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FISCAL YEAR 1991 SUMMARY REPORT OF NOAA ATMOSPHERIC SCIENCES MODELING DIVISION SUPPORT TO THE U.S. ENVIRONMENTAL PROTECTION AGENCY

Evelyn M. Poole-Kober
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Air Resources Laboratory
Silver Spring, Maryland
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UNITED STATES DEPARTMENT OF COMMERCE

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PREFACE

This document summarizes the Fiscal Year 1991 research and operational efforts and accomplishments of the Atmospheric Sciences Modeling Division (ASMD) working under interagency agreement EPA DW13934799-02 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, 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 F. Acronyms, publications, and other professional activities are listed in Appendixes A, B, C, D, and E.

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 1991 SUMMARY REPORT OF

NOAA ATMOSPHERIC SCIENCES MODELING DIVISION SUPPORT

TO THE U.S. ENVIRONMENTAL PROTECTION AGENCY

ABSTRACT. The Atmospheric Sciences Modeling Division provided meteorological research and operational support to the U.S. Environmental Protection Agency during FY-1991. Meteorological support consisted of the application of dispersion models, and the conduct of 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. This included development of the Regional Acid Deposition Model - Version 2.6, the Tagged Species Engineering Model, and the Asymmetrical Convective Model; examination of the effect of oxidant limitations on emission changes; publication of the Regional Oxidant Model user's guides; study of the effect of biogenic emissions on ozone concentrations; incorporation of a new method describing aerosol dynamics into the Regional Particulate Model; participation in a field study of sustained stagnation conditions; conduct of a wind tunnel study of the dispersion of dense gas jets; and a study of flow and dispersion through an urban industrial complex.

1. INTRODUCTION

In Fiscal Year 1991, 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 public and private research communities, the Division's primary efforts were studying 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 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. The Director's Office also engages in several international research exchange activities.

2.1.1 American Meteorological Society Steering Committee

Beginning in 1979, the Division established a cooperative agreement with the American Meteorological Society (AMS) to improve the scientific basis 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 Scientific Criteria for Model Evaluation

The AMS Steering Committee addressed the issue of defined objective scientific criteria with which to evaluate the performance of newly-developed regional dispersion models (oxidant, particulate, acid aerosol, and acid deposition). Committee members studied model evaluation techniques in such scientific and technical fields as weather forecasting, economics, risk assessment, nuclear releases, general circulation models, and climatology. The Committee's conclusion reinforced the commonly held belief that model evaluators must consider the ultimate needs of the user; and therefore, the evaluation criteria cannot be objectively established beforehand.

2.1.1.2 Model Revision Working Group

The AMS Steering Committee formed a Model Revision Working Group whose charter is to recommend the most appropriate formulations or modeling subsystems to simulate dispersion in flat or rolling terrain, and to indicate how these subsystems can be integrated into a model. Many of the concepts involved in improved parameterization of the planetary boundary layer are already formulated for modeling application. The Working Group will oversee the assembly of these concepts into a new or revised modeling system, and the subsequent evaluation of this modeling system using a variety of databases.

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 15 Federal government agencies, was formed in 1964 under Public Law 87-843 to provide the Executive Branch and the Congress with a coordinated, multi-agency plan for government meteorological services and for those research and development programs that directly support and improve these services. The Division Director assisted in preparing the annual Federal Plan for Meteorological Services and Supporting Research (U.S. Department of Commerce, 1991).

2.1.3 NATO/CCMS Steering Committee

The Division Director serves as the United States representative 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). A primary activity 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 19th NATO/CCMS International Technical Meeting held in Ierápetra, Crete, Greece, during September 1991, and served as session chairman. A conference summary and the proceedings will be published. The Steering Committee selected Valencia, Spain, as the site for the 20th International Technical Meeting to be held during spring 1993.

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 of scientific and regulatory research results pertaining to control of air pollution.

Under this agreement, three Japanese scientists visited the Division in September 1991 to learn about the Complex Terrain Dispersion Model and the Offshore and Coastal Dispersion Model. Plans for FY-1992 include a one-year sabbatical to the Division by a professor from the Tokyo Institute of Polytechnics to work on wake effects dispersion, and a one-month working visit by a Division scientist to the National Institute for Environmental Studies in Tsukuba, Japan.

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. There are four Projects under the Working Group 02.01-10:

Project 02.01-11: Air Pollution Modeling and Standard Setting,
Project 02.01-12: Instrumentation and Measurement Methodology,
Project 02.01-13: Remote Sensing of Atmospheric Parameters, and
Project 02.01-14: Statistical Analysis Methodology and Air Quality Trend Assessment.

Nine NOAA and EPA scientists participated in a US/USSR Symposium in Novgorod, USSR, during October 1990 and presented results of three joint roadway automotive exhaust field studies for intercomparing air pollution methods and characterizing the dispersion of volatile organic compounds from roadways. The studies were conducted in Research Triangle Park, NC (1987), Leningrad, USSR (1988), and Vilnius, Lithuania (1989). The symposium results led to improving air monitoring techniques and produced a comprehensive database for use in developing dispersion models for reactive compounds. Proceedings of the symposium will be published by the Voeikov Main Geophysical Observatory in St. Petersburg, USSR.

During March 1991, a delegation of seven Soviet scientists participated in Working Group and Project meetings at the NOAA Wave Propagation Laboratory in Boulder, CO; the EPA Environmental Monitoring Systems Laboratory in Las Vegas, NV; and the Division in Research Triangle Park, NC. Discussions were held regarding joint progress in mass spectroscopy of chemical compounds; complex terrain dispersion modeling; fluid modeling the effects of terrain irregularities on dispersion; and remote sensing of atmospheric parameters. A workshop was held on regulatory aspects of air pollution modeling at the EPA Office of Air Quality Planning and Standards in Durham, NC. A signed protocol outlined future exchanges of scientific information and planned the next Working Group Meeting and a workshop on regulatory aspects of air pollution modeling for the summer of 1992 in the Soviet Union.

FY-1991 accomplishments also included a working visit during September and October 1990 by three NOAA experts in remote sensing to the Institute of Atmospheric Optics in Tomsk, USSR; an October 1990 Project Meeting with three Soviet experts in remote sensing at the NOAA Wave Propagation Laboratory in Boulder, CO; a December 1990 visit by an EPA expert in statistical trends analysis to the Voeikov Main Geophysical Observatory in Leningrad, USSR, and a May 1991 reciprocal visit by two Soviet scientists with similar expertise to the EPA Office of Air Quality Planning and Standards in Durham, NC; and an April 1991 visit by three Soviet experts in mass spectroscopy of chemical compounds to the National Institute of Standards and Technology in Gaithersburg, MD.

Other activities included a May 1991 visit by a Soviet expert in remote sensing to the NOAA Wave Propagation Laboratory in Boulder, CO; a May through November 1991 working visit by a Soviet expert in remote sensing to the EPA Environmental Monitoring Systems Laboratory in Las Vegas, NV; a July 1991 visit by the Deputy Minister of the USSR State Committee for Environmental Protection to the Division; and a visit by the Division Director to the Voeikov Main Geophysical Observatory in Leningrad, USSR, for a meeting of the Working Group 02.01-10 Co-Chairmen.

Plans were made for an October-November 1991 working visit by three Soviet experts in remote sensing to the NOAA Wave Propagation Laboratory in Boulder, CO; a November 1991 visit by the Director of the Moscow Institute of Atmospheric Physics to the Division; a December 1991 working visit by two Soviet experts to the EPA Atmospheric Research and Exposure Assessment Laboratory in Research Triangle Park, NC, to compare monitoring methods for SO_2 and NO_2; a January-June 1992 repeat working visit by a Soviet expert in remote sensing to the EPA Environmental Monitoring Systems Laboratory in Las Vegas, NV; and a summer 1992 working visit by two Soviet experts to the Fluid Modeling Facility in Research Triangle Park, NC.

2.1.6 Eulerian Modeling Bilateral Steering Committee

The Division Director serves as the United States Co-Chairman of 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. Having coordinated the evaluation of the Canadian Acid Deposition and Oxidant Model (ADOM) and the United States Regional Acid Deposition Model (RADM) for their use in the NAPAP 1990 Integrated Assessment, the committee is now defining its future mission. One role being considered for the EMBSC is under the new United States/Canada Air Quality Agreement, signed in March 1991. Annex 2 of the agreement calls for the development and refinement of atmospheric models for determining source-receptor relationships, and transboundary transport and deposition of air pollutants.

2.1.7 National Research Council Accreditation

During FY-1991, the Division applied for accreditation under the National Academy of Science, National Research Council (NRC) Research Associateship Program. An NRC team visited Research Triangle Park during April 1991 to conduct an inspection tour of Division facilities and to interview the staff nominated as NRC research advisers. In June 1991, the Division received approval to participate in the Research Associateship Program and for eight Division scientists to serve as NRC advisers.

2.1.8 Visibility Research and Technical Support

Among the major tasks for FY-1991 were the management of several large visibility monitoring and modeling studies; visibility-related technical assistance to the EPA Office of Air Quality Planning and Standards; and interagency coordination on visibility research.

2.1.8.1 Project MOHAVE

A mandated project to estimate the frequency and magnitude of perceptible impacts of the Mohave Power Plant and other sources in the southwestern United States on visibility at such Class I Visibility-Protected Areas as the Grand Canyon resulted in developing a plan for Project MOHAVE (Measurement Of Haze And Visual Effects). A special committee of the National Academy of Sciences and more than 40 technical experts reviewed the plan.

The plan involves year-long continuous monitoring. The equipment was deployed during August 1991. During two month-long intensive study periods, perfluorocarbon tracers will be continually released at the Mohave Power Plant and monitored at each of 31 visibility-air quality monitoring sites. Using radar wind profilers, upper air monitoring will be increased to four and six locations in the study area during the winter and summer intensives, respectively. A regional meteorological deterministic model will be run for each day of the study with a resolution of 8 km during the year and a resolution of 0.5 km during intensives. Attribution of the haze levels at the receptor sites will be estimated by reconciliation of results from several independent interpretive analysis methods including deterministic air quality modeling, receptor modeling using artificial and endemic tracers, and spacial pattern (eigenvector) analysis.

2.1.8.2 IMPROVE Program

The Interagency Monitoring of PROtected Visual Environments (IMPROVE) program was designed in 1985 and initiated at 20 locations in 1987. The objective of the program is to monitor visibility in Class I Visibility Protected Areas (156 national parks and wilderness areas nationwide). Each site includes optical, particle, and scene monitoring. Non-technical field support personnel used specially designed instrumentation for the remote locations. Five agencies, the EPA, National Park Service, Bureau of Land Management, Fish and Wildlife Service, and Forest Service, oversee the operation of the program through a steering committee chaired by a NOAA meteorologist. Several agencies have adopted the instrumentation and protocols developed for IMPROVE to use in their programs, bringing the number of IMPROVE "look-a-like" sites to more than 40 in this country and nearly 60 worldwide.

During FY-1991, eight new complete IMPROVE sites were added to the program in the eastern United States. In addition, the interagency Clean Air Status and Trends NETwork (CASTNET), mandated by the Clean Air Act Amendments of 1990, adopted the IMPROVE approach for visibility monitoring to be employed at 30 sites that are planned for summer 1992.

2.1.8.3 Technical Support and Interagency Coordination

The EPA Office of Air Quality Planning and Standards required technical support for their evaluation of the visibility impact studies at the Grand Canyon to determine whether emission control equipment should be required on the Navajo Power Plant. Assistance in interpreting the results from two major studies and other measurement and modeling efforts was provided, with the result that controls were mandated. Other technical support activity included the development of regional haze research plans in response to requirements of the Clean Air Act Amendments of 1990.

To ensure cost-efficient use of federal resources for visibility research, a long-term effort was started more than ten years ago to coordinate federal programs and cooperate with private research activities where appropriate. During FY-1991, this program was responsible for the planning of and partial funding for a Regional Haze Workshop in December 1991. The workshop will develop a blueprint for timely scientific input to the Grand Canyon Visibility Transport Commission for use in addressing regional haze in the southwestern United States. The workshop participants will include scientists, policy and regulatory analysts, air quality planners, and decision-makers from environmental organizations, industry, and all levels of government.

2.2 Atmospheric Model Development Branch

The Atmospheric Model Development Branch develops, evaluates, and validates analytical and numerical models that describe the transport, dispersion, transformation, and removal of atmospheric pollutants on local, urban, and regional scales. These are comprehensive air quality modeling systems that incorporate physical and chemical processes, using state-of-science formulations.

2.2.1 Acid Deposition Studies

2.2.1.1 Regional Acid Deposition Model

The Regional Acid Deposition Model (RADM) is a comprehensive Eulerian grid modeling system with a three-dimensional transport, gas and aqueous phase chemistry, and wet and dry removal processes; with a configured domain of 15 vertical levels; and with a 35 x 38 horizontal grid with 80-km resolution. Meteorological data are provided by the Mesoscale Meteorological Model Version 4 (MM4) (Anthes et al., 1987) with Four Dimensional Data Assimilation (FDDA) (Stauffer and Seaman, 1990). The RADM system also includes several special processors, collectively known as the RADM Engineering Models (RADM/EM). The general features of regional scale deposition models are discussed by Binkowski et al. (1990). A detailed description of the RADM system is in the NAPAP State of Science and Technology Report No. 4 (Chang et al., 1990).

A more flexible version of RADM that is capable of both window and nested grid applications, using a 3/1 nesting ratio resulting in grid cell dimensions of 26.7 km, is described by Pleim et al. (1991). Dynamic boundary conditions are accomplished for one-way nesting by interpolating standard RADM concentration data along inflow boundaries of the nested domain. In this way, greater horizontal resolution simulations can be achieved without sacrificing knowledge of the larger scale environment. Window simulations are nested grids where resolution is not increased. Dynamic boundary conditions are provided for a smaller sub-domain by archived concentration data. Window simulations are useful for examining new algorithms and sensitivity studies, because a large number of runs can be made at a much reduced cost.

Another development, called the Asymmetrical Convective Model (ACM), is a new non-local closure scheme for vertical mixing in Convective Boundary Layers (CBL). This simple one-dimensional model is based on findings from CBL field studies and large-eddy simulations that show vertical transport in the CBL is inherently asymmetrical with rapid upward transport in convectively buoyant plumes and much slower downward transport in gradual subsidence. The ACM simulations were compared to large-eddy simulations of idealized test cases, applied in RADM, and compared to vertically resolved aircraft measurements. These tests along with a complete description of the model will be published.

2.2.1.2 RADM Engineering Models

For selected applications, simplification of RADM for sulfur chemistry predictions of source-receptor relationships of sulfur dioxide and its deposition in the modeling domain was required (Dennis et al., 1990b). To examine the role of simple linear gas-phase sulfur oxidation, the Linear Chemistry Model (LCM) was added to the RADM/EM family. The first three members of the RADM/EM family, the Tagged Species Engineering Model (TSEM), the Non-Depleting Model (NDM), and the Sulfate Tracking Model (STM), required input files from a RADM run to supply the necessary data fields to calculate sulfur dioxide oxidation by hydroxyl radicals in the gas phase, and by hydrogen peroxide and other oxidants in the aqueous phase. In contrast, RADM/LCM requires only meteorological and emissions information. The oxidation in the gas phase uses constant values of hydroxyl radical concentrations for daylight hours during each season and a constant nighttime value for all seasons. The cosine of the solar zenith modulates the daylight value of hydroxyl radical concentration to simulate the photochemical production of this radical. The aqueous scavenging of sulfur dioxide and sulfate is represented by a power-law approach using the precipitation rate. All aspects of RADM/LCM, apart from sulfur oxidation and precipitation scavenging, are identical to other RADM/EM members. The effect of this type of linearization can be explored directly. RADM/LCM is undergoing refinement and testing.

Other work included a direct comparison of RADM and TSEM estimates of the change in sulfate deposition for a hypothetical 50% across-the-board reduction in sulfur dioxide emissions. For three individual episodes, winter, summer, and spring cases, TSEM underpredicts this change compared to RADM by at most 1%. Because TSEM and RADM are identical, except in the way the gas-phase chemistry is simulated, the underprediction may be taken as an approximation of modeling uncertainty. The key difference between the models is the frequency of hydroxyl radical and hydrogen peroxide concentration updates. In RADM, these concentrations are updated at a variable chemical time step less than or equal to the advective time step of 10 minutes. These concentrations are then written to output files at hourly intervals. TSEM uses hourly values of hydroxyl and hydroperoxy radicals, ozone, and other species, and computes a new hydrogen peroxide concentration every advective time step. It is this smoothing of hydrogen peroxide production and loss that is taken as the explanation for the difference between RADM and TSEM.

2.2.1.3 RADM Meteorological Driver

The meteorological driver previously used by RADM, the Penn State/NCAR Mesoscale Meteorological Model 4 - Version 7 (MM4/V7) integrated with the Four-Dimensional Data-Assimilation (FDDA) algorithm, was upgraded to MM4 - Version 8 (MM4/V8). It incorporates all modifications necessary for FDDA applications using the Unix-based UNICOS command language employed by all Cray Y-MP systems. Prior to October 1, 1990, the MM4/FDDA driver ran on the CRAY X-MP supercomputer located at the National Center for Atmospheric Research (NCAR) in Boulder, CO.

To reduce the processing delays resulting from using the MM4/V8 on a remote computing system, the software system was placed on the Cray Y-MP at the North Carolina Supercomputing Center (NCSC) in Research Triangle Park, NC. A successful benchmark test at NCSC of the MM4/V8/FDDA, including the core module and run verification post-processing, showed perfect alignment with a parallel MM4/V8 application performed at NCAR. However, the on-line data storage capacity of the Cray Y-MP at NCSC is insufficient for large scale application of the MM4/V8. A data storage capacity is required for a 5-day application to proceed. NCSC is developing a peripheral data storage system similar to the Mass Storage System used for MM4 applications at NCAR. Work began on methods to reduce the data storage requirements of the MM4/V8 and to allocate the data storage capacities available to Division projects using the Cray Y-MP.

2.2.1.4 RADM Aggregation Methodology

A method of aggregating deposition fields from thirty 3-day episodic RADM simulations to produce seasonal and annual averages of acid deposition (Samson et al., 1990) was tested for its ability to reproduce annual frequency distributions of ambient concentrations of sulfate and sulfur dioxide. The 1989-1990 Acid-MODES data were used in the test. The eastern United States was partitioned into three regions by cluster analysis of ambient sulfate concentrations: a northeast transport region; a western high-source region; and a southeast low-source region. The RADM aggregation method generally showed improvement in reproducing the regional concentration frequency distributions, for both sulfate and sulfur dioxide, over a random selection of 30 episodes. The analysis of these data is continuing. The results are expected to impact the selection of cases for assessing the emission change effects on visibility using the Regional Particulate Model.

2.2.1.5 Acid Models Operational and Diagnostic Evaluation Study

The major activity in the Acid Models Operational and Diagnostic Evaluation Study (Acid-MODES) (Ching and Bowne, 1991) focused on completing the data processing and assuring the quality of the Acid-MODES field study database was adequate to meet the model evaluation requirements as described in Dennis et al. (1990a). A quality assurance synthesis report is being prepared to document the inter- and intranetwork precision of the five contributing networks to the overall study. These measurements, ending in May 1990, were obtained over a period of two years for evaluating regional acid deposition models. A description of the Acid-MODES and the other networks is found in Hansen et al. (1989). The contributing networks include the Electric Power Research Institute (EPRI) Operational Evaluation Network (OEN); the Ontario Ministry of the Environment (OME) Acid Precipitation In Ontario Study (APIOS); the Atmospheric Environment Service of Canada (AES) Canadian Air and Precipitation Monitoring Network (CAPMoN); and the Florida Electric Power Coordinating Group (FCG). Measurements at each of these sites included twenty-four-hour integrated aerometric samples that were analyzed for gaseous SO_2, HNO_3, NH_3, particulate sulfate, nitrate, and ammonium. Precipitation samples collected on a daily basis were analyzed for conductivity, pH, sulfate, nitrate, ammonium, Cl^-, Na^+, Ca^{2+}, and Mg^{2+}. Collocated sampling at the Penn State Scotia Range, PA, and at Egbert, Ontario, provided the requisite inter- and intranetwork information on precision and accuracy.

