NOAA Technical Memorandum ERL ARL-187

FISCAL YEAR 1989 SUMMARY REPORT OF NOAA ATMOSPHERIC SCIENCES MODELING DIVISION SUPPORT TO THE U.S. ENVIRONMENTAL PROTECTION AGENCY

Evelyn M. Poole-Kober
Herbert J. Viebrock
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Air Resources Laboratory
Silver Spring, Maryland
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PREFACE

This document summarizes the Fiscal Year 1989 research and operational efforts and accomplishments of the Atmospheric Sciences Modeling Division (ASMD) working under interagency agreement EPA DW13934038-01 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 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 ASMD conducts research activities in-house and through contract and cooperative agreements for the Atmospheric Research and Exposure Assessment Laboratory and other EPA groups. With a staff consisting of NOAA, EPA, and Public Health Service (PHS) Commissioned Corps personnel, the ASMD 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 ASMD are the Atmospheric Model Development Branch, Fluid Modeling Branch, Modeling Systems Analysis Branch, Global Processes Research Branch, Applied Modeling Research Branch, and Air Policy Support Branch. The staff is listed in Appendix E. Publications and other professional activities are listed in Appendixes A, B, C, and D.

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

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FISCAL YEAR 1989 SUMMARY REPORT OF NOAA ATMOSPHERIC SCIENCES MODELING DIVISION SUPPORT TO THE U.S. ENVIRONMENTAL PROTECTION AGENCY

ABSTRACT. During FY-1989, the Atmospheric Sciences Modeling 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 included development of the Regional Acid Deposition Model Version 2.0 and a sulfate tracking version of the RADM Engineering Model; development of a method of aggregating data from 3-day episodes to form seasonal and annual averages of RADM predictions; development of a Biogenic Emissions Inventory System (BEIS); continuation of the Acid-MODES field study; evaluation of the second-generation Regional Oxidant Model; completion of the Complex Terrain Dispersion Model with algorithms for unstable situations; conduct of dense-gas dispersion studies in a neutrally stratified wind tunnel; conduct of the Boston Wastewater Outfall study in a stratified towing tank; and conduct of a wind-tunnel study of smoke dispersion in building wakes.

1. INTRODUCTION

In Fiscal Year 1989, the Atmospheric Sciences Modeling Division (ASMD) continued its commitment for providing goal-oriented, high-quality research and development and operational support to the U.S. Environmental Protection Agency (EPA). Using an interdisciplinary approach emphasizing integration and close cooperation with the EPA and the public and private research communities, the Division's primary efforts were studying the basic processes affecting dispersion of atmospheric pollutants, modeling pollutant dispersion on all temporal and spatial scales, and studying the effects of global climate change on regional climate and air quality. The technology and research products developed by the Division are transferred to the public and private, national and international user communities. Section 2.1 discusses the Division participation in major international activities, while Sections 2.2 through 2.5 outline the Division research activities in support of the short- and long-term needs of the EPA and the rest of the environmental community. Sections 2.6 and 2.7 discuss Division support to the EPA operational programs and 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 Atmospheric Sciences Modeling 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 Atmospheric Sciences Modeling Division established a cooperative agreement with the American Meteorological Society (AMS) to improve the scientific bases of air quality modeling. Under this agreement, the AMS maintains a Steering Committee on Scientific Assessment of Air Quality Models to (1) provide scientific reviews of various types of air quality dispersion models; (2) assist in developing a more complete understanding of uncertainty as it affects different aspects of 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 Air Quality Modeling Uncertainty

To more completely understand modeling uncertainty, the AMS Steering Committee addressed the role of inherent uncertainty in evaluating dispersion models and prepared an unpublished assessment (Weil *et al.,* 1988). The assessment concludes that deviations between predicted model ensemble-averages and individual realizations are due to a combination of concentration random variability, model errors, uncertainties in model inputs, and measurement errors. As appropriate, the recommendations were incorporated by Division scientists into interpretations and applications of air quality dispersion model evaluations. The assessment is being prepared as a journal article.

2.1.1.2 AMS Committee Restructuring

The AMS Steering Committee is being restructured to address two topical issues concerning regulatory dispersion modeling. To that end, efforts will focus on (1) developing objective, defined scientific criteria with which to evaluate the performance of newly-developed regional dispersion models (oxidant, particulate, acid aerosol, and acid deposition); and (2) providing a means of specifying the quality of predictions obtained from dispersion model output, in the same fashion as one specifies in advance the required quality of measured field data. After preliminary investigations, a modelers' workshop will be held to address these issues.

2.1.2 Interdepartmental Meteorological Committee

The Division Director serves as a representative to the Interdepartmental Committee for Meteorological Services and Supporting Research (ICMSSR). The Committee, composed of representatives from 13 Federal government agencies, was formed in 1964 under Public Law 87-843 to provide the Congress and the Executive Branch with a coordinated, overall plan for government meteorological services and for research and development programs that directly support and improve these services.

Each year the ICMSSR publishes a Federal plan for meteorological services and supporting research (U.S. Department of Commerce, 1989). The Division was involved in preparing input for the Federal Meteorological Requirements - 2000 study. This report, to be published in FY-1990, will summarize requirements for meteorological services and supporting research to the year 2000 by addressing agency interdependence, mutual needs, and opportunities for further interagency coordination.

2.1.3 NATO/CCMS Steering Committee

The 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 various aspects of air pollution dispersion modeling. The meetings are rotated among different NATO members, with every third ITM held in North America and the two intervening ITMs held in European countries.

The Division Director helped organize the 17th NATO/CCMS International Technical Meeting held in Cambridge, England, during September 1988, and served as session chairman. A conference summary was prepared (van Dop *et al.,* 1989) and the proceedings were published (van Dop, 1989). The Steering Committee completed selection of papers to be presented at the 18th International Technical Meeting to be held during May 1990 in Vancouver, British Columbia.

2.1.4 United States/Japan Environmental Agreement

The Division Director serves as the United States Co-Chairman of the Air Pollution Meteorology Panel under the United States/Japan Agreement on Cooperation in the Field of Environment. 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 control of air pollution.

The Administrator of the U.S. Environmental Protection Agency and the Director General of the Japan Environment Agency co-chaired the Ninth Joint Planning and Coordinating Committee Meeting of the United States/Japan Environmental Agreement that was held in Washington, DC, during May 1989. Progress reports were presented by representatives of the 14 panels constituting the Agreement. The Air

Pollution Meteorology Panel Co-Chairman reported on the exchange of scientific and regulatory information relating to regional and global pollutant transport, modeling of acidic deposition, and technology transfer of completed dispersion models.

2.1.5 United States/Soviet Union Joint Environmental Committee

The 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 April 1989, a delegation of six Soviet scientists, headed by the Deputy Director of the Voeikov Main Geophysical Observatory in Leningrad, participated in Working Group and Project meetings in the United States. The meetings were held at the Smithsonian Institution and the National Institute of Standards and Technology in Washington, DC; at the Atmospheric Sciences Modeling Division in Research Triangle Park, NC; and at the EPA Office of Air Quality Planning and Standards in Durham, NC. Discussions were held regarding joint progress in the areas of mass spectroscopy of chemical compounds; acid deposition and complex terrain dispersion modeling; fluid modeling of terrain irregularities; results of joint roadway automotive exhaust field studies; and the use of modeling techniques in establishing regulatory standards for pollutant emissions. A protocol was signed outlining future exchanges of scientific information and planning the next Working Group Meeting to be held during May 1990 in Leningrad, Moscow, Tomsk, Vilnius, and Novosibirsk, USSR.

The two Working Group Co-Chairmen met again during September 1989 at the Main Geophysical Observatory in Leningrad. The purpose of the meeting was to negotiate the establishment of a third Working Group project dealing with remote sensing of atmospheric parameters, to be headed by the Director of the NOAA Wave Propagation Laboratory. Also, plans were made for a 1989 visit to the Main Geophysical Observatory by an EPA expert in pollution monitoring for regulatory enforcement, and a 1990 reciprocal visit by a Soviet scientist with similar expertise; a 1989-90 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 between the National Institute of Standards and Technology and the Soviet Institute of Organic Chemistry; and a 1990 symposium to be held in the Soviet Union to report on results of three joint roadway automotive exhaust field studies conducted in Research Triangle Park (1987), Leningrad (1988), and Vilnius, Lithuania (1989). The United States Co-Chairman was presented a combined annual report listing 1988 pollution levels for identified Soviet industrial areas. Data of this type have previously been unavailable outside the Soviet Union; for the years prior to 1988, only overall Soviet pollution trends were available publicly.

2.1.6 Eulerian Modeling Bilateral Steering Committee

The Division Director serves as a representative on the Eulerian Modeling Bilateral Steering Committee (EMBSC). This committee is composed of representatives from the Canadian Atmospheric Environment Service, the Ontario Ministry of the Environment, the Electric Power Research Institute, and the U.S. Environmental Protection Agency. The committee coordinates the evaluation of the Canadian Acid Deposition and Oxidant Model (ADOM) and the United States Regional Acid Deposition Model (RADM) in preparation for their use in the 1990 National Acid Precipitation Assessment Program (NAPAP) Integrated Assessment. Results of the evaluation will be presented to the international scientific and policy communities in February 1990.

2.2 Atmospheric Model Development Branch

The Atmospheric Model Development Branch develops, evaluates, and validates analytical and numerical models used to describe the physical and chemical processes impacting the transport, dispersion, transformation, and removal of pollutants from the atmosphere, and integrates these into comprehensive air quality modeling systems on local to regional scales.

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 was 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-1989, version 2.0 of the Regional Acid Deposition Model (RADM2.0) was refined into an operational model. Individual plume rise calculations were incorporated into the model for about 5000 major point sources and a similar number of groups of smaller point sources using day-specific meteorological inputs. A special treatment of vertical diffusivity was added that allows a time step shorter than the advective time step, to be used in cases where there is very strong vertical transfer by turbulent diffusion, as in a winter outbreak of very cold air over the warm waters of the Gulf Stream. This version of the model takes about 4 hours of CRAY X-MP™* time to simulate a 5-day event.

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*CRAY X-MP is a trademark of Cray Research, Inc.

A self-checking and self-documenting comprehensive file header system was built into the RADM system. When a given case study is run, all input files are automatically checked to verify that all input information corresponds to the specified case. A special processing system was developed for interactive analysis of RADM's voluminous output files and is undergoing testing. RADM2.0 will be used in the 1990 NAPAP Assessment.

A nested version of RADM was built which runs on a horizontal grid size of 26.67 km, one-third that of the RADM horizontal grid size of 80 km. Preliminary comparisons with the Oxidation and Scavenging Characteristics of April Rains (OSCAR) IV data for April 22-25, 1981, show that the nested version of RADM produces reliable estimates of deposition and concentration on this scale. The meteorological inputs for this version are provided from a two-way nested version of the Penn State/NCAR Mesoscale Meteorological Model Version 4 (MM4).

2.2.1.2 RADM Engineering Models (EMs)

The RADM system includes a series of Engineering Models (EMs) that require as input RADM emission and meteorological fields as well as RADM output chemical fields. The EMs allow the user to vary sulfur emissions to assess the effects of projected sulfur emission control scenarios. Because the EMs can be run on a VAX™-class computer,* they offer 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-1989, various EM versions were modified to be compatible with RADM2.0 and to use the new RADM file header structure. EM was exercised extensively to demonstrate the nonproportionality of the response of wet deposition to decreases in sulfur emissions. A simplification of EM, the Linear Chemistry Model (LCM), was developed to further study this nonproportional response. LCM decouples EM from the RADM gas-phase chemistry files by using seasonal average values of the hydroxyl radical and hydrogen peroxide concentrations to oxidize sulfur dioxide to sulfate in gas- and aqueous-phase reactions. This simplification prevents the oxidant limitation that can result from the exhaustion of hydrogen peroxide caused by its aqueous-phase reaction with sulfur. Comparisons of LCM and RADM simulations for the same events indicate the critical importance of oxidant limitation in sulfur control strategies.

2.2.1.3 RADM Meteorological Driver

The meteorological driver used by RADM, consisting of MM4 (Anthes *et al.,* 1987) integrated with the Four-Dimensional Data Assimilation (FDDA) algorithm (Seaman and Stauffer, 1989), became operational in 1988. This approach assures that meteorological information input to RADM is dynamically consistent and spatially correct with respect to observed synoptic-scale wind, temperature, and humidity data. During FY-1989, the modeling system was applied to prepare meteorological data sets for use in RADM

*VAX is a trademark of Digital Equipment Corporation.

applications and evaluation as part of the 1990 NAPAP Assessment. Meteorological fields were generated for thirty 5-day aggregation episodes and for two 6-week periods in August-September and November-December, 1988. The latter data sets will be used in preliminary evaluation of RADM. Evaluation statistics, consisting primarily of comparisons of observed and model-simulated precipitation patterns, were prepared for each of the case results.

