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FISCAL YEAR 1988 SUMMARY REPORT OF NOAA METEOROLOGY DIVISION SUPPORT TO THE U.S. ENVIRONMENTAL PROTECTION AGENCY

Evelyn M. Poole-Kober
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Air Resources Laboratory
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PREFACE

This document summarizes the Fiscal Year 1988 research and operational efforts and accomplishments of the Meteorology Division (MD) working under interagency agreement EPA DW13933335-01 between the U.S. Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA). The summary includes descriptions of research and operational efforts in air pollution meteorology, air pollution control activities, and abatement and compliance programs.

Established in 1955, the Meteorology Division is part of the Air Resources Laboratory and serves as the vehicle for implementing the agreement with the EPA, which funds the research efforts in air pollution meteorology. The MD conducts research activities in-house and through contract and cooperative agreements for the Atmospheric Sciences Research Laboratory and other EPA groups. With a staff consisting of NOAA, EPA, and Public Health Service (PHS) Commissioned Corps personnel, the MD provides technical information, observational and forecasting support, and consulting on all meteorological aspects of the air pollution control program to many EPA offices, including the Office of Air Quality Planning and Standards (OAQPS) and Regional Offices. The primary groups within the MD are the Atmospheric Modeling Branch, Fluid Modeling Branch, Data Management Branch, Terrain Effects Branch, Environmental Operations Branch, and Air Policy Support Branch. The staff is listed in Appendix D. Publications and other professional activities are listed in Appendixes A, B-1, and B-2, and C.

Any inquiry on the research or support activities outlined in this report should be sent to the Director, Meteorology Division (MD-80), Environmental Research Center, Research Triangle Park, NC 27711.

CONTENTS

CONTENTS (continued)

CONTENTS (continued)

CONTENTS (concluded)

FIGURES

FISCAL YEAR 1988 SUMMARY REPORT OF NOAA METEOROLOGY DIVISION SUPPORT TO THE U.S. ENVIRONMENTAL PROTECTION AGENCY

ABSTRACT. The Meteorology Division provided meteorological research and operational support to the U.S. Environmental Protection Agency. Basic meteorological operational support consisted of applying dispersion models and conducting dispersion studies and model evaluations. The primary research effort was the development and evaluation of air quality simulation models using numerical and physical techniques supported by field studies. Modeling emphasis was on the dispersion of photochemical oxidants and particulate matter on urban and regional scales, dispersion in complex terrain, and the transport, transformation, and deposition of acidic materials. Highlights during FY-1988 included applying the Regional Oxidant Model (ROM) to evaluate the effects of proposed strategies to control anthropogenic hydrocarbons and NO_x; implementing the ACID-MODES surface monitoring network and conducting an intensive ground and airborne sampling program to provide data for the evaluation of the Regional Acid Deposition Model (RADM); completing the Complex Terrain Dispersion Model (CTDM); completing the Acid Rain Mountain Mesoscale Model (ARM3); and conducting dense-gas dispersion studies in the Fluid Modeling Facility.

1. INTRODUCTION

During Fiscal Year 1988, the Meteorology Division (MD) continued to provide meteorological research and support to the U.S. Environmental Protection Agency (EPA). The Division's primary efforts were to research the basic processes affecting the dispersion of atmospheric pollutants, to model pollutant dispersion on all temporal and spatial scales, and to study the effects of atmospheric pollutants on regional climate. Major emphasis continued to be on oxidant dispersion on the urban and regional scales, particulate dispersion on the regional scale, dispersion in complex terrain, and processes related to acid precipitation. In the Fluid Modeling Facility, physical modeling experiments were conducted on the flow in complex terrain, building downwash, and the effects of building wakes. Participation continued in the Integrated Air Cancer Program and the joint United States/People's Republic of China research program, and work was begun on the effects of global climate change on regional climate and air quality. Section 2.1 discusses the Division participation in several major international activities, while Sections 2.2 through 2.5 outline the Division research effort. Sections 2.6 and 2.7 discuss meteorological support to the EPA Office of Air Quality Planning and Standards (OAQPS), the EPA Regional Offices, and other EPA groups, as well as to the general air quality model user community.

2. PROGRAM REVIEW

2.1 Office of the Director

The Office of the Director provides direction, supervision, program management, and administrative support in performing the Meteorology Division's mission and achieving its goals of advancing the state of the atmospheric sciences and enhancing the protection of the environment.

2.1.1 American Meteorological Society Steering Committee

Beginning in 1979, the Meteorology Division established a cooperative agreement with the American Meteorological Society (AMS) to improve the scientific bases of air quality modeling. The AMS has maintained a Steering Committee on Scientific Assessment of Air Quality Models, composed of alternating members, to (1) provide scientific review of various types of air quality dispersion models; (2) assist in developing a more complete understanding of uncertainty as it affects air quality modeling; (3) respond to specific requests regarding scientific aspects of the Division's air quality modeling practices; and (4) plan and conduct scientific workshops in an attempt to advance the state of regulatory dispersion modeling.

2.1.1.1 Completed AMS Scientific Workshops

During November 1983 in Baltimore, MD, the AMS Steering Committee conducted a specialty conference on modeling the nonhomogeneous, nonstationary urban boundary layer. The conference goals were (1) to examine and evaluate existing concepts, observations, and computational methods; (2) to identify and assess existing knowledge that can be applied to meteorological and air quality diffusion models; and (3) to identify new observations and understanding that will be needed to improve computer simulation of boundary layer flow and diffusion in urban areas. Thirty-seven scientists from eight countries participated in the conference. The AMS published a report containing 13 of the papers presented and summary remarks by 5 rapporteurs (American Meteorological Society, 1987).

2.1.1.2 Assessments of Air Quality Modeling Practices

Under the objective of responding to requests regarding the Division's air quality modeling practices, the AMS Steering Committee prepared two unpublished assessments on the following topics: mobile source modeling and short-term long-range models. As appropriate, Division scientists incorporated the recommendations from these assessments into the improvement and application of existing air quality dispersion models.

2.1.2 NATO/CCMS Steering Committee

The Meteorology Division Director serves as one of two United States representatives on the Steering Committee for International Technical Meetings (ITMs) on Air Pollution Modeling and its Application, sponsored by the North Atlantic Treaty Organization Committee on Challenges of Modern Society (NATO/CCMS). One of the main activities within the NATO/CCMS Pilot Study on Air Pollution Control Strategies and Impact Modeling is organizing a symposium every 18 months that deals with air pollution modeling. The meetings are rotated among different NATO member countries, with every third ITM held in North America and the two intervening ITMs held in European countries. The Division Director helped organize and served as Session Chairman during the 17th NATO-CCMS International Technical Meeting held in Cambridge, England, during September 1988. A conference summary was prepared (van Dop *et al.*, 1988).

2.1.3 United States/Japan Environmental Agreement

The Meteorology Division Director serves as Chairman of the Air Pollution Meteorology Panel under the United States/Japan Environmental Agreement. The purpose of this 1975 agreement is to facilitate, through mutual visits and reciprocal assignments of personnel, the exchange between the two countries of scientific and regulatory research results pertaining to the control of air pollution.

The Tenth Joint Meeting of the Air Pollution Meteorology Panel was held during March 1988 at the Meteorology Division in Research Triangle Park, NC. Representatives from the two countries exchanged scientific and regulatory information relating to regional and global pollutant transport, modeling of acidic deposition, and technology transfer of completed dispersion models. The Japan representative also visited the EPA Headquarters in Washington, DC, and the NOAA Air Resources Laboratory in Silver Spring, MD. Under the agreement, the Division Director and a Division Branch Chief were appointed as Scientific Advisory Members to the 2nd International Conference on Atmospheric Sciences and Applications to Air Quality, to be held in Tokyo during October 1988.

2.1.4 United States/Soviet Union Joint Environmental Committee

The Meteorology Division Director serves as the United States Co-Chairman of the US/USSR Working Group 02.01-10 on Air Pollution Modeling, Instrumentation, and Measurement Methodology, and as Co-Leader of the US/USSR Project 02.01-11 on Air Pollution Modeling and Standard Setting. The purpose of the 1972 agreement forming the US/USSR Joint Committee on Cooperation in the Field of Environmental Protection is to promote, through mutual visits and reciprocal assignments of personnel, the sharing of scientific and regulatory research results related to the control of air pollution.

During May 1988, the Division Director led a delegation of six United States scientists to a Working Group Meeting held at the Voeikov Main Geophysical Observatory in Leningrad and at the Institute of Physics, Academy of Sciences, in Vilnius, Lithuania. In addition to mutual discussions of research activities, plans were made for the following activities: a 1988-1989 visit of two Soviet scientists to the Fluid Modeling Facility in Research Triangle Park, NC; a 1989 visit of two Soviet remote-sensing scientists to the EPA Environmental Monitoring Systems Laboratory in Las Vegas, NV; an exchange of spectroscopic data bank information with the National Institute of Standards and Technology; and a joint performance of roadway automotive exhaust field studies in Leningrad during 1988 and in Vilnius during 1989. During the visit a protocol was drafted outlining future exchanges of scientific information and planning for the next Working Group Meeting to be held in May 1989 in Research Triangle Park, NC.

2.1.5 Domestic Policy Council State of Science Report

The Meteorology Division Director and a Division scientist worked with the Domestic Policy Council's Task Group on Sulfur Dioxide (SO_2) and Nitrogen Oxides (NO_x) Impacts and Control in preparing a state of science document. The document provides a summary and analysis of the current state of the science related to the emission, transformation, and disposition of atmospheric SO_2 and NO_x, and to the environmental, human health, and economic impacts of SO_2 and NO_x. The Division input constituted the section on atmospheric processes, which explained the relevant physical and chemical processes affecting the fate of pollutants and described the current capabilities for acidic deposition and visibility modeling (Clark and Schiermeier, 1987).

2.2 Atmospheric Modeling Branch

The Atmospheric Modeling Branch develops, evaluates, and validates analytical and numerical models whose scales range from local to global. These models are used to describe the relationships between air pollutant source emissions and resultant air quality, to estimate the distribution of air quality, and to describe and predict the state of the planetary boundary layer. The branch conducts studies to describe the physical processes affecting the transport, diffusion, transformation, and removal of pollutants in and from the atmosphere.

2.2.1 Acid Deposition Studies

2.2.1.1 Development of the Regional Acid Deposition Model (RADM)

A comprehensive Regional Acid Deposition Model (RADM) system is being developed as an integral component of the National Acid Precipitation Assessment Program (NAPAP). The project was initiated in 1983 through an agreement with the National Center for Atmospheric Research (NCAR) in Boulder, CO, and moved to the State University of New York at Albany in 1987. The modeling system incorporates a mesoscale dynamic model to drive a 6- to 15-layer state-of-the-science transport, transformation, and deposition model on an 80-km grid covering the eastern United States and southeastern Canada. The RADM system has evolved through several iterations of development, initial evaluation, and peer reviews.

During FY-1988, version 2.0 of the Regional Acid Deposition Model (RADM2.0) was completed. This version incorporates several upgraded components based on suggestions from the May 1987 peer review (National Acid Precipitation Assessment Program, 1987). First, the transport scheme was improved to reduce numerical diffusion. Second, the chemical mechanism was improved by incorporating a more detailed representation of organic species and peroxy radical chemistry. The improved mechanism was extensively tested and compared with laboratory data. A new, highly-efficient numerical solver for the new mechanism also was completed, which improved the overall performance of the model in comparison with the predictor-corrector method used previously. Third, improved representations of vertical turbulent transport and dry deposition were added. Finally, the geographical domain of the model was enlarged to include all of Florida and the Texas Gulf Coast. This larger domain will improve model performance by simplifying the boundary conditions to use only regional background concentrations. RADM2.0 will be used in the 1990 NAPAP Assessment and will undergo initial evaluation in FY-1989. Extensive testing and research applications were made in FY-1988 with earlier versions of RADM and significant enhancements were made to other components of the modeling system.

2.2.1.2 RADM Engineering Model (EM)

The RADM system includes an Engineering Model (EM), which requires as input RADM emission and meteorological fields as well as RADM output chemical fields. EM allows the user to vary sulfur emissions to assess the effects of projected sulfur emission control scenarios. Because EM can be run on a VAX-class computer, it offers significant resource savings compared with running the full RADM. The validity of the EM approach was shown by direct calculation using RADM, and the theoretical basis for this approach was independently verified (Kleinman, 1988).

During FY-1988, EM was enhanced in several ways. First, a Tagged Species Model (TSM) was developed that allows deposition at a set of receptor sites to be associated quantitatively with the emissions from a particular group of sources. EM outputs total wet and dry deposition fields, while TSM, in addition, outputs the deposition fields resulting from the tagged sources. This allows quantitative estimates of the influence of the tagged sources, including the effects of emission reductions. Second, a sulfate tracking model version of EM was created that allows studying the role of aqueous-phase chemistry in total sulfate production. The sulfate produced directly from the gas phase and that produced in clouds are tracked separately, so that the fraction of the total sulfate produced by aqueous chemistry is always available. This version is useful for investigating the nonlinearity issue discussed in Section 2.2.1.5.

2.2.1.3 RADM Meteorological Driver

MM4, the meteorological driver used for RADM (Anthes *et al.,* 1987), was improved significantly by adding an algorithm that allows the continuous assimilation of meteorological observations. The approach is referred to as Four-Dimensional Data Assimilation (FDDA) and was developed at The Pennsylvania State University and modified for the RADM program. Previously, MM4 was run as an initial value problem; that is, it was started with an initial data set and then run for a given time interval. At the end of the interval (usually 72 hours), MM4 results could depart significantly from the observed meteorological conditions. The FDDA approach corrects this problem by continuously passing information about the observed state of the atmosphere to MM4 and adjusting the calculated output to follow the observations. This ensures that the meteorological information input to RADM is dynamically consistent and spatially correct with respect to observed data. The approach is known as Newtonian relaxation (Stauffer *et al.,* 1985) and for this application assimilates three-hourly surface winds and specific humidities along with twelve-hourly upper-air winds, temperatures, and specific humidities. Dramatic improvements were made in the meteorological fields produced by MM4 after incorporating FDDA. This approach for providing meteorological data for RADM is being used for the 1990 NAPAP Assessment and is expected to become the standard for all air quality models in the future.

2.2.1.4 Development of a RADM Aggregation Methodology

RADM is an episodic model. Because long-term estimates of acid deposition impacts are needed, a method of aggregating deposition fields from a limited number of three-day episodic periods to produce seasonal and annual averages was developed. The method is based on stratifying three-day periods into categories of similar wind flow (transport categories) at about 1500 m above sea level, and substratifying precipitation patterns where justified. Because of resource limitations (the number of episodic periods that RADM can simulate reasonably), 30 three-day periods were selected from a four-year data period (1982-1985) by proportionate sampling from the transport categories; thus, the method emphasizes characterizing source-receptor relationships correctly. The 30 episodes, selected from 19 transport categories, account for about 85% of the annual wet deposition over the four-year period. The episodes contain a proportionate mix of seasonal cases, and therefore should include both linear and nonlinear deposition events. Initial evaluation of the aggregation approach showed that the estimated annual average produced using the 30 cases fell within 20% of the measured annual wet deposition for the four-year period. Independent evaluation of aggregation using 1986-1987 data showed similar agreement. This aggregation method will be applied in the NAPAP and will be improved as RADM development and evaluation continue. Modifications of the basic approach are being reviewed for potential applications by the Regional Oxidant Model and Global Climate Change Programs.