During summer 1988 and spring 1990 intensive field studies, measurements were made with specially instrumented aircraft. These experiments provided the databases for evaluating RADM and other regional models on a diagnostic basis (Dennis and Laulainen, 1988; Laulainen et al., 1990). The aircraft data from both studies were processsed (Spicer et al., 1989; Werhahn et al., 1990).

2.2.1.6 RADM Evaluation Studies

The Eulerian Modeling Evaluation Field Study (EMEFS) continued the RADM evaluation efforts following the 1990 completion of the 10-year National Acidic Precipitation Program (NAPAP) (Hansen et al., 1989; Dennis et al., 1990a). An evaluation workshop was held in July 1991. Model runs comprising Phase 1 of the RADM and ADOM (Acid Deposition and Oxidant Model) evaluation were finished, using comparisons and interpretations for the 33-day period from August 25 to September 27, 1988, and the 18-day period from July 19 to August 6, 1988. Of particular interest was testing the new model versions, RADM2.6 and ADOM2Bg, that incorporate major changes correcting for the large underprediction of sulfate noted in the NAPAP evaluation.

The improved RADM representation of the nonprecipitating cloud processes reduced the bias in the annual average SO_4^{2-} concentration from a factor of 0.6 with RADM2.1 to approximately a factor of 0.9 with RADM2.6. Predictions from RADM2.6 were compared to measurements averaged for the EMEFS evaluation period from August 25 to September 27, 1988. The original underprediction for the average over the 33-day period was eliminated for both models. Because the approach does not account for nonprecipitating clouds associated with stratiform systems, but uses a surrogate, convective-cloud, these corrections were not expected to remove the bias completely. Actually, there was little bias in the comparison.

An interpretive approach that examined design limitations of the models was used in the evaluation. Because RADM does not resolve the vertical gradients near the surface caused by rapid surface deposition and stagnant conditions, the design limitation analysis showed that a bias should be observed between model predictions and measurements taken at the surface. Preliminary results indicate that much of the SO_2 bias noted as part of the NAPAP evaluation can be explained by the design limits imposed by coarse grid resolution.

The ability of RADM to simulate vertical and horizontal spatial fields of airborne chemical concentrations was evaluated against measurements made using specially instrumented aircraft during the August 25 to September 27, 1988, Acid-MODES intensive study, following a protocol for diagnostic evaluation of RADM (Dennis and Laulainen, 1988). These studies involved simulations by RADM2.5 using 15 vertical levels and nested grid high resolution simulations with a 26.7 km grid cell size. A critical test of the zigzag-type transects (ZIPPER) and the vertical up-and-down sawtooth transects (CURTAIN) occurred during fair-weather conditions of August 31, 1988. Results of these studies show good agreement with magnitude and spatial gradient measurements. While simulation of NO_y agreed well with the measurements, NO_x concentrations were underpredicted and HNO_3 concentrations were overpredicted. The most pronounced disagreements between coarse and nested grid simulations were the greater resolution of primary species and substantial differences in ozone concentration, particularly in the Ohio Valley region. This latter result led to an in-depth analysis of ozone photochemistry in regions with large point source emissions of NO_x. These studies demonstrate the inability of Eulerian grid models to realistically simulate ozone formation in these areas and the need for subgrid reactive plume modeling. Several papers are being prepared describing comparison studies for the other measurement flights made during the 1988 campaign.

2.2.1.7 RADM Application Studies

Specific applications of RADM2.1/6 and RADM/EM provided final modeling results for the NAPAP 1990 Integrated Assessment. In FY-1991, planning for RADM applications related to mandates in the Clean Air Act Amendments of 1990 was emphasized. Studies called for in the 1990 Amendments with high priority are the effects on sulfur deposition reductions resulting from SO_2 emission allocation trading; the deposition impact of NO_x emission reduction trading for SO_2 allocations; and the feasibility of deposition standards. Application studies are planned for target loading maps of sulfur deposition for the North American negotiations with the Europeans; for nitrogen deposition and source attribution information on nitrogen deposition to the Chesapeake Bay coastal estuary; and for joint United States/Canadian studies of the effect of each nation's emission reductions on the sulfur deposition on critical effect regions and a determination of the responsibility for deposition in eastern North America.

2.2.2 Dry Deposition Studies

2.2.2.1 Inferential Model for Dry Deposition

An inferential model (Hicks et al., 1987) was used to calculate dry deposition fluxes for the National Dry Deposition Network (NDDN) sites. The program uses hourly meteorological data and weekly concentrations to calculate weekly deposition fluxes of ozone, sulfur dioxide, nitric acid, sulfate, and nitrate for 50 NDDN sites. Leaf Area Index (LAI) values are required as input to the inferential model. Initially, these were estimated from the literature; however, summer LAI was measured for all major vegetation species at each of the NDDN sites.

Analyses are being conducted to determine the precision and uncertainty of the calculated dry deposition fluxes. These include an analysis of collocated sites to determine within and between network precision; an analysis of error induced by the weekly concentration sampling protocol used by the NDDN; and an analysis of the inferential model approach using direct dry deposition measurements. A cooperative effort is underway with the Atmospheric Environment Service of Canada to compare the NDDN method for estimating dry deposition fluxes with a Canadian approach.

NDDN site characteristics--vegetation, meteorology, and pollutant concentration--may not be representative of the larger surrounding area; consequently, site deposition fluxes may not represent regional fluxes. A program was initiated at the Atmospheric Turbulence and Diffusion Division, Oak Ridge, TN, to characterize the potential bias of each of the NDDN sites to a larger (80 km to 100 km) surrounding area. The study will address the effects of land use, vegetation, and terrain on the spatial variability of deposition fluxes. Land use and vegetation activity are derived from high-resolution (1 km) satellite observations. Deposition velocities are calculated on an hourly basis for each 1-km grid point and adjusted for terrain features. Weekly mean and standard deviation of deposition fluxes will be determined for the larger area, and site values related to these statistics. Dry deposition fluxes are available for FY-1990. Fluxes for 1986 through 1991 will be available in 1992.

2.2.2.2 Direct Dry Deposition Measurement Program

A transportable dry deposition measurement system is being developed to evaluate the accuracy of the inferential model at specific NDDN sites. The system will have the capability for eddy correlation measurements of meteorological fluxes; for ozone and sulfur dioxide dry deposition fluxes; and for gradient measurements of nitric acid and sulfur dioxide fluxes. The system is expected to be completed by summer and deployed to selected NDDN sites for three to four weeks in FY-1993 and FY-1994.

2.2.3 Cloud Modeling and Processes Studies

Under a Cooperative Agreement with the University of North Dakota, two field studies designed to investigate the transport and entrainment processes of convective clouds were planned. In the first study, tracer released in the vicinity of clouds was tracked using a Citation jet, specially equipped with an atmospheric sampling system and a unique pointer system to provide air parcel position change information on a real time basis. Thus, the tracking aircraft can return to the "same" air parcel for repeated sampling. The experiments, conducted in central Illinois on 13 separate days, provided information on cloud top entrainment and detrainment processes, mass flux through the anvil of thunderstorms, and vertical exchange at the base of these clouds. This study provided strong evidence that cloud top and cloud sidewall entrainment processes are coupled; thus, rising air parcels at the top of growing cumuli complete their circulation back into the sides of the cloud element. Preliminary results from the first study were presented at the Seventh Joint Conference on Applications of Air Pollution Meteorology in January 1991 in New Orleans, LA.

The second field study is scheduled for spring 1992. The experiment will examine the flow-through-rates of chemical conversion in the aqueous phase of clouds induced by the onshore breeze circulation along the shoreline of the Great Lakes and the debris from evaporating clouds.

The NOAA GOES satellite data and concurrent National Weather Service (NWS) composite radar data, gridded on the same base coordinate system for the Continental United States, were collected each hour for nine months during the period from August 1988 to May 1990. Both sets of data were gridded and composited onto the same domain. The cloud and precipitation data were converted into false colored images and serials using specialized visualization software. Then the composited radar-satellite imagery was compared to the cloud and precipitation fields predicted by the MM4/FDDA and the resulting performance diagnosed. The continuing diagnostic analyses will evaluate the meteorological processor's ability to simulate the joint precipitation and cloud coverage fields over time, for different months of the year, and for a wide range of synoptic weather conditions.

2.2.4 Photochemical Modeling

2.2.4.1 Regional Oxidant Model

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 over regional scale (1000 km) areas of the 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. The focus of the ROM program during FY-1991 was the development of the next operational version, ROM2.2, and its application to the eastern United States. Advances and efficiencies in the computational structure have allowed ROM to be applied on a CRAY supercomputer; thus, making possible an expanded computational domain.

Also, the ROM research program focused on the sensitivity of simulated ozone concentrations to the uncertainty in natural source emission estimates; the generation of regional wind fields; and advanced computational techniques.

Additionally, progress was made on a two-year program to upgrade the Urban Airshed Model (UAM) system.

2.2.4.2 Development and Testing of ROM2.2

In preparation for additional model application projects, including support for the Clean Air Act Amendments of 1990 mandates, work continued on a new set of enhancements to the second generation ROM system. The updated system, ROM2.2, includes several major changes to the meteorological processes. First, the well-mixed boundary layer is allowed to develop to a fully extended state over a 3- to 4-h period beginning at sunrise. Previously, a fully mixed boundary layer became established shortly after sunrise. Second, the wind flow in the first model layer during nighttime inversion periods is calculated using ROM's standard diagnostic wind field interpolation scheme (P11). The prognostic meteorological model formerly used to predict the wind flows in the inversion layer was shown to consistently introduce bias in the wind fields, and its use was discontinued. The diagnostic interpolation technique used in P11 was modified to allow calculation of wind fields within the expanded ROM domain in the eastern United States (superdomain). Third, the turbulence representation over urban areas and the vertical cumulus cloud flux parameterizations were modified.

Other changes incorporated into ROM2.2 include the ability to initialize the ROM simulations at midnight (instead of noon); an upgrade to the Biogenic Emissions Inventory System (BEIS) with a new solar radiation algorithm; revision of rate constants for the PAN production and destruction reactions; and integration of the β-matrix calculations into the core model in anticipation of CRAY supercomputer ROM applications. New tracer species were added to the model to track the influence of initial and boundary conditions separately throughout a model simulation. Because of the increased size of the superdomain over previous ROM domains of application, concentrations of all species at all boundaries will be assumed to exist at clean tropospheric levels. The first simulations with ROM2.2 for the eastern United States will begin in FY-1992.

Work was also initiated to complete the development of ROM's layer 0, a shallow diagnostic surface layer of 10-30 m deep. The estimates of trace species concentrations in this layer will account for the heterogeneity in emission distribution within a layer 0 grid cell.

2.2.4.3 Sensitivity of Regional Ozone Modeling to Biogenic Hydrocarbons

Research for assessing the effects of biogenic hydrocarbon emissions on the formation of regional scale ozone continued. The research focus was on a study that examined the sensitivity of regional ozone (O_3) modeling in the northeastern United States to uncertainties in biogenic emission estimates (Roselle, 1991). This study included an analysis of results from several ROM simulations, where maximum predicted concentrations of selected pollutants over a 15-day simulation period were compared between each simulation. Biogenic emissions of hydrocarbons were decreased and increased by a factor of

3 to account for the existing range of uncertainty in these emissions. This produced dramatic changes in predicted hydrocarbon concentrations and caused predicted O_3 to change significantly, depending upon the availability of NO_x.

Two emission control strategies were examined in the study. One strategy called for a reduction in anthropogenic hydrocarbon emissions, while the other called for reductions in both anthropogenic hydrocarbon and NO_x emissions. Simulations showed that control of only hydrocarbon emissions was more beneficial to the New York City Metropolitan Area, while the combination of NO_x and hydrocarbon controls was more beneficial to the other areas of the northeastern United States. The effectiveness of each control strategy varied across the range of uncertainty in biogenic emissions. The effectiveness of the hydrocarbon controls increased as the level of biogenic emissions decreased, whereas the effectiveness of the combined strategy of NO_x and hydrocarbon controls increased as the level of biogenic emissions increased. These results demonstrate that uncertainties in biogenic emissions could lead to significant errors in O_3 predictions and possibly to a choice of a less effective control strategy. The analysis is being expanded to include comparisons of simulation results on both daily and hourly basis. This study will be completed in FY-1992.

2.2.4.4 Evaluation of ROM

Two separate operational evaluations of ROM were conducted as part of the biogenic sensitivity studies of the northeastern United States. The first evaluation focused on a four-day period in July 1980 (Roselle et al., 1991). This evaluation compared spatial plots of predicted daily maximum O_3 concentrations with actual observations. The evaluation showed that the model performed well in predicting the O_3 plume orientation, spatial extent, and concentration magnitudes. This evaluation did note, however, that the highest peak O_3 concentrations and rural O_3 concentrations were underpredicted by ROM.

The second operational evaluation (Roselle, 1991) focused on a 13-day period in July 1988 that included several days of very high observed O_3 concentrations. The evaluation consisted of comparisons of episodic O_3 data, daily maximum O_3 data, spatial plots of the maximum O_3 over a several-day period, and hourly O_3 data (time series analysis). The evaluation indicated that ROM has a tendency to underpredict O_3 when observed concentrations were above 70 ppb, and to overpredict O_3 when concentrations were below this value. On average, the model underpredicted O_3 by 14 ppb. Spatial plots comparing observations to predictions showed that the model did well in predicting spatial O_3 patterns and plume locations. Analysis of time series data showed that the model simulated the diurnal variations in O_3 better in urban areas than in rural areas. The model generally underpredicted daytime concentrations and overpredicted nighttime values. Also, the time series analysis indicated that the model predictions tended to lag observed values by 2 to 7 hours.

Planning for two other model evaluation projects was begun. One project will use the Cross Appalachian Tracer EXperiment (CAPTEX) database to evaluate the transport and dispersion components of ROM. Meteorological data processing for ROM for the tracer release and sampling periods from fall 1983 was begun, and the extent of the Northeast ROM domain was expanded to include the Dayton, OH, and Sudbury, Ontario, release points. Model runs, using a version of ROM with the chemistry switched off, will be conducted during FY-1992. The other project will intercompare ROM, RADM, and the Aeronomy Laboratory NOAA Oxidant Model (NOM). A series of runs with each model was proposed to compare the behavior of the models with each other using the field database from July 20 to August 6, 1988, for the eastern United States. ROM meteorological data processing for this period was begun.

2.2.4.5 A Nested Regional Oxidant and Urban Airshed Modeling Framework

The one-way, external nesting approaches contained in the ROM-UAM interface package generate input data files for the fine grid urban model based on the processed output files from the coarse grid regional model system (Godowitch and Schere, 1989). The computer software and documentation (Tang et al., 1990) represent an integral part of the UAM system, the photochemical grid model recommended for urban ozone regulatory applications. The interface programs must be used with a select set of data files retrieved from the ROM database containing gridded fields of predicted concentrations for initial and boundary conditions; winds and other relevant meteorological parameters; biogenic emissions; and surface geophysical parameters. The development of the software for this nesting effort was part of the Regional Ozone Modeling for NorthEast Transport (ROMNET) program (Possiel et al., 1991a). The interface package is operational and can be applied to urban domains situated in the northeastern United States.

Additional test simulations of UAM using data files generated by the interface programs were conducted in collaboration with the New York State Department of Environmental Conservation (Sistla et al., 1991). A sensitivity study was undertaken to assess the range of variation in peak ozone concentration between a base case and test cases consisting of a variation in a single process, input parameter, or model feature. Test simulations were performed with and without dry deposition, with and without biogenic emissions, single level and multiple level wind fields, and variations in the number of vertical UAM levels. The magnitude of peak ozone changes in some sensitivity test simulations was comparable to previous UAM results obtained from emission control strategy reduction scenarios. Refinement of some interface programs was performed based on test results and feedback from model users.

2.2.4.6 Development of Wind Fields for ROM

Research on the generation of wind fields for use with ROM continued, with several different methods being explored. During the testing of ROM2.2 on the expanded eastern United States model domain, the existing diagnostic interpolation technique using Fourier analysis of wind observations performed worse than it did with ROM's smaller domain. An alternate method using Barnes' (1973) interpolation techniques followed by a divergence-minimization step performed much better on the ROM superdomain. ROM2.2 wind fields will be generated for eastern United States applications using this technique.

Work was also started on adapting the meteorological outputs from the NCAR/Penn State Mesoscale Meteorological Model (MM4) (Anthes et al., 1987) to the ROM meteorological processing system (Alapaty et al., 1991). In the first phase of the work, hourly profiles of data for each vertical column of MM4 grid cells will be provided to the ROM system as quasi-observational data. During FY-1992, differences in the ROM wind fields generated by the MM4 data and by NWS observational data will be examined, along with the subsequent differences in ROM simulation results.

Work continued on exploring the generation of probabilistic wind fields for use in ROM simulations. In this technique, ensembles of possible wind fields are created that conform to the physical laws of momentum and energy conservation and that 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 journal article describing this work is in preparation.

2.2.4.7 Development of Optimized ROM Version for Supercomputing Applications

ROM and other large regional-scale Eulerian models require extensive computational resources. As the available speed and efficiency of computer platforms increase, so does the ability to resolve the scientific processes within the model and the spatial granularity of model estimates. The ROM core model code was transferred to the CRAY Y-MP supercomputer at the North Carolina Supercomputing Center (NCSC) for adaptation to that platform. Computer scientists worked to optimize the ROM code in the CRAY vectorized environment and to split the chemistry calculations in a parallel mode across the four central processing units (CPUs) available on the CRAY. The optimization work was successful; for a one-day simulation of the northeastern United States the ROM CPU usage dropped from 117 min to 24.5 min, and the elapsed wall-clock time dropped from 118.8 min to 8.8 min. These efficiencies were made with no loss of accuracy in model results. As a result, extensive ROM applications are planned on the CRAY Y-MP at NCSC for the expanded ROM superdomain covering the eastern United States during FY-1992.

2.2.4.8 Development of an Improved Urban Airshed Modeling System

The development effort that commenced during FY-1990 proceeded with emphasis on upgrading scientific components and computer algorithms of the Urban Airshed Model (UAM) and processor system (Morris and Myers, 1990). UAM is a photochemical grid model for urban ozone regulatory applications. An efficient, comprehensive meteorological processor program, designed to replace the existing outdated set of individual UAM processor programs, was developed for generating multiple meteorological data files.

The technical approaches incorporated into the meteorological processor rely on routine surface and upper air meteorological observations and surface geophysical data. The techniques include a diagnostic wind module for deriving 3-D wind fields; a surface energy budget module for generating micrometeorological parameters; an urban boundary layer height module for estimating spatially variable nocturnal urban mixing heights; an updated dry deposition module for computing hourly gridded pollutant deposition velocities; an improved methodology for determining multiple photolytic rates for the Carbon Bond IV chemical mechanism in UAM; and a vertical eddy coefficient scheme that existed in the UAM model code. Retrieval preprocessor programs were developed to access routinely-archived meteorological databases and to prepare input data files. The UAM point source emission processor was revised to allow plume emissions to be injected into multiple model layers. The UAM code was updated and restructured to read the new input files generated. Rigorous testing with UAM is being conducted to assess the impact on ozone concentrations from the revised methods used to determine the various model input parameters. An evaluation of this updated UAM system with intensive data from the Southern California Air Quality Study (SCAQS) will be performed.

2.2.5 Aerosol Modeling Program

The program objective is to develop and evaluate state-of-science atmospheric modeling systems that incorporate the physical and chemical processes important for predicting ambient concentrations and deposition of aerosols, including emissions, transport, chemistry, and removal on urban and regional scales. The modeling tools are used to assist in promulgating air quality standards for fine particles, visibility, and acid aerosols.

