8	65.7	65.5	65.3	66.1	65.2
11	63.2	63.5	63.7	64.5	65.6	65.8	66.0	65.9	67.3	65.9	65.3	65.3	65.3
12	62.0	62.8	63.8	64.5	65.3	65.7	65.5	65.3	65.8	66.0	65.7	65.3	65.3
13	63.2	63.8	64.5	65.6	66.0	65.8	65.7	65.6	65.6	65.5	65.3	65.3	65.3
14	64.0	64.0	64.4	65.3	65.8	65.9	66.1	65.8	65.4	65.1	65.0	64.8	65.6
15	64.5	64.6	65.0	65.5	65.7	65.5	65.5	65.4	65.3	65.2	65.0	64.9	65.3
16	61.5	62.6	64.0	65.1	65.6	65.7	65.5	65.5	65.5	65.3	65.2	64.9	65.2
17	62.8	63.1	64.6	65.6	65.8	65.6	65.6	65.6	65.4	65.1	65.0	65.1	65.4
18	61.0	62.1	64.2	66.2	66.0	65.8	65.8	66.0	65.8	65.8	65.0	64.5	65.2
19	60.2	61.6	63.9	65.4	65.7	65.2	65.5	65.8	65.0	66.4	67.6	66.6	65.3
20	58.5*	61.4	62.6	65.8	66.2	67.3	67.2	72.8*	72.8*	66.0	65.0	61.3*	65.4
21	61.0	62.5	64.7	65.7	65.8	65.3	66.2	65.8	67.0	65.5	65.1	65.4	64.8
22	61.0	61.0	62.9	64.7	66.5	66.4	66.5	66.3	65.8	65.5	65.1	64.3	65.2
23	59.6*	60.0*	62.6	64.8	65.5	65.7	65.8	65.3	65.5	65.5	65.0	64.8	64.9
24	61.3	61.8	63.6	65.0	65.8	66.0	66.0	65.8	65.9	65.8	65.7	65.4	65.2
25	63.5	63.0	63.0	64.4	65.7	65.8	66.4	66.0	66.0	65.7	65.6	65.4	66.0
26	63.1	63.5	63.6	64.4	65.3	66.0	66.1	66.2	66.0	65.8	65.7	65.6	65.6
27	65.7*	64.8	64.2	64.2	65.1	65.7	65.7	65.9	65.7	65.5	65.5	65.9	65.9
28	64.6	64.2	64.3	64.4	65.4	65.5	65.8	65.7	65.6	65.7	65.7	65.3	65.8
29	64.6	64.2	64.4	64.6	65.2	65.8	66.0	66.0	66.0	65.7	65.7	65.7	65.5
30	62.6	63.1	64.1	65.0	66.0	65.8	65.5	65.8	65.7	65.7	66.5	64.8	65.2
31	62.8	64.2	64.6	65.0	65.5	65.8	66.8	65.2	65.0	65.0	65.0	64.8	65.4
Monthly mean	62.4	62.9	63.9	65.0	65.7	65.9	66.0	65.9	66.0	65.6	65.4	64.9	65.29
Normal	62.5	63.0	63.9	65.0	65.7	65.9	66.0	65.7	65.7	65.6	65.4	65.2	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

FEBRUARY, 1889.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	65.0	65.0	65.7	66.0	65.5	65.8	65.8	66.0	66.2	67.6	65.8	62.2
2	65.5	65.5	65.7	65.7	65.9	65.8	66.0	66.7	67.4	67.8	66.8	65.0
3	65.3	65.4	66.0	66.0	66.3	66.0	66.5	67.0	68.3	68.8	65.7	62.8
4	65.0	65.5	65.5	65.6	65.9	65.6	66.5	68.4	69.2	68.7	67.4	65.3
5	65.3	65.0	65.4	65.5	65.2	65.8	65.8	66.8	67.9	68.1	66.4	63.8
6	64.8	65.0	64.5	65.3	65.6	66.1	65.8	67.5	68.3	67.5	66.8	64.8
7	65.8	64.5	64.7	65.4	65.4	65.6	65.2	64.7	67.2	67.4	67.0	65.3
8	66.0	64.0	65.8	67.8	65.8	65.0	66.2	67.2	68.2	67.8	66.1	64.4
9	65.4	65.0	65.1	65.2	65.0	65.3	64.8	65.8	67.3	68.0	67.7	66.2
10	64.8	64.8	65.0	65.3	65.2	65.3	65.5	66.2	67.2	67.0	65.5	64.2
11	65.2	65.2	65.1	65.0	65.0	65.3	66.0	66.5	67.8	67.5	66.0	64.0
12	65.2	65.1	65.1	65.5	65.5	65.7	66.0	67.0	67.5	67.8	66.5	65.0
13	64.9	64.8	64.8	65.0	65.2	65.5	65.8	66.5	66.7	[65.9]	64.0	62.3
14	67.5	67.2	70.0*	68.8*	68.2*	67.5	67.9	67.5	66.8	67.8	66.1	64.8
15	67.1	66.6	66.8	67.5	66.8	67.0	67.0	67.3	67.5	67.8	64.8	63.2
16	64.7	65.5	65.3	65.6	65.8	66.5	66.3	66.2	67.3	68.1	66.5	64.8
17	66.8	66.0	66.8	66.5	61.2*	68.0	67.7	66.6	68.5	67.5	66.8	64.2
18	65.0	65.3	65.5	64.3	64.8	64.0	63.8	65.5	67.3	67.9	67.5	66.0
19	65.0	65.3	65.3	65.2	66.0	65.8	65.8	66.4	66.7	66.6	66.4	64.3
20	66.0	66.8	65.4	65.5	65.0	65.5	65.8	67.8	67.2	66.8	66.2	64.9
21	65.4	65.2	65.2	65.2	65.8	65.7	66.4	67.8	68.3	68.8	68.0	66.7
22	65.8	66.0	65.4	65.6	66.5	66.3	66.8	66.6	67.5	67.3	67.8	67.0
23	65.3	65.2	65.1	64.5	65.5	65.7	65.6	65.8	67.6	68.3	67.4	65.3
24	65.5	65.3	65.3	65.4	65.6	65.5	66.0	67.3	67.8	67.1	65.1	62.8
25	65.1	65.3	65.1	65.4	65.8	65.8	66.5	67.8	67.3	65.8	65.2	63.8
26	65.0	64.9	65.1	65.4	65.5	65.7	66.0	66.6	66.5	67.4	66.1	65.0
27	65.7	65.5	65.9	66.1	65.5	66.0	65.5	65.3	66.6	64.1*	63.5*	63.6
28	65.8	65.8	66.0	66.2	66.1	65.8	66.0	66.6	67.0	66.7	65.8	64.7
Monthly mean	65.5	65.4	65.6	65.7	65.6	65.8	66.0	66.7	67.5	67.4	66.2	64.5
Normal	65.5	65.4	65.4	65.6	65.6	65.8	66.0	66.7	67.5	67.6	66.3	64.5

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794

Increasing scale readings correspond to increasing east declination.

FEBRUARY, 1889.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
1	61.6	63.2	64.9	66.3	66.9	66.9	66.7	66.4	66.0	65.9	65.7	65.5	65.5
2	64.3	64.5	64.8	65.1	65.9	65.9	66.3	66.0	66.0	65.8	68.0	65.8	65.9
3	62.1	63.0	64.5	65.0	65.8	66.0	66.3	66.4	66.3	66.0	65.5	65.5	65.7
4	64.4	63.2	62.8	63.6	64.8	65.5	65.8	65.9	65.9	65.8	65.7	65.4	65.7
5	62.4	62.4	63.4	64.3	64.8	65.4	65.5	65.7	65.7	65.7	65.6	65.2	65.3
6	63.3	61.5	63.0	63.5	65.1	65.0	65.9	65.9	66.4	65.0	65.4	65.8	65.3
7	64.7	63.7	64.7	64.6	65.5	66.1	65.8	66.0	66.5	66.4	65.8	66.3	65.6
8	63.5	63.5	63.9	64.3	65.0	65.3	65.5	65.5	65.5	65.5	65.2	65.3	65.5
9	64.0	63.2	63.8	64.9	65.3	65.5	66.0	65.4	65.5	65.2	65.0	65.0	65.4
10	63.7	64.1	64.3	65.0	65.5	65.5	65.7	65.8	65.8	65.6	65.3	65.3	65.3
11	62.5	62.0	62.7	64.0	65.3	65.5	65.8	65.8	65.8	65.7	65.5	65.3	65.2
12	63.4	63.5	64.5	65.5	65.8	65.5	65.5	65.5	65.4	65.2	65.0	65.0	65.5
13	61.7	62.6	63.7	65.2	66.1	66.1	66.7	66.5	66.5	66.5	66.7	67.0	65.3
14	63.1	63.2	63.8	64.2	67.4	67.0	67.2	67.3	67.3	67.1	67.3	68.2	66.8
15	61.5	61.8	63.5	65.0	64.8	66.6	65.5	66.0	65.6	66.0	66.2	66.1	65.8
16	62.8	62.3	62.6	64.5	65.5	65.8	65.8	66.0	66.2	66.0	66.0	66.0	65.5
17	63.9	63.0	63.8	63.2	64.7	66.0	66.5	68.3	69.0*	67.6	66.2	65.7	66.0
18	63.5	62.5	61.7	63.2	67.4	65.8	65.9	66.0	65.8	65.5	65.5	65.3	65.2
19	62.4	62.2	63.8	64.7	65.0	65.8	66.7	66.0	66.5	66.1	67.3	66.0	65.5
20	63.0	62.5	62.4	63.8	64.9	66.2	65.3	65.5	65.5	65.6	65.5	65.5	65.4
21	64.8	63.5	63.6	64.0	65.2	65.8	65.8	66.0	66.2	66.2	65.8	66.0	65.9
22	64.8	63.2	62.7	63.4	64.2	65.8	65.0	65.8	67.9	66.6	65.7	66.4	65.8
23	63.2	62.8	63.8	65.0	65.1	65.2	65.5	65.5	65.6	65.7	65.7	65.5	65.4
24	61.5	62.5	63.3	64.5	65.0	65.2	65.7	65.7	66.0	65.8	65.4	65.3	65.2
25	62.6	62.4	62.9	63.8	64.5	64.8	65.0	65.3	65.0	65.2	65.0	64.9	65.0
26	61.7	60.1*	61.8	64.0	64.5	65.1	65.8	64.9	64.3	64.2	65.7	65.8	64.9
27	64.2	64.2	63.8	64.7	66.2	66.1	65.8	66.1	66.2	65.4	65.6	65.6	65.3
28	63.3	62.1	63.6	63.8	65.3	65.6	66.3	66.7	70.3*	65.9	66.1	65.8	65.7
Monthly mean	63.1	62.8	63.2	64.0	65.0	65.8	65.9	66.0	66.2	66.2	66.2	65.7	65.52
Normal	63.1	62.9	63.2	64.0	65.0	65.8	65.9	66.0	66.0	66.2	66.2	65.7	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

MARCH, 1889.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	66.0	66.3	64.6	66.1	64.7	66.1	63.8*	68.2	69.4	66.5	65.2	64.8
2	66.0	65.7	64.7	65.0	66.0	66.4	66.2	66.3	67.2	67.0	65.8	63.5
3	65.6	65.8	65.9	66.2	66.0	67.6	67.3	68.6	69.9	68.2	66.5	63.7
4	66.0	66.2	66.5	66.7	68.6*	66.0	67.2	68.8	68.2	66.2	64.6	63.4
5	65.3	65.7	66.6	66.5	66.2	66.2	66.0	67.5	67.5	65.5	64.4	63.0
6	67.0	65.2	62.2*	66.8	61.8*	62.1*	58.8*	60.8*	65.8	66.0	65.0	64.0
7	65.6	65.0	63.8	65.2	65.5	66.0	65.8	67.8	67.8	67.3	66.2	64.0
8	66.2	66.0	65.8	64.8	65.3	65.0	66.4	68.2	67.8	66.9	65.3	63.5
9	65.0	65.4	65.4	65.0	65.8	66.1	67.0	68.8	70.3	68.3	64.8	63.0
10	65.5	65.4	65.4	64.8	65.8	66.0	67.3	68.6	69.5	68.8	67.0	65.0
11	66.0	65.9	65.8	65.8	65.8	66.2	66.9	68.8	68.6	67.4	65.3	63.0
12	65.5	65.6	65.7	65.8	66.0	66.3	66.7	68.2	68.8	67.8	65.8	64.2
13	67.8	67.3	67.0	66.8	66.4	66.2	66.7	68.8	68.1	67.3	66.0	63.0
14	65.5	65.8	65.8	65.8	65.8	66.0	66.7	66.2	66.5	66.0	65.3	63.8
15	65.2	65.8	65.8	66.3	65.4	66.5	68.8	69.0	68.2	66.0	64.0	62.6
16	66.0	66.0	65.7	66.3	65.4	66.2	67.3	68.6	69.0	68.2	66.8	64.3
17	65.2	65.6	66.0	65.7	65.8	67.0	68.8	70.3	68.2	65.7	62.6	61.3
18	66.1	65.7	65.7	65.8	66.0	66.5	68.2	69.2	68.8	66.6	64.3	62.7
19	65.0	65.2	65.5	65.8	66.0	66.0	66.8	67.5	67.5	65.8	64.5	62.8
20	65.5	65.5	65.9	66.4	66.8	66.4	67.5	67.7	67.6	66.8	64.9	62.1
21	65.0	64.9	65.0	65.4	65.8	65.8	67.2	68.8	68.6	67.6	65.3	2.1
22	66.2	66.8	66.7	65.2	65.8	66.0	66.8	67.8	69.0	66.2	63.1	60.4*
23	65.4	65.5	65.3	64.5	65.8	65.8	66.6	67.2	67.1	65.2	63.0	61.8
24	66.1	66.0	64.5	65.0	67.4	66.8	68.2	69.0	67.4	65.5	64.0	62.7
25	66.0	65.9	65.2	65.5	65.2	65.5	66.7	67.8	66.7	65.5	64.2	62.7
26	65.3	66.1	65.5	65.4	65.3	66.2	67.6	68.8	65.3*	64.0*	63.8	61.3
27	64.7	65.9	66.3	65.8	65.9	66.3	68.0	69.0	67.3	64.8	62.3	61.3
28	62.7*	65.6	65.5	65.2	63.5	67.6	68.6	70.2	66.5	65.0	62.6	59.4*
29	65.3	65.3	65.4	66.5	65.8	66.7	70.2*	71.0*	69.0	65.4	63.5	61.8
30	65.5	64.5	64.1	65.6	65.9	66.2	67.0	69.5	69.8	67.5	66.0	63.4
31	64.5	63.5	65.5	65.3	65.7	65.5	66.3	69.2	70.8*	69.8*	66.5	63.0
Monthly mean	65.6	65.6	65.4	65.7	65.7	66.1	66.9	68.3	68.1	66.6	64.8	62.8
Normal	65.7	65.6	65.6	65.7	65.8	66.2	67.2	68.4	68.1	66.6	64.8	63.0

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794

Increasing scale readings correspond to increasing east declination.

MARCH, 1889.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
1	63.9	64.2	64.5	64.8	65.6	65.3	65.6	65.8	65.8	66.0	66.3	67.1	65.7
2	61.3	61.8	62.6	63.3	64.9	65.3	65.4	65.3	65.5	65.3	65.5	65.3	65.0
3	62.2	61.9	63.2	64.5	65.3	65.2	65.0	65.0	65.8	66.0	66.5	65.8	65.7
4	62.3	62.2	63.0	64.8	65.8	65.4	65.5	65.8	66.2	66.0	65.5	65.5	65.7
5	62.7	63.0	62.6	64.1	65.0	65.1	65.5	66.0	67.1	68.2*	69.8*	69.5*	65.8
6	63.4	63.3	63.3	64.6	65.0	65.6	65.8	66.3	67.4	71.2*	70.4*	65.9	64.9
7	63.3	62.0	63.4	64.3	64.7	65.8	66.3	67.3	65.7	65.9	67.9	65.0	65.5
8	62.7	62.1	63.4	64.6	65.2	65.5	66.1	65.9	65.7	65.5	65.7	65.9	65.4
9	62.5	62.4	63.0	64.2	65.5	65.2	65.4	65.4	65.5	65.5	65.4	65.5	65.4
10	63.8	63.0	63.8	64.8	65.6	65.0	65.3	65.5	65.6	65.9	65.8	66.0	65.8
11	62.3	62.3	63.5	64.5	65.3	65.2	65.3	65.6	65.5	67.3	66.0	65.2	65.6
12	63.0	61.3	61.3	63.7	64.8	64.8	65.0	65.8	65.5	65.7	66.7	66.0	65.4
13	59.3*	61.2	61.5	62.0	62.2	62.7	67.7*	64.4	65.8	65.8	65.3	65.9	65.2
14	62.5	62.0	62.4	64.3	65.0	65.0	65.1	65.7	66.3	65.0	65.0	65.2	65.1
15	62.1	62.2	62.8	63.8	64.5	64.9	65.3	65.3	66.2	66.2	64.8	66.8	65.4
16	62.5	62.0	62.4	63.7	64.3	64.5	64.8	64.8	64.7	64.7	64.7	65.2	65.3
17	61.6	60.8	60.8	60.0*	59.7*	61.5*	61.9*	64.5	64.6	65.8	65.8	65.4	64.4
18	62.4	62.6	63.3	64.1	64.6	64.8	64.9	66.3	65.5	65.0	64.8	64.9	65.4
19	61.5	61.4	63.0	63.7	64.6	65.1	66.6	65.7	65.1	65.2	65.0	65.4	65.0
20	61.0	61.1	63.0	63.7	64.0	64.6	65.0	64.8	65.0	64.8	65.4	65.3	65.0
21	60.8	60.1	60.0*	61.7	63.0	63.2	63.8	64.0	64.1	65.6	66.8	65.8	64.6
22	60.0	59.6	61.7	63.5	63.4	63.7	64.0	64.4	64.6	64.5	65.1	65.8	64.6
23	61.5	61.3	62.2	63.7	64.8	65.0	64.9	64.8	64.7	65.0	64.8	65.5	64.6
24	62.4	61.7	62.5	63.4	64.0	64.0	64.2	64.0	64.8	65.2	64.5	66.0	65.0
25	62.4	62.8	63.8	64.6	65.0	64.6	65.0	65.1	64.9	65.5	65.0	65.2	65.0
26	61.4	61.7	62.3	63.8	64.6	64.2	64.2	65.2	64.8	64.8	64.8	65.2	64.6
27	61.0	61.3	62.8	63.9	64.4	64.3	63.6	67.8	65.6	67.7	65.3	67.8	65.1
28	58.8*	61.5	62.0	63.8	64.9	66.5	65.3	65.3	64.5	65.0	66.2	65.0	64.6
29	62.0	62.4	63.8	64.3	64.6	64.8	64.5	64.8	66.1	64.8	65.5	66.0	65.4
30	61.8	61.5	63.0	63.8	64.8	64.8	64.9	65.0	64.8	65.0	64.8	64.8	65.2
31	60.2	60.0	61.5	62.6	64.0	64.5	64.3	64.2	64.0	64.0	64.8	65.2	64.8
Monthly mean	61.9	61.8	62.7	63.8	64.5	64.7	65.1	65.4	65.4	65.8	65.8	65.8	65.17
Normal	62.1	61.8	62.7	63.9	64.6	64.8	65.1	65.4	65.4	65.5	65.5	65.7	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

APRIL. 1889.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	65.0	65.0	65.6	65.6	65.8	67.1	67.2	68.5	70.0	69.7*	67.8*	63.8
2	64.8	64.9	65.4	65.4	65.5	65.3	66.2	68.3	68.8	67.0	65.0	62.5
3	68.4*	65.8	65.8	65.5	65.4	65.5	65.6*	68.4	69.7	67.6	64.9	61.3
4	64.8	65.0	64.7	65.6	65.6	65.8	67.4	69.4	70.5	65.8	63.8	62.3
5	65.2	65.2	65.4	65.6	65.7	65.7	66.7	68.7	69.0	67.4	65.3	64.0
6	65.1	65.1	65.3	65.4	65.6	66.0	67.4	68.0	67.5	65.5	63.0	60.8
7	65.3	65.7	65.7	65.6	67.6	67.5	69.7	70.2	68.2	66.7	64.6	63.8
8	69.3*	67.5	66.2	66.6	66.4	67.5	67.7	67.0	68.1	66.2	63.8	63.0
9	65.0	65.6	65.0	64.7	65.8	67.4	68.3	68.7	65.7*	61.7*	59.0*	61.6
10	63.2	65.8	66.3	66.2	66.6	66.7	67.8	68.8	67.7	66.4	64.5	63.4
11	65.7	65.8	65.5	66.1	65.8	66.1	67.7	69.1	67.6	64.7	63.0	62.4
12	65.5	65.6	65.5	65.7	66.0	67.7	68.2	70.0	68.0	64.5	62.3	63.4
13	64.7	65.1	65.3	65.7	66.0	67.5	69.0	68.8	67.0	64.4	62.5	62.6
14	64.7	65.1	65.5	65.7	66.0	67.2	69.2	71.5	67.8	63.0*	60.5*	60.0
15	65.9	66.0	66.1	66.4	66.5	67.3	69.1	70.8	70.4	66.8	63.7	61.6
16	66.0	66.0	66.3	66.8	67.3	68.5	71.0	73.3*	71.6*	67.2	63.7	62.2
17	65.3	65.6	65.7	66.1	67.0	68.2	70.5	72.8*	70.0	66.0	64.0	63.3
18	65.3	65.4	66.0	66.5	67.0	68.2	69.6	71.3	70.2	65.6	62.4	61.0
19	65.3	64.7	65.5	66.4	66.5	67.8	68.3	68.8	69.0	67.7	65.4	63.8
20	65.3	66.0	65.1	66.3	66.2	67.3	68.8	68.8	68.1	65.7	62.6	61.0
21	65.5	65.0	65.4	65.7	66.3	67.6	69.0	68.8	68.2	66.7	65.0	63.4
22	64.7	65.3	65.9	66.3	66.6	67.3	68.7	69.2	68.3	65.7	63.3	62.7
23	64.7	64.5	65.4	65.3	65.5	66.8	68.3	70.6	67.2	65.4	63.0	62.1
24	64.5	64.7	64.9	64.8	65.3	67.8	67.8	68.8	67.8	65.4	62.9	62.5
25	65.1	66.0	65.8	66.0	66.7	68.3	69.0	69.4	67.7	64.2	60.0*	58.2*
26	64.7	65.5	65.7	66.1	66.8	67.4	68.8	68.9	66.9	63.7	60.8*	59.8
27	65.6	64.8	65.5	65.9	66.8	67.8	69.2	70.1	67.2	63.0*	59.7*	58.8*
28	65.6	65.5	65.5	66.1	67.8	69.0	71.0	71.1	67.9	64.3	61.4	60.8
29	65.0	65.0	65.8	66.0	66.8	68.2	69.3	70.1	69.5	[66.5]	63.8	63.2
30	66.3	66.6	65.9	65.2	66.2	67.3	68.6	70.2	69.8	66.2	63.3	61.8
Monthly mean	65.4	65.5	65.6	65.8	66.3	67.3	68.5	69.6	68.5	65.7	63.2	62.0
Normal	65.1	65.5	65.6	65.8	66.3	67.3	68.6	69.4	68.5	65.9	63.6	62.3

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794 Increasing scale readings correspond to increasing east declination.

APRIL, 1889.

Day.	13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
1	60.1	60.5	60.4	62.0	63.2	64.8	64.0	64.0	65.7	65.0	64.7	64.4	65.0
2	59.5	59.0	59.6	61.7	63.8	64.5	64.1	66.0	64.2	65.0	68.0*	66.8	64.6
3	59.3	58.8*	61.0	62.6	64.5	65.6	65.1	64.7	64.6	64.7	64.7	64.7	64.8
4	60.8	60.4	61.3	62.6	63.8	64.5	64.5	64.8	64.8	64.8	64.8	65.1	64.7
5	62.8	62.4	62.5	63.2	64.7	65.4	65.3	65.3	65.5	65.2	65.1	65.2	65.3
6	60.5	60.8	62.0	63.3	64.4	64.5	64.3	63.8	64.0	64.0	64.3	64.4	64.4
7	62.4	62.0	62.4	63.6	63.6	63.8	67.0	64.4	65.0	67.2	71.6*	72.8*	66.1
8	61.9	61.8	63.0	63.5	65.0	64.3	64.2	64.5	64.7	65.2	65.4	65.2	65.3
9	61.8	63.4	62.4	62.8	63.9	64.0	63.8	64.4	64.8	64.8	65.3	65.3	64.4
10	62.7	62.8	63.0	63.5	64.3	64.8	64.8	64.7	64.7	64.7	65.3	65.7	65.2
11	62.3	62.3	62.3	63.8	64.2	64.7	64.8	65.0	65.2	65.3	65.2	65.4	65.0
12	63.0	62.0	61.7	62.0	62.5	63.3	63.7	63.7	65.2	64.6	64.3	64.4	64.7
13	63.6	63.5	63.5	63.5	63.7	64.0	64.4	64.5	64.4	64.5	64.5	64.7	64.9
14	60.0	61.3	62.6	63.9	64.8	65.7	65.3	65.3	65.2	65.3	65.6	65.2	64.8
15	61.6	61.8	62.7	63.8	64.9	65.7	65.3	65.0	65.0	65.2	65.4	65.6	65.5
16	61.0	60.0	62.1	64.0	65.6	65.5	64.8	64.7	64.8	65.0	64.8	64.8	65.7
17	63.3	63.2	63.7	64.4	65.0	65.3	65.0	64.7	66.3	65.4	64.7	65.0	65.8
18	61.0	60.5	61.7	62.8	63.9	64.1	64.3	65.0	64.6	65.3	65.5	65.0	65.1
19	62.8	62.0	62.0	62.9	63.7	64.3	65.3	65.3	65.3	64.7	64.7	65.0	65.3
20	60.0	59.7	60.2	62.7	63.7	65.7	64.5	64.5	64.6	65.4	65.8	65.8	64.7
21	62.7	63.3	62.8	63.0	63.2	64.0	67.0	65.0	64.5	64.5	64.7	64.5	65.2
22	61.3	60.7	60.2	61.6	63.0	65.3	64.5	64.4	64.5	65.0	64.6	64.6	64.7
23	62.1	61.3	61.4	63.2	64.2	64.0	67.4	65.0	64.2	64.4	64.5	64.4	64.8
24	62.8	62.5	63.3	63.8	64.2	64.3	64.3	64.3	64.3	64.6	64.5	64.7	64.8
25	58.0*	58.7*	61.6	61.9	63.3	66.6	63.6	64.3	68.6*	66.3	65.2	65.3	64.6
26	60.0	61.3	63.1	64.8	65.8	65.4	64.5	64.7	64.6	64.6	65.3	66.2	64.8
27	59.3	60.1	60.7	63.7	64.2	64.8	67.5	68.3*	67.2	63.8	63.0	64.0	64.6
28	60.8	60.7	61.7	63.0	64.6	65.1	65.2	66.8	66.0	65.2	65.0	64.8	65.2
29	62.1	61.5	62.2	63.4	64.5	65.3	64.9	65.0	64.8	64.8	65.7	64.4	65.3
30	61.8	62.0	62.0	62.2	64.8	65.5	65.4	64.8	64.8	65.2	65.2	66.0	65.3
Monthly mean	61.4	61.3	62.0	63.1	64.1	64.8	65.0	64.9	65.1	65.0	65.2	65.3	65.02
Normal	61.5	61.5	62.0	63.1	64.1	64.8	65.0	64.8	64.9	65.0	64.9	65.1	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

MAY, 1889.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	65.4	65.3	65.8	66.2	66.4	67.7	69.1	70.3	68.7	66.0	63.8	62.3
2	65.1	65.4	65.6	65.8	66.3	67.1	68.9	70.3	68.6	66.2	63.2	62.2
3	65.2	65.5	65.8	66.2	66.8	68.8	71.6	72.4	70.3	66.5	63.8	62.3
4	64.5	64.6	65.6	66.8	69.0	69.1	70.9	72.4	70.3	68.0*	64.0	61.8
5	65.0	64.6	66.8	65.0	68.3	68.8	71.3	70.8	67.4	64.5	62.7	61.9
6	65.3	64.8	65.3	65.6	66.2	67.6	69.3	69.4	67.3	65.4	63.6	62.9
7	65.7	65.7	65.8	66.3	67.2	68.4	69.2	68.8	67.0	64.0	63.3	62.9
8	65.2	65.6	65.7	65.8	66.2	67.4	69.3	69.7	67.8	65.0	62.4	61.7
9	65.5	65.4	65.5	66.3	66.7	67.8	68.2	68.5	67.5	65.8	63.9	62.8
10	65.0	65.8	65.3	65.0	67.2	67.4	69.2	70.7	71.3*	67.9*	64.1	62.5
11	65.7	65.7	65.5	65.7	66.4	67.3	68.5	70.7	70.4	68.2*	64.4	61.7
12	65.4	65.5	65.7	65.9	67.0	69.0	71.6	72.7	71.0*	67.8*	64.3	63.0
13	66.7	65.7	65.8	66.2	66.5	67.8	67.3	68.8	67.7	65.3	63.1	61.7
14	65.0	65.3	65.5	65.8	66.2	68.0	71.0	70.8	67.2	63.7	61.7	60.8
15	65.2	65.5	65.8	66.0	66.5	67.6	69.9	70.8	68.2	64.5	61.3	60.6
16	65.0	65.2	65.4	65.7	66.0	67.5	69.9	71.3	68.3	63.6	61.3	61.3
17	64.7	64.8	65.2	65.5	66.6	68.2	70.8	71.4	70.0	66.8	61.7	59.8
18	64.4	64.8	64.8	65.4	66.7	68.4	70.7	70.9	68.8	66.1	63.5	61.6
19	67.7	67.0	67.2	66.8	67.3	68.6	69.8	70.7	68.2	65.1	61.7	59.5
20	65.0	65.4	65.4	65.5	66.0	68.2	70.2	69.1	66.0	63.8	61.9	62.3
21	65.2	65.5	65.8	65.7	66.8	68.0	69.2	68.4	64.2*	61.3*	61.4	62.3
22	65.7	66.2	67.6	68.8*	66.3	69.8	69.8	68.3	64.2*	61.0*	58.0*	58.2*
23	65.4	65.4	65.5	65.7	66.8	69.4	70.9	70.7	65.7	61.8*	61.0	60.0
24	65.7	65.7	67.1	67.8	67.3	69.8	71.0	69.4	66.7	63.5	62.6	62.8
25	65.6	65.4	65.7	66.3	66.7	67.7	69.0	69.3	66.4	64.2	62.5	60.8
26	64.9	70.5*	70.0*	66.2	69.0	70.0	71.8	71.8	71.7*	66.3	63.2	61.5
27	64.8	65.3	65.5	65.8	66.5	67.8	68.8	69.3	67.8	65.8	64.4	63.5
28	66.5	65.3	66.7	65.8	66.5	67.8	69.0	69.4	69.5	67.9*	65.7*	64.3
29	65.2	65.2	65.3	65.5	66.2	67.2	68.8	69.6	68.0	65.5	63.7	63.3
30	64.5	64.8	64.7	66.0	66.0	67.3	69.0	70.8	67.8	63.0	61.8	61.6
31	64.7	65.0	65.8	65.3	65.1	67.6	69.5	68.5	64.7*	62.3*	62.0	61.5
Monthly mean	65.3	65.5	65.9	66.0	66.7	68.2	69.8	70.2	68.0	65.1	62.8	61.8
Normal	65.3	65.4	65.8	65.9	66.7	68.2	69.8	70.2	68.1	65.0	62.8	61.9

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794

Increasing scale readings correspond to increasing east declination.

MAY, 1889.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
1	62.2	62.2	62.7	63.7	64.2	64.8	65.8	66.0	65.1	64.5	64.5	64.7	65.3
2	62.7	62.7	62.9	63.7	64.3	65.0	65.2	64.8	64.7	65.0	65.0	65.2	65.2
3	61.8	61.7	62.0	62.8	64.0	63.4	64.6	64.7	65.8	64.0	67.5	65.0	65.5
4	62.4	63.3	63.0	63.4	64.2	64.6	64.8	65.3	66.0	70.2*	66.8	67.0	66.2
5	61.8	62.3	62.8	63.0	63.8	64.5	64.6	64.8	65.8	66.0	65.5	64.7	65.3
6	62.5	62.5	63.2	63.4	63.8	63.7	64.0	69.5*	68.3*	66.4	65.3	64.4	65.4
7	63.2	63.2	63.6	63.9	64.4	64.9	64.5	64.9	66.0	65.5	64.8	64.8	65.3
8	62.5	63.1	64.3	64.4	64.6	64.7	64.9	64.9	64.9	65.0	65.2	65.3	65.2
9	62.4	61.5	62.2	63.3	64.0	64.5	64.5	64.6	64.7	64.7	64.7	64.7	65.0
10	62.1	62.6	63.2	63.9	64.8	65.3	64.7	64.7	65.0	65.3	65.6	65.7	65.6
11	61.8	60.9	62.0	63.1	63.7	64.5	64.7	64.7	65.1	65.3	65.5	65.6	65.3
12	62.7	63.3	63.0	63.2	64.6	64.7	64.8	68.2*	66.0	65.7	66.5	66.3	66.2
13	62.0	62.2	63.0	64.3	64.6	64.4	64.5	64.8	64.7	64.7	65.1	65.0	65.1
14	61.4	61.8	62.6	63.7	64.7	65.1	64.8	64.7	64.7	64.7	64.8	64.8	65.0
15	60.2	61.7	62.8	63.8	64.2	64.7	64.5	64.3	64.3	64.4	64.6	64.7	64.8
16	61.4	62.2	63.0	64.2	65.0	65.2	64.7	64.6	64.7	64.3	64.5	64.4	65.0
17	60.0	60.4	62.6	64.2	64.8	64.5	64.5	64.4	64.6	64.6	64.4	64.5	65.0
18	61.5	61.7	62.3	63.3	63.9	64.4	64.4	64.4	65.0	65.0	67.4	69.2*	65.4
19	59.4	60.8	62.2	63.5	63.5	63.7	64.0	64.0	64.2	64.4	64.5	64.7	64.9
20	62.7	63.0	63.7	64.4	64.7	64.5	64.8	65.0	64.7	64.7	64.9	65.1	65.0
21	62.3	63.3	64.7	65.7	65.3	64.5	64.3	64.5	70.0*	70.2*	70.4*	65.2	65.6
22	58.9*	60.3	62.7	64.3	64.7	64.7	64.0	64.0	64.5	64.6	64.8	65.0	64.4
23	60.8	62.8	64.5	65.2	66.0	65.2	64.4	64.3	64.3	64.5	64.8	65.2	65.0
24	63.2	63.8	64.5	65.3	65.3	64.8	64.3	64.4	64.7	64.8	64.9	65.3	65.6
25	60.5	62.0	63.4	64.7	64.8	64.4	64.1	64.0	64.7	64.0	65.8	64.8	64.9
26	59.8	60.7	61.4	63.2	63.8	65.2	65.1	66.0	65.0	66.3	67.2	66.3	66.1
27	61.8	61.8	62.7	63.5	64.4	65.0	65.8	65.0	65.0	65.0	65.0	66.0	65.3
28	62.9	61.8	61.7	63.0	64.5	65.2	65.4	65.0	65.0	65.4	65.5	65.4	65.6
29	63.0	62.7	62.6	62.6	63.1	63.8	64.8	64.6	64.8	65.1	65.4	65.2	65.0
30	61.4	61.3	61.3	62.4	63.0	62.7	67.5*	64.6	63.5	63.7	64.6	65.6	64.5
31	61.4	62.0	62.9	64.0	65.1	65.5	64.7	64.3	64.3	64.0	65.0	64.5	64.6
Monthly mean	61.7	62.1	62.9	63.8	64.4	64.6	64.8	65.0	65.2	65.2	65.5	65.3	65.24
Normal	61.8	62.1	62.9	63.8	64.4	64.6	64.7	64.7	64.9	64.9	65.4	65.2	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

JUNE, 1889.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	65.6	65.4	66.8	67.0	68.0	67.6	68.3	69.2	68.2	65.8	62.6	61.3
2	64.3	64.9	65.4	66.4	66.2	68.2	70.6	70.5	68.5	66.3	63.8	62.5
3	64.9	65.4	65.4	66.8	67.2	68.4	68.3	69.3	68.2	65.7	63.5	61.3
4	64.4	64.7	64.9	66.0	66.5	68.0	69.6	69.3	67.7	66.0	63.5	62.6
5	64.2	64.5	65.3	65.7	65.8	66.7	67.2	66.4	67.7	66.4	65.4	64.3*
6	64.7	64.8	65.4	65.8	65.4	66.4	67.4	66.8	65.5	63.7	63.4	63.6
7	65.3	65.5	64.8	65.8	66.4	67.2	67.6	66.8	66.0	65.0	62.8	62.1
8	64.5	64.7	65.2	65.7	66.5	68.1	68.8	68.3	66.3	63.9	62.0	61.3
9	65.2	68.1*	66.2	66.0	68.1	68.3	68.1	67.6	65.8	64.7	62.7	62.4
10	65.1	64.8	65.2	64.0	66.0	66.8	67.0	67.3	66.6	66.2	66.2*	64.5*
11	65.2	65.4	65.5	65.3	65.5	65.5	65.6*	65.7*	65.3	62.5	61.1	60.8
12	64.2	64.2	64.7	64.3	65.3	66.4	67.7	68.3	65.8	62.5	61.3	60.3
13	64.2	64.3	64.5	62.8*	67.3	67.4	69.8	70.4	70.4*	67.6*	65.3	62.9
14	70.4*	70.8*	71.3*	68.8*	66.7	68.4	69.5	69.3	65.5	65.0	62.7	60.3
15	64.6	64.5	64.7	65.7	66.8	70.0	70.8	70.3	66.4	63.5	60.6	59.8
16	64.0	64.4	64.6	65.5	66.8	67.8	69.9	70.3	68.4	66.0	62.3	59.3
17	64.4	64.5	64.6	64.8	65.5	67.2	68.8	68.6	68.0	66.2	63.9	62.4
18	64.5	64.6	65.0	65.5	66.0	67.2	67.8	67.0	66.1	63.9	61.8	61.3
19	65.0	64.8	65.0	65.4	66.1	68.0	68.9	67.8	67.5	66.1	63.7	61.7
20	64.5	64.3	65.0	65.8	65.8	67.0	69.5	70.0	68.1	65.5	63.8	61.7
21	69.3*	67.3	62.7	65.8	65.7	66.5	66.8	68.3	66.1	63.2	63.3	64.3*
22	65.6	65.5	64.5	65.9	67.7	68.6	70.5	72.7*	68.4	66.0	65.0	63.8
23	66.2	65.5	66.2	66.3	67.2	67.9	68.5	68.8	66.5	62.5	61.1	61.7
24	64.7	64.7	64.9	65.3	66.0	68.0	68.8	69.3	68.2	65.3	63.0	61.2
25	64.3	64.5	65.3	65.4	65.7	66.7	68.3	68.8	67.8	65.6	64.2	62.6
26	63.8	64.4	65.0	65.0	65.6	67.2	68.8	68.8	68.1	65.1	62.5	60.0
27	64.0	64.3	65.0	65.5	65.8	67.8	69.7	68.8	66.4	63.9	62.5	62.7
28	65.8	66.2	65.8	67.4	67.8	68.7	69.0	71.6*	70.2*	64.9	61.2	60.5
29	65.2	65.2	66.0	66.7	67.0	67.5	69.1	69.0	68.0	65.5	62.0	60.8
30	64.8	64.8	65.2	65.8	66.0	67.8	68.2	68.0	66.3	64.3	61.7	60.5
Monthly mean	65.3	65.2	65.3	65.7	66.4	67.6	68.6	68.8	67.3	65.0	63.0	61.8
Normal	64.8	64.9	65.1	65.7	66.4	67.6	68.7	68.6	67.0	64.9	62.9	61.5

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794 Increasing scale readings correspond to increasing east declination.

JUNE, 1889.

Day.	13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mid-night.	Daily mean.
1	61.0	60.8	62.0	63.8	64.3	64.5	66.2	64.8	64.1	64.3	63.8	64.0	65.0
2	62.0	61.7	61.7	62.1	63.3	64.5	64.8	64.7	64.3	65.7	65.4	64.7	65.1
3	60.8	60.8	60.5	61.8	63.3	63.7	64.8	66.8*	66.1	64.3	64.3	64.1	64.8
4	62.5	61.7	61.3	62.4	63.0	63.4	63.7	64.1	63.7	63.7	63.7	63.7	64.6
5	63.5	62.5	63.2	63.8	64.3	64.4	64.2	64.8	64.4	64.5	64.3	64.5	64.9
6	63.5	62.9	62.8	62.5	62.8	63.3	64.4	64.5	64.4	64.3	64.6	64.7	64.5
7	62.7	64.2	63.8	63.5	63.8	64.0	64.2	64.0	64.2	64.0	64.2	64.3	64.7
8	61.3	61.5	61.7	61.8	62.2	62.6	62.0	62.6	62.3	63.8	65.0	65.7	64.1
9	63.0	63.0	62.8	63.0	63.2	63.8	63.9	64.1	64.3	64.3	64.3	64.9	64.9
10	64.4*	65.2*	64.8	64.8	64.2	64.0	65.2	64.5	64.6	65.1	64.0	65.3	65.2
11	61.3	62.2	63.3	63.5	64.0	64.0	64.0	64.0	63.8	64.0	64.0	63.9	64.0
12	62.1	63.1	64.5	65.3	65.3	65.0	63.7	64.0	64.4	63.5	63.7	63.7	64.3
13	62.0	62.5	63.3	64.0	64.7	64.8	65.2	69.5*	65.8	67.7*	71.4*	70.0*	66.2
14	59.2	60.1	60.0	61.2	61.8	62.4	62.0	62.6	63.1	64.2	64.5	64.3	64.8
15	59.8	61.4	62.8	64.0	65.9	64.5	63.9	64.1	64.0	63.4	63.4	63.5	64.5
16	57.4*	58.8*	60.0	62.5	63.8	65.8	63.6	63.8	63.7	63.2	63.8	64.0	64.2
17	61.6	61.5	61.7	62.1	62.9	63.9	64.0	64.0	64.0	64.2	64.2	64.4	64.5
18	60.6	61.0	60.8	61.3	62.3	63.4	64.0	64.3	64.0	64.1	64.2	64.3	64.0
19	60.7	61.2	62.3	63.0	63.7	64.3	64.5	64.0	64.0	64.0	64.2	64.4	64.6
20	60.1	59.0*	61.7	62.2	62.5	63.0	64.0	63.5	63.8	64.7	64.2	66.0	64.4
21	63.8	64.3	64.3	63.7	63.8	69.3*	64.2	63.8	64.0	65.4	66.0	66.5	65.4
22	63.0	63.5	64.3	64.2	64.5	64.0	64.4	64.6	64.3	64.7	65.3	65.5	65.7
23	62.8	63.8	63.6	63.0	62.6	64.2	64.0	64.4	64.2	63.8	64.0	64.7	64.7
24	60.4	60.7	61.1	62.4	62.8	63.6	65.0	64.5	64.0	65.8	64.4	64.2	64.5
25	62.0	61.7	62.9	63.9	64.0	64.3	63.8	64.0	64.3	63.8	63.2	63.8	64.6
26	59.8	60.0	61.8	63.0	63.9	64.4	63.8	63.7	63.7	63.5	63.5	63.6	64.1
27	62.1	62.4	62.9	63.9	64.3	63.8	63.8	63.8	63.7	64.5	64.7	65.7	64.7
28	59.8	59.8	61.0	62.7	63.9	64.3	64.3	65.0	65.1	65.5	64.8	64.8	65.0
29	60.8	61.3	61.3	62.5	63.2	63.7	63.5	63.8	63.8	63.5	63.8	63.7	64.4
30	60.4	60.2	60.8	62.8	64.3	64.5	63.7	62.4	62.8	62.7	63.2	67.0	64.1
Monthly mean	61.5	61.8	62.3	63.0	63.6	64.2	64.1	64.3	64.1	64.3	64.5	64.8	64.68
Normal	61.5	61.8	62.3	63.0	63.6	64.0	64.1	64.0	64.1	64.2	64.2	64.6	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time.

300 divisions + tabular quantity.

JULY, 1889.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	67.5*	65.5	66.7	67.0	67.4	69.1	69.2	69.5	68.3	65.0	61.3	60.6
2	64.5	62.7	62.8	65.3	68.0	68.6	70.4	70.2	68.0	65.1	62.6	61.5
3	64.2	61.9*	64.6	65.3	65.0	66.9	68.7	69.7	68.2	65.8	63.7	61.4
4	63.8	63.7	64.9	65.1	65.8	66.3	67.4	66.7*	66.7	64.5	61.4	59.0*
5	64.5	64.5	64.5	64.6	65.9	67.9	69.3	69.8	69.2	65.5	63.8	62.4
6	64.3	64.3	64.7	65.6	65.8	67.0	68.0	70.7	68.3	65.4	61.9	59.8
7	63.8	63.8	64.0	63.8	65.0	66.8	68.3	68.5	67.0	63.8	60.0*	58.5*
8	64.3	64.4	63.7	64.8	65.0	66.8	68.8	70.2	69.2	67.1	64.2	61.3
9	64.4	64.6	64.5	65.4	65.8	67.0	68.8	70.0	68.1	65.4	63.5	62.8
10	64.3	64.0	64.8	64.9	66.1	68.8	71.0	71.0	68.4	62.8*	58.8*	56.0*
11	64.2	64.5	65.2	65.6	66.4	68.3	70.6	70.7	69.5	63.0*	62.8	60.3
12	64.8	65.4	66.0	66.5	67.3	69.5	70.3	69.7	65.4*	61.8*	59.3*	57.4*
13	64.6	65.0	65.4	65.5	66.8	69.2	69.4	69.8	68.7	66.3	63.5	61.7
14	64.5	64.8	65.7	66.3	66.0	67.5	69.0	71.7	69.9	63.8	60.8*	59.3*
15	64.7	64.8	65.0	65.4	66.0	66.9	67.7	68.0	67.0	66.7	65.7	63.3
16	64.2	64.8	65.3	65.7	66.5	68.0	69.8	68.8	67.3	65.9	64.4	63.1
17	72.5*	70.6*	68.8*	67.4	69.0*	68.3	64.2*	68.2	68.2	67.5	65.3	62.1
18	64.0	65.5	65.7	66.4	62.3*	64.8*	68.3	68.8	68.0	66.7	64.8	63.5
19	65.0	65.0	64.5	64.5	65.0	68.0	69.8	70.3	68.8	67.3	64.8	63.0
20	65.0	65.3	65.5	65.7	65.7	67.4	68.5	68.5	68.3	65.7	62.0	60.4
21	64.6	65.0	65.3	65.9	66.2	67.4	68.8	68.8	67.5	64.8	63.2	61.7
22	64.4	64.5	64.8	65.4	65.8	67.3	68.0	67.3	65.1*	62.7*	61.8	63.0
23	64.8	64.6	65.0	65.3	65.5	66.3	66.8	66.7*	65.8	65.0	63.3	62.7
24	64.7	65.6	65.8	66.0	67.3	68.7	70.6	69.0	68.7	64.7	62.9	62.6
25	64.8	65.2	65.6	66.0	66.2	67.1	68.7	68.0	66.3	64.8	63.5	62.2
26	65.1	64.3	65.2	65.7	66.3	67.0	68.3	68.3	68.3	66.7	65.0	62.4
27	64.4	64.5	64.8	65.1	65.0	66.5	68.0	70.3	70.4	67.9	65.2	62.8
28	65.2	65.0	65.3	65.3	65.8	66.8	68.9	70.3	70.0	67.0	62.9	61.6
29	66.6	63.5	64.8	65.7	65.8	66.7	66.0*	69.4	69.0	67.4	65.3	63.8
30	65.8	66.5	65.4	65.8	65.5	66.0	69.0	70.4	69.3	67.5	64.3	61.3
31	65.7	64.7	64.6	66.0	67.0	68.4	71.2	71.8	68.8	66.0	63.4	61.0
Monthly mean	65.0	64.8	65.1	65.6	66.0	67.5	68.8	69.4	68.1	65.5	63.1	61.4
Normal	64.7	64.7	65.0	65.6	66.1	67.6	69.0	69.6	68.3	65.9	63.6	62.0

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794 Increasing scale readings correspond to increasing east declination.

JULY, 1889.

Day.	13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Midnight.	Daily mean.
1	61.4	61.5	60.2	62.5	63.3	63.7	65.6	64.7	63.7	63.7	64.0	64.3	64.8
2	61.1	61.1	61.5	62.6	63.4	64.0	64.0	66.8	66.7	68.3*	64.5	63.8	64.9
3	59.7	58.4	60.8	62.7	64.5	64.9	64.6	64.4	64.5	64.5	64.4	64.4	64.3
4	59.4	60.2	61.6	63.7	64.2	64.5	64.1	64.0	64.0	65.9	66.9	66.0	64.2
5	61.3	61.3	61.3	62.3	62.8	62.8	63.2	65.2	65.8	65.3	63.8	63.8	64.6
6	58.8	59.7	61.4	62.3	62.7	68.0*	65.0	63.4	64.2	64.8	67.3*	63.1	64.4
7	58.8	59.6	61.8	63.4	64.2	63.8	63.4	64.7	64.0	63.8	64.0	64.3	63.7
8	60.3	60.7	61.4	63.0	63.7	64.6	64.4	63.8	64.3	64.5	65.0	64.8	64.6
9	62.4	61.9	62.8	63.6	64.3	64.3	64.2	64.3	64.0	64.0	64.2	64.4	64.8
10	57.3*	59.2	62.5	64.8	65.3	64.5	63.5	63.2	63.3	63.3	63.6	64.2	64.0
11	60.0	60.8	62.5	63.8	64.8	64.8	64.4	64.5	64.5	64.5	64.4	64.6	64.8
12	58.5	61.1	62.8	63.9	64.1	64.4	64.6	64.5	64.0	64.1	64.2	64.5	64.3
13	60.9	61.3	62.0	62.0	62.5	63.3	63.8	64.0	63.8	64.5	64.2	64.5	64.7
14	59.3	59.5	60.8	62.3	63.3	64.3	63.0	63.8	64.2	64.2	64.3	64.5	64.3
15	61.1	60.6	60.5	61.6	62.3	63.3	64.1	65.0	64.6	63.8	64.0	64.0	64.4
16	61.3	61.0	61.6	63.2	63.3	63.5	63.7	63.8	62.5	61.5*	64.0	72.5*	64.8
17	61.6	61.5	63.7	64.0	65.0	64.4	63.8	65.2	64.7	65.4	64.2	66.3	65.9
18	61.3	60.3	60.8	61.3	61.8	64.7	68.7*	67.4*	68.8*	65.8	65.3	66.6	65.1
19	62.0	62.9	63.6	63.6	63.5	64.0	64.8	65.5	64.9	65.0	65.0	64.8	65.2
20	60.9	62.0	63.1	63.7	67.4*	67.8*	65.5	70.0*	65.4	64.8	64.8	65.0	65.4
21	61.0	61.6	62.3	63.0	63.8	63.8	64.5	64.4	64.7	64.5	64.7	64.4	64.7
22	62.7	62.0	62.3	62.8	63.0	63.7	63.4	64.0	64.0	64.5	64.3	64.7	64.2
23	63.6*	63.7*	63.5	62.6	63.3	63.2	63.6	64.0	64.2	63.7	64.4	64.6	64.4
24	62.8	62.5	63.0	63.7	63.7	65.3	64.5	64.3	64.2	64.3	64.3	65.3	65.2
25	61.0	59.5	58.8*	60.0*	61.3	63.7	63.3	64.9	64.6	64.5	64.3	64.4	64.1
26	61.7	61.5	62.0	62.9	62.7	63.8	64.8	66.0	65.3	64.0	63.6	63.8	64.8
27	61.3	61.4	61.8	62.7	63.8	64.5	65.0	64.6	64.5	64.6	64.7	65.3	65.0
28	61.5	61.2	61.8	62.4	63.8	64.8	64.3	65.3	64.5	64.2	64.5	66.6	65.0
29	61.8	61.3	61.5	62.7	63.0	64.0	64.2	64.6	65.4	65.3	65.5	65.8	65.0
30	58.1*	59.0	60.5	63.0	65.0	65.4	65.2	64.7	67.0	71.0*	69.8*	65.4	65.4
31	59.8	60.8	62.0	63.3	64.6	66.4	64.7	64.5	65.5	65.5	66.0	65.8	65.3
Monthly mean	60.7	60.9	61.8	62.9	63.7	64.5	64.4	64.8	64.7	64.8	64.8	65.0	64.72
Normal	60.8	60.8	61.9	63.0	63.6	64.2	64.4	64.6	64.6	64.5	64.5	64.8	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

AUGUST, 1889.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	65.8	65.0	65.0	65.4	65.4	67.0	69.2	70.5	67.2	65.0	60.8	61.0
2	63.2	63.8	64.3	64.8	64.5	66.5	70.0	71.8	70.0	66.8	62.3	59.3
3	63.8	63.2	64.0	64.7	65.2	67.2	68.9	70.0	68.8	65.8	62.5	61.2
4	64.2	64.3	64.5	64.5	64.3	67.2	68.7	68.2	66.3	66.3	61.0	59.8
5	64.8	64.7	64.8	64.5	64.2	66.2	67.6	68.1	67.2	63.3	61.0	60.0
6	64.8	64.7	65.2	65.4	65.8	68.2	70.3	70.8	67.8	63.5	61.3	60.5
7	65.0	65.0	65.2	65.3	65.8	68.0	71.5	71.2	68.1	63.1	60.0	59.5
8	64.7	65.3	66.3	67.1	67.5	68.5	70.3	70.5	67.8	61.4*	59.4*	58.5
9	64.5	64.7	65.2	65.3	65.7	67.5	70.1	72.3	69.2	64.7	61.4	60.8
10	64.2	65.0	65.3	66.2	67.0	68.6	70.9	71.3	72.4*	63.8	61.3	59.8
11	66.3	66.8	66.7	67.4	68.0	69.5	70.8	72.7	70.0	66.3	62.8	60.5
12	64.5	64.3	65.8	65.8	65.8	66.5	70.0	71.0	70.2	66.6	63.8	61.7
13	64.2	64.6	66.3	61.5*	67.3	68.8	71.8	72.3	70.0	64.2	61.5	59.5
14	64.7	63.3	64.3	64.8	66.0	67.5	68.4	68.7	67.7	65.5	62.8	61.2
15	64.9	64.9	65.7	63.8	67.2	67.5	69.0	69.8	67.2	63.6	61.3	60.5
16	64.8	64.5	64.6	64.9	65.8	66.7	68.2	68.5	67.2	63.8	62.5	61.5
17	64.4	64.5	64.8	65.0	64.0	66.5	66.8*	69.2	66.3	62.3	60.5	59.8
18	64.5	64.3	64.7	64.8	65.7	67.1	68.8	68.7	67.4	65.6	63.8	64.0*
19	65.4	65.0	65.1	65.3	65.6	66.4	67.8	68.0	67.5	64.5	62.7	61.5
20	67.3	67.4*	64.8	64.5	68.9*	69.4	71.8	71.8	67.9	65.5	63.8	61.0
21	65.3	65.6	66.3	66.3	67.5	69.0	70.4	71.2	69.2	66.0	62.3	61.0
22	65.4	65.6	65.5	66.0	66.9	67.9	70.3	70.3	66.8	63.5	61.2	60.7
23	65.0	65.0	65.5	65.7	67.0	68.0	71.1	72.2	68.8	65.3	63.0	62.2
24	64.6	65.2	65.2	65.5	65.7	67.8	70.4	70.6	68.8	64.9	61.6	60.8
25	65.7	66.4	67.0	66.0	65.8	67.7	70.5	71.0	68.5	64.4	62.3	61.5
26	67.7*	62.6	64.2	66.8	67.4	66.4	70.8	69.0	66.3	62.0*	59.8	59.5
27	64.8	64.1	63.8	65.6	65.6	64.0*	68.7	70.5	67.3	63.0	61.7	61.7
28	64.3	64.7	65.0	66.1	65.4	68.2	70.8	70.0	68.3	65.0	61.7	59.7
29	64.5	64.4	64.3	65.8	66.0	68.4	69.1	70.3	67.6	64.8	63.2	61.9
30	65.5	64.4	62.8	66.0	66.3	68.2	71.0	70.3	68.8	66.5	64.8*	62.9
31	65.0	65.0	65.0	65.2	65.0	67.5	70.2	70.7	68.7	66.0	62.7	61.8
Monthly mean	65.0	64.8	65.1	65.4	66.1	67.5	69.8	70.4	68.2	64.6	62.0	60.8
Normal	64.9	64.7	65.1	65.5	66.0	67.7	69.9	70.4	68.1	64.8	62.0	60.7

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794 — Increasing scale readings correspond to increasing east declination.

AUGUST, 1889.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
1	60.4	61.2	63.0	63.2	63.8	66.6	65.8	65.5	65.8	66.2	65.5	64.3	64.9
2	59.3	59.7	62.2	63.1	63.8	63.7	63.8	64.0	65.6	64.0	63.8	63.9	64.3
3	61.0	61.8	63.1	63.6	64.2	64.5	64.3	64.3	64.6	64.0	64.3	64.1	64.5
4	59.0	59.5	60.9	62.4	62.9	63.8	64.4	64.6	64.8	64.8	64.8	64.8	64.0
5	59.8	60.5	62.3	63.6	64.0	64.3	64.5	64.6	64.7	65.0	65.0	64.8	64.1
6	60.0	60.8	62.0	63.4	63.8	63.6	63.5	63.8	64.3	64.5	64.5	64.5	64.5
7	60.8	62.2	64.2	65.0	64.8	63.6	63.0	63.0	63.4	65.2	64.8	64.5	64.7
8	59.3	61.0	62.0	63.6	63.8	63.2	62.7	63.4	63.7	64.3	64.5	64.2	64.3
9	60.5	61.2	63.0	62.8	64.0	64.3	63.8	63.5	64.3	64.0	63.8	63.6	64.6
10	61.1	62.6	64.0	64.0	64.2	63.5	62.7	62.8	62.8	63.0	63.0	66.6	64.8
11	59.3	60.1	61.8	63.2	64.8	64.7	64.5	64.8	63.3	65.0	66.0	65.5	65.4
12	61.0	61.7	61.7	62.4	63.2	65.8	64.8	64.0	64.5	79.5*	67.7*	64.3	65.7
13	59.2	59.9	62.8	63.5	64.4	64.2	63.8	64.2	65.7	65.3	65.0	64.8	64.8
14	61.0	61.8	62.3	63.2	64.2	65.1	64.3	63.7	64.3	64.2	64.7	65.1	64.5
15	60.9	61.8	63.2	64.3	64.7	65.0	64.8	66.1	65.8	65.9	64.8	64.3	64.9
16	61.5	62.6	64.4	64.3	64.3	64.7	64.2	63.8	63.8	63.8	64.0	64.2	64.5
17	59.7	61.0	62.8	64.3	64.8	64.5	64.7	64.8	64.0	65.4	64.5	63.8	64.1
18	63.4*	62.8	63.7	64.3	64.5	64.7	65.0	65.0	65.7	65.3	65.3	65.5	65.2
19	61.5	61.7	62.8	64.3	65.2	65.0	64.2	64.5	64.5	65.8	65.9	66.7	64.9
20	59.8	60.5	61.2	62.5	62.9	63.0	64.4	64.1	64.8	64.8	64.4	64.6	65.0
21	61.2	62.8	64.7	65.7	65.2	64.5	64.3	64.3	64.8	64.6	64.7	65.0	65.5
22	60.5	62.2	63.8	64.7	65.0	64.5	63.8	64.1	64.3	64.1	64.6	64.6	64.8
23	61.7	62.5	64.4	65.1	65.2	64.6	64.5	63.8	64.7	64.5	64.4	64.4	65.4
24	61.4	63.8	65.0	66.1	65.9	64.8	64.3	64.3	65.0	64.8	64.7	65.3	65.3
25	61.8	63.0	63.7	65.7	65.9	65.4	63.8	64.0	64.5	64.9	66.0	65.7	65.5
26	60.2	63.0	64.6	65.8	65.8	65.5	64.8	65.5	65.2	65.7	65.8	65.5	65.0
27	60.0	60.0	62.7	64.3	64.9	64.8	65.3	64.9	66.8	66.5	68.2*	65.4	64.8
28	59.6	60.8	61.8	63.8	65.0	65.9	66.2	67.8*	66.8	67.8*	65.0	64.0	65.2
29	61.5	61.7	61.7	63.4	64.5	65.8	66.6	64.8	65.3	66.2	65.0	65.6	65.1
30	61.8	61.7	63.2	64.2	65.0	65.7	65.7	65.7	65.5	65.3	65.8	65.0	65.5
31	61.4	61.7	62.6	63.8	65.3	65.0	64.8	65.1	65.2	65.3	65.3	64.7	65.1
Monthly mean	60.6	61.5	63.0	64.0	64.5	64.7	64.4	64.5	64.8	65.5	65.0	64.8	64.87
Normal	60.5	61.5	63.0	64.0	64.5	64.7	64.4	64.4	64.8	64.7	64.8	64.8	

DIFFERENTIAL MEASURES—

Hourly readings from the photographic traces of the unifilar magnetometer at

Local mean time. 300 divisions + tabular quantity.

SEPTEMBER, 1889.

Day.	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	Noon.
1	64.7	65.0	65.3	65.5	66.2	67.8	70.3	71.3	69.8	66.3	63.7	61.5
2	66.5	65.7	63.7	67.5	66.7	68.4	70.5	71.1	69.3	65.7	62.3	60.7
3	65.1	65.3	66.2	65.7	66.7	67.9	69.5	68.7	65.2*	62.8*	61.5	61.8
4	65.5	65.7	65.7	66.4	66.8	69.4	71.8	70.2	67.0	63.4	61.7	61.3
5	65.5	65.7	65.7	66.3	66.6	68.4	70.6	68.7	65.5*	62.4*	59.8*	59.8
6	65.2	65.3	65.5	65.8	66.0	68.0	70.5	70.0	68.7	66.4	64.6	63.1
7	65.2	65.4	65.7	66.3	66.7	68.7	71.0	70.2	67.8	64.2	62.5	60.5
8	65.4	65.7	66.8	66.7	66.8	68.4	70.4	68.7	67.8	63.7	61.0	59.0*
9	64.5	73.3*	72.0*	68.5	65.6	71.0*	72.1*	72.5*	69.2	65.3	63.0	60.9
10	68.2*	63.4	65.5	63.6*	64.8	66.7	68.3	70.3	71.0*	67.5	63.4	60.8
11	64.6	63.9	63.6	65.0	63.6*	65.8	68.8	70.2	68.1	66.7	64.5	62.6
12	61.7*	65.8	65.3	65.8	66.8	67.8	69.8	70.7	69.0	66.2	63.7	61.3
13	65.0	64.4	65.1	65.2	65.9	67.5	69.0	69.9	67.2	64.5	62.8	61.3
14	64.4	64.5	65.2	64.5	65.4	66.6	68.8	68.9	66.7	63.8	61.5	60.9
15	64.9	65.8	65.8	65.4	65.8	67.0	69.8	70.0	68.3	66.6	65.0	64.0
16	65.4	65.3	65.4	65.6	66.3	67.0	68.4	69.5	68.8	67.0	64.8	64.3
17	65.3	65.5	65.7	65.5	65.7	67.2	69.0	69.4	68.8	67.8	65.7	64.5
18	66.0	66.8	65.8	66.7	66.4	66.0	68.2	68.0	66.8	65.8	64.5	63.4
19	64.8	65.3	65.7	66.3	66.6	67.1	68.5	68.2	67.3	66.0	64.7	63.6
20	65.9	65.9	66.0	66.3	66.7	67.8	68.8	69.5	67.6	65.2	63.3	62.8
21	65.5	66.2	66.7	66.5	67.0	67.5	70.0	69.0	69.0	65.2	62.8	61.4
22	65.9	66.8	66.3	68.7	71.0*	68.5	70.5	65.3*	67.3	60.5*	59.8*	60.8
23	65.0	64.6	64.3	67.0	67.6	68.0	67.8	66.4*	64.5*	64.5	62.4	62.0
24	65.8	65.4	64.6	67.9	65.8	67.3	69.4	68.8	67.0	63.8	62.3	61.0
25	65.4	61.7*	64.3	66.4	66.8	67.0	69.0	69.0	67.9	65.4	63.5	62.8
26	65.8	65.0	65.0	65.3	65.8	66.8	68.0	68.2	68.0	64.6	62.6	62.1
27	62.3*	64.2	66.7	66.2	67.4	67.5	69.6	70.5	68.3	66.3	63.6	62.7
28	65.5	66.7	66.4	65.9	66 3	67.7	69.5	69.8	68.5	66.4	64.4	63.0
29	65.3	65.5	65.6	66.4	67.0	67.5	68.4	69.3	68.3	66.8	63.6	61.7
30	65.4	65.7	65.7	66.2	66.0	66.7	67.5	69.0	69.5	68.0	64.9	62.6
Monthly mean	65.2	65.5	65.7	66.2	66.4	67.6	69.5	69.4	67.9	65.3	63.1	61.9
Normal	65.0	65.4	65.5	66.3	66.4	67.5	69.3	69.5	68.2	65.7	63.4	62.0

DECLINATION—Continued.

the magnetic observatory of the Coast and Geodetic Survey, Los Angeles, Cal.

One division of scale = 0′.794 Increasing scale readings correspond to increasing east declination.

SEPTEMBER, 1889.

Day.	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	Mid-night.	Daily mean.
1	60.4	60.3	61.9	63.8	65.0	64.9	64.5	64.5	64.7	65.0	65.3	65.0	65.1
2	61.2	62.0	63.1	64.5	64.8	64.3	64.3	64.7	64.6	64.6	64.7	65.0	65.2
3	61.8	63.7	65.0	65.4	65.2	64.7	64.8	64.9	65.1	65.4	65.0	65.4	65.1
4	61.0	61.9	63.0	64.1	64.8	64.2	64.1	64.5	64.7	65.0	65.0	65.2	65.1
5	60.4	62.3	63.9	64.9	64.6	63.3	63.4	63.9	64.4	64.6	64.7	65.0	64.6
6	62.7	62.8	63.2	64.3	64.9	64.5	64.2	64.4	64.5	64.6	64.6	64.8	65.4
7	60.6	60.7	62.3	64.3	64.7	63.9	64.0	64.8	65.0	64.5	65.8	66.3	65.0
8	58.3*	59.5*	61.3	63.7	64.4	72.7*	63.0	71.0*	65.0	60.0*	69.5*	60.2*	65.0
9	61.5	62.4	63.3	69.5*	67.2	66.3	65.0	65.2	64.8	65.3	65.2	64.8	66.6
10	60.8	61.6	63.6	66.2	67.8	64.8	65.2	66.5	64.8	65.2	65.3	66.4	65.5
11	62.7	63.3	63.8	64.7	65.4	64.8	65.5	68.2*	64.8	64.3	63.8	65.0	65.2
12	61.2	62.5	63.8	64.8	65.0	64.5	64.3	64.6	64.8	64.8	64.3	64.3	65.1
13	61.7	63.0	63.4	64.3	64.8	64.6	64.5	64.7	65.3	65.3	64.3	64.7	64.9
14	61.4	62.2	63.9	65.0	65.5	64.8	64.6	65.0	64.9	64.9	64.8	65.8	64.8
15	63.5	63.6	64.2	64.5	64.3	64.7	64.8	65.6	64.8	65.4	65.3	65.3	65.6
16	63.9	63.3	63.5	64.0	64.0	64.4	64.3	64.7	64.9	65.2	65.3	65.3	65.4
17	62.8	63.0	64.3	64.8	65.3	64.5	64.7	64.9	65.0	65.2	64.9	66.8	65.7
18	61.7	62.4	61.8	62.8	64.4	64.5	65.0	65.6	64.8	64.5	65.0	65.1	65.1
19	63.7	64.4	65.3	65.6	65.3	65.5	65.2	66.1	65.7	65.7	65.5	65.7	65.7
20	63.3	64.4	65.3	65.6	65.0	64.7	64.6	65.2	65.3	64.8	65.0	65.2	65.6
21	62.7	64.4	65.3	65.8	66.1	64.8	64.0	64.5	64.6	66.0	64.5	64.5	65.6
22	61.8	62.7	63.6	66.2	65.8	65.3	64.7	64.5	65.3	64.0	67.1	63.0	65.2
23	62.3	64.7	64.7	65.6	65.7	66.4	65.8	66.2	64.8	64.5	64.7	62.0*	65.1
24	61.8	63.8	65.4	66.1	66.3	66.3	65.2	65.2	65.7	67.6*	64.8	64.7	65.5
25	62.8	63.7	64.8	65.6	65.8	65.8	68.5*	65.8	65.6	65.5	64.2	65.9	65.6
26	62.3	62.8	64.8	66.0	66.0	65.5	66.0	65.8	65.6	65.4	65.3	65.1	65.3
27	62.7	63.5	64.7	65.2	66.0	66.0	66.9	65.9	66.5	65.5	65.3	65.3	65.8
28	62.8	64.3	65.0	65.7	65.4	65.5	65.6	65.5	65.5	65.3	65.3	64.8	65.9
29	61.8	62.3	64.3	65.4	65.7	65.5	65.5	65.4	65.3	65.5	65.0	65.1	65.5
30	62.0	62.4	62.9	64.2	64.5	64.4	64.7	65.4	65.0	65.2	65.0	65.0	65.3
Monthly mean	61.9	62.8	63.8	65.1	65.3	65.2	64.9	65.4	65.1	65.0	65.2	64.9	65.34
Normal	62.0	62.9	63.8	64.9	65.3	64.9	64.8	65.1	65.1	65.0	65.0	65.2	

UNITED STATES COAST AND GEODETIC SURVEY

APPENDIX No. 10

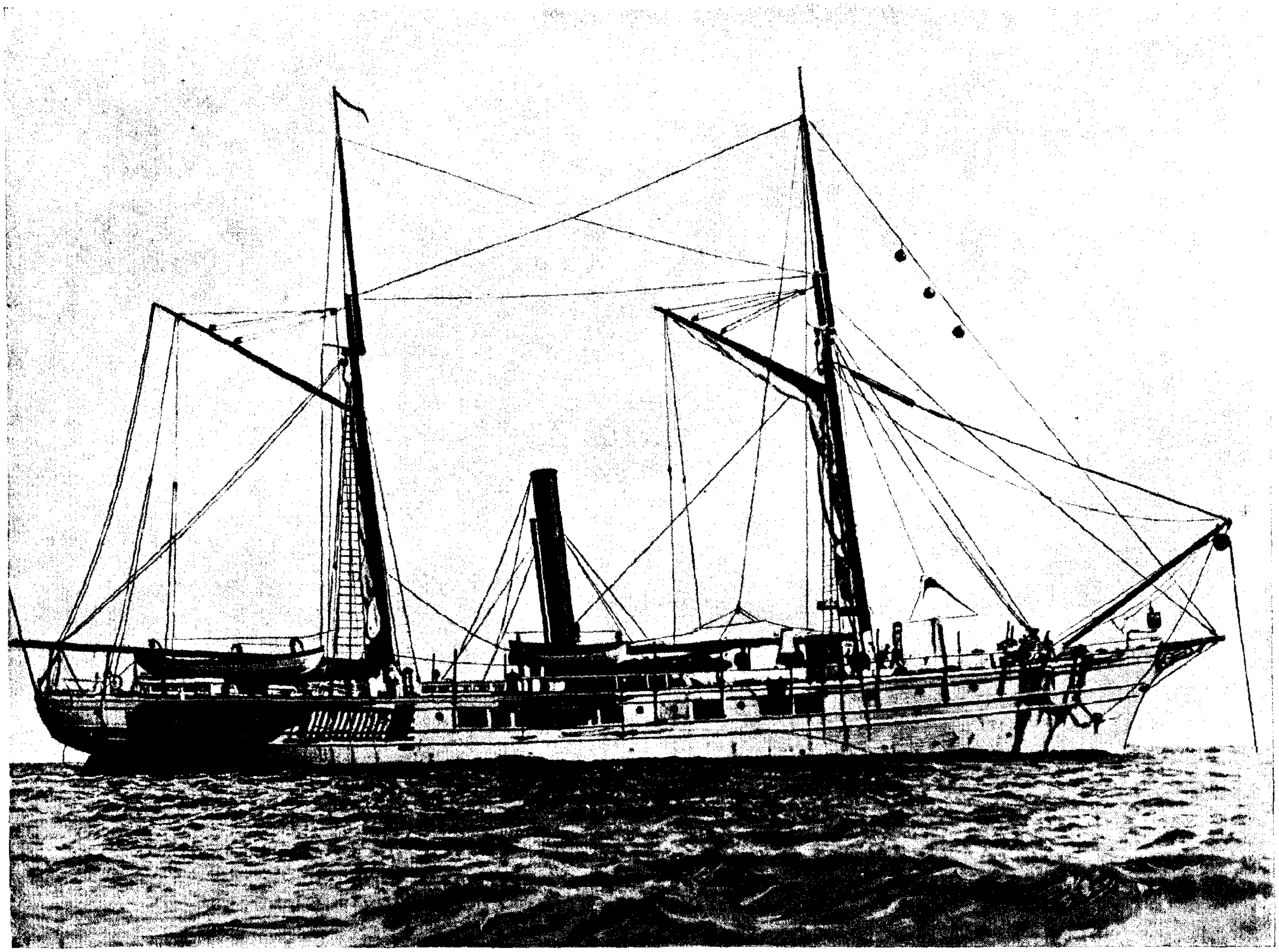
REPORT FOR 1890

THE GULF STREAM

METHODS OF THE INVESTIGATION

AND

RESULTS OF THE RESEARCH



U. S. COAST AND GEODETIC SURVEY STEAMER GEORGE S. BLAKE.

APPENDIX No. 10—1890.

THE GULF STREAM—A DESCRIPTION OF THE METHODS EMPLOYED IN THE INVESTIGATION, AND THE RESULTS OF THE RESEARCH.

By JOHN ELLIOTT PILLSBURY, Lieutenant, U. S. Navy,
Assistant U. S. Coast and Geodetic Survey.

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PREFACE.

The writer, while executive officer of the United States Coast and Geodetic Survey steamer *Blake*, devised an instrument in 1876 for the purpose of ascertaining the direction and velocity of the currents at any depth. This was intended to be used from a boat at anchor and to replace the system then in use, viz, floating and submerged cans with a log line.

Before the model could be tried he was ordered to other naval duty, and nothing further was attempted with the instrument until he was detailed for command of the same vessel in 1884. Permission was then granted by the Superintendent of the Coast and Geodetic Survey, at the request of the Hydrographic Inspector, Commander C. M. Chester, U. S. Navy, to have one of these instruments made with a view of using it on board the *Blake* while at anchor in the Gulf Stream. This current-meter has been used since that time, and the method devised for anchoring the vessel has been entirely successful up to 2,180 fathoms, the greatest depth attempted. This memoir has been written to describe the methods employed in the investigation of the Gulf Stream and the results of the research.

During the five years the writer commanded the *Blake* he received every encouragement and support from the officers of the Coast Survey.

The Hydrographic Inspectors, Commanders C. M. Chester and C. M. Thomas and Lieut. Commander W. H. Brownson, who were charged with the duty of supervising all hydrographic work, left it to the discretion of the commanding officer to decide all questions connected with the work. The Superintendents, Mr. F. M. Thorn and Dr. T. C. Mendenhall, have been most liberal in the allotment of the necessary money, and their instructions have been only the most general as to the time and locality of the examinations.

As a preliminary to the report of the work of the *Blake*, a history of previous investigations of the Gulf Stream has been inserted. Great assistance in preparing this portion has been derived from the manuscripts on the subject which were written for the Coast Survey by Dr. J. G. Kohl, Prof. W. P. Trowbridge, and Mr. O. H. Tittmann, Assistant, and also from the valuable collection of maps at the library of Harvard University, to which I have had free access through the kindness of the librarian, Mr. Justin Winsor.

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INTRODUCTION.

Geography, the science that gives to us a knowledge of the earth's surface, is divided into two branches: first, all that pertains to the configuration, usually called geography, and second, everything relating to the natural forces acting thereon, called physical geography. These subjects are interlaced with the study of nearly every branch of human knowledge tending toward the good of the race in its struggle toward improvement. At first the pursuit of wealth by the discovery of new lands and peoples, brought about a study of the configuration of the surface, but little by little it was seen that the study also of the physical forces assisted toward this end and to the ease and comfort of mankind at large.

The Sun without doubt is the greatest factor in the support of terrestrial life, but his intense heat is tempered and governed by the elements, air and water, without which life as at present constituted on our globe would be unsupportable. The total area of the earth's surface is about 200,000,000 square miles, and of this only about one-fourth is land. The mean elevation of the land above the sea is less than 2,500 feet, while the mean depth of the ocean is probably about 12,000 feet. The total volume of the land above the sea level, therefore, is only about one twentieth of the volume of the ocean.

The surface of the ground quickly becomes heated by the direct rays of the sun, but it also quickly radiates its heat into the air, producing an aërial current. The surface of the water, on the other hand, absorbing the sun's heat, rapidly communicates it to the adjoining stratum, and, radiation from its surface being comparatively slow, its currents transfer the heat so acquired to distant points. The tempering influence on the climate is the wind, taking the heat and moisture from this neated water and transferring it to the land. It is argued most forcibly that such a stupendous change in the climatology of the world as existed during the glacial period was caused by the precession of the equinoxes and the change in the eccentricity of the earth's orbit effecting an alteration in the great heat distributors, the ocean currents.

To commerce and navigation the study of these currents is of the utmost value. The length of the voyage is shortened, and the chance of safety to vessel, cargo, and lives is increased. A strong wind against a current produces a dangerous séa, and, by a knowledge of the laws of the water's flow, a vessel, by a trifling change of course, may escape the danger.

I venture to quote from a brochure on the subject of the Gulf Stream, by His Highness, Albert, Prince of Monaco. He says:

> Zoological geography may consider them [ocean currents] as highways which unite the zones of the ocean, and consequently cause the dissemination of species, and at the same time by the intensely progressive attenuation of salt and the temperature of these waters this highway facilitates the evolution of species. It is thus that the currents enter into the question so important to origins, monogenism, or polygenism.
>
> Anthropology, for example, holds them responsible for the solution of the great problem, that of human migrations, which spread even to the distant archipelagos the different varieties of the race *man*, at the time when there was scarcely a discernible difference between man and beast, and he had at his disposal only rudimentary means for struggling against the brute forces of nature.
>
> Botany and zoology ought to be interested in our researches, for the conditions of organic life in all its bearings are governed by these currents either warm or cold, which give to subterranean regions a veritable climate; and it is perhaps owing to certain disturbances which have taken place in the volume, direction, and temperature of these currents that the almost entire disappearance of several kinds of migratory fish is attributed, as, for example, that of the sardines, which formerly lined the coasts of France in countless numbers.
>
> It concerns geology also, for the oceans receive a deposit, the organic and mineral detritus which the winds and waves bring to it, the stones which the glaciers wrest from the polar regions and which the icebergs carry to the temperate regions. The sea currents charge themselves with distributing all these minerals

according to certain laws, and in this manner collections are formed which in later times convulsions of the earth bring to light.

Paleontology itself ought to be interested in our researches, for is it not evident that the rivers, drifting dead bodies across the continents, deposit them on sand banks far from their habitat to become the fossils of the future?

There is another reason for studying these currents which will ultimately have the most beneficial influence on mankind. It is now known that the currents vary through certain forces acting upon them, by periodic changes, entirely according to law, and again through apparently erratic forces. Probably every motion of these vast bodies is absolutely governed by laws which can be ascertained. The moisture and varying temperature of the land depends largely upon the positions of these currents in the ocean, and it is thought that when we know the laws of the latter we will, with the aid of meteorology, be able to say to the farmers hundreds of miles distant from the sea, "you will have an abnormal amount of rain during next summer," or "the winter will be cold and clear," and by these predictions they can plant a crop to suit the circumstance or provide an unusual amount of food for their stock. We will be able to say to the mariner, at such time the current will be so much an hour in such a direction, and the percentage of error will be but trifling. From a study of these great forces, then, we derive our greatest benefits, and any amount of well-directed effort to gain a complete mastery of their laws will revert directly to the good of the human race.

In the Atlantic Ocean the currents are probably more pronounced than in either the Pacific or Indian Oceans. Without entering upon a discussion at this point as to the causes of ocean flow or of any particular current, a brief description of the main streams will not be out of place, for they are all connected more or less intimately with our own Gulf Stream. The equatorial current is usually described as being a broad band of water moving slowly across the Atlantic in the tropics. The portion situated south of the equator is divided into two parts upon meeting the resistance of Cape St. Roque, the eastern salient point of the South American coast. One branch turns to the southward toward the Antarctic, and the other is forced to the westward along the shores of Brazil and Guyana. This branch is called the Guyana Coast current. The equatorial current has north of the equator an almost uninterrupted progress until it reaches the Windward Islands, but a portion of it impinges against the South American coast and perhaps increases the volume of the northern branch of the south equatorial current. At the Windward Islands all are united, and a portion of the water enters the Caribbean to assist in forming the Gulf Stream. Between the northern and southern portions of the equatorial current is the Guinea current, setting toward the east and southeast into the Gulf of Guinea. It was formerly thought to be a continuation of the North African current, "but later investigation," Findlay says, "seems to point to the fact that it is a flowing back of the waters heaped up to the westward by the prevalent winds." It seems to run strongest in the summer months, when it is felt as far west as longitude 45°, while in the winter it reaches only as far as the twenty-third meridian. In the Northern Atlantic Ocean the Labrador current sweeps down from the Arctic along the eastern shores of Greenland and from Baffin's Bay and passes the coasts of Labrador and Newfoundland, bearing with it vast fields of ice and enormous bergs. Reaching the Gulf Stream, it is said to underrun the latter, and also in part form a counter-current to the southward along our coast as far south as Cape Hatteras, or even to Cape Canaveral.

The Gulf Stream, the grandest and most mighty of any terrestrial phenomenon, receives its waters from the Caribbean Sea through the Straits of Yucatan. It is commonly said that a portion doubles Cape San Antonio and enters the Straits of Florida at once, while another part, after making the tour of the Gulf of Mexico, joins the first in its flow to the northward. Its waters are characterized by a deep blue color, great clearness, and high temperature. The eye can penetrate it to considerable depths, and frequently its meeting with the colder water from the polar regions can be at once distinguished.

It is difficult for the mind to grasp the immensity of this great ocean river. The observations taken at its narrowest point were between three and four thousand in number, surface and subsurface, and a calculation of the average volume passing Cape Florida in one hour gives the enormous sum of 90,000,000,000 tons. If this one hour's water were evaporated, the remaining salt would require more than one hundred times the number of sea-going vessels now afloat in the world to carry it. That this wonderful body is governed by law in all its motions there can be no doubt. It has its daily and monthly variations in velocity, direction, and temperature, changing with as perfect regularity as the tides in a harbor. Nor do I doubt that it has also a yearly fluctuation, and perhaps others occupying a cycle of many centuries to complete.

The Gulf Stream after leaving the Straits of Florida pursues a general northeasterly direction, pressing close to Cape Hatteras, passing between Bermuda and Nova Scotia, and as a defined and permanent stream is soon afterwards lost. Currents are found in the vicinity of the Azores Islands setting about southeast, and also on the coast of Africa setting south, which are sometimes called the southeast extension of the Gulf Stream. Warm water is found off the coasts of Ireland, Scotland, and Norway, giving evidence of a tropical flow, and this is called the northeast extension of the Stream. Whether or not these currents are wholly formed of the water issuing from the Straits of Florida remains to be discussed later.

Man stands with bowed head in the presence of nature's visible grandeurs, such as towering mountains, precipices, or icebergs, forests of immense trees, grand rivers, or waterfalls. He realizes the force of waves that can sweep away light-houses or toss an ocean steamer about like a cork. In a vessel floating on the Gulf Stream one sees nothing of the current and knows nothing but what experience tells him; but to be anchored in its depths far out of the sight of land, and to see the mighty torrent rushing past at a speed of miles per hour, day after day and day after day, one begins to think that all the wonders of the earth combined can not equal this one river in the ocean.

CHAPTER I.

GENERAL HISTORICAL ACCOUNT OF THE GULF STREAM AND ITS INVESTIGATIONS UP TO THE TIME OF FRANKLIN.

Before the time of Columbus's grand discovery of the New World the coasting vessels of the Old must have recognized that there were currents in the Atlantic Ocean which were entirely independent of the tides; but the first indication that currents on the coast of North America were noticed is found in the writings of the Northmen in their description of voyages to America. Several suggestive names were given to prominent objects of discovery, such as Straumsoe (Isle of Currents), Straumsfjörde (Bay of Currents), and Straummes (Cape of Currents), but their exact location can not be identified. Some claim that the voyages extended even to Florida, but it seems probable from later investigations that the points named were all in the vicinity of Cape Cod.

Columbus, before undertaking his voyage of discovery toward the west, resided for some time on the island of Porto Santo, and it was here that he was shown a piece of curiously carved wood that had evidently drifted there from other lands. Strange woods and other floating objects were continually being thrown upon the shores of Norway, Scotland, and Ireland, all of which, to a thoughtful mind like that of Columbus, must have induced the belief that there were other lands at no great distance to the west, and so it is probable that to the Gulf Stream in part the world owes the discovery of America.

In actual observations in the Gulf Stream, or rather in the currents contributing to it, Columbus was the pioneer. It is related that September 19, 1492, he sounded with a deep-sea line, and the lead, passing through the surface drift into the dead water below, showed at once that there was a current setting his vessels to the southward and westward. On his subsequent voyages he remarked the strong currents of the Caribbean Sea. He says, for example, "When I left the Dragon's mouth" (the northern entrance to the Gulf of Paria) "I found the sea ran so strongly to the westward that between the hour of Mass, when I weighed anchor, and the hour of Complines, I made 65 leagues of 4 miles each with gentle winds." He also says of the currents entering the Caribbean between the Windward Islands, "I hold it for certain that the waters of the sea move from east to west with the sky, and that in passing this track they hold a more rapid course, and have thus carried away larger tracts of land, and that from hence has resulted the great number of islands."

On his fourth voyage Columbus discovered and noted the strength of the current on the coast of Honduras, although it is probable that at this time the Gulf Stream itself in the Straits of Florida had been found by independent navigators. Peter Martyr says "he left in wryting that sailing from the Island of Guanassa toward the east he found the course of the waters so vehement and furious agaynst the fore part of his ship that he could at no time touch the ground with his sounding plummet, but that the contrary violence of the waters would bear it up from the bottom. He affirmeth also that he could never in one day with a good wynde wynn one mile of the course of the waters."

Columbus speculated as to the cause of these currents. He thought that the equatorial waters followed the motions of the heavens about the world—that is, the rotary motion by which the stars and air revolve about the globe (as was the opinion of the time), so also the water was supposed to partake of the same motion.

John and Sebastian Cabot, in 1497, crossed the North Atlantic Ocean, rediscovering the coast of Labrador. From this point they steered to the southward and westward, "so coasting still by the shore that he was brought so far into the south by reason of the land bending so much to the southward that he was then almost equal in latitude to the sea called Fretum Herculeum, having the north pole elevate in manner in the same degree. He sayled likewise in this track so far towarde the weste that he hadde the Island of Cuba in his left hande in manner in the same degree of longitude." * * * "He sayeth that he found the like course of the waters towarde the west, but the same to run more softly and gently than the swift waters which the Spanyards found in their navigation southward."

It is probable that the Cabots did not double Cape Hatteras and discover the Gulf Stream. It is thought by some that they entered the Straits of Florida, but from the testimony of Peter Martyr, quoted above, they were north of Hatteras and probably in the vicinity of the Delaware, but in the longitude of Columbus's discoveries in the West Indies. They did, however, notice the fact that a gentle counter current existed.

The Cortereals, between 1500 and 1502, on several voyages extending from Labrador toward Cuba, probably crossed the Gulf Stream and may have recognized its strength, but very little is known as to the exact localities visited.

In the year 1508 the Island of Cuba was for the first time circumnavigated. Sebastian de Ocampo, under the authority of the Governor of Hispaniola, sailed along the northern coast of the island through the old Bahama Channel and around the western point, Cape San Antonio. In this voyage eight months were occupied, and as it was against the Gulf Stream it would seem that he must have noticed it. As the times demanded however the custom of secrecy on all expeditions, no record has been left of the fact.

The first record, on which the evidence is satisfactory, of the discovery of the Gulf Stream current, is that of Ponce de Leon in his expedition in 1513 in search of the fountain of youth. In company with the after wards famous navigator, Antonio de Alaminos, he sailed from Porto Rico, along the northeastern side of the Bahamas, and crossed the Gulf Stream somewhere above Cape Canaveral. After reaching a latitude of about 30° north he turned and skirted the coast as far as Tortugas, thus stemming the current for a distance of several hundred miles. Referring to these currents, their journal says that they saw a current which, though they had a good wind, they could not stem. It seemed that they were going through the water fast, but they soon recognized the fact that they were being driven back and that the current was stronger than the wind. Two vessels, which were somewhat nearer the coast, came to anchor; the third vessel, a brig, being in deeper water, could not anchor, and was soon "carried away by the current and lost from sight although it was a clear day." Ponce de Leon, on this expedition, crossed the stream no less than four times, and Alaminos received his first apprenticeship in its navigation, which in after years proved to be of great benefit to him.

During the next few years the Spaniards crossed and recrossed the Stream between Cuba and Florida many times in their search for gold, and of course gained much practical knowledge of the strength and velocity of its currents.

It is interesting to note the speculations of the day as to the cause of this startling phenomenon, and its result on the sailing route to Europe. Peter Martyr in one of his letters written in 1515, being evidently as yet uninformed as to results of Ponce de Leon's expedition, says;

> Here we must somewhat digresse from cosmography, and make a philosophical discourse to search the secret of Nature. For when as they all affirm with one consent that the sea runneth there from east to west, as swiftly as if it were a ryver falling from high mountaynes, I thought it not goode to let such matter slipp untouched. The which, while I consider I am drawn into no small ambyguetie and doubt, whyther those waters have their course which flowe with so continual a tract in the circuite from the easte, as though they fledde to the weste never to retourne, and yet neyther the weste thereby any whit more fylled nor the east emptied.
>
> If we say that they fall to their centre (as in the nature of heavier things) and assign the equinoctial hyll to be the centre (as some affirme), what centre shall we appoint to be able to receive so great abundance of water, or what circumference shall be found wet. They which have searched those coasts have yet found no like reason to be here.
>
> Many think that there should be certayne large strayghts or entrances in the corner of that great land which we describe to be eight times larger than Italie, and the corner of that land to be full of gulfes, whereby they suppose that some strayghts should pass through the same lying to the weste side of the Island of Cuba, and that the said strayghts swallowe up those waters and so conveys the same into the weste, and from thence again into the easte ocean or north seas as some think. Others will, that the Gulf of that great lande be closed up and the lande to reach far to the north in the back side of Cuba, so that it embrace the north landes which the frozen sea encompasseth under the north pole, and all the lande of these coasts should joyne together as one firme lande. Whereby they conjecture that these waters should be turned about by the object or resistance of that lande

so tending toward the north, as we see the waters turned about the crooked banks of certayne ryvers. But this agreeth not in all points, for they also who have searched the frozen sea, and sayled from thence into the weste doe likewise affirme that those north seas flowe continually toward the weste although nothing so swiftly. * * * Wherefore it is not only more likely to be true but also of necessity to be concluded, that between both these landes hitherto unknown, there should be great certayne open places whereby the waters should thus continually passe from easte into the weste, which waters I suppose to be driven about the Globe by the incessant moving and impulsion of the heavens, and not to be swallowed up and cast out again by the breathing of Demo-gorgon as some have imagined, because they see the seas increase and decrease, flowe and reflowe.

The same writer continues at a later date:

Let us now therefore speake somewhat again of the later news and opinion as concerning the swift course of the sea toward the weste about the Coast of Paria. So it is therefore that Andreas Moralis, the pilot, and Ouidas (of whom we have made mention before) repayred to me at my house in the time of Matrite. As we met thus together there arose a contention between them two as concerning this course of the ocean. They both agree that these landes and regions pertayning to the Dominion of Castile, do with one continuale tract and perpetual bond embrace as one whole firme lande or continent all the mayne lande lying to the north of Cuba and the other islands, being also northwest from both Cuba and Hispaniola. Yet as touching the course of the waters they vary in opinion; for Andreas will, that his violent course of the water be received into the lappe of the supposed continent, which bendeth so much and extendeth so farre toward the north, as we have said, and that by the object or resistance of the lande so bending and crooking the water as it were, rebounde in compasse and by the force thereof be driven about the north side of Cuba and the other islands excluded outside the circle called Tropicus Canceri, where the largeness of the sea may receive the waters falling from the narrow streams and thereby represse that inordinate course by reason that the sea is there very large and great.

The Admiral himself, Diegas Colonus, sonne and heyre of Christophorus Colonus the first finder of these landes, being demanded of me what he found or perceived in sayling to and from, answered that there was much difficultie in retourning the same way by which they go; but whereas they first take their way by the mayne sea toward the north before they direct their course to

> Spayne, he sayth that in that tract he felt the shippe sometymes a little driven back by the contrary course of the waters, yet supposed that this chaunceth only by the ordinary flowing and reflowing of the sea, and the same not to be enforced by the circumflection of the water rebounding in compass as we have sayde; but thinketh that this mayne lande or supposed continent should somewhere be open.
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> * * * * * * * * *
>
> Ouidas agreeth with Andreas Moralis as touching the continual adherence of closeness of the sayde continent, yet neither that the water shoulde so beat agaynst the bending back of the weste lande, or be in such sort repulsed and driven into the mayne sea; but sayth that he hath diligently considered that the waters runne from the deepest and wyddest of the mayne sea toward the weste. Also that sayling near into the shore in small vessels, he found the same waters retourne agayne toward the east, so that in the same place they runne together with contrarie course. * * * Thus have we made you partner of such things as they have given us and written their divers opinions. We will then give more certayne reasons when more certayne truth shall be known. We must in the meantime leane to opinions until the day come appointed of God to reveal this secret of nature with the perfect knowledge of the pointe of the pole Starre.

It is certainly most remarkable, when we consider how imperfect was their knowledge of the form or extent of the continent, that their views should have been so near the truth. The Gulf of Mexico was not discovered until 1517, and explored the year after, when the current on the western side of the Straits of Yucatan must have been found. Ocampo, in circumnavigating Cuba, judging from experiences of the present day, could have found only the tidal currents in the vicinity of Cape San Antonio. The current in the passages in the eastern Caribbean was known to be strong and westerly, and on the Honduras coast the same. Alaminos and Ponce de Leon had found the current in the Straits of Florida, and evidently some of the speculators determined that the land was continuous and in some way the two parts of the flowing stream of water were connected.

Antonio de Alaminos was without doubt the most experienced navigator and pilot in the West Indian waters. He had been chief pilot with Columbus on his last voyage, had been with Ponce de Leon around and among the Bahamas and along the coast of Florida from St. Augustine to Tortugas, and had crossed and recrossed the stream several times. He had afterwards been with Cordova and Grijalva exploring the coast of Yucatan and the Gulf of Mexico. He was familiar with the fact that there was a passage north of Cuba from the Gulf to the Ocean, but beyond the Straits to the northward was unknown to him. He thought, however, as Herrera says, "that these mighty currents ought to empty somewhere into an open space." Upon fitting out the expedition for the conquest of Mexico, Cortez gave the chief command of the fleet to Alaminos, and when, later, it was thought necessary to send dispatches and presents to Spain, he was given the fastest vessel to carry the Envoys. Instructions were given him to hold his course north of Cuba and pass into the Atlantic through the Straits of Florida, not touching at any port or island in the West Indies. Probably this route was suggested to Cortez by Alaminos as being most favorable for a quick passage, and one by which he would be sure to avoid a chance meeting with an enemy either of his own or of a foreign country. The vessel sailed from Vera Cruz July 26, 1519, and after disobeying his instructions by making a stop at the port of Marien on the north side of Cuba, Alaminos passed through the Straits of Florida and reached Spain in safety. It is of course doubtful how far he followed the Gulf Stream, but it is probable that he did so well up the coast toward Cape Hatteras. His voyage changed the course of navigation from the West Indian ports and contributed largely toward the growth of Havana. This port soon became the rendezvous of the West Indian trading fleet, the distributing point of goods from Europe, and the starting port for the return home.

During the half century following the remarkable voyage of Alaminos, there were expeditions without number to the West Indies and the mainland, and while there are minute and detailed descriptions of the land, products, and people, yet scarcely anything is said of the sea currents.

Sir Humphrey Gilbert, writing before 1576, says that all the waters of the ocean "run by nature circularly from east to west, following the diurnal motions of the Primum Mobile." He traces the motion of the waters from the south of Africa and says that from there it strikes over to America. Not finding free passage "it runs all along the eastern coast of that continent northward as far as Cape Freddo, being the farthest known place of the same continent toward the north, which is about 4,800 leagues." He thinks that even if this current has not been traced all along the coast of America, "still it must exist either in uppermost or the nethermost part of the sea." For the reason that this current must have a free passage somewhere Gilbert says "it must either flow around the north of America into the South Sea or it must needs strike over upon the coasts of Iceland, Norway, and Finmark." He adopts the first of the alternatives, as he is anxious to prove the existence of the Northwest Passage. In the journal of his last voyage he mentions that in 50° north latitude they saw ice being carried to the southward, and so conjectured that a current must be setting in that direction. In 1579 and again in 1583 he made two unsuccessful attempts to establish colonies on the east coast of the present United States, and it is curious to see how great was the influence of the Gulf Stream, even at that time, in directing navigation. In considering the advisability of taking the southern passage from England or the more direct but more difficult northern one, he says, "by what way to shape our course, either from the south northward, or from the north southward. The first course, that is, beginning south, without all contraversie was the likeliest wherein we are assured to have commoditie of the currents, which from the Cape of Florida setteth northward, and would have furthered greatly our navigation, discovering, from the foresaid cape toward Cape Breton and all these lands lying to the north." The advantage of being able to provision the vessel at the Banks of Newfoundland led them to decide upon the northern route "although contrariety of currents descending from the Cape of Florida into Cape Breton and Cape Race would fall out to be great and irresistible impediments unto our further proceeding for that year, and compel us to winter in those northern regions."

The records of the voyages of Martin Frobisher are of great interest as showing the gradual extension of knowledge on the subject of ocean currents. He crossed the northern Atlantic six times during the years 1576–'77–'78. In the account of his third voyage he says:

> Sayling toward the northwest parts of Ireland we mette with a great current from out the southwest, which carried us [by our reckoning] one point toward the northeastward of our said

> course, which current seemed to us to continue itself toward Norway and other of the northeast parts of the world, whereby we may be induced to believe that this is the same which the Portugese mette at Capo de Buong Speranza [Cape of Good Hope], where, stricking over from thence to the Straits of Magellan and finding no passage there for the narrowness of the sayde Straits, runneth alongue to the great Bay of Mexico, where also having a let of land it is forced to strike back again toward the northeast, as we not only here but in another place also further northward by goode experience this year have found.

How the currents returned to the Cape of Good Hope from the "northeast parts of the world" is not stated, but the general course of the Atlantic system is very fairly laid out.

About this time there appeared the theory in "La Cosmographie" that the currents in the Straits of Florida were caused by the rivers emptying into the Gulf of Mexico, and this theory has been held by writers at much later dates. In 1596 it is recorded by D. Layfield, chaplain of the Earl of Northumberland, that between Bermuda and the Azores they thought they observed a current, but shortly before arriving at the latter they were sure of a current setting southward. The next expedition to that of Gilbert, for settling Virginia and North Carolina, was under Captains Amadas and Barlow. They took the southern passage, as did also all of those under Raleigh. Some of these left the Caribbean east of Cuba, and others continued to the westward and passed through the Straits of Yucatan and Florida.

In 1590 John White, who had been Governor of the colony at Roanoke, referring to the portion of the voyage from Florida Keys to Virginia, says: "We lost sight of the coast and stood to sea for to gaine the helpe of the current, which runneth much swifter farre off than in sight of the coast, for from the Cape of Florida to Virginia, all along the shore, are none but eddie currents setting to the south and southwest." This is the first instance in which there is indicated a knowledge of an approximate position of the axis of the Stream.

In 1606 an observation is recorded by Lescabot, which is evidently a meeting of the Labrador and Gulf Stream currents. He noticed that while in latitude 45° and "six times 20 leagues to the eastward of the Banks of Newfoundland, we found for the space of three days the water very warm, whilst the air was cold as before, but on the 21st of June quite suddenly we were surrounded by fogs and cold that we thought to be in the month of January, and the sea was extremely cold." He attributes this to the ice from the north which comes floating "down from the coast and sea adjoining to Newfoundland and Labrador, which is brought thither by the sea in her natural motion."

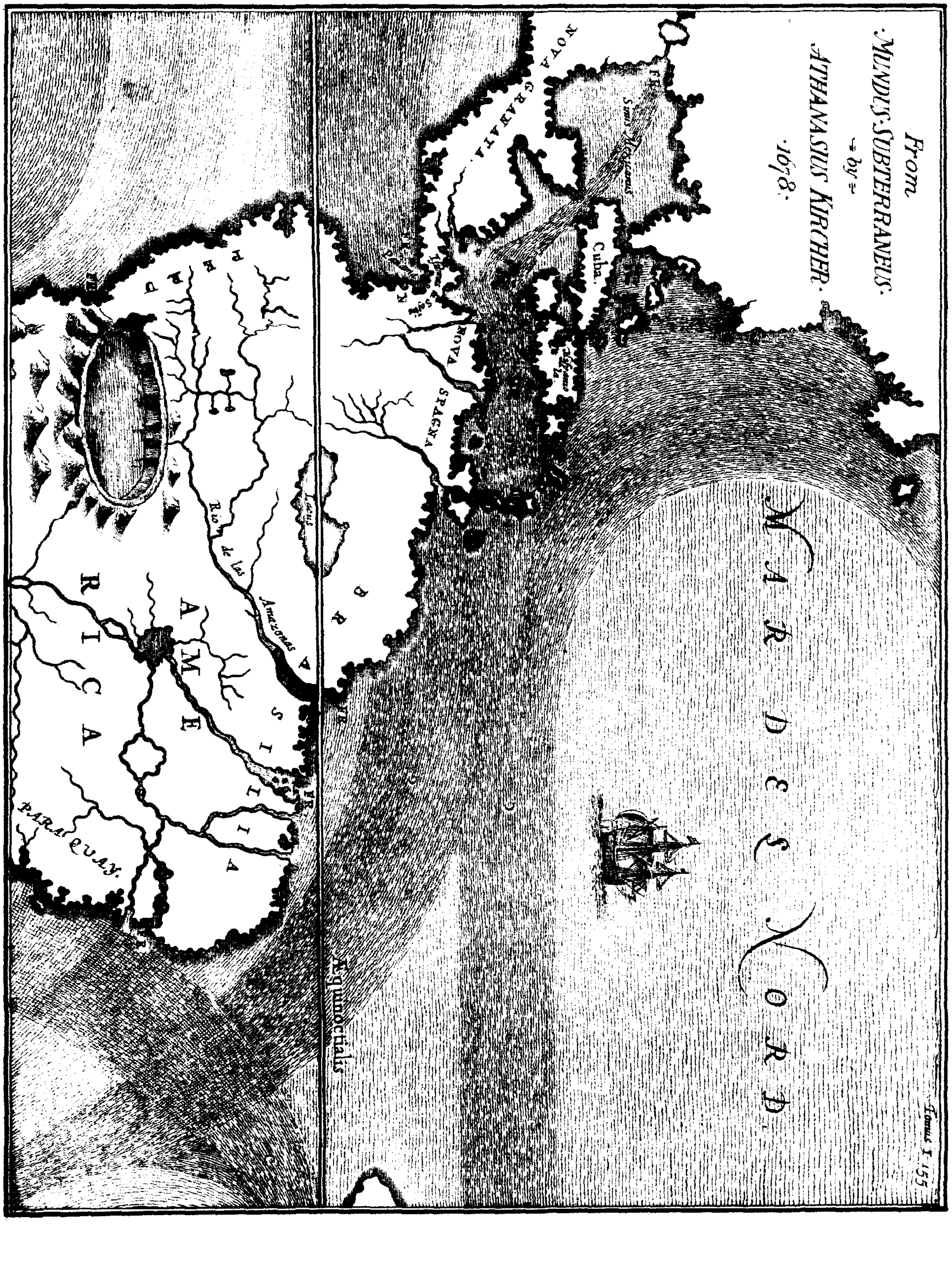
The influence of the Gulf Stream in the colonization of North America was about this time very great. In 1606 the English divided their possessions into two parts, the northern part of Virginia (New England and vicinity) was one, and the present North Carolina and Chesapeake Bay region the other, and for each a company was established and commissioned by the King. The route used in going to the first was that tried in 1602 by Capt. Bartholomew Gosnold, crossing the Atlantic on about the fortieth parallel, while the southern expeditions held the old passage through the trades and Caribbean. The Dutch vessels bound to New York adopted the West Indian route, so that Nantucket really became the dividing line of travel, and a difference in destination of a degree in latitude necessitated a difference of thirty degrees in route. This seems only to be accounted for by the real or imaginary assistance of the winds and currents in one and the impediment of the Stream in the other. After the English and Dutch settlements became firmly established and crossing the Atlantic a common thing, the personal experience of navigators was no longer thought to be of sufficient importance to print, and the time had not yet arrived for adopting a plan of collecting ship's journals and publishing such nautical information from them as would be of value to others. The writers on the subject, however, must have had access to these journals and corrected and improved their ideas on the subject of currents, and in the latter half of this century many works on hydrography appeared.

In 1650 Varenius gave the most complete description of currents which had been issued up to this time. He classified them into perpetual and periodical, special and general. The system of which the Gulf Stream forms a part he placed as a perpetual special motion of the sea, and describes it as a gigantic Stream beginning at the eastern Capes of Brazil, flowing from south to north and ending toward Florida. He adds, "a similar current from south to north is observed along the Philippine Islands and toward Japan." He also wrote that "some Copernicans, as for instance Keppler, pretend that also the movement of our globe contributes not a little toward it" (the currents), "because the water, not being adherent to the earth but only in a loose contact with it, cannot follow the quickness of its motion toward the east, but is left behind toward the west, so that the sea does not move from one part to the other, but on the contrary it is the earth which quits or leaves the parts of the sea, one after the other."

In 1663 Isaac Vossius wrote a work entirely devoted to the motion of wind and sea, and in it particularly describes most of the currents known in the present day. He says:

> With the general equatorial current, the waters run toward Brazil, along Guyana, and enter the Gulf of Mexico. From there, turning obliquely, they pass rapidly through the Straits of Bahama. On the one side they bathe the coasts of Florida and Virginia and the entire shore of North America, and on the other side they run directly east until they reach the opposite shores of Europe and Africa; from thence they run again to the south and join the first movement to the west, perpetually turning in this manner circuitously.

He emphasizes this by saying that "a ship without sails and sailors might be conveyed solely by the force of the currents from the Canary Islands to Brazil and Mexico, coming back from there by way of the Florida Stream toward Europe on a route some 4,000 German miles in length." Vossius's theory as to the cause of the ocean circulation was that the heat of the tropical sun attracted the ocean and at the same time increased its bulk and formed, as it were, a long mountain of water, "to which the vessels even have some difficulty in ascending when they sail toward the line." He concluded that the sun carried this mountain of water toward the South American shore, where it broke and ran along the coasts. A French hydrographer, George Fournier, some years later propounded a theory almost the opposite. It was that the sun evaporated enough water in the tropics to make a deep valley, and therefore the water from the poles was forced to run toward the equator along the coast of Africa to replace the lost water. He thought that the depression always


From
MUNDUS SUBTERRANEUS.
by
ATHANASIUS KIRCHER.
1678.
Cuba
NOVA SPAGNA
NOVA GRANATA
Lacus
Rio de las Amazonas
AMERICA
PARAQUAY.
Æquinoctialis
Tomus I 155

ran before or with the sun and the arriving polar water behind the sun and the rotatory system of currents was thus produced.

In 1678 Athanasius Kircher, a Jesuit, gave to the world in his "Mundus Subterraneus," the first published chart showing the system of ocean circulation and the Gulf Stream (Illustration No. 31). He says of the causes of the Gulf Stream:

> This motion touches many things, whether partly from the general motion of the trade winds against the opposing shores of that region and thence again reflected, which they call the Sailor's Current, or from wind-storms, or finally from the flow and the reflow caused by the moon's force.

He was, however, a strong believer in submarine abysses as the cause of vortices and special currents. In 1685 a German named Happelius published another chart of Ocean currents (illustration No. 32) quite similar to Kircher's. In his work he says:

> The general motion of the Ocean goes from east to west, and it is most obvious in the torrid zone. The sun is the cause of this general course of the sea as well as of the trade winds. The particular motions of the sea are of two kinds, one on a straight line and the other with a circulating or whirling movement. Of those which run in a straight line some are constant, regular, and perpetual the whole year through. Some show themselves only at times and change even in direction, are irregular, depending much on the direction of the wind. In the Atlantic from the Brazilian Cape of St. Augustine toward the Antilles and Florida is a constant and perpetual course of the sea from the south to north.

About this time the question began to be agitated in the minds of scientists as to how the strange fruits and woods were deposited on the shores of Ireland, Scotland, and other northern lands. The molucca bean was frequently found there, and the fact was thought to be proof of either a northeast or northwest passage to the East Indies. In 1696 Dr. Hans Sloan proved that these beans came from Jamaica. He says:

> It is very easy to conceive that, growing in Jamaica, and having got to sea by the rivers, they may be carried by the winds and by the current which is forced through the Gulf of Florida, going there constantly east into the North American Sea; but how they should come the rest of their voyage I can not tell, unless it

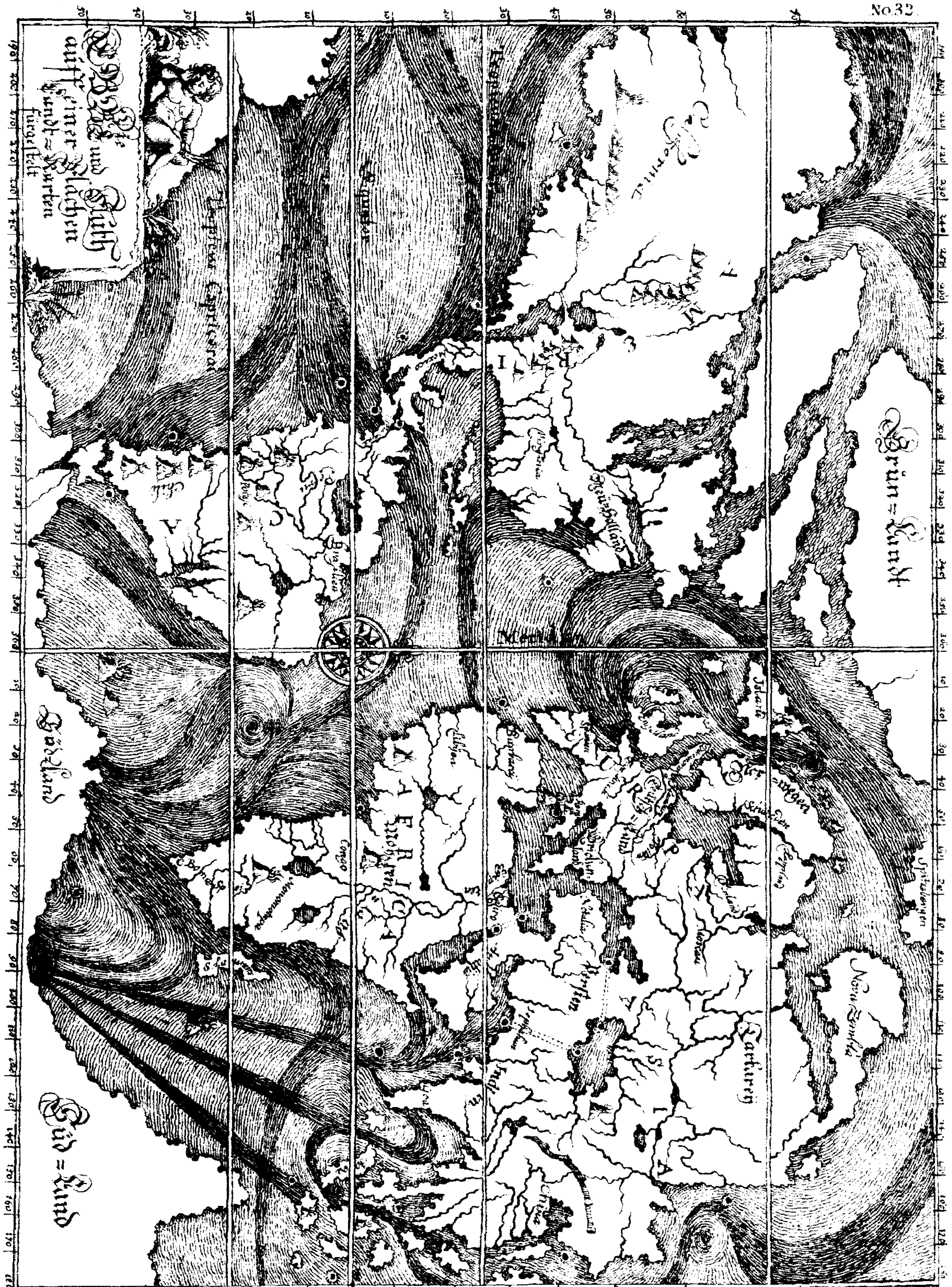
> be thought reasonable that the beans, being brought north by the current from the Gulf of Florida, are put into the westerly winds' way, and may be supposed by this means at last to arrive at Scotland.

This is exactly the opinion of many people at the present day.

In 1702 and again in 1720 the fact was stated that the Gulf Stream ran the strongest in the Straits of Florida during strong northerly winds, and as an explanation of this phenomenon Professor Leval thought that it could only be accounted for by the supposition that during the north winds in the channel in the Gulf of Mexico they were blowing from a more northwesterly direction, and in this way pushed the waters of the Gulf into the Straits and so forced them through the latter with increased velocity. The French route from Louisiana to Europe followed the Gulf Stream along the North Atlantic coast toward the Banks of Newfoundland, differing considerably from the more southern route taken by the Spaniards, but while adopting this most expeditious track they went to the other extreme in sailing from their Gulf to their West Indian possessions. They followed the Stream well up toward the Grand Banks, then south to the trade winds and west to their port.

Up to this time, with the exception of Kircher and Happelius in 1679 and 1685, there seems to have been no attempt to indicate the Gulf Stream upon the charts, and even these were more for scientific interest than for the practical benefit of mariners. One chart published in 1630 by the Earl of Northumberland gave the words "Corrento verso Greco," placed about half a degree from Cape Hatteras; but with this exception up to the first half of the eighteenth century, charts generally only show an inscription between Cuba and Florida, "Canalis Bahama versus Septentrionem semper fluit," or its translation into other languages. About the middle of the eighteenth century arrows appeared on the charts of the British colonies to indicate coast currents, and at the same time French charts indicated currents in the Caribbean and in the Straits of Florida in like manner. In 1772 detached indications of the Gulf Stream currents appear, and in 1775 on a special map of Carolina there are arrows near the coast pointing to the southward and westward, and farther off the coast pointing north.

No. 32.



FROM HAPPELIUS RELATIONES CURIOSAE
1685.

That the want of knowledge as to the limits of the Stream was felt is shown by the length of time consumed in passages between the same ports in opposite directions. A voyage from Boston, Massachusetts, to Charleston, South Carolina, would sometimes take three or four weeks, while a return trip would frequently be made in one week. The coasting captains and whalemen, however, were gaining experience regarding the Stream, and to the latter more than all others, up to the time of the Revolutionary War, Franklin was indebted for the information which led to the publication of his chart of the great Ocean current.

