# FORMATION OF NEW MOVING CENTERS SOUTH OF DEEP LOWS

(Preliminary Report)

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In an effort to develop principles that would aid in long range forecasting and in drawing synoptic weather maps over areas with relatively few reports, a study of northern hemisphere weather maps has been undertaken with respect to the development of new moving centers south of deep, quasi-stagnant lows.

It is believed that waves whose origin is primarily influenced by a deep low somewhere to the north can be classified into four groups. These are illustrated in Fig. 1. "1" is the type in which the wave is quite stable, is far removed from the old center, and only becomes unstable and develops after the trough of the succeeding system picks it up. "2" is the type most commonly found; it starts as a wave on the front extending southward from the old system. "3" is the case in which the peak of the warm sector breaks off from the old system and travels on as a new system. "4" is the rarest of the four cases; here cyclogenesis takes place somewhere along the warm front in advance of the old system; this probably happens most often in the case of a warm front occlusion.

Thus far the maps for thirteen fall, winter, and spring months have been examined. The procedure has been to catalogue the cases of development of new centers where the dominating influence has been a deep low somewhere to the north. Each case was classified according to one of the four types, and the following data were recorded: the location of the wave when first noticed on the synoptic map, the importance of the new center at the maximum of its development, the location of the old low center, and a brief description of the attending synoptic situation. In addition, for one month, the synoptic situations on the three kilometer maps were described and recorded.

Since most of the centers of this type develop over the oceans, the most intensive work was done in the Atlantic and Pacific areas. Only those developing over land quite near the coast line, or in the region of the Gulf of Mexico are listed. Thus it is quite probable that there were some centers which developed south of deep lows that are not listed here.

The months so far examined are November 1936, and 1937; December 1936; January 1935, 1936, 1937, and 1938; February 1937; March 1934, 1935, and 1937; April 1937; and May 1937. Since the only two fall months examined were those for November, they are grouped with the winter months in the summary.

In the study an effort has been made to determine the following things; favorite regions of formation for each type and for each season, the synoptic situations favorable for the formation of each type, and the synoptic situations which are not favorable for the formation of new centers.

For summarization the data were put into two groups: one for the winter months including November, December, January, and February; and one for the spring months including March, April, and May.

Fig. 2 gives the location of each of the waves of the winter months. The numbers refer to the type of the wave, and are placed at the spot where the wave was first observed on the synoptic map. The sign after the number refers to the importance of the center after it was fully developed. Since the Northern Hemisphere maps examined are drawn only for every twenty-four hour period, the waves are partially developed, as a rule, before they are picked up by the analyst. Thus the locations of the beginnings of the waves should probably be slightly SW of those locations given on the maps in Fig. 2 and Fig. 3. Fig. 3 gives the locations for the spring months.

The storms were classified as strong (+), moderate (✓), and weak (-) on a comparative basis. It is realized that the classification would have more significance if the classes where based on definite criteria; however, no satisfactory criteria have been formulated. The process has been to examine a month of maps, and after comparing the storms with one another, to arbitrarily classify them as strong, moderate, or weak.

In Fig. 2 there are sixty-two waves located in the Pacific and forty-one waves in the Atlantic. There were three more that developed into good centers, but they developed from a front where there were a series of waves and it was difficult to locate the wave that actually developed. It should be noticed that Fig. 2 and Fig. 3 do not include all of the waves that occurred during the months, but only those waves that actually developed into separate, moving centers and, as observed above, three of these are not included.

Of the sixty-two new centers forming south of deep lows during the winter months in the Pacific, fifty-two were type "2", six were type "3", and three were type "1". In classifying the waves as to type the analysis as given was accepted unless there was an obvious error. Since the maps are twenty-four hours apart, there is often much difficulty in determining by what process a center was actually formed. Types "1" and "2" are the easiest to recognize. It is quite possible that there were more of type "3". None of type "4" were located, but since it is one that is very difficult to pick up even on maps a shorter period of time apart, it is not particularly surprising that none were found on these maps. This does not necessarily indicate that there were none of this type -

it only means that there were none of this type so outstanding that the analyst was able to pick them up. The waves not listed on the map because of inability to give the exact location of the formation were all of type "2".

In the Pacific during the winter months most of the new centers formed in one of three regions. These regions are blocked in on the map and are labeled "A", "B", and "C". "A" and "B" are so close together that possibly more data would have indicated that they were both only one group. All of the waves of type "3" formed in one of these two blocks. In each case there was an old low "winding-up" over Kamchatka and the peak of the warm sector broke off from somewhere to the south.

The three waves of type "1" all formed west of the 160th meridian East. Two of them were just off the east coast of Japan and the third was in block "B".

Type "2" is found all over the Pacific, but the favorite regions of formation are areas "A", "B", and "C".