2.2.5.1 Regional Fine-Particle Field Study

From July 1988 to June 1990, a network of 35 cyclonic-separator samplers were operated with a size cut approximating 2.5 μm. At each sampling site, collocated with an Acid-MODES site, 24-hour air concentrations of fine particle, sulfur, calcium, magnesium, chlorine, and other elements were obtained from approximately 12,000 filters via gravimetric or XRF analyses. The protocols and results of initial analyses are summarized by Bennett and Stockburger (1991). These data will provide the bases for (1) evaluating regional models for fine-particle concentrations and (2) estimating upwind boundary conditions for urban particle models. Statistical and physical analyses are planned for FY-1992.

2.2.5.2 Regional Particulate Modeling

Work in regional particulate modeling involved updating and testing the Model for an Aerosol Reacting System (MARS) (Saxena et al., 1986) and incorporating the Modal Aerosol Dynamics (MAD) model in the Regional Particulate Model (RPM). MARS, a model for determining the chemical constituents of the aerosol, was updated to include new values of equilibrium constants, binary activity coefficients, and enhanced numerical algorithms for solving the mathematical equations. The importance of an accurate ammonia emission inventory for MARS was demonstrated by a study of the sensitivity of aerosol inorganic chemistry to ammonia emissions. The sensitivity testing results for a regional-scale modeling application were presented at an international scientific symposium (Bullock, 1990).

The introduction of MAD complements the development of MARS. The MAD model (Whitby et al., 1991) represents aerosol size by two log-normal distributions, and incorporates the method of moments using the zeroth, third, and sixth moment of the aerosol number distribution into rate equations. The equations account for growth, shrinkage, and coagulation of the aerosols. The model contains a technique for the estimation of dry deposition fluxes for particulate matter and accounts for the particle-size-dependent effects. A modified version that treats the sulfate aerosol as sulfuric acid was prepared. The algorithm for adding and removing liquid water to and from the aerosol in response to relative humidity uses the water activity of an aqueous solution of sulfuric acid. This same algorithm is being expanded to include other volatile species besides water. After completion of this preliminary work, the entire aerosol dynamics model will be incorporated into RADM. This work will be completed and tested in FY-1992.

2.2.6 Boundary-Layer Diffusion Research

A journal article is being written that discusses data analyses and conclusions derived from the convective diffusion field experiment CONDORS (CONvective Diffusion Observed with Remote Sensors)(Eberhard et al., 1988). The article includes 150 figures showing the behaviors of several dozen meteorological and diffusion variables. The results include field-based convective scaling parameterizations of vertical and lateral diffusion with source height and averaging time effects. Strong evidence supports laboratory physical models of vertical diffusion in convective turbulence that are different from standard Gaussian plume models.

An initiative for development of models for diffusion in stagnation conditions began with planning and participating in the STAGMAP field experiment in Medford, OR, during January 15-21, 1991. The experiment focused on testing non-stagnation models for predicting PM-10 concentrations in stagnation (low wind, very stable) conditions. This included measured releases of tracer gases every 6 or 9 hours. Satellite photos of pooled, valley fog in the Medford region during intense stagnation conditions were obtained from the National Environmental Satellite Data and Information Service. Profiles of meteorological variables within the valley layer up to 700 m AGL were obtained using tethersondes. The stagnation meteorology experiment, with its complex, terrain-driven flows resulting from uneven heating and cooling of slopes, cool air pooling, and dense, freezing fog, should facilitate development of more realistic models for diffusion in such extraordinary conditions.

2.2.7 Toxic Deposition to the Great Waters

Title III of the Clean Air Act Amendments of 1990 requires an assessment of the annual atmospheric deposition of toxic substances to the "Great Waters" that consist of the Great Lakes, the Chesapeake Bay, Lake Champlain, and coastal waters (U.S. Congress, 1990). This includes identification of the sources and assessment of their relative contributions.

2.2.7.1 **Airborne Toxic Deposition Studies**

An interim modeling effort was initiated to develop a comprehensive toxic deposition model. The objective is to calculate annual atmospheric loadings to the Great Waters using preliminary estimates of United States and Canadian toxic emissions and knowledge of the atmospheric processes and process rates.

In a cooperative effort with the EPA Regions III and V, the REgional Lagrangian Model of Air Pollution (RELMAP) is being adapted to simulate the atmospheric deposition of toxic substances to the Chesapeake Bay and Great Lakes. In this effort, it is assumed that the toxic substances are chemically inert and deposited at rates based on published physical attributes (i.e., Henry's Law coefficients, liquid-phase vapor pressures, and phase partitioning ratios, etc.) and empirical data (e.g., precipitation chemistry analyses). In addition to estimating the atmospheric deposition of 18 toxic substances, the model will rank relative contributions from individual unit-degree (latitude and longitude) source cells.

2.2.7.2 **Chesapeake Bay Evaluation and Deposition Committee**

In February 1991, in cooperation with the EPA Region III, the Chesapeake Bay Evaluation and Deposition (CBED) Committee was created to articulate and satisfy the atmospheric research and model needs pertaining to the ecology of the Chesapeake Bay. The focus of the Committee is on the atmospheric deposition of nitrogen and toxic substances. The Committee recommended and assigned priorities to a list of tasks. A high-priority task computationally linking RADM with bay water quality models was started.

Another task comparing available calculations of atmospheric nitrogen deposition to the bay was completed. An estimate of the atmospheric deposition is required for the development of emission control strategies. The Fisher et al. (1988) approach assumed that the nitrate wet deposition at the nearest National Acid Deposition Program site was representative of the entire bay surface and that dry deposition was equal to wet deposition. Another approach spatially integrated annually aggregated RADM dry and wet deposition calculations of nitrate for the bay surface. RADM-calculated nitrate deposition (8.47 million kg N/yr) was similar to the NADP estimate (8.3 million kg N/yr), but indicated that dry deposition dominated wet deposition (53.5% vs. 46.5% of the total).

2.2.8 Technical Support

2.2.8.1 **European Monitoring and Evaluation Program**

A Division scientist serves as the United States representative to the European Monitoring and Evaluation Program (EMEP) Steering Body that oversees the cooperative program for monitoring and evaluating long-range transmission of air pollutants in Europe. The primary goal of EMEP is to use regional air quality models to produce assessments regarding the influence of one country's emissions on another country's air concentrations or deposition. The United

States and Canadian representatives report on North American activities related to long-range transport. The scientist also evaluates European studies of special relevance to the program providing technical critiques of the EMEP work during informal and formal interactions; and developing and coordinating such programs with EMEP as the modeling studies of the Norwegians' Modeling Synthesizing Center-West (MSC-W).

2.2.8.2 Consortium for Advanced Modeling of Regional Air Quality

A Division scientist serves as the representative to the Consortium for Advanced Modeling of Regional Air Quality (CAMRAQ). This consortium is composed of representatives from the Electric Power Research Institute; American Petroleum Institute; Pacific Gas & Electric; California Air Resources Board; Department of Energy; National Oceanic and Atmospheric Administration; Environmental Protection Agency; Department of Defense; Defense Nuclear Agency; Atmospheric Environment Service of Canada; Ontario Ministry of the Environment; and EUROpean experiment on the TRAnsport and transformation of environmentally relevant trace Constituents in the troposphere over Europe. The CAMRAQ members share a mutual interest in making regional-scale atmospheric models usable tools for air quality and emergency response planning. The members agreed that forming a consortium to coordinate research and form a basis for collaboration on projects will enhance the ability of each to achieve respective goals regarding atmospheric modeling.

2.2.8.3 Regional Ozone Modeling for the NorthEast Transport

ROMNET was a major 3-year (FY-1988 through FY-1990) program that used 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. Final documentation (Possiel et al., 1991a,b) of the program was published. It was found that reductions in anthropogenic emissions along the entire Northeast Corridor may be necessary to reduce ozone levels below the national air quality standard (NAAQS). These emission reductions must include VOC and NO_x controls, although care must be exercised that NO_x controls are not locally counterproductive at reducing ozone. It was also found that the type of control measures and the degree of emission reductions necessary to reduce ozone below the NAAQS may vary among Corridor cities. Finally, it was found that the control technologies needed to achieve the emission reductions necessary to reduce ozone concentrations below the NAAQS in the northeastern United States are not available. The report urges that priority be given to developing such technologies.

The Clean Air Act Amendments of 1990 mandated the management of ozone air quality within some specific regional transport corridors, including the Northeast Corridor. An Ozone Transport Commission (OTC) was created to oversee air quality management within this Corridor. An OTC Modeling Committee was formed for providing regional modeling guidance regarding the potential effects of regional emission control strategies for ozone within the northeastern United States. A member of the ROM research staff was selected for membership on the OTC Modeling Committee.

2.2.8.4 Modeling Advisory Committee

The California Air Resources Board (CARB) initiated a Modeling Center within its Technical Support Group in Sacramento. The purpose is to coordinate all regulatory air quality modeling activities within the State and 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 CARB officials for fixed terms of membership. One representative from the Division is serving a 3-year term on the MAC.

2.2.8.5 Southern Oxidant Study

FY-1991 was the first year of the multiyear Southern Oxidant Study (SOS), a major field and modeling project concerned with the generation and control of ozone and photochemical processes in the southeastern United States. A consortium of Southeastern universities is coordinating the study. Division personnel are involved in providing technical leadership on aspects of air quality simulation modeling and emission inventory development and project officer assistance on various cooperative agreements. During the summer of 1991, major field intensives were conducted throughout the Southeast using regional scale monitoring networks for ozone, nitrogen, and hydrocarbon chemical species. Plans were set for an Atlanta, GA, urban-scale field intensive for the summer of 1992. A model coordination group was formed to guide the air quality modeling for the urban and regional portions of SOS. Several members of the Division are playing key roles in the modeling studies and coordination.

2.2.8.6 Eulerian Model Evaluation Field Study Program

The Eulerian Model Evaluation Field Study (EMEFS) program is a multiagency program for obtaining a database and evaluating regional scale acid deposition models, including RADM and ADOM. Contributors to this program include the Acid-MODES study; the Electric Power Research Institute Operational Evaluation Network; the Canadian Atmospheric Environment Service Canadian Air Pollution Monitoring Network; the Ontario Ministry of Environment Acid Precipitation In Ontario Study; and the Florida Coordinating Group Florida Acid Precipitation program. The Program Management Group (PMG), which oversees the project, consists of sponsor representatives and includes four teams: the Operations Measurements Team (OMT); the Diagnostic Measurements Team (DMT); the Emissions Inventory Team (EIT); and the Model Evaluation Team (MET). DMT and MET are chaired by Division scientists.

DMT developed the experimental design and quality assurance plans and conducted the data collection program of aircraft and special enhanced chemistry studies during summer 1988 and spring 1990 intensive field studies. DMT produced a high quality diagnostic model evaluation database for both intensive field studies. Targeted model versus observation comparisons are underway. MET developed the evaluation protocols used in the evaluation of RADM and ADOM for the NAPAP 1990 Integrated Assessment.

2.2.8.7 Interagency Work Group on Air Quality Models

Federal Land Managers from the Park Service, Forest Service, and Fish and Wildlife Service desire guidance in assessing the impact of new pollutant sources on Air Quality Related Values (AQRV). These include visibility and wet and dry deposition in Class I areas. Consequently, these Federal agencies and the U.S. Environmental Protection Agency agreed to a Memorandum Of Understanding (MOU) covering activities leading to recommendations for air quality models to use as policy tools in assessing the impact of new source permitting. Models will be nominated for review and databases selected for performance and diagnostic evaluation. The models will focus on the AQRV prediction for the Shenandoah National Park. The models will be regional in scale with transport times of one day or more, and must have the capability to predict both regional haze and plume blight.

2.2.8.8 National Acid Precipitation Assessment Program

A Division scientist served as chairman of NAPAP Task Group III, Atmospheric Transport and Modeling. This group completed the atmospheric processes component of the State of Science and Technology (SOS/T) reports for the NAPAP 1990 Integrated Assessment. The reports describe the use of major scenarios of future emission changes and RADM deposition and air quality predictions and analyses. The SOS/T reports included State of Science and Technology Reports No. 3 (Binkowski et al., 1990); No. 4 (Chang et al., 1990); No. 5 Part I (Dennis et al., 1990a); and No. 5 Part II (Dennis et al., 1990b).

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, around such obstacles as buildings, and within dense gas plumes. 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 deep. 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, the towing tank is used for simulation of strongly stable flow and salt water of variable concentration is used to establish density gradients in the tank. 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 flow and dispersion under convective conditions.

2.3.1 Concentration Fluctuations in Plumes

Under a subcontract with the Los Alamos National Laboratory, a wind-tunnel study was conducted to characterize the mean and fluctuating concentration fields in a plume originating from a point source in a simulated atmospheric boundary layer. Smoke was used as a tracer for plume visualization studies and ethane was used for quantitative concentration measurements. The ultimate goal was to determine statistics of concentration fluctuations in a general way that might be useful in the development of air quality models. The experiments were somewhat exploratory in nature since two new techniques, quantitative video image analysis (Lee et al., 1991) and fast-response hydrocarbon tracer analysis, were used to examine concentration fluctuations.

The experiments consisted of four distinct phases. In the first phase, the simulated boundary layer was characterized in terms of its mean velocity and turbulence structure. The velocity time-series data were recorded for analysis of the spatial and temporal scales of turbulent motions.

In the second phase, plume visualization studies were conducted using smoke as a tracer. Data were recorded simultaneously by both side-view and top-view video cameras for a variety of source heights and wind speeds. Based on these data, a set of parameters was chosen for the subsequent quantitative tracer measurements.

In the third phase, an ethane/air mixture was substituted for the smoke and the time-averaged concentration field was measured at two locations downstream of an elevated source. When integrated vertically or laterally, these concentration profiles provided the basic data that could be used to calibrate the video system in terms of line-integrated concentration.

In the last phase, a fast-response flame ionization detector (HFID) was applied to the measurement of concentration fluctuations at selected points for the same conditions as in phase three. Besides the concentration variance profiles obtained with the HFID, many concentration time-series were recorded for later analysis.

A data report (Lawson, 1990) was compiled that describes the apparatus and instrumentation used to acquire the data, the experimental procedures and techniques used during collection and processing of the data, and detailed listings and graphical summaries of the data set.

2.3.2 Building Amplification Factors

Last year, an extensive set of measurements of concentrations from point sources located near rectangular buildings was collected in a wind-tunnel study. Four rectangular building shapes were used with the point source located upwind, above, and downwind of each building. Concentrations were measured on the building surfaces and at ground level. Building amplification factors (the ratio of maximum concentration in the presence of the building to the maximum observed from an identical source in flat terrain) and the locations of the maximum concentrations were computed and tabulated in an in-house data report (Thompson, 1991). The data report was sent to the Main Geophysical Observatory, St. Petersburg, USSR, for use in the planning of a joint US/USSR research effort scheduled for FY-1992.

A subset of the database containing the results for sources located on and above the building top were included in a presentation at the June 1991 American Society of Heating, Refrigeration and Air-Conditioning Engineers Summer Meeting in Indianapolis, IN. The design of stacks for the release of laboratory exhaust to avoid uptake of the exhausted gases into building air ducts and to avoid excessive ground-level concentrations was addressed. A journal article presenting the complete data set and comparing the results with available field and laboratory data is being prepared.

2.3.3 Dense-Gas Jets

A wind tunnel study was performed to examine the dispersion characteristics of gas jets with densities heavier than that of air. An example might be the rupture of a relief valve on a propane storage tank. The experiments provided a data set for the development and evaluation of dense-gas dispersion models. Dense-gas jets were emitted into laminar cross flows, then repeated in a simulated atmospheric boundary layer. Major boundary layer characteristics were measured and compared favorably with corresponding field data. Jet dispersion was investigated photographically and by concentration measurements. Maximum plume rise and plume touch down positions and concentrations at these locations were determined and compared with corresponding results from earlier studies. The most remarkable differences were found in the large densimetric Froude number range, which is characteristic of jets emerging from release valves of pressurized storage tanks. Some measurements were also made of the fluctuating concentrations within the dense-gas plumes and of releases within the vicinity of buildings. The results were compiled into data reports (Schatzmann et al, 1991a; Snyder et al., 1991a), and a brief paper on the project was presented at a conference (Schatzmann et al., 1991b). Further papers are in preparation. Under a Cooperative Agreement with North Carolina State University, Raleigh, NC, this research was done in collaboration with a visiting German scientist.

2.3.4 Dispersion Through Building Arrays

A wind-tunnel study was conducted on the flow structure and dispersion of pollutants through arrays of cubical blocks that might simulate urban or industrial complexes. This work was conducted in collaboration with a visiting scientist from the University of Cambridge, England, who was supported through a grant from the United Kingdom Ministry of Defence. The purpose was to further understanding of the fundamental problem of dispersion through groups of obstacles and to provide a data set for the development and evaluation of mathematical models treating dispersion through building clusters. Two building arrays were constructed of cubical blocks placed in regular matrices: an aligned array and a staggered array. Extensive measurements were made of the mean and fluctuating flow fields between the blocks using hot-wire and pulsed-wire anemometry. Mean and fluctuating concentration fields were measured using flame-ionization detectors. The measurements were compiled into a data report (Snyder et al., 1991b) and a paper is in preparation.

2.3.5 Area Source Study

Upon a request from the EPA Office of Air Quality Planning and Standards, a wind-tunnel simulation of dispersion from area sources was conducted. The purpose was to provide a data set for the evaluation of a recently modified area-source dispersion algorithm for modeling releases at Superfund sites. The basic goal was to provide a data set characterizing the concentration fields downwind of area sources. These tests included

(a) two types of source geometry -- a 3:1 rectangle with three wind orientations (0°, 45°, and 90°), and a circle;

(b) two different surface roughnesses; and

(c) three wind speeds.

The tests also included measurements of the concentration fields downwind of a ground-level point source for comparison with the area source plumes. A data report was compiled (Snyder, 1991) that describes the experimental setup and instrumentation, the procedures and techniques used in collecting and processing of the data, detailed listings and graphical presentations of the data, and a cursory analysis of the data, primarily examining basic trends and internal consistencies.

2.3.6 Building in Stratified Flow

Laboratory studies of the flow structure in the wake of three-dimensional obstacles were conducted to ascertain the effects of stable stratification. Experiments were performed in the stratified towing tank to determine the shape and extent of the wake and separation bubble around square flat plates and cubical building models. The dependence of the wake structure on Reynolds and Froude numbers was studied by releasing effluent from ground level immediately downwind of the cubical building and measuring concentration patterns on the building surfaces as well as downstream. Experiments were also conducted in the meteorological wind tunnel where the building was submerged in a deep simulated atmospheric boundary layer; these results were contrasted with the results from the towing-tank experiments where the approach flow was nearly uniform and nonturbulent. The Reynolds-number tests (in neutral flows) suggested that a Reynolds number above about 11,000 is required for Reynolds-number independence when the approach flow is essentially uniform and nonturbulent; when the approach flow is highly sheared and turbulent, this minimum is reduced to about 4,000. The stratified flow experiments suggested that the flow structure is independent of stratification when the Froude number exceeds about 2.5. These results suggest that stratification in the full-scale atmosphere must be very strong to affect the flow structure near buildings. A paper reporting the results of this work will be prepared in FY-1992.

2.4 Modeling Systems Analysis Branch

The Modeling Systems Analysis Branch supports the Division by providing 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 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

ROM2.1 applications drew to a close and ROM2.2 production began. For the Regional Ozone Modeling of NorthEast Transport (ROMNET) program, ROM2.1 simulated more than 25 different emission control strategies and the results are summarized in a comprehensive report (Possiel et al., 1991a,b).