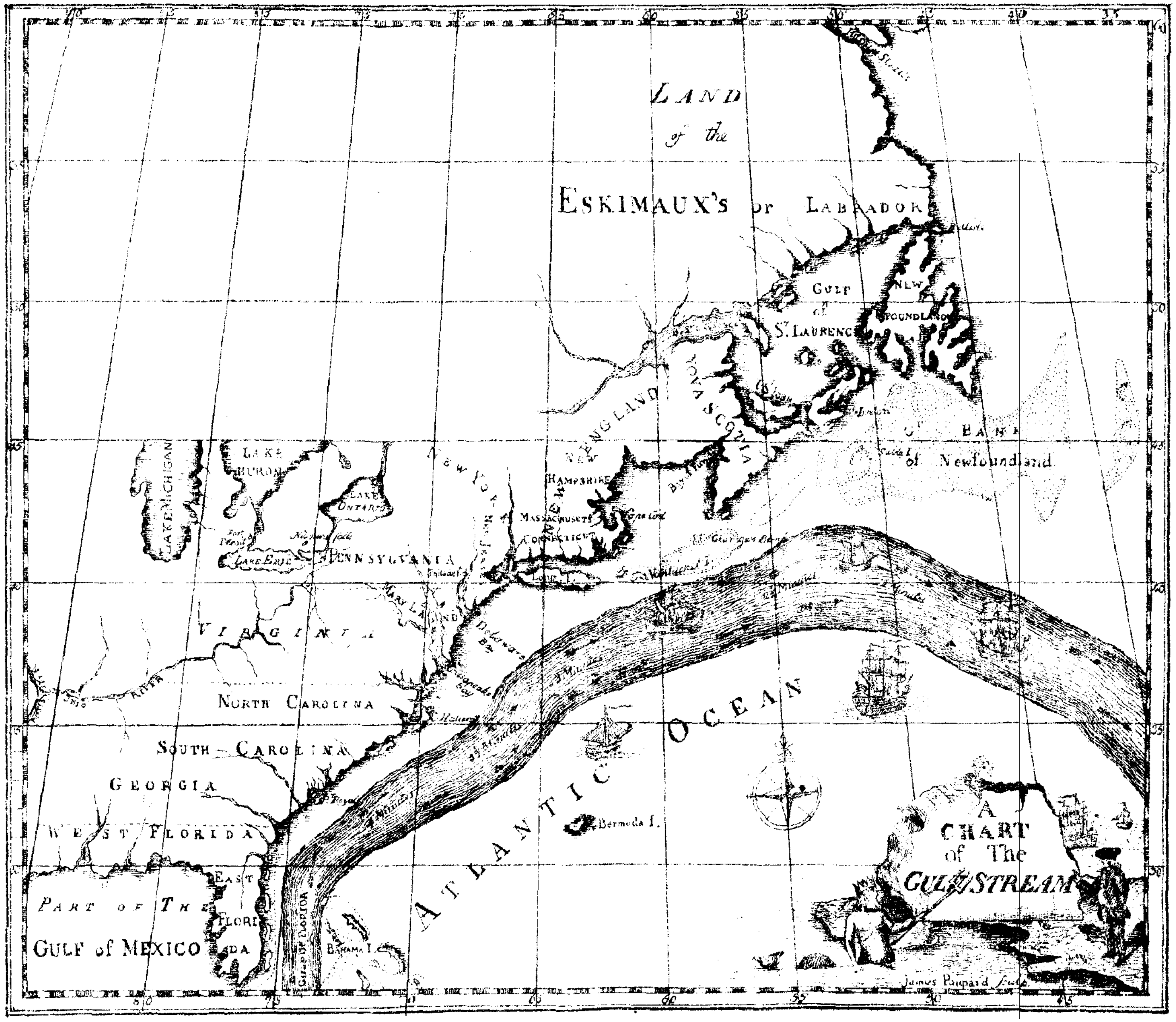
These whalers extended their search as far south as Bahama Bank and as far east as Newfoundland, or even to the longitude of the Azores. They discovered that the whales appeared to the north of a certain line and to the south of another line, and were but rarely seen between the two, and these lines they concluded were the limits of the Gulf Stream. The whale fishery soon became the school for American navigators, particularly of New England vessels, and in this way knowledge of the Gulf Stream was introduced into the commercial traffic of the times. The American shipmasters, from their superior information on the subject of currents, inaugurated a change in the sailing route from Europe, by which they could save two weeks or more in the passage. From England they crossed the Newfoundland Banks in about latitude 44 or 45 degrees, and thence on a course inside the limits of the Stream.

CHAPTER II.

GULF STREAM INVESTIGATIONS FROM THE TIME OF FRANKLIN TO THOSE MADE BY THE U. S. COAST SURVEY.

How long the American fishermen had been acquainted with the secret of the Gulf Stream's peculiarities before it was brought to the notice of Franklin it is impossible to state. They kept the secret, however, until, as Franklin says—

> About the year 1769 or 1770, there was an application by the Board of Customs at Boston to the Lords of the Treasury at London, complaining that the packets between Falmouth and New York were generally a fortnight longer in their passage than the merchant ships between London and Rhode Island, and proposing instead of New York that for the future they should be ordered to Newport.
>
> Being then concerned in the management of the American Post-Office, I happened to be consulted on the occasion, and it appearing strange to me that there should be such a difference, especially when the merchant ships were generally deeper laden and more weakly manned than the packets, and had from London the whole length of the river and channel to run before they left the land of England, while the packets had only to go from Falmouth, I could not but think the fact misunderstood or misrepresented.
>
> There happened then to be in London a Nantucket sea captain of my acquaintance, to whom I communicated the affair. He told me he believed the fact to be true, but the difference was owing to this, that the Rhode Island captains were acquainted with the Gulf Stream, while those of the English packets were not. "We are well acquainted with that stream, because in our pursuit of whales, which keep near the sides of it but are not met with in it, we run along the side and frequently cross it to change our side; and in crossing it have sometimes met and spoke with those packets who were in the middle of it and stemming it. We have informed them that they were stemming a current that was against them to the value of 3 miles an hour and advised them to cross it, but they were too wise to be councelled by simple American fishermen.



THE GULF STREAM ACCORDING TO BENJAMIN FRANKLIN

1770

When the winds are light," he added, "they are carried back by the current more than they are forwarded by the wind, and if the wind be good the subtraction of 70 miles a day from their course is of some importance."

I then observed that it was a pity that no notice was taken upon the charts, and requested him to make it out for me, which he readily complied with, adding directions for avoiding it in sailing from Europe to North America. I procured it to be engraved by order from the General Post-Office on the old chart of the Atlantic, at Mount & Page's, Tower Hill, and copies were sent to Falmouth for the captains, who slighted it, however, but it has since been printed in France, of which edition I hereto annex a copy (illustration No. 33).

Franklin's theory on the subject of the cause of the Gulf Stream is given in the same report. He says:

This stream is probably generated by the great accumulation of water on the eastern coast of America between the tropics by the trade winds which constantly blow there. It is known that a large piece of water, 10 miles broad and generally only 3 feet deep, has, by a strong wind, had its water driven to one side and sustained so as to become 6 feet deep, while the windward side was laid dry. This may give some idea of the quantity heaped upon the American coast, and the reason of its running down in a strong current through the islands into the Bay of Mexico and from thence proceeding along the coasts and banks of Newfoundland where it turns off towards and runs down through the Western Islands.

Franklin did not press his new chart on the notice of the English ship captains after they had once rejected it, but for the time being suppressed it, for political reasons, until the conclusion of the War of Independence. In the mean time, in 1775–'76, and in later years, whenever he made a voyage across the Atlantic, he took observations of the surface temperature of the ocean. He says:

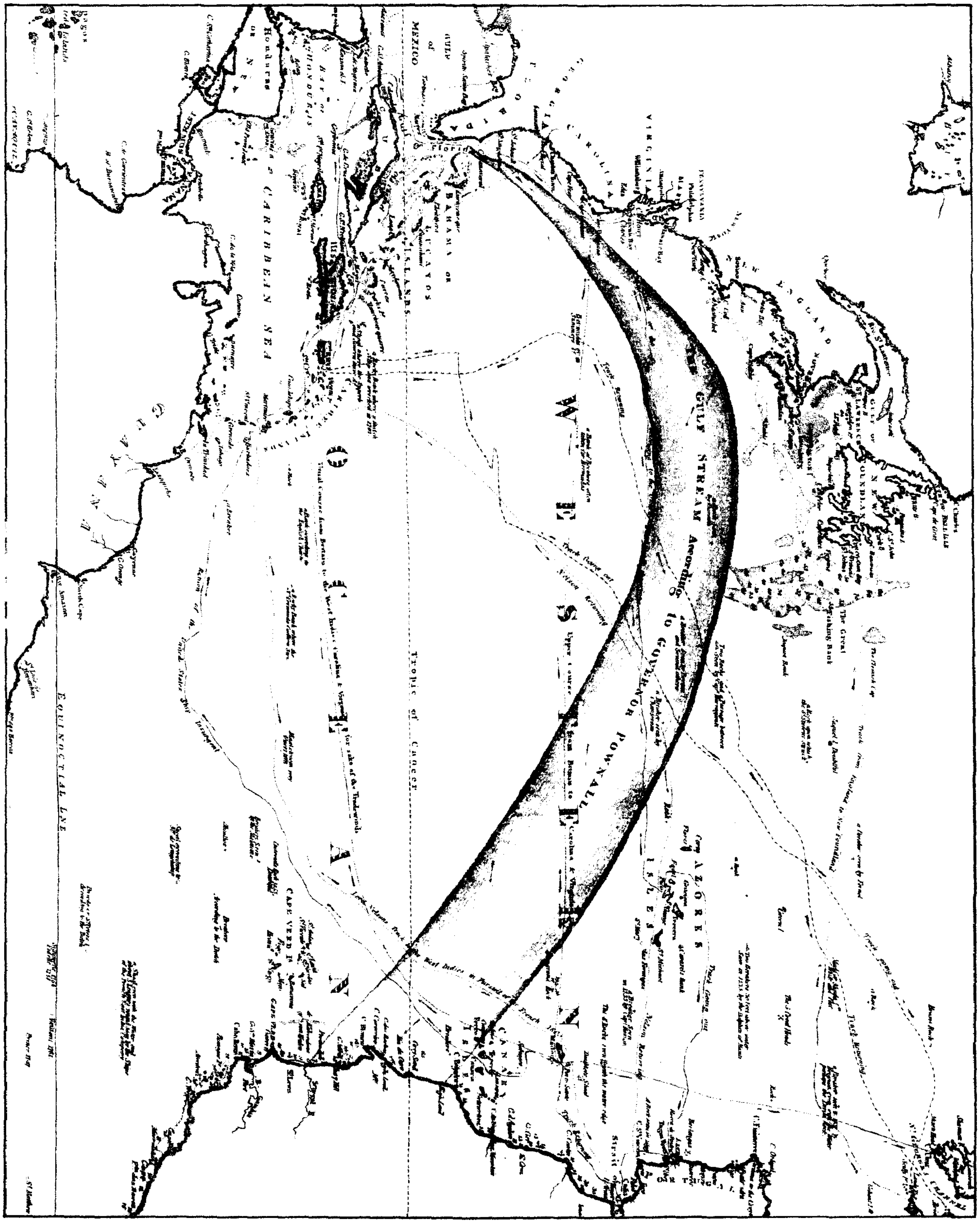
I find that it [the Gulf Stream] is always warmer than the sea on each side of it, and that it does not sparkle in the night. I annex hereto the observations made in two voyages and may possibly add a third. It will appear from them that the thermometer may be a useful instrument to the navigator, since currents coming from the northern into southern seas, will probably be found colder than the water of those seas as the currents from southern seas into northern are apt to be warmer.

On his last voyage, in 1785, he made the first attempt in submarine temperatures at moderate depths, using a bottle up to 20 fathoms, and afterwards a cask with valves in each end. Off the Delaware, in 18 fathoms, he discovered that the water at this depth was 58°, which was 12° colder than at the surface.

Although Franklin's chart of the Gulf Stream, published in London, had been rejected by the English shipmasters in 1770, it was certainly adopted by writers on hydrography. The information was given to the public through these works, and the name Gulf Stream came into general use. The importance, too, of gaining all possible information about this mighty river seems to have been realized at this time, and consequently nearly all government vessels were instructed to observe its phenomenon whenever opportunity offered. Among the most prominent investigators was Dr. Charles Blagden, of the Royal Army, while with the British fleet going to and in the American waters in 1776–'77. He observed the temperature in crossing the stream off Cape Fear, and also off the Chesapeake, communicating his results to the Royal Society, in 1781, in a letter urging the essential advantage to be derived by the use of the thermometer. These two, Franklin and Blagden, were the first to demonstrate the usefulness of that instrument, and, since the time of Alaminos, no discovery of like importance had been made which bore so directly on the question of utilizing this great river to the purposes of man's welfare.

Soon after Franklin's and Blagden's discoveries, Mr. Pownall, formerly Governor of Massachusetts, published in 1787 a large chart and a volume on Hydraulic and Nautical Observations on the Currents of the Atlantic Ocean. On this chart the Gulf Stream is laid down closely approximating to that of Franklin's (illustration No. 34). He also gives the correct course or tracks which vessels should take; that to Boston "along and beyond the northern edge of the Gulf Stream." To Virginia and Carolina he urged one in about latitude 35° instead of running down to 20°, as was usual.

Franklin on his last voyage was accompanied by a nephew, Col. Jonathan Williams, who was of great assistance in the thermometrical observations and record of results. Such interest was awakened in the mind of Williams that he was led to continue the experiments begun by his uncle.



THE GULF STREAM ACCORDING TO GOVERNOR POWNALL
1787

In a memoir read before the American Philosophical Society in 1790 he confirmed Dr. Franklin's account of the temperature of the Stream, and also advanced the theory that banks, shoals, and coasts might be discovered by the use of the thermometer. Williams published a work in 1799 on Thermometrical Navigation, containing a chart of the Gulf Stream (illustration No. 35) and the temperature of the water on adjacent banks. In 1800 a paper was read by Capt. William Strickland on the use of the thermometer in navigation. In his voyages across the Atlantic he had kept daily and sometimes hourly observations of surface temperature, in order to test the theory of Colonel Williams. His investigation was valuable from the discovery of the warm northeasterly extension of the Gulf Stream, for he found in latitude 46° 47′ north and longitude 38° 35′ west, a temperature of 68°. He says, of this northeast extension, "it probably continues in about a northeast direction entirely across the Atlantic till it ultimately strikes the coasts of Ireland and the Hebrides, after having lost, in its long course in these northern latitudes, much of its heat, and at last being reduced to the temperature of the sea through which it flows." He recommended the employment of vessels to define the limits of this northern branch between latitudes 47° and 60° by the use of the thermometer. Although others before Strickland had noticed floating weeds and American woods in these northern localities, and even Cabot had remarked upon the fact of the beer in the hold of his vessel getting warm, thus surmising a warm current, yet no one seems up to this time to have declared its existence a fact, based upon actual experience and scientific observation.

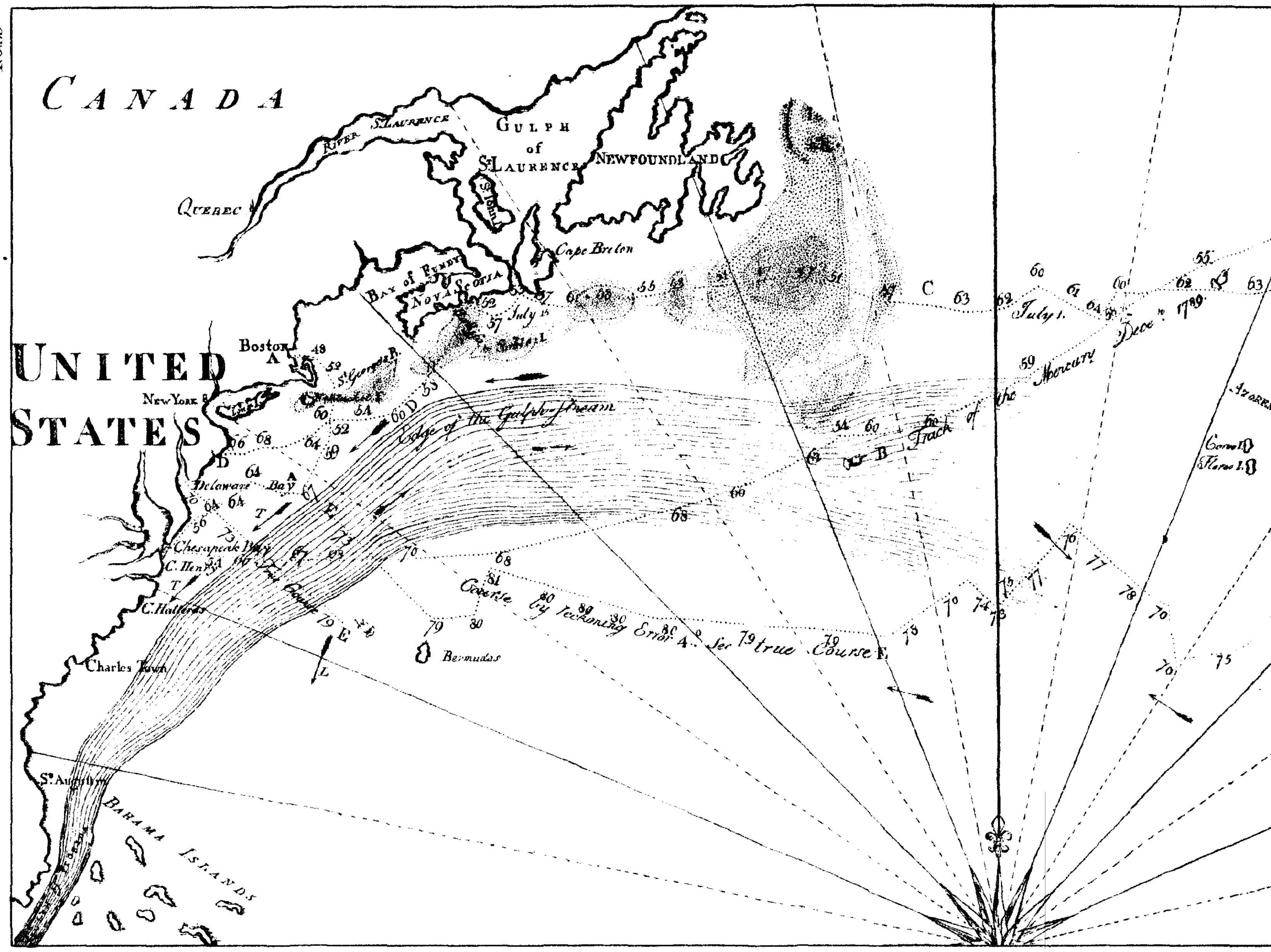
At the beginning of the nineteenth century, the subject of ocean currents was a favorite one for investigation by the navigator and hydrographer. The thermometer was the accepted instrument in the research, and by the chronometer, which was becoming of greater value and more generally used, the difference between the dead reckoning and the observed positions could be determined with greater accuracy. As we shall see later, from the time of Franklin and Blagden, for more than a century, all the investigation of ocean currents was based solely upon these two instruments, the thermometer and the chronometer, and upon, what in effect is the same as the latter, the drift of bottles. In the year 1802 the first bottle experiments seem to have been inaugurated, the English ship *Rainbow* throwing overboard several in the North Atlantic, and at intervals these experiments have been continued in all parts of the world up to the present day.

A remarkable thermometrical voyage was made in 1810 by the packet *Eliza*, from Halifax to England. It was found that in the midst of the warm water of the stream there existed patches of cool water of 10° to 15° lower temperature than the surrounding sea, and having a diameter of over 200 miles. They were thought to have been caused by icebergs and floes which had entered and been melted in the Gulf Stream. In 1811 and 1812, Sir Philip Broke made a great number of observations in the Gulf Stream and described its characteristics. Among other things he states "that beyond the southern boundary of the stream, from the Azores toward Bermuda and the Bahamas, there is a strong set to the southwest or west-southwest, that when this countercurrent arrives opposite the outfall of the Florida or Gulf Stream it turns to the southeast along the outer side of the Bahama Archipelago, receiving into its body a large offset of the Gulf Stream which rounds the Matanilla Bank." Another alleged characteristic of the current began to appear in the nautical works of the early part of the century: "That easterly winds press the current toward the American coast, and that the consequences of this pressure are that the breadth of the Stream and its distance from the shore is diminished and its velocity increased, and that in the contrary, winds which blow from the coast produce contrary effects."

Capt. John Hamilton gave to the American Philosophical Society, in 1825, the observations made by him during twenty-six voyages to and from Europe. They consist of temperature of air and water, current of the Gulf Stream for different months, average temperature of the water on soundings off the Delaware, Georges Bank, and on the coast of Ireland. Some of the conclusions arrived at by Captain Hamilton were of great value at the time. He decided that it was impossible to define the limits of the current of the Gulf Stream, owing to the variable influence of the wind; that after it passes the Grand Bank the main Stream proceeds to the southward, while several ramifications, generally not very strong, branch off to the northeast and from that to the east, with countercurrents in the

No. 35

Appendix 10 - Coast and Geodetic Survey Report for 1890.



THE GULF STREAM ACCORDING TO JONATHAN WILLIAMS.

1799

intermediate spaces; that by the frequent use of the thermometer the navigator may always discern where he touches the Gulf Stream, and take advantage of its current or avoid its influence. He further remarks:

> I was for a long time almost induced to conclude that some of these currents, particularly those which prevail between the coast of Newfoundland and Europe, were periodically running half the time in one direction and half the time in the other, and the foregoing tables seem to strengthen this conclusion, except the countercurrents near the edge of the stream.
>
> * * * * * * *
>
> When the current from the northward prevailed to any great extent, a set in the opposite direction near the bank of Newfoundland and on the west coast of Ireland were always observed.

The celebrated German, A. von Humboldt, published in 1814 a valuable description of the Gulf Stream, the result of his own observations in crossing it no less than sixteen times, as well as of all the information he could collect from the journals of navigators who had been possessed of the necessary means for exact astronomical observations at sea. He decided that the Gulf Stream was not the same in all seasons of the year, but that its force and direction depended to a large extent upon the changes in the trade winds, and also, that the general torpidity of the ice in the Arctic in the winter, and its melting in the summer, influenced it. Regarding the directions of ocean currents he says:

> Considering the velocity of the fluid elements which, in different latitudes, in consequence of the earth's rotation, is different, one should be tempted to think that every current from south to north ought to have at the same time a tendency to the east, and, *vice versa*, a current from north to south a tendency to the west.

He published a chart of the Gulf Stream in which he depicted its changeable limits as he believed they were.

During the next few years many navigators cruised in and examined the Gulf Stream, more particularly however in the vicinity of the route between Halifax and Bermuda. One of them in May, 1821, in about 64° west longitude remarked the fact that he observed a vein of cool water of a temperature of 54° between 72° and 73°, which seems to be the first time this phenomenon was noticed. The celebrated Englishman, Capt. W.

Scoresby, investigated the northern extension of the stream, and discovered in the vicinity of Spitzbergen that an under stratum of water was generally warmer than that at the surface. He believed that the warmer water, though of similar specific gravity was, in this case, the most dense, and that sea water followed the same law as fresh water with regard to extreme of density, being a few degrees above its freezing temperature. To this he attributed the fact that the polar ice in these waters could not extend far to the southward, and Humboldt adopted the same. The latter says: "In those regions which are warmed by a current from the southwest, navigation is uninterrupted even in the midst of the strongest winter."

Col. E. Sabine, in 1822 was a member of an expedition organized for the purpose of making experiments to determine the figure of the earth. Sailing from England he went to Madeira and to Sierra Leone, through the Caribbean and the Straits of Florida to New York and thence to England, thus making the complete circuit of the warm Atlantic currents. In his observations on ocean temperatures he found in the eastern Atlantic a body of water very much warmer than normal, and attributed this fact to an unusual elevation of the Gulf of Mexico and the Caribbean, due to abnormally strong trade winds. The weather was so unusual in the southern parts of Great Britain and in France as to have excited general remark, as "most extraordinary hot, damp, stormy, and oppressive," and that in November and December gales from the west and southwest were almost without intermission. We here see, not so much the direct influence of the warm water of the stream on the climate of England and France as the effect of the westerly and southwesterly gales.

During the first quarter of this century the British admiralty-office had collected a great quantity of material on the subject of ocean currents and meteorology, most of which had never become known to the public. Mr. James Rennell, who had devoted his life to the subject of geography, and particularly to ocean currents, was given the task of compiling and collecting the data. He combined the results on large charts of the ocean which were the admiration of the day, and also wrote a volume on "An investigation of the subject of the currents of the Atlantic Ocean." He died, however, before its entire completion, but two years later (1832) it was published by his daughter Lady Radel. In the charts were embodied the general courses of the currents with the limits of variations, the directions of the winds, accompanied by the date of observation, the depth and temperature of the sea, and some of the tracks of the vessels making specially important scientific observations.

Major Rennell adopted Dr. Franklin's theory as to the principal cause of ocean currents and divided them into two classes: Drift currents, caused by the effect of constant or long-continued winds on the surface of the water, and stream currents, which are formed by the accumulation of water by the drift current meeting an obstacle and thrown sideways or out of its usual course. The Gulf Stream he placed in the latter class, but concluded that it turned south toward the Azores and was lost, while he considered the movement of water in the northern part of the North Atlantic a drift current impelled by the prevailing westerly winds, and these also were the cause of the African current.

From his investigations he pronounced it to be abundantly proved—

(1) That there existed a change in the position and breadth of the column of warm water from time to time.

(2) That the breadth varied at times in the proportion of more than two to one.

(3) That these changes had been observed sometimes to be very sudden—as, for instance, it had once been found to be 140 miles in width, and ten weeks later at the same spot to be 320 miles broad.

(4) That these changes did not follow any regular course of season, for it was 320 miles wide in May, 1820, and only 186 miles in May, 1821, nearly at the same place.

(5) That on the northern side of the stream the body of warm water is more permanent than to the south, and also that the warmest water is found to the north, as if indicating the strongest part of the stream there.

(6) That the existence of warm water does not necessarily indicate the presence of the stream, but must be regarded as an overflowing or deposit of superabundant water, or even form a counter current.

(7) That there were without doubt veins of colder water within the body of warm current.

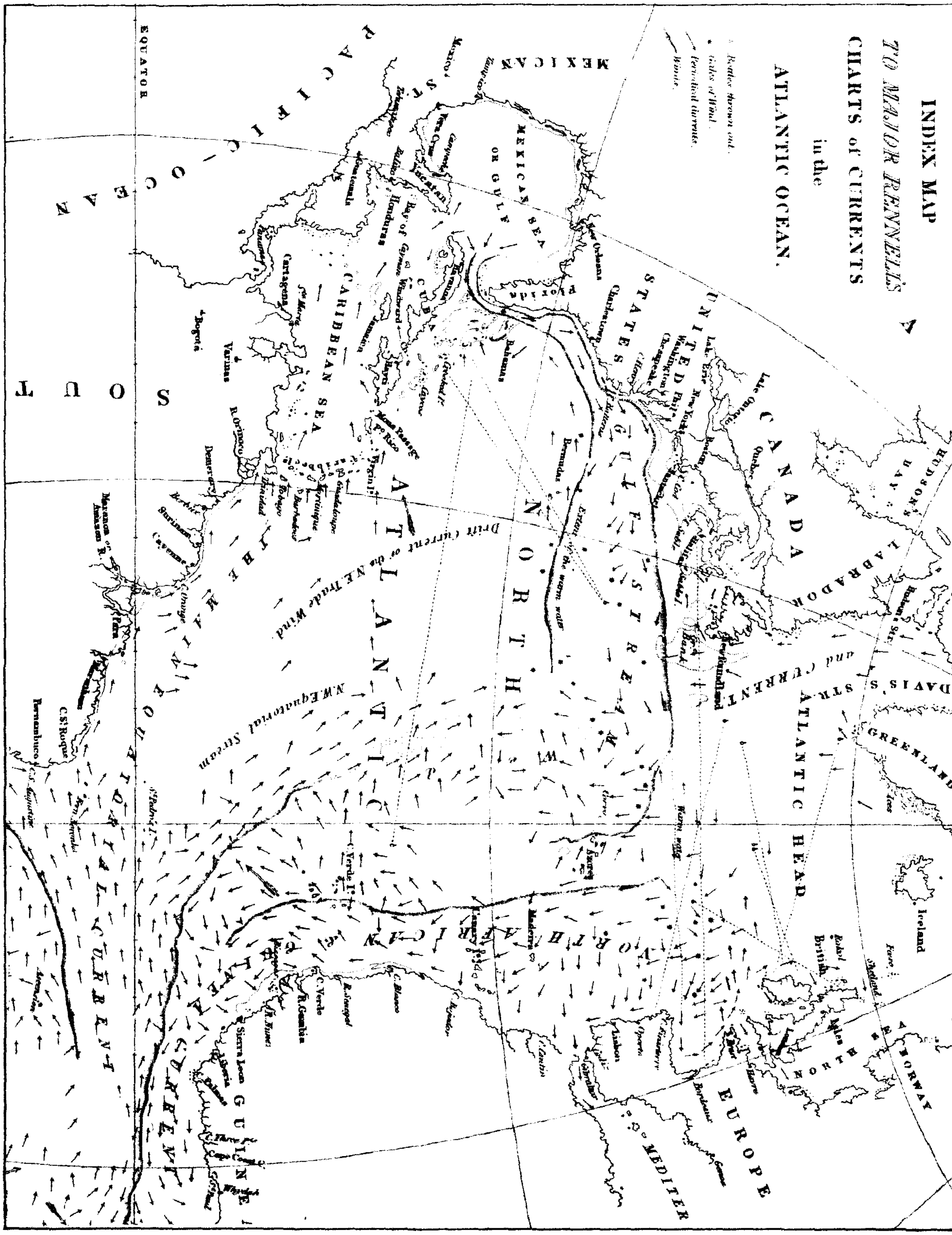
He pointed out the fact, and, indeed, it exists at the present day, that the position of the Stream east of Cape Hatteras is but imperfectly known, and that notwithstanding the great number of observations at his disposal, a want of system in their collection, the isolated and unconnected facts obtained by different observers at different seasons, and errors in determining longitude made it impossible at that time to state where the borders of the Stream should be placed. The observations discussed by Major Rennell were of the surface temperature, and we shall see later how great is the influence of the wind in spreading the warm water of the Stream without carrying the current with it. His work was the most valuable collection of results that had been made, and while some of his conclusions have since been disproved, it is a remarkable fact that he should have arrived at so near the truth in many of them. An index of his currents is shown in illustration No. 36.

For several years after the death of Major Rennell, observation of the Atlantic currents did not possess the attraction that it had previously, probably for the reason that his elaborate compilations were considered to have settled the question. Isolated observations were made, but no one took the trouble to combine them into average results. Rennell's theory of the elevation of the Gulf of Mexico and the Caribbean Sea was much shaken by Arago, who called attention to the observations made to ascertain the differences of level of the two oceans at the Isthmus of Panama. Triangulation was carried from Chagres to Panama, and a report made that the Atlantic might be from 3 to 5 feet lower than the Pacific.*

About this time a line of levels was carried across Florida from St. Mary's River to Apalachee Bay, with a difference of 7½ inches, the latter being the highest. It was thought, however, to be due to error of observations rather than to difference of level.

Arago believed "that with respect to currents the rotation of the earth ought principally to be taken into view, and that this, together with the cooling and warming of the water in the north and south, is the main cause of their more rapid or slower deviation and progress toward the east or

*The engineers in charge of the Panama Canal have accurately leveled across the Isthmus in recent years with entirely different results, as will be seen later.



THE GULF STREAM ACCORDING TO JAMES RENNELL.

1832.

west." He remarks, too, that "we ought to apply to the ocean the same theory which has already afforded a satisfactory explanation to the trade winds if we will decipher the question of currents."

During the first half of the century bottle experiments were numerous. The results were published, chiefly in magazines, in the shape of charts, giving the positions and dates of departure and arrival of these floats, connected by straight lines. Another chart, indirectly relating to ocean currents, was published by Mr. W. C. Redfield. It gave the positions of icebergs and fields observed by British and American navigators in the Atlantic from the year 1832 to 1844. Over one hundred of them were marked on this chart, and the fact observed that they sometimes entered the supposed limits of the Gulf Stream, thus showing the existence of an undercurrent.

In 1838 and 1840 a scientific mission was sent out by the King of France, under the direction of Paul Gaimard, to northwestern Europe. Among other subjects they observed the depth and temperature of the ocean, and concluded that "a broad current sets through the northern Atlantic in a NNE. direction toward the coasts of Great Britain and, passing between the Faroe and Shetland Islands, runs along the coast of Scandinavia as far as North Cape, from which it turns toward Cherry Islands and Spitzbergen."

The winter of 1845–'46 in England, and in fact in all of western Europe, was very abnormal. The weather was exceptionally mild, being 8 degrees above the average, and was accompanied by much rain and high southwesterly gales, similar to the winter of 1821–'22, when Colonel Sabine had observed an exceptional extension of the warm water of the Gulf Stream toward the shores of Europe. Struck by the similarity of weather, Colonel Sabine endeavored to discover if the same conditions of ocean temperature prevailed, but although hundreds of vessels crossed and recrossed this part of the ocean he could find none on which observations had been taken. He thought it reasonable to believe that through a course of years there might be a difference between the usual and extreme initial velocities, and consequently in some years, as 1776, 1821, and perhaps 1845, it might reach the shores of Europe. He thought, too, that it would be of the greatest practical value for Europe to be informed in advance of the yearly state and tendency of the Stream and the changes in its velocity. His idea was that ships might observe its elevation in the Gulf of Mexico and Straits of Florida; and that they, sailing faster than the flow, might make the changes known in England in advance of the arrival of the climate-influencing warm water.

After the death of Major Rennell the first renewed attempt to take up the task of collecting data on ocean meteorology was made by Lieut. M. F. Maury, U. S. N. While he was collecting, however, the U. S. Coast Survey, under Prof. A. D. Bache, began, in 1844, a systematic investigation, which continued with greater or lesser regularity until 1860. Before describing the latter, however, we will consider the labors of Lieutenant Maury and others up to the outbreak of the civil war. Lieutenant Maury, while Superintendent of the U. S. Naval Observatory, had collected all the log-books of vessels between the years 1840 and 1850, and averaging the data, gave to the public the results in a series of wind and current charts and sailing directions. After the first edition was published, he proposed a general Maritime Conference for devising a uniform system of observations at sea, and the meeting was held at Brussels in 1853. A plan of observations was adopted and the co-operation of nearly every nation assured. As a result, a mass of data was collected from which other editions of more elaborate charts and sailing directions were compiled. The charts were issued in condensed form by other governments, and his sailing directions, as well as his famous work entitled the "Physical Geography of the Sea," were translated into many languages.

It is stated in some recent works that it is difficult to ascertain from Maury's writings exactly what his ideas were as to the causes of the great ocean currents. He says in "Physical Geography of the Sea:"

> But they [modern investigations] seem to encourage the opinion that the Stream, as well as all constant currents of the sea, are due mainly to the constant difference produced by temperature and saltness in the specific gravity of the water in certain parts of the ocean. Such difference of specific gravity is inconsistent with aqueous equilibrium, and to maintain this equilibrium these great currents are set in motion. The agents which derange equilibrium in the waters of the sea, by altering the specific gravity, reach from the equator to the poles, and in these operations they are as

> ceaseless as heat and cold, and consequently call for a system of perpetual currents to undo their perpetual work.
>
> These agents, however, are not the sole cause of currents. The winds help to make currents by pressing upon the waves and drifting before them the water of the sea; so do the rains, by raising its level here and there; and so does the atmosphere by pressing with more or less superincumbent force upon different parts of the ocean at the same moment, as indicated by the changes of the barometric column. But when the winds and rains cease and the barometer is stationary, the currents that were the consequence also cease. But the changes of temperature and of saltness, and the work of other agents which affect specific gravity of sea water and derange its equilibrium are as ceaseless in their operations as the Sun in his course, and in their effects they are endless. Philosophy points to them as the chief cause of the Gulf Stream and of all the constant currents.

In another place, however, he says:

> The dynamical forces which are expressed by the Gulf Stream may with as much propriety be said to reside in those northern waters as in the West India seas; for on one side we have the Caribbean Sea and Gulf of Mexico, with their waters of brine, and on the other the great Polar basin, the Baltic, and the North Sea, the two latter with waters that are but little more than brackish.

This fact would of itself simply neutralize the differences in density due to heat, but later he expresses his conviction that—

> If we except the tides and the partial currents of the sea, such as those that may be created by the wind, we may lay it down as a rule that all the currents of the ocean owe their origin to difference of specific gravity between sea water at one place and sea water at another, for wherever there is such a difference, whether it being owing to difference of temperature or to difference of saltness, etc., it is a difference that disturbs equilibrium and currents are the consequence.

His belief was, then, in effect that differences of density caused the main currents, and that this might be modified by winds, rain, barometric pressure, evaporation, and the fauna and flora of the ocean.

CHAPTER III.

GULF STREAM INVESTIGATIONS MADE BY THE U. S. COAST SURVEY UNTIL 1884 AND THOSE CONTEMPORARY WITH THEM.

We have now reached the point in the history of Gulf Stream investigation where, for the first time, can be described a systematic and extensive examination into its secrets. Research had been going on for years in a casual way, data collected when chance offered, and at any point, but under the direction of no one who had the authority to say to the observers when, where, and how they should search. The scope of the Coast Survey only contemplated an examination of the Gulf Stream in the portions adjacent to the coast of the United States, but the laws have since been changed so as to include the Sargasso Sea and the Japan Stream, a study of these being considered advantageous to the commercial and scientific interests of this country and the world at large.

In 1842 a report was made by Admiral Sir Francis Beaufort urging the British Admiralty to undertake the work. The importance of an examination of the great rivers emptying into the Atlantic, to whose influence the Gulf Stream had been attributed, was suggested, and the details of a plan were given for a survey of the Stream from the Gulf of Mexico to the shores of Europe.

This plan proposed the employment of three steamers and one sailing vessel. One steamer was to remain in the Gulf of Florida for the purpose of keeping a continuous record of temperature and velocity at that point. The sailing vessel was to drift along in the axis of the Stream, while the other two steamers were to operate from the axis to the edges in conjunction with the sailing vessel.

When Prof. A. D. Bache assumed the direction of the Coast Survey, he formulated a complete method of administration and included in it the systematic exploration of the Gulf Stream. The plan first adopted, based upon the knowledge of the general features of the Stream, was as follows, but it naturally was modified by deductions and inferences from new facts which were brought to light as the Survey progressed:

I. To refer the observations to a medial line or axis, on each side of which it would be more or less similar in its temperatures, and to run sections perpendicular to this line across the whole width of the Stream.

II. To start from points on the coast whose positions are well known, and to determine by the best means known to nautical astronomy the position of the vessel at frequent intervals, and to check these results if necessary by a return to the coast.

III. To occupy positions at which the temperatures at different depths would be determined, the frequency of which would depend upon the greater or less rapidity of the change of temperature.

As regards seasons for explorations, the summer was regarded as the most favorable for the greater part of the Stream, for the reason that the winter season, at which time the storms and cold rendered observation more difficult, is also the season in which the equilibrium of the currents would be most disturbed by the rapid cooling of the water. Sounding in winter in stormy weather (with rope) was hardly practicable, and the results obtained were liable to great inaccuracies.

In the spring of 1845 the brig *Washington* was commissioned and placed under the command of Lieut. C. H. Davis, U. S. N., and the following instructions were given him. The first part is quoted almost in full, to show the clearness with which Professor Bache saw the details necessary for such an investigation in order to establish the laws of the Stream in the best manner with the instruments available at that time.

Professor Bache says:

> The following questions should be examined:
>
> First. What are the limits of the Gulf Stream on this part of the coast of the United States, at the surface and below the surface?
>
> Second. Are they constant or variable, do they change with the season, with the prevalent and different winds; what is the effect of greater or less quantities of ice in the vicinity?
>
> Third. How may they best be recognized, by the temperature at the surface or below the surface, by soundings, by the character of the bottom, by peculiar forms of vegetable or animal life, by meteorology, by the saltness of the water?

Fourth. What are the directions and velocities of the currents in this Stream and adjacent to it at the surface, below the surface, and to what variations are they subject? What peculiar arrangement of the currents takes place at the edge of the Stream in passing from the general waters of the ocean into those of the Gulf? Some of these questions will require long-continued observations to solve. If you can obtain something like approximation to the normal condition of the Stream in this summer's work it will be quite satisfactory. Make, then, as many cross sections of the Stream as convenient and as the investigation may show to be necessary. In these sections (1) determine the temperature at the surface and at different depths; (2) the depth of water; (3) the character of the bottom; (4) the direction and velocity of the currents at the surface and at different depths; (5) as far as practicable notice the forms of vegetable and animal life.

Project or note the results as obtained. In the diagram for the temperature at the surface the abscissa will correspond to distance, the ordinates to temperatures, upon a convenient scale arbitrarily assumed. The distance apart at which the observations should be made must depend upon the more or less rapid change of temperature; thus, on the borders of the Stream, they should be more frequent than on either side or within it. The diagrams of the scale of temperature, if made large, will be good guides to the work.

Examine the depth and character of the bottom at the same time. To determine the temperature at a great many depths and at or near the same position, will be difficult and tedious. To avoid the necessity for it, make a complete investigation of the change from the surface to the bottom, at as many points as may appear necessary; thus, for example, make an investigation on the several sections above referred to, on the following lines. Sound before reaching the edge of the stream two lines at or near the edge, two lines within, or as many as appear necessary, two at or near the outer edge and several beyond. As for the lines within the Gulf Stream which are the most interesting, the investigation will show how many will be required. The frequency of the observations in a given depth will be determned by the more or less rapid changes in temperature. Suppose a conjectural diagram to represent the results, the temperature changing rapidly near the surface about a point *a*, then slowly to a certain depth. A counter cold current being met at *b*, the change becoming rapid there, this low temperature ranging but slowly toward the bottom at *a* and *b*, the observations should be frequent. All the observations on depths and character of the bottom and temperature should be carried quite across the Stream.

It may and probably will turn out that there is a certain depth at which the temperature is invariable for the same position uninfluenced at least by season or by winds, and the assemblage of these points will give a line below the surface constant in direction and velocity, and to determine this will be a valuable practical result.

These sections, with the addition of lines run in the general direction of the Stream, will enable you to represent it on a chart in the usual way, showing the limits and axis, the velocity and direction and temperature at the surface and at any depth which is desirable as that of the line of invariable temperature. As to the character of the bottom, use the Stellwagen Cup and the apparatus which I have requested Lieutenant-Commanding Blake (if he can dispense with it) to send to you at New York. They may both answer the purpose. Characteristic specimens should be preserved, as heretofore, and duly marked with date and position. They will be arranged on your return to the office. The temperature at the surface obtain in the ordinary way or by using the instrument furnished to Commander Gedney last year, and which I shall speak of as the marine thermometer. The velocities and directions of the currents you should ascertain as far as practicable by comparing the positions determined by astronomical observations and by reckoning, by anchoring the vessel or a boat when such a thing is practicable, by the change of position in time of calm. The way of the vessel by Massey's Log.

The existence of a counter current of cold water from the poles below the warm current from the equator has been supposed. This current would produce a position of rest, in which if a heavy body attached to a light one at the surface were immersed, the light one would drift off down the stream of the superior current. If a light body were sent down to the counter current and then detached, it would rise at a point up the stream of the surface current. A boat might be anchored on it by attaching to it a body which would produce a considerable resistance to motion. Two boards put together crosswise would answer the purpose well. It may be that if there is no counter current the velocity near the bottom is so much checked as to cause a variation to be discernible in some such way.

The remainder of the instructions is devoted to details of observation.

Lieutenant Davis made two or three trips into the Gulf Stream, and although the means of observation were tentative on this first year's work, much valuable information was obtained.

In 1846 Lieut. George M. Bache, U. S. N., was detailed to continue the Gulf Stream investigation under practically the same instructions as his predecessor. After a summer's successful work in tracing the temperature across the Stream on three sections, the little vessel was overtaken by a hurricane off the North Carolina coast and Lieutenant Bache and ten of the crew were swept overboard by a sea and lost. The vessel managed to reach port almost a wreck, and the observations, made at such a cost in life, were preserved. Lieutenant Bache gave the name "Cold Wall" to the remarkable change in temperature usually found at what is supposed to be the inner edge of the stream, and he also confirmed the fact that there were alternations of hot and cold water across the stream.

In the following year the *Washington* was commanded by Lieut. S. P. Lee, U. S. N. His instructions contemplated tracing the axis of the Stream, and testing, on his return from the Gulf of Mexico, the existence of the cold wall south of Cape Hatteras. They also called for a resurvey of the section off Cape Henry in order to connect the series of observations made in different years. The observations made by Lieutenant Lee were in the main a confirmation of those of previous years. He found the alterations of hot and cold water, but their positions did not correspond. Lieutenant Bache found a second branch of the Gulf Stream separated by cold water, while Lieutenant Lee found more than one alternation, and the positions of the highest and lowest temperatures were different in the two years.

In 1848 the work was continued, but with improved means. Two Six's thermometers and two larger on the same plan were used, and also a metallic self-registering thermometer, designed by Mr. Joseph Saxton especially for this work. Instead of a sailing vessel, the U. S. steamer *Legaré* was commissioned under the command of Lieut. Richard Bache, U. S. N., and the section off Cape Henry resurveyed and a first examination of the Cape Hatteras section made. The observations of this year furnished data for comparison of the results obtained during three consecutive years on the Cape Henry sections, and were thought to develop the fact that, beginning with a minimum at the cold wall, the temperature rises to a maximum in the axis of the Stream, beyond which are two minima and two maxima.

After the observations above mentioned and until 1853, circumstances connected with the work of the Survey prevented the prosecution of Gulf Stream investigation, but in this year a party under Lieut. T. A. M. Craven, U. S. N., on board the steamer *Corwin*, was directed to run four sections across the Stream from Cape Canaveral, St. Augustine, St. Simon's Sound, and Charleston, and Lieut. J. N. Maffitt, U. S. N., on board the schooner *Crawford*, to run the sections from Charleston, Cape Fear, and Cape Hatteras.

In addition to copies of the instructions that had been sent to the former officers engaged in the work, Professor Bache also issued detailed instructions as to the special methods of prosecuting the examinations. The axis of the Stream or the point of highest temperature was to be traced by zigzags, by Lieutenant Craven, from Key West to Charleston, and afterwards as far north as the latitude of New York, and, with the exception of the latter, which was unavoidably prevented, all the work laid out was most faithfully executed. The soundings taken by both parties were with rope or by Massey's sounding machine, and from the depths obtained they supposed there were two submarine ridges running parallel to the coast. The soundings since taken with pianoforte wire have proved this to have been an error. The temperature curves obtained this year are of the same form as those previously found farther north, and in the duplication of the Cape Hatteras section it was found that the similarity of curve and the positions of the various warm and cold bands were remarkable.

It was concluded that there were alternations of temperature across the Gulf Stream, the cold water intruding and dividing the warm, making thus alternate streaks or streams of warm and cold water, and it was thought that the observations of Lieutenant Maffitt, on the Charleston and Cape Fear sections, showed a counter current where the cold streaks were found. That such is not always the case will be shown later in discussing the observations of the *Blake* in recent years. Professor Bache also decided that "the observations of this year have fully proved that in the Charleston section, and those south of it, the bands of cold and warm water are produced by the shape of the bottom of the sea." The progress of the explorations up to 1853 furnished data for the construction of a chart of the Gulf Stream from Cape Canaveral to the section off Sandy Hook, the alternations of temperature being shown by shading, the darker the shade the higher the temperature. (See illustration No. 37.)

The curves limiting the various bands were not in all cases drawn precisely through the points obtained on the several sections, but in no case but one was the distance from the point actually determined as great as the probable error in the determination of the points themselves. The bands appeared to be invariable in number and position. The supposed axis of the Stream (the highest temperature) was the best determined. The cold wall was the next best to that of the axis, and in the case of the other warm and cold bands the limits of uncertainty in their position at the point of crossing any section were less than half the average distance between the positions in that part of the section.

In 1854 it was thought to be desirable to continue the examination of the St. Simon's and Canaveral sections in winter for a comparison with the summer's work, and Lieutenant Craven was assigned to the duty. The temperatures obtained showed a remarkable dissimilarity of form from those of the summer. The thermometer at most of the positions was nearly constant from 20 to 100 or 120 fathoms, and below that depth it changed rapidly. At Canaveral the double division of the Stream was shown, but the first maximum was about 7 miles nearer the Cape than in 1853, and the second maximum was warmer. What would generally be taken by navigators as Gulf water was 65 miles from the Cape, "but there had evidently been some great disturbance of temperature just before these results were obtained."

Later in the year Lieutenant Craven investigated the Nantucket section, running a line SE. by S. from the Davis South Shoal light-vessel and making observations at about 20-mile intervals for a distance of 230 miles. He found the warmest water at this distance, which was 40 or 50 miles farther south and east in October, 1854, than it was in August, 1845. The alternations of warm and cold water were discernible, but, as in the case of the warmest, they were a greater distance off shore. In 1855 the work of research was continued, Lieutenant Craven running a section off Cape Florida in May, and Lieutenant Sands along the axis of the Stream in June, and also a section off Nantucket in October. The section off Cape Florida was completed successfully and the axis of the Stream followed as far as

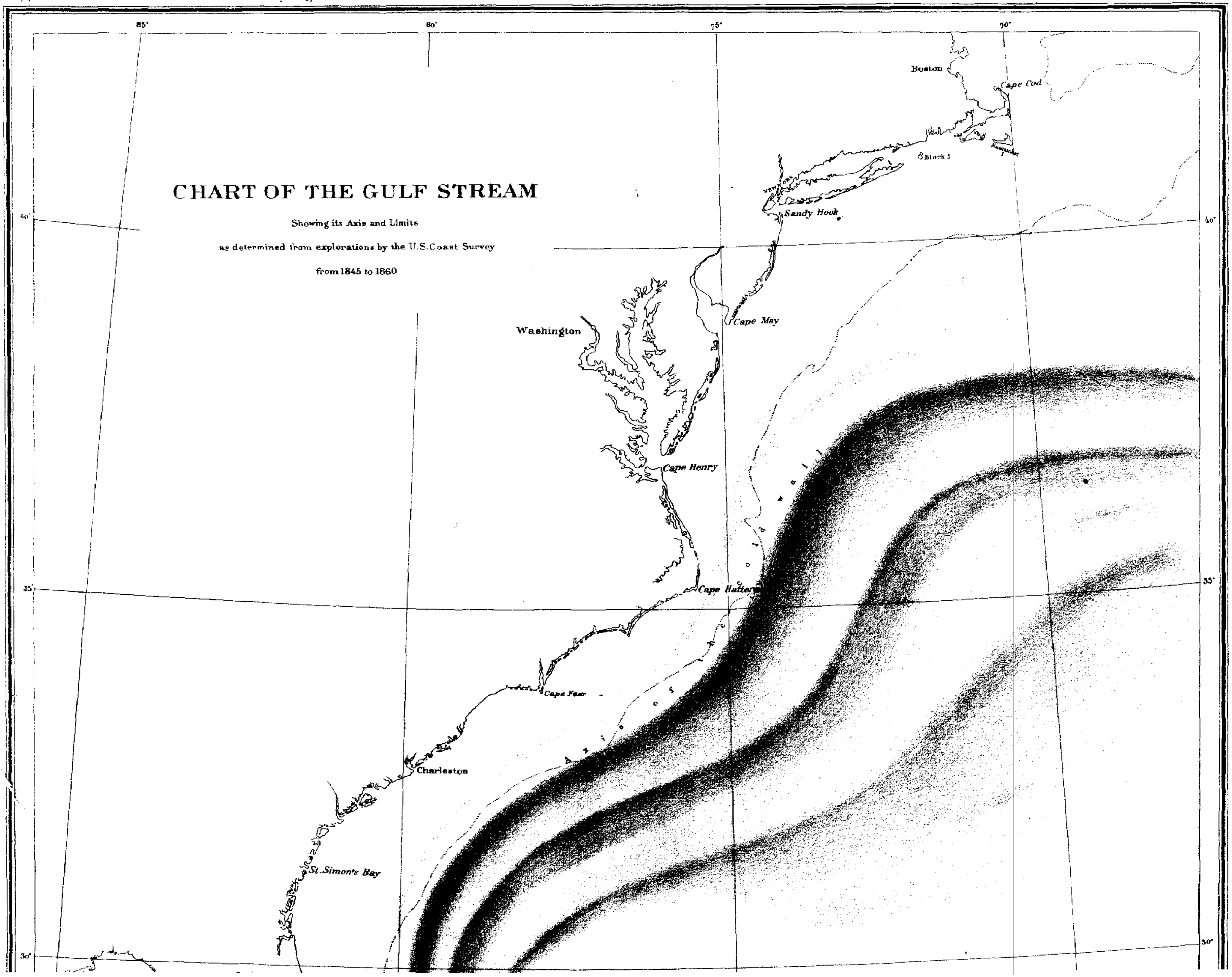
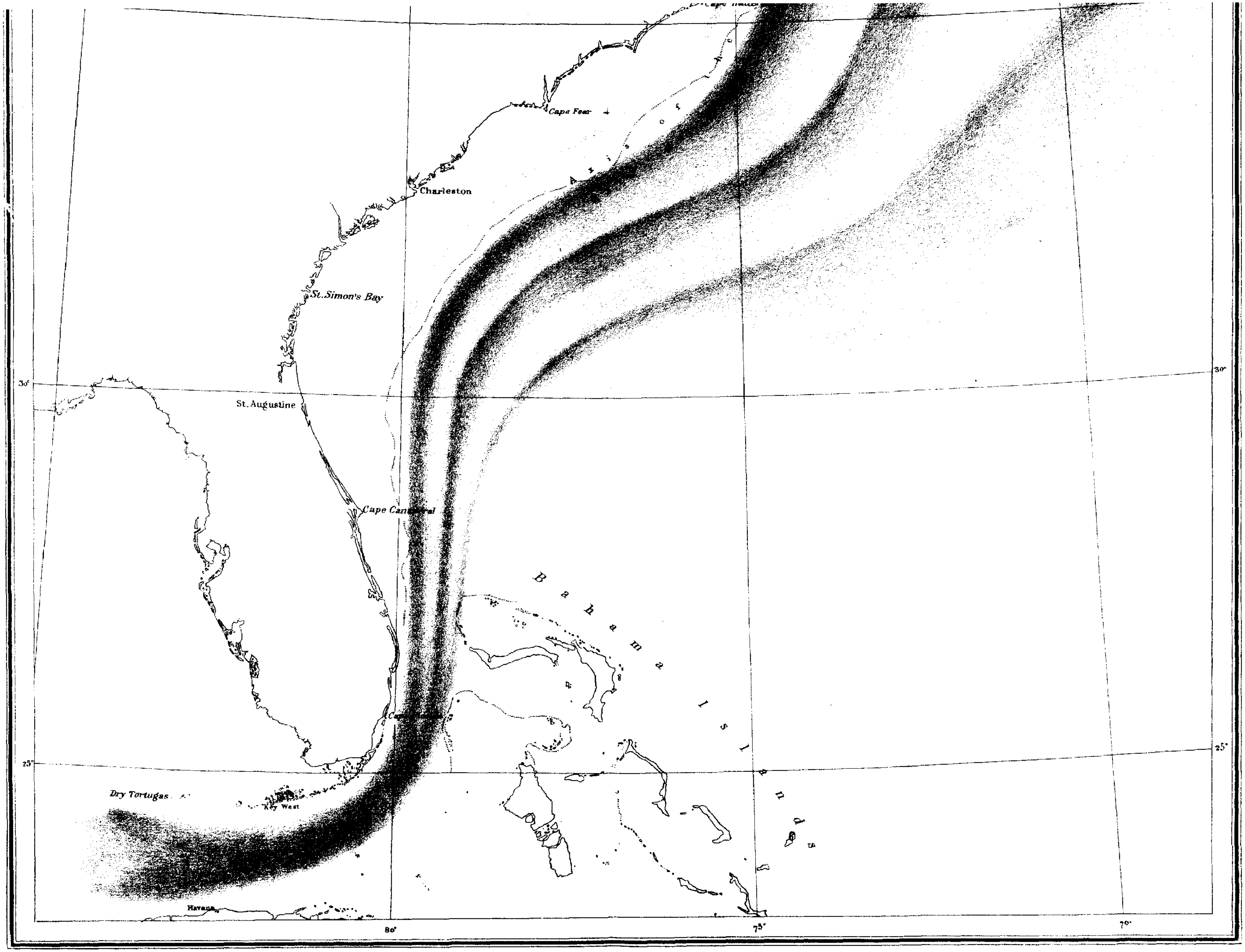


CHART OF THE GULF STREAM
Showing its Axis and Limits
as determined from explorations by the U.S. Coast Survey
from 1845 to 1860
85°
80°
75°
70°
40°
35°
30°
Boston
Cape Cod
Block I.
Sandy Hook
Cape May
Washington
Cape Henry
Cape Hatteras
Cape Fear
Charleston
St. Simon's Bay
Axis of the cold wall


Cape Fear
Charleston
St. Simon's Bay
St. Augustine
Cape Canaveral
Bahama Islands
Dry Tortugas
Key West
Havana
30°
25°
80°
75°
70°

Cape Lookout, but in the attempt to finish the Nantucket section only the warm water of the axis was reached. In 1857 a number of interesting observations were added to the Gulf Stream exploration. A section was run from Havana to Sand Key, Florida, the inner edge of the Stream was traced from Cape Canaveral to Cape Fear, the axis was traced from Tortugas to Cape Hatteras, and a line was run from Halifax in the direction of Bermuda. It was unfortunate, however, that the thermometers were not always in working order, as many temperature observations on both the Havana and the Halifax lines had to be discarded. During the next three years the work was chiefly confined to investigating the temperatures across the Straits of Florida.

Although the plan for the exploration of the Stream contemplated the determination of the density of the water and the direction and velocity of the currents, the actual work performed was the determination of temperature and depth. The existence of a polar current underlying and running counter to the Gulf Stream was assumed by Professor Bache, the assumption being founded mainly upon theoretical considerations, and not on actual current observations. Generally the only record of current was obtained by the difference between the dead reckoning and the astronomical positions of the vessels, as, for example, in the record of observations of one party it says:

> August 16.—A comparison of the afternoon with the morning sights for chronometer show a current of 5 miles eastwardly. The vessel was lying-to in the interval. The meridian observations showed a northerly current during the last 24 hours.

Another record was:

> August 18.—Tried the current with a boat anchored with 1,200 fathoms line (no bottom). Found it on the surface setting SW. by W. 0.29 mile per hour. At 25 fathoms depth, SSW., same velocity. This agrees with chronometer sights of morning and evening, the brig lying-to all day and drifting a little to the west with the sea.

The instruments employed in the investigation under Professor Bache were of the most approved patterns, were handled with the greatest care, and every observation scrutinized closely, but the difficulties against which they had to contend rendered the work very laborious and the results sometimes liable to doubt, which necessitated discarding the observation.

The thermometers were as follows: The self-registering instruments of Dr. Rutherford, of Edinburgh, and Six, of Canterbury; a metallic thermometer made by Breguet, of Paris, and another by Mr. Saxton, of the Coast Survey Office. Rutherford's is a minimum thermometer, the cohesion of the spirit drawing an enamel index to the lowest point reached by the contraction, where it is left as the fluid expands. To render it applicable to deep-sea temperatures it is inclosed in a glass globe made strong enough to withstand moderate pressures. In use it is necessary to keep the tube horizontal, which is not always possible. In using rope, too, for lowering, the centrifugal motion caused by the twisting or untwisting of the rope prevents accuracy or certainty of registration.

Six's thermometer is composed of a bent tube of glass, one of the branches terminating in a large expansion to form a cylindrical chamber and the other only slightly enlarged at the end. The lower part of the tube contains mercury, which partly fills both branches on either side of the bend. The upper part of each branch, including the chambers, is filled with highly rectified spirits of wine. A rise or fall of temperature will cause a greater expansion or contraction of the spirits in the larger end than in the smaller, which will cause the column of mercury in that branch to rise and fall, and thus a motion is communicated to its surface in both branches. A small index of steel, coated with glass and lightly held in place by a delicate spring, is pushed along by the surface of the mercury and remains at the farthest position when the mercury withdraws.

The Breguet metallic thermometer is constructed on the principle of the unequal expansion of metals. The compound bar is composed of laminæ of brass and steel united together and bent into horseshoe form. One end is firmly fixed and the other, being free to move under the influence of the unequal expansion or contraction of the two metals, gives rotary motion to an index and registers on a dial by means of an auxiliary hand held by friction at the highest or lowest point of temperature. The whole is inclosed in a brass case made sufficiently strong to withstand pressure.

The Saxton thermometer is the same as the Breguet in principle, but the laminæ are composed of silver and platinum and wound in a spiral instead of being bent into horseshoe form. It is heavily gilded and inclosed in a metal case, into which the sea water is admitted. According to our ideas at the present day these instruments were faulty.

The conclusions adopted by Professor Bache from the observations taken under his direction between 1854 and 1860 were as follows: That between Cape Florida and New York the Gulf Stream is divided into several bands of higher and lower temperatures of which the axis is the warmest, the temperature falling rapidly inshore and more slowly outside. This is not only the case at the surface, but, with modifications easily understood, at considerable depths. That between the coast and the stream there is a fall in temperature so abrupt that it has been aptly called the "cold wall." The cold wall extends, with varying dimensions and changes of its peculiar features, along the coast from Cape Florida northward as far as examined. Inside this wall of marked colder temperature there is another increase, while outside the warmest band, which is next the cold wall, there is another warm and one other cold band. The distances these are situated from the coast are shown in the following table:

Name of section.	Distance of cold wall from shore.	Width of first warm band.	Width of second cold band.	Width of second maximum.	Width of Gulf Stream proper.	Width of third minimum.	Width of third maximum.	Width of fourth minimum.
	Miles.	*Miles.*	*Miles.*	*Miles.*	*Miles.*	*Miles.*	*Miles.*	
Sandy Hook	240	60	30	37	127	60	50	Indefinite.
Cape May	125	55	30	40	125	70	65	70
Cape Henry	94	45	32	47	124	80	60	50
Cape Hatteras	30	47	25	45	117	37	75	70
Cape Fear	60	30	20	37	87	30	60	25
Charleston	62	25	15	30	67	26	35	----------
St. Simon's	87	25	13	20	58	25	25	----------
St. Augustine	70	20	13	12	47	22	20	----------
Cape Canaveral	35	20	------	------	35	14	12	----------
Cape Florida	------	25	------	------	25	5	------	----------

In the sections on which the work was duplicated, viz, the Cape Henry and the Cape Hatteras sections, the positions of the cold wall and axis of the Stream agreed within 5½ miles, and those of the succeeding points of maximum and minimum temperature within 7½ miles.

After the year 1860 Gulf Stream investigation ceased almost entirely until 1867, when Prof. Henry Mitchell of the Coast Survey sounded between Key West and Havana and observed the currents to the depth of 600 fathoms, the deepest ever attempted to that date. The method adopted to observe these currents was the following: Two globes or cans of equal surface were attached to each other by a line of the desired length. One of the globes was loaded so as to sink to the length of the connecting line, while the other was on the surface supporting its mate. Within the latter was a light reel upon which a small log line, passing through an aperture, was wound by a crank from without. To the end of the line was secured a third globe floating freely upon the surface of the water. When making an observation the log line was reeled in until the surface globes were together. At a signal the reel was released, and, if the currents influencing the two were different, the amount of separation in a given time indicated the relative velocities.

A trial was made of surface currents and at 300 and 400 fathoms depth, at a station 3.7 miles from Fort Chorrera, Cuba, and a velocity of about one knot was found at each. Another trial was made about 3 miles farther off shore, with the result, that at 600 fathoms depth the current was about 10 per cent. less than on the surface. From these experiments, Professor Mitchell was led to conclude that "the Gulf Stream has a nearly uniform velocity and constant course for a depth of 600 fathoms, although its temperature varies in this depth 40° F." In the following year Professor Mitchell continued current observations in the Santaren and St Nicholas Channels, using an anchored buoy for the initial point from which to start the float for service observations. His conclusion was that the water in these channels was motionless.

In 1868–'69–'70 expeditions were fitted out by the British Admiralty, and, under the scientific direction of Dr. William B. Carpenter, Mr. J. Gwyn Jeffreys and Prof. C. Wyville Thomson, sounded and dredged off the coast of Europe from the Faroe Islands to Gibraltar. Accurate temperature observations were taken, and from these Professor Thomson has given the course of the currents in what is called the northeastern extension of the Gulf Stream. By the term Gulf Stream he explains:

> I mean that mass of heated water which pours from the Straits of Florida across the North Atlantic and likewise a wider but less defined warm current, evidently forming part of the same great movement of water, which curves northward, to the eastward of the West Indian Islands. I am myself inclined, without hesitation, to regard this stream as simply the reflux of the equatorial current, added to, no doubt, during its northeasterly course by the surface drift of the anti-trades which follow in the main in the same direction.

Of the cause of the Gulf Stream he says: "It seems to me that the Gulf Stream is the one natural phenomenon on the surface of the earth whose origin and principal cause, the drift of the trade winds, can be most clearly and easily traced." He concludes that the Stream enters the North Atlantic and accumulates. Finding no free passage toward the northeast, a portion of it goes toward the Azores, but the accumulation to the northward forces a return eddy current to underrun certain portions of the warmer flow.

In 1873, the *Challenger* expedition, under the command of Capt. Sir George Nares, R. N., with a full staff of scientific gentlemen, of which Prof. C. Wyville Thomson was the head, added some most valuable data to the record of Gulf Stream investigation. They crossed the North Atlantic twice, and made passages north and south along the shores of both hemispheres, making the most accurate observations of temperature and specific gravity. In the passage of the *Challenger* across the Gulf Stream off New York, and between Halifax and Bermuda, the alternations of warm and cold water were found. They also at times made observations of the strength and direction of the currents, both surface and subsurface, using practically the same method as that employed by Professor Mitchell in the Straits of Florida in 1867.

The Coast Survey continued its examinations in the Gulf Stream in sounding and dredging during the years 1868 to 1878, with the steamers *Bibb*, under Acting Master Robert Platt, U. S. N., the *Bache*, under Commander J. A. Howell, U. S. N., and the *Blake*, under Lieut. Commander C. D. Sigsbee, U. S. N. Mr. L. F. Pourtales and Prof. Louis Agassiz accompanied the vessels at different times for the purpose of collecting and arranging the results of the dredging operations. In 1879 the investigation was extended into the Caribbean, and a theory advanced as to the flow of its waters by Commander John R. Bartlett, U. S. N., who commanded the vessel.

In his report accompanying the record of the season's work he concludes that the equatorial current, which sets directly against the Windward Islands, is by them and their connecting ridges deflected northward, and so following their outer edge passes around the Virgin Islands to the westward and through the deep channel to the northward of San Domingo. He suggests, also, that on reaching Cuba the current divides, a part flowing northwest through the old Bahama Channel and a part through the Windward passage between Cuba and San Domingo, and thus by Cape San Antonio into the Gulf of Mexico. His report states that the specimens of bottom taken in the Windward passage give evidence that the current moves in depths greater than 800 fathoms and that it reaches the bottom. He remarks, too: "The current, always found flowing north along the eastern side of South America, on reaching the island of Tobago divides, part joining the equatorial current setting north along the chain of islands, the remainder following the coast line of Trinidad and the Spanish Main, and so around the entire circumference of the Caribbean Sea, finding at last an outlet at the Mona Passage and the Anegada Channel to join the equatorial current on its way to the Gulf of Mexico." This circulation is so contrary to that found in the later investigation made by the *Blake* that it is given in full. Prof. Alexander Agassiz accompanied Commander Bartlett on this cruise, and while he quotes the latter on this subject he does not seem to adopt these ideas without question, for he says: "In the present state of our knowledge it is difficult to trace the path of the equatorial water as it is forced into the eastern Caribbean."

In 1877 the first attempt was made by the U. S. Coast Survey to systematically observe ocean currents from a vessel anchored at sea. The schooner *Drift* was built for this purpose, and under command of Acting Master Robert Platt, U. S. N., successfully observed the currents between Nantucket and Nova Scotia, occupying eight stations for varying periods, the longest time being over 90 hours and the greatest depth of water 135 fathoms.

The first reliable soundings which developed the bed of the Gulf Stream from the Straits of Florida to George's Bank were made by Commander Bartlett in 1881 and 1882. It will be remembered that the soundings by Lieutenants Davis, Lee, Craven, and others before 1860 were made with rope or registering devices, such as Massey's, and when these are used in a strong current or in considerable depths they are unreliable. Commander Howell, when in command of the Coast Survey steamer *Bache*, was provided with one of the Thomson wire sounding-machines, which had been so successfully used by Captain Belknap on board the U. S. S. *Tuscarora* in the Pacific. The principle of sounding with piano-forte wire was much improved by his successor, Lieutenant-Commander Sigsbee, so that any depth could be ascertained with certainty and accuracy in almost any weather, and since that time the *Blake* has used nothing else for the purpose.

Commander Bartlett ran lines about normal to the coast at intervals of 60 miles from Jupiter Inlet north. He says:

> Instead of a deep channel which had previously been reported, our soundings show an extensive and nearly level plateau extending from a point to the eastward of the Bahama Banks to Cape Hatteras. Off Cape Canaveral it is nearly 200 miles wide, and gradually decreases in width to the northward until reaching Hatteras, where a depth of more than 1,000 fathoms is found 30 miles off the shore. This plateau has a general depth of 400 fathoms, suddenly dropping on its eastern edge to 2,000 fathoms. The soundings in the strength of the current were all taken with a 60-pound shot, the time allowed for the sinker to reach the bottom being less than one minute to each 100 fathoms in depth.

In the lines crossing the Stream from Nantucket to Bermuda and returning to Cape Hatteras, Commander Bartlett took serial temperatures at short intervals and surface observations every mile. He says:

> In regard to the results of the investigation of this last season's work, I have been particularly interested in what I was expected to find—that is, the bifurcation of the stream into warm and cold bands. The warm and cold bands have been accepted for so long a time as a fact and have been reported by such reliable authorities that there must have been different conditions of weather during our observations. I have already stated that our observations did not indicate anything of the kind.

In 1883 Lieut, J. C. Fremont, jr., U. S. N., in command of the schooner *Drift*, was detailed for the first Gulf Stream current investigation to be made from a vessel at anchor. The vessel was supplied with 700 fathoms of galvanized wire rope three-quarters of an inch in diameter, and instructions issued to observe currents at various places near the 100-fathom curve along the coast, and also in the stream between Jupiter Inlet and Memory Rock. The *Drift* is a small deep-draft schooner of about 100 tons. Not being fitted with a steam windlass, the rope, which was coiled on deck, was veered and hove in by hand. In spite of this, Lieutenant Fremont succeeded in occupying five stations across the channel, the deepest anchorage being over 400 fathoms. The currents were observed by floating cans attached to a log line. It was discovered that, "contrary to expectation, the greatest velocity was not found at the supposed center of the stream, but somewhat to the westward of it. The greatest velocity noted was 4.7 knots in latitude 27° 05′ north and longitude 79° 44′ west. The depth here was only 190 fathoms, the distance west from the supposed axis 10 miles, and from the Florida coast about 20 miles."

Before beginning the description of the *Blake's* examinations of the Gulf Stream under my command there is one other investigation to which allusion should be made. His Highness the Prince of Monaco during the past years has been engaged in scientific researches on the coast of France. The object of his examination was primarily for the purpose of discovering the cause of the departure of the sardines from the Bay of Biscay; but in connection with this he has devoted much of his time to a study of the eastern portion of the Gulf Stream. In order to discover the velocity and direction of this current he adopted the method of floats, but carried it out in a manner and magnitude never before attempted. His floats were barrels and bottles to a limited number, but mostly were specially constructed copper globes, and all were ballasted so as to expose as little surface as possible to the wind and waves. The ballast of the barrels and globes was suspended several feet below the surface of the water, and so arranged that by the time the float accumulated a quantity of material (barnacles, grass, etc.) the ballast would become detached.

He put overboard from his yacht no less than one thousand six hundred and seventy-five of these floats. In 1885, one hundred and thirty-nine in a distance 170 miles northwest of Azores. In 1886, over five hundred more were placed along the twentieth meridian off the coast of France. In 1887, nine hundred and thirty-one were set adrift between the Azores and Newfoundland, and afterwards another line farther to the northward and eastward in the region of the supposed northeast extension of the stream near the fiftieth parallel. Dividing each of the lines into thirds for purposes of study, he found that most of the floats traveling to the southward came from the southward and middle groups, and of those going to the northward and eastward most of them belonged to the northern groups, but there were some from each group which had traveled in the opposite directions. Of those placed between the Azores and Newfoundland, one from near the northern end of the line and one from near the middle were found in Ireland, others from near the same points traveled to the coast of Norway, and more were distributed along the shores of France, Spain, and Africa. None of those started near the Azores were found north of Lisbon. Two of those from the northern end of the line off the coast of France found their way to the West Indies.

CHAPTER IV.

OUTFIT OF THE BLAKE FOR ANCHORING AT SEA AND OBSERVING THE CURRENTS.

From this brief history of the Gulf Stream investigation it is seen that all the theories as to causes, and all the facts as to limits, velocity, and direction have been based entirely upon drift of vessels, or inferences drawn from temperature observations, character of the bottom soil, presence of Gulf weed, tide rips, etc., the best of them only giving evidence of the existence of a current when it is strong, and not one of them giving anything conclusive or accurate as to velocity or direction, or an indication even of a regular variation either daily or monthly. The establishment of the axis of the Stream by the thermometer was at once proved to be an error, by Lieutenant Fremont's observations, and it has since been found that a current may be flowing south with a much warmer temperature than when, a few hours later, it is flowing north. It will be shown, too, that while a warm current may be flowing in its customary place, its warm water may be transported by the winds and waves to other localities, without an accompanying current. A conclusion drawn as to the direction or velocity of a current based upon temperatures is very apt to be wrong, unless expressed in the most general terms.

The drift of vessels, while showing the existence of a current within certain limits is open to many objections. When in sight of known objects on land and in the smoothest water, the determination of the difference between the actual and the supposed run of the vessel does not accurately show the current. The errors in steering, of the compass and log, of plotting on a chart distorted by unequal shrinking in the process of manufacture, all tend toward error. How much less the chance of accuracy when a vessel is at sea, the winds and waves driving her to leeward to an unknown amount, the motion of the vessel swinging the compass, the personal error or lack of judgment in the helmsman, the faulty astronomical position, never true except by chance, and often miles out, and last, the patent log, varying in accuracy with the speed of the ship and the height and direction of the waves. The surface current too is continually changing, and even if the drift of vessels did, by rare good luck, give the current from the time of one fixed astronomical position to the next, the positions are separated by so wide an interval of time that it is impossible to detect even the daily variation. The necessity, then, is obvious, that in order to gain a knowledge of the limit, velocity, direction, variations, and laws of any current, observations must be taken from a fixed point within the current.

In attacking the problem of the Gulf Stream, so important to all the commercial interests of the United States, and indeed to most of the civilized world, the Superintendent of the Coast and Geodetic Survey, Prof. J. E. Hilgard, authorized the attempt to anchor off Jupiter Inlet. Commander C. M. Chester, U. S. N., the Hydrographic Inspector, carried out the scheme, and the valuable observations of Lieutenant Fremont were the results. Although this attempt at arriving at a knowledge of the actual flow of water was made with inadequate instruments, at a considerable expense of time and money and under great difficulties, it was the greatest stride toward a solution of the problem that had been made. The use of a sailing vessel for the purpose was found to be impracticable. The long delay in arriving at the station when good weather appeared, and the fact that this was impossible in a calm, which was the very time when observations would be most accurate; the long hours necessary in heaving up the anchor by the hand windlass, and the danger to the vessel during this delay if bad weather was the cause of departure, all of these reasons brought about the decision that in the continuation of the work a fully equipped steamer should be used. The *Blake* was decided upon, as she was a substantial steamer, and, having the hoisting engines, reels, etc., used for dredging, a slight change in outfit would prepare her for anchoring.

As before stated, the surface of the ocean is most liable to fluctuations, and it would be necessary to go below the surface and ascertain what were the movements of the volume of the water in order to determine the laws of the flow. Upon being detailed for the command of the vessel in the summer of 1884, permission was readily granted the writer to try new methods of search, to fit the vessel for the work as he desired, and to have a current meter of his own design constructed for trial. The *Blake* (frontispiece) is a wooden schooner-rigged steamer of 218 tons, new measurement, built at Baltimore in 1873. Her length on the keel is 139 feet; greatest beam, 29 feet 6 inches. She has compound engines, giving her a speed of about 200 miles per day under favorable circumstances, on a consumption of coal of but little over 4 tons. In the dredging operations on board this vessel under former commanding officers steel-wire rope had been used and the jerking strains eased by means of a rubber accumulator. The working gear, however, was only called upon to withstand a maximum strain at any point of but little more than the breaking strain of the dredge rope, which was from 5,000 to 8,000 pounds. The first thing to do, therefore, in preparing for the cruise was to fit the vessel so that the operation of anchoring could be performed expeditiously and with safety. From motives of economy all the parts of the gear used for dredging that could be utilized were tried in the first anchorage, but changed in arrangement to meet the new requirements. The idea always kept in mind was that none of the parts should receive an undue share of strain, and that as far as possible the mast and booms should receive the force exerted upon them in the direction of their length.

The anchoring boom.—This is a hard pine spar 30 feet long and 13 inches greatest diameter, slightly tapered in both directions from the middle and banded with iron every 3 feet. At its outer extremity is a heavy iron band, into which is shackled the topping-lift on the upper side, and the pulley for the anchoring rope below. Just inside this band is another with eyes on the sides, to which are shackled the guys. At the inner end of the anchoring-boom there is a ball-and-socket joint, the socket being placed on the pawl-bitt 7 inches to starboard of the middle line, in order that the boom shall be clear of the head stays when it is secured on the knightheads.

Extending from the pawl-bitt are two smaller spars (see illustration No. 38), 8 inches in diameter, which project over the vessel's side and serve as spreaders for the guys which hold the head of the anchoring boom in its proper position laterally. They are so placed that a line joining their outer extremities shall pass through the center of the ball at the heel of the anchor-

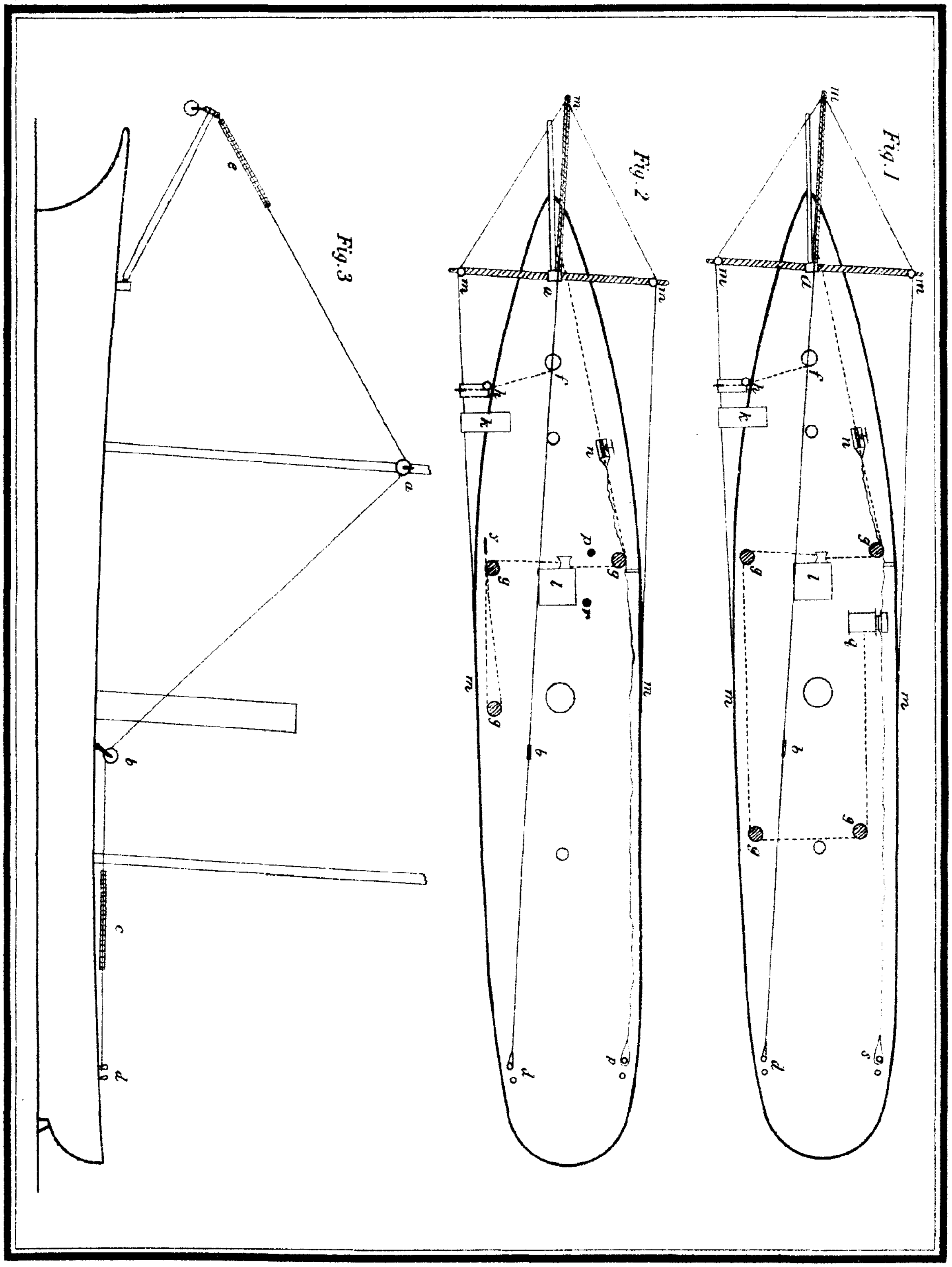


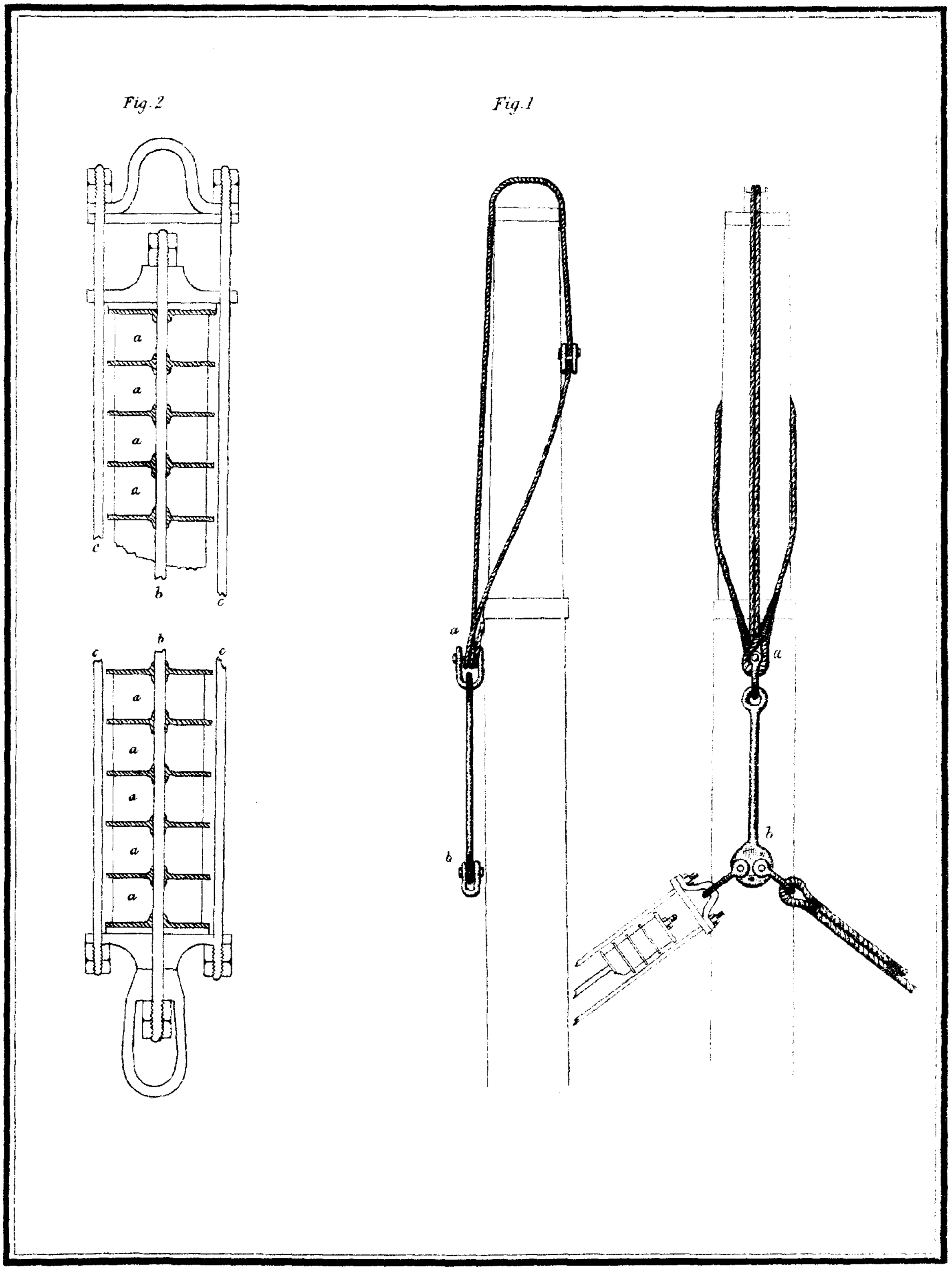
DIAGRAM SHOWING LEAD OF ANCHORING GEAR STEAMER BLAKE ing boom, and shall be at right angles to the plane of the latter's vertical motion. The outriggers or spreaders are held in position by straps at their heels, lashings at the rail, and at their outer ends steel-wire rope jumper-stays, set up by turnbuckles to heavy bolts in the ship's side near the water-line. The guys (*m. m. m.*) are of steel-wire rope five-eighths of an inch in diameter, shackling to the horizontal eyes at the head of the anchoring boom, passing through leaders at the ends of the outriggers, and setting up by heavy turnbuckles to wire-rope straps at the warping chocks on the main deck. The guy-leaders are iron sheaves, 6 inches in diameter, made to shackle to the wire-rope strap at the ends of the outriggers.

The accumulator and topping-lift.—The end of the anchoring boom projecting over the bow is held up at an angle of about 45 degrees (when with no weight other than its own) by a steel-wire rope topping-lift 1 inch in diameter passing to the foremast head, thence through a leader on the deck, and aft to the bitts on the port quarter (see Fig. 3, illustration No. 38). Interposed in this topping-lift is a rubber accumulator for the purpose, as already stated, of relieving the anchoring rope and the vessel of the sudden jerking strains due to the pitching. The bolt *b*, placed in the deck for the change of direction of the topping-lift, is situated so that when the anchoring boom is pulled down with the greatest strain allowable, the angle formed by the two legs of the topping-lift at the masthead shall be bisected by the mast. The anchoring boom being out of the middle line of the vessel to starboard, the topping-lift leads to the port side of the masthead, so that the boom, the masthead, and the bolt in the deck, previously mentioned, are all in the same vertical plane. When in use the boom is held by its guys in this same plane, and thus the strains give only a downward thrust on the mast (see *d. b. a. m.* Fig. 1, illustration No. 38). The horizontal angle made by the plane of the topping-lift with a vertical plane through the keel is about 11 degrees, and consequently the axis of the socket at the pawl-bitt points to starboard by this amount.

The accumulator, shown in illustration No. 39 is an arrangement of rubber springs devised by Lieutenant-Commander Sigsbee for use in dredging, and afterwards changed in some ways to meet the new requirements in anchoring. It consists of a number of rubber disks or buffers on a middle rod, so arranged that by compression they act as a spring. The middle rod *b* (Fig. 2, illustration No. 39) is $1\frac{1}{4}$ inches in diameter, and the side rods *c* 1 inch, all of tool steel. The rubber buffers *a*, cylindrical in shape, are 5 inches in diameter, $2\frac{1}{4}$ inches in thickness, with a cylindrical hole through the middle $1\frac{5}{8}$ inches in diameter. These buffers are separated from each other by a brass disk or washer $7\frac{1}{4}$ inches in diameter and one-eighth of an inch in thickness except at the middle, where an increase in the thickness of the metal gives a bearing surface as they slide on the rod, and at the same time prevents the rubber from grasping the rod as it is compressed. The diameter of the washers, it will be noticed, is over 2 inches larger than the rubbers. This is to give the latter a bearing surface as they expand in diameter when under strain. There are 70 rubbers in all, which will admit an effective compression of about 5 feet. The composition is known as "No. 23" by the New York Belting and Packing Company, from whom they have always been purchased.

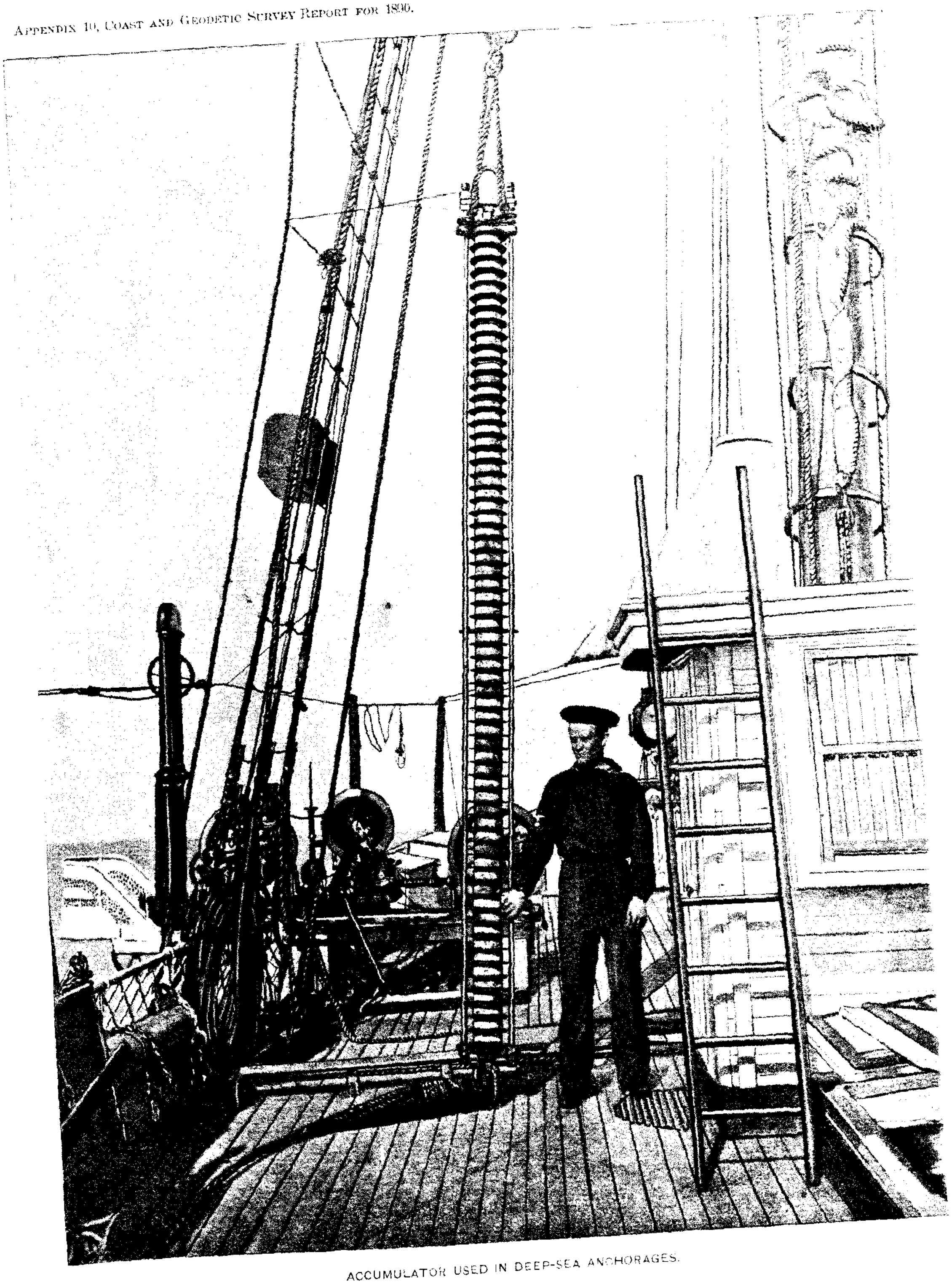
In assembling the different parts of the accumulator the middle rod is lubricated with black lead and tallow, care being taken not to allow it to get on the rubbers. Exposure to the sun causes the surface of the rubbers to crack slightly, and undue compression, causes an extension of the cracks. In order to prevent undue compression an additional wire rope, shown on the frontispiece, is shackled to the upper end of the accumulator and to the outer end of the anchoring boom. This rope (five-eighths of an inch in diameter) is called the preventer topping lift, and is of such a length that it will take the strain when the boom is pulled down before the rubbers are compressed to a dangerous limit. Except with a large anchoring rope the danger is but little with new rubbers, but as they become old they are liable to split.

In the first trial of the anchoring gear the topping lift passed over a large leader at the foremast head, and the accumulator was interposed in its after leg, as shown at *c*, Fig. 3, illustration No. 38. The play of the wire rope over the pulleys *a* and *b* caused the wires in the strands to break in a very short time. Fortunately it was discovered in time to prevent accident, when after a night of heavy pitching over sixty were found broken at *a* and more



DETAILS OF THE ACCUMULATOR USED IN DEEP-SEA ANCHORAGES.

STEAMER BLAKE



ACCUMULATOR USED IN DEEP-SEA ANCHORAGES.

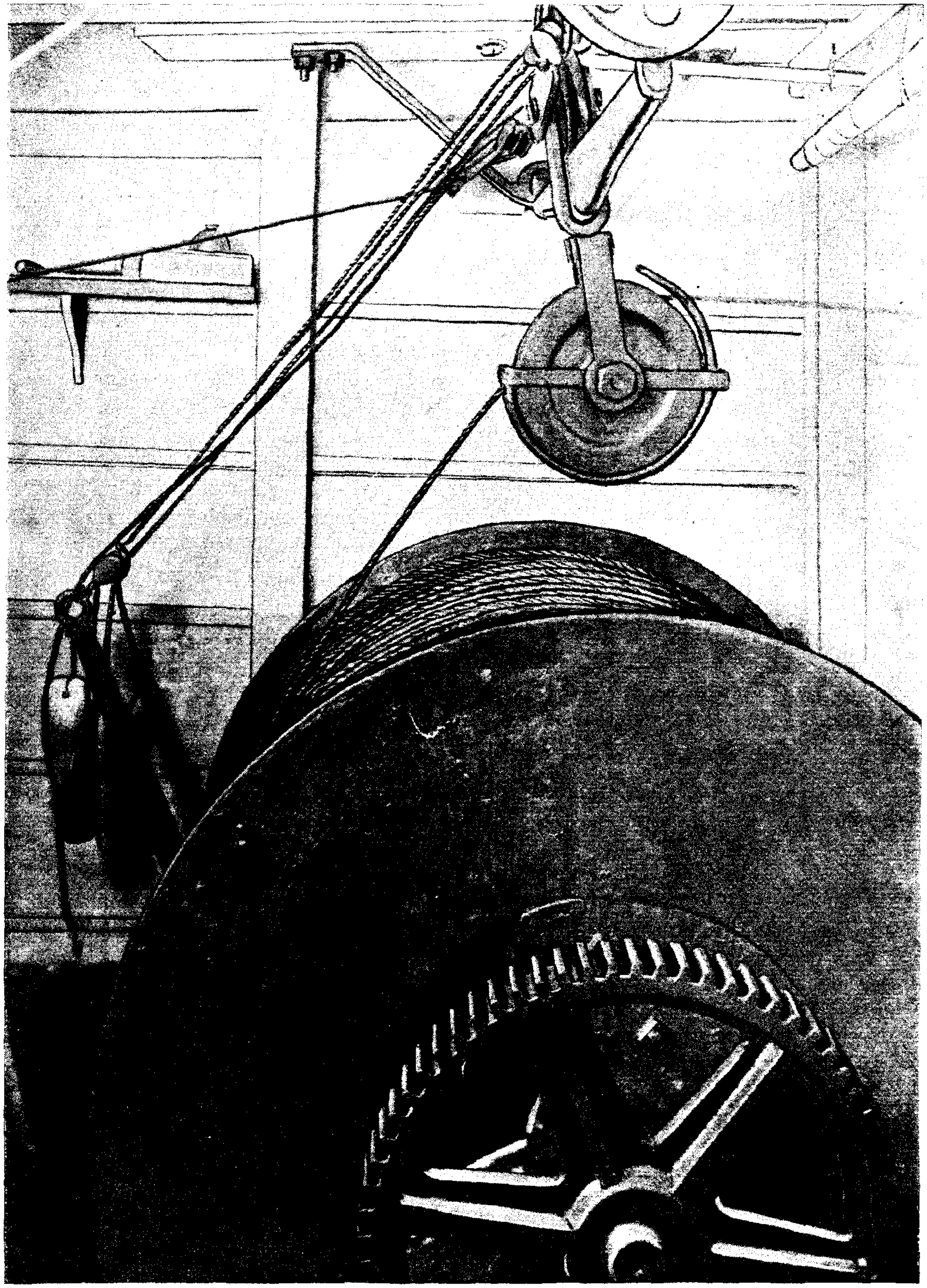
at *b*. The accumulator was then changed from *c* to *e*, but this position was not satisfactory, as it was very difficult to examine and oil the side rods when in use. It was then placed at the masthead, in which position, by a foot rope from the fore-rigging to the stay, a man can easily reach it. (See frontispiece.) The change of the accumulator to forward of the foremast did not entirely remedy the danger of stranding the topping-lift. The sudden relief of strain due to pitching caused sufficient sag in the two parts of the lift to give a slight motion over the pulleys, so another device was adopted, which accomplished the desired end.

From the sling at the foremast head is a bar of iron (*a b*, Fig. 1, illustration No. 39), 3 feet long and $1\frac{1}{2}$ inches in diameter. The two parts of the topping-lift, or, rather, the after-leg of the lift and the accumulator, shackle into this pendulum, and any change of strain simply vibrates it slightly back and forth. The part of the topping-lift from *b* to *d* (illustration No. 38), being a short length, causes but little vibratory motion at *b*, and consequently a long pendulum at the latter is unnecessary, and a shackle a foot long between the pulley and the deck bolt filled all requirements. In fitting the topping-lift there are no splices except on the forward leg at the accumulator, this one being necessary to prevent chafe on the forestay. The three other ends are turned up and seized. The length of the after-leg, of course, must be just sufficient to allow the pendulum at the masthead to assume a position exactly in line with the mast, when the strain is greatest.

The anchoring rope.—On the first cruise, in 1885, there was a quantity of old dredge rope on board (some 4,000 fathoms), and an attempt was made to use it, but it was quickly found to be altogether too weak. Of the wire rope purchased for the *Drift's* trial about 500 fathoms remained, and this had been taken on board before sailing. It was three-quarters of an inch in diameter, and this, supplemented by 300 fathoms more, five-eighths of an inch in diameter, was used in the first season's work. It answered very well, but was too large for the vessel. In a strong and deep current the skin friction on the wire is very great, and this causes a strain on the accumulator, which increases very rapidly as the size of the rope is increased. It was thought advisable to diminish the diameter in the next purchases, and after the experience of one more season the size finally adopted was a tapered rope, the inboard end being one-half inch, and the outboard seven-sixteenths and three-eights. The latter is perhaps a trifle small for all conditions, but it always held the vessel unless it was badly kinked.

This rope was manufactured by the Warrington Steel Works in England for the *Blake*, through the agents of the company, Hinkley Brothers & Co., of Boston. The specifications demanded the greatest breaking strain for the size, with no indication of brittleness in splicing, and clean and smooth galvanizing. Great pliability was not essential. The breaking strains guarantied were $\frac{3}{8}$-inch, 14,560 pounds; $\frac{7}{16}$-inch, 19,040 pounds; $\frac{1}{2}$-inch, 25,700 pounds; $\frac{5}{8}$-inch, 34,660 pounds, and no tests made have fallen below these figures. For convenience in transportation it is coiled on a rough reel in lengths no greater than 2,000 fathoms. The splices, made on board, are about 20 feet in length and are usually so smooth that it requires close inspection to detect where the ends are tucked. As received from the manufacturer there is a tendency to kink, and it frequently happens if the current is weak that the rope is paid out faster than the vessel drifts, and instead of being straight from the anchor, a few fathoms will be loose on the bottom. When a strain is brought on it in this condition the kinks straighten and the rope is weakened. This is not objectionable when the kinks are near the anchor, for in the event of the anchor becoming caught on the bottom, necessitating the breaking of the rope, this will occur with the least loss of material. Each time the anchor is hove up the lay of the rope as it is pulled through the water acts as a screw and the twist of the rope is taken out. After long use this process has gone to such an extent that upon slacking the rope it takes a reverse kink, and then, upon straightening under strain, the rope is easily broken.

The reel on which the wire rope is carried is shown in illustration No. 41. It has cast-iron flanges 4 feet in diameter between which is riveted a boiler-iron barrel 2 feet in diameter and 4 feet long. One of the flanges is provided with an ordinary strap brake lined with oak to control its revolutions. Within the barrel are two oak diaphragms bearing against its interior surface to support the crushing strain due to the accumulation of pressure as the turns of rope multiply on the outside. At one end of the shaft is a compact double engine, geared about 5 to 1, for revolving the reel in either



REEL CARRYING ANCHOR ROPE, STEAMER BLAKE.

direction. This reel was originally placed on the upper deck at the point g, fig. 1, illustration No. 38, and the lead of the wire rope is shown by the dotted line through the pulleys $g\ g\ g$ to the large hoisting engine l, thence through the pulley g to another at the heel of the anchoring boom at a. The last mentioned is for the purpose of giving the rope a straight lead along the line of the boom.

The great weight of the reel and rope on the light upper deck of the vessel made it impossible to keep the deck tight and caused considerable unnecessary strain on all the upper works. It was therefore determined to place it below, and for this purpose a space was bulkheaded from the bunkers, the reel and engine firmly secured to the keelsons, and fittings made for guiding on the wire properly. (See illustration No. 41.) In order that the control of the reel might be from the deck under the immediate supervision of the officer in charge, the throttle governing the engine was placed at r, and the line from its strap brake passed through the two decks in a tube at p (fig. 2, illustration No. 38). These are seen on illustration No. 42 also. The lead of the wire rope then is from the reel to the starboard hold across the vessel, and changing direction through the decks, appears at a vertical pulley at y, fig. 2, afterward following the dotted line through the pulleys $g\ g\ g$. It is seen by this arrangement that during the operation of anchoring or heaving-in the rope is always taut, the engine at the reel holding back from the hoisting engine and winding up the wire as fast as it is pulled in. This was the result of the experience of Lieutenant-Commander Sigsbee, who started the dredging operations, and who found, after many trials, that it was necessary in handling the wire rope to allow no slack between the hoisting engine and the reel.

The hoisting engine (illustration No. 42) is a most compact engine of about 30 horse power, driving a winch head by means of gearing of $3\frac{1}{2}$ to 1. Formerly the circumference of this winch head was 6 feet and revolutions were registered by means of a counter reading up to 10,000. It was found to be inadequate to the work in deep water and a strong current. One was ordered, therefore, of $4\frac{1}{2}$ feet in circumference, the register being so altered as to still read fathoms, and this one is now used. The grinding of the high tempered steel wire rope on the winch head renders it inadvisable to use iron at the wearing surface, and for this reason it is made with a steel ring on a cast-iron hub. Formerly the winch head was fitted with a strap brake for controlling the wire in paying out, the break at the reel being insufficient. This has been discarded and the engine alone used for the purpose. With but little weight of rope out, steam is used to drag it from the reel below. As the weight overboard increases steam is shut off. Increasing still more, the link is reversed notch by notch until it is entirely over. The steam chests are fitted with relief valves. When the engines are reversed and the strain on the rope is not quite enough to revolve the winch head against the compression of air in the cylinders, these are opened slightly and gradually closed as the strain becomes greater. A still greater strain is controlled by the admission of a little steam into the cylinders, and an increase of this stops the revolutions altogether.

The anchors.—Probably the best for use under all circumstences is what is known as a "Cape Ann" anchor. It is of very long shank, fairly large palms, and long wooden stock, and whenever an anchor was purchased for the *Blake* this pattern was selected if possible. The stock must be of hard wood, as the compression of a soft wood stock at great depths causes its loss. In coral rock bottom any anchor will answer, for it is only at a crack or coral head that it will nip, and an old condemned anchor of the ordinary type is as effective as the most costly new one, but in soft bottom the "Cape Ann" is the best. The weight used is generally from one-quarter to one-third the weight of the starboard bower, 400 to 500 pounds.

The pulleys.—Those at the anchoring boom end and on the starboard side of the hoisting engine, taking as they do the greatest strain in heaving up, are made very heavy. They are 24 inches in diameter with a 2-inch score, 3 inches thick at center, the pin of steel $2\frac{1}{2}$ inches in diameter, an oil cup in the end communicating with channel ways, and the pin hole bushed with brass. The straps are very heavy and made to shackle to their bolts. The pulley at the boom end has flat iron sides connected by socket bolts to prevent the anchoring rope from jumping between the sheave and strap. The other pulleys are of the same diameter, but less in thickness, and with pins $1\frac{1}{4}$ inches in diameter. All of those on the deck are provided with wooden beds, which hold them at the proper angle to receive and deliver the rope.

HOISTING ENGINE AND DECK OF STEAMER BLAKE.

The clamp.—In order to relieve the hoisting engine of the strain, when the vessel is at anchor, a heavy screw vise rests on a bed at *n*, Fig. 1, illustration No. 38. It is provided with brass jaws having scores cut in their faces to fit the various sizes of rope, and in order to allow its removal when not in use, it is not made a permanent fixture to the deck, but is attached by a long wire rope pendant to the bitts on the starboard quarter. Resting as it does immediately beneath, and with the opening between its jaws fair with the anchoring rope, it is only a moment's work to bear the latter into the score and set up on the screw. When the vessel is rolling heavily, the clamp, not being bolted to the deck, is apt to capsize, and for this reason the sling is made which shows on illustration No. 42.

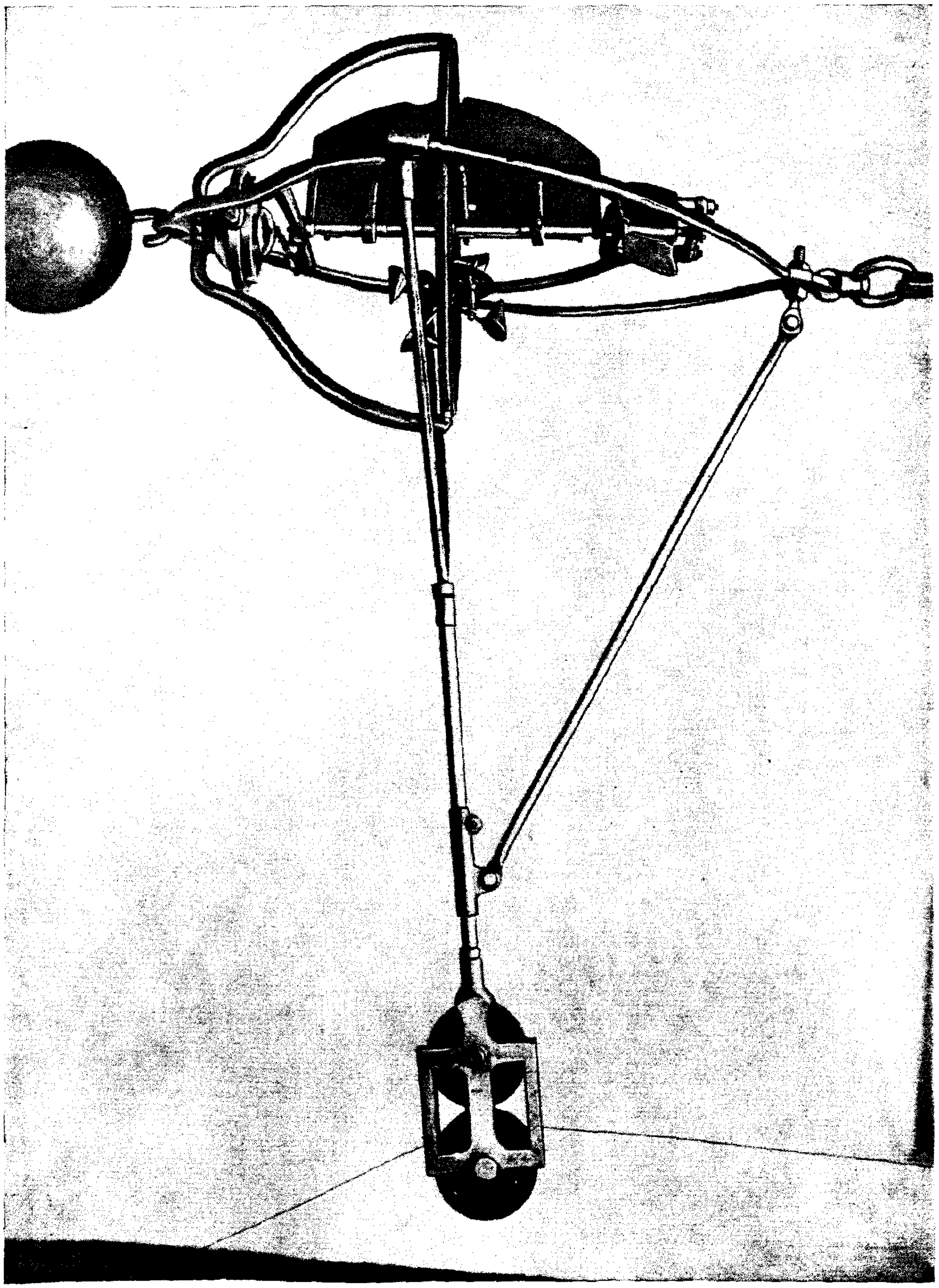
Ironwork.—Whenever it is possible, the use of iron is discouraged and wire rope substituted. Each part is so dependent upon all sustaining their own strains, that if one gives way under stress, the others receive their work at an unexpected angle, and a wreckage of the whole system is liable, perhaps with an accompaniment of loss of life. At first, the leaders at the ends of the outriggers were shackled into eye bands, and a defective weld in one of these came near causing just such an accident. Upon its breaking, the anchoring boom swung to starboard at an angle of about 40° with the keel, until the jumper, extending from the boom end to the hawse-hole, restrained it from farther deflection. A trifle more would have pried the ball from the socket, the heel of the boom would have launched violently inboard, and probably carried away the mast. As it was, the loss of the bowsprit was the extent of the damage, and since that time wire rope straps have replaced the wire bands. In case the anchoring rope breaks at or near the surface of the water, the accumulator, being suddenly relieved of its strain, acts like a catapult on the boom end, tending to throw it over on the deck. A defective shackle almost caused this accident at one time. To guard against such a mishap, a steel wire rope is shackled to the boom, the other end being secured on the main deck through the hawse-hole (see frontispiece).

In order to obtain the velocity and direction of the current at any depth it is necessary to have a registering apparatus recording the flow of water, a rudder which is free to assume a position in the direction of the flow, a compass to show the azimuth of the rudder, and a system by which these may be stopped at any desired time and held fast until the instrument can be hoisted to the surface and the data read.

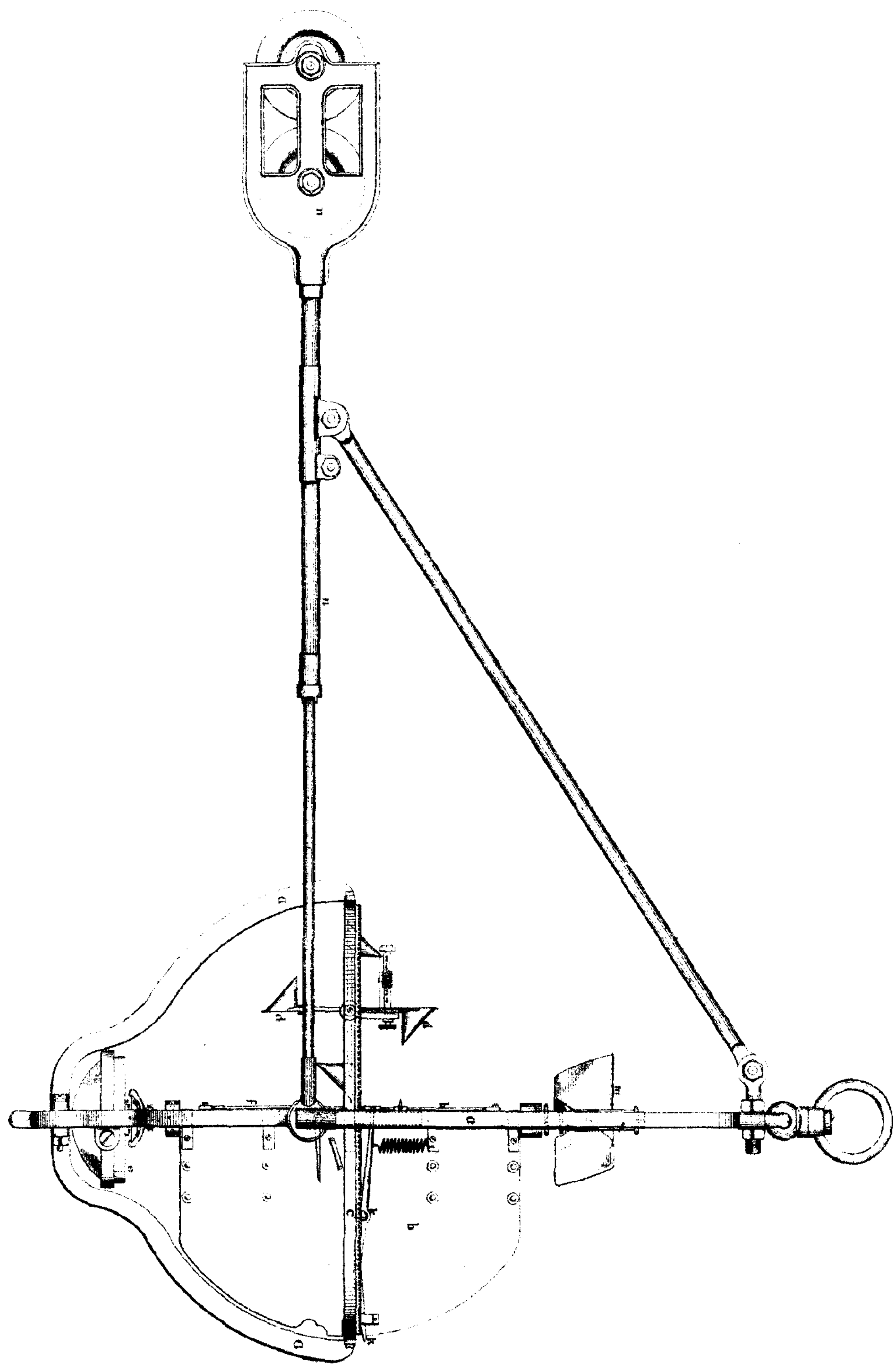
The current meter.—The instrument which the writer devised for this purpose (see illustrations Nos. 43, 44, and 45) consists of an elliptical framework of composition, around the minor diameter of which is a notched ring, *c* (illustration No. 44). Within the frame and ring is a freely moving rudder, *b*, having its stem in bearings at the major diameter of the elliptical frame. On the sides of the rudder are two fins, *k*, of thin metal, to which are attached levers ready to engage one of the notches of the ring whenever pressure is brought to bear upon their upper surfaces. A small spring of sufficient strength to overcome the weight of the fins holds the lever from the notches until a pressure is applied in the opposite direction.

Attached to the rudder on the opposite side of its stem and revolving with it is the velocity apparatus *d*. This consists of 4 cones placed at the extremities of arms or spokes, which are at right angles to each other. The cones are attached in such a way that the apices of all, point in the same direction with reference to the spokes, so that when in a current the base of the cone above the center and the apex of the one diametrically opposite are toward the current. They are placed also with the center of their bases and their apices at the same length of radius. At the axis of the system is a small shaft, which by a worm actuates geared wheels registering its revolutions. The number of these revolutions per knot is determined by the average of many hundred observations taken simultaneously with the meter and log, using with the latter a weighted pole 21 feet long instead of a log-chip.

Below the rudder stem is a compass needle in a weighted bowl, *o*, which is hung in gimbals, and between the rudder and bowl is a system of levers so arranged that they will lift and hold the needle whenever desired. Passing through the center of the rudder stem at its lower bearing is a small rod, its lower end communicating with the levers provided for locking the compass needle and with its upper end attached by the rod *f* to the fins at the side of the rudder. Pressure on the fins, therefore, simultaneously secures the rudder and the compass needle, thus giving the azimuth of the



THE PILLSBURY CURRENT METER.



DETAILS OF THE PILLSBURY CURRENT METER.

