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FISCAL YEAR 1993 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
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PREFACE

This document summarizes the Fiscal Year 1993 research and operational efforts and accomplishments of the Atmospheric Sciences Modeling Division (ASMD) working under interagency agreements EPA DW13935371, DW13935457, and DW13936892 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 agreements with the EPA, which funds the research efforts in air pollution meteorology. 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 Commissioned Corps personnel, 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 and Regional Offices. The primary groups within ASMD are the Atmospheric Model Development Branch, Fluid Modeling Branch, Modeling Systems Analysis Branch, Global Climate Research Branch, Human Exposure Modeling 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 the remaining appendices.

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.

CONTENTS

Page

FIGURES

FISCAL YEAR 1993 SUMMARY REPORT OF NOAA ATMOSPHERIC SCIENCES MODELING DIVISION SUPPORT TO THE U.S. ENVIRONMENTAL PROTECTION AGENCY

ABSTRACT. The Atmospheric Sciences Modeling Division, during FY-1993, provided meteorological research and operational support to the U.S. Environmental Protection Agency. Operational activities consisted of the application of dispersion models, the conduct of dispersion studies and model evaluations, and the provision of advice and guidance. The primary research efforts were the development and evaluation of air quality models using numerical and physical techniques supported by field studies, and the initiation of studies under the High Performance Computing and Communications program. These efforts included development of a high resolution version of the Regional Acid Deposition Model; development of the Comprehensive Sulfate Tracking Model; improvement of the advanced land-surface and PBL model; sensitivity analysis of the Regional Oxidant Model; analysis of visibility trends; development of an empirical model relating vehicle fleet-averaged emissions to repair and malfunction rates; conduct of a wind-tunnel study of dispersion from surface coal mines; development of a new version of the Biogenic Emission Inventory System; examination of the spatial and temporal variability of daily one-hour maximum ozone concentrations over non-urban areas; and conduct of an analysis of the meteorological factors associated with the high surface ozone in 1988 and 1990.

1. INTRODUCTION

In fiscal year 1993, 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 Division participation in international activities, while Sections 2.2 through 2.7 outline the Division research activities in support of the short- and long-term needs of the EPA and the environmental community. Section 2.8 discusses Division support to the 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 in 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 domestic and international research exchange activities, and provides NOAA meteorologists to an EPA laboratory in Las Vegas, Nevada, to conduct visibility and remote sensing research.

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 bases of air quality modeling. Under this agreement, the AMS maintains a Steering Committee on Scientific Assessment of Air Quality Models to (1) provide scientific reviews of various types of air quality dispersion models; (2) assist in developing a more complete understanding of uncertainty as it affects different aspects of air quality modeling; (3) respond to specific requests regarding scientific aspects of the Division's air quality modeling practices; and (4) plan and conduct scientific workshops in an attempt to advance the state of regulatory dispersion modeling.

The AMS Steering Committee and the EPA have formed the AMS/EPA Regulatory Model Improvement Committee (AERMIC) 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 Committee 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 (Weil, 1992).

2.1.2 Interdepartmental Meteorological Committee

The Division Director serves as an Agency representative on 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, multiagency plan for government meteorological services and for those research and development programs that directly support and improve these services. The Committee prepared the annual Federal Plan for Meteorological Services and Supporting

Research (U.S. Department of Commerce, 1993b). A Division scientist serves on the ICMSSR Working Group for Atmospheric Transport and Diffusion. This working group produced the Directory of Atmospheric Transport and Diffusion Models, Equipment, and Projects (U.S. Department of Commerce, 1993a).

2.1.3 NATO Committee on Challenges of Modern Society

The North Atlantic Treaty Organization (NATO) Committee on Challenges of Modern Society (CCMS) was established in 1969 with the mandate to examine how to improve, in every practical way, the exchange of views and experience among the Allied countries in the task of creating a better environment for their societies. The Committee considers specific problems of the human environment with the deliberate objective of stimulating action by member governments. The Committee's work is carried out on a decentralized basis through pilot studies, discussions on environmental issues, and fellowships.

2.1.3.1 International Technical Meetings

The Division Director serves as the United States representative on the Scientific Committee for International Technical Meetings (ITMs) on Air Pollution Modeling and Its Application, sponsored by NATO/CCMS. A primary activity within the NATO/CCMS Pilot Study on Air Pollution Control Strategies and Impact Modeling is organizing a symposium every eighteen 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 20th NATO/CCMS International Technical Meeting will be conducted in Valencia, Spain, from November 29 to December 3, 1993. The proceedings will be published, as were the proceedings from the 19th International Technical Meeting held in Ierápetra, Crete, Greece, (van Dop and Kallos, 1992). The Scientific Committee selected the eastern United States as the site for the 21st International Technical Meeting to be held during spring 1995.

2.1.3.2 Coastal Urban Air Pollution Study

The Division Director serves as the United States representative on the International Oversight Committee for the NATO/CCMS Pilot Study on Urban Pollutant Dispersion near Coastal Areas. This pilot study, sponsored by Greece, originated in a workshop held in Athens during February 1992. The purpose is to understand the causes of high air pollution episodes in coastal urban areas and to devise strategies to mitigate pollution problems caused by vehicular and industrial emissions in these areas. A NATO/CCMS advanced research workshop was held during May 1993 to design a reference experiment in the Athens coastal urban area to collect relevant ambient measurements and emissions for use in evaluation of existing urban dispersion models and for understanding the atmospheric boundary layer at the interface of land and water. A workshop report is under preparation.

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, a Division scientist spent two weeks touring wind tunnel facilities and exchanging information on fluid modeling techniques and practices in Tokyo, Tsukuba, Kumamoto, Aso, and Nagasaki, Japan.

2.1.5 United States/Russia Joint Environmental Committee

The Division Director serves as the United States Co-Chairman of the US/Russia (formerly USSR) Working Group 02.01-10 on Air Pollution Modeling, Instrumentation, and Measurement Methodology, and as Co-Leader of the US/Russia Project 02.01-11 on Air Pollution Modeling and Standard Setting. The purpose of the 1972 agreement forming the US/Russia 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
Project 02.01-14: Statistical Analysis Methodology and Air Quality Trend Assessment.

Progress under this Working Group was diminished considerably during FY-1993 by the absence of a Russian Co-Chairman, following the transfer in September 1993 of Dr. A. S. Zaitsev to the World Meteorological Organization in Geneva, Switzerland. Activities did include a June 1993 visit to the Division by Russian scientists from the Moscow Institute of Global Climate and Ecology; the continuation of a National Research Council (NRC) research associateship by a Russian expert in remote sensing to the EPA Environmental Monitoring Systems Laboratory in Las Vegas, Nevada; and the continuation of an NRC research associateship by a Russian scientist at the Division's Fluid Modeling Facility in Research Triangle Park, North Carolina. As Co-Chairman of Working Group 02.01-10, the Division Director participated in a meeting in Asheville, North Carolina, of the US/Russian Working Group 02.08-10 on Climate Change. Research interactions between the two Working Groups are being initiated.

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 Atmospheric Environment Service of Canada, Ontario Ministry of the Environment, Electric Power Research Institute, and Environmental Protection Agency (Atmospheric Environment Service, Environment Canada, 1993). Having coordinated the evaluation of the Canadian Acid Deposition and Oxidant Model (ADOM) and the United States Regional Acid Deposition Model (RADM), 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 United States Weather Research Program

The Division Director serves as an Agency representative on the interagency working group for the United States Weather Research Program (USWRP). This new initiative is designed to (1) increase benefits to the Nation from the substantial investment in modernizing the public weather warning and forecast system in the United States; (2) improve local and regional forecasts and warnings; (3) address critical weather-related scientific issues; and (4) coordinate governmental, university, and private-sector efforts. The program is broad in scope, encompassing the full range of atmospheric processes that are part of weather, including dynamics, thermodynamics, synoptics, cloud physics, atmospheric chemistry, electricity, and radiation, as well as their effects on hydrology. The strategic plan for the USWRP has been submitted to Congressional staffs and to participating Agency heads (U.S. Office of Science and Technology Policy, 1992).

2.1.8 NAS/NRC Board on Atmospheric Sciences and Climate

The Division Director serves as an Agency representative to the Board on Atmospheric Sciences and Climate (BASC) of the National Research Council, National Academy of Sciences. The activity of BASC that supports the work of the Division is the formation of a Panel on Atmospheric Aerosols. Specifically, the panel will review existing and new evidence regarding anthropogenic and natural aerosol-producing processes; their sources, characteristics and distribution; their transport and removal; and their quantified effects on atmospheric processes and on the global and regional radiation forcing of the climate system. The panel will advise on the observation, monitoring, and research strategies needed to understand atmospheric processes and aerosol characteristics important in weather and air pollution research. To coordinate the research efforts, Division scientists serve on the Climate Research Committee and the Panel on Atmospheric Aerosols.

2.1.9 European Monitoring and Evaluation Program

A Division scientist serves as the United States representative to the European Monitoring and Evaluation Program (EMEP) that oversees the cooperative program for monitoring and evaluation of the long-range transmission of air pollutants in Europe. The primary goal of EMEP is to use regional air quality models to produce assessments evaluating 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 Division scientist also evaluates European studies of special relevance to the program, providing technical critiques of the EMEP work during formal and informal interactions; and developing and coordinating such programs with EMEP as the modeling studies of the Modeling Synthesizing Center West (MSC-W) at the Norwegian Meteorological Institute in Oslo, Norway.

2.1.10 Clean Air Act Amendments of 1990 Section 812 Assessment Working Group

A Division scientist is a member of the 812 Assessment Working Group, in coordination with the EPA Office of Program Assessment and Review and the EPA Office of Policy Planning and Evaluation, with responsibility for developing approaches to assess regional air quality and acidic deposition. The responsibilities of this working group are to produce a retrospective assessment of the benefits and costs of the Clean Air Act (CAA) of 1970 and a prospective assessment of the benefits and costs of the Clean Air Act Amendments (CAAA) of 1990, assuming full implementation. Work in FY-1993 focused on the retrospective assessment, specifically on development of approaches and production of time trends of emissions from 1970 to 1990 for a CAA implementation case and a CAA non-implementation case.

2.1.11 Chesapeake Bay Program Air Quality Coordination Group and Chesapeake Bay Program Modeling Subcommittee

A Division scientist is a member of the Air Quality Coordination Group, an advisory committee to the Chesapeake Bay Implementation Committee. This group provides expert advice and leadership on atmospheric deposition to the Bay and in dealing with the influence of atmospheric deposition on Bay restoration efforts. The Division scientist is also an ex officio member of the Modeling Subcommittee of the Implementation Committee. This subcommittee has responsibility for overseeing the application of water quality models and coordinating the linkage of the Regional Acid Deposition Model (RADM) with those models and the interpretation of the findings. This subcommittee also works with other Chesapeake Bay committees to define the top priority air quality scenarios to be simulated by RADM.

2.1.12 Consortium for Advanced Modeling of Regional Air Quality

A Division scientist serves as an Agency 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 and Electric, California Air Resources Board, Department of Energy, National Oceanic and Atmospheric Administration, Environmental Protection Agency, Department of Defense, Atmospheric Environment Service, Environment Canada, Ontario Ministry of the Environment, and EUROTRAC (EUROpean experiment on the TRAnsport and transformation of trace atmospheric Constituents). The members of CAMRAQ share a mutual interest in making regional-scale atmospheric models usable tools for air quality and emergency response planning. They also share an interest in bringing the emerging power of high performance computing to regional air quality modeling. The members agreed that forming a consortium to coordinate research and to form a basis for collaboration on projects will enhance the ability of each to achieve their respective goals regarding atmospheric modeling.

2.1.13 National Acid Precipitation Assessment Program

A Division scientist serves as Chairman of the National Acid Precipitation Assessment Program (NAPAP) Subgroup on Processes and Deposition/ Air Quality Modeling of the Atmospheric Effects Working Group, following the new mandate and organization of NAPAP under the CAAA. This working group will help evaluate the benefits and effectiveness of the acidic deposition control program of CAAA Title IV and will help determine the reduction in emissions that are associated with deposition rates needed to prevent adverse effects. The working group will provide support for future NAPAP assessment activities required by the CAAA.

2.1.14 Eulerian Model Evaluation Field Study Program

The Eulerian Model Evaluation Field Study (EMEFS) program is a multiagency program for evaluating regional-scale acid deposition models, including the Regional Acid Deposition Model (RADM) and the Acid Deposition and Oxidant Model (ADOM). Sponsors of this program include the National Oceanic and Atmospheric Administration, Environmental Protection Agency, Electric Power Research Institute, Atmospheric Environment Service, Environment Canada, and Ontario Ministry of Environment. The Program Management Group (PMG) oversees the project and consists of representatives from each sponsor, including the chairmen from four teams: the Operational Measurements Team, the Diagnostic Measurements Team, the Emissions Inventory Team, and the Model Evaluation Team.

The Model Evaluation Team, chaired by a Division scientist, continues to evaluate RADM and ADOM for the United States/Canada Air Quality Agreement and the Eulerian Model Bilateral Steering Committee. Work in FY-1993 saw the production of ADOM and RADM runs using the spring 1990 field intensive database, a 75-day evaluation period ending May 30, 1990, for Phase 2 of the EMEFS evaluation. Evaluation work continued to explore comparisons based on the summer 1988 database, focusing on the behavior of the nitrogen chemistry, associated with oxidant formation as well as with nitrogen deposition, in the models.

2.1.15 Southern Oxidant Study

A Division scientist is a member of the Modeling and Model Science Team of the Southern Oxidant Study (SOS). Efforts are directed towards model evaluation using SOS data for the regional oxidant models coupled with urban oxidant models. As part of this work, the Division scientist is also a member of the Nashville Intensive Planning Team that is developing plans for the Nashville intensive field study campaign for summer 1995.

2.1.16 An International Task Force on Forecasting Environmental Change

A Division scientist is a member of the International Task Force on Forecasting Environmental Change. In February 1993, 21 participants of the Task Force met at the International Institute for Applied Systems Analysis in Laxenburg, Austria, to hold the first of three workshops on the methodological and philosophical problems of forecasting considering the possibility of significant structural changes in the behavior of physical, chemical, or biological systems.

2.1.17 RADM Application Studies

Efforts during FY-1993 concentrated on planning and executing RADM applications related to mandates in the 1990 Clean Air Act Amendments (CAAA) involving sulfur and nitrogen deposition and visibility. Studies called for in the CAAA are (1) the feasibility of deposition standards; (2) the impact on deposition of trading NO_x emission reductions for SO_2 allocations; and (3) the effects on sulfur deposition reductions that result from trading of SO_2 emission allocations (the SO_2 reductions assigned to each source). A new RADM Engineering Model for calculating light extinction, visual range, and DeciView, a parameter related to perception of visibility degradation due to sulfate in the air, was developed to support the assessment applications. RADM applications supported an EPA report to Congress (U.S. Environmental Protection Agency, 1993b).

Several other application studies are being planned. The EPA Region III Office and the Chesapeake Bay Office need nitrogen deposition and source attribution information related to nitrogen deposition to the Chesapeake Bay coastal estuary. They also need estimates of the reduction in nitrogen loading from the atmosphere to the Bay and the Bay watershed expected from implementation of the 1990 CAAA. Preliminary estimates were developed and made available to the Chesapeake Bay Program Office during FY-1993. The United States/Canada Air Quality Agreement also needs information on the effect of each nation's emission reductions on the sulfur deposition across each other's critical effects regions and a determination of how the responsibility for deposition in eastern North America is evolving.

2.1.18 Visibility Research and Technical Support

Among the major tasks for the FY-1993 visibility program 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 and assessment activities.

2.1.18.1 Measurement of Haze and Visual Effects

A congressionally-mandated project to estimate the frequency and magnitude of perceptible impacts of the Mohave Power Plant and other influential emission sources in the southwestern United States on visibility at such Class I visibility-protected areas as the Grand Canyon National Park resulted in developing a plan for Project MOHAVE (Measurement Of Haze And Visual Effects) (U.S. Environmental Protection Agency, 1991). Project MOHAVE was completed during FY-1992 and involved year-long continuous monitoring with two month-long intensive study periods (winter and summer).

During FY-1993, the measurement data were submitted to a centralized database, checked for internal consistency, and subjected to preliminary interpretive analyses. A regional windfield model was run for each day of the study, with resolution telescoped to 12 km during the year and additional resolution to 0.8 km during intensives. Based upon these windfields, transport and dispersion calculations started in FY-1993, and will be summarized in the database in the form of influence functions. 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 spatial pattern (eigenvector) analysis. Interpreting data and reporting activities will continue during FY-1994. Data from Project MOHAVE are also being used extensively in the analyses being conducted for the Grand Canyon Visibility Transport Commission.

2.1.18.2 Interagency Monitoring of Protected Visual Environments

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 monitoring site includes optical, particle, and scene monitoring. Most of the instrumentation used was specially designed to be operated in remote area locations by non-technical field support personnel. Five Federal agencies (Environmental Protection Agency, National Park Service, Bureau of Land Management, Fish and Wildlife Service, and Forest Service) and three member organizations of state air pollution control agencies (WESTAR, NESCAUM, and STAPPA) oversee operation of the program through a steering committee chaired by a Division meteorologist. Several agencies 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.

Two IMPROVE reports were prepared during FY-1993. One of these examines spatial trends based upon three years of fine particulate mass and composition, and visibility data from 36 monitoring sites across the country (Sisler *et al.*, 1993). The other summarizes visibility trends based upon five years of transmissometer data from 20 locations nationwide (Air Resource

Specialists, Inc, 1993). The IMPROVE network data are also being used in the analyses being conducted for the Grand Canyon Visibility Transport Commission.

2.1.18.3 Technical Support and Interagency Coordination

The EPA Office of Air Quality Planning and Standards required technical support to aid in its participation on the Grand Canyon Visibility Transport Commission. The Commission was mandated by the CAAA and is composed of the Governors of seven western states and representatives of several Federal agencies. The Commission is charged with evaluating regional haze impairment at the Grand Canyon National Park and recommending to the EPA by November 1995 any additional regulatory measures that may be needed. Division support of the Grand Canyon Visibility Transport Commission includes chairing the Aerosol and Visibility Technical Subcommittee.

Technical support included assessment of potential visibility impacts from a clean coal demonstration power plant funded by the Department of Energy (DOE) and proposed to be built three miles from Denali National Park in Alaska. This involved coordination with representatives of the EPA, DOE, and National Park Service, as well as officials from the state of Alaska and the utility company and its consultants. As a result of assessments by Division staff, significant additional emission reductions were agreed to by the power plant proponents.

2.1.19 Remote Sensing Technology Development and Evaluation

2.1.19.1 Remote Monitoring of Vehicle Exhaust

A device for monitoring tailpipe emissions of vehicles passing through an infrared light beam directed across the roadway was developed by scientists at the University of Denver under the REmote Monitoring Of Vehicle Exhaust (REMOVE) program. Evaluation and development of this technology started in 1988. In FY-1992, the instrument was used to assess the effects of oxygenated fuels on carbon monoxide emissions in Las Vegas, Nevada. A journal article describing the results of this study is being prepared. An empirical model was developed using a Las Vegas remote sensing data set to relate vehicle fleet-averaged emissions, as measured by the remote sensor, to repair and malfunction rates. A journal article describing the model was published (Pitchford and Johnson, 1993).

2.1.19.2 Ultraviolet Differential Absorption Lidar

Development of the UltraViolet DIfferential Absorption Lidar (UV-DIAL) is supported by the EPA, NOAA, and NASA. The goal is to build a compact active remote sensing system for the measurement of tropospheric ozone along with information about tropospheric aerosol properties (Moosmuller *et al.*, 1993). During testing and evaluation of the system, several ground-based tests and one airborne field test were conducted. These tests indicate that ozone measurements made with this system are accurate to within 5-parts-perbillion-volume (ppbv) of in situ measurements over a range of 2-3 km. Aerosol distributions can also be determined from the data that are provided by this system.

The UV-DIAL system was utilized in an airborne field mission as part of the Coastal Oxidant Assessment for Southeast Texas study over the Houston area. This ozone non-attainment study was conducted by the Texas Air Control Board during July and August 1993. Comparisons of UV-DIAL derived data with measurements made by in situ instrumentation on other aircraft will be possible with this data set. These comparisons will allow further validation of the UV-DIAL instrument and its measurements. The reduction and analysis of the large amounts (21 GBytes) of UV-DIAL data collected during this study are in progress and the results will be published as they become available.

A decision to move the UV-DIAL program out of the EPA Environmental Monitoring Systems Laboratory was made in late FY-1992. During FY-1993, the implementation of the transfer was reviewed and a transition plan formulated to transfer the UV-DIAL to the NOAA Environmental Technology Laboratory for continued development and operation. The preparations for this transfer are in progress and will be implemented early in FY-1994.

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 emissions-based Eulerian grid modeling system with a three-dimensional transport, gas and aqueous phase chemistry, and wet and dry removal processes. RADM is a major project begun in 1984 under the auspices of the National Acid Precipitation Assessment Program (NAPAP). The model has undergone an extensive series and several stages of program model development, refinements, and evaluation. Several versions have evolved depending on the specific required scientific or policy application. The most important contributing processes to the acidification of sulfur and nitrogen species are modeled. In its basic form, RADM has 15 vertical levels and 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 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). Greater spatial resolution is now possible with the development of HRADM, the high resolution version of RADM. Now, windowed or nested runs with several different resolutions (80 km, 40 km, 26.7 km, and 20 km) can be accomplished with one universal code. HRADM is the version used to facilitate a model comparison study between RADM and the Regional Oxidant Model (ROM). In the windowed version, users will have a choice of constant or dynamic boundary conditions. The windowed version includes routines for computing integrated reaction rates and mass budgets. This is useful for evaluating model processes because several diagnostic runs on the windowed domain can be performed without having to re-run the full scale HRADM. Several preprocessors and postprocessors were developed to accommodate the increased functionality. In the preprocessors, new interpolation routines were implemented to generate high resolution meteorological data sets needed for HRADM runs.

