NOAA Technical Memorandum ERL ARL-209

FISCAL YEAR 1994 SUMMARY REPORT OF NOAA ATMOSPHERIC SCIENCES MODELING DIVISION SUPPORT TO THE U. S. ENVIRONMENTAL PROTECTION AGENCY

E.M. Poole-Kober
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Air Resources Laboratory
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UNITED STATES DEPARTMENT OF COMMERCE

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NOTICE

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PREFACE

This document summarizes the Fiscal Year 1994 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.

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FISCAL YEAR 1994 SUMMARY REPORT OF NOAA ATMOSPHERIC SCIENCES MODELING DIVISION SUPPORT TO THE U.S. ENVIRONMENTAL PROTECTION AGENCY

ABSTRACT. The Atmospheric Sciences Modeling Division provided meteorological research and operational support to the U.S. Environmental Protection Agency during FY-1994. 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 conduct of studies under the High Performance Computing and Communications program. These efforts included wind-tunnel and numerical modeling studies of terrain downwash at a hazardous waste incinerator site; modeling studies of dispersion from surface coal mines; study of top-down and bottom-up diffusion in the convective boundary layer; study of the mechanics of wind erosion and dust production; statistical studies of the dependence of ozone on meteorology; development of an improved model for use in indirect exposure assessment; evaluation of the Regional Acid Deposition Model bias; refinement of the Urban Airshed Model; developmental studies on Models-3; and development of the Biogenic Emissions Inventory System, version 2.

1. INTRODUCTION

In fiscal year 1994, 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 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 maintained 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 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. AERMIC is overseeing 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). The cooperative agreement with the AMS terminated in FY-1994 and the responsibility for the AERMIC work transferred to the EPA Office of Air Quality Planning and Standards with continued participation by Division personnel.

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, 1994). A Division scientist serves on the ICMSSR Working Group for Atmospheric Transport and Diffusion and four other Division scientists serve on an ICMSSR panel to develop a National Agenda for Meteorological Services and Supporting Research.

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 two years 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 was held in Valencia, Spain, from November 29 to December 3, 1993. The proceedings will be published in 1995 by Plenum Press. The NATO/CCMS Scientific Committee selected Baltimore, Maryland, as the site for the 21st International Technical Meeting to be held during November 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 (Kambezidis, unpublished manuscript, a; unpublished manuscript, b). A NATO/CCMS advanced research workshop was held during May 1993 to design a reference experiment in a 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 summary was submitted for publication (Melas *et al.*, accepted for publication).

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. Although no reciprocal visits were made in FY-1994, interaction was maintained through correspondence and exchange of data.

2.1.5 United States/Russia Joint Environmental Committee

The Division Director serves as the United States Co-Chairman of the US/Russia 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/USSR Joint Committee on Cooperation in the Field of Environmental Protection is to promote, through mutual visits and reciprocal assignments of personnel, the sharing of scientific and regulatory research results related to the control of air pollution. There are four Projects under the Working Group 02.01-10:

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

Meetings were held during FY-1994 to discuss whether to combine or replace one or the other of the two bilateral agreements: (1) the 1972 Nixon-Podgorny Agreement forming the US/USSR Joint Committee on Cooperation in the Field of Environmental Protection; and (2) the 1993 Gore-Chernomyrdin Agreement forming the US/Russia Commission on Economic and Technological Cooperation. No decision was made, but most of the same scientists are implementing both agreements.

Progress under this Working Group continued during FY-1994. Activities included a June 1994 Working Group meeting at the Main Geophysical Observatory in St. Petersburg attended by the Working Group 02.01-10 U.S. Co-Chairman and the U.S. Co-Leader of Project 02.01-12; 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. In conjunction with the latter Russian scientist, the U.S. Co-Chairman wrote a paper comparing the characteristics and performance of U.S. and Russian complex terrain models (Genikhovich and Schiermeier, accepted for publication).

2.1.6 Eulerian Modeling Bilateral Steering Committee

The Division Director served as the United States Co-Chairman of the Eulerian Modeling Bilateral Steering Committee. This committee was 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, 1993). Having coordinated the evaluations of the Canadian Acid Deposition and Oxidant Model (ADOM) and the United States Regional Acid Deposition Model (RADM), the committee is now considered inactive.

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 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 government, 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 implementation plan for USWRP was submitted to Congress and to participating Agency heads (U.S. Office of Science and Technology Policy, 1994).

2.1.8 NAS/NRC Board on Atmospheric Sciences and Climate

The Division Director serves as the Agency liaison to the Board on Atmospheric Sciences and Climate (BASC) of the National Research Council, National Academy of Sciences. The BASC activity that relates to the work of the Division is the 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 regarding the observation, monitoring, and research strategies needed to understand atmospheric processes and aerosol characteristics important in weather and air pollution research.

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 emphasis is shifting from acidic deposition to ozone. 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 develops and coordinates EPA research with such EMEP programs as the modeling studies of the Modeling Synthesizing Center West 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-1994 focused on the retrospective assessment, specifically on development of regional model predictions associated with time trends of emissions from 1970 to 1990 for a control case (implementation of CAA) and a no-control case (non-implementation of CAA).

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. Work in FY-1994 addressed the delineation of a boundary for the airshed responsible for the nitrogen deposition to the Chesapeake Bay and the Bay watershed.

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 of 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 goal of the consortium is to coordinate research and to form a basis for collaboration on projects that will enhance the ability of each to achieve their respective goals regarding atmospheric modeling. A focus of activity is the development of plans for a CAMRAQ Comprehensive Modeling System that will coordinate with the development of an EPA Third Generation Modeling System, Models-3, and will allow interoperability between the two systems as well as to explore the development of community standards.

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 mandate and organization of NAPAP under the 1990 CAAA. This working group will help evaluate the 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 was 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 included the National Oceanic and Atmospheric Administration, Environmental Protection Agency, Electric Power Research Institute, Atmospheric Environment Service of Canada, and Ontario Ministry of Environment. The Program Management Group (PMG) oversaw the project and consisted 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, evaluated RADM and ADOM for the United States/Canada Air Quality Agreement and the Eulerian Model Bilateral Steering Committee. Work in FY-1994 saw the evaluation of ADOM and RADM model runs for the spring 1990 field intensive, a 75-day evaluation period ending May 30, 1990, for Phase 2 of the EMEFS evaluation. The Phase 2 evaluation work was peer reviewed in May 1994 by the standing External Peer Review Panel of 10 international experts. Following the peer review, the EMEFS program was formally brought to a close. It is anticipated that evaluation activity coordination will continue under auspices of the North American Research Strategy on Tropospheric Ozone (NARSTO) and the United States/Canada Air Quality Agreement, with a focus on behavior of the nitrogen chemistry and oxidant formation.

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 models coupled with urban 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 International Task Force on Forecasting Environmental Change

A Division scientist is a member of the International Task Force on Forecasting Environmental Change. In July 1994, 15 participants of the Task Force met at the International Institute for Applied Systems Analysis in Laxenburg, Austria, to hold the second of three workshops on the methodological and philosophical problems of forecasting under the expectation of significant structural changes in the behavior of physical, chemical or biological systems.

2.1.17 RADM Application Studies

Efforts during FY-1994 concentrated on completing several RADM application studies related to mandates in the 1990 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 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, and the report is under final review by the EPA Science Advisory Board.

Several other application studies are being planned. The EPA Region 3 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. Estimates of the airshed affecting the Bay and sector responsibility for nitrogen deposition were developed and made available to the Chesapeake Bay Program Office during FY-1994. 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-1994 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-1994, preliminary data analyses were carried out. These included descriptive summaries, spatial and temporal distribution analyses, multivariate statistical analysis to interrelate aerosol components to optical and aerosol data, and source apportionment by a variety of methods. Problems with the windfield model resulted in a serious setback for its use in source apportionment as part of the preliminary analyses period. The Colorado State University's Regional Atmospheric Modeling System (RAMS) windfields are being completely rerun and are not expected to be completed before spring 1995. The National Grid Model windfields from the National Weather Service (NWS) were also found not to be of practical use for data analyses, especially in the summer months. Also delayed are the submissions of the ambient perfluorocarbon tracer data from the 30 sites during the two intensive periods. The new schedule for receiving this data is early 1995.

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-1995. To complete Project MOHAVE on schedule (summer 1995), final analyses are being conducted with techniques that do not require windfield or tracer data. When the missing information is available, it will be incorporated into the final analyses. 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 have adopted the instrumentation and protocols developed for IMPROVE for use in their programs, bringing the number of IMPROVE look-alike sites to more than 40 in this country and nearly 60 worldwide.

During FY-1994, the IMPROVE network data were extensively used to characterize visibility and aerosols. For example, the Grand Canyon Visibility Transport Commission is using the data as the basis for the technical assessment; and over one-third of the approximately 150 papers presented at a conference held in Snowbird, Utah, during September 1994, reported on IMPROVE-related research, protocols, or data.

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.

2.1.19 Remote Sensing Technology Development and Evaluation

Development of the Ultraviolet Differential Absorption Lidar (UV-DIAL) was supported by the EPA, NOAA, and National Aeronautics and Space Administration (NASA). The goal was 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 indicated that ozone measurements made with this system are accurate to within 5 parts-per-billion-volume (ppbv) of in situ measurements over a range of 2-3 km. Aerosol distributions can also be determined from data that are provided by this system. 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 transfer was 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 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 several stages of program model development, refinement, 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 possible with the development of HRADM, the high resolution version of RADM. 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 the RADM and the Regional Oxidant Model (ROM). In the windowed version, users 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 window domain can be performed without having to re-run the full scale HRADM. Several preprocessors and postprocessors have been developed to accommodate the increased functionality. In the preprocessors, new interpolation routines are 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) 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. TSEM has 15 vertical layers to provide the vertical resolution needed in sulfate source apportionment. The Comprehensive Sulfate Tracking Model (COMSTM) version of 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 postprocessor was developed for TSEM that allows for an examination of the response of visual range to sulfur control strategies. The extinction coefficients used are empirical functions of sulfate mass and relative humidity.

RADM and RADM/EM typically simulate 3- to 5-day periods. When applied to these simulations, aggregation methods 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 included the U.S. Environmental Protection Agency 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; and the Florida Electric Power Coordinating Group.

Measurements at each of these sites included 24-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 intra-network information on precision and accuracy. Analysis and modeling studies using the aircraft measurements made during the summer 1988 and spring 1990 intensive field studies as part of Acid-MODES are the primary means to evaluate RADM on a diagnostic basis.

2.2.1.2 RADM Evaluation Studies

Studies to understand model bias due to the limited horizontal and vertical grid resolution continued. There were large differences between RADM results and measured surface ozone concentrations, particularly during the nocturnal periods. Comparison of the 15-layer 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 in RADM representing the deposition layer. The similarity theory 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 in the planetary boundary layer (PBL). The coarse vertical resolution in the deposition layer explains the considerable portion of the high bias of model O_3 concentrations at night. Air quality models should resolve, at least, the lower half of PBL to predict surface deposition fluxes correctly (Byun and Dennis, in press).