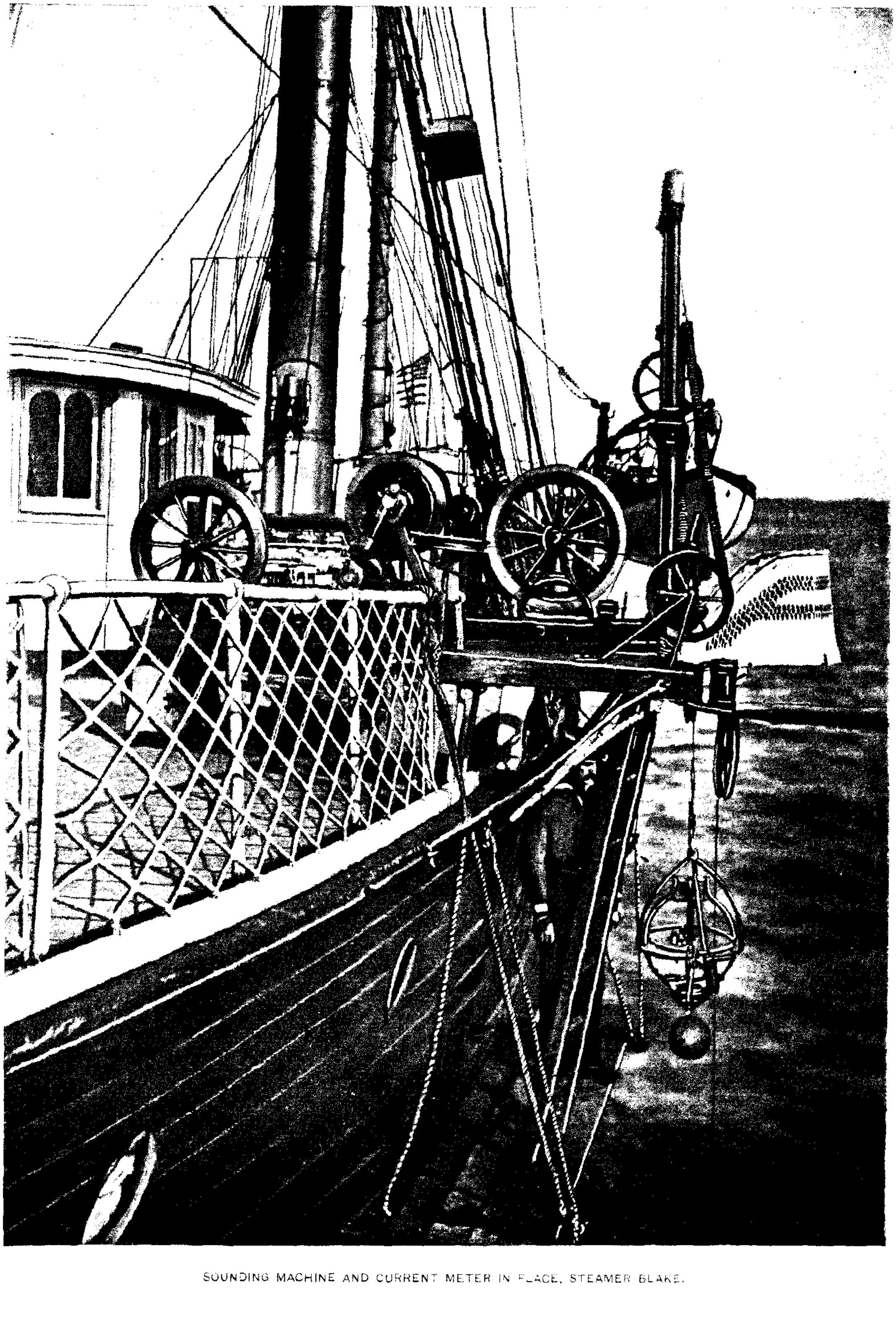
former. The glass top of the compass bowl is perforated so as to freely admit water. To prevent the needle being attacked by galvanic action it is coated with shellac, and when in use this must be done every three or four days. A deposit of gold or silver on the needle does not seem to be efficient for this purpose.

Above the rudder is a propeller having a clutch so arranged that upward motion through the water will give downward motion to a small rod passing through the center of the rudder stem, while motion in the contrary direction will not alter the position of the rod. Its office is to lock the fins after they have performed their duty of securing the rudder and compass. The action then is: the meter is lowered to any desired depth and a certain time allowed for it to register the velocity of the current. At a given signal it is hoisted, and immediately upon starting to rise through the water the pressure upon the fins secures the rudder and the compass needle, and as long as there is a continuous motion in the same direction both will remain secured until the surface of the water is reached. The propeller, however, also begins to revolve at the instant of hoisting, and, pushing its rod downward, locks the fins that have already caught the compass needle and rudder.

A device has been attached to the rudder by which the revolving cones were held fast in descent and were released upon stopping. Another attachment has been applied, by which the propeller would lock the cones upon hoisting, but both were discarded for this reason: the propeller by quick hoisting may be made to lock the fins through an ascent of but 6 feet, and again by lack of speed it will not lock through 60. If it was lowered fairly fast the cones would be certainly stopped, but if through carelessness the men should slow or cease lowering they would be released. This uncertainty led to their abandonment, and the following plan was adopted: The record is kept of the number of minutes and seconds occupied in lowering to the desired depth and in ascending from this depth to the surface of the water. During this time the cones were revolving from their movement through the water vertically and also from the passage of the flowing water transversely. These two in terms of revolutions are represented by the base and altitude of a right-angle triangle, and the hypotenuse represents the number of revolutions made during the operation. This is subtracted from the total reading for the whole interval to give the number due to the current alone during its stay at the desired depth.

The whole instrument is hung in trunnions at about its center of figure, so that it maintains an upright position when in the water. The total weight is about 25 pounds, and to this is added a lead shot of 75 pounds, and the whole is lowered by a steel wire of No. 16 gauge. In a strong current, in spite of the smallness of the wire and size of the weight, the meter is swept far astern. To force it to travel in nearly a vertical direction, the arm, *n*, illustration No. 44 (called a traveler), seen projecting from the bale of the meter, moves down a jackstay wire, which is held against the current by additional weight, etc.

The traveler is provided with two rollers or sheaves at its forward end which can readily be removed. Its rear end is secured to the bale alone, at the trunions and top, so as not to restrain the movable parts of the meter in assuming a vertical position. The jackstay wire is carried on a reel secured to the top of the steam capstan, and leads from that to guide wheels on a small wooden bed placed at the ship's side, the length of the traveler forward of the sounding machine, from which the meter is lowered (see *h*, fig 1, illustration No. 38, and also illustration No. 45). Attached to the end of the jackstay is a shot weighing about 200 pounds, and from it a line, called the distance line, secured to the anchoring rope. (See fig. 1.) The length of the latter depends upon circumstances; depth of water, strength of current, and depth of current, all of which must be judged before lowering. In shallow water (300 or 400 fathoms) and a strong current, the anchoring rope tends well ahead, and to lower the jackstay wire to 150 fathoms will require about 100 fathoms of distance line. In 1,500 fathoms of water with the same strength of current, 25 or 30 fathoms will be sufficient. The point to be aimed at is that the jackstay shall be as nearly vertical as possible. In practice, the distance line is fastened to the anchoring rope after the vessel is at anchor. The wire rope is veered, and at the same time the shot is lowered, care being taken that the former does not exceed the latter, for in that event the jackstay will be broken. To observe currents to 200 fathoms, 225 fathoms are veered on both anchoring rope and jackstay,



SOUNDING MACHINE AND CURRENT METER IN PLACE, STEAMER BLAKE.

and when both are out the full length the latter should leave the water about perpendicular. In a very weak current the distance line is apt to "hawser

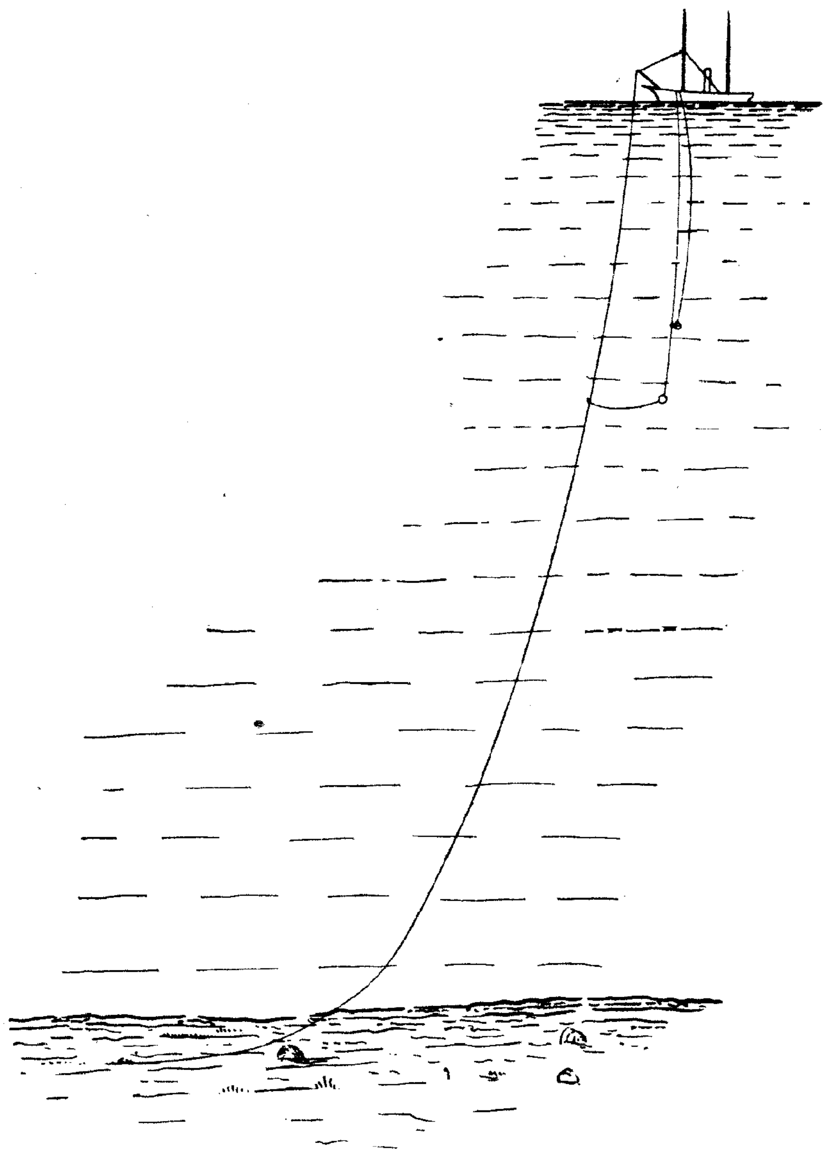


Fig. 1.—Jackstay and distance line in position for observing currents.

lay" around the anchor rope, from the torsion of the latter in veering and heaving in. To avoid this, it is sometimes fastened to a metal hank or thimble slipped over the anchoring rope, and then allowed to slide down to the depth it will assume upon lowering the shot. In a strong current, however, the inclination of the anchoring rope and the pull aft of the distance line, due to the friction of the current, prevents the hank from sliding more than a few fathoms. It sometimes happens that there has been a wrong conclusion arrived at, and the distance line is too long or too short, or an unexpected change in the volume of the current has altered the conditions. The only thing to do in such a case is to heave in and bend on afresh.

The wire used in lowering the meter is carried on the sounding reel, and the sounding machine designed by Lieutenant Commander Sigsbee is used in lowering. The usual depths observed are in fathoms, 3½, 15, 30, 65, 130, and 200. The friction of the current sweeps the wire astern in spite of its small size and the 100 pounds in weight at its lower end. To determine how much wire to pay out in order to allow the meter to reach the desired depth, many experiments were made by sending down a pressure sounding rod with the meter. In a 5-knot surface current, 195 fathoms of wire is veered to reach 130 fathoms depth, and in this strength of current to attain 200 fathoms with a fair degree of certainty is impracticable.

The care of the meter and jackstay wires should receive much attention. The latter, remaining as it does in the water during the whole anchorage, is galvanized. The meter wire is bright and both are rubbed and oiled every time they are hoisted. In their ends are thimbles, to which to attach lashings, and these are frequently renewed, that of the meter wire every day, if possible, during the observations, and of the jackstay wire after each anchorage. At the same time a few fathoms of wire are thrown away so as to change the position of wear and of galvanic action due to continually lowering the meter to the same point. The oil generally used is a neutral grease called cosmic, a preparation accompanying the manufacture of vaseline or cosmoline. Lime water or oil baths have not been used on board the *Blake* during the past five years even for the pianoforte sounding wire, but either cosmic or a neutral cylinder oil applied with the best results.

Considerable difficulty and loss of time was at first experienced in getting the anchor on board after it was at the surface of the water. Suspended from the end of the boom high up in the air, by the rolling of the ship it would swing from side to side, almost defying an attempt to "hook the fish." The following plan was soon adopted, which has since been found to be very convenient. A block is secured to the end and underneath the starboard outrigger, through which is rove a stout rope. In the forward end of the latter a small metal open snatch-block is lashed. When the anchor is nearing the surface a man standing on the bowsprit end hooks this block over the anchoring rope, while another passes the hauling part around the steam capstan. In an instant the bight of the anchoring rope is run up to the end of the outrigger (see Fig. 2), and, the hoisting engine going slowly at the same time, the ring is ready for passing the stopper, the anchor being well clear of the ship's side. A line is then thrown over the palm and the anchor fished with the shank parallel and close up to the outrigger. In the meanwhile the ship's engines have been started and the vessel put on her course before the anchor is even out of the water.

The operation of anchoring and observing currents is as follows: Two men are stationed in the reel-room, one at the anchor to slip, and the

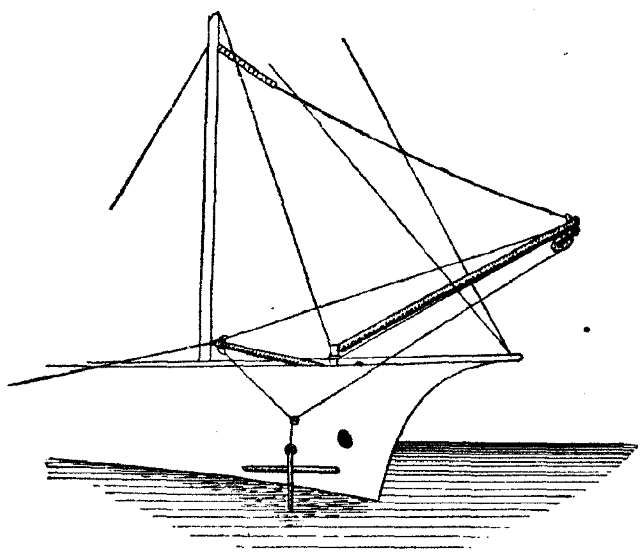


Fig. 2.—Securing the deep-sea anchor.

"leading man" at the hoisting engine and the line from reel-brake. The others prepare the jackstay wire, ship the platform over the side, and sling the meter to its wire. The vessel is stopped. She usually lays broadside to the wind when she is dead in the water. The wind is brought, therefore, on the side which will bring the expected current nearest ahead. The ring stopper is let go, leaving the anchor hanging from the boom end. When all is ready, a little steam is turned on the hoisting engine, the reel-brake lifted, and the anchor descends at the rate of from 50 to 80 fathoms per minute. If the water is but a few hundred fathoms deep the higher is the speed of veering. If very deep, the long-continued use, combined with high speed, heats the brake strap and reel and runs the risk of charring the wooden lining of the former.

Steam is gradually reduced on the hoisting engine as the length paid out increases, until at last the throttle is closed entirely. The vessel is drifting broadside to the wind and the anchoring rope stands well out on the weather beam. After a while it is noticed that the heading of the vessel is changing somewhat and the anchoring rope, instead of tending abeam, is coming ahead. This shows at once that the anchor is in dead water and is holding the vessel up against the surface current. A few fathoms before bottom should be reached the reel is checked, so that the anchor shall not be fouled, and the rope shall be fair on the bottom. The rate of paying out from this time on depends upon the indications as to strength of current. The only sure one is the speed of the water passing the vessel, or after the anchor is surely on the bottom a tremble in the anchoring rope as the anchor drags. If the current is deep, the vessel, the anchor, and the rope may be drifting with it almost as fast. If there are no indications of current the rope should be veered very slowly, 10 or 12 fathoms a minute, but under some circumstances 50 fathoms may be the speed. Gradually the rate of veering is diminished as the proper number of fathoms is approached, using the hoisting engine for controlling the rope. If the anchor is dragging over a smooth rock bottom and suddenly catches, the strain of bringing up the vessel is enormous. At the first indication of this, the main engines are started ahead full speed and the anchoring rope is slackened for an instant. The accumulator, by the amount of its compression, shows at once when the anchor is holding the vessel. If the anchor ceases to hold, the strain is released and the boom jumps. If this is the case another hundred fathoms is veered.

The proportion of anchoring rope to the depth varies with the character of bottom, the strength of current, and the depth of water, and somewhat with the size of the rope. In water less than 600 fathoms from two to three times the depth is required, and in 2,000 fathoms of water 3,000 fathoms of rope is generally sufficient. With a small rope, an advantage is gained by splicing a piece of larger size on the anchor end about 100 fathoms in length, to give additional weight at that point. When the vessel is at anchor, the distance line is fastened to the anchoring rope and the shot is lowered by the jackstay wire to the length of the former. The order is then given to veer together. The man at the hoisting engine calls out as he veers each 25 fathoms, as a mark to the officer at the jackstay. The latter, having started ahead by the length of the distance line, has lowered during the interval a proportionately less number of fathoms, so that both reach the desired depth at the same time. The rope is then clamped, the current meter is connected to the jackstay, and the men take their stations for lowering the meter.

The officer of the deck and a quartermaster are on the platform outside the vessel (see illustration No. 45); a man is at the friction line to control the revolutions of the reel carrying the meter wire, and the Recorder is at the timepiece in the pilot-house. The officer of the deck orders, "Lower to 3½ fathoms." The instant of striking the surface of the water he cries "Mark," for the Recorder to note the time. When the meter reaches the desired depth, the man at the friction line, who has before him the register showing the amount of wire out, cries "Time," and the Recorder again notes the hour, minute, and second. The meter is to remain at the depth 30 minutes from the last entry. Two minutes before the time has expired the Recorder informs the officer of the deck, who orders the machine to be manned. The engine is cleared of water, the belt shipped in the V-shaped score and tautened, a man with oil and canvas stands ready to guide on the wire, and the quartermaster and officer of the deck go on the platform. Upon the expiration of the 30 minutes the Recorder calls "Time," and the man at the engine hoists the meter. The instant it reaches the surface of the water the officer calls "Mark," whereupon the Recorder makes a record of this time and also the readings of the revolutions and direction shown by the meter as soon as the officer of the deck has read them. "Lower to 15 fathoms" is the next order, and the work continues.

At anchor.—The various conditions of wind and tide experienced by vessels at anchor in harbors are of course found at sea. The wind and current may form any angle and the vessel heads to the strongest force or a combination of the two. The *Blake* can remain at anchor with the wind blowing a force of six or even more, unless the wind is accompanied by a heavy sea, or unless it is about contrary to the current and the latter is strong. Steam in the boilers is always kept at full pressure and the engines ready to turn over at a moment's notice. The approach of a norther, the probability of collision with a vessel drifting in a calm, the breaking of a jackstay or meter wire, all require the use of the main engines at once.

The motions of the anchoring rope and the accumulator when the vessel is anchored in a current are of great value, and in fact are sure indications of whether or not the anchor is holding. The bow of the vessel falls in pitching. As it does so the strain on the accumulator is partially relieved, and the rubbers expanding, the boom rises. When the bow changes direction, the accumulator rubbers are compressed at once by the strain of lifting the wire rope, but there are two motions to it, the first part apparently being caused by the lift of the bow and the second by the stoppage and change of direction of the wire rope, which had just been descending. When the anchor nips on the bottom the accumulator rubbers are compressed steadily. If the anchor breaks ground, the re-action causes the boom end to rise more or less suddenly, depending on the character of the bottom. If it breaks from a rock, the rise is a jump of feet; if from ooze, the motion is so slow that it scarcely can be seen, and breaking out of clay gives a result between the two. In dragging, the accumulator will show the fact at once, except in ooze, and in this case even by a close watch it can generally be detected. The cause was correctly ascribed in one instance to a foul anchor dragging crown first over smooth rock bottom. In this case it was the tremble of the rope that gave the indication, there being no differences of strain to cause the accumulator to show the fact.

In a strong current, the rope has a vibration due to the passing water, and this is communicated to the wire rope clamp pendant, giving a hum of very low note. Sometimes with a very deep current the vibration seems to be started far down below the surface, and ascending, becomes more and more violent; but these are not to be mistaken for the trembling that is due to dragging. When the vessel remains at one anchorage for a considerable length of time, the anchoring rope and jackstay wire are veered 2 or 3 feet daily to change the nip in the pulleys. A man is generally at the ship's wheel to keep the anchoring rope "up and down" ahead, steering the vessel the same as at sea. The only time when he is not needed, is when there is but little or no current. In order that he can see the rope at night time a small white cotton flag is attached to it, and this is illuminated by a bull's-eye lantern fastened to the bowsprit end.

Getting underway.—Two men are stationed in the reel-room, one to guide the rope over the reel by the tackles shown in illustration No. 41, and the other to look out for the engines. The metre is sent below, and a man stands ready to guide on and oil the jackstay wire. The man at the hoisting engine lifts the break of the reel and turns the steam on to its engine. When the reel has turned over, and has taken in the slack between it and the winch-head, steam is admitted to the hoisting engine, the rope is removed from the clamp and everything is ready to heave-in. If the current is strong or the vessel is riding to a strong breeze, the main engines are started ahead for a few moments to relieve the strain, and afterwards at intervals if necessary. The anchoring rope and jackstay come in together, the man at the register calling out as each 25 fathoms is passed. When the distance line reaches the bow-sprit end, it is cast off and hauled on board with the shot.

There is of course more strain on the accumulator when heaving in than there is while at anchor in deep water, because of the increased skin friction on the rope due to its upward motion. At first the rate of progress is slow, not more than 8 or 10 fathoms per minute. The vessel is held up toward the anchor as much as possible, and particularly is this necessary on rocky bottom, for if the anchor breaks out at fairly long scope it is liable to catch again with a greater chance of loss. The instant the accumulator jumps, showing that the anchor has tripped, the throttles of the engine are opened, so as to make the anchor clear the bottom as soon as possible.

The speed then is from 50 to 80 fathoms per minute. If too much steam is on the reel engines, the tension of the rope between the reel and the winch-head will be too much, and there will be danger of crushing the barrel of the reel by the accumulation of pressure. The man at the hoisting engine regulates the speed of both, judging as to the one below by the amount of curve of the rope between the pulleys on deck. If, on the other hand, it is not running fast enough, the rope will either become slack, with danger of kinking, or it will slip on the winch-head. A very much preferable arrangement for reeling the rope under proper tension is one fitted to the dredge reel of the Fish Commission steamer *Albatross*. By an automatic spooling machine the wire rope is properly placed on the reel, and by a self-adjusting valve the tension is maintained fairly constant. When the anchor is off the bottom the vessel's head is allowed to pay-off as it will. A man is sent with the open snatch cat-block to the bowsprit end, and another man to be ready to take the rope to the capstan. About 12 fathoms from the anchor a "square-mark" of canvas has been placed, and when this appears the block is hooked, the vessel put on her course, and everything made secure.

Sometimes it happens that the anchor becomes caught on the bottom so that it is impossible to release it. The hoisting engine pulls until it can pull no more, the last being only by a single revolution at a time as the bow falls. If the sea is smooth and the rope free from kinks the *Blake's* hoisting engine can not break the rope. If there is much motion to the vessel, however, it can take in enough to cause the lift of the bow to do so, but there is more or less risk in this method. All the parts of the gear are under great strain, the sudden relief of which is not unlike an earthquake to the sensations of those on board. Breaking in one instance 200 fathoms from the bow, the anchoring rope was pulled through the water so violently, in spite of the great friction of such a length, that a great loop was thrown high into the air, falling as it came back around the end of the boom. The boom too gave a leap, and breaking the shackle of the jumper rose almost perpendicular, stopped an instant, and fortunately fell forward instead of aft. If the rope parts at the anchor no harm is likely to happen. To cut the rope is attended by no danger if the strain is eased first. A flogging chisel, heavy maul, and an anvil, or some other heavy piece of metal, are prepared for the cutting, which is best done between the hoisting engine and reel. When all is ready a few fathoms of the rope are payed out by steam as rapidly as possible. There is then only a strain on the gear equal to the weight of the wire rope, and before the vessel can be drifted by the current far enough to increase this strain the order is given to cut. The wire rope in slipping around the winch-head turn by turn with gradually increased speed relieves the gear of any sudden shock.

CHAPTER V.

CHARACTERISTICS OF THE GULF STREAM IN THE STRAITS OF FLORIDA AND IN THE YUCATAN PASSAGE.

In alluding to the different points of examination, each cross-section of the Stream has, for the sake of brevity, been given a letter, the initial one being the first section examined between Fowey Rocks, Florida, and Gun Cay, Bahama. This is called Section A, and those to the northward are given single letters, while those to the westward have double letters, as follows:

Section A, from Fowey Rocks, Florida, to Gun Cay, Bahama.

Section B, from Jupiter Inlet, Florida, to Memory Rock, Bahama.

Section F, from Cape Hatteras Shoals, about southeast.

Section C C, from Rebecca Shoal, Florida, to near Havana.

Section D D, from Cape San Antonio, Cuba, to Yucatan Bank.

Section E E, across the extreme western part of the Straits of Florida.

This last section has just been completed by Lieut. C. E. Vreeland, U. S. N., now commanding the *Blake*, and through his kindness I am enabled to combine his observations with those made by myself in former years. The sections to which the intervening lines belong have not been examined.

In the first season, work was contemplated on Sections A and D D, but the results from the beginning were so surprising, and the methods of anchoring and observing the currents so successful, that I was constrained to ask authority to abandon all idea of visiting the latter and to devote two seasons to the former section alone. This request was granted, and until the month of June in both the years 1885 and 1886 all the observations were made between Fowey Rocks and Gun Cay. In the following year, 1887, examinations were made between Rebecca Shoal, Florida, about south to a point 10 miles west of Havana, (Section C C,) and also from Cape San Antonio, Cuba, to Yucatan Bank (Section D D). During the early months of 1888 and 1889 the equatorial and Caribbean Sea currents were investigated, in order to ascertain the relation between these and the Gulf Stream in the Straits of Florida. The research was also extended to the current in the Old Bahama Channel, and, when opportunity offered during the summer seasons, to the flow off Cape Hatteras and Nantucket. The extent of the examination, however, that has been made at the latter points has not been sufficient to warrant conclusions on all the phenomena of the localities, and the results, therefore, are not complete.

For those navigating the Gulf Stream the most important questions to be answered are: What is the surface strength of the current and what is the direction of the flow? It is well known that these vary at many if not at all parts of the stream. Can a fair knowledge of these variations be predicted?

Section A, from Fowey Rocks, Florida, to Gun Cay, Bahama.—As the labors of two seasons were concentrated at this section the results are more complete than at the others, and in studying these results carefully we find the key to the solution of many of the apparent anomalies at points where there are fewer observations on which to base conclusions. The whole width of the Straits from shore to shore is 43 miles, and between the curves of 100 fathoms 39 miles. On the east side the bank is abrupt, 100 fathoms being found within one mile of Gun Cay. The current of the Stream sometimes runs in as far as the depth of 10 fathoms, but generally it is farther off shore. On the west side the slope is more gradual, but still the surface current frequently is found quite close to Fowey Rocks. The bottom varies at the different anchorages. At the station nearest the Bahama side of the channel, the anchors always dragged a considerable distance before taking hold. The dredge twice brought up quantities of small branch coral. At the axis, 11½ miles from Fowey Rocks, the anchor fouled the bottom three times, making it necessary to cut the anchoring rope to get under way. At the other anchorages there were evidences of rock bottom, but apparently only as outcroppings, for frequently the anchor or dredge brought up clay or mud.

The time actually employed in the observations at Section A amounted to over 1,100 hours, and the longest continuous anchorage 166 hours. In the first season, the anchorages were held as long as it was then thought to be possible, but during the second year changes were made from point to point, in the endeavor to discover the relative velocities at the different parts, and thus to establish, if possible, the axis of the Stream.

It will be remembered that the few observations made by Lieutenant Fremont off Jupiter Inlet, in 1884, indicated that the maximum surface flow was not situated where it was supposed to be by Professor Bache, but at some point farther to the westward. It required but few observations in the *Blake* to determine positively that this was the case. At Station 1, 8 miles distant from Fowey Rocks, the velocity at times was found to be greater than at Station 2, 7 miles nearer the middle of the stream, while the average at the latter exceeded the average at the former. Observations were then taken at a station midway between the two, and, whenever possible, changes were quickly made from this station to Station 1. Whenever this was done the velocity of the surface flow at the latter was generally less than at the former, and the average of all the observations at Station 1½ far exceeded those at stations on either side. At Station No. 2, however, the total volume was found to be much the greater, the area of a section of the prism representing 1 hour's current being 30 per cent. more than at Station No. 1½.

The hourly average in knots of all the observations taken at the various depths and stations is shown in the following table:

Station.	Distance in miles east of Fowey Rocks.	Velocity.				
		3½ fathoms.	15 fathoms.	30 fathoms.	65 fathoms.	130 fathoms.
1	8	2.661	2.346	2.252	1.590	0.634
1½	11½	3.461	2.895	2.936	2.421	1.611
2	15	3.156	3.062	3.182	2.947	2.202
3	22	2.727	2.667	2.695	2.503	1.860
4	29	2.123	2.099	2.116	1.975	1.450
5	36	1.707	1.572	1.489	1.565	1.449

These velocities are shown as curves in illustration No. 51 (see p. 550), placed at their proper stations in the cross section of the stream, but revolved around the initial point 90° from the direction of the current. From the table and from the vertical curves, it will be seen, that, with the exception of the surface velocity, the flow is greater at every depth at Station 2 than at a corresponding depth at other stations, and that the one exception is at Station 1½, where the surface velocity is greater than at any other station. This is the average position of the axis of surface velocity; but, as will be seen later, its flow is not at all times superior. The position of the maximum at different times during the month is intimately associated with the changes in the declination of the moon, and indeed, not only the position of the maximum but the velocity and width of the whole Stream as well. Other factors also enter the problem to cause regular variations, but they seem to be small in comparison with the influence of the moon. The effect of the barometric pressure is exerted to cause an irregular variation, and it is difficult for a single observer to be always sure that a certain result is to be assigned to this cause and not to some fixed and invariable law. It is only by a general average of all the observations that this can be reduced to a minimum

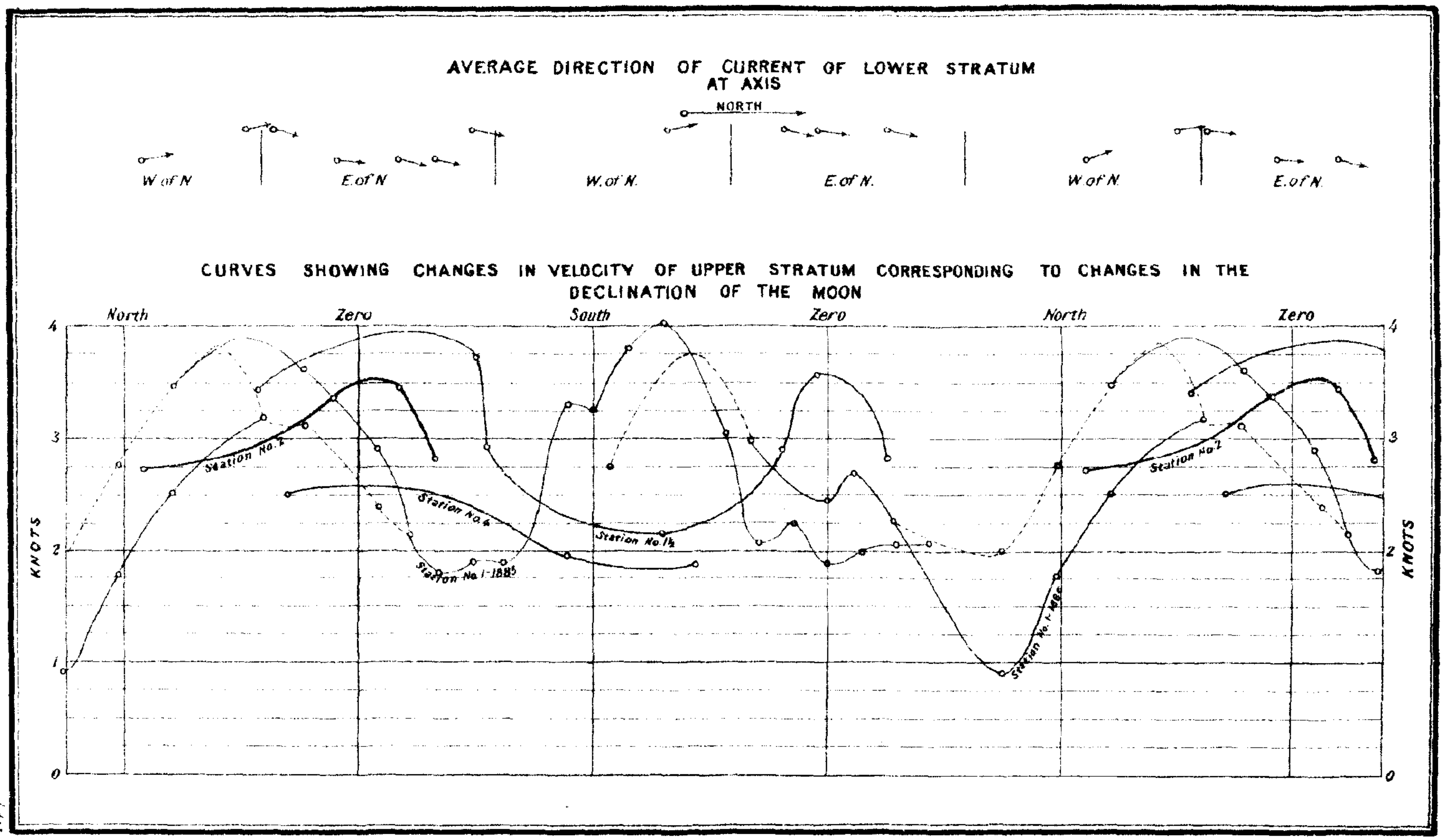
The monthly variation.—Following the changes in the declination of the moon, the velocity of the stream at any given point is accelerated or diminished, but while it is running faster at one place, at another it is running slower. It is in fact a reduction in velocity at the sides accompanying an increase in velocity at the axis, and the reverse, or in effect, an alternate expansion and contraction of the Stream in width. This is not marked on the east side of the Straits of Florida, and, as will be seen later, this is hardly to be expected. It is very marked on the west side of the Stream.

Illustration No. 46 shows the changes in the surface velocity for the different stations. The average of each day's observations is plotted at its proper position with reference to the declination of the moon, using, however, for the "surface" the observations obtained at 3½, 15, and 30 fathoms depth. The actual surface current follows the mean curve very closely, but by taking the average of the 3 depths, single errors of observations are thus reduced. It will be remarked at once that at northern declination, in the observations of 1886, the velocities at Station 1 were far below those at southern declination taken in 1885. This was a case of an abnormal condition of barometer in the Gulf of Mexico and Atlantic, and the dotted line represents more nearly the true current conditions. In passing the next zero declination the curve of Station 1 is excessively high. This part depends upon half day's observations taken at the time of the daily maximum. They are inserted to show the decrease in velocity as the moon changes its position. Above the curves are arrows showing the mean direction of the flow of the lower strata (65 and 130 fathoms). The short vertical lines separating the arrows into groups are drawn at intervals equal to the changes of declination of the moon, and it will be seen that within the limit of any space, all the arrows are inclined in the same direction. Those inclining upward indicate a current moving to the westward of north, and those inclining down a movement to the eastward of north.

The curves of velocity at Stations 1½ and 2 increase as the moon approaches zero declination, and at the same time the current at Station 1 is rapidly diminishing. The direction of the flow, as shown by the arrows, is then inclined slightly toward the east of north or toward the middle of the Stream and away from Station 1. As the moon approaches its greatest declination, the velocities at Stations 1½ and 2 decrease, the direction changes to the westward of north, and the speed of current at Station 1 rapidly increases. In this vibration it appears that the maximum velocity at the axis and the minimum at Station 1 arrives at two or three days after zero declination, and in the course of one-fourth of the lunar month the total expansion has taken place and the reverse conditions prevail. During this periodic change, the directions of the currents at the side stations follow the movements of the axis. At the time when the line of maximum velocity is moving toward east or near low declination, the lower currents at the side stations incline toward the center, and at the opposite movement of the axis, they incline outward or more nearly parallel with the axis. For example:

Declination.	Station 1.	Station 3.	Station 4.	Station 5.
High.	N. ¼ E	N	N. ½ W	N. by W.
Low.	N. by E. ¼ E	N. by W. ¼ W.	N. by W.	N. by W. ¾ W.

During the lunar month the temperature of the surface at the different parts of the Stream follows the direction of the lower currents at the axes most intimately. When the moon is in the vicinity of its greatest declination the


AVERAGE DIRECTION OF CURRENT OF LOWER STRATUM AT AXIS
NORTH
W. of N.
E. of N.
W. of N.
E. of N.
W. of N.
E. of N.
CURVES SHOWING CHANGES IN VELOCITY OF UPPER STRATUM CORRESPONDING TO CHANGES IN THE DECLINATION OF THE MOON
North
Zero
South
Zero
North
Zero
KNOTS
0
1
2
3
4
Station No. 2
Station No. 4
Station No. 1½
Station No. 1-1885
Station No. 1-1886
Station No. 2
KNOTS

lower currents at the axis being then inclined to the westward of north, the mean temperature of the surface water on the west side of the Stream is colder and on the east side warmer than it is when the currents are inclined toward the Bahama side of the channel:

	Station 1.	Station 1½.	Station 2.	Station 3.	Station 4.	Station 5.
	°	°	°	°	°	°
Mean of all surface temperatures observed	80.24	81.60	80.33	80.38	79.66	78.65
Temperature at surface with the current at axis setting westerly (high declination)*	[79.87]	[81.08]	[80.19]	80.65	79.82	79.19
Same with current setting easterly (low declination)*	80.36	81.86	80.42	[80.20]	[79.51]	[77.42]

*The lower temperatures are in brackets.

The table above gives these temperatures, and from it we see that at Station 2, the axis of volume, the difference is but little, and that the temperature at any of the other stations is lowest when the currents at the axis are setting in its direction. In other words, the axis inclining toward one side, its lower currents, which change most in azimuth and with greater constancy and regularity, force the colder water to the surface and lower the temperature at the sides. It is probable that the temperatures at an anchorage near the 100-fathom curve between Station 1 and Fowey Rocks would follow the same changes as those on the east side of the Straits.

Another illustration of the change in the velocity of the Stream following the declination of the moon is to be found on illustrations Nos. 47 and 48. In these the mean horizontal flow has been plotted *in situ* at the various sections in the Straits of Florida and Yucatan at which observations have been made. Illustration No. 47 shows the mean of the observations down to 30 fathoms and No. 48 the average at all depths, but for the sake of clearness on so small a scale the velocities have been exaggerated ten times greater than the scale of the chart. In obtaining the results, the observed speeds have been resolved in case of much departure from the general direction of the flow and only the one component taken; as, for instance, at Section C C the flow at the sides is toward the middle. The general direction of the Straits being east, these are resolved into their components and the easterly one taken. The directions accepted are north for Sections A and D D and east for Sections C C and E E. The mean of the results is obtained by combining all those falling within the limit of time represented by a westerly inclination to the currents at Section A as shown on illustration No. 46 and calling it "high declination," and all those at the time of the easterly set "low declination." This division includes in time one-fourth of a lunar month, beginning at nearly three days before and extending to about four days after the highest and zero declination.

Referring to illustrations Nos. 47 and 48 it is seen at Section A that at the time of highest declination, the mean velocity is about equal from the middle of the Stream to the western point at which observations were made; that is, the curve is flattened. At the time of zero declination, the axis is localized and much increased in velocity. In the first, however, the expansion of the axis very much increases the surface current at the westernmost stations at the time of its maximum, as seen from the adjoining cut, which represents for No. 1 station simply the average of the observations taken at and just after the highest declination instead of the mean of the observations for 2 lunar weeks as in illustration No. 46. This shows the strongest current on the west side at the time of high declination and a movement to the right at low declination. Referring to Section C C, off Havana, the curve of high declinations is flattened and the concentration of the axis takes place toward the right at low declination, or, in this case, to the southward. At Section E E the velocities at high declination are again the greatest on the northern side, and, as the moon is near

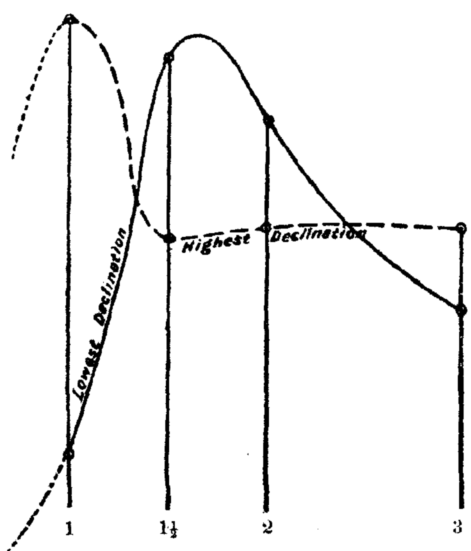
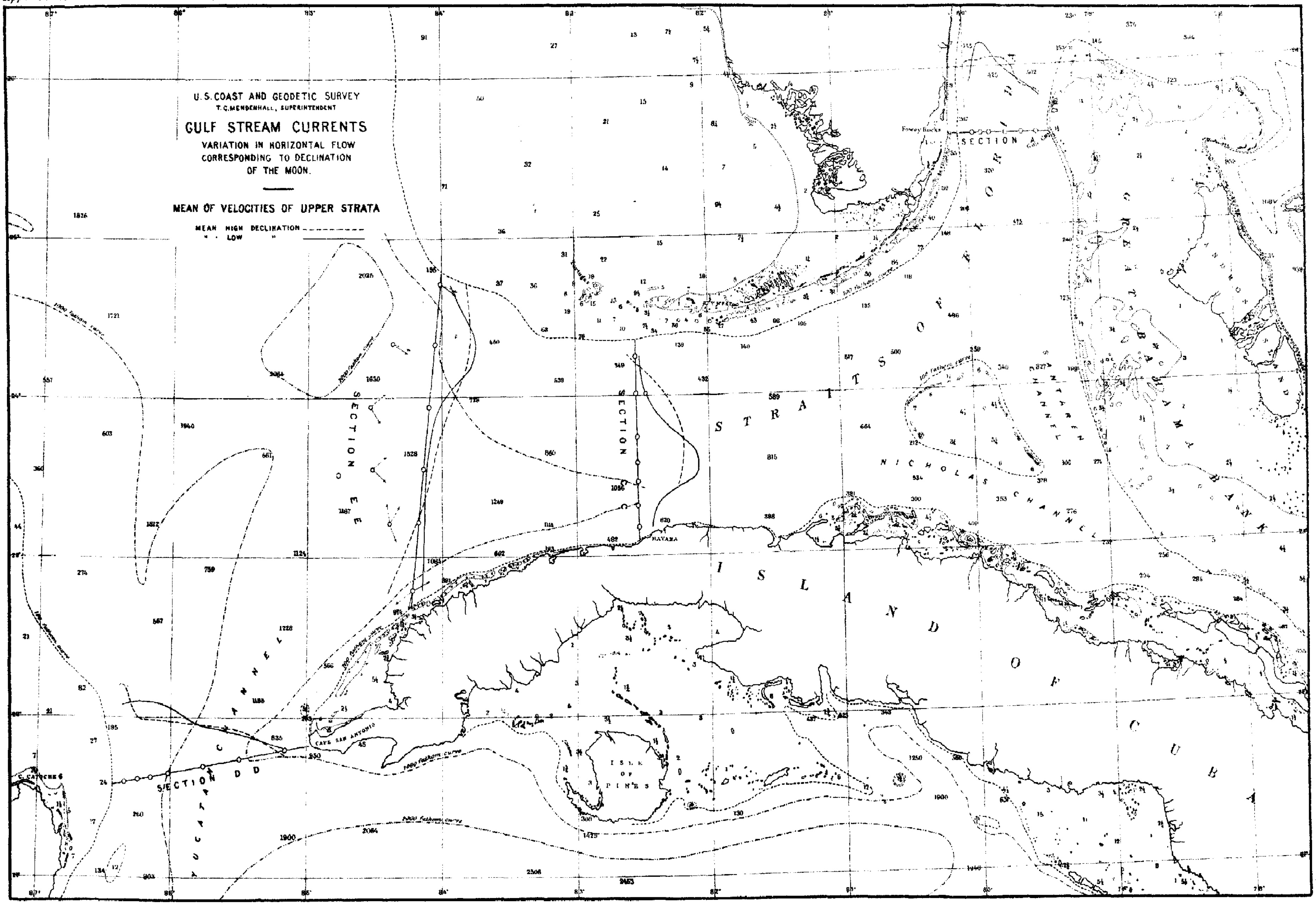
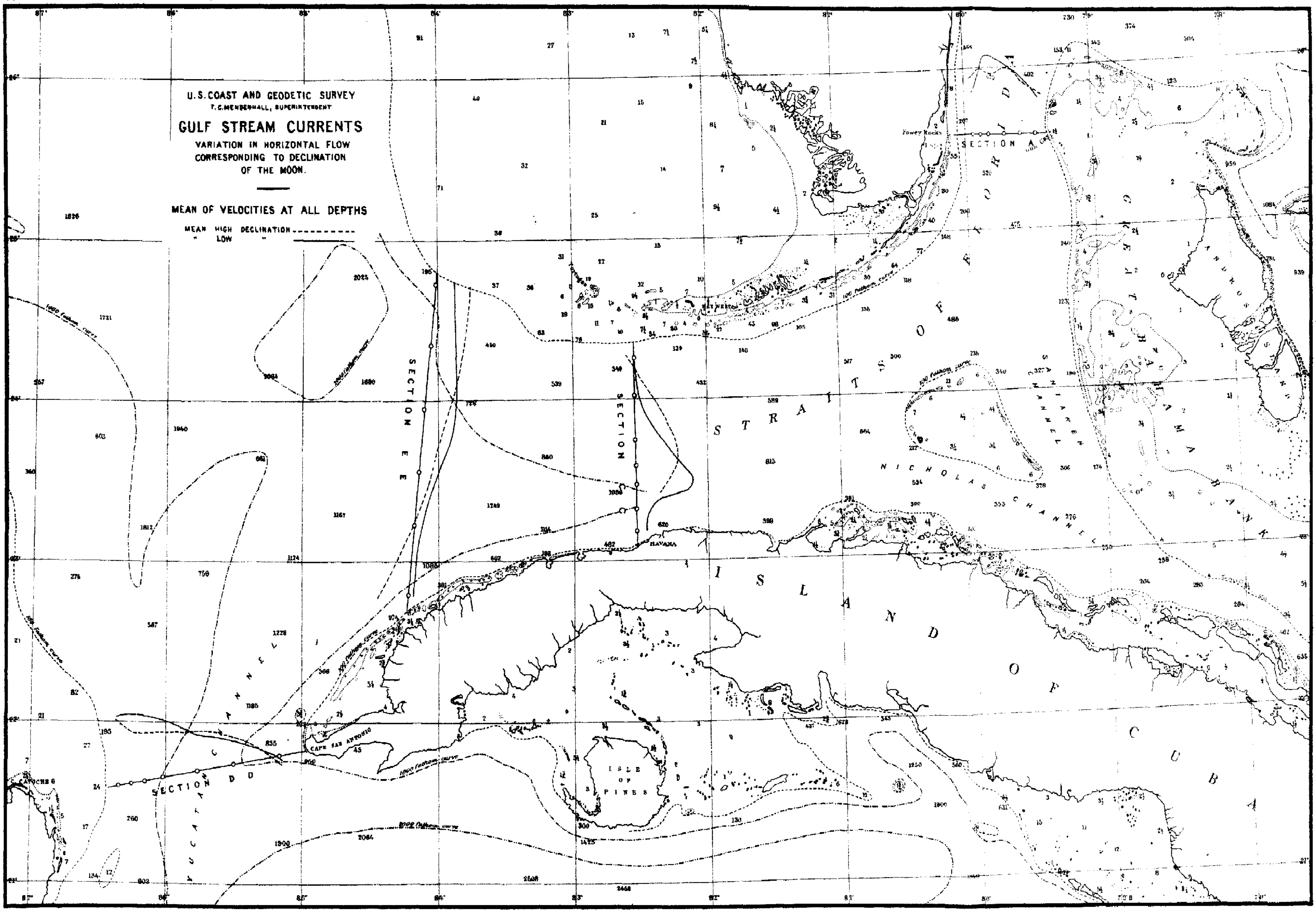


Fig. 3.


U.S. COAST AND GEODETIC SURVEY
T. C. MENDENHALL, SUPERINTENDENT
GULF STREAM CURRENTS
VARIATION IN HORIZONTAL FLOW CORRESPONDING TO DECLINATION OF THE MOON.
MEAN OF VELOCITIES OF UPPER STRATA
MEAN HIGH DECLINATION
LOW
Fowey Rocks
SECTION A
STRAITS OF FLORIDA
GREAT BAHAMA BANK
SANTAREN CHANNEL
NICHOLAS CHANNEL
HAVANA
SECTION
SECTION E
ISLAND OF CUBA
CAPE SAN ANTONIO
YUCATAN CHANNEL
SECTION D D
C. CATOCHE
ISLE OF PINES


U. S. COAST AND GEODETIC SURVEY
T. C. MENDENHALL, SUPERINTENDENT
GULF STREAM CURRENTS
VARIATION IN HORIZONTAL FLOW
CORRESPONDING TO DECLINATION
OF THE MOON.
MEAN OF VELOCITIES AT ALL DEPTHS
MEAN HIGH DECLINATION
" LOW "
SECTION A
SECTION E E
SECTION
SECTION D D
STRAITS OF FLORIDA
NICHOLAS CHANNEL
ISLAND OF CUBA
ISLE OF PINES
HAVANA
CAPE SAN ANTONIO
YUCATAN CHANNEL
Fowey Rocks

the equator, the speed increases and localizes at some point to the right and diminishes in velocity at the stations to the left. At Section D D the same is indicated, but here, unfortunately, the times at which the westernmost stations were occupied were at the maximum flow alone.

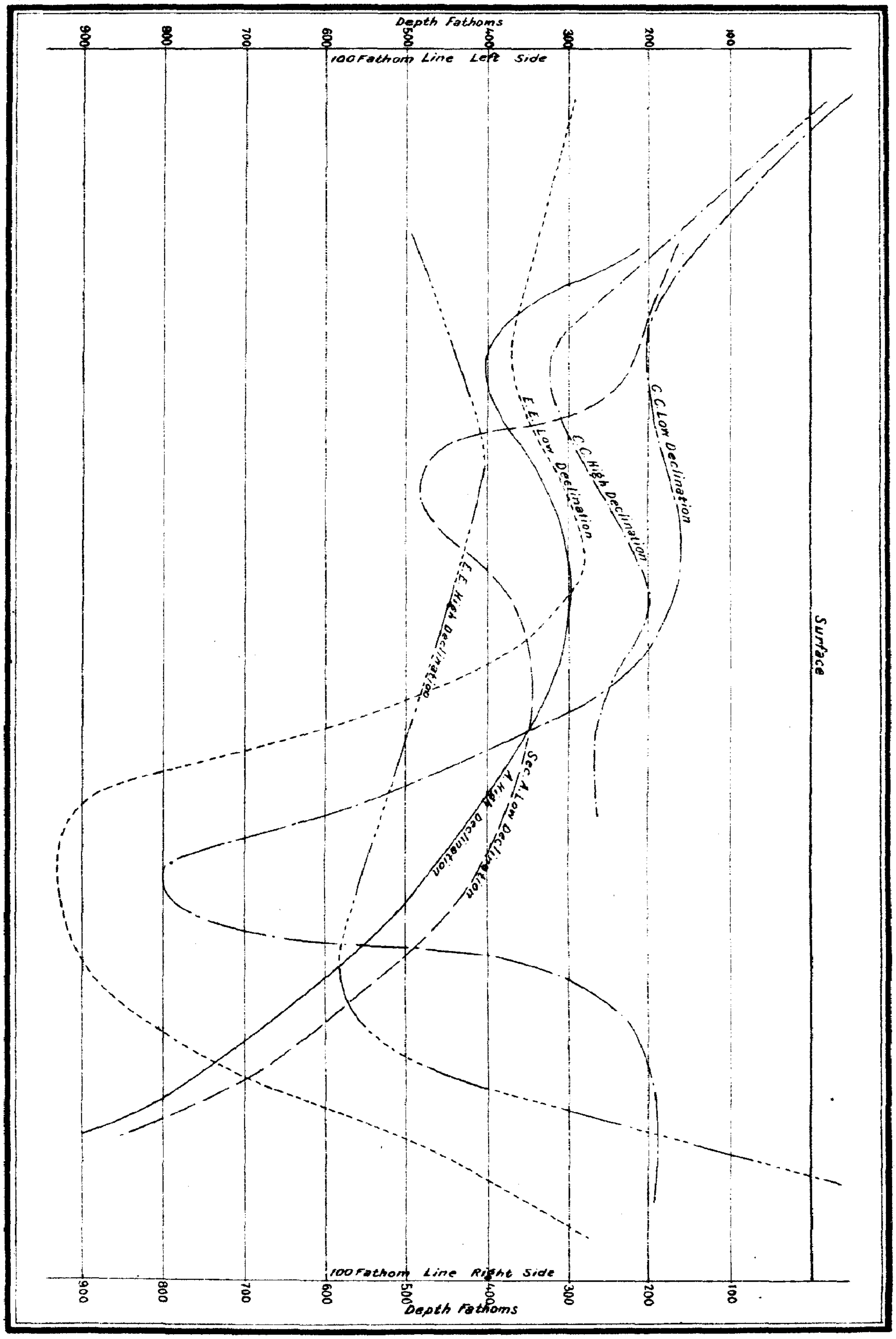
Still another illustration of the monthly change in the Stream following the changes in the moon's declination is shown in illustration No. 49. In its construction the vertical curves of velocity are divided into groups similar to those in which the arrows on illustration No. 46 are separated into high and low declination. The curves are carried to zero velocity (not the bottom) and the depths reached are joined by a continuous line. In plotting the points at the different stations the distances from the shore are expanded or contracted to a common width of Stream between the 100-fathom line. The distance below the surface of any part of the curves of one station bears no relation to the distance of another, for they depend upon the relative velocities at 65 and 130 fathoms. The curves only show that at the same relative point there is a difference in the depth of the Stream in the same direction at all the sections.

At Sections E E and C C it will be noticed that at low declination the curves drop to nearly double the depth of Section A at the same relative position from the 100-fathom curve, but that the latter shows a very deep current on the eastern side at both high and low declination. The cause of this is without doubt due to the inertia of the water which has been flowing east off Havana and is forced against the bank in rounding the curve of the Straits of Florida at Section A. At the latter section the lowest point of the western part of the curves is at low declination, and is situated approximately at the point of greatest contraction of the axis velocity. The lowest point of high declination is to the left or westward and corresponds to the movement of the axis. At Sections E E and C C the depth at high declination is the greatest on the extreme north, or, as in Section A, on the left of the Stream. There are other points of co-ordination or agreement in the curves and directions of the currents, as shown in the plates. At the time of high declination at Sections E E and D D, the strongest current being on the left side of the Stream, the eddy current is the strongest on the extreme right along the Cuban shore, and where the reverse conditions prevail, the axis being nearer the middle of the Stream, the eddies are lessened or entirely obliterated.

It seems, therefore, to be abundantly proved that the monthly variation in the Straits of Florida consists of an expansion at high declination and a contraction with an increased localized speed at low declination; that at the time of the contraction there is a deepening of the current at the axis, and at the time when the Stream has spread out it has diminished its depth, but has increased its velocity on the sides; that the most marked movement at high declination is an increased speed toward the left side and but little toward the right.

While this monthly change is taking place there is another rythmical oscillation, which is also governed by the moon. This is a regular *daily variation* in velocity which amounts in some instances to nearly 2½ knots. Sometimes when the wind is favorable for the formation of a "rip" this accompanies it, at which time the velocity of the current has been known to increase over one-half knot in a few moments. On May 21, 1886, when at anchor at Station 1, a rip was observed at 2 p. m., extending about north and south, at a distance of about three-quarters of a mile to the eastward of the vessel. The surface current for the previous half hour had been flowing at the rate of 3.29 knots. In the next 20 minutes the velocity increased to 3.9 knots, during which time the rip reached the vessel and passed to the westward. In the next 30 minutes the speed became 4.6 knots, the rip still very marked and moving to the westward.

The daily variation is most marked on the surface, and, like the monthly change, is far greater on the west side of the stream than it is on the east. There are in reality two periods of increase and two of decrease during the lunar day, somewhat similar to the tide and half-tide of the Gulf of Mexico, but this is chiefly confined to the upper currents, while the lower strata frequently flows with but a single daily fluctuation, indicating a solar influence. In the mean movement of the water, the first or highest maximum generally arrives at 9 hours before the upper transit of the moon, and the lesser at 9 hours before the lower transit.



CURVES REPRESENTING THE CHANGE IN SHAPE OF CURRENT PRISM FOLLOWING THE DECLINATION OF THE MOON

In order to show graphically the regularity of the changes, a diagram (illustration No. 50) has been constructed. The lunar days are represented by the heavy vertical lines. The mean of the hourly observations at all depths at each station has been plotted at its proper place with reference to the transit, and as nearly as possible at the declination of the moon at the time. This mean curve forms the lower side of the irregular shaded spaces. The upper side of each of these spaces is formed by the curve of surface velocities alone, drawn in the same manner, in order to show how closely the surface variations follow the average of the whole volume in point of time. The left side of the rectangular shaded spaces near the middle line represents the time at which the mean current reaches its maximum, and the hours intervening between this and the transit of the moon give what may be called the establishment of the current. This is only intended as a graphic illustration, to show the regularity of the changes to the eye. In the data from which the actual establishment has been fixed the curves were drawn on a scale sufficiently large to render it an easy matter to plot one one-hundredth of a knot or 2 minutes in time.

It has been seen that the currents change monthly in velocity, following the declination of the moon. This increase and decrease has a great influence in forming the curve of daily changes. At the time of the monthly increase, the minimum current for the day follows the greatest maximum by about 6 hours. In the next 6 hours there is an increase in velocity equal to or perhaps greater than the preceding maximum. In the third interval there is a halting or fall in speed to be succeeded by a still greater maximum 9 hours before the next upper transit. At the time of the monthly decrease in velocity the conditions are reversed, the minimum preceding the maximum and each succeeding maximum or minimum is less than the preceding. In the interval of change there is a short time of irregular velocities when the maximum for the day arrives before the lower transit instead of the upper, somewhat similar to certain tides in the Gulf of Mexico, where, as the declination changes its name, a high tide takes nearly the place of a low in time.

The average of all the daily differences of surface current at Section A is given in the table below:

Station.	Distance east of Fowey Rocks.	Mean variation in surface velocity.	Average surface velocity.
	Miles.	*Knots.*	*Knots.*
1	8	1.07	2.66
1½	11.5	1.64	3.46
2	15	0.92	3.16
3	22	0.56	2.73
4	29	0.42	2.12
5	36	0.55	1.71

The table shows that the daily variation is greatest at the point of greatest average velocity and is also more excessive to the westward of the axis than toward the east.

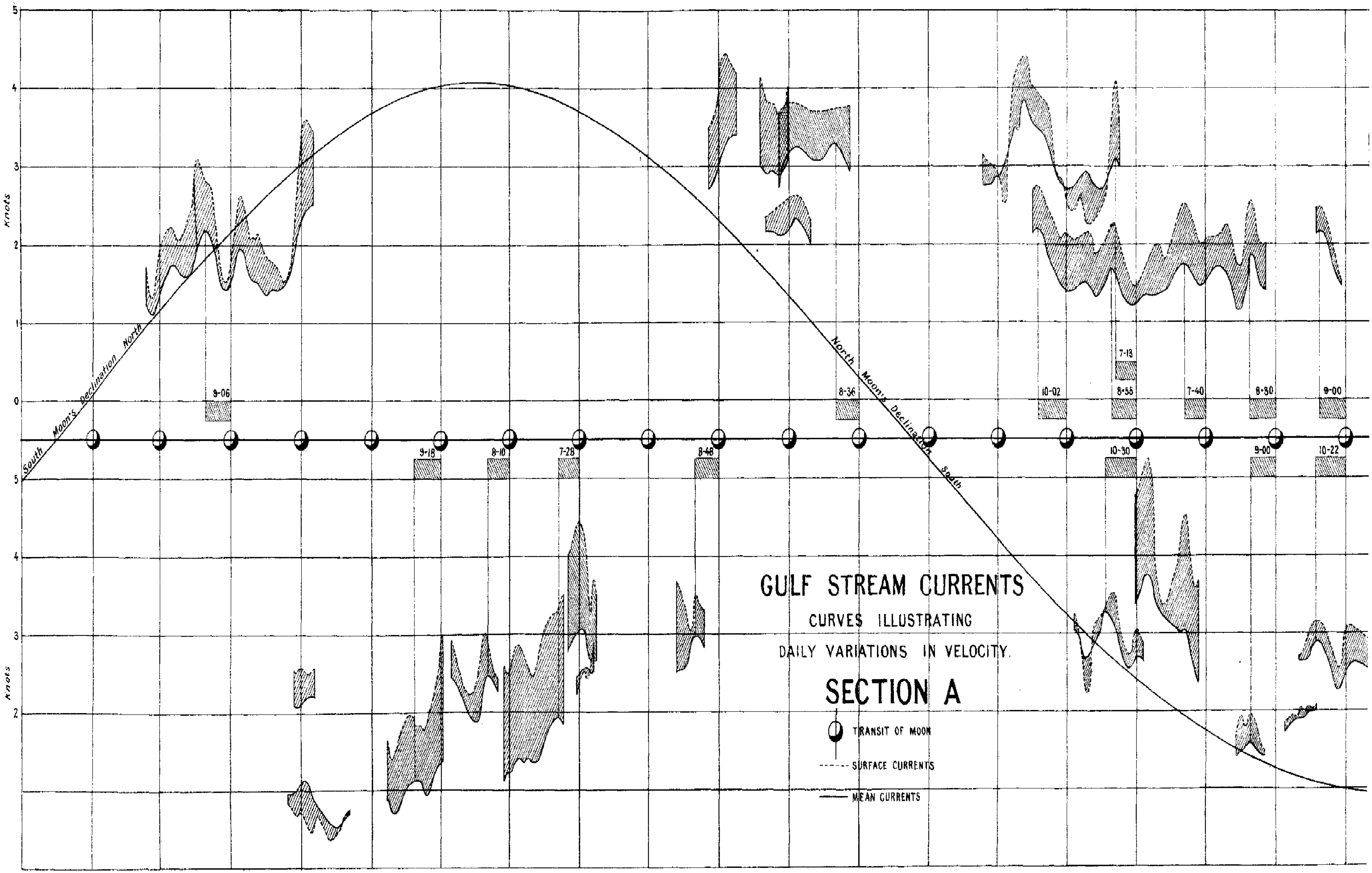
We have seen that the surface temperatures vary during the lunar month. In the same manner they change during each lunar day. The differences are most marked at the extreme Stations, No. 1 and No. 5. These are given in the table below together with Station 1½, for each 12 hours before and after the superior transit of the moon.

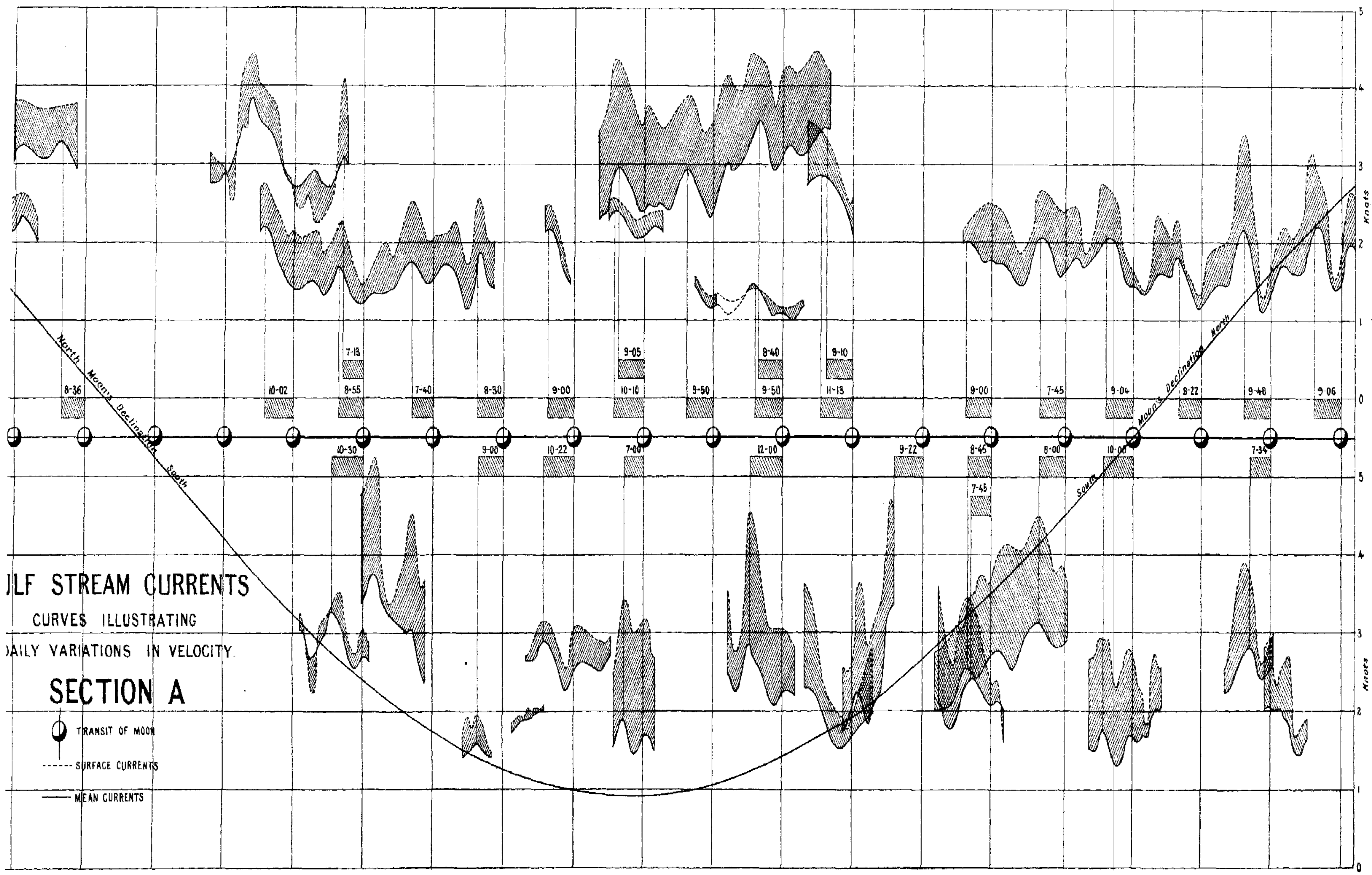
SECTION A.—*Daily temperatures at extreme stations.*

Before transit.	After transit.	Before transit.	After transit.	Before transit.	After transit.
°	°	°	°	°	°
-----------	80.25	[81.14]	81.83	81.90	[81.13]
[79.67]	79.93	[81.46]	82.33	[81.40]	82.40
[79.67]	79.93	[81.08]	81.83	[82.17]	82.66
80.50	-----------	[81.00]	82.17	[82.00]	83.60
[80.01]	80.20	80.69	[80.50]	[78.66]	79.83
[79.17]	79.78	[80.00]	80.70	-----------	80.00
[79.57]	79.98	-----------	-----------	[78.50]	78.81

NOTE.—The lower temperatures are in brackets.

It will be noticed that in every instance but two the temperature before the transit, which is during the period of decreasing current, is lower than


GULF STREAM CURRENTS
CURVES ILLUSTRATING
DAILY VARIATIONS IN VELOCITY.
SECTION A
TRANSIT OF MOON
SURFACE CURRENTS
MEAN CURRENTS
Knots
Knots
South Moon's Declination North
North Moon's Declination South
5
4
3
2
1
0
5
4
3
2
9-06
8-36
10-02
7-13
8-55
7-40
8-30
9-00
9-18
8-10
7-28
8-48
10-30
9-00
10-22


ULF STREAM CURRENTS
CURVES ILLUSTRATING
AILY VARIATIONS IN VELOCITY.
SECTION A
TRANSIT OF MOON
SURFACE CURRENTS
MEAN CURRENTS
North Moon's Declination South
South Moon's Declination North
Knots

it is during the 12 hours after. In a part of these observations the moon's transit was such that the 12 hours succeeding included the hours of day when the surface temperature would naturally be warmer. In about one-half of them, however, the conditions are reversed, the transit being between 6 p. m. and midnight.

This daily change in temperature is accompanied by a change in direction of the currents at the extreme stations and is more marked in the lower strata than in the higher. As the moon approaches the transit, or practically during the period of decreasing velocities, the currents at the extreme stations incline toward the axis, and during the 12 hours after the transit they are running more nearly parallel. The effect of this upon the surface temperature of the intermediate stations is to cause a lower temperature with an increasing current, as seen from the following table:

SECTION A.—*Daily temperature at intermediate stations.*

Before transit.	After transit.
°	°
80.0	[79.5]
[79.8]	79.9
80.5	[80.25]
80.7	[80.3]
81.2	[80.5]
81.2	[80.5]
80.0	[79.4]

NOTE.—The lower temperatures are in brackets.

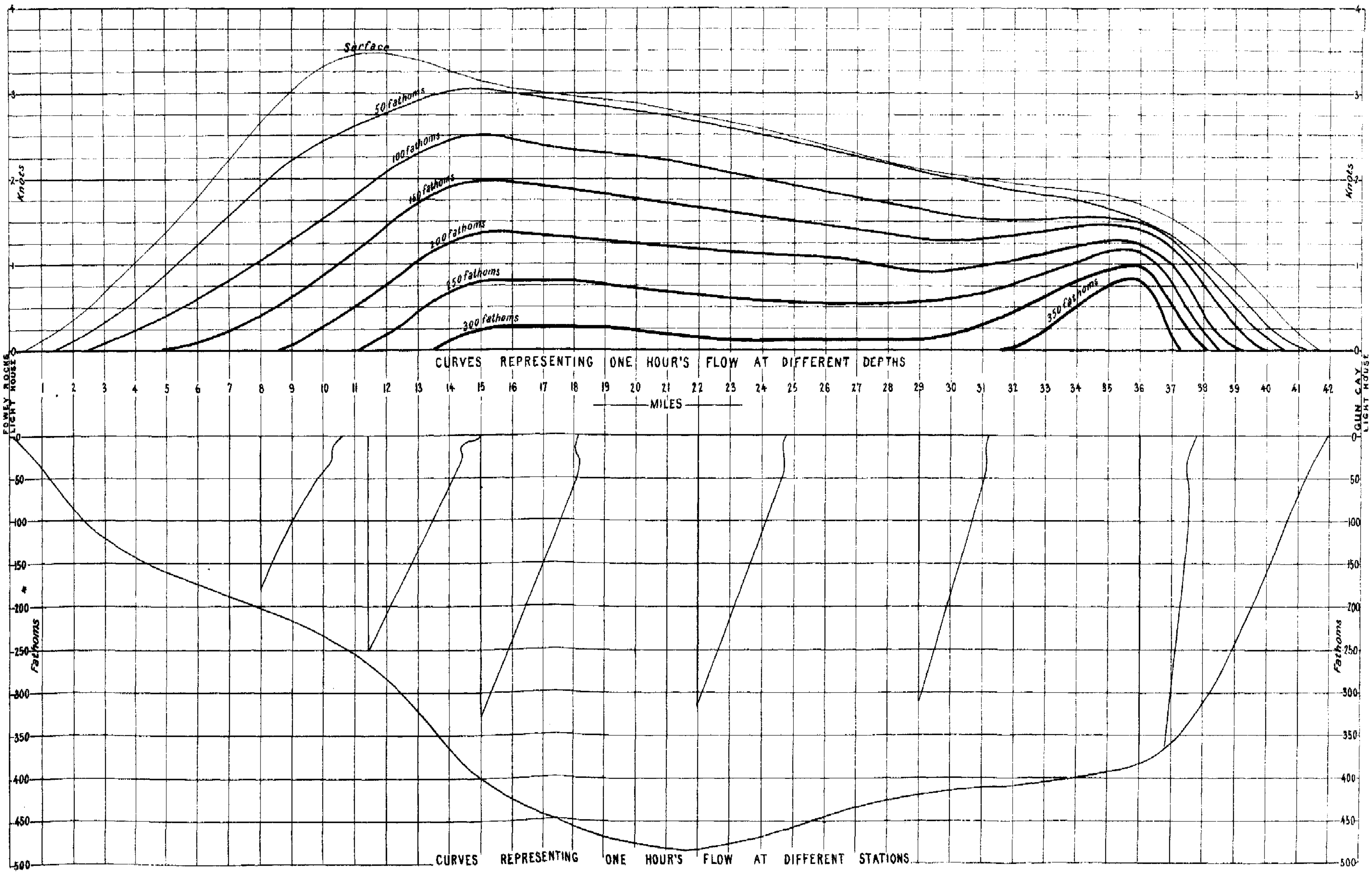
These changes in velocity, temperature, and direction, all point to the fact that the Stream contracts and expands daily as well as monthly. In the daily fluctuations the expansion is but trifling, and being short in duration in comparison with the monthly change, the surface temperatures at the sides increase with the velocity. As the monthly changes progress, however, the surface temperature is lowered and then raised, reaching its maximum and minimum at some time after the axis has actually changed its direction.

The *volume of the Stream* is best determined at Section A, for here it is confined in width by earth instead of water walls, and practically all its water passes into the Atlantic. At the next section (off Jupiter Inlet) at certain times there probably is an eddy current along the Little Bahama Bank and through the Northwest Providence Channel. Farther to the westward off Havana a small quantity passes, under certain conditions, through the Old Bahama Channel, but at Section A these variable conditions are eliminated. In calculating the volume the averages of all the observations at each station have been plotted on a large vertical scale, and from the deepest point of observation (130 fathoms) the curves have been continued to zero. The ordinates at different depths were then transferred to a horizontal or plan view, and curves were drawn through corresponding depths and from the extreme stations to the initial line. Deflections in the direction of the current, which varied much from north, were resolved into their component parts and only the northerly component taken. The thickness of the laminæ used in the computation was, 10 fathoms thick from the surface to 50 fathoms, thence 50 fathoms thick to the bottom, and the volume was calculated by Simpson's rules.

The result is a grand total of nearly 90,000,000,000 tons per hour, or, to give more nearly the actual figures, 89,872,000,000 tons, and of this amount almost exactly one-half is carried within 100 fathoms of the surface.

It will be noticed by referring to illustration No. 51 that, on the western slope, the mean depth to which the current reaches is near the bottom. At times, without doubt, it actually did so, and occasionally there was a reverse current. In every instance, however, when the average for the day was negative at 130 fathoms, the barometer in the Gulf of Mexico was lowest for the month or it was highest for the month along the Atlantic coast of the United States. It will be remarked that at Stations Nos. 2, 3, and 4 the average depth at which zero is reached is uniform at about 325 fathoms. The curve representing the vertical current line (illustration No. 51) should not in fact reach the zero so abruptly, for without doubt the actual speed diminishes by smaller and smaller increments as the effect of friction becomes greater. The actual volume, however, would be increased but little, probably not more than one or two per cent., a trifling amount relatively, although at the same time so large actually that the mind can hardly grasp it. At

GULF STREAM CURRENTS
SECTION A



Station 5 the curves show that the current actually reaches the bottom. In the discussion of the section off Havana the cause of this phenomenon will be seen.

The Straits of Florida, at Section C C, are about 73 miles in width between the curves of 100 fathoms depth. Situated as they are near the beginning of the Gulf Stream proper, with the direction of their flow at right angles to that of both the Straits of Yucatan and Section A off Cape Florida, they are a most interesting study. The current does not fill the banks as is generally the case at Section A, but has on its northern side a neutral zone of varying width, in which, at times, there is an eddy current setting to the westward. At Station 1, which is within this zone and about 3 miles from the 100-fathom curve, tidal currents were always found except on one occasion, at which time the barometer was the highest for the month at the Signal Service stations in the eastern part of the Gulf of Mexico, which without doubt caused the abnormal current. While the current is generally tidal, it is probable that in this part of the Stream the barometric influence is greater than elsewhere in this section. In the observations actually obtained, the predominating flow was easterly on the surface at low declination, but the current was so slight that it is difficult to decide in what direction the gentle flow would go with varying conditions. Resolving the directions into their east and west components, it is found that when the moon is near the equator the currents are more easterly than westerly, and when near the highest declination they are the reverse, although they are still so weak that, for the purposes of navigation, they are not of much value and are readily overcome by abnormal meteorological conditions.

At Station 2, 16 miles farther to the south, the currents are still irregular, this station being on the edge, as it were, of the Gulf Stream, sometimes wholly within its borders and again in the variable zone. Whether it has a true Stream current or not depends still upon the moon's declination, but, situated as it is between the Stream and the neutral zone, its lower currents are perhaps apt to partake of the characteristics of the latter when the meteorological conditions cause irregularities.

At high declination, as explained previously, the Stream spreads out its limits and increases the velocity at its sides. This fact is most beautifully exemplified at this station. The first time it was occupied, the wind was from the eastward and the vessel was generally lying broadside-to. The surface flow was easterly and quite constant in direction, the intermediate stratum was variable, and the lower current had a southerly set. Suddenly the surface velocity would increase a knot or more in 10 or 15 minutes, forcing the vessel to tail to it for a short time against the wind, and then return to its original heading. The next time the station was occupied, the declination of the moon was about the same, near zero, but instead of the surface water setting east, it was irregular, and the intermediate and lower strata had a southerly set. This difference was probably due to the meteorological conditions prevailing. The high barometer mentioned in connection with Station 1 had passed off, and was followed by a low area in the vicinity of the Mississippi Delta and Mobile, Alabama. The third time the station was occupied the moon was within a day of its highest declination. The surface and intermediate strata had a strong easterly current, while only the lower was irregular. The following table shows the varying conditions:

Stations.	Date.	Declination of the moon.	Surface strength.	Depth, having easterly set.	Depth, having irregular current.	Depth, having southerly set.
	1887.		*Knots.*	*Fathoms.*	*Fathoms.*	*Fathoms.*
2^b	May 9	High.	1.76	$3\frac{1}{2}$–15–30	65–130	....
2	Feb. 4	Zero.	0.86	$3\frac{1}{2}$	15–30	65–130
2^a	Feb. 11	do.	0.38	....	$3\frac{1}{2}$	15–30–65–130

The easterly components of the velocities are shown graphically in Fig. 4, from which it is seen that at high declination the edge of the Stream was well to the northward of the station. At No. 2 it was nearer, and at 2^a it was practically to the southward. Although the set was still slightly to the eastward with a variable current of two-tenths of a knot, it can hardly be called Gulf Stream.

The position of the axis at Section C C varies during the month in the same manner as at Section A, except on its northern side. The movement at high declination is to the left, but there is not an excessive increase in velocity at the extreme station. The maximum current at this time is to be found between Stations 3 and 3½, or about 34 miles from the light-house house at Havana, and at low declination about 16 miles distant.

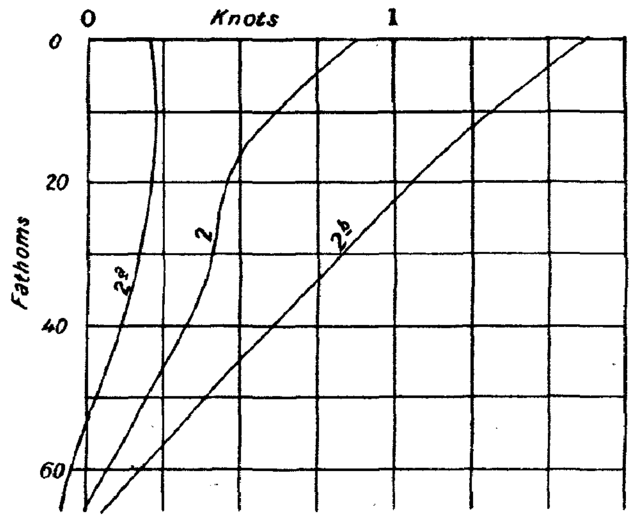


FIG. 4.

The average direction of the currents at the sides is more toward the axis at the latter time than at high declination. The directions are shown in the table below, togetherwith the temperature at each.

Declination.	Station 2.		Station 3.		Station 3½.	
		°		°		°
High	SE. ¼ E.	79.1	E. ¼ S.	77.7	E. ½ S.	79.8
Low	SE. ½ S.	77.5	E. ½ S.	77.4	--------	------

Declination.	Station 4.		Station 4½.		Station 5.	
		°		°		°
High	E. ¾ N.	77.5	-----------	------	---------	-----
Low	E. ½ S.	80.25	ENE. ¼ E.	77.6	NE. ½ E.	77.3

The temperatures show but little, for the reason that the observations were taken in two groups separated by an interval of about 3 months. The observations suitable for comparison, taken during the same month, were all on the northern side of the Stream, and in every instance the water was colder at low declination than it was at high. This is to be attributed directly to the changing direction of the current, and is the same in principle as at Section A, but with this difference in its execution. The latter section is narrow, and the current fills the strait with the axis nearest the western (left) shore. The surface is most constant in direction while the lower currents are changeable, thus causing the rise and fall in temperature shown in table on page 542. At Section C C the current does not fill the Strait, and the axis being nearer the right bank, the left-hand part of the Stream follows the same changes as the eastern portion at Section A, viz, warmer at high declination than at low.

The daily variations at Section C C are not as great as in the narrower part of the Stream, but they arrive with as great regularity. The time of the establishment is computed in the same manner as at Section A, by constructing a mean curve from all the observations and taking the average. This gives the time of the arrival of the maximum flow at $9^h\ 22^m$ before the transit of the moon, but there seems to be a difference between the arrival of the wave at the middle and at the side stations, though this may simply be a coincidence. The times are, beginning with the northern station, No. 2, $8^h\ 53^m$, $9^h\ 24^m$, $11^h\ 30^m$, $9^h\ 28^m$, and $8^h\ 22^m$. Section A shows nothing of the kind, but at the next section to the westward there are indications of the same system.

The observations at Section D D, extending across the Straits of Yucatan, resemble those of Section A more than those off Havana. The profile of the bottom is in general the same, except in depth. It rises precipitously on the eastern side from a considerable depth, and to the westward the slope is more gradual to the 100-fathom curve of Yucatan Bank.

The current does not fill the space from shore to shore. At Station No. 1, in 23 fathoms, and about 5 miles inside the 100-fathom curve of Yucatan Bank, the interference of the Stream current with the tidal current is very noticeable. On the surface, the flood tide, combining with the overflow from the Stream, runs about northwest for 18 hours. On the ebb tide, the resultant was east at the time of the observations, and the change from one to the other was by way of north. At 15 fathoms the direction was mostly to the eastward, the mean being ENE. ½ E. It seems probable that, at high declination of the moon, the overflow from the Stream may entirely overcome the ebb-tide current on the surface, in the vicinity of the 100-fathom curve.

On the east side of the Passage there was a light but persistent eddy current from the Gulf of Mexico into the Caribbean. The general direction of the surface current at the time of low declination of the moon was between NE. by N. and ESE., the mean of all being NE. by E. At high declination on the other hand, the surface direction was between E. and SE. by S. with a mean of ESE.

The table below shows the average strength of the current at the various depths under the two conditions, the value of the northerly component and the mean directions:

Station 6, Section D D.

Stations.	High declination.			Low declination.		
	Observed velocity.	Mean direction.	Northerly component.	Observed velocity.	Mean direction.	Northerly component.
3½	0.47	ESE.	—0.26	0.60	NE. by E.	0.27
15	0.64	E. by S.	—0.11	0.78	ENE.	0.30
30	0.73	SE. y E	—0.24	0.70	ESE.	—0.28
65	0.60	SE. ¾ E.	—0.40	0.57	SE. by E.	—0.35
130	0.43	SE.	—0.21	0.45	SE.	—0.18

We see from this table that the velocities and directions at and below 30 fathoms are about the same, but the surface currents vary in direction, flowing toward the Straits of Florida at the time of low declination of the moon, when the strength of the main current is farthest from the west side of the Straits, and that they are flowing toward the Caribbean Sea when the axis is nearest Yucatan. At the time of the observations at low declination the meteorological conditions were possibly abnormal. The Signal Service Review gives an account of an area of high pressure which appeared in Montana on March 18 and, moving southward, left the coast of Texas on the evening of March 22 with a maximum pressure of 30.25 inches. The review says: "The unusual southerly course of this high area appears to have been influenced by the presence of an area of low pressure in the western portion of the Gulf of Mexico having an easterly course." The area of low pressure had moved rapidly to the eastward and probably the high barometer had also disappeared when, two days later, the observations in question began. The mean barometer at the station during the time was

30.04, which was not far from normal. Even if the high pressure had not moved away from the Gulf regions at the time of the observations, the effect of its presence would be to make the eddy, which was running as a subcurrent, either too strong or wrong in direction, neither of which would affect the principle established, that in this part of the Yucatan Passage the upper currents move northeastwardly at low declination of the moon. The other stations at this section present the same characteristics as Section A. The directions of the surface currents vary but little from north, and the average of all is N. by E. There is no evidence at any station but the one nearest Cape San Antonio, described above, of a movement of the water directly into the Straits of Florida, and this station belongs to the eddy rather than to the main current.

The axis of the flow is situated west of the middle of the Stream, the same as at Section A, and the same movement to the right and left is well marked. At the time of high declination it is without doubt near the 100-fathom curve of the Yucatan Bank. Stations were occupied about this time as follows:

Station.	Time after highest declination of moon.		Distance from 100-fathom curve.	Average of velocity at all depths observed.
	d.	*h.*	*Miles.*	*Knots.*
2¼	0	12	10	2.11
2¼	1	11	10	1.80
2½	2	09	15	1.91
2	3	12	5	2.37

The first day at Station 2¼ the expansion was taking place, and probably at this point the velocity was greater than at any other part of the channel. On the second day the axis was farther to the westward, and changing the anchorage to Station 2½, was moving away from the axis. The mean of all was a trifle above the second day's currents at No. 2¼, but the surface velocity was $\frac{27}{100}$ of a knot below. Changing the position of the vessel to Station 2 placed her very near the axis at the time of its maximum flow. The actual current found, however, at this anchorage was probably in excess of the normal, due to the presence of an area of low barometer in the Gulf of Mexico. Station No. 3 was only occupied once with a middle declination of 1^{d} 17^{h} before zero and a mean velocity of 2.14 knots, which would certainly indicate a maximum three or four days later fully equal to that found at Station 2 with opposite conditions.

The daily variation is as marked here as elsewhere, and, as at Section A, is excessive on the west side. At one time it increased in five hours nearly 3 knots, and decreased in the next nine hours; at another time it increased $3\frac{1}{4}$ knots in three hours. The average time of the arrival of the maximum is ten hours before the moon's transit.

Section E E is situated at the extreme western entrance to the Straits of Florida, and is in reality the starting point of the Gulf Stream proper. Six stations were occupied by Lieutenant Vreeland, two or more times at each. The extremes were placed near the eighty-fifth meridian and about 5 miles distant from the 100-fathom curves of the Florida bank on the north and the Cuban shore on the south. The other stations were at about equal distances apart and on a curve (toward the Gulf) having a radius of about 90 miles. The northern stations are therefore on a line about perpendicular to a possible flow from the Gulf into the Straits of Florida, and the southern stations are similarily placed with reference to a current from the Yucatan Passage. The 100-fathom curves from Sections E E to C C converge, and the former section being at the large end of the funnel and near the source from which the supply of water comes (taking the source as either the Caribbean or the Gulf of Mexico), its currents vary greatly in direction. Owing to the great width of the section (about 125 miles) the velocities are more feeble and the characteristics which mark the other sections are less pronounced.

Station 1, situated near the Florida bank, occupies a position near the usual limit of flow of water to the southward and eastward. Its currents at the times of observation were always setting toward the Straits of Florida, except on one occasion, when the surface was moving to the westward, thus showing that at times the eddy of the neutral zone at Section C C sometimes reaches this point. The lower stratum was still flowing to the southeast. The direction of the currents at the next station was also to the southward and eastward, but at Stations 3, 4, and 5 they were running in that direction only during the period of low declination, while at high declination they were mostly in the northeast quadrant. Indeed, at Stations 1 and 2 the effect of the moon is visible on the directions, for during the former period the set was more to the eastward than during the latter. Station No. 5 is near the line between the Stream and an eddy, its currents at high declination varying between NE. and NW. Station No. 6 is entirely within the limit of a neutral zone which is sometimes flowing in one direction and sometimes in another. At high declination it was running the strongest to the southward and westward, in opposite directions to the currents at the other stations, while at low declination it belonged to the Stream current, although very feeble in strength.

The radical difference in the direction of the flow at all the stations is accompanied by the usual variation in velocity following the changes in declination. In the description given on page 541 illustrating the monthly variation, the velocities are resolved into their components. In the table below, the mean of the observed currents is shown, but all the observations at the various depths are taken and an equal value given to each set, whether it be for a greater or less number of hours:

Stations (Section E E).	High declination.	Low declination.
1	1.60	0.84
2	1.39	2.07
3	1.28	1.52
4	0.58	1.21
5	0.63	0.87
6	1.31	0.46

It is seen from this table that at high declination the maximum velocity was at Station 1, that it gradually diminished to Station 5, and that at Station 6, on the Cuban shore (where the direction was entirely negative—an eddy current), it increased considerably. At low declination the maximum was at Station 2, a change to the right in its position of about one-fifth the width of the Straits at this point.

The daily variation at Section E E is not as marked as elsewhere either as to time or amount. The differences between the extreme daily velocities are greater at the northern Stations 1, 2, and 3, Station 2 having the greatest. At these stations, too, it is greater at high declination than at low, while at the southern stations the reverse is the case. The time of the arrival of the maximum, using the observations of eight of the anchorages mostly at low declination, is 10 hours before the transit. Most of those at high declination give no result as to time, but four of them give 5 hours as the "establishment." The table below shows the data:

Stations.	High declination.		Low declination.	
	Amount of daily variation.	Time of establishment.*	Amount of daily variation.	Time of establishment.*
		h. m.		*h. m.*
1	0.62	5 30	0.34	9 35
		None.		
2	1.10	10 06	0.40	10 00
		5 38		
3	0.64	3 50	0.54	10 10
4	0.26	5 00	0.45	10 12
5	0.22	None.	0.32	None.
6	0.62	9 32	0.62	9 07

*At 130 fathoms.

CHAPTER VI.

THE GULF STREAM OFF JUPITER INLET AND CAPE HATTERAS. THE EQUATORIAL CURRENT.

Having drawn conclusions as to the characteristics of the Gulf Stream in the narrower parts, we will now continue the examination at points where a few isolated observations have been taken, to see if there are indications that the same laws prevail or if new characteristics present themselves. Observations of this kind have been made at Section B, between Jupiter Inlet and Memory Rock, at Section F, extending about southeast from Cape Hatteras Shoals, and in the equatorial current and Caribbean Sea. While it is a fact that at any one of these places the data are insufficient to definitely establish a law as to the current, yet it is thought that, viewed by the light we have obtained through the study already made, we shall be able to show that all currents are governed by the same laws.

At Section B, off Jupiter Inlet, two stations were occupied, one on the west side of the Stream about 18 miles distant from the light-house and the other on the extreme east about 5 miles from Memory Rock. The first observations were continued during a period of over 3 days, beginning at 7 p. m., May 30, 1886. From its situation we should place this anchorage very near the axis of the Stream, but as we have no data obtained under other conditions by which to establish the fact, we can only study it by itself. Separating the observations into equal periods of 24 hours each we find that the mean of the currents at all depths decreased in velocity, and the average temperature during those periods diminished. The middle declination of the moon for the first day was north and 3 days after passing the equator. The next day's declination was on the dividing line established at Section A between "high" and "low" declination, and the third day was within the limit of "high." It will be remembered that as the axis moves toward the east or west the temperature of the water rises and falls, the average during the time of the westerly movement being lower on the west side and higher on the east side than it is during the opposite period. At this anchorage the temperatures were high at first, it being the time of the easterly movement, and each day there was a decrease. Observations were not taken at 130 fathoms, and so a comparison of directions will not be of much value. The mean of all was N. by E. $\frac{1}{8}$ E. At 85 fathoms the last day's direction was N. by E. and the others N. by E. $\frac{1}{4}$ E. and NNE.

A comparison of the curves of surface current with those of Stations $1\frac{1}{2}$ and 2, Section A (Fig. 5), shows that the change in velocity accompanying the declination of the moon is as true here as elsewhere, and its shape and position fixes the anchorage at a point a little west of the mean position of the axis.

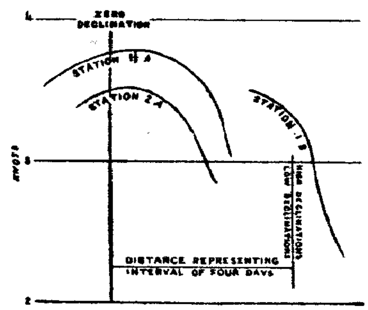


Fig. 5.—Comparison of Section B with Section A.

The other anchorage on this section was occupied for 36 hours, with the moon at about its highest southern declination. The directions seem to indicate that as the axis moves to the westward there may be an eddy current along the Bahama bank the same as at Sections E E and D D under similar conditions. Separating the data into intervals of 12 hours, we find that at all depths except at 130 fathoms, the directions change to the eastward. For the first 12 hours the mean was N. by W. $\frac{1}{4}$ W., for the second N. $\frac{3}{4}$ W., and for the third NE $\frac{3}{4}$ N.

The surface temperatures show the same regularity of change as at Station 1. Being on the east side of the Stream and the axis moving west, the lowest temperature had been reached and a rise was taking place. For the three 12-hour intervals the means were, 80°.17, 80°.40 and 80°.70. At Station 1, the time being at the change in direction of the axis, and, as stated on page 131, the actual minimum arriving at some period after the changes in direction, the temperatures were falling. The average of each 24 hours is given at all the depths in the table below. (At Station 6 only the surface temperatures were taken.)

Temperatures, Station 1, *Section B.*

Depths.	3½ fms.	15 fms.	30 fms.	65 fms.	85 fms.
	°	°	°	°	°
First 24 hours.	83.26	77.00	70.33	66.97	63.00
Second 24 hours.	83.10	75.70	69.17	65.10	62.00
Third 24 hours.	82.05	74.20	66.25	63.00	60.00
Ave.	82.80	75.63	68.58	65.02	61.67

As far as the observations go, this section seems to follow the laws as determined by the data obtained at the sections farther to the southward.

At Section F, off Cape Hatteras, the bottom deepens gradually from the extremity of the shoals, about 9 miles from the Cape, to the 100-fathom curve, 21 miles distant. From this point the bottom drops suddenly to nearly 2,000 fathoms in the next 20 miles.

The mean position of the three anchorages at Station 1, is about 5 miles outside the 100-fathom curve, in latitude 34° 52′, longitude 75° 15′. Its situation with reference to the general direction of the flow of the current (about NE.), would lead us to look for characteristics resembling those of Station 1 at Section A, where the current is flowing north, and also expect that they should somewhat partake of the peculiarity of Stations 1 and 2 of Section C C, where the general direction of the Stream is east; that is to say, as the current off Cape Hatteras flows in a direction which is a mean of the other two, its extreme left-hand station should resemble the corresponding stations of the other sections. It is very unfortunate that at every time observations were made at this station the weather either just before or after was so abnormal that there may be a doubt entertained as to whether the currents actually found were normal or not. It will be seen later, however, that while they may not be normal in velocity, the meteorological conditions were such that the departure in each case will not affect the principle established of changes according to declination, for all were influenced in the same way. This station was first occupied on the morning of May 28, 1887, and observations were continued over 50 hours. During this time the barometer was low at the Signal Service stations to the northward, a depression developing on the New England coast and moving in a curve to the southward on the 29th, receding toward

Nova Scotia on the 30th. It was relatively shallow and was unaccompanied by disturbances of marked strength, but still it is possible that the low area influenced the current to make it more rapid than usual toward the latter part of the time of observation.

The declination of the moon was near the dividing line between the high and low as previously established by the study of the observations in the Straits of Florida, the first half of the time being about 3½ days before zero declination. The current during the latter period should be less, according to theory, than during the former period, but, in fact, the reverse was the case, the average of all the depths being two-tenths of a knot greater. This was the time, however, when the effect of the barometer should be most potent in its influence on the current, for the low area reached its southern limit on the 29th and then moved away. The strength of the current was on the surface, the lower stratum apparently obeying the law, while the upper currents were possibly under the influence of the abnormal conditions. The first half of the observations, therefore, was probably about normal for the declination of the moon at the time, and during the last half the velocities were too great.

The next observations were taken on May 5 and 6, 1889, with the declination of the moon one day after its highest north. The directions were all to the northward and eastward and the current was strong and deep. There was a large area of high barometer covering the Atlantic and Gulf States during the 5th and 6th, which finally disappeared after reaching the South Atlantic coast. At the same time there was a depression about midway between Bermuda and the Bahamas, which moved to the northward and eastward. The effect of these areas would be somewhat the same as in the case of the first observations except, of course, in amount. The last observations, however, can well spare half their velocity, and even then the volume will be many times greater than during the first set.

The third time the station was occupied was on June 20 and 21, 1890, with a middle declination of zero. The directions were all to the southward and westward, averaging SW. ¼ S. On the morning of the 19th a tropical storm, which had made its way from the vicinity of Cuba, was central to the east of the Middle Atlantic coast. During the 19th it continued its northeasterly course, and it is probable that it united with a low area to the northward after that disturbance reached the lower St. Lawrence Valley. The latter is said to have disappeared to the northeastward of the Gulf of St. Lawrence during the 21st. At the time of the observations on the 20th and 21st the low area had moved so far away that probably its influence was hardly felt off Cape Hatteras. At all events its effect would have been to make the Stream either run in its normal direction (northeast) or to lessen the velocity of the current, which was setting to the southwest, neither of which would change the principle involved. Figure 6 shows the vertical curves of velocities at each of the three anchorages. From these it is seen at a glance that at high declinations the current is strong to the northeast, at mid-declination it runs to the northeast but with much less volume, and at zero declination the set is southwest. It seems hardly possible to ascribe enough influence to barometric effect to warrant the conclusion that these currents are not under the same law of changes according to declination of the moon which we have found in the Straits of Florida.

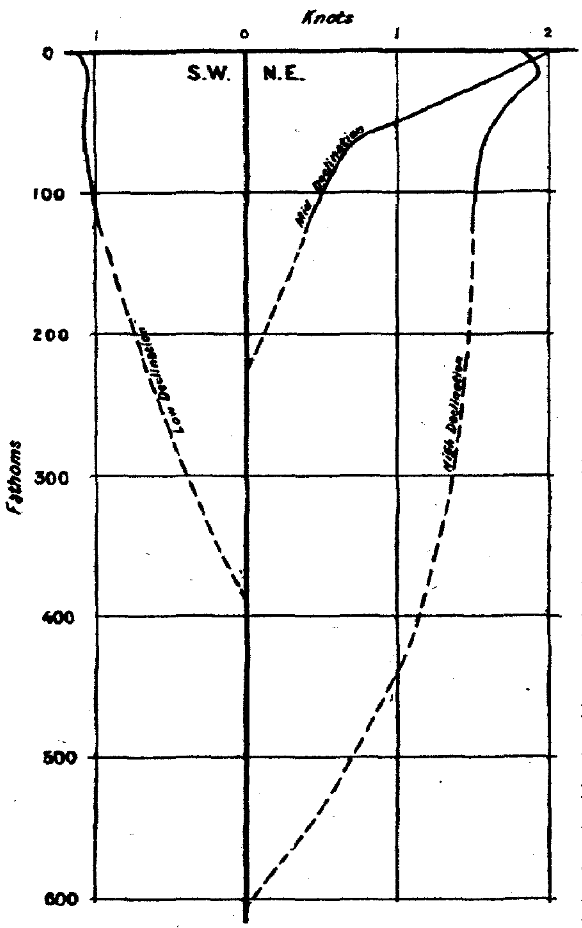
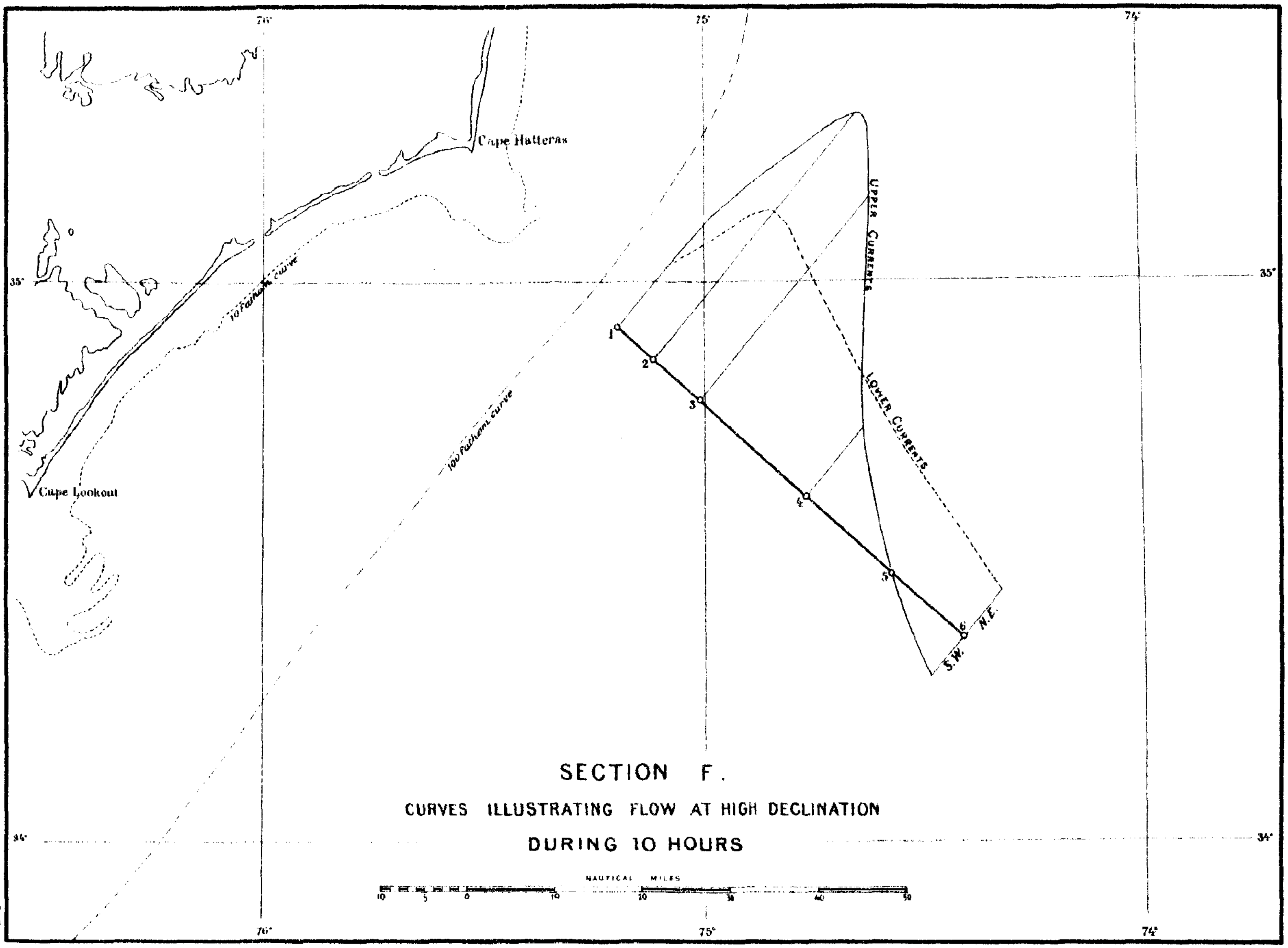


Fig. 6.—Station 1, Section F (Off Cape Hatteras).

The other anchorages at Section F were nearly in a southeast line from Station 1, and extended to a distance of about 76 miles from Hatteras lighthouse. With the exception of Station 5 all were at high declination and were occupied from 9 to 27 hours each. The directions at Stations 2, 3,



SECTION F.

CURVES ILLUSTRATING FLOW AT HIGH DECLINATION DURING 10 HOURS and 4 were mostly to the northward and eastward at all depths, while at 5 and 6, only the stratum below 65 fathoms was flowing steadily in that direction. Here again we find evidence of the movement of the axis to the right and left following the declination of the moon. Illustration No. 52 shows the curve of surface flow (above 30 fathoms) at high declination. Having no data obtained under opposite conditions with which to compare it, the illustration is only evidence that, at the time of the observations, the axis was situated about 10 miles outside the 100-fathom curve; that the surface width was practically the same as in the Straits of Florida; that there was a surface eddy current on the south side of the Stream, exactly the same as at Station 1 at low declination; and last, that there was a body of water on the right of the Stream setting to the northeast below the surface.

There is reason to believe, and indeed the proof is positive, that the current flowing along our coast is divided into warm and cold bands. At two anchorages, Nos. 4 and 5, the vessel happened to be placed at points where the fluctuations in temperature were excessive. A study of the relations existing between the directions of their currents and the temperatures at these stations, together with the position of the moon, seems to confirm the truth of the theory of the movement of the Stream to the right and left. The moon at Station 4 was 16 hours after passing its highest northern declination. At Station 5 it was 2 days before reaching zero. Both anchorages were in the year 1889, the first on May 4th and 5th and the second May 9th and 10th. It has been stated that at high declination the direction of the current at the sides is more nearly parallel to the general direction of the flow than at low declination, and this is more marked in the subcurrents than on the surface. The table below shows the currents in question averaged for each quadrant of the compass, with the number of observations:

Directions of the currents at Stations 4 and 5, Section F.

	3½ fathoms.		15 fathoms.		30 fathoms.	
	No.	Direction.	No.	Direction.	No.	Direction.
Station 4 (high declination)	3	N. by W.			2	N. by W. ½ W.
	4	NE. ½ N.	7	NE.	4	NE.
	2	SE. ½ E.			2	SE. ½ E.
Station 5 (low declination)	5	NW. ½ N.	4	NW. ½ W.	6	NNW.
	3	NNE.	3	N. by E.	4	N. by E.
	4	SE. by S.	4	SE. by S.	2	S.

	65 fathoms.		130 fathoms.		200 fathoms.	
	No.	Direction.	No.	Direction.	No.	Direction.
Station 4 (high declination)						
	3	NNE	7	NE.	3	E. by N.
	4	SE	2	E. by S.		
Station 5 (low declination)			4	NNW		
	10	N. by E.	6	NE. by N.	10	NNE.

From this it is seen that at Station 4 the mean directions are much more to the eastward than at Station 5. Comparing the surface temperatures and directions (Fig. 7) we find that not only is the daily movement indicated at each station, but also the monthly. At both stations the directions changed with fair regularity; at Station 4 from the southeast quadrant to the northwest, and in the reverse direction at Station 5. In the first case the temperature curve shows an abrupt fall, with an indication of a gradual rise to the end of the observations, and in the other case it is a gradual fall and a quick rise. It seems as if, at the time of the anchorage at Station 4, the maximum flow being on the north side of the stream, the southern edge, as represented by a cold band, was situated in its vicinity. At low declination this cold band had moved out some 13 or 14 miles and was at Station 5. If observations can be continued for a period of two lunar weeks at either of the stations, it probably will be found that the directions predominate first toward the north and then toward the east, and that the abrupt change in temperature will be less and less or more and more marked each day, as the edge of the Stream is progressing or retrograding; that the limit of northerly movement is somewhere not far north of Station 4, and of southerly movement outside Station 5.

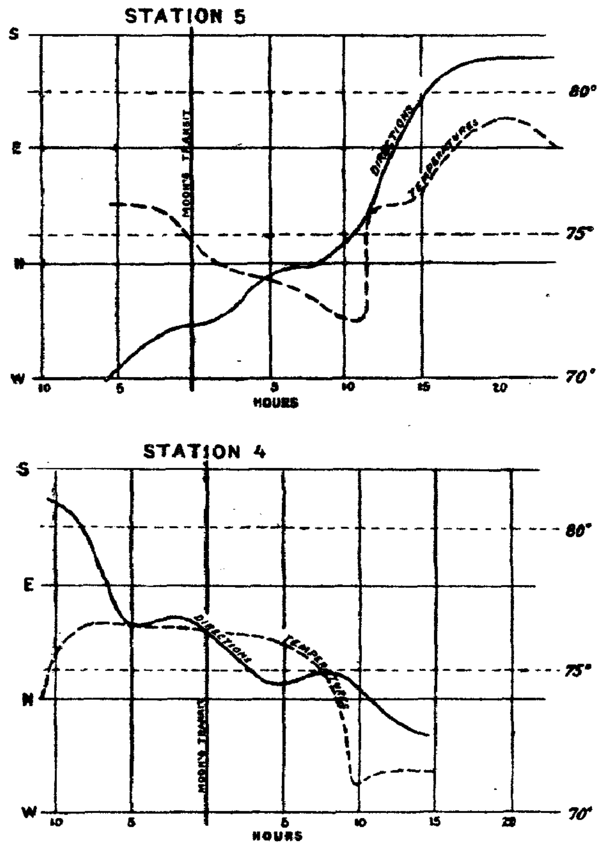


Fig. 7.—Comparison of temperatures and directions near Cold Wall, off Cape Hatteras.

The temperatures of all the stations form a peculiarly interesting study, as they show how absolutely unreliable is the commonly accepted idea that the warmer the water the stronger the current from the south. In the curves just referred to, it will be noticed that the temperature is warm in both cases when the flow is toward the southeast quadrant, and that the abrupt change comes in one instance where the flow is altering its direction from the northeast to the northwest, and, in the other, from the northwest to the northeast. At Station 1 the warmest water at the surface and at 15 fathoms was observed at low declination with a current setting southwest; it was cooler at mid-declination, and the coldest was found at high declination when the current was strongest to the northward and eastward. At the same time the temperatures at the lower depths were exactly the reverse, the coldest water coming from the north and the warmest from the south. The table below gives the mean temperature at the different points of observation:

Station.	Date.	Average direction of surface current.	3½ fathoms.	15 fathoms.	30 fathoms.	65 fathoms.	130 fathoms.	200 fathoms.
			°	°	°	°	°	°
1	May, 1887	NE. ¾ E	77.28	75.60	72.38	59.40	51.67	46.50
1a	May, 1889	N. by E. ½ E.	75.06	74.39	72.12	64.69	53.06	
1b	June, 1889	SW. by S.	80.19	76.19	69.13	58.13	49.56	44.75
2	May, 1889	NNE. ½ E	79.80	79.50	79.00	73.20		
3	May, 1887	NE. by E	78.56					
3a	May, 1889	E. by N	77.90	75.79	74.38	70.94	64.50	62.63
4	May, 1889	Variable; NE. by E	74.48	73.90	71.64	67.21	64.28	
5	May, 1889	Variable; NNE	74.82	73.20	71.38	70.83	65.06	61.11
6	May, 1889	W	77.50	76.70	74.85	70.81	64.50	62.20

The observations made within the limits of the *Equatorial current* were as follows: One anchorage about 60 miles north of Barbados, 8 between that island and Tobago, and also in all the principal passages between the islands from Trinidad to Cuba. The current reaching the Windward Islands is, according to generally accepted belief, composed of two bodies of moving water. One part is said to be from the South Equatorial current, which after crossing the Atlantic from Africa divides at Cape St. Roque, the eastern salient of South America, and forces a portion of its flow to the northward and westward along the coast of Brazil, past the mouth of the Amazon and the shores of Guyana, until it reaches the barrier of the Windward Islands. The other current is the drift caused by the northeast trade winds. Whatever may be the component parts or the cause of each it is a fact that the currents in the vicinity of Tobago are of a different character from those near Barbados. The first, moving as it does along the coast of South America, leaves the island of Tobago with a direction about NNW. The other, flowing in the general direction of the trade winds, causes a resultant direction at the point of meeting dependent upon the relative velocities of the two. The coast current has the most rapid flow, is deeper, and is probably more changeable than its mate. These conditions, in the combined current where the observations were made, render it difficult to determine whether the same laws hold good here which have been found farther to the westward.

The data obtained in the coast current would at first glance seem to point to a reversal of the law of change following the declination of the moon—that is, instead of the strongest surface current being found on the extreme left at high declination with a movement toward the right as the moon passes the equator, there are indications that the reverse is the case. The data are so slight on which to base a conclusion that this is true, and the conditions tending to produce irregularities are so strong, it is probable that the exceptions found are due to variations in the force of the primal cause of the flow. All of the anchorages between Barbados and Tobago were placed nearly on the line joining the islands, and were made, with one exception (Station 4^a), between January 26 and February 13, 1888. Station 1 was about 35 miles from Barbados, while Station 5 was about 3 miles from the 100-fathom curve off Tobago Island, and rather under the lee of the most salient point of the shoal water. At each station the flow of the upper stratum was quite constant in direction, and at 65 and 130 fathoms depths it was variable, generally between northeast and northwest, and the variation was more marked at the northern than at the southern stations.

Station No. 32, situated about 60 miles north of Barbados, was occupied 30 hours, during which time it was calm or the wind was very light and variable. The body of the current therefore may be considered as the normal drift for the date and season. The table below shows the character of the currents. The directions given are means of those falling within the limit of each quadrant of the compass separated by the intercardinal points. The number of observations is also given, together with the velocity.

Station 32.

3½ fathoms.			15 fathoms.			30 fathoms.		
No.	Direction.	Velocity.	No.	Direction.	Velocity.	No.	Direction.	Velocity.
5	W. by S	0.84	7	W. by S	0.92	6	W	0.98
4	SW. by S.	0.77	2	SSW	0.81	3	SW. by S.	0.76
65 fathoms.			**130 fathoms.**			**200 fathoms.**		
No.	Direction.	Velocity.	No.	Direction.	Velocity.	No.	Direction.	Velocity.
8	WSW	0.88	2	N. by E.	0.51			
2	SSW	0.81	1	WNW	0.63			
			5	S. by E.	0.53	8	S. by W	0.53
			2	ESE	0.55			

This table shows that to the depth of 65 fathoms there is a gentle flow to the southward and westward, predominating at W. by S.; that at 130 fathoms the character of the flow has changed from a steady current to a tidal current, but with a predomination to the southward; and that at 200 fathoms the current is again constant but at right angles to that of the surface. The same drift current exists south of Barbados, with the same tidal influence at the lower depths, but with the difference that the stronger coast current, meeting the drift current nearly at right angles, changes the direction of the latter.

The following table shows the velocities and directions, the distance of each station from Barbados toward Tobago, and the declination and age of the moon:

Station.	Distance from Barbados.	Moon.		3½ fathoms.		15 fathoms.	
		Age.	Declination.	Direction.	Velocity.	Direction.	Velocity.
	Miles.	*Days.*					
1	34	13.4	20° 26′ N	W. ¼ S	0.86	W. by S	0.63
2	60	14.9	19° 30′ N	WNW	0.58	NW. by W. ½ W.	0.54
3	80	16.2	16° 52′ N	NW	1.09	NW	0.83
4	91	18.6	7° 21′ N	NW. by N	1.24	NW. ½ N	1.08
4ᵃ	91	28.3	22° 00′ S	N. by W	1.98	N. by W	2.13
5	109	23.7	15° 25′ S	NNW	2.46	NW. by N	1.45
5ᵃ	109	25.1	19° 17′ S	NW. by N	1.90	NW. by N	1.44
5ᵇ	109	0.2	13° 41′ S	N. by W. ½ W.	1.76	N	1.35

Station.	30 fathoms.		65 fathoms.		130 fathoms.	
	Direction.	Velocity.	Direction.	Velocity.	Direction.	Velocity.
1	W	0.68	NW	0.72	NW. by W	0.83
			NE	0.31		
2	W. by N	0.53	NW. by W. ½ W.	0.70	NNW. ½ W	1.13
			NE	0.30	NE	0.36
3	NW. ½ N	0.75	NNW	0.90	N	0.65
			NNE	0.82		
4	NNW. ½ W	0.80	NNW. ½ W	0.61	N. by W	0.98
4ᵃ	N. by W	2.16	WNW	0.56	SW. ¼ S	0.58
			E	0.86	SE. by S	0.69
5	N. ½ W	1.17	SE. by E	0.72	N. ¼ E	1.37
			NW. ½ W	1.32		
5ᵃ	NW. by N	0.93	NW. by N	1.27	N. by W. ¾ W	0.97
5ᵇ	N. by W	0.90	N. by W	0.97	NNW	1.20

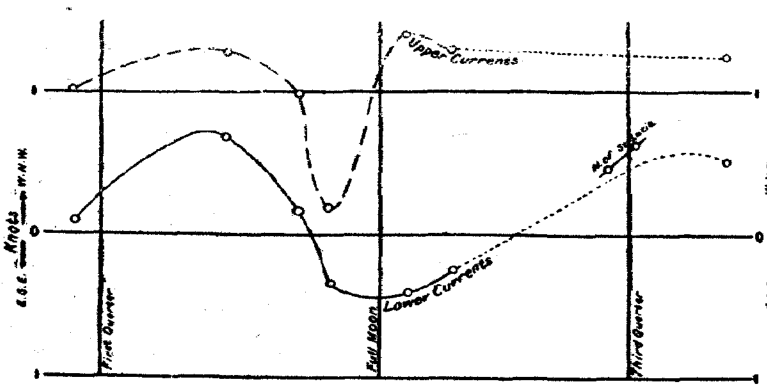
Taking the mean of the currents at 3½, 15, and 30 as the surface flow, we see that at one extreme of the line the drift has a course of W. ½ S., the same as at Station 32 north of Barbados, and at the other end (Station 5) the coast current sets N. by W. ¾ W., a difference of six points and three-quarters. In the portions of the Gulf Stream investigated, where the general flow is not on the meridional line, the differences in the direction of the current at the extreme stations have been found to be as great as those shown in the table above, and this would seem to warrant the conclusion that the coast current sometimes nearly fills the passage between Barbados and Tobago with a general axial direction of about NW. Comparing the directions at Station 1 with those at Station 32, we see that there is a considerable deflection of the lower currents at the former, which is probably due to the coast current.