The RADM Engineering Model (RADM/EM) was developed as a tool to examine the response of sulfate deposition (wet and dry) to sulfur control strategies. Subsequent versions include the Tagged Species Engineering Model (TSEM), which was used to examine the apportionment of deposition to particular sulfur source regions (McHenry *et al.*, 1992) and the Sulfate Tracking Model (STM) used to investigate pathways to sulfate formation. The TSEM has 15 vertical layers to provide the vertical resolution needed in sulfate source apportionment. The COMprehensive Sulfate Tracking Model (COMSTM) version of the RADM/EM allows the tracking of sulfate from every possible gas- or aqueous-phase chemical-reaction pathway included in the model (McHenry and Dennis, 1993). Finally, a post-processor was developed for TSEM, which allows an examination of the response of visual range to sulfur control strategies. The extinction coefficients used here are empirical functions of sulfate mass and relative humidity.

RADM and RADM/EM typically simulate 3- to 5-day periods. Aggregation methods when applied to these simulations, provide the means to produce seasonal and annual averages of acid deposition, and annual frequency distributions of ambient concentrations of sulfate and sulfur dioxide from these episodic outputs (Samson *et al.*, 1990).

The basis for the evaluation of the RADM is the Eulerian Model Evaluation Field Study (EMEFS) (Hansen *et al.*, 1989). This major program consisted of both a surface network of more than 100 sites in northeastern North America collecting aerometric and precipitation data over a 2-year period starting June 1988 for an operational evaluation, as well as aircraft and special chemistry studies for an extensive diagnostic evaluation. The contributing networks include the U.S. Environmental Protection Agency's Acid Models Operational and Diagnostic Evaluation Study (Acid-MODES) (Ching and Bowne, 1991) network; the Electric Power Research Institute Operational Evaluation Network; the Ontario Ministry of the Environment Acid Precipitation In Ontario Study; the Atmospheric Environment Service of Canada Canadian Air and Precipitation Monitoring Network (CAPMoN); and the Florida Electric Power Coordinating Group. 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, Pennsylvania, and at Egbert, Ontario, provided the requisite inter- and intranetwork information on precision and accuracy. Analysis and modeling studies using the aircraft measurements made during summer 1988 and spring 1990 intensive field studies as part of Acid-MODES is the primary means to evaluate RADM on a diagnostic basis.

2.2.1.2 RADM Window and Nesting

During FY-1993, HRADM, a high resolution version of RADM, was further developed to include window capability. With one universal code, window or nested runs with several different resolutions can be accomplished. Window modeling is not a new concept. It is very similar to the one-way nesting applied to many Eulerian air quality models. The only difference of window RADM (WRADM) from the one-way nested RADM, as presented by Pleim *et al.* (1991) is that WRADM uses limited domain (window) without changing horizontal resolution (grid size). This concept was applied to an earlier RADM version to facilitate development of a regional particulate model (RPM). In this implementation, a flexible RADM system was developed to replace the operational RADM. Unlike the original RADM, this version has a symmetric number of boundary cells in both horizontal directions. When used in a nested or window mode, the boundary conditions are interpolated at advection time steps using the hourly concentrations provided by coarse or full-domain RADM results (dynamic boundary conditions). All the processors in the RADM system should recognize four different modeling domains (MM4, RADM, HRADM, and WRADM domains) and provide consistent file information for subsequent processors. The new modification allows RADM runs at several different horizontal resolutions and at any window domain with or without dynamic boundary conditions.

RADM can be used in the window mode for the following modeling activities:

1. Diagnostic evaluation by generating diagnostic information without having to run the full-domain RADM for a targeted area.

2. Development and code debugging of new algorithms for chemistry and vertical processes. To address the scalability issue, it is essential to implement and test new algorithms in the operational version, capable of simulating at the full and window domains and high and coarse resolutions.

3. Screen to test hypothesis. WRADM may not give exactly the same results as the full-domain RADM, but it will provide similar sensitivity characteristics within specific error bounds. In studying the effect of local input changes in the window domain, the window model can be a good economic alternative to the full-domain model.

4. Technology transfer. WRADM can be used to teach comprehensive air quality modeling without big systems and large databases. The system is usable on a workstation computer.

Tests are underway to characterize window-mode RADM runs for the (1) number of cells required to maintain stability of the model results for different Courant numbers; (2) grid resolution and window domain size dependency; (3) treatment of out-flow boundary conditions; (4) method of computation of boundary fluxes for the horizontal diffusion process; (5) behavior of initial and boundary condition tracers to study boundary flux influence; and (6) capability of reproducing integrated-reaction rate and mass budget (Jang, 1992) information. The effects of window domain size and resolution on the reproducibility of original full domain results and sensitivity to model input parameters will be reported.

2.2.1.3 RADM Evaluation Studies

Studies continued to understand model bias due to the limited horizontal and vertical grid resolution. There were large differences between RADM results and measured surface ozone concentrations, particularly during the nocturnal periods. Comparison of the RADM results with surface measurements of hourly ozone concentrations from the National Dry Deposition Network (NDDN) sites showed distinct diurnal variations in the model high bias. Hypothetically, this phenomenon is partly caused by the coarse vertical resolution of RADM in representing the deposition layer. The similarity theory of the Planetary Boundary Layer (PBL) was applied to predict the high-bias of the model results (volume averages) to the surface observations (time series at a point) for the horizontally homogeneous case. The coarse vertical resolution in the deposition layer explains the situations of a considerable portion of the high-bias of model O_3 concentrations at night. The model should resolve, at least, the lower half of the PBL in order to predict surface deposition fluxes correctly.

For certain NDDN sites, the profile correction alone cannot fully explain the model's high-bias of daily minimum O_3. The rate of O_3 destruction can be influenced considerably by the NO emission strength as well as the dry deposition process. Besides the uncertainties in the NO_x emission database, the other possible explanation for the apparent low NO concentrations in the surface layer at nighttime is that the emissions are distributed too rapidly in the coarse vertical layer. Preliminary results show the effect of emission source distribution in representing the $NO-O_3$ titration process. The hypothesis is tested by introducing an additional surface-emission layer into a limited-domain RADM (WRADM). The results show that the details of vertical gradients in the emission distribution are very important in explaining the nighttime model bias. The preliminary study provides one example of the need for adequate vertical resolution in the photochemical model to minimize the model bias. The study will be continued using the full RADM system with increased vertical resolution and for many more meteorological cases.

2.2.2 Dry Deposition Studies

2.2.2.1 Inferential Model for Dry Deposition

The NOAA multilayer inferential dry deposition model (Meyers *et al.*, 1991; Hicks *et al.*, 1991) was implemented for batch calculations of dry deposition fluxes for the 50-site National Dry Deposition Network (NDDN). Weekly, seasonal, and annual dry deposition data for ozone, sulfur dioxide, nitric acid, sulfate, and nitrate were archived for 1987 through 1991. An overview of the NDDN inferential modeling program, including an initial assessment of uncertainty of the model calculations, was documented (Clarke and Edgerton, 1993).

Inferential dry deposition model results for six NDDN sites were compared with those from the monthly climatological and land-use classification model developed by Voldner *et al.* (1986), which is widely used in Canada. Annual dry deposition estimates by the two models were generally within the range of uncertainty associated with inferential model estimates. However, there were consistent differences that appeared to be related to surface type, chemical species, and/or time of year. These differences highlight the importance of applying the same model when examining regional differences in dry deposition rates.

2.2.2.2 Direct Dry Deposition Measurement Program

A transportable dry deposition measurement system was set up at a local site for evaluation. The system is equipped to determine eddy correlation surface fluxes of heat, momentum and water vapor, ozone, sulfur dioxide, and carbon dioxide. Fluxes of nitric acid and sulfur dioxide are also measured by a gradient approach. Meteorological and vegetation parameters necessary for the application of the inferential model are also monitored. The system will be deployed to selected NDDN sites in FY-1994 to provide a basis for assessing the accuracy and uncertainty of the inferential dry deposition model as applied in the NDDN.

2.2.3 Meteorological Modeling Studies

2.2.3.1 Evaluation of the Penn State/NCAR Mesoscale Model

A model evaluation effort was initiated to determine the accuracy of simulated wind, temperature, and moisture fields obtained from the Penn State/NCAR Mesoscale Model-Generation 4 (MM4) (Anthes *et al.*, 1987) at times and locations where observed data are not available for four-dimensional data assimilation (FDDA). FDDA techniques are typically employed during MM4 applications to guide the simulations toward the observed fields of wind, temperature, and water vapor mixing ratio (Stauffer and Seaman, 1990; Stauffer *et al.*, 1991). Simulation quality is partially judged based on comparisons of modeled fields to the spatially analyzed fields of observed data used for FDDA. Harsh forcing of the simulation toward the observed fields could produce good agreement at the observation times, but degrade the results otherwise. To strengthen the verification, the simulated precipitation fields are compared to observed precipitation fields since precipitation is not used for FDDA guidance and is influenced by complex physical relationships between the other variables. However, the possibility still exists that inaccurate parameterizations of two or more model variables could combine to produce accurate precipitation results. To eliminate this possibility, independent verification of simulated wind, temperature, and humidity is required using data that are not used in the FDDA process. Evaluation of MM4 performance is being conducted using supplemental rawinsonde data from the Cross-APpalachian Tracer EXperiment (CAPTEX). A total of 372 special rawinsonde soundings were made during September and October 1983 that will be used to perform the same type of statistical comparison to model results that are typically done with FDDA fields.

2.2.3.2 Adaptation of the MM4 for Workstation Application

Work continued on modifying the MM4 for operation on a commercially available computing workstation employing a UNIX-based operating system similar to that now used for MM4 applications on Cray Y-MP systems. Benchmark tests of the MM4 using FDDA on a DEC 3000 Model 500 AXP high-performance workstation were performed showing that simulations could be obtained at one-sixth the speed typically possible on Cray Y-MP systems. This application strategy promises to be a very economical alternative to the use of mainframe supercomputers for meteorological support of air-quality modeling projects. A paper describing this new application strategy was presented by Bullock (1993). Complete MM4 applications require the NCAR graphics software package for analysis of input and output data. Once the NCAR graphics software becomes available for the DEC 3000 workstation, full implementation of the MM4 software system can begin.

2.2.3.3 Application of the MM4 for Air-Quality Modeling Support

The MM4 system using FDDA was operated on Cray Y-MP computing systems at the North Carolina Supercomputing Center (NCSC), Research Triangle Park, North Carolina, and at the EPA National Environmental Supercomputing Center (NESC), Bay City, Michigan, in support of various RADM and ROM studies. In support of the Interagency Working Group on Air Quality Modeling (IWAQM), a large-scale simulation effort was begun with MM4 at NESC to simulate three-dimensional meteorology over all of the continental United States for calendar year 1990. All required input data files for this simulation project were collected at NESC totaling over eight gigabytes of information. It is expected that the total size of the output data files from this project will approach 40 gigabytes. IWAQM intends to offer these simulated meteorological fields to regulatory air-quality modelers to help define the meteorological conditions at spatial and temporal scales smaller than those that can be defined using data from standard observations.

2.2.3.4 Advanced Land-Surface and PBL Model in MM4/MM5

Efforts continued to develop a model to improve surface flux and PBL parameterizations in MM4/MM5. The model consists of a simple surface energy and moisture parameterization, including explicit representation of soil moisture (Noilhan and Planton, 1989), and the latest PBL scheme developed for RADM (Pleim and Chang, 1992). The coupled surface/PBL model performs integrated simulations of soil temperature and soil moisture in two layers as well as PBL evolution and vertical transport of heat, moisture, and momentum within the PBL. A one-dimensional prototype was applied to a 2-day period of the Wangara field study as well as several days from the First ISLSCP Field Experiment (FIFE) 1987 and FIFE 1989. These experiments show the model's ability to simulate ground temperature, surface fluxes, and boundary layer development accurately. Results of this study were presented by Pleim and Xiu (1993). The model was incorporated into MM4, essentially replacing the existing high resolution PBL model. For a 2-day simulation, the modified model compared well to the standard MM4 as well as fields objectively analyzed from observations. The model simulation of PBL development compared better to FIFE measurements than did the standard MM4. Work is continuing in code optimization, soil moisture initialization, advanced FDDA techniques for indirect nudging of soil moisture, cloud cover parameterizations, improved PBL algorithms, and incorporation of subgrid heterogeneity of soil moisture.

2.2.3.5 Dynamic Meteorological Modeling in Urban-Scale Domains

A hydrostatic, primitive equation model capable of simulating mesobeta scale (30-300 km) circulations generated from surface differential heating and terrain irregularities (Ulrickson and Mass, 1990) is being exercised to generate meteorological fields to drive urban photochemical grid model simulations. An upgraded version of this dynamic model being applied features a continuous FDDA technique. Initial test simulations of the model with FDDA focused on urban areas with recent intensive data sets (i.e. Los Angeles/ Southern California Air Quality Study (SCAQS); and Chicago/Lake Michigan Ozone Study (LMOS)). The objectives were to assess the effectiveness of the FDDA methodology through incremental reductions in the number of surface and upper air wind data sites and to determine the impact on the thermal and flow fields from variations in weighting coefficients for observed winds and temperatures. Results indicated that even when the intensive SCAQS and LMOS data sets were reduced to the spatial density of routine networks, modeled winds with data assimilation were more accurate than the simulated winds without FDDA (Douglas, 1992).

The dynamic model was installed and successfully executed on a SUN workstation, and VAX and Cray Y-MP computer systems. Numerous two- and three-dimensional test simulations lead to refinements in the model code. A Richardson number method was also installed to derive mixing heights based on the modeled temperature structure, which replaced the previous method that examined the turbulent kinetic energy profile.

Simulations were performed in urban domains where only routine observations are available. Winds, temperatures, and mixing height fields from the dynamic model and also from a diagnostic meteorological processor are being used to drive a revised version of the Urban Airshed Model (UAM) to examine differences in peak ozone concentrations and spatial pollutant patterns in the New York Metropolitan Area due to these different meteorological approaches. Preliminary evaluation results reveal that better agreement between modeled and observed ozone concentrations was achieved from assimilating the routine-surface and upper-air winds in the dynamic model simulation than without data assimilation. Furthermore, UAM results with the dynamic model inputs were better than those obtained with diagnostically-derived winds. Results of this effort will be reported in FY-1994.

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 scales (1000 km) in the eastern 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-1993 was on the evaluation and sensitivity of ROM2.2. Numerous sensitivity studies were carried out to probe the response of the regional photochemical system to key emission and meteorological parameters. Many emission sensitivity tests were performed, including a detailed modeling analysis of systematic reductions of NO_x and VOC emissions. Significant information was also learned about the sensitivity of the ROM results to particular meteorological variables, including boundary-layer heights, deposition velocities, and cloud amounts. Preliminary results were produced using the MM4 dynamic meteorological driver for ROM and using the MM4-predicted soundings as hourly gridded quasi-observations for the ROM diagnostic processors. Additionally, continued progress was made on a program to upgrade UAM.

The ROM research program is turning its attention to the development of a third-generation air-quality modeling system (Models-3) for regional and urban photochemistry, as well as other pollutants. Intercomparisons are being made of ROM and RADM in terms of their structure, science, numerical schemes, performance, and sensitivity response. Lessons learned from this study will be used in the development of the new multiscale modeling system.

2.2.4.2 Development and Testing of ROM2.2

ROM2.2 became operational during FY-1992. Many changes were made in the system as part of the 2.2 upgrade, including an improved boundary-layer parameterization scheme and a new diagnostic analysis technique for deriving regional wind fields from observations. During FY-1993, focus was on application and sensitivity testing of ROM2.2. One exception lies in the effort to implement an operational version of the ROM layer 0, the shallow (10-30 m) diagnostic layer between the surface and the bottom of the ROM prognostic layers. Although layer 0 was always a part of the ROM vertical structure (Lamb, 1983), and was used in the formulation of the model vertical fluxes, it was not treated as a separate entity for analysis of concentration estimates. The layer 0 algorithms use emission inhomogeneities to partition the volume of each grid cell into plume and non-plume portions. Rapid photochemistry is assumed to occur within the plume portions in which ozone is instantaneously scavenged by NO emissions. The layer 0 scheme is run in a post-processor mode, using concentration estimates and meteorology from the full ROM run as inputs. It is capable of producing concentration estimates from both the plume and the non-plume portions of the layer 0 grid cells. Diagnostic analysis of results shows that deposition velocity, vertical turbulence, and the specified plume volume fraction are all key parameters in the performance of layer 0 calculations. The scheme is most sensitive to the specified plume volume fraction, and it is this parameter that is the most difficult to specify, and contains considerable empiricism in its formulation. Several methods of calculating plume volume fractions, based on number and strength of emission sources, were tested. The largest differences between layer 0 and layer 1 estimated concentrations were seen over high emission areas as expected.

2.2.4.3 Sensitivity of Regional Ozone Modeling to Biogenic Hydrocarbons

The effect of uncertainties in biogenic hydrocarbon emission estimates on regional-scale ozone predictions was examined in a study using ROM (Roselle, 1992). Biogenic emissions of hydrocarbons were increased or decreased by a factor of 3 to account for the existing range of uncertainty in these emissions. Simulated hydrocarbon concentrations were directly impacted, causing predicted O_3 to change significantly, depending upon the availability of NO_x. Two emission control strategies were also examined in the study. One strategy included reductions in anthropogenic hydrocarbon emissions while the other reduced both anthropogenic hydrocarbon and NO_x emissions. Simulations showed that control of 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. For the most part, uncertainties in biogenic emissions did not change the preference for control strategy.

2.2.4.4 Evaluation of ROM2.2

An evaluation effort to investigate the transport and dispersion components of the ROM2.2 system involved model simulations of the Cross APpalachian Tracer EXperiment (CAPTEX) episodes. Model runs were performed with chemistry switched off and zero deposition to simulate the movement and spread across northeastern North America of a non-depositing, chemically-inert tracer released from either Dayton, Ohio, or Sudbury, Ontario. Analyses of both qualitative graphical displays of wind fields and spatial concentration patterns, and quantitative measures between observed and modeled concentrations were performed in a similar manner to those performed in a previous CAPTEX model evaluation (Godowitch, 1989). Trajectory analyses indicated that layer 2 winds, representative of transport over the bulk of the atmospheric boundary layer, dominated modeled plume paths across the region.

Spatial overlap of modeled and observed plumes was varied among the six episodes used and was dependent upon the amount of vertical speed and direction shear. Good agreement was found in the timing and location of impact of the modeled plume on the first sampling arc at 300 km downwind in the Dayton cases. However, the modeled plumes tended to arrive later than the observed tracer on the second day at sampling arcs further downwind. Modeled concentrations were also generally higher than observed values, and analyses of the dispersion formulation are underway to assess horizontal dispersion and vertical mixing in ROM and to compare modeled and observed plume widths as a function of distance. Results of this effort will be reported in FY-1994.

ROM2.2 was operationally evaluated for the period July 4-10, 1988, which included several days of very high observed O_3 concentrations. This evaluation included comparisons of episodic and daily maximum O_3 data. The evaluation indicated that the model has a tendency to underpredict ozone, and that the amount of underprediction increases with higher observed O_3 concentrations. On average, the model underpredicted episode maximum O_3 by 17 ppb (11%). Spatial plots, comparing observations to predictions, showed that the model did reasonably well in predicting spatial O_3 patterns and major plume locations.

A model intercomparison also continued during FY-1993 between ROM and RADM using the July 20-August 6, 1988, data for the eastern United States. Analysis of results for August 3, a relatively high ozone concentration day in the northeastern United States, showed that the models appear to be developing very similar ozone fields across the region, particularly when comparing the 18.5-km ROM and the 20-km high-resolution RADM results. The ROM fields, however, are characterized by a more spotty appearance with larger spatial concentration gradients than the smoother RADM fields. These differences are attributed principally to the combination of 80 km resolved meteorology coupled with the relatively diffusive Smolarkiewicz (1983) advection algorithm in RADM, and the observations-driven meteorology coupled with semi-Lagrangian numerical transport in ROM. Significant differences also appear in the oxidized nitrogen species, where RADM has produced relatively more PAN regionally and ROM has produced much more HNO_3. Model intercomparisons will continue through FY-1994 on understanding differences between the models by comparing with observations and normalizing for differences in input emissions, meteorology, and boundary conditions. Intercomparisons with model results from the NOAA Oxidant Model (NOM) based at the NOAA Aeronomy Laboratory, Boulder, Colorado, will also be conducted.

2.2.4.5 Development of Wind Fields for ROM

Work continued on adapting the meteorological outputs from MM4 to the ROM meteorological processing system. The hourly profiles of data from each vertical column of MM4 grid cells were provided to the ROM system as quasi-observational data. These data, denser spatially and temporally than the standard observational input, were then processed by the ROM system processors, which were slightly modified to analyze regular gridded data instead of the sparse data optimization analysis typically used. Differences in the ROM meteorological fields generated by the MM4 data and by NWS observational data were examined for an 8-day simulation period during the summer of 1988 over the eastern United States, along with the subsequent differences in ROM simulation results. While the general flow patterns were very similar in both the MM4 and the diagnostically-obtained analyses, the MM4-derived data led to lower processed values of mixed layer heights and a smaller diurnal range of atmospheric temperatures compared to those obtained from the diagnostic analysis. Also, differences present in horizontal wind speeds systematically affected the estimation of such other derived meteorological parameters as friction velocity, sensible heat flux, and processed emission data.

Comparison of results from ROM-predicted concentration data shows higher values, generally, for primary nitrogen and hydrocarbon species with the MM4-derived meteorology compared to results using the standard diagnostic meteorology. Results for ozone varied, depending upon the local chemical regime. This result is consistent with the lower predicted values of ROM layer 2 using MM4 meteorology. This project will continue, with results from the present study used in the ROM/RADM intercomparison project.