Petterssen[1] says that frontogenesis may commence in zones of maximum temperature gradient, but the resulting fronts will be found near the trough lines in the wind distribution. Area "C" is near the region of maximum temperature gradient, so a concentration of new centers would be expected there. Area "B" is one of the areas that Petterssen[1] and later Huang[2] calculated to be an intense area of frontogenesis. Area "A" is somewhat too far removed from the coast of Asia to be in what has generally been considered to be the most favorable frontogenetical zone. However, an examination of the resultant winds and air temperature charts of the Pacific, as given in the Atlas of Climatic Charts of the Ocean[3], reveals that in this area (A) there is a very large temperature gradient although not quite as much as nearer the coast, and that there is more cyclonic curvature to the isobars in this region during the winter months than in any of the neighboring regions; thus this region should be a region of frontogenesis. The fact that there is a quasi-permanent trough in this region in the winter time as indicated by the curvature of the stream flow, would explain the concentration of new centers given in the area "A".

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1. Petterssen, S. Weather Analysis and Forecasting, McGraw-Hill Book Company, Inc., New York, 1940; p. 269
2. Harney, Pat J. Note on H.C. Huang's Investigations of Frontogenesis in the North Pacific, M.W.R., 1937, Vol. 65, p 335
3. Atlas of Climatic Charts of the Oceans, U.S. Dept. of Agriculture, Weather Bureau, Government Printing Office, Wash. D.C., 1938

All of the intense systems that started during the winter months are found in one of the three areas. In areas "A" and "B", thirty-three of the sixty two centers started. Five more started in "C". If only those centers that developed to as much as moderate intensity are considered, over two-thirds started in the three areas. Twenty-six started in "A" and "B" and four started in "C". Only seventeen started throughout the rest of the Pacific.

In the Atlantic for the winter months most of the important new centers originated in the area "D" (Fig.2). This zone is the same as the one Petterssen had indicated to be the zone for maximum frontogenesis. Of the forty-two storms originating in the Atlantic only about two-fifths, or sixteen, originated in area "D"; however, of the storms that were as much as moderate in intensity, over half (fifteen out of twenty-eight) started in area "D".

There were thirty-six storms of type "2", four of type "1", one of type "3", and one of undetermined type. It is somewhat surprising that there were not more of type "3" near the tip of Greenland. It is possible that the analyst overlooked weak examples of this type.

In the Pacific, half of the new centers in spring started in area "E". There were one of type "1", three of type "3", and twenty-eight of type "2". The type "1" center started at the southern tip of Japan. The type "3" centers again broke off from the old low that was filling-up near Kamchatka; however, this time they were farther east before they actually broke off. Again the type "2" centers formed in all parts of the Pacific, but their most favored spot of formation was in area "E". This area agrees well with Petterssen's work on the theory of frontogenesis. In these months there was one storm, which later became one of the most important, that apparently started in the middle of Asia as indicated in Fig. 3. The data were not too plentiful on this particular map and there is considerable doubt as to just where the center did begin.

In the Atlantic there were three centers of type "1", 12 of type "2", and one of type "4". Eight of the sixteen were in area "F" (Fig. 3). The one of type "4" occurred south of Newfoundland. Its origin was rather obscure and there is no certainty that it was really of type "4". Of the centers that started in area "F" all became at least moderate systems, while of those outside this area only five developed to moderate intensity. This does not mean that all of the waves found in area "F" developed into moderate systems, because many of the waves did not develop into centers at all; but of those that did develop, all achieved at least moderate intensity.

It was thought that there might be some optimum distance from the old center at which the new center would form. To see if there was, the distances between the new and the old centers were plotted on graphs

(Fig. 4 for winter, and Fig. 5 for the spring). The difference in latitude between the two systems is plotted on the y-axis and the difference in longitude is plotted on the x-axis, with a negative value indicating that the new center was west of the old low, and a positive value indicating that the new center was east of the old low.

Of course the waves of type "1" were south and west of the old center, those of type "3" were either south or southeast, and the one of type "4" was southeast. Otherwise the only limitation as to the distance of the new system from the old system seemed to be that of analysis and definition. It could not be less than approximately $5^{\circ}$ distant, or the new center would have been considered part of the old system and not even analyzed separately. If it were more than approximately $50^{\circ}$ distant, it was generally considered to be under the influence of the succeeding systems rather than the deep low center, and was not catalogued.

## Observations Based on Examination of the Maps

1. New centers rarely form in strong W-E flow at surface.
2. There are often slow moving highs on each side of the incipient wave to give N flow on one side and S flow on the other.
3. The front must be moving slowly for the wave to develop.
4. Most favorable location is south of a deep low with well developed highs to east and west of the wave (Fig. 6). This is particularly true if the high to the west has its major axis oriented N-S so that a plentiful supply of cold air can be delivered to the cyclogenetic region. In all cases a wave developed under these circumstances unless the front was moving quite rapidly.
5. The waves do not develop when the front moves through the middle of a high (Fig.7). This also includes the case where there is a high on each side of the front, but one of the centers is very weak. The determining factor seems to be whether the two centers are each strong enough to give a convergent wind field at the front, or if one of the high cells is so weak that it is not able to counteract the subsidence that is usually present in a large high pressure area.
6. If the Azores high is quite strong, there is likelihood of wave development on a front moving across the Atlantic.
7. Another favorable situation for a wave development is in a long, deep, quasi-stationary trough extending S or SW of the main low center (Fig.8).
8. A strong high stagnated on the eastern coast of a continent or an enlongated W-E axis of a deep low with a long high oriented W-E to the south, usually gives a series of waves

running along the front (Fig. 9). Under either of these situations stable waves form and run into the old low for two or three days before any of them begin to occlude. It is only as the arrangement begins to break down that one of the stable waves develops into a good center. However, it is possible that it is the development of the center that breaks down the arrangement of the lows and highs that caused the series of waves.