The only stations occupied more than once were Nos. 4 and 5, and from the table it is seen that at high declination the velocity at Station 4 is greater than it is at low declination. At Station 5, however, the velocities show an exception to the rule established. At the first anchorage, with the moon midway between the equator and its highest declination, the current was strongest, and at the last anchorage, with the conditions exactly reversed, it was weakest. The situation of this station, however, makes it probable that its currents are fluctuated irregularly, and particularly so on the surface. This fluctuation is due to variations in either the strength or the direction of the trade winds, and is observable to a greater or less degree at all the stations in this passage.

Remembering the fact that there are two moving streams of water, one along the coast and the other inclined toward it, and assuming that they are governed partly at least by the same laws of changes that control the Gulf Stream in the Straits of Florida, the following would seem to reconcile all apparent discrepancies. The surface velocity of the coast current varies daily with great regularity, as will be seen later. The wind, however, is continually forcing the water toward the shore at a greater or less angle with its current, and the velocity of the escaping water depends largely upon this angle and the relative strength and persistency of the wind. After zero declination the regular current should be deep and strong at its axis, which, according to theory, should be farther to the northward and eastward, or off shore, than at high declination. At Station 4 this was the case with the lower stratum, but the reverse was true with the surface currents. To account for the latter, however, the wind at one anchorage was blowing NE. by E. ½ E. with a force of 3, which would cause a less velocity to the escaping surface water than at the time of the other anchorage, when the wind was blowing from ESE. ½ E. with a force of from 3 to 4.

The relative velocities of the currents at Station 5 should have been the reverse of those found, but the wind seems also to have been the cause of the irregularity. At the three anchorages this was as follows: Station 5, ENE., force from 3 to 7. Station 5[a], ENE., force from 3 to 4, and Station 5[b], NE. by E. force 4: that is, for the first two, the same direction of wind but with lessening force at the second anchorage, and for the last anchorage a direction more across the current and normal to the shore. The strong current which was observed at 130 fathoms on February 5, was found at 65 fathoms, when the station was occupied a day and a half later, and had again dropped to 130 fathoms at 5[b], as the time of the normal maximum had passed.

While the velocity of the surface currrent seems to be governed to a considerable extent by the wind, the lower stratum is apparently influenced by the phases of the moon, and this helps to mask the declination variation. When we examine the observations taken at the seven anchorages in the passage south of St. Lucia Island, we find but little evidence of the effect of the declination, but every evidence that the lower currents vary with the phases. The velocity from the surface to 30 fathoms depth is remarkably regular and constant, the former having a direction about WNW., seemingly the resultant of the trade drift and the coast current, and the latter inclining more to the westward as the depth increases. At the lower depths there was a decided tidal flow into and out of the Caribbean. The greatest daily fluctuation at all depths was found to be at the time of full and change, with a predominating easterly flow at the lower stratum.



Variations of currents outside of the St. Lucia Passage.

The following table, together with Fig. 8, will best explain the phenomenon. Where there is much departure in direction, the velocities are resolved and the WNW. components taken. All the stations given in the table were in the passage except Stations 20 and 21, which were to the eastward, opposite the middle of the passage.

Number of station.	Date.	Moon's age.	3½ fathoms.		15 fathoms.	
			Direction.	Velocity.	Direction.	Velocity.
		Days.				
20	Mar. 19, 1888	7.3	WNW.	1.52	WSW.	0.62
21	Mar. 21, 1888	8.4	WNW.	1.39	NW. by W.	1.58
9	Feb. 28, 1888	17.2	NW. by W. ½ W.	1.29	NW. by W.	1.35
10	Feb. 22, 1888	11.3	WNW. ½ W.	1.31	W. by N.	1.23
10^a	Feb. 24, 1888	13.2	WNW.	0.91	WNW.	0.91
10^b	Jan. 25, 1890	24.4	WNW.	1.32	W. by N.	1.17
11	Feb. 25, 1888	14.0	W. by N.	0.22	S. E.	0.29
			E.		WSW.	
12	Feb. 27, 1888	16.0	W. by N.	1.39	W. ½ N.	1.39

Number of station.	30 fathoms.		65 fathoms.		130 fathoms.	
	Direction.	Velocity.	Direction.	Velocity.	Direction.	Velocity.
20	WSW.	0.90	SW.	0.33	NE. by N.	—0.14
			NNW.		S.	
21	W. by N.	1.17	WSW.	1.00	S. by W.	0.01
9	WNW. ½ W.	1.27	W. by N.	0.20	W. by N.	—0.71
			E. by S.		ESE. ½ E.	
10	W. by N.	1.26	WNW.	1.11	SSE. ½ E.	0.26
					NW. ½ N.	
10^a	W. by S.	1.12	W. by S.	0.74	NW.	—0.39
			NNE.		ESE.	
10^b	W. by S.	1.20	NW. by N.	0.97	S. by E.	0.03
					NW. ¼ W.	
11	SSE.	0.00	SW.	—0.10	S. by E.	—0.55
	SW.		SSE.			
12	W.	1.39	E. by S.	0.34	ESE.	—0.58
			NW. by W.			

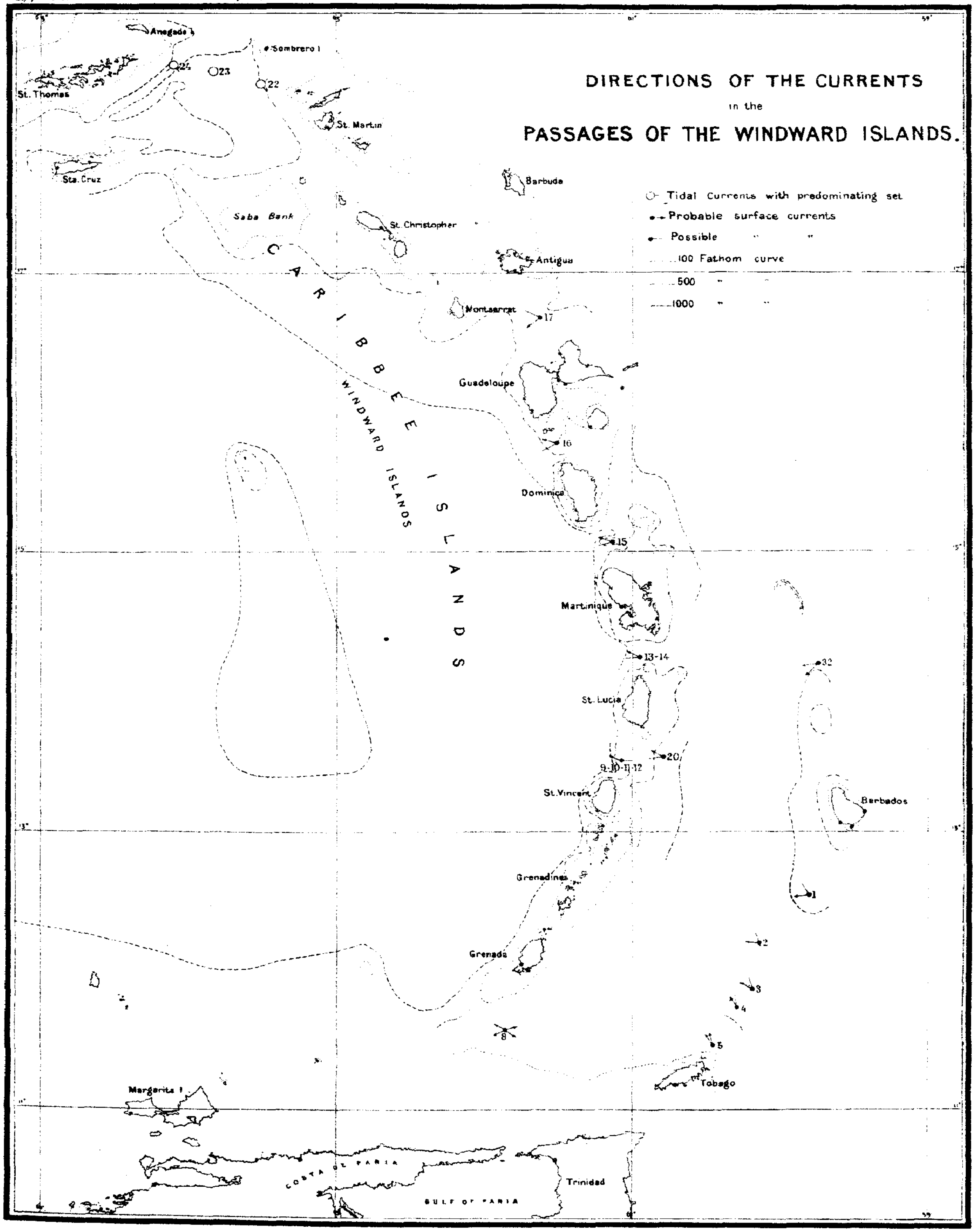
The sketch and the table above show how constant the surface flow is at all the stations with the exception of Station 11, and how sharply defined is the curve of the lower velocities. The observations of two days in the passage north of St. Lucia show the same rule governing the deep flow, and with the exception of Station 5, near Tobago, all the anchorages in the passage between that island and Barbados give like indications.

There can be no doubt that this last-mentioned passage is sometimes completely filled by the shore current, but it probably occurs only after a period of abnormally strong trade winds blowing from a point well to the eastward. Evidence of this increased width was observed on one occasion. Observations were made at Station 20, about 15 miles east of the passage between St. Lucia and St. Vincent, and an average surface velocity of 1.52 knots was found. Twenty miles farther to the eastward an anchorage was made on the following day, when the surface current was found to be 2.28 knots setting WNW. Unfortunately, bad weather prevented a continuance of the observations beyond five hours, but the same hours of the previous day, at Station 20, gave an average of 1.68 knots. It seems probable that either the general strength of the current was increasing during the time or else the change of anchorage placed the vessel nearer the axis. Upon steaming to Barbados after getting underway, and also during the passage to St. Lucia. the day after, the same strong current was found. It was common report among the nautical people at Bridgetown (Barbados) that the trade winds were and had been blowing with unusual strength along the South American coast. This strong current was only superficial, however, for, as will be seen from the table, the direction at 130 fathoms was S. by W., with a resultant force of but one one-hundredth of a knot toward the passage. These anchorages, Stations 20 and 21, happened to be within one day of highest northern declination, but the evidence does not seem to be in favor of increased strength due to this cause.

The daily variation seems to be well marked at all the anchorages here considered, except at Station 32 north of Barbados. An average of 25 maxima in the passages north and south of St. Lucia and south of Barbados give for the "establishment," or the time of the arrival of the maximum currents, 6 hours and 16 minutes before the transit of the moon. The two surface current waves follow almost exactly the same form as the curve of the tides. The differences between the daily maximum and minimum currents at the various stations in the vicinity show the mutual interference of the coast with the drift current. At the stations nearest Barbados the average variation is about one-half knot, at Station 4 it is six-tenths and at Station 5 nearly one knot. In the vicinity of the passage south of St. Lucia a mean of all the daily differences in velocity is seven-tenths of a knot, the greatest being observed just after full and probably it also occurs after new moon. The variation north of St. Lucia was found to be six-tenths of a knot.

As we proceed north from the island of Martinique the influence of the coast current on the flow of water through the passages disappears. It is seen between Martinique and Dominica only at the surface, where the direction is about WNW., with all the lower currents running to the southward and westward. Its effect is not observed north of Dominica, where the gentle flow of the drift current, complicated by tidal action, has taken its place.

In the Anegada, Mona, and Windward Passages a steady flow is not to be found, but only tidal currents, with an inclination in one direction or another depending upon local causes. In general, the predominating set in all these passages seems to be outward on the eastern and toward the Caribbean on the western sides. The opinion advanced by others that the flow through the Windward Passage is always toward the Caribbean, and that it reaches the bottom as evidenced by the character of the bottom soil specimens, is not confirmed by the observations of the actual current. That it is mostly tidal and feeble in force will be seen from the table below. The directions given are the means of all those falling within the quadrants limited by the intercardinal points. Station 27 is nearest Haiti; Station 28 is near the middle of the passage, and No. 29 is nearest the Cuban shore.


DIRECTIONS OF THE CURRENTS
in the
PASSAGES OF THE WINDWARD ISLANDS.
Tidal Currents with predominating set
Probable surface currents
Possible " "
100 Fathom curve
500 "
1000 "
Anegada I.
Sombrero I.
St. Thomas
St. Martin
Sta. Cruz
Saba Bank
Barbuda
St. Christopher
Antigua
Montserrat
CARIBBEE ISLANDS
WINDWARD ISLANDS
Guadeloupe
Dominica
Martinique
St. Lucia
St. Vincent
Barbados
Grenadines
Grenada
Tobago
Margerita I.
COSTA DE PARIA
GULF OF PARIA
Trinidad
24
23
22
17
16
15
13-14
32
9-10-11-12
20
1
2
3
4
5
8

Observed currents, Windward Passage.

Station.	Date.	3½ fathoms.			15 fathoms.			30 fathoms.		
		No.	Direction.	Velocity.	No.	Direction.	Velocity.	No.	Direction.	Velocity.
27	Apr. 19–20, 1888	2	NNE	0.51	4	N. by E	0.61	5	NNE	0.53
		7	E. ¾ N	0.67	4	E	0.55	4	E. by N	0.66
		1	S. by E	0.72	2	S. by W	0.59			
27a	Mar. 24–25, 1889	7	N. by E	0.45	6	N. by E	0.40	3	W. by N	0.47
		2	SE	0.46	2	SSE	0.54	3	N	0.49
								2	S. by W	0.61
28	Apr. 20–21, 1888	1	NW. by W	0.63	8	N	0.51	1	NW. by W	0.33
		9	NNE	0.60	2	NE. by E	0.61	8	N. ½ E	0.46
		1	E. by N	0.50				1	NE. by E	0.48
28a	Mar. 25–26, 1889	3	S	0.50	2	SSW	0.62	2	SSW	0.58
29	Apr. 21–22, 1888	9	SE. by S	0.89	10	SSE	1.01	10	SE. by S	0.86
29a	Mar. 22–23, 1889	6	NW. by N	0.73	5	N. by E	0.67	1	NNW	0.69
					2	W. ½ S	1.15	3	E. by N	0.63
								1	S. by E	0.67
								2	WSW	1.07

Station.	Date.	65 fathoms.			130 fathoms.			200 fathoms.		
		No.	Direction.	Velocity.	No.	Direction.	Velocity.	No.	Direction.	Velocity.
27	Apr. 19–20, 1888	3	N. by E	0.43	3	WNW	0.22	—	—	—
		6	E. ½ N	0.44	2	NNE	0.27			
					2	E. ½ S	0.35			
					2	S. by W	0.36			
27a	Mar. 24–25, 1889	2	WSW	0.57	2	W. by S	0.42	2	SSW	0.22
		2	N	0.42	3	N. by E	0.35	5	NE. ½ E	0.33
		4	S. by W	0.69	3	S. by E	0.29			
					1	E. by S	0.44			
28	Apr. 20–21, 1888	3	NW. by W	0.47	7	WNW	0.69	—	—	—
		5	N. by E	0.43	3	NNE	0.40			
		2	NE. by E	0.55						
28a	Mar. 25–26, 1889	2	S	0.62	2	N	0.43	1	N. by W	0.39
					1	SW. by S	0.54			
29	Apr. 21–22, 1888	9	S. by E	0.75	9	S. by E	0.48	6	SE. by S	0.43
								3	W. by S	0.39
29a	Mar. 22–23, 1889	4	S	0.72	1	N. by W	0.59	1	NW	0.51
		4	W	0.81	2	ENE	0.74	5	ESE	0.79
					2	SSW	0.36	1	SW. by S	0.10
					2	W. by N	0.63			

It certainly seems that no large body of water passed through the passage in either direction at the time of the observations. The current is evidently tidal, with a decided prominence of northeasterly directions at Stations 27, 27[a], and 28, and with a southerly set at Station 29. The feeble current always found, and the diminishing velocities as the depth of observation increased, seem to warrant the conclusion that the flow is only superficial.

On the southern side of the Caribbean Sea the currents are apparently erratic, and yet they probably are governed by the same laws as elsewhere. Between Grenada and Trinidad, at the time the observations were taken in 1888, the current at the deep-water station near the middle of the passage was found to be setting to the eastward at all depths. A year later at the same anchorage the flow was in the opposite direction, except at 65 and 130 fathoms, where it changed from WSW. to NE. and back again. These anchorages happened to be under almost identically the same conditions of moon's transit, age, distance, parallax, etc., and yet at one the set was always outward and at the other it predominated inward. This passage is peculiarly situated with regard to the two streams composing the Equatorial Current, and it is probable that on their relative strength the direction of the flow in the Grenada Passage is determined. At the lower depths there is probably a normal current setting east. The portion of the drift current which can enter the passage in question meets the coast current at nearly a right angle. If the latter is strong the former is deflected to the northward and the current in the passage is to the eastward at all depths. If, on the other hand, the coast current is weak, the drift current is able to reach the passage, thus causing a westerly surface current, a tidal current at intermediate depths, and probably an easterly set at the lowest. Of course this is in a measure complicated by the phase of the moon.

Between Curacoa and the mainland the eddy subcurrent was strong, constant, and perfectly marked. At an anchorage near the middle of the deep water, the current was northwest as far as 45 fathoms and southeast below that depth. Nearer the mainland, but still in fairly deep water (425 fathoms), the northwesterly current, only a stratum of 25 fathoms in thickness, was flowing with a velocity of 1.87 knots at the surface and 0.88 knot at 15 fathoms. This eddy subcurrent probably does not reach Grenada, for there is a barrier of shoal water extending to the northward from Margarita Islands which would prevent; but the evidence is that there is a similar eddy current in the deep water leading to the Grenada Passage, which, together with the relative values of the two streams forming the equatorial current, rule the direction of the surface current between Grenada and the bank off the Dragon's Mouth of the Gulf of Paria.

In the western Caribbean, anchorages were made between Jamaica and Pedro Bank, between the latter and Rosalind Bank, and in the shoal water east of Gorda Bank. The passage between Pedro and Rosalind Banks (Station 37), about 700 fathoms deep in the middle, has a strong, shallow current, but its direction is much inclined to the general axis of the channel. It is a part of the flow through the Caribbean, and probably has the same characteristics as the current outside the Windward Islands in the vicinity of St. Lucia. The surface has a direction between west and southwest with considerable velocity. The lower currents incline more to the northward of west as the depth increases, but the strength is maintained to 65 fathoms, below which there is a rapid diminution until 200 fathoms is reached, where tidal action appears. On the shoal east of Gorda Bank (Station 38), the direction of the flow is nearly at right angles to surface current in the passage mentioned above.

The following table gives the data obtained at these anchorages:

Station.	Date.	3½ fathoms.		15 fathoms.		30 fathoms.	
		Direction.	Velocity.	Direction.	Velocity.	Direction.	Velocity.
37	May 10–11, 1889	SW. by W	1.97	SW. by W	1.86	WSW	1.84
38	May 12–13, 1889	NNW	1.29	N. by E	1.25		

Station.	Date.	65 fathoms.		130 fathoms.		200 fathoms.	
		Direction.	Velocity.	Direction.	Velocity.	Direction.	Velocity.
37	May 10–11, 1889	W. by S	1.51	W. by N	0.67	W. by N E. by N	0.47 0.57
38	May 12–13, 1889						

CHAPTER VII.

CAUSES OF THE GULF STREAM AND OF ATLANTIC CURRENTS.

We have nearly completed the examination of the Gulf Stream observations taken in the *Blake* under my command, and it seems proper to take up the question of causes of the Atlantic currents before drawing conclusions for the benefit of "those who go down to the sea in ships." The facts which I have obtained may not prove positively what these causes are, but in the personal experiences of five years' work, watching the winds and waves and observing the currents, there are many things which may be considered as indicating very decidedly what it is that produces and keeps in motion these vast bodies of water.

It is necessary to an understanding of the subject to recapitulate some of the prominent theories which have been advocated. Although there were many ideas advanced before the time of Franklin, he seems to have been the first to give his theories widespread publication. He says:

> This stream is probably generated by the great accumulation of water on the eastern coast of America between the tropics by the trade winds which blow there. It is known that a large piece of water, 10 miles broad and generally only 3 feet deep, has by a strong wind had its waters driven to one side and sustained so as to become 6 feet deep while the windward side was laid dry. This may give some idea of the quantity heaped upon the American coast and the reason of its running down in a strong current through the islands into the Bay of Mexico.

Humboldt published in 1814 a description of the Gulf Stream, in which he says it is not the same at all seasons of the year, but that its force and direction depend to a large extent upon the changes in the trades, and also that the general torpidity of the ice in the Arctic in the winter and its melting in the summer influences it. He says also:

> Considering the velocity of the fluid elements, which in different latitudes in consequence of the earth's rotation is different,

> one should be tempted to think that every current from south to north ought to have at the same time a tendency to the east, and *vice versa*, a current from north to south a tendency to the west.

Arago advocated the same theory in part. He says that—

> With respect to currents, the rotation of the earth ought principally to be taken into view, and this, together with the cooling and the warming of the water in the north and south, is the main cause of their more rapid or slower deviation and progress toward the east or west. * * * We ought to apply to the ocean the same theory which has already afforded a satisfactory explanation to the trade winds if we will decipher the question of currents.

Lieutenant Maury, at the time of the publication of the last edition of the "Physical Geography of the Sea," was without doubt one of the hardest students and the most popular writer on the subject of the air and ocean. Many of his conclusions were entirely new and antagonized the ideas of others. At first glance he seems to attribute ocean circulation in part to forces which act diametrically opposite, viz, evaporation, whereby the specific gravity is increased on the surface near the equator, and heat, whereby its density is diminished; but later he expresses his conviction that—

> If we except the tides and the partial currents of the sea, such as those caused by winds, we may lay it down as a rule that all the currents of the ocean owe their origin to difference of specific gravity between sea water at one place and sea water at another; for wherever there is such a difference, whether it be owing to difference of temperature or to difference of saltness, etc., it is a difference that disturbs equilibrium, and currents are the consequence.

His belief was that while local currents might be caused by winds, rain, barometric pressure, etc., differences of density caused the grand circulation of the ocean.

Prof. C. Wyville Thomson has been a member of several scientific expeditions fitted out by the British Government on board H. M. S. *Porcupine* and *Lightning* in the years in 1868–'69 and '70, and in the famous *Challenger* expedition from 1873 to 1876. In both, the investigation as far as currents were concerned was mainly confined to the most accurate determination of temperatures, specific gravity, depth, and character of bottom specimens, from which Professor Thomson has drawn conclusions as to ocean circulation. He says, in "The Depths of the Sea," on this subject:

> The investigation is one of singular difficulty. Some currents are palpable enough, going at a rate and with a force which make it easy to detect them and even comparatively easy to gauge their volume and define their path; but it seems that the great movements of the water of the ocean, those which produce the most important results in the transfer of temperature and the modification of climate, are not of this character. These move so slowly, that their surface movement is constantly masked by the drift of variable winds, and they thus produce no sensible effect upon navigation. The path and limits of such bodies of water can only be determined by the use of the thermometer. The equalizing of the temperature of bodies of water in contact with one another and differently heated, by conduction, diffusion, and mixture, is, however, so slow, that we usually have but little difficulty in distinguishing currents from different sources.

This statement, in my opinion, is in the main true; for without doubt warm ocean water must come from the equatorial and cold water from the polar regions, and, whatever may be the cause of the transfer, the modification of climate is due to the presence of the water and not to the method of its delivery.

Professor Thomson says:

> By the Gulf Stream I mean that mass of heated water which pours from the Straits of Florida across the North Atlantic, and likewise a wider but less defined warmer current, evidently forming a part of the same great movement of water, which curves northward to the eastward of the West Indian Islands. I am myself inclined without hesitation to regard this stream as simply the reflux of the equatorial current, added to, no doubt, during its northeasterly course, by the surface drift of the anti-trades, which follow in the main the same direction.

Of the Gulf Stream he says:

> It seems to me that the Gulf Stream is the one natural phenomenon on the surface of the earth whose origin and principal cause, the drift of the trade winds, can be most easily traced.

He concludes that this whole flow, upon reaching the western shores of Europe and not finding a ready exit to the northward, banks down, filling the Northwestern Atlantic to a considerable extent. Owing to this resistance a portion of the current turns southward toward the Azores, while the accumulation to the northward forces an eddy current of colder water to the southward. The general bottom circulation he supposes comes from the southern oceans. The southern hemisphere is chiefly water, while the northern includes most of the land. The Atlantic and the North Pacific Oceans, therefore, are merely bays of the great water hemisphere. Later he says:

> Over the central part of the water hemisphere, precipitation is certainly greatly in excess of evaporation, while the reverse is the case in its extension to the northward. The water is therefore carried off by evaporation from the northern portion of the Atlantic and the Pacific, and the vapor is hurried down toward the great zone of low barometric pressure in the southern hemisphere, the heavy cold water welling up from the southward into the deepest parts of the northward-extending troughs to which it has free access, to replace it.

In effect, Professor Thomson's theories are that the surface currents are chiefly caused by wind drift, and that the lower currents are caused by unequal evaporation.

The most recent exponent of the specific gravity theory is Dr. Carpenter, who was a colleague of Professor Thomson on the scientific cruises of the *Porcupine* and *Lightning*. He based his belief largely upon the temperature observations of these expeditions, and upon the results of his examination of the current in the Strait of Gibraltar. In a lecture to the Royal Geographical Society, in 1870, to illustrate his ideas, he supposes two basins, one under equatorial conditions and the other under polar, connected by a strait:

> The effect of the heat of the tropical basin will be for the most part limited to its uppermost stratum, and may here be practically disregarded. But the effect of the surface cold upon the water of the polar basin will be to reduce the temperature of its whole mass below the freezing point of fresh water, the surface stratum sinking as it is cooled, by virtue of its diminished bulk and increased density, and being replaced by water not yet cooled to the same degree. The warmer water will not come up from below * * * but will be drawn into the basin from the surface of the surrounding area; and since what is thus drawn away must be supplied from a

> yet greater distance, the continual cooling of the surface stratum in the polar basin will cause a *set* of water toward it to be propagated backward (so to speak) through the whole intervening ocean in communication with it until it reaches the tropical area.

This is practically the theory of Lieutenant Maury expressed more in detail.

To repeat the oft-told story of the Mediterranean circulation is unnecessary. Dr. Carpenter considers that it aptly illustrates the whole system of ocean currents. He says:

> The vertical circulation is maintained in the Strait of Gibraltar by the excess of evaporation in the Mediterranean over the amount of fresh water returned into its basin, which at the same time lowers its level and increases its density, so that the surface inflow of salt water which restores the level (exceeding, by the weight of salt contained in it, the weight of fresh water which has passed off by evaporation) disturbs the equilibrium and produces a deep outflow, which in its turn lowers the level. * * * Circulation must, on the same principles, be maintained between polar and equatorial waters by the difference of their temperatures; the level of the polar water being reduced and its density increased by the surface cold to which it is subjected, whilst a downward motion is also imparted to each stratum successively exposed to it, and the level of equatorial water being raised and its density diminished by the surface heat to which it is exposed. * * * Thus a movement will be imparted to the upper stratum of oceanic water from the equator toward the poles, whilst a movement will be imparted to the deeper stratum from the poles to the equator.

It is difficult to reconcile this reasoning with what seems to me the actual state of the case. The Mediterranean is lowered by the excess of evaporation over the precipitation, and an inward surface current caused at Gibraltar. The ocean surface current, on the other hand, chiefly flows from the point where the evaporation is greatest toward the point where there is an excess of precipitation. Dr. Carpenter claims, however, that the difference of ocean level is from the difference of expansion due to heat. Without doubt there is a difference in expansion, but it is a question whether he is correct on the matter of level.

The temperature of the ocean in the vicinity of the equator reaches 37° at a depth of about 1,000 fathoms, below which the changes are slight to the bottom. The surface has a temperature not far from 80°. The expansion of the sea water due to this change in temperature is about .005, which for the column of 1,000 fathoms would be about 30 feet, giving a grade from the equator to the poles of about six one-hundredths of one inch to a mile. It would seem as if this infinitesimal difference might be easily obliterated by the excess of evaporation at one place and of precipitation at the other. In the immediate vicinity of the equator the rains are considerable, but it is without question that in both hemispheres the rainfall is least within the limits of the trade winds, outside of which it increases somewhat with the latitude. Of the total annual rainfall most of it is evaporated from the ocean direct, in latitudes lower than the thirty-fifth parallel. There must therefore be much more than the average taken from the equatorial belt and much more than the average deposited in the polar regions where the evaporation is but trifling, so that instead of an equatorial elevation from the expansion of the sea water by heat there ought to be a tendency toward depression due to evaporation.

Mr. J. J. Wild, one of the scientific staff of the *Challenger* expedition, seems to imply in "Thalassa" that he is a believer in the wind theory as the cause of ocean currents, but he says as a last word on the subject:

> The southern ocean is the main feeder of its three gigantic offshoots—the Atlantic, the Pacific, and the Indian Oceans—which it supplies through the medium of both surface and under currents. The former, driven by the westerly winds against the west coasts of Africa, Australia, and South America, are driven northward toward the equator; the latter, piled up by the rotating earth against the east coasts of these continents, flow as under currents in the same direction, both entering as warm currents toward their old home, the pole.

I confess that I am unable to fully understand the meaning of Mr. Wild in either of these statements. Most authorities agree, and, indeed, Mr. Wild gives an illustration showing it, that the west coasts of Africa and Australia are included within the limits of the trade winds or the belt of calms. It therefore does not appear how the westerly winds can cause the surface currents which he mentions. The same difficulty is experienced in the matter of the subcurrents which are said to be caused by the earth's rotation piling up the water on the east coasts, for Africa and South America, at least, present a wrong angle to allow the escape of water from this cause alone to flow in the direction of the equator.

At this day, after so many thinking men have investigated and have written on the subject of ocean physics, particularly on the Gulf Stream, and have advanced and advocated every possible theory as to the causes of currents, the only question for a new explorer to decide is toward which of the ranks will his own research lead him to incline.

We have seen that the two prominent theories are, first, surface drift, due to permanent or semi-permanent winds, and, second, gravity, due to differences of density of sea water. I place myself with those who advocate the wind theory as the chief cause of the Gulf Stream proper and of most ocean currents, but to differences in density we may attribute some variations in surface indications of the current. The prime mover, however, is generally wind, and I think my observations of the currents during the past five years will add much weight to the theory.

The winds, of which the trades are the most permanent, act in two ways to produce a surface movement. The friction of the air causes the particles of water with which it is in contact to move in its direction. Friction between the particles transmits the motion from layer to layer with a continually diminishing force as the depth increases.

Prof. Alexander Agassiz says in his recent publication, "Three cruises of the *Blake*:"

> Theoretically it has been calculated by Boeppritz that 100,000 years is ample time to allow the friction of the particles to extend from the surface to the bottom, say 2,000 fathoms, were the winds to blow without intermission in one direction during that time with the average power they are known to possess.

While the trade winds predominate in a westerly direction they do change sufficiently to prevent any great depth of current, even if there were no other conditions to prevent its consummation. In the Eastern Atlantic they incline much more toward the equator than they do in the western parts, and any currents established by these winds will, by their inertia, attempt to continue in the same course, and will be lessened in velocity by the currents produced by winds from other directions with which they may come in contact. That there are other causes tending to prevent any great depth of the frictional current is evident from the reports of skillful navigators, who have, in the midst of the region of the trade winds and at points where usually a drift current is to be reckoned upon, found a reverse set. This is generally a local influence, extending over a small space and for a short interval, but still, every such instance tends to break up or lessen the persistency of the flow and to diminish the depth of the frictional current.

The waves formed by the wind carry water to leeward, by the pressure of the wind on the back of the wave, which causes each particle near the surface to advance to a greater or lesser extent during each oscillation. This, in effect, is an increase of the frictional current and not readily distinguishable from it. It is, however, a very shallow movement, depending upon the height of the waves and the strength of the wind.

Another and far greater cause of the set to leeward is the break of the wave. Every ripple as it topples over sends a portion of its crest a certain distance in the direction of its travel, and, in a gale, tons of water drive a hundred or two feet to leeward in a few seconds.

Upon meeting an obstruction the water must either come to a stop or escape in the line of least resistance. The frictional current, upon reaching shoal water, becomes less and less as the friction on the bottom becomes greater. If the obstruction is at right angles to the course of the current there is a stoppage, an escape of a portion at the sides, and a reverse undercurrent. A current of this character does not seem to run readily over shoal water, the interference of the bottom quickly retarding it. The experience of our anchorage on the outside of the Grenadine Bank showed a set between southeast and southwest, which is parallel to the general trend of the shoal. Although the Sal Key Bank, in the Straits of Florida, is in the direct line of the current, there is only the ebb and flow of the tides over it. Even on the west side of the Bahama Bank the current does not extend to the very shore. If the obstruction is not at right angles to the current there is an escape of some portion to leeward, the amount depending upon the angle; but I believe a considerable proportion of the velocity is destroyed by the act of impinging and changing direction.

The action of the onward movement of the wave in causing the particles of its upper stratum to move in the same direction has been strongly impressed upon my mind during the past five years. When at anchor the surface currents were always observed with the meter at a depth of $3\frac{1}{2}$ fathoms, and also by an ordinary log line, using a weighted pole instead of the "chip." This pole was 21 feet long and 3 inches in diameter, weighted at its lower end so that but 6 inches of its length would show out of the water in a smooth sea, and with this slight amount of surplus buoyancy every wave would go over it. When there happened to be a light current and a fresh wind the vessel would ride to the latter, while the pole, from its small exposed surface above water and its deep draft would tail to the former. As the seas would roll over the pole it always disappeared in an upright position, but when it appeared again its upper end was always inclined in the direction of the traveling wave. This continual knocking or pushing to leeward caused the direction of the current as observed by this means to be an erroneous record, depending in amount on the relative strength and direction of the current and the velocity and height of the wave. The current meter suspended below the wave influence, to which the upper end of the pole was subjected, generally gave a direction from one to three points to windward of that given by the pole. As long as there are waves there is a quantity of water going slowly to leeward by this means.

A far greater amount, however, is being thrown violently in the same direction by the break of the sea, and unlike the frictional current it reaches to the very shore. The accumulation of water escapes by the line of least resistance. If the sea is directly on shore, with no chance of lateral escape, a reverse undercurrent is caused. This is noticed where the water is shoal by a deep draft and heavily laden vessel being set to windward, where a light draft vessel will be thrown on shore. Harbors are filled by this accumulation and the tides made very irregular. In the great hurricane at Samoa, which caused such destruction of life and property, the amount of water thrown into the harbor of Apia produced tremendous currents, not only along the beaches and reefs, but setting directly out of the harbor, and this assistance to the great engine power of H. M. S. *Calliope* may have turned the balance and rendered her escape from destruction possible. How many times do we read in the accounts of wrecks on shore of the great velocity of the currents. All along the shores of Long Island and New Jersey the fishermen report abnormal currents at times when the wind is blowing strong toward the land. These are caused, I believe, simply by the escape of the accumulated water thrown by the waves, and do not extend far off shore. I doubt if a single ordinary gale will produce an *ocean current* having a velocity of one-half knot per hour, and any current that is formed will be very shallow.

The gulf weed, so called, shows the effect of the break of the waves. Its home is the Sargasso Sea, near the northern edge of the trade wind region. Transported chiefly by the waves, it is found entering the Caribbean in the passages north of Guadeloupe, and is in greater quantities north of the West Indian Islands. In large masses, it acts like oil on the water to still the waves, and consequently the break of the sea can only detach fragments from the edges of the mass. As a rule it is seen streaming in long lines in the direction of the waves and not in the direction of the current unless the latter is very strong. In this case it accumulates at a point where there is a rip or a changing current in the same way that drift collects at the edge of an advancing tidal current. The fact of meeting it in strange regions is not necessarily an indication of a current, but that the wind has caused a sea which has thrown the weed to leeward.

The influence of the wind to transport the water without an accompanying current is seen in Key West. With a strong southerly wind the clear water from the Gulf Stream is thrown into the harbor in spite of an ebb tide, but upon a change of wind from the gulf, its water quickly clouds that of the harbor. Along the edge of the reefs in 20 fathoms, with the wind from the southward, the bottom can easily be seen. The Gulf Stream water has been thrown in by the waves, but the current maintains its normal position.

What, then, is the action of the wind in causing the Gulf Stream?

In the tropical regions east of the continent of America, the northeast and southeast trade winds are continually blowing, with an interval of calms between them. The southeast trades accumulate a mass of water on the South American coast, causing a shore current in both directions from Cape St. Roque. The volume of the northern branch (the Guyana current) for a considerable portion of the year is probably not as great as the accumulation of water thrown against the coast of South America by the northeast trades. The frictional currents of each of these drift streams will be shallow, but meeting each other, as they do, at quite an angle, the resultant velocity will not be the sum of the two. The act of impinging on the coast will give the combination a reduced value, and will form a counter subcurrent running to the eastward, the strength of which will depend upon the velocity and upon the angle of the currents with the coast.

The coast current thus formed sets toward the Windward Islands with varying strength, and, having received its final impulse, leaves the farthest point of its restraining shore (the Island of Tobago) with a course about NNW. The frictional current of the northeast trades has, in the mean time, been sending a certain amount of surface current toward the Windward Islands, and the two join forces southwest of Barbados. The flow then is through the passages between the islands, the strongest being in the one south of St. Lucia, and lessening in velocity in the others as the latitude of the passages increases.

During the winter months the northeast trades blow from a more northerly direction than they do during the summer, and at the same time they extend farther toward the equator. The observations taken on board the *Blake* were during this period, and no evidence was found that the coast current maintains its integrity as a separate current after it encounters the drift of the northeast trades, but there was every indication of a return subcurrent extending even into the southeastern Caribbean. At the stations outside the St. Lucia Passage the lower currents tended east and south; north of Barbados S. by E., and between that island and Tobago there was generally some indication of a deflection to the eastward. In the deep passage between the Leeward Islands and the mainland it was east below the surface stratum, while south of Grenada the same easterly set was observed at the greater depths. This all tends to show that in the escape of the accumulation, the surface goes to leeward, while some of the water of the lower stratum returns in a reverse direction.

During the summer months the southeast trades reach farther to the westward along the South American coast, while the northeast trade winds although not extending so far south, have a more easterly direction. There is therefore a larger body of water transported at this season from the African shore into the North Atlantic, and consequently the Guinea current is stronger and extends farthest west, reaching in August, according to Findlay, as far as the forty-fifth meridian. This, I believe, shows simply cause and effect. The increased volume of the accumulation of water from the south, and the more easterly direction of that from the north, both tend to produce the reverse subcurrent which appears on the surface farther to the eastward as the Guinea current.

The average of all the westerly flow between the islands from St. Vincent to Antigua gives a volume equal to about one-half that found in the narrowest part of the Straits of Florida. We have seen from the discussion of the observations of the currents in the Anegada, Mona and Windward passages, that the volume entering the Caribbean through these entrances, is little if any in excess of the outflow. What then can account for the other half? I am convinced that it is the water thrown to leeward by the waves, and does not appear as a current while it is in transit, except indirectly by the assistance it gives to the frictional current.

The total width of the passages south of Antigua is available for the entrance of water by this means, whereas the drift current of the trades is confined to the deeper portions only. The waves dash over shoals where a drift current can not flow. The former then have about three times the available space for entrance that the latter has, and, when we include the broader passages to the westward, we can realize what an enormous quantity of water may enter the sea whenever there is a wind to cause a wave. Once in the Caribbean, every wave formed gives the surface current an additional push by its momentum, so that by the time the Western Caribbean southwest of Jamaica is reached, the flow has greater velocity than in any of the passages between the Windward Islands or at any of the anchorages outside the islands, with the exception of those near Tobago, which are in the full strength of the Guyana current.

We have thus followed the water, driven by the *vis a tergo* of the trade winds from the coast of Africa to the Yucatan Channel, from which it flows into the Gulf of Mexico and through the Straits of Florida into the Atlantic.

We will leave it for the present to inquire whether there is any force to assist it on its march toward the European coast. It is true the Guyana current is but trifling in volume or velocity in comparison with the Gulf Stream as it issues from the Straits of Florida. But seeing, as we have, what a comparatively short distance the former is projected from its confining bank, one is led to agree with those who doubt whether even so large a body as the Gulf Stream can be driven very far toward the coast of Europe by the *vis a tergo* of the trades without the assistance of some force in the northern Atlantic.

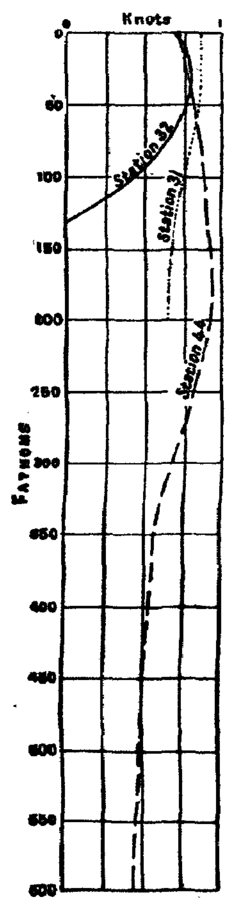


Fig. 9.—Vertical curves Stations 31–32–44.

It seems evident that two contributions are to be found which tend to force the Gulf Stream onward. One a current outside the West Indian Islands caused by the northeast trade winds, and the other the prevailing westerly direction of the anti-trades. In fact the whole system of winds in the North Atlantic tends to produce an oval-shaped flow, with the region known as the "horse latitudes" at the major axis. We have direct evidence of the flow outside the West Indian Islands in the observations taken on the line between Great Abaco Island, Bahama, and the extremity of Cape Hatteras Shoals. At the first anchorage (No. 31), about sixty miles from the Bahamas, the currents were all to the northward and westward, the surface NW. and at 200 fathoms NW. by N.

Midway between the ends of the line (Station 44), observations were carried to 600 fathoms where it was found, as seen in Fig. 9, that a deep but slow movement reached to a great depth. The directions here were all between NNE. and NE. by E. at all depths, with the exception of a single observation at 375 fathoms and at 600 fathoms, where the set was in the reverse direction. This current might be considered as an overflow from the Gulf Stream were it not for the fact that the observations at the outside station off Cape Hatteras show the direct effect of the impingement of one on the other. At the time of the observation at Station 6, Section F, the full width of the Stream proper did not extend as far off shore, and there was an eddy surface current between it and the current coming from outside the islands. The eddy current was but superficial (see Fig. 10), and the outside current showed itself as a subcurrent setting in the normal direction of the Stream. The question arises, why did it not appear on the surface and increase the visible velocity of the Gulf Stream. The answer to this is because its density was less.

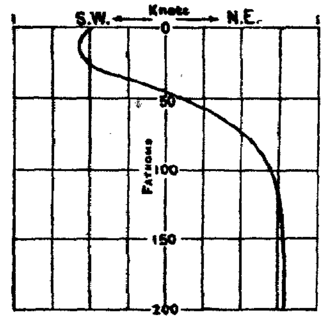


Fig. 10.

In order to avoid repetition, the cause of the alternations in temperature of the Gulf Stream is inserted here, as it is necessary in its discussion to enter upon the question of differences of density.[1] There has been a great deal of speculation and surmise on the subject of the alternations of warm and cold bands in the Stream, the existence of which Professor Bache established as beyond a doubt. He was led to believe that they are caused by irregularities in the ocean bed over which the current flows. The soundings on which he based this belief were made with rope or registering apparatus, neither of which is valuable in deep water or in the presence of a strong current. By more improved methods it has been shown that the ocean is not divided into hills and valleys along our coast. At one place off South Carolina there is a spot on the submarine plateau which has a depth of about 50 fathoms greater than the water outside of it, but it seems very doubtful if this can cause a variation in temperature off Cape Hatteras or still farther to the eastward, where the current certainly does not reach the bottom, nor could it cause the fluctuations found in the temperature at points farther to the south toward the Straits of Florida.

[1] The term density is used to mean the specific gravity of the water *in situ*, and specific gravity, the density of the water at 60° F.

In this part of the discussion by the term Gulf Stream is intended the whole flow from the western Atlantic.

It has been thought that the cause was to be found in an opposing cold counter-current forking out the warmer water into bands or ribbons. It is possible that this may be the case where two currents are directly opposed, but there is no evidence that there is a cold current flowing in a direction opposite to the portion of the Gulf Stream along our coast, and even if such a current does exist, it does not seem to be probable that it can fork the Stream into gradually converging lines which maintain their relative position throughout and follow the curves and turning of the Stream its whole length.

As before stated, the warm water upon approaching Europe is divided into two parts by the obstruction it meets. As the northern extension approaches the Arctic regions it is probably more or less forked by alternations in the temperature, for the following reasons: The warm water of the Gulf Stream from its greater heat is of very much less density than the polar water, but, owing to the superior amount of saline matter held in solution, it has a greater specific gravity. At a certain time in its progress northward it has cooled sufficiently to bring its density down to that of its opponent, and at the same times is actually warmer. A fall of another degree makes its density even less than the other, at which time the polar water gains the ascendency and slips over the warmer, the two strata arranging themselves according to their relative weights. For example, the equatorial flow may have a density of 1.027 at a temperature of 36° and the opposing Arctic current at 32° a density of 1.028. The latter being the heavier assumes a lower position, but when the former has lost something of its heat it becomes the heavier, and, although still at a higher temperature than the other, it seeks a lower level.

The whole width of the opposing waters is considerable and the different parts are under varying conditions. A single northerly gale will cool the warmer water in a certain locality, while an adjacent limited area may be subjected to reverse conditions. The low barometer accompanying the gale will help to change the temperature of the water by inducing a vertical current. Unusual temperature in the seasons north and south will produce a higher or a lower temperature than normal. From all these causes, as well as others, the position, the depth, and the angle of the line of meeting is continually changing. In the case of our equatorial water meeting the polar, both being under these variable conditions, the small differences in density will determine which water will override the other, and thus produce the alternations in the temperature at the Arctic end of the line. That the alternations exist both horizontally and vertically is abundantly proved. Prof. H. Mohn, the scientific head of the "Voringen" expedition found on the dividing line between the Atlantic and Arctic water very many instances of alternations in temperature vertically, the warm and cold layers of water being repeated between the surface and the bottom, or to some intermediate depth.

An illustration in "Thalassa," which I take the liberty of reproducing here (see Fig. 11), perfectly illustrates the point. The temperatures (centigrade) were taken in the *Challenger* expedition between the Antarctic ice barrier and Kerguelen Island. The curves show plainly how the cold water

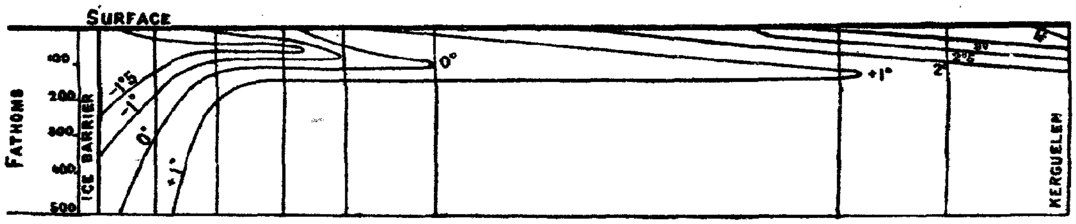


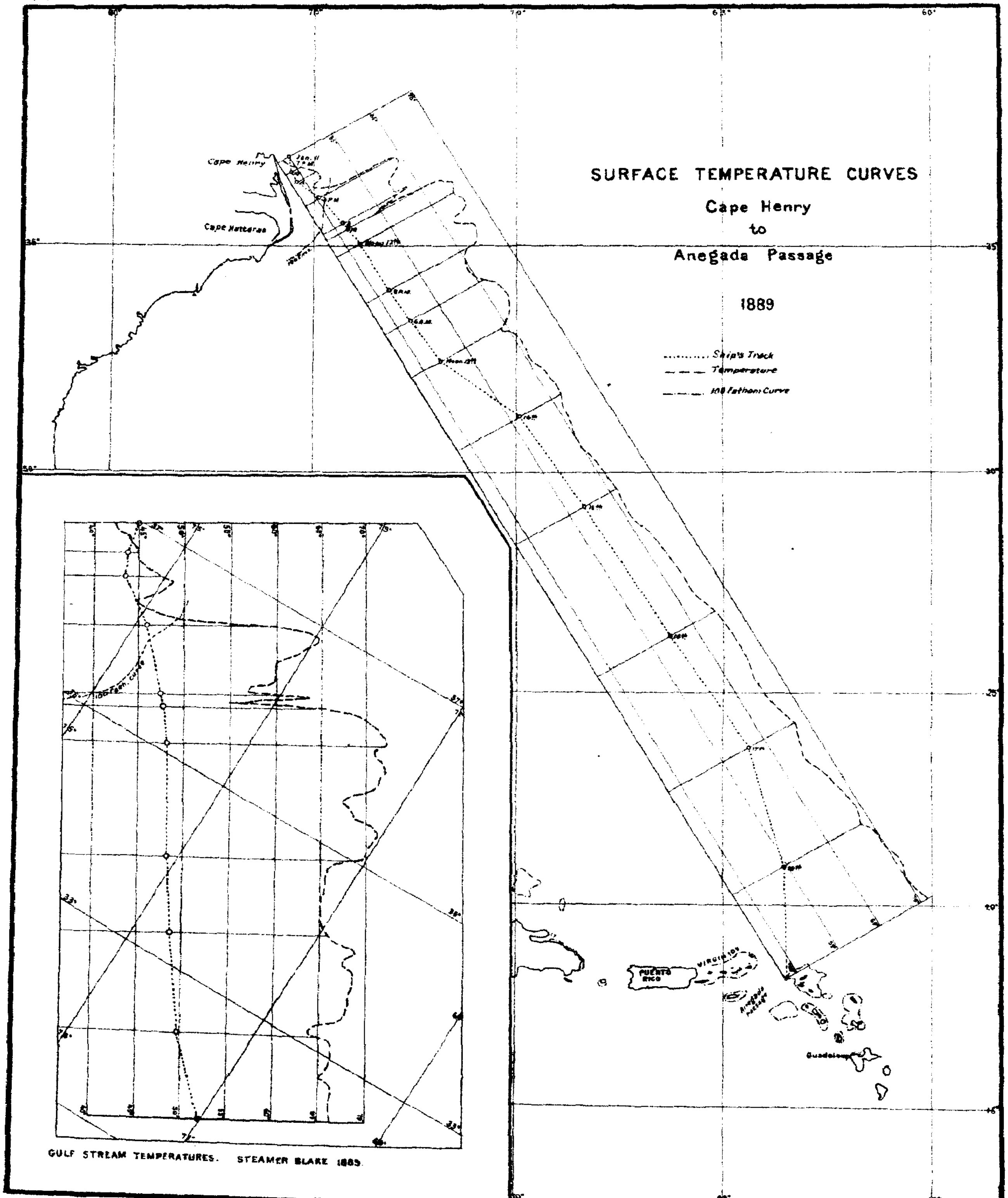
Fig. 11.

intrudes itself into the warmer, and the two arrange themselves according to their densities. Mr. Wild, the author of "Thalassa," says:

> The melting of these ice masses produces a quantity of water which, being fresher, is of less specific gravity than the salt water of the surrounding sea, and therefore floats in the immediate vicinity of the ice on the surface of the latter. But as the fresher water derived from the icebergs mixes by degrees with the surrounding salt water, the mixture being of lower temperature is rendered heavier and sinks below the surface, forming an intermediate stratum or wedge.

In the Gulf Stream along the coast of North America, the case is different. We find here a comparatively permanent alternation from the Straits of Florida to beyond the line between Bermuda and Halifax. Not only are the alternations found within the supposed limits of the Stream, but they are also both inside and outside of it. They are shown graphically in an illustration prepared by Professor Bache, illustration No. 37. Another example of the actual changes in temperature at about four feet below the surface is to be seen in illustration No. 54. These observations were taken on board the *Blake* with a thermometer, which, by an electric current, automatically recorded the temperature continuously. The positions of the various bands agree fairly with those of Professor Bache. It is seen on both these plates that there are fluctuations inside the Stream, off New York, for example (illustration No. 57), where, according to all belief, there is a current setting to the southward. There is certainly no northeasterly current in the vicinity of the inside warmer band extending from Cape Canaveral along the 100-fathom curve to Nantucket. The cause of this one at least can not be a cold current opposing a warm one.

In running lines of soundings, as the writer has, normal to the coast as far as the 100-fathom curve, and at intervals from Cape Hatteras to beyond George's Bank, it has been generally noticed that in the vicinity of a depth of from 40 to 80 fathoms, the temperature of the water suddenly changes, the colder being always found on the land side. It is very marked on George's Bank, and is probably due to the cold water from the outside being forced on the shoal by the advancing tidal impulse. It is generally conceded that this tidal impulse is in direction about normal to the coast of the United States, from the fact of its arrival at the salient points of the continent at the same hour. The Gulf Stream's course is at right angles to this advance. I believe that to this we may look for the cause of the lesser thermometrical variations, and that they are due to an interference of successive tidal impulses meeting the obstruction of the shore, whereby a vibratory motion is produced on the ocean's surface. This motion causes the alternation by what might be called attenuation and condensation of the warmer temperature; that is, in the former the surface stratum of warm water becomes thin, and the colder lower stratum rising, the temperature of the vertical column is lowered. In the latter the reverse operation takes place.


SURFACE TEMPERATURE CURVES
Cape Henry
to
Anegada Passage
1889
Ship's Track
Temperature
100 Fathom Curve
Cape Henry
Cape Hatteras
Puerto Rico
Virgin Is.
Anegada Passage
Guadeloupe
GULF STREAM TEMPERATURES. STEAMER BLAKE 1889.

The differences are more abrupt when the extremes of temperature are closest together; that is, in a shallow hot current or on the northern border of the Stream. They are less noticeable north of the current because the differences between the surface and lower temperatures are not so great, and consequently the intermingling of the surface and lower waters can not reduce the temperatures to so great an extent. The same is true south of the Stream, because the current is warm to a great depth, and also, because the vibrations diminish in intensity as the distance from the land increases. These alternations probably will be found on every coast where there is a warm surface current, if the trend of the land is nearly at right angles to the direction from which the tidal impulse comes.

To return now to the current off Cape Hatteras. The current outside the Bahamas curves to the northward as it meets the resistance of the coast. Its line of meeting the Gulf Stream proper varies in position because the latter changes its position according to the forces acting upon it. The width of the Stream off Cape Hatteras, however, is such that one of the cold bands is near the average position of its southern edge. When the outside current meets the Gulf Stream and the edge of the latter is to the northward of this cold band, the temperature of the latter will be lowered and it will underrun the former. In the curve of surface temperatures taken between Cape Henry and the Anegada Passage (illustration No. 54) it will be noticed that there is an abrupt rise at leaving the 100-fathom curve above Cape Hatteras and a fall at a distance of about 35 miles outside. This is the Gulf Stream itself. It is lower in temperature than the water next outside of it, although coming from the Caribbean, because its strong currents are continually changing in direction (as described in Chapter V.) and intermingling its waters from the surface to the bottom layer. The high temperatures just outside the Stream are from the waters which have swung around from the higher part of the curve in the vicinity of the Islands, the southerly portion with its high temperature coming next to the Stream. It is warmer than the Stream because its currents are slow, and are not interfered with by the bottom or mixed by excessive changes in direction. We have no means of knowing the width of this outside current except by taking the width of the higher fluctuations in temperature outside the Stream. This gives over 200 miles. It is slower in movement than the latter, but it is of much higher temperature, and by its addition to the Gulf Stream the amount of heat transferred to the northern Atlantic is very much increased.

The water is thus delivered by means of these two currents into the region of the westerly winds. It has had the confining bank of the continental line to the westward as far as Cape Hatteras, after leaving which its flow must depend upon something else than the force imparted to it by the trade winds. North of the calms of Cancer, the winds are mostly from the westward. The effect of this wind is to drive the surface water across the Atlantic in the form of a current, and to bank it up on the shores of Europe. These winds, however, are not persistent enough to cause as deep a current as the trades. Many authorities agree that the Gulf Stream itself ceases to be felt as a separate current to the eastward of the Grand Bank. After leaving this point it becomes a simple drift current. The mean direction of the wind between the latitudes of 30° and 50° north, deduced from numerous observations, has been determined by Kaemtz as follows: France, S. 88° W.; England, S. 66° W.; Germany, S. 76° W.; Denmark, S. 62°W.; Sweden, S. 50° W.; Russia, N. 87° W.; America, S. 86° W. When the sun is north of the equator the prevailing winds are from SW. to WSW. On the contrary, if the sun is in the southern hemisphere the winds are from WNW to NW.

Temperatures, Stations 44 and No. 6, Section F.

Station.	3½ fathoms.	15 fathoms.	30 fathoms.	65 fathoms.	130 fathoms.	200 fathoms.	375 fathoms.	600 fathoms.
6	77.5	76.7	74.8	70.8	64.5	62.2	------	------
44	73.0	72.5	72.5	70.5	68.1	65.2	58.4	43.6

Approaching the shores of Europe the drift current meets an obstruction nearly at right angles to its course, and the "banking down" mentioned by Sir Wyville Thomson takes place. A similar banking down is also seen in the temperatures of Station 44, on the coast of the United States, where the outside trade-wind current meets the obstruction of the continent. The latter escapes to the right inasmuch as that is the only avenue left open. The banking down on the shores of Europe has room to escape both to the northward and to the southward. The set to the northward, however, quickly encounters opposition in the Polar Sea, but is strong enough to overcome the obstacle and force the colder water before it to escape by the Labrador current. This current is said to partly underrun the Gulf Stream, and partly to flow as a countercurrent inside the Stream along the coasts of Nova Scotia and the United States. The countercurrent is certainly very feeble. Practically the main body of the current underruns the Stream, and, intermingling with its waters, joins the southern branch in its flow past the Azores and along the African coast. This branch is assisted on the way by the prevailing winds of that region, for the westerly winds gradually change in direction and merge into the northeast trade winds.

We must now examine the question as to whether there is a sensible elevation of the water in any part of the Gulf Stream's flow. The most accurate levels between the Atlantic and the Pacific Oceans have probably been run by the Panama Canal Company in the construction of the canal across the Isthmus. The result is in favor of the superior elevation of the Atlantic by about three-quarters of an inch, which difference may possibly be attributed to errors of observation. At Nicaragua, the levels run by the promoters of that canal have been of too rough a nature to determine small differences, and therefore the two oceans are considered to be on the same mean level. The actual result, however, was still in favor of the Caribbean Sea being the highest.

The reported difference of about 40 inches in level between the Gulf of Mexico at Biloxi, Mississippi, and the ocean at Sandy Hook is probably largely in excess of the actual difference, but at the same time it is probably a fact that the former is considerably higher than the latter. An accurate line has been run by the U. S. Coast and Geodetic Survey from Sandy Hook to St. Louis, Missouri. The levels from the Gulf of Mexico to St. Louis were executed in part by the Mississippi River Commission, a small portion by the U. S. Coast and Geodetic Survey, and another part by the U. S. Army as far as Lake Pontchartrain, which was said to be at the same level as the Gulf. The fact of the correctness of the total difference reported is to be questioned, but the existence of some difference, probably many inches, is hardly to be doubted.

There is certainly a yearly difference in the mean level of the Gulf of Mexico, as shown by the tide gauges. The result of two years' record at each of three stations in this Gulf gives a departure from the mean sea level in decimals of feet, as follows:

Station.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Biloxi, Miss	—.34	—.22	—.07	+.08	+.11	+.08	—.04	+.11	+.38	+.45	—.17	—.39
Fort Morgan, Ala	—.39	—.26	—.12	—.02	—.03	+.03	+.18	+.08	+.30	+.34	—.05	—.14
Key West, Fla	—.21	—.27	—.21	—.23	—.32	—.03	+.08	00	+.26	+.45	+.40	+.10
Mean	—.31	—.25	—.13	—.06	—.08	+.03	+.07	+.06	+.31	+.41	+.06	—.14

We see that in September and October the mean level is highest above the average and in January and February it is lowest. (See Fig. 12.) How much of this is caused by the trades and how much by local winds it is impossible to state. The maximum elevation follows by a short interval the time when the northeast trade winds are blowing with their greatest easting and the southeast trades extend farthest into the northern hemisphere.

Variation in Mean Level of Gulf of Mexico.

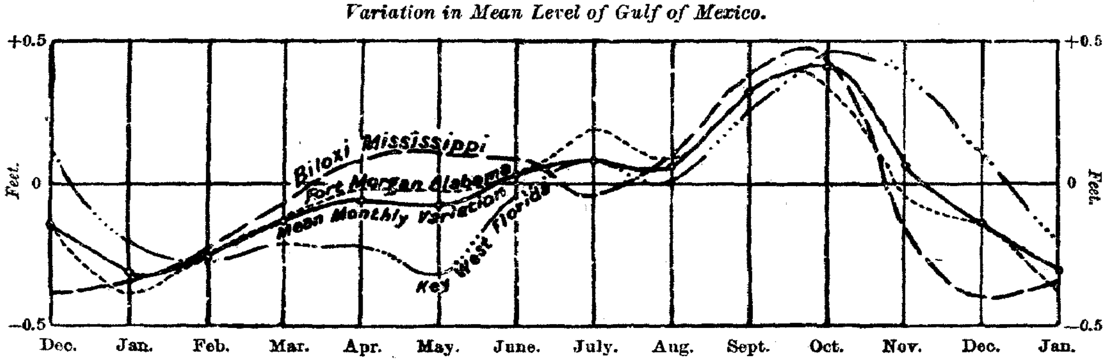


FIG. 12.

In the western Caribbean at Jamaica, and also on the coast east of Yucatan and Honduras, the winds during the summer months have the most southing in them, thus sending a great quantity of water toward the Yucatan Passage.

Most writers agree that the velocity of the Stream increases during the latter part of the year. Findlay places the strongest current in the winter months, but other writers state that its maximum flow is at the end of August or at the commencement of September. The evidence is, that the periodic changes of level of the Gulf of Mexico follow the changes in the trade winds, the highest level coming at the time when the winds are throwing the greatest amount of water into the western Caribbean, and that the yearly variation in the Gulf Stream's velocity follows this change in the level of the Gulf of Mexico.

I am led to the belief that the prevailing winds of the ocean raise the level of the sea on the leeward coasts, and, if we could but measure it, we should find that the Gulf of Mexico and western Caribbean are higher than the western Atlantic; that the Atlantic south of Cape Hatteras is above the level of the ocean northeast of that Cape; that on the northern European coast it is higher than at Labrador and Newfoundland; and, lastly, that on the tropical African shores the sea is lower than the same latitudes in South America. Probably, however, all of these differences are very small except that of the Gulf of Mexico.

The effect of atmospheric pressure on the surface of the ocean is to force or crowd the water away from the point of greatest to one of less pressure, thus causing a depression at the first and an elevation of the surface at the second place. In the case of two well-defined areas of high and low barometer over the deeper parts of the ocean there can be no great transfer of water from one to the other. The pressure exerted at one spot simply causes a rise at the other depending upon the relative size and differences of weight of the two, and the actual movement of water is along the bottom and is about equal to the amount of the rise. There is probably a trifling flow outward on the surface at the point of highest pressure and an inward flow at the center of the lowest pressure, but this surface influence can hardly have time enough to extend to any great distance, as the force exerted is but temporary.

In a partially confined body of water the case is different. While the elevation of water at the point of low pressure is no greater, the transfer of the water into or out of the confined body from the point of high pressure can not take place without an increase of velocity through the connecting strait. The Gulf of Mexico is a confined sea and is so placed that variations in the pressure between that exerted on its surface and on the western Atlantic causes a considerable retardation or acceleration of the current. The flow generally takes the direction of the Atlantic because the barometric variations in that ocean are very much in excess of those in the Caribbean.

A difference of 1 inch in the barometric column, or about one-half pound in atmospheric pressure, will give over 1 foot difference in the elevation of the surface of the sea. When we consider what the volume is which it may be necessary to supply to or take away from the Gulf of Mexico, we can imagine what abnormal variations there must be in the velocity of the current in the Straits of Florida. The study of the observations seems to show that the weaker parts of the currents are first influenced; that is, the bottom currents and at the sides, particularly on the left. It is exactly the same condition of affairs as is found at the entrances of many rivers, harbors, and sounds. Upon the arrival of the flood wave the current slips into the harbor along the bottom and at the sides, while the ebb current is still running on the surface in the middle. If the barometer is high in the vicinity of Cape Hatteras the pressure on the surface of the ocean probably elevates it in the neighborhood of the northern end of the Straits of Florida and retards the lower currents. A low barometer in the Gulf of Mexico has the same effect, and a high barometer in the Gulf acts in the opposite direction.

To explain the action of the variations in pressure we will examine some of the actual observations thought to be abnormal from this cause. The observations in the Straits of Florida in 1885 were apparently quite free from the influence of unusual atmospheric pressure. Observations were in progress from May 7 to 14 at Station 1. On May 10 and 11 a small Atlantic storm was reported east of Cape Hatteras, with a maximum barometer of 29.66, but it does not seem to have affected the currents off Cape Florida. On the 13th, however, a low area appeared off the southern coast, disappearing to the northward on the 15th, with a wind of 50 miles an hour at Block Island. The currents on the 14th were abnormal at all depths, but particularly on the surface where the current was very great. Station 1^{g} was occupied February 28 and March 1, 1886. The averages in knots of all the observations at each depth were: 3½ fathoms 2.90, 15 fathoms 1.86, 30 fathoms 1.81, 65 fathoms 1.42, and at 130 fathoms a southerly set with a velocity of 0,18. Just preceding the time of these observations the barometer was very low in the Gulf of Mexico, the lowest reading for the month at the Coast Stations east of New Orleans being on the 27th and 28th. In the Atlantic there was a storm center in the vicinity of Newfoundland from March 1 to 5, with a high barometer to the westward. The high pressure outside and the low pressure in the Gulf of Mexico united in causing the reverse current at 130 fathoms depth. The conditions had been so long continued that all the velocities were about a knot less than they should have been.

Station 1[1] was occupied April 30 and May 1. The current at 130 fathoms was southerly for about 18 hours, and then changed to northerly on May 1, increasing considerably in force. At 65 fathoms the velocity steadily increased during the anchorage. The lowest barometer for the month of April at all the Signal Service stations in the Gulf of Mexico occurred on April 27, 28, and 29, with the exception only of Key West. This extensive and slow moving area of low pressure was the evident cause of the abnormal subcurrent. On May 2 the currents had not returned to normal, as was shown by a partial obliteration of the daily variation.

The next observation of abnormal current was on May 5 and 6, at which time the surface velocity was far below what it should have been, followed on the 7th, 8th, and 9th by reverse lower currents and a surface velocity too small by over one knot. The Weather Review says that on the 3d of May an area of high pressure appeared off the southeastern coast of the United States, and was succeeded by lower pressure from the 7th to the 10th. The high area was the evident cause of the low surface velocities on the 5th and 6th, while the low area is responsible for the reverse bottom currents on the 7th, 8th, and 9th. The next noticeable variation from the normal velocity was on February 12, 1887, the anchorage being No. 3, Section CC. The surface velocity was decidedly too high, and was caused by the great atmospheric disturbances of the three previous days. An area of low barometer had traveled across the country, reaching the Atlantic coast on the afternoon of the 11th and causing the lowest barometer for the month at all the stations from Hatteras to Portland. This was followed by an extensive area of high barometer which arrived at the Atlantic on the 12th and embraced within its limits the entire coast. On account of the accompanying bad weather, observations could not be continued until the reverse effect of the latter was felt.

The unusual velocity observed at Station 1, Section CC, on March 2 and 3, is another instance of atmospheric pressure. At the end of February an area of high pressure was forming in the Rio Grande Valley and on the 1st day of March this had extended so as to embrace most of the Gulf of Mexico, if not the whole of it. The barometer on the latter date was the highest recorded for the month of March at all the stations near the Gulf coast from Key West to Brownsville. During the evening of May 4 and on May 5 currents were observed at Station 2[a]. On the 2d and 3d there had been an area of low barometer in the Rio Grande Valley and on the coast of Texas which had moved north, but its influence was felt at the anchorage by the irregularity of the currents found.

At Station 1, Section EE, on December 21 and 22, 1889, there was evidently a disturbance which caused a WNW. current at all depths except at 130 fathoms. This was the station nearest the edge of the Florida Bank. Examining the weather maps we find that there was an extensive area of low barometer extending from the Rio Grande Valley to British America. The center moved away from the Texan coast into the Gulf of Mexico on the 22d, and then, curving to the northward, passed over the mouth of the Mississippi, causing heavy winds on the Gulf coasts. This was evidently the cause of the reverse current found by the observers.

Sufficient illustrations have been given to show the certain influence of differences of pressure within and without the Gulf of Mexico. In every instance where an abnormal current seems to be evident there is reason to be found in the state of the barometer. In every instance, when the barometric differences were sharp at the time of an anchorage in the weaker currents, the effect of the former on the latter is visible. Not being able with one party to observe the currents at two places in the Stream at the same time, it is impossible to assert positively that the influence is not felt at all parts alike, but it seems that the weakest portions are first influenced, the bottom current is materially lessened or reversed, and the current in what has been called the neutral zone is quickly changed. In one or two instances, when at anchor in the deeper water, the effect of the abnormality on the current has not been found, and this is one reason for the conclusion that it is the weaker current at the bottom and at the sides which is first influenced. A long-continued difference of pressure will cause the effect to appear in the upper stratum.

CHAPTER VIII.

CONCLUSIONS.

The Gulf Stream receives its water from the Atlantic, partly by means of a current driven by the force of the southeast trade winds along the northeast coast of South America, and partly by a current from the northeast trade winds. The water, as a current, flows only through the passages between the Windward Islands, and not through the Anegada, Mona, or Windward Passages. All the water entering the Caribbean as described does not flow the length of that sea as a current, but a portion of it returns to the eastward through the Passages, usually as a subcurrent. In addition there is a large body of water thrown by the waves into the Caribbean through all the passages. The current found along the South American coast between Trinidad and Curaçoa is chiefly produced by the escape of water thrown there by the waves, no large body permanently entering the sea through the passage south of Grenada. The flow of water across the Caribbean is of the same character as that found outside the islands, a scarcely perceptible current on the surface at first, but increasing in its velocity as the longitude increases. The water accumulated in the western Caribbean escapes into the Gulf of Mexico, raising its surface level above that of the Atlantic.

The general circulation of the water of the Gulf of Mexico is erratic in direction and feeble in force. Lieutenant Vreeland's observations at twelve anchorages between the Mississippi Delta and the Yucatan Bank show a predominating direction to the southward and westward in the northern half of the Gulf, and also close to the Yucatan Bank, while between the two the flow was to the eastward. The passage of water into the Straits of Florida is sometimes from the Gulf and again from the Yucatan Passage. At the high declination of the moon it is from the latter, and at low declination it is from the former.

Passing through the Straits of Florida, the axis of the stream off Havana is nearest the southern edge of the current prism, but after making the bend between Salt Key Bank and Florida Reefs the axis is from 4½ to 11½ miles outside the 100-fathom curve on the west side. There is another body of water to the northward of the West Indian Islands, which, driven by the trade winds, is moving to the westward. This is a slow current, but when it joins the Gulf Stream proper off the southern Atlantic Coast of the United States it materially adds to the latter on its way toward the northern seas.

The width of the Gulf Stream off Cape Hatteras is about the same as when it leaves the Straits of Florida. It is, however, liable to more fluctuations in directions, particularly along its edges; and in its progress to the eastward, by the time the Newfoundland banks are reached, it is probable that these fluctuations entirely obliterate the Stream as a body distinguishable from its mate which has come by the outside passage from the trade region. In these latitudes, however (about 40° N.), the whole surface is slowly moving to the eastward, driven by the prevailing westerly winds. Approaching the shores of Europe it meets the obstruction of the Continent and escapes laterally, one branch to the southward from the Azores towards the coast of Africa; the other branch into the Arctic, where it forces a cold return surface current to escape along the shores of Greenland and Labrador.

The characteristics of the Gulf Stream and of also what may be called its tributaries are as follows: When the flow is in the vicinity of the land there is a marked daily variation in the velocity, caused by the elevation or depression due to the attraction of the moon and sun. There is a retardation in the effect produced by this tidal influence of about 3 hours. In the open sea the daily variation is not marked. The following table shows the time of the arrival of the maximum current *after* the moon's transit, or what has been called the "establishment" in these pages.

Localities.	Current establishment.	
	h.	*m.*
Equatorial Current near Tobago and St. Lucia Islands	6	10
Yucatan Passage	2	26
Straits of Florida off Havana	3	04
Straits of Florida off Cape Florida	3	26

In the vicinity of Barbados the time of high water is about 3 hours after the transit of the moon, giving retardation of the maximum flow of 3 hours and 10 minutes. The maximum in the Straits of Florida is the reverse of that of the Equatorial, its arrival being 2 hours and 15 minutes after mean low water at the southern Atlantic ports of the United States.

The following tables show the maximum daily variation observed at the various stations, the mean daily variation and the velocity of the surface flow. In the Straits of Florida, off Cape Florida, there is but one prominent maximum each day, usually arriving 9 hours before the upper transit of the moon.

Between Fowey Rocks, Florida, and Gun Cay, Bahama.

Stations.	Distance east of Fowey Rocks.	Mean surface velocity observed.	Maximum daily variation observed.	Mean daily variation.
	Miles.	*Knots.*	*Knots.*	*Knots.*
1	8	2.66	2.38	1.07
1½	11½	3.46	1.83	1.64
2	15	3.16	1.67	0.92
3	22	2.73	0.56	----------
4	29	2.12	0.58	0.42
5	36	1.71	0.95	0.55

The surface directions of the currents at the extreme stations incline toward the center of the stream at low declination of the moon and run more nearly parallel with the axis at high declination.

Between Rebecca Shoal Light-house, Florida, and Cuba, near Havana.

Station.	Distance south of Rebecca Shoal.	Mean surface velocity observed.	Greatest daily variation observed.	Mean daily variation.
	Miles.	*Knots.*	*Knots.*	*Knots.*
1	20	0.30	0.62	0.49
2	35	0.74	1.15	0.77
3	50	2.24	0.65	0.62
4	68	2.23	0.80	0.46
5	86	0.77	0.82	0.61

The surface directions of the currents at the side stations incline toward the axis at the time of low declination of the moon, and run more nearly parallel with the axis at high declination. Station 1 is outside the limit of the Stream and its currents are usually tidal in character and not strong. At the time of considerable differences of barometer between the Gulf of Mexico and the Atlantic, the currents at Station 1 are apt to run toward the area of low pressure.

Between Cape San Antonio, Cuba, and Contoy Island, Yucatan, the extreme daily variation was found at Station 2, at 5 miles distant from the 100-fathom curve of the Yucatan Bank; this was 3.95 knots at high declination of the moon. The mean of the velocities at the various stations is given in the table below, but it does not truly represent the average current to be expected, for at many of the stations the observations were only under one condition of the moon.

Station.	Distance east of Contoy Island, Yucatan.	Mean surface velocity observed.
	Miles.	*Knots.*
2	25	3.65
2¼	30	3.25
2½	35	2.37
3	45	2.79
4	60	1.56
5	76	1.07
6	90	0.51

The current at Station 6, nearest the Cuban shore, varies between NE. by N. and ESE. at the time of low declination of the moon, and between E. and SE. by S. at high declination. In other words, the current predominates to the southward at the latter time, and toward the Straits of Florida at the former.

At Section EE, between the Cuban shore and the 100-fathom curve 60 miles west of Tortugas, the direction of the currents is from the Straits of Yucatan at the middle stations during the period of high declination. Nearest the Cuban shore at this time they set toward the Straits of Yucatan, and on the north side they set from the Gulf of Mexico, but with a more easterly direction. At the time of the moon's low declination the currents are all to the southward and eastward.

The following table gives the position of the axis or the point where the greatest velocity may be found on the third day after the moon's highest and after zero declination. The *velocity* of the current at the point given as the position of the axis at high declination, changes more than at the other point; or in other words, the difference between the maximum and the minimum currents during the month is greatest near the place where the movement to the left ceases. At the mean position of the axis, however, a good current is always to be found.

	High declination.	Low declination.	Mean position.
	Miles.	*Miles.*	*Miles.*
East of Contoy Island, Yucatan	25	45	35
North of Havana, Cuba	16	34	25
East of Fowey Rocks, Florida	7	15	11
East of Jupiter Light-house, Florida	15	23	19
Southeast of Cape Hatteras Light-house	31	45	38

It is probable that from Jupiter Inlet to Cape Hatteras, the average position of the maximum current will be found between 11 and 20 miles outside the curve of 100 fathoms depth, disregarding the irregularities in the curve.

To gain the advantage of the strongest current, it is a question of judgment to be decided by the navigator at the time, how much he shall cut off in rounding the bends of the Stream. At high declination he can edge out so as to pass Fowey Rocks light-house 7 miles distant, and be sure of a good current, while, at low declination the maximum velocity at this distance will be found much less, and it will be necessary to go 4 or 5 miles farther to the eastward.

The data obtained off Cape Hatteras are not sufficient to enable us to assert positively how much the movement of the axis is. The width of the Stream at high declination is about 40 miles, reckoning from the 100-fathom curve, which is about the same width as in the narrowest parts of the Straits of Florida. It is probable that at low declination the position of the axis at Cape Hatteras is not more than 12 or 15 miles farther offshore than the distance given in the table, but the conditions of the current outside the Stream at this point cause a slow surface flow at times which may lead to the belief that the Stream itself is very broad.

I am convinced that the so-called "Cold Wall" is not the inner edge of the Stream, but is near the dividing line between the Gulf Stream proper and the outside Atlantic current, and that the maximum velocity will always be found some miles inside (to the northward) of it. The current outside the Stream is not comparable with the latter in point of velocity. Its speed probably is never much over one knot and usually much less. Its direction is to the northward and westward outside the Bahamas and to the northward and eastward off Cape Hatteras.

A steamer bound from Cape Hatteras to Havana or the Gulf ports crosses the Stream off Cape Hatteras. A fair allowance to make in crossing the Stream at right angles is 1½ knots per hour for a vessel's speed of 5 knots for a distance of 40 miles from the 100-fathom curve. In the run from the southern edge of the Stream to Matanilla Shoal, no allowance for current can be given. Upon sighting the Bahama Bank, time will be saved by running down the Stream on the east side as far as Gun Cay instead of crossing at Jupiter and running the latitude down on the Florida side of the channel. The current is weak on the Bahama side, and on the shoals there is practically none. This route will be difficult and perhaps impracticable until a light-house is built at Matanilla, unless the green water of the northwest corner of the bank is sighted before dark. Arriving at Gun Cay, Bahama, an allowance of 2¼ knots per hour for speed of the vessel of 5 knots per hour will make a course of west good to Fowey Rocks. This is for the average velocity of the Stream. The weakest current will be experienced about 3 hours before the transit of the moon, and if the crossing is made so as to arrive at the axis at about this hour time will be saved.

A vessel running inside the Stream from Cape Hatteras to Cape Canaveral should keep inside the 100-fathom curve, and, after passing the latter cape, as close to the Florida shore as prudence will allow.

Along the Florida Reefs the neutral zone which borders the northern edge of the Stream probably begins in the vicinity of "The Elbow," near

Carysfort Reef light-house, and gradually widens as the longitude increases, until off Rebecca shoal, it extends from 15 to 20 miles outside the 100-fathom curve. It is narrowest at high declination of the moon, at which time it probably begins at some point to the westward of "The Elbow." The direction of the current in this zone is ordinarily tidal in its character, but it is easily overcome by an abnormal current caused by differences in atmospheric pressure within and without the Gulf of Mexico.

Crossing the Stream from Havana, a fair allowance for the average current between the 100-fathom curves, is $1\frac{1}{10}$ knot per hour for a 5-knot speed of vessel.

A vessel rounding Cape San Antonio from the southward will find an eddy current from the Straits of Florida setting along the Colorado Reefs at a high declination of the moon. Thirty miles off shore it will be setting to the northward and eastward.

The current in the Santaren Channel is irregular in direction and very weak. In the St. Nicholas Channel and Old Bahama Channel the direction of the current depends upon the relative elevations of water in the Straits of Florida and Atlantic, and consequently flows in either direction for irregular intervals of time.

The subject of temperatures has already appeared incidentally in these pages. So much has been written on the question in times past, and the belief is so widespread at the present day, that the thermometer may be relied upon to indicate the presence of a current, that I wish to particularly accentuate the fallacy of the idea. In the Straits of Florida we have found that the highest average temperature is at the axis of the Stream, but there are times during the month when the sides are warmer than the axis was at some other recent time. Isolated observations are of but little value, for at the same place the variations are great even in an interval of a few days or perhaps hours. All we can say positively is that cold surface water comes from either a polar direction or from a lower stratum. The direction of its flow may be toward any point in the compass.

At Section A the temperatures were the most numerous. They are given in the table below for each month and at each station together with the number of anchorages. Equal value is given to the observations of each anchorage, whether it was 24 hours in duration or 7 days.

Station.	February.		March.		April.		May.	
	No.	Temperature.	No.	Temperature.	No.	Temperature.	No.	Temperature.
		°		°		°		°
1	1	75.80	2	78.77	2	80.04	13	79.98
1½	----	--------	----	--------	----	--------	6	81.61
2	----	--------	----	--------	1	79.80	3	80.52
3	----	--------	----	--------	----	--------	5	80.40
4	----	--------	----	--------	2	79.67	----	--------
5	----	--------	2	78.14	2	78.30	2	79.52

I can see no way of utilizing the thermometer for the purposes of accurate navigation, nor indeed of using it to indicate with certainty that the current is favorable or the reverse. Referring to the table on page 598, it is seen that the surface ~~current~~ temperature at Station 44 was 73°, while at Station No. 6, Section F, it was 77°.5. The current at the first was to the northward and eastward, and at the second to the southward and westward. At Station 4 the current toward the SE. quadrant had an average temperature of 73°.75, NE. quadrant 76°.82, and NW. quadrant 73°.30. In this case it was warmer when flowing toward the northeast. At Station 1, in May, a northeast current had a temperature of 75°.06, and in June, flowing southwest, it was 80°.19. At 15 fathoms depth the temperatures were 74°.39 and 76°.19 respectively, so the phenomenon could not have been due to the immediate action of the sun's heat. The warm water did not extend to 30 fathoms depth, however, and below it was much colder than at any other point in the Section. Any navigator, in rounding Cape Hatteras, upon meeting a temperature of over 80° would certainly conclude that his vessel was in a current setting to the northeast instead of toward the southwest.

The inner edge of the Stream, then, is not necessarily marked by a change of temperature. An abrupt difference may be encountered at the true edge of the current, the cold water may be moving northeast or the warm water may be flowing southwest. It is probable, however, that at about the time of high declination warm water off Cape Hatteras indicates a northeast current, and that at low declination the edge of the warm water has a set in the opposite direction.

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APPENDIX No. 11—1890.

REPORT IN RELATION TO A PORTION OF BOUNDARY LINE IN DISPUTE BETWEEN THE STATES OF MARYLAND AND VIRGINIA.

U. S. COAST AND GEODETIC SURVEY,
Washington, November 18, 1889.

DEAR SIR: In fulfillment of your instructions of the 4th instant I have examined the subject of the boundary line between Maryland and Virginia and respectfully submit a statement of my conclusions as to its location and determination.

In your letter of instructions, after referring to my previous report of my interview on the ground of the boundary with the gentlemen appointed to represent the States of Virginia and Maryland in considering the question of the boundary line between those States, you say:

"I desire that you will proceed to Baltimore on or before the 13th instant to meet these gentlemen again, and after first putting yourself in possession of all the information obtainable, by the inspection of original charts and documents and listening to any arguments which they may make, you will, I think, be able to bring the matter to a conclusion by defining and determining said boundary line in accordance with your judgment. As I understand the matter you are to be the sole arbiter in the case, as in the letter of Governor Jackson of October 10 I am requested to detail an officer 'to examine and locate that portion of the boundary line near Hog Island, in the lower Potomac River,' and in the letter of Governor Lee to Governor Jackson, bearing date of October 8, a copy of which was transmitted to me by Governor Jackson, he (Governor Lee) unites with Governor Jackson in asking the detail of an officer 'to examine and determine that portion of the boundary line now in dispute.'

"This in my judgment gives you full power, as you have been detailed by me for this purpose, and I trust that you will exercise your best judgment and without prejudice adjudicate the matter.

"When you have done this you will report at once to me at the Office."

I understand my examination of this subject to be confined to the declaration of the award of the arbitrators of 1877, which is also a law of Congress (Forty-fifth Congress, chapter 196, passed March 3, 1879, U. S. Statutes at Large, p. 481) and an interpretation of the same.

I have based my study on the conclusions arrived at and expressed by these arbitrators which bear directly on the case in question, namely, the shore line of the lower part of the Potomac River and the details of its physical features in their relation to this boundary line.

The arbitrators express the following opinion, viz:

"The intent of the charter is manifest all through to include the whole of the Potomac River within Lord Baltimore's grant. * * * Certainly there is nothing there which requires the line to leave the river bank. Apart from all this it looks utterly improbable that the two termini of this line should both have been fixed on the south side (right bank) of the river without a purpose to put the line itself on the same side. * * *

"For these reasons we conclude that the charter line was on the right bank of the Potomac, where the high-water mark is impressed upon it, and that line follows the bank along the whole course of the river, from its first fountain to its mouth."

In the text of the award of the arbitrators of 1877 the following declaration is made, viz:

"The latitudes, longitudes, courses, and distances here given have been measured upon the Coast Chart No. 33 of the United States Coast Survey (chart No. 3 of Chesapeake Bay), which is herewith filed as part of this award and explanatory thereof. The original charter line is marked upon the said chart and shaded in blue. The present line of boundary, as ascertained and determined, is also marked and shaded in red, while the yellow indicates the line referred to in the compact of 1785 between Smith's Point and Watkin's Point.

"In further explanation of this award the arbitrators deem it proper to add that—

"1. The measurements being taken and places fixed according to the Coast Survey, we have come as near to perfect mathematical accuracy as in the nature of things is possible. But in case of any inaccuracy in the described course or length of a line or in the latitude or longitude of a place the natural object called for must govern.

"2. The middle thread of the Pocomoke River is equidistant as nearly as may be between the two shores without considering arms, inlets, creeks, or affluents as parts of the river, but measuring the shore lines from headland to headland.

"3. The low-water mark on the Potomac, to which Virginia has a right in the soil, is to be measured by the same rule; that is to say, from low-water mark at one headland to low-water mark at another, without following indentations, bays, creeks, inlets, or affluent rivers."

In addition to the above text descriptive of the low-water mark on the Potomac River, so much of said low-water mark as is represented on said chart No. 33 is marked and shaded in red on said chart in the conventional sign adopted by the arbitrators to indicate the location of the boundary line declared to be ascertained and determined on said chart as a part of their award and explanatory thereof.

Setting aside for the time the cartographic representation of the boundary line, as above described, concerning the signification of which different opinions have been expressed, I submit the following statement of the technical interpretation of the data given as applied to the projection of a line representing the thread of a stream, and to that of a line along the shore which shall conform as nearly as may be to the physical system of a river as characterized by its area and figure:

In the first case the same rule would be applied as that laid down for the course of the boundary line in the Pocomoke River, viz:

"The *middle thread* is equidistant as nearly as may be between the two shores without considering arms, inlets, creeks, or affluents as parts of the river, but *measuring the shore lines* from headland to headland."

No other measurements would mathematically determine the *middle thread*, which must be a mean direction between the courses of the two shores.

Measuring *straight* lines from headland to headland would not determine the middle thread of a stream; because, in the bends of a river, straight lines giving equivalent results can not be measured on corresponding or opposite concave and convex shores.

Again, in the second case, the same rule would be applied as that laid down for the boundary line on the Potomac River, viz: "The *low-water mark is to be measured*"—from headland to headland—without following indentations, bays, creeks, inlets, or affluent rivers; for the reason that such lateral features are incidental to the general system of the river and can not properly be made factors in determining its true physical limits.

Referring again to the boundary line between Maryland and Virginia on the Potomac River refixed by the arbitrators of 1877 on the right bank of that river to coincide with the low-water mark, the descriptive text used and the conventional sign adopted can only be regarded as an intentional avoidance of more specific mention and definition of points and features which time and natural causes might so change as to render their future identification doubtful. Whereas, the right bank of the Potomac, in its general features, will always be the right bank so long as the river itself remains.

The only deviation made by the arbitrators of 1877 from the ruling of the original charter is in adopting the *low-water mark* instead of the high-water mark as the true line of boundary. Physically the lines are substantially the same as features of the river bank, while low-water mark is more in accordance with modern regulations pertaining to riparian rights.

CONCLUSION.

For the reasons given above I am prepared to say, on the part of the Coast and Geodetic Survey, that according to the text of the award of the arbitrators of 1877 as descriptive of the boundary line between Maryland and Virginia, no mathematical or physical construction can be put upon the meaning of said description which will locate and define the cognate boundary line and low-water mark in any other place, or make it conform to any other course of the river, than that which they have ascertained and determined to be the low-water mark on the south shore (right bank) of the Potomac River, as marked and shaded in red upon the Coast Chart No. 33 of the United States Coast Survey, which is filed as part of the said award and explanatory thereof. This clearly illustrates the intended location of the boundary line, and conforms to the terms and meaning of the award.

Very respectfully submitted,

HENRY L. WHITING,
Assistant, Coast and Geodetic Survey.

Prof. T. C. MENDENHALL,
Superintendent, Coast and Geodetic Survey.

APPENDIX No. 12—1890.

DETERMINATIONS OF GRAVITY AND THE MAGNETIC ELEMENTS IN CONNECTION WITH THE U. S. SCIENTIFIC EXPEDITION TO THE WEST COAST OF AFRICA, 1889-1890.

A report by E. D. PRESTON, Assistant.

U. S. COAST AND GEODETIC SURVEY,
Washington, D. C., June 30, 1890.

DEAR SIR: In obedience to your instructions of October 8, 1889, I took passage on the U. S. steamer *Pensacola*, Capt. A. R. Yates, U. S. N., commanding, bound for the west coast of Africa. Authority to accompany the U. S. Scientific Expedition under the direction of Prof. D. P. Todd, of Amherst College, was granted by Commodore Dewey, Chief of the Bureau of Equipment and Recruiting, Navy Department, and we sailed from New York at 6 a. m. on the 16th of October.

The following letters state the conditions under which the work was done, and define the position of the Coast and Geodetic Survey representative with reference to the Eclipse Party:

TREASURY DEPARTMENT, OFFICE OF THE SECRETARY,
Washington, D. C., September 24, 1889.

SIR: I acknowledge the receipt of your letter of the 15th instant requesting authority to detail an officer of the U. S. Coast and Geodetic Survey to accompany the Eclipse Party of Prof. David P. Todd to St. Paul de Loanda, West Africa, for the purpose of making observations in gravity and magnetism, and to pay his salary while executing the work, and any incidental and party expenses not to exceed the sum of $900, payable from the appropriation for "Party Expenses," Coast and Geodetic Survey, and from the item "Continuation of gravity experiments," it being understood that all expenses of transportation to and from stations outside the limits of the United States shall be borne by the Eclipse Party, and that the results shall be the property of the Coast and Geodetic Survey, publication in the report of Professor Todd being permitted.

In reply you are informed that the authority requested in your letter referred to above is hereby granted.

Respectfully yours,

W. WINDOM,
Secretary.

To the SUPERINTENDENT,
U. S. Coast and Geodetic Survey.

U. S. COAST AND GEODETIC SURVEY,
Washington, D. C., October 7, 1889.

SIR: In connection with the detail of Assistant Preston, of the Coast and Geodetic Survey, to accompany the Eclipse Expedition to the coast of Africa for the purpose of making pendulum and magnetic observations, I beg to invite your attention to the fact that the occasion will be a very favorable one for connecting our home stations with Foster's celebrated series made many years ago and reduced by Baily, as three of these stations will lie almost in the line of travel of the Expedition. These three are the islands of Ascension and St. Helena and the Cape of Good Hope. The first of these was occupied by both Foster and Sabine and the last by Foster and De Freycinet. The observations of Foster at the summit of Ascension indicated a deficiency in the force of gravity which is contrary to results more recently obtained. It has always been thought important by the highest authorities that a remeasurement should be made on the summit of Ascension whenever an opportunity should be offered, in order to test the validity of this anomalous result. It seems that this opportunity now presents itself, and I respectfully request that the honorable Secretary of the Navy be asked to grant permission for the *Pensacola*, which is to carry the expedition, to stop at these points to allow Assistant Preston to make the necessary observations. This will not only be of great value to geodetic science, but it will be an additional insurance against unfruitfulness of results should the Eclipse observations fail through unfavorable weather.

Very respectfully,

T. C. MENDENHALL,
Superintendent.

The SECRETARY OF THE TREASURY,
Washington, D. C.

INSTRUCTIONS.

U. S. COAST AND GEODETIC SURVEY,
Washington, D. C., October 8, 1889.

SIR: You are hereby directed to proceed to New York City in time to take passage in the U. S. steamer *Pensacola* in order to accompany the Eclipse Expedition to the west coast of Africa for the purpose of making gravity and magnetic observations.

You will occupy at least one station at or in the vicinity of St. Paul do Loanda and also on the Cape of Good Hope and the islands of St. Helena and Ascension, it being assumed that the vessel will land at these points to allow of the occupancy of these stations. You will bear in mind that your first duty is to secure as much information as possible relating to gravity and magnetics at the several stations you are able to occupy; and, while you will not undertake anything pertaining to the work of the expodition which will in any way interfere with your performance of this duty, it is my desire that you co-operate with Professor Todd, who is in charge of the Eclipse Expedition, in every way possible and render him all the assistance in your power.

I inclose herewith a copy of the letter of the honorable Secretary of the Treasury authorizing your detail for this work, a copy of which is also sent to Professor Todd, together with a copy of these instructions.

These instructions cover the necessary expense incurred by you for travel to join the ship *Pensacola* at New York and to return to this Office from any home port made by her at the conclusion of the work of the expedition.

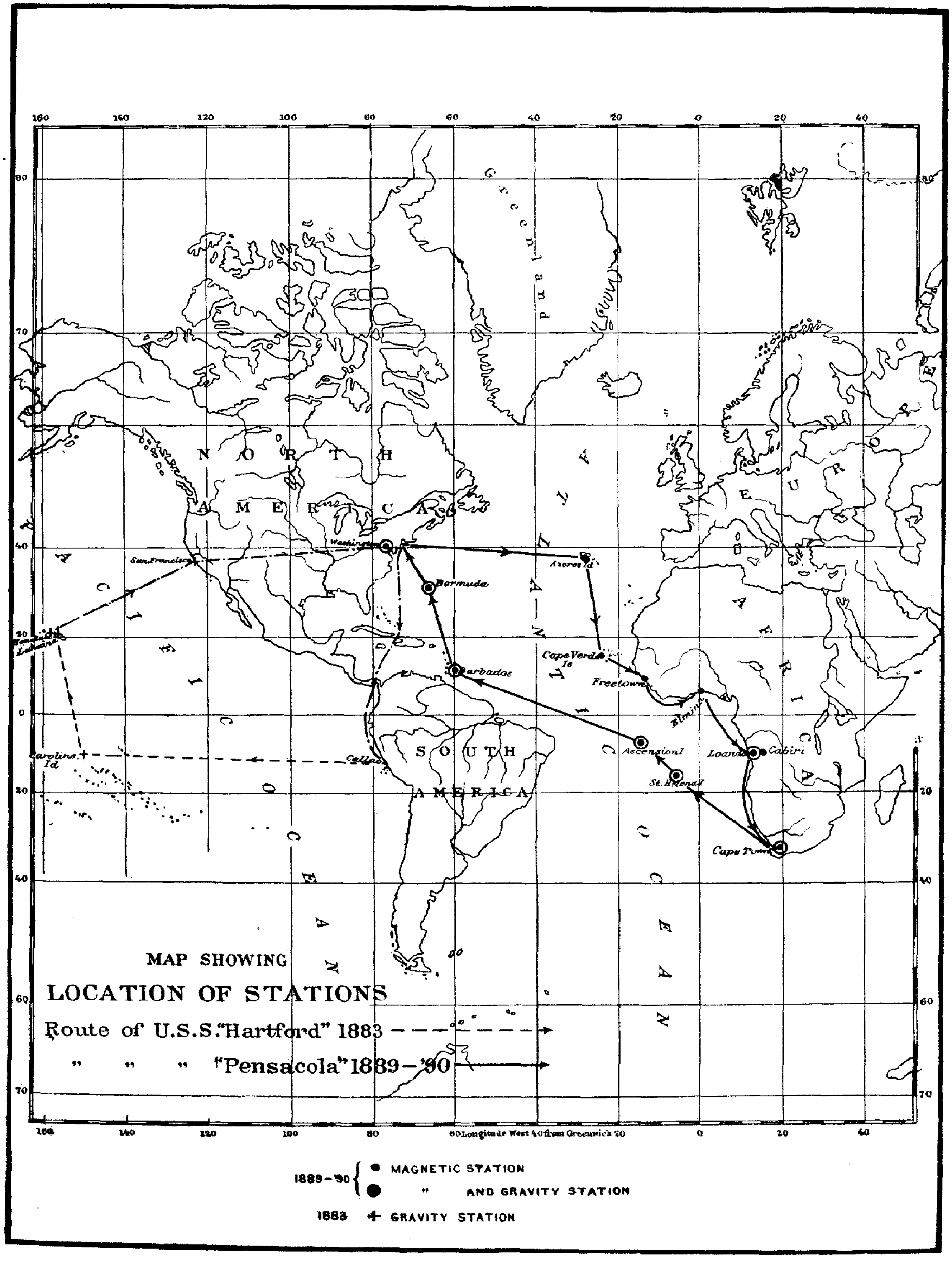
Yours respectfully,

T. C. MENDENHALL,
Superintendent.

Mr. E. D. PRESTON,
Assistant, U. S. Coast and Geodetic Survey, Washington, D. C.

As preliminary to the work of the voyage, pendulum observations were made at the Smithsonian Institution, the Peirce Pendulums Yard No. 3 and Metre No. 2 being swung, and magnetic observations were made at the Coast and Geodetic Survey Office in Washington. On November 2, after a passage of 17 days from New York, we touched at the Azores (see Illustration No. 55). Coaling at this point detained the vessel but 24 hours. By the kindness of Captain Yates, however, sailing was delayed a few hours and a full series of magnetic observations made on November 3. From Fayal we steamed directly to Porto Grande, Cape Verde Islands, arriving at 7 p. m. on November 10. Observations for magnetic declination, dip and horizontal intensity were made on the 11th. On the 12th we left for the coast, sighting the hills above Freetown on the afternoon of the 18th. Anchor was dropped at 5 p. m.; permission to make the observations was obtained from the Governor, and the location of station chosen the same evening. The next morning at 6 o'clock work began, and one determination of all the magnetic elements was made during the day. Coaling continued during the night, and we were off for the Gold Coast by sunrise the following morning. Eight days steaming, for the most part through the dense haze of a harmattan,* brought us to Cape Coast Castle. No coal could be obtained here and we ran up to Elmina where a two days' stop was made; on both days magnetic observations were made. On the evening of November 28 we left under way for St. Paul de Loanda, arriving on the eve of December 6. This town is situated in the province of Angola, about 100 miles south of the Congo. The *Pensacola* only remained a day here. A hasty visit to the town on the morning of the 7th, convinced me that facilities for the pendulum work were much better at this point than they could possibly be at Cape Ledo, where the Eclipse Party were going to establish their station. I therefore determined to leave the vessel and make the magnetic and gravity observations at Loanda. The ship sailed on December 7 after having landed my outfit. Cape Ledo is about 70 miles south of Loanda. It may be said that the real work of the voyage dated from this time. The magnetic observations at Azores, Cape Verde Islands, Freetown and Elmina were not contemplated in the orignal plan and were only made because the vessel stopped at these points for coal. No gravity work was attempted, as the time was altogether insufficient. At Loanda the basement of the American Mission house was occupied for gravity, and the magnetic measures were made in the immediate vicinity. The plan of operation followed at this station, which may be taken as a type for all the rest, was to swing two pendulums each during 72 consecutive hours, and to determine the magnetic declination, dip, and horizontal intensity on each of three consecutive days. The magnetic work was done on December 14, 15, and 16. One of the pendulums was swung before December 20 and the

* A dry and very hot wind from the interior of Africa which blows towards the Atlantic Ocean, and is usually accompanied by a haze often thick enough to obscure the sun.


MAP SHOWING
LOCATION OF STATIONS
Route of U.S.S."Hartford" 1883
" " " "Pensacola" 1889–'90
N O R T H
A M E R I C A
S O U T H
A M E R I C A
E U R O P E
A F R I C A
Greenland
Washington
San Francisco
Azores Id
Bermuda
Barbados
Cape Verde Is
Freetown
Elmina
Ascension I
Loanda
Cabiri
St. Helena I
Cape Town
Callao
Caroline Id
Longitude West 40 from Greenwich 20
1889–'90 • MAGNETIC STATION
" AND GRAVITY STATION
1883 + GRAVITY STATION

other after December 23; the time between these dates was spent at Cabiri, 50 miles inland, where magnetic observations were made on the day preceding, following and during the solar eclipse. The needle remained suspended during totality, but was apparently not influenced by this phenomenon. On January 6 at 6 a. m. we steamed out of the harbor of Loanda and turned towards the Cape of Good Hope. The passage was made in a little over eleven days. The Royal Observatory having been occupied by earlier observers, was chosen for our work. Two magnetic stations were made. One south of the observatory, and near the old magnetic house of Maclear, the other west of the observatory in a location apparently better adapted to these observations. But there have been so many buildings erected in the neighborhood since Maclear's time that the conditions may now be very different. Nearly three weeks were spent at Cape Town. We left for St. Helena on February 6, arriving on the 20th. Two pendulum and two magnetic stations were made here. The first at Jamestown at the sea level, the second at Napoleon's residence at Longwood, at an elevation of 1750 feet. Foster's station was at Lemon Valley. This was not re-occupied, for the reason that Jamestown offered much better facilities for expeditious work, and besides Foster's series had already been connected with ours at the Cape and would again be connected at two points on Ascension Island. The star observations at Longwood were obtained with difficulty on account of the continued cloudy weather.

The requisite number of stars was obtained only by having an observer at the telescope throughout the entire night during the continuance of the work. The magnetic station was near the old Magnetic Observatory. St. Helena was left on March 10, and Ascension sighted on the morning of the 16th. The affairs of Ascension are directed by the Admiral of the South Atlantic Squadron, whose headquarters are at the Cape of Good Hope. This being a British naval station, we were necessarily the guests of the Government. We had the good fortune to make the acquaintance of Admiral Wells at the Cape, who promised us every facility. Letters of introduction had preceded us, but in addition to this the British flagship *Raleigh* was riding at anchor off Georgetown when we arrived, so that every possible assistance was given us. A pendulum house and mess room were furnished in Bunghole Square. Sleeping apartments were given at the hospital, laborers were provided, and sentinels patroled off to guard the tent and instruments night and day. The first station was made at sea level, and is supposed to be within a few feet of Foster's location in 1829. The work was completed here on the eve of March 26, and the ascent of Green Mountain was begun on the following morning. From Foster's description it is impossible to say exactly where his point of observation was, but the height given (2230 feet), and the fact that the barracks mentioned in Baily's report were at the time the only buildings on the mountain make it very probable that the two stations are practically identical. Our pendulum was swung in what is known as Garden Cottage, having nearly the same elevation as that given by Foster, and situated less than 200 feet from the barracks. The magnetic observations were made in the garden adjoining. Observations were closed here on the eve of April 6. On the 7th the instruments and tents were taken down the mountain and reshipped. On the 8th the *Pensacola* sailed for Bridgetown, Barbados. A passage of 20 days brought us to our destination. The only available place here for the pendulum work was in the old Naval Hospital at Hastings. Permission to make the observations was granted by the Governor, his Excellency W. J. Sendall, and the building was put at our disposal by Gen. J. E. D. Hill. Ten days sufficed for the work. The outfit was all on board by Saturday morning, the 10th of May, and at noon the vessel left for Bermuda. Arriving at the latter port with some sickness on board, we were quarantined. The *Pensacola* left the following day for New York, after having landed the Coast Survey outfit and observer on Quarantine Island, where a stay of 10 days was required by the authorities before permission to land at St. Georges was granted. Occasion was taken during this enforced occupation of Nonsuch Island to make magnetic observations, and a complete series for declination, dip, and intensity was made on three successive days, besides hourly observations for declination on two other days. On leaving quarantine I landed at St. Georges, and established the pendulum station at that place. Being entirely without help, it was not possible to follow the usual plan of swinging night and day without interruption, but the exceptionally good temperature conditions prevailing in the pendulum house made these continual observations of less importance than they were at the other stations. The last star observations were made on June 7. The instruments were dismounted on the 8th, and sent to Hamilton on the 9th. On Thursday, the 12th, I sailed for New York, arriving on the Sunday following: the sea voyage terminating at this point having lasted 242 days, of which 123 were passed on shipboard and 119 on shore. Magnetic and gravity observations were made at 8 stations, viz: Loanda, Cape Town, St. Helena (Jamestown and Longwood), Ascension (Georgetown and Green Mountain), Barbados, and Bermuda. Magnetic observations alone were also taken at five additional points, viz: Azores, Cape Verde Islands, Freetown, Elmina, and Cabiri. These, with the two magnetic stations at Cape Town, give a total of 14 magnetic and 8 gravity stations. The cost of the work was comparatively slight, the whole party expenses, exclusive of subsistence, being about $250. Some bills were paid by the Eclipse Expedition, but this money was refunded by the Coast and Geodetic Survey on my return to the United States. The amount for subsistence while on the *Pensacola* has been deposited in the Treasury of the United States to the credit of the Eclipse party, so that all pecuniary obligations to the appropriation for the expedition have been discharged.

The small expense of the work is due to two causes: First, the material aid given by Captain Yates and the officers of the *Pensacola*, and the assistance rendered by Her Majesty's Government at Ascension and elsewhere; and, second, the shortening of the time of observation by swinging the pendulum night and day, and by carrying on the gravity and magnetic work simultaneously.

I was most ably assisted by the following naval cadets: Frank Marble, at the Azores and Cape Verde Islands; G. N. Hayward at Freetown; J. B. Patton at Elmina and Cape Town; G. R. Marvell at Loanda, Cabiri, St. Helena, Ascension, and Barbados; W. D MacDougall at St. Helena; and P. W. Williams at Ascension and Barbados.

Prof. F. H. Bigelow, a member of the Eclipse party, also took part in the observations at St. Helena and Ascension. At the former place Professor Abbé, of the U. S. Signal Service, determined barometrically a number of altitudes for use in correcting for the attraction of the mountain.

Between June 20 and 30 the time was occupied in closing up the work of the trip, settling accounts, transferring records and instruments, and doing miscellaneous office work.

An account of the trip would be incomplete without a due acknowledgment of the services rendered by the government officials at the different stopping places. At Loanda the Governor of the province of Angola gave us free passes for all railroad travel from the coast to Cabiri, where the party went to observe the eclipse on December 22. At the Cape of Good Hope every facility was given by the authorities. Her Majesty's Astronomer, Dr. Gill, kindly furnished myself and aid with quarters at the Observatory. He gave us the use of the Observatory clock, and made a separate determination of time every night for use in the pendulum work. The railroad officials gave special passes for a trip to the diamond fields at Kimberly, 600 miles into the interior. As St. Helena, his Excellency Governor Antrobus gave us the use of the public park for magnetic observations, and of the library room of the Police Court for pendulum observations.

The official courtesies, however, of which we were the recipients at Ascension, demand special recognition. The unique character of the island Government placed us under more than ordinary obligations. All persons being either naval officers or seamen, any service performed or labor done was necessarily on the part of Her Majesty's Government. Capt. R. H. Napier, R. N., placed at our disposition an entire building in Bunghole Square for the observations at the garrison. A pier was built for the transit, tents were erected for magnetic and astronomical work, and guard duty performed by the marines. A ration per day from the island stores was served to each member of our party during the stay. This ration included among other things fresh turtle steak and lime juice. When we consider that the supply of these articles is somewhat limited, we are able to appreciate the generosity of the island officials. One station was to be made on the summit of Green Mountain, because it was desirable to repeat Foster's observations made there 60 years ago. This made it necessary to erect a pier at Garden Cottage and cart the instruments from the sea level to the barracks. All this was done by Captain Napier with the government force with the care and dispatch characteristic of the British Navy. In addition, Garden Cottage was put in order and turned over for our exclusive use. The altitude of this point is about 2,250 feet. The pendulum was swung in one of the rooms, the others being used for living purposes.

At Barbados and Bermuda we were again on English soil, and received the usual generous welcome. At the former place Governor Sendall took much interest in the work, and made a personal examination of the instruments and methods of observing. At Bermuda the Governor, Lieutenant General Newdegate, kindly gave the use of the government launch for the transportation of the instruments from Quarantine Island to St. Georges, besides showing me other attentions of an unofficial character. Mr. James Atwood did much to lighten my labors in the way of selection of station, and preparatory work in general. Finally, I have to express my best thanks to Capt. A. R. Yates and the officers generally of the *Pensacola* for kind assistance throughout the voyage. The landing of the delicate instruments was often a difficult matter, but nothing was ever broken or lost, although the outfit was transferred nearly 30 times.

A bulletin (No. 22) has been published giving a concise statement of the results of the observations. In the present report the subject will be treated more in detail. The constants of the instruments are published for convenience of reference, and the summaries of results will enable us to compare this work with that previously executed and with that to be done in the future. Illustration No. 1 shows the route taken and the kind of observations made at each place. The gravity stations in 1883 are also shown. The pendulum used in this trip was also taken to Africa and the results of both voyages will eventually appear in one connected series.

In the computations of the gravity work I have been most ably assisted by Mr. G. R. Putnam, acting aid U. S. Coast and Geodetic Survey. The magnetic observations were reduced in the Computing Division by Mr. L. A. Bauer, under the direction of Assistant C. A. Schott.

The following is a list of the instruments and accessories used :

INSTRUMENTAL OUTFIT.

Transit instrument, U. S. C. S., No. 2. Focal length, 46 inches. Aperture, $2\frac{3}{4}$ inches. Magnifying power, 90.
Theodolite magnetometer, No. 11.
Dip circle, No. 4440.
Engineer's transit, No. 144.
Peirce pendulum, No. 2 (metre).
Peirce pendulum, No. 3 (yard).
Triangular wooden stand (see illustration No. 56).
Chronograph, No. 7.
Reading telescope, No. 300.
Pendulum head, No. 0.
Sextant, No. 30.
Thermometers (Baudin), Nos. 9243, 9252, 11316, 11319.
Amplitude scale (20ths of an inch).
Condensing lens, No. 17.
Mercurial barometer (Green), No. 1390 and 846.
Aneroid barometer (Green), No. 1163.
Sidereal chronometer, No. 220, Hutton.
Mean time chronometer, No. 177, Bond & Sons.
Temperature tube.
Switch board.
Steel tape, No. 64.

The following accessories were also taken .

Inside pendulum tent, No. 18 (*c*), outside pendulum tent, astronomical observing tent, No. 223, magnetic observing tent, No. 224, living tent, No. 212, plate glass, relay, plaster of Paris, observing keys, lanterns, heliotrope mirror, 4-cell gravity battery, 3 spare levels for transit, P. T. compass for dip circle, etc.

The values of the levels on transit No. 2 were—
1 div. striding level = $0''.83$. Temp. 72° F.
1 div. latitude level = $1''.33$. Temp. 72° F.

Magnetometer No. 11 is shown in illustration No. 61. It has a horizontal and vertical circle of 4 inches diameter. Angles can be read to the nearest minute by means of verniers. Time observations made with this instrument may be considered correct to the nearest tenth of a minute; that is, the error is not more than three seconds. A comparison made on Green Mountain, Ascension, with the work of the meridian telescope and chronograph, gave a difference of 2 seconds. The azimuths of our 4-inch theodolite may be relied upon within 1 minute when both morning and afternoon observations are made, as this method eliminates any error in the assumed latitude of the place of observation.

The Dip Circle is shown in illustration No. 62. It is of the Kew pattern, and is provided with two needles. Observations were made with both; two sets with each were always taken, the poles being reversed between the sets. Half the observations at a station were made with the circle and needle in the direct position and the remaining half in the reverse position. The results are therefore independent of errors of level, and of those dependent on the position of magnetic axis and the center of gravity of the needle.

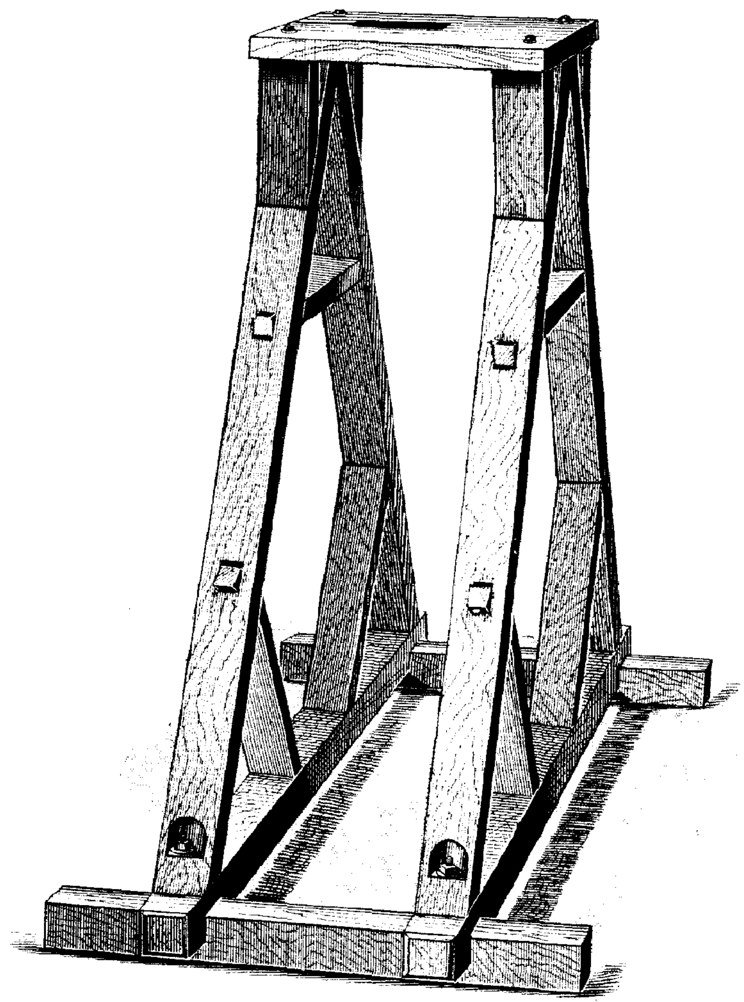
The form of the pendulum is shown in illustration No. 58. Illustration No. 56 is the stand used throughout the work. The flexure of this form of support is practically insignificant. Experiments were made at the Smithsonian Institution in July and August, 1890, to determine the influence of the movement of the stand on the period of oscillation. The head on which the pendulum swung is shown in illustration No. 57.

MEASUREMENT OF LENGTH.

A comparator, originally devised by Repsold, has been used in comparing the pendulums with the standard. It is shown in illustration No. 59, and consists of a vertical tube to which are attached horizontal microscopes above and below. The pendulum, standard, and comparator are all supported on the same stand. The apparatus is first made approximately level by means of foot screws. The knife-edge plane being accurately leveled, the pendulum is put in position and allowed to swing freely. By means of a small striding level the microscopes are made horizontal and the comparator vertical. The upper microscope is now focused on the knife-edge, and a fine silk plumb line is suspended between the pendulum and the standard and placed in the focus of the upper microscope. This gives a means of putting the lower microscope in the same vertical plane as the upper one, as well as the same distance from a vertical plane passing through the knife-edge of the pendulum. The standard is then put in position and adjusted to the microscopes.