2.2.1.4 RADM Aggregation Methodology

RADM is an episodic model. Because long-term estimates of acid deposition impacts are required for input to the 1990 NAPAP Assessment, a method of aggregating deposition fields from a limited number of 3-day periods to produce seasonal and annual averages was developed (Samson, 1989). The basic approach, which focused on sulfur deposition, resulted in the selection of thirty 3-day periods that statistically represent the annual 850-mb wind transport frequencies and the precipitation patterns in the northeastern United States. The approach reproduces annual average wet sulfur deposition over the Northeast within a 20% range on both developmental (1982-85) and independent (1986-87) data sets. The aggregation method developed for sulfur deposition also reproduces hydrogen ion and nitrate deposition in precipitation with about the same accuracy. An approach was developed to apply the aggregation method to RADM predictions of deposition resulting from changes in emissions, based on rationing the difference between the RADM base case and emission change predictions to the measured wet deposition over a 4-year period.

2.2.1.5 Acid-MODES Model Evaluation Field Program

A major field program to evaluate regional acid deposition models, primarily RADM, was implemented in June 1988. The Acid Models Operational and Diagnostic Evaluation Study (Acid-MODES) program consists of a 58-station surface monitoring network for operational evaluation and intensive aircraft sampling periods for diagnostic evaluation (Bowne *et al.,* 1989).

The surface network is coordinated with other networks sponsored by the Electric Power Research Institute (EPRI); the Ontario Ministry of the Environment (OME); the Atmospheric Environment Service of Canada (AES); and the Florida Electric Power Coordinating Group. Together, more than 100 sites are distributed throughout eastern North America, providing measurements from June 1988 through May 1990. Twenty-four-hour integrated aerometric samples from each Acid-MODES site are analyzed for gaseous SO_2, NO_2, HNO_3, and NH_3, and particulate sulfate, nitrate, and ammonium. Precipitation samples collected on a daily basis are analyzed for conductivity, pH, sulfate, nitrate, ammonium, Cl^-, Na^+, K^+, Ca^{2+}, and Mg^{2+}. Collocated sampling at the Penn State Scotia Range, PA, and at Egbert, Ontario, provides information on inter- and intranetwork precision. The Acid-MODES network also measures ozone on a continuous basis at 18 sites and S^{IV} in rainwater at 20 sites. All data from this network are archived in the Eulerian Model Evaluation Field Study (EMEFS) database.

An intensive field study was conducted from August 15 through October 7, 1988, to provide the observational basis for a diagnostic evaluation of RADM and other similar models. The study consisted primarily of measurements from three aircraft platforms flying regional patterns designed to obtain data to (1) test the models' abilities to predict the horizontal and vertical gradients and patterns in and downwind of the major Midwestern source region; (2) evaluate the clear-air chemistry model predictions; (3) test the models' abilities to predict gradients arising from regional source distributions; and (4) test the models' abilities to characterize synoptic-scale frontal dynamics with respect to buildup and cleanout of pollutant concentrations (Spicer *et al.,* 1989). Thirteen missions were flown and the data were processed, quality-assured, and archived in the EMEFS database at the Battelle Northwest Laboratory, Pullman, WA. An Advisory Group for Aircraft Measurements (AGAM) was established to formulate the experimental design and interpret the results leading to the diagnostic evaluation. Preliminary results indicate good agreement between RADM predictions and observed regional patterns and horizontal gradients of sulfur species. A second field study, which will emphasize aqueous-phase chemistry, is being planned for spring 1990.

2.2.1.6 Preliminary RADM Evaluation

The model evaluation protocol for the first phase of the RADM evaluation, the phase for use by NAPAP, was completed and reviewed by the Model Evaluation Team and the External Review Panel.

RADM1.0 predictions between August 31 and September 9, 1988, were compared against aircraft data to provide guidance on how best to develop interpretive comparisons. The analysis concentrated on flight patterns measuring regional horizontal gradients for August 31, 1988, and a frontal passage flight series between September 2 and 8, 1988. RADM very successfully captured the coupled meteorological-chemical dynamics for the sulfur system. However, RADM1.0 predicted levels of nitric acid, PAN, and hydrogen peroxide that were systematically higher than observed levels. RADM2.0, with its enhanced chemical mechanism, is expected to show better agreement for these species. The important conclusion from this initial work is that the RADM system basically is sound.

A preliminary evaluation and test of the use of aggregation with RADM was carried out using dry and wet deposition predictions from RADM1.0 for 14 of the full 30 aggregation cases. RADM predictions were frequency-weighted as required by the aggregation approach and compared to empirical data, including the 1982-85 average for wet sulfur deposition over the RADM domain and the 1985 dry deposition values over southern Ontario. For wet deposition, the best-fit line through the origin had a slope of 1.25 and a variance of 0.46. For dry deposition, the best-fit line through the origin had a slope of 0.775 and a variance of 0.77. These results are comparable to those from the linear models and are very encouraging, considering that only 14 of the 30 aggregation cases were used. The implication of this work is that the model does not have a serious problem with the overall sulfur budget or with the division of the budget between wet and dry deposition. A secondary implication is that this procedure for aggregating RADM predictions appears to be appropriate.

The first draft of State-of-Science/Technology Report No. 5 (Dennis *et al.,* 1989) was delivered to NAPAP. This report describes the current state of science and the results to date regarding the evaluation of regional acid deposition models. The report begins with extensive background material on the concepts of model evaluation in general and Eulerian-style evaluation in particular. It discusses the range of model evaluation activity for NAPAP with an emphasis on the new comprehensive Eulerian models, and provides an historical perspective of model performance on long-term averages of wet deposition.

2.2.1.7 ANATEX Model Evaluation Study (AMES)

The Across North America Tracer EXperiment (ANATEX) Model Evaluation Study was initiated in FY-1987 to obtain a database for assessing the performance of the transport and diffusion components of operational long-range models (Draxler and Heffter, 1989). The ANATEX database, compiled during the first quarter of 1987, consists primarily of 24-hour measurements from a 77-site surface-based network across central and eastern North America for three inert perfluorocarbon tracers released periodically from sites near St. Cloud, MN, and Glasgow, MT.

The model evaluation study, a joint effort of the EPA, the NOAA, and the U.S. Air Force Technical Application Center, assesses the performance of ten regional models (Clark *et al.,* 1988; 1989b). The evaluation protocol focuses 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 results from all models were received and the evaluation is underway.

2.2.1.8 Model Applications

Fourteen of the 30 aggregation cases were used with RADM1.0 to study the degree of nonlinearity for the annual average in the sulfur deposition system. A base case and a 10-million-ton reduction, approximately a 50% reduction, were simulated. The reduction was allocated to different states based on their emissions in excess of 1.2 pounds per million BTUs. The results showed that the sulfur system is nonproportional to sulfur emission controls, even for the annual average. For total (wet plus dry) sulfur deposition, a reduction of emissions by approximately 60% over the Ohio Valley region produced only a 40% reduction in sulfur deposition for that region. For eastern North America, integrating the sulfur deposition over the entire region, the 50% reduction in emissions resulted in only a 39% reduction in region-wide, total sulfur deposition.

A study of the importance of emissions trading on changes in deposition was carried out using RADM1.0 and the REgional Lagrangian Model of Air Pollution (RELMAP) (a linear model) with the OSCAR IV case. This study examined the differences in sulfur deposition resulting from different means of achieving a state-allocated emission reduction (a 1.2 pounds per million BTU formula) for a region-wide reduction of 10 million tons. The following cases were examined: R1, in which the reduction is borne by all sources equally; R2, in which the reduction is borne only by utilities and all utilities are reduced by an equal percentage; and R3, in which the reduction is borne by the top-ranked utilities in the state. RADM predictions indicated that trading would not make a dramatic difference in the deposition reductions in certain locations. Surprisingly, RELMAP predictions of sulfur deposition were insensitive to the different patterns of emission changes. Analysis indicates that the simpler meteorological driver for RELMAP is the cause of the problem. This appears to be a serious deficiency in RELMAP that is not related to the model chemistry.

2.2.2 Photochemical Modeling

2.2.2.1 Regional Oxidant Model (ROM)

The Regional Oxidant Model (ROM) was developed to provide a scientifically credible basis for simulating the regional transport and collective 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. ROM was applied to the southeastern United States for regional analyses, and also used to investigate the effect of emission controls on concentrations averaged over longer periods, in anticipation of a secondary ozone standard designed to protect such welfare interests as forests, crops, and materials.

The focus of the ROM program during FY-1989 was the development and testing of an updated second-generation model, ROM2.1. This version contains a number of significant improvements over ROM2.0, especially in the chemistry, dry deposition, and transport components. Also during FY-1989, the ROM research program focused on the effects of natural source emissions, the generation of wind fields, and innovative computational techniques. A major model evaluation study using ROM2.0 was completed for the northeastern United States and a new evaluation study using ROM2.1 commenced.

2.2.2.2 Development of ROM2.1 and Initial Testing

An updated second-generation version of ROM (ROM2.1) was completed. The changes made in upgrading the model are summarized in a report by Young *et al.* (1989). One of the principal changes was the generalization of the ROM system, enabling easier implementation in other geographical domains. In the original ROM, the northeastern and southeastern United States modeling domains were programmed into the system. ROM2.1 allows flexibility in specifying the location and horizontal extent of the modeling domain. The grid resolution remains fixed at 18.5 km for any modeling domain. The chemical kinetic mechanism was upgraded to the final version of Carbon Bond IV (Gery *et al.,* 1988). Changes to the mechanism included the explicit representation of singlet atomic oxygen and formaldehyde, more detail in the chemistry of the aromatics species, and updates of numerous rate constants. Water vapor concentration was added to the list of meteorological variables affecting the chemical rate constants because the singlet atomic oxygen pathway is sensitive to water vapor concentration.

The dry deposition module also was upgraded by improving parameterizations for species-dependent deposition resistances developed by Wesely (1988). Deposition velocities are now calculated for O_3, NO, NO_2, HNO_2, HNO_3, PAN, H_2O_2, formaldehyde, higher aldehydes, and CO. The deposition resistance of CO is large enough that it is effectively nondepositing on the time and space scales of ROM. All other species in the chemical mechanism also are considered to be nondepositing and are assigned the same deposition resistance as CO.

The ROM transport driver was modified to correct a westerly bias in the transport fields. ROM's lowest model layer (which has a depth of 100-300 m above ground) is now driven with surface-observed winds. Winds for the second layer are derived from a weighted average of surface and upper-air winds, and the third layer winds are derived solely from upper-air winds. This treatment of wind fields greatly improved the simulation of transport for East Coast plumes.

In addition, the upgraded model includes an improved natural hydrocarbon emission inventory. The Biogenic Emissions Inventory System (BEIS) was developed using the latest emission factors for natural emissions of isoprene and monoterpenes from various species of trees and crops. For forest areas, a canopy model was developed to account for the micrometeorological changes within the depth of the forest canopy and their effect on natural emission fluxes.

Initial testing of ROM2.1 included sensitivity tests to various wind field weightings, to specification of water vapor concentrations, to different versions of the biogenic emissions inventory, and to presence or absence of biogenic emissions in the simulation. These tests helped determine the final configuration of the ROM2.1 system.

2.2.2.3 Sensitivity of ROM to Biogenic Hydrocarbon Emissions

A series of sensitivity test runs of ROM were made to assess the importance of biogenic hydrocarbon emissions on the production of ozone. The time period modeled was July 12-18, 1980. There were four model runs using various combinations of biogenic and anthropogenic emissions: (1) anthropogenic emissions only, (2) Biogenic Emissions Software System (BESS) biogenic emissions and anthropogenic emissions, (3) BEIS biogenic emissions and anthropogenic emissions, and (4) BEIS biogenic emissions and anthropogenic NO_x emissions. The ozone maxima over this 6-day period for the four ROM executions are being compared. Preliminary results suggest that the effect of biogenic emissions on ozone production varies across the domain, depending upon its importance in the total amount of hydrocarbons present as precursor material.

2.2.2.4 Evaluation of ROM

The evaluation of ROM2.0 using the 1980 Northeast Regional Oxidant Study (NEROS) database was completed. The purpose of the project was to quantify the performance of ROM2.0 in predicting ozone and precursor species concentrations over regional scales and within major urban plumes on the regional scale. The model was run for the period of July 12 through August 31, 1980, which included several major ozone episodes in the northeastern United States.

The evaluation made use of approximately 200 monitors in the standard United States and Canadian air monitoring networks within the model domain. The evaluation was based on quasi-deterministic techniques because strict spatial pairing between observations and predictions was not used. Statistics of model performance were determined by comparing predictions with measurements within six coherent monitoring site clusters with similar frequencies of ozone concentrations (Schere and Wayland, 1989). Results show 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) 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. The model showed an overall 2% overprediction of the daily surface maximum ozone concentration, although the model predicted a narrower range of values than the observations showed, underestimating the highest values and overestimating the lowest values.

Model performance for NO_x and nonmethane hydrocarbons (NMHC) also was evaluated from data collected at the surface. Results showed that ROM2.0 significantly underpredicted NO_x and NMHC concentrations within and near urban areas, where most of the measurements were made. For the higher observed concentration levels, usually occurring during the morning period, observed-to-predicted concentration ratios were approximately 2 for NO_x and 4 to 5 for NMHC.

The spatial extent and concentrations of urban ozone plumes were generally simulated well. A bias in the transport direction along the East Coast, however, caused misalignment of the plumes in specific episodes. Aircraft data obtained during the NEROS field studies were used to determine model performance in upper layers and from a more regional perspective, since most of the surface monitors are urban-oriented. Comparison of aircraft-observed ozone data with model predictions showed that ROM2.0 performed quite well over and downwind of urban areas along the East Coast, while the model underpredicted region-wide ozone concentrations under episodic conditions by 20-30 ppb.