Work was completed on a project that explored 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 was published (Schere and Coats, 1992).

2.2.4.6 Development and Evaluation of a Refined Urban Airshed Model

The Urban Airshed Model (UAM) is the recommended photochemical grid model for regulatory applications in metropolitan areas required to demonstrate attainment of the hourly maximum ozone standard. The research and testing effort continued during FY-1993 on an upgraded version of the UAM code and the updated meteorological drivers designed to replace the existing UAM meteorological processor package. While the refined UAM retains the same vertical layer structure as the regulatory UAM, technical improvements include an updated horizontal advection scheme (Bott, 1989), inputs of hourly 3-D temperature and moisture fields, hourly 3-D photolytic rate constants, and improved hourly gridded pollutant deposition velocities. These latter input data files are generated by an efficient diagnostic meteorological processor (UAMMET) as described by Godowitch *et al.* (1992).

Work has proceeded on testing and model evaluation efforts in urban domains encompassing greater New York City and Los Angeles. Separate simulations with the refined UAM were performed using meteorological inputs generated by the diagnostic UAMMET processor and a dynamic meteorological driver, which features four-dimensional data assimilation. Preliminary results with the refined UAM using five vertical layers (i.e. two layers below the mixing height and three aloft) for the New York test case revealed similar ozone patterns with both types of wind modeling approaches. However, slightly higher peak ozone concentrations were produced using the dynamically-generated winds. Of greater significance, peak ozone concentrations increased dramatically in a UAM simulation with more lower layers (i.e. four layers below the mixing height and the same three layers aloft) when driven by dynamically-generated winds. Little change in the modeled peak ozone occurred in a comparable simulation driven by diagnostically-generated winds. Results of the ongoing model evaluations in New York and Los Angeles basin domains and an intercomparison of results with the regulatory UAM will be reported in FY-1994.

2.2.4.7 ROM Matrix of Emission Reduction Scenarios

A study continued in FY-1993 to compare various combinations of anthropogenic NO_x and VOC emission reductions through a series of model simulations. Seventeen simulations were performed with the ROM for a 9-day period in July 1988. Each simulation reduced anthropogenic NO_x and VOC emissions across-the-board by different amounts. Maximum O_3 concentrations for the period were compared between simulations. In addition, response surfaces of O_3 and other trace gases to emission reductions were developed. Analysis of the simulation results suggests that (1) most of the eastern United States is NO_x limited; (2) areas with large sources of NO_x are VOC limited; (3) meteorology plays an important role in the build-up of regional O_3 and influences the limiting factor for O_3 formation; and (4) behavior of other trace gases as predicted by ROM is consistent with our understanding of the chemical system responsible for the build-up of regional scale O_3.

2.2.5 Aerosol Modeling Program

The objectives of this effort are to develop, enhance, and evaluate scientifically-credible atmospheric modeling systems that address the environmental issues associated with aerosols, and that incorporate all the known major physical and chemical processes affecting the concentration distribution, chemical composition, and physical characteristics of atmospheric aerosols. Processes modeled include emissions, formation, transport, chemistry, and removal on both urban and regional scales. This program is primarily directed towards providing modeling tools to assist in promulgation of primary and secondary air quality standards for fine particles to protect human health (acid aerosols) and welfare (visibility and material damage). Eulerian and Lagrangian framework models will be developed and evaluated incorporating various levels of sophistication of aerosol chemistry and dynamics. In addition, either coupled urban and regional scale models or window and nested regional scale models will provide relative loadings between urban and regional sources.

2.2.5.1 Regional Particulate Modeling

The Regional Particulate Model (RPM) is an expansion of RADM. The added capabilities include aerosol chemistry and size distributions. Two size ranges are considered (Whitby, 1978); the size range associated with source emissions and particle production processes designated the nuclei mode, and the size range associated with longer term residence in the atmosphere designated the accumulation mode. Results showed the response of the preliminary version of the model for a base 1985 emission case and for a 50% reduction in emissions. These results are for non-cloudy conditions. Such integral properties as total particle number, total surface area, and total volume for the two modes respond proportionally to the emission reduction. The effective diameters for the modes show very slight response to the emission reduction.

The effort during FY-1993 concentrated on the role of size-dependent dry deposition. Deposition to a surface occurs by transfer of material from the atmospheric surface boundary layer, which is usually turbulent with a velocity scale of u* (the friction velocity), to a laminar sublayer dominated by molecular transfer. Within this layer the Schmidt number, the ratio of kinematic viscosity to Brownian diffusivity, characterizes the transfer of particles to the underlying receptor by molecular processes. As particle size increases, gravitational settling and inertial effects become more important. These effects are represented by the Stokes number, which is the gravitational settling velocity multiplied by the square of the friction velocity and divided by the kinematic viscosity and the acceleration of gravity. The deposition velocity is then a function of the resistance due to turbulent transfer in the surface boundary layer and the resistance of the surface laminar layer. For a polydispersion, two methods are available for calculating a deposition velocity. The first method calculates a deposition velocity for a set of discrete sizes and then calculates the total dry deposition as a numerical quadrature over the discrete sizes. This is done by experimentalists who have measurements in discrete size intervals. The second method uses a Brownian diffusivity and a gravitational settling velocity that are averaged over the log-normal modes. The RPM integral moments are the history variables with the geometric mean diameter and geometric standard deviation diagnosed from these moments (cf. Whitby *et al.*, 1991); therefore, the second method of using averaged quantities is more consistent with the model formulation and is preferred.

There are several methods of combining the Schmidt and Stokes numbers to represent dry deposition of particles. Two methods were tested. Stand-alone tests and full three-dimensional simulations showed the first method (Scire *et al.*, 1993) produced deposition velocities that were too large relative to measured field data (Wesely *et al.*, 1985). The second method (Pleim *et al.*, 1984) agreed very well with this field data and was incorporated into RPM.

2.2.5.2 Toxics Air-Gas Exchange Model: A Regional Scale Modeling of Semi-Volatile Air Toxic Pollutants

Many toxic air pollutants have long atmospheric residence times; therefore, their adverse human and ecological effects extend thousands of kilometers from their sources. When deposited to biomass, terrestrial, and aquatic systems, their impact is magnified through bioaccumulation. Many such pollutants are semi-volatile, coexisting in the atmosphere in both the gas and particle phases, and vaporizing back to the atmosphere after deposition. A model is being developed to predict wet and dry deposition of airborne semi-volatile organic toxic compounds (SVOCs) applicable on a regional scale. Using as its basis RPM, formulations are being tested to allow these pollutants to cycle between the aerosol and the gas phases. The parametric attachment formulation for these pollutants follows the work of Pankow (1987) where SVOCs are partitioned between the vapor and particle phases by use of a partition function. Initial modeling experiments are underway for selected organo-clorines and persistent aromatic hydrocarbon pollutants. An additional complication to be modeled is the revolatilized fraction from the ground surface (soil, vegetation, etc.). The method by Pankow (1993) that relates the partitioning of SVOCs between the atmosphere and the earth's surface will be tested.

2.2.6 Atmospheric Toxic Pollutant Deposition Modeling

2.2.6.1 National Assessment of Human Exposure to Toxic Pollutants

Prompted by Congressional mandates, two assessments of human risk to toxic pollutants in the environment will be conducted. The first study considers mercury emissions from all major anthropogenic sources, while the second study focuses on the mercury emissions and other designated toxic pollutants only from coal-fired utilities.

In a cooperative effort with the EPA research laboratories, multimedia model results are being provided to the Agency. The REgional Lagrangian Model of Air Pollution (RELMAP) (Eder *et al.*, 1986) is being adapted to simulate the emission, transport, dispersion, atmospheric chemistry, and deposition of mercury across the continental United States. The atmospheric chemistry algorithm, based on formulations of Petersen *et al.* (In press), considers the reaction of elemental mercury with ozone to produce inorganic mercury and the reduction of inorganic mercury to elemental mercury. After the model adaptation and testing have been completed, it will be applied to calculate 1989 monthly mean air concentrations and wet and dry deposition amounts across 40-km grid cells.

As a means of establishing model credibility, the original version of the model was evaluated using 1989 sulfur air concentration data from 28 sites of the Eulerian Model Evaluation Field Study (EMEFS) (Atmospheric Environment Service, Environment Canada, 1993) and 1989 sulfur wet deposition data from 59 sites of the National Atmospheric Deposition Program (National Atmospheric Deposition Program, 1990). Because of the unavailability of regional air toxics data, the model could not be evaluated specifically for toxic pollutants.

Model calculations of sulfur dioxide and sulfate air concentrations and sulfur wet deposition amounts were compared to the seasonal and annual average air concentrations and seasonal and annual deposition amounts across the eastern North American monitoring networks. The model calculations correlated well with the annual mean air concentration measurements (r=0.88 and bias of $-7.8\ \mu g/m^3$ for sulfur dioxide; r=0.80 and bias of $+0.5\ \mu g/m^3$ for sulfate) and annual total sulfur wet deposition measurements ($r=0.77$ and bias of +0.47 kg S/ha). All model calculations of annual sulfur wet deposition were within a factor of two of the measured values.

2.2.6.2 Deposition of Trace Metals to the Great Lakes

Using a trace metal emissions inventory being developed by a Division scientist, the annual 1989 atmospheric deposition of five trace metals (arsenic, cadmium, chromium, lead, and nickel) were calculated by RELMAP for Lakes Michigan and Superior (Clark, 1992; Clark, In press). Two particle sizes were considered in the RELMAP applications: 0.5 μm and 5.0 μm. These model results were provided to the EPA Region 5 and the International Joint Commission that was established between Canada and the United States by the 1909 Boundary Water Treaty.

The 1985 Lake Michigan wet deposition amounts dominated the total atmospheric deposition, regardless of particle size. For the smaller particles, wet deposition accounted for 90% or more of the total deposition, while for the larger particles, wet deposition accounted for approximately 62%. The total annual deposition amounts of the 0.5 μm particles ranged from 2.0×10^4 kg/year (for Cadmium) to 6.9×10^5 kg/year (for lead); the total annual deposition amounts of the 5.0 μm particles were 10% to 20% less.

The 1989 Lake Superior model calculations for the 0.5 μm particles ranged from 9.5×10^4 kg/year (for arsenic) to 9.82×10^5 kg/year (for lead). Annual deposition amounts of the 5.0 μm particles were 10% to 25% less. These amounts are an order of magnitude greater than independently calculated amounts (Eisenreich and Strachan, 1992); an indication that the emission inventory used in the model applications overestimates the emission rates by an order of magnitude. The Lake Superior analysis also indicated that (1) only 1% of the trace metal mass emitted to the atmosphere by anthropogenic sources within the model domain (i.e., east of 103° W. longitude and south of 55° N. latitude) was deposited to the Lake; (2) long-range transport of trace metals to Lake Superior is significant (source regions as far as 800 km can contribute as much as 70% of the total deposition to the Lake); and (3) the significance of long-range transport increases as particle size decreases.

2.2.6.3. Mesoscale Modeling of Toxic Pollutants

A mesoscale atmospheric deposition model, MESOPUFF-II (Scire *et al.*, 1984), and its data preprocessors are being adapted to simulate the transport and deposition of mercury across large metropolitan areas. The revised model, with a spatial resolution of 20 km or less, will first be applied to the Milwaukee/Chicago/Gary corridor and adjacent Lake Michigan waters. The model input consists of gridded annual mercury emissions, upper-air wind data from the National Weather Service Nested Grid Model, and hourly precipitation and surface meteorological data. The final model version will be used by the EPA Region 5 in its assessments of the relative contributions of sources to mercury deposition.

2.2.7 Models-3 Advanced Air Quality Modeling

One of the objectives of the Models-3 project is to develop a multipollutant, multiscale, user friendly air quality modeling system that can be used to solve complex environmental problems. Models-3 is a user-need driven modeling system that is highly flexible (scalable grid size and modeling domain), and modular (scientific and functional modules with interchangeable data structure). It is not a single model, but rather a system that helps to build, run, and study customized air quality models (AQMs). It consists of such subsystems as emissions, meteorology, chemistry-transport model (CTM), analysis and visualization, database, and input/output subsystems, as well as the user interface subsystem. Each subsystem is a complex processing system in its own right. However, the Models-3 system breaks down the traditional boundaries between model input preprocessing, model execution, and postprocessing analysis, treating all as integrated steps in simulation. Also, the system emphasizes integration of emission processing, meteorological model, and chemistry-transport model to maintain consistent scientific formulations throughout the modeling process. Each component of the Models-3 system will be expandable and functionally portable. New scientific simulation processors can be added to the model with minimal effort. A uniform input/output procedure across the subsystems is essential for the AQM, user interface, and visualization.

The project is directly linked to the High Performance Computing and Communication (HPCC) program. The Models-3 system is being developed within a high-performance computing technology framework to take advantage of and far surpass the computers and networking capabilities being used today. The system will rely on state-of-the-art information processing hardware, software, and networks across many different types of computers: multiprocessor vector supercomputers, massively parallel processors (MPP) computers, mainframes, and workstations. The real power of Models-3 will be its ease of use; the complicated system is transparent to the user. The user can build a customized model from the processor library, access data files, run the model, monitor interim results, and perform an interactive graphics rendering of model output in an X-Window environment. Models-3 is the system for future air quality modeling that can answer policy and scientific questions.

2.2.7.1 Models-3 Science Concept Development

New developments in both atmospheric and computer sciences will be incorporated into the Models-3 air quality modeling framework. The highest priorities are to ensure scalability of the modeling system from urban through regional air quality problems; and consistent implementation of model science across the system components. The Models-3 air quality models will have the following computational characteristics:

- a generalized computational framework,
- interchangeable and inter-linkable process modules,
- efficient algorithms and balanced accuracies among numerical methods,
- improved scientific modeling of environmental phenomena,
- systematic sensitivity and uncertainty analysis routines, and
- consistent software engineering practice across modules.

The science concepts for the air quality model prototypes are being developed. A paper is being written that discusses the multipollutant, multiscale Models-3 system that takes advantage of emerging advances in high-performance computing technology.

2.2.7.2 Models-3 Prototypes

The objective of the Models-3 AQM prototypes is to test the following science and system concepts: (1) flexibility (the ability to address such multiple air quality issues as regional- and urban-scale oxidant and acid deposition); (2) functional modularity and extensibility (modular and interchangeable science process implementation using a consistent input and output subsystem); (3) systematic and integrated sensitivity and uncertainty analysis; and (4) key algorithms adapted for high-performance computational platforms. The requirements of the initial operating version (IOV) are divided into two categories: (1) the *minimum requirements*, which specify the minimum acceptable functionality for an operational Models-3 system and the minimum hardware and system software necessary for system development and operation; and (2) the *targeted capabilities*, which describe the capabilities to be included in addition to those on the minimum requirements list.

AQM prototypes to be implemented into the Models-3 IOV are the initial operational and exploratory test-bed model versions. The initial operational versions include a linear chemistry model prototype, engineering model prototypes, RADM chemistry prototype, generalized-coordinate and generic grid prototypes, generalized chemistry-solver prototypes, sensitivity algorithm prototypes with automatic differentiation, and multilevel nesting prototypes with generalized coordinates. Also, exploratory model prototypes will be created for a data flow study, an atmospheric transport study, a two-way nesting and adaptive grid study, an uncertainty and sensitivity study, a massively parallel processing technology study, and an aerosol and particulate study.

Modularity in the Models-3 prototype system is achieved in the following fashion. Each science process module encapsulates the action of a single significant atmospheric process upon the concentration field. These modules (1) make the dependencies explicit upon coordinate systems and grid scales, (2) have no sequential data flow dependencies among themselves, and (3) employ a standardized interface to the driver process, promoting interchangeability and extensibility.

2.2.7.3 Investigation of Numerical Solvers for Chemical Kinetics

As part of the regional oxidant program support of the next generation Eulerian model development effort (Models-3), two different numerical solvers for chemical kinetics were tested as candidates for the Models-3 chemical module. A quasi-steady state solution using two passes (predictor-corrector) and a single-pass Crank-Nicholson type solution were investigated using the RADM chemical mechanism in a stand-alone mode. The solvers appeared to be of comparable accuracy when tested against each other and against a highly accurate Gear predictor-corrector scheme. Increasingly stressful tests, including the introduction of emission forcing during the chemical simulation, showed the two-pass scheme to be somewhat more accurate. A generalized version of the quasi-steady state two-pass scheme will be embedded into the initial operational version of Models-3 during FY-1994. Further refinements will include the lumping of selected nitrogen species during the simulation to ensure mass conservation, and to reduce the stiffness of the chemical system so larger time steps may be used.

2.2.7.4 Investigation of Numerical Solvers for Advection

A prototype AQM for the Models-3 system was developed. The modularity of this prototype allowed the incorporation of three alternate advection schemes. The development of a test-bed environment was initiated by generating input data for the prototype and simulating a series of evaluation cases. These cases consisted of simple tests routinely applied to evaluate advection schemes and a tracer experiment that allows more realistic evaluations. The objective of the study is to identify the desirable characteristics of advection schemes for future algorithm development.

The initial study concentrated on the time-split, one-dimensional versions of three advection schemes (Smolarkiewicz, 1983; Bott, 1989; Colella and Woodward, 1984). Such characteristics as mass conservation, positivity, monotonicity, numerical diffusion, and phase errors were studied. All three schemes satisfied the mass conservation and positivity requirements. Among the three schemes, only the piecewise parabolic method (PPM) by Colella and Woodward (1984) showed the monotonic property. It also had a steepening feature near discontinuities, and led to higher concentrations along the trajectory in the tracer experiment. Monotonic property is a desirable characteristic for tracking long-lived species in AQMs. The numerical diffusion in Smolarkiewicz (1983) was largest among the three schemes. Although the Bott (1989) scheme displayed a better diffusion characteristic in simple tests, the PPM resulted in a less diffused puff under actual atmospheric conditions because of its monotonic property.

2.2.8 Technical Support

2.2.8.1 Cooperative Regional Model Evaluation Project

The Cooperative Regional Model Evaluation Project was initiated during FY-1993. It involves applying ROM, UAM (Versions IV and V), and SARMAP Air

Quality Model to the 1991 Lake Michigan Ozone Study database, the 1990 San Joaquin Valley database, and the 1988 Northeast United States database. The American Petroleum Institute, the Electric Power Research Institute, and the Coordinating Research Council are sponsoring the project to apply and evaluate these contemporary regional and urban scale photochemical grid models to the intensive field databases. One Division representative is on the Steering Committee to provide technical guidance on the use of ROM, as well as to obtain required model runs and data for ROM input to the project contractor team. Both model evaluations, and diagnostic and sensitivity analyses will be performed.

2.2.8.2 Southern Oxidant Study

FY-1993 was the third 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 on various cooperative agreements. The focus of activities within SOS during the past year was on analyzing the data collected in major field intensives during the spring and summer of 1992. An SOS Data Analysis Workshop was held, and preliminary results began to emerge. Interesting findings on the vertical inhomogeneities in pollutant concentrations within the daytime boundary layer over the southeast United States were shown, and new hypotheses are being formulated and tested with the SOS data to explain these findings. Planning began for a 1994 field intensive to be centered on the Nashville, Tennessee, region. Prototyping activities started for a centralized data archive for SOS, to be located in Research Triangle Park, North Carolina.

2.2.8.3 Eulerian Model Evaluation Field Study Program

As part of the Eulerian Model Evaluation Field Study (EMEFS), a database was collected for evaluating regional scale air quality and deposition models. This program is co-sponsored by the U.S. Environmental Protection Agency; the Electric Power Research Institute Operational Evaluation Network; the Atmospheric Environment Service Canadian Air Pollution Monitoring Network; the Ontario Ministry of Environment Acid Precipitation In Ontario Study; and the Florida Coordinating Group; and is overseen by the Program Management Group, which consists of representatives of the co-sponsors. The database consists of surface precipitation and aerometric measurements of acid and acid precursor pollutants taken from a network of more than 100 sites located in eastern North America for the period June 1988 through May 1990, and from data collected by aircraft flights during summer 1988 and spring 1990 intensive field studies, and is available to interested parties. Although EMEFS data is available, distribution is pending publication of the three volume Quality Assurance Synthesis Report. Also, a modeler's database of hourly emission data for use in episodic models will be available pending permission by the utilities participating in this effort.

2.2.8.4 Interagency Work Group on Air Quality Modeling

The Interagency Work Group on Air Quality Modeling (IWAQM) was formed through a Memorandum of Understanding between the EPA, the U.S. Forest Service, the U.S. Fish and Wildlife Service, and the National Parks Service. The major objectives are to review existing air quality modeling techniques, to identify consistent modeling approaches, and to develop the modeling tools needed to assess individual and cumulative impacts of existing and proposed sources of air pollution on local and regional scales with special emphasis on the protection of Class I areas as defined by the Clean Air Act. The effort is proceeding in phases. First, a model based on the use of a modified version of MESOPUFF will be recommended as an interim measure for use by Federal land managers. Second, the model development effort will involve the incorporation of more advanced state-of-science process modules, including meteorological preprocessors, dispersion, and chemistry. The model and documentation of the interim recommendation were reviewed. The overall effort is focused on utilizing a modified CALPUFF model that incorporates the MM4-FDDA as its meteorological preprocessor. In its studies, IWAQM determined that air parcel trajectory displacement errors typical of regulatory modeling procedures can be significantly reduced by using wind information derived from the MM4-FDDA technique. A visibility component will incorporate an algorithm developed by the National Park Service.