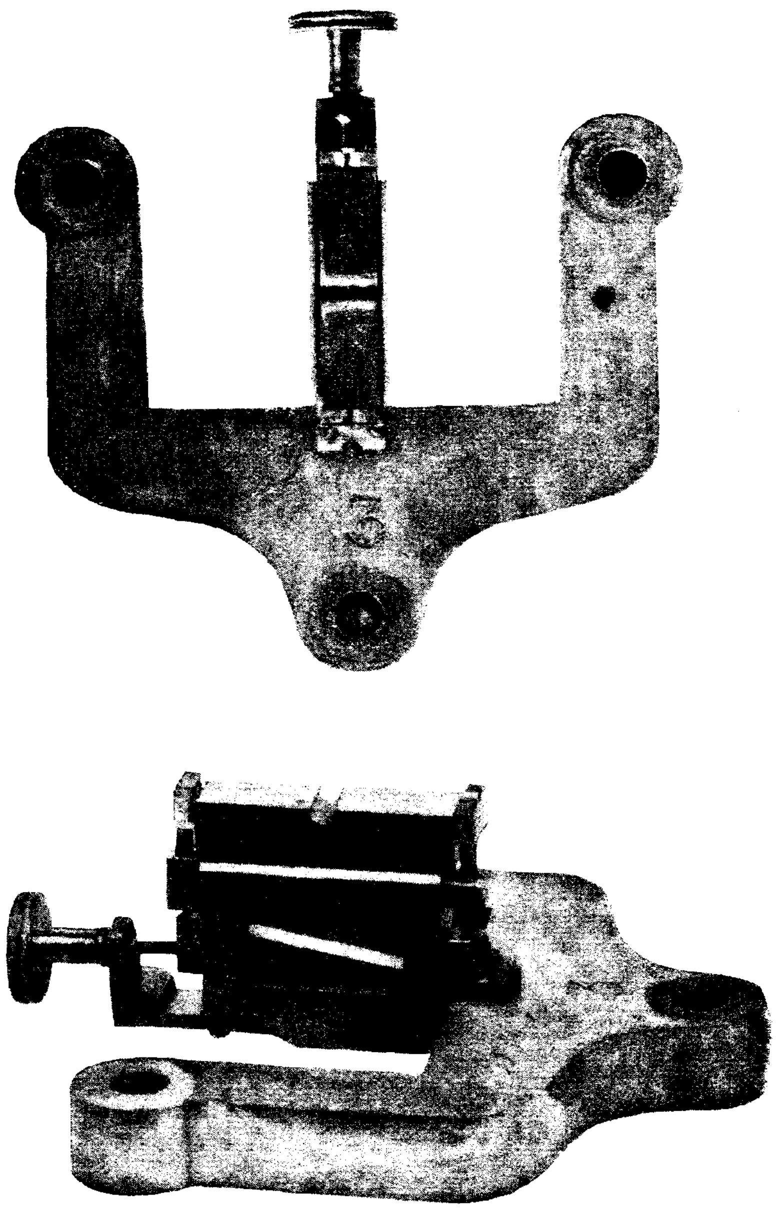
The illumination is obtained by means of incandescent burners of three-candle power, concentrated by means of lenses upon a prism placed before the objective and thrown by total reflection in upon the knife edge. Half the objective surface was cut off by the prism. The old method of throwing the light upwards and pointing on a bright and dark edge alternately was not employed. Polished planes of steel were used to give a reflection of the knife-edge. The arrangement was such that the distance between the direct and reflected images could be varied at will, so that measures could be made under different conditions. The lengths of the pendulums were determined, with heavy end up and heavy end down, by the reflected image and by pointing on the direct edge of the knife, the illumination being placed exactly behind. All these measures agreed sufficiently well to warrant the acceptance of their mean as the true value. Pointings on the direct edge with illumination behind have usually been distrusted on account of diffraction and of the glare which usually appears when looking towards the source of light. These unfavorable conditions entirely disappeared when the light was covered by a conical cap of paper. The whole field was equally illuminated by a uniform soft light in such a way that the micrometer threads were sharply defined, whether projected against the knife-edge or the open field. These measures agreed perfectly with those made by means of the reflecting planes.

The illumination was closed and opened from a switch board near by, the lamps only burning for a few seconds while the pointing was being made. Readings were made in the following order: Standard below, standard above, pendulum above, pendulum below. This completed the forward set. A backward set now followed in the reverse order, and the mean of the two determinations was adopted. For the first part of the work three pointings were made on each line, but experi-

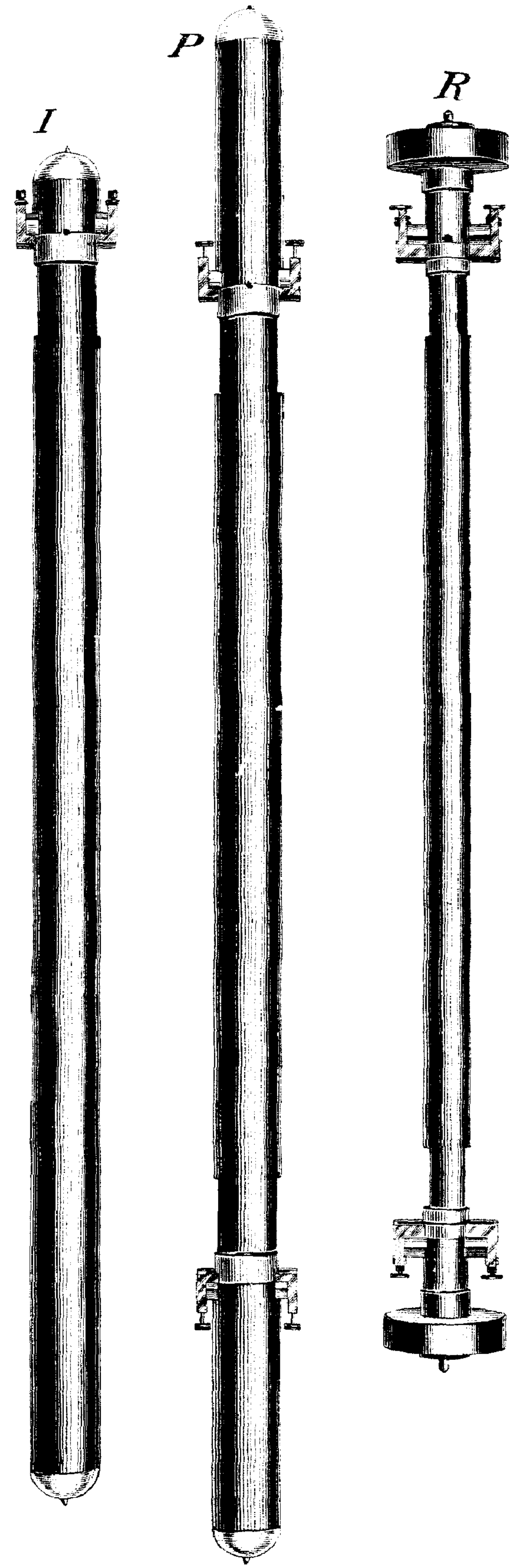


PENDULUM STAND.

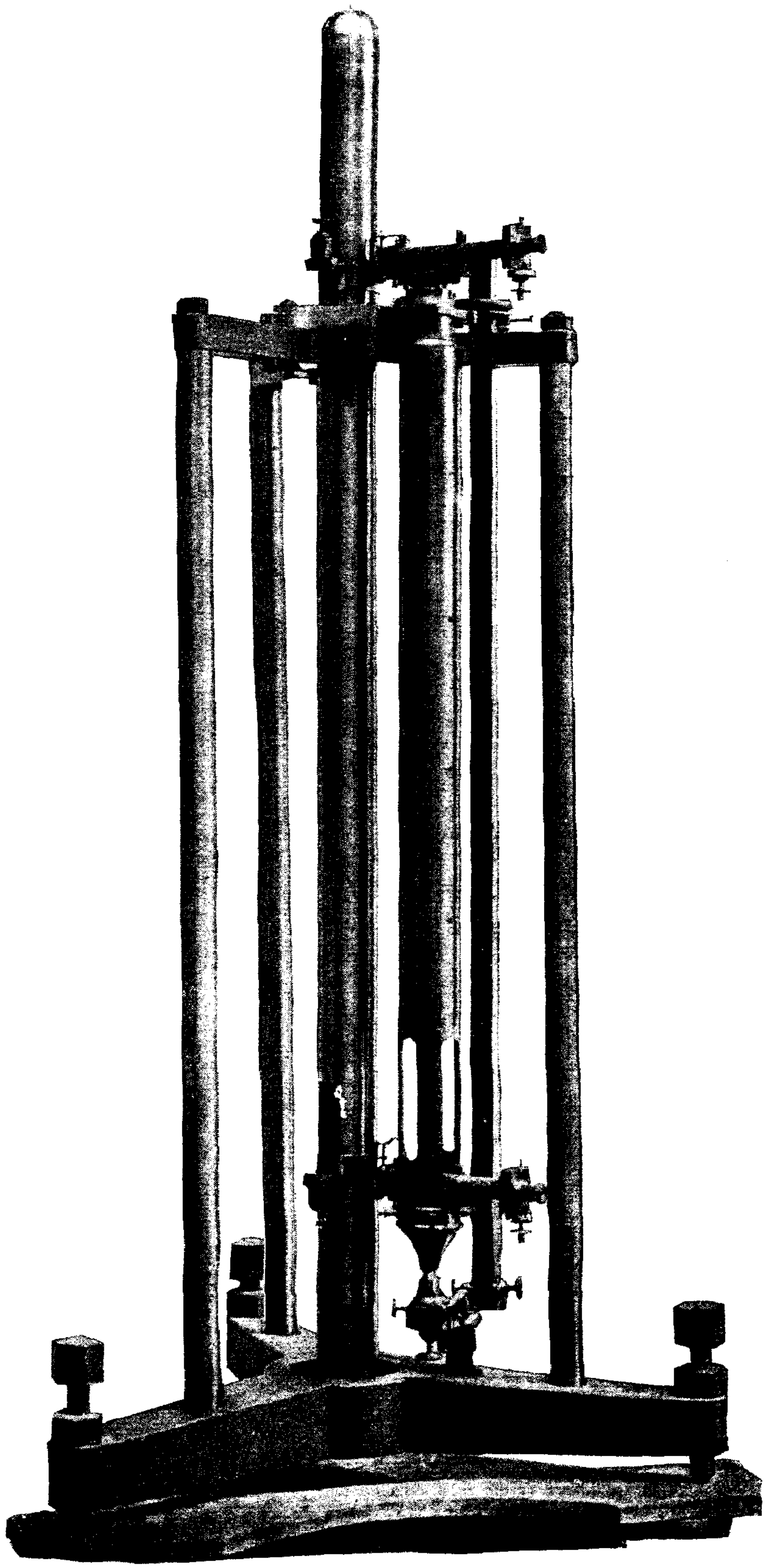
1889.



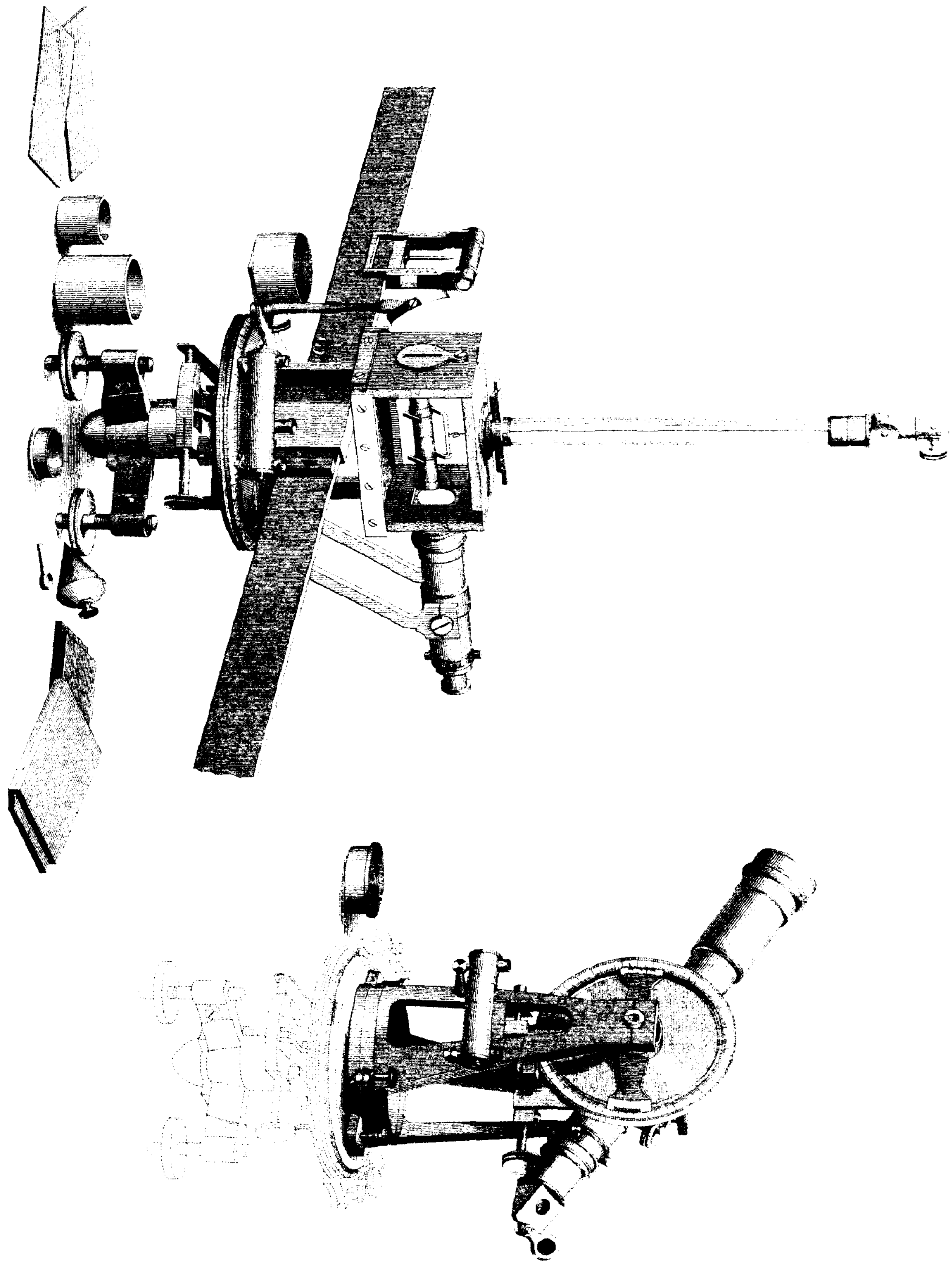
PENDULUM HEAD NO. 3.



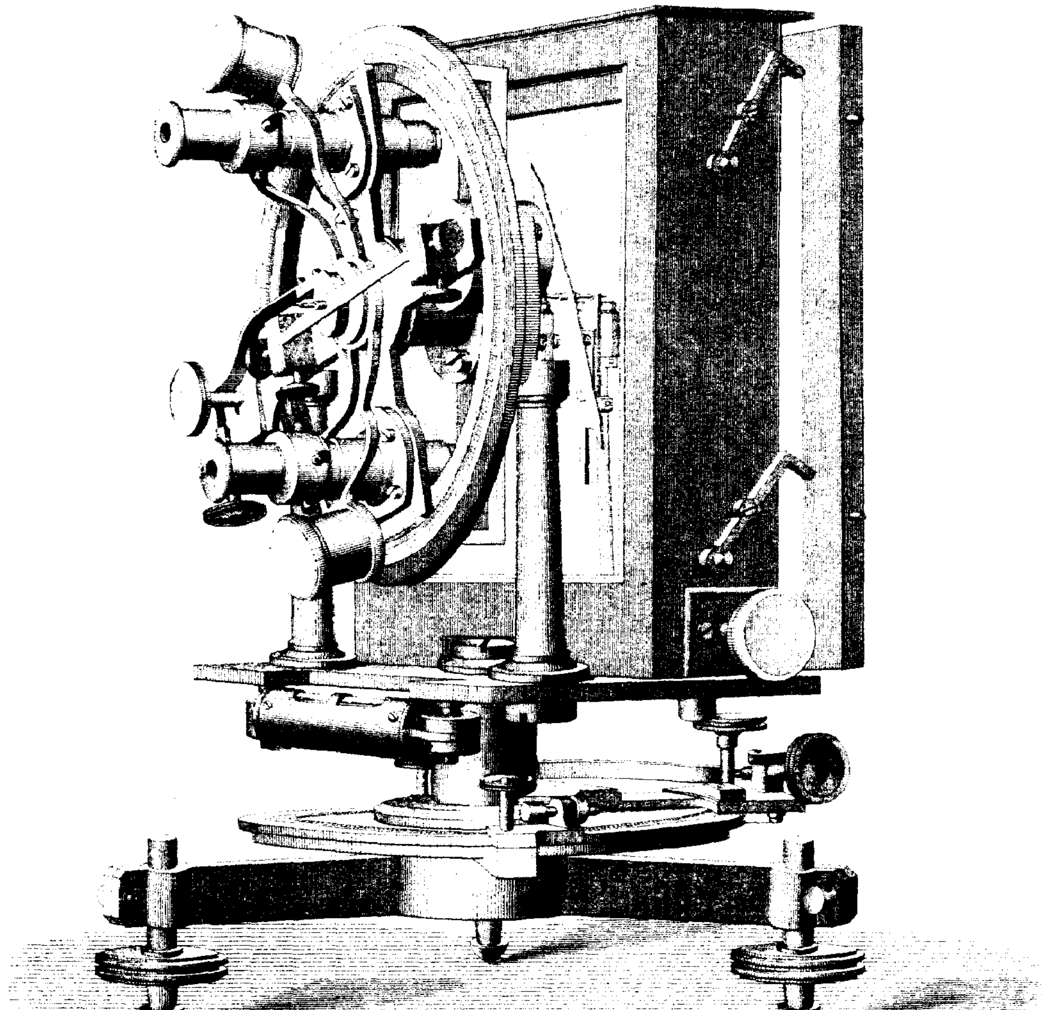
PENDULUMS.



REPSOLD VERTICAL COMPARATOR, WITH PENDULUM No. 4 AND "Y AND M No. 1"
IN POSITION.



ALT AZIMUTH AND MAGNETOMETER



DIP CIRCLE

(KEW PATTERN.)

ment showed that one pointing was practically as good as three, and many of the latter results depend on one only.

The comparisons were made between the pendulums and the standard bar known as "Yard and Metre No. 1," of which the following are the equations:

$$\text{Yard} = 1{\cdot}000000 \text{ yard} \quad + (t - 61^{\circ}{\cdot}17 \text{ F.}) \times {\cdot}000010 \text{ yard.}$$
$$\text{Metre} = 1{\cdot}0003056 \text{ metre} + (t - 17^{\circ}{\cdot}48 \text{ C.}) \times {\cdot}000018 \text{ metre.}$$

MEASUREMENT OF CENTER OF MASS.

The ratio of the distances of the two points of support from the center of mass is determined by means of an apparatus shown in illustration No. 60. This instrument, I believe, was originally constructed by Repsold, but it has recently undergone some modifications to adapt it to our larger form of pendulum. The knife-edge touches the abutting piece at (a), the center of mass being at (c). The pendulum is balanced about this point by turning the large disc. At (b) is a frame, in which the pendulum has a slight play. The point a being drawn backwards by means of a screw at d, the pendulum is brought into equilibrium about the point (c). (a) is then brought into contact with the knife-edge. The reading of the verniers at k and P gives the distance on the scale between them. The distances from k to the knife-edge and from P to the center of mass are unknown, but these two unknown quantities are eliminated and the ratio sought is determined by a similar measurement after reversing the pendulum. After reversal, the balancing part at c is placed very much nearer k. Contact is now made on the other knife-edge and the verniers read as before. The whole bar k P is accurately graduated into centimetres, while the two verniers consist of millimetres divided into tenths.

Let H and h represent the distances from the knives to the center of mass, x the distance from the vernier at k to the knife at a, y the distance from the vernier at P to the center of mass at c, and let a and b be known quantities read from the scale.

For the first position we have

$$\text{H} = x + a + y$$

where a is the distance between the two verniers.

After reversal we get

$$h = x + b + y$$

where b is the new distance between the verniers.

These equations gives us $\text{H} - h$. Their sum is known from the distance between the knives, and from these two H and h result.

The accuracy necessary in the determination of the position of the center of mass depends on the difference of the times of oscillation of the pendulum with heavy end down and heavy end up. Denoting the former by T and the latter by t, the time of oscillation of a simple pendulum with a length equal to the distance between the knives or $\text{H} + h$ is

$$\text{T}_o = \frac{\text{T H} - th}{\text{H} - h}$$

This is equal to

$$\text{T} - \frac{ah}{\text{H} - h} \text{ where } a = t - \text{T}$$

Regarding (a) as constant, the differential of this quantity will give the effect on the time of oscillation; the distance from the center of mass to the knives being the independent variable. The Peirce pendulums have the following values for $\text{T} - t$:

No. 1	+	$0^{s}{\cdot}0007$
2	−	${\cdot}00004$
3	+	${\cdot}0002$
4	+	${\cdot}00003$

It is evident, therefore, that for either No. 2, 3, or 4, with which we have to do, measures of the distances $\text{H} - h$, when made only to the nearest millimetre, introduce no error in the deduced period as great as its millionth part.

The following are the results for the measures of position of the center of mass:

Pendulum.	H	h.
No. 2	75·00 centimetres	24·99 centimetres
No. 3	26·942 inches	9·054 inches
No. 4	74·85 centimetres	25·14 centimetres

DESCRIPTION OF STATIONS.

The following sketches are intended to give essential lines only, in order that later observers may readily re-occupy the stations. No scale has been employed, and the directions are merely approximate:

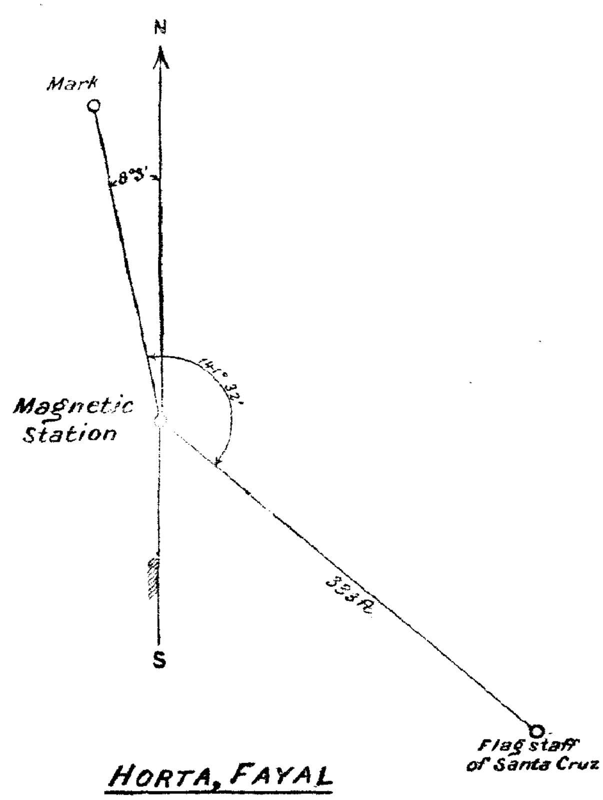
Washington, D. C.—Magnetic observations were made in the vacant lot south of the rear part of the Coast and Geodetic Survey office. The station is identical with that of Assistant Baylor in 1887.

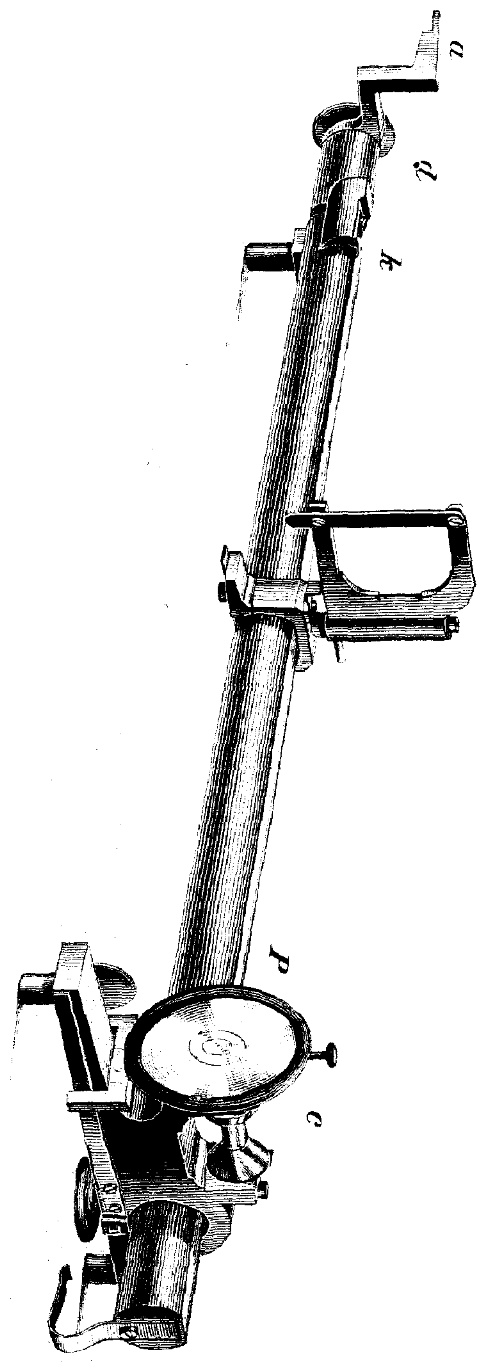
Pendulum observations were made in the northeast basement room of the Smithsonian Institution. This room was set aside by the late Professor Baird for the exclusive use of the Coast and Geodetic Survey as a fundamental gravity station for this country, and it has been occupied for this purpose by Lieutenant-Colonel Herschel, R. E., and by Assistants C. S. Peirce, Edwin Smith and E. D. Preston, Coast and Geodetic Survey.

Azores Islands.—The magnetic station was established in the town of Horta, on the island of Fayal. Observations were made in the garden of Mr. Dabney, the American consul, and 333 feet from the flagstaff of the castle of Santa Cruz.

Location of station at Horta.

FIG. I.

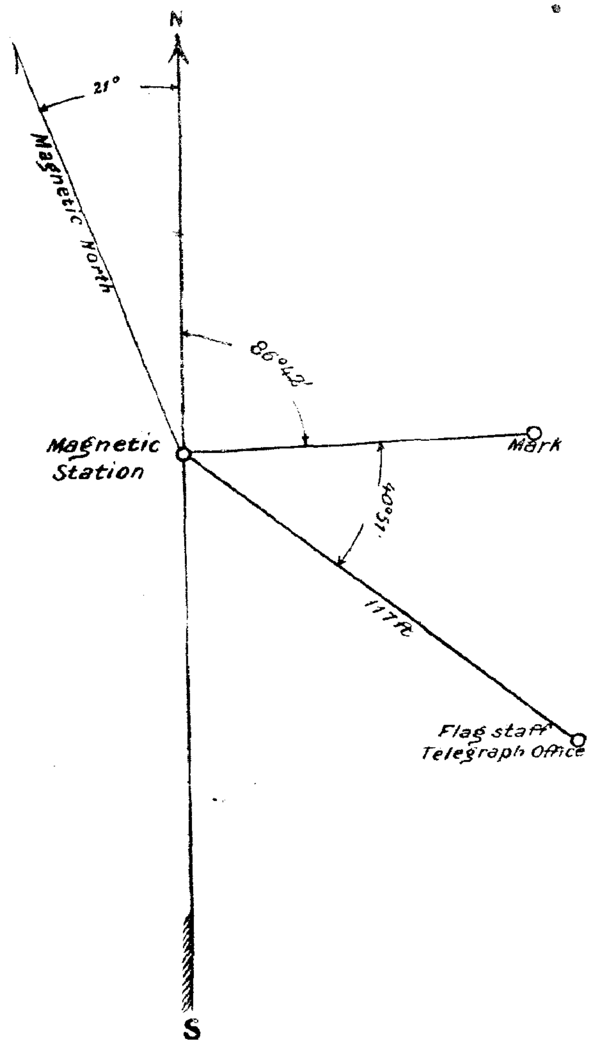




Instrument for Determining Center of Mass.

Cape Verde Islands.—The magnetic station was located at Porto Grande, on the island of St. Vincent. Observations were made in the yard of the office of the Submarine Telegraph Company. The instruments were placed 117 feet distant from the flag pole at the office door.

FIG. II.



PORTO GRANDE

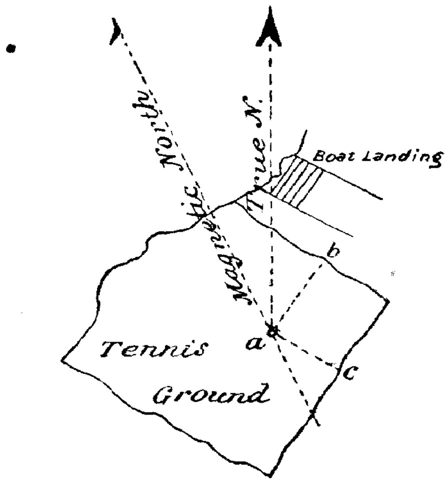
Sierra Leone.—The magnetic station was in the lower part of the village of Freetown. The instruments were set up near the middle of the tennis ground and about 300 feet northwest of the Cathedral. The relative positions of the boat landing and tennis ground are shown in the sketch (Fig. III). The station is at (*a*). The distance *ab* is 69 feet, and *ac* is 81 feet. This boat landing is the only one in use at present.

Gold Coast.—Observations were made at Elmina, about 7 miles west of Cape Coast Castle. The station occupied was on the Government reservation near Fort St. George. In the sketch (Fig. IV) the boat landing is at *A*. The boat entrance is at *B*. *C* is the Wesleyan Church. The distances from the station to the sea wall and to the military road are 108 feet and 180 feet, respectively.

Angola (*Loanda*).—Both magnetic and gravity determinations were made at St. Paul de Loanda. The magnetometer and dip circle were set up a short distance northwest of the American Mission

House, and the pendulums were swung in the basement of the same building. The magnetic station was established in the magnetic meridian passing through the Mission House. The posi-

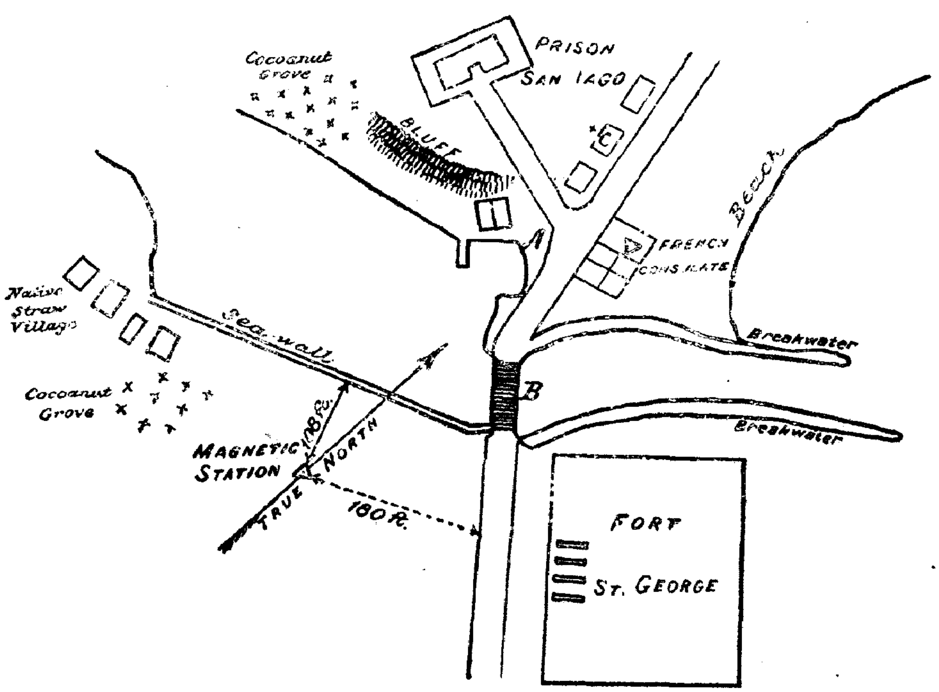
FIG. III.



FREE TOWN

tion of the astronomical pier is, $\varphi = 8^\circ\ 48'\ 48''$ South, and $\lambda = 13^\circ\ 14'\ 02''$ East. The latitude depends on observations of two pairs of stars, by the method of equal zenith distances. The

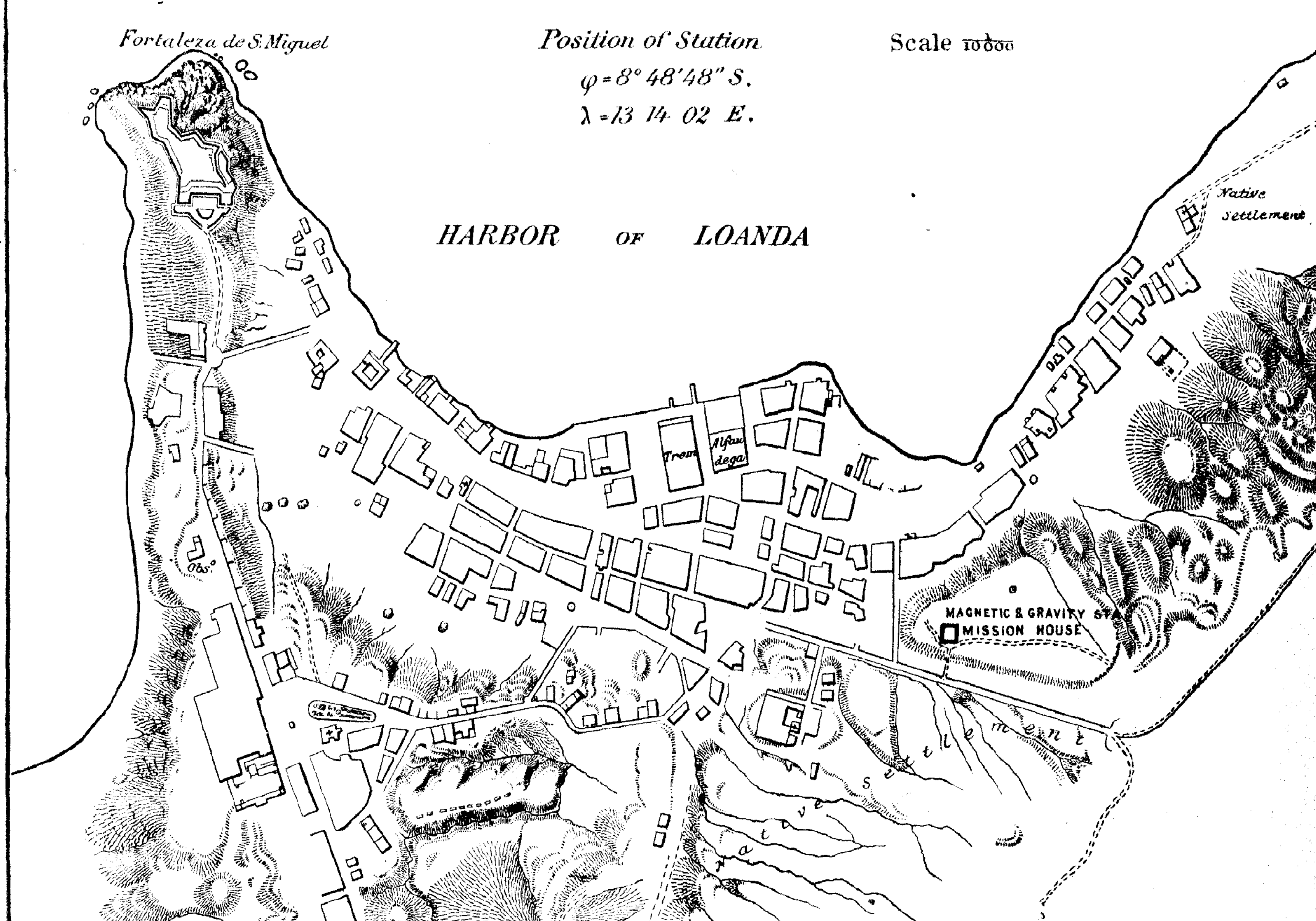
FIG. IV.



ELMINA

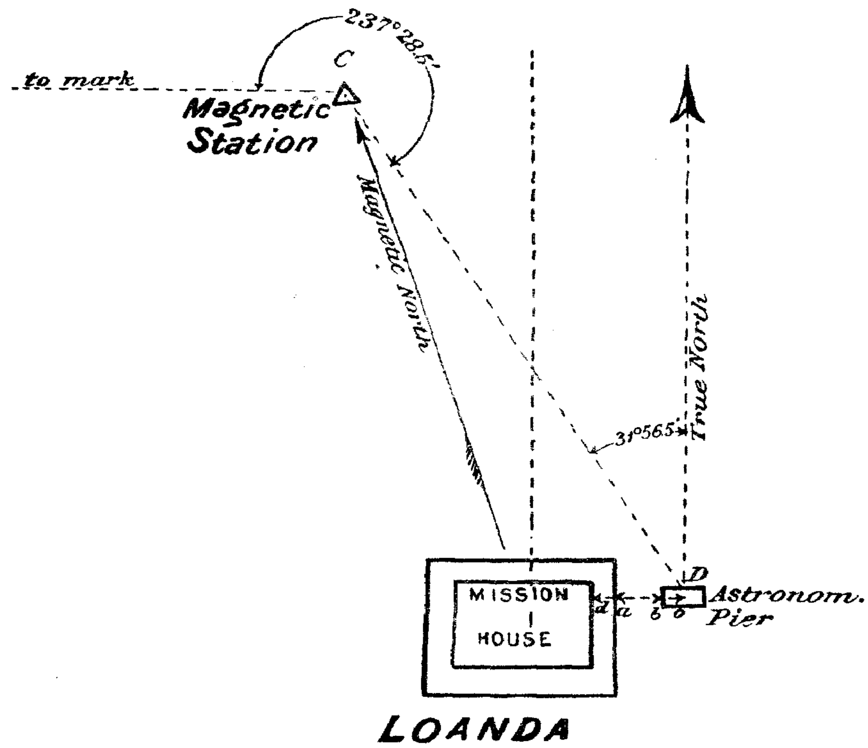
longitude results from a connection with Commander Pullen's telegraphic determination. This connection was made by Mr. L. H. Jacoby, of the Eclipse Party. Sketch V shows the general

FIG. V.


Fortaleza de S. Miguel
Position of Station
φ = 8° 48′ 48″ S.
λ = 13 14 02 E.
Scale 1/10000
HARBOR OF LOANDA
Native Settlement
Trem
Alfandega
Obs.°
MAGNETIC & GRAVITY STA.
MISSION HOUSE
Native settlement

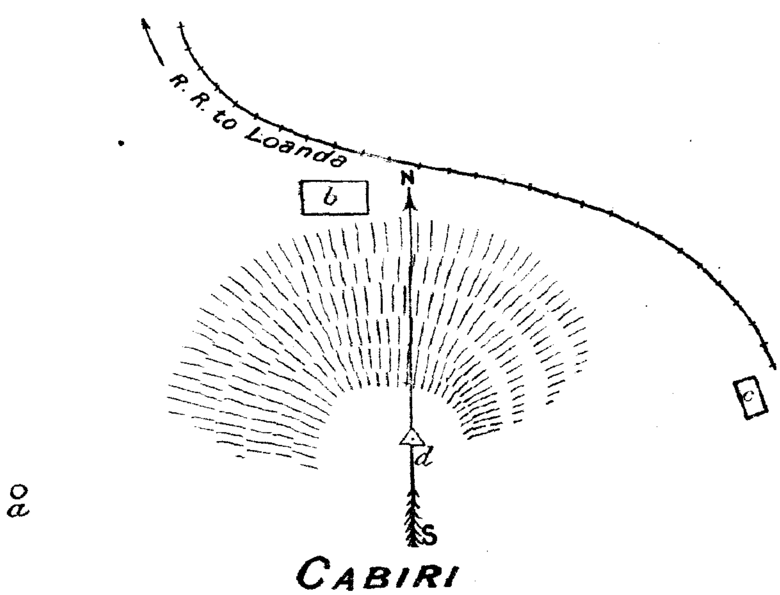
location of the station with reference to the town. Fig. VI gives an enlarged plan to aid in locating the exact point at which the magnetic observations were made for use in future work. The distances are as follows: CD = 163 feet, od = 10 feet, ab = 4 feet.

FIG. VI.



Angola (*Cabiri*).—The magnetic station was established on top of the hill south of the railroad. Observations were made on December 21, 22, and 23. In the sketch, C is the new depot, b is

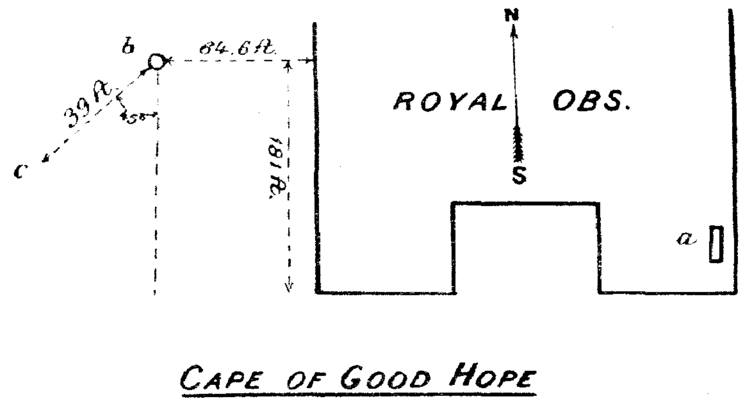
FIG. VII.



the new house of Senhor Bastos, a is the mark used for azimuth observations, and d is the point at which the instruments were placed. The distance bd is approximately 350 feet. The angle at d between b and C is 102°.

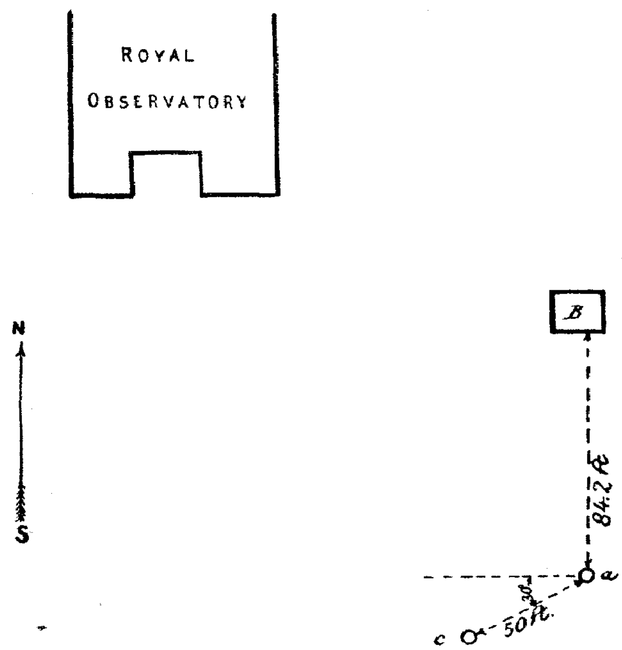
Cape of Good Hope.—The Royal Observatory was occupied for gravity observations, and the magnetic work was done in the immediate vicinity. Sketch VIII shows the location of the first magnetic station and the position of the pendulum stand; *b* is the point occupied by the magnetom-

FIG. VIII.



eter; the dip circle was at *c*; *a* is the pendulum stand. Sketch IX shows the second station; B is a stone building about 300 feet distant from the observatory. In this stone structure magnetic observations were made about 10 years ago; *c* is the approximate position of the permanent mag-

FIG. IX.



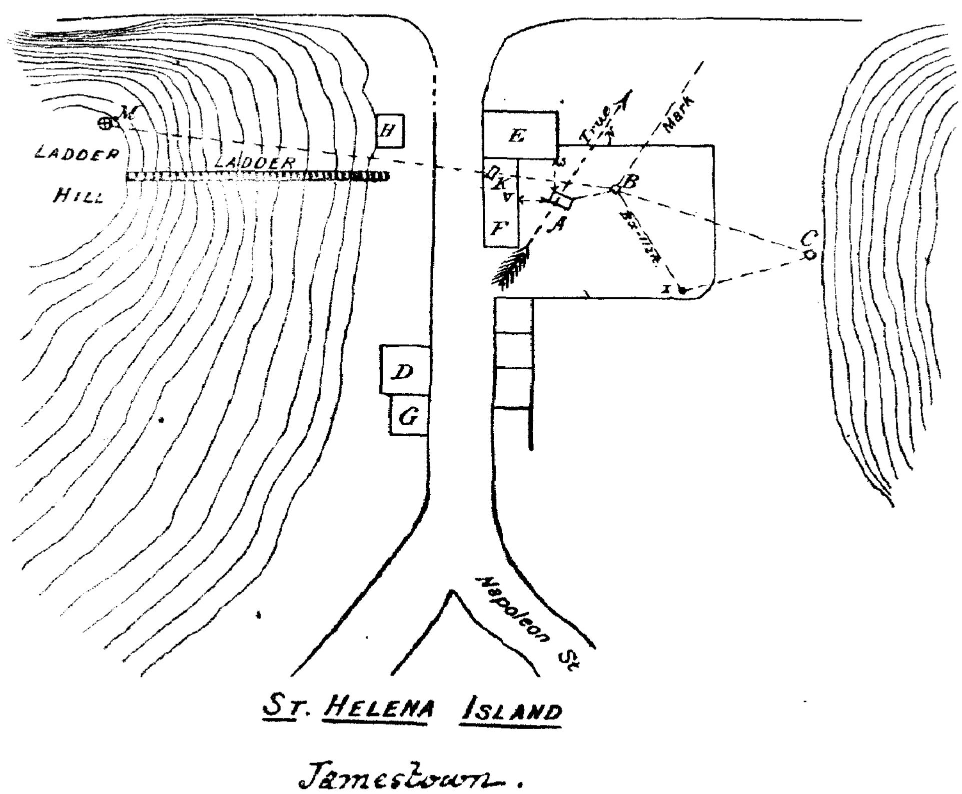
netic observatory from 1840 to 1850, the direction *ac* being about south 60° west; *a* is the Coast and Geodetic Survey station. It was impossible during our stay to occupy either the points B or *c*.

St. Helena (*Jamestown*).—Magnetic observations were made in the Public Garden and the pendulums were swung in the library room of the Police Court. The following references to Sketch X indicate the relative positions:

A = Pier of transit instrument.
B = Magnetic station (Coast and Geodetic Survey).
C = Magnetic station at Sisters Walk, occupied by Sir James Ross in 1840.
D = Hotel.
E = The castle.
F = Court-house.
G = American consulate.
H = Custom-house.
K = Pendulum stand.
M = Flag-pole on Ladder Hill.
Distances in feet: AV=35, AS=33, AB=42, Bx=112·3.

		°	′
Angles at B, between	M and mark	116	37
	mark and C	76	20
	C and x	39	03
	x and A	121	15
	A and M	6	45
Angle at x, between	B and C	113	28

FIG. X.



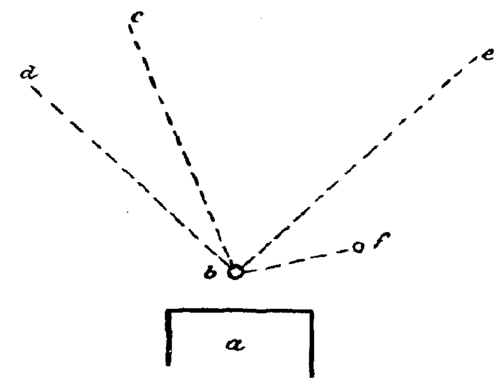
St. Helena (*Longwood*).—Magnetic observations were made near Sabine's magnetic observatory of 1840–'45 and the gravity determinations in what is now known as Napoleon's new house. The pendulums were swung in the kitchen, where the stand was placed on the solid stone floor. The position of Sabine's observatory is $\varphi=15° 56' 41''·2$ S. and $\lambda=5° 40' 28''$ west. Sketch XI shows the general location.

a=Sabine's observatory.
b=Estimated center of old front room (now removed) of observatory (distance from b to building 10 feet).

c=Sabine's meridian mark.
d=Sabine's magnetic meridian.
e=Pendulum station in Napoleon's new house.
f=Coast and Geodetic Survey magnetic station.

		° ′	
Angle at f	cfb=	76 55	Distance:
b	cbf=	103 50	be=350 feet.
b	cbe=	64 00	bf=110 feet.

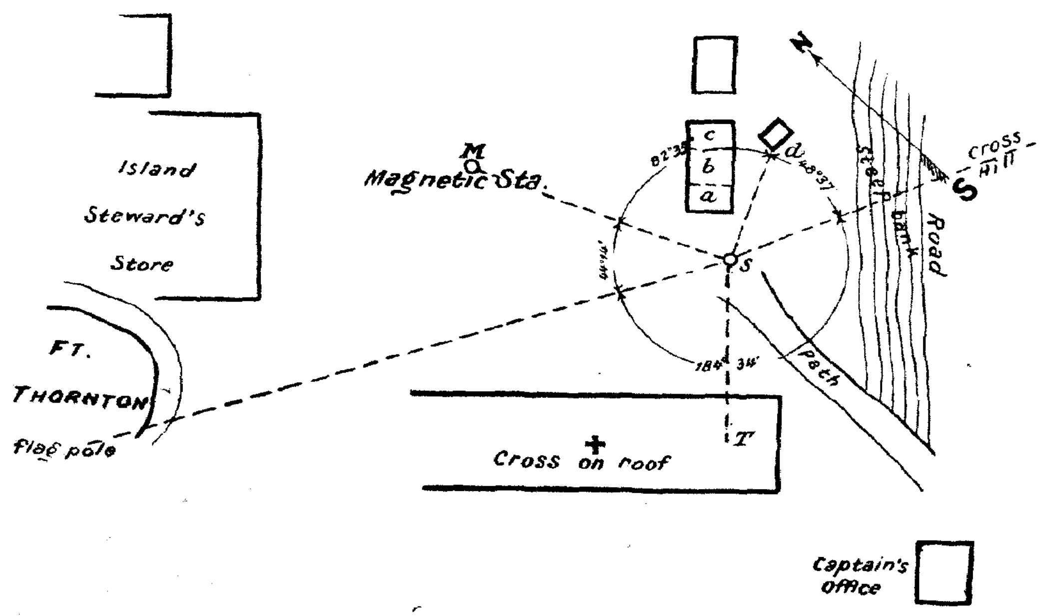
FIG. XI.



LONGWOOD

Ascension (Georgetown).—All observations were made in Bunghole Square. The magnetic instruments were set up near the center of the open space, and the pendulums were swung in a small stone building supposed to be very near the spot where Foster made his observations in 1829. In sketch XII a is the observing room, b the pendulum room, c a store room, d the transit pier. Distances: Sd=65 feet, SM=118 feet, ST=201 feet.

FIG. XII.



GEORGETOWN

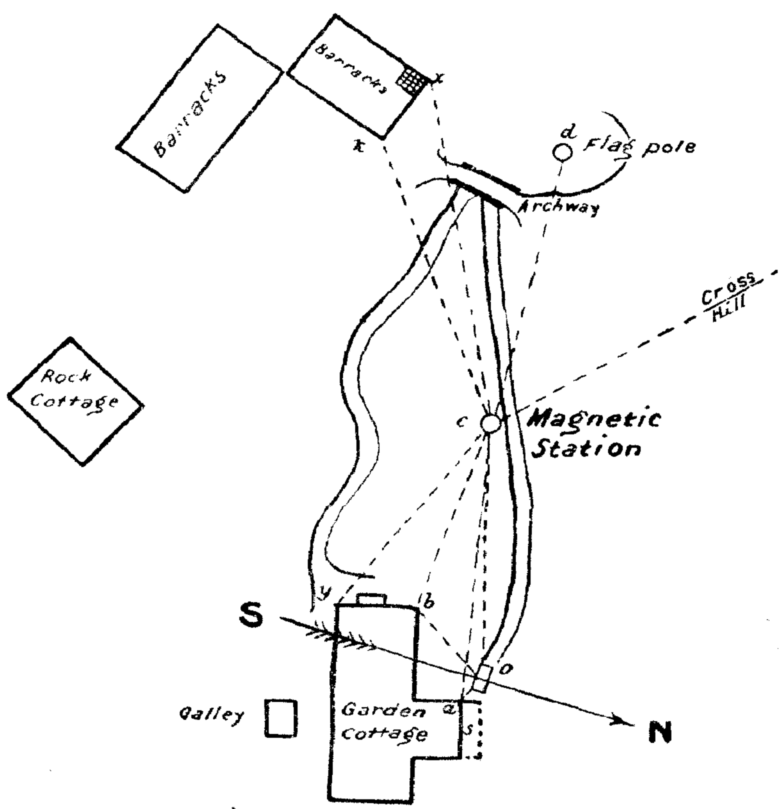
Ascension (Green Mountain).—Both stations on Green Mountain were near the barracks. The magnetic observations were made about midway between the archway and the Admiral's Cottage (sometimes called Garden Cottage). The pendulums were swung in the cottage, the transit pier being built close by. The following angles and distances fix the relative positions:

Readings of Horizontal Circle at c.

	°	′
Pole on Cross Hill (azimuth mark)	0	0
o	132	46
a	139	10
b	150	08
y	158	46
k	302	33
x	306	33
d	314	12

o=Transit pier.
s=Veranda.
c=Magnetic station.
x=Tower and clock.
Distances: *ao*=15.7 feet.
bo= 39.7 feet.
bc= 95.3 feet.
oc=118.6 feet.
kc=230.0 feet.

FIG. XIII.



GREEN MOUNTAIN

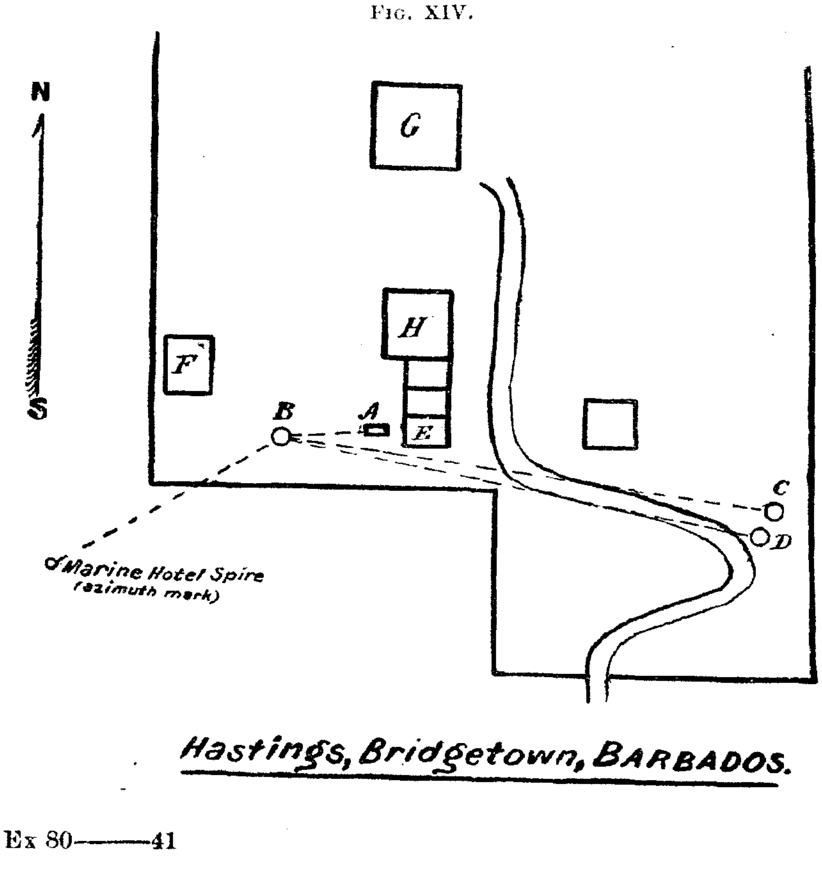
Barbados.—Determinations were all made at Hastings, near Bridgetown, on the grounds of the old Naval Hospital. This same location was occupied by Transit of Venus parties in 1882. Sketch XIV shows the relative locations.

A = Transit pier, 1890.
B = Magnetic station.
C = Transit of Venus pier 1882.
D = Heliostat.
E = Pendulum room, 1890.
F = Galley.
G = Surveyor—Engineer's house (Mr. T. Ivor Moore).
H = Stable.
Distances: AB = 35 feet.
BC = 310 feet.

Readings of horizontal circle at B.

	°	′
Marine Hotel spire (azimuth mark)	62	24
Pier of transit instrument, 1890	283	22
Light-house	311	54
Transit of Venus pier	314	00

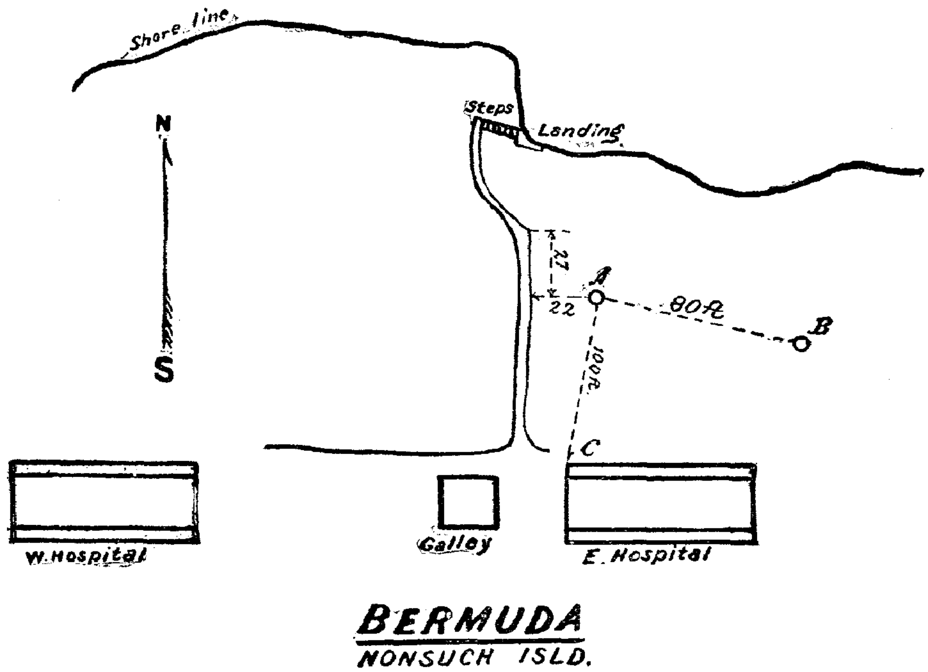
FIG. XIV.



Bermuda (*Nonsuch Island*).—Magnetic observations were made at a point about half way between the east hospital and the north shore of the Island. Sketch No. XV gives the location. The distances are in feet. There is but one landing place on the Island and that is on the leeward side.

A=Magnetic station. B=Quarantine flag pole. C=Portico.

FIG. XV.



Bermuda (*St. Georges*).—Pendulum observations were made in the basement of Mr. Hayward's house. The relative positions are shown in sketch No. XVI.

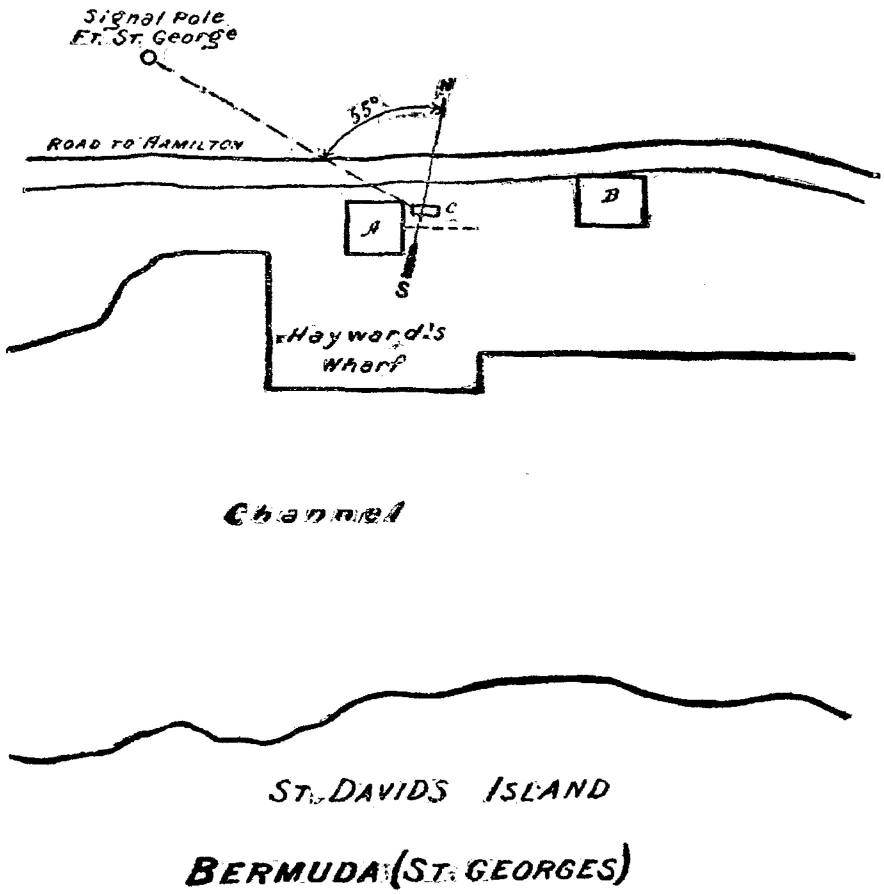
A is Mr. Hayward's house (pendulum station).

B is Mr. Atwood's house (U. S. consulate).

C is transit pier for time observations.

Distance from A to water line is about 75 feet.

FIG. XVI.



SUMMARY OF RESULTS OF MAGNETIC OBSERVATIONS.

Recapitulation of azimuths.

No.	Station.	Azimuth of mark.	Remarks.
		° ′	
1	Horta	8 02·5 W. of N.	
2	Porto Grande	86 41·6 E. of N.	
3	Freetown	77 44·6 W. of N.	
4	Elmina	102 50·9 E. of N.	For November 27.
	Elmina	102 56·1 E. of N.	For November 28.
5	St. Paul de Loanda	89 23·1 W. of N.	
6	Cabiri	94 32·1 W. of N.	
7	Cape Town	103 40·4 W. of N.	Station west of observatory.
	Cape Town	8 15·6 W. of N.	Station SE. of observatory.
8	Jamestown	0 34·2 E. of N.	
9	Longwood	77 42·9 W. of N.	Flagstaff at high knoll.
	Longwood	1 47·5 W. of N.	Sabine meridian mark.
10	Georgetown	173 07·5 W. of N.	
11	Green Mountain	70 57·0 W. of N.	
12	Bridgetown	134 22·2 W. of N.	
13	Nonsuch Island	25 41·6 W. of N.	

Recapitulation of constants of magnetometer No. 11.

Value of 1 *division of scale of long magnet* (NL_{11}) = 3′·72 determined by E. D. Preston, at Washington, D. C., September 23 and 24, 1889, and at various stations on Solar Eclipse Expedition.

Moment of inertia of NL_{11} *at* 62° *F., or* 16°·7 *C.*, with small balancing ring (K) 2·17^cm.^ from center of magnet, in C. G. S. units = 95·748± 0·094, determined by A. Braid, October 2, 3, 4, and 5, 1889, at Washington, D. C.

Temperature coefficient (q) *of* $N\,L_{11}$ = 0·00108 for 1° F. / 0·00194 for 1° C. } A. Braid, Washington, D. C., September 27 and October 1, 1889.

Induction factor (h) *of* NL_{11} in C. G. S. units = 0·0457 ±0·0006
Induction coefficient ($\mu = m\,h$) in C. G. S. units = 6·54 ±0·08 at 62° F. } C. A. Schott, December 6, 1890, at Washington, D.C.

First distribution coefficient (P) in C. G. S. units = −4±4. Determined by C. A. Schott, E. D. Preston, and L. A. Bauer, 1889, 1890.

Deflecting distances (short) = 30·54 Cm. / (long) = 45·78 } C. A. Schott, December 8, 1890.

The magnets used on the Survey are now designated by letters and subscripts; for example, (NL_{11}) means new long magnet of magnetometer No. 11.

Moment of inertia (I) *of balancing ring* (K) *of long magnet* NL_{11}.

Formula: $$I = W\left[\frac{1}{3}\left(x_2^2 + x_2 x_1 + x_1^2\right) + \frac{1}{4}\left(r_2^2 + r_1^2\right)\right]$$

W = 0·3 grammes = 4·63 grains. L. A. Fischer, February 3, 1891.

r_2 = outer radius = 4·89 Mm.
r_1 = inner radius = 4·24; thickness = 0·65 Mm.
Length = $x_2 - x_1$ = 2·35 } E. G. Fischer, January 30, 1891.

Station.	x_2 = dist. of outer edge of ring (K) from center of suspension.	x_1 = dist. of inner edge of ring (K)	Remarks.
	Mm.	*Mm.*	
Washington, D. C.	22·87	20·53	
Horta, Azores Islands.	22·87	20·53	
Porto Grande, Cape Verde Islands.	15·02	12·68	
Bermuda, Nonsuch Island.	14·02	11·68	May 21, 1890.
Bermuda.	15·02	12·68	May 23, 24, and 25, 1890.

Station.	Washington.	Porto Grande.	Bermuda [May 21].	Remarks.
	Cm.	*Cm.*	*Cm.*	
x_2^2	5·23	2·26	1·97	Supposing the weight concentrated at the center of gravity and computing I from the approximate formula $I = W\left(\frac{x_1+x_2}{2}\right)^2$ we get
x_1^2	4·21	1.61	1·36	
$x_2 x_1$	4·69	1·90	1·64	
(sum)	14·13	5·77	4·97	I
$\frac{1}{3}$ (sum)	4·710	1·923	1·657	
r_2^2	·239			Washington. 1·412
r_1^2	·180			Porto Grande. 0·575
$r_2^2+r_1^2$	·419			Bermuda. 0·495
$\frac{1}{4}$ (sum)	·105	·105	·105	
[F]	4·815	2·028	1·762	
I=W[F]	1·445	0·608	0·529	
M	95·748	------------	------------	Moment at 62° F. with ring as at Washington.
	94·303	94·303	94·303	Moment at 62° F. without ring.
	------------	94·911	94·832	

Moment of inertia (M) of long magnet NL_{11}.

Station.	M. at {62° F. / 16°·7 C.	Remarks. Position of balancing ring (K).
Horta.	95·748	Position same as at Washington {Inner edge from center, 20.5^{mm}. Outer edge from center, 22.9^{mm}.
Porto Grande.	94·911	7·85^{mm} nearer center than at Washington.
Freetown.	94·303	Not used.
Elmina.	94·303	Do.
St. Paul de Loanda.	94·303	Do.
Cabiri.	94·303	Do.
Cape Town.	94·303	Do.
Jamestown.	94·303	Do.
Longwood.	94·303	Do.
Georgetown.	94·303	Do.
Green Mountain.	94·303	Do.
Bridgetown.	94·303	Do.
Nonsuch Island (Bermuda).	94·832	8·85^{mm} nearer center than at Washington (May 21, 1890).
Do.	94·913	Same as at Porto Grande (May 23, 24, 25, 1890).

log M at any temperature τ° C. = log M_0 (62° F., or 16°·7 C.). + 0·0000106 (τ − 16°·7 C.).

log 95·748	1·98113
94·911	1.97732
94·832	1·97695
94·303	1·97453

Abstract of Results of Magnetic-Declination Observations.

Station.	Date, 1889–'90.	Scale reading of magnetic axis.	Magnetic declination* (west).
		d.	° ′
Washington, D. C.	Sept. 23	27·96	. . . . .
	24	28·04	4 13·3
	25	28·04	12·5
	26	27·95	19·5
Mean.		28·00	4 15·1
Horta, Fayal Island, Azores.	Nov. 2	. . . . .	25 52
	3	28·52	51
Mean.		. . . . .	25 52
Porto Grande, St. Vincent, Cape Verde Islands.	Nov. 11	28·82	20 45
Freetown, West Africa.	Nov. 19	28·72	19 17
Elmina, West Africa.	Nov. 27	28·75	17 12
	28	. . . . .	09
Mean.		. . . . .	17 10
Loanda, West Africa.	Dec. 14	28·29	17 44
	15	28·20	46
	16	27·77	48
Mean.		28·09	17 46
Cabiri, West Africa.	Dec. 22	. . . . .	18 11
	23	. . . . .	15
Mean.		. . . . .	18 13
Cape Town, Africa.	Jan. 21	28·10	29 31
	22	29·08	33
[West of Royal Observatory.]	23	28·88	33
Mean.		28·69	29 32
Cape Town [Southeast of Royal Observatory.]	Jan. 31	28·81	29 40
	Feb. 1	·72	40
Mean.		28·76	29 40
Jamestown, St. Helena Island.	Feb. 24	28·70	23 57
	25	·75	58
Mean.		28·72	23 57
Longwood, St. Helana Island.	Mar. 3	28·75	24 38
	4	28·62	35
	5	29·10	34
Mean.		28·82	24 36
Georgetown, Ascension Island.	Mar. 21	28·84	22 35
	22	28·97	37
	23	29·01	35
Mean.		28·94	22 36
Green Mountain, Ascension Island.	Mar. 30	28·97	23 21
	31	29·08	24
	Apr. 1	. . . . .	27
Mean.		29·02	23 24
Bridgetown, Barbados.	May 2	28·96	1 10
	4	. . . . .	12
	8	. . . . .	14
	9	. . . . .	14
Mean.		. . . . .	1 12
Nonsuch Island, Bermuda.	May 23	. . . . .	8 07
	24	28·72	01
	25	. . . . .	04
	26	. . . . .	04
Mean.		. . . . .	8 04

* Results refer to mean of day.

Abstract of Results of Magnetic-Dip Observations.

[+ signifies that *south* end of needle is *above* horizon; — that *south* end of needle is *below* horizon; N and S indicate the polarity of the marked end.]

Station.	Date, 1889–'90	Dip by needle No. 1. N.	S.	N–S.	Mean.	Dip by needle No. 2. N.	S.	N–S.	Mean.
		° ′	° ′	′	° ′	° ′	° ′	′	° ′
Washington, D. C.	Sept. 24	+70 27·4	+70 27·3	+ 0·1	+70 27·4	+70 23·2	+70 33·7	— 10·5	+70 28·4
	25	24·4	27·8	— 3·4	26·1	20·6	31·4	— 10·8	26·0
	26	23·2	22·6	+ 0·6	22·9	19·4	28·4	— 9·0	23·9
Horta, Fayal Isl., Azores	Nov. 2	+64 11·0	+64 10·8	+ 0·2	+64 10·9	+64 09·3	+64 23·8	— 14·5	+64 16·6
	3	12·4	14·8	— 2·4	13·6	8·8	19·4	— 10·6	14·1
Porto Grande, St. Vincent Island, Cape Verde.	Nov. 11	+42 19·5	+42 02·9	+16·6	+42 11·2	+41 56·0	+42 30·8	— 34·8	+42 13·4
Freetown, Sierra Leone, Africa.	Nov. 19	+14 48·6	+16 01·8	—73·2	+15 25·2	+15 06·2	+15 40·2	— 34·0	+15 23·2
Elmina, Guinea, Africa.	Nov. 27	+ 0 11·3	+ 1 17·8	—66·5	+ 0 44·6*	— 0 15·4	+ 1 23·2	— 98·6	+ 0 33·9
	28	14·9	+ 0 51·6	—36·7	+ 33·2	16·6	23·4	—100·0	33·4
Loanda, Angola, West	Dec. 14	—34 15·4	—34 02·2	—13·2	—34 08·8	—34 53·1	—33 34·0	— 79·1	—34 13·6
Africa.	15	16·8	33 40·0	—36·8	33 58·4	41·9	28·6	— 73·3	05·2
	16	43·5	34 01·6	—41·9	34 22·6	56·2	37·8	— 78·4	17·0
Cabiri, Angola, Africa.	Dec. 22	—34 02·0	—33 38·8	—23·2	—33 50·4	—34 47·4	—33 11·1	— 96·3	—33 59·2
	23	03·4	33·3	—30·1	48·4	34·5	16·7	— 77·8	55·6
Cape Town, Africa, sta-	Jan. 21	—57 32·4	—57 07·9	—24·5	—57 20·2	—57 36·1	—56 40·9	— 55·2	—57 08·5
tion west of Royal Ob-	22	24·0	05·4	—18·6	14·7	33·8	56 50·3	— 43·5	12·0
servatory.	24	25·6	07·8	—17·8	16·7	35·0	57 02·5	— 32·5	188
Cape Town, Africa, sta-	Jan. 31	—57 27·9	—57 04·3	—23·6	—57 16·1	—57 34·2	—56 57·8	— 36·4	—57 16·0
tion southeast of Royal Observatory.	Feb. 1	31·4	05·2	—26·2	18·3	32·2	49·3	— 42·9	10·8
Jamestown, St. Helena	Feb. 24	—29 51·0	—29 24·6	—26·4	—29 37·8	—30 24·0	—28 55·2	— 88·8	—29 39·6
Island.	25	30 08·3	20·8	—47·5	44·6	30 19·9	28 47·8	— 92·1	33·8
Longwood, St. Helena	Mar. 3	—31 38·1	—30 46·9	—51·2	—31 12·5	—31 56·4	—30 29·5	— 86·9	—31 13·0
Island.	4	36·1	57·5	—38·6	16·8	32 02·0	21·6	—100·4	
	5	22·4	46·1	—36·3	04·2	31 56·6	18·6	— 98·0	07·6
Georgetown, Ascension	Mar. 20	—12 00·1	—11 13·1	—47·0	—11 36·6	—12 27·7	—10 36·0	—111·7	—11 31·8
Island.	21	04·2	08·7	—55·5	36·4	28·3	51·8	— 96·5	40·0
	22	08·1	14·4	—53·7	41·2	30·0	52·3	— 97·7	41·2
Green Mountain, Ascen-	Mar. 29	—12 35·4	—11 46·0	—49·4	—12 10·7	—13 04·0	—11 11·8	—112·2	—12 07·9
sion Island.	30	33·8	50·2	—43·6	12·0	02·3	15·5	—106·8	08·9
	31	37·8	53·6	—44·2	15·7	09·1	21·5	—107·6	15·3
Bridgetown, Barbados.	May 1	+42 55·4	+43 07·4	—12·0	+43 01·4	+42 38·4	+43 35·0	— 56·6	+43 06·7
	2	59·8	20·6	—20·8	10·2	43·8	43·3	— 59·5	13·6
	4	55·8	24·1	—28·3	10·0	40·2	34·6	— 54·4	07·4
Nonsuch Isl., Bermuda.	May 21	+64 34·9	+64 51·0	—16·1	+64 42·9	+64 36·6	+65 01·8	— 25·2	+64 49·2
	22	42·0	48·8	— 6·8	45·4	37·0	01·8	— 24·8	49·4
	23	39·8	51·5	—11·7	45·6	43·1	04·0	— 20·9	53·5

* Weight, one-half.

Summary.

Station.	Date, 1889–'90.	Needles, 1–2.	Dip.
		′	° ′
Washington, D. C.	Sept. 24	− 1·0	+70 27·9
	25	+ 0·1	26·0
	26	− 1·0	23·4
		Mean	+70 25·8
Horta, Fayal Isl., Azores.	Nov. 2	− 5·7	+64 13·8
	3	− 0·5	13·8
		Mean	+64 13·8
Porto Grande, St. Vincent Island, Cape Verde.	Nov. 11	− 2·2	+42 12·3
Freetown, Sierra Leone, Africa.	Nov. 19	+ 2·0	+15 24·2
Elmina, Guinea, Africa.	Nov. 27	+ 7·2	+ 0 37·5
	28	− 0·2	33·3
		Mean	+ 0 35·4
Loanda, Angola, West Africa.	Dec. 14	+ 4·8	−34 11·2
	15	+ 6·8	01·8
	16	− 5·6	19·8
		Mean	−34 10·9
Cabiri, Angola, Africa.	Dec. 22	+ 8·8	−33 54·8
	23	+ 7·2	52·0
		Mean	−33 53·4
Cape Town, Africa, station west of Royal Observatory.	Jan. 21	−11·7	−57 14·4
	22	− 2·7	13·4
	24	+ 2·1	17·8
		Mean	−57 15·2
Cape Town, Africa, station southeast of Royal Observatory.	Jan. 31	− 0·1	−57 16·0
	Feb. 1	− 7·5	14·6
		Mean	−57 15·3
Mean of both stations			−57 15·2

Station.	Date, 1889–'90.	Needles, 1–2.	Dip.
		′	° ′
Jamestown, St. Helena Island.	Feb. 24	+ 1·8	−29 38·7
	25	−10·8	39·2
		Mean	−29 39·0
Longwood, St. Helena Island.	Mar. 3	+ 1·5	−31 12·8
	4	− 5·0	14·3
	5	+ 3·4	05·9
		Mean	−31 11·0
Georgetown, Ascension Island.	Mar. 20	− 4·8	−11 34·2
	21	+ 3·6	38·2
	22	0·0	41·2
		Mean	−11 37·9
Green Mountain, Ascension Island.	Mar. 29	− 2·8	−12 09·3
	30	− 3·1	10·4
	31	− 0·4	15·5
		Mean	−12 11·7
Bridgetown, Barbados.	May 1	− 5·3	+43 04·0
	2	− 3·4	11·9
	4	+ 2·6	08·7
		Mean	+43 08·2
Nonsuch Island, Bermuda.	May 21	− 6·3	+64 46·0
	22	− 4·0	47·4
	23	− 7·9	49·5
		Mean	+64 47·6

Probable error of a single observation for dip, $r = 0·675\sqrt{\frac{907·05}{72}} = \pm 2'·40$

Probable error of a mean from 2 needles $= \frac{2.40}{\sqrt{2}} = \pm 1'·70$

When observations are made on 2 days, $r = \frac{1·70}{\sqrt{2}} = \pm 1'·20$

When observations are made on 3 days, $r = \frac{1·70}{\sqrt{3}} = \pm 0'·98$

Abstract of Results of Magnetic-Horizontal-Intensity Observations.

Station.	Date, 1889–'90.	Horizontal intensity = H (C. G. S. units).	Magnetic moment (m) of long or intensity magnet (NL_{11}) at 62° F. (C. G. S. units).
Washington, D. C.	Sept. 24	0·2017	143·4*
	25	17	·2
	26	03	·4
Mean.		0·2012	143·3
Horta, Fayal Island, Azores.	Nov. 2	0·2072	140·6
	3	74	·3
Mean.		0.2073	140·4
Porto Grande, Cape Verde Islands.	Nov. 11	0·2738	140·7
Freetown, West Africa.	19	0·3193	134·3
Elmina, West Africa.	27	0·3100	128·8
	28	05	9·1
Mean.		0·3102	128·9
Loanda, West Africa.	Dec. 14	0·2640	128·9
	15	34	129·1
	16	25	130·3
Mean.		0·2633	129·4
Cabiri, West Africa.	Dec. 21	0·2632	135·0
	22	32	134·9
Mean.		0·2632	135·0
Cape Town, Africa, west of Royal Observatory.	Jan. 21	0·1918	134·2
	22	17	4·1
	23	13	4·6
Mean.		0·1916	134·3
Southeast of Royal Observatory.	Jan. 31	0·1918	133·7
	Feb. 1	20	4·2
Mean.		0·1919	133·9

Station.	Date, 1890.	H.	m. at 62° F. (16°·7 C.)
Jamestown, St. Helena Island.	Feb. 24	0·2503	133·3
	25	0·2483	4·4
Mean.		0·2493	133·9
Longwood, St. Helena Island.	Mar. 3	0·2291	133·7
	4	82	3·7
	5	87	3·8
Mean.		0·2287	133·7
Georgetown, Ascension Island.	Mar. 21	0·2761	134·2
	22	50	3·8
	23	55	3·5
Mean.		0·2755	133·8
Green Mountain, Ascension Island.	Mar. 29	0·2675	133·3
	30	75	4·0
	31	78	3·8
Mean.		0·2676	133·7
Bridgetown, Barbados.	May 1	0·3010	133·7
	2	31	3·5
	4	28	2·7
Mean.		0·3023	133·3
Nonsuch Island, Bermuda.	May 21	0·2337	. . . .
	23	35	132·1
	24	27	2·1
	25	34	1·4
		0·2334	131·9

*Small balancing ring (K) used in same position at Washington and Horta; at Porto Grande and Bermuda $7·85^{mm}$. nearer center; at all other stations not used.

Recapitulation of Results of Magnetic Observations.

Station.	Latitude (+North; —South).	Longitude (—W. of Greenwich; +E. of Greenwich).	Date, 1889–'90.	Declination west.†	Date, 1889–'90.	Dip (+N. end below horizon; —S. end below horizon).	Date, 1889–'90.	Horizontal intensity.	Total intensity.
	° ′	° ′		° ′		° ′		*dyne.*	*dyne.*
Washington, D. C.*	+38 53·2	—77 00·5	Sept. 24, 25, 26	4 15·1	Sept. 24, 25, 26	+70 25·8	Sept. 24, 25, 26	0·2012	0·6007
Horta, Fayal Island, Azores.	+38 31·8	—28 38·9	Nov. 2, 3	25 52	Nov. 2, 3	+64 13·8	Nov. 2, 3	0·2073	0·4768
Porto Grande, St. Vincent Island, Cape Verde.	+16 53·3	—24 59·4	Nov. 11	20 45	Nov. 11	+42 12·3	Nov. 11	0·2738	0·3696
Freetown, Sierra Leone, Africa.	+ 8 29·8	—13 14·7	Nov. 19	19 17	Nov. 19	+15 24·2	Nov. 19	0·3193	0·3312
Elmina, Guinea, Africa.	+ 5 04·8	— 1 20·3	Nov. 27, 28	17 10	Nov. 27, 28	+ 0 35·4	Nov. 27, 28	0·3102	0·3103
Loanda, Angola, Africa.	— 8 48·8	+13 14·0	Dec. 14, 15, 16	17 46	Dec. 14, 15, 16	—34 10·9	Dec. 14, 15, 16	0·2633	0·3183
Cabiri, Angola, Africa.	— 8 47	+13 59	Dec. 22, 23	18 13	Dec. 22, 23	—33 53·4	Dec. 21, 22	0·2635	0·3174
Cape Town, Africa:									
Station west of Royal Observatory.	—33 56·1	+18 28·7	Jan. 21, 22, 23	29 32	Jan. 21, 22, 24	—57 15·2	Jan. 21, 22, 23	0·1916	0·3542
Station southeast of Royal Observatory.	—33 56·1	+18 28·7	Jan. 31, Feb. 1	29 40	Jan. 31, Feb. 1	—57 15·3	Jan. 31, Feb. 1	0·1919	0·3548
Jamestown, St. Helena Island.	—15 55·0	— 5 43·7	Feb. 24, 25	23 57	Feb. 24, 25	—29 39·0	Feb. 24, 25	0·2493	0·2869
Longwood, St. Helena Island.	—15 56·7	— 5 41·5	Mar. 3, 4, 5	24 36	Mar. 3, 4, 5	—31 11·0	Mar. 3, 4, 5	0·2287	0·2672
Georgetown, Ascension Island,	— 7 55·5	—14 25·0	Mar. 21, 22, 23	22 36	Mar. 20, 21, 22	—11 37·9	Mar. 21, 22, 23	0·2755	0·2813
Green Mountain, Ascension Island.	— 7 56·7	—14 21·5	Mar. 30, 31, Apr. 1	23 24	Mar. 29, 30, 31	—12 11·7	Mar. 29, 30, 31	0·2676	0·2738
Bridgetown, Barbados.	+13 04	—59 36	May 2, 4, 8, 9	1 12	May 1, 2, 4	+43 08·2	May 1, 2, 4	0·3023	0·4143
Nonsuch Island, Bermuda.	+32 20·6	—64 39·2	May 23, 24, 25, 26	8 04	May 21, 22, 23	+64 47·6	May 21, 23, 24, 25	0·2333	0·5478

* Coast and Geodetic Survey Office.

† Results refer to mean of day.

Latitude and Heights at Ascension.

At the request of Capt. R. H. Napier, Royal Navy, Commandant of the Island, a few pairs of stars were observed for latitude at the pendulum station in Bunghole Square. The transit pier was connected by triangulation with the reference point of the Island, a small stone pier near the Captain's Cottage. The longitude of this point was determined in 1877 by Dr. Gill, Her Majesty's Astronomer at the Cape of Good Hope, who passed six months at Ascension while observing the opposition of Mars.

The result of our work was:

	°	′	″
Latitude of transit pier	7	55	47·7 south
Reduction to reference point			+12·8
Latitude of pier near Captain's Cottage	7	56	00·5

This depends on observations of six pairs of stars on two nights. The triangulation was done by means of a small (4-inch) Casella theodolite, reading to minutes. The deduced latitude is probably correct to the nearest second.

The height of the pendulum station on Green Mountain was determined barometrically. Ensign A. H. Scales, U. S. N., read the lower instrument in the pendulum room at Bunghole Square. The one at the upper station was read by myself. The barometers (mercurial, by Green, New York, Nos. 846 and 1390) were compared before and after the work, each observer reading his own instrument, thus eliminating personal equation. Readings were made five times daily at about 9 and 11 a. m. and at 1, 3, and 5 p. m. Observations were continued while the party was on the mountain, so that the result depends on more than fifty simultaneous readings. The probable error of the mean value was about one foot. The adopted values were:

	Feet.
Barometer on Green Mountain higher than barometer in Bunghole Square	2 238
Bunghole Square above sea level	15
Green Mountain barometer above floor of cottage	3
Floor of Garden Cottage above sea level	2 250

A number of heights were determined over the island by means of an aneroid barometer. These elevations refer to the pendulum station in Bunghole Square and are given only to the nearest 10 feet.

	Feet.
Pendulum station, Bunghole Square	0
Captain's office, Georgetown	50
"God be Thanked" tank	590
Path at foot of Red Hill	790
Boats (foot of ramp)	1 000
Two-Mile Point	1 420
Royal Naval Hospital	1 810
Northeast Cottage	2 030
Bells Cottage	2 340
Elliot's Pass, at tunnel near Summer House	2 440
"Sherry and Bitters"	2 450
Summer House	2 480
Summit of mountain	2 830

PENDULUM OBSERVATIONS.

As an entirely new form of instrument is about to be introduced into the Coast and Geodetic Survey Service for gravity determinations, and as no description of the different forms hitherto used has yet appeared, it has been thought advisable to insert here a concise enumeration of the several patterns. Large pendulums—that is, those having a virtual length of a metre or a yard—will probably not be employed in the future for relative determinations of the force of gravity. A half-second pendulum (25 c.m.) appears to give an accuracy in the results equal to that attained with larger forms, and has the great advantage of being much more portable. The present time therefore marks an epoch in the gravity work of the Survey, and a sort of history of the evolution of the instrument will be useful for reference.

Description of different forms of Pendulums used in the Coast and Geodetic Survey previous to July 1, 1890.

At the above-mentioned date the Survey was in possession of sixteen pendulums, of which the different types are shown in illustrations Nos. 58 and 63. Of these, ten are of the Kater invariable pattern, including one made of silver. One is a Peirce invariable pendulum (P in illustration No. 58), provided with only one knife-edge; one is the Repsold reversible metre pendulum; and four are of the Peirce pattern, and known as invariable reversible pendulums (see pendulums marked R and I in illustration No. 58).

The Kater numbers run from 1 to 10 with No. 7 lacking. Four forms of these pendulums are shown in illustration No. 63. Beginning at the left, the first figure is the silver pendulum, the three thermometers attached to it being shown in position. In the second and fifth figures are given two views of No. 4. The third and fourth figures are front and side views of No. 8. The sixth figure shows No. 2 in one position. One pendulum is unnumbered, but as it is in the same box as Nos. 1, 2, 4, and 5, it was probably intended for No. 3. The Peirce invariable pendulum is unnumbered, as likewise that of Repsold. The Peirce reversible pendulums are numbered from 1 to 4, all of them similar in form, and all measuring a metre between the knives, except No. 3, which measures a yard. No. 1 went to Lady Franklin Bay with General Greely in 1881. Nos. 2 and 3 were taken to Africa in 1889, No. 3 to the South Pacific in 1883, and Nos. 3 and 4 to the Sandwich Islands in 1887, by myself. Lieutenant Very carried the Peirce invariable one to Patagonia in 1882. The Repsold pendulum has been used in Europe as well as in this country by Professor Peirce, who has also done work here with his own pendulums. The Kater forms were used in the Hoosac Tunnel underground work.

The following are the dimensions and weights, given in millimetres and grams:

No. 1. Similar in shape to No. 2 (top piece removed):
- Cross section of bar, 8 by 13.
- Length of bar, 864·5.
- Diameter of bob, 74·5.
- Slant height of bob, 180.
- Weight of pendulum, 2 865·9.

No. 2:
- Cross section of bar, 9 by 14.
- Length of bar, 835·5.
- Diameter of bob, 74.
- Slant height of bob, 179.
- From top of bar to supporting pin, 35.
- Length of supporting pin, 31.
- Springs, 0.20 by 3·3.
- Diameter of disk, 20.
- Thickness of disk, 3·1.
- Weight of pendulum, 2 943·6.

No. 3 (broken and number lacking).

No. 4:
- Cross section of bar, 9·1 by 14·1.
- Length of bar, 917.
- Diameter of bob, 71.
- Slant height of bob, 180.
- Dimensions of knife, 6·5 by 6·5 by 25·3.
- From top of bar to lower edge of knife, 26.
- Weight of pendulum, 2 903·9.

No. 5. Similar in shape to No. 4:
- Cross section of bar, 8·2 by 14.
- Length of bar, 917.
- Diameter of bob, 71·1.
- Slant height of bob, 180.
- Dimensions of knife, 6·8 by 6·8 by 25·8.
- From top of bar to lower edge of knife, 26·8.
- Weight of pendulum, 2 886·3.

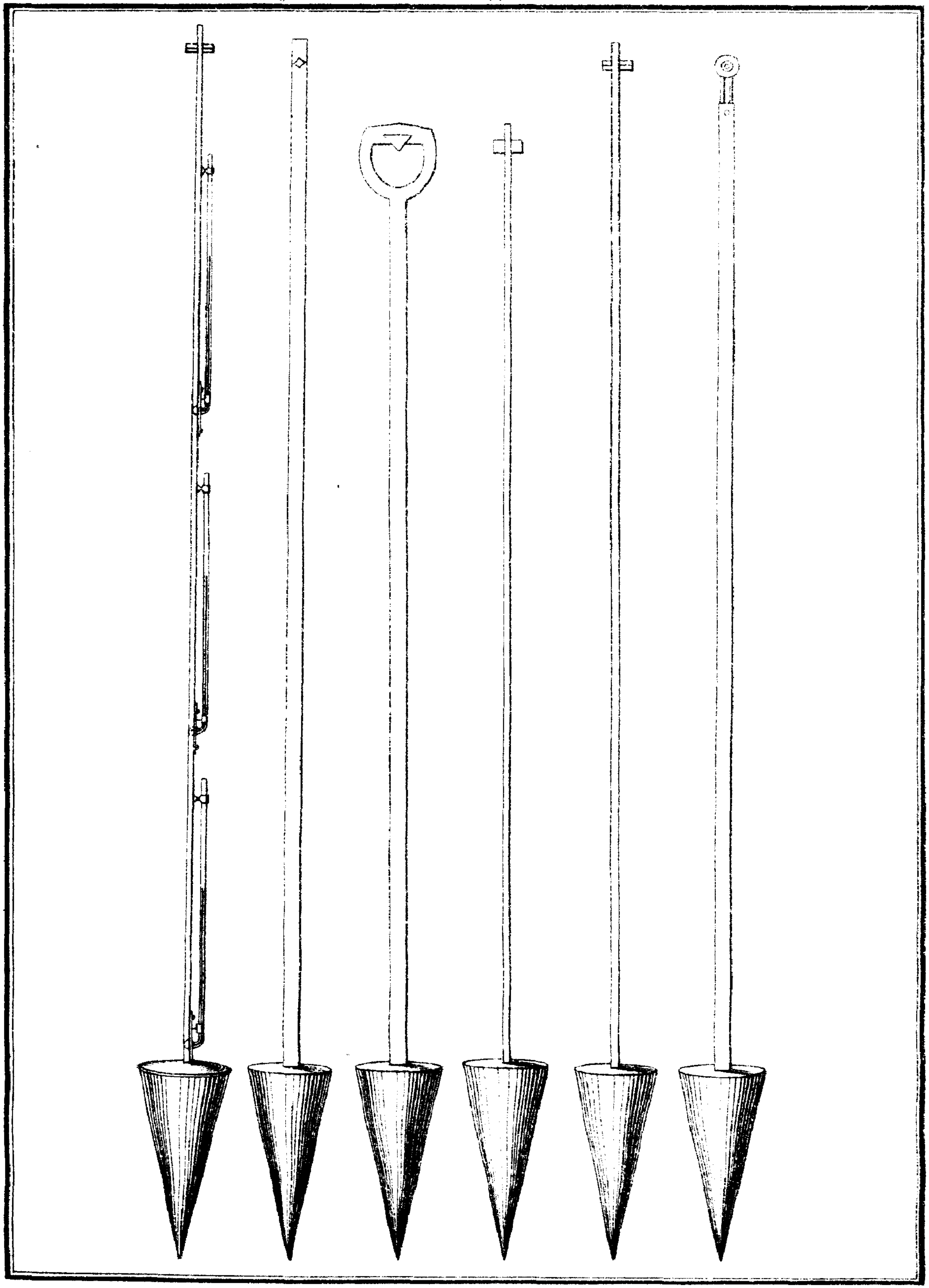
No. 6. Similar in shape to No. 4:
- Cross section of bar, 8·7 by 14.
- Length of bar, 917.
- Diameter of bob, 71.
- Slant height of bob, 181.
- Dimensions of knife, 7·0 by 7·0 by 25·5.
- From top of bar to lower edge of knife, 25.
- Weight of pendulum, 2 936·9.

No. 8:
- Cross section of bar, 6 by 14·9.
- Length of bar from bob to knife, 817·5.
- Diameter of bob, 75·1.
- Slant height of bob, 182.
- Dimensions of knife, 16 by 16 by 22·5 by 25·5.
- Dimensions of open space, 41 by 39.
- Width of bar at top of open space, 18·5.
- Width of bar at sides of open space, 11.
- Weight of pendulum, 2 935·6.

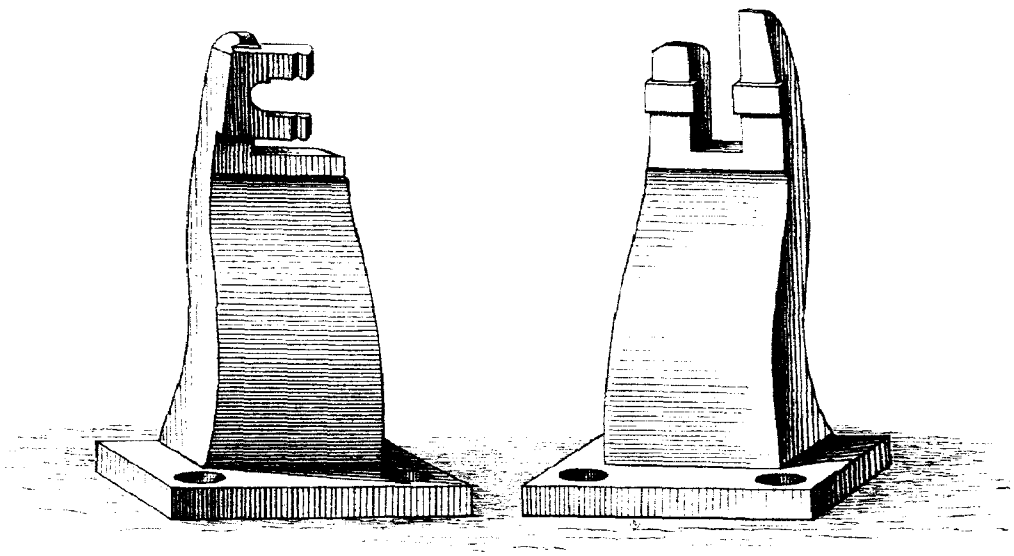
No. 9. Similar to No. 8:
- Weight of pendulum, 2 846·2.

No. 10. Similar to No. 8:
- Weight of pendulum, 2 887·4.

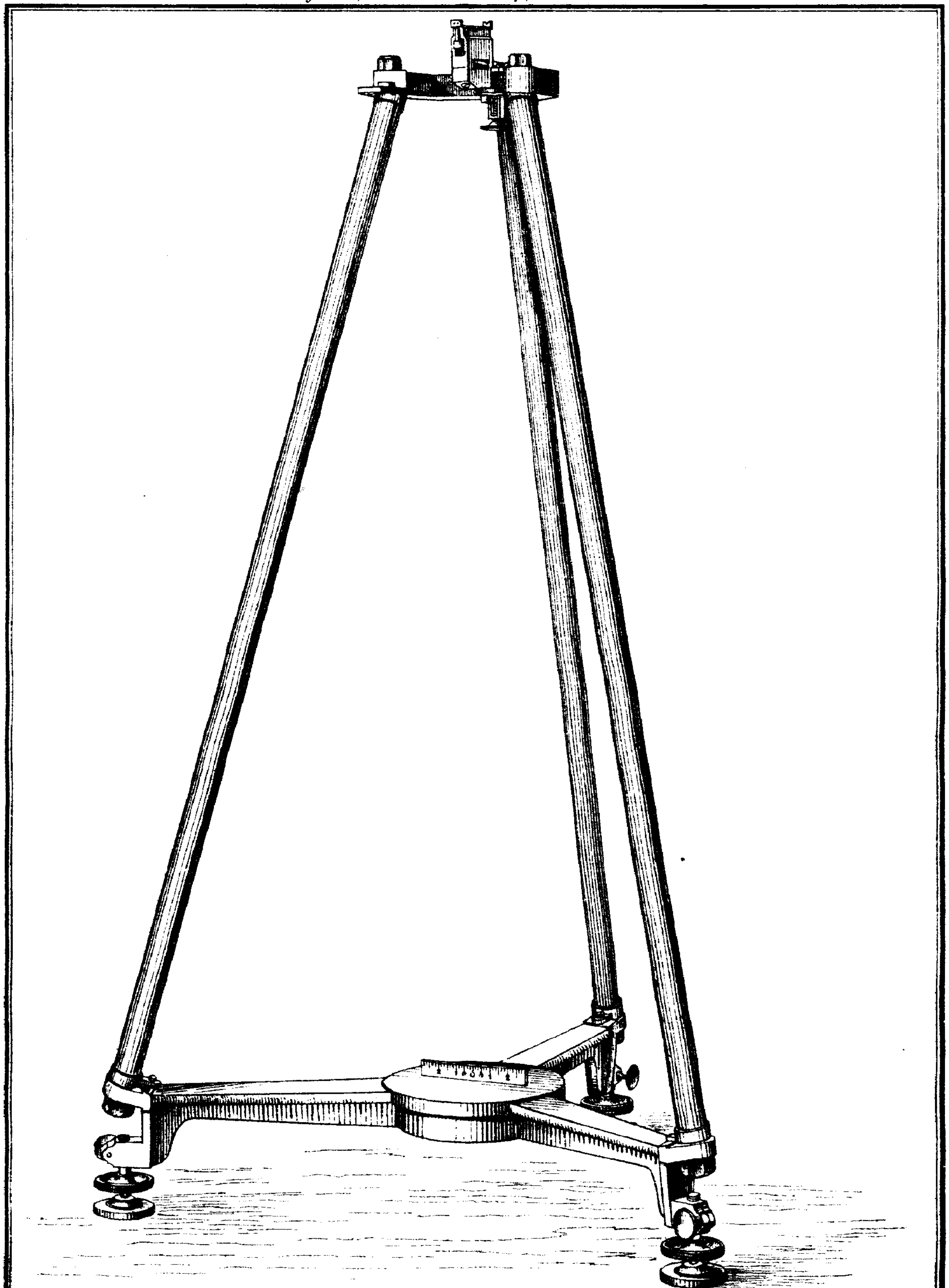
Silver pendulum. Similar in shape to No. 4. Top surface of bob spherical, radius = 182.
- Cross section of bar, 4·9 by 15·5.
- Length of bar, 930·5.
- Diameter of bob, 76·8.
- Slant height of bob, 182.
- Dimensions of knife of steel, 6·1 by 6·1 by 25·8.
- From top of bar to lower edge of knife, 25·8.
- Weight, including three thermometers, 3 480·1.



Kater Invariable Pendulum



Kater Pendulum support.



Repsold Pendulum support.

Peirce invariable pendulum (indicated by I in plate):

- Diameter of tube outside, 63·8.
- Thickness of tube, 1·5.
- Height of spherical cap, 31.
- Total length of pendulum, exclusive of points, 1 362.
- Length of knife, 95.
- Weight of pendulum, 8 451·8.

Repsold reversible pendulum (indicated by R in plate):

- Diameter of tube outside, 43·3.
- Thickness of tube, 1·8.
- Length between knives, 1 000.
- Total length, 1 268·8.
- Weight of pendulum, 6 308.
- Ratio of distance of center of mass to knife-edges is as 7 to 3.

Peirce reversible pendulums (indicated by P in plate).

Nos. 1, 2, and 4. Similar in construction:

- Diameter of tube, 63·7.
- Thickness of tube, 1·5.
- Length between the knives, 1 000.
- Total length exclusive of points, 1 567.
- Length of each point, 8·0.
- Weight of pendulums:
  - No. 1, not weighed (knives missing).
  - No. 2, 10 635·2.
  - No. 4, 10 680·3.

No. 3. Dimensions similar to Nos. 1, 2, and 4, except—

- Length between knives, 914·4 = 1 yard.
- Total length, exclusive of points, 1 429.
- Length of each point, 8·0.
- Weight of pendulum, 9 972·3.
- Ratio of distance of center of mass to knife-edges for all Peirce reversible pendulums = 3 to 1.

The supports upon which the pendulums have been swung are of various forms. The Kater pendulums were suspended from a brass bracket shown in illustration No. 64. This was secured to a wall or any solid upright by means of bolts. The flat abutting surface was 71^{mm} square and the distance of the knife-edge plane from this surface was 90^{mm}.

The Repsold support shown in illustration No. 65 consisted of a tripod. The legs are fastened to the base below and to the head above by means of nuts. This tripod was taken down and set up at each new station.

All the Peirce pendulums, including the invariable one, were supported on a head shown in illustration No. 57, the head itself being secured to a plank resting on some solid foundation or forming part of a stand constructed for the purpose. Several forms of this stand have been used. The one employed in the African work is shown in illustration No. 56.

OBSERVATIONS FOR TIME.

The determination of the corrections to the timepieces was made entirely from star observations. The sun was observed in one or two instances as a check, but these values were not used in the final computation. From the nature of the circumstances under which the work was done, it was not always in the best interest of economy to insist on a perfect adjustment of the instrument or of its position in the meridian before beginning the regular pendulum work. A slight defect in the construction of the ocular of the telescope which could not be remedied immediately made it necessary to have a large collimation error for the first few days at Loanda. Notwithstanding the large azimuth which usually existed during the first night's work at all the stations, the star residuals are quite as small as on the other evenings, and it was always deemed advisable to begin immediately on arriving at the place of observation, thus detaining the vessel as short a time as possible. The expenses of the *Pensacola* were not far from $1,000 per day, and as the length of the cruise was prolonged by the scientific work to about twice the time first estimated, the observations were shortened in every way consistent with accuracy. The following tables give the constants of the instrument and the corrections to the time-piece at the different stations

Instrumental constants and chronometer corrections.

LOANDA, ANGOLA.

[Transit No. 2, Hutton Sid. Chron. 220.]

Date.	Epoch.	Inclination.		Azimuth.		Collimation.	δt.	Rate per day + losing − gaining.
		E.	W.	E.	W.			
1889.	h. m.	s.	s.	s.	s.	s.	m. s.	s.
Dec. 17	1 54	−1.40	−1.26	+ 7.82	+ 8.43	−12.24	+2 11.20	------
18	2 12	−1.63	−1.31	+ 9.13	+ 8.72	−12.62	23.92	+12.56
19	1 15	−0.02	+0.19	+ 4.15	+ 4.01	−12.48	36.03	+12.58
20	1 00	0.00	+0.25	[− 2.91]	− 2.91	−12.53	48.06	+12.16
24	2 18	−0.49	------	+ 5.88	------	[− 0.30]	+3 37.99	------
25	1 20	−0.21	−0.15	+ 0.09	+ 0.21	− 0.30	49.71	+12.19
26	1 15	−0.39	−0.22	+ 0.20	+ 0.22	− 0.50	+4 01.90	+12.23
27	0 53	------	−0.43	------	[+ 0.24]	[− 0.41]	13.88	+12.16
28	1 34	−0.67	−0.48	[+ 0.27]	+ 0.27	− 0.32	27.24	+12.98

JAMESTOWN, ST. HELENA.

[Transit No. 2, Negus Sid. Chron. 1520.]

Date.	Epoch.	Inclination E.	Inclination W.	Azimuth E.	Azimuth W.	Collimation.	δt.	Rate per day.
1890.								
Feb. 21	7 30	−0.26	−0.03	[+1 58.45]	+1 58.45	+ 0.46	+0 24.41	------
22	5 20	+0.19	+9.27	+0 11.28	−0 11.23	+ 0.49	24.20	+ 0.23
23	6 00	+0.26	+0.30	− 1.12	− 1.03	+ 0.46	23.98	+ 0.21
24	7 20	+0.03	+0.37	[− 0.86]	− 0.86	+ 0.45	23.59	+ 0.37
25	5 30	+0.04	+0.16	− 0.57	− 1.09	+ 0.42	22.64	+ 1.02
27	7 34	------	+0.23	------	[− 0.83]	[+ 0.42]	22.06	+ 0.28

LONGWOOD, ST. HELENA.

[Transit No. 2, Negus Sid. Chron. 1520.]

Date.	Epoch.	Inclination E.	Inclination W.	Azimuth E.	Azimuth W.	Collimation.	δt.	Rate per day.
Mar. 2	6 30	−0.71	−0.54	[+ 13.94]	+ 13.94	+ 0.36	−0 09.72	------
3	6 30	−0.09	+0.19	− 10.28	− 10.31	+ 0.42	10.10	− 0.38
4	6 30	−0.58	−0.33	− 2.27	[− 2.27]	+ 0.45	10.44	− 0.34
5	6 00	+0.21	+0.62	+ 0.62	[+ 0.62]	+ 0.24	10.71	− 0.28
6	5 30	------	+1.26	------	[+ 0.65]	[+ 0.25]	[10.90]	------
7	6 30	+0.59	+0.62	[− 0.66]	− 0.66	+ 0.25	11.36	− 0.31

Instrumental constants and chronometer corrections—Continued.

GEORGETOWN, ASCENSION.

[Transit No. 2, Negus Sid. Chron. 1520.]

Date.		Epoch.	Inclination. E.	Inclination. W.	Azimuth. E.	Azimuth. W.	Collimation.	δr	Rate per day + losing —gaining.
1890.		h. m.	s.	s.	s.	s.	s.	m. s.	s.
Mar.	19	10 35	−0·40	−0·23	−44·79	−44·76	+0·61	−0 00·01	------
	20	7 30	+0·20	−0·64	+ 1·55	+ 1·30	+0·57	+0 01·01	+1·15
	21	7 00	+0·24	+1·48	+ 1·65	+ 1·48	+0·32	02·16	+1·18
	22	6 45	−0·10	+0·05	+ 1·67	+ 1·23	+0·45	03·15	+1·00
	23	6 45	+0·19	−0·29	+ 1·39	+ 1·39	+0·48	04·54	+1·39
	24	9 00	+0·33	[+0·33]	[+ 1·40]	[+ 1·40]	[+0·50]	06·48	+1·76
	25	6 50	+0·38	+0·41	+ 1·47	+ 1·49	+0·69	08·62	+2·34
	26	6 50	+0·66	+0·77	+ 1·41	+ 1·59	+0·52	10·63	+2·01

GREEN MOUNTAIN, ASCENSION.

[Transit No. 2, Negus Sid. Chron. 1520.]

Mar.	31	8 05	−0·26	−0·08	−35·55	−34·86	+0·35	+0 27·35	------
Apr.	1	6 40	+0·02	+0·33	− 2·59	− 2·74	+0·38	27·25	−0·10
	2	7 00	+0·05	+0·06	− 2·48	− 2·65	+0·43	27·21	−0·04
	3	7 00	+0·07	+0·26	− 2·78	− 1·96	+0·43	26·96	−0·25
	4	7 00	−0·18	+0·16	− 2·50	− 2·14	+0·46	27·10	+0·14
	5	7 00	−0·11	+0·01	-------	− 2·32	[+0·45]	27·06	−0·04
	6	6 00	+0·22	------	− 2·16	-------	[+0·45]	26·52	−0·56

BRIDGETOWN, BARBADOS.

[Transit No. 2, Negus Sid. Chron. 1520.]

					m. s.	m. s.			
May	2	15 00	−1·87	−1·35	−4 10·86	−3 54·70	+2·24	−0 12·45	------
	3	13 00	+0·50	+0·60	−0 2·50	−0 2·98	+0·34	9·82	+2·85
	4	12 00	−0·36	−0·36	− 2·63	− 2·48	+0·45	9·30	+0·54
	5	14 30	−0·91	−0·67	+ 0·31	+ 0·23	+0·43	8·17	+1·01
	6	12 00	------	−1·00	---------	[+ 0·43]	[+0·36]	7·55	+0·68
	7	10 00	−1·30	−1·01	+ 0·58	+ 0·63	+0·29	6·86	------
	7	13 00	−0·04	+0·35	+ 0·60	[+ 0·60]	+0·16	6·68	+0·80
	8	10 00	+0·03	+0·19	+ 0·68	+ 0·51	+0·35	6·10	+0·71
	9	12 00	−0·17	+0·10	+ 0·62	+ 0·47	+0·31	5·61	+0·45

ST. GEORGES, BERMUDA.

[Transit No. 2, Bond Mean Time Chron. 177.]

1890.		h. m. s.	s.	s.	s.	s.	s.	h. m. s.	s.
May	31	8 30 32	+0·18	+0·31	− 1·58	− 1·86	+0·58	+4 59 45·56	--------
June	1	8 21 43	−0·01	+0·03	− 1·12	− 1·06	+0·56	+5 03 24·92	+220·71
	2	8 12 19	−0·06	+0·14	− 1·73	− 1·90	+0·56	+5 07 04·26	+220·78
	3	8 13 55	−0·07	+0·06	[− 1·14]	− 1·14	+0·56	+5 10 44·96	+220·45
	4	9 18 34	−0·12	+0·11	[− 1·24]	− 1·24	+0·51	+5 14 35·35	+220·49
	7	9 39 46	−0·32	0·00	− 1·24	− 1·17	+0·56	+5 25 39·95	+220·45

Observatory Clock Corrections.

WASHINGTON, NAVAL OBSERVATORY.

[Standard Mean Time Clock.]

Date.	Epoch.	Correction.	Date.	Epoch.	Correction.
1891.		s.	1889.		s.
October 1	Noon.	+ 6·63	October 4	Noon.	+ 5·91
2	Do.	+ 6·31	5	Do.	5·59
3	Do.	+ 6·15	8	Do.	+ 4·67

CAPETOWN, ROYAL OBSERVATORY.

[Standard Sidereal Clock—Dent, 39714.]

1890.	h. m.	s.	1890.	h. m.	s.
January 22	4 19	—68·29	January 27	4 07	—63·46
23	4 19	—67·32	28	4 19	—62·39
24	4 23	—66·30	29	4 24	—61·27
25	4 19	—65·31	30	4 19	—60·19
26	4 07	—64·38			

WASHINGTON, NAVAL OBSERVATORY.

[Standard Mean Time Clock.]

1890.		s.	1890.		s.
July 29	10 a. m.	+20·15	August 4	10 a. m.	+21·09
	10 p. m.	+20·17		10 p. m.	+21·14
30	10 a. m.	+20·24	5	10 a. m.	+21·22
	10 p. m.	+20·31		10 p. m.	+21·30
31	10 a. m.	+20·38	11	Noon.	0·00
	10 p. m.	+20·48	12	Do.	+ 0·03
August 1	10 a. m.	+20·58	13	Do.	— 0·04
	10 p. m.	+20·67	14	Do.	— 0·02
2	10 a. m.	+20·77	15	Do.	+ 0·13
	10 p. m.	+20·86	16	Do.	— 0·06
3	10 a. m.	+20·96	18	Do.	+ 0·09
	10 p. m.	+21·06	19	Do.	+ 0·14

REDUCTION OF THE PENDULUM OBSERVATIONS.

The corrections for amplitude depend on a formula first given by Borda, and which gives all the accuracy necessary. The pendulums were usually started at nearly the same arc of vibration, so that the corrections were but slightly different for the whole work. A table was devised and computed by Mr. G. R. Putnam which made it possible to take out the corrections for the separate swings by simple inspection, the entire number of stations only requiring a few hours' work.

The temperature corrections employed were as follows:

Pendulum.	Corrections to period per degree centigrade.	
	Heavy end down.	Heavy end up.
	s.	s.
No. 2	0·00000921	0·00000920
No. 3	0·00000877	0·00000878

In correcting for atmospheric effect, coefficients were used which have already been employed for this form of pendulum (Appendix No. 14, Coast and Geodetic Survey Report for 1888). The usual plan has been followed of first making differential corrections to reduce to the mean temperature and pressure of each station, and then reducing to a standard condition to which all stations are referred. The coefficients given in the report for 1888 for pendulum No. 4 have been used here for No. 2, as they are exactly alike in form and material.

The time of oscillation of an equivalent simple pendulum is given by the formula

$$\frac{TH-th}{H-h}\sqrt{1-\frac{(T-t)^2Hh}{(TH-th)^2}}$$

T and t being the times of oscillation with the heavy end down and heavy end up, respectively, and H and h being the distances from the center of suspension to the center of oscillation for the same positions. As $T-t$ is not more than $0{\cdot}0002^s$, for any of the pendulums, and as the fraction

$$\frac{Hh}{(TH-th)^2}$$

is less than unity, the radical may be omitted.

$$\frac{TH-th}{H-h}$$

may then be put in the form

$$t+H\left(\frac{T-t}{H-h}\right)$$

where $\frac{H}{H-h}=1{\cdot}500$ for pendulum No. 2 and $1{\cdot}506$ for pendulum No. 3.

By this formula the times of oscillation in the two positions were combined.

The object in observing with two pendulums was to have a check on any change from accidental causes. Their agreement was quite satisfactory. The following table gives the increase in the time of one oscillation for heavy end down at the different stations in terms of the Washington period:

Station.	Pendulum No. 2.	Pendulum No. 3.
Loanda.	0·001003	0·001001
Cape Town.	261	258
Jamestown.	746	748
Longwood.	808	812
Georgetown.	942	951
Green Mountain.	1021	1040
Barbados.	983	990
Bermuda.	178	181

The actual differences when corrected for change of gravity were as follows:

Differences between No. 2 and No. 3.

Station.	One oscillation.		Seconds per day.		Difference from mean in seconds per day.	
	Down.	Up.	Down.	Up.	Down.	Up.
	s.	s.				
Washington.	0·044202	0·044387	3819·0	3835·0	0·5	2·1
Loanda.	202	399	9·0	6·1	0·5	1·1
Cape Town.	204	409	9·2	6·9	0·7	0·2
Jamestown.	196	437	8·5	9·4	0·0	2·2
Longwood.	197	428	8·6	8·6	0·1	1·4
Georgetown.	191	379	8·1	4·4	0·4	2·8
Green Mountain.	182	410	7·3	7·0	0·8	0·2
Barbados.	194	434	8·4	9·1	0·2	1·9
Bermuda.	199	423	8·8	8·2	0·2	1·0

GRAVITY OBSERVATIONS.

Final Results of Separate Swings.

WASHINGTON [STAND OF 1889] PENDULUM NO. 2.