ROM, consisting of a four volume user's guide (Milich et al., 1991a,b; Young et al., 1991; and Hallyburton et al., 1991) and 19 magnetic tapes, was released to the public during 1991. The code, specifically designed to run on a system of VAX and IBM mainframe computers, requires 9.5 h of CPU time to run the core model on an IBM 3090 and 12 h of CPU time to run the preprocessors on a VAX 8650 for a typical 3-day simulation of the northeastern United States.

Transferring the ROM code to the CRAY Y-MP supercomputer at the North Carolina Supercomputer Center reduced CPU time for a 3-day simulation from 9.5 h on an IBM 3090 to 22 min on the CRAY Y-MP. The savings in CPU time will allow greater flexibility in making ROM simulations to support regulatory needs resulting from the Clean Air Act Amendments of 1990.

2.4.2 Natural Emissions

A personal computer version of the Biogenic Emissions Inventory System (BEIS) was developed (Pierce, 1990). A description of PC-BEIS was published (Pierce and Waldruff, 1991). PC-BEIS enables state air pollution agencies to develop biogenic emission inventories for any county in the contiguous United States and calculates hourly fluxes of isoprene, monoterpenes, and other unspeciated nonmethane organic hydrocarbons.

Research on natural emissions continued in several areas. A technique was developed that uses detected lightning strike data to generate hourly and spatially resolved estimates of lightning-generated NO_x emissions. A video was presented and a conference paper was published (Pierce et al., 1991).

Estimates with this procedure showed that contributions from lightning are less than 10% of the overall NO_x burden in the eastern United States, but that the contribution from lightning could be appreciable during periods of frequent lightning and in remote areas removed from anthropogenic sources of NO_x.

At the June 1990 Symposium on the Role and Importance of Nitrogen Oxide Emission Controls in Ozone Attainment Strategies for Eastern North American at Cambridge, MA, Pierce and Novak discussed revisions to the natural emission processor and the sensitivity of ROM to natural emissions. Revisions to the emission processor included a new method for lightning and additional soil NO_x factors (Williams and Fehsenfeld, 1991). Work continues on incorporating updates to the biogenic emissions processor.

A Division member, involved in the Southern Oxidant Study (SOS) Southern Oxidant Research Program on Emissions and Effects (SORP-EE), organized two SOS workshops: the first to coordinate emission and atmospheric modeling needs; and the second to determine natural emission research needs. Two SORP-EE research projects were conducted. A pilot study was undertaken in Baltimore's Fort McHenry tunnel to determine the overall accuracy of the motor vehicle emission inventory by examining in a controlled setting ambient measurements of carbon monoxide (CO), nonmethane hydrocarbons (NMHC), and NO_x; and a project was undertaken near Metter, GA, during summer 1991 to measure ambient air concentrations and fluxes of biogenic hydrocarbons.

2.4.3 Compilation of a Composite Toxic Emission Inventory

A composite toxic emission inventory of point and area sources for approximately 28 high-priority toxic compounds, including mercury, lead, benzene, and cadmium, for the United States and Canada is underway. The inventory will provide emission data for dispersion and deposition modeling of the Great Lakes Region using the REgional Lagrangian Model for Air Pollution (RELMAP) (Eder et al., 1986). An earlier inventory was restricted to urban areas around Lake Michigan (Engineering Science, 1990). The national inventory was compiled using speciated particulate matter (PM) and volatile organic compound (VOC) emissions from the 1985 National Acid Precipitation Assessment Program (NAPAP). The NAPAP inventory provided the best available geographic coverage suitable for modeling.

Available emission factors were used in the absence of speciation factors. Emission data from the National Emissions Standards for Hazardous Pollutants Program (NESHAP) covering the period from the late 1970's to 1986 and the 1989 Toxic chemical Release Inventory System (TRIS) were compared with the speciated NAPAP emissions by facility location using a Geographic Information System (GIS). Non-duplicative emission data were added to the NAPAP-based data. Where data were duplicated, the higher quality data were selected in the order: NESHAP, NAPAP, TRIS. The composite toxic emission inventory has the advantages of wide geographic coverage and relative completeness. However, there are several weaknesses, including the incompleteness and inaccuracies in speciation profiles and emission factors, errors or omissions in reporting, and increasingly dated information that is not all from a common year. Despite these drawbacks, a composite emission inventory is the best available short-term source for evaluation and establishment of future air toxic research priorities.

The toxic emission inventory data are quality controlled by checking geographic location, high and low values, spot checks of individual calculations, reasonableness of values, etc. The emission data are being gridded using the GIS at 1 degree spatial resolution and 1/2 by 1/3 degree of latitude and longitude spatial resolution. The gridded emission data will be used for identification and data verification of relative geographical "hot spots." For some toxic compounds, notably pesticides, there are few data available in existing databases. Addition of pesticide emissions based on volatilization calculations of pesticide applications are being pursued. The composite toxic emission inventory will serve as an important resource in support of Title III of the Clean Air Act Amendments of 1990.

2.4.4 High Performance Computing and Communications Program

A Division representative serves on the Federal Coordinating Council for Science, Engineering, & Technology (FCCSET) High Performance Computing and Communications Information Technology Subcommittee. Plans were developed for advancement and dissemination of computational techniques and software related to environmental assessment activities. High Performance Computing and Communications (HPCC) (Committee on Physical, Mathematical, and Engineering Sciences, 1991) research program includes optimization of key algorithms for computers with multiple and massively parallel architectures; development of an advanced framework for environmental models to allow integration with emerging high performance computers; development of new analysis capabilities based on visualization techniques to better interpret and understand answers from environmental models; investigation of molecular modeling algorithms on parallel architectures; linkage of air and water quality models; and development of prototype approaches for technology transfer to state, federal, and industrial clients.

Research on the linkage of RADM and water quality models for the Chesapeake Bay area was initiated. Use of the Applications Visualization System (AVS) as a graphical user interface to control air pollution model computation and visualization in a distributed, heterogeneous computing environment was demonstrated.

2.4.5 Development of a Third Generation Air Quality Modeling System

The conceptual framework for a third generation air quality modeling system (Models-3) was established. One key purpose is to consolidate the functionality of several existing air quality and deposition models to provide a consistent platform for research and application, which can be transferred to emerging high performance architectures. Another key purpose is to provide direct user access to the models and the related information. Functionally, the first prototype will be designed to address regional and urban scale ozone issues and issues related to regional acid deposition.

The Models-3 system will consist of five main components: the user interface and system manager; the core models and processors; the database management subsystem; the I/O subsystem; and the analysis subsystem. The design will provide for a common data processing framework and file structure flexible enough to address multiple air quality problems. The core models will be capable of operating at several scales through the use of variable grids, multi-level nesting, and eventually adaptive grids. Standardization of data flows, internal clocks, and numerical algorithms will provide for interchange of scientific modules, extensibility, and more flexibility in adapting to high performance computing and communication environments.

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 irregular terrain on pollutant dispersion and establishes mathematical relationships among air quality, meteorological variables, and physical processes affecting air quality.

2.5.1 Global Climate Change Program

The goal of the Global Climate Change Program (GCCP) is to understand the physical and chemical elements of climate and the atmosphere, including their properties, feedback mechanisms, and potential for change under present and future conditions. To support this goal, studies are conducted on the impact of climate change on ecosystems and air quality; the impact of urban emissions on regional and global atmospheric composition; and the development of future climate scenarios for assessing air quality and environmental effects.

The climate research was conducted through cooperative agreements. At the National Center for Atmospheric Research (NCAR), Boulder, CO, research involved the use of nested models to examine scale issues for the Great Lakes basin. Results will be presented at the American Meteorological Society's annual meeting in Atlanta, GA, in January 1992. Another effort at NCAR examined the climate from the perspective of extreme events and variability (Katz, 1991; Brown and Katz, 1991). At the North Carolina State University in Raleigh the trend in global temperature was examined. The climate spectra and the importance in detecting climate change were also investigated. At the University of North Carolina at Chapel Hill a framework for developing climate change scenarios was provided (Robinson and Finkelstein, 1991). A journal article will be published that discusses a method that provides scenarios based on temperature thresholds.

Emphasis was placed on the development and application of statistical methods in climate change research. However, of special interest are climate features of significance to impact studies on ecological aspects of the environment. In joint research with the U.S. Forest Service Southern Global

Change Program (SGCP), development of climate change scenarios is underway. The SGCP is one of four regionally-managed, national research programs of the U.S. Forest Service Global Change Research Program, including Southeastern and Southern Forest Experiment Stations and 12 states from Texas to Virginia. A primary area of concern in this region is the possible effects of carbon dioxide on forest species. This includes direct and indirect effects of carbon dioxide and its role in potential climate change. Further, the study of temperature and moisture stress together with pollutants is needed to determine the effects of global change on forest health in the region. The SGCP implementation plan discusses the use of general circulation models for predicting climate in the southern United States. Regional climate change scenarios appropriate for use in U.S. Forest Service timber process and production models are being prepared.

2.5.2 Environmental Monitoring and Assessment Program

The Environmental Monitoring and Assessment Program (EMAP) is a long-range effort to monitor status and trends in the major ecological resources of the United States. Recognition of the importance of climate conditions to the monitoring, interpretation, and assessment of ecosystem status, health, and trends resulted in participating in this nationwide undertaking. Although EMAP considers the recent past, studies of such climate issues as the potential importance of changes in climate means and variability associated with increased levels of greenhouse gases are part of the EMAP objectives.

Studying the role of climate in the EMAP program began with forest ecosystems. Long-term climatological means and extremes, perturbations in these long-term patterns (variability), and such smaller scale disturbances as windstorms and severe weather can impact ecosystems; therefore, climate should be considered in detail. Because these conditions apply to ecosystems in general, contacts were made with near-coastal, wetlands, surface water, arid lands, and agro-ecosystems EMAP resource groups and the integration and assessment cross-cutting task group. The Division acts as coordinator of climate-related EMAP activities; provides climatological expertise to EMAP resource and cross-cutting groups; locates and summarizes climatological data for inclusion in the program database; and participates in resource integration and assessment activities.

2.5.3 Complex Terrain Dispersion Modeling

A screening version (CTSCREEN) (Perry et al., 1990) of the Complex Terrain Dispersion Model PLus algorithms for Unstable Situations (CTDMPLUS) was completed (Perry et al., 1989). CTSCREEN, along with CTDMPLUS, is proposed by the EPA as a recommended model for pollutant sources in complex terrain. Testing and evaluation of CTSCREEN and a user's manual were completed. Two conference papers described the performance characteristics of CTSCREEN (Burns et al., 1991) and CTDMPLUS (Perry et al., 1991).

CTSCREEN, which requires no meteorological input data, was evaluated against three complex terrain screening models using three air quality field study databases. Two of the models, RTDM (Paine and Egan, 1987) and COMPLEXI (U.S. Environmental Protection Agency, 1986), require on-site meteorological measurements as inputs, while the third, VALLEY (Burt, 1977), assumes worst case impact conditions. CTSCREEN makes no assumptions of worst case meteorology for the wide variety of sources and terrain to which it may be applied. Instead, it uses a variety of possible conditions, which it tests for the maximum impacts. The results of the comparisons indicate that CTSCREEN provides worst case estimates that are significantly closer to the observations than COMPLEXI or VALLEY and comparable to RTDM estimates. For the three databases, CTSCREEN provides estimates that are above the observed concentrations, a desirable characteristic for a regulatory screening model. CTSCREEN performs as well as RTDM, which utilizes a full year of on-site meteorological conditions; thus, can be utilized by the vast majority of source and terrain situations where on-site data is unavailable.

Final performance results for CTDMPLUS were reported based on the analysis of the model characteristics compared to the one-year field study database at the Lovett Power Station in eastern New York. CTDMPLUS was also compared with RTDM and performed well, particularly in estimates of high 24-h SO_2 concentrations. The model was biased in these high concentration estimates toward overprediction, but the estimates fell within a factor of two of the observations during stable conditions and closer during convective conditions. The regulatory model, RTDM, computes high concentration estimates with a bias of a factor of five too high compared to observations.

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 Modeling Carbon Monoxide Exposures Using Personal Exposure Monitoring Data

Since exposures from emission sources in the immediate surroundings of individuals are not well characterized, data collected at fixed sites may not adequately reflect personal carbon monoxide (CO) exposures. The concentration levels in the microenvironments are from a superposition of two processes: exchange of air from outside of the microenvironment and emissions from within the microenvironment. To define the sequence of microenvironments and the durations of each microenvironment, activity pattern data obtained from Denver, CO, and Washington, DC, personal CO exposure field studies were used.

In the analysis, it was assumed that the average ambient CO concentration, dominated by automotive emissions, was directly proportional to the automotive CO emission rate. Because of local climate and meteorological effects, different cities with the same automotive CO emission rate may not have the same ambient CO concentration; therefore, it was assumed that local climate effects are much smaller than differences caused by the automotive emissions.

Stochastic human exposure models were proposed for modeling exposures to emissions from immediate surroundings. A statistical model was developed using the normalized microenvironmental values to characterize the concentrations from the infiltration of ambient air and from such source emissions as smoking or a gas appliance. The simulation process involved selecting random samples from the normalized microenvironment concentration distributions.

Efforts were started to acquire new data from the Denver and Washington CO exposure studies that consistently specify the activities and microenvironments; thus, allowing direct analysis of the impact of smokers. Improved data will provide better source apportionment estimates, which may resolve the tendency to simulate higher than observed exposures. Neglecting observed exposures below 2 ppm, twice Personal Exposure Monitoring (PEM) threshold, average simulated 1-hour exposures are 45% greater than observed in Washington and 41% in Denver; the simulated 8-hour exposures are 20% greater than observed in Washington and 11% in Denver.

More detailed activity pattern data will improve discrimination of gas appliance and smoking effects. Results from other receptor modeling field studies may be used to better apportion the automotive versus industrial contributions to the ambient concentration levels. This will provide a means for extrapolating ambient monitoring results to personal exposure values, which may be used to assess the effectiveness of current ambient air quality standards for protecting human health. For example, the observed and simulated exposures suggest that some individuals experienced exposures greater than the ambient air quality standard (NAAQS) for CO, 35 ppm for 1-h and 9 ppm for 8-h. The simulation model could be modified to determine whether the routine exposure experienced by certain individuals or segments of the population is greater than the NAAQS. Another modification could determine the incremental reductions from the various sources needed to insure that less than 1% of the population experience 1-hour or 8-hour exposures greater than the NAAQS.

A basic assumption is the existence of a universal distribution for simulating the concentration fluctuations within microenvironments caused by pollutant infiltration. Independent data are needed to test the assumption, and to develop and test whether a similar concentration fluctuation distribution exists for source emissions within a microenvironment. Verification of the assumption is needed to confirm the basic model and to provide a basis for modifying the model to use with other pollutants and situations.

2.6.2 A Sensitivity Analysis of Serial Correlation Effects on Exposure Estimates

The complexities involved in correlating the temporal and spatial concentration variations within microenvironments with the location of people led to the use of statistical methods for determining concentrations in human exposure estimates. The number of variables and the associated uncertainty make deterministic models difficult to use. SHAPE and NEM include statistical methods for characterization of the concentration values for different microenvironments and are examples of human exposure models that are a combination of deterministic and statistical methodologies. In SHAPE, a Monte-Carlo technique is used to estimate levels by sampling from a concentration distribution for a given microenvironment. In the simulations conducted, the SHAPE model ignored serial correlation effects. This approach tends to underestimate maximum exposures because the concentration in a given microenvironment is related to source terms and atmospheric processes and neglects repeated exposures. This approach also tends to underestimate the intracluster correlation effects. For example, correlation effects occur for individuals in such dirty microenvironments as commuting that expose them to particularly high CO levels for every commute. Monte-Carlo simulations made no provision for correlation effects; therefore, underestimate the highest exposures and overestimate the lowest exposures. The purposes of the sensitivity study were to evaluate the factors affecting serial correlation in indoor microenvironments and to examine how personal exposure monitoring data can be used to infer the variable values needed to estimate such indoor concentrations as the rates of air exchange, pollutant removal, and pollutant generation.

Indoor concentration values were simulated by using a mass consistent box model driven by a 48-hour SO_2 Regional Air Pollution Study (RAPS) data set. One thousand 8-hour averages were generated for three different scenarios. The Monte-Carlo simulations underestimated the highest concentrations by about 20% and overestimated the lower concentrations by about 30%. The difference between using each hour's actual air exchange rate versus each microenvironment's average air exchange rate during the 48-hour period was small. This suggests that NEM could be updated with a mass consistent box model to include the effects of serial correlation.

The use of PEM data may be useful for deriving the order of magnitude estimates of rate constants. However, more study is needed to ascertain if the positive correlations and relative magnitudes of the time-averaged cross-products terms would behave similarly using real-world data. If only one or two processes are in effect, the use of PEM data would underestimate air exchange rates, underestimate emission rates, and overestimate removal rates.

2.6.3 Modeling Effects Studies

Evaluation was begun of pollutant concentrations in the building cavity regions. A paper, presented at the May 1991 US EPA/A&WMA Symposium on Measurement of Toxic and Related Air Pollutants in Durham, NC, summarized and discussed characterization and model estimation of pollution dispersion in the building cavity region. The cavity concentrations vary greatly within very short distances. Concentrations are not uniform and show variations characteristic of the airflow near the building. Wind tunnel model studies can detail information, but are limited by time constraints, availability of modeling facilities, and inherent modeling restrictions. Therefore, numerical simulation methods are needed to provide the detail necessary to characterize the flow and critical concentration values near buildings.

A project was begun for developing computational fluid dynamic methods for building effects studies. The TEMPEST computer code, obtained from Battelle Pacific Northwest Laboratory, is being transferred to the EPA IBM mainframe and to the CRAY Y-MP at the North Carolina Supercomputing Center. TEMPEST is a three-dimensional transient, non-hydrostatic finite difference model for incompressible hydrothermal analyses. The model is being used to examine the effects of incident wind shear on the flow around a cubical building.

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 in developing and enforcing Federal regulations and standards and assisting the EPA Regional Offices.

2.7.1 Modeling Studies

2.7.1.1 Regional Ozone Model Regulatory Applications

A major regional ozone study was completed for the northeastern United States, while another was initiated for the southern Lake Michigan area. In the first study, activities were completed on the Regional Ozone Modeling for NorthEast Transport (ROMNET) program, a multi-year effort to assess the impacts of various emission control strategies on regional ozone transport in the Northeast using the Regional Oxidant Model (ROM). The results are being used by State air pollution control agencies to guide decision makers on the merits of optional approaches for reducing emissions to attain the ozone NAAQS. A final report was prepared and distributed to program participants (Possiel et al., 1991a). The major findings and conclusions of ROMNET were:

1. Controls on NO_x may be more effective than additional VOC controls in many areas of the northeastern United States;

2. The efficacy of NO_x versus VOC controls varies from city-to-city and in some cities from day-to-day, depending on meteorological condition and emission ratios;

3. Unlike VOC controls, in some cities NO_x controls can be counter productive by increasing ozone;

4. Controls on emissions outside the Northeast Corridor may be necessary for attainment of the ozone NAAQS inside the Corridor because of regional transport;

5. Strategies that reduce the reactivity of emissions appear to be most effective in areas that are "VOC limited" and have the greatest benefit near the emission source area; and

6. Emission controls beyond the existing control programs may be necessary to reach attainment in the Northeast Corridor, even with the range of uncertainty in biogenic emissions.

Briefings on ROMNET and the project findings and conclusions were presented to the ROMNET Management Review Committee, the Ozone Transport Commission, the Environmental Secretary of the State of Virginia, and representatives of the major Northeast utility companies.

As follow-on to ROMNET, the Clean Air Act Amendments (CAAA) of 1990 established an Ozone Transport Commission (OTC) for the northeastern United States to (1) assess the degree of regional ozone transport and (2) to develop and test the efficacy of regional emission control strategies for attainment of the ozone NAAQS in this region. Briefings were provided at OTC meetings on the results and conclusions of ROM simulations that examined the impacts of several regional controls on ozone in the northeastern United States. The OTC requested additional ROM simulations to investigate the relative effectiveness of various optional motor vehicle control programs and more stringent controls on stationary sources of nitrogen oxides than required by the CAAA. Much of the work focused on the design of scenarios and the development of ROM input files. ROM applications to address the OTC control issues will be performed during FY-1992.