2.2.1.5 RADM Research Application Studies

The RADM system, including the enhanced EM, was used extensively in FY-1988 to study the sensitivity of the system and the role of physical and chemical processes in regional-scale sulfur deposition.

Emission sensitivity studies. Review of the 1980 NAPAP sulfur emission inventory revealed that the top sulfur emitters in the United States are utility boilers, and that approximately 75% of the daily variation in boiler emissions is due to the intermittent behavior of these units, that is, whether a unit is on or off on a given day. The residual hourly variability explains only an additional 10% of the total variability. Experiments with the RADM system (EM and TSM) in which specific emission sources representing about 50% of the total sulfur emissions east of the 95th meridian were randomly perturbed produced the following results (Dennis *et al.,* 1988). The influence of the variability of the emissions from a particular plant was damped because of the influence of surrounding emissions. The response of the dry deposition field was about half as large as the emission variability in high-source areas, whereas the wet deposition response was about one quarter of the emission variability. The response decreased sharply with downwind distance from the major source areas.

A second issue associated with emission sensitivity is how deposition patterns respond to the geographic distribution of emission reductions. In a preliminary analysis of a proposed state reduction plan, two strategies were tested to achieve the reductions. The first approach was to eliminate sources, starting with the largest, until the state level of reduction was achieved. This method is related to the retirement of sources. The second approach was to apportion the reduction fraction over all sources. The resulting deposition patterns were quite different. These preliminary results indicate that, within a state, the geographic distribution of reductions significantly affects the pattern of deposition.

RADM nonlinearity studies. RADM/EM was used to study the degree of nonlinearity in the wet deposition processes as a function of source region. Four meteorological episodes formed the basis of the study: three April 1981 cases from the Oxidation and Scavenging Characteristics of April Rains (OSCAR) studies, and one August 1979 case from the Northeast Regional Oxidant Study (NEROS).

A significant degree of nonlinearity occurred in the high-emissions Ohio Valley region. For a 50% reduction in SO_2 emissions, there was only a 30% to 35% reduction in wet deposition. Oxidant limitation occurred across an extensive domain for the spring OSCAR cases, and also across a smaller domain for the summer NEROS case. The degree of oxidant limitation decreased with distance from the high-emission source regions. In the oxidant-limited region, hydrogen peroxide accounted for approximately 60% of the in-cloud conversion of SO_2, but in the oxidant-unlimited region farther downwind, H_2O_2 accounted for 90% of this conversion.

Particulate sulfate processed through the RADM wet scavenging module accounted for 60% to 70% of the total wet sulfate deposition, while in-cloud oxidation of SO_2 accounted for 30% to 40%. However, for the OSCAR cases, roughly half the particulate sulfate came from production in clouds and half from gas-phase chemical conversion. Since the sulfate produced by cloud processes is also influenced by oxidant limitation, the reduction in sulfate wet deposition due to a reduction in emissions is nonproportional for both sulfate scavenging and direct in-cloud SO_2 oxidation pathways. The nonproportional response of particulate sulfate to a change in emissions is an important part of the overall nonproportionality predicted by EM.

Comparison of RADM with linear models. Quantifying source-receptor relationships, an important component of assessing acid deposition, is usually based on simulation modeling results. Because the lack of empirical data prohibits direct checks on the accuracy of model estimates of source-receptor influences, indirect means must be used to judge them. One indirect method is to compare the estimates from one model with those from another. Estimates of source influence across space for an Ohio Valley source area were compared from TSM and the Regional Lagrangian Model of Air Pollution (RELMAP).

The analysis focused on major differences between the normalized dry deposition fields predicted by the two models. First, a systematic displacement downwind of RELMAP's deposition pattern appeared to be caused by the particular time-step (3 h) used. Second, a systematic occurrence of deposition to the north in the TSM predictions did not appear in the RELMAP field; this difference appears to be related to RELMAP's insensitivity to wind shear between the surface layer and the upper transport layer at 850 mb. Third, the fraction of dry deposition attributed to the Ohio valley source region differed between the two models. RELMAP predicted that 35% of the dry deposition came from the Ohio Valley sources, but TSM predicted that 72% came from the Ohio Valley sources. There were also major differences between the two models' predicted wet deposition patterns. The differences apparently were due to RELMAP's coarser resolution of physical and chemical processes, suggesting caution in using simple linear models for predicting source-receptor relationships.

2.2.1.6 Model Evaluation Program

Regional Acid Deposition Model evaluation. A program to evaluate regional-scale acid deposition models, primarily RADM, is being implemented with guidance from an External Review Panel (ERP) of ten international experts. The program consists of an initial evaluation directed toward the 1990 NAPAP Assessment with a more comprehensive evaluation to be completed in FY-1992. A model evaluation protocol is evolving that will guide the comparisons of model predictions and observations using the ACID-MODES surface measurements and data from the first aircraft intensive field study. A model evaluation protocol foundation document was developed in 1988 and will be reviewed by the ERP in early FY-1989.

Also, an advisory group was established to provide critical scientific guidance on the evaluation protocol using aircraft measurements. This group met several times and developed the model evaluation protocol for the diagnostic evaluation, which was the guide for the aircraft intensive program carried out from August 15 to September 30, 1988.

ACID-MODES surface monitoring program. The Acid Model Operational and Diagnostic Evaluation Study (ACID-MODES) surface sampling program was established in June 1988 with a network of 58 surface sampling sites covering the northern two-thirds of the eastern United States to obtain data for evaluating the numerical and scientific credibility of RADM and other regional acid deposition models. This program is coordinated with the Operational Evaluation Network (OEN) sponsored by the Electric Power Research Institute (EPRI); the Acid Precipitation in Ontario Study (APIOS) network sponsored by the Ontario Ministry of the Environment (OME); the CapMON network of the Atmospheric Environment

Service of Canada (AES); and the Florida Acid Deposition Monitoring Program (FADMP) network of the Florida Electric Power Coordinating Group. Collectively, these networks provide measurements from more than 100 monitoring stations. Formal data collection began in June 1988 for a two-year period ending in May 1990. The ACID-MODES program consists of a basic network of 33 sites, a network of 12 sites to measure gradients over Pennsylvania and New York, a network of 4 sites to characterize variability within the RADM grid, and 9 supplementary sites. Integrated air samples are collected over 24-hour periods and analyzed for SO_2, NO_2, HNO_3, and NH_3; and particulate (diameter less than 10 μm) sulfate, nitrate, and ammonium are collected using filter packs and Transition Flow Reactors (TFR). Precipitation samples are collected on a daily basis and analyzed for H^+ (as pH), conductivity, SO_4^{2-}, NO_3^-, NH_4^+, Cl^-, Na^+, K^+, Ca^{2+}, and Mg^{2+}. Continuous measurements of O_3 are made at the 16 gradient and variability sites and near the 33-site basic network. Additionally, S^{IV} in rainwater is sampled at 18 sites.

ACID-MODES intensive field study program. The first ACID-MODES intensive field study was conducted from August 15 through September 30, 1988, to obtain special measurement data for diagnostic evaluation of RADM and other regional Eulerian-based acid deposition models. The study integrated an aircraft sampling program with special enhanced surface chemistry sites over the eastern United States and Ontario, Canada. Three aircraft were involved: a G-1 aircraft operated by the Battelle Memorial Institute, a Hawker-Siddley 125 operated by the Fraunhofer Research Institute (under cosponsorship with the Federal Republic of Germany), and the NOAA King Air. Unique and varied flight patterns were flown to obtain chemistry measurements related to regional patterns and distributions of primary and secondary pollutants; clear-air photochemistry; precipitation scavenging rates resulting from passage of a frontal system; and temporal changes in pollutants aloft over multiday simulation periods. Special enhanced surface chemistry sampling programs were conducted in Canada at Egbert, Dorset, and Borden, Ontario; and in the United States at White Face Mountain, NY, Scotia Range, PA, White Top Mountain, VA, Brasstown Bald, GA, and Bondville, IL. The experimental database will be used to evaluate models from different perspectives, including, but not limited to, point-to-point comparisons between modeled and observed fields, and characterization of subgrid-scale variability. A second field study is planned for the spring of 1990.

ANATEX Model Evaluation Study (AMES). The Across North America Tracer Experiment (ANATEX) Model Evaluation Study was initiated in FY-1987 as a joint effort of the EPA, the NOAA, and the U.S. Air Force Technical Application Center, to assess the performance of the transport and diffusion components of operational long-range models (Clark *et al.,* 1988). The ANATEX database, obtained from January through March 1987, consists of 24-hour measurements from a 77-site network across central and eastern North America for 3 perfluorocarbon tracer gases released for 3 hours every 2 1/2 days from sites near St. Cloud, MN, and Glasgow, MT.

The study will compare nine models. The evaluation protocol will focus on the comparison of time series and ensemble frequency distributions along bands of monitoring sites equidistant from the release sites, and on the transport of discrete tracer puffs. The utility of the performance measures, designed specifically for this evaluation data set, was tested using the measurements and the calculations for one of the nine models, and the evaluation protocol was confirmed. Model results from the eight other models were received and the evaluation is in progress.

2.2.1.7 Data Analysis in Support of the Acid Deposition Program

Dry deposition of cations. The dry deposition of base cations is comparable to that of their wet deposition in the neutralization of acidic deposition. Because of the dearth of measurements for cation deposition, washout ratios were developed to provide interim estimates of base-cation dry deposition to the EPA aquatic effects program. The washout ratio for a given species is defined as the ratio of its concentration in surface-level precipitation to its concentration in surface-level air. Both theoretical and empirical studies using surface and aircraft measurements support the validity of a washout ratio approach for nonurban areas and long-term averages.

This study was based on APIOS data. Only those sites that measured both ambient concentrations and precipitation concentrations of Ca^+, Na^+, Mg^+, and K^+ were included in the analysis. For each ion at each site, annual concentration values were used for the three-year period from 1983 through 1985. The correlation coefficients between the ambient and precipitation concentrations for each ion were 0.92 for Ca^+, 0.82 for Na^+, 0.89 for Mg^+, and 0.62 for K^+. Coefficients for estimating annual dry deposition based on annual wet deposition were developed.

The aquatics effects models also require input information on the seasonality of the dry deposition of the base cations. The seasonal trend in the ambient concentrations of the base cations was developed using the monthly APIOS data for 1982 through 1986. The data were smoothed via a median smoother, and strong seasonal signals were evident. Monthly factors or adjusters were calculated from the smoothed data for stations representing remote, rural, and near-urban regions. The residuals between the raw and the smoothed data were analyzed to provide estimates of the uncertainty about the smoothed monthly seasonal pattern, which ranged from 40% to 50% and was independent of season.

Sulfur dry deposition estimates for the EPA aquatic effects research program. At the request of the EPA aquatic effects research program, estimates of annual sulfur dry deposition were developed for more than 7000 lakes in the northeastern United States (Dennis and Seilkop, 1987). These estimates were interpolated from annualized RADM calculations of sulfur dry deposition that were systematically adjusted to minimize the root mean square error (RMSE) between empirical data and model calculations for 22 sites.

The analysis was repeated in FY-1988 because much more empirical data were available. The database used to estimate dry deposition included 4 sites of the COre Research Establishment (CORE) network (Hales *et al.,* 1987) and 18 sites of the APIOS network (Ro *et al.,* 1988). Three regional models, RADM, RELMAP (Eder *et al.,* 1986), and the Advanced Statistical Trajectory Regional Air Pollution (ASTRAP) model (Shannon, 1985), were applied to construct spatial patterns of annual sulfur dry deposition. Both

RADM and ASTRAP calculations were systematically adjusted to minimize the RMSE (normalized by the observed means of 34% and 74%, respectively). RELMAP calculations were not adjusted because the normalized RMSE for RELMAP (58%) could not be reduced significantly.

The plausibility of each model's spatial pattern was determined by looking at similarities between spatial features (e.g., magnitudes and gradients) identified by the empirical data and by the adjusted/unadjusted model calculations. Although all models tended to smooth the spatial gradients (i.e., underpredicting the highest amounts and overpredicting the lowest amounts), the adjusted RADM pattern best replicated both the magnitude of the empirical data at the 22 sites and the steep gradient downwind of the significant SO_2 emission region between Lakes Huron and Erie.

Principal component analysis of wet deposition data. The spatial and temporal variabilities of SO_4^{2-} concentrations in precipitation over the eastern United States during the period 1981 through 1986 were examined using principal component analysis. Spatial mapping of the component loadings identified seven statistically significant modes of variability that together accounted for 74.2% of the total variance. The first component, which represents the dominant pattern, accounted for 44.9% of the total variance and identified an in-phase oscillation across the entire study area. The remaining six components, which account for 29.3% of the total variance, each identified out-of-phase oscillations. Application of Kaiser's Varimax orthogonal rotation delineated seven contiguous subregions, each displaying statistically unique SO_4^{2-} concentration characteristics, which corresponded with major SO_x emission patterns. Examination of the time series associated with each subregion revealed a general seasonality; periods of high concentrations were more likely during the summer, while periods of low concentrations were more likely during the winter. This seasonal cycle, however, was more prevalent in subregions that contained few major emission sources, and was less prevalent and often obscured by perturbations in subregions that contained many major emission sources.

2.2.2 Photochemical Modeling

2.2.2.1 Regional Oxidant Model (ROM)

Development of the Regional Oxidant Model (ROM) began nearly ten years ago after it was generally accepted that ozone and its precursor species generated from major urban areas could travel relatively long distances and affect air quality over very broad areas. It became clear that, for many states, viable emission control plans could not be developed without accounting for the influx of ozone and precursor species from outside sources. ROM was developed to simulate the regional transport and fate of emissions from all sources in the northeastern United States, and thereby to serve as a basis for developing regional emission control policies for attaining the primary ozone standard in the most cost-effective way. Since its inception, ROM was applied to the southeastern United States for regional analyses there and was used to investigate the effect of emission controls on concentrations averaged over longer time periods, in anticipation of a secondary ozone standard designed to protect such welfare interests as forests, crops, and materials.

The second-generation version of the model, ROM2.0, became operational during FY-1987. During FY-1988, the ROM program emphasized model applications. To support the Vice President's Task Force on Clean Coal Technology, ROM simulations were made for the northeastern United States using data from July and August 1980. The goal of these applications was to assess the effects on region-wide ozone patterns of volatile organic compound (VOC) emission controls versus NO_x emission controls alone or combined VOC and NO_x controls. The simulation results indicated that the combined VOC and NO_x emission reductions would be more effective at reducing peak ozone concentrations than would reduction of either emission species independently; controlling NO_x emissions alone provided the potential to locally increase ozone concentrations in emission-rich areas. Applications also were performed to support analyses of the primary ozone standard. These simulations were performed for the northeastern United States with July 1980 data and various combinations of VOC and NO_x emission controls. Simulations were also conducted for the northeastern and southeastern United States to assess the incremental impact on maximum ozone concentrations of emissions from hazardous waste treatment, storage, and disposal facilities. Results showed only localized impacts immediately downwind of the major facilities (Pierce and Schere, 1988). Regional-scale impacts were not discernible.

Two other major FY-1988 activities in the ROM program included the ROM2.0 evaluation using the 1980 NEROS databases and the implementation of a technique for extrapolating the results of episodic ROM simulations to an entire season. Model development activities continued during FY-1988 toward the goal of producing a new version of the second-generation model (ROM2.1) for use in the upcoming Regional Ozone Modeling for Northeast Transport (ROMNET) applications project. Significant changes to the model and preprocessor system included providing greater flexibility in moving and/or changing the size of the modeling domain, upgrading the chemical kinetic mechanism to the final version of the Carbon Bond IV mechanism (Gery *et al.,* 1988), incorporating a more realistic treatment of the biogenic emission processes, and improving the methods for generating gridded wind fields.