Model evaluation exercises for ROM2.1 began late in FY-1989. They will proceed in two phases. The first phase involves comparison of model results for episodes from July and August of 1985 with ambient ozone data. These episodes are being modeled as part of the verification phase for the Regional Ozone Modeling for Northeast Transport (ROMNET) application in the northeastern United States. Since no field project was in effect during the summer of 1985, only routine surface-based measurements of ozone will be used in the evaluation. The second phase of the evaluation will involve tests of the transport, vertical flux, and chemical components of the model using hypothetical cases with analytic solutions. These tests are designed to ensure the adequacy of the numerical solution procedures and the links between component modules within ROM2.1.

2.2.2.5 Regional-to-Urban Model Interface Program Development

A set of computer preprocessor programs was developed that will enable a user to interface ROM and the Urban Airshed Model (UAM). A data retrieval routine allows users to access ROM data sets to create output files of the parameters needed in the interface preprocessors for the space and time selected for UAM applications. Model parameters include pollutant concentrations, meteorological parameters, biogenic emissions, and surface characteristics. ROM output concentrations for 20 chemical species are applied to establish the initial conditions and lateral- and top-boundary UAM values. The methodologies for interpolating ROM output concentrations and parameters for the horizontal resolution and vertical structure of the UAM system were described in Godowitch and Schere (1989). The interface programs are undergoing extensive testing to assess the sensitivity of UAM output concentrations to changes in interfacing methods and procedures.

This regional-to-urban model interface development effort is an integral component of the ROMNET program. The interface programs will be run at State and local levels when applying the UAM system in emission control strategy simulations for ozone reduction.

2.2.2.6 Generation of Probabilistic Wind Fields for ROM

Research on the generation of "probabilistic" wind fields for use with ROM continued during FY-1989. From a set of wind observations, ensembles of possible wind fields are created that all conform to the physical laws of momentum and energy conservation, and agree with measurements at observation times and locations. The differences between the wind fields represent the stochastic nature of the atmosphere and the uncertainties generated from the sparseness of the data and the inherent errors in the measurements. A method of assigning probabilities of occurrence to each member field is being developed. When these wind fields are used with ROM, pollutant concentration fields that result from the simulations are probabilistic rather than deterministic (those that result from the use of a single wind field). The use of ROM in this stochastic sense will be explored during FY-1990.

2.2.2.7 Development of the ROM Multi-Processor Custom Computing Equipment

ROM and other large regional-scale Eulerian models require extensive computational resources. A disparity between the growth rate of model size and 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 air quality models for applications work. The feasibility study showed that the optimum computer architecture for ROM should be designed around a system of loosely coupled parallel processors. The study showed that a 100-fold increase in speed may be possible using an accelerator based on a loosely coupled processor architecture of a "tiled" design.

A prototype device, based on the feasibility study, was constructed through a cooperative agreement. The design of the prototype consists of 22 VAX 1000 computers for individual processing elements and a VAX Workstation acting as the host computer. The specific architecture decided upon for the prototype uses the host machine to calculate the horizontal transport portion of the model while the microprocessors solve the chemical and flux portions. The chemical calculations can account for nearly 90% of the model's computational time. The resulting version of ROM, Regional Oxidant Model Multi-Processor (ROMMP), demonstrated peak performance speed 11 times faster than that of the VAX single-processor version of the model, with average performance showing a speed 7.5 times faster. The results are documented in a report by Roberts *et al.* (1989). Work was started on the "tiled" architecture for distributing ROM onto the multi-processors, which has the potential for far larger efficiencies in model execution speed.

2.2.3 Aerosol Modeling Program

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. The modeling tools are used primarily to assist in promulgating air quality standards for fine particles, visibility, and acid aerosol. Section 2.4.2 details a major effort to incorporate aerosol dynamics and chemistry into the RADM system.

2.2.3.1 Regional Fine-Particle Network

A 33-site network of cyclonic separator samplers was established to obtain consecutive 24-hour samples of fine particles in rural areas of the northeastern United States to provide (1) an evaluation database for regional fine-particle models and (2) estimates of upwind fine-particle boundary conditions for Northeastern urban areas. This network, a subset of the Acid-MODES network, was operational during 6-week periods of the summer and autumn of 1988 and the winter of 1989, as well as a 10-month period beginning in the summer of 1989.

Fine-particle concentrations were determined for the first three sessions, while the concentrations of constituent elements on each filter of the first two sessions were determined via X-ray fluorescence analysis. The major elements with concentrations above quantifiable limits were S, K, Mg, and Ca; occasionally other elements such as V, Cr, and Pb were quantifiable.

Collocated fine-particle concentrations for the first three sessions at Plainsville, IL, and State College, PA, indicated good agreement between samplers; session means were within 5% of each other and mean coefficients of variation were not more than 0.25.

2.2.3.2 Modification and Sensitivity Testing of the ASTRAP Model

The original 1985 code of the Argonne National Laboratory's Advanced Statistical Trajectory Regional Air Pollution (ASTRAP) Model (Shannon, 1985) was adapted to the EPA VAX 8600 for use as a regional screening model for fine-particle mass (Clark and Coventry, 1989). The model grid configuration also was modified for compatibility with the meteorological preprocessors.

The cumulative effect of these modifications on the results was assessed by comparing quarterly 1980 predictions of sulfur wet deposition from both model versions. The seasonal correlation coefficients and standard errors were not significantly different from each other at the 0.05 level, demonstrating that the two model versions indeed produced similar results.

The sensitivity analysis indicated that the model is most sensitive to three parameters: the model time step, the truncation of trajectories near wind-data-void regions, and the temporal aggregation of ensemble trajectory statistics.

2.2.3.3 Regional Visibility Modeling

Aerosol dynamics and chemistry were incorporated into the RADM Engineering Model. This initial version of a regional aerosol model was applied to assess the reasonableness of its predictions of sulfate concentrations and to demonstrate the potential utility of the model for assessing visibility improvements from sulfur emission reductions (Clark *et al.,* 1989a). As sulfate concentration measurements did not exist for the periods when processed meteorological data were available, predictions of sulfate concentrations were compared to observed visibilities across the eastern United States, which are highly correlated with sulfate concentrations, especially in the summer. Preliminary comparisons for 2 days of July 1985 revealed that the spatial patterns of predicted hourly-average sulfate concentrations replicated the basic features of the visibility pattern. That is, predicted sulfate concentrations tended to be highest where observed visibilities were lowest. Additional tests will be conducted after the processes governing nitrate and organic aerosols are added to the model.

2.2.4 Boundary-Layer Diffusion Research

Basic physical arguments were used to support suggestions for simple ways to estimate the effects of various city sizes and other major surface inhomogeneities (e.g., rivers and lakes) on daytime convective turbulence and diffusion rates (Briggs, 1988). City size affects mixing depth and wind speed, and convective turbulence typically requires 2 to 4 km of travel to respond fully to a change in surface heat flux, as when flow enters a city or crosses water; a several-kilometer-wide river or lake can engender a stationary downdraft that carries pollutants from near-shore industries downward, substantially increasing surface concentrations.

Convective diffusion was investigated further in a presentation (Briggs, 1989) analyzing the entire set of oil fog-lidar data from the CONvective Dispersion Observed with Remote Sensors (CONDORS) field experiment in terms of convective scaling parameters; this facilitated comparisons with numerical and laboratory simulations that had revealed highly non-Gaussian vertical diffusion behaviors. Seventy-five percent of the time the field data behaved much like the simulations, strengthening earlier conclusions from preliminary analyses. The remaining CONDORS data, including chaff-radar plume mappings compensated for chaff settling speed and extensive comparisons of oil, chaff, and SF_6 patterns with each other and with vertical and horizontal wind distributions measured near the release point, were analyzed in preparation for a major journal article for FY-1990.

A journal article (Briggs *et al.,* 1989) describing the heavy-gas diffusion experiments of FY-1988 (Poole-Kober and Viebrock, 1989) also was prepared.

2.2.5 Technical Support

2.2.5.1 Regional Ozone Modeling for Northeast Transport (ROMNET) Program

ROMNET is a major 3-year (FY-1988 through FY-1990) program involving the use of ROM to assess the effects of region-wide VOC and NO_x emission control strategies in the northeastern United States on the resulting region-wide ozone distributions and to estimate future-year boundary conditions for urban models. Results of the future-year simulations for base cases and emission control strategies will be provided to State and local air pollution control agencies so that they can estimate initial and inflow boundary conditions when using urban air quality models in future-year emission scenario testing. Meteorological scenarios from episodic periods in 1980, 1983, 1985, and 1988 are being used, along with the projected inventories for 1995 and 2005. During FY-1989, work focused on constructing and verifying the emission inventories for the base and future years, and on defining the initial set of emission control strategies to be used. Simulations began with the 2005 base emission inventory and five control strategies. Technical guidance is provided through 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).

2.2.5.2 Modeling Advisory Committee

The California Air Resources Board (ARB) has initiated a Modeling Center within its Technical Support Group in Sacramento. The purpose of the Center is to coordinate all regulatory air quality modeling activities within the State, as well as to develop and test tools needed for air quality modeling. 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 Committee is composed of members from the scientific community elected by ARB officials for fixed terms of membership. One representative from the Division is serving a 2-year term on the MAC. MAC meetings during FY-1989 were concerned with model evaluation protocols for grid-type urban photochemical models and with the adequacy of anthropogenic emission inventories for modeling.

2.2.5.3 Urban Airshed Model (UAM)

Two representatives from the Division are serving on working groups providing technical assistance to the EPA on two UAM application projects. One is the SCOPE project, in which the New York State Department of Environmental Conservation is attempting to interface ROM and UAM. The working groups are providing wind fields and initial and boundary concentrations from ROM for a limited number of single-day UAM simulations. This project is being coordinated with the more extensive in-house effort to interface these two models. The other project is the five-city UAM demonstration, in which UAM will be exercised on routinely available databases from several cities to demonstrate the model's accuracy and flexibility when being used in a scaled-down implementation. The cities included in this demonstration project are New York, St. Louis, Philadelphia, Atlanta, and Dallas.

2.2.5.4 Southeast Oxidant Study (SOS)

Planning for a multiyear Southeast Oxidant Study (SOS) of the generation and control of ozone and photochemical processes in the southeastern United States began in FY-1989. A consortium of Southeastern universities is coordinating the study. Recent evidence indicates that the traditional policy of controlling hydrocarbon emissions to ameliorate the ozone problem is not very effective in the Southeast. One reason for this may be the abundance of natural hydrocarbons from the region's forests and vegetation. Plans were made for a Southeast Regional Oxidant Network (SERON) program and a Southern Oxidant Research Program (SORP). The SERON program is a long-term data collection effort over the region; SORP is a more intensive field effort in selected urban airsheds within the Southeast. In addition to the field measurement program there will be modeling studies on the regional and urban scales.

2.2.5.5 National Acid Precipitation Assessment Program (NAPAP)

A Division scientist serves as chairman of NAPAP Task Group III, Atmospheric Transport and Modeling. During FY-1989, this group provided support to the NAPAP Office of the Director regarding the Assessment Plan Update published in August 1989. The support involved the atmospheric processes component of the 1990 NAPAP Assessment. Aid was provided to structure the description of the major models to be used in the Assessment, resulting in a "model pedigree." A major structuring exercise provided NAPAP with an approach to link the effects models with the atmospheric model outputs and the approach was codified for the Assessment Plan Update. Other support included providing the NAPAP Office of the Director with preliminary RADM results for internal use and writing the first draft of State-of-Science/Technology Report No. 5 (Dennis *et al.,* 1989).

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 convection 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. Generally, it is used for simulation of strongly stable flow. A convection tank measuring 1.2 m on each side and containing water to a depth of 0.5 m is used to study the convective boundary layer and to study flow and dispersion under convective conditions.

2.3.1 Dispersion of Dense Gases

In FY-1989, data analysis and write-ups were completed on earlier experimental work in the meteorological wind tunnel to examine the flushing of dense gases from valleys. In the first 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 (Briggs *et al.,* 1989). In the second project, the gas density was too low 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 (Kumar, 1989).

A further dense-gas project was conducted during FY-1989. Carbon dioxide or sulfur hexafluoride was released from circular sources flush with a rough flat surface in the meteorological wind tunnel. The primary goal was to examine the near-source characteristics of the dense-gas plumes (upwind extent, plume width and depth, and concentration patterns) as functions of the effluent flow rate, ambient wind speed, effluent density, and source diameter. The focus of the study was to understand the physical processes relevant to such near-source behavior, to quantify those physical processes, and to specify the near-source plume structure in a consistent framework. The data were compiled into a summary (Snyder and Britter, 1989) that documents the techniques and procedures used in the simulations.

2.3.2 Video Image Analysis of Building Wakes

Work was completed on the last in a series of joint wind-tunnel experiments between the Earth and Space Sciences Division of the Los Alamos National Laboratory (U.S. Department of Energy) and the Fluid Modeling Facility. The objective of the study was to develop a video-based concentration measurement system for use in the wind tunnel and to apply the system in determining concentration distributions resulting from pollutant releases near buildings and clusters of buildings. The data from these experiments will be used to develop a better understanding of the physics involved in the interaction of building wakes with near-surface emissions; this will enable theoretical modelers to develop better ways to predict the consequences of such interactions. Prior work established a quantitative relationship between video-image intensity and vertically integrated concentration in the wakes of individual buildings. FY-1989 experiments extended that work to examine horizontally integrated concentration patterns and to include building clusters as opposed to single buildings.