In the second study, the multi-year Lake Michigan Ozone Study (LMOS), an integrated data collection, modeling and data analysis project, was undertaken by the States of Wisconsin, Illinois, Indiana, and Michigan, and the U.S. Environmental Protection Agency. The purpose of LMOS is to develop (1) an improved understanding of the air quality in the Southern Lake Michigan Area (SLMA) and (2) the dynamics of atmospheric and emissions processes that influence ozone concentrations in that area. The overall objective is to provide a technically valid basis for the development of an area-wide control strategy for attainment of the ozone NAAQS in the SLMA. The LMOS effort included an extensive field study in summer 1991, and the development and evaluation of an enhanced version of the Urban Airshed Model (UAM) that is capable of treating meteorological conditions associated with the "lake breeze" transport along the western shore of Lake Michigan. ROM applications simulating a domain covering much of the eastern United States for at least three ozone episodes will be performed to support the UAM evaluation effort. In addition, the application plan includes simulations using observed meteorological data and data generated by a prognostic meteorological model with four-dimensional data assimilation. The regional model predictions will supplement field observations for specifying boundary concentrations to UAM. A work plan for ROM applications was completed and several preliminary test simulations were performed using historical episodes. The results reveal plumes of high ozone extending downwind from the major Midwest cities with the transported ozone at concentrations in the NAAQS range extending beyond 500 km. This project will continue into 1993.

2.7.1.2 Dense Gas Model Performance Evaluation

A report was published that summarized the performance evaluation study of several models used in determining the impact of routine (nonaccidental) atmospheric releases of toxic dense gases (Zapert et al., 1991). Seven dense gas models, including two public (DEGADIS and SLAB) and five proprietary (AIRTOX, CHARM, FOCUS, SAFEMODE, and TRACE) were evaluated using three databases: the Desert Tortoise ammonia releases, the Goldfish hydrogen fluoride releases, and the Burro liquefied natural gas releases. Model performance was evaluated by comparing observed and predicted concentrations and using statistical measures. Results of the evaluation study were presented at a conference (Touma et al., 1991).

2.7.2 Modeling Guidance

2.7.2.1 Revisions to the Guideline on Air Quality Models

The Fifth Conference on Air Quality Modeling, held March 19-20, 1991, in Washington, DC, served as the public hearing for the proposed revisions, Supplement B, to the Guideline on Air Quality Models (Revised) (U.S. Environmental Protection Agency, 1987). About 140 attendees heard a presentation on the technical aspects of the proposal (Dicke, 1991), and representatives of the American Meteorological Society (AMS), Air & Waste Management Association, several Federal agencies, one State, and consultants and members of the general public made statements and comments. Most comments addressed three issues: (1) instrumentation for and evaluation of the new on-site stability determination scheme, (2) on-site instrumentation and data requirements for the CTDMPLUS model, and (3) concerns about the ISC model, especially the area source algorithm. The public comment period closed on May 6, 1991, and written comments were received from 50 individuals and organizations.

A summary document covering all the comments and responses to them was prepared for review by the EPA regulatory work group. Although a few of the proposed revisions are being modified in response to the public comments, virtually all the proposals are proceeding to final rulemaking.

2.7.2.2 Support Center for Regulatory Air Models

The Support Center for Regulatory Air Models Bulletin Board System (SCRAM BBS), one of several electronic bulletin board systems that comprise the OAQPS Technology Transfer Network (TTN), was created to foster technology transfer among all users of regulatory air quality models. The SCRAM BBS is a mechanism for providing technical support for air modeling activities. Users experiencing problems with regulatory models can leave messages on the BBS or call designated telephone numbers to obtain assistance.

SCRAM BBS publishes *SCRAM NEWS*, which provides articles on new features and models added to the BBS, tips on using models, and discussions of issues related to modeling guidance. Division meteorologists contributed articles and announcements relating to models and to model revisions that are on the SCRAM BBS. These included a full page article describing the recoded Industrial Source Complex model (ISC-2) and the Industrial Source Complex Short-Term (ISCST) model; a longer article describing how to obtain meteorological data for ISCST and similar models; what to do to use the data as input to ISCST; and articles providing tips on modeling in complex terrain and using ISCST.

2.7.2.3 Recoding the Industrial Source Complex Model

The short- and long-term versions of the Industrial Source Complex model were completely recoded in structured form, and the user's guide was completely rewritten. A draft version, ISC-2, was placed on the SCRAM BBS. The mathematical basis was not changed, and the new model gives the same answers as the old; however, exceptions occur because some coding errors were discovered in the old version of the model during the recoding process.

Why ISC-2? The ISC model was released in 1979 and modified numerous times. With each modification, the model code became more convoluted; more difficult to make modifications with any degree of accuracy; and very difficult to find and correct errors. The solution was to reprogram the model in modern structured form; which greatly facilitates revising and debugging the model.

The input and output formats were revised to make the programs easier to use. The formatted input was replaced with a pathway and keyword approach; and a file conversion utility was developed to facilitate conversion of ISCST input files.

2.7.2.4 Model Clearinghouse

The FY-1991 activities for the Model Clearinghouse included the following:

1. Responding to 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-1991 activities.

6. Entering FY-1991 records into a computerized database.

7. Providing direct modem access for the Regional Offices to the computerized database.

8. Disseminating Clearinghouse memoranda and reports to the public through a bulletin board system.

There were 126 modeling referrals to the Model Clearinghouse from the Regional Offices during FY-1991. These included 14 regulatory modeling problems, each of which required a written response, 93 referrals, each of which required an oral response, and 19 referrals, each of which only required discussion without Clearinghouse recommendations being requested. Requests for assistance, either written or by telephone, came from the 10 Regional Offices, indicating that there is an awareness of and a desire for Clearinghouse support throughout the Agency.

The Clearinghouse conducted or participated in coordination and information exchange activities with the Regional Offices. In October 1990, a Clearinghouse report was prepared and distributed to the Regional Offices; the report informed Clearinghouse users about issues and responses that occurred during FY-1990.

The Clearinghouse continued its policies of sending copies of written responses and incoming requests to the Regional Offices, to keep them informed of decisions affecting their modeling activities; attaching to each response an updated list of all Clearinghouse memoranda issued during the fiscal year to help the Regional Offices maintain complete records; and, seeking advance opinions from the Regional Offices on particularly sensitive issues with national implications. One sensitive case arose involving Prevention of Significant Deterioration (PSD) increment modeling in Virginia. The proposed Clearinghouse response was circulated to all Regional Offices for comment before the response was finalized.

The Model ClearingHouse Information Storage and Retrieval System (MCHISRS), a PC software system for storing key information on each Clearinghouse referral, allows the user to search the MCHISRS database electronically to find records with like characteristics and to consider the consistency aspects of new referrals. There are approximately 925 referrals in the database. The Regional Offices are able to directly access MCHISRS to make their own national consistency determinations.

Agency memoranda and Clearinghouse reports are available to the public through the SCRAM BBS. The bulletin board includes three types of information: (1) selected historical memoranda on generic and recurring issues generated by the Clearinghouse from FY-1981 through FY-1991; (2) FY-1989 and

FY-1990 Clearinghouse memoranda; and (3) FY-1989 and FY-1990 Model Clearinghouse reports.

2.7.2.5 Urban Airshed Modeling Guidance

A final guidance document for applying the Urban Airshed Model (UAM), a photochemical grid model used for evaluating control strategies for reducing ozone in nonattainment areas and for developing State Implementation Plans (SIPs), was prepared (U.S. Environmental Protection Agency, 1991a). Under Title I of the Clean Air Act Amendments of 1990, photochemical grid modeling is required for specified urban ozone nonattainment areas. Also under Title I, development of a comprehensive modeling program is required for ozone attainment demonstrations for SIP submittals.

The guidance document will ensure a consistent application of modeling programs among the EPA Regional and State agencies conducting the photochemical model studies. Provisions on procedures for developing and conducting a consistent and comprehensive modeling program include (1) developing modeling protocol; (2) selecting ozone episodes; (3) determining meteorological, air quality, and emission data requirements; (4) diagnostic testing of the model; (5) evaluating model performance; and (6) using the model predictions in ozone attainment demonstrations.

2.7.2.6 TSCREEN Model

Improvement efforts continued on the air dispersion screening model, TSCREEN (U.S. Environmental Protection Agency, 1990), for use in Superfund toxic and hazardous pollutant impact activities. The easy to use personal computer program is useful for assessing screening level impacts of toxic air pollutants from releases at Superfund sites and other sources. TSCREEN guides the user through a set of logical decision processes by way of interactive menus and data input screens. Default values, valid ranges of input variables, extensive help menus, a chemical database library, and a method of graphing, viewing, and saving the modeled results are among the many features. The model can estimate impacts on elevated terrain and handle instantaneous and continuous releases of dense gas toxic pollutants. Model features and uses were described by Touma and Stroupe (1991).

2.7.2.7 Guidance on the Application of Refined Dispersion Models for Air Toxic Releases

Refined air toxic models are being used to assess the impact of toxic air pollutants released into the atmosphere. A document was published (U.S. Environmental Protection Agency, 1991b) to provide guidance for applying refined dispersion models to atmospheric releases and to show processes required for applying the models by the non-expert user. Four specific models applicable for denser-than-air (DEGADIS, HEGADIS, and SLAB) and neutrally buoyant releases (AFTOX) are discussed in the document. Two sample applications are provided for each model with a step-by-step explanation of all model input parameters and model output.

2.7.3 Additional Support Activities

2.7.3.1 Regional and State Modelers Workshop

The modelers annual workshop was held May 20-23, 1991, at the National Park Service (NPS), Grand Canyon National Park, AZ; thirty-three attendees represented the 10 Regional Offices, ORD, OAQPS, eight State agencies, and one county agency. The sessions focused on (1) discussing and resolving Regional Office and State modeling issues; (2) modeling visibility and air quality related values in Class I areas; and (3) modeling ozone, including the 1990 CAAA requirements and related activities. Small groups developed positions on the modeling issues and reported their findings and recommendations. NPS staff discussed the new modeling system and its applications and the group toured several monitoring sites in the Park. Ozone modeling policy and the Urban Airshed Model guidance and model development activities were presented and discussed. A member of the AMS Steering Committee discussed the results of a recent boundary layer model workshop affecting a new regulatory model under development. In addition, Division personnel participated in four modeling-related workshops at the Regional Offices.

2.7.3.2 Urban Airshed Modeling Workshops

Four regional workshops were conducted on the application of UAM for regulatory purposes. The workshops provided technical descriptions of model processors and input data requirements and hands-on exercises for test case simulations using the model processors and core model. A major portion of the workshop provided technical presentation and hands-on demonstration of the ROM-UAM Interface Program System that was developed to interface ROM results with UAM. Workshops were conducted for State staffs in Regions V, VII, and VIII, in January 1991; Region VI in February 1991; and in the remaining Regions in April and June 1991.

2.7.3.3 Interagency Work Group on Air Quality Models

The EPA has not recommended a refined dispersion model for regulatory application to assess the air quality impacts of a source on distant receptors (>50 km), especially in Federal Class I areas. This is also true of models for multiple sources on a regional- or long-range transport scale. Any model proposed for such an application must be approved on a case-by-case basis accompanied by extensive technical and performance justification.

In August 1991, the U.S. Environmental Protection Agency, National Park Service, Fish and Wildlife Service, and Forest Service produced a draft Memorandum of Agreement to foster cooperation in the development, evaluation, and application of air quality dispersion models for such situations and to mutually assist in rulemaking to adopt acceptable models according to the EPA modeling guideline. The Agreement established an Interagency Work Group comprised of technical staff representing OAQPS, ORD, and Regional Offices. The Work Group met August 22-23, 1991, in Durham, NC, to resolve the wording of the Agreement; develop the framework for a workplan with an objective accomplishment schedule; and brief members on the status and plans for the Regional Particulate Model (RPM) project. RPM is a candidate for conducting the impact assessments needed by Federal Land Managers of Class I areas. The Work Group selected the National Park Service representative as its chairman.

2.7.3.4 Regulatory Work Groups

Meteorologists participate in various regulatory work groups and task forces. As experts on models, databases, and interpretation of model results, they generate sound technical positions and options on key issues facing policymakers. 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 Prescribed Burning Work Group; the Interagency Work Group on Air Quality Models; the AMS/EPA Regulatory Model Improvement Committee; the Work Group on the Lead SIP Requirements Pursuant to the New Lead NAAQS; the Emission Trading Policy Update Task Force; and the Ozone Transport Commission Modeling Committee.

3. REFERENCES

Alapaty, K., D. Olerud, C. Coats, J. Young, A. Hanna, and K. Schere. Utilization of MM4 prognostics in driving the meteorology for the Regional Oxidant Model (ROM): A new meteorological driver - Phase 1. Internal report, Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC, 12 pp. (1991).

Anthes, R.A., E.-Y. Hsie, and Y.-H. Kuo. Description of the Penn State/NCAR Mesoscale Model Version 4 (MM4). NCAR/TN-282+STR, National Center for Atmospheric Research, Boulder, CO, 66 pp. (1987).

Barnes, S. A technique for maximizing details in numerical weather map analysis. *Journal of Applied Meteorology* 3:396-409 (1973).

Bennett, R.L., and L. Stockburger. A regional fine particulate field study: Database and initial observations. EPA/600/3-91/065, Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC, 64 pp. (1991).

Binkowski, F.S., J.S. Chang, R.L. Dennis, S.J. Reynolds, P.J. Samson, and J.D. Shannon. Regional acid deposition modeling. Acidic Deposition: State of Science and Technology Report 3. Volume I, Emissions, Atmospheric Processes and Deposition, National Acid Precipitation Assessment Program, 722 Jackson Place, N.W., Washington, DC (1990).

Brown, B.G., and R.W. Katz. Characteristics of extreme temperature events in the U.S. midwest and southeast implications for the effects of climate change. Preprints, Seventh Conference on Applied Climatology, September 10-13, 1991, Salt Lake City, Utah. American Meteorological Society, Boston, J30-J36 (1991).

Bullock, O.R., Jr. The effect of size-dependent dry deposition velocities in an Eulerian regional-scale particulate model. Preprints, 18th International Technical Meeting of NATO/CCMS on Air Pollution Modeling and its Application, Volume 1, May 13-17, 1990, University of British Columbia, Vancouver, B.C., Canada. NATO/CCMS, Brussels, Belgium, 145-152 (1990).

Burns, D.J., S.G. Perry, and A.J. Cimorelli. An advanced screening model for complex terrain applications. Preprints, Seventh Joint Conference on the Applications of Air Pollution Meteorology with AWMA, January 14-18, 1991, New Orleans, Louisiana. American Meteorological Society, Boston, 97-100 (1991).

Burt, E.W. Valley model user's guide. EPA-450/2-77-018, Office of Air Quality Planning and Standards, Research Triangle Park, NC, (1977).

Chang, J.S., P.B. Middleton, W.R. Stockwell, C.J. Walcek, J.E. Pleim, H.H. Lansford, F.S. Binkowski, N.L. Seaman, J.N. McHenry, S. Madronich, P.J. Samson, and H. Hass. The Regional Acid Deposition Model and Engineering Model. Acid Deposition: State of Science and Technology Report 4. Volume I, Emissions, Atmospheric Processes and Deposition, National Acid Precipitation Assessment Program, 722 Jackson Place, N.W., Washington, DC (1990).

Ching, J.K.S., and N.E. Bowne. Acid-MODES: A major field study to evaluate regional scale air pollution models. Proceedings, Remote Sensing of Atmospheric Chemistry Conference, Orlando, FL, April 1-3, 1991. Society of Photo-Optical Instrumentation Engineers, Bellingham, WA, 1491:360-370 (1991).

Committee on Physical, Mathematical, and Engineering Sciences. Grand Challenges: High Performance Computing and Communications. Office of Science and Technology Policy, Washington, DC, 57 pp. (1991).

Dennis, R.L., W.R. Barchet, T.L. Clark, and S.K. Seilkop. Evaluation of regional acidic deposition models: Part 1. Acidic Deposition: State of Science and Technology Report 5. Volume I, Emissions, Atmospheric Processes and Deposition, National Acid Precipitation Assessment Program, 722 Jackson Place, N.W., Washington, DC (1990a).

Dennis, R.L., F.S. Binkowski, T.L. Clark, J.N. McHenry, S.J. Reynolds, and S.K. Seilkop. Selected applications of the Regional Acid Deposition Model and Engineering Model: Part 2, Appendix 5F. Acidic Deposition: State of Science and Technology Report 5. Volume I, Emissions, Atmospheric Processes and Deposition, National Acid Precipitation Assessment Program, 722 Jackson Place, N.W., Washington, DC (1990b).

Dennis, R.L., and N. Laulainen. Protocol for the diagnostic evaluation of Eulerian models. Internal report, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 81 pp. (1988).

Dicke, J.L. Overview of proposed changes to the modeling guideline and special topics of complex terrain, roadway intersections and stability classifications. Fifth Conference on Air Quality Modeling, Washington, DC, March 1991. In *EPA Docket A-88-04, Item III-B-1*, U.S. Environmental Protection Agency, Washington, DC, (1991).

Eberhard,W.L., W.R. Moninger, and G.A. Briggs. Plume dispersion in the convective boundary layer. Part I: CONDORS field experiment and example measurements. *Journal of Applied Meteorology* 27:599-616 (1988).

Eder, B.K., D.H. Coventry, T.L. Clark, and C.E. Bollinger. RELMAP: A REgional Lagrangian Model of Air Pollution user's guide. EPA/600/8-86/013, Atmospheric Science Research Laboratory, Research Triangle Park, NC, 137 pp. (1986).

Engineering Science, Inc. Air toxic emission inventories for the Lake Michigan Region. Contract 68-02-4398, Work Assignment No.17, Region V, Air and Radiation Division, U.S. Environmental Protection Agency, Chicago, IL, 31 pp. (1990).

Fisher, D., J. Ceraso, T. Mathew, and M. Oppenheimer. *Polluted coastal waters: The role of acid rain.* Environmental Defense Fund, New York, NY, 102 pp. (1988).

Godowitch, J.M., and K.S. Schere. Plans for the development of a ROM-UAM interface program. Internal report, Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC, 13 pp. (1989).

Hallyburton, S., C. Maxwell, L. Milich, and J. Young. The Regional Oxidant Model (ROM) user's guide. Part 4: The ROM system user tutorial (Processor network and core model). EPA/600/8-90/083d, Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC, 75 pp.(1991).

Hansen, D.A., M.H. Barnes, M. Lusis, and K.J. Puckett. A North American field study to evaluate Eulerian models. In *Air Pollution Modeling and its Application VII*, Han van Dop (ed.), Plenum Press, New York, NY, 297-306 (1989).

Hicks, B.B., D.D. Baldocchi, T.P. Meyers, D.R. Matt, and R.P. Hosker, Jr. A preliminary multiple resistance routine for deriving deposition velocities from measured quantities. *Water, Air and Soil Pollution* 36:311-330 (1987).

Katz, R.W. Towards a statistical paradigm for climate change. Preprints, Seventh Conference on Applied Climatology, September 10-13, 1991, Salt Lake City, Utah. American Meteorological Society, Boston, 4-9 (1991).

Laulainen, N., Fraunhofer Institute for Atmospheric Environmental Research, Federal Republic of Germany, and Members of the EPA Advisory Group for Aircraft Measurements. Design criteria for the diagnostic evaluation of Eulerian models, Volume 2: Spring 1990 intensive field campaign. Internal report, Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC (1990).

Lawson, R.E., Jr. Wind tunnel study of concentration fluctuations in plumes. Fluid Modeling Facility Internal Report, Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC (1990).

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. *Atmospheric Environment* 25A:1211-1225 (1991).