The 10,000 foot maps for one month were examined. The following were found to be true:

1. In every case where a wave developed into a center, there was cyclonic curvature at 10,000 feet, and usually there was at least a weak trough.
2. In most cases the wind was WSW. However, there was one case in which the wind was coming from slightly north of west.
3. In most cases the winds at 10,000 feet were comparatively light immediately above the incipient wave.

These conclusions regarding the 10,000 foot maps are inconclusive for two reasons: Only one month has been examined with any great detail. Secondly, the upper maps were constructed from data extrapolated from the surface data, so the analyst probably favored preconceived ideas when drawing the maps, so long as he could do so without disregarding the data too much.

After examining many maps of the summer season, the conclusion was reached that a detailed study such as was made for the winter and spring months was not worthwhile, because there were not many systems developing which could be placed in one of the four classifications; and even those that did develop when there was a deep low pressure somewhere to the North seemed to be influenced more by other factors. In many cases the development of the stable wave into an occluded system appeared to be entirely independent of the deep low to the North.

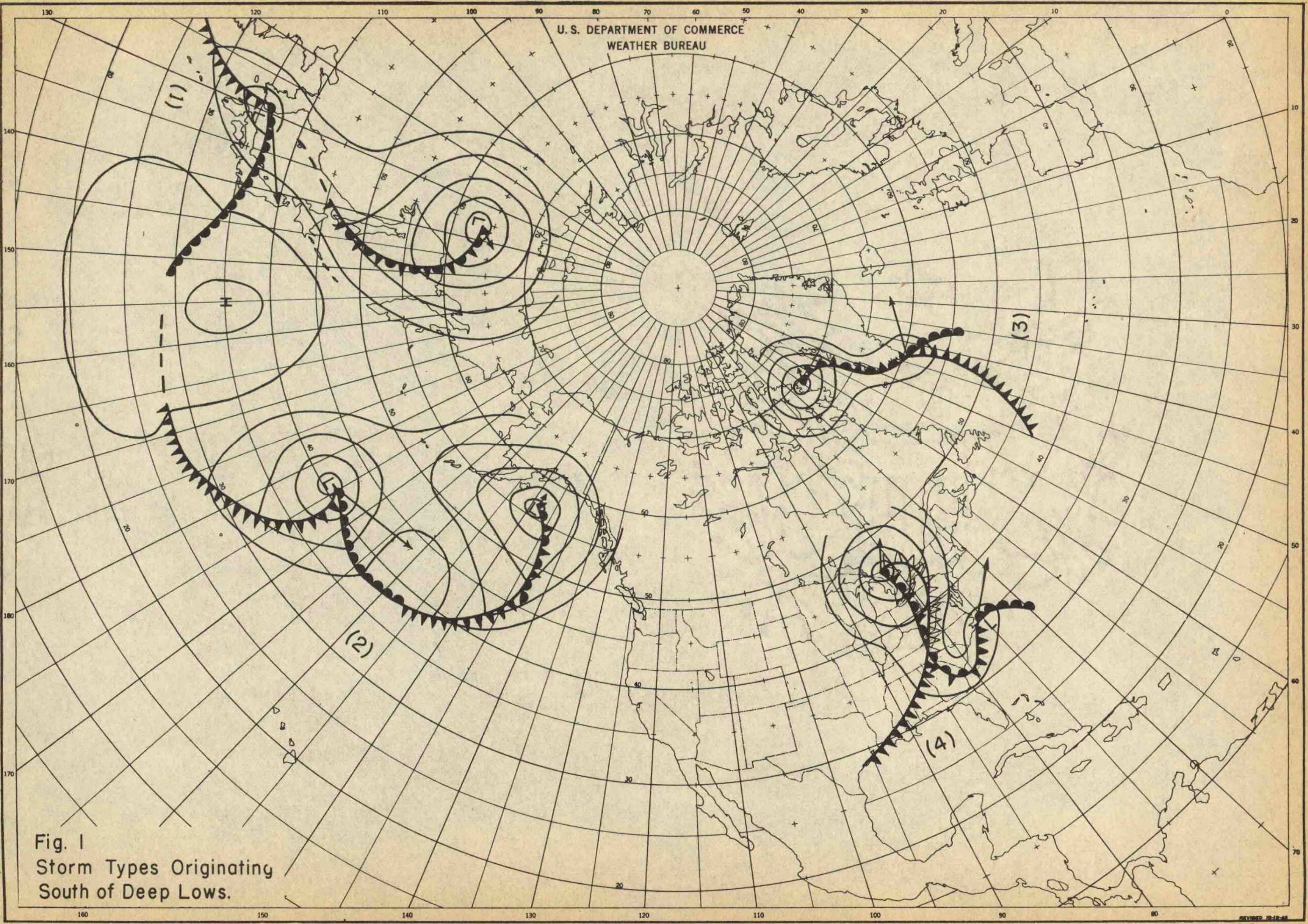
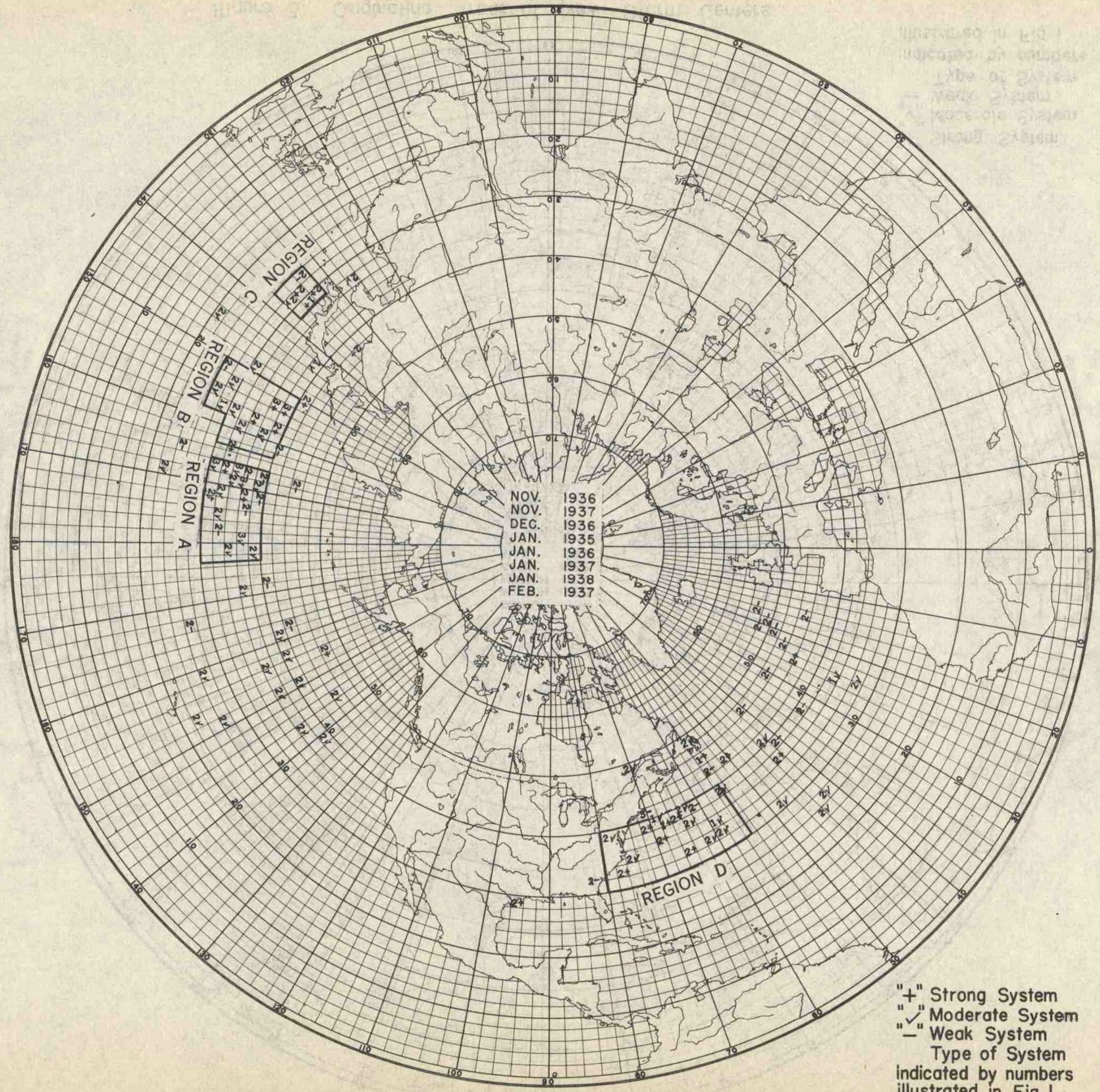
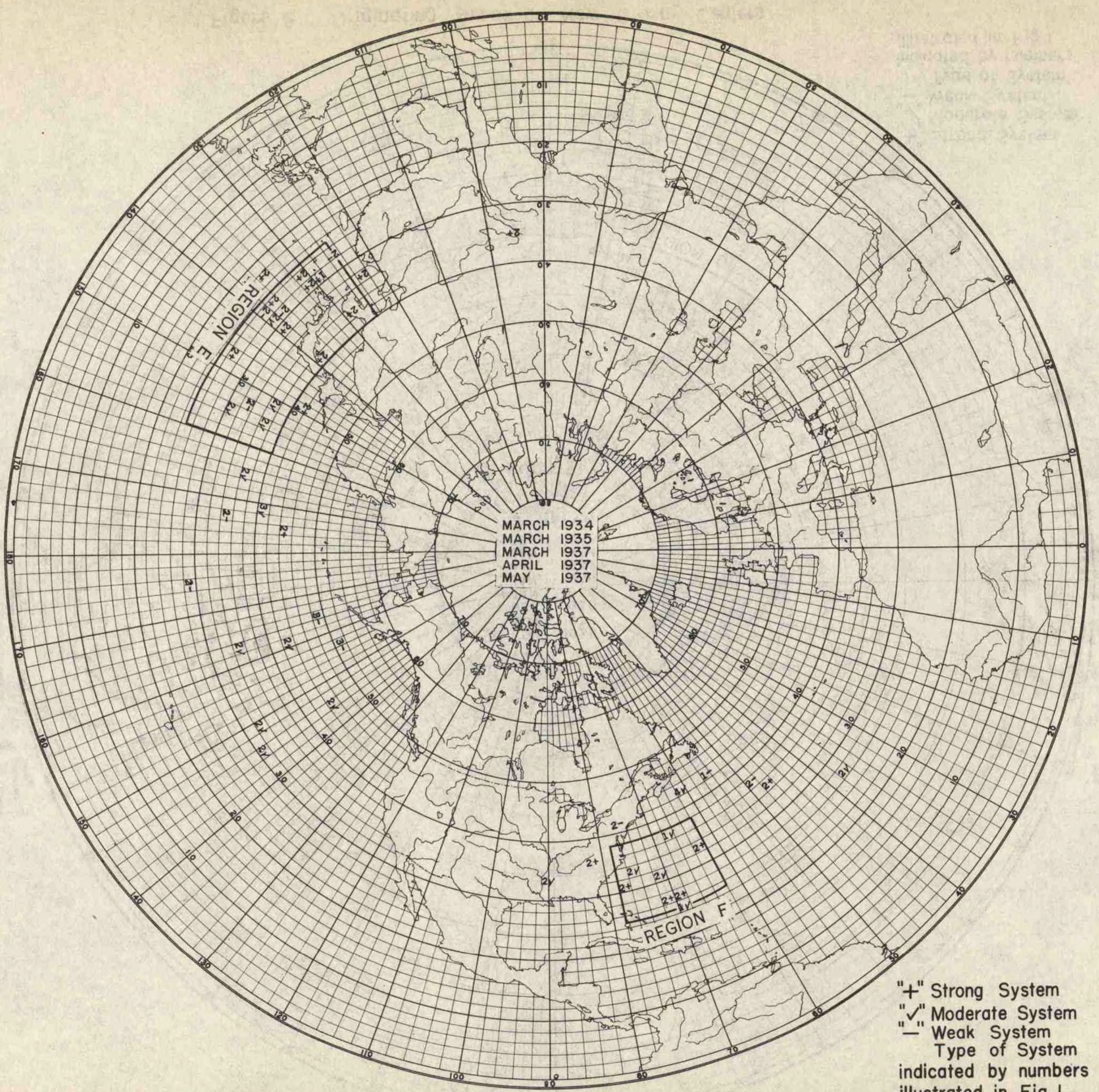