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 with a limited-domain RADM (WRADM) show the effect of emission source distribution in representing the NO-O_3 titration process. 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. A study is underway with the 30-layer RADM system for many more meteorological cases. Some study results were reported in two conference papers (Byun and Dennis, unpublished manuscript; Dennis and Byun, 1994) and a journal article (Byun and Dennis, in press).

2.2.1.3 Field Study on Cloud Processes

A 5-year cooperative agreement with the University of North Dakota, Grand Forks, North Dakota, which focused on aircraft studies of the transport and transformation of gaseous and particulate trace species in cumulus clouds, was completed in June 1994. The final report, which is being prepared, will describe two aircraft field campaigns and results of the data analysis. The principal facility for these experiments was the University of North Dakota Cesna Citation fan-jet aircraft, instrumented for detailed microphysical, chemical, and kinematic measurements. The first study, based in Champagne, Illinois, took place in August 1990 and involved releasing an inert tracer (SF_6) below cloud base and flying through the cloud at several heights to study convection and entrainment processes. The second study, based in Milwaukee, Wisconsin, took place in summer 1992 and focused on the modification of aerosols by convective clouds. The data showed relative size increases of accumulation mode aerosols in air that was processed by cumuli. Also, clear air eddy correlation measurements of ozone, CO_2, and aerosol fluxes were made both over the lake and over land.

2.2.1.4 Heterogeneous Reactions in RADM

Two heterogeneous reactions were added to RADM to study their potential importance to oxidant photochemistry. One is the heterogeneous reaction of N_2O_5 with H_2O on wetted aerosols to form HNO_3. The reaction is a key step in the nighttime conversion of NO_2 to HNO_3; and hence, the termination of photochemically active NO_x (Mozurkewich and Calvert, 1988). The other is the conversion of the HO_2 radical to H_2O_2. There is evidence that this reaction occurs on wetted aerosols when aqueous copper concentration is sufficiently high to act as a catalyst (Mozurkewich *et al.*, 1987). Gas-aerosol reactions are often limited by the rate of transport to the aerosol, which is a function of total aerosol surface area. Therefore, a simple technique for estimating ambient aerosol surface area using sulfate and ammonia concentrations and relative humidity was added to RADM. Aerosol composition is determined by the sulfate to ammonium ratio, then the mass is apportioned into two log-normal size-distribution modes, nucleation and accumulation. The aerosols are allowed to grow or shrink according to thermodynamic equilibrium with the ambient relative humidity. A pseudo-first order reaction rate is computed as a function of total aerosol surface area, the rate of diffusion of gaseous N_2O_5 and HO_2 to the aerosols, and the reaction probabilities (Pleim *et al.*, 1993). In the case of the HO_2 reaction, an additional calculation of aqueous copper concentration is made based on an assumed copper concentration in the dry aerosol. When the aqueous copper concentration falls below cutoff value, suggested by laboratory measurements, the reaction is terminated.

These experiments showed that these reactions may have a significant impact on oxidant photochemistry. This technique is recommended for adoption for the modeling of the N_2O_5 heterogeneous reaction in RADM since this mechanism and its reaction probability are fairly well established. The HO_2 heterogeneous reaction mechanism, however, is much more controversial and more complex since it seems to depend on the copper content of the aerosols, which is not generally well known. While this reaction is potentially the more important of the two, it is not yet sufficiently understood to include in the operational model.

2.2.2 Dry Deposition Studies

A transportable dry deposition measurement system was completed, tested, and deployed successfully at three field sites during the 1994 growing season. The system is equipped to measure surface fluxes of heat, momentum, water vapor, O_3, SO_2, and CO_2 by eddy correlation; and HNO_3 by the gradient technique. In addition, the system has a complete suit of meteorological, vegetation, and chemical measurements to support modeling activities, micro-meteorological research activities, and quality assurance (QA).

The system was deployed at the North Carolina State University research farm, Raleigh, North Carolina, during spring 1994; at the Beaufort, North Carolina NDDN site during summer 1994; and at the Bondville, Illinois, NDDN site during late summer and fall 1994. The system operated over 100 days and collected 1.2 gigabytes of data. QA and initial data evaluation showed excellent results.

During the 1994-1995 winter months, the data will be studied and initial model evaluations will begin. During 1995, the system will be deployed at sites in Alabama and Kentucky. Figure 1 shows the systems deployed at a field site.

Figure 1. Dry deposition measurement system deployed at the Bondville, Illinois, site.

2.2.3 Meteorological Modeling Studies

2.2.3.1 Evaluation of the Penn State/NCAR Mesoscale Model

A model evaluation was performed 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 was conducted using supplemental rawinsonde data from the Cross-Appalachian Tracer Experiment. A total of 372 special rawinsonde soundings were made during September and October 1983 and were used to perform the same type of statistical comparison to model results that are typically done with FDDA fields.

The results showed that the model-to-observed differences in temperature and wind at non-FDDA locations are double those typically calculated for FDDA data locations. Similar comparisons of water vapor mixing ratio data showed a much degraded result near the earth's surface. The result of the sensitivity testing of FDDA strength suggested that a software error might be present in the MM4-FDDA FORTRAN code, but none has been isolated.

2.2.3.2 Adaptation of the MM5 for Workstation Application

The National Center for Atmospheric Research (NCAR) released to the public a workstation version of MM5, the fifth generation of the Penn State/NCAR Mesoscale Model. Future meteorological modeling will be performed with MM5; thus, no further effort is planned to modify MM4 for workstation applications.

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 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 completed at NESC with MM4 to simulate three-dimensional meteorology over all of the continental United States for calendar year 1990. All required input data files for this project were collected at NESC totaling over eight gigabytes of information.

The total size of the output data files from this project is over 20.5 gigabytes. IWAQM intends to offer these simulated meteorological fields to regulatory air-quality modelers in CD-ROM format to help them 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 is based on 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 temperatures 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 (Clarke *et al.*, 1971) 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 the MM4, replacing the existing high resolution PBL model. The model is being tested against the standard MM4 and data is being observed for several case study episodes. During this process many parameterizations in the surface model were modified to be more consistent with published modeling techniques and laboratory studies. Also a soil moisture initialization procedure was developed that uses data published in the *Weekly Weather and Crop Bulletin*. Initial implementations of advanced FDDA techniques for indirect nudging of soil moisture were made. Work continued in code optimization, soil moisture initialization, cloud cover parameterizations, improved PBL algorithms, and incorporation of subgrid heterogeneity of soil moisture.

2.2.3.5 Dynamic Meteorological Modeling on Urban-Scale Domains

A hydrostatic, primitive equation model that simulates the evolution of the three-dimensional (3-D) flow, thermal, and moisture fields generated from differential surface heating/cooling and terrain irregularities (Ulrickson and Mass, 1990) was exercised to generate meteorological parameter fields to drive photochemical grid-model simulations in urban domains. The dynamic model contains a four-dimensional data-assimilation (FDDA) technique for incorporating available routine or intensive observed surface- and upper-air wind and temperature data into the numerical calculations (Douglas, 1992). A bulk Richardson number approach was also installed in the model to derive time-varying mixing heights, an essential input parameter for the photochemical grid-model simulations. The approach, which utilizes the modeled wind and temperature profiles, determines gridded hourly mixing heights over the entire diurnal cycle. An additional parameter retrieved from the dynamic model output for use in the photochemical model simulations included 3-D hourly fields of the vertical eddy exchange coefficient.

Simulations with the dynamic/FDDA model were performed in urban domains where there were both routine and intensive meteorological observations available. The meteorological output was processed through an interface program to create compatible input data files of winds, mixing heights, and vertical eddy diffusivity fields. Dynamically generated data sets and diagnostically created meteorological inputs were both employed in a series of simulations of a refined Urban Airshed Model (UAM) as reported by Godowitch and Vukovich (1994). Further work is underway to allow specification of spatially resolved fields of the geophysical parameters and to provide a better representation of urban land use subsurface features in the model.

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. FY-1994 marks the tenth year of ROM as an operational ozone model within EPA for research and air quality management studies. The ROM research program focused on diagnostic and sensitivity studies during FY-1994.

The program also supported efforts to develop interaction with the third-generation air-quality modeling system (Models-3), which will include advanced simulation capabilities for photochemical oxidants, acid deposition, and particles. Sensitivity studies were performed that probed 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 learned about the sensitivity of the ROM results to particular meteorological driver models, including the standard ROM diagnostic processors and the MM4 dynamic meteorological model. Also, the project that compares ROM and RADM in terms of their structure, science, numerical schemes, performance, and sensitivity response continued into FY-1994. Lessons learned from the study will be used in the development of the new multiscale modeling system (Models-3). Additionally, the research program to improve UAM continued to make progress.

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. ROM2.2 represents the final major revision before the shift of model development activities to the Models-3 effort. During FY-1994, some efforts continued in pursuit of an operational layer 0, the shallow (10-30 m) diagnostic layer between the surface and the bottom of 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 scheme is run in a postprocessor mode, using concentration estimates and meteorology from the full ROM run as inputs. Diagnostic analysis of results shows that deposition velocity, vertical turbulence, and the specified plume volume fraction, the fraction of a grid cell volume occupied by source plumes, are all key parameters in the performance of layer 0 calculations. The scheme is most sensitive to the specified plume volume fraction, which 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. Whether an explicit layer 0 postprocessor becomes a part of the operational ROM system for applications is uncertain, but it is available for research studies with ROM.

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 with ROM (Roselle, 1994). 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

A model intercomparison continued during FY-1994 between ROM and RADM using the July 20 to 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 were seen in the model oxidation pathways for nitrogen, although both models converted the primary-emitted nitrogen species to secondary products very rapidly. Work started on expanding the analysis to include more days of the simulation period, and comparing model concentration estimates to observed concentrations obtained during that time period at a research site near Scotia, Pennsylvania, and from aircraft measurements over the region.

2.2.4.5 Development of Wind Fields for ROM

Work was completed 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.

2.2.4.6 Development and Evaluation of a Refined Urban Airshed Model

Research and evaluation efforts continued using an upgraded version of UAM, an Eulerian photochemical grid model. The refined UAM exhibits scientific improvements that include an updated horizontal advection scheme (Bott, 1989), inputs of hourly 3-D temperature and water vapor fields, hourly 3-D photolytic rate constants, and improved hourly gridded pollutant deposition velocities. These latter input data files are generated by a comprehensive, diagnostic meteorological processor (UAMMET) program described in Godowitch *et al.* (1992).

Numerous model test simulations and evaluation efforts in urban domains encompassing the greater New York City and Los Angeles areas were completed. A series of simulations with the refined UAM were performed using meteorological data sets generated by the diagnostic UAMMET processor and a dynamic meteorological driver, which features FDDA. Results with the refined UAM using five vertical layers (i.e. two layers below the mixing height and three aloft) for the New York domain 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 noticeably 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. In contrast, little change in the modeled peak ozone occurred in a comparable simulation when driven by the diagnostically generated winds. Further analyses revealed greater speed and direction shear across the UAM layers below the mixing height during the daytime hours with the diagnostic winds, compared to the dynamically generated wind fields. Additionally, statistical results and graphical analyses of the UAM ozone concentrations simulated with dynamically generated meteorological fields provided better agreement with hourly ozone measurements in both urban domains than results produced using diagnostic meteorological data sets (Godowitch and Vukovich, 1994).