Milich, L., J. Eichinger, C. Maxwell, A. Van Meter, T. Boehm, S. Fudge, D. Olerud, R. Wayland, C. Coats, D. Jordan, R. Tang, J. Young, O.R. Bullock, T.E. Pierce, K.L. Schere, J.H. Novak, and S.J. Roselle. The Regional Oxidant Model (ROM) user's guide. Part 1: The ROM preprocessors. EPA/600/8-90/083a, Atmospheric Research and Assessment Laboratory, Research Triangle Park, NC, 332 pp. (1991a).

Milich, L., J. Eichinger, C. Maxwell, A. Van Meter, T. Boehm, S. Fudge, D. Olerud, R. Wayland, C. Coats, D. Jordan, R. Tang, J. Young, O.R. Bullock, T.E. Pierce, K.L. Schere, J.H. Novak, and S.J. Roselle. The Regional Oxidant Model (ROM) user's guide. Part 2: The ROM processor network. EPA/600/8-90/083b, Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC, 338 pp. (1991b).

Morris, R.E., and T.C. Myers. User's guide for the Urban Airshed Model. Volume I: User's manual for UAM(CB-IV). EPA-450/4-90-007A, Office of Air Quality Planning and Standards, Research Triangle Park, NC, 259 pp. (1990).

Paine, R.J., and B.A. Egan. User's guide to the Rough Terrain Diffusion Model (RTDM) - Revision 3.20. ERT Document PD-535-585, ERT, Inc, Concord, MA (1987).

Perry, S.G., D.J. Burns, L.A. Adams, R.J. Paine, M.G. Dennis, M.T. Mills, D.G. Strimaitis, R.J. Yamartino, and E.M. Insley. User's guide to the Complex Terrain Dispersion Model PLus algorithms for Unstable Situations (CTDMPLUS): Volume 1. Model description and user instruction. EPA/600/8-89/041, Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC, 196 pp. (1989).

Perry, S.G., D.J. Burns, and A.J. Cimorelli. User's guide to CTMPLUS: Volume 2. The screening mode (CTSCREEN). EPA/600/8-90/87 (PB91-136564), Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC (1990).

Perry, S.G., J.O. Paumier, and D.J. Burns. Evaluation of the EPA Complex Terrain Dispersion Model (CTDMPLUS) with the Lovett Power Plant data base. Preprints, Seventh Joint Conference on Application of Air Pollution Meteorology with AWMA, January 14-18, 1991, New Orleans, Louisiana. American Meteorological Society, Boston, 189-192 (1991).

Pierce, T.E. User's guide to the personal computer version of the Biogenic Emissions Inventory System (PC-BEIS). EPA/600/8-90/084, Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC, 43 pp. (1990).

Pierce, T.E., D.H. Coventry, J.H. Novak, and A.R. Van Meter. Estimating lightning-generated NO_x emissions for regional air pollution models. Preprints, Seventh Joint Conference on Applications of Air Pollution Meteorology with AWMA, January 14-18, 1991, New Orleans, Louisiana. American Meteorological Society, Boston, 160-163 (1991).

Pierce, T.E., and P. Waldruff. A personal computer version of the Biogenic Emissions Inventory System (PC-BEIS). *Journal of the Air & Waste Management Association* 41:937-941 (1991).

Pleim, J.E., J.S. Chang, and K. Zhang. A nested grid mesoscale atmospheric chemistry model. *Journal of Geophysical Research* 96(D2):3065-3084 (1991).

Possiel, N.C., L.B. Milich, and B.R. Goodrich (eds.). Regional Ozone Modeling for NorthEast Transport (ROMNET). Project final report. EPA-450/4-91-002a, Office of Air Quality Planning and Standards, Research Triangle Park, NC, (1991a).

Possiel, N.C., L.B. Milich, and B.R. Goodrich (eds.). Regional Ozone Modeling for NorthEast Transport (ROMNET). Appendices. EPA-450/4-91-002b, Office of Air Quality Planning and Standards, Research Triangle Park, NC, 696 pp. (1991b).

Robinson, P.J., and P.L. Finkelstein. The development of impact-oriented climate scenarios. *Bulletin of the American Meteorological Society* 72:481-490 (1991).

Roselle, S.J. Sensitivity of modeled ozone concentrations to uncertainties in biogenic emissions estimates. M.S. thesis, North Carolina State University, Raleigh, NC, 136 pp. (1991).

Roselle, S.J., T.E. Pierce, and K.L. Schere. The sensitivity of regional ozone modeling to biogenic hydrocarbons. *Journal of Geophysical Research* 96(D4):7371-7394 (1991).

Samson, P.J., J.R. Brook, and S. Sillman. Estimation of seasonal and annual acid deposition through aggregation of the-day episodic periods. EPA/600/3-90/059, Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC, 146 pp. (1990).

Saxena, P., A.B. Hudischewsky, C. Seigneur, and J.H. Seinfeld. A comparative study of equilibrium approaches to the chemical characterization of secondary aerosols. *Atmospheric Environment* 20:1471-1483 (1986).

Schatzmann, M., W.H. Snyder, and R.E. Lawson, Jr. Ausbreitung von Schwergasstrahlen. Berichtsband, IV. Symposion Schwere Gase und Sicherheitsanalyse, 26./27.09.1991, Bonn, Germany (1991b).

Schatzmann, M., W.H. Snyder, and R.E. Lawson, Jr. Dense gas jets. Part A: Flow field and mean concentrations. Fluid Modeling Facility Internal Report, Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC (1991a).

Sistla, G., S.T. Rao, and J.M. Godowitch. Sensitivity analysis of a nested ozone air quality model. Preprints, Seventh Joint Conference on Applications of Air Pollution Meteorology with AWMA, January 14-18, 1991, New Orleans, Louisiana. American Meteorological Society, Boston, 250-255 (1991).

Snyder, W.H. Wind-tunnel simulation of dispersion from Superfund area sources. Internal Report, Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC (1991).

Snyder, W.H., M.J. Davidson, and R.E. Lawson, Jr. Building array - neutral plumes. Fluid Modeling Facility Internal Report, Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC (1991b).

Snyder, W.H., R.E. Lawson, Jr., and M. Schatzmann. Dense gas jets. Part B: Fluctuating concentrations. Fluid Modeling Facility Internal Report, Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC (1991a).

Spicer, C.W., C. Lindsey, J. Anderson, K. Busness, D. Daly, R. Hannigan, M. Holdren, J. Hubbe, G. Keigley, T. Kelly, G. Laws, R. Lee, R. Parkhurst, D. Sharp, D. Smith, P. Sticksel, and J. Ward. Data report for Acid Model Evaluation Study--G-1 aircraft results. Final report to ENSR Consulting & Engineering, Inc./U.S. Environmental Protection Agency (1989).

Stauffer, D.R., and N.L. Seaman. Use of four-dimensional data assimilation in a limited-area mesoscale model. Part I: Experiments with synoptic-scale data. *Monthly Weather Review* 118:1250-1277 (1990).

Tang, R.T., S.C. Gerry, J.S. Newsom, A.R. Van Meter, R.A. Wayland, J.M. Godowitch, and K.L. Schere. User's guide for the Urban Airshed Model. Volume V: Description and operation of the ROM-UAM interface program system. EPA-450/4-90-007E, Office of Air Quality Planning and Standards, Research Triangle Park, NC, 168 pp. (1990).

Thompson, R.S. Building amplification factors. Fluid Modeling Facility Internal Report, Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park NC (1991).

Touma, J.S., and K.T. Stroupe. TSCREEN: A personal computer system for screening toxic air pollutant impacts. Preprints, International Conference and Workshop on Modeling and Mitigating the Consequences of Accidental Releases of Hazardous Materials, May 1991, New Orleans, Louisiana. American Institute of Chemical Engineers, New York, 712-723 (1991).

Touma, J.S., J.G. Zapert, H. Thistle, R.L. Londergan, and R. Topazio. Performance evaluation of air toxics dispersion models for simulating heavier-than-air releases. Preprints, International Conference and Workshop on Modeling and Mitigating the Consequences of Accidental Releases of Hazardous Materials, May 1991, New Orleans, Louisiana.. American Institute of Chemical Engineers, New York, 735-746 (1991).

U.S. Congress. Senate. *An Act to amend the Clean Air Act*, Public Law 101-549, 101st Congress, 1st session, November 15, 1990, S.1630 (1990).

U.S. Department of Commerce. The Federal plan for meteorological services and supporting research--Fiscal year 1992. FCM P1-1991, Office of the Federal Coordinator for Meteorological Services and Supporting Research, National Oceanic and Atmospheric Administration, Washington, DC, 146 pp. (1991).

U.S. Environmental Protection Agency. Guidance on the application of refined dispersion models for air toxics releases. EPA-450/4-91-007, Office of Air Quality Planning and Standards, Research Triangle Park, NC, 165 pp. (1991b).

U.S. Environmental Protection Agency. Guideline for regulatory application of the Urban Airshed Model. EPA-450/4-91-013, Office of Air Quality Planning and Standards, Research Triangle Park, NC, 89 pp. (1991a).

U.S. Environmental Protection Agency. User's guide for TSCREEN, A model for screening toxic pollutant concentrations. EPA-450/4-90-013, Office of Air Quality Planning and Standards, Research Triangle Park, NC, 32 pp. (1990).

U.S. Environmental Protection Agency. Guideline on air quality models (Revised) and Supplement A. EPA-450/4-78-027R, Office of Air Quality Planning and Standards, Research Triangle Park, NC, 310 pp. (1987)

U.S. Environmental Protection Agency. COMPLEXI model in the User's Network for Applied Modeling of Air Pollution (UNAMAP) Version 6. Office of Air Quality Planning and Standards, Research Triangle Park, NC (1986).

Werhahn, J., F. Slemr, A.M. Hoff, E. Schaller, H. Giehl, W. Junkermann, P. Matuska, L. Newiadomsky, J. Peschke, F. Ponig, K. Schlitt, G. Schufmann, and C. Wackerle. Data report for Acid Model Evaluation Study--HS-125 aircraft results. Final report to ENSR Consulting & Engineering, Inc./U.S. Environmental Protection Agency (1990).

Whitby, E.R., P.H. McMurray, U. Shankar, and F.S. Binkowski. Modal aerosol dynamics modeling. EPA/600/3-91/020 (PB91-161 729), Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC (1991).

Williams, E., and F. Fehsenfeld. Measurement of soil nitrogen oxide emissions at three North American ecosystems. *Journal of Geophysical Research* 96(D1):1033-1042 (1991).

Young, J., L. Milich, and D. Jorge. The Regional Oxidant Model (ROM) user's guide. Part 3: The core model. EPA/600/8-90/083c, Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC, 99 pp. (1991).

Zapert, J.G., R.J. Londergan, and H. Thistle. Evaluation of dense gas simulation models. EPA-450/4-90-018, Office of Air Quality Planning and Standards, Research Triangle Park, NC, 107 pp. (1991).

APPENDIX A: ACRONYMS

Acid-MODES	Acid Models Operational and Diagnostic Evaluation Study
ACM	Asymmetrical Convective Model
ADOM	Acid Deposition and Oxidant Model
AES	Atmospheric Environment Service of Canada
AMS	American Meteorological Society
APIOS	Acid Precipitation In Ontario Study
AQRV	Air Quality Related Values
BEIS	Biogenic Emissions Inventory System
CAAA	Clean Air Act Amendments of 1990
CAMRAQ	Consortium for Advanced Modeling of Regional Air Quality
CAPMoN	Canadian Air and Precipitation Monitoring Network
CAPTEX	Cross-APpalachian Tracer EXperiment
CARB	California Air Resources Board
CARB/MAC	CARB Modeling Advisory Committee
CASTNET	Clean Air Status and Trends NETwork
CBED	Chesapeake Bay Evaluation and Deposition Committee
CBL	Convective Boundary Layer
COMPLEXI	A complex terrain dispersion model.
CONDORS	CONvective Diffusion Observed with Remote Sensors
CPU	Central Processing Unit
CTDMPLUS	Complex Terrain Dispersion Model PLus algorithms for Unstable Situations
CTSCREEN	A screening version of CTDMPLUS
CURTAIN	Vertical up and down sawtooth aircraft transect pattern.
EMAP	Environmental Monitoring and Assessment Program
EMBSC	Eulerian Modeling Bilateral Steering Committee
EMEFS	Eulerian Model Evaluation Field Study
EMEFS/DMT	EMEFS Diagnostic Measurement Team
EMEFS/EIT	EMEFS Emissions Inventory Team
EMEFS/MET	EMEFS Model Evaluation Team
EMEFS/OMT	EMEFS Operations Measurement Team

EMEFS/PMG	EMEFS Program Management Group
EMEP	European Monitoring and Evaluation Program
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
EUROTRAC	EUROpean experiment on the TRAnsport and transformation of trace atmospheric Constituents
FCCSET	Federal Coordinating Council for Science, Engineering, and Technology
FCG	Florida Electric Power Coordinating Group
FDDA	Four Dimensional Data Assimilation
GCCP	Global Climate Change Program
GIS	Geographic Information System
HFID	Fast response flame ionization detector
HPCC	High Performance Computing and Communications Program
IMPROVE	Interagency Monitoring of PROtected Visual Environments
ISC-2	Industrial Source Complex model - Version 2
ISCST	Industrial Source Complex Short-Term model
ITM	International Technical Meeting
IWAQM	Interagency Work Group on Air Quality Models
LAI	Leaf Area Index
LCM	Linear Chemistry Model
MAD	Modal Aerosol Dynamics model
MARS	Model for an Aerosol Reacting System
MCHISRS	Model ClearingHouse Information Storage and Retrieval System
MM4	Mesoscale Meteorological Model - Version 4
Models-3	Third generation air quality modeling system
MOHAVE	Measurement Of Haze And Visual Effects
MOU	Memorandum Of Understanding
MSC-W	Norwegian Modeling Synthesizing Center - West
NAAQS	National Ambient Air Quality Standards
NADP	National Acid Deposition Program
NAPAP	National Acid Precipitation Assessment Program
NATO/CCMS	North Atlantic Treaty Organization Committee on Challenges for Modern Society
NCAR	National Center for Atmospheric Research

NCSC	North Carolina Supercomputing Center
NDDN	National Dry Deposition Network
NDM	Non-Depleting Model
NEM	NAAQS Exposure Model
NESHAP	National Emission Standards for Hazardous Air Pollutants
NOAA	National Oceanic and Atmospheric Administration
NOM	Aeronomy Laboratory NOAA Oxidant Model
NPS	National Park service
NRC	National Research Council
OAQPS	Office of Air Quality Planning and Standards (EPA)
OEN	Operational Evaluation Network
OME	Ontario Ministry of the Environment
ORD	Office of Research and Development (EPA)
OSTP	Office of Science and Technology Policy
OTC	Ozone Transport Commission
PEM	Personal Exposure Monitoring
PSD	Prevention of Significant Deterioration
RADM	Regional Acid Deposition Model
RADM/EM	RADM Engineering Model
RELMAP	REgional Lagrangian Model for Air Pollution
ROM	Regional Oxidant Model
ROMNET	Regional Ozone Modeling for NorthEast Transport
RPM	Regional Particulate Model
RTDM	Rough Terrain Dispersion Model
SCAQS	Southern California Air Quality Study
SCRAM BBS	Support Center for Regulatory Air quality Models Bulletin Board System
SGCP	Southern Global Change Program (U.S. Forest Service)
SHAPE	Simulation of Human Activity and Pollutant Exposure
SIP	State Implementation Plan
SLMA	Southern Lake Michigan Area
SOS	Southern Oxidant Study
SOS/T	State Of Science and Technology reports
STAGMAP	STAGnation Model Analysis Program
STM	Sulfate Tracking Model

TEMPEST	Transient Energy Momentum and Pressure Equations Solutions in Three-dimensions
TRIS	Toxic chemical Release Inventory System
TSEM	Tagged Species Engineering Model
TTN	Technology Transfer Network (OAQPS)
UAM	Urban Airshed Model
US/USSR	United States/Union of Soviet Socialist Republics
VALLEY	A complex terrain dispersion model
VOC	Volatile Organic Compounds
ZIPPER	Zigzag aircraft transect pattern

APPENDIX B: PUBLICATIONS

Alkezweeny, A.J., D. Burrows, C.A. Grainger, L.F. Osborne, and J.L. Stith. Effects of air pollution on cloud microphysics and its relationship to climate. *Journal of World Resource Review* 3:42 (1991).

Alkezweeny, A.J., J.L. Stith, and J.K.S. Ching. Observations of transport of trace gases by vigorous convective clouds. Preprints, Seventh Joint Conference on Applications of Air Pollution Meteorology with AWMA, January 14-18, 1991, New Orleans, Louisiana. American Meteorological Society, Boston, 224-227 (1991).

Barchet, W.R., R.L. Dennis, and S.K. Seilkop. Evaluation of RADM using surface data from the Eulerian model evaluation field study. Preprints, Seventh Joint Conference on Applications of Air Pollution Meteorology with AWMA, January 14-18, 1991, New Orleans, Louisiana. American Meteorological Society, Boston, 63-66 (1991).

Binkowski, F.S., J.S. Chang, R.L. Dennis, S.J. Reynolds, P.J. Samson, and J.D. Shannon. Regional acid deposition modeling. Acidic Deposition: State of Science and Technology Report 3. Volume I, Emissions, Atmospheric Processes and Deposition, National Acid Precipitation Assessment Program, 722 Jackson Place, N.W., Washington, DC (1990).

Binkowski, F.S., J.N. McHenry, and J.S. Chang. Estimation of the contribution of Canadian versus United States emissions to sulfur deposition. Preprints, Seventh Joint Conference on Applications of Air Pollution Meteorology with AWMA, January 14-18, 1991, New Orleans, Louisiana. American Meteorological Society, Boston, 54-57 (1991).

Bullock, O.R., Jr. The effect of sub-grid-scale rainfall analysis on sulfate wet deposition estimates in the Regional Lagrangian Model of Air Pollution (RELMAP). Preprints, Seventh Joint Conference on Applications of Air Pollution Meteorology with AWMA, January 14-18, 1991, New Orleans, Louisiana. American Meteorological Society, Boston, 81-84 (1991).

Burns, D.J., S.G. Perry, and A.J. Cimorelli. An advanced screening model for complex terrain applications. Preprints, Seventh Joint Conference on the Applications of Air Pollution Meteorology with AWMA, January 14-18, 1991, New Orleans, Louisiana. American Meteorological Society, Boston, 97-100 (1991).

Byun, D.W., and F.S. Binkowski. Sensitivity of RADM to point source emissions processing. Preprints, Seventh Joint Conference on Applications of Air Pollution Meteorology with AWMA, January 14-18, 1991, New Orleans, Louisiana. American Meteorological Society, Boston, 81-84 (1991).

Chang, J.S., P.B. Middleton, W.R. Stockwell, C.J. Walcek, J.E. Pleim, H.H. Lansford, F.S. Binkowski, N.L. Seaman, J.N. McHenry, S. Madronich, P.J. Samson, and H. Hass. The Regional Acid Deposition Model and Engineering Model. Acidic Deposition: State of Science and Technology Report 4. Volume I, Emissions, Atmospheric Processes and Deposition, National Acid Precipitation Assessment Program, 722 Jackson Place, N.W., Washington, DC (1990).

Ching, J.K.S., and N.E. Bowne. Acid-MODES: A major field study to evaluate regional-scale air pollution models. Proceedings, Remote Sensing of Atmospheric Chemistry Conference, Orlando, Florida, April 1-3, 1991. Society of Photo-Optical Instrumentation Engineers, Bellingham, WA, 1491:360-370 (1991).

Ching, J.K.S., J.S. Chang, C.W. Spicer, and E. Schaller. Investigation of RADM performance using aircraft measurements. Preprints, Seventh Joint Conference on Applications of Air Pollution Meteorology with AWMA, January 14-18, 1991, New Orleans, Louisiana. American Meteorological Society, Boston, 42-45 (1991).