2.3.3 Hydraulic Modeling Study of the Boston Wastewater Outfall

Under the Federal Technology Transfer Act, modeling of the Boston Wastewater Outfall (BWO) was conducted in the stratified towing tank of the Fluid Modeling Facility to aid in the engineering design of the outfall. Several scaled sectional models of the outfall were towed through the tank while the characteristics of the waste field (plume rise, thickness, and dilution) were measured as functions of discharge riser spacing, number of discharge ports per riser, effluent density and flow rate, and ambient current speed, direction, and stratification. A total of 110 simulations was completed, requiring colorimetric analysis of over 10,000 samples. Results of these tests indicated that the original design proposal for discharging the effluent through 80 risers was unnecessarily conservative and that the number of risers could be reduced to 55 without adverse environmental effects. Also, the original design of 12 discharge ports per riser caused a merging of individual plumes and therefore insufficient dilution of the effluent, whereas 8 ports per riser performed satisfactorily. The recommendations from this study will result in very significant cost savings (about $25 million) and improved performance characteristics over the preliminary engineering design. Data (Marsh, 1989) and final (Roberts, 1989) reports that summarize the results and document the simulation techniques and procedures were completed.

2.3.4 Convective Boundary Layer Simulation

During FY-1989, the Fluid Modeling Facility was in the process of developing a capability for physically simulating the convective boundary layer to study the diffusion of pollutants under convective conditions. The convection tank consists of acrylic sidewalls and an aluminum floor; it measures 1.2 m on each side and is filled with water to a depth of approximately 0.5 m. The floor of the tank can be heated to initiate thermal convection in the water. A separate heating grid is used to set up an initial ambient temperature stratification, which moderates the effects of convection and limits the height to which pollutants can be mixed. The first study undertaken in the convection tank will examine the effects on the surrounding environment of a "heat island," which is a city or other large area where a concentration of heat sources and materials retains heat and is substantially warmer than the surrounding countryside. The temperature difference between the city and its environs results in a thermally driven circulation. This study will examine the general physical structure of the heat island, including the mean temperature distributions and circulation patterns, as functions of the surface heat flux, heat island size, and ambient temperature gradient. The principal investigator is a graduate student working under a cooperative agreement with North Carolina State University.

2.3.5 Flow and Dispersion in Complex Terrain

Under the auspices of the US/USSR Bilateral Agreement on Cooperation in the Field of Environmental Protection, two Soviet scientists spent 4 months at the Fluid Modeling Facility conducting wind-tunnel studies of flow structure and pollutant dispersion in valleys and comparing the results with a Soviet theoretical model. Three 2-dimensional model valleys were used, having maximum slopes of 10°, 16°, and 26°. Measurements of mean and turbulent velocity fields were made upstream, within, and downwind of each of these valleys. Concentration distributions were measured downwind of tracer sources placed at an array of locations within each of the valleys. The data were displayed as maps of terrain amplification factors, defined as the ratios of maximum ground-level concentrations in the presence of the valleys to the maxima observed from sources of the same height located in flat terrain; maps also were constructed showing the distances to locations of the maximum ground-level concentrations. The concentration patterns were interpreted in terms of the detailed flow structure measured in the valleys. These data also were compared with results of a mathematical model for treating flow and dispersion over two-dimensional complex terrain. This model used the wind-tunnel measurements to generate mean flow fields and eddy diffusivities, and these were applied in the numerical solution of the diffusion equation. Measured concentration fields were predicted reasonably well by this model for the valley of small slope and somewhat less well for the valley of medium slope. Because flow separation was observed within the steepest valley, the model was not applied in this case. A report (Khurshudyan *et al.,* 1989) and a journal article (Snyder *et al.,* 1989) were completed.

2.3.6 Vertical Concentration Distributions

A theoretical study was completed in which mathematical and wind-tunnel simulations of vertical diffusion from point-source releases were compared with diffusion experiments carried out in the atmospheric boundary layer during near-neutral conditions. The mathematical simulations were performed with a K-theory, non-Gaussian diffusion model, which approximates the essential features of a vertically inhomogeneous turbulent shear flow through power-law velocity and vertical eddy diffusivity profiles, and includes effects of mass deposition at the surface. The vertical concentration distributions from surface releases were shown to be exponential: $C(z) \propto \exp(-kz^{\alpha})$, with α in the range of 1.5 (as opposed to the Gaussian value of 2.0). This work resulted in a Master's thesis (Brown, 1989) and a conference presentation (Brown *et al.,* 1989).

2.4 Modeling Systems Analysis Branch

The Modeling Systems Analysis Branch supports the other Division Branches by providing the computer programming and systems analysis needed in the development of mathematical and statistical models. The Branch is the focal point for modeling software design and systems analysis in compliance with stated

Agency quality control and assurance requirements. The Branch operates the Facility for Advanced Research Model Operation and Analysis (Research Modeling Facility) to provide proper expertise in the application and interpretation of advanced dispersion models and to establish 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 Model (ROM) Applications

During FY-1989, ROM2.1 was prepared for application to the Regional Ozone Modeling for Northeast Transport (ROMNET) program. Details on the development of ROM2.1 are noted in Section 2.2.2.2 of this report and are discussed in Young *et al.* (1989).

Application runs of ROM2.1 for ROMNET began during the summer of 1989. These runs were coordinated closely with the EPA Office of Air Quality Planning and Standards, Office of Research and Development, and Regional Offices, and several State air pollution control agencies in the northeastern United States. After an extensive analysis of surface ozone concentrations and meteorology (Doll *et al.*, 1989), several meteorological episodes were selected for ROM simulations. Thus far, most simulations have involved meteorology from July 1988. Surface ozone during this period exceeded the National Ambient Air Quality Standard (NAAQS) of 120 ppb in most areas of the northeastern United States. While Vermont reported its first exceedance in history, ozone concentrations observed near New York City were comparable to extreme values found near Los Angeles (greater than 250 ppb). Estimates from ROM2.1 showed widespread exceedances during July 1988 (Figure 1). A direct comparison between model estimates and observations is not warranted because the baseline emissions come from 1985 and the meteorology is from 1988.

Other activities included an evaluation and sensitivity analysis of ROM2.1. The evaluation compared surface ozone observations with ROM estimates for July and August, 1985. This work complements an extensive evaluation of ROM2.0 (Schere and Wayland, 1989), which was based on 1980 emission data, while the ROM2.1 evaluation was based on 1985 emission data. The evaluation also assessed ROM's effectiveness for producing ozone boundary conditions for use in the smaller, finer-scale Urban Airshed Model (UAM). In addition, a set of ROM2.1 runs was used to assess the sensitivity of the model's ozone predictions to biogenic emissions of hydrocarbons. Three types of emission scenarios are being analyzed: (1) anthropogenic emissions only, (2) anthropogenic and biogenic emissions, and (3) anthropogenic NO_x and biogenic emissions. Preliminary results indicate that biogenic hydrocarbon emissions contribute significantly to ozone in rural areas and can contribute moderately during high-ozone events near urban areas. Results on both the evaluation and the sensitivity analysis will be published during FY-1990.

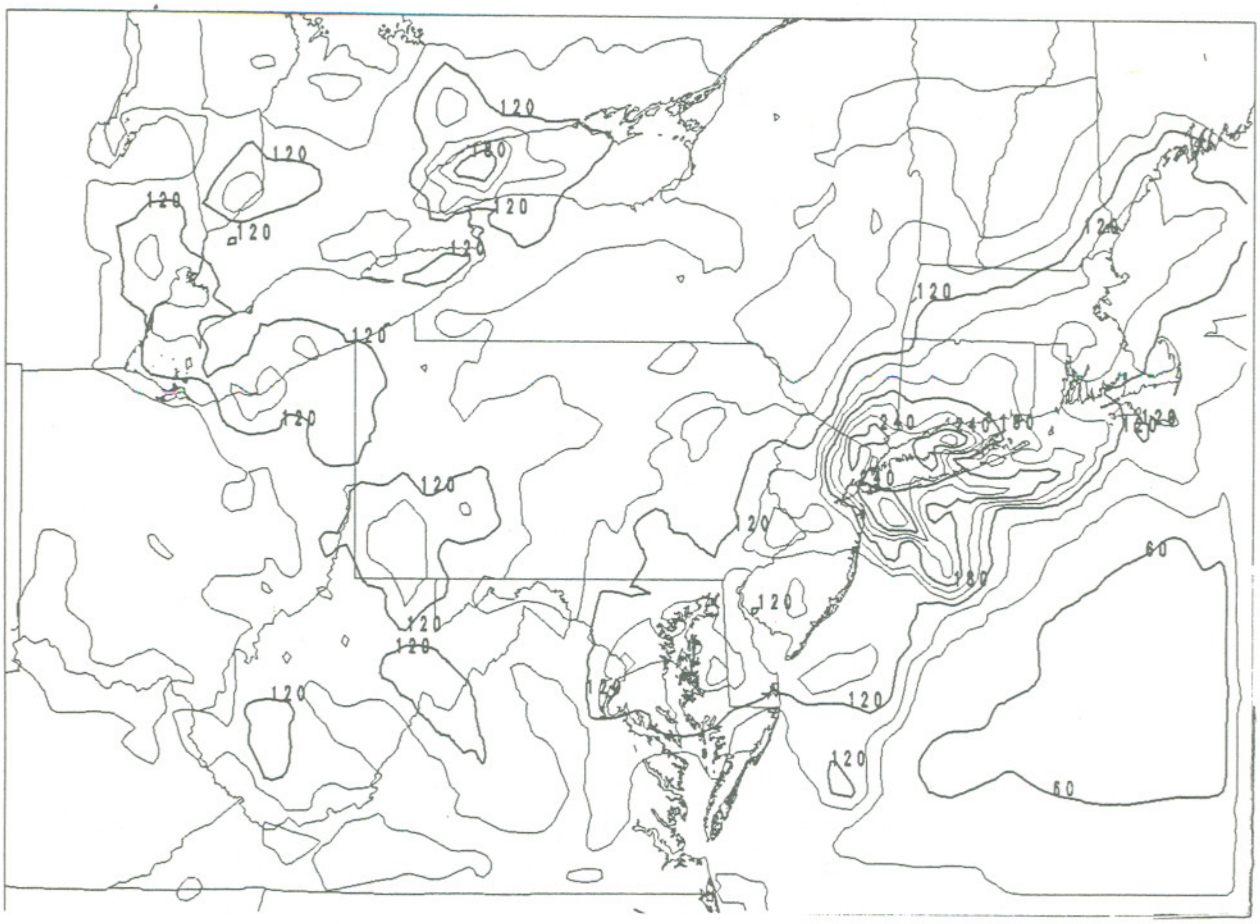

Figure 1.--Predicted episode maximum ozone (ppb) for July 2-17, 1988 (2005 base case emissions).

2.4.2 Regional Particulate Model Development

2.4.2.1 Development of the Engineering Aerosol Model (EAM)

A first-generation Engineering Aerosol Model (EAM) was developed (Bullock *et al.,* 1989) to assist in policy development and promulgation of air quality standards for fine particles, visibility, and acid aerosols. To create EAM, the RADM Engineering Model (EM) was modified significantly and an aerosol chemical and kinetic mechanism was added. A three-dimensional, regional-scale Eulerian system, EAM simulates episodic concentrations of gas-phase chemicals and aerosol particles. The operational characteristics of EAM and EM are similar, except that EAM models sulfate aerosols in seven size ranges rather than in a bulk sense, and it considers the effects of nucleation, condensation, evaporation, coagulation, and aqueous aerosol chemistry.

The first test application of EAM with the aerosol mechanism fully activated was performed for the Northeast Regional Oxidant Study (NEROS) period from 0000Z August 3 through 0000Z August 6, 1979. EAM results showed that the highest concentrations of small aerosols were near the particulate emission source areas and that the highest concentrations of large aerosols, those sizes in the accumulation mode, were downwind of the source areas. The layer 1 fields of the Mie scattering coefficient for visible light based on the model concentrations of all EAM aerosol species were compared to observed visual range values. The correlation between the simulated regions of maximum scattering coefficient and observed regions of low visual range was significant.

A second test application of EAM was performed for the Oxidation and Scavenging Characteristics of April Rains (OSCAR) period from 0000Z April 22 through 1200Z April 24, 1981, referred to as OSCAR IV. Again, the simulations showed that the small-aerosol concentration maxima were near the source regions and the large-aerosol concentration maxima were downwind. This test case demonstrated EAM's ability to model accurately the horizontal advection and wet removal processes, and showed that the model's aqueous chemistry produced sulfate in an area of convective mixing capped by fair-weather cumulus behind a cold front.

2.4.2.2 Modification of the Aerosol Coagulation Mechanism

The dependence of EAM aerosol coagulation rates on temperature and pressure for various particle diameters was investigated. The variation with temperature was nearly linear, with higher temperatures resulting in greater coagulation. Also, decreasing the pressure resulted in higher coagulation rates. To include these significant effects of temperature and pressure on coagulation in EAM, a linear regression analysis on temperature was performed for the coefficients in the coagulation governing equations at 1013.25 mb, 850 mb, and 700 mb. This analysis provided characteristic variations in the coefficients associated with given temperature changes.