DOWN.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Corrections. Rate.	Temp.	Press.	Corrected period.
		1889.	*h.*		*s.*				*s.*
1	Out.	Oct. 2	13·1	S.	1·0062113	+898	−21	+11	1·0063001
2		2	17·3	P.	102	+898	− 7	+ 7	3000
3		2	22·0	F.	148	+821	+ 8	− 5	2972
4		3	2·5	F.	177	+821	+22	− 6	3014
5		3	6·8	F.	184	+821	+19	−10	3014
									3000
6	In.	3	9·7	S.	1·0062291	+712	− 7	− 2	1·0062994
7		3	13·8	S.	263	+712	−17	+12	2970
8		3	17·6	P.	278	+712	+ 5	+ 8	3003
									2989

UP.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Rate.	Temp.	Press.	Corrected period.
1	Out.	Oct. 4	22·1	F.	1·0062881	+767	+12	−44	1·0063616
2		4	23·3	F.	996	+767	+13	−42	734
3		4	0·8	F.	960	+767	+13	−37	703
4		5	2·0	F.	858	+767	+11	−30	606
5		5	3·2	F.	900	+767	+12	−34	645
6		5	4·6	F.	892	+767	+12	−34	637
7		5	6·0	F.	965	+767	+12	−34	710
8		5	7·7	F.	842	+767	+12	−37	584
9		5	8·5	F.	801	+767	+12	−40	540
									642
10	In.	5	9·8	S.	1·0062945	+767	+ 2	−30	1·0063684
11		5	11·2	S.	834	+767	− 7	−14	580
12		5	12·6	S.	822	+767	− 9	0	580
13		5	13·9	S.	760	+767	−10	+14	531
14		5	17·1	S.	870	+767	−10	+33	660
15		5	15·2	P.	886	+767	− 7	+45	691
16		5	18·6	P.	875	+767	+ 1	+46	689
17		5	20·2	P.	802	+767	+ 7	+47	623
									630

Final Results of Separate Swings—Continued.

WASHINGTON [STAND OF 1889.] PENDULUM NO. 3.

DOWN.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Corrections. Rate.	Temp.	Press.	Corrected period.
		1889.	*h.*		*s.*				*s.*
1	Out.	Oct. 3	22·1	F.	0·9620235	+661	+18	+5	0·9620919
2		4	2·3	F.	309	+661	+18	+4	992
3		4	6·6	F.	290	+661	+12	0	963
									958
4	In.	4	9·7	S.	0·9620140	+794	−4	−2	0·9620928
5		4	13·8	S.	156	+794	−35	−2	913
6		4	17·8	P.	158	+794	−24	−6	922
									921

Final Results of Separate Swings—Continued.

LOANDA, ANGOLA, PENDULUM NO. 2.

DOWN.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Corrections.			Corrected period.
						Rate.	Temp.	Press.	
		1889.	*h.*		*s.*				*s.*
1	Out.	Dec. 24	1·2	P.	1·0071755	+1421	+24	− 2	1·0073198
2		24	4·5	M.	670	+1421	+40	− 5	126
3		25	8·7	M.	733	+1421	+74	−11	217
4		25	12·6	P.	672	+1421	+72	−11	154
5		25	16·3	P.	647	+1421	+14	+ 2	084
6		25	20·3	P.	795	+1421	−20	+12	208
									165
7	In.	25	0·1	P.	1·0071932	+1426	+ 6	+ 4	1·0073368
8		25	4·5	M.	901	+1426	+40	− 4	363
9		26	8·6	M.	809	+1426	+52	− 7	280
10		26	12·4	P.	929	+1426	+36	− 7	384
11		26	16·4	P.	911	+1426	−16	+ 2	323
12		26	20·4	P.	892	+1426	−36	+ 8	290
									335

UP.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Rate.	Temp.	Press.	Corrected period.
1	Out.	Dec. 26	0·5	P.	1·0071812	+1422	−23	+12	1·0073223
2		26	1·8	P.	965	+1417	−15	+ 5	372
3		26	3·1	P.	928	+1417	+ 3	−12	336
4		26	4·6	M.	672	+1417	+15	−19	085
5		26	6·1	M.	742	+1417	+22	−19	162
6		27	7·5	M.	702	+1417	+25	−14	130
7		27	9·0	M.	706	+1417	+26	−12	137
8		27	10·6	M.	729	+1417	+33	−19	160
									201
9	In.	27	12·4	P.	1·0071888	+1417	+16	−19	1·0073302
10		27	13·8	P.	731	+1417	− 6	−15	127
11		27	15·2	P.	773	+1417	−17	− 2	171
12		27	16·7	P.	976	+1417	−34	+11	370
13		27	18·2	P.	783	+1417	−55	+21	166
14		27	19·7	P.	759	+1417	−76	+42	142
15		27	21·2	P.	639	1417	−78	+49	027
16		27	22·7	P.	696	+1417	−66	+37	084
17		27	0·2	P.	704	+1417	−48	+19	092
18		27	1·7	P.	859	+1417	−27	+ 4	253
									173

Final Results of Separate Swings—Continued.

LOANDA, ANGOLA, PENDULUM NO. 3.

DOWN.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Corrections. Rate.	Temp.	Press.	Corrected period.
		1889.	*h.*		*s.*				*s.*
1	Out.	Dec. 17	1·1	P.	0·9629463	+1400	+25	− 4	0·9630884
2		17	3·8	M.	305	+1400	+49	− 6	748
3		18	8·0	M.	297	+1400	+57	− 7	747
4		18	11·4	P.	312	+1400	+40	− 8	744
5		18	15·7	P.	347	+1400	−22	+ 3	728
6		18	19·8	P.	395	+1400	−56	+11	750
									767
7	In.	18	0·1	P.	0·9629364	+1401	−32	0	0·9630733
8		18	4·0	M.	312	+1402	− 2	− 6	706
9		19	8·2	M.	312	+1402	+20	− 5	729
10		19	12·0	M.	299	+1402	− 1	− 4	696
11		19	16·1	P.	366	+1402	−47	+ 5	726
12		19	20·0	P.	374	+1402	−61	+11	726
									719

UP.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Rate.	Temp.	Press.	Corrected period.
1	Out.	Dec. 19	0·1	P.	0·9627555	+1402	−47	+20	0·9628930
2		19	1·4	P.	575	+1355	−29	+ 7	908
3		19	2·8	P.	624	+1355	−12	0	967
4		19	4·2	M.	530	+1355	+ 1	− 4	882
5		19	5·6	M.	339	+1355	+11	− 6	699
6		20	6·9	M.	401	+1355	+17	− 6	767
7		20	8·5	M.	335	+1355	+23	− 6	707
8		20	9·9	M.	278	+1355	+27	− 9	651
									814
9	In.	20	11·7	P.	0·9627343	+1355	+32	−21	0·9628709
10		20	13·3	P.	454	+1355	+42	−28	823
11		20	14·7	P.	401	+1355	+30	−23	763
12		20	16·4	P.	313	+1355	−11	− 4	653
13		20	17·8	P.	335	+1355	−41	+16	665
14		20	19·3	P.	276	+1355	−49	+27	609
15		20	20·8	P.	320	+1355	−49	+33	659
16		20	22·2	P.	247	+1355	−46	+32	588
17		20	23·5	P.	318	+1355	−43	+31	661
									681

Final Results of Separate Swings—Continued.

CAPE TOWN PENDULUM, No. 2.

DOWN.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Corrections. Rate.	Temp.	Press.	Corrected period.
		1890.	h.		s.				s.
1	Out.	Jan. 22	15·3	Pa.	1·0065582	+113	− 77	+10	1·0065628
2		22	19·5	Pa.	550	+113	− 29	+ 5	639
3		23	23·9	Pa.	525	+113	− 20	+ 4	622
4		23	4·2	P.	525	+119	− 35	+ 3	612
5		23	8·1	P.	564	+119	− 77	+ 8	614
6		23	11·7	P.	518	+119	− 80	+ 7	564
									613
7	In.	23	15·2	P.	1·0065246	+119	− 40	+ 2	1·0065327
8		23	19·4	Pa.	230	+119	− 22	+ 2	329
9		24	23·7	Pa.	261	+119	− 27	+ 3	356
10		24	3·9	P.	219	+116	− 31	+ 2	306
11		24	8·1	P.	276	+116	− 75	+ 9	326
12		24	11·5	P.	332	+116	−119	+19	348
									332

UP.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Rate.	Temp.	Press.	Corrected period.
1	Out.	Jan. 24	15·1	P.	1·0065724	+116	−113	+57	1·0065784
2		24	16·6	P.	809	+116	−104	+47	868
3		24	18·2	P.	832	+116	− 93	+31	886
4		24	19·5	Pa.	690	+116	− 82	+39	763
5		25	21·1	Pa.	609	+116	− 71	+35	689
6		25	22·6	Pa.	683	+116	− 59	+33	773
7		25	0·1	Pa.	781	+116	− 53	+29	873
8		25	1·5	Pa.	666	+116	− 54	+26	754
9		25	3·4	Pa.	671	+116	− 61	+25	751
									793
10	In.	25	4·4	P.	1·0065606	+109	− 68	+31	1·0065678
11		25	6·0	P.	566	+109	− 75	+37	637
12		25	7·5	P.	608	+109	− 81	+42	678
13		25	9·0	P.	561	+109	− 86	+47	631
14		25	9·8	P.	566	+109	−119	+62	618
15		25	11·3	P.	479	+109	−167	+83	504
16		25	12·9	P.	657	+109	−194	+95	667
17		25	14·0	P.	637	+109	−188	+93	651
18		25	15·2	P.	535	+109	−160	+83	667
									637

Final Results of Separate Swings—Continued.

CAPE TOWN PENDULUM, No. 3.

DOWN.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Corrections. Rate.	Temp.	Press.	Corrected period.
		1890.	h.		s.				s.
1	Out.	Jan. 27	3·5	P.	0·9623046	+119	+ 47	—14	0·9623198
2		27	7·5	Pa.	2994	+119	+ 61	—18	156
3		28	11·6	Pa.	3002	+119	+ 79	—26	174
4		28	16·3	P.	3150	+119	+ 88	—31	326
5		28	20·5	P.	3093	+119	+ 62	—28	246
6		28	0·5	P.	3208	+119	+ 55	—26	356
									243
7	In.	28	3·3	P.	0·9623227	+125	+ 90	—30	0·6023412
8		28	7·6	Pa.	142	+125	+115	—30	352
9		29	12·0	Pa.	079	+125	+137	—30	311
10		29	16·4	P.	093	+125	+139	—30	327
11		29	21·1	P.	126	+125	+ 73	—14	310
12		29	1·2	P.	194	+125	+ 62	— 6	375
									348

UP.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Rate.	Temp.	Press.	Corrected period.
1	Out.	Jan. 29	8·0	Pa.	0·9621250	+120	+106	—18	0·9621458
2		30	9·6	Pa.	249	+120	+ 85	+ 1	455
3		30	11·2	Pa.	252	+120	+ 76	+13	461
4		30	12·9	Pa.	264	+120	+ 77	+ 9	470
5		30	14·6	Pa.	279	+120	+ 76	+ 7	482
6		30	16·3	P.	370	+120	+ 72	+ 5	567
7		30	17·2	P.	357	+120	+ 69	+ 6	552
8		30	18·6	P.	414	+120	+ 67	+ 4	605
									506
9	In.	30	20·1	P.	0·9621347	+120	+ 67	+ 7	0·9621541
10		30	21·6	P.	310	+120	+ 48	+13	491
11		30	23·3	Fi.	285	+120	+ 14	+22	441
12		30	0·8	Fi.	264	+120	— 12	+25	397
13		30	3·4	P.	418	+120	— 4	+ 7	541
14		30	4·8	P.	364	+120	— 2	— 5	477
15		Feb. 1	19·8	G.	239	+120	+139	—75	423
16		1	21·5	G.	411	+120	+119	—74	576
									486

***Final Results of Separate Swings*—Continued.**

JAMESTOWN, ST. HELENA, PENDULUM NO. 2.

DOWN

No.	Pos.	Date.	Epoch.	Obs.	Period.	Corrections. Rate.	Temp.	Press.	Corrected period.
		1890.	h.		s.				s.
1	Out.	Feb. 22	16·6	Mc.	1·0070564	+27	+ 57	—12	1·0070636
2		22	20·8	Mc.	655	+27	— 40	+ 5	647
3		22	0·9	P.	666	+27	— 6	+ 4	691
4		22	4·8	P.	639	+24	+ 55	— 7	711
									671
5	In.	22	9·3	Mc.	1·0070466	+24	+ 70	— 6	1·0070554
6		23	14·1	Mc.	501	+24	+ 57	— 6	576
7		23	18·3	B.	528	+24	— 63	— 5	484
8		23	22·5	B.	591	+24	—108	+16	523
9		23	2·7	P.	598	+24	— 53	+ 8	577
									543

UP.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Rate.	Temp.	Press.	Corrected period.
1	Out.	Feb. 26	5·0	P.	1·0071053	+32	— 29	+ 9	1·0071065
2		26	6·5	P.	1053	+32	— 20	+ 6	1071
3		26	7·9	P.	1084	+32	— 7	+ 6	1115
4		26	9·8	M.	1001	+32	+ 11	+ 9	1053
5		27	11·4	M.	0986	+32	+ 24	+ 2	1044
6		27	12·9	M.	0866	+32	+ 30	—15	0913
7		27	14·5	M.	0985	+32	+ 40	—23	1034
8		27	15·9	M.	1012	+32	+ 52	—23	1073
									1046
9	In.	27	17·3	Mc.	1·0071023	+32	+ 54	—24	1·0071085
10		27	18·8	Mc.	1055	+32	+ 33	—19	101
11		27	20·2	Mc.	0990	+32	+ 50	—23	049
12		27	21·6	Mc.	1023	+32	+ 18	— 6	067
									076

***Final Results of Separate Swings*—Continued.**

JAMESTOWN, ST. HELENA, PENDULUM NO. 3.

DOWN.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Corrections. Rate.	Temp.	Press.	Corrected period.
		1890.	*h.*		*s.*				*s.*
1	Out.	Feb. 23	7·3	P.	0·9628205	+ 41	+ 18	+ 1	0·9628265
2		23	9·5	M.	140	+ 41	+ 49	— 3	227
3		24	13·7	M.	138	+ 41	+ 61	— 8	232
4		24	18·2	Mc.	126	+ 41	— 2	+ 1	166
5		24	22·6	Mc.	188	+ 41	— 96	+14	147
6		24	2·7	P.	181	+ 41	— 68	+ 9	163
									200
7	In.	24	6·7	P.	0·9628355	+114	— 10	— 2	0·9628457
8		24	9·7	B.	238	+114	+ 10	— 2	360
9		25	13·8	B.	152	+114	+ 36	— 5	297
10		25	17·4	M.	201	+114	— 12	— 1	302
11		25	21·5	M.	279	+114	— 80	+11	324
12		25	1·6	P.	265	+114	— 71	+ 9	317
									343

UP.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Rate.	Temp.	Press.	Corrected period.
1	Out.	Feb. 25	5·9	P.	0·9626499	+ 31	— 25	+ 9	0·9626514
2		25	7·4	P.	457	+ 31	+ 1	+12	501
3		25	9·7	Mc.	287	+ 31	+ 25	+ 5	348
4		26	11·3	Mc.	309	+ 31	+ 32	— 8	364
5		26	12·7	Mc.	310	+ 31	+ 34	—15	360
6		26	14·2	Mc.	325	+ 31	+ 34	—18	372
7		26	15·6	Mc.	255	+ 31	+ 28	—21	293
									393
8	In.	26	17·6	B.	0·9626157	+ 31	+ 27	—25	0·9626190
9		26	19·0	B.	252	+ 31	— 4	—16	263
10		26	20·5	B.	260	+ 31	— 43	— 1	247
11		26	21·9	B.	288	+ 31	— 74	+12	257
12		26	23·4	B.	344	+ 31	— 99	+27	303
13		26	0·9	B.	321	+ 31	—111	+40	281
14		26	2·3	B.	498	+ 31	— 75	+27	481
15		26	3·8	B.	343	+ 31	— 40	+15	349
									296

Final Results of Separate Swings—Continued.

LONGWOOD, ST. HELENA, PENDULUM NO. 2.

DOWN.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Corrections. Rate.	Temp.	Press.	Corrected period.
		1890.	h.		s.				s.
1	Out.	Mar. 4	6·2	P.	1·0070662	—32	+ 4	0	1·0070634
2		4	10·3	Mc.	80	—32	+ 6	—5	649
3		5	14·0	Mc.	59	—32	+10	—5	632
4		5	17·9	M.	08	—32	+ 5	—2	579
5		5	21·9	M.	30	—32	—15	—1	582
6		5	2·1	P.	26	—32	— 6	+1	589
									611
7	In.	5	10·2	B.	1·0070645	—36	+16	+2	1·0070627
8		6	14·3	B.	634	—36	+34	0	632
9		6	18·0	Mc.	619	—36	+29	—3	609
10		6	22·1	Mc.	535	—36	— 7	+2	494
11		6	2·1	P.	604	—36	— 8	+4	564
									585

UP.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Rate.	Temp.	Press.	Corrected period.
1	Out.	Mar. 6	6·2	P.	1·0070682	—36	— 6	+1	1·0070641
2		6	8·0	P.	797	—36	—18	—4	739
3		6	10·3	M.	772	—36	—18	—3	715
4		6	11·7	M.	778	—36	—14	0	728
5		7	13·1	M.	736	—36	—12	+2	690
6		7	14·7	M.	795	—36	—15	+4	748
7		7	16·3	M.	671	—36	—10	—2	623
									698
8	In.	7	17·8	B.	1·0070624	—36	—11	—9	1·0070568
9		7	19·2	B.	657	—36	—25	—7	589
10		7	20·8	B.	592	—36	—33	—4	519
11		7	22·2	B.	580	—36	—36	—1	507
12		7	23·7	B.	357	—36	—23	0	298
13		7	1·1	P.	588	—36	—11	+3	544
									504

Final Results of Separate Swings—Continued.

LONGWOOD, ST. HELENA, PENDULUM NO. 3.

DOWN.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Corrections. Rate.	Temp.	Press.	Corrected period.
		1890.	h.		s.				s.
*1	Out.	Mar. 2	6·0	P.	0·9628330	—42	+12	+ 1	0·9628301
2		2	10·1	B.	282	—42	+11	+ 1	252
3		3	14·3	B.	270	—42	+42	— 2	268
4		3	17·9	Mc.	167	—42	+40	— 4	161
5		3	22·0	Mc.	251	—42	+11	+ 2	222
6		3	2·1	P.	312	—42	+ 4	+ 2	276
									247
7	In.	3	5·8	P.	0·9628398	—37	+ 4	— 1	0·9628364
8		3	9·9	M.	316	—37	+20	— 3	296
9		4	14·1	M.	305	—37	+25	— 2	291
10		4	18·1	B.	243	—37	+ 2	+ 1	209
11		4	22·2	B.	261	—37	— 3	+ 3	224
12		4	2·2	P.	270	—37	+ 2	+ 4	239
									271

UP.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Rate.	Temp.	Press.	Corrected period.
1	Out.	Mar. 7	3·8	P.	0·9626307	—35	—11	+ 4	0·9626265
2		7	5·2	P.	5739	—35	— 7	0	5697
3		7	7·1	P.	5489	—35	— 2	— 4	5448
4		7	8·4	P.	5887	—35	+ 2	— 6	5848
									5815
5	In.	7	10·3	Mc.	0·9626291	—35	— 4	— 2	0·9626250
6		8	11·7	Mc.	327	—35	— 7	+ 6	291
7		8	13·1	Mc.	290	—35	— 5	+10	260
8		8	14·5	Mc.	151	—35	— 9	+13	120
9		8	16·0	Mc.	173	—35	+ 2	—10	130
									210

Final Results of Separate Swings—Continued.

GEORGETOWN, ASCENSION, PENDULUM NO. 2.

DOWN.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Corrections. Rate.	Temp.	Press.	Corrected period.
		1890.	h.		s.				s.
1	Out.	Mar. 20	6·4	P.	1·0072619	+138	+ 73	−11	1·0072819
2		20	11·5	M.	600	+138	+100	−13	825
3		21	15·4	M.	608	+138	+110	−14	842
4		21	19·0	W.	525	+138	+ 64	−11	716
5		21	23·0	W.	565	+138	+ 21	− 3	721
6		21	3·1	P.	598	+138	+ 27	− 1	762
									781
7	In.	21	7·2	P.	1·0072606	+117	+ 40	− 6	1·0072757
8		21	11·4	B.	605	+117	+ 53	− 6	769
9		22	15·5	B.	582	+117	+ 56	− 6	749
10		22	19·1	M.	592	+117	+ 35	− 4	740
11		22	23·1	M.	626	+117	− 10	+ 2	735
12		22	3·1	P.	618	+117	+ 3	+ 2	740
									748

UP.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Rate.	Temp.	Press.	Corrected period.
1	Out.	Mar. 25	7·8	P.	1·0072522	+234	− 24	+ 5	1·0072737
2		25	9·2	P.	507	+234	− 9	− 5	727
3		25	11·4	W.	448	+234	0	− 5	677
4		26	13·2	W.	474	+234	+ 4	+ 3	715
5		26	14·8	W.	552	+234	+ 9	+ 4	799
6		26	16·2	W.	369	+234	+ 17	− 2	618
7		26	17·7	W.	263	+234	+ 25	−11	511
									683
8	In.	26	19·2	B.	1·0072160	+234	+ 20	−16	1·0072398
9		26	20·6	B.	249	+234	− 6	−10	467
10		26	22·0	B.	290	+234	− 35	− 1	488
11		26	23·3	B.	299	+234	− 57	+11	487
12		26	0·9	B.	245	+234	− 72	+25	432
13		26	2·5	B.	302	+234	− 80	+34	490
14		26	3·7	P.	259	+234	− 85	+36	444
									458

Final Results of Separate Swings—Continued.

GEORGETOWN, ASCENSION, PENDULUM No. 3.

DOWN.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Corrections. Rate.	Temp.	Press.	Corrected period.
		1890.	*h.*		*s.*				*s.*
1	Out.	Mar. 22	7·6	P.	0·9630224	+155	+15	− 2	0·9630392
2		22	11·6	W.	221	+155	+26	+ 1	403
3		23	15·7	W.	164	+155	+39	0	358
4		23	19·1	B.	187	+155	+ 8	+ 1	351
5		23	23·2	B.	290	+155	−42	+ 9	412
6		23	3·1	P.	282	+155	−44	+ 9	402
									386
7	In.	23	7·4	P.	0·9630274	+196	−18	+ 3	0·9630455
8		23	12·1	M.	201	+196	+ 2	+ 1	400
9		24	16·0	M.	157	+196	+17	0	370
10		24	19·2	W.	282	+196	+ 1	0	479
11		24	23·1	W.	134	+196	−44	+ 6	292
12		24	3·4	W.	171	+196	−52	+ 8	323
									387

UP.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Rate.	Temp.	Press.	Corrected period.
1	Out.	Mar. 24	7·2	P.	0·9628227	+196	−27	+ 4	0·9628400
2		24	8·7	P.	131	+261	−25	− 3	364
3		24	10·3	P.	250	+261	−18	− 9	484
4		24	11·4	B.	091	+261	+ 1	−11	342
5		24	12·8	B.	078	+261	+ 7	− 7	339
6		25	14·3	B.	103	+261	+11	− 4	371
7		25	15·6	B.	045	+261	+17	− 5	318
8		25	17·0	B.	014	+261	+25	− 8	292
9		25	18·3	B.	124	+261	+28	−12	401
									368
10	In.	25	19·3	M.	0·9628034	+261	+20	−12	0·9628303
11		25	20·8	M.	8082	+261	+ 4	− 9	338
12		25	22·3	M.	8029	+261	−20	0	270
13		25	23·6	M.	8021	+261	−40	+11	253
14		25	1·1	M.	7992	+261	−52	+19	220
15		25	2·9	P.	8109	+261	−61	+26	335
16		25	4·8	P.	8135	+261	−54	+24	366
17		25	6·2	P.	8184	+261	−37	+13	421
									313

Final Results of Separate Swings—Continued.

GREEN MOUNTAIN, ASCENSION, PENDULUM No. 2.

DOWN.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Corrections. Rate.	Temp.	Press.	Corrected period.
		1890.	*h.*		*s.*				*s.*
1	Out.	Mar. 31	8·7	P.	1·0072889	−12	+154	−18	1·0073013
2		31	12·8	M.	754	−12	+162	−16	2888
3		Apr. 1	17·1	B.	787	−12	+178	−18	2935
4		1	20·9	B.	796	−12	+123	−14	2893
5		1	0·9	M.	885	−12	− 1	+ 4	2876
6		1	4·9	P.	924	−12	− 9	+ 4	2907
									2919
7	In.	1	8·8	P.	1·0072901	− 5	+ 76	−10	1·0072962
8		1	12·8	W.	784	− 5	+ 99	− 9	869
9		2	16·8	M.	793	− 5	+130	−12	906
10		2	20·8	M.	790	− 5	+ 65	− 5	845
11		2	1·2	W.	893	− 5	− 27	+ 2	863
12		2	5·3	P.	946	− 5	− 13	+ 3	931
									896

UP.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Rate.	Temp.	Press.	Corrected period.
1	Out.	Apr. 5	7·5	P.	1·0072911	65	− 61	+20	1·0072805
2		5	9·1	P.	906	−65	− 27	+ 3	817
3		5	10·6	P.	895	−65	− 18	− 3	809
4		5	11·7	P.	857	−65	− 8	− 5	779
5		5	13·1	B.	851	−65	− 2	− 3	781
6		6	14·5	B.	851	−65	+ 3	0	789
7		6	15·7	B.	774	−65	+ 11	+ 1	721
8		6	17·1	W.	744	−65	+ 10	− 2	687
9		6	18·7	W.	875	−65	+ 15	−10	815
									778
10	In.	6	20·2	W.	8·0072609	−65	+ 24	−14	1·0072554
11		6	21·0	B.	530	−65	+ 20	−16	469
12		6	22·4	B.	609	−65	− 4	−12	528
13		6	23·8	B.	666	−65	− 38	+ 2	565
14		6	1·1	W.	552	−65	− 92	+30	425
15		6	2·5	W.	671	−65	−139	+52	519
16		6	5·4	P.	706	−65	−103	+49	587
									521

Final Results of Separate Swings—Continued.

GREEN MOUNTAIN, ASCENSION, PENDULUM No. 3.

DOWN.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Corrections. Rate.	Temp.	Press.	Corrected period.
		1890.	h.		s.				s.
1	Out.	Apr. 2	8·6	P.	0·9630633	−28	+ 34	− 4	0·9630635
2		3	13·1	B.	658	−28	+ 54	− 5	679
3		3	17·1	W.	587	−28	+ 69	− 8	620
4		3	21·1	W.	583	−28	+ 26	− 4	577
5		3	1·0	B.	702	−28	− 74	+10	610
6		3	4·9	P.	691	−28	− 61	+ 9	611
									622
7	In.	3	9·1	P.	0·9630655	+15	+ 8	− 3	0·9630675
8		3	12·9	M.	601	+15	+ 14	− 2	628
9		4	17·0	B.	618	+15	+ 8	− 2	639
10		4	20·9	B.	602	+15	− 32	0	585
11		4	0·9	M.	746	+15	−115	+11	657
12		4	5·0	P.	748	+15	−104	+11	670
									642

UP.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Rate.	Temp.	Press.	Corrected period.
1	Out.	Apr. 4	9·4	P.	0·9628357	− 5	− 25	− 1	0·9628326
2		4	10·9	P.	296	− 5	+ 4	−12	283
3		4	12·5	W.	234	− 5	+ 11	−10	230
4		5	14·0	W.	168	− 5	+ 14	− 5	172
5		5	15·6	W.	186	− 5	+ 28	− 7	202
6		5	17·0	M.	161	− 5	+ 40	−13	183
7		5	18·6	M.	222	− 5	+ 5	− 5	217
8		5	19·8	M.	171	− 5	− 17	− 3	146
									220
9	In.	5	21·2	M.	0·9628105	− 5	+ 52	−29	0·9628123
10		5	22·7	M.	107	− 5	− 3	− 9	090
11		5	0·1	M.	177	− 5	− 62	+20	130
12		5	1·4	W.	193	− 5	−123	+40	105
13		5	2·7	W.	161	− 5	−148	+47	055
14		5	4·1	W.	268	− 5	−133	+48	178
15		5	5·4	P.	274	− 5	−102	+37	204
									116

Final Results of Separate Swings—Continued.

BRIDGETOWN, BARBADOS, PENDULUM No. 2.

DOWN.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Corrections. Rate.	Temp.	Press.	Corrected period.
		1890.	*h.*		*s.*				*s.*
1	Out.	May 3	9·7	P.	1·0073076	+ 62	− 6	− 1	1·0073131
2		4	15·5	Mc.	3052	+ 62	−30	− 2	082
3		4	19·0	Mc.	3103	+ 62	−36	− 2	127
4		4	21·7	M.	2951	+ 62	+ 9	− 1	021
5		4	2·1	M.	3007	+ 62	+26	+ 4	099
6		4	6·0	P.	3015	+ 62	+21	+ 6	104
									094
7	In.	4	9·5	P.	1·0072980	+ 90	+ 1	0	1·0073071
8		4	14·4	W.	986	+118	+12	− 2	114
9		5	18·3	W.	946	+118	+25	− 2	087
10		5	22·3	Mc.	879	+118	+18	− 4	011
11		5	2·2	M.	933	+118	−20	+ 3	034
									063

UP.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Rate.	Temp.	Press.	Corrected period.
1	Out.	May 8	8·2	P.	1·0072206	+ 67	−17	+ 8	1·0072264
2		8	12·0	P.	2131	+ 52	− 2	− 2	2179
3		8	14·9	W.	2079	+ 52	− 1	0	2130
4		9	16·6	W.	1993	+ 52	− 2	+ 5	2048
5		9	18·0	W.	1996	+ 52	− 2	+10	2056
6		9	19·7	W.	1912	+ 52	− 3	+11	1972
7		9	21·2	W.	1942	+ 52	− 3	+ 9	2000
									2093
8	In.	9	22·3	Mc.	1·0072956	+ 52	− 7	+ 9	1·0073010
9		9	0·0	Mc.	2979	+ 52	−17	+11	025
10		9	1·6	Mc.	2990	+ 52	−27	+16	031
11		9	2·9	Mc.	3121	+ 52	−39	+24	158
12		9	4·2	P.	2977	+ 52	−43	+33	019
13		9	5·8	P.	2957	− 52	−31	+37	015
14		9	11·5	P.	3007	+ 52	−20	+33	072
									047

***Final Results of Separate Swings*—Continued.**

BRIDGETOWN, BARBADOS, PENDULUM No. 3.

DOWN.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Corrections. Rate.	Temp.	Press.	Corrected period.
		1890.	h.		s.				s.
1	Out.	May 5	6·2	P.	0·9630622	+113	− 8	+ 5	0·9630732
2		5	9·3	P.	585	+113	+31	0	729
3		5	14·3	Mc.	572	+ 76	+47	− 4	691
4		6	18·4	Mc.	545	+ 76	+56	− 8	669
5		6	22·0	W.	437	+ 76	+51	−10	554
6		6	2·0	M.	538	+ 76	+17	− 5	626
7		6	6·3	P.	583	+ 76	+ 8	− 3	664
									666
8	In.	6	9·5	P.	0·9630581	+ 82	+40	− 8	0·9630695
9		6	14·4	W.	509	+ 89	+46	− 9	635
10		7	18·9	W.	530	+ 89	+47	− 7	659
11		7	22·1	Mc.	531	+ 89	+17	− 7	630
12		7	2·4	M.	574	+ 89	− 9	− 4	650
13		7	5·4	P.	607	+ 89	− 6	− 3	687
									659

UP.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Rate.	Temp.	Press.	Corrected period.
1	Out.	May 7	10·8	P.	0·9628468	+ 84	+ 5	−13	0·9628544
2		7	12·4	P.	437	+ 79	+16	−17	515
3		7	14·9	Mc.	422	+ 79	+18	−15	504
4		8	16·3	Mc.	386	+ 79	+11	− 6	470
5		8	17·8	Mc.	460	+ 79	+ 7	− 1	545
6		8	19·2	Mc.	413	+ 79	+ 4	− 1	495
7		8	20·8	Mc.	388	+ 79	0	− 3	464
									505
8	In.	8	22·1	W.	0·9628294	+ 79	− 4	− 7	0·9628362
9		8	23·8	W.	308	+ 79	− 8	− 9	370
10		8	1·9	M.	370	+ 79	−19	− 3	427
11		8	3·4	M.	394	+ 79	−35	+ 9	447
12		8	4·9	M.	378	+ 79	−51	+20	426
13		8	6·5	M.	416	+ 79	−46	+20	469
									417

***Final Results of Separate Swings*—Continued.**

ST. GEORGES, BERMUDA, PENDULUM NO. 2.

DOWN.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Corrections.			Corrected period.
						Rate.	Temp.	Press.	
		1890.	*h.*		*s.*	(*)			*s.*
1	Out.	May 31	5·5	P.	1·0038926	+25644	+ 92	+10	1·0064672
2		June 1	5·7	P.	923	+25644	+110	+ 5	682
3		1	9·6	P.	943	+25644	+ 92	+ 4	683
4		1	1·3	P.	970	+25644	+ 62	+ 7	683
									680
5	In.	1	5·6	P.	1·0038932	+25644	+ 38	+ 8	1·0064622
6		2	5·8	P.	901	+25652	+ 19	+ 4	576
7		2	9·8	P.	908	+25652	+ 10	+ 2	572
8		2	1·4	P.	951	+25652	— 4	+ 4	603
									593

UP.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Rate.	Temp.	Press.	Corrected period.
1	Out.	June 6	6·7	P.	1·0039324	+25613	— 17	+19	1·0064939
2		6	8·2	P.	300	+25613	— 19	+18	912
3		6	9·8	P.	264	+25613	— 27	+20	870
4		6	11·4	P.	264	+25613	— 35	+21	863
									896
5	In.	6	12·9	P.	1·0039523	+25613	— 36	+22	1·0065122
6		6	2·4	P.	375	+25613	— 41	+25	4972
7		6	3·9	P.	456	+25613	— 47	+25	5047
8		6	6.4	P.	468	+25613	— 52	+23	5052
9		6	7·7	P.	394	+25613	— 58	+24	4973
									5033

* Mean time chronometer used.

Final Results of Separate Swings—Continued.

ST. GEORGES, BERMUDA, PENDULUM NO. 3.

DOWN.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Corrections. Rate.	Temp.	Press.	Corrected period.
		1890.	h.		s.				s.
1	Out.	June 2	5·8	P.	0·9598096	+24490	— 9	0	0·9622577
2		3	5·9	P.	7949	+24490	+30	— 7	462
3		3	10·2	P.	7951	+24490	+23	— 8	456
4		3	1·2	P.	8001	+24490	+ 3	— 6	488
									496
5	In.	3	5·4	P.	0·9598108	+24490	—14	— 6	0·9622578
6		4	5·9	P.	087	+24494	+11	—14	578
7		4	10·2	P.	054	+24494	+10	—16	542
8		4	12·7	P.	086	+24494	0	—13	567
9		4	4·1	P.	087	+24494	—12	—11	558
									565

UP.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Rate.	Temp.	Press.	Corrected period.
1	Out.	June 4	8·2	P.	0·9596273	+24494	—25	—30	0·9620712
2		5	6·8	P.	169	+24489	— 8	—26	624
3		5	8·4	P.	090	+24489	—10	—24	545
4		5	9·9	P.	126	+24489	—11	—22	582
5		5	11·5	P.	135	+24489	—17	—16	591
									611
6	In.	5	1·1	P.	0·9596167	+24489	—24	— 7	0·9620625
7		5	2·5	P.	207	+24489	—28	0	668
8		5	3·9	P.	163	+24489	—31	+ 4	625
9		5	5·3	P.	153	+24489	—33	+ 9	618
10		5	6·7	P.	205	+24489	—39	+ 7	662
									640

Final Results of Separate Swings—Continued.

WASHINGTON [STAND OF 1890], PENDULUM No. 2.

DOWN.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Corrections.			Corrected period.
						Rate.	Temp.	Press.	
		1890.	*h.*		*s.*				*s.*
1	Out.	July 29	2·4	P.	1·0063029	— 12	+110	—26	1·0063101
2		29	6·8	F.	3012	— 12	+101	—25	3076
3		29	10·9	P.	2998	— 12	+ 82	—21	3047
4		29	15·2	P.	3041	— 12	+ 81	—21	3089
5		29	19·6	F.	2906	—101	+ 93	—23	2875
6		30	0·2	F.	3016	—101	+ 82	—24	2973
									3027
7	In.	30	4·5	P.	1·0063047	—101	+ 71	—21	1·0062996
8		30	8·8	P.	3064	—115	+ 71	—16	3004
9		30	13·1	P.	3029	—115	+ 71	—13	2972
10		30	17·3	F.	3001	— 98	+ 67	—11	2959
11		31	21·7	F.	2977	— 82	+ 63	—12	2946
12		31	2·0	F.	2941	— 82	+ 40	— 4	2895
									2962

UP.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Rate.	Temp.	Press.	Corrected period.
1	Out.	July 31	6·5	P.	1·0063318	— 82	+ 18	+ 3	1·0063257
2		31	7·9	P.	297	— 95	+ 20	+11	233
3		31	9·4	P.	184	— 95	+ 24	+18	131
4		31	10·8	P.	258	— 95	+ 24	+24	211
5		31	12·3	P.	297	— 95	+ 20	+31	253
6		31	13·9	P.	122	— 95	+ 18	+36	081
7		31	15·4	P.	149	— 95	+ 26	+50	130
									185
8	In.	31	17·0	P.	1·0063057	— 95	+ 14	+37	1·0063013
9		31	18·6	F.	3124	— 95	+ 12	+36	3077
10		31	20·1	F.	2794	— 95	+ 13	+23	2735
11		Aug. 1	21·7	F.	2919	— 95	+ 13	+23	2860
12		1	23·2	F.	3078	— 95	+ 13	+23	3019
13		1	0·7	F.	2947	— 95	+ 6	+22	2880
14		1	2·2	F.	3081	— 95	+ 6	+21	3013
									2942

Final Results of Separate Swings—Continued.

WASHINGTON [STAND OF 1890] PENDULUM NO. 3.

DOWN.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Corrections.			Corrected period.
						Rate.	Temp.	Press.	
		1890.	*h.*		*s.*				*s.*
1	Out.	Aug. 1	4·6	P.	0·9621054	—90	—24	+11	0·9620951
2		1	8·8	P.	1016	—90	—23	+13	916
3		1	13·0	P.	1007	—90	—23	+12	906
4		1	17·1	P.	1043	—90	—23	+ 6	936
5		1	19·3	F.	0962	—90	—19	+ 6	859
6		1	23·9	F.	0959	—90	—27	+ 4	846
									902
7	In.	2	3·7	P.	0·9621148	—90	—44	+ 1	0·9621015
8		2	7·8	P.	150	—90	—46	+ 3	1017
9		2	12·0	P.	048	—90	—46	+ 3	0915
10		2	16·1	P.	102	—90	—47	+ 1	0966
11		2	20·1	F.	085	—90	—48	+ 1	0948
12		3	0·3	F.	060	—90	—50	+ 2	0922
									0964

UP.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Rate.	Temp.	Press.	Corrected period.
1	Out.	Aug. 4	4·6	P.	0·9619408	—90	—43	— 8	0·9619267
2		4	6·0	F.	263	—90	—43	—14	116
3		4	7·5	F.	255	—90	—50	— 5	110
4		4	9·0	P.	353	—90	—57	+ 8	214
5		4	10·4	P.	344	—90	—56	+16	214
6		4	11·9	P.	340	—90	—56	+22	216
7		4	13·4	P.	371	—90	—57	+26	250
									198
8	In.	4	15·0	P.	0·9619391	—90	—55	+24	0·9619270
9		4	16·5	P.	315	—90	—55	+20	9190
10		4	17·8	P.	353	—90	—55	+14	9222
11		4	19·3	F.	074	—90	—56	+12	8940
12		4	20·8	F.	170	—90	—57	+11	9034
13		5	22·2	F.	372	—90	—57	+11	9236
14		5	0·9	F.	292	—90	—57	+11	9156
15		5	2·5	F.	196	—90	—58	+11	9059
									9138

Final Results of Separate Swings—Continued.

WASHINGTON—[1890—BRACKETS], PENDULUM NO. 2.

DOWN.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Corrections.			Corrected period.
						Rate.	Temp.	Press.	
		1890.	*h.*		*s.*				*s.*
1	Out.	Aug. 12	4·5	P.	1·0062923	— 63	+25	+ 2	1·0062887
2		12	9·2	P.	916	— 86	0	+ 2	832
3		12	13·5	P.	881	— 86	+10	— 3	802
									840
4	In.	13	3·5	P.	1·0062997	— 86	+ 8	— 6	1·0062913
5		13	7·8	P.	981	— 86	+ 3	— 2	896
6		13	12·1	P.	990	—122	+ 9	+ 1	878
									896

UP.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Rate.	Temp.	Press.	Corrected period.
1	Out.	Aug. 14	3·3	P.	1·0063245	—122	+21	+ 4	1·0063148
2		14	4·7	P.	203	—122	+17	+ 4	102
3		14	6·2	P.	265	—122	+13	+ 6	162
4		14	7·7	P.	414	—122	+10	+10	312
									181
5	In.	14	9·3	P.	1·0063275	— 63	+ 8	+17	1.0063237
6		14	10·7	P.	312	— 63	+ 7	+26	282
7		14	12·2	P.	208	— 63	+ 6	+32	183
									234

Final Results of Separate Swings—Continued.

WASHINGTON—[1890—BRACKETS], PENDULUM No. 3.

DOWN.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Corrections. Rate.*	Temp.	Press.	Corrected period.
		1890.	*h.*		*s.*				*s.*
1	Out.	Aug. 15	5·3	P.	0·9620986	− 61	+ 8	+ 1	0·9620934
2		15	9·4	P.	951	−105	+10	+ 3	859
3		15	13·5	P,	933	−105	+10	+ 3	841
									878
4	In.	16	5·7	P.	0·9620953	−105	+ 4	−14	0·9620838
5		16	9·8	P.	942	− 72	+ 4	−12	862
6		16	13·9	P.	955	− 72	+ 4	−11	876
									859

UP.

No.	Pos.	Date.	Epoch.	Obs.	Period.	Rate.	Temp.	Press.	Corrected period.
1	Out.	Aug. 18	4·7	P.	0·9619254	− 72	−17	− 9	0·9619156
2		18	6·1	P.	194	− 72	−19	−11	092
3		18	7·5	P.	234	− 72	−20	−13	129
4		18	9·1	P.	280	− 72	−22	−13	173
									138
5	In.	18	10·6	P.	0·9619323	− 72	−25	−11	0·9619215
6		18	11·6	P.	250	− 72	−26	− 7	145
7		18	13·4	P.	347	− 72	−28	− 3	244
8		18	14·8	P.	325	− 72	−31	− 2	220
									206

***Reduction to Standard Temperature and Pressure. Observations of* 1889–1890.**

[Pressure, 29.554 inches. Temperature, 15° C.]

Station.	Pendulum No. 2. Down.	Pendulum No. 2. Up.	Pendulum No. 3. Down.	Pendulum No. 3. Up.
	s.	*s.*	*s.*	*s.*
Washington, 1889.	1·0062994	1·0063636	0·9620940	No observations made.
Temperature correction.	— 653	— 653	— 623	
First atmospheric correction.	+ 21	+ 63	+ 20	
Second atmospheric correction.	— 3	— 8	— 2	
	1.0062359	1·0063038	0·9620335	-----------
Loanda.	1·0073250	1·0073187	0·9630743	0·9628748
	— 1098	— 1098	— 1047	— 1047
	+ 115	+ 345	+ 108	+ 307
	+ 1	+ 4	+ 1	+ 4
	1·0072268	1·0072438	0·9629805	0·9628012
Cape Town.	1·0065472	1·0065715	0·9623296	0·9621496
	— 732	— 732	— 699	— 699
	+ 56	+ 168	+ 53	+ 150
	0	— 1	0	— 1
	1·0064796	1·0065150	0·9622650	0·9620946
Jamestown.	1·0070607	1·0071060	0·9628272	0·9626344
	— 1011	— 1011	— 965	— 965
	+ 84	+ 252	+ 79	+ 224
	0	— 1	0	— 1
	1·0069680	1·0070300	0·9627386	0·9625602
Longwood.	1·0070598	1·0070601	0·9628259	0·9626012
	— 500	— 500	— 478	— 478
	+ 204	+ 610	+ 191	+ 543
	+ 11	+ 32	+ 9	+ 27
	1·0070313	1·0070743	0·9627981	1·9626104
Georgetown.	1·0072765	1·0072570	0·9630386	0·9628340
	— 1227	— 1227	— 1171	— 1171
	+ 111	+ 330	+ 104	+ 294
	0	+ 1	0	+ 1
	1·0071649	1·0071674	0·9629319	0·9627464
Green Mountain.	1·0072908	1·0072650	0·9630632	0·9628168
	— 778	— 778	— 743	— 743
	+ 300	+ 894	+ 281	+ 796
	+ 16	+ 47	+ 13	+ 39
	1·0072446	1·0072813	0·9630183	0·9628260
Barbados	1·0073078	1·0072570	0·9630662	0·9628461
	— 1095	— 1095	— 1045	— 1045
	+ 90	+ 268	+ 84	+ 239
	0	— 1	0	— 1
	1·0072073	1·0071742	0·9629701	0·9627654

Reduction to Standard Temperature and Pressure. Observations of 1889–1890—Continued.

Station.	Pendulum No. 2.		Pendulum No. 3.	
	Down.	Up.	Down.	Up.
	s.	s.	s.	s.
Bermuda.	1·0064636	1·0064964	0·9622530	0·9620625
Temperature correction.	— 683	— 683	— 651	— 651
First atmospheric correction.	+ 19	+ 57	+ 18	+ 51
Second atmospheric correction.	— 3	— 8	— 2	— 7
	1·0063969	1·0064330	0·9621895	0·9620018
Washington, 1890.	1·0062994	1·0063064	0·9620933	0·9619168
[Stand.]	— 857	— 857	— 817	— 817
	+ 46	+ 139	+ 44	+ 123
	— 2	— 6	— 2	— 5
	1·0062181	1·0062340	0·9620158	0·9618469
Washington, 1890.	1·0062868	1·0063208	0·9620868	0·9619172
[Brackets.]	— 741	— 741	— 707	— 707
	+ 33	+ 97	+ 31	+ 87
	— 2	— 7	— 2	— 6
	1·0062158	1·0062557	0·9620190	0·9618546

After having found the reduced times of oscillation for each station, the relative times were calculated with the value at Washington as unity. This was done for each pendulum separately. A mean being taken, we have the final values as given in the table. These quantities are then corrected for elevation by the formula

$$\frac{dt}{t}=\frac{h}{r}\left(1-\frac{3}{4}\frac{\delta}{\Delta}\right) \text{ Clarke's Geodesy, p. 326.}$$

and for latitude in accordance with Professor Helmert's latest formula for the length of the seconds pendulum

$$l=0^{m}\cdot993549-\cdot002631 \cos 2\varphi$$

(Verhandlungen, Conferenz der Europäischen Gradmessung, Paris, 1889.)

Taking a mean value of t when reduced to the sea level and equator, and comparing with individual values resulting from each station, we get the following residuals in oscillations per day. The positive sign indicates an excess of gravity:

Washington	— 2.5	Georgetown	+ 1.2
Loanda	— 3.8	Green Mountain	+ 0.3
Cape Town	— 5.4	Barbados	— 0.6
Jamestown	+ 7.0	Bermuda	+ 6.8
Longwood	+ 5.4		

From this it appears that the coast stations are light and the island stations are heavy. Barbados seems to fall rather on the side of the continental stations, or at least about halfway between the mean island and mean continental value. This might be expected, inasmuch as the Windward Islands, besides being comparatively near the South American continent, are themselves but the summits of a vast submarine plateau.

The relative forces of gravity at the sea and summit for both St. Helena and Ascension are found by comparing the observations when the pendulum was swinging with the heavy end down. This makes the work comparable with Foster's determination, as he used an invariable pendulum capable of being oscillated in only one position. Besides, there can be no possible doubt as to the correctness of the coefficients for atmospheric effect for elevations under 3,000 feet.

The result is that a pendulum beating seconds at the sea level would lose 5·4 oscillations per day at Longwood, St. Helena; and 7·3 oscillations per day on Green Mountain, Ascension. As the correction for elevation in the former case is 7·2 oscillations and in the latter is 9·2, we have an acceleration due to the mountain matter of 1·8 oscillations per day for St. Helena and 2·0 for Ascension. If we assume, as is customary in correcting for continental attraction, the mean density of the land to be one-half the mean density of the earth, we should have a decrease in the number of oscillations from both causes of 4·5 for St. Helena and 5·8 for Ascension, so that neither island shows as much attraction as this supposition requires. Substituting the relative forces of gravity in the equation we get St. Helena to be 0·34 of the Earth's mean density, and Ascension to be 0·29 of the Earth's mean density. The specific gravity of the surface rocks is about 2·8, while the mean density of the whole island from the gravity determinations is not far from 1·8 for either St. Helena or Ascension.

The pendulum observations embodied in this paper were not intended to be used for absolute measures of gravity. But as oscillations were made in both positions of the instrument, and as the length was measured in order to test its invariability, a comparison can be made with values of g otherwise deduced.

Helmert assumes for the length of the seconds pendulum at Washington the value

$$l = 0{\cdot}99299 \text{ metres}$$

This is based on his formula previously cited. The value of l at Hoboken depending on the work of Heaviside, Peirce, and Herschel when reduced to Washington gives

$$l = 0{\cdot}99302 \text{ metres}$$

The observations of our metre pendulum give

$$l = 0{\cdot}99300$$

We may therefore accept as a close approximation to the value of gravity at Washington

$$g = 980{\cdot}05 \text{ dynes}.$$

On this supposition the absolute values in the table which follows have been calculated. It need hardly be added that in deducing these results, both the flexure of the support and the amplitude of oscillation of the pendulum were considered. They are, however, still uncorrected for the flexure of the pendulum head.

Results of Gravity Observations.

Station.	φ	λ	h.	t.	g. Relative.	g. Absolute.	Date.	Observers.
	° ′	° ′	feet.					
Washington.†	+38 53	+77 02	34	1·000000	1·000000	980·05	Oct. 3, 1889 July 30, 1890	P. F.
Loanda, Angola.	− 8 49	−13 14	150	1003	·997997	978·09	Dec. 22, 1889	P. M.
Cape Town.	−33 56	−18 29	37	0252	·999496	979·56	Jan. 31, 1890	P. Pa.
Jamestown, St. Helena.	−15 55	+ 5 44	33	0736	·998530	978·61	Feb. 25, 1890	P. M. Mac. B.
Longwood, St. Helena.	−15 57	+ 5 41	1750	0807	·998388	978·47	Mar. 4, 1890	P. M. Mac. B.
Georgetown, Ascension.	− 7 56	+14 25	15	0952	·998099	978·19	Mar. 22, 1890	P. M. W. B.
Green Mountain, Ascension	− 7 57	+14 22	2250	1030	·997943	978·03	April 2, 1890	P. M. W. B.
Bridgetown, Barbados.	+13 04	+59 36	60	0989	·998025	978·11	May 2, 1890	P. M. W. Mac.
St. Georges, Bermuda.	+32 23	+64 40	7	0177	·999646	979·70	June 3, 1890	P.

† Smithsonian Institution.

Observers:

- P—E. D. Preston, U. S. Coast and Geodetic Survey.
- F—S. Forney, U. S. Coast and Geodetic Survey.
- M—G. R. Marvell, Naval Cadet, U. S. Navy.
- Pa—J. S. Patton, Naval Cadet, U. S. Navy.
- Mac—W. D. MacDougal, Naval Cadet, U. S. Navy.
- W—P. Williams, Naval Cadet, U. S. Navy.
- B—F. H. Bigelow, Nautical Almanac Office.

Respectfully submitted,

E. D. PRESTON,
Assistant U. S. Coast and Geodetic Survey.

Dr. T. C. MENDENHALL,
Superintendent U. S. Coast and Geodetic Survey.

APPENDIX No. 13—1890.

ON AN APPROXIMATE METHOD FOR COMPUTING PROBABLE ERROR.

By CHAS. H. KUMMELL, Computing Division, U. S. Coast and Geodetic Survey.

[Submitted for publication January 25, 1890.]

Considering the nature of the quantity usually called probable error, there seems required by the rigorous method, especially for a great number of observations, far too much work in proportion to the value of the quantity. It is proposed here to develop a method to compute this quantity from each of the residuals if required, but principally from the larger ones, which give the best value. It is all-important that we keep such a method logically correct if no more may be assumed for it. Now the fundamental assumption is:

Any series of residuals *resulting* from a problem of least squares is as nearly as possible an ideal series, or, in other words, such a series conforms as nearly as possible to the law of error. According to the fundamental conception, we may find by counting, a middle value, which is as often exceeded as not. But we obtain theoretically an identical quantity by using Table IX A, Chauvenet's Method of Least Squares.

This gives the probabilities of a quantity to the argument of its ratio to the probable error. Supposing, then, there are m observations $v_1, v_2, v_3, \ldots \; v_{m-1}, v_m$, which we suppose here arranged according to their numerical magnitude, such that v_m is the largest residual, then we have very nearly—

$$\frac{2m-1}{2m} = \text{probability not to exceed } v_m = \Theta(\rho t'_m)$$

$$\frac{2m-3}{2m} = \qquad v_{m-1} = \Theta(\rho t_{m-1})$$

$$\frac{3}{2m} = \qquad v_2 = \Theta(\rho t'_2)$$

$$\frac{1}{2m} = \qquad v_1 = \Theta(\rho t'_1)$$

Each of these assumptions furnishes a tabular argument t' and we have, denoting the probable error of the residuals by r',

$$r' = \frac{v_m}{t'_m}$$

$$\text{or} = \frac{v_{m-1}}{t'_{m-1}}$$

$$\cdot \quad \cdot \quad \cdot \quad \cdot$$

$$= \frac{v_2}{t'_2}$$

$$= \frac{v_1}{t'_1}$$

These relations obviously have the same weight if written thus:

$$t_m r' = v_m$$
$$t_{m-1} r' = v_{m-1}$$
$$\cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot$$
$$t'_2 r' = v_2$$
$$t'_1 r' = v_1$$

$\therefore$ $[t'] r' = [v =$ sum of residuals regardless of sign, and

$$r' = \frac{[v}{[t']}$$

It is important to state here that this quantity r' is, or should be, the middle value of the series. It is not, however, yet the probable error of observation. Suppose the problem involves n unknown quantities; then, if $r =$ probable error of observation, we have—

$$r = r' \sqrt{\frac{m}{m-n}}$$

The probable errors of the unknown quantities depend on this in a known manner.

For an illustration of the method I shall take the example in Chauvenet's Least Squares, page 495. We have here $m=40$ and $n=1$, and arranging the series of residuals according to their magnitude we have the following table:

i	v_i	$\frac{2i-1}{2m}$	t'_i	r'	Δ_i	i	v_i	$\frac{2i-1}{2m}$	t'_i	r'	Δ_i
40	0·45	0·9875	3·70	±0·121	0·49	20	0·12	0·4875	0·97	±0·124	0·13
39	·41	·9625	3·08	·133	·41	19	·11	·4625	·91	·121	·12
38	·40	·9375	2·76	·145	·36	18	·11	·4375	·86	·128	·11
37	·38	·9125	2·53	·150	·33	17	·10	·4125	·80	·125	·11
36	·31	·8875	2·35	·132	·31	16	·10	·3875	·75	·133	·10
35	·30	·8625	2·20	·136	·29	15	·10	·3625	·70	·143	·09
34	·29	·8375	2·07	·140	·27	14	·09	·3375	·65	·139	·09
33	·29	·8125	1·95	·149	·26	13	·09	·3125	·60	·150	·08
32	·28	·7875	1·85	·151	·24	12	·06	·2875	·55	·110	·07
31	·27	·7625	1·75	·154	·23	11	·05	·2625	·50	·100	·07
30	·26	·7375	1·66	·157	·22	10	·05	·2375	·45	·111	·06
29	·23	·7125	1·58	·146	·21	9	·04	·2125	·40	·100	·05
28	·20	·6875	1·50	·133	·20	8	·03	·1875	·35	·086	·05
27	·17	·6625	1·42	·120	·19	7	·02	·1625	·31	·065	·04
26	·16	·6375	1·35	·119	·18	6	·02	·1375	·26	·077	·03
25	·15	·6125	1·28	·117	·17	5	·01	·1125	·21	·048	·03
24	·14	·5875	1·21	·116	·16	4	·01	·0875	·16	·063	·02
23	·14	·5625	1·15	·122	·15	3	·01	·0625	·12	·084	·02
22	·14	·5375	1·09	·129	·14	2	·01	·0375	·07	·143	·01
21	0·12	0·5125	1·03	·117	0.14	1	0·00	.0125	·02	·000	·00

Now, each of the values in column r' is a single application of the method, but they are obviously of very different precision, those derived from the largest residuals being the best. Taking sums we have—

$$[v = \quad 6{\cdot}22$$
$$[t'] = \quad 47{\cdot}15$$

hence

$$r' = \pm\ 0{\cdot}132$$

and

$$r = r' \sqrt{\frac{40}{40-1}} = \pm\ 0{\cdot}134$$

Its value by the rigorous formula is

$$= \pm 0{\cdot}136$$

If carried out completely by computing the sums $[v$ and $[t']$ the method can of course not be considered short, not even rigorous. It is a short method only, if we confine it to a few values from the largest residuals which should be correctly combined for a final value.

In the last column $\triangle_1$ I have also exhibited a theoretical series of residuals, which show a satisfactory agreement with the actual series.

There is, however, a still more rough use of the method which does not require the knowledge of the residuals. We can then use the range which may be considered as the sum of the two largest residuals; dividing this by the corresponding sum of t' we obtain a fair value of r' and hence of r.

In above example we have

$$\begin{aligned} \text{range} &= 0{\cdot}86 \\ t'_{40}+t'_{39} &= 6{\cdot}78 \\ r' &= \pm 0{\cdot}127 \\ r &= \pm 0{\cdot}129 \end{aligned}$$

Appendix No. 13—1890.

THE DETERMINATION, BY THE METHOD OF LEAST SQUARES, OF THE RELATION BETWEEN TWO VARIABLES, CONNECTED BY THE EQUATION Y=AX+B, BOTH VARIABLES BEING LIABLE TO ERRORS OF OBSERVATION.*

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[Submitted for publication February 26, 1891.]

The method of least squares furnishes the complete solution of the problem of the determination of the most probable relation between two variables, when the theoretical linear equation connecting them is known, provided the measured values of one variable be regarded as free from errors of observation. Thus let

$$ax+b-y=0 \qquad (1)$$

and let observations be made upon y for different values of x, the latter being supposed to be without error. Then, using the usual notation of the method of least squares (namely $[x]=x_1+x_2+\ldots+x_n$, $[x^2]=x_1^2+x_2^2+\ldots+x_n^2$, $[xy]=x_1y_1+x_2y_2+\ldots+x_ny_n$, etc.), the most probable values of a and b are found from the normal equations

$$\begin{aligned} [x^2]\,a + [x]\,b - [xy] &= 0 \qquad (2) \\ [x]\,a + nb - [y] &= 0 \end{aligned}$$

in which n is the number of observations. But if the values of x are observed and those of y are free from error the equation would be written

$$\frac{1}{a}y - \frac{b}{a} - x = 0$$

and the normal equations would be

$$\begin{aligned} [y^2]\frac{1}{a} - [y]\,\frac{b}{a} - [xy] &= 0 \qquad (3) \\ [y]\,\frac{1}{a} + n\,\frac{b}{a} + [x] &= 0 \end{aligned}$$

*The reader's attention may also be directed to an article in the "Analyst," July, 1879 (Vol. VI, No. 4), headed "Reduction of observation equations which contain more than one observed quantity," by Chas. H. Kummell, now of the U. S. Coast and Geodetic Survey.

The values of a and b found from (2) are in general quite different from those found from (3), the difference being due to the assumptions concerning the errors of the observations of x and y. In fact, in (2) the observed values of x are regarded as having a weight infinitely greater than those of y, while in (3) just the reverse assumption is made.

It is the object of this paper to set forth a method by which the most probable values of a and b in equation (1) can be deduced from observed pairs of values of x and y. The weight of the observed values of x will be taken as g, and the weight of the observed values of y as unity. Formulas for a and b are to be deduced; and these, when g is made infinite, will give the same results as (2), while if g is made zero they will give the same results as (3). This general solution will be applicable to many classes of observations arising in engineering and physical science.

Let x_1 and y_1, x_2 and y_2, etc., be n pairs of observations of the quantities x and y, supposed to be connected by the relation

$$ax + o - y = 0 \quad . \quad . \quad . \quad (1)$$

Let the weight of each of the observations x_1, x_2, etc., be g, and the weight of each of the observations y_1, y_2, etc., be unity. Let n be the number of pairs of observations. Let x_1' and y_1' be the adjusted values of the observations x_1 and y_1 so that the corresponding residual errors are $x_1'-x_1$, and $y_1'-y_1$. The fundamental principle of the method of least squares requires that the sum of the weighted squares of all the residual errors shall be made a minimum, or,

$$g\,(x'_1-x_1)^2+g\,(x'_2-x_2)^2+ \quad . \quad . \quad . \quad +(y'_1-y_1)^2+y'_2-y_2)^2+ \quad . \quad . \quad . \quad = \text{a minimum} \quad . \quad . \quad . \quad (4)$$

This function is now to be expressed in terms of the observed values and of a and b; then the vanishing of the first derivatives with respect to a and b will furnish two conditions from which their most probable values can be deduced.

The values x'_1 and y'_1 will satisfy equation (1) and so for each of the n pairs of adjusted values. This equation is that of a straight line referred to rectangular coördinates, a being the tangent of its inclination to the horizontal. Let a second straight line be drawn through the point whose coördinates are x_1' and y_1' and the point whose coördinates are x_1 and y_1, that is, through the adjusted point and the observed point; let a' be the tangent of the inclination of this line to the horizontal; then its equation is $y-y_1=a'\,(x-x_1)$. Combining this equation with (1) gives the coördinates of the adjusted point, thus

$$x'_1=\frac{1}{a'-a}(a'x_1+b-y_1) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

$$y'_1=\frac{1}{a'-a}(a'ax_1+a'b-ay_1)$$

From the first of these subtracting x_1 and from the second y_1 gives the residual errors

$$x'_1-x_1=\frac{1}{a'-a}(ax_1+b-y_1) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

$$y'_1-y_1=\frac{a'}{a'-a}(ax_1+b-y_1)$$

Squaring each of these and substituting in (4) it becomes

$$\frac{g+a'^2}{(a'-a)^2}[(ax_1+b-y_1)^2+(ax_2+b-y_2)^2+ \ . \ . \ .] = \text{a minimum} \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

from which a', a and b are to be determined.

Taking the first derivative of this function with respect to a' and equating it to zero gives the condition

$$a'=-\frac{g}{a} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

which determines the direction in which the observed point must be moved in order to become adjusted; if $g=\infty$ it is moved parallel to the axis of y_1, if $g=0$ parallel to the axis of x; if $g=1$ it is moved perpendicular to the line whose equation is $ax+b=y$.

Substituting in (7) the value of a' just found it reduces to

$$\frac{g}{g+a^2}\left[(ax_1+b-y_1)^2+(ax_2+b-y_2)^2+\ .\ .\ .\right]=\text{a minimum} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

Here the expression within the brackets is the condition given by the method of least squares when the observed values of x are taken without error, or for the case $g=\infty$.

Taking the first derivative of (9) with respect to a and b separately and equating each to zero furnishes the two conditions

$$\left.\begin{array}{l} a^2[xy]-a^2b[x]-a[y^2]+2ab[y]-nab^2+ga[x^2]-g[xy]+gb[x]=0 \\ a[x]+nb-[y]=0 \end{array}\right\} \quad . \quad . \quad . \quad (10)$$

from which a and b can be deduced. The best practical method appears to be to first eliminate b, thus deriving a quadratic for a, namely,

$$a^2+\frac{ng[x^2]+[y]^2-g[x]^2-n[y^2]}{n[xy]-[x][y]}a-g=0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

One of the values of a found by the solution of this equation renders (9) a minimum, while the other renders it a maximum. In any practical case there is no difficulty in selecting the former root, and then the value of b is,

$$b=\frac{[y]-a[x]}{n} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

The values of a and b thus found are the most probable ones deducible from the given observations, and inserting them in (1) the most probable relation between x and y is obtained. Inserting them also in (6) and putting for a' its value the adjusted results for x_1 and y_1 are

$$\left.\begin{array}{l} x'_1=x_1-\dfrac{a}{g+a^2}(ax_1+b-y_1) \\ y'_1=y_1+\dfrac{g}{g+a^2}(ax_1+b-y_1) \end{array}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

and similar expressions obtain for each pair of observed values. Each pair of these adjusted values will exactly satisfy the equation $ax+b-y=0$.

If in (11) the observed values of x be without error, then $g=\infty$, and it reduces to

$$a=\frac{n[xy]-[x][y]}{n[x^2]-[x]^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (14)$$

which is the same result as given by (2). If on the other hand the observed values of y be without error, then $g=0$, and it becomes

$$a=\frac{n[y^2]-[y]^2}{n[xy]-[x][y]} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

which agrees with the value deduced from (3). Whatever may be the value of g formula (11) furnishes the means of deriving the most probable value of a.

As an example of the application of the method let there be two thermometers having different scales, and let x and y be corresponding readings when the thermometers have the same exposure. Then the relation between the two scales is,

$$ax+b-y=0$$

Let now nine pairs of observations be taken, all having the same weight, giving the values,

No. =	1	2	3	4	5	6	7	8	9
$x=$	6°	7°	7°	8°	8°	8°	9°	9°	10°
$y=$	7	7	8	7	8	9	8	9	9

and it is required to determine the most probable values of a and b, and then to compute the adjusted readings. Here $g=1$, $n=9$, $[x]=72$, $[y]=72$, $[x^2]=588$, $[y^2]=582$, $[xy]=582$. These substituted in (11) give

$$a^2+a-1=0$$

from which $a=+0{\cdot}618$ or $-1{\cdot}618$, the former value evidently being the condition for the minimum. Then from (12) $b=+3{\cdot}056$. Hence the most probable relation between the two scales is—

$$y=0{\cdot}618\,x+3{\cdot}056.$$

Next from (13) the adjusted values of x and y for any pair of observations are—

$$x'_1=x_1-0{\cdot}4472\ (0{\cdot}618\,x_1+3{\cdot}056-y_1)$$
$$y'_1=y_1+0{\cdot}7236\ (0{\cdot}618\,x_1+3{\cdot}056-y_1)$$

and putting $x_1=6^\circ$ and $y_1=7^\circ$ there is found $x'_1=6^\circ+0'{\cdot}11$ and $y'_1=7^\circ-0^\circ{\cdot}17$. In this manner the following results are deduced for the adjusted values of the readings:

No. =	1	2	3	4	5	6	7	8	9
$x=$	6·11°	6·83°	7·28°	7·55°	8·00°	8·45°	8·72°	9·17°	9·89°
$y=$	6·83	7·28	7·55	7·72	8·00	8·28	8·45	8·72	9·17

The points located by these coördinates all lie upon the line whose equation is $y=0{\cdot}618\,x+3{\cdot}056$. The sum of the squares of the residual errors will be found to be 2·30, and this is smaller than for any other system of adjusted points.

If in the above observations the values of x be regarded as free from error there will be found by (2) the relation $y=0{\cdot}5\,x+4$. If, however, the values of y be taken as free from error there is found by (3) the relation $x=y$. For the first case the sum of the squares of the residual errors is 2·4, and for the second case it is 3·0, while the correct adjustment gave 2·3.

Let the values of a given by (14) and (15) be called a_1 and a_2, the former being for the case when the observed x's have no error and the latter for the case when the observed y's are without error. By comparing the expressions for these values with the coefficient of a in (11) it is seen that the value of that coefficient is $\frac{g}{a_1}-a_2$, and hence (11) may be written

$$a^2+\left(\frac{g}{a_1}-a_2\right)a-g=0 \quad \ldots \ldots \ldots \ldots \quad (16)$$

From this formula a can be computed when a_1 and a_2 have first been found. Thus for the above numerical example $a_1=0{\cdot}5_1$ $a_2=1{\cdot}0$ and $g=1$; hence $a^2+a-1=0$, as before deduced.

The last formula may prove of use in computing the value of g when a is known *a priori*. For instance, let the following six pairs of observations be the results of the estimation of the stellar magnitudes of six stars by two observers,

$$x_1=8,\ x_2=9,\ x_3=10,\ x_4=10,\ x_5=10,\ x_6=12,$$
$$y_1=9,\ y_2=9,\ y_3=11,\ y_4=\ 9,\ y_5=10,\ y_6=11.$$

The weight of each observed y being unity it is required to find the weight of an observed x. Here it is known that $a=1$, from (14) there is found $a_1=\frac{22}{32}$, and from (15) $a_2=\frac{29}{22}$. Then (16) gives

$$g=\frac{a_2-a}{\frac{1}{a_1}-\frac{1}{a}} \quad \ldots \ldots \ldots \ldots \quad (17)$$

from which g is found to be $\frac{7}{10}$; that is, 10 observations of the first observer are equal in value to 7 of the second.

APPENDIX No. 14—1890

ON THE USE OF OBSERVATIONS OF CURRENTS FOR PREDICTION PURPOSES.

Report by JOHN F. HAYFORD, Tidal Division, U. S. Coast and Geodetic Survey.

[Submitted for publication April 18, 1890.]

PREFATORY NOTE.

It is believed that the paper here presented on the use of observations of currents for prediction purposes points out a practical method of deriving from current observations results which will be of value to the navigator, and which may be represented graphically on the charts.

The paper has been prepared by Mr. John F. Hayford, of the Tidal Division, at the request of Mr. Alex. S. Christie, chief of that Division, and was submitted as a report to the Assistant in charge of the Office of the Survey.

Material for discussion has been found in the observations of currents which have accumulated in the Archives since the year 1844. These observations Mr. Hayford has carefully arranged and tabulated with reference to dates, localities, and methods of observation. The systematic prediction of currents, based whenever practicable upon long series of observations, and referred at any given locality to the predicted times of high and low water, will soon become a necessary adjunct to the Tide Tables.

T. C. MENDENHALL,
Superintendent.

The principal discussions hitherto made in the Coast Survey of current observations for prediction purposes are:

Three reports on the currents, on Nantucket Shoals, Muskeget Channel, and northeast coast of Martha's Vineyard, and in Long Island Sound, by Assistant C. A. Schott (now in charge of the Computing Division), published as Appendices 48, 49, and 50 of the Report for 1854.

A report on the "Physical Hydrography of the Gulf of Maine," Appendix No. 10 of the Report for 1889, by Assistant Henry Mitchell.

And a "Report on a New Rule for Currents in Delaware Bay and River," Appendix No. 18 of the Report for 1881, by Assistant Henry Mitchell.

The three appendices referred to of the Report of 1854 may be considered as the beginning of current prediction in the Coast Survey, many of the results there deduced being published as current arrows on charts and as current tables on the margins of charts. The times of maximum current and of slack water are in these predictions referred to the moon's transit, the *observed* luni-current intervals being corrected to the *mean* luni-current intervals on the assumption that the semimonthly inequality in the luni-current intervals is the same as the semimonthly inequality in the luni-tidal interval.

In the various Coast Pilots which have been published by the Survey there are a number of tables of predicted currents in which the times are referred to moon's transit as above. And from time to time many such tables have appeared on the Coast Survey charts and a few of them in the Reports, in all of which the times were referred to the moon's transit.

In the Coast Survey Bulletin No. 8, bearing the date December 18, 1888,* the currents of six

* NOTE.—The edition of this Bulletin, issued in December, 1888, was superseded by the second edition, published in February, 1889.

stations in New York Harbor and approaches are referred to the tides at Sandy Hook. That is instead of using the interval from the moon's transit to any phase of the current as a means of prediction, the interval from Sandy Hook high water or low water is used, and the current predictions are thus based upon the tide predictions.

This Bulletin was made the basis of information and tables relating to currents in New York, Bay and Harbor, on pages 226–227 of the Tide Tables for the Atlantic Coast for the year 1890, and thus forms the beginning of current predictions in the Tide Tables.

In August, 1889, the systematic prediction of currents having been assigned to the Tidal Division, a careful study of the subject was undertaken as a necessary basis for thorough future work. From the study of the phenomena, as shown by the observations, and from a study of all that could be found in the published works of the Survey, and in a few other miscellaneous publications, together with the suggestions derived from a number of letters received from various assistants and naval officers in the Survey in response to a request for their written opinions, a method of reduction for prediction was decided upon.

As a test of the adopted method, nine of the longest and most reliable series that could be found were then reduced, and the residuals of the reduction carefully examined as an index of the accuracy of the method.

The method is perhaps best explained by the following example of the method of reduction, with the appended explanation.

Ebb Current Reduction.

[Station No. 4, Hell Gate, 1857.]

Date.	Time of—			Velocity strength.	Slack interval.	Strength interval.	Velocity slack.	Remarks.
	Slack.	H. W.	Strength.					
1857.	*h. m.*	*h. m.*	*h. m.*		*h. m.*	*h. m.*		
May 23		7 47	12 01	38·2		4 14		Subassistant H. Mitchell,
	21 30	19 54	24 01	37·5	1 36	4 07		chief of party.
24	10 06	8 42	12 59	38·6	1 24	4 17		Velocities, in fathoms per 30
	22 26	21 17	25 05	37·5	1 09	3 48		sec., observed with a log.
25	10 55	9 20	13 48	33·0	1 35	4 28		
	23 28	21 57	27 02	35·3	1 31	5 05		
26	11 55	10 15	15 04	34·3	1 40	4 49		
27	0 10	22 47	3 03	35·9	1 23	4 16		The H. W.'s were observed
	12 47	11 21	16 08	30·7	1 26	4 47		at Governors Island, New
28	1 28	0 02	4 02	33·1	1 26	4 00		York Harbor.
	13 53	12 06	16 32	30·7	1 47	4 26		
29	2 18	0 41	5 32	33·0	1 37	4 51		
	15 00	13 13	18 02	32·5	1 47	4 49		The H. W.'s are given in
30	3 12	1 26	6 17	28·5	1 46	4 51		*apparent* time. Therefore
	15 55	14 13	18 30	32·0	1 42	4 17		it is necessary to apply a
31	4 25	2 14	6 50	30·0	2 11	4 36		correction of + 3^m to the
	16 48	15 06	19 31	32·0	1 42	4 25		tide-current intervals.
June 1	5 20	3 09	7 33	31·7	2 11	4 24		
				18 604·5	17 1 653	18 4 510		
				33·6	1 38	4 28		
				In knots per hour.	Corrected.	Corrected.		
					h. m.	*h. m.*		
				3·96	1 41	4 31		

Flood Current Reduction.

[Station No. 4, Hell Gate, 1857.]

Date.	Time of— Slack.	L. W.	Strength.	Velocity strength.	Slack interval.	Strength interval.	Velocity slack.	Remarks.
1857.	*h. m.*	*h. m.*	*h. m.*		*h. m.*	*h. m.*		
May 23	15 27	14 04	18 35	43·0	1 23	4 31		
24	4 07	3 04	6 32	39·5	1 03	3 28		
	16 20	14 58	17 38*	42·3	1 22	2 40*		Velocities, in fathoms per 30
25	4 45	3 59	8 30	39·0	0 46	4 31		sec., observed with a log.
	17 10	15 49	20 33	38·0	1 21	4 44		
26	5 55	4 47	9 02	37·9	1 08	4 15		
	18 00	16 43	21 00	38·0	1 17	4 17		
27	7 01	5 32	10 03	36·8	1 29	4 31		The L. W.'s were observed
	18 56	17 33	22 32	36·6	1 23	4 59		at Governors Island, New
28	7 44	6 27	11 34	36·8	1 17	5 07		York Harbor.
	19 57	18 37	22 29	34·3	1 20	3 52		
29	8 47	6 58	11 31	33·5	1 49	4 33		
	21 02	19 26	24 01	32·7	1 36	4 35		The L. W.'s are given in
30	9 52	8 22	12 04	32·5	1 30	3 42		*apparent* time. Therefore
	22 13	20 38	1 04	33·0	1 35	4 26		it is necessary to apply a
31	10 38	9 03	14 04	33·3	1 35	5 01		correction of $+3^m$ to the
	23 15	21 42	1 31	30·5	1 33	3 49		tide-current intervals.
				17 617·7	17 1 384	16 4 381		
				36·3	1 23	4 24		
				In knots per hour.	Corrected.	Corrected.		
					h. m.	*h. m.*		
				4·28	1 26	4 27		

* Rejected.

Ebb Current Reduction.

[Station No. 4, Hell Gate, 1857.]

Date.	One-quarter.		Three-quarter.		Remarks.
	Time.	Velocity.	Time.	Velocity.	
1857.	*h. m.*		*h. m.*		
May 23	10 36	30·4	13 44	28·7	Velocities, in fathoms per 30 sec., measured with a log.
	22 55	30·3	26 24	24·0	
24	11 31	31·4	14 37	31·5	
	23 51	27·3	27 02	27·6	The times of one-quarter ebb were obtained by adding $1^h\ 25^m$ to the observed time of slack before ebb.
25	12 20	29·0	15 27	27·5	
	24 53	31·3	28 12	24·1	
26	13 20	27·8	16 17	29·7	
27	1 35	29·5	5 18	24·3	
	14 12	29·1	17 13	24·7	The times of three-quarter ebb were obtained by subtracting $1^h\ 43^m$ from the observed time of slack before flood.
28	2 53	24·5	6 01	23·0	
	15 18	26·0	18 14	23·5	
29	3 43	27·3	7 04	21·4	
	16 25	25·5	19 19	24·1	
30	4 37	24·6	8 09	21·8	
	17 20	26·0	20 30	25·0	
31	5 50	27·3	8 55	21·2	
	18 13	25·4	21 32	21·0	
June 1	6 45	25·8			
		18 498·5		17 423·1	
		27·7		24·9	
		Knots per hour, 3·27		Knots per hour, 2·94	

Flood Current Reduction.

[Station No. 4, Hell Gate, 1857.]

Date.	One-quarter.		Three-quarter.		Remarks.
	Time.	Velocity.	Time.	Velocity.	
1857.	*h. m.*		*h. m.*		
May 23	16 57	28·2	19 56	32·1	The times of one-quarter flood
24	5 37	27·0	8 32	33·4	were obtained by adding 1^h
	17 50	39·2*	20 52	27·9	30^m to the observed times of
25	6 15	26·9	9 21	33·9	slack before flood.
	18 40	31·7	21 54	31·6	
26	7 25	28·0	10 21	32·0	The times of three-quarter flood
	19 30	30·8	22 36	31·6	were obtained by subtracting
27	8 31	27·5	11 13	28·2	$1^h\ 34^m$ from the observed times
	20 26	33·5	23 54	. .	of slack before ebb.
28	9 14	25·4	12 19	28·2	
	21 27	28·8	24 44	25·9	Velocities, in fathoms per 30 sec.,
29	10 17	26·3	13 26	25·2	measured with a log.
	22 32	25·3	25 38	27·7	
30	11 22	26·0	14 21	24·5	
	23 43	25·8	26 51	24·8	
31	12 08	22·4	15 14	23·9	
	24 45	26·2	27 46	23·7	
		$\overset{16}{439{\cdot}8}$		$\overset{16}{454{\cdot}6}$	
		27·5		28·4	
		Knots per hour,		Knots per hour,	
		3·25		3·35	

* Rejected as abnormal.

The first five columns are results taken directly from the records of observation, and hence need no explanation. The values in the column headed "Slack interval" are obtained by subtracting in turn each time of H. W. (or L. W.) from the time of the corresponding slack. Similarly the values in the column headed "Strength interval" are obtained by subtracting the time of H. W. (or L. W.) from the time of the following strength.

The column headed "Velocity—Slack" is ruled to provide for the tabulation of the velocity at slack for those stations at which the current never completely ceases but merely reaches a minimum velocity at about the time when it is changing direction most rapidly.

By one-quarter ebb, or flood, is meant that phase of the current which occurs midway in time between the slack and strength of the current. Similarly the phase called three-quarter ebb or flood occurs after the strength or maximum of the current and midway in time between it and the following slack.

Since in this case slack before ebb occurs on an average at $1^h\ 41^m$ and strength of ebb at $4^h\ 31^m$ after Governors Island H. W., one-quarter ebb comes at $3^h\ 06^m$ $\left(=\frac{1^h\ 41^m+4^h\ 31^m}{2}\right)$ after Governors Island H. W. or $1^h\ 25^m$ $(=3^h\ 06^m-1^h\ 41^m)$ after slack before ebb, in the average.

Hence the column of times of one-quarter ebb may be filled out either by adding $3^h\ 06^m$ to each of the *observed* times of Governors Island H. W., or by adding $1^h\ 25^m$ to each of the *observed* times of slack before ebb. In general the first method of procedure should be used, but in cases like the present in which the times of slack are quite accurately determined the second method is allowable. The time of three-quarter ebb is in the same way made to depend on the time of L. W. at the reference tide station, or on the time of slack before flood, by the addition or subtraction of a constant quantity. Similarly for one-quarter and three-quarter flood, the general rule being to make each quarter point depend upon the nearest slack or upon the H. W. or L. W. at the reference tide station corresponding to that slack. The reference to H. W.'s or L. W.'s is decidedly preferable in all cases except those in which the slacks are very accurately determined. Having put in the times of quarter points the filling of the corresponding velocity columns is a mere question of interpretation of the record at those times.

From the means of the various columns the following tabular statement may be made:

Currents at Station 4, *Hell Gate* (1858). *Referred to the tides at Governors Island.*

	After high or low water at Governors Island.	Velocity in knots per hour.	Compass direction.
Slack before ebb.	H. W. + $1^h\ 41^m$	0·00	------
One-quarter ebb.	H. W. + $3^h\ 06^m$	3·27	S. W.
Strength of ebb.	H. W. + $4^h\ 31^m$	3·96	S. W.
Three-quarter ebb.	L. W. — $0^h\ 17^m$	2·94	S. W.
Slack before flood.	L. W. + $1^h\ 26^m$	0·00	------
One-quarter flood.	L. W. + $2^h\ 56^m$	3·25	NE. ½ N.
Strength of flood.	L. W. + $4^h\ 27^m$	4·28	NE. ½ N.
Three-quarter flood.	H. W. + $0^h\ 07^m$	3·35	NE. ½ N.

Having tabulated direction observed at each of the times given in the reduction as one-quarter ebb, the mean of these directions is the value given in the table. Similarly we obtain the mean directions corresponding to the other entries in the table.

In all cases the currents are to be referred finally to one of the principal stations of the Tide Tables. When simultaneous tidal observations were not made at such a station the currents may usually be first referred to some subordinate tidal station in the vicinity at which observations were made at the same time as the current observations, and the results may then be referred to the principal station by means of the tidal differences. When no tidal observations were made at the same time as the current observations, which will but rarely be the case, the tides for those particular days at the principal station may be predicted and these predicted tides used in the reduction.

This method of reduction of currents for prediction purposes depends upon the following assumptions:

I. That the interval from high water, or low water, at the current station to the following slack water at the station is a constant.

II. That the interval between high water, or low water, at the current station, and the preceding or following strength of current is a constant.

III. That the interval between the time of high water at the reference tide station and the time of high water at the current station is a constant. The same assumption is made with respect to the low waters at the two stations.

IV. That the velocity and direction of any phase of any ebb (or flood) current is the same as that of the corresponding phase of any other ebb (or flood) current at the station.

None of these assumptions are strictly true and there must be small errors in the results due to the errors of the assumptions. But theory and the records of observations confirm each other in showing that for the region from Hell Gate to Cape Henlopen the errors arising from the assumption are smaller than those arising from the *errors of observation*, especially if that term is used to designate the discrepancies between the velocities and directions as shown by the record, and the velocities and directions which would be facts at the station if no causes were acting except the astronomical forces and the forces due to *constant* winds, currents, and fresh-water outflows.

If in any region the errors due to these assumptions are small as compared with the errors of observation, as defined above, it is evident that no further complication in the method of reduction and prediction is desirable. And, indeed, it will be shown later in this report that there are other reasons why more accurate methods of reduction are undesirable.

It is probable that the error introduced by assumption (I) is very small. It should be noticed that according to this assumption the time of slack water is supposed to be subject to the same periodic variations, due to the moon's phase, declination, and distance, and the sun's declinations and distance, as the times of high water and low water at the station.

Assumption (II) involves the same idea as assumption (I), but it also involves the supposition that the interval from high water to the following low water, or from low water to the following high water, is a constant. This is not true. But since *only a part* of the error is introduced into the result it is sufficiently near the truth.

(III) is an assumption already familiar from its use in referring the subordinate stations of the Tide Tables to the principal stations. Its error is probably insensible with the distances usually involved.

Assumption (IV) declares that there is no variation in the velocity (or direction) at strength or at the quarter points corresponding to the daily, semimonthly, and other periodic variations in the height of high water and of low water. There can be no doubt but that such variations exist, but, as will be shown later, they are so small as to be nearly masked by the errors of observation.

For a test of these assumptions we may look to the numerical results of nine of the longest and most reliable series that could be found. The location of each station and the length of the series of observations is given below.

"No. 3, Hell Gate, 1857," is near the north end of the channel between Blackwells Island and Manhattan Island; eight days of observation.

"No. 4, Hell Gate, 1858," is near the north end of the channel between Blackwells Island and Long Island; nine days of observation.

"No. 6, Hell Gate, 1857," is off Polhemus Dock; eight days of observation.

"No. 2, Hell Gate, 1858," is between Lawrence Point and Sunken Meadow, in East River; eight days of observation.

"G, New York Harbor, 1858," is in the Narrows in the middle of the channel opposite Fort Tompkins Light; four days of observation.

"No. 9, New York Harbor, 1858," is near the west side of East Bank; nine days of observations.

"Pettys Island, Delaware River, 1886," is near the foot of that island at Philadelphia; five days of observation.

"New Castle, Del., 1886," is off New Castle, about one-third across the river from the Delaware shore; seven days of observation.

"Cape Henlopen, Delware, 1886," is near Cape Henlopen, about 1 mile west of the whistling buoy; three days of observation.

Although the series just named are not unbroken the breaks are short, and the length given above refers to what is left after the breaks are deducted. The measurements were made with log and line at all of the stations except Pettys Island and New Castle, on the Delaware, where Price current metres were used.

The following table shows the results of the treatment of the time residuals:

Station.	Flood or ebb.	Mean error of a single observation.		Moon's transit.	
		Slack interval.	Strength interval.	Begin-ning.	End.
		m.	*m.*	*h.*	*h.*
No. 3, Hell Gate, 1857.	Ebb.	20	49	23	7
	Flood.	20	29		
No. 4, Hell Gate, 1857.	Ebb.	15	21	12	19
	Flood.	14	29		
No. 6, Hell Gate, 1857.	Ebb.	19	44	20	1
	Flood.	13	31		
No. 2, Hell Gate, 1858.	Ebb.	15	38	13	19
	Flood.	11	26		
G. New York Harbor, 1858.	Ebb.	22	32	3	6
	Flood.	16	45		
No. 9, New York Harbor, 1858.	Ebb.	28	24	7	15
	Flood.	16	52		
Pettys Island, Delaware River, 1886.	Ebb.	19	57	3	13
	Flood.	8	29		
New Castle, Del., 1886.	Ebb.	19	46	14	20
	Flood.	11	24		
Cape Henlopen, Delaware, 1886.	Ebb.	8	17	7	10
	Flood.	14	27		
Means.		16	34		
Probable errors.		11	23		

The ordinary formula $m=\sqrt{\frac{[vv]}{n-1}}$ was used in the work

As the variation most likely to occur in these quantities, on account of the error of the assumptions, is that arising from the semimonthly variation in the tide due to the moon's phase, a column is added showing the time of the moon's transit at the beginning and end of the observations.

The underscoring shows the cases in which there is a well-defined grouping of signs of residuals.

A consideration of the nature of the quantity measured and the means of measuring it would seem to indicate that the deduced probable error of a single observation, 11^m for slack interval and 23^m for strength, is wholly due to the errors of observation as defined above. But, on the other hand, the grouping of the signs of the residuals in six cases out of thirty-six suggests a semimonthly variation due to the error of the assumption. But it is only a suggestion, and might or might not be verified by a longer series of observations. It may be due to meteorological causes which may be classed as accidental.

The following table shows the results of the treatment of the velocity residuals:

Mean error of a single observation.

Station.	Flood or ebb.	Strength.		One-quarter.		Three-quarter.	
		Knots.	Per cent.	Knots.	Per cent.	Knots.	Per cent.
No. 3, Hell Gate, 1857.	Ebb.	0·34	8	0·40	12	0·33	10
	Flood.	0·26	6	0·44	14	0·52	20
No. 4, Hell Gate, 1857.	Ebb.	0·36	9	0·27	8	0·37	12
	Flood.	0·41	10	0·32	10	0·43	13
No. 6, Hell Gate, 1857.	Ebb.	0·25	11	0·21	11	0·35	22
	Flood.	0·19	6	0·35	16	0·24	13
No. 2, Hell Gate, 1858.	Ebb.	0·19	8	0·29	15	0·16	10
	Flood.	0·36	11	0·24	10	0·29	13
G. New York Harbor, 1858.	Ebb.	0·22	12	0·16	14	0·30	20
	Flood.	0·15	14	0·19	24	0·16	25
No. 9, New York Harbor, 1858.	Ebb.	0·18	8	0·28	19	0·34*	26
	Flood.	0·27	22	0·34	40	0·21	25
Pettys Island, Delaware River, 1886.	Ebb.	0·05	3	0·10	6	0·13	8
	Flood.	0·07	4	0·09	5	0·11	7
New Castle, Del., 1886.	Ebb.	0·07	3	0·17	10	0·09	5
	Flood.	0·20	7	0·31	15	0·27	11
Cape Henlopen, Del., 1886.	Ebb.	0·34	15	0·20	13	0·37	27
	Flood.	0·22	16	0·15	12	0·11	10
Means.		0·23	10	0·25	14	0·27	15

The probable error of a single observation as derived from the final means, is:

Velocity at strength, 0.15 knots, or 7 per cent. of total value.
Velocity at one-quarter, 0.17 knots, or 9 per cent. of total value.
Velocity at three-quarters, 0.18 knots, or 10 per cent. of total value.

The formula $m=\sqrt{\frac{[vv]}{n-1}}$ was used in deducing the mean error of a single observation in each case, and the probable error taken as two-thirds of the mean error.

As before, the underscoring indicates a well-defined grouping of the signs of the residuals.

The average value of the probable error is so small that it can easily be accounted for as arising from the errors of observation—using that term as defined above. The residuals do not indicate any diurnal inequality corresponding to the diurnal inequality in the height of the tide. In sixteen cases out of fifty-four the residuals show, by a grouping of signs, a regular increase or decrease during the period of observation. This is probably due to regular periodic variations in the current, corresponding to similar variations in the tide, which are so small as to be concealed by the errors of observation in the other cases, and are nearly concealed in these cases.

It should be noticed that for the two stations where the Price current meters were used the mean errors are considerably smaller than at the other stations.

In making the reduction for these nine stations only nine observations of time were rejected and twelve observations of velocity.

For a comparison of methods, a second separate reduction was made for each of these nine stations in which the times of slack and of strength were referred to the moon's transit. The residuals were treated in precisely the same way as in the other reduction. As an average from the nine station, the computed probable error of a single reference of slack water to the moon's transit is 15 minutes, as compared with 11 minutes in the case of the reference to highs and lows, with thirteen cases in which the residuals showed a grouping of signs as compared with four cases. The probable error of a single reference in both cases for strength is 23 minutes, with three cases of well defined grouping of signs of residuals in the reference to transit and two in the reference to highs and lows.

In comparing the two methods of prediction it must be remembered that there is no sensible error in the predictions of the moon's transit, while there must be an error in each prediction of a high or low water which will produce the corresponding error in the current predictions. But even when this is considered, it is still probable that the errors will be smaller in predicting by reference to highs and lows than by the other method.

In so far as any conclusion can be drawn from the residuals from such short series as those dealt with, the errors of approximation involved in the adopted method of reduction are smaller than the errors in the results due to errors of observation, as defined above, for the region from Hell Gate to Cape Henlopen.

Judging by the character of the tides this conclusion probably holds good for all the Atlantic coast north of Cape Henlopen, except perhaps in the region about Nantucket, where there is a marked interference between two tidal systems. In extending the use of the method beyond the region in which it has already been used it will be necessary to be cautious.

It is quite evident that it can not be used without modification on the Pacific coast, on account of the large diurnal inequality of the tides.

As bearing upon the validity of assumptions (I) and (III), that the interval between high or low water at the reference tide station and the corresponding slack water at the current station is a constant, the following table of results deduced by the party of Assistant G. Bradford from observations made during the years 1871–'75 may be interesting. It is reasonable to suppose that the error in this assumption would be shown clearly by the difference between the value of the interval as derived from the higher highs (or lower lows) and the value derived from lower highs (or higher lows) in San Francisco Bay, where the diurnal inequality in the tide is quite large.

Let L_F be the interval in each case from lower low water to the slack before the large flood and S_F be the interval from higher low water to the slack before the small flood. Let L_E and S_E have the same meanings with respect to the ebb currents and high waters. Then the results obtained are shown by the following tables:

Station.	$L_F - S_F$	Station.	$L_F - S_F$	Station.	$L_F - S_F$	Station.	$L_F - S_F$
1	-65^m	13	-35^m	25	$+15^m$	37	-80^m
2	0	14	-23	26	-18	38	-65
3	-45	15	-36	27	$+25$	39	-15
4	-10	16	$+10$	28	0	40	-25
5	. .	17	-20	29	$+2$	41	-55
6	. .	18	-30	30	-10	42	-55
7	$+25$	19	. .	31	-85	43	-35
8	$+20$	20	. .	32	-12	44	0
9	0	21	$+35$	33	-45	45	-20
10	0	22	$+5$	34	-12	46	$+50$
11	$+15$	23	-95	35	-42	47	$+10$
12	0	24	$+60$	36	. .	48	-10
						Mean	-16^m

Station.	$L_E - S_E$	Station.	$L_E - S_E$	Station.	$L_E - S_E$
1	− 5	17	− 57	33	+ 20
2	0	18	+ 20	34	− 5
3	. .	19	0	35	+ 10
4	. .	20	. .	36	. .
5	− 20	21	+ 90	37	+ 30
6	− 50	22	+ 20	38	+ 20
7	− 30	23	− 40	39	+ 15
8	− 30	24	+ 60	40	+ 20
9	+ 5	25	+ 10	41	+ 25
10	. .	26	−147	42	− 40
11	− 80	27	− 50	43	− 30
12	− 40	28	0	44	+ 15
13	− 60	29	− 10	45	+ 30
14	− 10	30	0	46	+ 20
15	− 10	31	+ 15	47	− 20
16	− 70	32	+ 10	48	+ 35
				Mean	− 8m

At each station about three days of current observations were taken. The result shows that even with such peculiar tides as those in San Francisco Bay assumptions (I) and (III) are allowable.

In deciding what degree of accuracy is desirable in a method of reduction and prediction it is necessary to consider not only the magnitude of the accidental errors arising in the course of the observations, as has been done above, but the rapidity of the variation of the current with a change of position must also be considered. Predictions made from observations taken at a single point can in strictness only be claimed to apply to that single *point*. But predictions, to be of any practical use, must apply to some *area*, large or small as the case may be. In making a prediction which is to apply to an area by using observations at a point or points within that area it is evident that the error made in the extension of the data will depend directly upon the rapidity with which the current varies with a change of position. Hence the degree of accuracy desirable at a point will depend on the rapidity of this change.

That the velocity of tidal currents, as well as of river currents, depends so closely upon the shape of the bottom and shores and the total area of the cross section of the channel, that in most cases there is a rapid change in velocity in passing from point to point is a well established fact. And this fact makes the allowable errors of approximation in the methods of reduction and prediction, at least in so far as the velocities are concerned, much larger than they would be otherwise.

But the variations of the *times* of slack and of strength of the current with a change of position are much slower, and hence, in the prediction of these times, more accuracy is desirable than in the prediction of velocities. For the same reason the value to the mariner of the prediction of times is greater than that of the prediction of velocities.

In passing *across* a channel there is usually found to be a variation of a few minutes in the times of slack and of strength. In many cases it has been found that slack water and the reversal of direction of the current occurs first in the more sheltered portions of the channel and later in portions of the channel where the water has more freedom of motion.

In passing from point to point *lengthwise* a channel, keeping in the deeper parts, the times of slack and of strength vary in general with about the same rapidity as the times of high water and of low water, and therefore the variation in the intervals local high water to local slack before ebb, local high water to strength of ebb, etc., is comparatively slow.

The following table will serve as a numerical test of the statement just made, and as an index of the type of the tide.

In each case the interval refers to the *local* tide and the *local* current.

Station.	High water to slack before ebb.	High water to strength of ebb.	Low water to slack before flood.	Low water to strength of flood.
	h. m.	h. m.	h. m.	h. m.
Old Ferry Point.	−2 31	+0 44	−2 51	+0 29
Lawrence Point.	−1 24	+1 02	−1 51	+1 19
Off Polhemus Dock.	−1 06	+1 13	−1 25	+1 24
Blackwells West Channel.	−0 01	+2 40	+0 20	+3 35
Blackwells East Channel.	−0 05	+2 45	+0 01	+3 02
East River, Twenty-third street.	+0 50	+3 50	+0 43	+3 38
Hudson River, Thirty-ninth street.	+2 54	+6 09	+3 08	+5 38
The Narrows.	+1 36	+4 51	+2 37	+5 17
West side of East Bank.	+1 51	+6 07	+2 38	+4 47
Fourteen-foot Channel.	+1 20	+4 15	+1 00	+4 00
East Channel.	+0 50	+4 30	+1 10	+4 20
Swash, Main, and Gedney Channels.	+0 25	+3 35	+1 00	+3 35
Cape Henlopen.	+0 53	+4 42	+1 34	+4 06
New Castle, Del.	+1 42	+4 27	+0 53	+3 34
Pettys Island, Philadelphia.	+1 15	+4 54	+0 39	+2 59

To sum up briefly, the following statements may be made in regard to current predictions:

Current observations have been made by Coast Survey parties at more than 1,800 stations, the length of series at each station varying from a few hours to 14 days. In addition to these observations, much general current information has been gathered, principally in connection with the Coast Pilots.

While these observations are in most cases somewhat defective in having been made by crude methods and with instruments not admitting of accurate observation, their principal defect for the purposes of prediction is the shortness of the series. This shortness of the series makes it impossible to eliminate the accidental errors to any considerable extent, and leaves but a slight basis for the estimation of the magnitude of such errors. But a much more serious difficulty is that such series furnish no adequate means of determining the semimonthly or other periodic variations; *nor of testing satisfactorily the validity of assumptions on which the methods of reduction and prediction are based.*

Three or four series of one month each of continuous observations, with the instruments now available, at widely-separated stations—at least one of them being on the Pacific coast—would serve to put current prediction on a sound basis and *would add greatly to the worth of the observations already recorded.* Such would be the immediate practical value of a few long series, even though their scientific bearing on tidal theory and physical hydrography be ignored.

Of the current observations actually made but a small proportion have been used in making current predictions.

Until 1888 the predictions made were published as tables in the Coast Pilots and on charts, supplemented on the charts by arrows placed at the station of observation showing the direction and velocity at various phases of the current. In all these tables the times, if given at all, are referred to the moon's transit.

Now that by means of accumulated tidal reductions the tides can be predicted quite closely on all important parts of our coast it seems desirable that these current predictions should be referred to the tidal predictions instead of to the moon's transit, although the latter reference was probably the better of the two at the time when it was made. Such a reference of the currents to the tides is fully as convenient for use as the reference to moon's transit and is to be preferred because it will probably represent the facts more accurately.

This new system of reference was commenced in Bulletin No. 8 and is extended to fifteen stations in the Atlantic Tide Tables for 1891.

As to the exact method to be used in the reference of the currents to the tides, that is a matter which must be determined by future experience and which can only be settled on a sound basis by the treatment of a few series of at least one month's observations. The method set forth in this report has the support of such series as have been treated, and promises to apply with sufficient accuracy and rapidity to the Atlantic coast of the United States north of Cape Henlopen.

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APPENDIX No 15—1890.

COMPARISON OF THE PREDICTED WITH THE OBSERVED TIMES AND HEIGHTS OF HIGH AND LOW WATER AT SANDY HOOK, NEW JERSEY, DURING THE YEAR 1889.

A report by ALEX. S. CHRISTIE, in charge of the Tidal Division, U. S. Coast and Geodetic Survey Office, of the results of an investigation made under his direction by John F. Hayford, tidal computer.

[Submitted for publication July 18, 1890.]

The tidal station at Sandy Hook, New Jersey, at which two automatic gauges, Saxton C. & G. S. Nos. 30 and 40, have been in simultaneous operation since December 1, 1886, is located on the west side of the Hook, at the terminus of the New Jersey Southern Railroad, in the northern edge of a small recess or cove of Sandy Hook Bay called the Horseshoe, in latitude 40° 26′ 52″ N., longitude 74° 00′ 12″ W. from Greenwich. The times and heights of high and low water annually published by the Coast and Geodetic Survey in Tide Tables for the Atlantic Coast of the United States have been predicted, beginning with the volume for 1885, by means of Professor Ferrel's maxima and minima tide-predicting machine, the amplitudes and epochs of the tidal components used in the setting being taken from Professor Ferrel's Report on the Harmonic Analysis of the Tides at Sandy Hook, Appendix No. 9, Coast and Geodetic Survey Report for 1883. Professor Ferrel's analysis covered the six years, 1876–'81, and as the observations for that period were made at a station in Horseshoe Cove within a few hundred feet at the most of the site of the present gauges, a comparison of the predictions with the present series of observations seemed a fair test of our power to predict for that station, using the results of the harmonic analysis in Professor Ferrel's synthetic machine.

It seemed highly desirable to institute such a comparison. No extended and thorough comparison, with adequate discussion, had yet been made for the purpose of testing the whole apparatus engaged in the production of the annual Tide Tables—the observations upon which they are based, the method of the harmonic analysis of tides, the sufficiency of the tide-predicting machine, the faithfulness of the operator, the copyist, the compositor, and the proof reader. The station lies close to the pathway of an enormous commerce, and here, if anywhere, we should know exactly what we are doing; the more so that our predictions of the tidal currents in that locality have recently been referred to the times of high and low water, instead of to the moon's meridian transit as formerly.

The observations for the calendar year 1889, although not absolutely continuous, nor wholly free from small defects both in time and height relations, were better than those for any other year, and they were accordingly selected for the purpose. The times and heights of high and low water were read from the tidal curve produced by gauge No. 30, of which the scale is approximately $\frac{1}{9{\cdot}7}$—that being the better gauge of the two and affording a more continuous record—and omissions, which were few, supplied when possible from the curve of gauge No. 40, of which the scale is approximately $\frac{1}{12}$. The reading scale was set to give directly the heights on the staff used since September 2, 1887, and the times were corrected for the clock error noted on the tidal roll. This last-mentioned record of clock error was somewhat defective, and there is reason for believing that errors of 3 or 4 minutes, and occasionally of double that amount, affect from time to time the values adopted. The number of tides occurring at Sandy Hook during the year was 705 high and 705 low waters; 700 high and 701 low waters were observed by means of the two gauges. These were tabulated and compared with the tides afforded by machine prediction.

In order that the heights derived from observation and prediction might be directly comparable it was necessary to reduce the observations to the plane of mean low water of the charts, which was not possible for lack of proper references of the chart plane to extant benchmarks ashore. Nor were the levels between bench mark and tide staff sufficiently frequent or precise during the progress of the earlier self-registering series at this station (1875–'84) to warrant the adoption of the low-water plane of that series. To obtain an approximate plane I proceeded as follows: The half-tide level, derived in October, 1888, from the high and low waters observed from the inception of the present series, December 1, 1886, to March 31, 1888, including therefore 16 complete and 2 incomplete lunations, reads on the staff used in 1889:

$$\overset{\text{Ft.}}{6{\cdot}922} \pm \overset{\text{Ft.}}{0{\cdot}023}$$

The mean range, derived from several series from 1844 to 1858, aggregating about 3 years of record, is 4.66 feet, and the semi-range is 2.33 feet, with an unknown probable error estimated at 0.1 of a foot; hence, the reading upon the staff of 1889 of the plane of mean low water derived from 3 years of observations is

$$\overset{\text{Ft.}}{4{\cdot}59} \pm \overset{\text{Ft.}}{0{\cdot}10}$$

The predicted heights of high and low waters are given to tenths of feet, the observed heights are also tabulated to tenths; hence, for the purposes of this comparison, we reduced the observations of 1889 to the approximate or assumed plane of reference of the charts and tide tables by subtracting 4.6 feet from each individual height. The observations are made in Eastern Standard (75th meridian) time, which is 5 hours slower than Greenwich mean civil time; the predictions published for 1889 are in mean local civil time. For this comparison we subtracted 4 minutes from the published predictions and thus reduced them to standard time.

The fundamental harmonic elements at Sandy Hook, used in the published predictions and in this investigation, are given in the following table. A is the amplitude or semi-range and ε the lag. In addition to the published predictions it was decided to compare two other sets of predictions with the observations, and hence it will be well to define the methods of setting the machine to obtain the several sets.

TABLE I.

Component.	Fundamental constants.		Component.	Fundamental constants.	
	A	ε		A	ε
	Feet.	°		*Feet.*	°
M_2	2·25	217	S_2	0·43	246
ν_2	0·11	198	K_1	0·33	90
μ_2	0·07	227	O_1	0·17	97
K_2	0·13	37	P_1	0·10	104
L_2	0·09	31	Sa_1	0·07	208
N_2	9·49	199			

For the notation see Appendix No. 10, Report for 1883.

I. The published predictions for Sandy Hook, 1889, were obtained from a single setting of the machine according to the formula—

$$\begin{cases} M = A_1 + \Sigma \dfrac{i_1 + i_e}{2i_1} A_e \cos(u_e t + C_e) \\ N = 0 + \Sigma \dfrac{i_1 + i_e}{2i_1} A_e \sin(u_e t + C_e) \end{cases}$$

where M is the inner, N the outer side of the machine. This method is numbered I throughout this paper.

II. A second set of predictions was obtained by running through the year first for times, the machine being set by formula (6) of Appendix 10, 1883, viz:

$$\begin{cases} M' = A_1 + \Sigma \frac{i_e}{i_1} A_e \cos (u_e t + C_e) \\ N' = 0 \quad + \Sigma \frac{i_e}{i_1} A_e \sin (u_e t + C_e); \end{cases}$$

and afterward running through for heights, the machine set by formula (3) of the Appendix, viz.:

$$\begin{cases} M = A_1 + \Sigma A_e \cos (u_e t + C_e) \\ N = 0 \quad + \Sigma A_e \sin (u_e t + C_e) \end{cases}$$

This method is numbered II throughout this paper.

III. A third set of predictions was obtained by running through the year once, the machine being set as suggested by Mr. John F. Hayford, viz., by the formula

$$\begin{cases} M = A_1 + \Sigma A_e \cos (u_e t + C_e) \\ N = 0 \quad + \Sigma \frac{i_e}{i_1} A_e \sin (u_e t + C_e) \end{cases}$$

This method is numbered III throughout this paper.

The following table exhibits the setting of the machine for each of the three methods of prediction considered:

TABLE 2.

Component.	I.—Published predictions.			II.—Rigorous method.			III.—Hayford's method.		
	Times and heights.			Outer and inner cranks.			Times and heights.		
	Outer cranks.	Inner cranks.	Epoch 0^h, Jan. 1.	Time.	Height.	Epoch 0^h, Jan. 1.	Outer cranks.	Inner cranks.	Epoch 0^h, Jan. 1.
	Feet.	*Feet.*	°	*Feet.*	*Feet.*	°	*Feet.*	*Feet.*	°
M_2	. .	4·55	163	2·27	2·27	163	2·27	2·27	163
ν_2	0·23	0·22	295	0·11	0·11	295	0·11	0·11	295
μ_2	0·15	0·14	347	0·07	0·07	347	0·07	0·07	347
K_2	0·27	0·26	345	0·13	0·13	345	0·13	0·13	345
L_2	0·19	0·18	211	0·09	0·09	211	0·09	0·09	211
N_2	1·02	0·97	4	0·48	0·49	4	0·48	0·49	4
S_2	0·92	0·88	311	0·45	0·43	311	0·45	0·43	311
K_1	0·51	0·49	255	0·17	0·33	250	0·17	0·33	250
O_1	0·26	0·25	241	0·08	0·17	236	0·08	0·17	236
P_1	0·16	0·15	283	0·05	0·10	278	0·05	0·10	278
Sa_1	. .	0·14	152	0·14	0·14	152	0·14	0·14	152
	Scales $D = \frac{1}{8}$.			Scales $C = \frac{1}{16}$.			Scales $C = \frac{1}{16}$.		

TABLE 3.—*Predicted minus Observed. Means A. M. and P. M. for each month.*

Month.	A. M. or P. M.	I—O.				II—O.				III—O.			
		Time.		Height.		Time.		Height.		Time.		Height.	
		High water.	Low water.	High water.	Low water.	High water.	Low water.	High water.	Low water.	High water.	Low water.	High water.	Low water.
		m.	*m.*	*Feet.*	*Feet.*	*m.*	*m.*	*Feet.*	*Feet.*	*m.*	*m.*	*Feet.*	*Feet.*
Jan.	A. M.	−19·4	−21·0	+0·02	+0·11	−18·1	−17·0	+0·07	+0·08	−12·3	−11·1	+0·06	+0·11
	P. M.	−14·6	−17·1	+0·23	+0·14	− 8·4	−16·1	+0·15	0·00	− 1·3	−10·0	+0·14	+0.04
Feb.	A. M.	− 6·2	−16·2	+0·39	+0·53	− 2·9	−15·9	+0·39	+0.43	+ 2·7	− 9·9	+0·39	+0·46
	P. M.	−14·4	−14·5	+0·64	+0·60	−11·8	− 9·6	+0·57	+0·49	− 4·4	− 3·3	+0.56	+0.51
Mar.	A. M.	−11·7	−16·4	−0·51	−0·52	− 6·0	−17·7	−0·46	−0·59	+ 0·1	−11·4	−0.48	−0·57
	P. M.	−11·7	−10·9	−0·38	−0·40	−10·8	− 2·6	−0·43	−0·44	− 4·0	+ 4·2	−0·43	−0·43
Apr.	A. M.	− 4·7	−13·8	−0·32	−0·31	+ 0·3	−16·7	−0·31	−0·45	+ 7·2	−10·4	−0·31	−0·41
	P. M.	−10·9	−11·4	−0·41	−0·33	− 9·1	− 3·2	−0·34	−0·28	− 3·3	+ 3·6	−0.37	−0·27
May	A. M.	+ 0·9	−11·5	−0·08	−0·08	+ 5·5	−14·4	−0·09	−0·22	+14·2	− 7·6	−0·10	−0·18
	P. M.	−12·7	−11·3	−0·17	−0·13	− 9·1	− 3·6	−0·09	−0.08	− 4·1	+ 2·4	−0·12	−0·07
June	A. M.	− 8·6	−25·7	+0·03	−0·03	− 4·0	−26·2	−0·01	−0·14	+ 3·5	−19·4	−0·01	−0·11
	P. M.	−10·6	−16·4	−0·14	−0·15	− 7·6	−10·6	−0·03	−0·08	− 2·1	− 5·1	−0·05	−0·05
July	A. M.	−13·4	−27·2	−0·14	−0·18	− 9·5	−25·4	−0·17	−0·25	− 2·5	−18·3	−0·16	−0·23
	P. M.	−14·3	−21·2	−0·30	−0·25	−10·6	−16·6	−0.24	−0·21	− 4·7	−10·8	−0·26	−0·17
Aug.	A. M.	−12·5	−20·0	−0·15	−0·09	− 8·7	−12·9	−0·18	−0·11	− 1·4	− 6·5	−0·19	−0·09
	P. M.	−11·1	−14·1	−0·35	−0·20	− 7·2	−13·6	−0·29	−0·21	− 1·1	− 7·4	−0·29	−0·19
Sept.	A. M.	−10·7	−28·0	−0·35	−0·45	− 7·0	−19·5	− 0·34	−0·45	− 1·0	−13·0	−0·36	−0·44
	P. M.	−12·0	−16·0	−0·61	−0·50	− 6·8	−17·5	−0·58	−0·58	− 0·5	−10·8	−0·57	−0·57
Oct.	A. M.	−23·2	−21·5	−0·56	−0·56	−23·5	−12·5	−0·58	−0·52	−15·9	− 6·7	−0·58	−0·49
	P. M.	−26·6	−21·7	−0·66	−0·63	−19·2	−24·4	−0·63	−0·76	−14·6	−17·6	−0·66	−0·75
Nov.	A. M.	−14·9	−19·3	−0·24	−0·21	−14·8	−11·2	−0·25	−0·20	− 6·1	− 6·0	−0·23	−0·16
	P. M.	−10·5	−17·2	−0·20	−0·14	− 0·9	−19·2	−0·20	−0·30	+ 2·7	−12·5	−0·27	−0·26
Dec.	A. M.	− 8·7	−20·2	−0·19	−0·08	− 9·3	−14·8	−0·14	−0·09	− 3·4	− 7·6	−0·15	−0·07
	P. M.	−13·9	−20·6	0·00	−0·09	− 6·7	−20·7	−0·09	−0·22	+ 0·3	−16·1	−0·10	−0·19
Weighted mean.		−12·4	−18·0	−0·19	−0·17	− 8·6	−15·0	−0·18	−0·22	− 2·3	− 8·8	−0·19	−0·20

The weighted mean of Table 3, that is, the constant part of the error of prediction, being subtracted from the individual errors, we obtain the variable part of the error of prediction exhibited in Table 4.