2.2.8.5 Ozone Chemistry and Modeling Research Planning

An ad hoc Committee on Atmospheric Chemistry and Modeling convened in fall 1992 to prepare a general research plan to support Section 185B of the CAAA of 1990. The committee, chaired by a Division scientist, consisted of more than 30 eminent research scientists involved in various aspects of photochemical modeling from the academic, private, and public communities in the United States and Canada. The committee reviewed the science basis of modeling photochemical oxidants, considering in part the recommendation of the National Research Council's report on rethinking the ozone problem in urban and regional air pollution (National Research Council, 1991). Subsequently, a long-term research plan addressing all the important science issues on the photochemistry and modeling of ozone was formulated to provide science supported ozone control strategies. The recommendations of the Committee were integrated into an overall plan, the North American Research Strategy for Tropospheric Ozone (NARSTO). In NARSTO, other research issues addressed included health and ecological effects, monitoring, emission control systems, alternative fuels, and emission inventories.

2.3 Fluid Modeling Branch

The Fluid Modeling Branch conducts laboratory simulations 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; salt water of variable concentration is used to establish density gradients in the tank, which simulate the nighttime temperature gradient in the atmosphere. 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 Exhaust Recirculation Investigation at the Proposed EPA Research and Administration Facility

A wind-tunnel study was conducted on the first detailed design of the proposed Research and Administration Facility (RAF) of the Environmental Protection Agency at Research Triangle Park, North Carolina, to examine a major design issue: the location of exhaust stacks from laboratory fume hoods and the likelihood of reentrainment of potentially noxious exhaust gases into the primary fresh-air intakes of the building complex. A total of 300 laboratory hoods in the research laboratories are to be ducted to the roofs of four laboratory buildings and vented through twelve chimneys that extend 20 feet (6.1 m) above the roofs. In addition, exhausts from fume hoods and possibly other sources on a high-bay building will be exhausted from another chimney atop that building. All of these chimneys are quite short in comparison with the heights of the buildings (around 100 ft or 30 m), so that building-downwash of the effluent is expected much of the time; diluted exhaust gases are therefore expected to be recirculated to the fresh-air intakes. Thus, the primary question to be answered in the wind-tunnel study was what dilutions of exhaust gases may be expected to occur at the fresh-air intakes as a function of meteorological conditions.

A model of the terrain and buildings was constructed at a scale ratio of 1:192 and placed in the Meteorological Wind Tunnel (see Figure 1). A simulated atmospheric boundary layer with appropriate characteristics was generated upwind of the model. A mixture of air and ethane was emitted from each of the 13 model stacks, and flame ionization detectors were used to measure concentrations at each of 30 sampling ports located at each of the fresh-air intakes and other points of interest in the vicinity of the RAF complex. Wind speed and direction were systematically varied to determine the worst-case conditions or minimum dilutions of exhaust gases at the sampling points. For a few of these worst-case conditions, we probed further to ascertain the individual contributions from each of the 13 stacks. Also for a few of these worst-case conditions, we examined the effect of increasing the stack heights by 10 ft (to a total of 30 ft above the roofs). Over 350 combinations of wind speed, wind direction, emitting sources, and stack height were tested.

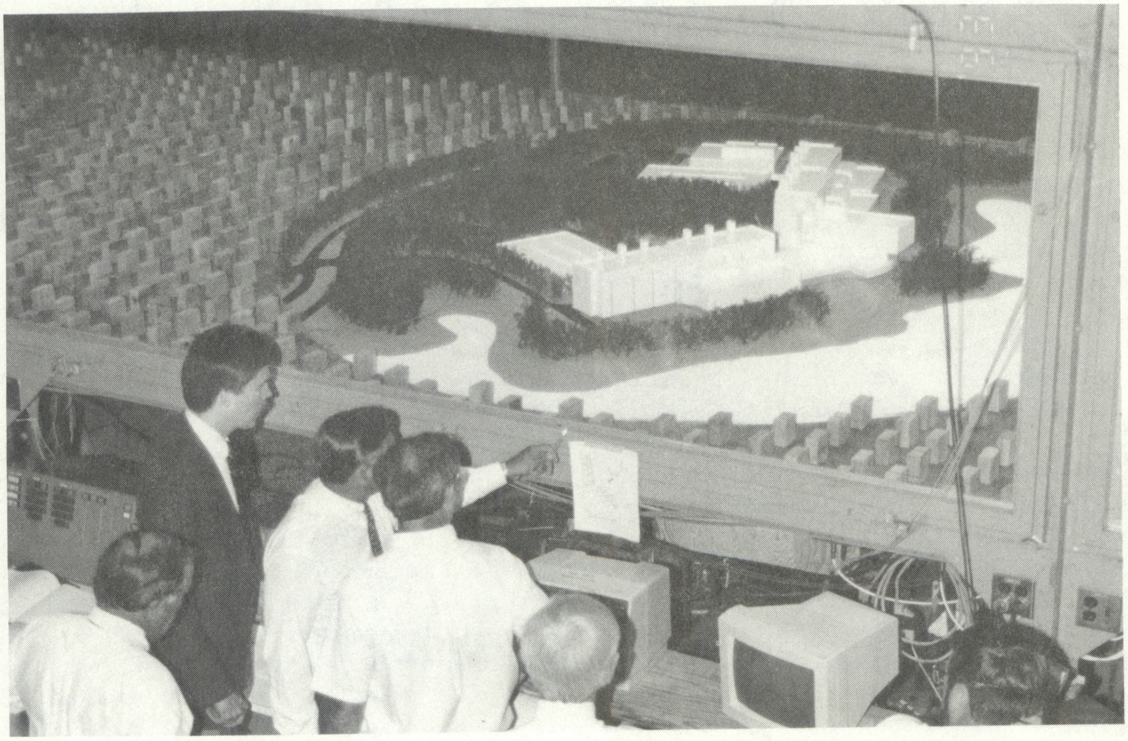

Figure 1. View of RAF model in Meteorological Wind Tunnel. The wood blocks simulate the forest surrounding the site.

Analysis of the measurements with all 13 sources emitting simultaneously suggested that the critical wind speeds for the fresh-air intakes were in the neighborhood of 20 mph (9 m/s). (A critical wind speed is that at which the concentration of exhaust gases is a maximum or the dilution is a minimum.) Critical wind speeds at a series of downwind ports (about 400 m downwind of the center of the building complex) were much lower, about 8 mph (4 m/s). The values of the minimum dilutions at the downwind ports did not vary greatly with wind direction, ranging by less than a factor of 2 (from 93 to 170) over the full range of wind directions (every 15° for 360°). The minimum dilutions at the fresh-air intakes on the buildings were only slightly higher (from 105 to 180), although there was a range of wind directions where the dilutions were much larger and, therefore, comparatively insignificant.

Minimum dilutions of *individual* sources were typically 3 to 5 times as large as those observed with all sources emitting simultaneously, *i.e.*, minimum dilutions of individual sources were typically 300 to 500. Minimum dilutions of individual sources at the *downwind* ports were generally 5 to 6 times as large as those observed with all sources emitting. The taller stacks resulted in increased dilutions in the range of 15% to 50% at the fresh-air intakes, but such benefits were generally negligible at the downwind points.

A data report and an executive summary (Snyder and Thompson, 1993a; 1993b) were prepared to provide a full description of the experimental details, a comprehensive data set, and an analysis and summary of results. These should be complemented with a meteorological analysis that assesses the relative frequencies of occurrence of the conditions that lead to the minimum dilutions. A further assessment should then be made by health specialists as to whether these exposures are acceptable.

2.3.2 Dispersion from Surface Coal Mines

At the request of the EPA Office of Air Quality Planning and Standards (OAQPS), the Fluid Modeling Facility conducted a wind-tunnel study of dispersion from surface coal mines. Surface coal mining operations (blasting, shoveling, loading, trucking, *etc.*) are sources of airborne particles. The 1990 Clean Air Act Amendments direct the EPA to analyze the accuracy of the Industrial Source Complex (ISC) model (U.S. Protection Agency, 1992e) and the AP-42 emission factors (U.S. Environmental Protection Agency, 1985), and to make revisions as may be necessary to eliminate any significant over-prediction of air concentration of fugitive particles from surface coal mines. This laboratory study provides a database obtained under controlled conditions for evaluation of the mathematical model.

It is not possible to model particle motions at the reduced scale of this type of wind-tunnel study. Measurements of the concentration of a tracer gas released from a point source within the mine, however, provide some useful information on the dispersion processes involved. Both transient and steady-state concentration measurements were made. Each model mine was a rectangular hole in the floor of the wind-tunnel test section. A total of 26 different combinations of mine shape, point source location within the mine, and wind direction were considered. Flame ionization detectors were used to measure the steady-state concentrations. For the transient concentration measurements, a flame ionization detector was modified to improve its response time.

From the transient measurements, a residence time was determined. The residence time is related to the escape fraction, that is, the fraction of particles generated that eventually escape the boundary of the mine. A transient experiment consisted of turning on the source of tracer gas and allowing the concentration field to reach steady-state; then rapidly turning off the source. The concentration on the downwind lip of the mine was monitored with the modified flame ionization detector from a few seconds before turning off the source until it fell to the limit of the selected range of the instrument (at least two orders of magnitude). For each case, 40 realizations were averaged and fit with an exponential function to determine the exponential decay or residence time. An empirical formula for the residence time was found that incorporated the mine's geometry and orientation to the wind.

The steady-state experiments for each mine consisted of measuring lateral profiles of ground-level concentration at the downwind edge of the mine and at the full-scale distance of 1 km. Then, vertical profiles were obtained at the position of the maximum observed in the laterals. Gaussian plume approximations fit the majority of the concentration profiles quite well; when the source was near the sidewall of the mine, a Gaussian fit was not as good. These profiles define the shape of the plume at those positions and can be compared directly with numerical model predictions.

A data report (Thompson, 1993a) was compiled, which describes the experimental details and the data set and contains some preliminary analyses. An internal report describing the transient measurements and presenting the formula for the residence time as a function of the geometry of the mine and wind direction (Thompson, 1993b) was delivered to the OAQPS. A paper is being prepared for a conference presentation.

2.3.3 Flow and Diffusion in the Vicinity of High-Rise Buildings

In collaboration with a professor from the Tokyo Institute of Polytechnics, Tokyo, Japan, a wind-tunnel study was conducted to examine both the flow-field patterns and diffusion characteristics near high-rise buildings. In particular, the study centered on determining the effects of twin high-rise buildings on emissions released near the base of the downstream building, both with and without a terrace section at the lower levels. Because of the substantial energy requirement for heating and/or cooling large buildings, cogeneration power plants are frequently located in or near the base of such buildings. The emissions from these power plants are vented near the lower levels of the building and may result in adverse concentrations of pollutants being entrained into the ventilation system.

The study was conducted in two phases. In the first phrase, a pulsed-wire anemometer was used to map the flow-field components in the vertical centerplane and in a horizontal plane near the surface. Measurements were taken for a wide variety of building geometries: a single building with various heights, two buildings with various heights and streamwise separations and, finally, two buildings with various heights and separations mounted atop a lower level or terrace section. Based on streamline plots constructed from the velocity measurements, a range of emission source locations (both heights and distances from the building) was chosen, which was anticipated to produce the worst-case building-surface concentrations. All locations were in the downstream wake of the downstream building. In the second phrase, tracer gas was emitted from these source locations and concentrations were measured on the downstream face of the downstream building. For some source locations, concentrations were also measured in a vertical plane downstream of the building.

Results from the flow-field measurements showed very complex flow patterns near the buildings. For the single building and for the upstream building in the twin-building case, the flow separated near the upstream edges of the building. Recirculation was evident downstream of all buildings and was pronounced between the twin buildings. For the twin-building case, separation of the flow near the edges of the downstream building appeared to be substantially retarded. There was little difference in the gross flow patterns observed with and without the terrace section in place. In all cases, the near-surface flow downstream of the buildings was opposite to the mean flow, implying that emission sources located in those regions would be carried toward the downstream face of the building.

Results from the tracer measurements showed that concentrations on the downstream face of the downstream building for the twin-building cases were higher than those measured on the downstream face of the single building. This is consistent with flow-pattern measurements in that retardation of separation in the wake of the downstream building leads to a smaller turbulent wake into which emissions are diluted. With source positions restricted to the downwind building wake, the source elevation was not found to strongly affect the building surface concentration distributions even though the concentration maxima appeared at slightly different locations. Variation of the separation distance between the twin building models did not substantially affect the downwind surface concentration contours on the downwind building. The addition of the terrace section at the lower level had little effect on the building-surface concentrations.

A data report (Ohba *et al.*, 1993) was compiled to document the experimental conditions, measurement techniques and results obtained. The report provides graphic plots of the data and includes all data files on floppy diskettes. Two papers are being prepared for conference presentation. One paper will summarize results obtained from the flow-field measurements, while the second will summarize the results obtained from the concentration measurements. The data obtained from the study is being utilized to evaluate predictions obtained from a numerical model.

2.3.4 Mathematical Model of Pollutant Dispersion Near a Building

Through collaboration with a Senior Research Associate under the NOAA/NRC Resident Research Associateship Program, a new mathematical model of pollutant dispersion near a building (MDNB) was developed and tested using results of both wind-tunnel and field measurements. Designed for regulatory applications, the model is compatible with existing Gaussian models of atmospheric diffusion in the absence of buildings, in particular, with the Industrial Source Complex (ISC2) model. It uses empirical information about the geometry of cavities (recirculation regions), which depend on building dimensions. MDNB includes such physical effects as distortion of streamlines outside the cavities, interaction between plumes and cavities, rapid mixing of pollutants within the cavities, and intermittency of cavities as the result of low-frequency oscillations in wind direction. MDNB can be used to predict concentrations at arbitrary receptor points outside the building, including points within the cavities and on the building surfaces. Far from the building, the model reproduces concentrations close to those predicted by standard Gaussian models in the absence of buildings. Comparisons of model calculations results with measurements taken in the Meteorological Wind Tunnel as well as with field measurements taken in the United States, Japan, and Russia show that MDNB outperforms such diffusion models as ISC2 and SCREEN2, which are used for building downwash predictions in regulatory applications. A poster presentation was made. Discussion and details on the development and initial evaluation of the model will be provided in a conference paper.

2.3.5 Diffusion in the Convective Boundary Layer

Through a cooperative agreement with the Pennsylvania State University, experiments were conducted in the Convection Tank to investigate transport asymmetry, the difference in diffusion properties of scalars introduced at the bottom and top of convective boundary layers (CBLs). During the 1980s the numerical technique called large-eddy simulation (LES) predicted striking differences between top-down and bottom-up vertical diffusion from large area sources within the convective boundary layer. The objective of the current experiments was to test this hypothesis of transport asymmetry in the laboratory.

The 1.2 m square tank was filled with water to a depth of 35 cm and 144 electric heaters were affixed to the underside of the aluminum plate at the bottom to provide the heating. To simulate the inversion layer that lies above the daytime CBL, a stably stratified temperature profile was formed by passing a grid of heating wires through the upper 20 cm of water in the tank. Two scalars were used to measure the transport asymmetry, temperature for bottom-up diffusion, and food dye for top-down diffusion.

An interim report was produced (Wyngaard and Piper, 1993), which suggested that the difference in diffusivities for the top-down and bottom-up processes, or transport asymmetry, is even more pronounced than LES had predicted. Thus, it is even more important in geophysics than initially thought.

2.3.6 Wind-Tunnel Measurements of Flow Structure and Diffusion Around Buildings

In the continuing program to better understand the flow structure around buildings and associated diffusion of pollutants, a series of measurements was begun using a pulsed-wire anemometer (PWA) in the wind tunnel to determine how the streamline patterns change as the primary building dimensions and orientation change. The buildings were rectangular-shaped blocks, which were immersed in a simulated atmospheric boundary layer in the wind tunnel. Four series of measurements were made, wherein the crosswind, alongwind, and vertical dimensions of the building, as well as the building orientation were systematically varied. In all cases, the ground-plane streamline patterns were measured. In the cases with symmetry, the vertical-centerplane streamline patterns were measured.

Figure 2 shows an example of the streamline patterns deduced from the PWA measurements in the centerplane for the first series of experiments, where the only parameter varied was the crosswind width of the building. The main features of upstream stagnation point, separation and reattachment streamlines, and cavity are immediately apparent in Figure 2. The cavity size obviously increases as the crosswind width of the building increases, but other aspects of the flow field change markedly also. More discussion and details will be provided in a conference paper. Further analysis of data collected last year on diffusion in the vicinity of idealized power plants resulted in two papers (Snyder, In press a and b).

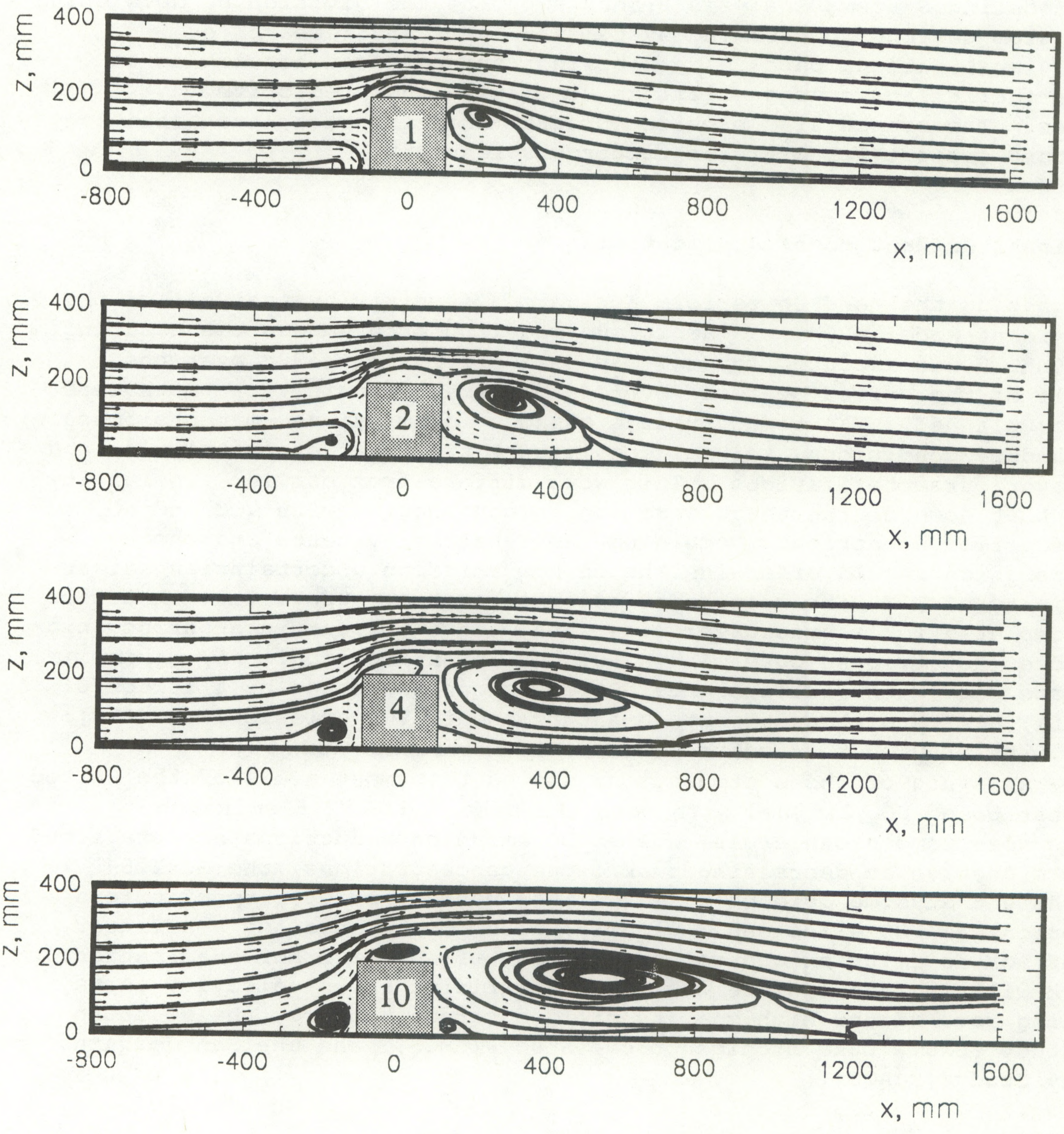

Figure 2. Streamline patterns around buildings of various crosswind widths. Number on building is the ratio of crosswind width to height of building. Alongwind length of building is equal to its height.

2.4 Modeling Systems Analysis Branch

The Modeling Systems Analysis Branch supports the Division by developing modeling system designs; performing systems analysis and research on scientific visualization; parallel processing; and advanced networking to support air quality and source emissions simulation and predictive applications. The branch also provides programming, graphics, and technology infrastructure support for Division research scientists.

2.4.1 Regional Oxidant Model Applications

Recognizing the need to perform a rigorous sensitivity analysis of the Regional Oxidant Model (ROM), an ambitious modeling program was begun during FY-1993. ROM2.2 was executed for a 7-day period from July 1988 over the eastern half of the United States. Over 40 different sensitivity tests were completed or planned. The tests include changes in emissions, meteorological inputs, boundary conditions, initial conditions, treatment of photolysis, and boundary layer parameterizations. This work differs from earlier sensitivity studies in that some of the tests were run in conjunction with VOC and NO_x emission reduction scenarios. Combining the sensitivity tests and the emission scenarios should offer insight on how emission uncertainties affect the sensitivity of ROM with respect to emission control strategies. A set of runs was completed for a base case; base case with a 50% cut in anthropogenic VOC emissions (HC50); base case with a 50% cut in anthropogenic NO_x emissions (NOX50); base case with mobile source VOC emissions increased by a factor of 2.5 (HCx2.5); HCx2.5 with a 50% cut in anthropogenic VOC emissions (HXHC50); and HCx2.5 with a 50% cut in anthropogenic NO_x emissions (HXNX50). Preliminary analysis of these simulations showed that most areas of the United States appear to be NO_x limited with both the base and HCx2.5 emission scenarios. Near some urban areas, where VOC emission reductions are predicted to be more effective at decreasing peak ozone concentrations, the HCx2.5 scenario shows that some grid cells may either benefit more or benefit less with reductions in VOC emissions. Clearly, this complicated and non-linear response of ROM to emission control strategies warrants further examination. Future work will include synthesizing and summarizing the sensitivity tests, and analyzing some of the high-quality field observations from the Southern Oxidants Study (SOS), Lake Michigan Ozone Study (LMOS), and the San Joaquin Air Quality Study (SJAQS).