2.2.2.2 Seasonal Extrapolation of ROM Results

Efforts to promulgate a secondary ozone standard that would protect crops and forests have created the need for a seasonal ozone model, one that can estimate the effects of emission changes on the daily daylight ozone concentration averages during the growing season. It is not realistic to perform such long-time-scale simulations with numerical grid models of air quality because of computational constraints. Methods of aggregating or extrapolating results from representative simulated episodes to a season or a longer time period are required. Lamb (1988) outlines such a technique that may be used with ROM simulation results and presents a demonstration of its preliminary implementation. The method is based on analyzing source-receptor relationships for a limited subset of receptors from a meteorological perspective during several modeled episodes within a season. A similar analysis is performed for the full season, and then each source-receptor relationship occurring in the full season is represented by an analogous relationship obtained from one of the modeled episodes through a mapping procedure. Simulation results from the episodes are then similarly mapped into the full season using the resulting extrapolation matrix. Two-week episodes from April, July, and August 1980 for the northeastern and southeastern United States were used to test the extrapolation methodology, as were control strategy simulation results for these domains.

2.2.2.3 Evaluation of ROM2.0

The evaluation of ROM2.0 using the 1980 NEROS database began in FY-1987 and continued through FY-1988. The purpose of the project is to quantify the performance of ROM2.0 in predicting ozone concentrations over regional scales and within major urban plumes on the regional scale. The model was run with data from July 12 through August 31, 1980; during this time there were several major ozone episodes in the northeastern United States. Although the evaluation is focusing on ozone, model performance for NO_x and hydrocarbons is being evaluated as well.

The evaluation of ROM2.0 for surface ozone measurements made use of approximately 200 monitors in the standard United States and Canadian air monitoring networks within the model domain. The evaluation was conducted using quasi-deterministic techniques in which strict spatial pairing between observations and predictions was not used. Statistics of model performance were calculated from comparison of predictions and measurements within six coherent clusters formed from the network of ozone monitoring sites. Results showed that ROM2.0 predicts hourly ozone concentrations above 80 ppb fairly well, and concentrations between 60 and 100 ppb particularly well. The average percentage of daylight hours (0800-1900 LST) over the simulation period showing concentrations above 80 ppb was 21.7% in the observed data set and 19.3% in the predicted data set for the clusters of monitoring sites with the highest ozone concentrations. ROM2.0 showed an overall 2% overprediction of the daily surface maximum ozone concentration. The model predicted a narrower range of values than the observations showed, underestimating the highest values and overestimating the lowest values.

Spatial patterns of maximum ozone concentrations during episodic periods were evaluated for several major episodes during the simulation period. The spatial extent and concentrations of urban ozone plumes were generally simulated well, although a bias in the transport direction along the East Coast caused misalignment of the plumes in specific episodes. Plume patterns and locations were compared qualitatively between observations and predictions. Aircraft data obtained during the NEROS field studies are being used to determine model performance in upper layers and from a more regional perspective, since most of the surface monitors are urban-oriented. ROM2.0 simulations of NO_x and hydrocarbons are also being evaluated, using data collected both at the surface and aloft. However, far fewer surface monitors were available for these species than for ozone, thus evaluation techniques employed will be more diagnostic than those used for ozone, with fewer rigorous statistical techniques used in the comparisons.

2.2.2.4 Development of ROM Multiprocessor Custom Computing Equipment

The development of large regional-scale Eulerian models like ROM has required increases in the computer resources needed to execute these modeling systems, compared with the smaller urban-scale grid models. A disparity between the growth rate of model size and the relative computational power and speed motivated a study to determine the feasibility of building a custom digital hardware device that could be attached to a minicomputer to accelerate the execution speed of ROM and other large models. The information necessary to design such an accelerator was acquired by running the ROM code under software "instrumentation" to show how the computational load and data transfer rates between model steps are distributed within the model. These data revealed that a model like ROM is not amenable to acceleration using a vector-type architecture because the computational burden is too inhomogeneous in space and time. Instead, the optimum computer architecture would be designed around a system of loosely-coupled parallel processors. The design of two such systems was explored in the feasibility study, which showed that speed could be increased a hundredfold by using an accelerator based on a loosely-coupled processor architecture of a tiled design (McHugh *et al.,* 1987).

Based on the feasibility study, a prototype device is being constructed at the Research Triangle Institute, Research Triangle Park, NC, through a cooperative agreement with the Division. The prototype device will consist of two VAX 1000 computers for individual processing elements and a VAX workstation acting as the host computer. The goals of the project are to accelerate ROM execution speed by up to ten times the uniprocessor speed, and to investigate and implement parallel processing techniques within the ROM code to accomplish this speed-up. The prototype architecture will use the host machine to calculate the horizontal transport portion of the model, while the microprocessors will solve the chemical and flux portions. The chemical calculations can account for nearly 90% of the model's computational time. If this prototype is successful, then the more difficult tiled architecture with its potential hundredfold increase in execution speed may be explored.

2.2.2.5 Regional to Urban Model Interface Program Development

Methodologies and procedures are being established as a prerequisite to developing a preprocessor interface system between ROM and the Urban Airshed Model (UAM). As part of the ROMNET program, ROM concentrations and processor outputs will be produced for selected episodes for various emission scenarios over the northeastern United States. The interface programs to be developed will provide a link between the ROM processor files and the UAM preprocessor system. This work is being performed as an effort to revise and update the UAM system.

Interurban transport of ozone and precursor species is an important consideration in urban-scale modeling along the Northeast Corridor, where several major metropolitan areas are located. Since considerable difficulty exists in adequately specifying initial, lateral, and top boundary conditions from monitoring site data for models, an important part of the interface program will be to prepare ROM results as initial and boundary concentrations in UAM applications for various cities in the region. Another important element is the matching of wind fields. Methods to derive values at the levels of vertical cells and on the finer horizontal grid of UAM from the three-layer gridded ROM concentrations are being explored. Plans also include an examination of differences in transport when using ROM winds versus processed wind profile observations as input to a diagnostic wind model that will generate wind fields for UAM. Code development of the interface program, testing, and preparation of an operations manual are scheduled for FY-1989.

2.2.3 Particulate Matter Modeling

This program's objective is to develop and evaluate atmospheric modeling systems that address the physical and chemical processes of aerosol emissions, transport, chemistry, and removal on both urban and regional scales. These modeling tools will be used primarily to assist in promulgating air quality standards for fine particles, visibility, and acid aerosols. This section discusses the development of a Lagrangian model and a program to obtain a database to evaluate both Lagrangian and Eulerian models. Section 2.4 details a major effort to incorporate aerosol dynamics and chemistry into RADM.

2.2.3.1 Fine Particle Database for Model Evaluation

To evaluate regional models of fine particulate matter, a 33-site network of cyclonic separator samplers was established to obtain 24-hour concentrations of fine particles (diameters less than 2.5 μm) in rural areas of the northeastern United States. This network is a subset of the ACID-MODES network (see Section 2.2.1.6). Sampling was conducted during the summer of 1988 and will continue through the spring of 1990. In addition to total mass, the concentrations of constituent species will be determined using X-ray fluorescence analysis.

During Session I (August 15 through September 25, 1988), approximately 1000 filters collected fine particles on a daily basis. Collocated measurements obtained at Plainsville, IL, and State College, PA, showed very good agreement for the last five weeks of Session I. For Plainsville, the correlation coefficient was 0.98 and the mean coefficient of variation was 0.08, and for State College the correlation coefficient was 0.84 and the mean coefficient of variation was 0.21.

2.2.3.2 Evaluation and Sensitivity Analyses of the MESOPUFF II Model

The MESOPUFF II regional Lagrangian puff model was evaluated against measurement data from the Cross-Appalachian Tracer Experiment (CAPTEX). Plume trajectory differences were assessed by computing concentration-weighted centroid positions of the modeled and observed plumes and then using them to quantify the downwind distance difference and separation distance between the plumes at 6-h intervals. The separation distances between plume centroid locations varied from 100 to 300 km at downwind distances of 500 to 1000 km. The mixed-layer averaged wind field performed better than a surface or 850-mb single-level wind field in transporting model plumes during the daytime, based on comparisons with the time and location of impact of observed plumes. The model overpredicted peak concentrations. This was attributed to underestimation of vertical dispersion with the Gaussian distance-dependent method under neutral conditions, the stability class generally specified during the afternoon release periods.

2.2.4 Boundary Layer Studies

2.2.4.1 Wide-Area Ozone Dry Deposition Study

Analyses of the spatial variability and temporal behavior of the vertical flux of ozone and related dry deposition parameters from turbulence measurements collected during long horizontal aircraft flight legs over agricultural and forested landscapes in Ohio and Pennsylvania were completed (Godowitch, 1988). Ozone fluxes displayed a significant height dependency over the lower half of the convective boundary layer, with the strongest negative (downward) values occurring at the lowest flight levels, near 100 m above ground. Stronger negative fluxes occurred in urban plume segments downwind of Columbus, OH, under conditions of high ozone concentrations. However, the deposition velocity displayed no systematic variation as a function of location in the urban plume flight legs. Further, there was no difference in the mean flux between more heavily forested areas and agricultural areas in this region. Notable variations in ozone fluxes were found in other regions where flight legs were made over water and surrounding forests. Ozone fluxes were reduced over nonirrigated versus irrigated farmland under hot, dry conditions. These experimental results support the deposition parameterization model and surface resistance formulation (Wesely, 1988) developed for RADM.

2.2.4.2 Boundary Layer Diffusion Research

Data analyses and results of the CONvective Dispersion Observed with Remote Sensors (CONDORS) field experiment were described in detail in Eberhard *et al.* (1988). The cross sections of near-surface chaff, oil fog, and SF_6 concentrations agreed well with each other. Surface values of crosswind-integrated concentration versus distance were found to agree better with laboratory and numerical simulations than with predictions from Gaussian plume models. These data were used to support a simple probability distribution function (PDF) model for vertical diffusion in convective conditions (Li and Briggs, 1988). Also, a simple approach was developed for estimating the response of convective turbulence to major surface heat flux anomalies like rivers, lakes, and industrial "hot spots" (Briggs, 1987b); in some cases, stationary convective downdrafts or updrafts develop, causing major increases or decreases in surface concentrations of pollutants from elevated sources. Suggestions were made for parameterizing lateral diffusion in terms of scale velocities for neutral to very unstable conditions (Briggs, 1987a). Techniques for analyzing diffusion field experiment data in terms of meteorological variables were surveyed and evaluated (Briggs, 1988).

2.2.4.3 Heavy Gas Diffusion Experiments

To provide data useful for planning emergency response procedures for the spill of a toxic, dense gas into a valley or other topographic depression, two series of experiments involving diffusion of heavier-than-air gases were carried out in the large wind tunnel at the Fluid Modeling Facility (described in Section 2.3). The object was to find out how rapidly the gas is removed by turbulent entrainment produced by the wind.

The first series used CO_2 distributed into the bottom of a V-shaped, two-dimensional valley at a steady rate. A pool of dense gas formed. Measurements were begun after it reached an equilibrium height, so that the outflow (entrainment) rate could be assumed equal to the inflow rate. As expected from theory, the entrainment rate was proportional to U^3 at larger wind speeds, where U is the wind speed measured just above the surface of the dense gas. At smaller wind speeds, molecular diffusion became important and the entrainment rate was proportional to $U^{1/2}$. The second series of experiments involved using fixed amounts of CO_2 and SF_6 in two different valley shapes. Outflow versus time was measured after a sliding cover was quickly removed from the valley. These results supported the analytical predictions resulting from the series of steady-state experiments.

2.2.5 Global Climate Change Studies

To assess potential impacts of climate change on environmental resources, future climate change scenarios are required for input to atmospheric and effects models. The development of climate scenarios is still in a rudimentary stage and must be supported by acquiring a better understanding of past variability of such climate variables as temperature and precipitation. Thus, a study examined the variability of both temperature and precipitation on a climate division level for the contiguous United States for the period from 1895 through 1985.

The temperature variances and standardized ranges revealed a continentality phenomenon in which the largest variances and ranges occurred in the upper Midwest, while the smallest variances were generally found along coastal regions. The coefficients of variation and the standardized ranges for precipitation depicted a propensity for the largest seasonal and annual variation and ranges to occur over the southwestern states; the smallest coefficients of variation were found over the northeastern sections of the country. Climate scenarios, whether derived from global climate models or from analogue techniques, should replicate the variability statistics and basic pattern that were found.

2.2.6 Technical Support

2.2.6.1 Regional Ozone Modeling for Northeast Transport (ROMNET) Program

In the three-year (FY-1988 through FY-1990) ROMNET program, ROM is being used to estimate future-year boundary conditions for urban models applied to areas in the northeastern United States. The purpose of the program is to test the effects of region-wide VOC and NO_x emission control strategies on region-wide ozone distributions for the years 1995 and 2005. Results from these simulations for the future years for base case and emission control scenarios will be provided to state and local air pollution control agencies to estimate initial and inflow boundary conditions for urban air quality models in future-year emission scenario testing. Meteorological scenarios from episodic periods in 1980, 1983, 1985, and 1988 will be used, along with a current emission inventory for 1985 and projected inventories for 1995 and 2005.

Technical guidance is provided by ROMNET technical committees, including the Modeling Committee (with two Division representatives), the Emissions Committee (with one Division representative), and the Management Committee (with one Division representative).

2.2.6.2 Modeling Advisory Committee

The California Air Resources Board (ARB) has initiated a Modeling Center within its Technical Support Group in Sacramento. The purposes of the Center are to coordinate all regulatory air quality modeling activities within the state and to develop and test tools needed for these activities. A Modeling Advisory Committee (MAC) was established to review and comment on the Center's programs and activities and to provide ongoing expert opinion on a variety of modeling subjects, including model evaluation, model application, and uncertainty in the modeling process. The MAC is composed of members from the scientific community elected by ARB officials for fixed terms of membership. Currently, one representative from the Division is serving a two-year term on the MAC.

2.2.6.3 Urban Airshed Modeling

The Division has one representative serving on working groups providing technical assistance for UAM applications projects. One is the SCOPE project, in which the New York State Department of Environmental Conservation is attempting to interface ROM and UAM by providing UAM with wind fields and initial- and boundary-condition concentrations from ROM for a limited number of single-day UAM simulations. The other project is the five-city UAM demonstration where the model will be exercised on routinely available databases from New York, St. Louis, Philadelphia, Atlanta, and Dallas, to demonstrate the model's accuracy and flexibility when being used in scaled-down implementations.

2.2.6.4 Technical Support to the National Acid Precipitation Assessment Program

A Division scientist serves as chairman of the NAPAP Task Group II, Atmospheric Transport and Modeling. During FY-1988, the major support provided to the NAPAP Office of the Director involved structuring and writing the draft plan and schedule for the 1990 NAPAP Assessment reports (National Acid Precipitation Assessment Program, 1988). The primary support was directed towards the atmospheric processes component of the 1990 Assessment to establish the format and content of the major Assessment questions to be addressed by the NAPAP. Other support included providing outlines of the major atmospheric modeling State-of-Science/Technology papers. The draft plan will be completed early in FY-1989 for public review. The plan will be the key planning document for the 1990 NAPAP Assessment.