Chu, S.-H., and D.C. Doll. Summer blocking highs and regional ozone episodes. Preprints, Seventh Joint Conference on Applications of Air Pollution Meteorology with AWMA, January 14-18, 1991, New Orleans, Louisiana. American Meteorological Society, Boston, 274-277 (1991).

Clark, T.L., and R.D. Cohn. Performances of Lagrangian and Eulerian transport and diffusion models across continental scales. Preprints, Seventh Joint Conference on Applications of Air Pollution Meteorology with AWMA, January 14-18, 1991, New Orleans, Louisiana. American Meteorological Society, Boston, 89-92 (1991).

Coats, W.G., J.T. Snow, and C.B. Baker. A comparative study on the dynamic performance of bivanes. Preprints, Seventh Symposium on Meteorological Observations and Instrumentation, January 14-18, 1991, New Orleans, Louisiana. American Meteorological Society, Boston, 86-91 (1991).

Coats, C.J., and K.L. Schere. Wind field development for the EPA Regional Oxidant Model. In *Ozone*, Volume 5. Proceedings of the 84th Annual Meeting of the Air & Waste Management Association, Vancouver, B.C., Canada, June 16-21, 1991. Air & Waste Management Association, Pittsburgh, Paper No. 91-67.7 (1991).

Conklin, P.S., K.R. Knoerr, and C.B. Baker. Wind tunnel and field tests of two designs for omnidirectional static pressure probes. Preprints, Seventh Symposium on Meteorological Observations and Instrumentation, January 14-18, 1991, New Orleans, Louisiana. American Meteorological Society, Boston, 92-95 (1991).

Cooter, E.J., S.K. LeDuc, L.E. Truppi, and D.R. Block. Climate data and analysis for the New England Forest Health Monitoring project (NEFHM/EMAP-Forest). Preprints, Seventh Conference on Applied Climatology, September 10-13, 1991, Salt Lake City, Utah. American Meteorological Society, Boston, 57-62 (1991).

Dennis, R.L., W.R. Barchet, T.L. Clark, and S.K. Seilkop. Evaluation of regional acidic deposition models: Part 1. Acidic Deposition: State of Science and Technology Report 5. Volume I, Emissions, Atmospheric Processes and Deposition, National Acid Precipitation Assessment Program, 722 Jackson Place, N.W., Washington, DC (1990).

Dennis, R.L., F.S. Binkowski, T.L. Clark, J.N. McHenry, S.J. Reynolds, and S.K. Seilkop. Selected applications of the Regional Acid Deposition Model and Engineering Model: Part 2, Appendix 5F. Acidic Deposition: State of Science and Technology Report 5. Volume I, Emissions, Atmospheric Processes and Deposition, National Acid Precipitation Assessment Program, 722 Jackson Place, N.W., Washington, DC (1990).

DiChristofaro, D.C., and J.S. Touma. Development and sensitivity analysis of the Shoreline Dispersion Model (SDM). Preprints, 19th International Technical Meeting of NATO/CCMS on Air Pollution Modeling and its Application, Volume I, September 29 - October 4, 1991, Ireâpetra, Crete, Greece. NATO/CCMS, Brussels, Belgium, 153-160 (1991).

Dicke, J.L. Overview of proposed changes to the modeling guideline and special topics of complex terrain, roadway intersections and stability classifications. Fifth Conference on Air Quality Modeling, Washington, DC, March 1991. In *EPA Docket A-88-04*, U.S. Environmental Protection Agency, Washington, DC (1991).

Eklund, B., S. Smith, J.F. Durham, and J.S. Touma. Estimation of emissions, ambient air concentrations, and health effects from air stripping of contaminated water. Proceedings of the 84th Annual Meeting of the Air and Waste Management Association, Vancouver, B.C., Canada, June 1991. Air and Waste Management Association, Pittsburgh, 91-13.3 (1991).

Eskridge, R.E., W.B. Petersen, and S.T. Rao. Turbulent diffusion behind vehicles: Effect of traffic on pollutant concentrations. *Journal of the Air & Waste Management Association* 41:312-317 (1991).

Finkelstein, P.L., and L.E. Truppi. Spatial distribution of precipitation seasonality in the United States. *Journal of Climate* 4:373-385 (1991).

Gaynor, J.E., C.B. Baker, and B.D. Templeman. Fine time-scale comparisons between doppler sodar and sonic anemometer-derived winds. Preprints, Seventh Symposium on Meteorological Observations and Instrumentation, January 14-18, 1991, New Orleans, Louisiana. American Meteorological Society, Boston, 401-404 (1991).

Huber, A.H., S.P. Arya, S.A. Rajala, and J.W. Borek. Preliminary studies of video images of smoke dispersion in the near wake of a model building. *Atmospheric Environment* 25A:1199-1210 (1991).

Irwin, J.S., and J.O. Paumier. Characterizing the dispersive state of convective boundary layers for applied dispersion modeling. *Boundary-Layer Meteorology* 53:267 296 (1991).

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. *Atmospheric Environment* 25A:1211-1225 (1991).

McHenry, J.N., and R.L. Dennis. Partitioning of the sulfate budget into gas- and aqueous-phase components in the Regional Acid Deposition Model (RADM). Preprints, Seventh Joint Conference on Applications of Air Pollution Meteorology with AWMA, January 14-18, 1991, New Orleans, Louisiana. American Meteorological Society, Boston, 143-147 (1991).

Meyer, E.L., N.C. Possiel, D.C. Doll, K.A. Baugues, and K.A. Baldridge. A summary of ROMNET results and outputs. Preprints, Seventh Joint Conference on Applications of Air Pollution Meteorology with AWMA January 14-18, 1991, New Orleans, Louisiana. American Meteorological Society, Boston, 246-249 (1991).

Meyers, T.P., and C.B. Baker. Ocean/atmosphere exchange of momentum, heat, moisture and CO_2 in shallow water zones. Preprints, Seventh Symposium on Meteorological Observations and Instrumentation, January 14-18, 1991, New Orleans, Louisiana. American Meteorological Society, Boston, 26-29 (1991).

Milich, L., J. Eichinger, C. Maxwell, A. Van Meter, T. Boehm, S. Fudge, D. Olerud, R. Wayland, C. Coats, D. Jordan, R. Tang, J. Young, O.R. Bullock, T.E. Pierce, K.L. Schere, J.H. Novak, and S.J. Roselle. The Regional Oxidant Model (ROM) user's guide. Part 1: The ROM preprocessors. EPA/600/8-90/083a (PB91-171926), Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC, 332 pp. (1991).

Milich, L., J. Eichinger, C. Maxwell, A. Van Meter, T. Boehm, S. Fudge, D. Olerud, R. Wayland, C. Coats, D. Jordan, R. Tang, J. Young, O.R. Bullock, T.E. Pierce, K.L. Schere, J.H. Novak, and S.J. Roselle. The Regional Oxidant Model (ROM) user's guide. Part 2: The ROM processor network. EPA/600/8-90/083b (PB91- 171934), Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC, 426 pp. (1991).

Paumier, J.O., and J.S. Irwin. Comparison of modified Carson and EPA mixing height estimates using data from five field experiments. Preprints, Seventh Joint Conference on Applications of Air Pollution Meteorology January 14-18, New Orleans, Louisiana. American Meteorological Society, Boston, 282-285 (1991).

Perry, S.G., D.J. Burns, and A.J. Cimorelli. User's guide to CTDMPLUS: Volume 2. The screening mode (CTSCREEN). EPA/600/8-90/087 (PB91-136564), Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC, 74 pp. (1990).

Perry, S.G., J.O. Paumier, and D.J. Burns. Evaluation of the EPA Complex Terrain Dispersion Model (CTDMPLUS) with the Lovett Power Plant data base. Preprints, Seventh Joint Conference on Application of Air Pollution Meteorology with AWMA, January 14-18, 1991, New Orleans, Louisiana. American Meteorological Society, Boston, 189-192 (1991).

Pierce, T.E. User's guide to the personal computer version of the biogenic emissions inventory system (PC-BEIS). EPA/600/8-90/084 (PB91-136549), Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC, 43 pp. (1990).

Pierce, T.E., D.H. Coventry, J.H. Novak, and A.R. Van Meter. Estimating lightning-generated NO_x emissions for regional air pollution models. Preprints, Seventh Joint Conference on Applications of Air Pollution Meteorology with AWMA, January 14-18, 1991, New Orleans, Louisiana. American Meteorological Society, Boston, 160-163 (1991).

Pierce, T.E., and P. Waldruff. PC-BEIS: A personal computer version of the biogenic emissions inventory system. *Journal of the Air & Waste Management Association* 41:937-941 (1991).

Pleim, J.E., J.S. Chang, and K. Zhang. A nested grid mesoscale atmospheric chemistry model. *Journal of Geophysical Research* 96(D2):3065-3084 (1991).

Poole-Kober, E.M., and H.J. Viebrock (eds). Fiscal year 1990 summary report of NOAA Atmospheric Sciences Modeling Division support to the U.S. Environmental Protection Agency. NOAA Technical Memorandum ERL ARL-188, 65 pp. (1991).

Poole-Kober, E.M., and H.J. Viebrock (eds). Fiscal year 1989 summary report of NOAA Atmospheric Sciences Modeling Division support to the U.S. Environmental Protection Agency. NOAA Technical Memorandum ERL ARL-187, 60 pp. (1990).

Possiel, N.C., L.B. Milich, and B.R. Goodrich (eds). Regional Ozone Modeling for NorthEast Transport (ROMNET). Project final report. EPA-450/4-91-002a, Office of Air Quality Planning and Standards, Research Triangle Park, NC (1991).

Possiel, N.C., L.B. Milich, and B.R. Goodrich (eds). Regional Ozone Modeling for NorthEast Transport (ROMNET). Appendices. EPA-450/4-91/002b, Office of Air Quality Planning and Standards, Research Triangle Park, NC (1991).

Roselle, S.J. Sensitivity of modeled ozone concentrations to uncertainties in biogenic emissions estimates. M.S. thesis, North Carolina State University, Raleigh, NC, 136 pp. (1991).

Roselle, S.J., T.E. Pierce, and K.L. Schere. The sensitivity of regional ozone modeling to biogenic hydrocarbons. *Journal of Geophysical Research* 96(D4):7371-7394 (1991).

Schaller, E., J.S. Chang, J. Boatman, J.K.S. Ching, M. Meyer-Wyk, J.E. Pleim, and C.W. Spicer. Evaluation of RADM predictions for a mesoscale-β box volume over northeastern Pennsylvania. Preprints, Seventh Joint Conference on Applications of Air Pollution Meteorology with AWMA, January 14-18, 1991, New Orleans, Louisiana. American Meteorological Society, Boston, 50-53 (1991).

Schere, K.L., T.E. Pierce, D.A. Doll, L.B. Milich, and J.O. Young. The ROMNET modeling system. In *Regional Ozone Modeling for NorthEast Transport (ROMNET)*, N.C. Possiel, L.B. Milich, and B.R. Goodrich (Eds.). EPA-450/4-91-002a, Office of Air Quality Planning and Standards, Research Triangle Park, NC, 2.3-2.49 (1991).

Sistla, G., S.T. Rao, and J.M. Godowitch. Sensitivity analyses of a nested ozone air quality model. Preprints, Seventh Joint Conference on Applications of Air Pollution Meteorology with AWMA, January 14-18, 1991, New Orleans, Louisiana. American Meteorological Society, Boston, 250-255 (1991).

Snyder, W.H., L.H. Khurshudyan, I.V. Nekrasov, R.E. Lawson, Jr., and R.S. Thompson. Flow and dispersion of pollutants within two-dimensional valleys. *Atmospheric Environment* 25A:1347-1375 (1991).

Snyder, W.H., and R.E. Lawson, Jr. Fluid modeling simulation of stack-tip downwash for neutrally buoyant plumes. *Atmospheric Environment* 25A:2837-2850 (1991).

Spicer, C.W., T.J. Kelly, J. Chang, J.K.S. Ching, R.L. Dennis, E. Schaller, K. Busness, R. Lee, C. Lindsey, and J. Anderson. Diagnostic evaluation of Regional Acid Deposition Model (RADM) performance during a period of frontal passage using aircraft measurements. Preprints, Seventh Joint Conference on Applications of Air Pollution Meteorology with AWMA, January 14-18, 1991, New Orleans, Louisiana. American Meteorological Society, Boston, 139-142 (1991).

Stogner, R.E., J.S. Irwin, W.B. Petersen, M. Aissa, and A. Lansari. Two indoor air exposure modeling studies: CONTAM modeling results, and serial correlation effects. EPA/600-3-91/013, Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC, 149 pp. (1991).

Thompson, R.S., M.S. Shipman, and J.W. Rottman. Moderately stable flow over a three-dimensional hill -- a comparison of linear theory with laboratory measurements. *Tellus* 43:49-63 (1991).

Touma, J.S., J.G. Zapert, H. Thistle, R.L. Londergan, and R. Topazio. Performance evaluation of air toxics dispersion models for simulating heavier-than-air releases. Preprints, International Conference and Workshop on Modeling and Mitigating the Consequences of Accidental Releases of Hazardous Materials, May 1991, New Orleans, Louisiana. American Institute of Chemical Engineers, New York, 735-746 (1991).

Touma, J.S., and K.T. Stroupe. TSCREEN: A personal computer system for screening toxic air pollutant impacts. Preprints, International Conference and Workshop on Modeling and Mitigating the Consequences of Accidental Releases of Hazardous Materials, May 1991, New Orleans, Louisiana. American Institute of Chemical Engineers, New York, 712-723 (1991).

U.S. Environmental Protection Agency. Errata for the user's guide to SDM - A Shoreline Dispersion Model. EPA-450/4-88-017, Office of Air Quality Planning and Standards, Research Triangle Park, NC, 110 pp. (1990).

U.S. Environmental Protection Agency. Guideline for regulatory application of the Urban Airshed Model. EPA-450/4-91-013, Office of Air Quality Planning and Standards, Research Triangle Park, NC, 89 pp. (1991).

U.S. Environmental Protection Agency. Guidance on the application of refined dispersion models for air toxics releases. EPA-450/4-91-007, Office of Air Quality Planning and Standards, Research Triangle Park, NC, 165 pp. (1991).

van Dop, H., R.L. Dennis, J.C.R. Hunt, G. Kallos, G. McBean, T.R. Oke, F.A. Schiermeier, and J.D. Shannon. Conference Report: 18th International Technical Meeting of NATO-CCMS on Air Pollution Modelling and its Application. *Atmospheric Environment* 25A:1730-1732 (1991).

Viswanathan, R., M. McGown, J. McElroy, M. Pitchford, C. Edmonds, and D. Bundy. Lidar application for estimating relative particulate flux. Preprints, Seventh Joint Conference on Applications of Air Pollution Meteorology with AWMA, January 14-18, 1991, New Orleans, Louisiana. American Meteorological Society, Boston, J217-J218 (1991).

Wakamatsu, S., and K.L. Schere. A study using a three-dimensional photochemical smog formation model under conditions of complex flow -- Application of the Urban Airshed Model to the Tokyo Metropolitan Area. EPA/600/3-91/015, Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC, 84 pp. (1991).

Whitby, E.R., P.H. McMurray, U. Shankar, and F.S. Binkowski. Modal aerosol dynamics modeling. EPA/600/3-91/020 (PB91-161729), Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC (1991).

Zapert, J.G., R.J. Londergan, and H. Thistle. Evaluation of dense gas simulation Models. EPA-450/4-90-018, Office of Air Quality Planning and Standards, Research Triangle Park, NC, 107 pp. (1991).

APPENDIX C: PRESENTATIONS

Binkowski, F.S. Elements of regional scale modeling. Presentation at the Comprehensive Modeling System Workshop, Atlanta, GA, November 7-8, 1990.

Binkowski, F.S. EPA aerosol research and modeling programs. Presentation at the National Center for Intermedia Transport Workshop, UCLA, Los Angeles, CA, March 7-8, 1991.

Binkowski, F.S., and K. Alapaty. Performance of a prototype regional particulate model. EUROTRAC Workshop on Regional and Global Modeling of Minor Atmospheric Constituents, 16th General Assembly of European Geophysical Society, Wiesbaden, Federal Republic of Germany, April 23-26, 1991.

Ching, J.K.S. Hot issues of the 90's. Invited presentation to the AMS First Weather Education Resource Agent Conference, New Orleans, LA, January 13, 1991.

Clark, T.L. AREAL approach to modeling the atmospheric deposition of toxic substances to the Chesapeake Bay. Atmospheric Deposition Work Group, Annapolis, MD, May 2, 1991.

Clark, T.L. Model estimates of annual atmospheric deposition of toxic pollutants to the Chesapeake Bay basin. Presentation at the 1991 U.S. EPA/AWMA International Symposium on Measurement of Toxic and Related Pollutants, Durham, NC, May 10, 1991.

Clark, T.L., and J.K.S. Ching. Modeling the annual deposition of toxic substances to the Great Lakes: Approach and preliminary results. Seminar presented at the U.S. EPA Region V and Great Lakes National Program Office, Chicago, IL, July 25, 1991.

Clarke, J.F., E.S. Edgerton, and R.P. Boksleitner. Routine estimation and reporting of dry deposition for the U.S.A. Dry Deposition Network. Poster session presented at the Fifth International Conference on Precipitation Scavenging and Atmospheric-Surface Exchange Processes, Richland, WA, July 15-19, 1991.

Dennis, R.L. Partitioning of the sulfate budget into gas and aqueous phase components in the Regional Acid Deposition Model (RADM). Poster session presented at the Seventh Joint Conference on Applications of Air Pollution Meteorology with AWMA, New Orleans, LA, January 14-18, 1991.

Dennis, R.L. RADM model evaluation/applications. Invited presentation to the AMS Seventh Joint Conference on Applications of Air Pollution Meteorology with AWMA, New Orleans, LA, January 14-18, 1991.

Dennis, R.L. Effect of incommensurabilities between single point measurements and model design on comparisons between model and data. Summary report, Convention on Long Range Transboundary Air Pollution EMEP Workshop on Combined Analysis of Measurements and Model Results with Special Emphasis on NO_x\VOC\Oxidants, Halifax, Nova Scotia, Canada, September 16-20, 1991.

Dennis, R.L. RADM and ADOM evaluation results: Discovery and correction of model errors through comparisons against field data. Summary report, Convention on Long Range Transboundary Air Pollution EMEP Workshop on Combined Analysis of Measurements and Model Results with Special Emphasis on NO_x\VOC\Oxidants, Halifax, Nova Scotia, Canada, September 16-20, 1991.

Dicke, J.L. Technical summary of the proposed Supplement B to the guideline on air quality models. Fifth Conference on Air Quality Modeling, Washington, DC, March 19-20, 1991.

Fernando, H.J.S. (Arizona State University, Tempe, AZ). Turbulent mixing in stratified turbulent patches. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, February 12, 1991.

Huber, A.H. The characterization and model estimation of pollution dispersion in the building cavity region. Presentation at the U.S. EPA/A&WA Symposium on Measurement of Toxic and Related Air Pollutants, Durham, NC, May 6-10, 1991.

Irwin, J.S., and W.B. Petersen. Modeling carbon monoxide (CO) exposure within microenvironments given personal exposure data. Presentation at the U.S. EPA/A&WMA Symposium on Measurement of Toxic and Related Air Pollutants, Durham, NC, May 6-10, 1991.

Lansari, A., R.A. Strelitz, and J.S. Irwin. Theoretical study of the effects of variable meteorological conditions on indoor ozone concentration distribution. Presentation at the U.S. EPA/A&WMA Symposium on Measurement of Toxic and Related Air Pollutants, Durham, NC, May 6-10, 1991.

Novak, J.H. EPA's grand challenge problems. Presentation at the Federal Coordinating Council for Science, Engineering, & Technology (FCCSET) Committee, Science and Engineering Working Group, Research Triangle Park, NC, May 21, 1991.

Novak, J.H. Geographic information systems. Presentation at the First International Conference and Workshop on Integrating Geographic Information Systems and Environmental Modeling, Denver, CO, September 16-18, 1991.