2.2.4.7 ROM Matrix of Emission Reduction Scenarios

A study continued in FY-1994 to compare various combinations of anthropogenic NO_x and VOC emission reductions through a series of model simulations (Roselle *et al.*, 1994). Seventeen simulations were performed with 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 among 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 the understanding of the chemical system responsible for the build-up of regional scale O_3.

2.2.5 Aerosol Modeling Program

The objectives of the aerosol modeling program 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.

The program is primarily directed towards providing modeling tools to assist in the promulgation of primary and secondary air quality standards for fine particles to protect human health (acid aerosols) and welfare (visibility and materials 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 windowed and nested regional scale models will provide relative loadings between urban and regional sources.

During FY-1994, the parametric formulation for dry deposition by particle size and for in-cloud and dissipating cloud aqueous phase processes were developed, tested, and incorporated into the model. The model invokes a bi-modal distribution, the finest size mode corresponding to nucleation, condensation, and evaporative processes, while the larger mode represents particles that have coalesced into the so-called accumulation stage.

2.2.5.1 Regional Particulate Modeling

The Regional Particulate Model (RPM) is an expansion of RADM. The added capabilities include aerosol chemistry, size distributions, and modified cloud processor. Two size ranges are considered (Whitby, 1978): the source emissions and particle production processes that designate the nuclei mode, and the longer term residence in the atmosphere that designate the accumulation mode.

The effort during FY-1994 concentrated on examining the role of size-dependent dry deposition and cloud interactions. Comparison of sulfate dry deposition from the RADM Engineering Model without clouds and from RPM simulations using a size-dependent dry deposition algorithm showed that values of deposition from RPM were about a factor of 2 or 3 lower than those from RADM. However, the basic patterns were preserved. The processor algorithm (Binkowski and Shankar, 1994) assumes that all aerosol particles in the accumulation mode serve as cloud condensation nuclei and that the particles in the nuclei mode are unactivated interstitial aerosols. All new aerosol sulfate mass produced by aqueous chemistry is added to the accumulation mode. The wet deposition of aerosol mass follows the RADM paradigm of scaling with the precipitation rate.

Comparisons of RPM with and without clouds (Shankar and Binkowski, 1994) show the total aerosol volume increases much earlier in the simulation where there are nonprecipitating clouds, but the final concentration is not much different because the total sulfur remains the same in both cases. The more rapid conversion of sulfur dioxide to sulfate in clouds produces very similar results to the slow oxidation in the gas phase when clouds are ignored. When sulfate concentrations are compared between RADM and RPM with clouds, RPM produces slightly more sulfate because the size-dependent dry deposition in RPM is less than that in RADM. For cases with precipitating clouds, the total aerosol volume decreases sharply because of wet deposition. Because RADM does not recognize the presence of interstitial aerosol, RPM wet deposition is slightly less than RADM for cases where significant interstitial aerosol was not scavenged.

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.

Formulations are being tested to allow these pollutants to cycle between the aerosol or 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 organochlorines and persistent aromatic hydrocarbon pollutants.

Preliminary model results were prepared that express the particulate distribution in the eastern United States in terms of total surface area, S, of fine mass (<2.5μ) particulate on an 80 km x 80 km grid. The results demonstrate the large range of the value of S across the modeling domain. The parameter S is a major variable controlling the gas particle partition function for the semi-volatile 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 are being 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 electric power generating utilities.

In a cooperative effort with other research laboratories, multimedia model results are being provided to the Agency. The REgional Lagrangian Model of Air Pollution (RELMAP) (Eder *et al.*, 1986) was 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. Model adaptation and testing were completed, and it was used to calculate 1989 monthly mean air concentrations and wet and dry deposition amounts of mercury across 40-km grid cells.

Modifications are being made to RELMAP for the simulation of arsenic, cadmium, lead, and various dioxin congeners. Focus is on the most toxic congener of dioxin, 2,3,7,8-tetrachlorodibenzo-*p*-dioxin. Because each of the various congeners of dioxin has different vapor pressures and gas/particle mass partitioning ratios in the atmosphere, a scientifically credible treatment of the transport and deposition of total dioxin toxicity may require that each congener be modeled explicitly. Initially, dioxins will be modeled in separate congener groups based on their vapor pressures.

To establish 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) (Lusis *et al.*, 1993) and 1989 sulfur wet deposition data from 59 sites of the National Atmospheric Deposition Program (NADP) (National Atmospheric Deposition Program, 1990). Regional air toxics data were unavailable and the model was not 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 2 of the measured values.

2.2.6.2 Deposition of Trace Metals to the Great Lakes

Special RELMAP simulations of atmospheric mercury transport and deposition were performed to estimate the effects of various emission control strategies in the eight-states bordering the Great Lakes: Minnesota, Wisconsin, Michigan, Illinois, Indiana, Ohio, Pennsylvania, and New York. Three atmospheric mercury source categories, electric utility boilers, municipal waste combustors, and all other sources within the states were modeled to determine the possible reductions in wet and dry deposition to the Great Lakes from various levels of emission control. All mercury source types in the EPA's emission inventory outside the eight-state area were modeled as a group to estimate their effect on the wet and dry depositions of mercury to the Great Lakes. The RELMAP modeling results will be used in a cost-benefit analysis of various industrial atmospheric emission control strategies for the eight Great Lakes states.

2.2.7 Models-3 Advanced Air Quality Modeling

One of the goals of the Models-3 project is to develop a flexible, general modeling system to support computational scalability for multipollutant air quality modeling. Scientific objectives of the Models-3 project are to (1) develop a state-of-the-art air quality modeling system capable of handling multipollutant issues (e.g., oxidants, acid deposition, visibility, and particulate matter); (2) provide a standard interface that facilitates interchange of science modules; (3) provide advanced air quality modeling capabilities with the flexibility to operate at a spectrum of spatial scales, including regional, urban, and point source; (4) serve as a basis for research into advanced science issues (e.g., visibility, air toxics, and acid aerosols), multiscale interactions (e.g., multilevel nesting and adaptive grids), mixed-media issues, and physical and chemical processes; (5) serve as a basis for diagnostic evaluation and continuing modeling system development; (6) incorporate an advanced approach to sensitivity and uncertainty analysis; (7) more closely couple meteorological models with chemistry-transport models; (8) take advantage of the enhanced computational capabilities provided by high performance computing and communications (HPCC) architectures; and (9) offer sufficient extensibility to address and fulfill the Agency's anticipated air quality research modeling needs.

The project is directly linked to the High Performance Computing and Communications (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 to be the system for future air quality modeling that can answer policy and scientific questions.

2.2.7.1 Models-3 Science Design Workshops

The immediate effort of the Models-3 project is to develop the initial operational version (IOV) of the air quality modeling system, which will be completed by October 1996, and ready for the evaluation process. IOV will be evaluated for use by regulatory users, scientists, developers, and production staff. The requirements of IOV are divided into three categories: the minimum requirements, which specify the minimum acceptable functionality for an operational Models-3 system; the targeted capabilities, which describe the capabilities intended for inclusion in IOV in addition to the minimum-requirements list (Byun *et al.*, unpublished manuscript); and the extensions, which describe additional features planned for inclusion in the Models-3 system after the initial evaluation phase.

As an effort to complete the design of Models-3 science components, two Models-3 science workshops were held August 8-11, 1994, and September 13-14, 1994. Approximately fifty scientists participated and developed detailed tasks for the completion of the Models-3 IOV. Key research areas identified are soil moisture, resistance, and subgrid land use; cloud process and aqueous chemistry; hydrostatic and nonhydrostatic modeling issues for MM5 and the chemistry-transport model; emissions modeling; generalized coordinates and nesting technique; plume-in-grid modeling; gas-phase chemistry reader and solver; horizontal diffusion; aerosol modeling; actinic flux and radiation; and observation database for model evaluation.

The Models-3 science workshops were intended to compile state-of-the-art information in the key science areas for the development of IOV. These include functional description with a complete, consistent equation set; initial solution methodology; top-level structure diagram and data dependency; initial/boundary condition specification including formulation and required data sets; complete variable dictionary; first-cut estimates of computational resource usage; and references and code description if available.

2.2.7.2 Models-3 Prototypes

The purpose of the Models-3 air quality model (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. There are two main categories in the IOV requirements: 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 the targeted capabilities, which describe the capabilities to be included in IOV in addition to those on the minimum requirements list (Byun *et al.*, unpublished manuscript).

AQM prototypes to be implemented into the Models-3 IOV are 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 MPP 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 make the dependencies explicit upon coordinate systems and grid scales; have no sequential data flow dependencies among themselves; and employ a standardized interface to the driver process, promoting interchangeability and extensibility (Coats et al., unpublished manuscript).

2.2.7.3 Investigation of Numerical Solvers for Chemical Kinetics

A version of the quasi-steady state two-pass solver was included in a Models-3 prototype with the RADM2 reference mechanism. Simulations were conducted for representative episodes over the eastern United States. Comparisons with RADM simulations for the same episodes indicated that the solver replicates the evolution of various chemical species over the entire modeled domain, consequently showing the efficacy of the solver over a variety of chemical conditions. However, compared to the single-pass solver employed by RADM, the scheme was more CPU intensive. This is primarily due to the generalized nature of the solver in that no assumptions are made regarding the chemical characteristics; the solution technique determines the appropriate form for each species as the simulation progresses.

Further, the technique also has an automatic time-step control based on the stiffness of the evolving chemical system. The methodology provides for a seemingly more general approach relatively free of mechanism specifics wherein the solution technique is independent of the mechanism detail. The relative merits of generality and efficiency need to be carefully evaluated for future model applications where optimal balance between accuracy, efficiency, and generality are required.

Refinements to the two-pass solver approach are in progress. These include lumping of specific species to ensure mass conservation and to reduce stiffness of the system. Experiments with lumping of nitrogen species, in particular, showed improved mass conservation and solution efficiency. The CB-IV mechanism was also included within the above framework to demonstrate the generality of the solver. Construction of a generalized reader for the solver is in progress, which will allow for easy replacement or enhancement of chemical mechanisms in the future.

2.2.8 Technical Support

2.2.8.1 Cooperative Regional Model Evaluation Project

The Cooperative REgional Model Evaluation (CREME) 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 (LMOS) database, the 1990 San Joaquin Valley database, and the 1988 northeastern 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/sensitivity analyses are being performed. During FY-1994, work concentrated on the comparisons of UAM-IV and UAM-V for LMOS.

2.2.8.2 Southern Oxidant Study

FY-1994 was the fourth 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 was on analyzing the data collected in major field intensives conducted in the Southeast during the spring and summer of 1992, and in carrying out pilot studies in and around Nashville, Tennessee, in preparation for a major field intensive during 1995.