2.4.2 Southern Oxidants Study

Active involvement continued in the emissions research portion of the Southern Oxidants Study (SOS). As part of the Atlanta Summer 1992 ozone field study, a research-grade inventory is being developed that will consist of hourly gridded NO_x and VOC emissions for the Atlanta modeling domain. The inventory is being assembled at the Georgia Institute of Technology and is an improvement over the standard State Implementation Plan (SIP) inventory. It provides greater temporal and spatial resolution of emissions by incorporating operating schedules from major stationary sources, especially fossil-fuel fired power plants, traffic counters from major roadways to obtain daily estimates of vehicle miles traveled, and surveys from such specific area sources as automobile body shops and printing operations. The biogenic emissions portion of the inventory was developed. It includes circa 1990 forest statistics for estimating tree crown coverage and tree species distribution in Atlanta and uses a Geographical Information System to incorporate satellite-based land-use data from the Atlanta Regional Commission.

The Southern Oxidants Study involved collaboration with many academic and government institutions, including the National Center for Atmospheric Research (NCAR), Boulder, Colorado; North Carolina State University, Raleigh, North Carolina; Washington State University, Tokoma, Washington, and the Tennessee Valley Authority, Oak Ridge, Tennessee. Activities included the analysis of data from the Oak Ridge isoprene flux experiment, surveys of VOC emissions from major vegetation species in the southern United States, an intercomparison of chamber techniques for soil NO emissions, and organization of a workshop to examine research needs for soil NO emission fluxes. In the future, SOS will examine verification of biogenic VOC and NO emissions using micrometeorological techniques, identification and quantification of oxygenated VOC compounds, and development of a research-grade inventory for the Nashville Field Experiment.

2.4.3 Biogenic Emissions

Since passage of the 1990 CAAA and release of the National Academy of Sciences report on ozone, greater emphasis was placed on the role of biogenic VOC emissions in tropospheric photochemistry. The Division was a leader in developing algorithms for estimating biogenic VOC emissions (Novak and Reagan, 1986). As demonstrated in Novak and Pierce (1993) and Lamb *et al.* (1993), the Division continued developing improved algorithms for estimating VOC emissions from vegetation and NO emissions from soil microbial activity.

By working closely with scientists at the EPA Air Engineering and Energy Research Laboratory and NCAR, a new version of the Biogenic Emissions Inventory System (tentatively called BEIS-2) is nearing completion. This system will include new land-use data to replace the aging Oak Ridge National Laboratory geoecology data set. The land-use data set will include county-level tree species coverage from the U.S. Forest Service forest inventory program, county-level agricultural crops from the U.S. Department of Agriculture 1987 agricultural census, and geographical boundaries of urbanized areas from the 1990 census. The forest data are particularly valuable because most biogenic VOC emissions come from trees. The forest statistics are derived from over 10,000 survey points in the eastern two-thirds of the United States. At each site, the U.S. Forest Service deployed ground survey teams that reported tree species and diameters for approximately a one acre area. From this database, Geron *et al.* (In press) computed crown coverage for each tree species for each county having survey information. The tree species information is being coupled with new emission factors from Guenther *et al.* (In press). This national inventory approach closely parallels the effort to develop a global biogenic VOC emission inventory. Biogenic emission research is also being coordinated with the EPA Joint Emissions Inventory Oversight Group program and the Southern Oxidants Study. Efforts are continuing to collect additional surveys of vegetation types around the country to understand the environmental and meteorological forcing factors affecting biogenic VOC emissions and to use micrometeorological techniques to verify VOC emissions.

As reported in Novak and Pierce (1993), the BEIS includes an algorithm for computing NO emissions from soils. Based on Williams *et al.* (1992), the algorithm computes hourly emissions as a function of vegetation and crop type and air temperature. The vegetation type attempts to capture differences in fertilizer application that affects NO emission rates, because crops having higher fertilizer application (such as corn and cotton) tend to have higher emissions of NO than crops having low fertilizer application (such as soybeans). Preliminary sensitivity studies show that enhanced soil NO emissions in the agricultural midwest could make a modest (5-10 ppb) increase in low-level ozone concentrations during the summer. During FY-1993, a cooperative agreement with North Carolina State University, Raleigh, North Carolina, was initiated to study NO emissions from major soils in the southern United States and to attempt to compare chamber measurements of soil emissions with micrometeorological techniques; only gradient measurements of NO, NO_2, and NO_x are planned.

2.4.4 Compilation and Improvement of an Interim Toxic Emissions Inventory

During FY-1993, preparations were made to upgrade the quality and expand the interim toxic emission inventory compiled in FY-1992 for the contiguous United States and Canada. The inventory provides an emission database for modeling transport and deposition of selected toxic emissions. The initial focus was on deposition of 28 pollutants to the Great Lakes using the REgional Lagrangian Model for Air Pollution (RELMAP) (Clark, 1992). The air toxic inventory and modeling scope were expanded to address transport and deposition of 60 chemicals for all of the United States as required by several Sections of Title III of the 1990 CAAA (Clean Air Act Amendments, 1990), including the Great Waters Program (Section 112(m)), the Urban Area Source Program (Sections 112(c)(3) and (k)), emission of seven specified chemicals (Section 112(c)(6)), maximum achievable control of air toxic emissions (Section 112(e)), and assessment of mercury emissions (Section 112(n)(1)). The Great Waters Program addresses the deposition of toxic emissions to the Great Lakes, Lake Champlain, Chesapeake Bay, and the coastal waters of the United States; while the Urban Area Source Program identifies and controls the area sources of the 30 toxic emissions responsible for 90 percent of cancer risk in urban areas.

Revision of the interim toxic emission inventory began in FY-1993 by using many new emission factors to reduce reliance upon speciation of inventories of volatile organic compounds (VOC) and particulate matter (PM) (Blackley and Blackard, 1993). Because the number of air toxic emission factors remains limited, improved source-category specific-speciation profiles are also being used (Radian, 1992). Quality control procedures were improved to include additional range and total checks, location accuracy checks, and comparisons with independent estimates. The previous interim toxic emission inventory relied upon speciation of the 1985 National Acid Precipitation Assessment Program (NAPAP) VOC and PM inventories (Benjey and Coventry, 1992). The revised interim toxic emission inventory uses the 1990 national interim VOC inventory and the 1985 NAPAP national PM inventory. The 1990 VOC inventory does not address PM; an improved PM inventory is expected to be available in approximately one year. When available, the 1990 base-year State Implementation Plan (SIP) VOC inventories for non-attainment areas will be incorporated within the VOC inventory and be reflected in the derivative toxic emission inventories. Point source emissions are identified and located by latitude and longitude, while area and mobile sources are identified at the county level. The emissions are gridded using 1/6 degree by 1/4 degree cells in a geographic information system for use with RELMAP. Emission grids can be produced by source category classification and for total emissions.

Assistance in planning an air toxic emission inventory and system was provided to the Office of Air Quality Planing and Standards (OAQPS). The OAQPS recognizes the need for a flexible, easily accessed emission inventory to store and manipulate increasing amounts of toxic emission data being provided by the states. Recommendations for evaluation of a possible emission processing system were made after gathering emission inventory and system user's needs. The plans to further develop and pursue the recommendations, which are compatible with the interim emission processing development being conducted for Models-3 under the High Performance Computing and Communications program.

The toxic emission inventories are not intended for use in assessing health risk. Health risk requires much more detailed individual exposure information and consideration of household and other uses of pesticides.

2.4.5 High Performance Computing and Communications Program

The High Performance Computing and Communications program is part of a large multiagency effort sanctioned under Public Law 102-194 (High Performance Computing Act, 1991) and coordinated through the interagency Federal Coordinating Council for Science, Engineering, and Technology (FCCSET). The major program goals are: 1) build advanced capabilities to address multipollutant and multimedia issues, 2) adapt environmental management tools to high performance computing and communications environments, and 3) provide a computational and decision support environment that is easy to use and responsive to environmental problem solving needs of key State, Federal, and industrial users.

2.4.5.1 Multipollutant Assessment

The concept document and project management plan for development of a computational and decision support system for air quality management was completed. An early prototype of a simplified air quality model with linear chemistry demonstrated that a modular approach could effectively provide interchangeability among science modules. Generic scalable algorithms for key physical and chemical processes are being developed. New technologies for computer-human interaction are being tested to enable this assessment tool to be used directly by scientists, regulators, and industrial analysts to provide more accurate and efficient assessment of the interaction on multiple pollutants in evaluation of pollution control options.

2.4.5.2 Linkage of Air and Water Quality Models

Three single-disciplinary models were transmitted to the EPA National Environmental Supercomputer Center (NESC): namely, a comprehensive regional air quality model, a watershed-water quality model, and a three-dimensional, bay hydrologic-water quality model. The models address the nitrogen eutrophication of the Chesapeake Bay. Research focuses on linking the models together when there is only minor feedback among the different media; thereby, maintaining the full disciplinary complexity of known and tested individual models while demonstrating the added benefit of multimedia modeling for environmental decision making.

2.4.5.3 Massively Parallel Algorithms

Research was conducted in-house and through cooperative agreements with universities and technology centers to develop and evaluate the performance of key algorithms that form the computational foundation of air, water, and molecular models on a variety of massively parallel architectures. Benchmark tests on ROM were conducted to evaluate the relative performance of a Digital Equipment Corporation (DEC) 3000/500 (Alpha/AXP) high performance workstation to a clustered VAX 6000/620. Subsequently, ROM benchmarks were done using a Single Instruction Multiple Data massively parallel DECmpp 12000, which has 4096 parallel processing elements. The Alpha/AXP significantly outperformed the VAX 6000 (almost 2 to 1), which was expected. But even though the DECmpp's processing elements are far less powerful than the AXP's central processing unit, there are so many of them that the DECmpp generally outperformed the AXP. A 24-hour simulation starting at midnight showed Central Processing Unit (CPU) time increasing by as much as 137% on the AXP as the simulation entered the daylight hours and the stiff photochemistry caused more domain grid cells to take longer to complete their processing. On the DECmpp there was only a slight diurnal variation in CPU time throughout the simulation because it takes about the same amount of time to complete a grid of 4096 cells whether only one cell or all were stiff. Although much faster per cell, the VAX or AXP's sequential processing is subject to the total number of stiff cells that must be computed. Thus, the best total CPU for the AXP was about 99 minutes for the 24-hour simulation, but about 90 minutes for the DECmpp. For comparison, ROM optimized on the vector-processing CRAY Y-MP used about 22 minutes CPU for a similar scenario.

2.4.5.4 Technology Transfer

A cooperative agreement was awarded to North Carolina State University, Raleigh, North Carolina. The agreement was for 1) development of decision support concepts to enable the use of advanced air quality models for evaluation of decision options, 2) exploration of innovative training technologies including computer and video networking, on-line help, computer-based modules, and collaborative computing, and 3) exploration of technologies for effective human-machine interaction including visualization, expert systems, intelligent databases, and interactive training techniques.

2.4.5.5 Enhanced Analysis Techniques

Several Application Visualization System (AVS) modules were written to provide in-house researchers with desk-top data analysis and animation capabilities. Initial versions of modules for X-Y plots, colored tiles, colored mesh, and colored tile and colored mesh comparison were created and linked with a generic reusable AVS module named Run Visualization, which serves as a driver for selecting and running data display modules. Division scientists are able to visualize both input and output data associated with ROM, RADM, and UAM. These tools handle data access across computing platforms, plotting and manipulating graphic images, and automatic selection of background maps. Modules were also developed for integrating geographic data directly from ARC/INFO, a Geographic Information System software package, into AVS. High quality video animations of air quality and sediment transport in lakes and streams were also developed.

2.4.5.6 Infrastructure Support

Division computer infrastructure was improved significantly during FY-1993. Thirteen Sparc LX's were procured for use by personnel as client machines in a client/server arrangement. Two servers were procured, a SUN Sparc 10 and a SGI Challenge. In addition, over 30 Gigabytes of space were added to the file structure of the servers. Plans are being implemented to transfer less computational models running on Crays to workstations. Parallel implementation of models is also being tested on the SGI Challenge.

New network technologies and computing paradigms are being tested to prepare for a smooth transition to the use of remote collaborative technologies for joint research and applications. A high speed 100 Mbit/sec research network was established to satisfy the bandwidth requirements for collaborative visualization, distributed data management, and heterogeneous computing. In addition, 1.5 Mbit/sec telecommunication lines were established with the EPA Environmental Research Laboratory in Athens, Georgia, and the Chesapeake Bay Program Office to support research on the linkage of air and water quality models.

2.5 Global Climate Research Branch

The Global Climate Research Branch performs and directs research to obtain qualitative and quantitative analyses of regional climate and its relationship to air quality for use in evaluating the sensitivities and responses of major environmental systems. The Branch has particular interest in tropospheric ozone and the relationship to meteorological variables. Remotely sensed data is being evaluated for estimating ecological parameters at various spatial and temporal scales.

2.5.1 Global Climate Change Research

The goal of global climate change research is to understand the physical and chemical elements of the climate and the atmosphere, including their properties, feedback mechanisms, and the 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.

Research was initiated to develop climate change scenarios for the U.S. Forest Service Southern Global Change Program (SGCP), and included the update and use of a historical 1° climate database developed at the University of Oklahoma. Summaries were transmitted by the University of Oklahoma to Division scientists who studied the applicability of Kriging these data. The study utilized statistical software from Cornell University and original software developed by a U.S. Forest Service statistician. The software was adapted to personal computers (PCs) and workstation platforms, Beta-tested, and then used to determine the potential value of Kriging monthly precipitation data in the South. Although a number of regional and directional searches were explored, it was determined that Kriging did not add significant value over less resource intensive data estimation techniques for this time and space resolution (monthly and 1°).

The 1° historical database was used to develop a suite of climate change scenarios to be used as input to forest production models on temporal scales ranging from annual to hourly. Scenarios were based on widely used difference and ratio transformations of historical time series of maximum and minimum temperatures, precipitation, solar radiation, and humidity. More innovative scenarios that reflect current research in climate change detection are being developed as well. Scenarios that reflect differential warming conditions (nighttime increases roughly 3 times that of daytime warming) were completed. Output from the Goddard Institute of Space Studies, Geophysical Fluid Dynamics Laboratory, Oregon State University, and the United Kingdom Meteorological Office GCMs that were archived at NCAR are used as the point of departure for scenario development. Several regional assessments based on these scenarios are expected to be completed during 1994 by USFS scientists. A journal article and Forest Service Technical bulletin, which discuss the use of General Circulation Model output in forest assessment applications, were produced (Cooter *et al.*, 1993; Cooter *et al.*, In press). A journal article summarizing the development of a statistical climate change paradigm was published (Katz, 1993).

2.5.2 The Spatiotemporal Variability of Non-Urban Ozone

The spatial and temporal variability of the daily 1-hour maximum ozone (O_3) concentrations over non-urban areas of the eastern United States was examined over the period 1985-1990 using principal component analysis (Eder, 1993; Eder *et al.*, In press). Utilization of Kaiser's Varimax orthogonal rotation led to the delineation of six contiguous subregions or influence regimes, each of which displayed statistically unique O_3 characteristics that corresponded well with the path and frequency of anticyclones. For one of these subregions (the South), a two-stage clustering approach was utilized as part of an objective meteorological classification scheme designed to better elucidate ozone's dependence on meteorology.

When applied to 10 years (1981-1990) of meteorological data for Birmingham, Alabama, the classification scheme identified seven statistically distinct meteorological regimes, exhibiting significantly different mean daily 1-hour maximum O_3 concentration characteristics. Of the seven clusters, the three associated with anticyclones, the *Transitional Anticyclone* (mean = 75.01 ppb), the *Bermuda High* (71.32), and the *Migratory Anticyclone* (69.11), exhibited the highest daily 1-hour maximum concentrations and the largest diurnal ranges (63.37, 58.76, and 59.31, respectively). Of the 14 (73) days during the study period when observed concentrations exceed 120 (100) ppb, 7 (35) occurred in *the Transition Anticyclone*, 3 (11) occurred in *the Migratory Anticyclone*, and 4 (24) occurred in *the Bermuda High*. The mean daily 1-hour concentrations of O_3 exhibited by the four remaining clusters were considerably less, as were the amplitudes of their diurnal patterns. Two of these clusters, the *Southwesterly Flow* (mean = 46.85, diurnal range = 28.86) and the *Easterly Flow* (54.07, 33.36) advect moisture laden maritime air from the Gulf of Mexico and the Atlantic Ocean, respectively. The other two clusters, the *Cold Frontal Passage* (50.78, 35.89) and the *Warm Frontal Passage* (55.64, 34.56) are transitional in nature. Contrary to the results associated with the anticyclonic clusters, none of these four clusters experienced concentrations exceeding 120 ppb, and on only 3 days out of a possible 685 days did these clusters record concentrations greater than 100 ppb.

Results from this two-stage clustering approach were then used to develop seven refined stepwise regression models to identify the optimum set of independent meteorological parameters influencing the O_3 concentrations within each meteorological cluster; and weigh each independent parameter according to its unique influence within that cluster. Large differences were noted in the number, order, and selection of independent variables found to significantly contribute to the variability of O_3. When this unique dependence was taken into consideration, a better parameterization of O_3's dependence on meteorology resulted through the development and subsequent amalgamation of the seven individual regression models into a composite model.

2.5.3 Feasibility of Using Satellite Derived Data

Principal component analysis (PCA) was applied to six years (1985-1990) of surface data obtained from the EPA Aerometric Information and Retrieval System (AIRS) and satellite ozone data from the National Satellite Service

Data Center (NSSDC) to determine whether ozone measurements derived from satellites could be used to infer surface-layer concentrations (Eder *et al.*, 1993). Examination of the spatial and temporal characteristics associated with the first nonrotated principal components (which are the dominant components, explaining 37.95% and 41.25% of the total variance of the surface and satellite data sets, respectively) revealed considerable coherence between the data sets suggesting that on continental-scales, seasonal O_3 patterns derived from the satellite data replicate, quite well, those of the surface. This coherence diminishes, however, when daily patterns are compared. Upon orthogonal rotation, the PCA delineated four contiguous and statistically unique subregions with each data set (the *Northwest*, *Northeast*, *Southwest*, and *Southeast*) that were very similar, suggesting that the satellite data may be able to discern O_3 patterns on spatial scales as small as 1000 km.

2.5.4 Impacts Assessment of 1990 Clean Air Act Amendments

The 1990 amendments called for reduction in emissions and reports on change in emission, air quality, and deposition, and the impacts. In FY-1993, the EPA prepared a draft of the First Biennial Assessments of the Impacts. The status of aquatic and terrestrial ecosystems was also addressed. The Assessment utilized model results, data, and data analyses for the various components, and established the baseline conditions for future comparison for sulfate, nitrate, and ozone.

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 air toxic pollutants in the near field. 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 Stagnation Diffusion Studies

As part of the Stagnation Model Analysis Program (STAGMAP), several existing air dispersion models were technically considered for inclusion in a model-performance evaluation using the STAGMAP field measurements (Briggs, 1992). Three models were selected for the evaluation: the Gaussian-plume model, ISCST2 (U.S. Environmental Protection Agency, 1992e); the five-layer, Eulerian grid model, WYNDVALLY (Harrison, 1988); and the multilayer, Gaussian-based, Lagrangian puff model, CALPUFF (Scire *et al.*, 1990b). Other grid-based and puff-based models were considered and eliminated for various reasons. In FY-1994, the three selected models will be tested and evaluated against both the tracer experiments and the particulate experiments of the STAGMAP field study. The evaluation will result in recommendations for modeling PM-10 particles less than 10 microns in diameter in stagnation conditions, using existing models and suggestions for developing future models.

2.6.2 AMS/EPA Regulatory Model Improvement Committee

To expedite the inclusion of state-of-the-art modeling concepts into the EPA regulatory models, the AMS and EPA formed the AMS/EPA Regulatory Model Improvement Committee (AERMIC). A Division scientist serves on this committee. AERMIC has the charter to formulate and recommend changes in the scientific basis of regulatory models and to participate in the evaluation and implementation of recommended model improvements. The committee recommended improvements to the ISCST2 (U.S. Environmental Protection Agency, 1992d) in the areas of dispersion in convective and stable conditions for both elevated and surface pollutant releases, interaction of plumes with complex terrain, plume penetration into elevated stable layers, and parameterization of meteorological profiles in the surface boundary layer. These improvements were coded into the ISCST2 framework, with the improved model named AERMOD. A meteorological preprocessor, AERMET, was coded and testing begun as a driver for AERMOD. The preprocessor will provide estimates of surface heat flux, surface friction velocity, mixing height, and Monin-Obukhov Lengths. Evaluation databases from seven field studies were prepared for the first phase of model evaluation to take place in FY-1994. In addition, a document detailing the technical basis for the AERMOD model formulation is being prepared. The document and results of the model evaluation will be critical elements in the effort to implement AERMOD into the regulatory environment.

2.6.3 Modeling Particulate Emissions from Surface Coal Mines

The EPA is required by the CAAA to re-examine methods for modeling fugitive particles, specifically PM-10, from open-pit, surface coal mines; ISCST2 is specifically named as needing further study. A two-part effort was initiated to assess the ISCST2 estimates of near-field particulate concentrations downwind of typical surface mines. The primary evaluation of the model was based on wind-tunnel measurements of concentrations downwind of scaled open-pit mines with a variety of pit dimensions, pit depths, and wind directions. A sensitivity analysis of the wind-tunnel data indicated that the important parameters for modeling are the pit depth and along-wind dimension, the height of the source above the floor within the pit, and the wind direction relative to the longest dimension of the pit. Initial comparisons of the model estimates with the wind-tunnel results indicate that a typical open pit, with the ratio of pit depth to alongwind dimension of about 0.2, can be adequately modeled as a surface-level area-source where the emissions are greatest near the upwind edge of the pit. As a result of these comparisons between model and wind-tunnel data, final recommendations regarding the use of the ISCST2 for applications to surface coal mines will be provided in FY-1994.