TABLE 4.—*The Variable Part of the Error of Prediction. Means without regard to sign A. M. and P. M. for each month.*

Month.	A. M. or P. M.	$I-O-(I-O)_0$				$II-O-(II-O)_0$				$III-O-(III-O)_0$			
		Time.		Height.		Time.		Height.		Time.		Height.	
		High water.	Low water.	High water.	Low water.	High water.	Low water.	High water.	Low water.	High water.	Low water.	High water.	Low water.
		m.	*m.*	*Feet.*	*Feet.*	*m.*	*m.*	*Feet.*	*Feet.*	*m.*	*m.*	*Feet.*	*Feet.*
Jan.	A. M.	18·7	21·0	0·56	0·74	17·3	17·5	0·58	0·73	17·6	17·7	0·58	0·75
	P. M.	16·8	14·3	0·83	0·63	18·5	16·5	0·80	0·58	18·3	17·0	0·79	0·60
Feb.	A. M.	21·6	16·0	0·75	0·84	21·3	16·7	0·76	0.82	21·4	16·5	0·76	0·83
	P. M.	13·7	15·4	0·89	0·90	14·9	19·5	0.84	0·82	15·4	19.4	0·84	0.83
Mar.	A. M.	13·8	19·0	0·72	0·60	14.2	18·9	0.70	0·61	14.0	18·9	0·71	0·61
	P. M.	16·8	18·7	0·64	0·58	15·0	22·0	0·66	0·67	15.0	22·4	0·64	0·65
Apr.	A. M.	14·6	16·2	0·40	0·41	16·5	16·9	0·42	0·47	16·5	16·7	0·42	0·45
	P. M.	12·4	17·2	0·38	0.47	13·2	20·7	0·38	0·43	13·3	21·2	0·39	0·44
May	A. M.	18·9	18·9	0·27	0·24	20·4	15.7	0·26	0·24	20·3	16·1	0·27	0·24
	P. M.	12·2	16·1	0·30	0·24	12·8	20·0	0·33	0·28	13.8	19·8	0·33	0·26
June	A. M.	13·6	16·1	0·40	0·29	14·9	18·6	0·39	0·27	15·7	17·4	0.43	0·27
	P. M.	14·7	14·7	0·32	0·32	12·9	11·8	0·37	0·30	12·8	12·7	0·36	0·32
July	A. M.	14·0	16·2	0·21	0·29	15·4	19·2	0·21	0·32	16·9	18·3	0·23	0·31
	P. M.	13.6	14.5	0·24	0·25	12·7	9·5	0·20	0·28	13·7	9·6	0·20	0·27
Aug.	A. M.	15·1	15·8	0·31	0·30	15·6	18·6	0·28	0·31	16·1	17·9	0·27	0·33
	P. M.	14·0	14.5	0·20	0·27	12·0	11·1	0·18	0·27	11·9	10·9	0·19	0.25
Sept.	A. M.	13·9	20·3	0·43	0·59	15·2	19·7	0·40	0·64	15·1	19·7	0.41	0·65
	P. M.	12·6	17·0	0·51	0·64	14·8	18·1	0·52	0·64	14·3	17·6	0·51	0·66
Oct.	A. M.	15·4	15·5	0·53	0·61	18·7	18·2	0·53	0·56	17·7	18·8	0·52	0·55
	P. M.	21·5	18·1	0·58	0·63	18·4	19·2	0·54	0·70	20·4	18·2	0·58	0·72
Nov.	A. M.	12·5	17·5	0·43	0·41	15·9	21·0	0·42	0·39	13·8	21·6	0·40	0·38
	P. M.	21·1	26·3	0·45	0·55	19·3	25·6	0·41	0·59	22·0	25·4	0.46	0·60
Dec.	A. M.	17·9	9·8	0·49	0·45	17·6	9·8	0·50	0·44	17·5	11·0	0·49	0·47
	P. M.	16·2	21·7	0·52	0·48	15·9	22·4	0·51	0·49	17·0	20·4	0·53	0·47
Weighted mean.		15·7	17·1	0·47	0.49	16·0	17·8	0·46	0·49	16·2	17·7	0·47	0·49
Probable error of a single prediction.		13·3	14·5	0·40	0·41	13·5	15·1	0·39	0·42	13·7	15·0	0·40	0·42

TABLE 5.—***Number of cases, in each month, in which the arithmetical difference between prediction and observation was less than* 14.5 *minutes in time; also number of cases in which it was less than* 0.45 *feet in height***

Month.	I.				II.				III.			
	Time.		Height.		Time.		Height.		Time.		Height.	
	High water.	Low water.	High water.	Low water.	High water.	Low water.	High water.	Low water.	High water.	Low water.	High water.	Low water.
January.	23	26	29	38	28	22	32	34	31	29	33	36
February.	30	17	23	18	27	23	23	20	26	21	22	19
March.	27	24	30	32	33	23	30	28	31	26	29	28
April.	37	22	36	38	36	24	36	36	31	28	36	37
May.	31	33	46	51	35	35	47	51	30	32	44	53
June.	32	24	43	48	35	28	40	49	35	29	39	49
July.	28	16	46	44	30	18	48	40	28	28	45	44
August.	27	20	46	47	29	27	50	43	34	32	50	45
September.	30	21	33	34	30	22	33	32	31	21	32	32
October.	13	23	26	27	19	23	28	27	22	28	26	28
November.	25	22	31	31	25	19	31	30	33	19	30	30
December.	34	20	30	34	32	29	32	33	33	29	29	32
For the year.	337	268	419	442	359	293	430	423	365	322	415	433
Per cent.	48	38	60	63	51	42	62	60	52	46	59	62

TABLE 6.—***Number of cases, in each month, in which the arithmetical difference between prediction and observation exceeded* 60 *minutes in time; also number of cases in which it exceeded* 2.5 *feet in height.***

Month.	I.				II.				III.			
	Time.		Height.		Time.		Height.		Time.		Height.	
	High water.	Low water.	High water.	Low water.	High water.	Low water.	High water.	Low water.	High water.	Low water.	High water.	Low water.
January.	3	2	.	1	3	2	.	1	2	2	.	1
February.	.	1	1	.	.	1	1	.	.	.	1	.
March.	.	2	.	.	.	2	.	1	.	2	.	.
April.	.	2	.	.	.	1	.	.	.	.	.	.
May.	1	2	.	.	1	1	.	.	1	.	.	.
June.	.	1	.	.	.	1	.	.	.	1	.	.
July.	.	.	.	.	.	.	.	.	.	.	.	.
August.	.	.	.	.	.	.	.	.	.	.	.	.
September.	.	1	1	2	.	2	1	2	.	1	1	2
October.	1	2	.	.	1	2	.	1	1	1	.	.
November.	1	2	.	.	2	2	.	.	2	1	.	.
December.	1	5	.	.	1	2	.	.	2	2	.	.
For the year.	7	20	2	3	8	16	2	5	8	10	2	3
Per cent.	1	3	$\frac{3}{10}$	$\frac{4}{10}$	1	2	$\frac{3}{10}$	$\frac{7}{10}$	1	$1\frac{1}{2}$	$\frac{3}{10}$	$\frac{4}{10}$

TABLE 7.—*Number of cases during the year in which the arithmetical difference between observation and prediction, by method III, fell between given limits; that is, the distribution of such discrepancies.*

Times.					Heights.				
P—O without regard to sign.	High water.		Low water.		P—O without regard to sign.	High water.		Low water.	
	Number.	Percentage.	Number.	Percentage.		Number.	Percentage.	Number.	Percentage.
m. *m.*					*Feet.* *Feet.*				
0 to 9	273	39	219	$31\frac{2}{10}$	0·0 to 0.4	415	$59\frac{3}{10}$	433	$61\frac{8}{10}$
10 to 19	185	$26\frac{4}{10}$	209	$29\frac{8}{10}$	0·5 to 0·9	192	$27\frac{4}{10}$	170	$24\frac{3}{10}$
20 to 29	135	$19\frac{3}{10}$	119	17	1·0 to 1·4	56	8	47	$6\frac{7}{10}$
30 to 39	73	$10\frac{4}{10}$	82	$11\frac{7}{10}$	1·5 to 1.9	26	$3\frac{7}{10}$	27	$3\frac{9}{10}$
40 to 49	16	$2\frac{3}{10}$	42	6	2·0 to 2·4	9	$1\frac{3}{10}$	17	$2\frac{4}{10}$
50 to 59	9	$1\frac{2}{10}$	18	$2\frac{6}{10}$	2·5 to 2·9	2	$\frac{3}{10}$	5	$\frac{7}{10}$
60 to 69	5	$\frac{7}{10}$	8	$1\frac{2}{10}$	3·0 to 3·4	0	0	1	$\frac{1}{10}$
70 to 79	2	$\frac{3}{10}$	2	$\frac{3}{10}$	3·4 to ∞	0	0	†1	$\frac{1}{10}$
80 to 89	0	0	0	0					
90 to 99	2	$\frac{3}{10}$	1	$\frac{1}{10}$					
100 to ∞	0	0	*1	$\frac{1}{10}$					
	700	100	701	100		700	100	701	100

* P. M., January 9, low water occurred $104^m = 1^h\ 44^m$ later than the predicted time.
† P. M., September 10, low water was 3·7 feet higher than the predicted height. This was during the great storm.

TABLE 8.—*Recapitulation of some of the more important results.*

		I.	II.	III.
Constant part of P—O, with regard to sign,	High water times.	—12·4 minutes.	— 8·6 minutes.	— 2·3 minutes.
	Low water times.	—18·0 minutes.	—15·0 minutes.	— 8·8 minutes.
	High water heights.	— 0·19 foot.	— 0·18 foot.	— 0·19 foot.
	Low water heights.	— 0·17 foot.	— 0·22 foot.	— 0·20 foot.
Variable part of P—O, probable error,	High water times.	±13·3 minutes.	±13·5 minutes.	±13·7 minutes.
	Low water times.	±14·5 minutes.	±15·1 minutes.	±15·0 minutes.
	High water heights.	± 0·40 foot.	± 0·39 foot.	± 0·40 foot.
	Low water heights.	± 0·41 foot.	± 0·42 foot.	± 0·42 foot.
P∼O less than 14·5 minutes, percentage of all cases,	High water times.	48 per cent.	51 per cent.	52 per cent.
	Low water times.	38 per cent.	42 per cent.	46 per cent.
P∼O less than 0·45 feet, percentage of all cases,	High water heights.	60 per cent.	62 per cent.	59 per cent.
	Low water heights.	63 per cent.	60 per cent.	62 per cent.

The following facts noted while doing the numerical work are important as bearing upon the problem of determining to what extent the observed differences between prediction and observation are due to meteorological and other causes not connected with the machine, and to what extent they are due to error in the machine.

The error in height usually has the *same* sign for *all four* of the predicted points occurring during any one day.

There is a tendency for *all* the height differences to retain the same sign for several days at a time.

Both the above remarks apply to the time differences also; but to a much smaller degree.

There is no relation apparent between the signs of the height differences and the signs of the time differences occurring on the same day.

There is no relation apparent between the magnitude of the height differences and the magnitude of the time differences occurring on the same day.

In general the error in the *range* is less than the error in the *height.*

As shown both by the tabulated individual differences and by the tabulated means, sums, etc., the three independent predictions *agree with each other much more closely* than any one of them agrees with the observations.

As shown by the tables of monthly means of the differences, during about one-half the year the *forenoon* high water time differences are slightly greater than the afternoon high water time differences, and the reverse is true during the other half of the year.

The same statement is true with respect to the low water time differences. During any particular month when the forenoon high water time difference is *greater* than the afternoon high water time difference, the forenoon low water time difference is usually *less* than the afternoon low water time difference, and *vice versa.*

Similarly, there is a slight diurnal inequality in the height differences for both low water and high water, which in each case persists for about six months before changing sign. For any one month the sign of this *height* inequality is usually the *same* for highs as for lows in contrast to the *difference* in sign in the case of times.

Any error in the position of the sliding frame of the machine which has a horizontal motion will at this station affect heights but slightly, and will cause the times of both highs and lows to be in error in the same direction by the same amount in the mean.

Any error in the position of the sliding frame of the machine which has a vertical motion will affect the times but slightly, and will change the *range* and tend to cause the error in high water height to have the opposite sign from that of the error in low-water height.

As bearing upon the question of how large a part of the recorded differences between prediction and observation can be accounted for as errors in registering the tides and in interpreting the record, the following statement is pertinent here. From a comparison of 148 highs and 148 lows observed with a self-registering gauge at Mission Street Wharf, San Francisco, Cal., September 28–December 15, 1889, with a simultaneous self-registered record at Sausalito, Cal.:

Probable error of a single observation of high-water time . . . . . $=\pm 5.8^{m}$.
Probable error of a single observation of low-water time . . . . . $=\pm 4.7^{m}$.
Probable error of a single observation of height at high or at low water $=\pm 0.1$ foot.

These deduced results depend upon the assumption that the difference in time and height of the tide at the two places is a *constant.* The error in this assumption must have the effect of *increasing* the deduced result.

Illustrations Nos. 66 and 67 exhibit graphically the distribution with respect to magnitude of the discrepancies between prediction by method III and observation. As explained on the plates themselves, the broken line represents the distribution of the actual discrepancies, the discontinuous line is the same, but rendered less jagged by four successive bisections of chords, and, for comparison, the smooth curve has been added to represent the theoretical distribution of the same number of errors purely accidental.

To obtain a measure of the error of adjustment and setting of the machine, the first twenty days of January were predicted five consecutive times by method III, the machine being re-adjusted before each setting. The probable error of adjustment and setting so found is—

For high-water times $\pm 3{\cdot}1^{m}$.
For low-water times $\pm 3{\cdot}2^{m}$.
For high-water heights $\pm 0{\cdot}03$ foot.
For low-water heights $\pm 0{\cdot}03$ foot.

The following conclusions are based upon the results of the preceding investigation:

(1) The plane of reference of the soundings and charts at Sandy Hook being lost and irrecoverable, for lack of a permanent benchmark ashore connected with the tide staff by levels, the tide

tables can not be made to exactly fit the charts at that station. But as this discrepancy is most probably not in excess of a half foot, it is rather a theoretical than a serious practical defect, the rise and fall being of more importance than niceties in the absolute depths. Nevertheless it is a defect easily avoidable, and it should always be avoided, by the establishment of shore marks of a permanent character. The quantity—two-tenths of a foot—by which the observed appear to exceed the predicted heights in 1889 (see Table 8) depends for magnitude and sign upon a plane of reference derived through doubtful levels from a series other than that used in reducing the soundings, and hence has no special significance for the problem in hand. The mean range of the tides predicted and published for 1889 was less than that derived from observation by only two-hundredths of a foot. Setting the machine by Mr. Hayford's method (III) reduces the discrepancy to two thousandths and reverses its sign. In both cases it is practically zero.

(2) The Tide Tables for 1889 on an average gave the times of high water too early by 12^m, and the times of low water too early by 18^m. Having carefully adjusted the machine and set it by Mr. Hayford's method these numbers would have been 2^m and 9^m, respectively. Hence, setting the machine by Mr. Hayford's method after careful adjustment and putting the solar hand forward 5^m we should expect the machine to give the high waters 3^m late and the low waters 4^m early—quantities of the same order as the unavoidable errors of careful adjustment and setting of the machine, and from every practical point of view insignificant. But until the matter is tested by another actual experiment it would be unsafe to say that we can predict another year, by any method, with so small an average error for the year. I would prefer to say that this constant part of the error would not exceed 6 or 8 minutes.

(3) There is a barely perceptible failure in the predictions to take full account of the diurnal inequality, probably due to a slightly erroneous value of the amplitude and lag of the component of sidereal speed. With this exception, the variable part of the discrepancy between prediction and observation is accidental, meteorological, hence non-predictable. The non-predictable part of the discrepancy is considerably larger than the constant part considered in the preceding paragraph, and greatly in excess of any failure to take account of the tidal components themselves.

(4.) Method II, in which the machine is set for time, afterward for height, the year being run through for each setting, is unnecessarily laborious. The use of a compromise setting and the prediction of both times and heights by running through the year once, which is a part of Professor Ferrel's system, is fully justified. The compromise setting proposed by Mr. Hayford (III) seems better than the one hitherto in use (I) and will be employed in the predictions for 1892. Method I is the traditional one in the tidal division, but as it differs from the compromise method published by Professor Ferrel—formula (19), pp. 258, Appendix No. 10, Report for 1883—in multiplying the amplitudes by the factor $\frac{i_1+i_e}{2i_1}$ on *both* sides of themachine, I suspect that it may have arisen from some misunderstanding of Professor Ferrel's verbal directions at a time when the machine and the whole process was novel. Professor Ferrel's formula (19) will be used in the next comparison of prediction with observation. The process of comparison is a laborious one and I found that it was not advisable to go farther with it this year before beginning the predictions for 1892.

A slight modification of the amplitude on the outer cranks, and of the epochs of the diurnal components, to correct for the yielding of the parts of the machine, resorted to in Method I (see Table 2), does not seem necessary, nor to be justifiable in principle, from an inspection of the machine in operation. The working of the mechanism is indeed freer from defects, and the errors arising from such mechanical defects are smaller, than would appear probable at first sight. There is some slack motion in epoch, more marked of course in the larger components, but this is symmetrical about a mean position (with which initially the setting should coincide), is small, and is partly eliminated by non-agreement of sign among the several components.

This is the most thorough test to which Professor Ferrel's tide-predicting machine has yet been subjected. It may be reiterated that the comparison is a test of the character of the observations in 1876–'81, and in 1889, of the predicting machine, of the correctness of Professor Ferrel's analysis of the Sandy Hook tides (Appendix 9, Report for 1883), of the principles of the harmonic analysis of tides, of our ability to use the combined apparatus for prediction purposes and see that the published predictions are not vitiated by clerical and typographical errors.

The result is a very gratifying one. It enables us to assert that our predictions for Sandy Hook are almost as perfect as they can ever be made by any means whatever, and, in view of meteorological disturbances, as perfect as it is desirable to have them. We are now also able to state with precision how large the meteorological disturbances usually are and how often disturbances of an assigned magnitude are likely to occur. In short, we now know what we are doing, what more we should endeavor to do, and what can not be done.

This work has been executed with characteristic ability and thoroughness by Mr. John F. Hayford, and this paper is essentially his. For the results of former comparisons of the machine predictions with observation, I would refer to page 271, Appendix 10, Report for 1883.

APPENDIX No. 16—1890.

ON THE RELATION OF THE YARD TO THE METRE.

By O. H. TITTMANN, Assistant.

[Published June 15, 1889. Submitted for republication, with additions, January, 1891.]

PREFATORY NOTE.

The paper prepared by Assistant O. H. Tittmann, with the title "On the Relation of the Yard to the Metre," was first published in June, 1889, as U. S. Coast and Geodetic Survey Bulletin No. 9. It has been deemed desirable to republish it as an appendix to this report, not only to give it a more permanent form, but also because the results reached by Mr. Tittmann have since been confirmed by some comparisons made between English standards and the metric standards of the International Bureau of Weights and Measures, as shown in his concluding statement.

T. C. MENDENHALL,
Superintendent of Weights and Measures.

It has seemed to me highly desirable to investigate the sources of the discrepancy in the values assigned to the ratio of the yard to the metre. The inherent difficulty of comparing a line measure, such as a yard, with an end measure, such as the French metre, standards which have no aliquot part in common, and the uncertainties introduced by the difference in the standard temperatures and in the materials of which the standards are composed, have been deemed sufficient to account for the divergencies alluded to. On the other hand, the values usually cited were deduced by men skilled in the art of comparing standards, and not only perfectly familiar with the knowledge of their times, but who were themselves the authorities to whom others looked for information.

I therefore sought for the cause in the standards which they used, and have succeeded in reconciling the discrepancies within unexpectedly narrow limits by referring all the observations to a common standard—the present British Imperial Yard—using the Committee Metre (the U. S. Coast and Geodetic Survey standard) as the metric unit, and as the intermediary by means of which this was made possible. It will appear from the following brief statement that by means of our knowledge of the coefficient of expansion of our Committee Metre, the absolute expansions of the following length measures involved in this discussion can be established with a greater or less degree of accuracy:

TS.—The U. S. Troughton scale of 82 inches, compared by Hassler in 1817 with the Committee Metre, CM.

No. 6.—An iron metre belonging to the U. S. Coast and Geodetic Survey, and compared by Clarke in 1868–9 with

OM.—The Ordnance Metre compared by Clarke with the Ordnance Survey Yard 55, and with

PM.—The Platinum Metre *à traits*, belonging to the Royal Society, used by Kater in 1818 for comparison with the Shuckburgh scale, and by Baily in 1835 for comparison with the Royal Astronomical Society's scale, with his own scale, No. 5, and with Simms's scale, No. 4.

As previously stated, the results depend on the coefficient of expansion of the Committee Metre, CM.—the U. S. Coast and Geodetic Survey standard. This is an iron bar standarded by the French Committee in 1799.[a] It bears the stamp of the Committee and the marks ∵ which distinguish it from the fourteen other bars standarded by that Committee.[b] Its coefficient of expansion in terms of the standard Hydrogen thermometric scale of the International Bureau of Weights and Measures is[c]

$$11{\cdot}795 \times 10^{-6}.$$

HASSLER'S COMPARISONS.

Hassler compared the CM. with the Troughton 82-inch scale, TS,[d] at various temperatures, between 1817 and 1832. His comparisons were very numerous, and although his final results have been published[e] only a few of them can be recomputed, because the temperatures at which he made his comparisons are not given. His final result is stated with both metre and scale at 32° Fahr., and as given by him is

$$\text{CM.} = 39{\cdot}3809171 \text{ inches.}^{e}$$

The only comparisons available for our purposes, because the temperatures as given are taken from the publications cited in the foot-notes, namely, Transactions of the American Philosophical Society, and House Document No. 299, Twenty-second Congress, first session. Hassler's method was to abut together the Committee Metre and the Lenoir Iron Metre, LM. (also in our possession), and to compare their total length with the Troughton scale, TS.

The known relation between CM. and LM. is

$$\text{CM.} - \text{LM.} = 0{\cdot}0000263 + 0{\cdot}000000167\,(t - 32^\circ \text{ F.})$$
$$\pm 4$$

Hassler's earliest comparisons with the Troughton scale as published are:[f]

		Inches.	Obs'd Temp.
1817, March 15, a. m.	CM. + LM. =	78·760402	33·7° F.
1817, March 15, p. m.	CM. + LM. =	78·756448	47·1° F.
1817, March 18, p. m.	CM. + LM. =	78·755522	50·5° F.

Another set of comparisons were taken April 12, 183(1)? and are given as follows:

CM. + LM. = 78·757487 at 46·2° Fahr.

But substituting the value of LM. above given in each of these equations, we obtain

		Inches TS.
1817,	March 15, a. m.	CM. = 39·38073 at 33·7° F.
183(1)?	April 12,	39·37931 at 46·2° F.
1817,	March 15, p. m.	39·37879 at 47·1° F.
1817,	March 18, p. m.	39·37834 at 50·5° F.
	Mean	39·37929 at 44·4° F.
		±7

From the known value of the coefficient of expansion of CM. and the differential expansion between it and TS deduced from these observations, namely, 0·0001392 inches, we obtain the
±53
differential coefficient 0·000003536, and hence the coefficient of TS = 0·0000101 for 1° F.

[a] Transactions American Philosophical Society, New Series, VOL. II, Philadelphia, 1825—p. 252.

[b] House Document No. 299, 22d Congress, 1st session—p. 75.

[c] The relation between the Metric Standards of Length of the U. S. Coast and Geodetic Survey and the U. S. Lake Survey. Report by Assistants C. A. Schott and O. H. Tittmann. Appendix No. 6, C. & G. S. Report, 1889. See also Appendix No. 7, C. & G. S. Report, 1882.

[d] See Appendix No. 12, C. & G. S. Report, 1877.

[e] House Document No. 299, 22d Congress, 1st session.

[f] Transactions American Philosophical Society, New Series, VOL. II, Philadelphia, 1825.
House Document No. 299, 22d Congress, 1st session.

But expressed in terms of the Imperial Yard, the mean yard of the Troughton scale is standard at 59°·62 F.[a] Reducing CM. to 32° F. and TS. to 59·62° by means of these coefficients, we obtain

CM.=39·36994 inches of the Imperial Yard.

KATER'S COMPARISONS.

The results of Kater's comparisons[b] in 1818, between the Shuckburgh scale and the Royal Society's Platinum Metre *à traits* PM., and with a platinum metre *à bout*, as computed by him, gave the well-known value 39·37079 inches. Before we can reduce his observations, it becomes necessary to deduce the coefficient of expansion of the Royal Society's metre *à traits* PM., which we can do with much accuracy, as follows:

The coefficient of CM. is $11{\cdot}795 \times 10^{-6}$.

The relative expansion between CM. and No. 6 is expressed by the equation between these bars

$$\text{CM.} - \text{No. } 6 = 0{\cdot}0000073^{\text{m}} + {\cdot}000000124\,t;$$
$$\pm 1$$

hence the coefficient of No. $6 = 11{\cdot}671 \times 10^{-6}$. But according to Clarke:[c]

$$\begin{aligned} \text{No. } 6 &= \text{OM.} + \overset{my}{44{\cdot}37} \pm {\cdot}33 \text{ at } 32^\circ \text{ F.} \\ \text{No. } 6 &= \text{OM.} + 54{\cdot}55 \pm {\cdot}37 \text{ at } 62^\circ \text{ F.} \\ & \qquad\ \ \overline{10{\cdot}18} \quad \text{for} \quad \overline{30^\circ} \text{ F.} \end{aligned}$$

hence the relative expansion is $\overset{\mu}{9{\cdot}3077}$ for 30° F., or
${\cdot}558$ for 1° C.;
and since the coefficient of No. 6 = $11{\cdot}671 \times 10^{-6}$,
the coefficient of OM. = $\overline{11{\cdot}113} \times 10^{-6}$.

Clarke derived a coefficient of expansion of OM. from two indirect determinations of the expansion of Ordnance Yard 55, differing considerably, namely, $\overset{my}{6{\cdot}650}$ and $\overset{my}{6{\cdot}514}$ for 1° F., and found the expansion of a yard of the OM. to be $\overset{my}{0.411}$ less than that of Y55 for 1° F. This former value gives, for the coefficient of OM.:

$11{\cdot}230 \times 10^{-6}$, and the latter
$10{\cdot}985 \times 10^{-6}$, and he adopts the mean, viz:
$\overline{11{\cdot}108 \times 10^{-6}}$;

taking the mean of this and of the value derived through No. 6, above given, we get for that of OM. $11{\cdot}110 \times 10^{-6}$ but Clarke also gives

$$\begin{aligned} \text{PM.} - \text{OM.} &= \overset{my}{45{\cdot}26} \text{ at } 32^\circ \text{ F.} \\ \text{PM.} - \text{OM.} &= \ \ 9{\cdot}08 \text{ at } 62^\circ \text{ F.} \\ & \quad \overline{36{\cdot}18} \text{ for } \overline{30^\circ} \text{ F.} \end{aligned}$$

hence the relative expansion is $\overset{\mu}{33{\cdot}08}$ for 30° F., or
$1{\cdot}984$ for 1° C., and since
the coefficient of OM. = $11{\cdot}110 \times 10^{-6}$, the coefficient of
PM. = $\overline{9{\cdot}126} \times 10^{-6}$.

Now Kater found that at 60°·76 F. = 15·98° C., PM. = 39·37600 inches, and as this is very near Kater's standard temperature of the brass Shuckburgh scale, the effect of any error in the assumed coefficient of expansion will be small; taking it with Baily at 18.86 for 1° C., we obtain the differential expansion = .00026 inch, and hence at 62° F. PM. = 39·37574. Reducing the Platinum Metre to zero with the coefficient found as above, we obtain ·00599, which, applied to 39·37574, gives 39·36975 for the value of the metre *à traits* in terms of the distance 0 to 39·4 of the Shuckburgh scale. But Baily compared this distance of the Shuckburgh with the 39·4

[a] See Appendix No. 12, C. & G. S. Report, 1877.

[b] See Experiments relating to the Pendulum, etc., read before the Royal Society February 5, 1818, and ordered printed by the House of Commons 25th May, 1818.

[c] Comparisons of Standards of Length, etc., by Lieut. Col. A. R. Clarke, R. E. Philosophical Transactions, pp. 463 *et seq.* Read June 19, 1873. (Clarke's unit throughout his paper is the millionth part of a yard, which he designates by *my*.)

inches of the Royal Astronomical Society's scale, and found the former equal to 39·399393 mean inches of the latter; hence the value of the metre *à traits* found by Kater, but expressed in mean inches of the Royal Astronomical Society's scale, equals 39·36914 inches. But Sheepshanks found the Royal Astronomical Society's scale standard at 60·78° F[a]. = 15·99° C.; hence the metre *à traits* = 39·36964 inches in terms of the present Imperial Yard.

But according to Clarke and the Coast and Geodetic Survey comparisons, as previously stated, the following relations exist between the several bars:

$$\begin{aligned}
\text{No. 6} &= \text{OM.} + \overset{\mu}{40{\cdot}57} \\
\text{No. 6} &= \text{CM.} - 7{\cdot}3 \\
\text{PM.} &= \text{OM.} + 41{\cdot}38, \text{ and hence} \\
\text{OM.} &= \text{CM.} - 47{\cdot}87 \\
\text{PM.} &= \text{CM.} - 6.49 = {\cdot}00026 \text{ inch, and}
\end{aligned}$$

substituting this value of PM., expressed in terms of CM., as the standard, we get, as the result of Kater's observations:

CM. = 39·36990 inches of the Imperial Yard.

BAILY'S COMPARISONS.

In 1835 Baily made an extended and very carefully conducted series of comparisons [b] between the Royal Astronomical Society's scale and PM. He assumed a coefficient of $5{\cdot}05 \times 10^{-6}$ for 1° F. = $9{\cdot}09 \times 10^{-6}$ for 1° C. for PM., which agrees so closely with the one deduced by me from actual observations on its relative expansion, namely, 9·126, as previously shown, that a recomputation of his numerous results does not appear necessary. His comparisons were made at temperatures varying between 28·6° and 80·9° F. The mean temperature (according to his way of combining the observations) of his comparisons was about 54 F. = 12·2° C., and therefore, by introducing the coefficient deduced by me, his value would be changed by only $12{\cdot}2 \times 39{\cdot}37 \times {\cdot}000000036 = {\cdot}000017$ inch, by which amount it must be diminished. The final result as given by him is PM. = 39·368985; diminishing this value by the quantity 0·000017, we obtain as his result PM. = 39·368968 inches of the Royal Astronomical Society's scale; but since this scale, as compared with the present Imperial Yard, is standard at 60·78° F.,[c] we obtain, using Baily's coefficient for the scale, viz: $10{\cdot}48 \times 10^{-6}$ for 1° F., PM. = 39·36947 inches of the Imperial Yard; substituting for PM., its value in terms of CM., we get, as the result of Baily's observations·

CM. = 39·36973.

It should be noted that Baily also compared PM. with his own Tubular scale No. 5 and with Simms' Tubular scale No. 4, and his mean of these comparisons differs only .000026 inch from the result of the comparison with the Royal Astronomical Society's scale, being that much greater; but as their values depend on the correctness of the metre distance on the Royal Astronomical Society's scale, the result would not be sufficiently independent to be quoted here.

CLARKE'S COMPARISONS.

In the "*Comparisons of Standards of Length*," the length of OM. in terms of the Imperial Yard is given, namely:

at 61·25° F. (16·25° C.) OM. = 1·0937480;

using the coefficient found on page 47

$11{\cdot}110 \times 10^{-6}$ for 1° Centigrade we obtain,

at 0° C., OM. = 1·0935506, but as found on page 48
" 0 " OM. = CM. — 523 we get
CM. = 1·0936029 or
CM. = 39·36970 inches of the Imperial Yard.

[a] See account of the construction of the New National Standard of Length and its Principal Copies, by Sir G. B. Airy, Philosophical Transactions, Part III, for 1857. London, 1858.

[b] See Memoirs of the Royal Astronomical Society, Vol. IX, London, 1836.

[c] See account of the construction of the New National Standard of Length, etc., by Sir G. B. Airy. Philosophical Transactions, Part III, for 1857. London, 1858.

The value 39·370432, usually quoted as Clarke's value of the metre, is derived from his admirable comparisons of the yard with certain Toises (reduced to the Toise du Perou), whence the value of the metre was inferred from the legal definition of its ratio to the Toise; but it is not derived from the comparison of the yard with the Mètre des Archives or any well authenticated copy. If Arago's certificate accompanying the Royal Society's Platinum Metre refers to the Metre of the Observatory as the standard, the correction $+ 17{\cdot}59\mu$ given by him should be diminished by about 3μ, the excess of the metre of the Observatory over that of the Archives, found in 1826.[a]

But there is reason to believe that Arago's certificates can not be relied on to give the degree of accuracy implied by their wording. It is shown in this paper that the Platinum Metre of the Royal Society is about 7μ too short.

COMSTOCK'S VALUE.

This is derived from comparisons of the U. S. Lake Survey Standard Metre (RM.)[b] with a steel end yard, compared by Colonel Clarke, R. E., with Standard Yard 55. of the Ordnance Survey. The length of the U. S. Lake Survey standard (RM.) was compared at the International Bureau of Weights and Measures at Paris, and through the adopted Provisional International Standard it is referred to the Mètre des Archives. The value given by Comstock is

$$1 \text{ metre} = 39{\cdot}36985 \text{ inches.}^{c}$$

The U. S. Lake Survey standard RM. was compared at this office with CM., and it was found[d] at

$$0^\circ \text{ C., RM.} = \text{CM.} + 98{\cdot}18\mu \pm 0{\cdot}7\mu$$

from which it follows that CM. agrees with the Mètre des Archives within about 1μ as derived through the value assigned by the International Bureau of Weights and Measures to RM.

RECAPITULATION.

The values of the metre expressed in inches, but in reality referring to different metric and British units as commonly published, are here recapitulated in the third column, and the last column gives the results of the comparisons as reduced by me, to the Committee Metre, CM., in terms of the Imperial Yard.

Date.	Authority.	Inches.	Value in terms of British Imperial Yard, and of the Committee Metre CM.
1817–32	Hassler.	39·380917	39·36994
1818	Kater.	39·37079	39·36990
1835	Baily.	39·369678	39·36973
1866	Clarke.	39·370432	39·36970
1885	Comstock.	39·36985	39·36984
	Indiscriminate mean.		39·36982

Since the foregoing was written, a paper has been published in the proceedings of the Royal Society (February, 1890) by Gen. J. T. Walker, "On the unit of length of the Shuckburgh scale," etc.

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[a] Recherches Historiques sur Les Etalons De Poids et Mesures De L'Observatoire, Par M. C. Wolf, Paris, 1882, page C. 55.

[b] Professional Papers Corps of Engineers, U. S. Army, No. 24, Primary Triangulation U. S. Lake Survey, Washington, 1882, page 48.

[c] Professional Papers Corps of Engineers, U. S. Army, No. 24, Appendix V, page 925, February, 1885.

[d] Report by Assistants C. A. Schott and O. H. Tittmann, Appendix No. 6, C. & G. S. Report for 1889.

From this it appears that the Shuckburgh scale was taken to the International Bureau of Weights and Measures near Paris, and that the space 0 — 39·4 of the scale was compared with the metric standards of that Bureau.

It was found that at 9·315° C. the space 0 — 39·4 Shuckburgh = 1^{m}·000624. As stated on a previous page, this space = 39·399393 inches at 15°·99 C. Taking the coefficient of expansion of the Shuckburgh scale = ·00001886 per degree C., and reducing the comparisons made at the International Bureau to this temperature, we find that at 15·99° C. 0 — 39.4 = 1^{m}·000749, and hence

$$1^{m} = \frac{39·399393}{1·000749} = 39·36990 \text{ inches,}$$

which tends to confirm the relation of the Yard to the Metre found in the preceding discussion, and also to confirm the value deduced for the Royal Society's Platinum Metre PM.; that is, PM. = $1^{m} - 7·0\mu$ at 0° C.

Another value is furnished by the Spanish four-metre bar, so well known in the history of modern geodesy.

The length of this bar in terms of the Imperial Yard was determined by Clarke in 1869 to be

4·37493562 yards at 16°·25.

Its length in terms of the International Prototype Metre, as determined at the International Bureau of Weights and Measures in 1885, was found to be

$$4^{m} - \overset{\mu}{309·84} + (45·701 + 0.0326t)t$$

therefore its length at

$$16°·25 = \overset{m.}{4·000441},$$

and from these two values it follows that

$$1 \text{ metre} = \overset{\text{Inches.}}{39·37008}.$$

This agreement with the values previously found is quite within the uncertainty which the use of different thermometric scales may have caused.

APPENDIX No. 17—1890.

INTERNATIONAL GEODETIC ASSOCIATION.—NINTH CONFERENCE.

Paris, October 3-12, 1889.

Address of GEORGE DAVIDSON, Assistant U. S. Coast and Geodetic Survey, appointed as Delegate to the Association on the part of the United States.

Mr. President and Delegates of the International Geodetic Association:

An Act of Congress at its last Session authorized the President of the United States of America to appoint a delegate to this Association; and on the 7th of September Professor Mendenhall, the recently appointed Superintendent of the United States Coast and Geodetic Survey, gave me, after two conferences, the necessary instructions to appear as the representative of that great national work.

I bring from him kindly greeting and good will to you all, a hearty sympathy with the objects and labors of the Association, and a conviction that its views will grow with the breadth of the New World before it.

For myself and my colleagues in the Coast and Geodetic Survey I repeat the sentiments of the Superintendent; and feel that we shall learn much by the free interchange of experiences and opinions with you all, personally and officially.

The Superintendent directed me to bring such outline schemes of the later progress of the work of the Survey in its different branches as would enable me to make explicit explanations of the objects, scope, methods, means, rate of progress, and prospective views of the Coast and Geodetic Survey.

I did not expect to give more than a verbal description of the work, but in order to conform to your system in the Conference, I feel compelled even at such short notice to put my remarks upon paper.

Before I take up the subject-matters referred to in my instructions, it will be well for us to bear in mind the *extent of the territory of the United States*, excluding Alaska. It stretches from the sixty-seventh nearly to the one hundred and twenty-fifth degree of longitude, and from the forty-ninth to the twenty-sixth degree of latitude. The lengths of the diagonals from the northern part of the State of Maine to San Diego and from Key West in Florida to Cape Flattery at the Strait of Juan de Fuca are nearly equal at 2 880 statute miles, or 4 640 kilometres. The line along the parallel of 30° is 2 628 statute miles in length, or 4 250 kilometres.

On the north we have the Dominion of Canada, some of whose scientific authorities have expressed their hope of co-operation with the United States in the measurement of arcs of the meridian and of the parallel, so that we can stretch northward to the Arctic Ocean. On the south lies our sister Republic of Mexico, through whose territory the great central arc of the meridian can be carried as far south as latitude 10°.

But for our present purpose we are necessarily restricted to the limits of the territory of the United States as I have roughly described them.

The views of the Coast and Geodetic Survey have expanded with the acquisition of new territory and the new demands of all our industries; and their influence has been far-reaching and yet eminently practical. The different States have become interested, and many of them are conducting trigonometrical surveys based upon standard lines furnished by our work. The Government of the United States has called upon the Coast and Geodetic Survey for the determination of fundamental positions in the boundaries of the newer States; and it is only this season that two of our parties have been dispatched to the Yukon and Porcupine Rivers in northern Alaska, to fix the position of the one hundred and forty-first meridian, which marks part of the boundary between Canada and the United States.

The marvelous development of commerce, agriculture, and manufactures upon the Pacific coast of the United States within the last forty years demanded novel methods for the rapid production of preliminary but safe charts; and the increasing needs of navigation have within the last few years demanded a new feature by the execution of topographical reconnoissances with the plane table of those wild and forested parts of the northern coast where land transportation is extremely difficult, and which the regular operations will be a long time in reaching. Hundreds of miles of this rocky coast were successfully surveyed in one short season.

The PHYSICAL FEATURES of the surface of the territory of the United States will bear a few words of explanation and description.

Along the coasts of the Atlantic and Gulf of Mexico the shores are low and nearly all sandy. The "landfall" is generally made by a vessel when she is well on soundings. Far behind this low coast lies the the range of mountains, attaining an elevation of over 6 000 feet (1 830 metres), and extending from Maine to Alabama. These mountains are invisible from seaward, except in the northeast. Westward of this range lies a broad rolling country, extensive prairies, and then the enormously long, gentle, and treeless slopes to the high flank of the Rocky Mountains. The great range of the Rocky Mountains extends north and south through and beyond the territory of the United States, and is the backbone of the country. Thence westward the mountains and the high plateaus and the intervening valleys reach to the Pacific Ocean. Along that coast the Sierra Nevada and Cascade Mountains and the immediate Coast Ranges lie parallel with the coast line. Instead of the low shores of the Atlantic and Gulf coasts, we have on the Pacific, mountains that reach an elevation of 5 000 feet (1 530 metres) within less than three miles (five kilometres) of the shore. The "landfall" is made at seventy and eighty nautical miles (125 to 145 kilometres), far within which distance the plateau of the bottom of the Pacific Ocean reaches the profound depth of 2 000 fathoms, or 3 660 metres. These bold and extraordinary features of the coast have compelled the Coast and Geodetic Survey to increase the breadth of its topographical work, and to carry it far enough inland to embrace the crestline of the immediate coast mountains as seen from seaward.

Through part of the mountainous country between the eastern line of the Rocky Mountains and the eastern flanks of the Sierra Nevada and the Cascade Mountains the climate is exceptionally dry, the temperature very high in summer and very low in winter, the sky generally cloudless and the land arid. You will therefore readily understand that throughout that section of the country, where elevations of 13 000 feet (3 965 metres) have to be occupied with large instruments commanding lines over 100 miles (160 kilometres) in length, and where no or very few roads exist, and the population is extremely sparse, the execution of the work is very severe upon officers, men, and animals; and the cost is relatively large. The mountains in that region are treeless; but on the Pacific coast the mountains north of 38½ degrees of latitude are covered with enormously large timber to their summits; and either large areas of this forest must be cleared at each station or very high observing structures must be erected.

Over this broad and many featured country the Coast and Geodetic Survey twenty years since connected the triangulation of the Atlantic coast with that of the Pacific by telegraphic longitude; and projected the transcontinental arc of the parallel to link the two schemes by a strong chain of triangles.

It would be impracticable and too tedious to place before you the mass of interesting and instructive materials which the progress of the Coast and Geodetic Survey has devoloped; or to speculate upon the magnitude and importance of the practical work which it sees ahead; and so I come back to the short and succinct memoranda which I have made upon the points which the Superintendent has briefly mentioned in his instructions.

If at any point I shall venture to express views that are open to differences of opinion, I beg that you will believe that I express them without bias, freely and independently, and with a sincere desire to correct my judgment.

I.—THE PLAN OF THE TRIANGULATION ALONG THE COASTS OF THE UNITED STATES.

Primarily the United States Coast Survey was organized by the Government for the survey of the coast, as its name clearly implies. This necessarily involved the obtaining of information to give the geographical positions of islands, headlands, anchorages, harbors, and dangers to navigation, the determination of the proper location and character of aids to navigation; the depth of water on the bars at the entrances to harbors and rivers, and the courses and depths of the rivers to the heads of navigation; the collection of data for the prediction of the tides, and for the course of currents. Then followed the publication of seacoast and harbor charts, and the later publication of "Coast Pilots," compiled from the charts, and gathered from the experience of the officers. These are some of the first legitimate results of such a scheme.

This principal object has been persistently and faithfully adhered to in the administration of the Survey, as is shown by the publication of many hundreds of charts, of lists of geographical positions, of "Methods and Results," of tide tables, of notices to mariners, and of the Coast Pilots; and of special correlated investigations.

Through such an extended seaboard as that of the United States it must be evident to you all that the most trustworthy results can only be obtained by the high character of the triangulation upon which the project is founded, and by the practical value and importance of the topography and hydrography.

In the execution of these correlated branches the material has necessarily been acquired for the measurement of arcs of the meridian in various sections of the coast. As the Survey developed, and as new territory was acquired, and new applications were found for the work, it was seen that larger schemes of triangulation would be necessary, both as a matter of economy and greater accuracy, and because they would furnish a higher and more extensive class of measures for Geodetic purposes. Every practical demand upon the service has been promptly met, and with increased efficiency. Whenever the Survey has shown to the Congress of the United States the advantages and the necessity for broader scope in its operation, it has received the attention and the active support of that august body.

II.—THE PLAN OF THE TRANSCONTINENTAL TRIANGULATION ON THE PARALLEL OF 39° NORTH.

This arc of the parallel will be more explicitly mentioned under the heading III. It was intended primarily to connect the schemes of the triangulations following the coast lines of the Atlantic and the Pacific seaboards. My earliest duties on the Pacific coast had been, among other things, the determination of the latitude and longitude of important headlands, islands, and harbors, before a continuous triangulation was feasible along a coast that had then more than 3 000 nautical miles (5 550 kilometres) of shoreline. The triangulation was in progress, but its execution was carried on in many localities where commerce demanded aids to navigation. Early in 1869 the telegraphic difference in longitude between San Francisco and the eastern triangulation was effected; and all the triangulations were subsequently connected. But as the principal triangulation on the Pacific expanded, the Superintendent decided to carry a line of triangulation as broad as possible across the continent. This would afford means and data to check important State boundaries, to afford standard lines and geographical positions for the use of the independently conducted State surveys; and would incidentally give the data for the measure of so long an arc. The Government approved of this scheme of triangulation, and has annually supported it by appropriations. The Pacific coast triangulations had been dependent upon base lines measured with secondary apparatus at each locality. This new departure demanded a higher class of base apparatus, and to-day the western end of the chain depends upon the measurement of the Yolo base line, which also serves for the expansion of the Pacific arc of the meridian to the north and to the south.

And probably it will be as well to introduce in this place the different operations which have been made at all the stations on the Pacific coast, and in the adjacent schemes. The stations so occupied number twenty-three from the Sierra Nevada westward, and fifteen or more to the eastward.

I present to the Association several "progress sketches" which are also regularly published in the annual reports of the Superintendent. On these are exhibited the lines observed, the base figures adjusted, the parts already reconnoitered, and the spaces yet unfinished. One of these sketches exhibits not only the western part of the chain of triangles, but the extension of the triangulation for the Pacific arc to the south and to the north. At all the stations of the main triangulation on the Pacific coast and extending eastward therefrom along the arc of the parallel of 39°, the observations comprise the following:

Horizontal directions.—These are made under all conditions of the atmosphere, when the signals can be seen with the telescope. No more than two sets of observations are made in any one morning or in an afternoon. Each set consists of an observation with the telescope and circle direct, and one with the telescope and circle reverse. For lines under 100 miles in length (160 kilometres), 46 observations have been made in twenty-three positions; and for lines over 100 miles in length, 69 sets of observations were made at the last stations. Two sets have heretofore been made in one position of the horizontal circle, but my experience dictates that hereafter only one set shall be made in one position, and the number of positions will necessarily be nearly doubled. In 1876 the method of using the ocular micrometer was introduced at Mount Diablo station, and the observations have been improved thereby. The theodolite circle is 20 inches or 50·8 centimetres in diameter, and is read by three microscope micrometers. The objective is 7·5 centimetres in diameter. The instrument rests upon a specially devised position circle which is cemented upon the stone or brick pier.

Azimuth observations.—The theodolite which is employed for the horizontal directions is also used for the determination of the azimuth of one of the lines of the triangulation, or upon a reference station that is usually 6 to 10 miles distant. The stars usually observed upon are α Ursæ Minoris and 4165 B. A. C. at opposite elongations, and as near elongation as practicable. The series generally includes observations before and observations after elongation. I have made the same number of observations at each base-line station as at all the other stations.

Latitude observations.—These are made with the Zenith telescope or with the Davidson Meridian Instrument according to the Talcott method, and generally embrace observations upon 25 to 30 pairs of stars through 7 to 10 nights. I have made the same number of observations at each base-line station as at all the others. The north polar distances of the stars are obtained from about thirty original authorities.

Observations for height.—Double zenith distances are measured upon the signals at all the other stations between the hours from noon to one or two o'clock in the afternoon. They are continued through as many days as practicable. The vertical circle is usually 12 inches (or 30 centimetres) in diameter.

Observations for magnetism.—Observations for intensity, dip, and declination are made with portable instruments upon three or more days at every station.

The *signals* used in this work are always heliotropes even for the base-line stations; and the area for the silvered glass is determined by formula for the distance observed, with an abitrary addition for a smoky and hazy atmosphere, as suggested by experience. These signals have been seen with the unassisted eye at distances to 160 miles or 256 kilometres. A curious optical feature of these images is the decomposition of the solar light into the spectrum red, white, and blue, or more rarely into red, yellow, and green, in lines that are over 60 or 70 miles in length, the intervening air acting as a prism.

At important stations in the main triangulation a *topographical survey* has been made so as to embrace an area of about 4 square miles around the station. In this survey the contours are drawn in for every 10 or 20 feet of vertical height.

All the foregoing operations are carried on simultaneously, and the observations of horizontal directions govern the time of the occupation of each station. The period of observation reaches 60 days when the stations are numerous and the distances great, and the principal drawback to progress is the very smoky atmosphere of summer in the Great Valley of California. This smoky atmosphere rises to an elevation of 8 000 feet (2 410 metres); and as the coast mountains reach from 3 900 to 7 000 feet (1 190 to 2 140 metres), the smoke necessarily lies in the line of sight.

The personnel of a party.—The largest number of persons at one of the Sierra Nevada stations when the party had to go through deep snow, and come out through deep and extensive snows, was as follows: Chief of party and three assistants, one packer, one cook, and five men. Six or eight pack animals. Hired wagons for general transportation where roads exist.

At each distant station which is observed upon there is one heliotroper, who cooks for himself. At some very difficult stations there are two heliotropers who relieve each other. A system of heliotrope signals is used to signify to the heliotroper the character of his work, when to change his direction to another station or for any of the usual movements of the party.

At the Round Top station of 1879 the party experienced a temperature below zero of Fahrenheit; wind that blew 100 miles (or 160 kilometres) per hour, and deep snows. When the observations were finished the party came out through snow drifts 24 feet (over 7 metres) deep; and the general depth was 6 feet or 2 metres for many miles. All the instruments and material had to be carried into and from this station for the last 800 feet (250 metres) of elevation.

In the occupation of Mount Conness in the Sierra Nevada next spring, my party will be forced through the snows of the Yosemite Valley, or possibly reach the station through the State of Nevada from the eastward. The height of this station is 13,000 feet, 4,000 metres.

Local deflection of the plumb line.—In these operations of the triangulation the observations of the latitude and azimuth have exhibited great irregularities in the local deflection of the plumb line at the various stations. In the meridian the range of deflection from the mean which has been adopted amounts to nearly seven seconds of arc plus and minus, and in the prime vertical to nearly the same amount. This has led to the adoption of provisionally standard geodetic data for a given station and for a given line; that is, a certain station has assigned to it a given latitude and longitude, which is very closely the means of all the stations reduced thereto, and the azimuth from that station to another given station is adopted as the true azimuth thereof. The direction of these deflections of the plumb line can sometimes be predicted from surrounding geological and orographical conditions, but in some cases, as on the Plains of Los Angeles, large deflection was found where none had been anticipated. In this connection I may say that the Superintendent has directed me to present to the Association twenty or more photographs which exhibit some of the physical features of the trigonometrical stations which have been occupied in the line of the Sierra Nevada by the party under my direction. Besides this they give proof of the frequent clearness of the atmosphere in showing sharply mountain outlines that were at least sixty miles (96 kilometres) distant. One of these exhibits a summer view of the Yosemite Valley through which the triangulation party will pass to Mount Conness.

III.—THE PRINCIPAL ARCS OF THE MERIDIAN AND OF THE PARALLEL THAT HAVE BEEN, OR WILL BE, DEVELOPED FROM THE COAST TRIANGULATIONS.

I shall enumerate these very briefly.

1. The *Nantucket arc of the meridian:* $3\frac{1}{8}^\circ$ have been finished, and it will be extended to 6°. It lies between $41^\circ\ 15'$ and $47^\circ\ 30'$.

2. The *Pamplico-Chesapeake arc of the meridian:* $4\frac{1}{2}^\circ$ have been finished, and it will be extended to $11\frac{1}{2}^\circ$ between the latitudes 35° and $46\frac{1}{2}^\circ$.

3. The *Lake Superior and Gulf of Mexico arc of the meridian:* $10^\circ\ 12'$ of this arc were executed before 1878 by the Corps of United States Engineers, and it will be extended by the Coast and Geodetic Survey to the Gulf of Mexico, making a total length of $18^\circ\ 35'$ between the latitudes $30^\circ\ 10'$ and $48^\circ\ 45'$.

4. The *Pacific arc of the meridian.* The triangulation has been executed from about latitude 39° to latitude 34°, and it will be extended through California, Oregon, and Washington to the boundary between the United States and British Columbia in latitude 49°; making a total of 15° within the limits of the United States. Northward of the United States it can be carried through British North America to the Arctic Ocean.

Within the limits of the United States this main triangulation is carried on between the Sierra Nevada or the Cascade Mountains on the east, and the Coast Range on the west, and involves lines of great length. The longest line yet observed has been 192 miles or 307 kilometres; and the longest reconnoitred is 244 miles or 390 kilometres. This great scheme was inaugurated to check and control the immediate triangulation of the coast that had much shorter sides, and was much impeded by the peculiarities of the rocky or forest-covered coast ranges which lie very close and parallel to each other.

As early as 1859 I made some observations upon the Sierra Nevada from the station Mount Tamalpais in the westernmost of the coast ranges. The distance was about 165 miles or 260 kilometres, and as I was already familiar with the relation of the coast ranges with the Cascade Range and the Sierra Nevada, I foresaw the development of a great scheme of triangulation to the north and south between these mountain ranges, with extraordinarily favorable opportunities for measuring base lines of almost any desired length in the nearly level plains of the Great Valley of California. Since then this scheme of triangulation has been carried out, and that of the transcontinental arc of the parallel includes and starts nearly from this Tamalpais station.

5. The *Oblique Arc of the Atlantic Coast* has been executed for a length of 17° 24′, and will be continued southwestward to the shore of the Gulf of Mexico, and northeastward to Cape Breton in the Dominion of Canada. The total length will be 20¾°, equal to 1 202 miles or 1 920 kilometres, and that small part to the northeast of Maine will necessarily be executed by Canada.

6. A *number of sub arcs* have been executed on different parts of our coasts. There are 19 of these, and they have an average length of 138 miles or 224 kilometres.

7. The *Great Central Arc of Longitude on the parallel of* 39°. It extends from Point Arena on the coast of California to Cape May on the Atlantic coast, and has a total length of 48¾° of longitude, equal to 2 628 statute miles or 4 230 kilometres. Thirty-four degrees of this arc have been executed in four sections. I have already stated that this great transcontinental arc was projected to connect the scheme of the triangulation on the Atlantic and Pacific coasts.

Along this line the telegraphic longitude observations are nearly completed, the geodetic levelings have progressed from the Atlantic to beyond the Missouri River, and the gravity determinations will be made systematically from ocean to ocean.

I need say little about the character of the triangulation upon this parallel. In some parts of the country it is made with difficulty on account of the heavy forests and the absence of prominent heights. There, and in other parts, the lines are necessarily shorter than is desirable, but base lines will be more numerous, and astronomical observations will be frequently repeated. From the eastern line of the Rocky Mountains to the Pacific Ocean the size of the triangles, quadrilaterals, and pentagons is sufficiently large for the highest character of work. As a general rule the atmospheric conditions are favorable, but the difficulties to be overcome in such an arid region, very sparsely populated, are extreme. It requires the utmost devotion and exertion to carry forward the work, and especially when a party is caught at a station from 10 000 to 13 000 feet elevation (3 050 to 3 965 metres) in the cold weather of the early winter.

The Association can learn the character of the work near the western extremity of this arc from the published accounts of the measurement of the Yolo base line and the treatment of the geometrical figures comprising "the Davidson quadrilaterals." As observers we are satisfied that we have gone beyond the best efforts of the instrument makers, and we now demand a higher class of instruments of precision—especially theodolites and base apparatus.

8. The *secondary arc of the parallel of* 42°. This arc was commenced by the Corps of United States Engineers, who executed nearly one half of it, and since 1878 it has been extended by the United States Coast and Geodetic Survey. It stretches from Cape Cod, in longitude 70° to longitude 88°, near Chicago, and is 17¾° in length; equal to 500 miles, or 800 kilometres. About two-thirds of the arc has been finished.

9. *Projected arc of the meridian. This great Central Arc of Latitude* extends from the southern boundary of British Columbia, in latitude 49°, to the boundary with Mexico, on the Rio Grande, in latitude 26°, through 23° of latitude. Its length within the territory of the United States is therefore 1 600 miles, or 2 560 kilometres. But it can be extended southward through Mexico to Point Sacrificios on the Pacific coast, in latitude 10°; and northward through British Columbia to the Arctic Ocean. It is projected, near the meridians of 98° and 99° west.

10. *It is proposed that two great Transcontinental Arcs of the Parallel* be hereafter measured, principally within the limits of the United States.

The *northern one* will extend through 60° of longitude, from Cape Disappointment, at the mouth of the Columbia River, in latitude 46° 10′ and longitude 124°, eastward to the Great Lakes, and thence through the Dominion of Canada to Cape Breton. This arc will cross the Pacific Coast arc of the meridian in longitude 120½°; the Great Central arc of longitude in 99° or 98°; the Lake Superior and

Gulf of Mexico arc in longitude 88°; the Pamplico-Chesapeake arc in longitude 76°; the Nantucket arc in longitude 70°; and it will reach the oblique arc of the Atlantic coast at Cape Breton, in longitude 64°. Its length will be about 2 850 statute miles, or 4 580 kilometres.

11. The *second proposed Transcontinental Arc of the Parallel* will extend through 38⅝° of longitude, from the southern extremity of the Island of San Clemente, on the Pacific coast, in latitude 32° 40′ and longitude 118¼°, wholly through the territory of the United States to the vicinity of Charleston, on the Atlantic coast, in longitude 79⅝° west. This arc will cross the projected Great Central arc of latitude in longitude 99° or 98°, the Lake Superior and Gulf of Mexico arc in longitude 88°, and the oblique arc of the Atlantic coast in longitude 85½° west. Its length will be about 2 200 statute miles, or 3 500 kilometres.

The Association will thus see that the Coast and Geodetic Survey of the United States has fairly comprehended the broad geodetic problems which the great area of the United States permits, and which the necessities of its commerce, its boundaries, its State surveys, and a hundred other legitimate objects demand. A résumé of the partial measurements of arcs already made shows 4 000 kilometres in the principal arcs of the meridian, 2 600 kilometres in sub-arcs of the meridian, and about 3 900 kilometres in arcs of the parallel.

IV.—THE CHARACTER OF THE WORK AS EXHIBITED IN THE PUBLICATIONS OF THE COAST AND GEODETIC SURVEY.

The publications of the Survey have not been so numerous as would seem desirable. There is a very large amount of material in the archives, but the publication of the practical results for the benefit of the industries of the country, or to answer the special demands of the Government, are always given the preference. I have brought to the Association for its acceptance a few pamphlets, which illustrate the manner in which the results are made more available than through the large annual reports of the Superintendent. The roll of charts intended for the Association has not reached me. I was anxious to present some of the later charts of the Pacific coast, because on those which exhibit the harbors and their approaches the old style of hachuring has been abandoned, and the contours of vertical heights have been given with more satisfaction to the navigator, and certainly with more definite information to the engineer, civil and military. Such a plan is not feasible along the low and sandy shores southward of New York, but it is particularly satisfying on the bold shores of the Pacific coast.

The *practical character of the work* is shown in the publication of the Coast Pilots. Those of the Atlantic coasts have been developed to extreme details, because the surveys have been complete for the parts of the coasts described. On the Pacific coast the first edition of my Coast Pilot of California, Oregon, and Washington was published when the surveys of the whole coast had been in operation but seven years. Necessarily a different type of description was adopted, that dealt largely in generalities, which were fortified so far as practicable with details of special localities. During the last forty years these generalities have largely given place to details, and the fourth edition of this Coast Pilot, with many illustrations, brings to date the data and the experiences of that period.

The *scope of the publications* of the Coast and Geodetic Survey is seen in the descriptions of total solar eclipses observed by its officers; in the observations of the Transits of Venus in 1874 and 1882; in the recovery of the French station of the Transit of Venus of 1769 at San José del Cabo, in Lower California; in the research upon the first landing place of Columbus; in the examination of the voyages of Ulloa, Cabrillo, Ferrelo, Vizcaino, and Drake on the Pacific coast between the years 1539 and 1603; in the report upon the irrigation systems of India, Egypt, and Italy.

All these works and very many others have been incidental to or directly connected with the practical work of the Survey.

V.—THE MANNER OF MEASURING THE BASE LINES OF THE TRIANGULATION AND THE SPECIAL DIFFICULTIES TO BE OVERCOME IN A NEW COUNTRY.

The first base line for the U. S. Coast Survey was measured by Ferdinand R. Hassler, who was the first Superintendent of the Coast Survey. He used four 2-metre steel bars placed in line, and this he designated as one, using two microscopes to mark the ends of each measure of this quadruple system.

The next apparatus was a compensation apparatus of steel and brass, devised by Superintendent Bache who used the Bessel lever of contact in the measures. With this apparatus the base lines on the Atlantic and Gulf coasts, except the first base line, were measured, and were generally 5 or 6 miles long (8 or 10 kilometres).

On the Pacific coast when transportation was very difficult and costly, the prices of labor excessively great, and the demands for immediate practical results, imperative, local base lines of 2 to 6 miles in length (3 to 10 kilometres) were measured with secondary apparatus of various characters.

After the schemes of triangulation had largely developed, and the transcontinental arc of the parallel had been commenced, the present apparatus of Assistant Schott (composed of steel and zinc bars, very nearly compensated and using the slide contact) was sent to the Pacific coast in 1881 for the measurement of the Yolo base line of 17 486 metres.

I had chosen the location of this line because it was one side of the first quadrilateral leading through three quadrilaterals to the line Mount Diablo–Mount Helena in the Coast Range; whence another quadrilateral stretched across the Great Valley of California to the Sierra Nevada with lines from 117 miles to 142 miles (189 to 229 kilometres) in length.

The base line passed over several water courses nearly at right angles; through ploughed fields and across country roads. It should be particularly borne in mind that, while the Survey receives the support of all the State Governments, it can not enter any man's property without his consent, so that we are thrown very much upon the good will of the proprietors and the tenants of the lands crossed. It is therefore a consideration to disturb as little as possible the actual surface of the ground. We can only put a temporary gate in the fence surrounding any property by consent of the owner, and by paying for any damages incurred. Moreover the expense of properly grading so long a line would be excessive in a country where wages are exceedingly high.

Therefore in measuring these bases all these matters must largely govern the choice and decision of the officer in charge of the selection and measurement.

In the Yolo base line I decided to do no grading except in one or two places where the surface presented some abrupt change. From what I have read of the descriptions of the base lines in Europe, the conditions of the surface are wholly distinct. On the Yolo base line there was one place where the surface of the "adobe" (a tough clay soil) was so deeply and generally cracked by shrinkage that it required some judgment to properly place the plates for the tripods to rest upon.

It happened on this line that there was no grade to exceed five degrees, and the largest inclination was near the northwest end.

In the measurement of the Los Angeles base there were greater surface difficulties to be overcome. For more than one-half the distance the land was in its natural condition; it had never been ploughed, and had innumerable irregularities. It was covered with large tussocks of stiff grasses which were the only obstructions removed; it was cut across by several deep sloughs, and it crossed two railroads diagonally. Only in four or five places was the spade used to cut through a sand hillock or a clayey mound, to fill in a water way or to lessen the abrupt change to another water way.

We prepared it at the beginning of the rainy season, and when the first measurement was being made we were compelled to stop operations on account of heavy rains; when the weather cleared we found the apparatus bogged in a broad shallow basin of clayey soil.

These and other practical difficulties were sometimes almost disheartening, and they, together with the character of the apparatus, decided me to measure the bases not less than twice, and three times if the appropriations would permit.

The manner of measuring the base is simple and may be exemplified by a condensed record of a day's work. Early in the morning the two field bars used in the measurement are compared with the "field standard bar"; the adjustments of the sectors and of the aligning telescopes are examined. The first bar is placed in line and the after end adjusted over the base mark or the mark of the previous day. The second bar is brought into line and the after end is raised or lowered to the height of the forward end of the back bar; the Borda scales and the thermometers and the sector are read after the bar and tripods have been slightly tapped to relieve any undue strain in the supports; contact is made under slight magnifying power and the after bar withdrawn and carried forward.

The measures proceed under a movable canvas cover carried by a framework mounted on four wheels; this cover is 51 feet long, and the officers and the men who carry the bars, and those who handle the foot plates and the tripods are the only ones admitted within this cover which four men move forward. In crossing water courses the bars are carried on a central wooden structure firmly built in the line and wholly distinct from the footways upon which the wheels of the movable cover run, and upon which the men handle the apparatus.

At certain times during the day, before and after crossing the railroads or especially difficult places, at the half kilometre stones and at evening, the end of the forward bar is transferred by a transit sector to a proper mark fixed in a heavy piece of stone sunk to the surface of the ground. The apparatus is under charge of a watchman at night.

The tripods supporting each bar are strong wooden ones shod with heavy brass points, and weigh 35 pounds each; the iron plates upon which they rest, and which are well fixed on the surface of the ground, weigh a little over 9 pounds.

Each bar with its beam and covering weighs 162 pounds and is handled by two men.

After all the men become familiar with the *modus operandi*, there arises among them an ambition not only to make no mistakes, but to execute the measures as rapidly as practicable. This spirit is fostered not only for the economy involved, but because I believe it is best to allow the bar to remain upon such supports through the least possible time.

The whole line of the Yolo base was subdivided by kilometre stations marked on copper bolts in heavy granite blocks sunk below the surface of the ground, and also by similar marks placed under all the fences which were encountered.

The Los Angeles base line was subdivided by half kilometre stations marked as in the Yolo base. On both base lines each measurement was referred to all the kilometres, fence, and half kilometre stations.

I need not mention the rapidity with which the Los Angeles and Yolo base lines were measured, because I believe the Association has received from the Superintendent of the Survey a preliminary report on the subject. The number of officers employed in the actual measurement was three; the number of employés, excluding the watchman and extra driver, but including the four men, moving the movable cover, was eleven.

I would, however, ask your patience still longer while making a few remarks upon the precautions I have taken to get the best possible results from this apparatus, and to express an opinion upon some other form of bar.

Having had serious doubts about the use of two metals, such as steel and zinc, as a Borda thermometer, and although the apparatus was furnished with very sensitive thermometers, I was induced from my experience in the Yolo base measurement to incase the outside wooden case and iron beam of the Standard field bar with blankets, boiler felting, and canvas, to the thickness of about three quarters of an inch, say 2 centimetres. In the measurement of the Los Angeles base line the measuring bars were similarly incased; and the result has been that the change of temperature through the additional covering has been very slow. Sometimes the change of the temperature of the outside atmosphere has not exhibited itself in the thermometer for 2½ hours.

With this experience I believe in thoroughly incasing the base bar in a non conducting material, and in performing all the operations of comparison and measurement at such times and under such cover as I have used. I would use a single hollow metal bar of steel or platinum with sensitive thermometers placed as experiment directed; or, perhaps still better, I would have this hollow metal bar filled with mercury with proper appliances that should indicate the mean temperature of the bar. Difficulties present themselves to the practical application of this idea, but it is possible they may be overcome. I should determine by preliminary experiment whether to use two bars with the slide contact and moderate magnifying power, or one bar with the traces and the necessary microscopes.

If one bar and the microscopes proved satisfactory, I should then propose to the Superintendent of the Survey to permit me to measure a short base line of about 1 000 metres twice with the apparatus of the Yolo and Los Angeles base lines, and twice with the single bar and microscopes, using a line where the surface features of the ground would be nearly like what we have already worked over and may expect to work over. By such comparative tests a fair criterion would be afforded of the relative value of the two systems in accuracy and cost.

These are some of the suggestions which my experience has forced upon me, for in my judgment we have not yet reached the best apparatus nor the best method.

I would like to mention here that in selecting the location of the Los Angeles base line I prescribed that it should be one side of a quadrilateral lying to the southwest, and of another quadrilateral lying to the southeast, and that all the stations of those two figures should be intervisible. Such are the conditions which now surround this base line; and I am very sorry that I brought no tracing of the scheme to exhibit to the Association, but I will have a drawing made and forwarded to the permanent secretary, Dr. Hirsch.

VI.—THE PLAN OF THE TELEGRAPHIC LONGITUDE WORK, WITH THE MAIN LINES OF THE LATEST WORK EXHIBITED THEREON.

It is contemplated to cover the whole country with a complete and checked system of telegraphic longitudes. The more recent operations have looked to the completion of the network across the continent in the parallel of 39°, and to a connection with the triangulation stations of the transcontinental arc of the parallel. There remain but a few stations to be occupied to complete this part of the great scheme. I present a rough plan which exhibits the lines finished and in progress since 1884, the date of the last adjustment of the Computing Division of the Survey.

VII.—THE SCHEME OF THE TRANSCONTINENTAL LEVELING AND THE CONNECTION OF THE ATLANTIC OCEAN, THE GULF OF MEXICO, AND THE PACIFIC OCEAN.

I present a chart which exhibits the lines that were leveled by the U. S. Corps of Engineers before 1878, and those that have been leveled by the U. S. Coast and Geodetic Survey. On the Atlantic coast the lines start from two stations in New York, one from Annapolis in the northern part of Chesapeake Bay, and one from the southern part at Fortress Monroe; another is to start from Cape Henlopen, at the entrance to Delaware Bay. These lines, with their proper checks to be introduced, have been joined in Maryland, and then one line has been continued westward to Jefferson City about half way between the Mississippi River and the Missouri in longitude 92⅓°.

This line will be intersected by two lines from Mobile and New Orleans on the Gulf of Mexico. A short line from the Atlantic to the Gulf will cross the northern part of the peninsula of Florida from Fernandina to Cedar Keys. For many years the Coast and Geodetic Survey has maintained self registering tide gauges at important ports on the Atlantic and Gulf coasts, and also on the Pacific coast from San Diego to Alaska. In time these will all be connected.

VIII.—THE TRANSCONTINENTAL LINE OF GRAVITY DETERMINATIONS FROM PENDULUM EXPERIMENTS.

The publication of the Gravity determinations has been much retarded, but I present herewith several pamphlets of Methods and Results. The scheme has not been thoroughly systematic heretofore, and the stations already occupied are shown by green circles on the charts of the Transcontinental Leveling and the Telegraphic Longitude.

It is now proposed to carry a line of gravity stations along the course of the transcontinental arc of the parallel of 39°.

IX.—THE RELATION OF THE TRANSCONTINENTAL TRIANGULATION, TELEGRAPHIC LONGITUDE, LEVELING, AND GRAVITY MEASURES.

This subject need only be stated to satisfy the Association that the Coast and Geodetic Survey has fully comprehended the importance of the combination of the thoroughly practical uses of the work and the higher use of the material which it is gathering to determine the figure of the earth. In the progress and development of the work similar combinations will be effected in all the arcs of the meridian and the parallel.

X.—THE INVESTIGATIONS FOR THE COEFFICIENT OF ATMOSPHERIC REFRACTION.

These were undertaken in California between two seacoast stations, Mount Ross and Bodega Head, in 1859; between two stations, Mount Diablo and Martinez, on the eastern flank of the coast range of mountains, in 1880; and in the interior between Round Top and Jackson stations, on the western flank of the Sierra Nevada, in 1879. In this series the lowest station is about 100 feet, or 33 metres, above the level of the sea, and the highest station is 10 600 feet, or 3 230 metres. The observations comprise the measure of simultaneous and reciprocal zenith distances every hour, for as many as twelve days and nights on the Mount Diablo–Martinez line; observations of the barometer; observations of the temperature of boiling water; and spirit levelings repeated. The results at Mount Ross-Bodega and Mount Diablo–Martinez have been published; and those of Mount Diablo are herewith presented to the Association.

XI.—THE INVESTIGATIONS IN MAGNETISM THAT HAVE BEEN MADE THROUGHOUT THE WHOLE COUNTRY; AND WHICH REACH INTO MEXICO AND INTO ALASKA AS FAR AS THE ARCTIC OCEAN.

They have been carried on for forty-five years, and while the observations have been particularly full on the seacoasts, yet special expeditions have been made into Mexico, the Northwest Territories, and the southern and western part of Alaska. Between the years 1850 and 1889 the maximum easterly variation of the magnetic needle has been reached along the Pacific seaboard from 49° to 23°, except in the region of San Francisco, latitude 37° 47′, where the indications point to the epoch 1893–'95 as the time of the maximum 16° 35′.

The deductions from all these observations combined with the measures of other observers have been graphically exhibited for a given epoch upon the map of the United States, of which a copy is presented. The practical value of the deductions in these investigations is seen in the numerous and important calls made for the variation of the magnetic needle at given epochs when the early surveys of the country were made almost wholly by compass courses and distances.

Except where special expeditions have been fitted out, the magnetic observations are made by the triangulation parties during the occupation of a station, and never interfere with or prolong the regular work. In the transportation of a party for long distances, as in the earlier geographical expeditions to Alaska, and in the present movement of the parties to the Yukon and Porcupine Rivers, advantage is taken of every stoppage to obtain magnetic as well as astronomical observations. Two magnetic observatories have been maintained by the Survey where the records of the different instruments are made by photography.

I present herewith a chart exhibiting the isogonic lines for the epoch January, 1885, within the limits of the United States.

XII.—THE HYDROGRAPHIC WORK ON THE SEABOARDS AND THE DEEP-SEA INVESTIGATIONS.

For the use of the navigator, the depths of the water along the coast are usually carried to moderately deep soundings. The distances from shore are increased as the immediate demands of close shore work are filled. The Atlantic and Gulf seacoast depths differ wholly from those along the Pacific coast at the same distances. A broad submarine plateau exists off the eastern coast; on the Pacific coast there is no such plateau. The depths reach 2 000 fathoms in a distance of fifty or sixty miles off the California coast, and the coast mountains attain an elevation of 5 000 feet within less than three miles of the sea. On the Atlantic and Gulf seaboards the hydrographic work is well advanced, and more attention is permitted to the investigation of currents and the study of bar formations.

As far back as 1845 the Superintendent of the Survey instituted investigations in the off-shore waters of the Atlantic seaboard, in order to embrace the whole of the course of the Gulf Stream. The work has been continuously carried on, and has led to the examination and study of the waters of the Gulf of Mexico. The methods and means of deep-sea investigation have been thereby thoroughly developed by the officers of the United States Navy who execute this work under the direction of the Superintendent. The breadth, velocity, and direction of the currents of the Gulf Stream and the temperature of the water are determined for the surface and for different depths; they are also measured for different times of the year and for different years. The temperature and movement of the adjacent colder waters are determined with equal care. In connection with these practical problems the Survey has materially aided the investigation and study of the deep sea flora and fauna, as shown in the earlier work of the elder Agassiz and of Pourtales; and in the later work of Alexander Agassiz detailed in his "Three Cruises of the Blake."

On the Pacific coast the hydrographic surveys have developed some curious features along the seaboard. To this date no less than eleven submarine valleys of great depth, narrow, with very steeply inclined sides have been discovered, heading directly and very close in to the shore. In some instances these submarine valleys head directly upon the low sandy shores, as off Point Hueneme in the Santa Barbara Channel, off Monterey Bay and other locations. In other instances they head directly on the shore under bold mountains that reach as much as 4 256 feet (1 300 metres) elevation within a few miles. These latter examples are principally under the coast range near Cape Mendocino, about latitude 40°. These curious features have a practical importance as affecting the current immediately under the shores; they may affect the position of the vessel, and their great depths may mislead the navigator who approaches the coast in foggy weather and depends upon his dead reckoning and soundings. They have another value to the geologist as affording data in the study of the rise and subsidence of the coast; and to the naturalist in the distribution of the fauna along the immediate seaboard.

The investigation and study of littoral currents, and of the currents at the mouths of rivers and the entrances of bays and harbors, has occupied the continued attention of the Survey not only for the purposes of the navigator, but to suggest improvements in channels and the best form and location of jetties and breakwaters.

XIII.—TIDAL STATIONS; SELF-REGISTERING TIDE GAUGES.

I have already mentioned that long series of tidal observations have been continued at important locations on the Atlantic and Gulf of Mexico coasts. On the Pacific coast these self-registering tide gauges have been in operation for about 36 years. At San Diego on the south and at Astoria on the north, observations were continued without any important break for more than 20 years; at Port Townsend and at St. Paul, Kadiak Island, Alaska, for shorter periods. At the Golden Gate of San Francisco the self-registering gauge has been recording the tides for about 35 years, and the station is still maintained. The transcontinental line of levelings will be referred to the bench-marks of this gauge.

Besides these gauges the Survey has at different times established self-registering gauges at Mazatlan, under the direction of a Mexican engineer officer, and at Cape San Lucas, the southern point of Lower California. Between these principal stations numerous secondary stations have been established, where observations have been carried on through two or more lunations.

From the discussion of the observations at the primary or continuous stations the prediction of the tides is practicable, and tables are now published annually giving the times and heights of every high and low water throughout the year for the principal ports, with constants to apply thereto for obtaining the times and heights at all intermediate ports.

One of the incidental records upon the self-registering gauges is that of the earthquake waves which reach the shores of the Pacific coast from great earthquakes in distant parts of the world; such as that at Krakatoa, when the San Francisco record showed some profound disturbance long before the locality or the event was otherwise known.

XIV.—ALASKA.

The shore line of the coast of Alaska, including the islands and the great sounds, amounts to not less than 26 000 statute miles, or 41 600 kilometres. The first explorations by the Coast and Geodetic Survey were made by my parties in 1867 and 1869, and a Coast Pilot was published in the latter year. Within the last ten years Congress has made appropriations for the survey of those interior channels of the Archipelago Alexander, which are traversed by the United States mail steamers and other vessels. The shores are rocky, high, very forbidding, and covered with a dense forest of large trees to the water's edge. There is no plain in this Archipelago, although it has mainland and island shore lines amounting to nearly 8 000 miles, or 12 800 kilometres. There is no opportunity whatever for a base line so far as very extensive examinations have been made. And yet, novel devices have been adopted, so that a preliminary triangulation and survey of the shores is being executed as a basis for the necessary hydrographic surveys. Every year a Coast Survey steam vessel, under the command of naval officers attached to the Survey, has been pushing the surveys with vigor to answer the pressing demands of commerce. The longitudes have been determined by differences from Port Townsend, Washington, and from the primary station of 1867 and 1869 at Sitka. Latitude observations are made with the Davidson meridian instrument by the Talcott method. Most of the channels are extremely deep, the currents are strong, and the unseen dangers to navigation very numerous. Seasons of good weather are uncommon, and, therefore, astronomical observations are difficult.

With further appropriations from Congress, it is expected that preliminary surveys will be carried up the river courses to establish points on the boundary line between southeastern Alaska and British Columbia. These surveys and explorations may probably develop the feasibility of measuring some base line, whence a triangulation can be carried among the high peaks of the almost innumerable islands, and thence through the different channels.

I recall no country where the peculiarities of the high islands densely wooded, and the deep channels with rocky shores, and the wet and cloudy climate, conspire so completely to retard geodetic progress.

This concludes the summary which I have written since the Conference of October 2, and I shall now present briefly the suggestions which the Superintendent has made in his instructions:

(1) The Superintendent directs me *to call attention to the advisability of a remeasurement of the Peruvian arc.*

There are probably not two opinions concerning the weakness of this arc, on account of its peculiar location and the fewness of the astronomical determinations. We believe the arc should be remeasured with all the resources and skill of the present day, and that France should, within a reasonable period, undertake this duty.

I understand that at the coming meeting of the Delegates from the American States, at Washington, the subject-matter of the remeasurement of this base, or the measurement of another base nearer the level of the sea, and not so surrounded by great mountains, will be brought to the consideration of the Delegates. Information will then be solicited about the practicability of measuring a new arc of 5° or 6° in length near the equator in British Guiana. It is, perhaps, premature to say what country or countries should measure this arc if it be practicable.

(2) The Superintendent instructs me to express the view of the Coast and Geodetic Survey as *adverse to the use of Ferro for the initial longitude of some of the maps in the reports of the Association*, because it can have no real scientific weight. He hopes that the adoption of the prime meridian will be in accordance with the decision of the International Conference at Washington.

The Coast and Geodetic Survey has no partisan feeling in this matter whatever, and is simply anticipating by a few years what will very probably become universal at the end of the century.

GEORGE DAVIDSON,
Assistant, U. S. Coast and Geodetic Survey.

PARIS, *October* 8, 1889.

APPENDIX No. 18—1890.

HISTORICAL ACCOUNT OF UNITED STATES STANDARDS OF WEIGHTS AND MEASURES, CUSTOMARY AND METRIC; OF THE INCEPTION AND CONSTRUCTION OF THE NATIONAL PROTOTYPES OF THE METRE AND THE KILOGRAMME; OF THEIR TRANSPORTATION FROM PARIS TO WASHINGTON; OF THEIR OFFICIAL OPENING AND CERTIFICATION, AND OF THEIR DEPOSIT IN THE OFFICE OF WEIGHTS AND MEASURES.

Compiled by O. H. TITTMANN, Assistant, in charge of the Office of Weights and Measures.

It is the purpose of this paper to give a history of the new National Prototypes of the Metre and Kilogramme recently received by the United States, and to preface it with a brief account of the Weights and Measures in customary use in this country.

The Constitution empowers Congress to "fix the standard of weights and measures," but it will presently be seen that while Congress has from time to time considered the subject, it has not deemed it expedient to enact much legislation in regard to it.

Washington, in his message to the First Congress, said: "Uniformity in the currency, weights, and measures of the United States is an object of great importance, and will, I am persuaded, be duly attended to." Acting upon this suggestion the House of Representatives referred the matter to Jefferson, who was then Secretary of State, for a report, and in July, 1790, he submitted two plans, one of which proposed to define and render uniform the existing system; the other "to reduce every branch to the decimal ratio already established for coins, and thus bring the calculation of the principal affairs of life within the arithmetic of every man who can multiply and divide."

While this report was under consideration it became known that the National Assembly of France was taking steps which should lead to uniformity in the weights and measures of commercial nations, and in view of this fact the Senate Committee, to whom Jefferson's propositions were referred, reported that since "a coincidence of regulation on so interesting a subject would be desirable, your Committee are of opinion that it would not be eligible at present to introduce any alteration in the measures and weights which are now used in the United States."

Washington, in his opening address to the Second Congress, again urged the necessity for action, and a committee reported in 1792 in favor of Jefferson's second plan. Notwithstanding this report, and although various committees were appointed, no legislation followed.

After the war of 1812 the subject was again taken up in compliance with an urgent appeal of President Madison. The Senate, as in the case of Jefferson, referred the matter for a report to the Secretary of State, John Quincy Adams, who, after much study, made his well-known report, at the conclusion of which he submitted his plan, which was:

(1) To fix the standard with the partial uniformity of which it is susceptible, for the present excluding all innovation.

(2) To consult with foreign nations for the future and ultimate establishment of universal and permanent uniformity.

As before, no legislation resulted, and in consequence the weights and measures lawful in Great Britain during our colonial period remain in customary use in this country.

While Congress was considering this matter, the executive branch of the Government acquired certain standards, among them a platinum kilogramme and metre of the same material, procured by Albert Gallatin in 1821; the Troughton 82-inch brass scale ordered by Hassler for the use of the Survey of the Coast in 1814, and a troy pound procured by Gallatin in 1827 for the use of the United States Mint.

However much confusion might be tolerated in the weights and measures used for commercial transactions it was found necessary to legalize some particular weight for the uses of the Mint, and this was done by act of Congress, May 19, 1828, in the following language:

For the purpose of securing a due conformity in weight of the coins of the United States to the provisions of this title, the brass troy pound weight procured by the Minister of the United States at London in the year eighteen hundred and twenty-seven, for the use of the Mint and now in custody of the Mint at Philadelphia, shall be the Standard Troy Pound of the Mint of the United States, conformably to which the coinage thereof shall be regulated.

This weight was sent to the United States in charge of a special messenger, and was by him deposited with Mr. Samuel Moore, Director of the Mint at Philadelphia, in September, 1827. Here it was retained without opening the casket in which it was transmitted, until the arrival of President John Quincy Adams, on October 12 of the same year, whose certificate and the others given below lend authenticity to the weight.

CERTIFICATE OF PRESIDENT JOHN QUINCY ADAMS IN RELATION TO THE OPENING OF THE CASKET CONTAINING THE BRASS TROY POUND OBTAINED BY MR. GALLATIN FOR THE UNITED STATES.

Be it known, That on the twelfth day of October, one thousand eight hundred and twenty-seven, in the city of Philadelphia, the Director of the Mint of the United States exhibited before me, John Quincy Adams, President of the United States, a box or casket, enveloped in a paper covering, sealed with five seals, and bearing the following endorsement and address, viz: On one side as follows:

On public service
Legation of the United
States of America
at London,
Albert Gallatin.
A Copy of the British
Standard Troy pound.

And on the opposite side as follows:

To
Samuel Moore, Esqr.,
Director of the Mint of
the United States,
Philadelphia.
By
Mr. Cucheval.

That the impression on the seals aforesaid was recognized as that of the private seal of Albert Gallatin, Minister of the United States at London; that the above-recited indorsement and address were recognized as being in his handwriting; that at the same time were also exhibited two Certificates, hereto annexed, each bearing the seal of the Legation of the United States of America to Great Britain; one signed Henry Kater, dated the 30th of June, 1827, and the other dated July 24, 1827, signed by and in the handwriting of Albert Gallatin, Minister of the United States, as therein recited. That the Director of the Mint did affirm that the aforesaid certificates and box or casket, purporting to contain the Troy pound to which they relate, had been delivered to him on the sixth of September *ultimo*, in Philadelphia, by the hands, as he then supposed and then verily believed, of Mr. Cucheval, named on the envelope as aforesaid, who stated that he had received the same from the hands of Mr. Gallatin at London, in the order in which they were thus delivered; that the Director of the Mint did further affirm that the said box or casket had remained in his possession sealed, with its contents and envelope undisturbed in every particular, from the date of its delivery aforesaid until thus exhibited.

The aforesaid box or casket being thereupon carefully opened in my presence, was found to contain a brass weight, in good preservation, and, apparently, in every particular, in the same state as when first inclosed therein, having thereon the figure or impression of a Crown, and the following inscription:

Pound Troy
1824.
Bate. London

Which Brass Weight I therefore confidently believe to be the identical copy of the "Imperial Standard Troy Pound" of Great Britain, intended and referred to in the aforesaid annexed certificate of Henry Kater and Albert Gallatin.

JOHN QUINCY ADAMS. [SEAL.]

PHILADELPHIA, *October* 13, 1827.

CERTIFICATE OF CAPT. HENRY KATER IN RELATION TO DETERMINATION OF THE VALUE OF THE NEW BRASS TROY POUND FOR THE UNITED STATES.

{ Seal of the Legation of the United States of America to Great Britain. }

In delivering to Mr. Gallatin a copy of the Imperial Troy pound for the Government of the United States of America, I feel that so important a document ought to be accompanied by an account of the manner in which it was prepared.

The Balance used on this occasion was made by Mr. Robinson, and is of a similar construction to that which I employed in adjusting the new standards of weight for the United Kingdom. The beam is 10 inches long, and the delicacy of the instrument is such that, with a pound in each scale, the index moves through two divisions (equal to nearly two-tenths of an inch) by the addition of one-hundredth of a grain: each division of the scale may be readily subdivided by the eye to tenths.

Mr. Gallatin having procured from the House of Commons the Imperial Troy pound of 1758, it was placed in one of the scale pans and counterpoised by a brass weight. When the extent of the vibrations made by the index did not exceed one or two divisions, the mean was taken and registered as the point of rest. The Imperial pound was then removed and the copy being substituted, the mean of the extent of the vibrations was again taken and registered, and so on alternately. In some of the comparisons the balance was allowed to attain a state of rest. I may here remark that the time of one complete vibration, or of the index returning to the same point, was more than two minutes.

The first rude trials not registered showed that the copy (which had not been finally adjusted by the maker) was more than 0·22 grain in defect. Two wires, one of 0·2 grain, and another of 0·02 grain, were inclosed in the weight and the following comparisons made.

The signs prefixed to the divisions indicated that the weight examined exceeded or fell short of the counterpoise, the latter being taken as zero:

Date.	Imperial Troy Pound of 1758.	Copy.	Difference.
	Divisions.	Divisions.	Divisions.
June 28, 1827	+ 0·60	− 1·62	− 2·22
	+ 0·75	− 1·20	− 1·95
	+ 0·95	− 0·70	− 1·65
	+ 0·30	− 0·90	− 2·20
June 29, 1827	+ 0·80	− 0·80	− 1·60
	+ 0·90	− 0·70	− 1·60
	+ 0·90	− 0·75	− 1·65
	+ 0·90	− 0·75	− 1·65

Mean − 1·81 = − 0·009 grain, by which the copy was lighter than the original.

I now inclosed a third wire equal to one-hundredth of a grain in the copy and proceeded to make the following comparisons:

Date.	Imperial Troy Pound of 1758.	Copy.	Difference.
	Divisions.	Divisions.	Divisions.
June 30, 1827	+ 1·05	+ 0·50	− 0·55
	+ 0·10	+ 0·30	+ 0·20
	+ 0·15	+ 0·75	+ 0·60
	0·00	+ 0·60	+ 0·60
	+ 0·40	+ 0·70	+ 0·30
	+ 0·30	+ 1·00	+ 0·70

Mean + 0·31 = + 0·00155 grain.

From the above comparisons it appears that the copy exceeds the original ·0015 of a grain, an error so minute that I have not attempted to rectify it.

It may be seen that the greatest difference between the comparisons in the first table is 0·62 of a division, or ·0031 of a grain; and in the second table 1·25 division, or ·0062 of a grain.

The copy of the Imperial Troy Pound which I have the honor to deliver to Mr. Gallatin may therefore be considered as exceeding the original ·0015 of a grain, without the probability of material error.

HENRY KATER.

YORK GATE REGENT'S PARK, LONDON, *June* 30, 1827.

CERTIFICATE OF THE HONORABLE ALBERT GALLATIN, ENVOY EXTRAORDINARY AND MINISTER PLENIPOTENTIARY OF THE UNITED STATES TO GREAT BRITAIN IN RELATION TO THE BRASS TROY POUND PROCURED BY HIM FOR THE UNITED STATES.

The undersigned, Envoy Extraordinary and Minister Plenipotentiary of the United States of America to His Britannic Majesty, does hereby certify that the signature to the annexed statement is that of Capt. Henry Kater, F. R. S., etc.; the same gentleman who has compared and adjusted the several standards of British weights and measures deposited at the Exchequer, Westminster, at Guildhall, London, at Edinburgh and at Dublin; that the brass troy pound, procured for the Mint of the United States, herewith transmitted, and which is that alluded to in Captain Kater's annexed report was, by order of the undersigned, constructed by Mr. Bate, the same artist who had prepared the above-mentioned standards of British weights; that Captain Kater, with great kindness and from public considerations, undertook, at the request of the undersigned, to compare it with the troy pound of the year 1758, in the custody of the Clerk of the House of Commons, which by Act of Parliament has been declared the original Unit or only standard measure of weight in the British dominions, and which was, on the application of the undersigned, confided to Captain Kater's care for that purpose; that the said brass troy pound, procured for the Mint of the United States, was thus compared and adjusted by Captain Kater with his usual scrupulous attention, in the manner stated in his annexed report, by the same method which had been used in comparing and adjusting the above-mentioned standards of British weights, and with a balance, or beam, made by Mr. Robinson, the same artist who had made that used in comparing the said British standards; and that there is every reason to believe that the said brass troy pound, procured for the Mint of the United States and herewith transmitted, does not, as thus adjusted, differ more than one five-hundredth part of a grain from the above-mentioned troy pound of 1758, which now is by law the "Imperial Standard Troy Pound" of Great Britain.

In witness whereof the undersigned has signed this certificate and affixed thereunto the seal of this Legation. Done at London this 24th day of July in the year of our Lord one thousand eight hundred and twenty-seven.

ALBERT GALLATIN.

{ Seal of the Legation of the United States of America to Great Britain. }

From the preceding record it appears that the Troy pound of the Mint was adjusted in 1827, with a high degree of accuracy to the British Troy Pound of 1758, which became the Imperial standard of weight after May 1, 1825.

This Imperial standard and the standard yard of Great Britain were destroyed by fire in 1834, and new standards were constructed about 1844. Certain copies of the Imperial Troy pound of 1758 were used to derive the new Imperial standard of weight, which is an Avoirdupois pound containing 7 000 of such grains, of which the lost standard contained 5 760.

The history of national legislation in this country in regard to weights and measures may be resumed with the passage of a resolution by the Senate, May 29, 1830, directing the Secretary of the Treasury to cause a comparison to be made of the standards of weight and measure used at the principal custom-houses in the United States and to report to the Senate at its next session. Conformably to this resolution comparisons were instituted, and large discrepancies were disclosed in the weights and measures in use.

By virtue of the general powers vested in it, and in execution of the Constitutional provision that the duties, imposts, and excises shall be uniform throughout the United States, the Treasury Department reported to Congress, as the outcome of the comparisons, that it had adopted the Troughton scale as the unit of length and the Troy pound of the Mint as the unit of weight from which the Avoirdupois Pound was to be derived, so that the ratio of its weight to that of the Troy pound should be as 7 000 is to 5 760.

For liquid measure the Wine Gallon of 231 cubic inches, and for dry measure the Winchester Bushel of 2 150·42 inches, according to the standard of the English Yard referred to in the report of the Department of March 3, 1831.

In June, 1836, Congress passed the following resolution:

That the Secretary of the Treasury be and he hereby is directed to cause a complete set of all the weights and measures adopted as standards, and now either made or in the progress of manufacture for the use of the several customs-houses and for other purposes, to be delivered to the Governor of each State in the Union, or such person as he may appoint, for the use of the States respectively, to the end that a uniform standard of weights and measures may be established throughout the Union.

No other legislation than that cited in the foregoing pages has been passed in regard to our customary measures. Its bearing on particular representatives of the units of length, weight, and capacity can now be recapitulated under the respective headings referring to them.

CUSTOMARY LENGTH MEASURE.

There is no difference between the customary unit of length of the United States and of Great Britain.

The Treasury Department adopted the yard comprised between the twenty-seventh and sixty-third-inch divisions of the Troughton Scale as its yard. This was supposed to be equal to the British yard, but had never been directly compared with it. It was assumed to be standard at 62° F. until indirect comparisons between it and the present Imperial Standard proved it to be too long by 0·00083 inch at that temperature. Comparisons have shown it to be equal to the Imperial Standard at 59·6° F.

It has already been stated that the British standard of length was destroyed by fire in 1834. A new standard, known as the Imperial Yard, was constructed, under the direction of the Committee of 1843, by reference to accredited copies of the one destroyed.

When the new Imperial Standard was constructed, about fifty additional copies were made and compared with the former. Two of these copies, known respectively as Low Moor Iron No. 57 and Bronze No. 11, were presented to the United States, and were received in 1856. The true length of the Troughton-scale yard was derived from comparisons with these.

No. 11 and No. 57 were taken to England and again compared directly with the Imperial Standard between 1876 and 1888, and their relation to the latter is known with the highest degree of accuracy attainable. Recourse is had to these yards whenever great precision is required; the Troughton scale being unsuitable for a standard on account of its form and on account of the coarseness of its defining lines.

CUSTOMARY STANDARD OF WEIGHT.

The Troy pound of the Mint has been declared by Act of Congress to be the standard according to which the coinage of the United States shall be regulated.

The Avoirdupois pound adopted by the Treasury Department was derived from the Mint Troy pound. As the densities of these weights are not known, and as they are made of brass, a material which oxidizes readily under atmospheric influences, they are not suitable for standards of precision.

The Troy pound from which our Avoirdupois pound was derived is a copy of the lost Imperial Standard of 1758, and since the present Imperial Standard was derived from the same standard, it may be inferred that there is no difference between the Avoirdupois pound of the United States and that of Great Britain.

The British Imperial Standard of weight is the Avoirdupois pound, a platinum mass, standard in vacuo.

The British Commercial pound is an ideal pound, having the same mass as the Imperial Standard, but of such a density that its proper proportional part, $\frac{5760}{7000}$, would exactly counterpoise the lost Standard of 1758 in air of a definite buoyancy.

When the present Imperial Standard was constructed, certain secondary standards of weight were also made, and one of them, known as No. 5, was presented to the United States in 1856. Upon its receipt comparisons were made between it and the Treasury Standard, which gave an outstanding difference between the latter and the British commercial pound of only about one one-thousandth of a grain.

CAPACITY MEASURES.

The capacity measures adopted by the Treasury Department are the wine gallon of 231 cubic inches and the Winchester bushel of 2150·42 cubic inches, which were lawful standards before the separation of the Colonies from Great Britain.

The gallon and bushel measures and their subdivisions, constructed under the Act of Congress already cited, have their standard capacity at the temperature at which water has its maximum density, that is, at 3·93° C. = 39·07° F. Owing to the difficulty of obtaining accurately the interior dimensions of a vessel by linear measurements, capacity measures are standardized by determining the weight of distilled water they will contain when full. From the known weight of a definite volume of distilled water at a given temperature the contents can then be computed.

WEIGHTS AND MEASURES FOR AGRICULTURAL COLLEGES.

As a matter of interest, but without any special bearing on the subject of Standards, the following joint resolution, passed March 3, 1881, may here be quoted:

JOINT RESOLUTION authorizing the Secretary of the Treasury to furnish States, for the use of Agricultural Colleges, one set of standard weights and measures, and for other purposes.

Resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That the Secretary of the Treasury be, and he is hereby, directed to cause a complete set of all the weights and measures adopted as standards to be delivered to the Governor of each State of the Union, for the use of agricultural colleges in the States, respectively, which have received a grant of lands from the United States, and also one set of the same for the use of the Smithsonian Institution: *Provided* That the cost of each set shall not exceed two hundred dollars; and a sum sufficient to carry out the provisions of this resolution is hereby appropriated out of any money in the Treasury not otherwise appropriated.

In accordance with this resolution, under the direction of this Office, sets of customary weights and measures were constructed and distributed. Each set comprised a yard scale, Avoirdupois weights, and dry and liquid measures of capacity.

METRIC STANDARDS.

As the result of much public agitation, and on the direct recommendation of a Committee of Congress, which submitted an elaborate report, and of which Hon. John A. Kasson was chairman, Congress passed the following act on July 28, 1866:

AN ACT to authorize the use of the Metric System of Weights and Measures.

Be it enacted by the Senate and House of Representatives of the United States in Congress assembled, That from and after the passage of this act it shall be lawful throughout the United States of America to employ the weights and measures of the metric system, and no contract or dealing, or pleading in any court, shall be deemed invalid or liable to objection because the weights or measures expressed or referred to therein are weights or measures of the metric system.

SEC. 2. *And be it further enacted,* That the tables in the schedule hereto annexed shall be recognized in the construction of contracts, and in all legal proceedings, as establishing, in terms of the weights and measures now in use in the United States, the equivalents of the weights and measures expressed therein in terms of the metric system; and said tables may be lawfully used for computing, determining, and expressing, in customary weights and measures the weights and measures of the metric system.

Measures of length.

Metric denominations and values.		Equivalents in denominations in use.	
Myriametre	10 000 metres.	6·2137	miles.
Kilometre	1 000 metres.	0·62137	mile, or 3,280 feet 10 inches.
Hectometre	100 metres.	328	feet 1 inch.
Decametre	10 metres.	393·7	inches.
Metre	1 metre.	39·37	inches.
Decimetre	1-10 of a metre.	3·937	inches.
Centimetre	1-100 of a metre.	0·3937	inch.
Millimetre	1-1000 of a metre.	0·0394	inch.

Measures of capacity.

Metric denominations and values.			Equivalents in denominations in use.	
Names.	Number of litres.	Cubic measure.	Dry measure.	Liquid or wine measure.
Kilolitre or stere	1 000	1 cubic metre	1·308 cubic yards	264·17 gallons.
Hectolitre	100	1-10 of a cubic metre	2 bushels and 3.35 pecks	26·417 gallons.
Decalitre	10	10 cubic decimetres	9·08 quarts	2·6417 gallons.
Litre	1	1 cubic decimetre	0·908 quart	1·0567 quarts.
Decilitre	1-10	1-10 of a cubic decimetre	6·1022 cubic inches	0·845 gill.
Centilitre	1-100	10 cubic centimetres	0·6102 cubic inch	0·338 fluid ounces.
Millilitre	1-1000	1 cubic centimetre	0·061 cubic inch	0·27 fluid drams.

Measures of surface.

Metric denominations and values.		Equivalents in denominations in use.
Hectare	10 000 square metres.	2·471 acres.
Are	100 square metres.	119·6 square yards.
Centare	1 square metre.	1 550 square inches.

Weights.

Metric denominations and values.			Equivalents in denominations in use.
Names.	Number of grammes.	Weight of what quantity of water at maximum density.	Avoirdupois weight.
Millier or tonneau	1 000 000	1 cubic metre	2 204·6 pounds.
Quintal	100 000	1 hectolitre	220·46 pounds.
Myriagramme	10 000	10 litres	22·046 pounds.
Kilogramme or kilo	1 000	1 litre	2·2046 pounds.
Hectogramme	100	1 decalitre	3·5274 ounces.
Decagramme	10	10 cubic centimetres	0·3527 ounce.
Gramme	1	1 cubic centimetre	15·432 grains.
Decigramme	1-10	1-10 of a cubic centimetre	1·5432 grains.
Centigramme	1-100	10 cubic millimetres	0·1543 grain.
Milligramme	1-1000	1 cubic millimetre	0·0154 grain.

Approved July 28, 1866.

To enable the States to procure metric standards of weights and measures, the following Joint Resolution was approved July 27, 1866:

JOINT RESOLUTION to enable the Secretary of the Treasury to furnish each State one set of the standard weights and measures of the Metric System.

Be it resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That the Secretary of the Treasury be, and he is hereby, authorized and directed to furnish to each State, to be delivered to the Governor thereof, one set of standard weights and measures of the Metric system for the use of the States respectively.

The following is a list of the standards constructed by this Office and furnished to the States.

Length: One Metre, end measure.
One Metre, line measure, divided.

Weight: One Kilogramme.
One Demi-Kilogramme.
One Gramme, with subdivisions.
One ten Kilogramme.

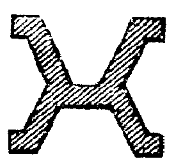
Capacity: One Litre.
One Decalitre.

It will be noticed that, as in the case of the customary standards of length and weight, Congress did not specify any particular material representatives of the Metre and Kilogramme. The standards made for distribution were therefore constructed to represent, as closely as could be determined at the time, the length and mass, respectively, of the legal Metre of France, known as the *Mètre des Archives,* and that of the legal Kilogramme of France, known as the *Kilogramme des Archives.*

In 1866 the copies of the legal French standards in use in different countries differed among themselves, and their relation to their prototypes was not known with a degree of precision in keeping with the requirements of science; and the standards of the Archives themselves, made in the latter part of the last century, were not constructed with the degree of perfection attainable in modern times.

These considerations, and the spread of the metric system, induced the Government of France to invite the Governments of the world to send delegates to Paris for the purpose of forming an International Commission, having for its object the construction of a new Metre as an International Standard of length. In response to this invitation Prof. Joseph Henry and Mr. J. E. Hilgard were appointed by the President scientific delegates, without diplomatic functions, to represent the United States. A first meeting was held at Paris in August, 1870, but, owing to the existing political complications in Europe, little was done until the second meeting, in 1872, when a general plan was outlined and definite propositions as to the mode of procedure to attain the objects in view were adopted. The most important of these propositions were to make the International Metre a line measure, whose length at 0° C. should be equal to that of the *Mètre des Archives*, and to make the mass of the Kilogramme equal to the mass of the *Kilogramme des Archives* in its actual state, and to use for the material of the standards an alloy of platinum iridium containing 10 per cent. of iridium, with a tolerance of 2 per cent. in excess or deficiency.

The cross-section of the metre bars was also decided upon. It is that proposed by M. Tresca, and is that which was ultimately given to the prototypes. It is shown in the accompanying figure.



The shape adopted for the Kilogramme is that of a cylinder, whose height is equal to its diameter, and having slightly rounded edges.

On May 20, 1875, a metric convention was signed at Paris by the representatives of seventeen Governments, among them that of the United States, for the purpose of establishing and maintaining, at the common expense, a scientific and permanent International Bureau of Weights and Measures near Paris. By this treaty, the operations of the International Bureau are put under the exclusive direction and supervision of an International Committee, which latter is under the control of a General Conference composed of delegates from all the contracting governments. According to "Article 6" of the convention, the International Bureau of Weights and Measures is charged with—

(1) All comparisons and verifications of the new prototypes of the metre and kilogramme.

(2) The custody of the International Prototypes.

(3) The periodical comparison of the National Standards with the International Prototypes and with their test copies, as well as the comparison of Standard thermometers.

(4) The comparison of the prototypes with the fundamental standards of non-metrical weights and measures used in different countries for scientific purposes.

(5) The standardizing of and comparison of geodetic measuring bars.

(6) The comparison of standards and scales of precision, the verification of which may be requested by Governments or scientific societies, or even by constructors or men of science.

On the basis of this convention the International Bureau was organized and established in the Pavillon de Breteuil, in Sèvres, near Paris.

Before its establishment, however, the International Commission began its labors by making preliminary studies of the questions involved, and the Committee charged with the construction of the prototypes prepared an ingot weighing 250 kilogrammes of platinum iridium, known as the alloy of 1874. This did not meet the requirements established by the Commission as to the purity of material, nevertheless several bars were prepared of this alloy and one of them is in the possession of this Government. The bars made of this alloy, however, form a separate group from the International and National Prototypes, the construction of which will now be briefly described: The alloy was prepared by Messrs. Johnson, Mathey & Co., of London, in the following manner: Finely powdered platinum and iridium were weighed in the prescribed proportions and were thoroughly mixed in quantities of 10 kilogrammes at a time. Each of these quantities was compressed into a cake and heated to red heat in a covered platinum crucible. Each cake was then put in a furnace of pure lime and melted in an oxyhydrogen flame; the alloy was then poured into molds also made of pure lime. The ingots thus obtained were cleaned with dilute hydrochloric acid and washed in distilled boiling water. They were then put into a muffle furnace. The interior of the muffle was lined with thick sheets of platinum and was heated with the vapor of one of the heavier hydrocarbon oils (*huile lourde*), burning in compressed air, according to the method of Sainte-Clair Deville. The heat thus obtained was constant, and the interior of the muffle was freed from dust and consequently from iron. The ingots, having been first heated to the temperature of melting gold, were forged under a powerful trip hammer, and after each forging the hammer and anvil of polished steel were carefully cleaned with leather and powdered lime. The metal was then passed between oiled and polished steel cylinders so as to reduce it to plates about 2 millimetres thick. Each plate was cut into three parts, which were cleaned in a solution of boiling caustic soda and treated with dilute hydrochloric acid. Notwithstanding all the precautions taken during the forging, the plates were discolored by oxide of iron. To remove this they were kept in contact during five hours with potassium bisulphate in a state of fusion in a covered platinum vessel.

Specimens of each plate were sent to Paris and Brussels for analysis. From the beginning it was required that the alloy should be remelted three times in order that it should become perfectly homogeneous. The chemists of the International Committee and of the French section having found the metal satisfactory after the second casting, the third casting was made on May 26, 1884, with perfect success in a large furnace of pure lime containing the whole mass (65 kilogrammes).

The metal thus obtained was heated with oxyhydrogen gas in a furnace specially constructed for this purpose of blocks of lime. When the surface began to melt, it was removed and put under a trip hammer and forged into a rectangular bar 52 centimetres long, 7 centimetres thick. This bar was in turn heated in a muffle lined with pure platinum with vapor of "huile lourde," into which air had been forced. It was then rolled between steel cylinders which transformed it into a cylindrical bar 200 centimetres long and 44 millimetres in diameter. At this stage new specimens were taken from the bar and analysed. The analyses showed it to be free from ruthenium and from iridium in a free state, that the rhodium present was well within the limits of the prescribed tolerance, and that the proportion of iron present was less than $\frac{277}{10000000}$. The bar was then cut into 40 cylinders, and each one being inclosed in a collar was then subjected twelve times to a pressure of 360 tons. They were then sent to Paris.

The metal for the metre bars was prepared in about the same way. After two meltings, the mass was divided into five lots. These having been examined and found pure and homogeneous were each divided into three parts. These were then arranged in groups made up from each of the five lots, melted together and cast into ingots each of which contained sufficient material for one standard. The bars after having been forged were passed between rollers until they assumed approximately the shape desired. They were then put upon a specially devised planing machine which gave them their final shape. The work of straightening the bars, making the edges sharp and the neutral surface plane, as well as cutting the bars to the required length, was intrusted to Messrs. Brunner Brothers, in Paris, who finished their part of the work in 1886 and 1887.

The defining lines were then traced on the bars at the Conservatoire des Arts et Metiérs. Small surfaces near each end of the bar were highly polished and on these the lines were ruled. Three lines nearly 0·5 millimetre apart are traced near each end, the distance between the middle lines of each group being the lines which define the metre.

COEFFICIENT OF EXPANSION OF THE METRE BARS.

The necessity of adopting a thermometric scale presented itself at the outset to the International Committee, and very elaborate and successful thermometric studies were made, as the result of which the indications of mercurial glass thermometers can be made strictly comparable.

In October, 1887, the International Commission adopted a standard centigrade thermometric scale based on the expansion of hydrogen under certain definite conditions.

General formulæ were developed for reducing the indications of mercurial thermometers made of certain kinds of glass to this standard scale.

The coefficient of expansion of the bars was determined relatively to the coefficient of one bar whose expansion had been determined by absolute measurement of its increase in length, with increasing temperatures. The coefficient thus determined was verified by determining the expansion of small sections of the metal cut from the ends of the bar when it was being reduced to its standard length. This method is based on the measurement of the displacement of interference fringes of light, produced between two plane surfaces by their diffierential expansions.

The coefficients of the several bars were found to be nearly identical.

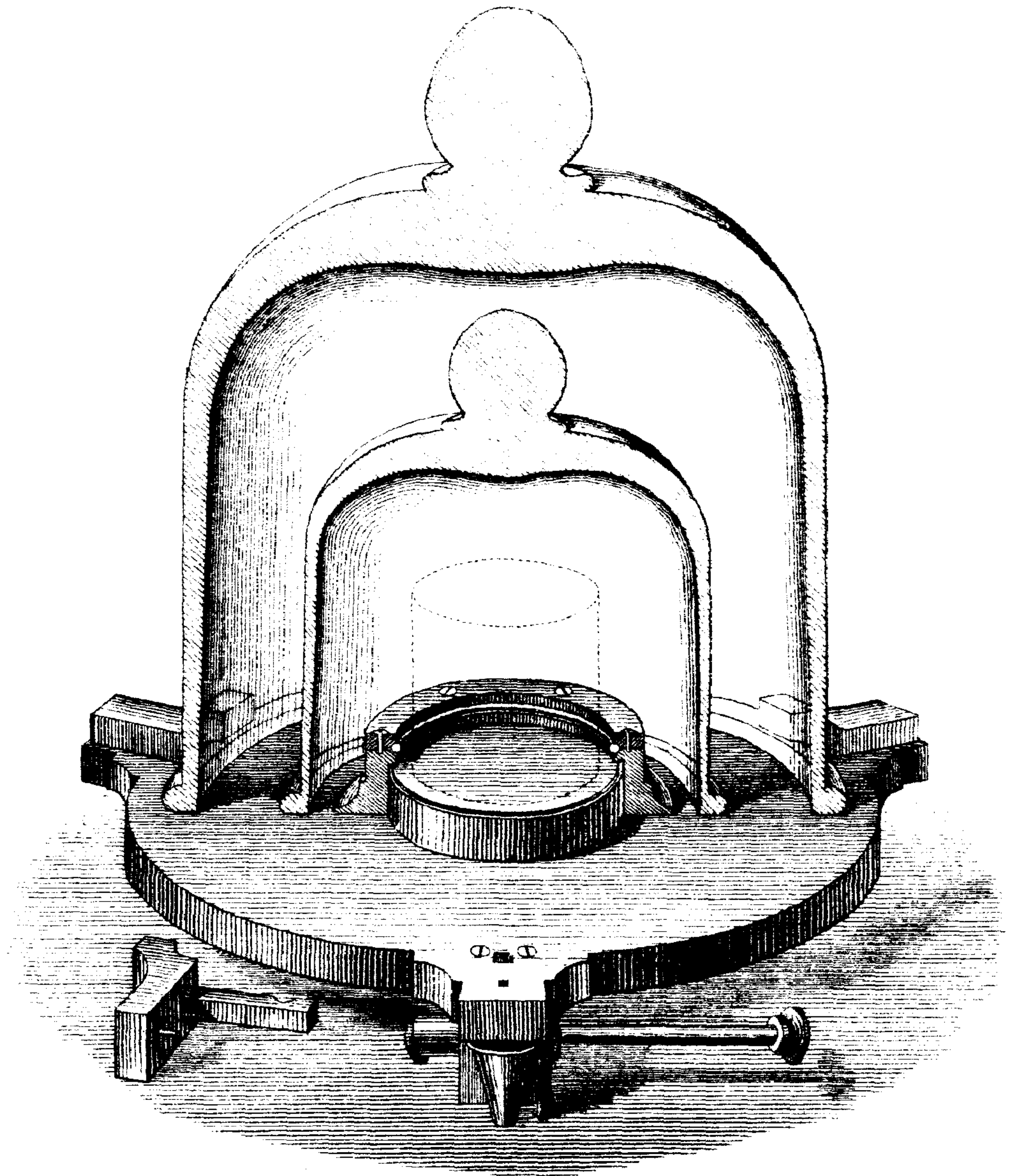
The bars were also examined for the purpose of determining their coefficient of elasticity, and this was found equal to about 19700 $\frac{\mathrm{Kg}}{\mathrm{mm}^2}$

The thirty-one prototype bars were then all compared with each other and with an auxiliary bar whose length in terms of the Mètre des Archives had been carefully determined.

After the comparison had been made, one bar, the length of which at 0° C was found equal to that of the Mètre des Archives, was selected for the International Prototype. The other bars being intended for distribution to the various Governments are called National Prototypes, and their relation to the International Prototype is known with the highest degree of accuracy attainable. The degree of accuracy may be inferred from the estimate placed upon it by the International Committee. The probable error of comparison of the National Prototypes with the International Mètre was found from the observation to be $\pm$ 0·04 μ, where μ stands for micron, or the one-millionth part of a metre.

Taking into account the uncertainties in the coefficient of expansion and other sources of error, it is estimated that the probable uncertainty in the lengths at temperatures between 20° and 25° centigrade lies between $\pm$ 0·1 μ and $\pm$ 0·2 μ.

The success with which the plans for the construction of the prototype metres were carried out is stated by the International Committee, in general terms, to have been such that among the new prototypes three or four had so nearly the true length of the metre that it was almost a matter of indifference which of these should be selected as the International Prototype. Exactly one-half of the prototypes were longer, the other half shorter, than this length, and the mean length of all is found to be exactly equal to the length striven for. The difference on one side or the other from this mean length was rarely as large as one-half of the prescribed tolerance of error, and in most cases it fell considerably below.



SUPPORT AND BELL-GLASSES

FOR

NATIONAL PROTOTYPE KILOGRAMME No. 20.

(The Standard Kilogramme occupies the space indicated by the dotted lines.)

CONSTRUCTION OF THE KILOGRAMMES.

The method by which the metal was prepared has already been described. The densities of the several Kilogrammes were carefully determined by hydrostatic weighings.

After they had been intercompared they were compared with the International Prototype, the weighings being made on a balance constructed for comparisons in vacuo, but the weighings were made in air, because it could be done with much greater ease, and because the densities of the Kilogrammes were so nearly alike that the minute correction for buoyancy of air could be applied without sensible error. The balance was so constructed that the necessary manipulation could, by certain mechanical appliances, be made by the observer at a distance of about 4 metres from the balance.

One of the Kilogrammes with which all the others were compared has become the *International Kilogramme*, and it is preserved at the International Bureau together with the Prototype Metre.

The accuracy of the comparisons was such that the relation of any one of these Kilogrammes to the International Prototype was determined to within less than the one-hundredth part of a milligramme. When the construction of the metric prototypes had been completed, a General Conference was convened in Paris in September, 1889, and by it the labors of the Commission were approved and the prototypes finally accepted. The distribution was effected by lot, and those apportioned to the United States were—

Metres Nos. 21 and 27.
Kilogrammes Nos. 4 and 20.

Each of the metres is accompanied by small sections of the bars, cut off when the bars were being reduced to the required length, and by two mercurial thermometers, the errors and constants of which were carefully determined by the International Bureau. They are made of "verre dur," and are numbered respectively 4331, 4332, 4333, 4334, 4335, and 4336, the last two belonging to Metre No. 12 of the alloy of 1874, previously referred to.

The standards having been accepted were packed and sealed under the direction of the United States delegate, Dr. B. A. Gould, a copy of whose report is appended, and were transfered to the care of Mr. Whitelaw Reid, the United States Minister to Paris. From him Metre No. 27 and Kilogramme No. 20, and also Metre No. 12 of the alloy of 1874, were received by Prof. George Davidson, Assistant, United States Coast and Geodetic Survey, by whom they were brought to Washington and deposited in the Office of Weights and Measures. The care with which they were transported is attested by one of the appended documents.

On January 2, 1890, Metre No. 27 and Kilogramme No. 20 were carried to the Cabinet room in the Executive Mansion, where the ceremony of breaking the seals upon the boxes was performed in the presence of the President of the United States, the Secretary of State, and the Secretary of the Treasury, together with a distinguished company of scientific men. A formal certificate declaring the condition of these standards at the opening of the boxes was signed by the President and witnessed by the Secretary of State and the Secretary of the Treasury. A somewhat similar certificate was signed by the other gentlemen present. In consequence of this official act of the President of the United States, Metre No. 27 and Kilogramme No. 20, will be guarded as our National Prototype Metre and Kilogramme.

The Metre No. 21 and Kilogramme No. 4 belonging to the United States, which, at the request of the United States Minister, remained deposited at the International Bureau of Weights and Measures in Paris, were brought to Washington by Mr. O. H. Tittmann, Assistant, U. S. Coast and Geodetic Survey, whose report on their safe transportation is appended. All these standards are now deposited in the fireproof standards room of the United States Office of Weights and Measures. Each metre is inclosed in a wooden case lined with velvet, and this in turn fits into a cylindrical brass tube. The manner in which the Kilogrammes are kept is shown in the plate (illustration No. 68) and requires no description. The Kilogrammes rest immediately on a quartz plate of about the same diameter as the standard. The whole support is covered by two glass bells which exclude all dust.

The relation between the National Metric Prototypes and the International is given by the following equations:

Length:

Metre No. $27 = 1\,\mathrm{m} - 1{\cdot}6\mu + 8{\cdot}657\mu\, T + 0{\cdot}00100\mu\, T^2$.
Metre No. $21 = 1\,\mathrm{m} + 2{\cdot}5\mu + 8{\cdot}665\mu\, T + 0{\cdot}00100\mu\, T^2$.

Mass:

Kilogramme No. 20=1 Kg−0·039 mg.
Kilogramme No. 4=1 Kg−0·075 mg.

Metre of the alloy of 1874:

Metre No. $12 = 1\,\mathrm{m} + 3{\cdot}3\mu + 8{\cdot}634\mu\, T + 0{\cdot}00100\mu\, T^2$.

Further details will be found in the appended certificates.

REPORT OF DR. B. A. GOULD, DELEGATE FROM THE UNITED STATES TO THE INTERNATIONAL CONFERENCE OF WEIGHTS AND MEASURES, HELD AT PARIS, SEPTEMBER, 1889.

CAMBRIDGE, MASS., *October* 16, 1889.