Interesting findings on the vertical inhomogeneities in pollutant concentrations within the daytime boundary layer over the southeastern United States were shown, and new hypotheses are being formulated and tested with the SOS data to explain these findings. Activities for a centralized data archive for SOS, to be located in Research Triangle Park, North Carolina, continued.

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 was co-sponsored by the U.S. Environmental Protection Agency, the Electric Power Research Institute Operational Evaluation Network, the Canadian Atmospheric Environment Service, Canadian Air Pollution Network; the Ontario Ministry of Environment Acid Precipitation in Ontario Study; and the Florida Coordinating Group, and was overseen by the Program Management Group, which consisted 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. A two-volume quality assurance synthesis report for the EMEFS network data program was prepared (Atmospheric Environment Service, 1994a; 1994b).

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, Forest Service (FS), Fish and Wildlife Service (FWS), and National Parks Service (NPS). The major objectives are to review existing air quality modeling techniques, identify consistent modeling approaches, and 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 North American Research Strategy for Tropospheric Ozone

The North American Research Strategy for Tropospheric Ozone (NARSTO) is a plan for a coordinated 10-year research strategy to pursue the science-based issues that will lead to better management of the North American tropospheric ozone problems. It includes a management plan for performing this coordination across the public and private sector organizations sponsoring ozone research, as well as those groups performing the research, including the university community. Canada and Mexico are also participating in the continental NARSTO plan.

During FY-1994, several Division representatives were involved in chairing key planning committees for the continental NARSTO program and in helping develop and refine the research agenda. FY-1995 will be the first year of implementation of NARSTO. Within the EPA, all non-effects scientific aspects of tropospheric ozone research, including atmospheric chemistry, modeling, monitoring and field studies, methods development, emissions research, and emissions control technology are being coordinated and managed by a Division member as part of the EPA contribution to NARSTO.

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 obstacles such 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. A new activity added to the Branch is resuspension mechanics/wind erosion. While this activity is experimental with primarily outdoor studies, usage of one of the Branch wind tunnels is planned for some detailed studies.

2.3.1 Terrain Downwash Study of Hazardous Waste Incinerator

The Fluid Modeling Facility conducted a wind-tunnel study of terrain downwash at the Waste Technology Industries (WTI) hazardous waste incinerator located in East Liverpool, Ohio. The EPA Region 5 Office and Office of Solid Waste and Emergency Response requested the study. A peer-review panel reviewed the draft risk-assessment plan and expressed concern that terrain-induced downwash could be a problem in the deep Ohio River Valley at this site and recommended that a wind-tunnel study be conducted. Figure 2 shows the model built and installed in the wind-tunnel for the study.

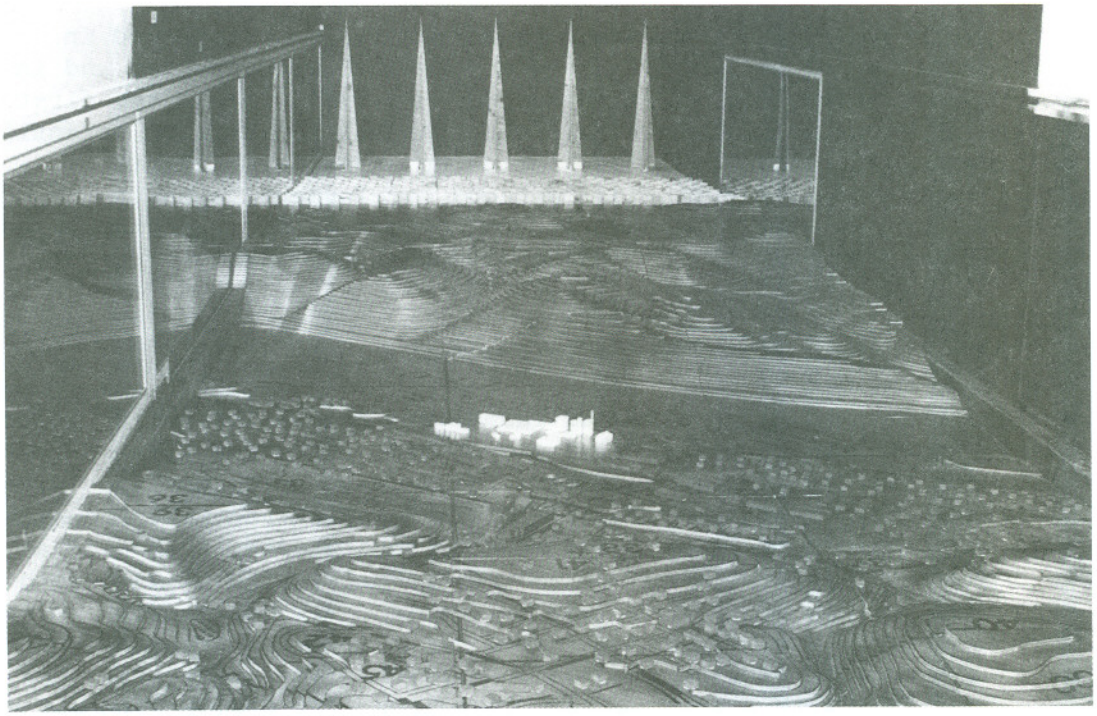

Figure 2. Scale model (1:480) of the WTI plant and surrounding terrain in Meteorological Wind Tunnel.

A scale model of the terrain was constructed at a ratio of 1:480, representing a full-scale section approximately 1 mile wide and 3 miles long. The river valley itself is approximately 500 ft (150 m) deep. The wind direction chosen was that expected to produce the most severe terrain-downwash effects, *i.e.*, with the most prominent hill directly upwind of the stack. This model, centered on the incinerator stack, was placed in the meteorological wind tunnel, with a simulated atmospheric boundary layer approaching it.

Methane was metered from the model stack as a tracer to simulate the buoyant effluent, and flame ionization detectors were used to measure concentrations, primarily ground-level values, downwind. Three stack heights were examined, including the existing stack height of 45.7 m, the calculated good-engineering-practice stack height of 72.7 m, and an arbitrarily chosen "tall" stack height of 120 m (about 80% of the valley depth). At each stack height, ground-level concentration (glc) patterns were measured over a range of wind speeds to ascertain the maximum possible glcs. The model was then rotated by 180° and a similar set of measurements was performed. Finally, the terrain model was replaced by a flat-terrain model with equivalent surface roughness to determine terrain effects with reference to those in flat terrain.

A total of 47 cases was studied including the two wind directions in the complex terrain as well as the flat terrain, the three stack heights, and several wind speeds for each combination of the above conditions. A majority of the measurements was made to develop surface concentration maps, an example of which is shown overlaid on the terrain map in Figure 3. The values of the maximum glcs at each downwind distance are underlined, and the overall maximum is circled. In this case, the maximum glc is located at the upwind base of the first hill downwind of the stack. There is some slight indication of the plume being directed around the south side of the first hill.

Whereas a large number of surface maps and vertical profiles of concentration as well as flow-structure and turbulence measurements were made, the results are difficult to interpret from a scientific viewpoint. Many interacting factors contribute to the differences in the glc patterns observed as a result of emissions from the WTI site and those observed from the same source in flat terrain. The upwind hills tend to reduce the wind speeds at the stack top, which should increase the plume rise and reduce the maximum glcs. On the other hand, the upwind hills tend to produce downward components of wind velocity at stack top and to increase the intensity of ambient turbulence; both effects tend to increase the glcs. The downwind hills also tend to increase glcs, but the degree of increase depends upon the hill shape. Building influences were also observed, although the present study was not designed to investigate them. In spite of the inability to isolate and describe in detail the specific causes of the results, the broad picture is understood, and the concentration patterns and values should be eminently usable for the intended purpose. A data report and an executive summary (Snyder and Thompson, 1994a; 1994b) were prepared and under review at the end of the fiscal year.

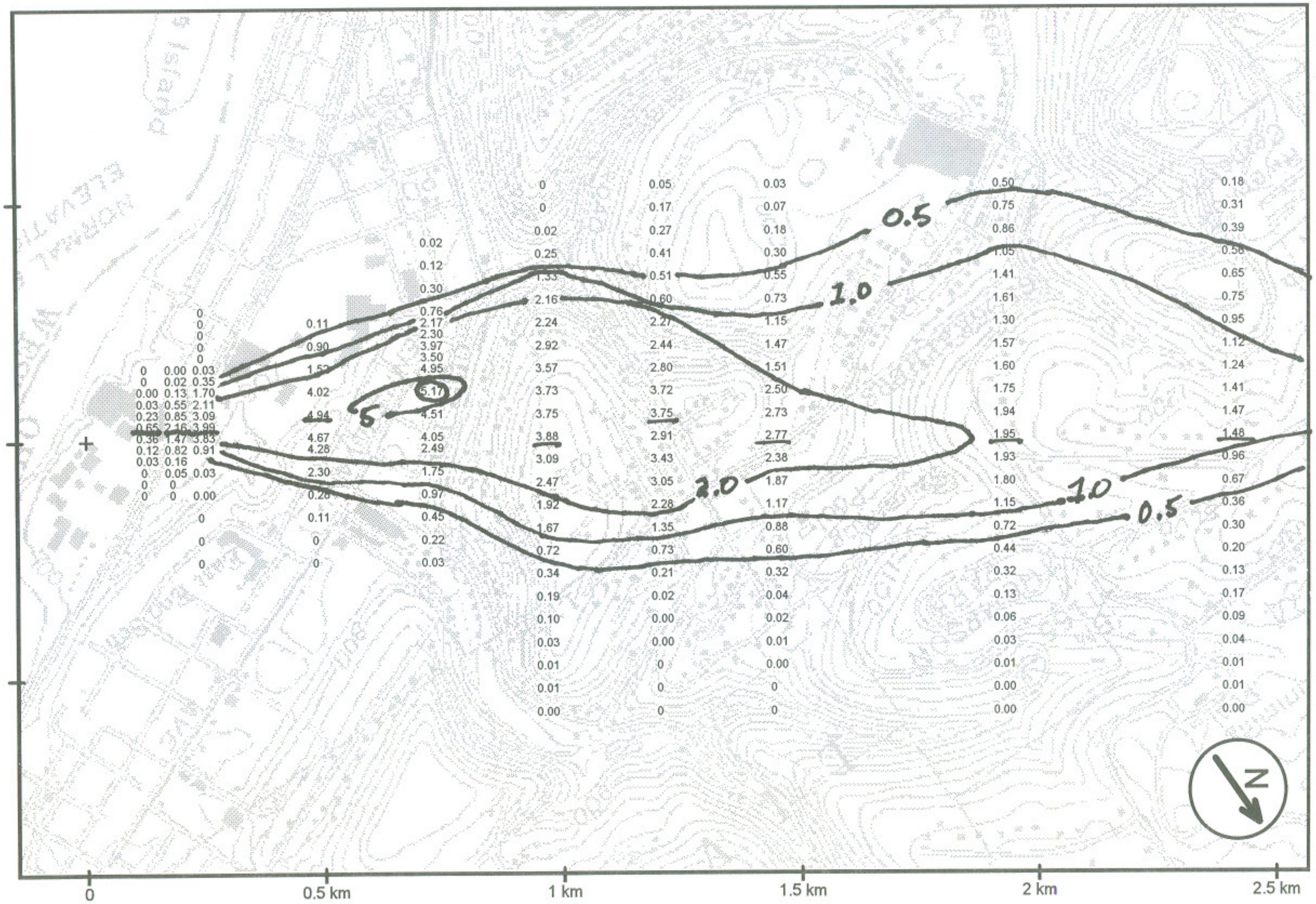

Figure 3. Typical concentration map for the WTI plant as obtained from wind-tunnel measurements.