2.4.2.3 Development of Particle-Size-Dependent Dry Deposition

EAM uses the dry deposition model of EM, in which sulfate is deposited in a bulk sense without regard to the size distribution of the sulfate particles. A technique was developed for EAM that accounts for the particle-size-dependent effects of Brownian motion, inertial impaction, and gravitational settling.

2.4.2.4 New Formulation for the Mie Scattering Coefficient

The initial aerosol mechanism calculated a Mie scattering coefficient for visible light based on the total aerosol concentrations in all size ranges. Attempts to verify the equations used in this calculation by a separate derivation were unsuccessful. The original developers used an unspecified averaging technique for the aerosol size distribution within individual size ranges, a nonstandard wavelength range for visible light, and an unspecified refractive index for the aerosol particles. To enhance the scientific credibility of EAM, a new formulation of the equations for the Mie scattering coefficient was developed and incorporated into EAM.

2.4.3 Regional Acid Deposition Model (RADM) Applications Support

2.4.3.1 Emissions Processing for RADM

The system for preparing emissions input data for RADM was used to process the 1985 base case emissions for 30 selected meteorological episodes. Coordinate transformations were performed on the point- and area-source data to convert from the NAPAP latitude and longitude coordinate system to the Lambert conformal projection used in RADM. Plume rise was calculated hourly for approximately 6,000 major point sources to ensure proper allocation of major source emissions in RADM's six vertical layers. Summertime mobile-source emissions were adjusted for daily temperature variations and hydrocarbon speciation was adjusted to reflect redistribution of reactivity due to temperature effects. Hourly SO_x and NO_x emissions collected from approximately 274 point sources during the Acid-MODES field study were integrated into the base 1985 emissions to form the emissions input data for RADM evaluation executions.

2.4.3.2 Model Applications

RADM1.0 was run for 14 selected meteorological cases at the National Center for Atmospheric Research (NCAR) in Boulder, CO, for preliminary testing of the aggregation methodology. RADM2.0 runs were completed for August 13 through September 30, 1988, for the first phase of the model evaluation, and approximately 20 of the 30 meteorological episodes for the full aggregation were completed for the 1985 base case.

A preliminary EM study was performed to assess the effect of potential emissions trading scenarios on sulfate deposition. Preliminary results for one episode indicated that trading options may have a slight effect on deposition patterns, but major effects are not likely. EM and a tagged species variant of the model were converted from the VAX to the IBM® 3090™* to provide greater computational speed for the NAPAP applications.

A master audit and file tracking system was implemented to assist in managing over 20,000 files that will be generated on as many as six different computer systems during the RADM and EM applications in support of NAPAP. Data processing and model executions automatically send status records to the National Computer Center VAX master database over nationwide telecommunication lines.

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*IBM and 3090 are a registered trademark and a trademark, respectively, of International Business Machines Corporation.

2.4.4 Eulerian Model Evaluation Field Study (EMEFS) Data Analysis

Data from the Eulerian Model Evaluation Field Study (EMEFS) monitoring sites continued to be received from the contractor; archiving and review of the data to determine the overall quality were performed. In a multivariate analysis of the analyte (SO_4^{2-}, NO_3^-, Cl^-, Ca^{2+}, K^+, Na^+, NH_4^+) relation to the hydrocarbon ion concentration, more than 85% of the variance was explained by SO_4^{2-} at most stations. There is a strong intercorrelation between the SO_4^{2-}, NO_3^- and NH_4^+ analytes. These data will be merged with data from the Electric Power Research Institute (EPRI) Operational Evaluation Network (OEN), the Canadian Atmospheric Environment Service (AES) Canadian Air Pollution Monitoring Network (CAPMoN), and the Ontario Ministry of the Environment (OME) Acid Precipitation in Ontario Study (APIOS) network. A preliminary analysis of a portion of the combined data from the networks and aircraft was prepared for comparison with RADM predictions.

2.4.5 Interactive Display of Environmental Data

A pilot project to demonstrate the utility of Geographic Information Systems (GIS) for spatial analysis of environmental data was completed (Novak and Birth, 1989) as a joint effort involving several EPA Offices and Laboratories. There are two main advantages of the GIS. One, the menu-driven interface provides researchers with direct access to a flexible graphics tool that can create contours, gridded maps, and data overlays and explore relationships among a variety of data sets. Two, the centralized database management provides easy access to a variety of environmental databases essential for comprehensive data analysis. The limited scope of the initial pilot project was expanded to create a production system for interactive display of environmental data, which is being used to support analyses for such major modeling programs as the ROMNET program and the 1990 NAPAP Assessment. Further GIS developmental work is being done by the Research Modeling Facility.

2.4.6 Development of the Biogenic Emissions Inventory System (BEIS)

Such researchers as Chameides *et al.* (1988) and Trainer *et al.* (1987) have demonstrated that natural emissions need to be considered when modeling regional-scale pollution. In 1986, the first known system for estimating regional-scale biogenic emissions (Novak and Reagan, 1986) was developed. During FY-1989, desirable features from this system and the methodology of Lamb *et al.* (1987) were combined to form the Biogenic Emissions Inventory System (BEIS). BEIS computes hourly gridded hydrocarbon emissions from vegetation. Figure 2 shows a comparison of natural hydrocarbon emissions to anthropogenic emissions. For the highly urbanized region of the northeastern United States, over 50% of estimated emissions come from biogenic sources. It should be noted, however, that anthropogenic emissions are much more highly concentrated in urban areas. Research to understand ROM's sensitivity to biogenic emissions is ongoing.

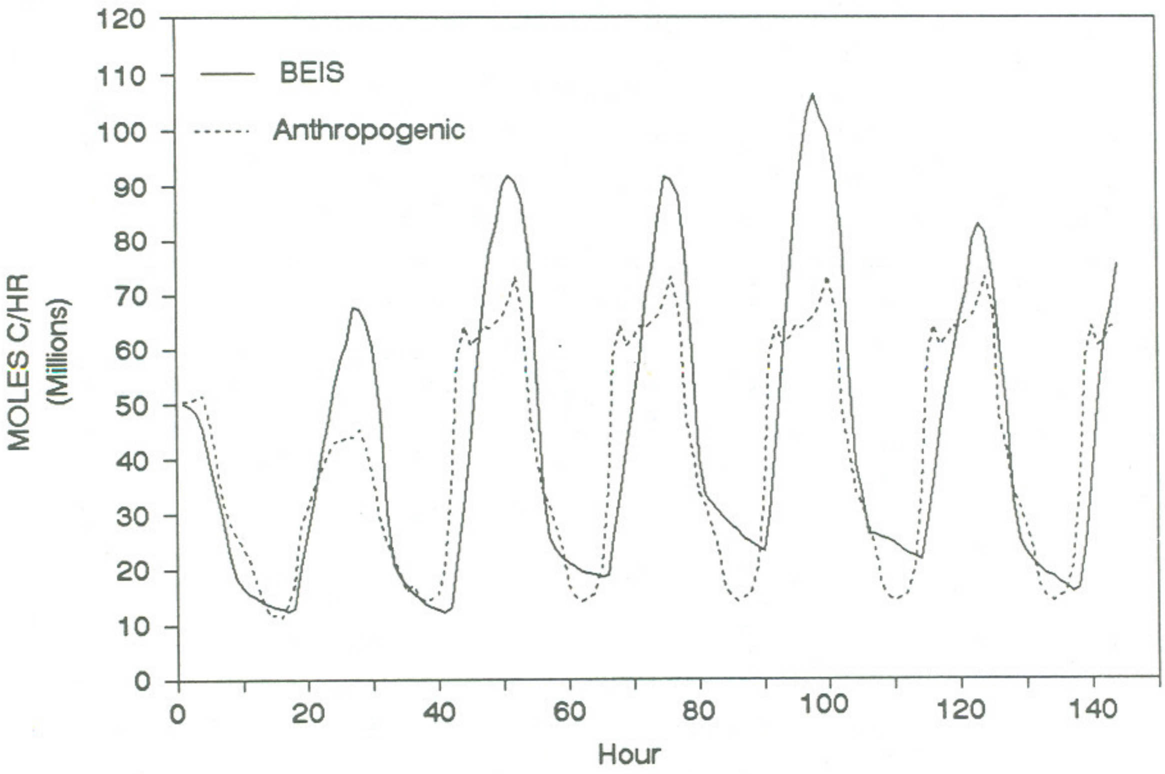

Figure 2.--Hourly total nonmethane hydrocarbon emissions for July 12-18, 1980, for the northeastern United States.

BEIS also includes a canopy model (Gay, 1987) that estimates vertical profiles of temperature and sunlight within idealized canopies of deciduous and coniferous forests. Use of the canopy model was prompted by the highly sensitive nature of terpene and isoprene emissions to sunlight and temperature. Additional testing and refinement of this model is planned for FY-1990.

Efforts were initiated in FY-1989 to incorporate natural emissions of NO_x into BEIS. To estimate grassland NO_x emissions, a simple algorithm was developed and used in this version of BEIS. Efforts to incorporate natural emissions of NO_x derived from lightning strike data continue. Results of these efforts will be published in FY-1990.

2.5 Global Processes Research Branch

The Global Processes Research Branch performs and directs research to obtain qualitative and quantitative predictions of regional climate and air quality changes caused by global climate fluctuations for use in evaluating the sensitivities and responses of major environmental systems to climate change. The

Branch also studies the effects of complex irregular terrain and man-made surface features on pollutant dispersion, and establishes mathematical relationships among air quality, meteorological parameters, and physical processes affecting air quality.

2.5.1 Global Climate Change Program

Understanding the physical and chemical elements of climate and the atmosphere, including their properties, feedback mechanisms, and potential for change under present and future conditions, is the goal of the Global Climate Change Program. Supporting this goal, the Branch conducts research on the impact of climate change on the environment, including ecosystems and air quality; the impact of urban emissions on regional and global atmospheric composition; and the production of future climate scenarios for assessing air quality and environmental effects.

A scenario production seminar series was held, providing substantial information for a report that includes a summary of scenario production techniques and recommendations for technique development and improvement (Robinson and Finkelstein, 1989). The report also contains results from a climate scenario users survey, indicates current needs, and provides guidance for research efforts.

Two climate scenario efforts using observed historical data are underway. The first effort is developing climate scenarios to investigate the important climate-forcing functions for forest production in the Great Lakes Region of North America. The basis for this investigation is a quality-assured data set containing daily precipitation data for a regularly-spaced network. The second effort is identifying synoptic types associated with episodes of poor air quality.

With the ARC/INFO® system,* changes in the seasonality of precipitation over time were studied using the historic climate database developed at the National Climatic Data Center. The study also evaluated the capabilities of the present generation of Global Circulation Models (GCMs) to model precipitation seasonality over the United States. A final report is in preparation.

To establish a linkage with surface climatology, the Division and the NOAA National Weather Service Climate Analysis Center are working together to define clusters of days based on the upper-air circulation patterns in the geopotential height field for the Northern Hemisphere. The resulting information will be used by the GCM modelers, including the NOAA Geophysical Fluid Dynamics Laboratory (GFDL).

NCAR provided global climatic output grids from computer models developed by Goddard Institute for Space Studies (GISS), GFDL, Oregon State University, and the United Kingdom Meteorological Office. The data consist of (1) values from control runs (designated 1XCO2) that simulate the present climate, and (2) values from runs (designated 2XCO2) in which the model atmosphere contains twice the amount of CO_2 and is brought to a steady state. In addition, there are data from two long simulations

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done by GISS, in which the amount of gases and volcanic activity were gradually changed over a number of decades. The data were archived, and data from global grids related to North America and East Asia were extracted for study.

2.5.2 Complex Terrain Dispersion Modeling

The in-house research effort to expand the capabilities of the Complex Terrain Dispersion Model (CTDM) to simulate convective conditions was completed and a user's guide prepared (Perry *et al.,* 1989). The improved model, the Complex Terrain Dispersion Model PLus Algorithms for Unstable Situations (CTDMPLUS), is described in the user's guide. For unstable or convective situations, the vertical pollutant distributions are based on a probability distribution function (Li and Briggs, 1988) with adjustments for flow distortion by terrain. The Gaussian horizontal distribution includes dispersion parameters based on convective scaling concepts, and the simulation of distortion in the depth of the mixed layer is based on results from a fluid modeling experiment (Perry and Snyder, 1989) in which the parameters of hill height, mixing height, and hill Froude number were found to be of greatest importance.

The sensitivity of CTDMPLUS to the meteorology was studied for a wide variety of source and terrain characteristics. In convective conditions, the model predictions were found to be most sensitive to wind direction and speed, the depth of the mixed layer, and the strength of the convection as measured by the convective scaling velocity.

The performance of CTDMPLUS was evaluated using field study data of sulfur dioxide emissions and impacts at and around an industrial facility. The model showed superior performance in a regulatory sense. The top 25 predicted 1-hour concentrations were all within 20% of the corresponding top 25 observed concentrations. For time pairings of predictions to observations, CTDMPLUS overpredicted on average by about 40%.