2.3 Fluid Modeling Branch

The Fluid Modeling Branch conducts physical modeling studies of fluid flow and pollutant dispersion in complex flow situations, including flow and dispersion in complex terrain, near and around obstacles, and at coastal outflows. The branch operates the Fluid Modeling Facility consisting of large and small wind tunnels, a large water channel/towing tank, and a convective tank. The large wind tunnel has an overall length of 38 m with a test section 18.3 m long, 3.7 m wide, and 2.1 m high. It has an airflow speed range of 0.5 to 10 m/s and is generally used for simulating transport and dispersion in the neutral atmospheric boundary layer. The towing tank has an overall length of 35 m with a test section 25 m long, 2.4 m wide, and 1.2 m high. It has a speed range of 0.1 to 1 m/s, and the towing carriage has a range of 1 to 50 cm/s. It is generally used for simulation of strongly stable flow. A convective tank is now under construction to study flow and dispersion under convective conditions.

2.3.1 Dispersion of Dense Gases

In a prior year, measurements were made of the behavior of heavy gas plumes in the simulated atmospheric boundary layer of the wind tunnel. Sulfur hexafluoride (five times as dense as air) and carbon dioxide (50% heavier than air) were used as source gases for comparison with previous measurements using the air itself (neutrally buoyant) as the source gas. The measurements of the heavy-gas plumes showed much broader lateral spreading and much narrower vertical distributions due to their larger negative buoyancy. In FY-1988, several dense-gas models were evaluated using these measurements, and the results were presented as a paper at the 17th International Technical Meeting of the NATO-CCMS on Air Pollution Modelling and its Application, held in Cambridge, England, in September 1988 (Petersen *et al.,* 1988).

Two projects were conducted in the meteorological wind tunnel examining the flushing of dense gases from valleys. In one project, the gas was sufficiently dense to form an undiluted pool in the valley bottom, and thus to be removed from the valley by entrainment through the density interface between the two gases. In the second project, the gas density was too small to result in pool formation, but nevertheless significantly affected the flushing rate. Data were collected to develop formulas for predicting the removal rate (or residence time) of the dense gases from the valleys. Three sizes of valley models, two-dimensional with triangular cross sections, were used to determine steady-state pool depths as a function of the rate gas was supplied through a line source at the valley bottom, the density of the gas, and the crossflow wind speed. Of particular interest was the determination of the Reynolds number dependence of the entrainment process. An additional valley model with a sliding-door cover was used to obtain transient flushing rates by filling the valley with dense gas, quickly opening the cover, and then measuring the flux of gas just downwind of the valley using a vertical rake of sampling ports.

2.3.2 Convective Boundary Layer Simulation

The stratified towing tank was used to investigate the displacement of the daytime mixed layer as it encountered complex terrain. The ambient stratification, intended to simulate the most basic stratification of the convective atmospheric boundary layer, consisted of a neutrally-stratified layer extending from the surface to some particular height z_i and a continuously linearly-stratified layer above (to the full depth of the tank). Two hills were used (both of height H), one axisymmetric, the other elongated in the crosswind direction. A total of 78 tows was made in which stratification strength, mixed-layer height, hill type, and towing speed were varied, each time measuring the deflection of the mixed-layer height. Current formulations for regulatory models provide a correction factor that results in adjustments for z_i, ranging from no change to one that is terrain-following. For example, the Rough Terrain Diffusion Model (Paine and Egan, 1987) applies a "half-height" correction to both the plume and z_i in unstable conditions. This approach has merit because it is based on potential flow solutions for distortions of streamlines over two-dimensional terrain. However, consideration should be given to variations in terrain shape and meteorology. Preliminary analysis of the data from this study indicates the following:

1. Deflections in the mixing-height streamline can be scaled adequately by two dimensionless parameters: the hill Froude number and the ratio of the upstream mixing height to the hill height;

2. Magnitude of the deflections monotonically increases with increasing Froude number and with decreasing z_i/H;

3. Shape of the terrain is clearly an important factor; deflections over a ridge-like feature are significantly greater than those over a more symmetrical, three-dimensional feature; sensitivity of streamline deflections to hill shape clearly is greater for initial z_i-streamlines at and above the hill top;

4. Notable ranges of Froude numbers over which only minor variations in mixing-height deflections were observed; and

5. Comparison of the experimental data with calculations from a commonly-used modeling approach suggests that improved estimates of mixing height deflections are needed.

These results are being used to develop an algorithm, a convective front end, for use in the Complex Terrain Dispersion Model.

2.3.3 Flow Visualization Techniques

A new ink-dot technique (Langston and Boyle, 1982) was used to investigate the surface flow patterns within the highly turbulent and recirculating wakes downwind of surface-mounted bluff obstacles (buildings). The results were presented at the Eighth Symposium on Turbulence and Diffusion, held in April 1988 in San Diego, CA (Lawson *et al.,* 1988). It was found that obstacles dividing the stream laterally produce central downwash in their wakes, whereas those lifting the flow predominantly over their crests produce central upwash in their wakes. This finding has important implications regarding the placement and heights of stacks in the vicinities of buildings. Previous work showed such behavior in laminar flows; the current work demonstrated its applicability to the highly turbulent and unsteady flows in nature.

Previously, video-image analysis was used only to obtain qualitative flow visualization and some limited quantitative information on scales and frequencies of vortex shedding (Huber and Arya, 1985). A video-image-analysis system was developed to quantitatively relate smoke intensity to vertically-integrated concentrations in the wind tunnel. This is useful because it allows the analysis of the concentration patterns over the entire field of view (as opposed to painstaking point-by-point measurements), as well as measurements of concentration fluctuation statistics. The technique is limited because the measured concentrations are vertically integrated and not point measurements, but further work will attempt to use sheet lighting to obtain point concentration fields. This system was used to obtain concentration measurements in building wakes, and the results were prepared for presentation at the Fourth International Conference on Wind and Water Tunnel Modeling of Atmospheric Flows and Dispersion to be held in October 1988 in Karlsruhe, West Germany.

2.3.4 Flow and Dispersion in Complex Terrain

Data collected in earlier years describing the streamline patterns over an isolated three-dimensional hill in stratified flow for Froude numbers greater than 1.0 were compared with numerical solutions of the linearized equations of motion for an inviscid fluid (Thompson *et al.,* 1988). The streamlines were obtained in a stratified towing tank using a stereographic method to determine paths of dye released upwind of the hill. Velocities over the hill center were obtained by analyzing video recordings of the dye plumes and with a propeller anemometer. Agreement was found for Froude numbers (based on the hill height) greater than about 2.0. For Froude numbers greater than about 4.0, flow patterns were observed to differ only slightly from those for neutral flow.

Towing-tank studies examined upstream columnar modes, drag, and unsteadiness in laboratory modeling of stratified flow over complex terrain. The impetus for these studies involved the ability to simulate stratified flows in laboratory facilities. Another project was started to investigate vortex shedding on the lee side of hills in strongly-stratified flows.

2.4 Data Management Branch

The Data Management Branch supports the model development activities of the other Division Branches by providing modeling software design and systems analysis. The branch is the focal point for compliance with Agency quality control and assurance requirements. The branch operates the Facility for Advanced Research Model Operation and Analysis (the Research Modeling Facility). This facility provides expertise in applying and interpreting advanced dispersion models and establishes definitive scientific standards for model evaluation and policy analysis that are consistent with standards followed in the research and model development efforts.

2.4.1 Regional Oxidant Studies

2.4.1.1 Regional Oxidant Model (ROM2.0) Applications

The second-generation Regional Oxidant Model (ROM2.0) was used to investigate ozone control strategy applications. In support of the Vice President's Task Force on Clean Coal Technology, ROM2.0

was used to examine NO_x control strategies for two multiday elevated ozone episodes, July 12-27, 1980, and August 20-31, 1980, in the northeastern United States. This study showed that NO_x controls resulted in marginal decreases in ozone concentrations, although a few scattered areas (primarily within large NO_x plumes downwind from power plants) showed increases in peak ozone concentrations.

ROM2.0 was used to examine various combinations of volatile organic compound (VOC) and NO_x control strategies with July 1980 meteorological data. Even with VOC reduced by 90% and NO_x reduced by 30%, predicted peak ozone values were still slightly above the National Ambient Air Quality Standard (a 1-h peak of 120 ppb). This sensitivity study will be used in designing control strategies for the Regional Ozone Modeling of Northeast Transport (ROMNET) project.

Using an extrapolation methodology developed by Lamb (1988), hourly ozone concentrations from 45 days of ROM2.0 simulations were extrapolated for the 1980 growing season (April through October) in the southeastern and northeastern United States. Economists and health scientists will use these extrapolated concentrations to assess the long-term benefits of ozone improvement. Of special interest is what effect prolonged ozone concentrations above 80 ppb will have on southeastern pine forests. Because this work is preliminary, more development and testing of the extrapolation methodology is anticipated for FY-1989 and FY-1990.

2.4.1.2 Regional Ozone Modeling for Northeast Transport (ROMNET) Project

During FY-1988, preparatory work began for the ROMNET project. This project is a major three-year modeling effort undertaken in cooperation with the EPA and state and local air pollution control agencies in the northeastern United States. The ROMNET effort will focus primarily on using ROM2.0 to simulate the effects of ozone control strategies for 1985, 1995, and 2005 emission inventories. In support of the ROMNET project, two tasks were initiated during FY-1988.

Using an objective screening methodology developed for this project, three meteorological episodes from 1980, 1983, and 1985 were selected for ROM2.0 simulation. Because of the unusually high ozone levels, data from the summer of 1988 will be examined for possible inclusion in the ROMNET project.

In response to requests from ROMNET committee members who wanted to enlarge the modeling domain in the northeastern United States, it was increased to extend from Maine to North Carolina and west to the Ohio/Indiana border. Technical improvements to a new version of ROM2.0 (ROM2.1), which uses the new domain, include an updated biogenic emissions processor with a canopy model for predicting leaf temperature and solar radiation, the latest version (version 4.2) of the Carbon Bond IV mechanism (Gery *et al.*, 1988), and the expanded use of buoy data to improve prediction of meteorological data fields over water. Work on ROM2.1 will be completed by early FY-1989 and ROMNET executions should begin during the spring of 1989.

2.4.2 Regional Acid Deposition Model (RADM) Applications Support

An acid deposition modeling production team was established that includes members from both the Division and the model development staff at the State University of New York at Albany. In FY-1988, this team designed and implemented a systematic approach for RADM and RADM Engineering Model (EM) executions and database management in support of the National Acid Precipitation Assessment Program (NAPAP) Integrated Assessment and State-of-Science/Technology reports. This plan will ensure quality research results for the NAPAP applications. For both the RADM and the EM versions, all input and output file structures were modified to include file headers. Input data processors and the RADM code now generate audit information for a master database that provides up-to-date status information on all production executions. Also, the team added restart capability and quality control features to the various versions of the model.

An interagency agreement with the National Science Foundation was established to provide supercomputer access at the National Center for Atmospheric Research (NCAR) in Boulder, CO, for executing RADM and for preparing meteorological and emission input data. Direct high-speed telecommunications were established and numerous file conversion routines were written to implement job submission and file transfers between the Division and the NCAR.

A software system was developed that transforms the NAPAP emission inventory into a form directly compatible with RADM. A revised plume rise algorithm was implemented to apportion major point source emissions into the appropriate RADM layers. Summer mobile source emissions are adjusted to reflect Mobile 4.0 emission factors and to account for daily temperature variation. Pollutant species and grid transformations are performed.

Assistance was provided in the approval and siting process for the ground-station network of the Acid Model Operational and Diagnostic Evaluation Study (ACID-MODES). Site visits to 22 ground stations proved valuable in uncovering irregularities between station operations. Samples were changed simultaneously throughout the network in both eastern and central time zones, except in Indiana which remained on central standard time throughout the year.

2.4.3 Regional Particulate Model Development

The first-generation Regional Particulate Model (RPM) was developed and executed in FY-1988. RPM was developed from version 2 of RADM/EM (RADM/EM2) by linking the aerosol chemistry/dynamics mechanism developed by Systems Applications, Inc., to the existing gaseous and aqueous chemistry mechanisms. This development task required complex modifications to the data storage array structure, the chemical species list, and the input/output file structure. RPM was evaluated for a 72-hour period corresponding to a period previously modeled by RADM/EM2 for sulfur tracking. The particulate sulfate fields predicted by RPM agreed well with the predicted sulfate fields from RADM/EM2 and showed the effects expected from cloud nucleation processes on sulfate particles.

As part of RPM development, a software system for storing and analyzing hourly precipitation data was created. This data handling system was used to provide hourly precipitation data and statistics to the NAPAP, and will be used within the Division to study the structure and effect of precipitation processes on aerosol particles. Other related developments include a "smart system" for recognizing convective cumulus clouds from nonconvective cloudiness, and a system for decoding and analyzing 3DNEPH global cloud data sets from the U.S. Air Force Global Weather Central.

2.4.4 Advanced Statistical Trajectory Regional Air Pollution (ASTRAP) Model Sensitivity Study

During FY-1988, sets of sensitivity analyses were performed with the Advanced Statistical Trajectory Regional Air Pollution (ASTRAP) model. The study compared 1980 quarterly predictions of sulfur wet deposition amounts from nine series of model applications; each series assessed the sensitivity of the predictions to changes in either a modeling assumption or the value of a model parameter. Predictions were not compared at every cell in the North American modeling domain, but instead were compared along a band stretching from central Alabama to southern Quebec.

The model was most sensitive to changes in the time-step and the temporal aggregation of trajectory statistics. Decreasing the time-step from 6 h to 3 h increased sulfur wet deposition by as much as 15% to 45% depending on the season. When trajectory statistics were not aggregated, deposition increased by as much as 5% to 45% depending on the season.

Predictions were also sensitive to the modeling assumption that the trajectories terminate at the borders of wind-data-void regions (e.g., the Atlantic coast). This assumption caused a downward bias in the spacing between the endpoints of the mean trajectory segments in eastern North America. The alternative approach of extrapolating the trajectories across data-void regions decreased predicted sulfur wet deposition across New York and Quebec by as much as 20% to 25%.

2.4.5 Geographic Information System (GIS) Pilot Project

A Geographic Information System (GIS) is a computerized tool for storing, manipulating, and displaying geographic information. To demonstrate the utility of a GIS for spatial analysis of multiple environmental data sets, several EPA offices and laboratories undertook a cooperative effort to design and implement a GIS pilot project. The geographic scope of the project was defined as the Northeast Regional Oxidant Study (NEROS) modeling domain and the following types of data were included in the pilot design: ROM predicted pollutant concentrations, NAPAP point and area source emissions, biogenic hydrocarbon emissions, air quality measurements, land use data, and population data.

The software system is divided into two major subsystems: data interface and database management, and data display and analysis. A menu-driven interface was implemented so that researchers with little GIS experience can use the system. The menus include database management features to provide easy access to several different types of data sets useful for assessing environmental problems. The pilot prototype system provides researchers with a powerful graphics tool for creating contours, gridded maps, and overlays and for exploring relationships among a variety of data sets.

2.4.6 ADP Objective Analysis Software Development

Many of the atmospheric modeling activities in the Division require that objective spatial analyses be performed with a variety of data types. Often the purpose of these analyses is to provide model input data on appropriate spatial grids, or to graphically analyze model output data. To expand the Division's spatial analysis capabilities, an improved system of FORTRAN software was developed that allows analysis on partial domains while still using the prevalent Barnes technique of objective analysis. This improvement allows researchers to employ the Barnes technique on only part of a full model domain, the part where sufficient data are available for a confident analysis. This modified procedure also reduces the domain boundary effects that occur with the ordinary Barnes analysis procedure.