2.3.2 Dispersion from Surface Coal Mines

Based on the wind-tunnel study of dispersion from surface coal mines conducted last fiscal year, the data were analyzed and two papers were prepared to describe the results. Residence times for emissions within a surface mine were presented by Thompson (1994), and considerations for modeling of steady-state ambient concentrations downwind of a surface mine were presented by Perry *et al.* (1994a).

2.3.3 Diffusion in the Convective Boundary Layer

Top-down and bottom-up diffusion processes were studied in the convection tank under a cooperative agreement with the Pennsylvania State University, University Park, Pennsylvania. The basic purpose of the experiments was to test predictions of large eddy simulations (LES), which indicate that the diffusivity of a scalar introduced into the bottom of the atmospheric convective boundary layer is radically different from that of a scalar introduced at the top. Mean gradients of two scalars, temperature and dye concentration, were measured in a replica of the Willis-Deardorff convection tank, and flux profiles were inferred to calculate vertical profiles of the top-down and bottom-up eddy diffusivities. The experimental results were in good agreement with the LES results. Because of rather large scatter in the experimental measurements, a new technique using laser-induced fluorescence is being developed to measure the dye concentration profiles. The results will be published in a journal article.

2.3.4 Mathematical Model of Pollutant Dispersion Near a Building

In the second year of collaboration with a Senior Research Associate under the NOAA/NRC Resident Research Associateship Program, the mathematical model of pollutant dispersion near a building was further developed. The development and initial evaluation of the model during the first year was described in a conference presentation (Genikhovich and Snyder, 1994). New additions to the model during the second year include distance-dependent plume rise, the incorporation of stability effects, and the ability to model wind flows not perpendicular to one of the building faces. A manuscript on distance-dependent plume rise was in preparation at the end of the fiscal year.

2.3.5 Numerical Simulation of Flow and Dispersion Around Buildings

A numerical modeling study on flow and dispersion around buildings was completed under a cooperative agreement with North Carolina State University, Raleigh, North Carolina. The TEMPEST model (Trent and Eyler, 1989) used a turbulent kinetic energy/dissipation (κ-ϵ) closure scheme to compute the flow fields and concentration patterns, and to determine the effects of approach flow shear, turbulence, and atmospheric stability. The neutral flow simulations and their comparisons with experimental (wind-tunnel) data showed that the model predicts the mean velocity fields quite well, but it predicts the turbulence fields poorly, especially in the impingement areas. The model further showed that upwind shear promotes the development of an upwind *horseshoe* vortex at the front of the building, while it reduces the size and strength of the cavity in the lee of the building. Turbulence in the approach flow promotes reattachment of the separated flow; thus, it reduces the size of the lee-side cavity. The influence of shear or turbulence is maximum in the absence of the other factor.

Simulations with a stable approach flow around a cubical building are in qualitative agreement with the available experimental (towing-tank) data. Both show that the cavity length decreases with decreasing Froude number (increasing stability) when $Fr \leq 3$ ($Fr = U/Nh$, where U is the wind speed, N is the Brunt-Väisïlä frequency, and h is the building height). The cavity length and associated flow fields become essentially independent of stratification when $F \geq 6$. The largest difference between predicted and measured values of the cavity length occurs at $Fr = 3$, where much larger stratification effects are observed from the measurements. Fair agreement is observed between predicted and measured concentration fields resulting from a source located within the cavity region for weakly stratified conditions ($Fr \geq 3$), but poor in the strongly stratified cases ($Fr < 2$). The results were reported by Zhang (1993).

2.3.6 Investigation of Motion of Large and Heavy Particles

A theoretical investigation was made of the motion of large and heavy particles as they settle through the atmosphere under the action of gravity. Analytical and numerical solution techniques were employed to predict the motion of such particles in flows as mesoscale terrain-induced waves, shear flows, oscillating fluids, and isotropic turbulence. The more important findings were that (a) the wave structure associated with strong stratification produces an apparent focusing of particle trajectories, which is absent under neutral conditions (Stout *et al.*, 1993); (b) if the initial particle concentration is uniform, then the redistribution of particle trajectories by terrain-induced wave motions produces a more uniform surface deposition compared with particles following straight-line trajectories to the surface (Stout, 1994a); and (c) the effect of nonlinear drag on the particles is to produce reductions in settling velocity (Stout, 1994b). The importance of mean shear was assessed by calculating trajectories of particles falling through simple shear layers (Stout and Arya, 1994).

2.3.7 Investigation of Resuspension Mechanics and Wind Erosion

Analysis of the multinational wind erosion/dust emission experiment was the principal activity during the year. Lake Owens Dust Experiment was initiated and led by a Division scientist. In March 1993, more than 25 scientists from the United States, France, and Russia carried out the experiment in Owens (dry) Lake. A primary area of focus was the mechanics of wind erosion and dust production. Analysis work was finished on the cause of the fetch effect, i.e., the increase or decrease of mass flux of airborne eroded soil particles with downwind distance. The fetch effect was shown to be caused by three mechanisms. First, avalanching of soil particles, where one particle would dislodge one or more particles upon impact of the surface. This effect is typically of small scale and the mass flux reaches equilibrium within a few meters. Second, aerodynamic feedback, where aerodynamic roughness height is increased by the airborne particles themselves; increased momentum flux results from increased aerodynamic roughness height that in turn increases particle flux. This positive feedback was observed for friction velocities larger than a minimum velocity determined by the undisturbed aerodynamic roughness height. Third, soil resistance mechanism, which expresses the change of threshold velocity with distance downwind, dominated the other two mechanisms of the fetch effect and was caused by inhomogeneities of the soil composition and size distribution.

2.4 Modeling Systems Analysis Branch

The Modeling Systems Analysis Branch supports the Division by developing modeling system designs and by 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

Although the Division shifted its research emphasis away from the Regional Oxidant Model (ROM) towards the next-generation regional air quality model (Models-3), ROM continues to be used by the regulatory community. It provides boundary conditions for UAM applications, and it calculates regional ozone levels in support of provisions under the 1990 CAAA. Papers related to the sensitivity of ROM to uncertainties in meteorological and emission inputs were presented by Olerud *et al.* (1993) and Pierce *et al.* (1993a). The emission sensitivity papers highlighted for policy makers the importance of input uncertainties when designing emission control scenarios.

A set of model applications were performed to test the effect of a new biogenic emissions system (Geron *et al.*, 1994) on ozone calculations. The new emissions are of interest because estimated isoprene emissions in the eastern United States are five times higher than previous estimates. Sensitivity runs with ROM showed significant changes in calculated ozone, particularly in VOC-limited areas around New York City, where the peak ozone increased by over 40 ppb for a 9-day episode during the summer of 1988. In this simulation, the calculated ozone with the new emissions inventory did not compare as well to measured routine surface observation values as the previous version of the model. This is of particular concern and raises a number of research questions. One, do chemical concentrations estimated with the new inventory agree more favorably with measured values (especially for compounds such as isoprene, formaldehyde, nitric oxide, and nitrogen dioxide)? Two, does the new inventory change the direction of emission control requirements for ozone attainment in the eastern United States? And three, if ozone were predicted fairly well with the old inventory, why then does a scientifically improved inventory produce less satisfactory results? These questions will be examined with a prototype of Models-3 and with more complete chemical observations coming from SOS.

2.4.2 Southern Oxidant Study

A Division scientist continued active involvement by serving as a scientific liaison to the emissions research portion of SOS. As part of this collaboration, a biogenic emissions inventory was estimated for the Atlanta modeling domain (Pierce *et al.*, 1993b). The new inventory suggested a factor of 7 increase in base level isoprene emissions. This generated a modest level of excitement in the SOS modeling community (Sillman and Cardelino, personal communication), which found a significant underestimate in UAM-predicted isoprene concentrations compared to levels measured during the 1992 Atlanta field experiment.

Meetings were held to begin development of a research-grade inventory for the 1995 Nashville field experiment. The inventory is expected to reflect modest improvements over the 1990 State Implementation Plan inventory, including hourly NO_x emissions from major TVA point sources, daily traffic flow patterns for mobile source emissions, and improved land use for biogenic emissions.

Participation in SOS continued to foster coordination of and collaboration with other national programs involved in biogenic emissions research. A workshop was held in Boulder, Colorado, May 1993, where the 1992 Oak Ridge isoprene flux experiment and the proposed 1995 study were discussed. The consensus arising from the workshop participants was that the 1995 study should return to Oak Ridge, Tennessee, and that the experiment should concentrate on the isoprene emission footprint and the quantification at the leaf level for isoprene emissions from selected tree species, especially oak and sweet gum.

2.4.3 Biogenic Emissions

The Division continues to be recognized as a leader in biogenic emissions inventory systems. A new methodology was developed that incorporates new emission factors and an updated land use inventory (Geron *et al.*, 1994). The system, BEIS2, was incorporated into ROM. The FORTRAN source code and land use data were made available via anonymous FTP. A similar system was adopted by the International Global Atmospheric Chemistry-Global Emission Inventory Activity working group on biogenic VOC emissions (Guenther *et al.*, in press). A Division scientist is a member of this working group.

To develop an improved understanding of NO_x emission fluxes from soils, the Division asked North Carolina State University, Raleigh, North Carolina, to host a March 1994 workshop to design a field experiment for comparing chamber-based measurements to micrometeorologically-derived NO_x fluxes. Because emission factors rely on chamber-based measurements, which may not provide an accurate view of the flux of NO_x into the atmosphere, more accurate estimates of NO_x emissions are needed to improve the ability to model tropospheric ozone. A journal article reported the workshop results (Aneja, 1994). Plans are underway for a 4- to 6-week experiment that will be held in a fertilized field in eastern North Carolina during May and June 1995. Substantial involvement by other interested participants is anticipated.

A Division scientist serves as co-chair of a biogenic emissions committee sponsored by the STAPPA/ALAPCO/EPA Emission Inventory Improvement Plan. The role of this committee is to develop a consistent and improved methodology for estimating biogenic emissions related to the Clean Air Act.