Fig. 1
Storm Types Originating
South of Deep Lows.




"+" Strong System
"✓" Moderate System
"–" Weak System
Type of System
indicated by numbers
illustrated in Fig. I

Figure 2 Originating Areas of New Storm Centers




"+" Strong System
"✓" Moderate System
"–" Weak System
Type of System indicated by numbers illustrated in Fig. I

Figure 3 Originating Areas of New Storm Centers

Longitude of Old Center Minus Longitude of New Center Versus Latitude of Old Center Minus Latitude of New Center (Winter)

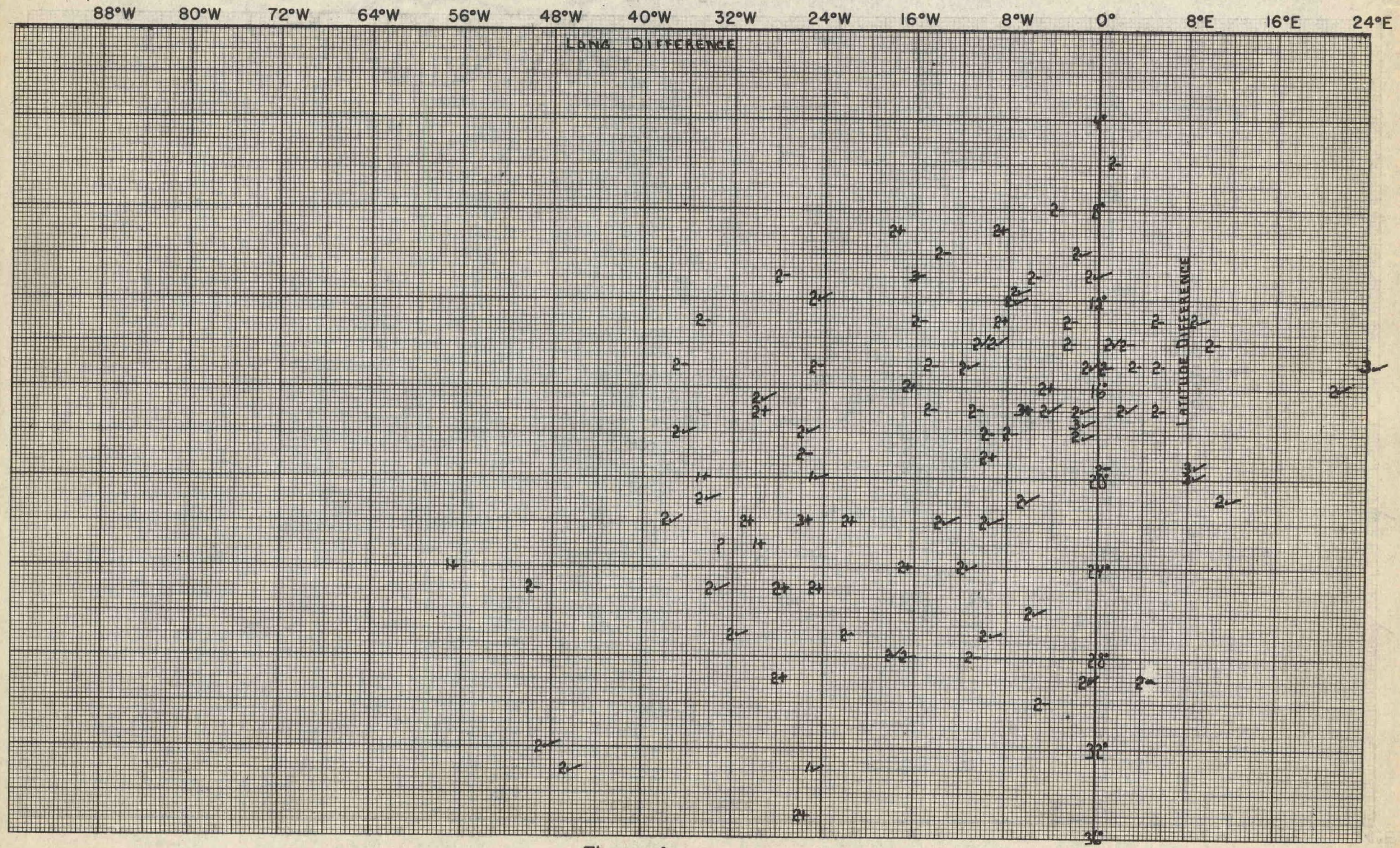



Figure 4

Longitude of Old Center Minus Longitude of New Center Versus Latitude of Old Center Minus Latitude of New Center (Spring)