2.5.3 United States and People's Republic of China Joint Research

In 1984, the United States and the People's Republic of China conducted a long-range tracer experiment in the Beijing area. The results of this experiment are being analyzed and will be published in FY-1990. A planned second joint meteorological-tracer experiment in Fuzhou was delayed from November 1989 to November 1990.

2.5.4 Integrated Air Cancer Program

In 1985, a long-term integrated air cancer research program was initiated to investigate the toxicity of airborne pollutants. The first phase of this program was investigating the chemical composition and mutagenicity of woodsmoke. The transport and diffusion of woodsmoke in an urban setting was studied and the results of these experiments will be published in FY-1990.

A second experiment was conducted in Roanoke, VA, in the winter of 1988-89. Roanoke Valley is a pooling valley and is expected to behave quite differently from the Boise River Valley in Idaho, where the first experiment was conducted in the winter of 1986-87. In Roanoke, a 50-m tower was instrumented with two sonic anemometers, two propeller and vane anemometers, and two delta T systems. The resulting data from eight meteorological and tracer experiments are being analyzed.

2.5.5 Wake Effects Studies

Research is being conducted to develop and apply video image analysis techniques to the study of smoke plumes in the wake of wind-tunnel model buildings. Video image analyses were especially useful for studying the temporal-spatial plume distributions in ways not obtainable from traditional point-tracer measurements. Temporal and spatial scales of vortex-shedding of smoke puffs were estimated through the calculations of spectral densities and autocorrelations (Huber, 1988). The temporal-spatial distributions of cross-stream profiles were analyzed as functions of coordinates in time and space (Huber and Arya, 1989). Additional methods of image analysis are being evaluated under a cooperative research agreement with North Carolina State University.

The data analyzed in these studies were from video images of smoke illuminated by a floodlight. Each smoke picture represents a two-dimensional view of smoke-scattered light integrated through the third dimension. The digitized luminance value, called image intensity, represents an indirect measure of the smoke particle concentration through the field of view. A system for illuminating the smoke with a thin sheet of laser light was set up and evaluated. The image intensities for the laser sheets represent point concentrations. Preliminary analyses found expected small-scale detail within the light sheet that could not be obtained within the floodlighted images. Also, the light sheet can be used to examine concentrations near the surface of buildings without reflections off the surface. Reports on these experiments will follow in FY-1990.

Results from the video image analysis studies and a study of the influence of building width and orientation (Huber, 1989a) are being incorporated into the Gaussian Integrated Puff Model. A preliminary evaluation of this model was reported by Huber and Petersen (1989). The transport of material from the cavity flow near the building can be dominated by periodic shedding of vortices. A puff model formulation can estimate the primary fluctuating spatial-temporal scales of the shed vortices. Additional development and evaluation of this approach is planned for FY-1990.

A paper was prepared summarizing a study of the relationship between Gaussian plume models and wind-tunnel models (Huber, 1989b). Wind-tunnel measurements of tracer concentration distributions downwind of a point source in the near wake of a rectangular model building were evaluated. These measurements were obtained in low turbulence and simulated atmospheric boundary layer experiments. The differences between the results for these two flows were not significant very near the building, but increased in significance at downstream distances greater than 10 times the building height. The application of a modified Gaussian plume model showed it to be a simple, well-suited complement to wind-tunnel measurements of mean concentrations.

2.6 Applied Modeling Research Branch

The Applied Modeling Research Branch investigates and develops applied numerical simulation models of sources, transport, fate, and mitigation of pollutants in microenvironments. Databases are assembled and used for model development and research on flow characterization and dispersion modeling. Research is coordinated with other agencies and researchers.

2.6.1 Dispersion Model Evaluation

TUPOS-2, a point-source air quality simulation model, was evaluated (Turner *et al.,* 1989) using selected data from SF_6 tracer studies conducted at the Kincaid power plant in central Illinois by the Electric Power Research Institute in 1980 and 1981. Most of the 96 hours of data are from periods representing daytime convective conditions, when the impact of an elevated buoyant source would be expected to be greatest at ground level. Approximately 200 tracer measurement stations on four to six arcs were operating during each hour of the study. A reasonable estimate of the maximum concentration along each arc was made, and these maximum concentrations were the principal values used for comparing tracer measurements with model estimates.

In addition to making comparisons between tracer measurements and TUPOS-2 estimates, comparisons were made using the MPTER model. The means of residuals from the hourly maxima were not statistically different at the 95% confidence level for the two models.

The performance results were used to make changes to TUPOS-2. These changes were the determination of the fluctuation statistics and wind speed and direction for a height midway between effective plume height and ground level, rather than at plume height. The enhanced model showed improved performance when it was tested on the dependent data set used to evaluate the original model. Based on all data for all arcs for all hours (580 data pairs), the mean of the differences between model and tracer concentrations for the revised model, 7.9 parts per trillion (ppt), was found to be significantly different at the 95% confidence level from the mean of the differences for the original model, -13.1 ppt. Model performance shifted from underestimation of the concentration by the original model to slight overestimation by the revised model. While an independent data set would have been more beneficial, the revised model results are still useful for directing changes that can be made to improve modeling.

2.6.2 Diffusion Meteorology Characterization Evaluation

Estimates from semi-empirical models that characterize surface heat flux, mixing depth, and profiles of temperature, wind, and turbulence were compared with observations from atmospheric field studies conducted in Colorado, Illinois, Indiana, and Minnesota. In addition, for wind and turbulence profiles, sodar observations were compared with tower measurements made at the Colorado site. The median surface heat flux, as calculated using surface-layer flux-profile relationships and an energy budget model, was consistently overestimated by 20% to 80%. Three mixing depth models were evaluated: first, one that integrates the hourly surface heat flux and friction velocity (CWB model); second, one that solves for the time rate of change of virtual potential temperature profiles (Garrett model); and third, one that uses the interpolation scheme in regulatory dispersion models (EPA model). Comparison of these mixing depth models showed that, for the late afternoon, the CWB and EPA models performed noticeably better than the Garrett model; 80% to 90% of the estimates from the CWB and EPA models were within 40% of observed values. For the morning hours after sunrise, the CWB model performed twice as well as the other two, but all were less accurate.

Temperature estimates from surface-layer flux-profile relationships compared well with observations within the mixed layer, but were too low for the inversion layer aloft. Wind profiles were derived using surface-layer flux-profile relationships, a wind-profile power law based on Pasquill stability category, and sodar observations. The sodar observations were superior to both types of estimates. Turbulence profiles were derived from sodar observations and from semi-empirical similarity relationships based on mixing depth and Obukhov length. The scatter in the comparisons of the sodar observations with the tower data was twice that seen in the comparisons of the empirical profile relationships with the tower data. Overall, it appears that uncertainty as low as 20% to 30% in the characterization of the diffusion meteorology is the exception rather than the rule.

2.6.3 Building Wake Dispersion Simulations

In a study to model dispersion in building wakes, a puff model formulation was modified to estimate the primary fluctuating spatial-temporal distribution of centerline concentrations. Fluctuations in the spatial-temporal scales of the shed vortices and meander in the plume centerline were related to the scales of the mean velocity and the building. The model simulations were compared with the cross-stream distributions derived from video imaging of smoke dispersion simulation experiments in the wake of a building conducted in the Fluid Modeling Facility.

The study was performed using INPUFF (Petersen and Lavdas, 1986), a Gaussian integrated puff model that is particularly adaptable to simulating concentrations in the building wake, where rapid puff release rates are necessary. The Gaussian puff diffusion equation is used to compute the contribution to the concentration at each receptor from each puff every time step.

Several changes were made to INPUFF to simulate concentrations in the wake of a 200:1 scale prototype building (20 m by 40 m by 20 m) comparable to the wind-tunnel model measurements. Parameters to characterize the puffs were chosen based on the video image analyses. Virtual source distances were calculated and incorporated into the model so that at $x=0$ the initial dispersion parameters were set equal to $0.7H$, where x is downwind distance and H is building height. In the puff simulations of dispersion, the same characterizations were used for the rate of growth for the lateral and downwind dispersion as a function of stability class and downwind distance. Two subroutines were added to the model to allow modification of the source emission rate and source location. The source location moved with a superimposed random component between the building edges based on a 24-second period of oscillation. One puff was released every 6 seconds. The first puff was released on the centerline, the second at the peak $-y$ position, the third on the center, and the fourth at the peak $+y$ position, where y is the crosswind distance. This same pattern was repeated for every cycle except for differences caused by a superimposed random component, which was included for added realism in the model simulation. The movement in the smoke images was estimated to cycle over a period 0.07-0.15 times the ratio of the building height to the mean wind speed. Thus, for a building 20 m high, the 24-second cycle may correspond to a 2.9-5.8 m/s wind speed. A wind speed of 5.8 m/s was used for this model demonstration. The source strength (Q=1 g/s) was distributed so that each of the two puffs released along the building sides contained $Q/3$ and each of the two centerline puffs contained $Q/6$. Also, a random component of $0.2Q$ was incorporated for added realism.

The lateral distributions of several statistics for the times series of video image data and INPUFF model calculations were compared. The video image values were normalized by the mean centerline value, and the INPUFF values for ground-level calculations were normalized by their mean centerline value. Both normalized series corresponded to the cross-stream distribution of vertically averaged values at $x/H=3$. Comparisons of the profiles for the mean, standard deviation, maximum, minimum, skewness, and kurtosis indicated that a four-puff-per-cycle model can be used to simulate the overall characteristics of building wake dispersion. Also, the performance of INPUFF was examined over a range of downstream positions. Downstream profiles for the mean and the standard deviation divided by the mean at cross-stream positions $y=0$ and $y=1.5H$ showed that puff-simulated building wake effects were not very significant beyond $x/H=20$, for this case.

In summary, the time series of simulated concentrations compared well with the wind-tunnel data. Lateral profiles out to 20 building heights were simulated well by the model. These comparisons indicate that a Gaussian puff model can be used to simulate the overall characteristics of building wake dispersion. Work is underway to generalize the adaptations in INPUFF to incorporate different building geometries and wind orientations.

2.6.4 Sonic Intercomparison

The flow distortion induced by three different sonic anemometer arrays was studied in a wind tunnel. This experiment was conducted to examine the flow distortion caused by different sonic anemometer geometries and their effect on flux measurement. Blockage effects due to the probe arrays in the tunnel were negligible. The sonics were rotated through ±90° in the horizontal and ±15° in the vertical at three different flow speeds. It was found that the flow distortion parameterization must be determined for the entire probe assembly, and that a wind tunnel is necessary to provide the controlled conditions necessary to obtain the shape of the response curve for each geometric configuration. The error in the horizontal components of the wind speed was found to be as much as 15%, while the accuracy of the estimated wind direction calculated from the horizontal components was 3%. It was concluded that momentum flux measurements under convective conditions would be better measured with sonic arrays that have all three components in front of the support arm.

2.6.5 International Sodar Intercomparison Experiment 1988

An International Sodar Intercomparison Experiment was conducted from August 27, 1988, to September 21, 1988, at the Boulder Atmospheric Observatory (BAO) in Colorado. Sponsored by the EPA, the U.S. Army, and the NOAA, the experiment focused on assessing the current state of sodar Doppler wind measurements, particularly as they pertain to air quality requirements. Three commercial sodar manufacturers participated in a tightly controlled test meant to simulate an operational environment, and four other groups operated their sodars in an experimental mode. A tethered balloon was periodically deployed to extend the comparisons above the 300-m BAO tower. The mean wind components and speeds and directions were quantitatively compared between the sodars and the tower under a variety of conditions. The sodar-derived standard deviations of the three wind components were compared with those calculated from sonic anemometers on the BAO tower. The results were interpreted in terms of the spatial separation between the measurements, volume versus point measurements, and the atmospheric conditions.

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, state, and local air pollution control strategies for attainment and maintenance of National Ambient Air Quality Standards (NAAQS); and (3) providing meteorological assistance and consultation to support the OAQPS 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) Program

During FY-1989, efforts continued in the 3-year ROMNET 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 January 1989, the ROMNET base year (1985) emission inventories for hydrocarbons (HC), nitrogen oxides (NO_x), and carbon monoxide were completed (Battye *et al.,* 1989). Five additional inventories reflecting projected emissions for the year 2005 and several HC and NO_x control strategies were developed during the remainder of 1989. The inventories for mobile and stationary sources were altered to reflect the effects of day-specific temperature on emission levels. In addition, biogenic HC emissions were estimated for the modeling region and coupled with the anthropogenic data for ROM simulation. In the total modeling domain, biogenic sources contribute roughly half of the reactive HC emissions. However, natural emissions are highest in rural areas where ground-level NO_x emissions are quite low, whereas high anthropogenic HC and NO_x emissions generally are collocated in or near urban areas.

Applications were performed for emission scenarios using the most severe ozone episode that occurred in the Northeast between 1980 and 1988. This 16-day episode--July 2-17, 1988--was selected using an objective procedure (Doll *et al.,* 1989) based upon the magnitude, frequency, and spatial distribution of ozone levels in the Northeast corridor. Simulated strategies included the implementation of HC controls at the maximum level of existing technology and the combinations of HC and NO_x controls that represent alternative scenarios being considered by the EPA and the Congress in amending the Clean Air Act. Preliminary analysis of the ROM ozone predictions for these strategies indicated that the HC and NO_x controls in proposed legislation would reduce the frequency and spatial extent of ozone exceeding the NAAQS from 73% to 100% in the vicinity of major Northeast urban areas. Also, these strategies lowered peak 1-hour concentrations by 10% to 20% across broad areas of the region. Other findings indicated that combining NO_x and HC controls is more effective in reducing ozone than implementing comparable HC controls alone. During FY-1990, additional scenarios will be designed and simulated with ROM and the results will be analyzed.