2.4.5 High Performance Computing and Communications Program

The HPCC program is part of a larger multiagency Federal High Performance Computing and Communications program sanctioned under Public Law 102-194 *High Performance Computing Act, 1991* and coordinated through the Committee on Information and Communications of the National Science and Technology Council. 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 modeling 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 Framework for Air Quality Modeling and Decision Support

A flexible environmental modeling and decision support system, Models-3, is being developed to provide air quality assessment and decision support tools for use directly by Federal, State, and industrial organizations engaged in a wide variety of environmental research and applications. The initial development effort is focused on multiscale, multipollutant air quality modeling related to ozone nonattainment, acid deposition, and fine particles. However, since many of the fundamental technology and science issues being addressed are directly applicable to other environmental modeling domains, the long-term goal is to extend the system to handle integrated cross-media assessments and to serve as a platform for community development of complex environmental models.

The modeling framework is designed to automate many of the activities associated with air quality model development, evaluation, and execution. The framework design isolates system interfaces and specific hardware/software platform solutions to ensure that advances in technology can be integrated without major revision to the structure of the system. Graphical user interfaces provide ease of use for such major functions as planning and executing a study, managing data, or building a new model. An environment layer contains a number of system features (e.g. Unix, MS Windows, etc.) that adapt Models-3 to the particular platform, system software, and platform-dependent files available. Data access is through a standard input/output applications programming interface. Numerous rapid prototypes were developed to test the feasibility of various components of the system. Testable system requirements were prepared from interviews with potential users and knowledge gained through early prototypes. An early prototype that simplifies the data preparation, execution, and data analysis of UAM was released to several groups for initial testing and feedback.

2.4.5.2 Emission Data Processing for Models-3

An evaluation was made of available emission inventory processors to determine which could be adapted for use in the initial release of Models-3. To be minimally acceptable, the emission inventory processing system must be Unix-based and able to spatially (grid) and temporally allocate point, area, and mobile source data, and speciate emission data into chemical substances and/or groups. There are three primary options for an emission-inventory processor: (1) the Flexible Regional Emissions Data System (FREDS) (U.S. Environmental Protection Agency, 1989); (2) the Emission Processing System associated with UAM (U.S. Environmental Protection Agency, 1990); and (3) the Geocoded Emission Modeling and Projection (GEMAP) system (U.S. Environmental Protection Agency, unpublished manuscript). Primarily because of its design and GIS capability, GEMAP was selected as the basis for Models-3 emission processing. The GEMAP software was obtained, and training and initial familiarization runs and debugging begun.

2.4.5.3 Numerical Solver and Parallel Algorithm Research

A highly vectorized version of the quasi-steady state approximation gas-phase chemistry solver was developed and implemented for the Models-3 alpha prototype using the RADM2 chemistry mechanism. This solver makes minimal assumptions about the type of mechanism employed and is a basic algorithm for the development of general gas-phase chemical mechanisms in Models-3. In addition, a simplified testbed model was developed from ROM using this solver and the RADM2 mechanism. This testbed provides an initial, representative chemistry-transport model as a solver development and testing environment for distributed and massively parallel computing architectures. The testbed was implemented on a Cray T3D massively parallel processing system in both the Parallel Virtual Machine (PVM) programming model and the Cray Research Adaptive ForTran model.

2.4.5.4 Computing Infrastructure Support

Division computer infrastructure was improved significantly by the purchase of fifteen Sparc 10/40 and Sparc 20/502 workstations for desktop use by laboratory researchers. A 2100 Alpha was purchased as a specialized computer server. The existing SUN application server was upgraded to a two CPU system and the SUN file server system was upgraded with a faster CPU.

New technologies and computing paradigms were integrated with the research network. The main servers and graphics workstations were connected to form a high speed 100 Mbit/sec research network. Equipment purchases and planning for a 155 Mbit/sec ATM network were completed. The ATM network facilitates the use of key technologies including clustered workstations, remote collaborative technologies, and distributed data management.

File management technologies were integrated with the Division computer infrastructure. The Unitree Central File Manager (UCFM) software system was implemented on a Division server. UCFM provides Unix users with a hierarchical file storage space that is automatically managed, virtually unlimited in capacity, and transparent to the user. A total of 180 gigabytes of long-term storage and 30 gigabytes of short-term storage was integrated with the infrastructure.

Infrastructure improvements enabled the transition of developmental modeling codes from supercomputers to workstations. A testbed model was ported from a Cray supercomputer to a workstation cluster. The ported model uses PVM version 3.3 developed by Oak Ridge National Laboratory, Oak Ridge, Tennessee. PVM is a software system that permits a network of heterogeneous Unix workstations to be used as a single large parallel computer. Preliminary indications are that wall clock speed-ups are possible on lightly loaded workstation clusters as compared with highly loaded supercomputers. Plans were developed to use the testbed model for parameterizing network and computational performance for use in further model transitions.

2.4.5.5 Software Configuration Management

Configuration management is a formal software engineering discipline that provides stability to the evolution of software products with the purpose of enhancing their integrity, quality, and reliability in a visible and traceable manner. A software configuration management plan was established in the Division to provide scientists, software developers, and users with the methods and tools to establish software baselines, control changes to those baselines, record and track their status, and audit their development. This approach applies to source code; executable load modules (object code); test data; database structures and element definitions; data libraries; control directives; job control language, procedures, rules, and associated documentation; and data pertaining to the development, operation and maintenance of Models-3 and other production modeling codes such as RADM. The use of formal configuration management is an integral part of the Division quality assurance effort.

2.5 Global Climate Research Branch

The Global Climate Research Branch performed and directed 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 various ecological systems. The Branch has particular interest in tropospheric ozone and the relationship to meteorological variables.

2.5.1 Global Tropospheric Ozone

One of the primary goals of the EPA global change program is to determine and understand the effects of such air pollutants as ozone on a global basis. In addition to being a major greenhouse gas and possibly as important as carbon dioxide, tropospheric ozone was linked with the large-scale decline of forest and agricultural ecosystems. Accordingly, research was initiated to develop a quasi-global (50° N - 50° S) climatology of tropospheric ozone utilizing remotely sensed data. This data was derived from two separate instruments aboard the NASA satellite, Nimbus-7. The first of these instruments, the Total Ozone Mapping Spectrometer (TOMS), measures the total column ozone (stratospheric and tropospheric components) in Dobson Units (1 D.U. = 2.69×10^{16} molecules of ozone cm^{-2}). The second instrument, the Solar Backscatter Ultraviolet (SBUV), provided data used in conjunction with tropopause height data from the NWS gridded analysis to determine the stratospheric contribution to the total ozone. From these two measurements, the daily integrated tropospheric residual values were calculated and gridded on a 100 x 288 matrix (1° lat. by 1.25° long.).

The NWS gridded data used with the SBUV data were for a global grid of 2.5° latitude by 2.5° longitude cells from 50° S to 50° N from 1979 to 1993. There were two grids per day, 0000z and 1200z. Since the United States falls within the latitude boundaries of the grid, there was a comparison between gridded tropopause heights and tropopause heights reported by the network of RAdiosonde OBservation (RAOB) stations operating in the United States. At each RAOB sounding, a tropopause level (mb) was determined by the observer using a tropopause template to find the lowest level with respect to altitude (at or between 500 mb and 30 mb) at which the temperature lapse rate decreases to 2° C/km or less. The average lapse rate from this level to any point within the next higher 2 km must not exceed 2° C/km, and the sounding must extend at least 2 km above the tropopause level. If a tropopause were not found at pressures 500 mb or less, the same criteria were used except the sounding must have extended to a pressure of 200 mb or less, and the average lapse rate must not have exceeded 3° C/km for at least 1 km in any higher layer up to and including 100 mb.

Sixty-five RAOB stations were operated in the United States during the years 1979 to 1993, and the locations were identified with specific grid cells. This arrangement produced a computed file of paired tropopause heights from observed RAOB soundings and gridded values for the same date and time. The gridded data agreed well with the observations of tropopause height. These gridded data were then used to determine the ozone in the stratosphere.

The tropospheric ozone was derived by subtracting the stratospheric contribution from the total ozone. The spatial and temporal variability of the integrated tropospheric ozone residuals was examined for the period 1985 through June 1990 using rotated principal component analysis. Preliminary analysis revealed 10 to 12 contiguous subregions, each of which displayed a statistically unique ozone climatology. The morphology of the subregions appeared to be determined by such large-scale circulation patterns as the Hadley cell, monsoons (both the Asian and African), the quasi-biennial oscillation, and the intertropical convergence zone. Spectral density analysis will be utilized to better characterize the temporal variability of the unique subregions.

2.5.2 Regional Global Change Effects on Ecosystems

Climate change scenarios were completed for the U.S. Forest Service Southern Global Change Program. The database consists of daily historical data (1949-1988) and doubled CO_2 scenarios derived from four General Circulation Models (GCMs) from the National Center for Atmospheric Research (NCAR) archives. Forty-year time series of daily maximum and minimum temperature, precipitation, vapor pressure deficit, and solar radiation were estimated for a 1° latitude x 1° longitude uniform grid covering the southern and southeastern United States. The research was reported at a meeting, and database documentation is available on request (Cooter *et al.*, 1994). The database was used in research conducted by the Air Resources Research Consortium located at North Carolina State University, Raleigh, North Carolina. This project attempted to estimate the impact of climate change on crop growth, production, and disease loss in the southeastern United States.

As part of the database development process, an existing solar radiation algorithm was re-examined using the solar radiation database, SAMSON (Solar And Meteorological Surface Observation Network). New radiation model parameters were estimated and the algorithm's performance in a plant process model at a sample location was evaluated. Results of this analysis will be reported in a journal article.

In addition to independent regional climate change assessment activities at the regional level, the Forest Service is sponsoring a national assessment effort. The Division staff is advising the National Assessment Scenario Development Task Force in the areas of historical database acquisition and application, GCM output application, down-scaling, and empirical modeling of climate variables, with an emphasis on radiation.

2.5.3 Dependence of Ozone on Meteorology

A two-stage, average linkage, then convergent *k* means clustering approach was utilized as part of an automated meteorological classification scheme designed to better elucidate the dependence of ozone on meteorology (Eder *et al.*, 1994). When applied to 10 years of meteorological data (1981-1990) for Birmingham, Alabama, which was found by Eder *et al.* (1993) to be representative of the southern United States, the classification scheme identified seven statistically distinct meteorological regimes. The majority of regimes exhibit significantly different daily 1-hour maximum ozone concentration distributions. Results from this two-stage clustering approach were used to develop seven refined stepwise regression models, which served two purposes: first, they identified the optimum set of independent meteorological parameters influencing the ozone concentrations within each meteorological cluster; and second, weighed each independent parameter according to its unique influence within that cluster. Large differences were noted in the number, order, and selection of significantly contributing independent variables, for example, with 90% confidence, to the variability of O_3. When this unique dependence was taken into consideration through the subsequent amalgamation of the seven individual regression models, a better parameterization of O_3's dependence on meteorology was achieved. The composite model exhibited a significantly larger explained variation (R^2 = 0.59) and a smaller root mean square error (RMSE = 12.80 ppb) when compared to results from an overall model (R^2 = 0.53, RMSE = 13.85 ppb) in which the meteorological data were not clustered.