2.5 Terrain Effects Branch

The Terrain Effects Branch studies the effects of complex irregular terrain and man-made surface features on ambient pollutant dispersion; establishes mathematical relationships among air quality, meteorological parameters, and physical processes affecting the air quality; and conducts research on the impact of global climate change on regional climate and air quality.

2.5.1 Global Climate Change Program

The Global Climate Change Program's goal is to study the impact of climate and climate change on the environment. In support of this goal, the program is geared to conduct research on the impact of climate change on air quality, the impact of urban emissions on regional and global atmospheric composition, and the production of future climate scenarios for air quality and environmental effects.

A major FY-1988 activity was developing implementation plans for producing regional climate scenarios. A complete survey of available scenario production techniques and user needs was completed. The results will be given in a report being prepared for publication in FY-1989. A scenario production seminar series was conducted in which each of twelve guest speakers spent a day or two with the Division.

Using the ARC/INFO® system,[1] changes in the seasonality of precipitation over time are being studied. This research is based on the National Climatic Data Center's historic climate database.

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1. ARC/INFO is a registered trademark of Environmental Systems Research Institute.

In conjunction with the NOAA Climate Analysis Center, the Division began a new research program on the relationship of clusters of upper-air circulation patterns to detailed regional precipitation and temperature records. If successful, methods developed in this program will be linked with general circulation models as part of the scenario production efforts.

2.5.2 Complex Terrain Dispersion Modeling

The Complex Terrain Dispersion Model (CTDM), with a series of user manuals, was released in January 1988 to permit its use for regulatory applications and to allow public scrutiny. The EPA will be soliciting public comment on the model and its use in FY-1989. To facilitate user understanding of this new technology, the Division developed and held a two-day training workshop in which federal, state, and local regulatory modelers discussed CTDM's technical basis and received hands-on experience with its application.

In order to establish minimum input data requirements for CTDM and to develop a screening mode for the model, the CTDM Technology Transfer Work Group (TTW) performed a series of sensitivity tests for a wide variety of meteorological and source/terrain configurations. Because of the dividing streamline height concept and the numerical modeling of three-dimensional flow distortions, the model's output concentrations were found to be particularly sensitive to wind speed, vertical potential temperature gradient, and shape and orientation of the terrain. As a result of these sensitivity studies, a matrix of meteorological inputs for CTDM was designed and will be considered by the TTW for regulatory applications in FY-1989.

Since CTDM is not applicable to unstable or convective conditions, an in-house research effort was formulated to develop algorithms for modeling source releases in these situations. A review of previous research on pollutant releases in convective layers (Briggs, 1985) describes the basis for the concepts to be used to develop the vertical and horizontal distribution functions for an enhanced CTDM. Specifically, work by Li and Briggs (1988) provided the framework for the probability distribution function (PDF) used in the vertical pollutant distribution function. The flow model in CTDM was linked with the PDF approach to adjust the particle trajectories for terrain-induced flow distortions. These algorithms are near completion and will be tested and improved in FY-1989; they will then be combined with CTDM.

A fluid modeling experiment executed in the Fluid Modeling Facility's towing tank was used to investigate the influence of terrain on the deflections in the height of the mixing layer. The hill Froude number and the ratio of the undisturbed mixing height to the hill height were found to be the controlling nondimensional parameters. Relationships between these parameters and mixing height deflections will be used to develop adjustment techniques for the expanded CTDM in FY-1989.

2.5.3 Western Mesoscale Acid Rain Model

The Rocky Mountain Acid Deposition Model Assessment project was designed to review and select currently available mesoscale meteorological and acid deposition models for incorporation into a Rocky Mountain mesoscale acid deposition modeling system. The result of this work, conducted under a contract with Systems Applications, Inc., included the final version of a user's guide (Morris *et al.,* 1988). The model handles dispersion, chemical conversion, and dry and wet deposition processes over a mesoscale complex terrain area. A workshop with the Western Acid Deposition Task Force was conducted to demonstrate how to use the model.

2.5.4 Wake Effects Studies

In-house research is being conducted to develop and apply video image analysis techniques to study smoke plumes in the wake of wind tunnel model buildings (Borek and Huber, 1988; Huber, 1988; Huber and Arya, 1988). Video image analyses are shown to be especially useful for studying the temporal-spatial plume distributions in ways not obtainable from traditional point-tracer measurements. Additional methods for analyzing video images are being evaluated through a cooperative research agreement with North Carolina State University (NCSU). A final report on the NCSU work will be prepared in FY-1989.

Although no new wind tunnel studies were conducted during FY-1988, an in-house building wakes research project to evaluate the effects of building wakes on plume dispersion is continuing. Data from previous field studies and in-house wind tunnel modeling studies are being examined.

2.5.5 United States and the People's Republic of China Joint Research

In 1984, the United States and the People's Republic of China (PRC) conducted a long-range tracer experiment in the Beijing area. SF_6 was released from the meteorological tower in Beijing after the passage of strong cold fronts. Samplers were set out in arcs approximately 40 km, 70 km, and 150 km from the tower. The Chinese provided a helicopter that was used to obtain vertical profiles of concentration. Although the planned data exchange with the Chinese was delayed until the fall of 1986, the meteorological and tracer data were analyzed and a publication is being prepared. Planning for a second joint experiment was done in China in June 1988. The United States and the PRC agreed to perform a meteorological-tracer experiment in Fuzhou, China, in November 1989.

2.5.6 Integrated Air Cancer Program

In 1985, a long-term research program was initiated to investigate the toxicity of airborne pollutants. The first phase of this program is investigating the chemical composition and mutagenicity of woodsmoke. The transport and diffusion of woodsmoke in urban areas are being studied to determine the relative effect of nearby sources on the chemical samples taken at a single site and to determine how woodsmoke diffuses.

The first field study was conducted in Boise, ID, in the winter of 1986-1987. To study woodsmoke transport and diffusion, a 30-m tower was instrumented with two sonic anemometers, two bivane anemometers, and a delta T system. During December, six tracer experiments were conducted using four different tracer gases, which were released from houses located from 100 m to 800 m from the primary site where the tower was located. The tracer data were analyzed to determine the impact on the chemical samplers of near versus distant sources. Analysis of the meteorological data indicates that dispersion of the tracer gases is due primarily to wavelike motion rather than turbulence.

As part of the Integrated Air Cancer Program, wind and stability measurements were taken on a 30-m tower in a Boise residential area. The meteorological data were taken primarily in stable drainage flows. Because spectra and autocorrelations of the data did not follow the pattern expected for daytime measurements, additional efforts were required to analyze these data in terms of filters, transforms, and averaging.

2.6 Environmental Operations Branch

The Environmental Operations Branch improves, adapts, and evaluates new and existing air quality dispersion models, makes them available for use, and assists users in applying them properly. The research work includes two major areas: model availability and evaluation, and dispersion meteorology characterization.

2.6.1 Evaluation and Assessment of UNAMAP

The User's Network for Applied Modeling of Air Pollution (UNAMAP) is a software library of air quality simulation models provided by the Meteorology Division. To facilitate the ongoing effort to improve UNAMAP's utility and availability to the public, the software library was evaluated under contract with the Information Systems Section of Battelle Memorial Institute, Columbus Division, Washington, DC (Baumann and Dehart, 1988). The study resulted in a plan for implementing a series of improvements to the UNAMAP program. The plan consists of a definition of strategy consistent with the EPA's objectives for UNAMAP, and a schedule and budget for implementing the specific recommendations.

The recommendations are based on technology and user requirements. Technology requirements determine what computer systems, data, and modeling technology are available to UNAMAP users now and what will be available in the near future. User requirements determine what areas of UNAMAP utilization are most difficult and where improvement would be most beneficial. The study's conclusions and recommendations were based on research and analysis performed in three phases. First, the technology available to UNAMAP was determined during a technology assessment. Second, data were collected (by interview and questionnaire) and analyzed. Third, recommendations were derived; each recommendation was formulated to take advantage of the current technological environment and to help meet expressed and implied user requirements. The recommendations, when taken as a whole, will allow UNAMAP to achieve the following goals:

- To function as the public source of newly-developed and refined air quality models.

- To distribute models that are easily executed on a variety of commonly-used computers of all sizes.

- To provide a wide set of models that are relatively easy to execute, even for the novice or occasional user.

- To offer modelers a central source of technical information, meteorological data, and user support.

To attain these goals, a long-range strategy and approaches are required. The first part of the implementation plan is a strategic framework designed to strike a balance between the two objectives of UNAMAP: advancing research in dispersion modeling and transferring modeling technology to the public.

As it is implemented, the strategy will first expand the users' abilities to work with the models, and then advance the modeling technology being used. The initial changes must allow UNAMAP to evolve to meet the current expectations of the modeling community. When using the regulatory models becomes less difficult, modelers will be able to turn more of their attention to the research aspects of modeling. As in the early days of UNAMAP, the user community may become more involved in the process of testing and validating new models as part of the research cycle. The strategy can be executed through the following ten recommendations:

- Establish an electronic bulletin board on a multiuser computer system.

- Provide a set of end-user documentation for each UNAMAP model.

- Provide models that execute on IBM® mainframes, DEC™ VAX™ computers, and IBM PCs and compatibles.[2]

- Improve the accuracy of models.

- Develop consistent user-friendly interfaces for all models.

- Consolidate all support for all UNAMAP models.

- Establish a meteorological data clearinghouse.

- Include more special-purpose models in UNAMAP.

2. IBM is a registered trademark of International Business Machines Corporation. DEC and VAX are trademarks of Digital Equipment Corporation.

- Support the collection and use of additional and more accurate meteorological data.
- Support the electronic distribution of UNAMAP documentation and updates.

2.6.2 Meteorological Processor for Regulatory Models (MPRM-1.1)

Guidance was issued on using meteorological data, collected during an on-site measurement program, for regulatory modeling applications (U.S. Environmental Protection Agency, 1987a). The meteorological processors currently available, however, cannot process user-collected on-site meteorological data as directed by the guidance document. Therefore, MPRM-1.1 (Irwin *et al.,* 1988) was designed to construct meteorological data files of upper-air, mixing height, surface, and on-site data for air pollution dispersion models used routinely in EPA regulatory decision making. Specifically, the processor can accommodate the following dispersion models recommended for use in the Guideline on Air Quality Models (Revised) (U.S. Environmental Protection Agency, 1986):

- Those requiring RAMMET-formatted data: BLP, RAM, ISCST, MPTER, CRSTER, and COMPLEX1.
- Those requiring STAR-formatted data: CDM (with 16 or 36 wind-direction sectors), ISCLT, and VALLEY (long-term).
- Those requiring special formats: CALINE-3 and RTDM (default).

Because the list of approved dispersion models may change and the changes may call for the use of various processing methods, the structure of MPRM-1.1 is highly modular. To avoid computer conflict problems, the processor was tested in three computer environments: a personal computer, an IBM 3090 mainframe, and a VAX minicomputer. The input structure will ultimately support use of a menu-driven data-entry system. This will allow construction of the input files through a computer-controlled question and answer session and possibly will increase the usability of the processor by a variety of users.

MPRM-1.1 can be envisioned as a three-stage processing system (Fig. 1). During the first stage, the processor extracts upper-air, mixing height, and surface data from National Climatic Data Center raw data files and on-site data from the raw data files developed from the on-site measurement program. The extracted data are processed through a series of quality assessment checks that generate reports of missing and suspect values. During the second stage, the processor combines the available data for each midnight-to-midnight 24-hour period (twice-daily upper-air soundings and mixing height data, hourly surface weather observations, and hourly on-site data) and stores these data in a combined (merged) format. During the third stage, the processor reads the merged data and develops a meteorological data file for the dispersion model selected by the user.

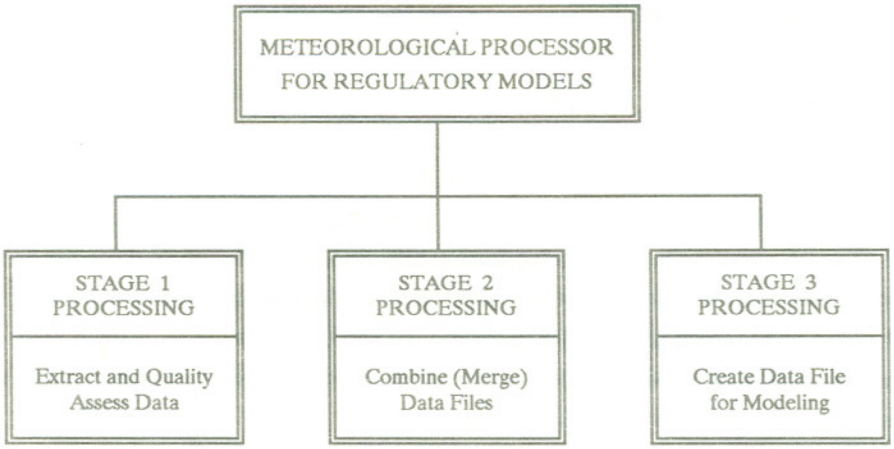

Figure 1.--Overview of processing stages within MPRM-1.1.

2.6.3 Doppler Sodar Intercomparison Experiment

The International Sodar Intercomparison Experiment (ISIE), which evaluated advances in Doppler sodar technology, was conducted in September 1988 at the Boulder Atmospheric Observatory operated by the NOAA. The ISIE had two objectives:

1. To compare such parameters as means and standard deviations of wind components and temperature structure that fall within the claimed capability of commercial Doppler sodars.

2. To test new concepts and experimental devices, phased arrays, and other parameters that can be derived from sodar measurements.

The ISIE included six three-axis Doppler systems from both commercial vendors and individual researchers in the United States, Europe, and Japan. The experiment was sponsored jointly by the NOAA and the EPA. The data are being analyzed.

2.6.4 Wind Tunnel Investigation of Sonic Anemometer Flow Distortion

The flow distortion induced by three different sonic anemometer arrays was systematically studied in a wind tunnel. Blockage effects due to the probe arrays in the tunnel were negligible. The anemometers were rotated through ±90° in the horizontal and ±15° in the vertical, at three different wind speeds. It was found that the flow distortion parameterization must be done for the entire probe assembly and that a wind tunnel is necessary to provide the controlled conditions required for obtaining an accurate response curve for each geometric configuration.

2.6.5 Evaluation of Wetness Sensors

The National Dry Deposition Network (NDDN) program needs to measure total duration of surface wetness at all the program sites. To meet this need, an evaluation examined and assessed the accuracy of the different types of wetness sensors that were currently available. The measurements for the evaluation were made in a grassy area where the vegetation varied over the measurement period from patchy with bare spots to very dense and 12 inches high. The period of investigation was from August 28 to November 19, 1987. During this period there were 31 dew events; about half had a large enough sample to ascertain the representativeness of the various wetness sensors.

The sensor accuracy in measuring the total duration of dew was determined by physically observing the onset and cessation of dew and by measuring a number of variables that would help determine the physical response of the sensors: wind speed, net infrared radiation, air temperature, surface temperature, relative humidity, temperature of the wetness sensors, total amount of dew, and observed duration of dew. The data were collected and archived on a computer.

Each wetness sensor was evaluated by examining its thermal response, time of response, sensitivity, and representativeness of measuring the total duration of dew. Studies indicate that the type of paint and substrate used for wetness sensors are critical to ensuring adequate thermal emulation of particular surfaces. This study examined these indications by comparing the temperature of the vegetated surface to that of each wetness sensor under various conditions. It also quantified the time of response for each sensor, which is the time required for condensing vapor to be detected. In addition, this study examined the sensitivity of each wetness sensor by determining the minimum amount of condensation necessary to cause each sensor to respond. All of these factors affect sensor accuracy and representativeness in measuring the total duration of condensation on the ground.