2.6.4 Indirect Exposure Assessment

An effort was initiated to develop an improved model for predicting near-field concentrations and dry and wet deposition fluxes in both simple and complex terrain for use in indirect exposure assessments. The COMPlex terrain DEPosition model (COMPDEP)(U.S. Environmental Protection Agency, 1990), which is recommended by the EPA for use in indirect exposure assessments, was developed by adding methods for modeling plume depletion and dry and wet deposition of particles to the COMPLEXI model (U.S. Environmental Protection Agency, 1993d), a regulatory screening-level model for complex terrain applications. COMPDEP was reviewed and several areas were identified as needing improvement. As a result, a new version of COMPDEP is being developed, with ISC2 as its foundation and is being called ISC-COMPDEP. The improved version will contain all of the capabilities of the existing ISC2, including the recent improvements to the area source and particle dry deposition algorithms as well as algorithms for modeling complex terrain effects, wet deposition of particles and deposition of gases. The development of ISC-COMPDEP is expected to be completed in FY-1994.

2.6.5 Complex Terrain Dispersion Modeling

The Complex Terrain Dispersion Model (CTDMPLUS)(Perry, 1992) and its screening version (CTSCREEN) (Perry *et al.*, 1990) are recommended regulatory models for pollutant sources in complex terrain. Several technical improvements were made to these models in FY-1993. The first improvement involved the calculation of travel time from the source to the receptor for stable and neutral conditions. In these models, the actual terrain is fit to mathematical shapes. Originally, the travel time was calculated using the actual downwind distance from source to receptor while the streamlines were determined for flow around the fitted terrain. To yield a more realistic relationship between the terrain distorted plume and receptor, the models were revised so that receptors that are outside of the fitted ellipse are moved from their actual location to their corresponding position on the fitted terrain to determine the travel time from the source to the receptor. A second major improvement made to CTSCREEN involved the determination of the mixing height. In CTSCREEN, the meteorological inputs are provided or determined from other model inputs; no actual data are used. The original formulation for determining mixing height was based solely on the height of the hill being modeled. This method is inappropriate for cases with small hills and/or highly buoyant sources since plumes will likely penetrate the calculated mixed layer and maximum impacts at receptors will be underestimated. In the revised model, mixing heights are determined as a function of hill height and plume buoyancy. This insures that the model will capture the often worst-case situations where plumes are trapped within shallow mixed layers. Finally, an improved convergence scheme was implemented in both CTDMPLUS and CTSCREEN for determining the position of the streamline that passes through the source.

2.6.6 Chemical Hazards of Atmospheric Releases Research

The 1990 CAAA authorizes the EPA, in coordination with the Department of Energy (DOE) and Federal Coordinating Counsel for Science, Engineering and Technology, to oversee an experimental program on releases of hazardous substances into the atmosphere. This is to be carried out at the DOE Liquified Gaseous Fuels Spills Test Facility, on the Nevada Test Site, through contracts with the Desert Research Institute and the Western Research Institute with the Division responsible for scientific guidance and contract monitoring. Experiments will be carried out to improve atmospheric diffusion models, source characterization models, and mitigation of accidental releases; especially for dense (heavier-than-air) gases or aerosol clouds.

An initial experiment was carried out in July 1993 to provide some baseline information on dense gas diffusion with the following idealizations: a constant, continuous, low momentum source of dense, non-reactive gas near ambient temperature — so that heat transfer is not an issue — released over flat terrain. The gas used was CO_2, which provides dense gas effects with negligible toxicity. Emphasis was placed on testing newly purchased real-time CO_2 sensors, by collocating them with bag samplers, and on measuring the mass flux balance with a dense, five-level array 40 m from the source. The latter was done because accurate determinations of source strength were lacking in most past field experiments, especially when ruptures or pool evaporation and boiling were involved. A methodology adequate for future experiments needs to be developed and proven.

Four successful releases were made just before sunset, when the thermally-driven winds from the southwest were diminished enough to obtain pronounced density-driven effects. Plume width to height ratios ranged from 14 to 25 for the 5 and 3 m/s wind speed experiments, respectively. Quality assurance checks on the data are not complete, but preliminary comparisons of time-integrated CO_2 sensor and collocated bag sampler concentrations are quite encouraging.

2.7 Human Exposure Modeling Branch

The Human Exposure Modeling Branch conducts research to develop and improve human exposure predictive models focusing principally on urban environments where exposures are high. The research includes building wake and cavity models for characterization of gaseous and particulate concentrations from releases within and in the near vicinity of buildings; tracer studies to elucidate air parcel movement within the buildings; and microenvironmental simulation models for human exposure assessments within enclosed spaces in which specific human activities occur. The branch also develops and provides meteorological instrumentation and measurement support to the division field studies programs.

2.7.1 Modeling Human Exposures to Acid Aerosols

An intensive air pollution monitoring and analysis program, the five-year, five-city Metropolitan Aerosol Acidity Characterization Study (MAACS), is ongoing to characterize and model human exposure to acid aerosols and other related pollutants. The first phase of MAACS is the Philadelphia Aerosol Acidity Characterization Study, which was completed during 1993. Exposure models will be used to ascertain the extent of human exposures to acid aerosols and provide support for the establishment of an aerosol acidity air quality standard based on human exposure rather than ambient concentrations.

Acid aerosols represent a class of secondary pollutants formed through both heterogeneous and homogeneous phase oxidation of such primary pollutants as sulfur dioxide, nitrogen oxides, and hydrocarbons. Slow reactivity rates, long-distance transport, and meteorological conditions create a wide variety of human exposure patterns. Indoor sources can contribute to exposure as well. Acid aerosols are neutralized by the reaction with gaseous ammonia, but under certain conditions coexist with ammonia.

A symposium paper was prepared that discussed issues related to sampling and study requirements important to modeling of human exposures to acid aerosols (Zelenka and Suh, 1993). The paper outlined a sampling strategy that enhances the database necessary for effectively modeling human exposure to acid aerosols. A symposium paper (Zelenka *et al.*, 1993) was prepared that discussed the ability of a new model to calculate acid aerosol concentrations for an indoor environment different from the type used for the original model development. Indoor acid aerosol concentrations were calculated from a single model even though such various extraneous factors as housing type and population density may differ.

Research was begun on investigating the relationship between ambient acid aerosol concentrations and regional and local meteorological effects. This work will help increase the understanding of how acid aerosol concentrations in ambient air are affected by local and regional meteorology. A better understanding of meteorological effects on acid aerosol concentrations will aid in predicting locations of potentially high levels of acid aerosol; thus, laying the groundwork for developing more accurate exposure models. Research will use the 1992 and 1993 Philadelphia data.

2.7.2 The Hazardous Air Pollutant Exposure Model and the NAAQS Exposure Models for Mobile Sources

The Hazardous Air Pollutant Exposure Model (HAPEM) estimates human exposure to air pollution and characterizes the health risks associated with these exposures (Johnson *et al.*, 1992). The revised version, HAPEM-MS, was developed to estimate exposure to pollutants emitted by mobile sources. The enhanced version, HAPEM-MS2, with additional exposure indices, increases the accuracy of an exposure estimate. Work started on preparing an evaluation of the model and a user's guide. HAPEM-MS2 calculates the annual average exposure of each cohort to the pollutant and the estimated annual cancer incidence associated with that exposure. Estimates are summed over all cohorts to provide exposure and cancer risk estimates for the entire study area. The NAAQS Exposure Model (NEM) provides hour-by-hour exposures for individuals but computational limitations prevents its use for long-term cancer risk estimates. Work started on evaluating NEM and examining possible improvements for application to human exposure to mobile sources.

2.7.3 Exposure to Alternative Fuels

The agency completed an assessment of potential health risks of MTBE (Methyl Tertiary Butyl Ether) -oxygenated gasolines. As required by the 1990

CAA amendments, MTBE is used in 39 areas of the country that exceed the NAAQS for carbon monoxide. A review of data on ambient air quality and microenvironmental exposures to MTBE during refueling, inside cars, and in residential garages found the data too limited for a quantitative estimate of population exposures. Special studies were conducted by the EPA, the Center for Disease Control, and the American Petroleum Institute during March and April 1993 to provide new measurements of MTBE exposures. At best, the data can be used to estimate broad ranges of potential exposures. Because of the immediate interest in exposure to MTBE, a paper (Huber, 1993) was prepared that evaluated the potential range of exposures.

The development of an air quality model for estimating human exposures in residential garages is ongoing (Lansari, 1993). Pollutant concentrations from tailpipe and evaporative emissions are being examined to develop concentration estimates that are being integrated with population activity patterns to estimate human exposures. Future studies of the potential effect of human exposure to hazardous pollutants from alternative fueled automobiles will include additional microenvironments.

2.7.4 Sulfur Dioxide Exposures at Mae Moh, Thailand

A cooperative research effort with the Royal Thai Government was begun to assist in mitigating episodes of high exposures to SO_2 near the Mae Moh Power Station in northern Thailand. A multiyear human exposure study in the area near the station is being anticipated. High SO_2 concentrations were observed and it is likely that high acid aerosol concentrations occur daily during the cool season (October - January) and may occur during periods of inversion breakup and resulting plume fumigation. A plume fumigation algorithm is being developed for incorporation into the CALPUFF air dispersion model for application on conditions of high SO_2 concentrations near Mae Moh. Also, assistance is being provided to upgrade meteorological instrumentation near the Mae Moh Power Station and to develop meteorological measurement capabilities needed to support the model.

2.7.5 National Dry Deposition Network

A mobile dry deposition monitoring system was designed to acquire high frequency (> 1 Hz) measurements of horizontal and vertical wind velocity, air temperature, water vapor, carbon dioxide, ozone, and sulfur dioxide. From these data, fluxes of momentum, sensible heat, latent heat, carbon dioxide, ozone, and sulfur dioxide can be computed using eddy correlation techniques as well as deposition velocities for the latter two pollutants. This information is intended to refine an inferential model, which estimates pollutant fluxes based on data acquired at CASTNET sites across the country. Both fast and slow response sensors were mounted on or near a light weight, 10 m aluminum telescoping tower. The system was also designed to obtain data to estimate a surface energy heat budget. Ancillary measurements were provided for quality control information and to determine if the meteorological conditions were appropriate for flux estimation. Data from the fast response sensors were primarily used for computations of the turbulent fluxes. Data from the slow response sensors were primarily used to provide quality control information for the fast response sensors and to provide additional input information for the inferential model.

Three special programs were written to perform the operations required to acquire, manipulate, present, and store data. The first program, which was written in assembly language, was designed to run in a background mode and to generate a highly accurate timed interrupt, which transmitted that signal to the A/D converter. The second program, which was written in BASIC, read in the data from the A/D converter, performed various statistical computations, and displayed the data in a near-real time fashion. The program was designed to share time between data acquisition and data processing. A third program was designed as a terminate and stay-resident program, which monitored the modem for incoming calls from remote users of the database.

2.7.6 Meteorological Instrumentation and Measurement Support

Efforts are ongoing to upgrade the level of meteorological measurement capability and to improve field monitoring support, involving fast response sensors, sounding systems, open path monitors, basic meteorological platforms, data logging capabilities, radiation sensors, vertical temperature arrays, and calibration and audit equipment. Laboratory space was set aside to be used as a calibration facility, and a testing, evaluating, and staging area for all meteorological equipment for field studies. Upgrades will allow greater emphasis on field studies incorporating meteorological monitoring; on efforts dealing with evaluating instrumentation; and on developing quality assurance (QA) and quality control (QC) for new sensor technology.

Work was started to establish QA/QC guidelines, standard operating procedures, and site guidance for remote profiling instruments. These systems include 915 MHz wind profiling radars, 2 KHz sound ranging and detection systems (SODAR), and 2 to 5 KHz radio acoustic sounding systems (RASS). The wind profiling radar and SODAR systems are capable of determining three-dimensional wind velocity components through the depth of the atmospheric boundary layer. RASS determines virtual temperature profiles. Very little guidance is available for scientists using instrumentation. Preliminary documentation should be completed by the middle of FY-1994. A field study of these systems is being planned at the Boulder Atmospheric Observatory.

Field support was provided for a pilot study of automobile evaporative emissions from a garage into an attached residence. A data report on wind velocity, temperature, and humidity outside near the garage door and temperature and humidity inside the garage is near completion. Meteorological support is being given to a human exposure study being conducted in Brownsville, Texas. Wind speed, wind direction, and air temperature data were acquired at a receptor site. Back trajectories are being computed from the wind data to be used with chemical data to trace various pollutants. In addition, routine meteorological data taken at the National Weather Service station located at the local airport are being used to supplement the study data.

2.8 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.

2.8.1 Modeling Studies

2.8.1.1 Regional Ozone Model Regulatory Applications

The Regional Oxidant Model (ROM) was applied for the Ozone Transport Commission to assess the relative benefits of reducing ozone concentrations by controlling emissions of oxides of nitrogen (NOx) in various geographic sectors of the Northeast Transport Region. As part of this effort, four emission scenarios were designed and simulated using ROM. The results, which were presented to the Commission in January 1993, are being used to develop geographically-targeted emission strategies within the Transport Region.

Work continued with ROM applications to support states required to demonstrate ozone NAAQS attainment. Regional inventories were developed reflecting emissions for simulating ozone concentrations during episodes in the years 1987 through 1991. A total of 15 base-case and 35 control-strategy scenarios were defined for model simulation. Simulations for the base-case scenarios were begun and emission factors were developed for strategy scenarios that reflect control programs mandated in the 1990 CAAA.

2.8.1.2 Surface Coal Mine Study

Section 234(a) of the CAAA requires that the EPA analyze the accuracy of the Industrial Source Complex (ISC2) dispersion model in predicting the effect on air quality of fugitive emissions from surface coal mines. In support of the requirement, an extensive study was initiated at a large surface coal mine in Wyoming's Powder River Basin. Phase I of the study involved the collection of meteorological and air quality data at the mine. Nine Particulate Matter and PM-10 monitors and two meteorological towers, one inside the mine pit, were installed and operated at an intensive schedule for 60 days. Field personnel took detailed observations of all operations at the mine during this period to determine emission estimates. Meanwhile, wind tunnel simulations of the mine were made at the Fluid Modeling Facility, and an analysis of the sensitivity of near-field downwind surface concentrations was conducted. The next phase of the study involves development of an objective model evaluation protocol to test the performance of the ISC2 model, as well as other dispersion models, to determine model performance.

2.8.2 Modeling Guidance

2.8.2.1 Revisions to the Guideline on Air Quality Models

The Guideline on Air Quality Models (Revised), as modified by Supplement A (U.S. Environmental Protection Agency, 1987), lists the air quality models for estimating ambient air concentrations due to sources of air pollution. On February 13, 1991, the EPA issued a Notice of Proposed Rulemaking to significantly augment the Guideline via Supplement B with several new modeling techniques. The purpose was to provide models for situations where specific procedures were not available and to improve several adopted techniques. Among the revisions to the guideline are improvements to the regulatory model, VISCREEN, that is used to estimate perceptibility of individual plumes, the user's guide, and a workbook of screening techniques for assessing visual plume impacts (DiCristofaro *et al.*, 1993; Touma *et al.*, 1993; U.S. Environmental Protection Agency, 1992f and g). New methods were offered for characterizing dispersion of isolated point sources in complex terrain, of mobile source emissions in signalized intersections, and of multiple point and area source emissions associated with airports. In compliance with policies of the Office of the Federal Register, promulgation of Supplement B published the entire Guideline as appendix W to part 51 of the Code of Federal Regulations. Previous to this action, the Guideline had been included in the regulations by reference. A Notice of Final Rulemaking promulgating Supplement B to the Guideline was published in the Federal Register on July 20, 1993. This rulemaking became effective on August 19, 1993.

2.8.2.2 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, 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 model revisions that are available on the SCRAM BBS.

During FY-1993, several noteworthy activities were accomplished by the SCRAM Systems Operator. The Guideline on Air Quality Models with Supplement B (U.S. Environmental Protection Agency, 1993d) improvements, including new and revised dispersion models and related documentation, were uploaded to the

SCRAM BBS. This action affected seven models: SCREEN2, CAL3QHC, CTDMPLUS, CTSCREEN, PLUVUE II, OCD, and VISCREEN. Also, a model tutorial area was established, providing SCRAM users tutorials online for SCREEN, VISCREEN, PCRAMMET, ISC2, TSCREEN, WRPLOT, and CTSCREEN. In addition, another new area, Topics for Review and Comment, was established. This area allows the modeling community the opportunity to review and comment on new modeling algorithms under consideration.

2.8.2.3 Model Clearinghouse

The FY-1993 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 for activities of FY-1993.

6. Entering FY-1993 records into a computerized database.

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

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

There were 118 modeling referrals to the Model Clearinghouse from the Regional Offices during FY-1993. These included 19 regulatory modeling problems, each of which required a written response, 77 referrals, each of which required an oral response, and 22 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 1992, a Clearinghouse report was prepared and distributed to the Regional Offices; the report informed Clearinghouse users about issues and responses that occurred during FY-1992.

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. During FY-1993, three such sensitive cases arose. One involved the interpretation of Table 9.1 of the Guideline on Air Quality Models (Revised) as it applies to secondary PM-10 precursors in the Denver area. Another involved the rounding of ozone model estimates in the Georgia State Implementation Plan demonstration. The other involved the justified raising of a stack height because an obstruction was built that caused downwash of the existing stack. In each case, 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 1186 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-1993; (2) FY-1989 through FY-1993 Clearinghouse memoranda; and (3) FY-1989 through FY-1992 Model Clearinghouse reports.

2.8.2.4 Guidance on Indirect Exposure Modeling for Air Toxic Release

Concerns about the accumulation of toxic substances in the soil and biota and about hazardous waste incineration served as an impetus in improving air toxic modeling. However, indirect exposure assessment requires greater skill in the ability to model both dry and wet deposition of various compounds than for inhalation risk assessment. Division scientists chaired the EPA subgroup on emission and dispersion modeling, which reported to an Agency-wide indirect exposure assessment work group. Guidance was developed that relied on existing tools on an interim basis, with the goal of developing a better model as research efforts are completed. A detailed plan was developed to describe the various components needed for such a model.

Concerns about the hazardous waste incinerator being operated by Waste Technology Inc.,in Ohio, provided another impetus for improving methodology for indirect exposure assessment. The recommendations of the modeling subgroup were also used to assess the impact of the facility. Based on the immediate need of the EPA Regional Office dealing with the facility, a model called ISC-COMPDEP is being assembled to analyze the indirect exposure impact. This model borrows heavily from work done over the last three years on deposition modeling and a new area source algorithm for simulating ground-level releases.

2.8.2.5 New Modeling Techniques

Two improved modeling techniques were released for peer review and public testing. Both deal with major enhancements to the Industrial Source Complex (ISC2) regulatory dispersion model. The first was the result of several activities related to testing and developing a new area source algorithm that provides a major improvement to an accurate assessment of impact from ground-level releases. These releases are typical of such pollutants regulated under CAAA as PM-10 from surface coal mines, as well as toxic air pollutants from municipal waste and hazardous waste landfills regulated by the EPA. This effort culminates over three years of planning and effort (Touma *et al.*, 1993; U.S. Environmental Protection Agency, 1992a, b, and d).

The second deals with a new algorithm for modeling deposition (U.S. Environmental Protection Agency, 1992c). The existing deposition algorithm in ISC2 was designed for treating large particles, but with new emphasis on such small particles as PM-10, as well as toxic air pollutants, the importance of a new algorithm was recognized for some time. Work has focused on developing and testing such an algorithm. Funding was obtained for testing an algorithm that can estimate deposition from gases. With increased emphasis on indirect exposure modeling from hazardous waste combustors, this algorithm improved estimates. The deposition and the area source algorithms are being incorporated into a revised version of the ISC2 model that will be the focus of a new proposal to revise the Guideline on Air Quality Models (Revised) (U.S. Environmental Protection Agency, 1987).

2.8.2.6 Guidance on Models for Contingency Analysis from Toxic Air Releases

There is increasing need for guidance on how to use atmospheric dispersion models for contingency planning and decision making at Superfund and other industrial sites where there is a potential for air toxic releases (Touma *et al.*, 1993; U.S. Environmental Protection Agency, 1992h). A typical emergency responder will have access to modelers who will be able to carry out a quick analysis of the ambient air impact. However, there is a wide variety of releases that may potentially be encountered at such sites and the most difficult task is to prepare input data that adequately represent these scenarios. There is also a wide variety of models that can be chosen and each has limitations on the types of releases it can handle and the type of data needed for input. Practical and systematic guidance on an approach to the decision criteria needed by the responder and modeler was prepared (Kaiser *et al.*, 1993; U.S. Environmental Protection Agency, 1993a and c). It illustrates the possible range of accidental releases of hazardous air pollutants that might take place at Superfund sites; and demonstrates how atmospheric dispersion models, including dense gas models, should be applied.

2.8.3 Additional Support Activities

2.8.3.1 Regional, State, and Local Modelers Workshop

The annual meeting of the EPA Regional, State, and local air pollution modelers conference was held in Raleigh, North Carolina, April 26-30 1993. Of the 32 participants, 19 were from Regional Offices, 7 from State and local agencies, and several from the EPA. The main topics of this year's workshop were (1) the new area-source algorithm for use in the ISC2 dispersion model; (2) the new dry deposition algorithm for use in the ISC2 model; (3) the plume dispersion model being outlined by AERMIC; and (4) the long-range dispersion model being developed by IWAQM for assessing regional haze impacts in Federal Class I areas. Besides these programs, reviews were presented on other topics ranging from status of draft guidance, Superfund/Toxic modeling to Model Clearinghouse procedures and referrals of general interest.