Because of the success of this approach, it was utilized by others. Statisticians at the National Institute of Statistical Sciences are using the approach in studies examining ozone in Houston, Texas. Also, the EPA is examining particulate matter in Pittsburgh and Philadelphia, Pennsylvania, with this method.

2.5.4 Assessment of Ecosystems

Climate information was used in the interpretation of ecological samples. The EPA Ecological Monitoring and Assessment Program Forest Resource Group conducted a demonstration project in the southeastern United States. Samples were taken of lichen at several sites. In cooperation with Oregon State University Botany Department, Corvallis, Oregon, climate data were used to observe the effects of temperature and moisture conditions on these lichen. Centroids of the hexagons, which define the ecological sample location, were intersected with the location of climate divisions using the geographic information system, registered trademark ARC/INFO. Climate parameters used for the analysis of lichen sensitivity were 30-year averages of annual precipitation, January temperature, and July temperature, for years 1961-1990.

The Division contributed to the development and production of a prototype assessment of the exposure of ecological systems to selected pollutants and the effect of Clean Air Act enactment on these exposure levels. Climate information and projections from air quality models were included in the assessment.

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 to model development and research on flow characterization and dispersion modeling. Research is coordinated with other agencies and researchers.

2.6.1 Indirect Exposure Assessment Modeling

The development of an improved model for predicting near-field concentrations and dry and wet deposition fluxes for a wide-range of compounds in both simple and complex terrain continued during FY-1994. The model, based on ISCST2 (Industrial Source Complex - Short Term) (U.S. Environmental Protection Agency, 1992), is ISC-COMPDEP (Industrial Source Complex - COMPlex terrain DEPosition) and described in Schwede and Scire (1994). ISC-COMPDEP will be used for indirect exposure assessments as well as modeling for compliance with ambient air quality standards. To better understand the model's response to variations in input parameters associated with the deposition algorithms, a sensitivity study was performed.

The following input parameters were varied: particle size distribution, particle density, scavenging coefficients, resolution of the particle size distribution, and terrain grid specification. Of the parameters tested, the model was most sensitive to values provided for the scavenging coefficient. Maximum predicted annual wet deposition decreased by 38% due to a decrease of one standard deviation in the input scavenging coefficients.

However, the model does not contain algorithms for calculating the dry deposition of gas-phase pollutants. To address this deficiency, an evaluation of algorithms began. The algorithms evaluated were those that calculated the dry deposition velocity of gases and were suitable for inclusion into ISC-COMPDEP. The results from the first phase of the evaluation are described in Chinkin *et al.* (1994). Algorithms previously documented in the literature were included as well as one hybrid algorithm developed from combining desirable features of two existing algorithms.

The program names associated with these algorithms are:

- CALPUFF (Scire *et al.*, 1990)
- Massman (Massman, 1993)
- NOAA/ARL I & II (Hicks *et al.*, 1987)
- RADM (Sheih *et al.*, 1986)
- Russell (Russell *et al.*, 1993)
- UAM-V (Gray *et al.*, 1991)
- Wesely (Wesely, 1989)

All the algorithms use the resistance analogy to calculate the deposition velocity. Observational databases of HNO_3, SO_2, and O_3 deposition velocities for a variety of land use types were used in the evaluation. Both statistical and diagnostic evaluations were included. The statistical evaluation compared predicted deposition velocities against observed deposition velocities for a given set of meteorological conditions. The fractional bias of the average deposition velocity was used to quantify the degree of over or underprediction of the model. The fractional bias of the standard deviation of the deposition velocity was used to examine the variability of the estimates.

Figure 4 shows a plot of the fractional bias of the average and the fractional bias standard deviation for all models and all data sets. Data points within the box indicate predictions that are within a factor of 2 for the fractional bias of the average and the standard deviation. From this figure, it can be concluded that no one model performed significantly better for all of the gases tested. To better understand why certain models performed better for particular data sets, a diagnostic evaluation was begun. Individual resistances to the predicted deposition velocity are being examined to identify aspects of the models that are important for particular chemicals and land-use types.

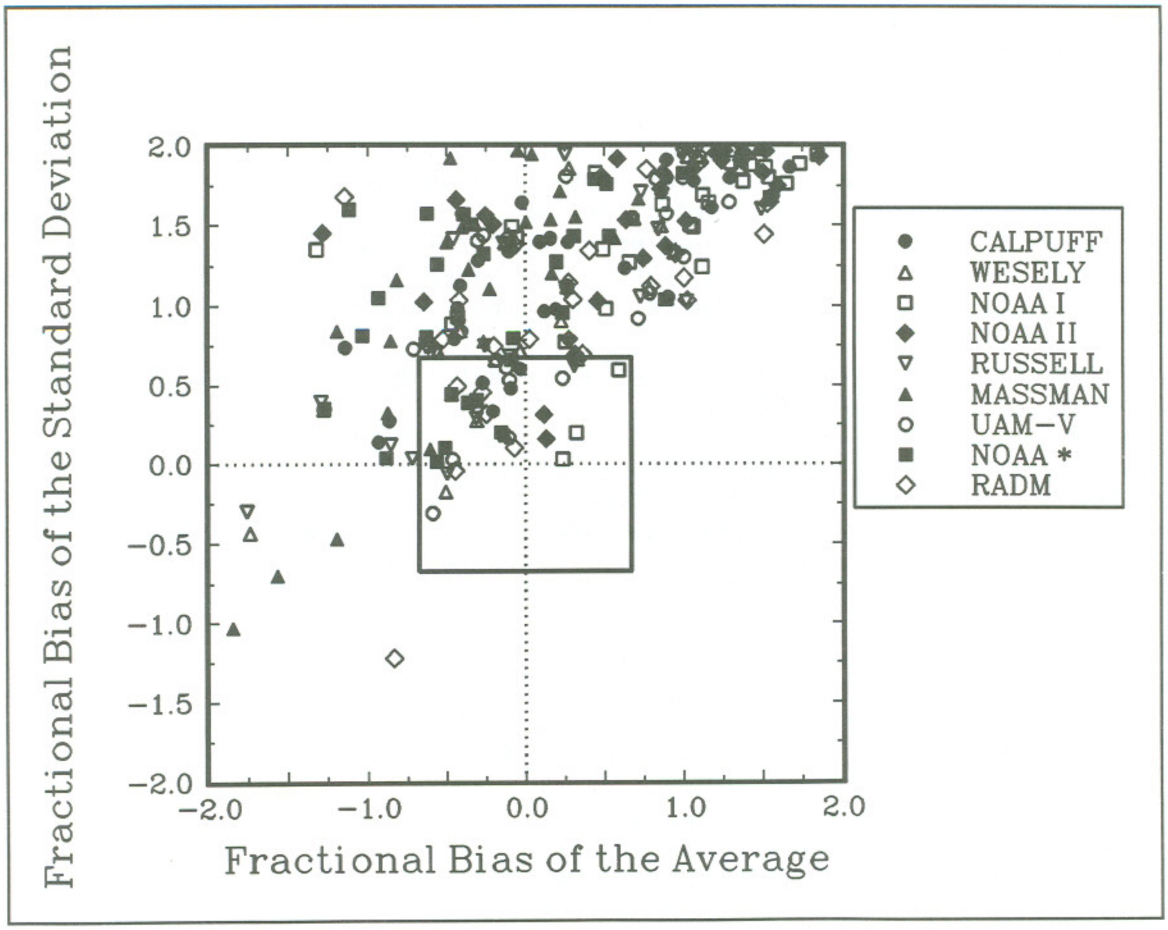

Figure 4. Scatter plot of fractional bias of the average deposition velocity versus the fractional bias of the standard deviation for all data and all models for each of the 28 subsets used in the evaluation.

2.6.2 AMS/EPA Regulatory Model Improvement Committee

To expedite the inclusion of advances in atmospheric boundary layer understanding into the EPA regulatory models, the AMS and EPA formed the AMS/EPA Regulatory Model Improvement Committee (AERMIC). In FY-1994, the work group completed the initial version of the vastly improved ISCST2 and named it AERMOD. The areas of advancement over regulatory plume models include dispersion formulations and rates in both convective and stable conditions for elevated and surface level pollutant releases, interaction of plumes with complex terrain, plume penetration into elevated stable layers, and parameterization of meteorological vertical profiles in the surface boundary layer. Also, advancements were made concerning the estimation of effective winds and turbulence based on position and vertical spread of the plume to use in transport and diffusion calculations, and thus, accounted for vertical inhomogeneity of the meteorology and the effects of convective turbulent velocities on plume rise. The coding of AERMOD and its meteorological preprocessor was completed in FY-1994 and the developmental evaluation phase was begun. The manner in which AERMOD handles near surface level sources and the extreme inhomogeneity at that low level were improved in light of comparisons against the Prairie Grass tracer database (Barad, 1958). The developmental evaluations continue with other databases. A document was completed and is updated as the model develops, detailing the technical basis for AERMOD. A paper describing AERMOD was presented by Perry *et al.* (1994b).

2.6.3 Modeling Particulate Emissions from Surface Coal Mines

The 1990 CAAA required the EPA to re-examine the methods used for modeling fugitive particles, particularly PM-10, from open-pit surface coal mines. ISCST2 was specifically named as the model needing further study. From results of wind tunnel simulations, steady state flow fields and concentration patterns within and downwind of model coal-mining pits (Perry *et al.*, 1994a), a methodology was developed for modifying and applying ISCST2 to open-pit surface coal mines.

The wind-tunnel simulations indicated that emissions from a shallow pit were concentrated near the upwind edge of the pit due to recirculations in the pit. Therefore, the method included a definition of the emissions as a surface level area source positioned on the upwind edge of the actual pit. The dimensions of the modeled area were dependent on the wind direction, actual dimensions, and depth of the pit. The turbulence in the pit and its influence on vertical dispersion was accounted for with an enhancement to the vertical dispersion parameter as a function of the pit depth.

The improved ISCST2 estimates were compared against the wind-tunnel data where emissions were released throughout many areas along the floor of the mine. Favorable comparisons were found. Where the original ISCST2 overpredicted maximum impacts along the downwind edge of the pit by a factor of 3, the modified model overestimated by less than 30 percent. It is anticipated that additional wind-tunnel simulations will be performed in the future with a wide variety of wind directions to further evaluate the proposed method. ISCST2, with surface coal mine algorithms, will be evaluated in FY-1995 against field study data collected over a 2-month period at an actual operating surface coal mine. The open-pit algorithm was described by Perry *et al.* (1994a).

2.6.4 Chemical Hazards of Atmospheric Releases Research

Under authorization of the 1990 CAAA, the Chemical Hazards of Atmospheric Releases Research (CHARR) program began in FY-1993 and continued in FY-1994 with quality assurance (QA) and analysis of the July 1993 experiment carried out at the Department of Energy (DOE) Liquified Gaseous Fuels Spills Test Facility (STF) on the Nevada Test Site. Extensive planning for further experiments involving use of STF in FY-1995 is expected. The 1993 experiment measured the diffusion of dense, continuous CO_2 releases. Planned work includes a second experiment, CO_2 evaporation experiments, and more complex CO_2 experiments in collaboration with a Petroleum industry Environmental Research Forum (PERF).