All of the moisture sensors were placed 0.3 m above the surface on a 10-ft tower; all were faced north and tilted downward. At the beginning of the experiment the vegetation was sparse with a few bare spots. During the experiment, the vegetation grew until it reached the height of the sensors.

This experiment began with five different methods of determining the total duration of dew on the ground. The premise was that

$$R_n + \mathrm{LE} + H = 0$$

where R_n is the net radiation, LE is the latent heat flux, and H is the convective heat transfer. Although H is important in determining the total amount of dew that can form at night and also influencing the evaporation stage in the early morning hours, this study showed that R_n and LE were the governing terms. One method used was to measure the difference between the dewpoint temperature (T_d) and the surface temperature (T_{sfc}); when $T_d - T_{sfc} < 0$, the water vapor is going into the liquid state onto the surface forming dew. The second method used a dew gauge to measure the total mass accumulation as a function of time. This gauge, which is a balance and is surrounded by a wind screen, consists of a 100-cm^2 dew screen connected to a long moment arm. The dew screen has a low thermal mass and is approximately 0.15 m above the ground. The dew collects on the screen and the total mass is recorded on a seven-day rotating drum chart.

The other three methods used sensors that changed resistance with condensation forming on their surfaces. The three sensors tested included a bare sensor with no latex paint, a sensor painted with a base coat of black and a top coat of gray, and a sensor painted aquamarine. These sensors consist of a circuit board with interlacing fingers of gold-plated copper. As condensation forms on their surfaces, the resistance change goes through a signal conditioner to provide a voltage output. Small droplets of water will not affect sensor resistance because they do not span across the fingers. Therefore, this type of sensor is often coated with flat latex paint to spread the water droplets. The bare sensor was used only to test the hypothesis that it was indeed necessary to paint these sensors; the hypothesis was proven valid. The gray sensor had signal conditioning that provided for a logical wet/dry, on/off signal or a high analog signal when wet. The aquamarine sensor had applied to it a 7-kHz AC signal that was then converted to a DC voltage. The signal conditioning in the aquamarine sensor, however, did not yield an adequate signal-to-noise ratio, so it was difficult to include this sensor in the comparison.

Another sensor, based on detecting changes in the sensor capacitance, was created by modifying a rain detector. The sensor capacitor is a digital metallic pattern sputtered onto the sensor plate surface with a thin layer of glass fused onto the capacitance pattern for protection from corrosion. When water collects on the sensor plate, the capacitance increases and at the threshold value the output goes from a high state to a low state.

This study showed that the thermal response of the resistance and capacitance type wetness sensors is adequate. The sensors should be as close to the top of the vegetation as possible, where maximum radiative cooling occurs. The most important features are the time of response and sensitivity. Also, this study indicated that either the modified capacitance method or the resistance method can be used by the NDDN. The duration of wetness in the current algorithm is used to change the deposition velocity of SO_2 to surrogate surfaces. The uncertainty in the absolute value of duration of wetness between the resistance method and the capacitance method is 10%. The uncertainty in the true value of the deposition of SO_2 to surrogate surfaces is much greater than 10%.

2.6.6 Dispersion of Dense Gas Releases in a Wind Tunnel

Given that exposure to toxic substances could be life-threatening or severely incapacitating, there is an urgent need to develop and validate modeling approaches relevant to the atmospheric dispersion of airborne toxic and hazardous materials. Tools for modeling releases of neutrally-buoyant nonreactive toxic chemicals in the atmosphere are already available. However, many hazardous chemicals are heavier than air and tend to hug the ground and not mix well with the ambient air. These releases may be due to evaporation of highly volatile liquids or to venting of pressurized vessels, which may be significantly affected by the buoyancy forces. The available experimental data suggest that these types of releases displace the atmospheric flow in the near field, increasing the dwell time of the cloud at any particular location.

The objectives of a report by Petersen *et al.* (1988) were to illustrate the transport and dispersion of dense gas plumes using data collected in a wind tunnel and to discuss the performance of two available dispersion models using the CO_2 and SF_6 concentration data from the wind tunnel experiments. The atmospheric dispersion models used were a state-of-the-art dense gas model and a Gaussian puff model appropriate for neutrally-buoyant releases. Although simple Gaussian models do not include the relevant physics for dense gas spread and diffusion, they may be useful in estimating ground-level centerline concentrations from a surface release.

Figure 2 compares the longitudinal concentration profiles of CO_2, SF_6, and air scaled by the source concentration. The profile shapes are quite similar. The larger differences in CO_2 and SF_6 close to the source were probably caused by the somewhat different sampling elevations with CO_2 measured at an effective elevation of 5 mm and SF_6 at ground level. If the concentrations had been scaled in the way most often used (i.e., by $\chi U/Q$, where χ is concentration, U is wind speed, and Q is emission rate), the two profiles would be spread apart even farther, by the ratio of the wind speeds, resulting in an 18% difference.

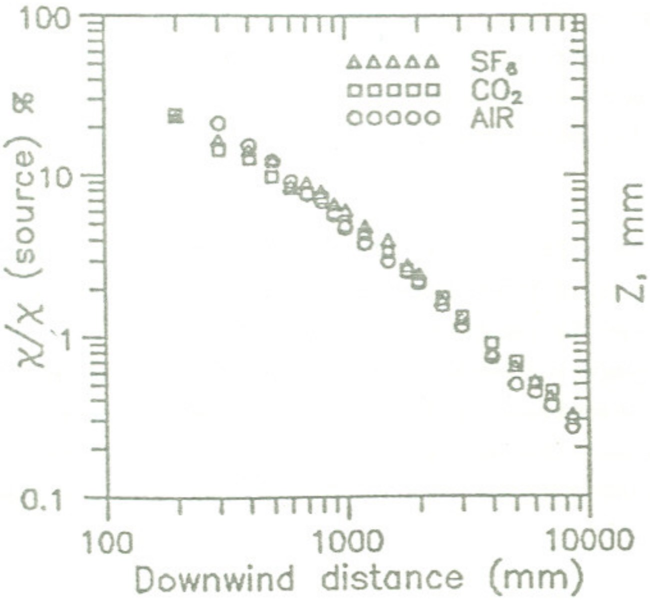

Figure 2.--Longitudinal concentration profiles of SF_6, CO_2, and air.

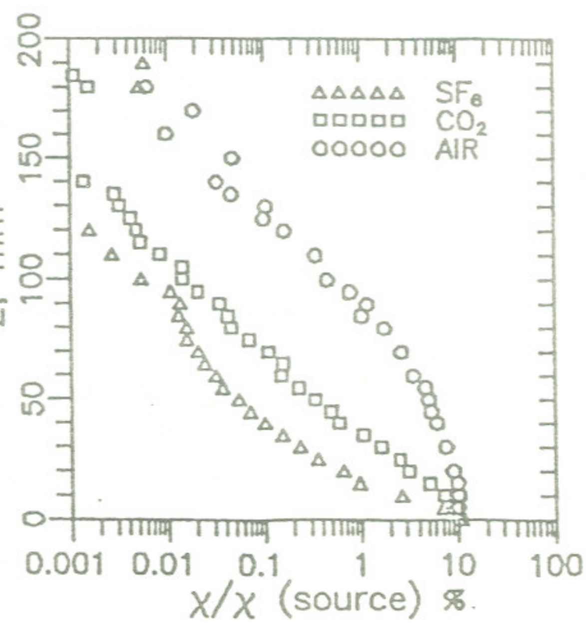

Figure 3.--Vertical concentration profiles of SF_6, CO_2, and air, at $x = 600$ mm.

Figure 3 compares the vertical concentration profiles of CO_2, SF_6, and air, at $x = 600$ mm, where x is downwind distance. In spite of the different wind speeds and very different densities and vertical distributions, the surface concentrations are essentially identical. The greater density of the SF_6 is clearly significant, however, as the shapes of the vertical distributions are qualitatively different for the three gases. The distributions can be fitted with exponentials of the form $\chi/\chi_{max} = \exp(-Az^n)$, where χ_{max} is maximum concentration and z is height. For the neutrally-buoyant plume, $n = 1.5$; for the CO_2 plume, $n = 1$; and in the outer portions of the SF_6 plume, $n \approx 0.6$.

Figure 4 shows the lateral concentration profiles of SF_6, CO_2, and air, again at $x = 600$ mm. The SF_6 plume was much wider than the CO_2 plume. Two lateral profiles for SF_6 are displayed, one with an effective sampling height at 5 mm and the other at 0 mm. The 0-mm profile shows much less scatter and up to a factor of two larger concentrations than the 5-mm values. These differences were clearly due to the extremely steep concentration gradients close to the surface and near the source. Farther downstream, the vertical gradients approached zero, so that the differences in these two profiles also approached zero. The repeatability of the measurements was excellent. In the two independently measured lateral profiles not shown (both at $z = 5$ mm), the "scatter" in the sense of measurement reproducibility is generally within 2%. Clearly, the scatter was related to the difficulty of precisely positioning a measurement probe above a rough surface.

The two models evaluated against the measured CO_2 and SF_6 concentrations were INPUFF and DEGADIS. INPUFF is a Gaussian integrated puff model that uses a series of puffs to simulate a continuous plume. The dispersion coefficients used in the model are those from the P-G scheme (Turner, 1970). DEGADIS is a dense-cloud model developed for the United States Coast Guard that treats the dispersion of the cloud in three distinct regimes: negative buoyancy dominated dispersion in the near field, stably stratified shear flow in the intermediate field, and passive turbulent dispersion in the far field. The near field buoyancy dominated dispersion is modeled through gravity spreading of the dense cloud and entrainment of the ambient air into the cloud using an entrainment velocity. The downwind dispersion phase is modeled by assuming a power law concentration distribution in the vertical direction, a modified Gaussian profile with a central homogeneous section in the horizontal direction, and a power law for the vertical wind profile.

Model runs were performed assuming a scale ratio of 1:100, e.g., 500 mm in the wind tunnel equated to 50 m real scale. This scaling provided simulations appropriate for the wind speeds of interest for this experiment. The relevant dimensionless groups for modeling a steady release are U^2/gL, and q_o/UL^2, where U, g, q_o, and L are the wind speed at the top of the boundary layer, the acceleration due to gravity, the emission rate, and the height of the boundary layer, respectively. To model at full scale, these dimensionless ratios must remain the same as those in the wind tunnel. The wind speeds were computed and extrapolated to a 10-m height assuming a wind profile exponent of 0.15, which is appropriate for neutral atmospheric conditions. The wind speeds used in the model runs for CO_2 and SF_6 were 6.7 m/s and 7.9 m/s, respectively. The emission rates used were 91.5 kg/s for CO_2 and 303.7 kg/s for SF_6.

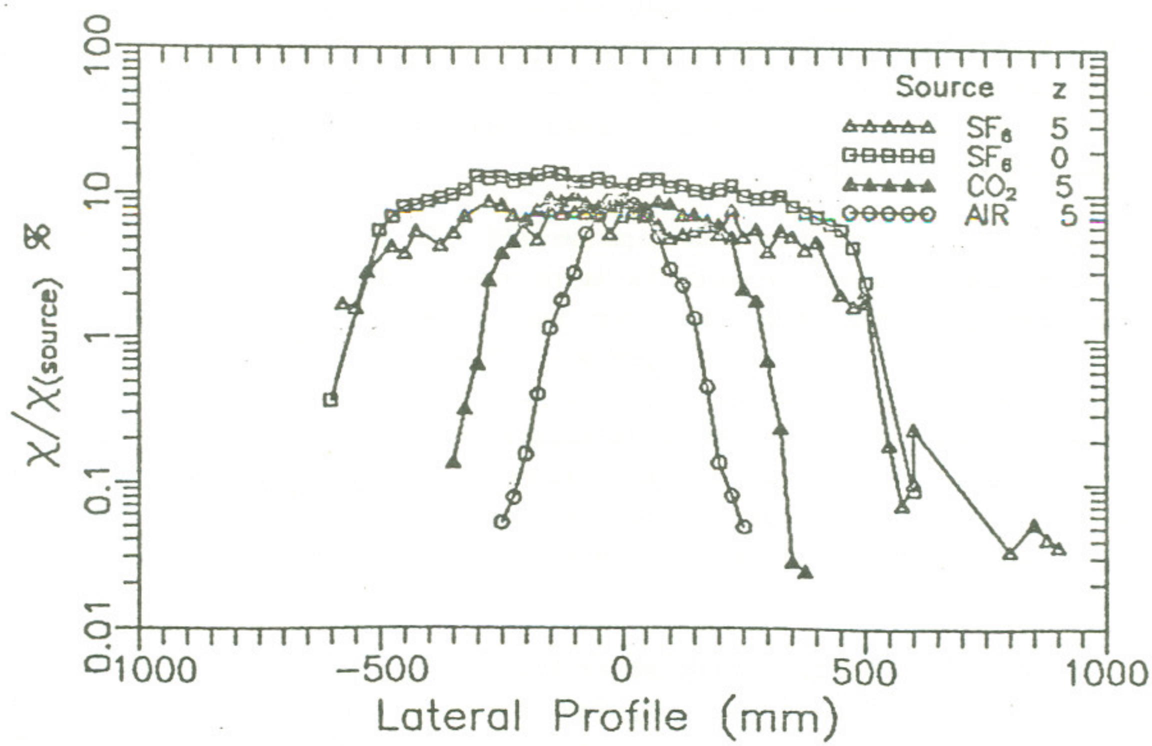

Figure 4.--Lateral concentration profiles of SF_6, CO_2, and air, at x = 600 mm.

Predicted centerline concentrations of SF_6 and CO_2 as functions of downwind distance from the source showed that INPUFF underestimated downwind concentrations for both SF_6 and CO_2 by about the same amount. DEGADIS simulated CO_2 dispersion well, but performed about the same as INPUFF for SF_6.

The vertical profiles for the observed and predicted concentrations by DEGADIS and INPUFF at 60 m and 500 m downwind showed that DEGADIS was in agreement with the observations, while INPUFF underestimated the ground level concentrations and significantly overestimated concentrations aloft. In general, vertical profiles predicted by DEGADIS improved with downwind distance for both CO_2 and SF_6. These results suggest that the assumption of a Gaussian distribution for vertical plume spread in such a passive gas model as INPUFF does not describe properly the vertical dispersion process for heavier-than-air gases.

Horizontal crosswind profiles for the observed and predicted concentrations at 60 m and 500 m downwind showed that the measured CO_2 concentrations close to the source displayed a wider top hat shape with sharper edges than those predicted by DEGADIS and INPUFF. However, DEGADIS provided a good characterization of lateral spread in the near field for SF_6. The INPUFF SF_6 plumes were narrower than those observed and the centerline concentrations were somewhat lower than their corresponding observed values. The reasonable agreement of the surface centerline concentrations was probably due to the model's enhanced vertical diffusion. At downwind distances beyond 250 m, crosswind profiles of predicted and observed CO_2 concentrations agreed well, indicating that the profiles were near Gaussian in shape and dispersing as a passive release. The near Gaussian shape in the crosswind profiles of SF_6 was not observed until the plume had traveled 850 m.

The results indicated that DEGADIS predicted CO_2 concentrations reasonably well but underestimated the SF_6 concentrations at greater downwind distances. This suggests that DEGADIS needs improvement for the treatment of plume lateral spread due to gravity effects. INPUFF overpredicted plume height and underpredicted plume width and the combination of these effects resulted in an underestimation of the surface centerline concentrations. The narrow plume estimated by INPUFF also led to erroneous predictions of off-centerline concentration values.