2.8.3.2 AMS/EPA Regulatory Model Improvement Committee

The AMS and the EPA established AERMIC to assist in the introduction of state-of-the-art modeling concepts into regulatory dispersion models. AERMIC formulates and recommends changes in the scientific components of regulatory air models and participates in the evaluation and implementation of these new methodologies. The initial focus is on the Industrial Source Complex (ISC) model because of its wide use in regulatory applications. Improvements are expected in the areas of dispersion, plume rise, complex terrain, and the surface-layer parameterizations.

The committee completed the design of the model, which consists of a meteorological interface that scales surface-layer parameters (friction velocity, convective velocity scale, Monin-Obukhov length, etc.) with height, convective boundary layer dispersion module, a stable boundary layer dispersion module, and a terrain module. The surface-layer parameters are provided by a meteorological preprocessor developed earlier. A preliminary version of the code is nearly completed. A developmental evaluation was designed to provide a test to determine if the preliminary model needs significant revisions in design.

2.8.3.3 Interagency Work Group on Air Quality Models

In October 1991, the EPA, National Park Service (NPS), Fish and Wildlife Service (FWS), and U.S. Forest Service (USFS) signed a Memorandum of Agreement to foster cooperation in the development, evaluation, and application of air quality dispersion models for assessing air quality impacts of source emissions on distant receptors (>50 km), especially in federally protected forest and parks (Federal Class I areas). The Agreement established an interagency Work Group comprised of technical staff representing the NPS, FWS, USFS, and EPA. The objective of the Work Group is to foster the development of mutually acceptable techniques for characterizing these impacts and to assist in the development of rulemaking to adopt acceptable models according to modeling guideline (U.S. Environmental Protection Agency, 1992i).

During FY-1993, the Work Group drafted recommendations (U.S. Environmental Protection Agency, 1993e) offering interim modeling procedures for use while effort continues in the development of more comprehensive techniques. Given the time constraints and the practical limitations of resources and hardware, the interim recommendations were designed to provide the best approach from existing off-the-shelf-techniques. The interim approach recommends the use of the Lagrangian puff dispersion model, MESOPUFF-II (Scire *et al.*, 1984) to assess distant source impacts in satisfaction of the regulations associated with the EPA Prevention of Significant Deterioration (PSD) program.

Work initiated towards development of more comprehensive modeling methods includes: comparing alternate diagnostic methods for characterizing mesoscale transport winds; comparing the Lagrangian puff models MESOPUFF-II and CALPUFF (Scire *et al.*, 1990a and b), and Gaussian plume modeling routinely used in EPA regulatory assessments; using the MM4-FDDA, (Anthes and Warner, 1978; Anthes *et al.*, 1987)] to develop regional wind fields for several trials of the 1983 Cross-APpalachian Tracer EXperiment (CAPTEX); initiating an evaluation to assess the performance of puff dispersion models using the CAPTEX MM4-FDDA winds. Reports are being drafted summarizing this work in preparation for distribution in FY-1994.

2.8.3.4 Harmonization of Regulatory Assessment Dispersion Models Within the European Community

A Workshop on Intercomparison of Advanced Practical Atmospheric Dispersion Models was conducted in Manno, Switzerland. This was the second of a series of three planned workshops whose purpose is to improve international cooperation and harmonization in atmospheric dispersion modeling. The workshop was attended by about 50 scientists and engineers from more than a dozen countries, focused primarily on defining and testing procedures for the evaluation of air quality models. The workshop included a pilot study of a proposed model evaluation approach. This consisted of the application of the evaluation procedures to the Danish OML model and the American ISCST2 model. Division meteorologists participated both in the development of the model evaluation methods and in the pilot study evaluation of the ISCST2 model.

2.8.3.5 Carboelectrica Power Stations, Coahuila, Mexico

Dispersion modeling analyses were conducted to assess ambient SO_2 impacts from the Carboelectrica Power Stations in northeastern Mexico. Carbon I and II power stations are coal-fired steam electric generating facilities located about 30 km south-southwest of the United States/Mexican border in northeastern Mexico. Carbon I, the Rio Escondido Power Plant, is an existing facility comprised of four 300 MW units. Carbon II, which is under construction, will be comprised of four 350 MW units. Estimated emissions of sulfur dioxide from the two facilities are 112,000 tons per year from Carbon I and 130,000 tons per year from Carbon II.

The EPA requested the analysis as part of important bilateral discussions with Mexico on the North America Free Trade Agreement. A critical element in the analysis was the assessment of ambient impacts in the Big Bend National Park, a Class I PSD area about 220 km northwest of Carbon I and II. Estimates of ambient impacts in Big Bend were provided to the National Park Service for use in estimating the impact on visibility and other air quality related values in the Park.

2.8.3.6 Meteorological Factors Associated with the Ozone Seasons of 1988 and 1991

An assessment was conducted of the meteorological factors associated with high surface ozone levels during the summers of 1988 and 1991. At issue was the interpretation of recent ozone trend data and the difficulty involved in separating effects due to changes in emissions from effects due to changes in meteorology. Summer 1988 was of interest because of the unusually frequent and severe ozone episodes that occurred during this period and attributed in part to the hot, dry, stagnant conditions, prevailing during summer 1988. In succeeding summers, the frequency and severity of ozone episodes has diminished. However, it was unclear to what extent this improvement in ozone air quality could be attributed to reductions in precursor emissions or to more favorable meteorology.

In addition to an in-depth literature search, staff contacted several NOAA laboratories as well as other Federal agencies for information on related research. Conversations with personnel at the Climate Monitoring and Diagnostics Laboratory in Boulder, Colorado, were helpful in providing information on research in global climate monitoring and the use of general circulation models. Follow-up conversations with personnel at the Geophysical Fluid Dynamics Laboratory in Princeton, New Jersey, affirmed that summer 1988 was unusual in terms of the extent and severity of the drought and that this was linked to an unusual circulation pattern. Discussion with personnel at NCAR provided information based on research using General Circulation Models and suggested that the anomalous circulation in 1988 was caused by anomalous sea surface temperatures in the tropical Pacific (an aftermath of the 1987 El Nino). Charts and graphics were provided by personnel at the Climate Analysis Center and at the National Climatic Data Center.

How unusual was the summer of 1988? Or, in a quasi-hydrological framework, what is the expected return period of the meteorology that led to the summer of '88 ozone levels? Two of the databases suggest a return period in the range of 40 to 50 years. The first, the drought data indicate that 1988 was the most severe drought in the Midwest since 1936, suggesting a return period of 42 years. The second, the El Nino data indicate that 1988 was the strongest cold episode in 50 years. However, 1983 was also an extreme year for ozone and was associated with the strongest warm El Nino episode in the century, the 1982/83 El Nino.

In its climate assessment of the 1981-1990 decade, (U.S. Department of Commerce, 1991) notes that "there have been small, but significant, systematic shifts in the hemispheric circulation patterns during the 1980's." The DOC assessment continues that "while ... records were set during the 1980's, it is still not clear whether these are simply large excursions of the climate or whether these variations signal trends towards a clearly different climate." This could have profound implications for ozone trends analyses, which were based largely on data for the 1980's.

It remains unclear to what extent improvements in ozone air quality since 1988 can be attributed to reductions in precursor emissions or to more favorable meteorology. Therefore, additional initiatives directed at this question are underway. These include additional 1) simulations with ROM using 1988 and 1991 emissions with 1988 and 1991 meteorology; 2) statistical analyses relating ozone to meteorology and ozone trends analyses to remove the dependence of ozone trends on meteorology; and 3) synoptic analyses to better quantify circulation features associated with high ozone levels. Results from these evaluations will be included in a comprehensive reports.

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APPENDIX A: ACRONYMS

Acid-MODES	Acid Models Operational and Diagnostic Evaluation Study
ADOM	Acid Deposition and Oxidant Model
AERMET	Meteorological preprocessor for AERMOD
AERMIC	AMS/EPA Regulatory Model Improvement Committee
AERMOD	Improved ISCST2 Model
AIRS	Aerometric Information and Retrieval System
AMS	American Meteorological Society
APIOS	Acid Precipitation In Ontario Study
AQM	Air Quality Model
ASMD	Atmospheric Sciences Modeling Division
AUSPEX	Atmospheric Utility Signatures, Predictions and EXperiments
AVS	Application Visualization System
BASC	Board on Atmospheric Sciences and Climate (NAS/NRC)
BEIS	Biogenic Emissions Inventory System
CAA	Clean Air Act of 1970
CAAA	Clean Air Act Amendments of 1990
CALPUFF	CALifornia PUFF model
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
COMPDEP	COMPlex terrain DEPosition model
COMPLEXI	A complex terrain dispersion model.
COMSTM	COMprehensive Sulfur Tracking Model
CPU	Central Processing Unit
CTDMPLUS	Complex Terrain Dispersion Model PLus algorithms for Unstable Situations
CTM	Chemistry Transport Model
CTSCREEN	A screening version of CTDMPLUS
DOE	Department of Energy
EMAP	Environmental Monitoring and Assessment Program
EMBSC	Eulerian Modeling Bilateral Steering Committee
EMEFS	Eulerian Model Evaluation Field Study
EMEFS/PMG	EMEFS Program Management Group
EMEP	European Monitoring and Evaluation Program
EPA	Environmental Protection Agency
EUROTRAC	EUROpean experiment on the TRAnsport and transformation of trace atmospheric Constituents
FCCSET	Federal Coordinating Council for Science, Engineering, and Technology
FDDA	Four Dimensional Data Assimilation
FIFE	First ISLSCP Field Experiment

FWS	Fish and Wildlife Service
HAPEM	Hazardous Air Pollutant Exposure Model
HAPEM-MS	Hazardous Air Pollutant Exposure Model-Mobile Source
HPCC	High Performance Computing and Communications program
HRADM	High resolution RADM
ICMSSR	Interdepartmental Committee for Meteorological Services and Supporting Research
IMPROVE	Interagency Monitoring of PROtected Visual Environments
IOV	Initial Operating Version
ISC2	Industrial Source Complex model - version 2
ISCST2	Industrial Source Complex Short-Term model
ITM	International Technical Meeting
IWAQM	Interagency Work Group on Air Quality Models
LES	Large Eddy Simulation
LMOS	Lake Michigan Ozone Study
MAACS	Metropolitan Aerosol Acidity Characterization Study
MCHISRS	Model ClearingHouse Information Storage and Retrieval System
MDNB	Mathematical mode of Dispersion Near a Building
MESOPUFF	MESOscale Lagrangian PUFF dispersion model
MM4	Mesoscale Meteorological Model - version 4
Models-3	Third generation air quality modeling system
MOHAVE	Measurement Of Haze And Visual Effects
MPP	Mohave Power Plant
MSC-W	Modeling Synthesizing Center - West (Norwegian Meteorological Institute)
NAAQS	National Ambient Air Quality Standards
NAPAP	National Acid Precipitation Assessment Program
NARSTO	North American Research Strategy for Tropospheric Ozone
NASA	National Aeronautics and Space Administration
NATO/CCMS	North Atlantic Treaty Organization Committee on Challenges of Modern Society
NCAR	National Center for Atmospheric Research
NCSC	North Carolina Supercomputing Center
NDDN	National Dry Deposition Network
NEM	NAAQS Exposure Model
NESC	National Environmental Supercomputing Center (EPA)
NESCAUM	NorthEast States for Coordinated Air Use Management
NOAA	National Oceanic and Atmospheric Administration
NOM	NOAA Oxidant Model (Aeronomy Laboratory)
NPS	National Park Service
NRC	National Research Council
OAQPS	Office of Air Quality Planning and Standards (EPA)
PBL	Planetary Boundary Layer
PC	Personal Computer
PCA	Principal Component Analysis
PM	Particulate Matter
PPM	Piecewise Parabolic Method
PSD	Prevention of Significant Deterioration
PWA	Pulsed-Wired Anemometer
RADM	Regional Acid Deposition Model
RADM/EM	RADM Engineering Model
RAF	Research and Administration Facility (EPA)

RELMAP	REgional Lagrangian Model for Air Pollution
REMOVE	REmote Monitoring Of Vehicle Exhaust
ROM	Regional Oxidant Model
RPM	Regional Particulate Model
SARMAP	SJVAQS/AUSPEX Regional Modeling Adaptation Project
SCAQS	Southern California Air Quality Study
SCRAM BBS	Support Center for Regulatory Air quality Models Bulletin Board System
SIP	State Implementation Plan
SJVAQS	San Joaquin Valley Air Quality Study
SOS	Southern Oxidant Study
STAGMAP	STAGnation Model Analysis Program
STAPPA	State and Territorial Air Pollution Program Administrators
STM	Sulfate Tracking Model
TSCREEN	Air dispersion screening model
TSEM	Tagged Species Engineering Model
UAM	Urban Airshed Model
UAMMET	Urban Airshed Model METeorological module
USFS	U.S. Forest Service
US/USSR	United States/Union of Soviet Socialist Republics
USWRP	United States Weather Research Program
UV-DIAL	UltraViolet-DIfferential Absorption Lidar
VOC	Volatile Organic Compounds
WESTAR	WEstern STates Air Resources council
WRADM	Window RADM
WYNDVALLEY	A five layer Eulerian grid model

APPENDIX B: PUBLICATIONS

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APPENDIX C: PRESENTATIONS

Benjey, W.G. Estimation of regional emissions from agricultural pesticides. Presentation at the First Workshop on Emissions and Modelling of Atmospheric Transport of Persistent Organic Pollutants and Heavy Metals, Durham, NC, May 6, 1993.

Benjey, W.G. Agricultural pesticide emissions associated with common crops in the United States. Presentation at the 86th Annual Meeting of the Air & Waste Management Association, Denver, CO, June 16, 1993.

Binkowski, F.S. Aerosol processes and air quality modeling. Invited presentation at the 8th EUMAC Workshop, Graz, Austria, September 7, 1993.

Binkowski, F.S., and U. Shankar. Model predictions of aerosol characteristics in industrial source regions and rural areas. Presentation at the Eleventh Annual Meeting of the American Association for Aerosol Research, San Francisco, CA, October 14, 1992.

Brown, M.J. (North Carolina State University, Raleigh, NC). A non-local model for prediction of the probability density function of turbulent fluctuations in boundary-layer flows. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, March 9, 1993.

Clark, T.L. Potential EPA needs for routinely monitoring and reporting air toxic pollutants. Presentation at the NADP/NTN Toxic Deposition Initiative Meeting, Cocoa Beach, FL, October 20, 1992.

Clark, T.L. Status of the RELMAP adaptation and applications for the atmospheric deposition of toxic pollutants. Presentation at the EPA/EPRI/DOE Workshop on Mercury and Multimedia Risk Assessment, Durham, NC, October 22, 1992.

Clark, T.L. Status of modeling the atmospheric deposition of toxic pollutants. Presentation at the Chesapeake Bay Toxics Subcommittee Meeting, Annapolis, MD, November 5, 1992.

Clark, T.L. Using RELMAP to calculate the atmospheric deposition and source/receptor matrices for toxic pollutants. Presentation to the EPA Office of Air Quality Planning and Standards, Durham, NC, November 16, 1992.

Clark, T.L. RELMAP calculations of annual atmospheric deposition of toxic pollutants. Seminar presented to the EPA Office of Air Quality Planning and Standards, Durham, NC, April 28, 1993.

Cooter, E.J. Recent frost date trends in the northeastern United States. Presentation at the Department of Geography Weekly Colloguium Series, University of North Carolina at Chapel Hill, Chapel Hill, NC, April 2, 1993.

Cooter, E.J. Statistics for environmental assessment application. Presentation at the Duke University TIP/Women in Mathematics Statistics Weekend, Duke University, Durham, NC, April 17, 1993.

Dennis, R.L. Issues of uncertainty and forecasting in the mechanical paradigm of regional air quality. Presentation at the Task Force on Forecasting Environmental Change Workshop, IIASA, Laxenburg, Austria, February 22, 1993.

Dennis, R.L. Reductions in atmospheric deposition of nitrogen to Chesapeake Bay due to the 1990 Clean Air Act Amendments. Presentation to the Chesapeake Bay Modeling Subcommittee, Annapolis, MD, April 6, 1993.

Dennis, R.L. An exploration: Do the chemical mechanisms extrapolate to the real world? Presentation at the EMEP Workshop on the Control of Photochemical Oxidants in Europe, Porvoo, Finland, April 21, 1993.

Dennis, R.L. Linked water and air quality management. Presentation at the High Performance Computing and Communications Workshop on Grand Challenge Applications and Software Technology, Pittsburgh, PA, May 5, 1993.

Dennis, R.L. Summary report from application panels: Environment and earth sciences. Presentation at the High Performance Computing and Communications Workshop on Grand Challenge Applications and Software Technology, Pittsburgh, PA, May 7, 1993.

Dennis, R.L. How representative are our surface sites? Presentation at the Southern Oxidants Study Data Workshop, Denver, CO, May 13, 1993.

Dennis, R.L. Overview of the National Acid Precipitation Assessment Program. Presentation at the Workshop on Air Quality and Acid Deposition Models: Developments, Evaluation, and Assessment Applications, Taipei, Taiwan, June 15, 1993.

Dennis, R.L. Operational evaluation of the RADM against the National Dry Deposition Network and the NTN/NADP wet network. Presentation at the Workshop on Air Quality and Acid Deposition Models: Developments, Evaluation, and Assessment Applications, Taipei, Taiwan, June 15, 1993.

Dennis, R.L. Concepts of model evaluation, illustrated with results from the RADM evaluation using Eulerian Model Evaluation Field Study Data. Presentation at the Workshop on Air Quality and Acid Deposition Models: Developments, Evaluation, and Assessment Applications, Taipei, Taiwan, June 15, 1993.

Dennis, R.L. EPA's high performance computing and communications program and components related to multimedia visualization and collaborative computing. Presentation at the Great Lakes Environmental Visualization Workshop, Cleveland, Ohio, July 15, 1993.

Dennis, R.L. Preliminary estimates of the airshed of the Chesapeake Bay watershed. Presentation to the Chesapeake Bay Modeling Subcommittee, Annapolis, MD, September 2, 1993.

Eder, B.K. Invited speaker at the National Institute of Statistical Sciences, Research Triangle Park, NC, December 1, 1992.

Eder, B.K. The spatial and temporal analysis of non-urban ozone over the eastern United States using rotated principal component analysis. Seminar presented at North Carolina State University, Raleigh, NC, April 2, 1993.

Genikhovich, E.L. (Main Geophysical Observatory, St. Petersburg, Russia). Dispersion of pollutants around a building. Poster presentation at the NATO Advanced Study Institute: Wind Climate in Cities, Karlsruhe, Germany, July 5-16, 1993.

Genikhovich, E.L. (Main Geophysical Observatory, St. Petersburg, Russia). Mathematical modeling of air pollution dispersion near a building. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, January 26, 1993.

Godowitch, J.M. Urban meteorological and photochemical modeling: A current research and development effort. Presentation at the National Institute for Environmental Studies, Tsukuba, Japan, October 1, 1992.

Godowitch, J.M. Current research efforts supporting ozone modeling. Presentation at the Urban Airshed Modeling Workshop, Atlanta, GA, May 12, 1993.

LeDuc, S.K. Mathematics in meteorology. Seminar presented at Orange County High School, Hillsborough, NC, January 21, 1993.

LeDuc, S.K. Satellites. Seminar presented at West Millbrook Middle School, Raleigh, NC, May 4, 1993.

Lee, R.F. Pilot Study: Evaluation of the ISCST2 Model. Presentation at the Workshop on the Intercomparison of Atmospheric Modeling Systems, Manno, Switzerland, August 30, 1993.

Lee, R.F. Overview of U.S. Environmental Protection Agency's model evaluation activities. Presentation at the Workshop on the Intercomparison of Atmospheric Modeling Systems, Manno, Switzerland, August 30, 1993.

Lu, J. (North Carolina State University, Raleigh, NC). A laboratory simulation of urban heat-island induced circulation in a stratified environment. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, December 2, 1992.

Novak, J.H. EPA's HPCC program. Presentation at Supercomputing '92, Minneapolis, MN, November 17, 1992.

Novak, J.H. EPA's HPCC program. Briefing for the Acting Assistant Administrator, Office of Research and Development, U.S. Environmental Protection Agency, Washington, DC, April 7, 1993.

Novak, J.H. MSAB research activities. Presentation at the Regional, State, and Local Modeler's Workshop, Raleigh, NC, April 26, 1993.

Novak, J.H. HPCC research activities. Briefing for the OMMSQA Management Review, U.S. Environmental Protection Agency, Research Triangle Park, NC, August 17, 1993.

Perry, S.G. Briefing to the EPA Office of Air Quality Planning and Standards on the Status of the Stagnation Model Analysis Program (STAGMAP), Research Triangle Park, NC, November 3, 1992.

Perry, S.G. Review of STAPMAP program. Presentation at the Regional, State, and Local Modelers Workshop, Raleigh, NC, April 29, 1993.

Petersen, W.B. Overview of ORD research activities. Presentation at the Regional, State, and Local Modelers Workshop, Raleigh, NC, April 26, 1993.

Petersen, W.B., and D.B. Schwede. COMPDEP and indirect exposure assessment work. Briefing for the Acting Assistant Administrator, Office of Research and Development, U.S. Environmental Protection Agency, Washington, DC, August 31, 1993.

Pierce, T.E. An alternative method for estimating biogenic VOC emissions in EPA Region 1. Presentation at the EPA/AWMA International Conference on Tropospheric Ozone: Nonattainment and Design Value Issues, Boston, MA, October 30, 1992.

Pierce, T.E. An improved method for computing biogenic emissions for the North Carolina Urban Airshed Modeling domain. Presentation to the North Carolina UAM Science Advisory Board, Research Triangle Park, NC, February 4, 1993.