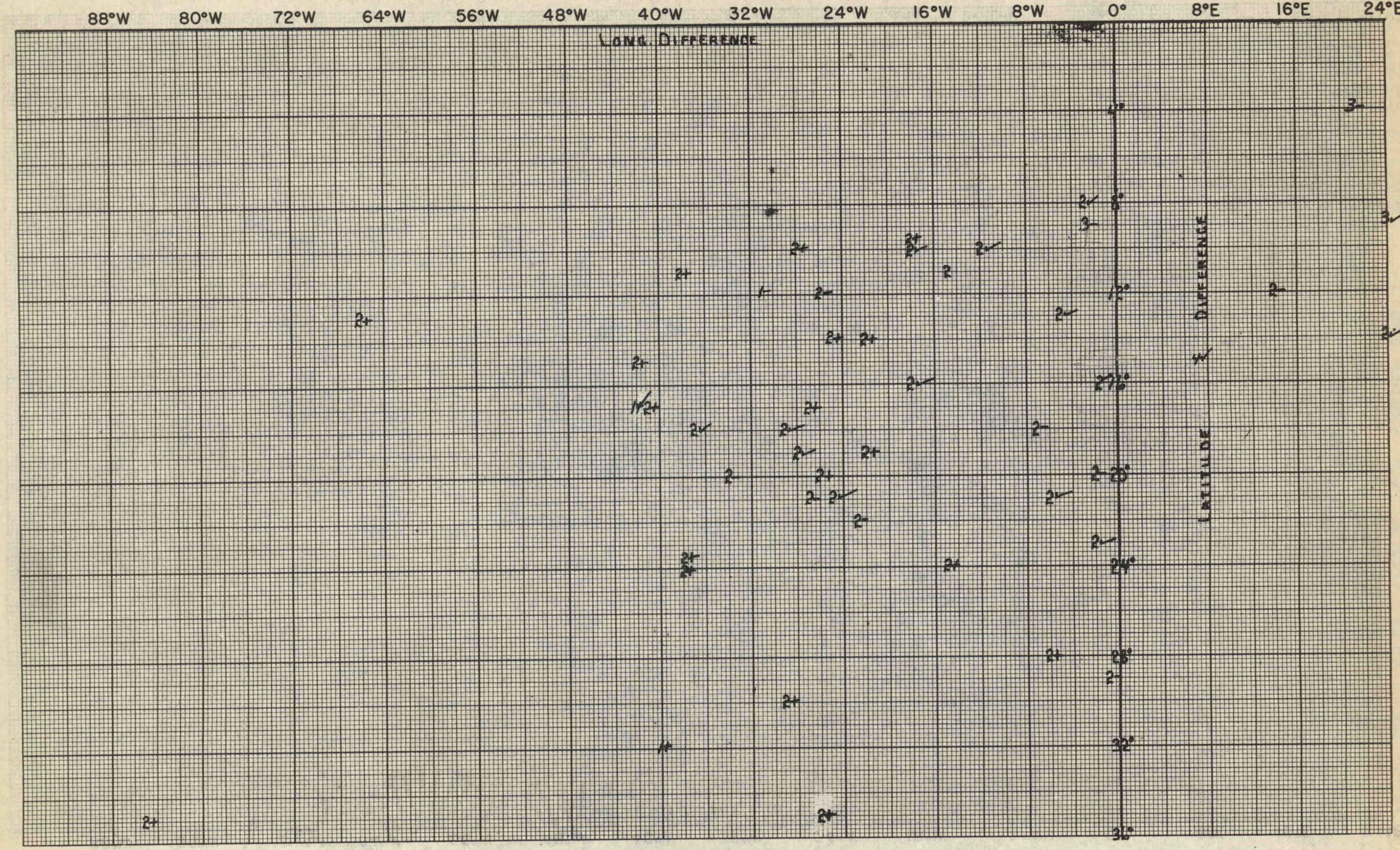



Figure 5

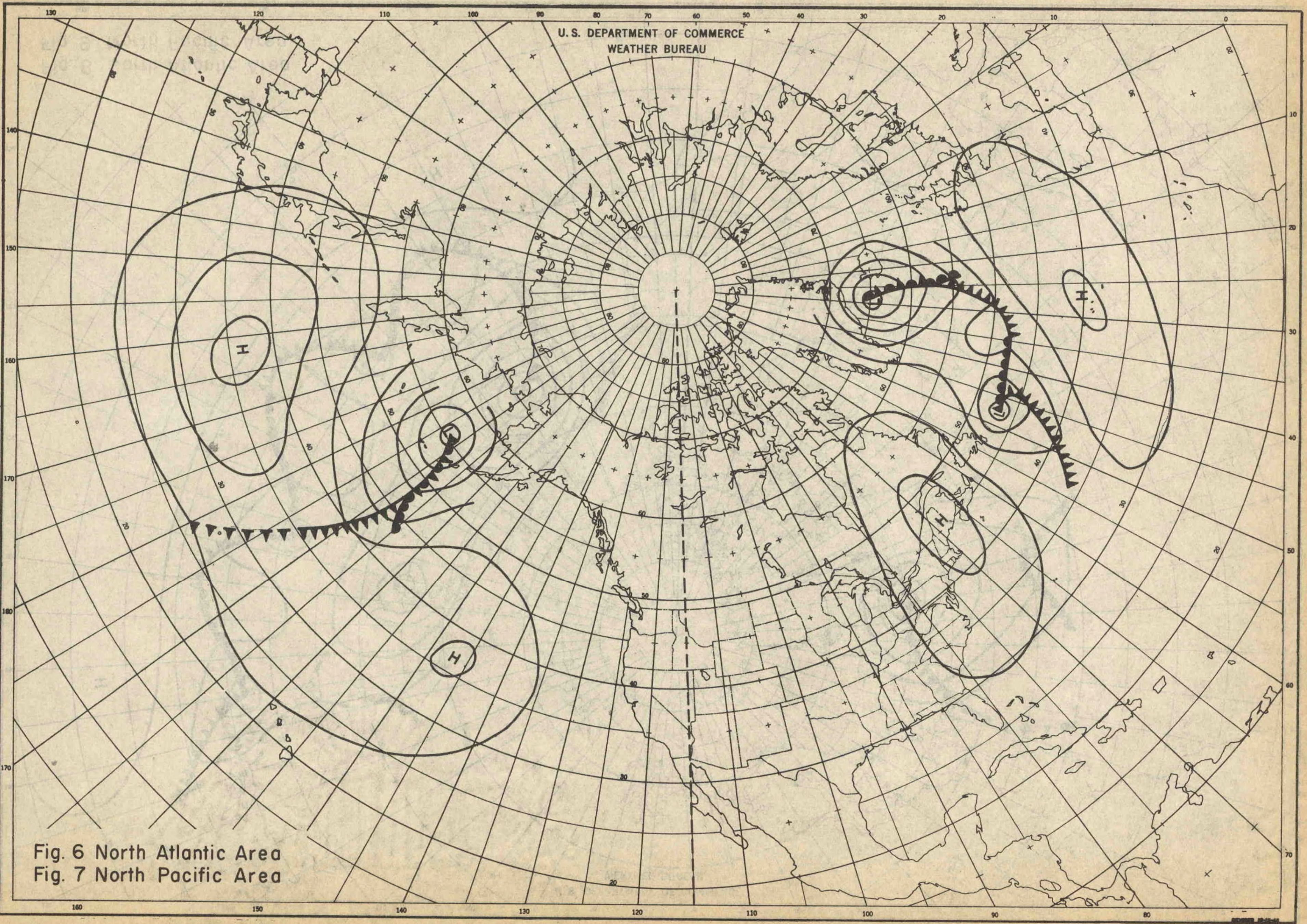



Fig. 6 North Atlantic Area