2.7 Air Policy Support Branch

The Air Policy Support Branch supports activities of the EPA Office of Air Quality Planning and Standards (OAQPS). The Branch's general responsibilities include (1) evaluating, modifying, and improving atmospheric dispersion and related models to ensure adequacy, appropriateness, and consistency with established scientific principles and Agency policy; (2) preparing guidance on applying and evaluating models and simulation techniques that are used to assess, develop, or revise national, regional, and local air pollution control strategies for attainment and maintenance of ambient air quality standards; and (3) providing meteorological assistance and consultation to support OAQPS's broad responsibilities for developing and enforcing Federal regulations and standards and assisting the EPA Regional Offices.

2.7.1 Modeling Studies

2.7.1.1 Regional Ozone Modeling for Northeast Transport (ROMNET)

During FY-1988, efforts continued on a three-year program to quantify ozone and precursor transport in the northeastern United States using the Regional Oxidant Model (ROM). This program is designed to (1) provide air pollution control agencies in the Northeast with information on ozone and precursor transport between urban areas; (2) assess the impact of regional emission controls on ozone concentrations and interurban transport; and (3) provide guidance to States for incorporating ozone and precursor transport in future State Implementation Plan (SIP) development activities. In October 1987, there was a presentation of the project and modeling scenarios at a workshop in Bamberg, Germany. In May 1988, a paper that discussed using ROM to evaluate control strategies was presented at the 3rd US-Dutch International Symposium in The Netherlands.

Three committees were established in FY-1988 to oversee the technical aspects of the ROMNET program and the committees developed a program implementation plan. Division meteorologists serve as ROMNET Technical Coordinator and as chairmen of the Strategy and Modeling Committees. The FY-1988 technical accomplishments of the three committees follow.

The Strategy Committee identified six general categories of regional emission control strategies to be used with ROM: applying maximum control technology; applying an alternate control technology in which controls on selected source categories are relaxed with respect to maximum existing control technology; applying across-the-board reductions beyond maximum existing control technology; spatially varying the control levels within the Northeast Corridor; varying control levels outside the Northeast Corridor; and placing highest priority controls on source categories emitting the most reactive volatile organic compounds (VOC). Individual strategies within each category include VOC or VOC and NO_x controls.

The Modeling Committee identified three priority ozone episodes to be used in ROM simulations: July 12-23, 1980; June 9-20, 1983; and June 4-13, 1984. The choice of episodes was based on analysis of surface ozone observations and characterization of meteorological flow conditions. Twenty-one episodes from 1983 through 1987 plus two 1980 episodes were analyzed using objective procedures developed by the Committee.

The Emissions Committee agreed on a series of tasks for revising and updating the 1985 National Acid Precipitation Assessment Program (NAPAP) emission inventory that will be used in ROM simulations. The tasks include identifying procedures for adjusting mobile source and temperature-sensitive stationary source emissions to reflect actual temperatures occurring during the simulated ozone episodes; developing methods for estimating the increase in mobile source emissions speciated as evaporative emissions due to running losses and excess evaporative emissions; developing estimates on rule effectiveness, i.e., the percentage of the emission reduction actually expected to be achieved, for existing VOC area source emissions; and identifying estimates of future growth rates.

2.7.1.2 Regional Ozone Impact Analysis

Treatment, storage, and disposal facility (TSDF) analyses. During FY-1988, a report was prepared under contract (PEI Associates, Inc., 1988a) that describes the application of two regional-scale oxidant models, ROM and RTM3, to quantify the impact of VOC emissions from hazardous waste TSDFs on short-term peak ozone concentrations. ROM was applied for the northeastern and southeastern United States modeling domains. Results from the modeling analyses were used to estimate the costs and benefits of TSDF source controls for agricultural yields and human health.

The models were applied using emission and meteorological data for two high ozone episodes that occurred during 1980. Approximately 30 days were simulated, and the simulation included two TSDF emission scenarios. One assumed no control on TSDF VOC emissions, while the other assumed 100% TSDF emission control, i.e., zero VOC emissions. Model results for the two scenarios were compared to determine the reduction in daily maximum hourly peak ozone concentrations attributable to 100% TSDF emission control. Predicted percentage reductions ranged from 2% to 10% in isolated areas within the modeling domain, primarily areas near large TSDF sources. In most locations, there was no discernable difference in predicted peak concentrations. The major exceptions to these small changes in predicted peak ozone occurred in two areas of the Gulf of Mexico, south of Houston, TX, and south of Louisiana, where 50% reductions were predicted.

The report noted three important factors to consider when interpreting regional-scale modeling results demonstrating ozone reduction potential due to TSDF controls: the spatial dimensions used in the modeling may not allow evaluation of the impact of individual TSDF sources on peak ozone concentrations on a smaller spatial scale than used in the modeling; the small percentage of TSDF VOC emissions relative to total VOC emissions and the assumption that controls on other VOC source categories do not occur prior to applying TSDF controls may lead to minimal impact on regional ozone; and the uncertainties or changes in the VOC emission inventories may cause the VOC percentage reductions resulting from TSDF controls to be underestimated.

Regional ozone control strategies. During FY-1988, ROM was used to examine the effects of selected emission control strategies on ozone levels; eight strategies were simulated in the Northeast and three in the Southeast. These analyses were conducted to address ozone policy issues and for use in the ozone Regulatory Impact Analysis (RIA) that is part of the periodic review of the ozone National Ambient Air Quality Standard. Several of the scenarios were also analyzed at the request of the Vice President's Task Force on Clean Coal Technology, and the task force was briefed on the results in March 1988.

Three 1980 high-ozone episodes were simulated for each region. The results were extrapolated to a seasonal time period, April through October, for use in the RIA to assess the control impacts on mean ozone concentrations. The strategies examined included VOC emission controls only, NO_x controls only, and several combinations of VOC and NO_x controls. The results showed that NO_x emission controls alone could be counterproductive, resulting in increased ozone levels close to the major source areas, with slight localized reductions in rural areas. Controls on VOC emissions alone produced appreciable downwind areas impacted by urban plumes. However, widespread declines of ozone in rural areas and enhanced reductions in urban plumes were achieved with the combined regional VOC and NO_x control scenarios. The Administrator of the Environmental Protection Agency was briefed on these results in April 1988.

2.7.2 Modeling Guidance

2.7.2.1 Guideline on Air Quality Models (Revised)

The regulatory process to further revise the modeling guideline document (U.S. Environmental Protection Agency, 1986) resulted in the publication of Supplement A to the guideline (U.S. Environmental Protection Agency, 1987b) and its promulgation in the *Federal Register* on January 6, 1988. This was preceded by a public comment period and preparation of a response-to-comments document concerning the four proposed models in FY-1987. Supplement A lists page changes to the text of the guideline and adds the four models to it: the Rough Terrain Diffusion Model (RTDM) (Paine and Egan, 1987), which is proposed as a third-level screening technique for complex terrain applications; the Offshore Coastal Dispersion (OCD) model (Hanna *et al.,* 1984); the revised Industrial Source Complex (ISC) model, which includes an improved building downwash algorithm; and the AVACTA II model (Zannetti *et al.,* 1985).

Before Supplement A was published, it was apparent that additional models and new techniques were available that should be considered for inclusion in the modeling guideline. In March 1988, another regulatory action was initiated to revise the guideline again, and a work group was established to oversee the project. Two Division meteorologists are members of the work group. The decision was made to use the Conference on Air Quality Modeling required by the Clean Air Act as a public forum to present and discuss these new models and techniques.

2.7.2.2 Fourth Conference on Air Quality Modeling

Section 320 of the Clean Air Act requires that a conference on air quality modeling be held every three years. Since the third conference was held in January 1985, the EPA announced in the *Federal Register* of August 23, 1988, that the fourth conference would be held October 12-13, 1988, in Washington, DC. The purpose of this conference is to advise the public on new modeling techniques and to solicit their comments to guide consideration of any rulemaking needed to further revise the modeling guideline.

2.7.2.3 Model Clearinghouse

The FY-1988 activities for the Model Clearinghouse included the following:

1. Responding to the EPA Regional Office requests for review of nonguideline models proposed for use.

2. Reviewing draft and formally submitted *Federal Register* actions.

3. Documenting Clearinghouse decisions and discussions.

4. Summarizing Clearinghouse activities at various meetings.

5. Issuing an internal summary report of FY-1987 activities.

6. Developing a revised operational plan reflecting the expansion of the Clearinghouse scope of activities to include all criteria pollutants.

There were 126 modeling referrals to the Model Clearinghouse from the Regional Offices during FY-1988. Also, the Clearinghouse was expanded to cover all criteria pollutants, including O_3 and NO_2, and five additional employees who serve in various capacities were added. A revised Model Clearinghouse operations plan was issued to reflect these changes.

In FY-1988, the Clearinghouse conducted or participated in coordination and information exchange activities with the Regional Offices. In October 1987, a Clearinghouse report was prepared and distributed to the Regional Offices; the report informed Clearinghouse users about issues and responses that occurred in FY-1987. In May 1988, the issues and responses during the first half of the fiscal year were discussed at the annual EPA Regional/State Modelers Workshop.

The Clearinghouse continued its policy of sending copies of its written responses and incoming requests to all the Regional Offices, keeping them informed of decisions affecting their modeling activities. Also during FY-1988, the Clearinghouse began attaching to each response an updated list of all Clearinghouse memoranda issued during the fiscal year to help the Regional Offices maintain complete records.

The Model Clearinghouse has a policy whereby an advance opinion is sought from the Regional Offices on particularly sensitive issues with national implications. In FY-1988, four such cases arose. The proposed Clearinghouse responses were either provided to the Regions for comment or were discussed in some detail at the 1988 Regional/State Modelers Workshop before the responses were made final.

2.7.2.4 Revised Screening Procedures Document for Regulatory Modeling and the SCREEN Model

The revised screening procedures document (Brode, 1988) presents guidance for using screening procedures to estimate the air quality impact of stationary sources and updates the guidance in effect since 1977. In addition, the SCREEN model was developed for use on a personal computer to provide estimates based on the revised screening procedures. The document should be printed and distributed early in FY-1989. The SCREEN model is available on diskette as part of the revised procedures publication. The document and model include screening procedures for simple point sources in flat terrain, as well as procedures for such special situations as building downwash, fumigation, simple elevated and complex terrain, flare releases, and simple area sources. The document was placed in the rulemaking docket for the Fourth Conference on Air Quality Modeling. Public comments will be solicited on the technical validity of these screening techniques.

2.7.2.5 Revised Plume Visibility Impact Assessment Techniques

The techniques for evaluating visibility impairment traceable to a single source or small group of sources needed to be updated and improved to reflect recent scientific developments in visibility modeling. Through an interagency agreement with the National Park Service, meteorologists at both agencies joined resources to develop VISCREEN (U.S. Environmental Protection Agency, 1988), a personal computer model that implements these methods. VISCREEN can evaluate plume visual effects along multiple lines of sight across the plume's length for two different viewing backgrounds and two different viewing angles, and it can evaluate the potential perceptibility of plumes using psychophysical concepts. The workbook contains several example applications illustrating the use of these methods. Public comment will be solicited on the technical validity of the techniques and on whether to adopt the workbook for regulatory applications.

2.7.2.6 Shoreline Dispersion Model

Unique meteorological conditions occur near the shorelines of all large bodies of water. A plume emitted from a tall stack into a stable marine layer travels with little dispersion. Upon entering the thermal internal boundary layer at some distance inland, however, this plume fumigates downward and creates high ground-level concentrations. In FY-1988, a shoreline dispersion model was completed that consists of two separate dispersion algorithms based on the Misra method (Misra, 1980) and on the air quality model MPTER. The details of the shoreline dispersion model are described in a report (PEI Associates, Inc., 1988b) that should be printed and distributed early in FY-1989. Public comment will be solicited on whether to adopt this model as a preferred technique for regulatory applications involving tall stacks located on coastlines.

2.7.2.7 Air Toxics Modeling Workbook

In modeling the ambient impact of air toxic pollutant releases, a reasonable degree of assurance is needed that, from a meteorological perspective, the maximum short-term ground-level concentration estimate is obtained. Primarily to foster the use of a consistent meteorological approach to determine ambient impact, a workbook (TRC Environmental Consultants, Inc., 1988) was developed under contract. The workbook is built around a series of 18 scenarios considered typical of the means by which toxic pollutants become airborne. For each scenario, the workbook helps the user determine release and emission rates and then guides the user through all the steps required for making an atmospheric dispersion screening estimate. An example application of the emission and associated dispersion estimation methods for each release scenario is provided. Selective use of the methods section of the workbook allows extending the applications to scenarios not specifically represented. This publication has proved to be valuable to many users, and plans are underway to develop an expert system that implements the methods described in the workbook.

2.7.3 Additional Support Activities

2.7.3.1 Air Toxics Modeling Workshops

The EPA developed and presented a series of three week-long air toxics modeling workshops in Boston, MA, Kansas City, MO, and San Francisco, CA, with over 80 State and local modelers attending. Division staff members served as project officers for the effort, coordinated the activities of the EPA Regional Offices involved, and presented workshop sessions. The workshops featured a combination of lectures, demonstrations of air toxics models, and hands-on PC modeling exercises. Each class was divided into teams to run a series of problems using at least six air toxics models. Several other Federal agencies and commercial model vendors demonstrated their products, including the NOAA ALOHA model, by applying them to the class exercise problems. In addition, the workshops served as a good mechanism for obtaining user reaction and comment on the draft workbook of screening techniques for assessing the impacts of air toxics (TRC Environmental Consultants, Inc., 1988).

2.7.3.2 Regional/State Modelers Workshop

The annual Regional/State Modelers Workshop was held May 17-20, 1988, in Boston, MA. Major workshop topics included the status of regulatory model codes, draft technical documents, and future needs; the upcoming Fourth Conference on Air Quality Modeling; Model Clearinghouse activities; work group reports on CTDM, VOC point source modeling, CO intersection modeling, valley stagnation, and on-site meteorological data; and Division modeling activities. Each State and Regional Office presented modeling highlights and issues of concern. The 1989 workshop will be held in Region X in Seattle, WA.

2.7.3.3 Regulatory Work Groups

Meteorologists provide important technical assistance and consultation by participating in various regulatory work groups and task forces. As experts on models, databases, and interpretation of results, staff members help generate sound technical positions and options on key issues facing policymakers. In FY-1988, Division meteorologists served on the Work Group to Revise the Modeling Guideline; the Technology Transfer Work Group; the Visibility SIP Work Group; the On-Site Meteorological Data Work Group (Chairman); the Valley Stagnation Work Group; the Stack Height Remand Task Force; the NO_2 PSD Increment Work Group; the Open Burning/Open Detonation Technical Steering Committee; the Integrated Sulfur Strategy Work Group; and the PM_{10} Monitoring Task Force.

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Wesely, M.L. Improved parameterizations for surface dry deposition to gaseous dry deposition in regional-scale, numerical models. EPA/600/3-88/025 (PB88-225099), Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 50 pp. (1988).

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APPENDIX B-1: PRESENTATIONS

Bliss, D.B. (Duke University). Late wakes in a stratified fluid and the pancake vortex. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, July 13, 1988.

Briggs, G.A. Buoyant plumes among the thermals and future modeling challenges. Lecture presented at the Fluid Modeling Facility, Research Triangle Park, NC, March 30, 1988.

Briggs, G.A. The versatile convective tank. Lecture presented at the Fluid Modeling Facility, Research Triangle Park, NC, March 23, 1988.

Briggs, G.A. Into the 80's: Stirring up more evidence. Lecture presented at the Fluid Modeling Facility, Research Triangle Park, NC, March 16, 1988.