2.7.1.2 Pilot Program for the Geographic Information System (GIS)

One Division meteorologist participated in a pilot program to design and install a Geographic Information System (GIS) on the EPA National Computer Center VAX, providing the ability to display and relate complex air pollution databases graphically. The operational system used is the ARC/INFO GIS. The system is geared toward analyzing and interpreting data sets associated with ROM, including gridded hourly concentrations of ROM-predicted pollutant species for three vertical layers, gridded and point emission data, ambient air quality data, land use data, and population data. Data sets are retrieved via a user-friendly, menu-driven system. The features included are color tile (spatial) plots of gridded data; color and black-and-white contouring; grid-to-county translations; overlays of multiple data sets (e.g., contours of concentration over emission files); identification and display of data attributes (e.g., characteristics of the monitoring site of a given pollutant measurement); and aggregation and display of one data set, given constraints on a related data set (e.g., a display of the population older than 65 years of age for the area with measured ozone exceeding the NAAQS). User's guides and training for researchers and analysts will be completed in FY-1990.

2.7.1.3 Dense-Gas Model Performance Evaluation

In FY-1989, a study was begun to evaluate the performance of models used in determining ground-level concentrations downwind of routine releases of negatively buoyant gases into the atmosphere. The study began by archiving data from four appropriate field experiments. Nine models, both proprietary and public, were acquired and are being tested. Statistical performance measures recommended by the American Meteorological Society are being used to determine how well model results compare with the field databases. This evaluation allows model developers to initialize the models with respect to treatment of release density, aerosol formation, jet effects, and other parameters, so that the releases can be simulated for comparison with the field test data.

2.7.1.4 Evaluation of Area-Source Algorithms

The spatial and temporal distributions of hazardous and toxic air pollutant emissions are often very different from the continuous point-source scenarios treated by the existing Gaussian dispersion models. During FY-1989, an effort was begun to review available area-source modeling techniques, perform sensitivity analyses, and compare algorithm outputs to a field database. The objective of this study is to provide recommendations on the best algorithm for estimating ambient concentrations from area sources of toxic and hazardous pollutants. The evaluation examined the ability of some algorithms to estimate maximum ground-level concentrations near the source versus far downwind and to estimate short-term concentrations versus those on an annual basis. A final report will be published.

2.7.2 Modeling Guidance

2.7.2.1 Fourth Conference on Air Quality Modeling

Section 320 of the Clean Air Act requires that a conference on air quality modeling be held every 3 years. The fourth conference was held October 12-13, 1988, in Washington, DC, and was attended by nearly 200 persons. The purpose of the conference was to advise the public on new modeling techniques and to solicit their comments to guide the EPA in any rulemaking needed to revise the *Guideline on Air Quality Models (Revised) and Supplement A* (U.S. Environmental Protection Agency, 1987). Among the new models and techniques presented for public comment were (1) CTDM, a new model for complex terrain applications (Paine *et al.,* 1987); (2) VISCREEN, a personal computer model for estimating the visibility impact of specific sources (U.S. Environmental Protection Agency, 1988b); (3) SDM, a model for evaluating the impact of emissions from tall power plants near the shorelines of large bodies of water (U.S. Environmental Protection Agency, 1988a); (4) SCREEN, a personal computer model and accompanying revised screening procedure document for estimating the air quality impact of stationary sources (Brode, 1988); and (5) MPRM, the meteorological processor for regulatory models (Irwin *et al.,* 1988).

During the public comment period that closed in February 1989, the EPA received comments from 44 individuals and organizations. Responses to these comments were drafted and a final document summarizing comments and responses will be placed in the rulemaking docket. Additional technical studies to support several of the specific proposals were completed. The complete proposal for the next set of modeling guideline revisions, Supplement B, will be published in the Federal Register in late 1990.

2.7.2.2 Support Center for Regulatory Air Models (SCRAM)

The OAQPS started the Support Center for Regulatory Air Models (SCRAM) with an electronic bulletin board system (BBS) as the main mode of public communication. The SCRAM BBS is the primary means for disseminating regulatory air quality model codes, test data, and utility programs to the modeling community. News and bulletins provide information of general interest as well as information on such topics as the status of regulatory models and model modifications. Modeling questions are answered either through the message facility of the BBS or by telephone.

Ongoing support is provided to the modeling community that uses the regulatory air quality models available on the SCRAM BBS. This includes responding to individual questions on model use, testing and revising the models, and preparing documentation and notices for the model user community. Assistance to model users, by telephone and through the SCRAM BBS, is an ongoing daily activity.

During FY-1989, both the Industrial Source Complex Short Term (ISCST) and Long Term (ISCLT) models were revised to correct errors and to bring the code up to ANSI Standard FORTRAN-77. As a result, these models can be run on a much wider variety of computers, including IBM PCs and compatibles. A project to recode the ISCST and ISCLT models using modern structured programming approaches was designed and will be implemented in FY-1990.

2.7.2.3 Model Clearinghouse

The FY-1989 activities for the Model Clearinghouse included the following:

1. Responding to the EPA Regional Office requests to review 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-1988 activities.
6. Completing the input of historical Clearinghouse records into a computerized database.

There were 121 modeling referrals to the Model Clearinghouse from the Regional Offices during FY-1989, including 27 regulatory modeling problems that required written responses and 78 referrals that required oral responses. There were 16 referrals that were discussed, but a Clearinghouse recommendation was not requested. Requests for assistance, either written or by telephone, came from the ten Regional Offices, indicating that there is an awareness and a desire for Clearinghouse support throughout the Agency.

In FY-1989, the Clearinghouse conducted or participated in coordination and information exchange activities with the Regional Offices. In October 1988, a Clearinghouse report was prepared and distributed to the Regional Offices, informing Clearinghouse users about issues and responses that occurred in FY-1988. In June 1989, important Clearinghouse issues that occurred during the first half of the fiscal year were discussed at the annual EPA Regional/State Modelers Workshop.

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

The Model Clearinghouse seeks advance opinions from the Regional Offices on particularly sensitive issues with national implications. During FY-1989, four such cases arose. In these cases the proposed Clearinghouse responses were either provided to the Regional Offices for comment or were discussed in some detail at the 1989 Regional/State Modelers Workshop before the responses were finalized.

In FY-1987, the Clearinghouse installed the Model Clearinghouse Information Storage and Retrieval System (MCHISRS), a PC software system that allows certain key information on each Clearinghouse referral to be stored in a data bank. This software allows users to electronically search the database to locate records with like characteristics that can be used to consider the consistency aspects of new referrals. During FY-1989, the Clearinghouse staff entered approximately 700 historical referrals into MCHISRS. Access to this information will be provided in FY-1990 to the Regional Offices.

2.7.2.4 Treatment, Storage, and Disposal Facility (TSDF) Screening Procedures

A screening procedure was developed for estimating maximum annual average particulate matter (PM) concentrations due to fugitive PM emissions from hazardous waste treatment, storage, and disposal facilities (TSDFs). Fugitive PM sources of concern include landfills, land treatment, waste stabilization basins, dry surface impoundments, and roads. These sources are regulated by a site-specific permitting system for TSDFs under the authority of the Resource Conservation and Recovery Act (RCRA).

The screening procedure was included in a guidance document published as part of a proposed regulation to provide a TSDF control program (U.S. Environmental Protection Agency, 1989b). This guidance document provides TSDF analysts with sufficient information to (1) identify sources of contaminated fugitive PM emissions; (2) estimate the magnitude of emissions; (3) select viable control measures; and (4) estimate effectiveness of the control measures (e.g., by modeling) to ensure that unacceptable health risks do not occur.

The screening procedure yields estimates of maximum χ/Q, where χ is the concentration and Q is the source strength, versus distance for six generic area-source sizes. Utilizing this procedure involves a three-step approach. First, an estimate is made of the combined fugitive PM area-source size for the particular facility. Second, an estimate is calculated of total annual fugitive PM emissions from this combined area source. Third, an estimate is obtained of the maximum annual average PM concentration for various distances from the combined area source.

2.7.2.5 Ozone Monitoring Season Analysis and Guidance

An analysis of promulgated State ozone monitoring seasons was conducted to determine the feasibility of designating alternative seasons within States, allowing the States more flexibility in allocating resources to conduct the required ozone monitoring. Generally, monitoring is required from April to October for most northern States and all year for some southern States, when exceedances of the ozone NAAQS are likely to occur. However, for States with significant north to south extents, having one statewide season may cause unnecessary monitoring.

In the analysis, an extensive review was conducted of the databases used to establish the promulgated State ozone monitoring seasons. These databases contain comparisons of observed maximum ozone concentrations to various meteorological parameters. Additionally, results from smog chamber studies that evaluated the relationship between critical ozone concentration formation and ambient temperature were reviewed. The analysis showed that ambient temperature was the most reliable indicator of the potential formation of critical levels of ozone. Specifically, the analysis indicated that a temperature of approximately 55 °F (286 K) or greater was necessary for the potential formation of ozone concentrations greater than approximately 0.08 ppm.

Based upon this relationship, guidance was proposed (U.S. Environmental Protection Agency, 1989a) allowing States the option of establishing alternative ozone monitoring seasons within their boundaries using the climatological occurrence of monthly mean daily maximum temperatures of 55 °F or greater. Thus, within States with distinctive climatological regimes, the required ozone monitoring seasons may be different. A State with a large north-to-south extent, like Texas, may require ozone monitoring only from April to October in the northern portions and in southern portions may require monitoring all year round.

2.7.2.6 Air Toxics Screening Model

In modeling the ambient impact of toxic air pollutant releases from a meteorological perspective, a reasonable degree of assurance is needed that the maximum short-term ground-level concentration estimate is obtained. To foster the use of a consistent meteorological approach to determine ambient impact, a workbook was published (U.S. Environmental Protection Agency, 1988c). The publication has proved valuable to many users, and contract work is underway to develop a computerized system to implement the methods described in the workbook. This system will contain easy-to-use interactive menus and data entry screens and will be available in FY-1990.

2.7.3 Additional Support Activities

2.7.3.1 Regional/State Modelers Workshop

The annual Regional/State Modelers Workshop was held May 15-19, 1989, in Seattle, WA. Major workshop topics included a summary of comments received from the Fourth Conference on Air Quality Modeling; Model Clearinghouse activities; work group reports on CTDM, on-site meteorological data, VOC point-source modeling, CO intersection modeling, and valley stagnation; and Division modeling activities. The workshop's major focus was group discussions of the prepared responses to the public comments received on the items the EPA presented at the Fourth Conference on Air Quality Modeling. Consensus was reached on the general form and specific items that should be proposed as the next revision to the modeling guideline.

2.7.3.2 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-1989, 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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Young, J.O., M. Aissa, T.L. Boehm, C.J. Coats, Jr., J.R. Eichinger, D.J. Grimes, S.W. Hallyburton, W.E. Heilman, D.T. Olerud, Jr., S.J. Roselle, A.R. Van Meter, R.A. Wayland, and T.E. Pierce. Development of the Regional Oxidant Model Version 2.1. EPA/600/3-89/044, Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC, 55 pp. (1989).

APPENDIX B: PRESENTATIONS

Baker, C.B. Data acquisition as it pertains to meteorological measurements. Lectures presented at the University of Michigan, Ann Arbor, MI, September 19-20, 1989.

Baker, C.B. Experimental meteorology. Lecture series presented at North Carolina State University, Raleigh, NC, winter 1989.

Baker, C.B. Measurement physics. Discussion with the Measurements Planning Committee, American Meteorological Society, Anaheim, CA, February 3, 1989.

Baker, C.B. Flow distortion around sonic anemometers and some implications to design considerations. Seminars presented at the National Center for Atmospheric Research and the NOAA/ERL Wave Propagation Laboratory, Boulder, CO, October 1988.

Binkowski, F.S., and J.K.S. Ching. Application of RADM. Briefing to the Committee on Earth Sciences and Subcommittee on Atmospheric Research of the Federal Coordinating Council for Science, Engineering and Technology. National Science Foundation, Washington, DC, April 6, 1989.

Britter, R.E. (University of Cambridge, Cambridge, England). Development of a workbook for dense-gas dispersion. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, July 24, 1989.

Carruthers, D. (University of Cambridge, Cambridge, England). Structure of turbulence and waves at the top of the Convective Boundary Layer. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, April 27, 1989.

Clark, T.L. A resource for evaluating regional transport and diffusion models, Across North America Tracer EXperiment (ANATEX). AREAL seminar, Research Triangle Park, NC, November 22, 1988.

Dicke, J.L. Additional modeling activities and other issues. Presentation at the U.S. Environmental Protection Agency Fourth Conference on Air Quality Modeling, Washington, DC, October 12, 1988.

Dicke, J.L. Mobile source modeling. Presentation at the U.S. Environmental Protection Agency Fourth Conference on Air Quality Modeling, Washington, DC, October 12, 1988.