Fig. 7 North Pacific Area

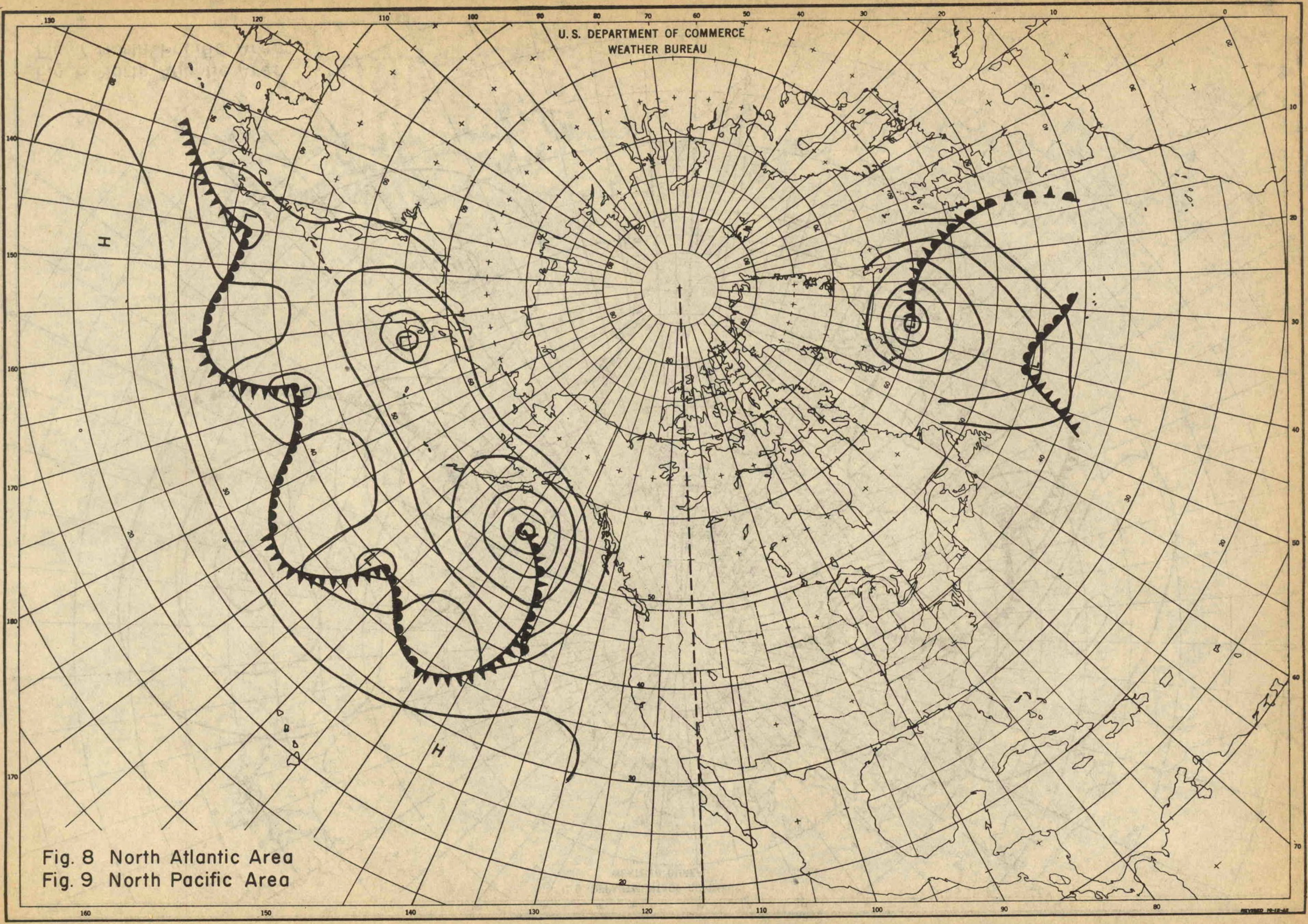


Fig. 8 North Atlantic Area
Fig. 9 North Pacific Area