SIR: I have the honor to report that my mission, as delegate to the International Conference of Weights and Measures has been fulfilled, and that the standards have been disposed of in conformity with the instructions given in your letter of August 24.

Deferring accounts of the proceedings of the International Committee and of the General Conference for subsequent communication, I beg leave to report at this earliest opportunity the disposition made of the prototypes of the Metre and Kilogramme.

The standards prepared by the Committee were submitted to the General Conference, together with a detailed report of the work of the Committee, and an account of the standards constructed under their direction and supervision; as also of the results of the several comparisons between these, and the selection of those which are to serve as the international or fundamental prototypes. This report, in printed form, has been transmitted to the United States Government, in the usual way, through the Legation at Paris.

The work and results of the International Committee received the unanimous indorsement and sanction of the Conference, and on the 26th of September, the International Prototypes of the Metre and Kilogramme were formally adopted. Thereupon they were deposited in the subterranean chamber constructed for the purpose, and the door was secured by three locks, the keys of which were respectively given to the Superintendent of the Archives of France, to the President of the Committee, and to the Director of the Bureau, as provided by article 18 of the "Reglement" annexed to the "Convention du Mètre" of May 20, 1875.

With each of the International Prototypes were deposited two other and similar standards which had been compared with them with the same care as that bestowed upon the National Prototypes prepared for distribution

The assignment of the National Prototypes to the several States was determined by lot.

The number of metre prototypes was thirty, twenty-seven of which were thus distributed. Those falling to the United States bear the numbers 21 and 27.

Four metre standards had been constructed and compared, made from the "alloy of 1874." Of these the United States had called for one, and that assigned by lot to their share bears the number 12.

The Kilogramme Prototypes falling to the share of the United States are those numbered 4 and 20.

The length of the metre standards received by this country is as follows:

For the two Prototypes,

No. 21 equals $1\,\mathrm{m} + 2{\cdot}5\mu + 8{\cdot}665\mu\,\mathrm{T} + 0{\cdot}001\mu\,\mathrm{T}^2$
No. 27 equals $1\,\mathrm{m} - 1{\cdot}6\mu + 8{\cdot}657\mu\,\mathrm{T} + 0{\cdot}001\mu\,\mathrm{T}^2$

For the standard from alloy of 1874,

$$\text{No. 12 equals } 1\text{m} + 3{\cdot}3\mu + 8{\cdot}634\mu\, T + 0{\cdot}001\mu\, T^2$$

in which equations μ denotes a micron or thousandth part of a millimetre, and T represents the number of degrees of the Centigrade scale of the hydrogen thermometer.

The mass, or weight at normal altitude, of the two kilogramme prototypes is as follows:

No. 4 equals 1kg — 0·075mg, its volume being 46·418ml.
No. 20 equals 1kg — 0·030mg, its volume being 46·402ml.

It may not be amiss to add here that the probable error of a comparison of the metre bars does not exceed two-tenths of a micron, and that of a comparison of the kilogramme prototypes does not exceed five-thousandths of a milligramme.

The three metre standards and the two kilogramme standards above mentioned, were officially accepted in behalf of the United States, by the undersigned, using the form herewith inclosed* and marked "A." This was then exchanged for a second receipt given by the Director of the Bureau in the form of which a copy is likewise inclosed,* marked "B." By this the Director engaged himself to take the same care of these standards as in the past and to hold them subject to the order of the undersigned.

On the 28th of September I again personally examined each of the five prototypes, according to the instructions of the Honorable Secretary, and satisfied myself that they were in perfect order for safe transportation, and arranged in conformity with the rules established for the purpose by the International Committee. After closing the inner cases I placed my personal seal upon each in such manner that they can not be opened without breaking the seals. This is a Gothic letter, 𝔊, surmounted by a crest, and the same as that used for the envelope of this report.

The cases containing the metre prototype No. 27, and standard No. 12, and the kilogramme prototype No. 20, were then carefully packed at the Bureau under my own supervision, and the same seal was placed over two of the screws with which the lid of each box is fastened. These were then delivered to the Minister of the United States, Mr. Reid, who took personal charge of them, giving me his official receipt therefor, and conveying them to the Legation in his own carriage.

The other two prototypes, viz, Metre No. 21, and Kilogramme No. 4, remained deposited at the International Bureau, after having received the seal of the United States Legation. The previous receipt from the Director of the Bureau was then exchanged for a similar one by which they were held subject to the order of the Minister of the United States, who then relieved me from further responsibility by giving me his official receipt for these also.

Instructions for the transportation, unpacking, and safe keeping of the prototypes have been prepared by the International Committee, and printed copies will be given to persons to whom their transportation is intrusted. A copy of these "Indications" is herewith inclosed,* and gives detailed instructions as to the manner in which the cases should be opened and their contents withdrawn.

Boxes similar to those containing the Kilogramme prototypes, but specially marked, accompany each of these, and contain the bell glasses under which the Kilogrammes are to be kept after removing them from the metallic covers which are to protect them during transportation. But inasmuch as it is desirable that the metallic covers be used only during travel the Kilogramme No. 4, now at the Bureau, will remain for the present under its double bell glass. Consequently it will be necessary to break the seals when it is prepared for transportation.

With each metre bar is inclosed a small piece of the same metal, cut from the end of the bar previous to its graduation. And in the boxes containing the bell glasses for each Kilogramme is a package containing the ring which is to support them, and the plate of rock crystal upon which the prototype is to rest. Finally, a small case is sent containing the pincers to be used in handling the prototype.

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* Omitted.

The thermometers belonging to the metre bars do not accompany them, having been already called for and transmitted to Washington.

Hoping that in all these matters of detail my action may meet with the approval of the Department, I have the honor to be, sir,

Very respectfully, yours,

B. A. GOULD.

The SECRETARY OF STATE.

PROTOTYPES OF THE STANDARD METRE AND KILOGRAMME OF THE "BUREAU INTERNATIONAL DES POIDS ET MESURES."

Report of Assistant GEORGE DAVIDSON upon delivering one set of these prototypes to Prof. T. C. MENDENHALL, Superintendent United States Coast and Geodetic Survey and Weights and Measures.

OFFICE OF THE U. S. COAST AND GEODETIC SURVEY
AND OF WEIGHTS AND MEASURES,
Washington, November 27, 1889.

SIR: In compliance with your instructions of September 10, 1889, which directed me to receive from the Minister of the United States to France one set of the prototypes of the Standard Metre and Kilogramme of the "Bureau International des Poids et Mesures" and to bear them to you, I hereby report that on the 27th day of October, 1889, I received from Hon. Whitelaw Reid, Minister of the United States at Paris, the boxes containing the prototypes referred to, and have brought them with the utmost care to this office, where I now deliver them to you.

The boxes containing these prototypes were, when received by me, sealed and marked as described in Exhibit A. Upon each box I placed the paper seals of the U. S. Coast and Geodetic Survey and an address to identify them.

These invaluable instruments of precision have received no shock or rough treatment whatever while in my charge; they have not been subjected to other vibration than what is incidental to carriage, railroad, and steamship travel, and even then they have been carried on cushions or rugs; and they have not passed through a greater estimated range of temperature than from 55 to 85° or 90° of F.

In more detail of the dates and circumstances of my receiving and transporting these prototypes from Paris to Washington I have drawn up some memoranda (Exhibit A), which I append as part of the history of the instruments.

Very respectfully yours,

GEORGE DAVIDSON,
Assistant, U. S. Coast and Geodetic Survey.

Prof. T. C. MENDENHALL,
Superintendent Coast and Geodetic Survey and Weights and Measures.

EXHIBIT A.

[Memoranda to accompany the letter of George Davidson, Assistant, when delivering the prototypes 12 and 27 of the Standard Metre and the prototype 20 of the Standard Kilogramme to Prof. T. C. Mendenhall, Superintendent U. S. Coast and Geodetic Survey and Weights and Measures, at Washington, November 27, 1889.]

On the 24th of September, 1889, when attending the Ninth General Conference of the "Association Géodésique Internationale" at Paris, I received a letter of instructions from Prof. T. C. Mendenhall, Superintendent U. S. Coast and Geodetic Survey and Weights and Measures, dated September 10, 1889, together with his letter of September 13, and the letter of Hon. W. Windom, Secretary of the Treasury of the United States, dated September 12, 1889.

These letters show that the Honorable Secretary of State had been requested by the Honorable Secretary of the Treasury, upon the recommendation of Superintendent Mendenhall, to issue the necessary instructions to Hon. Whitelaw Reid, Minister of the United States to France, to deliver to me one set of the National prototypes of the Standard Metre and Kilogramme of the "Bureau International des Poids et Mesures;" and the instructions of the Superintendent direct and empower me to receive the same from him, and to carry and deliver them at Washington.

I presented copies of the three letters to the Minister of the United States and conferred with him about the transfer. He had attended one conference of the "Conférence Générale des Poids et Mesures," and at the next conference he would receive one set of prototypes and hold them until I was ready to start for the United States.

I verbally communicated the fact of my appointment as bearer to Dr. B. A. Gould, the delegate from the United States to the "Conférence Générale des Poids et Mesures," and stated to him that the Superintendent of the Coast and Geodetic Survey had directed me to express his wish that he should be the bearer of the second set. Dr. Gould said he was going direct to Boston and not to Washington, that his health was not strong, and that he felt unlike assuming the responsibility of the care and transportation of such valuable instruments.

On the afternoon of the 27th of September I visited the "Pavillon de Breteuil" at Sevres, the establishment of the "Bureau International des Poids et Mesures," and was cordially received by Dr. René Benoit, the Director. At my request he exhibited to me the three prototypes 12, 21, 27 of the standard metre, then replaced them, and with Dr. Chappuis I sealed the metallic tubes with the ordinary seal BI of the Bureau. The tubes were left to be boxed, and I have not seen them since.

Mr. Thiesen exhibited to me the prototype No. 20 of the Standard Kilogramme. I assisted in securing and sealing it preparatory to being boxed. I have not seen it since. I did not see the other prototype of the standard Kilogramme.

On the 30th of September I visited Hon. Whitelaw Reid and he informed me that he had received from the "Bureau International des Poids et Mesures" the above prototypes, and that he held them subject to my requisition. I asked for his good offices with the proper authorities in Great Britain to obtain permission for the sealed boxes to enter England without examination by the Customs officers. Through Hon. Robert T. Lincoln, Minister of the United States at London, he effected this object.

On Saturday, October 26, I received a telegram from the United States Legation at London, stating that the boxes would be admitted into England without examination.

On Sunday, the 27th of October, at 2 p. m., I received from the United States Minister the following boxes:

One box made of half-inch "deals," 47 by $6\frac{1}{4}$ by $6\frac{1}{4}$ inches, stencil-marked 12, with no other designation; sealed in dull-red wax at each end of the top over a screw head, with lion rampant over old English G. No handles or strap.

One box made of half-inch "deals," 47 by $6\frac{1}{4}$ by $6\frac{1}{4}$ inches, stencil-marked 27, with no other designation: sealed as the preceding. No handle or strap.

One box made of half-inch "deals," 11 by 11 by 7 inches, stencil-marked $\frac{A}{20}$, with no other designation; sealed as the preceding; and it has also a black seal over each hook with the old English letters W. R. The top is hinged. One rough iron handle.

One box made of half-inch "deals," 10 by 9 by 10 inches, stencil-marked $\frac{B}{20}$ with no other designation. Sealed at each end. No handle or strap.

One very small hinged box, mahogany, varnished, 9 by 5 by $1\frac{1}{4}$ inches; locked; no mark or designation. I opened it and found the chamois lined lifter for the kilogramme.

Upon the delivery of these boxes I signed a receipt which Mr. Reid wrote, except the added paragraph which I wrote.

COPY OF RECEIPT.

LEGATION DES ETATS UNIS D'AMÉRIQUE, 59 *rue Galilée,*
Paris, October 27, 1889.

Received this day, in good condition and with seals unbroken, from Whitelaw Reid, Minister of the United States in France:

Two prototypes of the Standard metre issued for the United States by the International Congress of Weights and Measures, which met in Paris, October, 1889, numbered 12 and 27.

One prototype of the Standard Kilogramme, issued at the same time for the United States by the same Congress, numbered 20.

GEORGE DAVIDSON,
Assistant, U. S. Coast and Geodetic Survey, U. S. Delegate to "L'Association Géodésique Internationale."

In addition to the above, which are in separate boxes, there are two boxes of accessories to the kilogramme.
GEORGE DAVIDSON.

As the boxes were sealed I did not see their contents. In the presence of Mr. Reid I placed paper seals of the U. S. Coast and Geodetic Survey on all the boxes; and subsequently I marked each box with proper address for traveling. These additional seals and the addresses in ink are as follows:

From the
International Bureau
of Weights and Measures,
Paris.
For the
United States
Coast and Geodetic Survey,
George Davidson, Washington, D. C.,
United States.
27 = Standard Metre,
from the
Minister of the United States,
October 27, 1889, Paris.

There was a red paper seal of the U. S. Coast and Geodetic Survey placed over each edge of the box 27, midway of its length and under the strap which I had placed around the box.

The box 12 was marked and sealed in the same manner.

Upon box $\frac{A}{20}$ I placed the same address, and after 20 wrote "*standard kilogramme.*" I added two Coast Survey red paper seals on the front and back edges. I added a strap.

Upon box $\frac{B}{20}$ I placed the same address, and under 20 wrote "accessories." I added two Coast Survey red paper seals on the edges. I wrapped the box with twine.

Upon the bottom of the small mahogany box I placed the same address, with the addition $\left\{ \begin{array}{c} \text{No. 5,} \\ \text{for kilogramme} \\ \text{20.} \end{array} \right\}$

I added a Coast Survey red paper seal over the front edge over the keyhole.

These paper seals were expected to be torn and probably rubbed off in handling.

On the 28th of October I carried these boxes to London *via* Calais and Dover, and on the 30th to Liverpool. They were moved carefully on the cushioned seats of the transfer 'bus, and the cushioned seats of the railway carriages, and of the Calais-Dover steamer.

They remained in my room at the Northwestern Hotel until the 6th of November, when I transferred them to the steamship *Germanic* of 5 004 tons, upon which I had the sole use of a stateroom for their safe-keeping. Before starting I secured the boxes against "fetching away" in a storm, but we had a fine passage and no rough weather.

On the 15th of November the steamship reached New York, and the boxes were carefully transferred to a palace car for Washington, where they were deposited in the fireproof building of the Coast and Geodetic Survey on the afternoon of that day, until I made this written report and transfer to Superintendent Mendenhall.

Up to this time the boxes have been constantly under my eye or locked in my room in my absence; I have witnessed each handling, accompanied each transfer, and there has been no shock to them, and no vibration except such as is inevitable to railway and steamship travel. Even this vibration has been very much lessened by the cushions or rugs upon which the boxes have been placed. There has been no large range of temperature; I estimate the lowest temperature experienced about 55°, and the highest about 85° or 90° F.

GEORGE DAVIDSON,
Assistant, U. S. Coast and Geodetic Survey.

CERTIFICATE OF PRESIDENT BENJAMIN HARRISON IN RELATION TO THE OPENING OF THE NATIONAL PROTOTYPES OF THE METRE AND KILOGRAMME.

EXECUTIVE MANSION.

Be it known, That on this second day of January, A. D. one thousand eight hundred and ninety, in the city of Washington, there were exhibited before me, Benjamin Harrison, President of the United States, by T. C. Mendenhall, Superintendent of the United States Coast and Geodetic Survey, two packing boxes, described as follows:

One box bearing the stencil number 27, and sealed twice with red wax bearing the impress of a crest over the Gothic letter 𝔊.

One small hinged box bearing the stencil number 20 and the letter A, and sealed twice with red wax bearing the impress of a crest over the Gothic letter 𝔊 as before described, and with two black seals with the Gothic letters 𝔚 𝔑

That the impression of the red-wax seals aforesaid was recognized as that of the private seal of Dr. Benjamin Apthorp Gould, United States Delegate to the International Conference on Weights and Measures, convened at Paris September 24th, 1889, that there was also exhibited a report by said B. A. Gould to the Secretary of State, reciting that he received and accepted, on behalf of the United States, a Prototype Metre numbered 27, together with another one numbered 21, and a metre bar of the alloy of 1874 numbered 12, together with two Prototype Kilogrammes, one numbered 4, and one numbered 20, with their accessories, excepting thermometers, and that he enclosed said Prototype Metre No. 27, and said Prototype Kilogramme No. 20, with its accessories in their inner cases, and these in their turn in boxes marked and thereafter sealed by him as above described, and that said boxes were delivered by him to Mr. Whitelaw Reid, United States Minister at Paris; and there was also exhibited a report by George Davidson, Assistant United States Coast and Geodetic Survey, affirming that these boxes were received by him from the United States Minister at Paris, on October 27th, 1889, as being the boxes supposed to contain the National Prototype Metre No. 27, and the National Prototype Kilogramme No. 20, with its accessories.

That the Superintendent of the Coast and Geodetic Survey did affirm that these boxes were received by him from the said George Davidson on the 27th day of November, 1889, at the office of the Coast and Geodetic Survey in Washington, D. C., and that they have remained in his possession, sealed and with their contents undisturbed in every particular, from the date of their delivery aforesaid until thus exhibited.

That the aforesaid boxes being thereupon opened in my presence were found to contain the inner cases as described in the aforementioned report of Dr. B. A. Gould, and these inner cases being opened were found to contain a Metre bar numbered 27, and a Kilogramme weight No. 20, in good preservation and, apparently, in every particular in the same state as when first enclosed therein, and which I therefore confidently believe to be the identical Standards referred to in the aforesaid reports.

By the President:

BENJ. HARRISON.

JAMES G. BLAINE,
Secretary of State.
WILLIAM WINDOM,
Secretary of the Treasury.

JANUARY 2, 1890.

The ceremony of breaking the seals of the Prototype Metre No. 27 and Kilogramme No. 20, which took place at the Executive Mansion at 1 o'clock p. m. of Thursday, January 2, 1890, was witnessed by the undersigned, who have attached their signatures hereto in testimony thereof:

T. C. MENDENHALL, Superintendent U. S. Coast and Geodetic Survey and of Weights and Measures.
S. P. LANGLEY, Secretary Smithsonian Institution.
R. M. HUNT, President American Institute of Architects.
THOS. LINCOLN CASEY, Chief of Engineers, U. S. Army.
R. L. PHYTHIAN, Captain U. S. Navy, Superintendent U. S. Naval Observatory.
WM. HENRY TRESCOT, U. S. Delegate to International Congress of Three Americas.
OBERLIN SMITH, President American Society of Mechanical Engineers.
E. O. LEECH, Director of the Mint.
MARSHALL MCDONALD, U. S. Commissioner of Fish and Fisheries.
F. W. CLARKE, U. S. Geological Survey.
T. H. CARTER, M. C., Montana, House Committee on Coinage, Weights, and Measures.
E. H. CONGER, M. C., Seventh Congressional district Iowa, Chairman House Committee on Coinage, Weights, and Measures.
JOS. H. OUTHWAITE, M. C., Thirteenth Congressional district Ohio.
J. E. HILGARD, Ex-Superintendent U. S. Coast and Geodetic Survey and of Weights and Measures; first U. S. Delegate International Convention Weights and Measures.
WILLIAM A. ROGERS, Professor of Physics, Colby University.
EDWARD W. MORLEY, Professor of Chemistry, Western Reserve University.
CHAS. A. SCHOTT, U. S. Coast and Geodetic Survey.
CHAS. M. THOMAS, Commander U. S. Navy, Hydrographic Inspector U. S. Coast and Geodetic Survey.
A. W. GREELY, Chief Signal Officer, U. S. Army.
JAMES C. PILLING, Chief Clerk, U. S. Geological Survey.
S. F. EMMONS, Ex-Vice President American Institute of Mining Engineers.
E. W. FOX, Washington Press.
J. R. WILLIAMS, M. C., Nineteenth Congressional district Illinois, House Committee on Coinage, Weights, and Measures.
JOHN K. REES, Columbia College, New York, and American Metrological Society.
B. A. COLONNA, Assistant in charge U. S. Coast and Geodetic Survey Office and Topography.
O. H. TITTMANN, U. S. Coast and Geodetic Survey, in charge of Standards.
FRANCIS H. PARSONS, U. S. Coast and Geodetic Survey.
LOUIS A. FISCHER, Adjuster, Office Weights and Measures.

REPORT OF ASSISTANT O. H. TITTMANN UPON THE TRANSPORTATION OF NATIONAL PROTOTYPE METRE NO. 21 AND NATIONAL PROTOTYPE KILOGRAMME NO. 4 FROM PARIS TO WASHINGTON.

U. S. COAST AND GEODETIC SURVEY,
OFFICE OF WEIGHTS AND MEASURES,
Washington, D. C., July 18, 1890.

At the instance of T. C. Mendenhall, Superintendent U. S. Coast and Geodetic Survey, the Secretary of the Treasury requested the Secretary of State to charge me, the undersigned, with the duty of bringing these Standards from Paris to Washington.

The letter of instructions from the Secretary of State, prepared in accordance with that request, is dated March 19, 1890. It contemplates the performance of other correlated duties which are more fully set forth in a letter of instructions from Superintendent Mendenhall, dated April 19, 1890.

After the performance of the other duties I presented myself again at the United States Legation in Paris, and on July 4 received the receipt which Dr. René Benoit, Director of the International Bureau of Weights and Measures, had given to Mr. Whitelaw Reid, United States Minister to France, when the latter deposited the standards for safe-keeping at the International Bureau of Weights and Measures, subject to his, the United States Minister's, orders.

On the presentation of this receipt, by previous appointment, on the afternoon of July 4, 1890, at 3 o'clock p. m., the sealed metallic case containing Metre No. 21 was taken from an iron safe in the International Bureau building by Dr. Guillaume, Scientific Assistant of the Bureau, in my presence.

The case was sealed with three seals, that of the United States Legation, that of Dr. B. A. Gould, and that of the International Bureau.

The seals were examined by me and were found intact, but were not touched. The case containing the metre and the small box containing the end pieces cut from the metre bar, after having been wrapped in paper, were put in a deal packing box filled with hay, the lid of which was then screwed down.

Kilogramme No. 4, mounted on its base under its double bell-glass cover, was then taken from another iron safe. The bell-glasses were sealed to the base in such a way by two seals (Dr. Gould's private seal and the seal of the United States legation) that access to the Kilogramme could not be had without breaking the seals. Having identified them, and having assured myself that they were intact, I broke them in order that the Kilogramme might be packed for transportation. In the presence of Dr. Guillaume, Dr. Chappuis, and myself, Dr. Benoit took out the Kilogramme and packed it for transportation in accordance with the method prescribed by the International Commission. The bell-jars and other accessories were also packed in my presence. The complete set of standards was thus packed in three boxes. These were immediately taken to a carriage in waiting and deposited inside. Taking my place along side of them I was driven to Paris, where I deposited the boxes in my room at the Hotel de la Tamise, at about 6 p. m. They remained undisturbed until about 11.30, when they were put in a carriage into which I also entered together with the "concierge" of the hotel whom I employed to assist me in unloading them and carrying them to the railway car in which a coupé had been reserved for me. The boxes having been carefully deposited in the coupé, remained under my eyes until our arrival in Le Havre. Two porters and I then carried them into my stateroom on the steamship *La Gascogne*, where they were secured under the sofa and where they remained undisturbed from the time of sailing, July 5, until our arrival in New York, July 14. From the steamer they were carried to a carriage, deposited inside, and were thus transported to Desbrosses-street ferry, thence, with the assistance of a porter, to the Pennsylvania Railroad waiting room, where they remained under my eyes until the departure of the 3.30 p. m. train. They were then carried by me and a porter into the Pullman car and placed on the floor alongside of my seat. On my arrival in Washington they were handed over to Messrs. F. H. Parsons, Assistant, and Mr. Louis Fischer, Adjuster, of Office of U. S. Weights and Measures, by whom they were put into the Coast and Geodetic Survey spring wagon. From the wagon they were taken immediately to the Standards Room, Butler Building, Coast Survey Office, where they remained deposited until to-day. At 11 o'clock of this day they were taken by Mr. L. A. Fischer and myself from the standards room and carried to the room of the Superintendent, to whose charge I then committed them, together with two certificates, inclosed in brass tubes, relating to these standards.

Thus the Standards were brought from Paris to Washington without accident or injury.

O. H. TITTMANN,
Assistant, U. S. Coast and Geodetic Survey.

CERTIFICATE CONCERNING THE OPENING.

UNITED STATES COAST AND GEODETIC SURVEY,
OFFICE OF WEIGHTS AND MEASURES,
Washington, D. C., July 18, 1890.

At 10.45 a. m., July 18, 1890, the three packing boxes supposed to contain National Prototype Metre No. 21 and National Prototype Kilogramme No. 4 and their accessories were brought from the standards room in the Butler Building by Assistant O. H. Tittmann and Mr. L. A. Fischer to the room of Superintendent Mendenhall, Coast and Geodetic Survey Office.

The boxes were then carefully opened in the presence of the undersigned.

Metre No. 21 was found sealed by a paper tied over the keyhole end of the metal tube, and sealed with three wax seals (which were found intact) bearing the impressions, respectively, of the Bureau of International Weights and Measures, that of the United States Legation at Paris, and Dr. B. A. Gould's private seal. The paper also had Assistant George Davidson's autograph on it.

The case was opened and the Metre was found to be in apparent perfect condition upon examination.

The Kilogramme No. 4 was not sealed (see Mr. Tittmann's report); the box was unpacked and the kilogramme was examined by those present, and appeared in apparent perfect condition. It was placed on its crystal base and covered with two glass bells.

T. C. MENDENHALL,
Superintendent U. S. Coast and Geodetic Survey and of Weights and Measures.
CHAS. A. SCHOTT,
R. S. WOODWARD,
O. H. TITTMANN,
ANDREW BRAID,
FRANCIS H. PARSONS,
Assistants, Coast and Geodetic Survey.
L. A. FISCHER,
Adjuster Weights and Measures.

CERTIFICATE FOR PROTOTYPE METRE, NO. 27.

[Translation.]

International Committee of Weights and Measures. Certificates of the International Bureau of Weights and Measures for Prototype Metre No. 27, allotted to the United States of America.

This prototype was made by Messrs. Johnson, Matthey & Co., of London, in the form of a bar 20 centimetres long, with a transverse section called X, out of an alloy of platinum-iridium containing 10 per cent. of iridium. The bar was straightened and wrought by hand and finally polished and cut to the length of 102 centimetres by Messrs. Brunner Brothers, of Paris.

The lines were traced on elliptical spaces, the surfaces of which were specially polished by Mr. G. Tresca, Engineer, attached to the French section of the Metric Commission. All this work was done at the Conservatoire des Arts et Metiers, at Paris, under the direction of Mr. Cornu, Membre de l'Institut, as delegate of the French Section, and of Mr. Broch, Director of the International Bureau, as delegate of the International Committee.

The burr on the traced lines was removed at the International Bureau by Mr. Boinot, aid in this establishment.

The prototype is accompanied by two specimens cut from the two ends of the bar. They were prepared by Mr. L. Laurent, of Paris, for the study of their expansions by Fizeau's method. The prototype is inclosed in a special case, made of a cylinder of solid wood into which a groove was cut to hold the bar, and which is inclosed in a strong cylinder of brass closed by a screw cap.

DESCRIPTION.

The transverse section of the bar has the shape called X, the sides of the circumscribed square of which are 20 millimetres long.

The upper surface of the medial rib, on which the lines are traced, is in the plane of the neutral axis; it was made to coincide with the mean height of the section by slightly thinning the lower legs of the X.

On the polished surfaces near each extremity three lines, from 6 to 8 microns wide, are traced 0·5 millimetres apart. The length of the standard is defined by the distance between the middle lines of each of these two groups. The position of the axis is defined by two longitudinal lines 0·2 millimetres apart, ruled on the polished surfaces.

On the upper surface of the upper flange, cut with a graver, on the left is the inscription A.27, on the right B. 27. The two specimens, which accompany the prototype in a separate box, have the same numbers and letters cut upon them with a graver as the ends from which they were cut.

CHEMICAL COMPOSITION.

The preparation of the platinum and iridium used for the alloy of the ingot from which the bars were drawn was controlled by Mr. Stas, member of the Academy of Sciences of Brussels, delegate of the International Committee, by Henri Sainte-Claire-Deville, and after his death by Debray, members of the "Institute of France," and delegates of the French section.

The analysis of the alloy was made by these savants by means of several specimens taken directly from the finished bars. According to the results of these analyses the alloy contained no trace of iridium in a free state, nor any ruthenium, and only an extremely small quantity, one or two ten-thousandths, of rhodium, and one ten-thousandth of iron. The percentage of iridium was found equal to 10.08 to 10.09.

Mr. Tornöe, Aide in the International Bureau, took part under the direction of Mr. Debray in the analyses made in the laboratory for advanced studies of the normal high school in Paris. After the death of Mr. Debray, Mr. Tornöe edited a detailed report on these analyses, which is published in volume VII of the "Travaux et Memoires" of the International Bureau.

DETERMINATION.

Coefficient of expansion.—The determination of the coefficient of expansion was intrusted to Mr. R. Benoit, principal assistant of the International Bureau, with the co-operation of Mr. Ch. Guillaume, attaché of the Bureau. This determination was made by comparing Prototype No. 27 with the International Prototype $\mathfrak{M}$ in the trough of the comparator for expansions, at eight different temperatures comprised between 0·1° and 37·4°. The expansion of the International Prototype had been previously determined by the absolute method by means of the comparator for expansion as well as by Fizeau's method.

These observations gave the following result: Coefficient of expansion of Prototype No. 27 from 0° to $t°$

$$\alpha = 10^{-9}\,(8606 + 1{\cdot}70t),$$

where t stands for the temperature in degrees of the Tonnelot mercurial thermometers made of "verre dur," or

$$\alpha = 10^{-9}\,(8657 + 1{\cdot}00\,T),$$

where T stands for the temperature according to the standard scale adopted for the International Weights and Measures Service (*scale of the hydrogen thermometer*).

Length at zero: The comparisons for length were made on the Brunner comparator, in the water trough, under the immediate direction of the Director, Mr. Broch, by Messrs. Boinot and Isaachsen, Aides in the Bureau.

The National Prototypes, numbering 30, were compared among themselves in 11 crossed groups—that is to say, in 5 groups of 6 bars and in 6 groups of 5 bars. Besides, each one was compared on the one hand with the provisional prototype I_2, belonging to the International Bureau, and which was compared in 1882 with the Mètre des Archives of France, and on the other hand with the new International Prototype $\mathfrak{M}$. Finally these two, I_2 and $\mathfrak{M}$, were compared with each other.

In each group the comparisons were made in all possible combinations. Each complete comparison consisted of four individual comparisons in the four different positions into which the bars could be put relatively to the two microscopes and to the observers.

The result of these 196 complete or 784 individual comparisons gave for Metre No. 27

$$\text{Prototype No. } 27 = 1\text{m} - 1{\cdot}6\mu \pm 0{\cdot}1\mu.$$

The equation of this prototype is therefore

$$\text{Prototype No. } 27 = 1\text{m} - 1{\cdot}6\mu + 8{\cdot}657\mu\,T + 0{\cdot}00100\mu\,T^2 \pm 0{\cdot}2\mu.$$

where T designates the temperature expressed in degrees of the standard scale adopted for the International Weights and Measures Service.

Distance between the auxiliary lines.—These spaces were determined in water with the micrometers of the Brunner comparator by observing at each end the two spaces and their sum. The observations were repeated ten times under each of the two microscopes. If, in going from the extremity A towards the extremity B, the lines are designated by the numbers 1, 2, 3, and 4, 5, 6, the numbers 2 and 5 being the defining lines of the metre, the spaces have the following values:

		μ	μ
Extremity A space	(1–2) =	500·4	± 0·1
	(2–3) =	508·5	± 0·1
	(1–3) =	1008·9	± 0·2
Extremity B space	(4–5) =	501·3	± 0·1
	(5–6) =	497·0	± 0·1
	(4–6) =	998·3	± 0·2

The Director of the Bureau,

Dr. René Benoit.

International Bureau of Weights and Measures,

Pavillon de Breteuil, near Sevres, September 28, 1889.

Certified for the International Committee of Weights and Measures.

The President,
Genl. **Marquis de Mulhacen.**

The Secretary,
Dr. Ad. Hirsch.

CERTIFICATE FOR PROTOTYPE KILOGRAMME NO. 20.

[Translation.]

International Committee of Weights and Measures. Certificate of the International Bureau of Weights and Measures for Prototype Kilogramme, No. 20, allotted to the United States of America.

This prototype was made in the form of a cylinder the diameter of which is equal to its height, of an alloy of platinum-iridium containing 10 per cent. of iridium, by Messrs. Johnson, Matthey & Co., of London. It was then turned and polished with fine emery, and its final adjustment was made at the International Bureau after its volume had been determined. These different operations were performed by Mr. Collot, of Paris.

DESCRIPTION.

The Kilogramme has the form of a right cylinder 39 millimetres high and 39 millimetres in diameter, with slightly rounded edges. On its cylindrical surface, two-thirds of the way up, the number 20 is marked with a burnisher. It is kept under double bell glass on a support which carries a rock crystal plate. For transportation it is fixed on its support by screws protected with chamois skin especially prepared for this purpose, and it is then protected by a copper case.

CHEMICAL COMPOSITION.

The preparation of the platinum and of the iridium used for the ingot from which the cylinders were made was controlled by Mr. Stas, member of the Academy of Sciences of Brussels and Delegate of the International Committee, by Henri Sainte-Claire-Deville and after his death by Debray, members of the Institute of France and delegates of the French section.

According to the results of analysis the alloy contained no trace of iridium in a free state, nor any ruthenium, and only an extremely small quantity, one or two ten-thousandths of rhodium, and one ten-thousandth of iron.

The amount of iridium was found equal to 10·08 or 10·09 per centum.

Mr. Tornöe, aid in the International Bureau took part, under the direction of Mr. Debray, in the analyses made in the laboratory for advanced studies of the normal high school of Paris. After the death of Mr. Debray, Mr. Tornöe edited a detailed report on these analyses, which is published in volume VII of the "Travaux et Mémoires" of the International Bureau.

DETERMINATION OF VOLUME.

The study of the density of the Kilogramme was intrusted to Mr. Thiesen, assistant in the International Bureau.

The determination of the volume was made before the final adjustment of the cylinder, the weight of which exceeded a Kilogramme by $3{\cdot}44^{mg}$.

Ten determinations were made at a mean temperature of 17.9° in three separate specimens of distilled water. They were reduced to the temperature of melting ice by adopting for the coefficient of cubical expansion of platinum iridium between 0° and $t°$:

$$K = 10^{-9}\,(25707 + 8{\cdot}6\,t)$$

where t denotes the temperature in degrees of Tonnelot mercurial thermometers made of "verre dur" or

$$K = 10^{-9}\,(25859 + 6{\cdot}5\,T)$$

where T denotes the temperature expressed according to the standard scale adopted for the International Weights and Measures Service (scale of the hydrogen thermometer). From the value found for the volume at zero

$$46{\cdot}4019\text{ml} \pm 0{\cdot}0001\text{ml}$$

which corresponds to a density of

$$21{\cdot}5509$$

was deduced, for the Kilogramme after its final adjustment, the value

Volume of Kilogramme No. 20, 46·402ml.

MASS OF THE KILOGRAMME.

The comparison of the prototypes among themselves was made by Mr. Thiessen, Assistant in the Bureau, on the balance designated Rueprecht No. 1, and by Mr. Kreichgauer, Aid in the Bureau, on the balance designated Rueprecht No. 5. The comparisons with the International Prototype were made by Mr. Thiessen on the Bunge balance.

The forty-two Prototypes were compared among themselves in six groups of 7 Kilogrammes each, and in seven groups of 6 Kilogrammes, and finally each Kilogramme was compared with the new International Prototype of the kilogramme 𝔎. The last mentioned, compared in 1880 with the Kilogramme des Archives, was found to be identical with it within the limits of the errors of observation. In each group the comparisons were made in all possible combinations.

Each complete comparison comprises four individual weighings; between each weighing the load of the balance was modified by the addition of auxiliary weights or by changing the plates of rock crystal on which the Kilogrammes rested during the weighings.

The combined results of the 273 complete or 1,092 individual weighings gave, by the adjustment of the whole system by computation, for Kilogramme No 20 the following equation:

$$\text{Prototype No. } 20 = 1\text{kg} - 0{\cdot}039\text{mg} \pm 0{\cdot}002\text{mg}.$$

The Director of the Bureau,

Dr. René Benoit.

International Bureau of Weights and Measures,
Pavillon de Breteuil near Sevres, September 28, 1889.

Certified for the International Committee of Weights and Measures.

The President,
General Marquis de Mulhacen.

The Secretary,
Dr. Ad. Hirsch.

CERTIFICATE FOR PROTOTYPE METRE NO. 21.

Prototype Metre No. 21.

The certificate accompanying this bar is like that accompanying No. 27, except in the following particulars:
The inscription on the upper flange of metre No. 21 is

On the left A. 21.
On the right B. 21.

The coefficient of expansion of prototype No. 21 from 0° to t is

$$\alpha = 10^{-9}\,(8614 + 1{\cdot}70t)$$

where t denotes the temperature in degrees of the Tonnelot mercurial thermometers made of "verre dur," or

$$\alpha = 10^{-9}\,(8665 + 1{\cdot}00\text{T})$$

where T stands for the temperature according to the standard scale adopted for the International Weights and Measures Service (scale of the hydrogen thermometer).

Length at zero:

Prototype No. $21 = 1\text{m} + 2{\cdot}5\mu \pm 0{\cdot}1\mu$.

The equation of the Prototype is therefore

$$\text{Prototype No. } 21 = 1\text{m} + 2{\cdot}5\mu + 8{\cdot}665\mu\,\text{T} + 0{\cdot}00100\mu\,\text{T}^2 \pm 0{\cdot}2\mu,$$

where T denotes the temperature expressed in degrees of the standard scale adopted for the International Weights and Measures Service.

Value of auxiliary spaces:

		μ	μ
Extremity A space	(1–2) =	499·7	± 0·1
	(2–3) =	508·9	± 0·1
	(1–3) =	1008·6	± 0·2
Extremity *B* space	(4–5) =	503·1	± 0·1
	(5–6) =	493·9	± 0·1
	(4–6) =	997·0	± 0·2

CERTIFICATE FOR PROTOTYPE KILOGRAMME No. 4.

Prototype Kilogramme No. 4.

The certificate appearing to this Prototype is like that relating to Kilogramme No. 20, except in the following particulars:

DETERMINATION OF VOLUME.

The volume was determined before the final adjustment of the cylinder, which exceeded a Kilogramme by 16·71mg. The mean temperature was 9·8°.

From the value found for the volume at zero:

$$46{\cdot}4183\ \text{ml} \pm 0{\cdot}0003\ \text{ml}$$

corresponding to a density

$$21{\cdot}5436$$

was deduced for the final value of the adjusted Kilogramme the Volume of Kilogramme No. 4:

$$46{\cdot}418\ \text{ml}$$

Mass of the Kilogramme

$$\text{Prototype No. } 4 = 1\ \text{kg} - 0{\cdot}075\ \text{mg} \pm 0{\cdot}002\ \text{mg}.$$

Certificate for Metre of the Alloy of 1874.—*No.* 12.

[Translation.]

International Committee of Weights and Measures; certificate of the International Bureau of Weights and Measures for Prototype Metre No. 12, *allotted to the United States of America.*

This prototype is made of an alloy of platinum iridium, containing 10 per cent. of iridium drawn from an ingot cast at the Conservatoire des Arts et Metiers on the 13th of May, 1874. It was made from a bar which was first forged, then shaped into the X form by drawing, in the forging establishment of Audincourt. It was then dressed, cut to a length of 102 centimetres, and polished and traced under the care of the French Section of the International Metric Commission. It was traced by Mr. G. Tresca, engineer, connected with the French Section, on specially polished elliptical spaces.

All this work was done at the Conservatoire des Arts et Metiers, under the immediate direction of H. Tresca, member of the Institute, at that time Secretary of the French Section.

The prototype is accompanied by two specimens cut from its two extremities and prepared by Mr. Laurent, of Paris, for the determination of the coefficient of expansion of the bar by means of Fizeau's method.

The prototype is inclosed in a special case, made of a cylinder of solid wood, into which a longitudinal groove was cut to hold the bar. This is encased in a strong cylinder of brass, closed with a screw cap.

DESCRIPTION.

The transverse section of the bar has the shape called X, the sides of the circumscribed square of which are 20 millimetres long.

The upper surface of the medial rib on which the lines are traced is in the plane of the neutral axis; it was made to coincide with the mean height of the cross section by slightly thinning the lower legs of the X. On the polished surfaces near each extremity three lines, from 6 to 8 microns wide, are traced 20 microns apart. The length of the standard is defined by the distance between the middle lines of each of the two groups. The position of the axis is defined by two stronger longitudinal lines 0·1 millimetre apart ruled on the polished spaces.

On the exterior edge of one of the lateral flanges the bar carried the following inscription cut with a graver.

No. 12 Alliage de 1874.

Chemical composition

The alloy was submitted for examination to a commission composed of Messrs. Henri Sainte Claire-Deville, member of the French Section, Broch and Stas, members of the International Committee. According to the analysis of several specimens taken from the finished bar, published in a report of the Commission which appears in the Process Verbaux of the sessions of the International Committee for 1877, this alloy contains in 100 parts by weight 87·7 platinum, 9·4 iridium, 0·4 rhodium, 0·1 palladium, 1·4 ruthenium, 0·2 copper, and 0·8 iron.

DETERMINATION.

Coefficient of Expansion.—The determination of the expansion was intrusted to Mr. Ch. Ed. Guillaume, Attaché of the International Bureau.

This determination was made by comparing Prototype No. 12 with the International Prototype $\mathfrak{M}$ in the trough of the expansion comparator at eight different temperatures included between 0°·2 and 37°·7. The expansion of the International Prototype had been previously determined by the absolute method by means of the expansion comparator as well as by Fizeau's method.

The observations gave the following result:

Coefficient of expansion of Prototype No. 12 from 0° to $t°$:

$$\alpha = 10^{-9}\,(8583 + 1{\cdot}70\,t)$$

where t denotes the temperature in degrees of the Tonnelot mercurial thermometers of "verre dur," or

$$\alpha = 10^{-9}\,(8634 + 1{\cdot}00\,T),$$

where T denotes the temperature in degrees of the standard scale adopted for the International Weights and Measures Service (scale of the hydrogen thermometer).

Length at Zero.—The length comparisons were made on the Brunner comparatar in the water trough, under the immediate direction of the Director, Mr. Broch, by Messrs. Boinot and Isaachsen, Aides in the Bureau.

The four prototypes of this group were compared in all possible combinations among themselves with the Provisional Prototype I_2, of the International Bureau, which was compared with the Metre des Archives de France, and with the new International Prototype 𝔐.

Each complete comparison consisted of four individual comparisons in the four different positions into which the bars could be put relatively to the two microscopes and to the observers.

The combined results of the fifteen complete or sixty individual comparisons gave for Prototype No. 12 at zero:

$$\text{Prototype No. } 12 = 1\text{m} + 3{\cdot}3\mu \pm 0{\cdot}1\mu.$$

The equation of the prototype is therefore

$$\text{Prototype No. } 12 = 1\text{m} + 3{\cdot}3\mu + 8{\cdot}634\mu\,T + 0{\cdot}00100\mu\,T^2 \pm 0{\cdot}2\mu,$$

where T denotes the temperature in degrees of the standard scale adopted for the International Weights and Measures Service.

The Director of the Bureau,

Dr. R. BENOIT.

INTERNATIONAL BUREAU OF WEIGHTS AND MEASURES,
Pavilion de Breteuil, near Sevres, September 28, 1889.

Certified for the International Committee of Weights and Measures.

The President,
General MARQUIS DE MULHACEN.

The Secretary,
Dr. AD. HIRSCH.

APPENDIX No. 19—1890

NOTES ON AN ORIGINAL MANUSCRIPT CHART OF BERING'S EXPEDITION OF 1725–1730, AND ON AN ORIGINAL MANUSCRIPT CHART OF HIS SECOND EXPEDITION; TOGETHER WITH A SUMMARY OF A JOURNAL OF THE FIRST EXPEDITION, KEPT BY PETER CHAPLIN, AND NOW FIRST RENDERED INTO ENGLISH FROM BERGH'S RUSSIAN VERSION.

By WILLIAM HEALEY DALL.

[Submitted for publication June 23, 1890.]

EARLY EXPLORATIONS IN THE REGION OF BERING SEA AND STRAIT.

In 1648 the tide of exploration and adventure setting eastward through Siberia impelled the fitting out of seven small trading boats on the Kolyma River. Three of these, in charge of Simeon Deshneff, Gerasim Ankudinoff, and Feodor Alexieff, respectively, reached Bering Strait. Ankudinoff's boat was wrecked on East Cape, but his party were accommodated by the others. There were hostilities with the Chukchi, the two boats were separated, and Deshneff's alone finally reached Kamchatka. Next year he constructed the trading post on the Anadyr River, subsequently known as Anadyrsk.

There is a tradition that in 1654 a trader named Taras Stadukin followed Deshneff's route, made a portage across the neck of East Cape, circumnavigated Kamchatka, discovered the Kurile Islands, and finally reached the Gulf of Penjina in safety.

In 1711 an emissary named Peter Iliunsen Popoff was sent to East Cape by the Russians, to induce the Chukchi to pay tribute. In this he failed; but brought back an account of islands beyond East Cape, and of a continent reported by the Chukchi to exist beyond these islands. Some statements which he made in regard to the people of this continent were regarded by geographers of the last century as fictitious, but, with our better knowledge, they set the seal of authenticity upon Popoff's report, and show that his journey was really made.*

The political disorders which prevailed in western Russia about this period prevented any attention from being directed to the reports of these explorations, which were preserved in the archives at Yakutsk. Somewhat later the attention of geographers was directed toward this unknown corner of the world, and the subject was brought to the notice of Peter the Great. He took great interest in it, drew up instructions for an expedition with his own hand, and delivered them to Count Apraxin, with orders to see them executed. A few days later, in January, 1725, he died; but the Empress, desiring to carry out all the plans of her deceased husband as closely as possible, ordered their execution. Fleet-Captain Vitus Ivanovich Bering was nominated to the command of the expedition, and Lieutenants Martin Spanberg and Alexie Chirikoff to be his assistants.

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* For instance, he reported that the Chukchi said that the natives on the great land opposite East Cape wore tails. This was regarded by Müller, to whom we owe all our knowledge of Popoff's journey, as manifestly absurd. But all who are familiar with the Eskimo of the American side of Bering Strait know that, on formal occasions, at dances or festivals, they do tie a wolf's or dog's tail in the middle line of the back as if it grew there; so that the Chukchi report to Popoff was quite true.

Bering and Spanberg were Danes who had taken service with Russia, Chirikoff was a Russian, and so was Peter Chaplin, one of the most promising cadets of the Naval College at St. Petersburg, who was detailed for service on the expedition.

The literature resulting from this expedition, our sources of information about it, and the practical results obtained for geographical research have been detailed and discussed by the writer in a recent publication,* from which the introductory paragraphs of this paper have been taken. To that the reader is referred for most of the details. It contains a complete translation of Bering's official report, which previously was accessible only in the Russian tongue and in a rare and little-known periodical. This report had been used by various writers, abstracted or paraphrased in some of its parts, but not completely rendered into any of the languages of western Europe. Another source, which may be regarded as nearly original, is the abstract by Vasili Bergh of the journal of Peter Chaplin, one of the members of the party. Bergh found this in the archives of the Imperial Naval College, of which Chaplin was a cadet. He also had access to the journal of Alexie Chirikoff, one of Bering's lieutenants. From these sources he compiled a history of the voyage†, which was printed at St. Petersburg, in 1823, in the Russian language. This book has been used, through the medium of a manuscript translation, by Peter Lauridsen, the latest biographer of Bering. A somewhat condensed translation of Lauridsen's book has recently appeared in this country. The original appeared in Danish. Lauridsen did not quote exactly from Bergh or indicate precisely what part of his book was derived from that source, and, having filtered through three translations and been twice abridged, it is evident that whatever originality appertains to Bergh's material in the first place can in no wise have been preserved. Beside the difficulties referred to, a number of serious errors, typographical or of the translators, make the value of Lauridsen's book and its English abridgment, for historical purposes, very slight indeed. I have, therefore, while quite aware of the slenderness of my own equipment as a Russian scholar, thought that a straight-forward rendering of the facts preserved by Bergh would be an acceptable document to those who are interested in the history of the exploration of our northwestern coasts and the region of Bering Sea. The book is now exceedingly rare. I am indebted to the kind offices of Baron Nordenskiöld and to the extraordinary liberality of the University of Upsala for an opportunity of examining it.‡ There are two or three copies in St. Petersburg and one in the library of the British Museum. I have been unable to trace any others.

Bergh does not always state his facts in Chaplin's own language, though he has done it in what seemed to him important matters. It is quite evident, however, that all his facts not derived from Müller are from the journals of Chaplin and Chirikoff, except where he states otherwise. I have therefore extracted from Bergh, in the notes hereto appended, all the facts he gives about the expedition, omitting nearly all his reflections upon them, and all that he derived from Müller and other accessible authorities. The Russian language in 1823 was less fully formed than it is to day, and many of the words used in Chaplin's journal are archaic, obsolete, or peculiar. The translation has therefore been somewhat difficult, yet it is believed to be free from serious error, and is submitted to the charitable judgment of the reader. The publication first of Bering's report and now of the summary of Chaplin's journal puts before those who read English the only original documents hitherto printed, which have not, up to the present time, been accessible to students.

In brief it may be said that the expedition crossed northern Asia with wagons, barges, boats, sledges, or pack horses, observing latitude and variation of the compass when possible, and working out their longitude by the computation of directions and distances. They built a vessel at Okhotsk and transported themselves across the Okhotsk Sea to the western shore of Kamchatka;

*National Geographic Magazine, vol. II, No. 2, pp. 111–169, with a map; May, 1890.

† First Sea Voyages of the Russians, undertaken for the settlement of this geographical problem—Are Asia and America united?—and performed in 1827–'28–'29, under the command of fleet captain of the first rank, Vitus Bering. To which is added a short biographical account of Captain Bering and some of his officers. St. Petersburg, at the Imperial Academy of Sciences, 1823.

8°, 3 prel. l., IV, 126 pp., 1 table, 1 map.

This book was printed at the Academical printing office and issued there, as many private books are, but was not a publication of the Academy.

‡ Since this was written the Imperial Academy of Sciences at St. Petersburg has generously loaned a second copy for examination.

carried their stores by boat and sledges across that peninsula; built another vessel in which they sailed northward along the coast to Bering Strait, and then returned to Kamchatka and wintered. The next year they put to sea, made a brief search for land east of Kamchatka without success; then circumnavigated the southern part of that peninsula and returned to Okhotsk, and thence to St. Petersburg.

The days of the journal which follows are nautical days, extending from one noon to the next; and the calendar is the Julian one to which eleven days should be added for new style.

A SUMMARY OF CHAPLIN'S JOURNAL DERIVED FROM THE WORK OF VASILI NIKOLAIEVICH BERGH.

[Translated from the Russian by W. H. Dall.]

On the 24th of January, 1725, Midshipman Peter Chaplin with the advance party of the expedition left the Admiralty College, the whole number amounting to 25 people: Lieutenant Chirikoff, a surgeon, a geodesist, a garde marine officer, a quartermaster, clerk, 10 sailors, 2 ship carpenters, an officer with three marines, 4 calkers and sailmakers and several other workmen, together with 25 wagonloads of material.

On the 8th of February the party arrived at Vologdie, and on the 14th were joined by Fleet Captain Vitus Ivanovich Bering, Lieutenant Spanberg, 2 mates, and 3 sailors.

Instructions had been drawn up for Captain Bering by the Tsar Peter I, December 23, 1724, and were comprised under the following three heads:

INSTRUCTIONS.

(1) There should be built on the Kamchatka [River], or at some other place adjacent, one or two boats with decks.

(2) With these boats [you are directed] to sail along the coast which extends northwards and which is supposed (since no one knows the end of it) to be continuous with America.

(3) And therefore [you are directed] to seek the point where it connects with America and to go to some settlement under European rule, or if any European vessel is seen learn of it what the coast visited is called, which should be taken down in writing, an authentic account prepared, placed on the chart, and brought back here.

The officers of the expedition, partly brought from St. Petersburg, partly engaged at Tobolsk or Okhotsk, were as follows: Captain of the First Rank Vitus Bering; Lieutenants Alexie Chirikoff and Martin Spanberg; Midshipman Peter Chaplin; Clerk Simeon Turchaninoff; Surgeon Nieman; Geodesists Feodor Luzhin, ——— Putiloff; Mates Richard Engel, George Morison; Chaplains Father Hilarion, Brother Ignatius Kozuirevskoi; Commissary Durasoff; Artisans Kozloff and Endoguroff; Navigators Mashkoff and Butin, together with the nobles Alexie and Ivan Shestakoff and ——— Antipin.

[1725.] *March* 16, 1725, all had arrived safely at Tobolsk and Chaplin determined the latitude of that place at 58° 05′ N. and the variation of the compass to be 3° 18′ easterly. [The route traveled was laid down by courses and distances from the starting point, the general direction and distance being computed by the aid of a traverse table, corrected by observations for latitude and for the variation of the compass as often as possible.

May 15.—They started on their long journey with four barges and seven canoes. [The dates are of the Julian calendar and counted by the nautical day which begins at noon of the civil date preceding, so that the first 12 hours of the day is a day in advance of that noted ordinarily; *e. g.*, from noon of the 1st of the month to noon of the 2d would by their account be wholly reckoned as the second day of the month, etc.] Chirikoff states in his journal that they platted their route on a Mercator's projection, and in this way checked the accuracy of their work.

May 22.—Chaplin was ordered to proceed in advance with 10 men to Yakutsk, where he arrived on the 6th of September and reported to the local Voivod Poluëkhtoff and Prince Kirilie Galitzin. The town at this time comprised about 300 houses. Chaplin dispatched some workmen thence to Okhotsk, to get out timber for a vessel. [He seems to have wintered at Yakutsk, while Bering's winter quarters were at Ilimsk.]

May 9, 1726.—Chaplin received orders from Captain Bering to prepare 1,000 pairs of rawhide flour sacks. On the 1st of June the captain arrived at Yakutsk with 9 barges, Lieutenant Spanberg, the surgeon, 2 mates, 2 geodesists, and other members of the party. On the 16th Lieutenant Chirikoff arrived with 7 barges. Six hundred horses loaded with flour were started for Okhotsk, divided into three parties. At the same time Captain Bering obtained from the Voivod the services of the monk Kozuireffski.

Brother Kozuireffski had borne an important part in the subjection of the northeastern extreme of Siberia. He was first stationed, in 1712 and 1713, near the Kurile Islands, and obtained information about those and other islands. He served many years in the settlements at Kamchatka, Oliutorsk, and Anadyrsk. He received the tonsure in 1717, and entered the convent at Lower Kamchatka. In 1720 he came to Yakutsk, where excellent reports of him were received from the local traders of Kamchatka, when the Yakutsk authorities as well as Captain Bering sought him out.

On the 7th of June Lieutenant Spanberg left Yakutsk with 13 barges and 204 people. While at Yakutsk Bering detached on special service the noble Ivan Shestakoff, who afterward went to make war on the Chukchis with his uncle, Afanasius Shestakoff, Hetman of Cossacks. Chaplin's journal notes that he bought of the noble Ivan 11 oxen, for which he paid 44 rubles, or about $32.

All the material and provisions being started for Okhotsk, Bering himself departed for that place on the 16th of August, 1726, with Chaplin and others, leaving Lieutenant Chirikoff behind to follow in the spring. The latter determined the latitude of Yakutsk as 62° 08′ and the variation of the compass 1° 57′ easterly.

In the last days of March, 1727, an epidemic of measles developed in Yakutsk, so severe that by the middle of April every one was ill, where none had been ill before. No such pestilence had been known for half a century and none such occurred for 45 years afterward.

April [Query, August?] 29, 1726, there were forwarded to Okhotsk, 58 oxen, 4 cows, and 2 pigs. "Okhotsk settlement," says Chaplin, "stands on the bank of the river Okhota and contains 11 houses built of logs. The inhabitants subsist chiefly on the fishery, as grain is not grown. There are many tributary natives in the vicinity of the place. The Lamuts call the Okhotsk Sea Lamo."

By the 27th of October 278 horses with 546 sacks of flour had arrived at Okhotsk, less than half of those which had been started from Yakutsk. Lieutenant Spanberg (who had started by water, in the hope to reach a land-mark erected by the Siberian pioneers near the Yudoma River, a crucifix known as the Cross of Yudoma) was caught by frost near the mouth of the Gorbeh River a long distance from his destination. Artisan Kozloff lost during his journey 24 horses, and left their packs of flour at Yudoma Cross. The surgeon lost 12 horses, and of 11 oxen only 1 arrived. Nor did the horses at Okhotsk fare better. Chaplin states that on the 11th of November, of the remaining horses 121 were dead. During November the party were all engaged in getting out timber for houses. On the 19th there was an extraordinary high tide which flooded the whole town, the latter being situated on a low gravel spit. During the whole month the wind blew from the north. On the 2d of December Captain Bering occupied a newly erected house.

The setting in of winter found Spanberg in a barren and uninhabited region where nothing could be procured. His party were obliged to proceed by land to Yudoma Cross and for food were reduced to the greatest extremity. On the 21st of December a report from him was received to the effect that his party was on the road with 90 sledges, having left a mate and 9 soldiers in charge of the barges; the next day 10 sledges of provisions, and twenty-four hours later 39 men with 37 sledges, were dispatched to his relief.

[1727.] Early in January, 1727, Spanberg arrived with 7 sledges at Okhotsk. On the 14th of February a party with 76 sledges started to bring in Spanberg's goods, returning two weeks later, and by the 6th of April most of the material had arrived at Okhotsk.

Towards the end of April the clerk, Turchaninoff, became insane—a man who until then had been trusted by Bering with serious or dangerous duties with perfect confidence. He was immediately put under a strong guard and sent to Yakutsk to be returned to St. Petersburg.

In the month of June, 1727, everything being made ready for transportation to Kamchatka, the newly built vessel, named the *Fortuna*, was launched June 8 at Okhotsk. On the 11th Luzhin and the remaining goods arrived from Yudoma Cross. Toward the end of the month the vessel had been rigged and loaded with cargo for Kamchatka. Chaplin determined the latitude of Okhotsk to be 59° 13′ N.

July 1, 1727, Spanberg sailed for the Bolshoia River, Kamchatka, in the *Fortuna*. Two days after Lieutenant Chirikoff arrived from Yakutsk with the goods which had been left there, 110 horses and 200 sacks of flour in charge of Quartermaster Borisoff.

On the 10th a boat arrived from Bolsheretsk belonging to the Treasury Department, and bringing two commissioners who had been sent out in 1725 to collect the Kamchatkan tribute. This was the same vessel which made the first voyage from Okhotsk to Kamchatka in 1716. Parties with additional supplies of flour, to the amount of about 600 sacks, arrived during this month and 50 oxen to supply salt beef for the expedition. On the 20th a sergeant with reports for the Admiralty College was sent off.*

August 4 the old vessel, having been repaired, was launched. On the 7th a high wind from the sea drove in a multitude of ducks which the whole expedition set out to capture, bringing in 3,000, while as many more escaped or were allowed to get away. On the 11th of the month Lieutenant Spanberg, with the *Fortuna*, returned from Bolsheretsk. August 19, 1727, the command went on board the vessels, Bering and Spanberg on the *Fortuna*, Chirikoff and Chaplin on the old vessel, whose name is not mentioned. On the 22d they set sail. The vessels kept company, and the notes which follow were taken by Chaplin on his own vessel.

On the 29th they saw the coast of Kamchatka in latitude 55° 15′; came to anchor and sent a boat for water to a river which was called Krutogoroff by those acquainted with the coast.

On the 1st of September, in the afternoon, they weighed anchor and stood to the southward. At 3 o'clock on the 2d they arrived at the mouth of the Bolshoia River, and at 6 p. m. they were joined by the *Fortuna*. It was highwater at 7:30, four hours and fifty-four minutes before the moon's transit over the meridian. The latitude was 52° 42′ N. The difference of longitude between Okhotsk and Bolsheretsk was computed to be 13° 43′. The place was observed to be in latitude 52° 45′, and the variation was 10° 28′ easterly. At noon on the 6th of September, Bering, Spanberg, and the surgeon went ashore and were followed by most of the party in small boats. On the 9th Lieutenant Chirikoff also left his vessel for the shore. Most of the month was employed in taking cargo in small boats up the river Bolshoia as far as possible to save labor later on. About the middle of the month Spanberg left Bolsheretsk on his way to Lower Kamchatka settlement.

There were 17 houses at Bolsheretsk, according to Chirikoff's journal.

On the 6th of October the above-mentioned boats arrived at Lower [? Upper] Kamchatka, the only losses being 2 anchors and 8 sacks of flour.

[1728.] *January* 4, 1728, 78 sledges of different goods and the commander's baggage set out for Upper Kamchatka settlement. January 14, Bering himself, and his whole party followed. January 25 all arrived safely at Upper Kamchatka, a distance of 486 versts from Bolsheretsk. This settlement of 17 houses was situated on the left bank of the Kamchatka River, and principally occupied by the officers who collected the tribute and their employés.

The settlement of Upper Kamchatka, according to Chirikoff's journal, contained 40 Russians. It is situated in latitude 54° 28′, and the variation of the compass is 11° 34′ easterly. [Krashininikoff wintered here in 1738, when there were 22 houses and 56 Russian residents.] Here Bering remained 7 weeks supervising the dispatch of goods on sledges to Lower Kamchatka, for which place he and the rest of his party started on the 2d of March, arriving there safely on the 11th.

The settlement was on the right bank of the Kamchatka River, and consisted of about 40 houses, scattered along the bank for the distance of a verst. Seven versts to the SE. by E. are the hot springs, where there was a church and 15 houses. Here Spanberg was recruiting, his health being impaired. From Upper Kamchatka to Lower Kamchatka the distance was regarded as 397 versts, so that all the goods and material had been transported 883 versts.

*These dispatches took nearly a year to reach their destination.

A note and abstract in the archives of the University of Upsala, filed with Waxel's chart of the expedition of 1741, states that on the 28th of August, 1728, the Admiralty College ordered that from the journals and charts sent by Captain Bering a chart should be prepared showing his complete route, of which an abstract follows, which states that for that part of the journey beyond Okhotsk no report had at the time of writing been received. This note is neither dated or signed, but appears to be a news-brief of the time to which it refers. The journals, etc., are undoubtedly those above referred to.

On the 4th of April, 1728, all the party joined in beginning the construction of the vessel. Bering issued a bountiful allowance of wine to all hands. By observation the latitude (of Lower Kamchatka) was found to be 56° 10′. On the 30th of May Lieutenant Chirikoff arrived with all the remaining people of the command. In March, April, and May, strong southerly gales were experienced.

On the 9th of June the newly built vessel was dedicated and named the *Gabriel*, with religious services, and successfully launched. The commander celebrated the occasion by the free distribution of two and a half buckets of wine.

On the 9th of July all was put on board the vessel, and on the 13th, with all sail set, they left the mouth of the river Kamchatka and entered the sea. The surveyor, Luzhin, was left behind on account of illness. [He was the man who had been sent by Peter the Great, in 1719, to explore for gold the six Kurile Islands.] Four soldiers were also left as a guard for the barracks and stores.

Lieutenant Chirikoff says: "Below this place, near the mouth of the Kamchatka River, on the coast, the point from which we took our departure was reckoned in longitude as the first meridian to which it is necessary to add the difference of longitude from St. Petersburg. Starting with the longitude obtained by the observation of an eclipse at Ilimsk, October 10, 1725, the sum of all the calculated longitudes to this place (Lower Kamchatka) is 126° 01′ 49″."

"The respected Chirikoff, in his statement of the longitude observed at Ilimsk," says Bergh, "has made an important error. Observations of his on shipboard are much more accurate. His journal of the river voyage from Tobolsk to Ilimsk makes the whole longitude 36° 44′, which is admitted at present; the observation above mentioned only 30° 13′. From correct observations, or from the chart of Captain Cook between the position of Kamchatka Cape and St. Petersburg, the total longitude is 132° 31′, that of Chirikoff only 126° 01′, to which, if we add 6° 31′, we also obtain 132° 32′. This 6° 31′ is the difference between the marine observations and that of the eclipse at Ilimsk (p. 31). Those who know how difficult the observations of such phenomena are will not give the less praise to our sea navigator, Captain Chirikoff, for the discrepancy between his observations and those made on board ship."

July 14, 1728.—Captain Bering sailed southward for 24 hours in order to round the Kamchatka Cape, which projects far out into the sea. His calculations started from the Lower Kamchatka meridian, and the latitude adopted in the journal for the point of departure is 36° 03′, with a variation of the compass of 13° 10′ easterly.

July 15.—Cloudy weather, with little wind, so that at midnight only 18 miles had been made. From 3 o'clock a. m. fog completely hid the shore near which the vessel was sailing. At sunrise the variation of the compass was observed to be 14° 45′ easterly. The total run for the day was 35 miles ENE.

July 16.—At noon [from which the nautical day is calculated] the wind was fresh from the SSW., and the vessel was making 6½ knots an hour. At sunset the variation of the compass was observed to be 16° 59′ easterly. In the evening the wind was light, the horizon foggy, and hoar frost was noted. In the morning the variation was observed to be 16° 59′ easterly.

July 17.—Wind light, weather thick and foggy. At 6 p. m. white mountains were seen, covered with snow, revealing the proximity of the shore. [It is supposed that this was Ozernoi Point.] Beyond, directly to the north, land was seen [probably Ukinskoi Point, which on old charts is shown as mountainous and visible at a distance, though shown as lower on new maps].

July 18.—Calm and hazy weather. Only 8 miles northing was made this day. For fear lest they should approach Ukinskoi Point too closely, the vessel stood for some hours to the SSE. and ESE. The latitude was observed to be 57° 59′, and the variation 18° 48′ E.

July 19.—Cloudy, calm weather. Only 22 miles were made NE. by N. this day, but Karaginskoi Island was seen by Bering, who notes driftwood on the shores and, though uncertain, supposed it to be insular.

July 20, 1728.—Fresh winds and fog. This day 92 miles were made NE. by E., and Karaginskoi Point [which juts out 22 miles seaward] was rounded.

July 21.—Fresh winds and fog. One hundred miles were run this day and numerous points of land seen to which Bering gave no name. [He only says in his journal, "saw mountains covered with snow; saw high mountains; saw separate mountains; saw mountains close to the sea." Chaplin says not a word about Oliutorskoi Bay, in which they sailed for 24 hours.]

July 22.—Fresh winds and hazy weather. The course lay along the land about 15 miles from the high rocky mountains. One hundred miles was the day's run, and the latitude was observed to be 60° 16′, the variation 16° 56′ easterly. The gain in latitude was computed to be 14 miles.

July 23.—Moderate winds and hazy weather. The course lay along the shore at a distance of about 20 miles. At sunrise the variation was 19° 37′ E.; three hours later 25° 24′ E. The course was NE. by N. ¾ N. (true) until 11 a. m., when the wind died away. The whole shore along which they sailed was bordered by high mountains. One of them, which still retained snow in several places, was named Pestrovidnoi (Harlequin) Mountain. Forty-eight miles were made good and the latitude observed to be 61° 3′.

July 24.—At noon the water was warm and pleasant; the vessel becalmed off the coast. In the evening the wind strengthened and blew in gusts from the mountains.

July 25.—After noon rain with a strong breeze, which lessened toward evening and was followed by a heavy sea. To the north they saw a prominent cape, which projected from the high range of mountains. The latitude by observation was 61° 32′, which agreed well with the ship's reckoning. The variation was 24° 00′ E.

July 26.—Wind light, with clear weather. The vessel was coasting along parallel with the shore under all sail, at a distance of about twenty miles. In the evening they saw a bay lying to the NW. by N. [supposed by Bergh to be the estuary of the Khatirka River]. Eighty miles were made good on this day, and the variations of the compass were determined on two occasions as 21° 05′ and 21° 10′ easterly, respectively.

July 27, 1728.—Light changeable winds and bright sunshine. A cape was passed at a distance of 3 miles, the general trend of the coast parallel to the vessel's course being distant about 15 miles. In this vicinity a river appears to enter the sea. Near the cape [St. Thaddeus] many whales, seals, walrus, and different birds were seen. Soundings were had hereabouts in 70 to 87 fathoms. During the calm weather many eatable fish were caught, of the salmon family.

July 28.—Light winds and rain. A current was observed to the SE. by S. of a knot an hour. Porpoises, whales, sea lions, walrus, and birds were abundant. Under all sail 30 miles N. by W. were made. At noon the shore was distant about 15 miles, and high craggy mountains were observed close to the sea.

July 29.—Variable winds and overcast foggy weather. The land which had hitherto been bordered by high mountains now appeared to be less elevated. Soundings were had in 12 fathoms, fine sand. Thirty-four miles were made good to the NW. by N. this day. At midnight Captain Bering ordered the vessel laid to until daybreak, when she proceeded along the land at a distance of a mile and a half, the depth being 10½ fathoms.

July 30.—Overcast weather and changeable wind. At 5 p. m. raining; the shore being distant a mile and a half the vessel anchored in 12 fathoms, and Chaplin was sent to find a watering place near which sheltered anchorage could be had. On reaching the shore he found neither a watering place nor a safe anchorage, except perhaps at flood tide. The bay could be ascended only with difficulty, as the shoals were not visible. On Chaplin's return they weighed anchor and stood along the shore in about 14 fathoms water.

July 31, 1728.—The whole day foggy and overcast. The shore to the NW. and NE. was occasionally visible. The vessel made 85 miles in a NE. direction. The depth of the water continued to be from 10 to 13 fathoms. About noon they observed that the water began to be discolored and changed its appearance, which was explained by the appearance, everywhere to the north, of land which was very near by.

August 1, 1728.—Dark, foggy weather, with rain, the wind gradually rising. As they were sailing only 3 miles from the high and rocky coast Bering made all sail to the S. and SW. to make an offing. Against the current the sails made nothing remarkable. At 2 in the morning tacked ship and carried away the iron traveler to which the boom tackle was made fast. In the morning they calculated that they were 16 miles off shore, toward which they stood in again. As the day was the Græco-Russian festival of the Holy Cross, Bering gave that name to the bay in which they were, and called the river Bolshoia (Great) River.*

August 2.—Calm overcast weather continued until 8 p. m. The depth was 58 fathoms, muddy bottom. At 8 a moderate breeze sprang up and at midnight land was visible to the ENE., 5 miles distant. The depth here was 12 to 14 fathoms, stony bottom. At noon the latitude was observed to be 62° 25′.

August 3.—Weather dark and wind moderate. [Bering during two days had endeavored to find a harbor conveniently situated to a stream so that a supply of fresh water could be obtained, keeping the vessel under sail; but it appears that he did not succeed in his design and gradually reached the southeast point of entrance to the Bay.] Nothing noteworthy occurred this day.

August 4.—Overcast weather and moderate airs. Beyond the southeast point of entrance to Holy Cross Bay the vessel sailed parallel to a high rocky coast and made 36 miles to the ESE. The depth was about 12 fathoms, gravelly bottom.

August 5, 1728.—Calm and gloomy weather. The course and shore continued about the same. Nothing of importance occurred.

August 6.—Moderate breeze and cloudy weather. From 1 to 9 o'clock careful watch was kept for any watering place, the stock on board having become reduced to a single cask. At 6 o'clock they approached high rocky mountains extending to the northward like a high wall. At a valley between the mountains a small bay was discovered and anchorage had in 12 fathoms gravel. In honor of the church festival the bay was named Preobrazhenia, or Transfiguration Bay.

August 7.—At noon Chaplin was sent with 9 or 10 men to bring fresh water and sketch the shore line. From a small mountain stream fed by the snow on the peaks they obtained 22 casks of water. They also found an empty hut, which appeared to have been recently occupied by Chukchi. In many places foot paths were noted. By seven the sketch of the bay was done [but no copy of it is now discoverable].

August 8.—Wind moderate, weather cloudy. At noon weighed anchor and proceeded SE. by S. along the coast, which continued high and rocky. At 9 o'clock a bay was observed, which extended to the NNE. with a width of about 9 miles. At 7 o'clock a. m. a canoe was seen paddling toward the ship, containing 8 men. There were on the ship two Kariak interpreters, who were directed to address the people in the canoe. The natives said they were Chukchi, and inquired whence and why the vessel came. Captain Bering told the interpreters to ask the natives to come to the vessel. After a good deal of delay one of the men at last came swimming to the vessel on inflated sealskins. The Chukchi said that many of their nation lived along the coast, and that they had heard of the Russians a long time ago. Being asked where the Anadyr River was, they replied a long way to the westward. On a fair day, at a narrow cape not far from there, the Chukchi said an island would be visible near the coast. Receiving a small gift from Captain Bering the native returned to his canoe. The interpreters asked him to persuade his companions to come up near the vessel. They approached for a short time, then made off again. The interpreters said that there was much difference between the Kariak dialect and that of these Chukchi, so that they were not able to get from them all the information that would have been desirable. The Chukchi canoe was made of skins. The latitude of the place where they saw these Chukchis was 64° 41′.

August 9.—Calm, cloudy weather. They were all day getting round the Chukchi Cape, and sailed only 35 miles on various courses. Two observations gave the variation of the compass as 26° 38′ and 26° 54′ easterly, respectively. The latitude was observed at noon to be 64° 10′.

August 10.—Calm, clear weather. All this day working round the Chukchi Cape. Though 62 miles were sailed on various courses, only 8 miles of latitude were gained, and at noon the latitude was 64° 18′.

* Bergh, from platting Bering's track, came to the conclusion that the Holy Cross Bay of Bering was the gulf which lies west and northwest from Cape Bering, and that the Bolshoia River was that which enters the sea at Rudder Bay. This is misrepresented on Lauridsen's so-called reproduction of Bergh's map. Without the original log book it is impossible to test this theory, but it is certainly more in accordance with some of the facts now known than the supposition that Bering entered the shallow estuary now known as Holy Cross Bay, although the latter is represented on Bering's chart.

August 11.—Cloudy weather, with light winds. At 2 p. m. the above-mentioned island was observed to the SSE., which Bering, in honor of the saint of the day, named St. Lawrence. At 7 p. m. land was seen SE. ½ E., part of the island previously seen, and which lay from the *Gabriel* south and east about 4½ miles. At noon ending this day the latitude was reckoned at 64° 20′. The depth between St. Lawrence Island and the Chukchi Cape ranged from 13 to 21 fathoms.

August 12.—Thick weather and moderate wind. Sixty-nine miles were sailed this day, but only 21′ of latitude gained. The narrow point (now known as Cape Chaplin or Indian Point) which makes out north from the Chukchi Cape was passed. At sunset, by an observation of amplitude, the variation was determined to be 25° 31′ E. At noon the latitude by observation was 64° 59′.

August 13, 1728.—Fresh wind, cloudy weather. Bering sailed this 24 hours out of sight of land, and made 78′ of latitude while sailing 94 miles.

August 14.—Light wind, moderate weather. Sailed this day 29 miles, which was augmented by current 8¾ miles, as mentioned by Bering, from SSE. to NNW. "At noon," says Chaplin, "we saw high land behind us, and also about 3 o'clock saw high mountains, which were probably on the continent." At noon the latitude was reckoned at 66° 41′.

August 15.—Light wind, cloudy weather. At noon saw many whales. Since the 12th of August the sea water had been discolored, the depth, 23 to 36 fathoms. Sailed 58 miles this day, to which the current added 8¾ more.

August 16.—Light wind, cloudy weather. From noon to 3 p. m. sailed to the NE., making 7 miles. Then the course was changed to S. by W. ½ W. The journals of both Chirikoff and Chaplin say, "at 3 o'clock Captain Bering announced that it was necessary for him, in spite of his instructions, to return and put the vessel about, with orders to steer S. by SE. by compass." The latitude of the point from which Bering turned back was 67° 18′, and it was reckoned to be 30° 17′ E. from Lower Kamchatka. According to Bergh, who does not give the exact language of the journal, there was a fresh wind, and the vessel made over 7 knots an hour on her southerly course. At 9 a. m. they saw high mountains on the starboard (right) hand, "on which," says Chaplin, "live Chukchis," and later to seaward (on the left hand) an island. According to Bergh, Bering named this island St. Diomede, in honor of the saint of the day, as was customary.* This day 115 miles were sailed, and the latitude was reckoned at 66° 02′.

August 17, 1728.—Fresh wind and moderate weather. The course was parallel to the land, on which numerous natives were seen and at two places dwellings were observed. The Chukchi were seen from the vessel to run to the high rocky hills. At 3 p. m. very high gusts were felt coming from the highland and mountains, from which lowlands made out, in which a small bay was observed. This day 164 miles were sailed, and the latitude was observed to be 64° 27′.

August 18.—Light wind and clear weather. At noon many whales were seen. At 5 o'clock a bay was seen navigable and affording shelter. At sunset the variation of the compass was observed by amplitude observations to be 26° 20′ easterly, and afterwards by azimuth 27° 02′. At midnight the weather was clear, the moon was visible, and later there was an aurora. At 5 a. m. St. Lawrence Island was seen 20 miles ENE. The latitude was reckoned to be 64° 10′.

August 19.—Light wind and moderate weather. This day was spent near the Chukchi Cape, but owing to the fog the coast was invisible. The latitude was computed to be 64° 35′.

August 20.—Calm and foggy. From midnight to 5 o'clock the weather was so thick that the vessel was laid to and the sails taken in. At 6 a. m. sounded in 21 fathoms. At 8 a. m. the weather cleared up a little, and the coast was seen half a mile away. A light wind arose from the north, and the fore and main sails were set. At 10 a. m. they set the topsail and took note of the direction of the coast, observing that behind them it extended to the east and beyond them to the W. by N., when 4 canoes came off to them from the shore, and the vessel lay to drifting, to enable them to come up. The natives in the boats were Chukchis, and appeared good humored and well behaved. They came up to the vessel, and told the interpreters that they had been acquainted with the Russians for a long time, and one of them claimed to have visited the Anadyrsk trading post. They said that they traveled as far as the Kolyma River with reindeer, and that they never trav-

* On the only published chart which is claimed to have proceeded directly from Bering in person this island is named St. Demetrius.

eled there by sea. The Anadyr River was situated far to the southward, and all along the coast lived people of the Chukchi nation; they knew nothing of any others. The natives brought reindeer meat, fish, fresh water, red and Arctic foxes, and four walrus teeth, which they traded. This day were sailed 37 miles; the latitude was estimated to be 64° 20′.

August 21, 1728.—Fresh wind and moderate weather. Sailed this day 160 miles SW. ½ W., and at noon saw Preobrazhenia Bay, where they had anchored August 6, bearing N. by W. about 7 miles.

August 22.—Fresh wind and moderate weather. An azimuth observation made the variation 20° easterly. Saw and named Cape Thaddeus (Navarin) at a distance of 25 miles bearing W. by S. This day sailed 142 miles and observed the latitude to be 61° 34′.

August 23.—Calm and clear. By amplitude the variation of the compass was observed to be 18° 40′ easterly. The latitude was observed to be 61° 44′, the difference between the reckoning and observation being due to a current to the NE. by E.; 35 miles were sailed this day.

August 24.—Calm, clear weather. All day the shore was visible at about 15 miles distant. The day's run was only 20 miles, and the variation of the compass 13° 53′ easterly.

August 25.—High winds and gloomy weather. The run was only 34 miles, and the observed latitude 61° 20′, differing widely from the reckoning.

August 26.—Clear, with a fresh breeze. The run was 105 miles, and the observed latitude 60° 18′; the calculated latitude 60° 22′, and by amplitude and azimuth the variation was found to be 18° 32′ and 18° 15′, respectively.

August 27.—Clear, with fresh wind. The vessel made 5 to 7 knots, and once, at night, 9 knots were reported. From midnight to the following noon the weather was thick with rain and no observations were made.

August 28, 1728.—Cloudy, with fresh wind. The day's run was 98 miles; the observed latitude 57° 40′, the reckoning 57° 49′; the difference was ascribed to a SE. ¾ E. current.

August 29.—Calm and clear. The variation of the compass was 16° 27′, the observed latitude 57° 35′, and the day's run 54 miles.

August 30.—Fresh wind and clear weather. The day's run was 100 miles. No land had been seen since the 24th instant. The estimated position was latitude 56° 33′ and longitude 1° 38′ E. of the meridian of Lower Kamchatka.

August 31.—High wind and dark weather. At 4 o'clock the coast was seen WSW. through the fog at a distance of 3 miles or less. The direction of the land was SE. by S. and N. by W., and the fore-topsail was furled, the fore and mainsails reefed, which was not soon or easily done, owing to the strength of the wind. At this time the vessel was within half a mile of the shore, which offered no shelter, being bold, rocky and high. Until 10 o'clock they worked against the headwind to gain sea room. At 10 p. m. the fore and main halyards gave way and the sails fell, becoming entangled with the rigging. On account of the high sea the rigging could not be slackened up, so they were obliged to let go the anchor in about 21 fathoms, a mile or less from the shore. They worked with great difficulty to clear the rigging and repair damages until noon, when they were ready to get under way again. The day's run was 32 miles to the SW.

September 1, 1728.—Wind moderate, weather gloomy. At 1 o'clock Bering ordered the anchor weighed. With much trouble they got in a few fathoms of the cable, when it parted and was lost. Sail was made at once to the SSE.

September 2.—Weather moderate and wind fresh. At 5 p. m. the vessel entered the Gulf of Kamchatka, but on account of fog was unable to reach the mouth of the river until 7 a. m., when they entered the river, furled all sail and anchored the vessel securely. A current was noted off the mouth of the river running 10 knots an hour to the SW. ½ S.

[In the mouth of the river was anchored the old ship *Fortuna* from Okhotsk, but the journal says nothing as to how she reached the river, or who commanded her on the voyage around the peninsula of Kamchatka, which she was the first to make.]

The winter was passed by Bering and his party at Lower Kamchatka without notable incident except the announcement of the death of the Emperor Peter II, which news was received seventeen months after the event. In the spring Bering put the two vessels into condition for service and assigned to the *Gabriel* 35 men and 4 officers, and to the *Fortuna* 5 officers and 7 men, who are not more particularly identified. On the first of June their arrangements were complete. Owing to the impression which prevailed in Kamchatka that land existed in the eastward across the sea now known as Bering Sea, a belief which was supported by the statements of the Chukchi and other circumstantial evidence, Bering decided to make an attempt to investigate the matter before returning finally to Okhotsk. The following extracts from Chaplin's journal are derived from the publication already drawn upon for the data in relation to the voyage of 1728:

June 6, 1729.—Light wind and cloudy weather. Bering sailed from the mouth of the Kamchatka River and, taking his departure from Cape Kamchatka, sailed E. by S.

June 7, 1729.—Light wind, clear weather, and sea coming from the NNE. No observations were taken this day, but the latitude was calculated to be 55° 37′ and the longitude 2° 21′ east from Lower Kamchatka.

June 8.—Gloomy weather and strong wind from the NNW. The vessel lay to under the mainsail all day, drifting about five points. At noon the latitude was estimated to be 55° 32′ and the longitude 4° 07′ east from Lower Kamchatka.

June 9.—Gloomy weather and strong wind. Bering sailed 2 miles further on an ESE. course and then tacked and stood SW. by W. Up to this time, on the search for land, in all the run amounted to 114 miles. From the time of abandoning the search to the following noon the run was 150 miles. The coast of Kamchatka was seen in the morning. At noon the latitude was observed to be 54° 40′.

June 10.—Light wind and cloudy weather. All day the vessel sailed in sight of the coast and at midnight the wind failed entirely, the whole run amounting to only 35 miles. By an amplitude observation the variation of the compass was determined to be 11° 50′ to the eastward, and the observed latitude was 54° 07′.

June 11.—Light wind and clear weather. The mountains called Kronokakh and Zhupanoff were seen and also the Avatcha volcano. All this day sailed in sight of the land, at a distance of from 6 to 10 miles. By azimuth and amplitude the variation of the compass was found to be 8° 31′ and 8° 46′ easterly, respectively. The observed latitude was 53° 13′. "From this time forward up to the 20th instant," Chaplin observes, "variable currents were observed near the shore ranging between south and west, and offshore between south and east."

June 12.—Clear weather and light winds. At midnight the wind became high and in the morning it was foggy. Made in all 42 miles sailing in sight of the coast, including 12 miles due to current, to the SE. by E. ¼ E.

June 13.—Light wind and thick fog in the morning. The vessel was turned about by the current on three occasions. The run was 34 miles, including current.

June 14, 1729.—Gloomy weather with rain and little wind. The current was exceptionally strong and the courses various. The estimated latitude was 52° 58′.

June 15.—Moderate wind and dark weather. The vessel drifted most of the time and made about 12 miles on account of the current.

June 16.—Gloomy weather and light wind. The run was 38 miles, including 8 miles gained by current to the SE. by E. ½ E. The weather was so thick that the shore was not visible. The estimated latitude was 51° 59′.

June 17.—Calm, thick weather. The coast was hidden by fog and the run was 27 miles.

June 18.—Cloudy weather and moderate SW. wind. The vessel stood to the NW. The observed latitude was 52° 14′, or 24 miles more northerly than the reckoning.

June 19.—Fresh wind from the SSW. with rain. The vessel steered N. by E. and at noon saw Zhupanoff Mountain at a distance of 25 miles.

June 20.—Fresh southerly winds and dark foggy weather. The vessel stood to the NE. by E., and at noon her latitude was 54° 04′.

June 21.—Wind moderate or light and thick weather. The run was 20 miles NE. by E., with 8 miles westerly current. The estimated latitude was 54° 16′.

June 22.—Foggy weather, and in the morning light wind, with a heavy sea from the SW., followed by a strong southerly wind, during which the vessel lay to under bare poles, making a drift of about 4 miles westerly, in all about 8 miles WNW.

June 23.—Clear weather and light SSW. wind. By observation at sunset and sunrise the variation of the compass was determined to be 11° 50′ and 10° 47′ easterly. At noon the coast was seen 13 miles NNW., the latitude was observed to be 54° 12′, and the run 28 miles W. by S.

June 24.—Weather clear, with a light SSW. wind. The run was in sight of the coast, 30 miles W. by N., and the estimated latitude 54° 15′.

June 25.—Light airs from the SE. and SSW., with rain. The course was S. by W. 26 miles, in sight of land, and the observed latitude 53° 53′.

June 26.—Moderate wind with occasional cloudy sky. At noon the Avatcha volcano bore W. ¾ S., 20 miles distant. No latitude was observed.

June 27, 1729.—Clear weather, with fresh wind and high sea from the westward. The run was 90 miles SSW. and the observed latitude 52° 03′.

June 28, 1729.—Clear, with light winds. At 5 a. m. saw the shore, distant about 5 miles. The observed latitude was 52° 01′ and the variation 7° 42′ easterly.

June 29.—Clear and calm. The run was 17 miles NW. by W., with the land in sight. The estimated latitude was 52° 06′.

June 30.—Clear, with moderate wind. The run was along the land SW. by S., and the estimated latitude 51° 38′.

July 1.—Thick weather and moderate wind. At noon Cape Lopatka bore NW. by N., and a shoal extended seaward from it about a verst.

July 2.—Fine weather and moderate wind. The northernmost Kurile Island, Alaida, was seen [which Chaplin states on old charts was named Anfinogena]. A high mountain was seen bearing SW. by S. ¼ S. The run this day was 70 miles N. 2° 55′ W., the variation 11° easterly, and the latitude 52° 18′.

July 3.—At 5 o'clock in the afternoon the vessel entered the Bolshoia River mouth and came to anchor. The *Fortuna* and an older vessel were already there. The party were occupied with the transfer of stores and other business preparatory to departing for Okhotsk.

[Bering made the difference of longitude between Bolcheretsk and Lower Kamchatka equal to 6° 29′. According to Bergh, Chaplin states in his journal that the difference of longitude between Okhotsk and Bolsheretsk was computed on the first voyage to be 13° 43′ and on the return 13° 14′.

SUBSEQUENT PROCEEDINGS.

On the 14th of July, having been rejoined by Lieutenant Spanberg, Bering sailed for Okhotsk, where he arrived on the 23d of the month. The party celebrated their return by firing a salute of 51 guns, which was repeated from the shore. The vessel was beached and dismantled.

On the 29th of July Bering started by land with horses for the Cross of Yudoma. On the journey he met Afanasius Shestakoff, Hetman of Cossacks, who was on his way to open the Chukchi country by force of arms, and who was, in March of the following year, routed and killed near Penjinsk Gulf by a body of natives commanded by their chief, Shelágin, whose name is appropriately preserved to posterity on charts of the Arctic coast of his country, through the medium of the Shelaginskoi Cape, in latitude 70° N.

Bering reached Yakutsk, August 29, 1729, and Tobolsk in October, where he remained some time, finally reaching St. Petersburg March 1, 1730.

Chaplin, whose journal has, through the medium of Bergh, preserved many facts in regard to this remarkable expedition, was recorded in 1723 as one of the most promising naval cadets. On joining the expedition he was made midshipman; on their return, in 1729, promoted to be sub-lieutenant, and in 1733 to be lieutenant. He is said to have died at Archangel, in Russia, in 1764, having attained the rank of Captain-Commander. The journal itself, with many other documents, is deposited in the archives of the Naval College of the Admiralty in St. Petersburg.

In order that the differences of calendar and account, and the errors of previous publications may be more easily avoided, I add a carefully corrected itinerary of the expedition reduced to the modern dates. In some cases, where the authorities are discrepant, I have adopted the date which from all the circumstances seems most probably correct.

Itinerary of Bering's Expedition, reduced to new style and civil account.

	1725.	Saw Cape [afterward named Thaddeus]	1728. Aug. 6.
Advance party under Chirikoff left St. Petersburg	Feb. 4.	Sailed in Holy Cross Bay of Bering	Aug. 10-13.
Bering followed	Feb. 16.	Entered Preobrazhenia Bay	Aug. 16.
Bering arrived at Tobolsk	Mar. 27.	Met baidar with Chukchi	Aug. 19.
Bering left Tobolsk	May 26.	Were off Chukotski Cape	Aug. 20-21.
Chaplin, with advance guard, reached Yakutsk	Sept. 17.	Saw St. Lawrence Island	Aug. 21.
Bering and main body reached Ilimsk	Oct. 10.	The expedition passed Cape Chaplin	Aug. 23.
Chirikoff observed eclipse of the moon at Ilimsk	Oct. 21.	Passed East Cape in the fog without seeing it, and later in the day saw "high land behind" them and mountains "on the continent"	Aug. 25.
	1726.		
Bering arrived at Yakutsk	June 12.	Reached their farthest north and turned back	Aug. 26.
Spanberg, with flotilla, left Yakutsk	June 18.	Saw East Cape and the larger Diomede Island	Aug. 27.
Chirikoff, with rear guard, reached Yakutsk	June 27.	Passed St. Lawrence Bay and Mechigme	Aug. 28.
Bering left Yakutsk for Okhotsk	Aug. 27.	Saw St. Lawrence Island again	Aug. 29.
Bering reached Okhotsk	Oct. 11.	Rounded Chukotski Cape	Aug. 30.
Provision trains arrived	Nov. 7.	Saw four baidars with natives	Aug. 31.
	1727.	Saw Preobrazhenia Bay	Aug. 31.
Spanberg reached Okhotsk	Jan. 12.	Saw again and now named Cape St. Thaddeus	Sept. 1.
Vessel *Fortuna* launched at Okhotsk	June 19.	Anchored and rode out storm	Sept. 11.
Spanberg sailed with *Fortuna* for Kamchatka	July 11.	Reached the mouth of the Kamchatka River	Sept. 13.
Chirikoff arrived at Okhotsk	July 14.	Entered the river and ended the voyage	Sept. 14.
Spanberg returned with the *Fortuna* to Okhotsk	Aug. 22.		1729.
The expedition left Okhotsk for Kamchatka	Sept. 1.	Total eclipse of the moon, visible in this region	Feb. 13.
They arrived at the mouth of Bolshoia River	Sept. 13.	Bering put to sea in search of land	June 16.
They reached the settlement of Bolsheretsk	Sept. 15.	The search was given up	June 19.
Spanberg started for Lower Kamchatka post	Sept. 20.	The vessel rounded Cape Lopatka	July 12.
Spanberg arrived at Lower Kamchatka	Oct. 17.	Arrived at Bolsheretsk	July 14.
	1728.	Sailed for Okhotsk from Bolsheretsk	July 25.
Bering left Bolsheretsk	Jan. 24.	Arrived at Okhotsk	Aug. 2.
Bering reached Upper Kamchatka village	Feb. 6.	Bering started homeward from Okhotsk	Aug. 9.
Eclipse of the moon visible in Kamchatka	Feb. 25.	Reached Yakutsk	Sept. 9.
Bering left Middle for Lower Kamchatka	Mar. 13.	Reached the Lena River	Oct. 12.
Bering arrived at Lower Kamchatka	Mar. 22.		1730.
Construction of the vessel *Gabriel* begun	Apr. 15.	Reached Tobolsk	Jan. 21.
The *Gabriel* launched	June 20.	Arrived at St. Petersburg	Mar. 12.
The *Gabriel* put in commission	July 20.		
The expedition put to sea in the *Gabriel*	July 24.		

NOTES ON THE MANUSCRIPT CHART [Illustration No. 69] OF BERING'S EXPEDITION OF 1725-'30, BELONGING TO THE COLLECTION OF BARON ROBERT KLINCKOFSTRÖM, STAFSUND, SWEDEN.

In the article in the National Geographic Magazine, already referred to, I have given a summary of existing information in regard to the cartographic results of Bering's first Kamchatka expedition. We may infer from the facts known to us that a rough chart of the land journey was made from day to day and also, when practicable, during the sea voyage, and that with the monthly report to the Admiralty College, which was required by his instructions, copies of these rough sketches were forwarded when opportunity served. Bering had two professional cartographers beside Chirikoff and Chaplin, educated Naval surveyors. After his return to Kamchatka he wintered at the settlement near the mouth of the river known as Lower Kamchatka and during this time, without doubt, supervised the preparation of a chart of the voyage as well as his report. He returned to St. Petersburg in March, 1730, bringing a chart with him. It is probable that tracings of this chart and brief abstracts of his report were sent out as matters of news, as the custom then was, and one of these sketches was published by the Jesuit father Du Halde as an appendix to his monumental work on the history and geography of China. All the copies, even of this simple sketch on a very small scale, which were printed before 1748 were more or less imperfect, but what seems to be a complete rendering of it appears in Campbell's edition of Harris's collection of voyages in 1748. This was a small engraving on copper measuring about 12·5 by 32·0 centimetres on the neat lines. After Bering's arrival in St. Petersburg it is probable that a general recomputation and revision of his data was made, and we are informed by Lauridsen that the charts (which we may regard as official and final) were prepared at Moscow in 1731. These were much more elaborate and detailed charts, with ethnological, topographic, hydrographic, and magnetic details upon them which are entirely wanting in the earlier maps. This map, though a number of copies must have been sent out, was never engraved or published. Other geographers may and probably did use data compiled from it, but the map, as a whole, never appeared in print. The remarkable results of the great Siberian expedition, of which Bering was the executive officer, may have drawn attention away from the earlier work. Whatever the reason, until now, this document so interesting from its bearing on the geographical history of America and the progress of discovery, and not without attractions for the student of terrestrial magnetism, is now for the first time presented to the public.

The title, enshrined in a fine ornamental escutcheon, reads in translation:

Geographic chart from Tobolsk to the Chukchi [Cape], *made during the Siberian Expedition under the command of Fleet-Captain* [a blank space].

The blank space with which this inscription terminates was intended to receive the autograph of Bering, which for some reason was not appended; though, in at least one of the other copies known, it is present.

This copy was evidently prepared for use in Sweden. The Russian words and names are (rather badly) transliterated into their supposed phonetic equivalents in Roman or Italic letters. Under explanatory remarks, thus transliterated, is a rendering of them in archaic Swedish.

At the northwestern angle of Chukchi-land is a legend stating that "this region is called Shelagin's." Shelagin was the Chukchi leader, who, shortly after Bering's expedition in 1730, defeated the Russian forces in a pitched battle and killed Shestakoff, their commander. Shelagin's name is retained in modern maps by the northernmost point of Siberia east from the Kolyma River, Cape Shelaginski, sometimes shortened to Shelagskoi.

The northern coast of Chukchi-land has a note to the effect that "This land is put down from older charts and information," so that for the erroneous extension northward of a part of it neither Bering nor Müller are blamable.

The high range of mountains along the eastern shore of Kamchatka carries the following note: "On these mountains the snows lie in summer and winter, and from them there are violent squalls or gusts of wind."

On the northern part of Kamchatka peninsula is written, "Here live tributary Kamchadals speaking several dialects."

In the northern part of the Okhotsk Sea, beginning at the river Okhota, it is stated, "From this river around to the river Krutogorova is put down from older charts and information." In the southwestern part of the same sea, "This coast is according to older maps."

At Cape Lopatka, here called Osnoi (which is a corruption of Osernoi in reference to the lake Oser, just behind it; or, more probably, of Uzhnoi, meaning southern), it is noted this is the "southern point of the land of Kamchatka."

Elsewhere on the map are phrases evidently derived from Bering's Report, as near Okhotsk, "Hereabouts live the tributary reindeer Tunguses," and "These hereabouts are Lamuts." Further west "From the river Vitim and on the banks of the rivers [eastward] beyond live the so-called Yakuts and Tunguses, who pay tribute to the Russian Crown."

The whereabouts and religious state of various other tribes are indicated by similar inscriptions at various points on the western part of the map.

This map measures 51 by 20½ inches between the neat lines. It is in black and white, the mountains washed in, the only color being small green trees as a conventional sign for wooded country. There is no name of draughtsman or place or date of making. The geographical part has been made with an ink which has turned brown with age. The ornamental escutcheon was drawn by a different hand in another kind of ink which has retained its color.

There are two manuscript maps in the Royal archives of Sweden of this general character, which have been briefly noticed by E. Dahlgren.* They are more elegantly and profusely ornamented and differ slightly in names, and one has a number of soundings between St. Lawrence Island and the Diomede Islands. They are of the same size and doubtless were made at the same time as the Klinckofström chart, but, being intended for an exalted personage, were more highly ornamented.

The geographical peculiarities of this, as compared with other charts of the first voyage of Bering, are discussed in the National Geographic Magazine (Vol. II, No. 2, 1890) as previously mentioned, and to that paper is referred the reader who desires fuller and more technical details.

It is only just to call attention to the liberality of Baron Klinckofström in permitting this valuable relic to go beyond the seas for the information and accommodation of American students of geography, and to express for this courtesy our sincere gratitude.

NOTES ON THE ORIGINAL CHART BY WAXEL OF THE VOYAGE OF BERING IN 1741.

[Illustration No. 70.]

Lieut. Sven Waxel, executive officer of Bering's vessel, was a Swede in the Russian service. In June, 1741, he sailed from Avacha Bay in the ship *St. Peter*. Later on in the voyage, as the scurvy with which they were scourged reduced the commander, Bering, to such a state that he was obliged to take to his bed, Waxel practically commanded the vessel. After their return from the island named after Bering, who died and was buried upon it, Waxel was senior officer, and when the forces of the expedition were gathered at Tomsk in Siberia, where they remained until 1745, according to Lauridsen, Waxel for a time was in general command.

The manuscript chart, of which the accompanying outline is a facsimile, is supposed to have been made for Waxel's own use by some draughtsman under his supervision, or from his own notes, so that it represents what were to him the geographical results of the voyage of the *St. Peter*. The results obtained by Chirikoff on the *St. Paul*, which early in the voyage became separated from the *St. Peter*, were of course different, and to some extent discrepant. The attempt to combine these two discrepant charts has made the charts of Müller and others much more confused and confusing than either of the originals would have been separately.

The opportunity of examining this valuable historical relic is due to the liberality of the authorities of the University of Upsala, Sweden, of whose library it forms a part.

By reproducing it we place in the hands of students another original document which hitherto has been inaccessible, and the data of which were available only to such as were acquainted with the Russian language.

Apart from its geographical interest, which will be considered presently, this chart has another interest. It is well known to naturalists and those familiar with Alaskan history that the crew of Bering's vessel discovered on Bering Island, or living about its shores, an enormous species of manati or sea cow, which afforded excellent meat, and which was so hunted for food within a few years afterward that it soon became extinct, and is now known only by some more or less imperfect skeletons and a dried fragment of its hide. This animal was described by Steller and is known as Steller's sea cow (*Rhytina stelleri* or *gigas*). It had a very thick rough skin marked by deep folds which enabled it to bend itself with more facility, and its posterior flippers were shaped like the tail of a whale, more or less forked. Steller made a drawing of it which is known only by a copy, the original being lost, and the form of the tail has been in dispute owing to an alleged ambiguity in the original description, and the fact that some of the other sea cows have a rounded tail and not a forked one. In the absence of Steller's original drawing of the northern sea cow, the sketch on this manuscript is probably the only existing protrait of that animal which was ever

* Ymer, for 1884, p. 93.

seen by anyone who had seen the living animal itself. As it shows the forked tail, the question in regard to its shape is thereby settled beyond controversy. There are also two fur seals very well portrayed on the chart, and the fact that these are drawn with remarkable fidelity to nature allows one to infer that the portrait of the sea cow is not less faithful.

The examination of the chart with regard to its geographical features suggests an answer to several questions which have hitherto been in controversy owing to the manner in which the charts of the voyage have been confused together.

In the first place, if this chart had been published separately, the confusion as to Bering's first anchorage on the American coast need never have arisen. Kaye Island, with Cape Martin opposite, in Controllers Bay, are perfectly recognizable. This was long ago determined to be the case by Sokoloff, who published in the Journal of the Russian Hydrographic Department the sketch chart made by Khitroff, Waxel's mate, of the island and harbor. But this publication is a rare and almost inaccessible book and the information was slow in spreading.

The expedition was prevented by fog or darkness from observing the passage north of the Kadiak group, but a cape which is probably Cape Greville is represented by Waxel, and though not named on this chart is likely to be that named Hermogenes by the expedition. The identification of Cape St. Hermogenes with Marmot Island made by Cook receives no confirmation from this chart.

The fictitious island of St. Stephen is absent from Waxel's chart, but the banks northeast from Chirikoff (Ukamok or Foggy) Island are detailed with many soundings, and the identification of Foggy (Tumannoi or on this chart Tomano) Island with that now called Chirikoff Island is complete and can not be reasonably questioned any longer. The Semidi islands are in their proper place with Aghiyuk Island and Chiginagak Volcano northward from them. In this matter Sokoloff was right, as usual, in his judgment of the question.

The Shumagin islands have been identified correctly from the beginning. This chart shows that the anchorages of the *St. Peter* were between Nagai and Little Koniushi, and that the unfortunate seaman for whom the group was named was probably buried on the eastern side of Nagai Thence westward is a long gap until we reach the vicinity of the mountain named on the chart St. John. Here the positions are so wild and the islands so little characteristic that a guess is all that can be hazarded. The general circumstances suggest that this might be the high peak (about 6,000 feet) on the north end of Adakh Island. The "high snow-capped island" named by the expedition St. Marcian would then probably be the island of Tanaga; it could not be the island of Amchitka, as alleged by Lauridsen, since that is low, flat, and without any peaks. Taking the relative positions into account it is not improbable that the island next laid down, under the name of St. Stephen, or St. Stepan, is intended for *Semisopochnoi*, which is high and has several islets near it. St. Abraham, the last of the Aleutians seen by them, is probably Kyska, the only island in that part of the chain with a smaller island close to its northeastern shore. The latitude of the vessel observed that day was 52° 31′, which is conformable with this supposition. The identification of this with the Semichilow, rocky, islets is absurd, and would not have been made by anyone familiar with the islands.

Bering Island and its surroundings are depicted in a manner to cause astonishment. There are several nonexistent islets shown, and the largest, which may be meant for Copper Island, is altogether out of place, yet the party were more than six months on Bering Island. The want of discipline consequent on the death of the commander, and the quarrels and illness among the officers, are probably responsible for the character of this part of the map.

I have assumed that the party on the *St. Peter* did not see anything of the Nearer islands, Attu, Agattu, etc. They appear, however, to have been seen by Chirikoff; and the attempt to identify what was seen by one party with different things seen by the other party has resulted in the confusion of Müller's and other charts based on this ill-judged conglomeration.

If the log books of the two vessels could be published verbatim many of these interesting historical problems might, by the aid of modern charts, be brought to a satisfactory solution. As it is, however, one must be satisfied with adding something to the stock of accessible information, and with the hope that the remainder will be brought to light at some future time.

APPENDIX No. 20.—1890.

NOTES ON AN EARLY CHART OF LONG ISLAND SOUND AND ITS APPROACHES.

By CHARLES HERVEY TOWNSHEND.

[Submitted for publication March 5, 1891.]

The recent discovery in the British Records Office, by Capt. Charles Hervey Townshend, of New Haven, of an elaborate chart of the North American coast from Cape Cod to the Navesink Hills, including Long Island Sound and approaches, has been deemed of sufficient importance to justify the publication of an accurately traced copy in this report. [Illustration No. 71.]

Captain Townshend is of opinion from evidence afforded by the chart itself, and by the copious notes it contains relative to the coasts, shoals, and passages embraced within its limits, that it was constructed by a hydrographical survey party, composed of British naval officers, between the years 1715 and 1720. There are, however, some indications that parts of it had an origin from 20 to 30 years earlier.

The geographical and historical value of charts of this character has long been admitted. For reference with regard to the early spelling of geographical names, the identification of localities, and the changes in topographical and hydrographical features, they are worthy of careful study.

From the full description of this old chart, which has been communicated by Captain Townshend to the Superintendent, the following abstract has been made for publication here:

The chart furnishes positive proof of the existence of one of the closed passages that tradition says existed in early times through Cape Cod, and sustains the statement of Capt. Bartholomew Gosnold, in 1602, that Cape Cod was then an island. That one of these passages remained open as late as 1717 is shown by a marginal note on the chart commenting on the loss of the pirate ship *Whido*, as follows:

"Ye place where I came through with a whale boat, being ordered by ye Governor to look after ye pirate ship *Whido*, Bellamy commander, castaway ye 26th day of April, 1717, where I buried one hundred and two men drowned."*

Hutchinson's History of Massachusetts Bay, volume 2, page 233, states that in the month of April, 1717, a pirate ship, the *Whido*, of 23 guns and 130 men, Samuel Bellamy commander, ventured upon the coast of New England, near Cape Cod, and after having taken several vessels seven of the pirates were put on board of one of them, who soon got drunk and went to sleep. The master of the vessel which had been taken, having been left aboard with the prize crew, ran her ashore on the back of the cape, and the seven pirates were secured.

Soon after the pirate ship, in a storm, was forced ashore near the table-land, and the whole crew, except one Englishman and one Indian, were drowned. Six of the prize crew, which were saved as before mentioned, upon trial by a special court of admiralty, were pronounced guilty and executed at Boston, November 15, 1717.

The main passage used by small vessels, which is here shown, was plainly laid down through the towns of Eastham, Chatham, and Orleans, on Cape Cod. This passage was much used in early colonial times by small vessels and boats when making voyages from the bay of Maine to Virginia. It is shown on the early Dutch and French charts, and on the one sketched by Schipper Adrian Block, in 1614, and this may have been the passage mentioned by Capt. Thomas Dermer, in 1619, when he was making his boat voyage from Monahiggan (Maine) to Virginia. It is interesting also to note that in this very passage, in a salt marsh, has lately been discovered the remains of an ancient ship, which was exhumed by the action of the sea May 6, 1863. It lay within the lands of what is now the town of Orleans.

* This officer was probably Captain Cypian Southack, a Boston pilot, who commanded a ship in the expedition against Quebec, 1690. On his return, September 16, 1690, to Boston, he saved South Church from the flames.

These voyages, with the well-sustained tradition handed down to us from the Eaton and Davenport settlers, who came to Quinnipiac in 1637-'38, after a voyage of 14 days in boats via a passage across Cape Cod, and the fact of the return of Rev. Ezekiel Rogers from Quinnipiac to Rowley, Mass., the next year, in a pinnace which he sent to fetch them, is abundant proof to me of the then existence of this passage, or others, and the investigations of the late Professor Agassiz give also conclusive evidence thereof. These memorable passages were closed up, as I have been told by Capt. William Foster of Brewster, Mass., about 150 years ago, during a furious gale of wind, which was accompanied by a tidal wave. This herculean effort of the elements changed the whole east and south shore of the Cape, and deposited in the salt marshes and lowlands sand hills sixty feet high, and completely washed away a sand point off Nauset, where to this day, at extreme low tides, stumps of former trees have been laid bare, which have been seen by men now living who visited the spot for that purpose.

Before following the navigable approach to Long Island Sound, as shown on this chart, through the waters of Nantucket and Marthas Vineyard Sound and the "Sea of Rhoad Island," brief mention may be made of the following facts: (1) That the Rose and Crown Shoal, then (1717) marked "dry," has at this date (1891) 12 feet of water over it, and (2) that the islands of Nantucket and Marthas Vineyard are on this chart shown as six islands, an illustration of the action of the sea during the past two centuries in moulding the shore.

Across the east entrance to Long Island Sound are given the names of numerous islands, viz: Fisher's Island, Gull Island, and Plum Island, forming with sunken reefs a continuous chain.

The site of the Pequot fort, now in the town of Groton, and marked with the Mason monument, is called Lanthorn Hill, and New London is here mentioned as follows: "A small river, but with a good harbor and farms; navigable for ships and small vessels; a place of great trade; they build many vessels here."

Pine Island off the east point, and Bartlett's Reef off the west point of the harbor, are located, with the mention of tide, full and change of the moon at 10 o'clock, sounding outside 25 fathoms of Blue Owse. Here at Winthrop Point, is given a sketch of Governor Winthrop's house, and the Governor's name is noted; also a church and several houses.

The Connecticut River is mentioned as being a very long river, and having a great many fine towns and farms on the several branches of it, and as being navigable for small vessels. On the chart is added: "Ye seaboard town to the river is Sherbrook (Saybrook). They build a great many small vessels here, and much copper ore mined."

The Long Island towns are also carefully located, and Peconic Bay, about the site of River Head, is noted. Here it is written: "I commanded ye first ship that ever was in this place, in 1692," and as several anchorages are marked in this backwater, and a canoe "place" or portage is marked down between this, through the south beach to the ocean west of Shinnicook, it is quite probable that at this date there existed a boat passage which was used by Colonel Meigs during the Revolutionary war, when he captured Sag Harbor with an expedition fitted out from New Haven and returned without losing a man. Guilford and Branford, on the Connecticut shore, are mentioned as having small rivers and good farms, and both noted as having churches.* These towns, it is added, lie north of the "Sea of Connecticut," with the Hundred Islands (Thimbles) and Falcon's (Faulkner's) Islands off the coast.

The ironworks at Stony River, East Haven, have a special mention and are shown as being on a considerable river, and as this was the third ironworks and bloomery in America, it was then considered of much note. It will be perhaps of interest to state here that I have collected a mass of original material concerning these ironworks, which will at a later date be published. The ironmaster (John Cooper or Cowper's) house (stone built), in old English style, is still standing in a good state of preservation on the west bank of Stony River, near the stone bridge. This, with the overflowing milldam and red gristmill nearby, imbedded in a green foliage during the summer, backed by the brown-faced evergreen Saltonstall mountains, while in the distance appears the graceful spire of East Haven stone meeting-house, with other scenery, rewards excursionists for the effort made to visit one of the most picturesque and pretty bits of landscape in this section of the country.

But we must not tarry here at this secluded spot, but push on to the more pretentious harbor of the Quinnipiac (or New Haven of our day). Here laid down on the chart is noted the time of high water, 9 o'clock on the full and change of the moon, and opposite the harbor, which is only sketched as the entrance of a small river guarded by a rocky channel, with soundings 10 fathoms off its entrance, it says (in the notes) there are many good farms. It is shown on the chart as having a pretentious church, and several houses are sketched, giving an air of importance to the vicinity.†

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*And here Sachem's Head, which was the scene of a tragedy when Uncas, chief of the Mohigans, captured a pursued Pequot sachem, and, after shooting him to death with arrows, cut off his head, which was set in the crotch of an oak tree and remained for years after the tree had grown, holding it thereto. Hence the name Sachem's Head.

†Maverick's description of New England, about 1660, says Tocott. Branford from Guilford to Tocott 9 miles. These two Townes are under Newhaven Government.

Newhaven.—From Tocott to Newhaven it is 7 Miles. This Town is the Metropolis of that Government, and the Government took its name from this Towne, which was the first built in those parts. Many stately and costly houses were erected here and the Streets layd out in a Gallante form, a very stately Church; but ye Harbor proveing not Como-dious, the land very barren, the Merchants either dead or come away, the rest gotten to their Farmes. The Towne is not so glorious as once it was.

Milford.—From Newhaven to Milford it is about 10 Miles. This Towne is gotten into some way of Tradeing to Newfoundland, Barbados, Virginia. So also hath some other towns in this Government.

Directly across the sound from our harbor on Long Island is noted the village of Weding (now Wading River), so called as it is navigable for boats, which can be towed inside by wading the river. The bottom of the sound is blue owse, depth 20 to 25 fathoms, and the tide runs full sea at 1 o'clock. Milford, Stratford, and Fairfield are all located as good farms, while the islands off the Housatonic River and located by Block in 1614, are marked sand banks, and are now washed away save the dangerous remnant known as Stratford shoals. which has 15 fathoms close to [new chart 27 fathoms]. This demands more than casual mention, as they with Faulkner's Island, illustrate the powerful effect of the wind and tidal force on the shore of this arm of the sea, as has been before remarked. Proof positive is still extant of my theory of the dispersion of the islands of the sound, and the late Captain Moore, a noted shipbuilder of Bridgeport, Conn., informed me that he had visited Stratford shoals early in this century at low tide for shellfish, and had observed sedge and other marine grasses growing there, and had also examined walking sticks and canes cut from grove or scrub cedars which stood on this island about 150 years ago. The canes are still in the possession of some of the residents of the neighborhood of Port Jefferson, Long Island. I have been told by Mr. James Park, purser of the steamer *Nonowan Tuc* of the Port Jefferson and Bridgeport route, and who was ten years master of the Stratford light-ship; that in 1860 Captain Kuinis of Port Jefferson, Long Island, then about 75 years of age, told him he had cut rushes on Stratford shoal grounds. There is also a tradition to the same effect from Stratford towns from people who had the ownership of lands of these islands, and Capt. Joel Stone informed me that the Stratford light-ship keeper told him he had walked 40 yards on Stratford shoal when laid bare at extreme low spring tide, which occurred during a continuous west gale in the month of March. Mr. Henry N. Beardsley, of Bridgeport, writes that his father has seen Stratford shoal ground often bare for six rods.

The site of Penfield reef and bar in 1720, called Lewis Island, now marked with a light-house, off Black Rock and Fairfield, is shown as a continuous rocky chain, and served to locate the most eastern island of the archipelago (Norwalk Island) of the first explorer, and there is still at low tide a long bare sand spit which connects the land. Could this or Charles Island, Milford, have been the "marriage point" recommended by Captain Davenport to Governor Winthrop for settlement after the recent conquest, 1637? Opposite, on Long Island, are designated the two points, Eaton and Lloyd, once part of the estates of Gov. Theophilus Eaton and his kinspeople, the Lloyds.

Here Long Island is mentioned as having "fine towns on it, and on the west end many good farms, but towards the east end is much barren land, though there are some places where there are good farms." Mention is also made of Huntington, Oyster Bay, Whitestone, and Flushing, on the Island shore; also Greenwich, Mamaroneck, East and Westchester, on the continent, which terminates at Manhattan Island; also there is given a description of this arm of the sea and its shores at the entrance of the "Inferno" of the Dutch, and in full view of "Hell Gate," the terror of ancient mariners.

Having completed the description of this ancient chart, save brief mention of some of the most western Long Island towns laid down thereon, viz, Jericho, Jamaica, Bedford, and Gravesend, also numerous small inlets for "ye small vessels on ye north side" and a ferry from the now site of Brooklyn to Manhattan Island, separated from "ye main by ye Spyten Divil Creek" [or Harlem River], there remains only to make mention of the meeting of the tides of the East and North [or Hudson] Rivers, and at their junction at Nutting [or Governors] Island connected to Long Island at low water with a narrow sand spit, over which within the past 100 years cows were driven at low tide to pasture from Long Island to Governors Island, and through which a channel has now been forced (by the encroachment by docks on East River), and now known as "Buttermilk Channel."

Here at the meeting of these waters off the Battery of our day are shown the magnificent upper and lower harbors of New York, and southward Staten Island and Sandy Hook, and still farther in the distance, the waters of the broad Atlantic.

PROGRESS SKETCHES AND ILLUSTRATIONS.

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National Oceanic and Atmospheric Administration

Annual Report of the Superintendent of the Coast Survey

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