Doll, D.C., T.J. Mohin, R. McDonald, and P. Eckhoff. Assessment of public health risks associated with chloroform emissions from pulp and paper mills. Poster presentation at the Society for Environmental Toxicology and Chemistry Annual Meeting, Washington, DC, November 14, 1988.

Huber, A.H. Wind tunnel and Gaussian plume modeling of building wake dispersion. Presentation at the Fourth International Workshop on Wind and Water Tunnel Modelling of Atmospheric Flow and Dispersion, Karlsruhe, West Germany, October 3-6, 1988.

APPENDIX B (continued)

Huber, A.H., S.P.S. Arya, S.A. Rajala, and J.W. Borek. Applications for video image analysis of smoke dispersion in the near wake of a model building. Presentation at the Fourth International Workshop on Wind and Water Tunnel Modelling of Atmospheric Flow and Dispersion, Karlsruhe, West Germany, October 3-6, 1988.

Khurshudyan, L.H. (Main Geophysical Observatory, Leningrad, USSR). Particle dispersion from ground-level sources. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, January 19, 1989.

Kumar, A. (North Carolina State University). Flushing of heavy gas from a valley by elevated crosswinds. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, July 12, 1989.

LeDuc, S.K. Linkage of two dependent Markov chains. Presented at 150th Statistical Meeting of the American Statistical Association, Washington, DC, August 8, 1989.

Lee, J.T., D.L. Call, R.E. Lawson, Jr., W.E. Clements, and D.E. Hoard. A video image analysis system for concentration measurements and flow visualization in building wakes. Presentation at the Fourth International Workshop on Wind and Water Tunnel Modelling of Atmospheric Flow and Dispersion, Karlsruhe, West Germany, October 3-6, 1988.

Nekrasov, I.V. (Moscow State University, Moscow, USSR). Artificial upwelling in stratified flow. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, January 19, 1989.

Novak, J.H. U.S. EPA experience in developing gridded emission inventories for modeling. Presentation at the California Air Resources Board Model Advisory Committee Meeting, Sacramento, CA, May 23, 1989.

Novak, J.H. NAPAP assessment and other ASMD model application programs. Presentation at the Air Resources Laboratory Program Review, Boulder, CO, March 6, 1989.

Novak, J.H. Supercomputer needs for atmospheric models. Presentation at the U.S. EPA Scientific Computing Planning Conference, Raleigh, NC, November 9, 1988.

Perry, S.G. The Environmental Protection Agency's model for complex terrain applications (CTDM). Presentation at the Fourth Conference on Air Quality Modeling, Washington, DC, October 13, 1988.

Petersen, W.B. Dense gas dispersion in a wind tunnel. Presented at the Vapor Cloud Committee Meeting, American Petroleum Institute, Washington, DC, December 14, 1988.

Pierce, T.E. Biogenic emissions. Briefing to the U.S. EPA Corvallis Environmental Research Laboratory, Research Triangle Park, NC, September 13, 1989.

Pierce, T.E. Biogenic emissions. Briefing to the U.S. EPA Office of Air Quality Planning and Standards, Durham, NC, August 31, 1989.

Pierce, T.E. Biogenic emissions. Briefing to the U.S. EPA Athens Environmental Research Laboratory, Charlotte, NC, August 24, 1989.

APPENDIX B (continued)

Pierce, T.E. Biogenic emissions. Briefing to the Emissions Committee of the Regional Ozone Modeling for Northeast Transport (ROMNET) project, Philadelphia, PA, November 15, 1988.

Pierce, T.E. Development of boundary conditions for the Regional Oxidant Model. Briefing to the Modeling Committee of the Regional Ozone Modeling for Northeast Transport (ROMNET) project, Philadelphia, PA, November 14, 1988.

Possiel, N.C. Application and use of a menu-driven Geographical Information System (GIS) for analysis of regional air pollution problems. Presentation at the Environmental Protection Agency GIS Pilot Project Demonstration, Research Triangle Park, NC, May 4-5, 1989.

Possiel, N.C. Estimated benefits of VOC and NO_x controls on population exposure. Presentation to the Congressional Office of Technology Assessment, Washington, DC, March 21, 1989.

Schere, K.L. ROM control strategy results. Invited presentation at the Gordon Conference on Atmospheric Chemistry, University of Colorado, Boulder, CO, June 23, 1989.

Schere, K.L. U.S. EPA Regional Oxidant Model: Evaluation results. Briefing to the Modeling Committee of the Regional Ozone Modeling for Northeast Transport (ROMNET) project, Philadelphia, PA, November 14, 1988.

Schiermeier, F.A. EPA research accomplishments in regional modeling of acidic, oxidant, and particulate pollutants. Seminar presented at Main Geophysical Observatory, Leningrad, USSR, September 21, 1989.

Schiermeier, F.A. Regulatory applications of the Atmospheric Sciences Modeling Division theoretical and fluid model development research activities. Presentation to management representatives of EPA Regional Offices, Research Triangle Park, NC, August 28, 1989.

Schiermeier, F.A. Status and needs of air toxics dispersion modeling. Presentation at the NOAA/OAR Air Quality Research Workshop, Washington, DC, August 2, 1989.

Schiermeier, F.A. Evaluation requirements for regional scale pollutant dispersion models. Presentation to the AMS Steering Committee on Scientific Assessment of Air Quality Models, Brookings Institute, Washington, DC, July 18, 1989.

Schiermeier, F.A. Exchange of scientific and regulatory information by the Air Pollution Meteorology Panel. Presentation at the Ninth Joint Planning and Coordinating Committee Meeting of the United States/Japan Environmental Agreement, Washington, DC, May 4, 1989.

Schiermeier, F.A. Recent developments in US/USSR environmental cooperation under the Joint Committee on Environmental Protection. Interview with TASS News Agency, Washington, DC, April 18, 1989.

Schiermeier, F.A. Welcoming address and plans for Working Group research activities. Presentation at US/USSR Working Group 02.01-10 Meeting on Air Pollution Modeling, Instrumentation, and Measurement Methodology, Smithsonian Dillon-Ripley Conference Center, Washington, DC, April 17, 1989.

APPENDIX B (concluded)

Schiermeier, F.A. Overview of Atmospheric Sciences Modeling Division research programs. Presentation at the NOAA/OAR/ERL Air Resources Laboratory Program Review, Boulder, CO, March 6, 1989.

Schiermeier, F.A. Scientific and policy implications of the EPA global climate change research program. Presentation to NOAA/ERL management personnel, Boulder, CO, November 4, 1988.

APPENDIX C: WORKSHOPS

EPA Region V State/Local Modelers Workshop, Chicago, IL, October 4, 1988.

R.W. Brode
J.S. Irwin

NESCAUM Modelers Workshop, Saratoga Springs, NY, October 5-6, 1988.

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

National Air Toxics Modeling Workshop, San Francisco, CA, October 17-21, 1988.

J.S. Touma

EPA PM-10 Monitoring Task Force Meeting, Denver, CO, October 24-25, 1988.

D.A. Wilson

EPA Region III State/Local Modelers Workshop, Philadelphia, PA, November 10, 1988.

R.W. Brode
J.S. Irwin

U.S. EPA Advisory Group on Aircraft Measurements (AGAM) Workshop, Garmisch-Partenkirchen, Federal Republic of Germany, November 14-18, 1988.

J.K.S. Ching

EPA Region X State/Local Modelers Workshop, Seattle, WA, November 16, 1988.

R.W. Brode
J.S. Irwin

EPA Region IV State/Local Modelers Workshop, Research Triangle Park, NC, December 5-7, 1988.

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

APPENDIX C (continued)

U.S. EPA Advisory Group on Aircraft Measurements (AGAM) Workshop, Boston, MA, December 19-20, 1988.

J.K.S. Ching

EPA Office of Air Quality Planning and Standards, Long-Range Planning Workshop (PM-10), Burlington, NC, January 18-19, 1989.

D.A. Wilson

Joint US/USSR Working Group 02.01-10 Meeting on Air Pollution Modeling, Instrumentation, and Measurement Methodology, Washington, DC, and Research Triangle Park, NC, April 17-21, 1989.

S.G. Perry
F.A. Schiermeier

California Air Resources Board Workshop on the CALGRID Model, Sacramento, CA, April 18-19, 1989.

K.L. Schere

Workshop on the SouthEast Regional Oxidant Network (SERON), University of Alabama-Huntsville, Huntsville, AL, April 27-28, 1989.

K.L. Schere

Ninth Joint Planning and Coordinating Committee Meeting of the United States/Japan Environmental Agreement, Washington, DC, May 3-4, 1989.

F.A. Schiermeier

EPA Regional/State Modelers Workshop, Seattle, WA, May 15-19, 1989.

R.W. Brode
J.L. Dicke
M.E. Garrison
L.H. Nagler
J.S. Touma
D.B. Turner
D.A. Wilson

U.S. EPA Advisory Group on Aircraft Measurements (AGAM) Workshop, Albany, NY, May 16-17, 1989.

J.K.S. Ching

APPENDIX C (concluded)

EPA Quality Assurance-Meteorological Measurements Workshop, Research Triangle Park, NC, May 22-24, 1989.

R.W. Brode

Global Climate Change Advisory Committee Meeting, U.S. Environmental Protection Agency, Chapel Hill, NC, June 21-22, 1989.

F.S. Binkowski
J.F. Clarke
B.K. Eder

EPA Regional Office Annual Workshop, Southern Pines, NC, July 18-21, 1989.

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

NOAA/OAR Air Quality Research Workshop, Washington, DC, August 1-2, 1989.

F.A. Schiermeier

U.S. EPA Air Quality Management Workshop, Southern Pines, NC, August 20, 1989.

T.L. Clark
J.F. Clarke

U.S. EPA Advisory Group on Aircraft Measurements (AGAM) Workshop, Albany, NY, August 22-24, 1989.

J.K.S. Ching

U.S. EPA Advisory Group on Aircraft Measurements (AGAM) Workshop, Albany, NY, September 18-19, 1989.

J.K.S. Ching

APPENDIX D: VISITING SCIENTISTS

1. R.E. Britter, Lecturer
   Department of Engineering
   University of Cambridge
   Cambridge, England

Spent 1 month at the Fluid Modeling Facility under a cooperative agreement with North Carolina State University. Experiments were conducted to examine the near-source characteristics of dense-gas releases in the meteorological wind tunnel. Extensive measurements were made of plume characteristics as a function of wind speed, effluent release rate, effluent density, and physical source size.

2. L.H. Khurshudyan
   Main Geophysical Observatory
   Leningrad, USSR

   and

   I.V. Nekrasov
   Moscow State University
   Moscow, USSR

Spent 4 months at the Fluid Modeling Facility under the US/USSR Bilateral Agreement on Cooperation in the Field of Environmental Protection. Extensive wind-tunnel measurements were made of the flow structure and concentration fields resulting from sources placed within three different shapes of two-dimensional valleys, and comparisons were made with a Soviet theoretical model.

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

Spent 1 month at the Fluid Modeling Facility performing wind-tunnel studies. Previous work had confirmed the relationship between video-image intensity and vertically integrated concentration in the wakes of individual buildings. This work was extended to examine horizontally integrated concentration patterns and to include building clusters as opposed to single buildings.

4. P.J.W. Roberts, Professor
   Department of Civil Engineering
   Georgia Institute of Technology
   Atlanta, GA

Spent two 1-month periods at the Fluid Modeling Facility under a Federal Technology Transfer Agreement conducting stratified towing-tank studies to aid in the engineering design of the proposed Boston Wastewater Outfall.

APPENDIX E: ATMOSPHERIC SCIENCES MODELING DIVISION STAFF FISCAL YEAR 1989

All personnel are assigned to the U.S. Environmental Protection Agency from the National Oceanic and Atmospheric Administration, except those designated "(EPA)," who are Environmental Protection Agency employees, or "(PHS)," who are 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 Model Development 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
Kenneth Schere, Meteorologist
Alvinia Boyd, Secretary

Fluid Modeling Branch

Dr. William H. Snyder, Physical Scientist, Chief
Michael Stroud, Engineering Aid
Lewis Knight, Electronics Technician
Robert Lawson, Physical Scientist
Ralph Soller, Mechanical Engineering Technician (until December 1988)
Roger Thompson (PHS), Environmental Engineer
Anna Cook, Secretary

APPENDIX E (concluded)

Modeling Systems Analysis Branch

Joan H. Novak, Computer Systems Analyst, Chief
William Amos (EPA), Computer Programmer
O. Russell Bullock, Jr., Meteorologist
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

Global Processes Research Branch

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

Applied Modeling Research Branch

D. Bruce Turner, Meteorologist, Chief (until August 1989)
Dr. C. Bruce Baker, Meteorologist
Mark Garrison, Meteorologist (Philadelphia, PA) (until August 1989)
John Irwin, Meteorologist
Dr. Ralph Larsen (PHS), Environmental Engineer (until November 1988)
Lewis Nagler, Meteorologist (Atlanta, GA)
William Petersen, Meteorologist
Everett Quesnell, Meteorological Technician
Sylvia Coltrane, Secretary (until September 1989)

Air Policy Support Branch

James L. Dicke, Meteorologist, Chief
Thomas Braverman (EPA), Environmental Engineer
Roger Brode, Meteorologist (until August 1989)
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

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