Petersen, W.B., and J.S. Irwin. A sensitivity analysis of the effects of serial correlation on exposure estimates. Presentation at the U.S. EPA/A&WMA Symposium on Measurement of Toxic and Related Air Pollutants, Durham, NC, May 6-10, 1991.

Pierce, T.E. Estimating lightning-generated NO_x emissions for regional air pollution models. Video presentation at the Seventh Conference on Applications of Air Pollution Meteorology, New Orleans, LA, January 17, 1991.

Pierce, T.E. Estimating natural emissions for EPA's regional models. Presentation at the U.S. EPA/AWMA Specialty Conference on Emissions, Durham, NC, September 12, 1991.

Pierce, T.E. Natural emissions for the Regional Oxidant Model. Seminar presented at the Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC, September 25, 1991.

Pitchford, M.S. Conceptual plan for Project MOHAVE. Presentation to members of the Haze in National Parks and Wilderness Areas Committee of the National Research Council, National Academy of Science, University of California-Irvine, March 14, 1991.

Pitchford, M.S. Strawman plan for Project MOHAVE. Presentation at the Project MOHAVE planning workshop, Denver, CO, April 30, 1991.

Pleim, J.E. Evidence of chemical and dynamical interactions in the convective boundary layer. Presentation to the Atmospheric Chemistry Colloquim for Emerging Senior Scientists (ACCESS) at MIT, Cambridge, MA, June 13-15, 1991.

Pleim, J.E., and J.S. Chang. Vertical mixing in atmospheric chemistry models. Presentation to the 1990 Fall Meeting of the American Geophysical Union, San Francisco, CA, December 3-7, 1990.

Possiel, N.C. Results of ROMNET control strategy assessment - Implications for Virginia. Briefing to Environmental Secretary for the State of Virginia, Richmond, VA, June 14, 1991.

Possiel, N.C. Development and use of emission inventories for regional scale model applications. Presentation to the Southeast Oxidant Study Modeling Coordination Committee, Raleigh, NC, August 19, 1991.

Schatzmann, M. (Meteorological Institute, University of Hamburg, Hamburg, Germany). Experiments with heavy gas jets in laminar and turbulent cross flows. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, July 10, 1991.

Schatzmann, M. (Meteorological Institute, University of Hamburg, Hamburg, Germany), W.H. Snyder, and R.E. Lawson, Jr. Modeling of heavy gas jet releases. Presentation at the Workshop on Vapor Cloud Source Modeling at the International Conference and Workshop on Modeling and Mitigating the Consequences of Accidental Releases of Hazardous Materials, New Orleans, LA, May 20, 1991.

Schatzmann, M. (Meteorological Institute, University of Hamburg, Hamburg, Germany), W.H. Snyder, and R.E. Lawson, Jr. Ausbreitung von Schwergasstrahlen. Presentation at the IV Symposiom Schwere Gase und Sicherheitsanalyse, Bonn, Germany, September 26, 1991.

Schere, K.L. Regional ozone modeling in the northeast and southeast United States. Presentation at the SOS Symposium at the American Chemical Society National Meeting, Atlanta, GA, June 18, 1991.

Schiermeier, F.A. Modeling the impact of point source VOC/NO_x emissions on ozone concentrations. Presentation at Standing Air Simulation Work Group Meeting, Palm Springs, CA, October 27, 1990.

Schiermeier, F.A. Modeling needs for high performance computing and scientific visualization. Presentation to U.S. Congressional Staff, Research Triangle Park, NC, January 10, 1991.

Schiermeier, F.A. Welcoming address and plans for Working Group research activities. Presentation at Fifteenth US/USSR Working Group Meeting on Air Pollution Modeling, Instrumentation, and Measurement Methodology, Research Triangle Park, NC, March 11, 1991.

Schiermeier, F.A. Invited opening address at the EPA workshop on nitrogen and toxics deposition to Chesapeake Bay, Research Triangle Park, NC, April 25, 1991.

Schiermeier, F.A. Overview of Atmospheric Sciences Modeling Division research programs. Presentation to Deputy Minister for the USSR State Committee for Environmental Protection, Research Triangle Park, NC, July 10, 1991.

Schiermeier, F.A. Invited opening address at EPA/DOE workshop on selection of chemicals to be tested and modeled at the DOE Liquified Gaseous Fuels Spill Test Facility, Research Triangle Park, NC, July 17, 1991.

Schiermeier, F.A. Overview of Atmospheric Characterization and Modeling Division research programs. Presentation at Interim Joint Meeting of the United States/Japan Air Pollution Meteorology Panel, Research Triangle Park, NC, September 11, 1991.

Snyder, W.H. Physical modeling of complex flows. Invited presentation at the Workshop on Dispersion in Non-Flat, Obstructed Terrain and Advanced Modeling Techniques at the International Conference and Workshop on Modeling and Mitigating the Consequences of Accidental Releases of Hazardous Materials, New Orleans, LA, May 20, 1991.

Stroupe, K.T., and J.S. TOUMA. TSCREEN: An interactive air transport model for Superfund site applications. Presentation at the 1991 U.S. EPA/A&WMA International Symposium on Measurement of Toxic and Related Air Pollutants, Durham, NC, May 6-10, 1991.

Thompson, R.S. Concentrations from above-roof releases of laboratory exhausts - a wind tunnel study. Presentation at American Society of Heating, Refrigeration, and Air Conditioning Engineering Annual Meeting, Indianapolis, IN, June 22, 1991.

Touma, J.S. Modeling activities concerning evaluation of area source algorithms and development of TSCREEN. EPA Air Superfund Technical Advisory Committee Meeting, Seattle, WA, December 4, 1990.

Touma, J.S. Modeling activities concerning evaluation of area source algorithms and development of TSCREEN. EPA Air Superfund Technical Advisory Committee Meeting, Cincinnati, OH, April 5, 1991.

Touma, J.S. Modeling activities concerning evaluation of area source algorithms and development of TSCREEN. EPA Air Superfund Technical Advisory Committee Meeting, New York, NY, September 17, 1991.

Uno, I. (National Institute for Environmental Studies, Tsukuba, Japan). Observed structure of the nocturnal urban boundary layer and the behavior of air pollutants at Sapporo, Japan. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, April 24, 1991.

APPENDIX D: WORKSHOPS

U.S. Army Regional Aerosol Transport Simulation (ARATS) Workshop, London, England, October 29-30, 1990.

T.L. Clark

Clean Air Act/EMAP Nonurban Monitoring Workshop, Research Triangle Park, NC, November 7-8, 1990.

John F. Clarke

Electric Power Research Institute, United States, and Canada Comprehensive Modeling System Workshop, Atlanta, GA, November 7-8, 1990.

F.S. Binkowski
J.K.S. Ching
R.L. Dennis
J.H. Novak
K.L. Schere
F.A. Schiermeier

Interagency Monitoring Of Protected Visual Environment (IMPROVE) Workshop, Research Triangle Park, NC, November 7-9, 1990.

T.L. Clark
M.L. Pitchford

Lake Michigan Ozone Study (LMOS) Planning Workshop, Chicago, IL, December 12-14, 1990.

K.L. Schere

Methane Emissions from Natural Gas Industry Advisory Committee Workshop, Mobile, AL, December 13-14, 1990.

W.G. Benjey

Human Exposure Modeling Workshop, Dallas, TX, December 17-20, 1990.

J.S. Irwin
W.B. Petersen

Urban Airshed Model Hands-On Workshop, Chicago, IL, January 8-10, 1991.

D.C. Doll

ROSE Data Review Workshop, Boulder, CO, January 8-12, 1991.

K.L. Schere

Great Lakes Air Toxics Monitoring Workshop, Research Triangle Park, NC, January 22-24, 1991.

W.G. Benjey
J.K.S. Ching
T.L. Clark

Urban Airshed Model Hands-On Workshop, Dallas, TX, February 5-7, 1991.

D.C. Doll

AMS Workshop on Planetary Boundary Layer Parameters, Denver, CO, February 20-22, 1991.

D.T. Bailey
G.A. Briggs
J.S. Irwin
R.F. Lee
D.A. Wilson

Great Waters Toxic Deposition Workshop, Research Triangle Park, NC, February 25, 1991.

W.G. Benjey
J.K.S. Ching
T.L. Clark

Clean Air Status and Trends NETwork (CASTNET) Workshop, Durham, NC, February 26-28, 1991.

T.L. Clark
J.F. Clarke

Comprehensive Modeling System Computational Technology Workshop, San Diego, CA, March 5-6, 1991.

R.L. Dennis
J.H. Novak

US/USSR Dispersion Modeling Workshop, Durham, NC, March 6-8, 1991.

R.F. Lee
W.B. Petersen
J.S. Touma
D.A. Wilson

Fifteenth US/USSR Working Group 02.01-10 Meeting on Air Pollution Modeling, Instrumentation, and Measurement Methodology, Boulder, CO, Las Vegas, NV, and Research Triangle Park, NC, March 6-13, 1991.

F.A. Schiermeier

Great Lakes Air Toxics Research Priorities Workshop, Gray Freshwater Biological Institute, University of Minnesota, Navarre, MN, March 13-14, 1991.

W.G. Benjey
J.K.S. Ching
T.L. Clark

Ozone Depletion Workshop, Ann Arbor, MI, March 14-18, 1991.

C.B. Baker

EPA Fifth Conference on Air Quality Modeling, Washington, DC, March 19-20, 1991.

W.B. Petersen

Atmospheric Modeling Workshop on Hanford Dose Study, Richland, WA, March 24-27, 1991.

W.B. Petersen

Lake Michigan Urban Air Toxics Study Planning Workshop, Research Triangle Park, NC, April 8, 1991.

W.G. Benjey
J.K.S. Ching
T.L. Clark

Urban Airshed Model Hands-On Workshop, Research Triangle Park, NC, April 9-11, 1991.

D.C. Doll

EPA Region X State Air Quality Modelers Workshop, Seattle, WA, April. 24-26, 1991.

S.G. Perry

Nitrogen and Toxics Deposition Modeling Workshop, Research Triangle Park, NC, April 25-26, 1991.

F.S. Binkowski
J.K.S. Ching
T.L. Clark
J.F. Clarke
R.L. Dennis
J.H. Novak
J.E. Pleim
F.S. Schiermeier

Southeast Marine and Aquatic Information Centers Workshop, National Marine Fisheries Service, Charleston, SC, April 29, 30, and May 1, 1991.

Evelyn M. Poole-Kober

Measurement Of Haze And Visual Effects (MOHAVE) Planning Workshop. Denver, CO, April 30-May 1, 1991.

J.K.S. Ching
M.L. Pitchford

Southern Ozone Study Model Coordination Workshop, Huntsville, AL, May 13-14, 1991.

K.L. Schere

International Conference and Workshop on Mitigating the Consequences of Accidental Releases of Hazardous Materials, New Orleans, LA, May 19-23, 1991.

W.B. Petersen

Regional, State, and Local Modelers Workshop, Grand Canyon, AZ, May 20-23, 1991.

J.L. Dicke
J.S. Irwin
L.H. Nagler
D.A. Wilson

Model Evaluation Workshop at the International Conference and Workshop on Modeling and Mitigating the Consequences of Accidental Releases of Hazardous Materials, New Orleans, LA, May 20-24, 1991.

G.A.Briggs

Urban Airshed Model Hands-On Workshop, Research Triangle Park, NC, June 10-12, 1991.

D.C. Doll

Third US/Dutch Expert Workshop on UV-B Measurements, Exposure, and Effects, Bellevue, WA, June 10-16, 1991.

C.B. Baker

Department of Energy Spill Test Program User Forum, Las Vegas, NV, June 25-26, 1991.

W.B. Petersen
F.A. Schiermeier

Chesapeake Bay Evaluation and Deposition Committee Workshop, Research Triangle Park, NC, July 8-9, 1991.

J.K.S. Ching
T.L. Clark
R.L. Dennis
J.E. Pleim

EPA Air Quality Management Training Workshop, Greensboro, NC, July 8-12, 1991.

D.G. Atkinson
D.C. Doll
N.C. Possiel
D.A. Wilson

EPA/DOE Workshop on Selection of Chemicals to be Tested and Modeled at the DOE Liquified Gaseous Fuels Spill Test Facility, Research Triangle Park, NC, July 17-18, 1991.

W.B. Petersen
F.A. Schiermeier
W.H. Snyder

Model Evaluation Workshop, Chapel Hill, NC, July 31-August 2, 1991.

F.S. Binkowski
J.K.S. Ching
R.L. Dennis
J.E. Pleim

Workshop on Coordination of Emission Inventories and Atmospheric Chemical Modeling for the Southern Oxidant Study, Raleigh, NC, August 19-20, 1991.

T.E. Pierce
N.C. Possiel

NOAA Air-Surface Exchange Workshop, Oak Ridge, TN, August 27, 1991.

J.F. Clarke

Convention on Long Range Transboundary Air Pollution EMEP Workshop on Combined Analysis of Measurements and Model Results with Special Emphasis on NO_x\VOC\Oxidants, Halifax, Nova Scotia, Canada, September 16-20, 1991.

R.L. Dennis

NATO/CCMS International Technical Meeting (ITM) Round-Table Discussion on the Harmonization of Atmospheric Dispersion Models, Ierâpetra, Crete, Greece, October 2, 1991.

J.S. Irwin

APPENDIX E: VISITING SCIENTISTS

1. S. Chicherin
   E. Yu. Bezuglaya
   Main Geophysical Observatory
   St. Petersburg, USSR

Drs. Chicherin and Bezuglaya spent 2 weeks at the Atmospheric Sciences Modeling Division and the EPA Office of Air Quality Planning and Standards developing a statistical analysis methodology, assessing United States and Soviet Union air quality trends, and participating in the AWMA/EPA Conference on Measurement of Toxic and Related Air Pollutants. This work was performed under the US/USSR Working Group 02.01-10, Project 02.01-14.

2. M.J. Davidson
   Department of Applied Mathematics and Theoretical Physics
   University of Cambridge
   Cambridge, England

Dr. Davidson spent 6 weeks at the Fluid Modeling Facility (FMF). He and FMF staff jointly conducted wind-tunnel measurements on the flow structure within and around arrays of cubical buildings as well as the concentration fields resulting from tracer released at various positions upstream of the arrays. Both regular and staggered arrays were studied. Dr. Davidson was supported through a grant from the United Kingdom Ministry of Defence.

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

Dr. Lee spent 4 weeks at the Fluid Modeling Facility as monitor and participant in work conducted by FMF staff under a subcontract with Los Alamos National Laboratory. A wind tunnel study was conducted to characterize the mean and fluctuating concentration fields within a plume originating from a point source in a simulated atmospheric boundary layer.

4. Steven Onclay and Steven Semmer
   National Center for Atmospheric Research
   Boulder, CO

Drs. Onclay and Semmer spent one week at the Fluid Modeling Facility. They used the Meteorological Wind Tunnel to calibrate and test the response of new sonic anemometer designs.

5. T.A. Reinhold, Principal Engineer
   Applied Research and Engineering Services
   Raleigh, NC

Dr. Reinhold completed a 3-month visit at the Fluid Modeling Facility under a cooperative agreement with the North Carolina State University. He made extensive measurements of the pressure fields on the lee sides of two-dimensional and truncated cylinders (stacks). The mean speeds and turbulence scales and intensities of the approach flows were varied in order to determine appropriate conditions for conducting realistic laboratory-scale simulations of full-scale stack-tip downwash of buoyant plumes.

6. M. Schatzmann, Professor
   Meteorological Institute
   University of Hamburg
   Hamburg, Germany

Dr. Schatzmann spent 6 months at the Fluid Modeling Facility (FMF) under a cooperative agreement with the North Carolina State University. He and FMF staff jointly conducted wind tunnel experiments on dense-gas jets as might be released from high-pressure storage tanks.

7. I. Uno
   National Institute for Environmental Studies
   Tsukuba, Japan

Dr. Uno spent one week at the Fluid Modeling Facility consulting with FMF staff on wind-tunnel modeling techniques. He intends to conduct simulations of the urban heat island using the Institute's wind tunnel in Japan.

8. Dr. Shinji Wakamatsu
   Head, Urban Air Quality Section
   National Institute for Environmental Studies
   Tsukuba, Japan

Dr. Wakamatsu spent 2 weeks (October 1-13, 1990) visiting the Division to discuss areas of mutual interest in modeling and field monitoring of photochemical pollution. He presented a seminar on October 10, entitled, "The relative roles of NO_x and VOCs in ozone photochemistry." Discussions were also held on possible joint collaborative projects.

APPENDIX F: ATMOSPHERIC SCIENCES MODELING DIVISION STAFF FY-1991

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.

Office of the Director

Francis A. Schiermeier, Meteorologist, Director
Herbert J. Viebrock, Meteorologist, Assistant to the Director
Marc L. Pitchford, Meteorologist, (Las Vegas, NV)
Evelyn M. Poole-Kober, Technical Publications Editor
Joan K. Emory, Secretary (until December 1990)
Barbara R. Hinton (EPA), Secretary (since September 1991)

Atmospheric Model Development Branch

Dr. Jason K.S. Ching, Meteorologist, Chief
Dr. Francis S. Binkowski, Meteorologist
Dr. Gary A. Briggs, Meteorologist
O. Russell Bullock, Jr., Meteorologist
Terry L. Clark, Meteorologist
Dr. John F. Clarke, Meteorologist
Dr. Robin L. Dennis, Physical Scientist
James M. Godowitch, Meteorologist
Dr. Jonathan A. Pleim, Physical Scientist (since December 1990)
Shawn J. Roselle, Meteorologist
Kenneth L. Schere, Meteorologist
B. Ann Warnick, Secretary

Fluid Modeling Branch

Dr. William H. Snyder, Physical Scientist, Chief
Cheryl Blancher, Engineering Aid
Lewis A. Knight, Electronics Technician
Robert E. Lawson, Jr., Physical Scientist
L. Michael Stroud, Engineering Aid
Roger S. Thompson (PHS), Environmental Engineer
Anna L. Cook, Secretary

Modeling Systems Analysis Branch

Joan H. Novak, Computer Systems Analyst, Chief
William E. Amos (EPA), Computer Programmer
Dr. William G. Benjey, Physical Scientist
Dale H. Coventry, Computer Systems Analyst
Thomas E. Pierce, Jr., Meteorologist
Alfreida D. Rankins, Computer Programmer
James A. Reagan (PHS), Statistician (until July 1991)
John H. Rudisill, III, Computer Specialist
Barbara R. Hinton (EPA), Secretary (until September 1991)

Global Processes Research Branch

Dr. Peter L. Finkelstein, Meteorologist, Chief
Dr. Ellen J. Cooter, Meteorologist
Brian K. Eder, Meteorologist
Dr. Sharon K. LeDuc, Statistician
Dr. Steven G. Perry, Meteorologist
Lawrence E. Truppi, Meteorologist
Ella L. King (EPA), Secretary

Applied Modeling Research Branch

John S. Irwin, Meteorologist, Chief
Dr. C. Bruce Baker, Meteorologist (until August 1991)
Dr. Alan H. Huber, Meteorologist
Lewis H. Nagler, Meteorologist (Atlanta, GA)
William B. Petersen, Meteorologist
Everett L. Quesnell, Meteorological Technician
Brian D. Templeman, Meteorologist
Dana L. Bailey, Secretary

Air Policy Support Branch

James L. Dicke, Meteorologist, Chief
Dennis G. Atkinson, Meteorologist
Dr. Desmond T. Bailey, Meteorologist
Thomas N. Braverman (EPA), Environmental Engineer
C. Thomas Coulter (EPA), Environmental Protection Specialist
Dennis C. Doll, Meteorologist (until August 1991)
Russell F. Lee, Meteorologist
Norman C. Possiel, Jr., Meteorologist
Jawad S. Touma, Meteorologist
Dean A. Wilson, Meteorologist
Brenda P. Cannady (EPA), Secretary

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