Briggs, G.A. CBL revelation of the 70's: Bottom heating a controversy. Lecture presented at the Fluid Modeling Facility, Research Triangle Park, NC, March 9, 1988.

Brown, M.J. (North Carolina State University). Vertical diffusion from surface and elevated releases. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, February 3, 1988.

Castro, I. (University of Surrey, England). Turbulence structure in separated flows. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, September 7, 1988.

Clark, T.L. Overviews of the International Sulfur Deposition Model Evaluation (ISDME), the ANATEX Model Evaluation Study (AMES), and the presentation of EPA spatial analyses of sulfur dry deposition. National Acid Precipitation Assessment Program Peer Review, Richmond, VA, May 1-6, 1988.

Clark, T.L. Suggested protocol for evaluating long-range transport and diffusion models using the Across North America Tracer Experiment (ANATEX) data. Presentation at the ANATEX Model Evaluation Workshop, Orlando, FL, October 20-21, 1987.

Clarke, J.F. Acid deposition: A science update. Presentation at the University of Alabama at Huntsville, AL, July 25, 1988.

Clarke, J.F. Status of ORD modeling activities at the Atmospheric Sciences Research Laboratory. EPA Standing Air Simulation Working Group, Hall of the States, Washington, DC, May 13, 1988.

Dennis, R.L. Task Group III presentation at the Office of Management and Budget hearing on the National Acid Precipitation Assessment Program, Washington, DC, September 30, 1988.

Dicke, J.L. Considerations in developing and promulgating EPA guidelines for air toxics modeling assessments. Presentation at the U.S. Environmental Protection Agency Modeling Workshop for Toxic Air Contaminants, Boston, MA, April 15, 1988.

Dicke, J.L. Air toxics modeling activities in OAQPS. Presentation at the Region III/State Modelers Workshop, Virginia Beach, VA, October 8, 1987.

Doll, D.C. Regional-scale photochemical oxidant modeling in the eastern United States. Presentation at the OECD Workshop on Emission Reduction Scenarios and Application of Long-Range Transport Models, Bamberg, Federal Republic of Germany, October 14, 1987.

Hunt, J.C.R. (Cambridge University, England). Simulating turbulence and diffusion and possible developments in regulatory dispersion modeling. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, June 20, 1988.

Ide, Y. (Mitsubishi Heavy Industries, Japan). Simulation of wind direction fluctuations in the wind tunnel. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, October 1, 1987.

Jindal, M. (North Carolina State University). A wind-tunnel study of dispersion of dense gas released on sloping terrain. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, August 31, 1988.

Jindal, M. (North Carolina State University). Dispersion of dense gas on sloping terrain. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, February 10, 1988.

Kumar, A. (North Carolina State University). Flushing of heavy gas from a valley by elevated cross winds. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, September 29, 1988.

Lee, J.T. (Los Alamos National Laboratory). Video techniques for the study of flow and dispersion around buildings. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, November 6, 1987.

Long, R. (The Johns Hopkins University). Stratified Flow. Film fest presented at the Fluid Modeling Facility, Research Triangle Park, NC, July 28, 1988.

Mizumoto, N. (IH Heavy Industries, Japan). Plume spread in wind tunnel and numerical simulation in complex terrain. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, May 23, 1988.

Possiel, N.C. The ROMNET study protocol. Presentation at the Northeast States Transport Advisory Group, Newark, NJ, September 7, 1988.

Possiel, N.C. Effects of VOC and NO_x control strategies on regional concentrations. Briefing for Administrator, Headquarters, U.S. Environmental Protection Agency, Washington, DC, April 11, 1988.

Possiel, N.C. Potential impact of utility NO_x controls on ozone levels in the Northeast. Briefing for the Vice Presidential Task Force on Clean Coal Technology, Executive Office Building, Washington, DC, March 17, 1988.

Possiel, N.C., J.A. Tikvart, J.H. Novak, K.L. Schere, and E.L. Meyer. Evaluation of ozone control strategies in the northeastern region of the United States. Presentation at the 3rd US-Dutch International Symposium on Atmospheric Ozone Research and Its Policy Implications, Nijmegen, The Netherlands, May 9-13, 1988.

Roller, J.G. (North Carolina State University). Video image analysis of simple particle motion. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, January 27, 1988.

Rottman, J.W. (North Carolina State University). Atmospheric bores. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, December 18, 1987.

Rottman, J.W. (North Carolina State University). Severe downslope winds. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, December 11, 1987.

Rottman, J.W. (North Carolina State University). Shallow water theory for stratified flow over topography. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, December 4, 1987.

Schere, K.L. NO_x emission strategies (1-Ohio Valley point source controls) performed with ROM2. Briefing to Director, Office of Air Quality Planning and Standards, Research Triangle Park, NC, February 4, 1988.

Schere, K.L., and F.A. Schiermeier. Effect on ozone concentration levels of Regional Oxidant Model simulations of VOC and NO_x control strategies. Presentation to Administrator, Headquarters, U.S. Environmental Protection Agency, Washington, DC, April 13, 1988.

Schere, K.L., and R.A. Wayland. Development and evaluation of the Regional Oxidant Model for the northeastern United States. Presentation at the 3rd US-Dutch International Symposium on Atmospheric Ozone Research and Its Policy Implications, Nijmegen, The Netherlands, May 9-13, 1988.

Schiermeier, F.A. Risk assessment and uncertainty analysis for toxics modeling. Presentation to the AMS Steering Committee on Scientific Assessment of Air Quality Models, Brookings Institute, Washington, DC, July 26, 1988.

Schiermeier, F.A. Development and application of the EPA Complex Terrain Dispersion Model (CTDM). Presentation at US/USSR Working Group 02.01-10 Meeting on Air Pollution Modeling, Instrumentation, and Measurement Methodology, Main Geophysical Observatory, Leningrad, USSR, May 25, 1988.

Schiermeier, F.A. Recent developments in US/USSR environmental cooperation under the Joint Committee on Environmental Protection. Interview on Vilnius radio station, Vilnius, Lithuania, USSR, May 23, 1988.

Schiermeier, F.A. Role of the Meteorology Division in air pollution dispersion model development, evaluation, and application. Presentation to the Central North Carolina Chapter, American Meteorological Society, Research Triangle Park, NC, April 21, 1988.

Schiermeier, F.A. Overview of Meteorology Division research programs. Presentation at the Tenth Joint Meeting of United States/Japan Air Pollution Meteorology Panel, Research Triangle Park, NC, March 23, 1988.

Schiermeier, F.A. Potential incorporation of remote-sensing capabilities into the EPA acid deposition field study. Presentation to Soviet delegation from the USSR Institute of Atmospheric Optics and the University of Tomsk Laser Optics Laboratory, Research Triangle Park, NC, October 5, 1987.

Snyder, W.H. Fluid modeling research in complex terrain. Seminar presented at Los Alamos National Laboratory, Los Alamos, NM, April 25, 1988.

White, B. (University of California at Davis). Usage of boundary-layer wind tunnels to study extraterrestrial phenomena and special topics (dense gases). Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, March 3, 1988.

Willis, G.E., and J.W. Deardorf (Oregon State University). Convective Tank Experiments. Film fest presented at the Fluid Modeling Facility, Research Triangle Park, NC, July 28, 1988.

APPENDIX B-2: WORKSHOPS

Across North America Tracer Experiment (ANATEX) Model Evaluation Study Workshop, Orlando, FL, October 20-21, 1987.

T.L. Clark

Model Evaluation Field Study Programs, Program Management Group (PMG), Chicago, IL, November 12-13, 1987.

J.K.S. Ching

EPA Advisory Group on Aircraft Measurement (AGAM), Research Triangle Park, NC, January 11-13, 1988.

J.K.S. Ching

RADM Aggregation Workshop, Ann Arbor, MI, January 25-28, 1988.

J.F. Clarke
R.L. Dennis

Meeting to coordinate experiments in the First Intensive Field Study, Toronto, Ontario, Canada, February 3-4, 1988.

J.K.S. Ching

Model Evaluation Field Study Programs, Program Management Group (PMG), Research Triangle Park, NC, February 5, 1988.

J.K.S. Ching

EPA Advisory Group on Aircraft Measurement (AGAM), Research Triangle Park, NC, February 17-19, 1988.

J.K.S. Ching

Long-Range Planning Workshop, Office of Air Quality Planning and Standards, Burlington, NC, March 9-10, 1988.

J.L. Dicke

Tenth Joint Meeting of the United States/Japan Air Pollution Meteorology Panel, Washington, DC, and Research Triangle Park, NC, March 21-24, 1988.

J.F. Clarke
J.M. Godowitch
S.G. Perry
K.L. Schere
F.A. Schiermeier

National Air Toxics Modeling Workshop, U.S. Environmental Protection Agency, Boston, MA, April 11-15, 1988.

J.L. Dicke
W.B. Petersen

Meeting to coordinate experiments in the First Intensive Field Study, Toronto, Ontario, Canada, April 12-14, 1988.

J.K.S. Ching

Model Evaluation Field Study Programs, Program Management Group (PMG), Toronto, Ontario, Canada, April 15, 1988.

J.K.S. Ching

National Acid Precipitation Assessment Program Peer Review of the ACID-MODES Field Study, Richmond, VA, May 1-6, 1988.

J.K.S. Ching

Workshop on the technical basis and use of the EPA Complex Terrain Dispersion Model, Research Triangle Park, NC, May 3-4, 1988.

S.G. Perry

Regional/State Modelers Workshop, U.S. Environmental Protection Agency, Boston, MA, May 17-20, 1988.

R.W. Brode
J.S. Touma
D.A. Wilson

Joint US/USSR Working Group 02.01-10 Meeting on Air Pollution Modeling, Instrumentation, and Measurement Methodology, Leningrad and Vilnius, Lithuania, USSR, May 23-27, 1988.

F.S. Binkowski
F.A. Schiermeier

U.S. Army Open Burning/Open Detonation Program Steering Committee Workshop, Salt Lake City, UT, July 6-8, 1988.

J.L. Dicke

Regional Office Annual Workshop, U.S. Environmental Protection Agency, Southern Pines, NC, July 19-21, 1988.

J.L. Dicke
D.C. Doll
N.C. Possiel
J. S. Touma

Workshop on Measures and Interpretation for Regional Model Evaluation, Research Triangle Park, NC, August 19, 1988.

R.L. Dennis

Workshop on the Great Lakes Regional Ozone Problem, Environmental Monitoring Systems Laboratory, Las Vegas, NV, August 22-24, 1988.

J.K.S. Ching

NOAA Peer Review of ARL/ATDD Emergency Preparedness/Response to Accidental Releases from DOE Uranium Processing Plants, Oak Ridge, TN, August 24-26, 1988.

F.A. Schiermeier

APPENDIX C: VISITING SCIENTISTS

1. I.P. Castro, Lecturer
   Department of Mechanical Engineering
   University of Surrey
   Guildford, Surrey, ENGLAND

   Spent two months at the Fluid Modeling Facility under a cooperative agreement with North Carolina State University completing towing-tank studies dealing with upstream columnar modes, drag, and unsteadiness in laboratory modeling. Initiated a project to investigate vortex shedding on the lee side of hills in strongly-stratified flows.

2. J.T. Lee, Research Scientist
   Atmospheric Sciences Group
   Los Alamos National Laboratory
   Los Alamos, NM

   Spent one month at the Fluid Modeling Facility performing wind tunnel studies to confirm the relation between video-image intensity and vertically-integrated concentration. After establishing the calibration procedure, the vertically-integrated concentration pattern in the lee of several building configurations was examined. Both building geometry and source location were varied during the experiments.

3. L. Robertson and L. Wern
   Climate Section
   Swedish Meteorological and Hydrological Institute
   Norrkoping, SWEDEN

   Spent one week visiting members of the Division. Principal interest was modeling air quality in the vicinity of airports.

4. J.W. Rottman, Senior Research Associate
   Department of Marine, Earth and Atmospheric Sciences
   North Carolina State University
   Raleigh, NC

   Spent seven months at the Fluid Modeling Facility under a cooperative agreement with North Carolina State University refining and documenting a numerical model for the determination of flow around complex terrain. In addition, theoretical and experimental investigations were performed to determine the conditions leading to the formation of severe downslope winds on the lee sides of mountains.

APPENDIX D: METEOROLOGY DIVISION STAFF
FISCAL YEAR 1988

All personnel are assigned to the U.S. Environmental Protection Agency from the National Oceanic and Atmospheric Administration, except those designated (EPA) = Environmental Protection Agency employees or (PHS) = Public Health Service Commissioned Corps personnel.

Office of the Director

Francis A. Schiermeier, Meteorologist, Director
Herbert Viebrock, Meteorologist, Assistant to the Director
Marc Pitchford, Meteorologist (Las Vegas, NV)
Evelyn M. Poole-Kober, Technical Information Clerk
Joan Emory, Secretary

Atmospheric Modeling Branch

Dr. John F. Clarke, Meteorologist, Chief
Dr. Francis Binkowski, Meteorologist
Dr. Gary Briggs, Meteorologist
Terry Clark, Meteorologist
Dr. Jason Ching, Meteorologist
Dr. Robin Dennis, Physical Scientist
Brian Eder, Meteorologist
James Godowitch, Meteorologist
Dr. Robert Lamb, Meteorologist (until January 1988)
Kenneth Schere, Meteorologist
Alvinia Boyd, Secretary

Fluid Modeling Branch

Dr. William H. Snyder, Physical Scientist, Chief
Joseph Aquino, Engineering Aid
Lewis Knight, Electronics Technician
Robert Lawson, Physical Scientist
Ralph Soller, Mechanical Engineering Technician
Roger Thompson (PHS), Environmental Engineer
Anna Cook, Secretary

Data Management Branch

Joan H. Novak, Computer Systems Analyst, Chief
William Amos (EPA), Computer Programmer
O. Russell Bullock, Jr., Computer Systems Analyst
Adrian Busse, Computer Specialist
Dale Coventry, Computer Systems Analyst
Thomas Pierce, Jr., Meteorologist
Alfreida Rankins, Computer Programmer
James Reagan (PHS), Statistician
John Rudisill, Computer Specialist
Barbara Hinton (EPA), Secretary

Terrain Effects Branch

Dr. Peter L. Finkelstein, Meteorologist, Chief
Dr. Robert Eskridge, Meteorologist
Dr. Alan Huber, Meteorologist
Dr. Sharon LeDuc, Statistician (since September 1988)
Dr. Steven Perry, Meteorologist
Dr. Francis Pooler, Jr., Meteorologist
Lawrence Truppi, Meteorologist
Hazel Hevenor (EPA), Secretary

Environmental Operations Branch

D. Bruce Turner, Meteorologist, Chief
Dr. Clifford B. Baker, Meteorologist
Mark Garrison, Meteorologist (Philadelphia, PA)
John Irwin, Meteorologist
Dr. Ralph Larsen (PHS), Environmental Engineer
Lewis Nagler, Meteorologist (Atlanta, GA)
William Petersen, Meteorologist
Everett Quesnell, Meteorological Technician
Sylvia Coltrane, Secretary

Air Policy Support Branch

James L. Dicke, Meteorologist, Chief
Thomas Braverman (EPA), Environmental Engineer
Roger Brode, Meteorologist
Dennis Doll, Meteorologist
Russell Lee, Meteorologist
Norman Possiel, Jr., Meteorologist
Sharon Reinders (EPA), Environmental Protection Specialist
Jawad Touma, Meteorologist
Dean Wilson, Meteorologist
Phyllis Wright (EPA), Secretary