Pierce, T.E. Variations in leaf area index (LAI) and its relation to leaf biomass. Presentation at the Workshop on the Oak Ridge Isoprene Flux Experiment, Boulder, CO, March 9, 1993.

Pierce, T.E. Sensitivity of the Regional Oxidant Model to uncertainties in emissions. Presentation at the Southern Oxidant Study Data Analysis Workshop, Denver, CO, May 12, 1993.

Possiel, N.C. Sensitivity of regional ozone to reductions in NO_x and VOC emissions. Presentation to the Ozone Transport Commission, Portland, ME, October 20, 1992.

Possiel, N.C. Estimated impacts on ozone of NO_x controls applied in attainment versus nonattainment areas of the Ozone Transport Region. Presentation to the Ozone Transport Commission, Arlington, VA, January 8, 1993.

Roselle, S.J. Regional precursor emissions and modeled ozone distribution. Southern Oxidants Study Data Analysis Workshop, Denver, Colorado, May 11, 1993.

Roselle, S.J. ROM predictions that indicate the relative effectiveness of NO_x Southern Oxidants Study Data Analysis Workshop, Denver, Colorado, May 13, 1993.

Schere,K.L. Results and science/policy considerations of ROM emission matrix simulations. Seminar presented at the EPA Office of Research and Development, U.S. Environmental Protection Agency, Washington, DC, November 2, 1992.

Schere, K.L. Uses of data in air quality modeling. Presentation at the CIRAC (Canadian) Workshop on Oxidant Model Evaluation and Application, Montreal, Canada, November 9, 1992.

Schere, K.L. Data management within the Southern Oxidants Study. Presentation at the Second Annual Southern Oxidants Study Workshop, Atlanta, GA, November 17, 1992.

Schere, K.L. ROM results for the Nashville Region. Presentation at the Southern Oxidants Study Nashville Design Team Workshop, Nashville, TN, January 20, 1993.

Schere, K.L. The EPA Regional Oxidant Modeling System. Seminar at the National Institute of Statistical Sciences, Research Triangle Park, NC, April 20, 1993.

Schere, K.L. The Southern Oxidants Study central data archive. Presentation to the Southern Oxidants Study Data Analysis Workshop, Denver, CO, May 13, 1993.

Schiermeier, F.A. Support for Panel on Atmospheric Aerosols to augment Division aerosol research. Presentation at Meeting of NRC/BASC Committee on Atmospheric Chemistry, National Academy of Sciences, Washington, DC, December 1, 1992.

Schiermeier, F.A. Overview of Atmospheric Characterization and Modeling Division research programs. Presentation to Canadian Consortium of High Performance Computing (HYPERCOM), Research Triangle Park, NC, January 27, 1993.

Schiermeier, F.A. Overview of Atmospheric Characterization and Modeling Division research programs. Presentation to visiting Russian scientists from Moscow Institute of Global Climate and Ecology, Research Triangle Park, NC, June 10, 1993.

Schiermeier, F.A. Primary areas of atmospheric research in the EPA Office of Research and Development. Presentation at Meeting of NRC Board on Atmospheric Sciences and Climate, Washington, DC, September 8, 1993.

Schowalter, D. (University of California, San Diego, LaJolla, CA) Streamwise vorticity in the stratified shear layer. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, September 16, 1993.

Schwede, D.B. Technical and operational overview of COMPDEP and the Complex Terrain Dispersion Model. Presentation to the Regional Modelers for Region 5, Chicago, IL, September 30, 1993.

Snyder, W.H. Wind-tunnel simulation of building downwash from electric-power generating stations. Invited presentation to the Regional, State, and Local Modelers Workshop, Raleigh, NC, April 28, 1993.

Snyder, W.H. Downwash of plumes in the vicinity of buildings: A wind-tunnel study. Invited presentation at the NATO Advanced Research Workshop: Recent Advances in the Fluid Mechanics of Turbulent Jets and Plumes, Viana do Castello, Portugal, June 28, 1993.

Snyder, W.H. Interim report on the wind-tunnel simulation of exhaust-gas recirculation problems at the EPA research and administration facility. Presentation to the Architectural and Engineering Design Review Committee at the Fluid Modeling Facility, Research Triangle Park, NC, August 4, 1993.

Snyder, W.H. Flow fields and plume downwash in the vicinity of buildings: A wind-tunnel study. Invited presentation at the Sixth EURASAP-International Workshop on Wind and Water Tunnel Modeling of Atmospheric Flow and Dispersion, Aso, Japan, August 25-27, 1993.

Touma, J.S. Clean Air Act Amendments, Section 234, Surface Coal Mine Study, Program Design Review. Presentation to the Wyoming Coal Association, Gillette, WY, July 14, 1993.

Touma, J.S. Tools for toxics: Dispersion modeling. Presentation at the Air Toxics Implementation Workshop, Office of Air Quality Planning and Standards, Durham, NC, September 1, 1993.

Walter, G.L. High performance workstations. Presentation to the North Carolina Department of Environment, Health, and National Resources, Raleigh, NC, September 23, 1993.

APPENDIX D: WORKSHOPS

Southern Interagency Climate and Emission Group Workshop, Raleigh, NC, October 6, 1992.

W.G. Benjey

NADP/NTN Toxic Deposition Initiative Workshop, Cocoa Beach, FL, October 20, 1992.

T.L. Clark

The Second Penn State/NCAR Mesoscale Model User's Workshop at the National Center for Atmospheric Research, Boulder CO, October 20-23, 1992.

O.R. Bullock

EPA/AWMA Toxic Emission Inventory Workshop, Durham, NC, October 22, 1992.

W.G. Benjey

EPA/EPRI/DOE Workshop on Mercury and Multimedia Risk Assessment, Durham, NC, October 22, 1992.

T.L. Clark

Workshop on Photochemical Oxidant Research - Integrating Federal, Public, and Private R&D, Boston, MA, October 26-27, 1992.

J.K.S. Ching

U.S. Army Workshop on Virtual Reality and Synthetic Environments in Training, Durham, NC, October 28-29, 1992.

F.A. Schiermeier

Chesapeake Bay Evaluation and Deposition Committee Workshop, Annapolis, MD, November 5-6, 1992.

W.G. Benjey
T.L. Clark

CIRAC (Canadian) Workshop on Oxidant Model Evaluation and Application, Montreal, Canada, November 8-10, 1992.

J.K.S. Ching
R.L. Dennis
K.L. Schere

CAMRAQ Steering Body Meeting, Montreal, Canada, November 12, 1992.

R.L. Dennis

Second Annual Southern Oxidant Study Workshop, Georgia Institute of Technology, Atlanta, GA, November 17-19, 1992.

R.L. Dennis
T.E. Pierce
K.L. Schere

IADN Quality Assurance Workshop, Durham, NC, November 17-19, 1992.

T.L. Clark

NRC/BASC Planning Workshop for Panel on Atmospheric Aerosols, Washington, DC, December 1, 1992.

F.A. Schiermeier

Workshop on Photochemical Oxidant Research, San Diego, CA, December 3-4, 1992.

J.K.S. Ching
K.L. Schere

Great Lakes Mass Balancing and Virtual Elimination: Peer Review Workshop, Toronto, Ontario, December 7-8, 1992.

T.L. Clark

OAQPS Mercury Risk Assessment Workshop, Durham, NC, January 7, 1993.

T.L. Clark

Southern Oxidants Study Nashville Planning Workshop, Knoxville, TN, January 18, 1993.

R.L. Dennis
K.L. Schere

Office of Air Quality Planning and Standards Long Range Planning Workshop, Southern Pines, NC, January 19-22, 1993.

J.S. Irwin
N.C. Possiel

Dry Deposition Measurement Workshop, Research Triangle Park, NC, January 26-27, 1993.

J.F. Clarke

Third Global Emission Inventory Activity (GEIA) Workshop, Amersfoort, The Netherlands, January 31-February 5, 1993.

W.G. Benjey

Airship Research Platforms Potential Users Working Group Strategy and System Analysis Meeting, Alexandria, VA, February 6, 1993.

T.L. Clark

Task Force on Forecasting Environmental Change Workshop, IIASA, Laxenburg, Austria, February 22-24, 1993.

R.L. Dennis

Workshop on the Oak Ridge Isoprene Flux Experiment, Boulder, CO, March 7-10, 1993.

T.E. Pierce

Regional, State, and Local Modelers Workshop for Regions 1 and 2 on the Technical and Operational Features of the Complex Terrain Dispersion Models, CTDMPLUS/CTSCREEN, Boston, March 23-24, 1993.

S.G. Perry
D.B. Schwede

Workgroup Planning Meeting for Summer '93 Nevada Test Site Liquid Spills Facility Dense Gas Experiments, Research Triangle Park, NC, April 20, 1993.

G.A. Briggs
W.B. Petersen

EMEP Workshop on the Control of Photochemical Oxidants in Europe, Porvoo, Finland, April 20-22, 1993.

R.L. Dennis

Regional, State, and Local Modelers Workshop, April 26-30, 1993, Raleigh, NC.

D.G. Atkinson
D.T. Bailey
J.K.S. Ching
C.T. Coulter
J.S. Irwin
J.H. Novak
J.S. Touma
D.A. Wilson

NATO/CCMS Workshop on Air Pollution Transport and Diffusion Over Coastal Urban Areas, Athens, Greece, May 3-5, 1993.

J.M. Godowitch
F.A. Schiermeier

High Performance Computing and Communications Workshop on Grand Challenge Applications and Software Technology, Pittsburgh, PA, May 4-7, 1993.

D.W. Byun
R.L. Dennis
J.H. Novak
J.O. Young

First Workshop on Emissions and Modeling of Atmospheric Transport of Persistent Organic Pollutants and Heavy Metals, Durham, NC, May 6-7, 1993.

W.G. Benjey

Workshop on Emissions of NO_x from Soils, Denver, CO, May 10-11, 1993.

T.E. Pierce

Southern Oxidants Study Data Analysis Workshop, Denver, CO, May 11-14, 1993.

J.K.S. Ching
R.L. Dennis
T.E. Pierce
S.J. Roselle
K.L. Schere

Environmental Assessment for the SouthEast (EASE), Raleigh, NC, May 12-13, 1993.

E.J. Cooter
S.K. LeDuc

Urban Airshed Modeling Workshop, Atlanta, GA, May 12-14, 1993.

J.M. Godowitch

Third Annual Southeast Affiliate of IAMSLIC Libraries (SAIL) Workshop, Mote Marine Laboratory, Sarasota, FL, May 13-14, 1993.

E.M. Poole-Kober

DOE Background Aerosol and Visibility Workshop, Boulder, CO, June 1-2, 1993.

M.L. Pitchford

Workshop on Air Quality and Acid Deposition Model: Developments, Evaluation, and Assessment Applications, Taipei, Taiwan, June 14-17, 1993.

R.L. Dennis

Florida Atmospheric Mercury Study Workshop, Research Triangle Park, NC, June 16-18, 1993.

T.L. Clark

Southern Oxidants Study Nashville Planning Workshop, Nashville, TN, July 12-13, 1993.

R.L. Dennis
K.L. Schere

AIRCAMP Workshop Session on Geographic Initiatives, Research Triangle Park, NC, July 12-16, 1993.

N.C. Possiel

Great Lakes Environmental Visualization Workshop, Cleveland, Ohio, July 15-16, 1993.

R.L. Dennis

Grand Canyon Visibility Transport Commission, Workshop on Technical Methods for Examining "Clean Air Corridors", Reno, NV, August 16-18, 1993.

M.L. Pitchford

Toxic Emissions Implementation Workshop, Durham, NC, August 30-September 1, 1993.

W.G. Benjey

Interagency Workgroup on Air Quality Modeling (IWAQM), National Park Service, Richmond, VA, August 30-September 1, 1993.

O.R. Bullock
J.K.S. Ching
J.E. Pleim

EMEP Steering Body Meeting, Geneva, Switzerland, August 30-September 2, 1993.

R.L. Dennis

Workshop on Intercomparison of Advanced Practical Short-Range Atmospheric Dispersions Models in Manno, Switzerland, August 30-September 3, 1993.

R.F. Lee

Eighth EUMAC Workshop, Graz, Austria, September 6-7, 1993.

F.S. Binkowski

NO_x, the Awakening Giant II, Washington, DC, September 20-21, 1993.

N.C. Possiel

Model Evaluation Team Workshop to Prepare RADM and ADOM Phase 2 Evaluation Results of the Eulerian Model Evaluation Field Study (EMEFS) for External Review Panel Review, Buffalo, NY, September 23-24, 1993.

J.K.S. Ching
R.L. Dennis

APPENDIX E: VISITING SCIENTISTS

1. Drs. Laszlo Bozo and Laszlo Horvath
   Institute for Atmospheric Physics
   Budapest, Hungary

   Dr. Tamas Weidinger
   Department of Meteorology
   Eotvos Lorand University
   Budapest, Hungary

Drs. Bozo, Horvath, and Weidinger visited the Division on April 8 and 9, 1993. Topics discussed with the EPA and NOAA scientists included United States and Hungarian efforts to monitor criteria pollutants, model acidic precipitation and toxic pollutant deposition, and compile toxic pollutant emissions inventories. The scientists also visited the Division's instrumented tower site.

2. Dr. Uri Dayan
   Soreq Nuclear Research Center
   Israel Atomic Energy Commission

Dr. Dayan, visiting from August 16, 1993 through July 31, 1994, is working on developing a method of integrating air pollution transport to determine risk for use in the Second Biennial Assessment of the Impacts of the 1990 CAAA.

3. Mr. Frederic Edouard Delsol
   Director of Research and Development
   World Meteorological Organization
   Geneva, Switzerland

Mr. Delsol spent October 14-15, 1992, at the Atmospheric Sciences Modeling Division to learn about (1) global meteorological policy making and implementation; (2) United States policies on atmospheric phenomena of international relevance, including ozone depletion and climate change; and (3) grassroots contributions to policy making on meteorological issues.

4. Dr. E.L. Genikhovich
   Main Geophysical Observatory
   St. Petersburg, Russia

Dr. Genikhovich spent the full year at the Fluid Modeling Facility as a Senior Research Associate under the NOAA/National Research Council Resident Research Associateship Program. He and the FMF staff developed a model to handle the downwash of pollutants from sources in the vicinity of buildings.

5. Dr. Chong-Bum Lee
   Department of Environmental Science,
   Kangweon National University,
   Chuncheon 200-701, Korea

Dr. C.-B. Lee visited the Division to study regional and urban scale air quality models in cooperation with Division scientists. He worked on the Urban Airshed Model (UAM) and the Regional Acid Deposition Model (RADM). He implemented windowing capability in the RADM to develop Window RADM (WRADM). Dr. Lee studied effects of window size in the reproduction of pollutant concentrations, and sensitivities of the model to meteorological parameters. Also, he converted WRADM and its preprocessor codes to run on a workstation. Dr. Lee intends to apply the model to the Far East and use windowing capability to study local effects on urban and regional air pollution before returning to Kangweon National University.

6. Dr. M. Ohba
   Department of Architecture
   Tokyo Institute of Polytechnics
   Tokyo, Japan

Dr. Ohba spent March 1992 to March 1993 and August and September 1993 at the Atmospheric Sciences Modeling Division. With the Fluid Modeling Branch, he examined flow and diffusion in the vicinity of high-rise, twin-tower buildings. With the Human Exposure Modeling Branch, he conducted numerical simulation modeling and scientific visualization research of wind and pollution in building microenvironments.

7. Dr. Oranut Paisarnuchapong
   Pollution Control Department
   Ministry of Science and Technology
   Bangkok, Thailand

Dr. Paisarnuchapong spent three months in 1993 with the Atmospheric Sciences Modeling Division for training and collaborative research planning for an exposure assessment study in Thailand near the Mae Moh Power Station. This visit was sponsored through the United States and Asia Foundation.

8. Dr. T.A. Reinhold
   Department of Civil Engineering
   Clemson University
   Clemson, SC

Dr. Reinhold spent four days at the Fluid Modeling Facility working on a data report from an earlier wind-tunnel study on stack-tip downwash.

9. Dr. Panneer Selvam
Department of Civil Engineering
University of Arkansas
Fayetteville, Arkansas

Dr. Selvam spent May 1993 to July 1993 at the Atmospheric Sciences Modeling Division. He conducted numerical simulation modeling research of wind and pollution in building microenvironments. Dr. Selvam was a NOAA/NRC Research Fellow.

10. Dr. Ilan Setter
Director of Research and Development
Meteorological Service of Israel
Bet Daga, Israel

Dr. Setter spent December 2, 1992, at the Atmospheric Sciences Modeling Division getting acquainted with the recent research accomplishments in source-oriented forecasting schemes for modeling transport and diffusion of pollutants, with special regard to coastal areas and complex terrain. Dr. Setter investigated the possibilities of cooperative projects, with the prospect of funding by the bi-national Israel/United States science fund.

11. Mr. Opas Ujjin
Electric Generating Authority of Thailand
Bangkok, Thailand

Mr. Ujjin spent three months in 1993 with the Atmospheric Sciences Modeling Division for training and collaborative research planning for an exposure assessment study in Thailand near the Mae Moh Power Station. This visit was sponsored through the United States and Asia Foundation.

12. Dr. Jeffery C. Weil
National Center for Atmospheric Research
Boulder, Colorado

Dr. Akula Venkatram
College of Engineering
University of California - Riverside
Riverside, California

Drs. Weil and Venkatram spent three two-day periods (November 4-5, 1992; April 13-14, 1993; June 24-25, 1993) in Research Triangle Park working with the AMS/EPA Regulatory Model Improvement Committee (AERMIC) on its efforts to develop a greatly updated replacement for the Industrial Source Complex Model (ISCST2). They brought much experience and expertise to the committee in the areas of dispersion in convective and stable boundary layers, complex terrain, and model evaluation.

APPENDIX F: ATMOSPHERIC SCIENCES MODELING DIVISION STAFF FY-1993

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

Office of the Director

Francis A. Schiermeier, Supv. Meteorologist, Director
Herbert J. Viebrock, Meteorologist, Assistant to the Director
Dr. Raul J. Alvarez II, Physical Scientist (Las Vegas, NV)
Dr. Robin L. Dennis, Physical Scientist
Dr. Peter L. Finkelstein, Physical Scientist
Dr. Marc L. Pitchford, Meteorologist (Las Vegas, NV)
Evelyn M. Poole-Kober, Technical Editor
Barbara R. Hinton (EPA), Secretary
B. Ann Warnick, Secretary

Atmospheric Model Development Branch

Dr. Jason K.S. Ching, Supv. Meteorologist, Chief
Dr. Francis S. Binkowski, Meteorologist
O. Russell Bullock, Jr., Meteorologist
Dr. Daewon W. Byun, Physical Scientist
Terry L. Clark, Meteorologist
Dr. John F. Clarke, Meteorologist
Gerald L. Gipson (EPA), Physical Scientist
James M. Godowitch, Meteorologist
Dr. Jonathan A. Pleim, Physical Scientist
Shawn J. Roselle, Meteorologist
Kenneth L. Schere, Meteorologist
Kelly M. Davis, Secretary (Since 2/93)

Fluid Modeling Branch

Dr. William H. Snyder, Supv. Physical Scientist, Chief
Eric R. Hilgendorf, Engineering Technician (5/93-8/93)
Aly G. Khalifa, Engineering Technician (Until 5/93)
Lewis A. Knight, Electronics Technician
Robert E. Lawson, Jr., Physical Scientist
Roger S. Thompson (PHS), Environmental Engineer
Anna L. Cook, Secretary (Until 1/93)
Pamela V. Bagley, Secretary (Since 4/93)

Modeling Systems Analysis Branch

Joan H. Novak, Supv. Computer Specialist, Chief
William E. Amos (EPA), Computer Programmer
Dr. William G. Benjey, Physical Scientist
Dale H. Coventry, Computer Specialist
Thomas E. Pierce, Jr., Meteorologist
John H. Rudisill, III, Computer Specialist
Alfreida R. Torian, Computer Specialist
Gary L. Walter, Computer Scientist
Dr. Jeffrey O. Young, Mathematician
Pamela P. Thomas, Secretary

Global Climate Research Branch

Dr. Sharon K. LeDuc, Supv. Physical Scientist, Chief
Dr. Ellen J. Cooter, Meteorologist
Dr. Brian K. Eder, Meteorologist
Lawrence E. Truppi, Meteorologist
Ella L. King (EPA), Secretary

Applied Modeling Research Branch

William B. Petersen, Supv. Physical Scientist, Chief
Dr. Gary A. Briggs, Meteorologist
Victoria O. Edem, Physical Scientist (Philadelphia, PA) (Since 2/93)
Lewis H. Nagler, Meteorologist (Atlanta, GA) (Until 7/93)
Donna B. Schwede, Physical Scientist (Since 1/93)
Dr. Steven G. Perry, Meteorologist
Lisa M. Lewis, Secretary

Human Exposure Modeling Branch

Dr. Alan H. Huber, Supv. Physical Scientist, Chief
Gennaro H. Crescenti, Physical Scientist
Everett L. Quesnell, Meteorological Technician, (Until 5/93)
John J. Streicher, Physical Scientist (Since 1/93)
Brian D. Templeman, Meteorologist (Boulder, CO)
Dr. Michael P. Zelenka, Meteorologist
E. Frances Horvath (EPA), Secretary

Air Policy Support Branch

John S. Irwin, Supv. Meteorologist, Chief
Dennis G. Atkinson, Meteorologist
Dr. Desmond T. Bailey, Meteorologist
C. Thomas Coulter (EPA), Environmental Protection Specialist
Russell F. Lee, Meteorologist
Norman C. Possiel, Jr., Meteorologist
Jawad S. Touma, Meteorologist
Allan R. Van Meter, Meteorologist (Until 8/93)
Dean A. Wilson, Meteorologist
Brenda P. Cannady (EPA), Secretary

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