The QA checks of the July 1993 STF experiment were quite satisfactory except for logging errors at certain levels of the meteorological tower; fortunately, the data capture was adequate. Data capture from the 45 bag samplers was 97%, and the 37 real-time CO_2 sensors recorded satisfactorily with no instrument saturation in 95% of the cases. The 30 collocated instruments agreed quite well on mean CO_2 concentrations, except for some factor-of-2 disagreements during the most meteorologically stable run (Test 2). The CO_2 mass flow measured through the main arc (at 40 m) divided by the measured release mass averaged 0.99 for the real-time sensors and 0.92 for the bag samplers, an excellent indication of quality, except for the errant Test 2 (0.70 average).

The goal of the next CO_2 series at STF is to extend the test into far more stable, low-wind speed conditions than any previous experiments; 30 more real-time sensors will be employed, with fewer collocations, allowing two additional arcs. The evaporation experiments will use very accurately weighed pans repeatedly filled with liquid chlorine and liquid ammonia at various set temperatures below their boiling points; these will be done in the STF outdoors-situated wind tunnel, which will be retrofitted to provide realistic boundary-layer flow. The PERF CO_2 experiments will be done using CHARR's instrumentation array, but with several combinations of much larger surface roughness and obstacle arrays resembling model-scale refineries added.

2.6.5 Modeling Spray Drift from the Application of Agricultural Pesticides

In FY-1994, Division scientists initiated a research effort in the area of pesticide spray drift. Drift of airborne pesticide from the intended target is a source of environmental concern due to potential human and ecological impacts. Because significant uncertainty and, therefore, controversy exists on the magnitude of offsite drift and deposition, improved assessment methodologies were needed to evaluate drift under a variety of application and environmental scenarios. Development of practical modeling tools for the EPA as well as pesticide manufacturers was the focus of this work. Division scientists cooperated with both the chemical industry and the academic community in attacking this important problem.

In March 1994, a Cooperative Research and Development Agreement was signed with the agricultural chemical industry's Spray Drift Task Force (SDTF). The 3-year goal of the agreement is to validate an assessment methodology for use in evaluating the risk of offsite drift from agricultural pesticide spray operations. Methodology will be used in the pesticides registration process to assess human and ecological exposures. SDTF completed numerous field studies of aerial and ground spraying, which will provide a basis for model development and assessment.

In addition, the EPA awarded a cooperative agreement to New Mexico State University, Las Cruces, New Mexico, and University of Connecticut, Storrs, Connecticut, to specifically investigate pesticide spray drift from orchard airblast type spraying operations. This cooperative research will center on the interactions of canopy structure and spray drift, the transport of fine droplets both locally and up to 30 or so kilometers downwind, and the characterization of dispersion climatology for different agricultural areas. The purpose of characterizing climatology is to enable performances of generic assessments and to develop uncertainty estimates of pesticide exposure from intermittent spraying operations.

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 developing models for the characterization of gaseous and particulate concentrations from releases within and near buildings; tracer studies to elucidate air parcel movement within the buildings; and microenvironmental simulation models for human exposure where specific human activities occur. Contributions to exposures from multiscale and multipathways are integrated with human activities to model total human exposures. The Branch also develops and provides meteorological instrumentation and measurement support to the Division field studies programs.

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

The Hazardous Air Pollutant Exposure Model (HAPEM), which estimates human exposure to air pollution and characterizes the health risks associated with these exposures (Johnson *et al.*, 1992) and the revised version, HAPEM-MS, which estimates exposure to pollutants emitted by mobile sources, were enhanced with additional exposure indices to increase the accuracy of an exposure estimate. The enhanced version, HAPEM-MS2, was used to evaluate trends in CO exposures for Denver, Colorado (Glen and Zelenka, 1994).

HAPEM-MS2 calculates the annual average exposure of each cohort to the pollutant and the estimated annual cancer incidence associated with that exposure. Ongoing research will provide enhancements to the model input parameters. Analysis of data on indoor/outdoor ratios of Benzene/Toluene/Xylene (BTX), CO, and air exchange tracer concentrations obtained in real time and correlated with temporal changes with monitored meteorology, and SF_6 tracer measurements should provide improvements for increasing the reliability of the model's estimates. Analysis of additional meteorological parameters for choosing activity patterns from a 3-city database instead of, or in addition to temperature used, should provide improvements for increasing the certainty in correctly tracking human activity patterns.

The probabilistic National Ambient Air Quality Exposure Model applied to Carbon Monoxide (pNEM/CO) estimates the frequency distributions of population exposure to CO and the resulting carboxyhemoglobin (COHb) levels within a defined area. An evaluation of the model was completed using data from the

Denver personal exposure monitoring study, where 450 people carried a personal exposure monitor for two consecutive days. The model was evaluated for 1-hour and 8-hour daily maximum exposures for persons residing in homes both with and without gas stoves (Law *et al.*, 1994). Based on this evaluation, problem areas of the model are being investigated.

2.7.2 Characterizing the Effects of Meteorology on Concentrations of Acid Aerosols

To better understand the effects of human exposure to acid aerosols, epidemiologic air pollution studies were conducted characterizing the spatial and temporal distribution of acid aerosols. To fully understand the processes responsible for the distribution of acid aerosols, a rigorous analysis is required of local and regional meteorology and its effect on acid aerosol (H^+) concentrations. Because few studies have included a comprehensive analysis of the effects of meteorology on acid aerosol concentrations, an examination of the relationship was undertaken (Zelenka, 1994; Zelenka and Suh, 1994). Ambient air samples of strong acid aerosol (H^+), sulfate ($SO_4^=$), ammonia (NH_3), and ammonium (NH_4^+) that were collected in Uniontown, Pennsylvania, during the summer of 1990, were analyzed for their relationship to local and regional meteorological parameters. Standard measures of atmospheric conditions included temperature, pressure, relative humidity, and precipitation. The analysis provided information on the synoptic scale and mesoscale meteorological parameters that coincided with acid aerosol episodes. This knowledge can be used to predict the expected occurrence of high-acid aerosol concentrations for other cities in the Northeast.

2.7.3 Exposure to Alternative Fuels

The 1990 CAAA requires programs for both oxygenated and reformulated fuels to help reduce ambient air quality concentrations of carbon monoxide and ozone. While reducing carbon monoxide and ozone, the alternative fuels contain additives that may have significant health risks. With a stream of new fuel additives, human exposure modeling is needed for health risk assessments. During FY-1994, exposures to methyl-tertiary-butyl ether, ethyl-tertiary-butyl ether, manganese, and copper were evaluated.

Human exposures are estimated primarily for microenvironments, where concentration are expected to be highest (i.e., refueling, commuting, garages). Pollutant concentrations from tailpipe and evaporative emissions are being examined to develop models for estimating concentrations integrated with population activity patterns to estimate human exposures. The development of an air quality model for estimating human exposures in residential garages is ongoing (Zhang *et al.*, 1994). The development of a model for the urban street canyon microenvironment has begun. Model development includes research on both simple analytical models and high performance computing for numerical simulation.

2.7.4 Sulfur Dioxide Fumigation in Mae Moh Valley, Thailand

A cooperative research project with the Royal Thai Government was started in FY-1993 and continued in FY-1994 to provide assistance in developing an understanding of the cause and mitigation of high SO_2 episodes in the vicinity of the Mae Moh Power Station in northern Thailand. The project provided the Royal Thai Government scientific advice on the nature of surface- and upper-air meteorology over the Mae Moh Power Plant; on the ability to forecast potential air pollution emergency; and the modeling approach needed to assess potential concentration levels and time period for an air pollution emergency. A joint field study was conducted from early December 1993 to mid-February 1994 with the NOAA Environmental Technology Laboratory, Thailand Department of Pollution Control, and Electric Generating Authority of Thailand, which maintains a network of surface SO_2 monitors and a 100 m meteorological tower.

During the study, NOAA provided additional meteorological measurements (horizontal and vertical wind velocities, air temperature, relative humidity, and solar radiation) from in situ sensors mounted on a 100 m tower; atmospheric boundary profiles of three-dimensional wind velocities and virtual air temperature obtained by a 915 MHz wind profiling radar and radio acoustic sounding system, respectively; low-level three-dimensional wind velocity profiles (50 m to 500 m) from a sodar; and qualitative thermal structure of the atmospheric boundary layer (surface to 700 m) from a single-beam monostatic sodar. These data will be summarized in a technical report and will be used in modeling efforts to reproduce high pollution fumigation events. Methods are being developed to provide a synoptic based 1- to 3-day forecast for potential episodes. A puff model was developed to simulate the plume fumigation during high pollutant episodes. These models will be used to develop control methods needed to minimize human exposures during episodes.

2.7.5 Meteorological Instrumentation and Measurement Support

2.7.5.1 Meteorological Guidance for Photochemical Assessment Monitoring Stations

Guidance on meteorological measurements was provided to the Photochemical Assessment Monitoring Stations (PAMS) program. Areas that have ozone nonattainment problems are required to establish a PAMS network in the affected region, which includes measurements of surface- and upper-air meteorology. This guidance will be included in a revised technical assistance document for sampling and analysis of ozone precursors. Presentations were given on PAMS meteorological monitoring guidance by Crescenti (1994) and Templeman (1994).

2.7.5.2 Quality Assurance Handbook for Remote Sensing Instrumentation

A draft guidance handbook was prepared to discuss quality assurance (QA) and quality control (QC) procedures for ground-based remote-sensing systems, including wind profiling radars, acoustic sounding systems, and radio acoustic sounding systems. This was the first attempt to establish guidance for this type of instrumentation since the adoption of this technology by the regulatory community for environmental monitoring purposes.

A sodar characterization study will be conducted in April 1995 at the Boulder Atmospheric Observatory tower in Erie, Colorado. The 300 m tower will be instrumented with sonic anemometers at several levels. These data will then be compared against those obtained by sodars placed around the perimeter of the tower. Experience obtained in QA/QC as well as standard operating procedures will be incorporated into the next iteration of the QA Handbook.

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 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 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 program, which uses the Regional Oxidant Model (ROM) to support states required to demonstrate attainment of the ozone NAAQS, completed Phase I and Phase II during FY-1994. The completion of the Phases I and II enables states, through ROM, to obtain boundary condition estimates for ozone and precursor species concentrations for UAM applications.

In Phase I, ROM was applied for 15 high-ozone episodes during the period 1987 through 1991. Base case simulations were made for each episode to provide estimates of precontrol boundary conditions. In addition, these data are being used to evaluate ROM's performance for estimating boundary condition concentrations.

In Phase II, the base emissions were projected to the required ozone attainment years of 1996, 1999, 2005, and 2007. The projections reflected expected emission changes as a result of growth and the effects of control programs mandated in the 1990 CAAA. ROM simulations of these future-year scenarios were made for a subset of the 15 episodes. In total, over 600 days were simulated for the various scenarios and episodes. Predictions for these model runs were provided to the states via an electronic data retrieval system.

In Phase III, the work involves simulations of emission scenarios that include alternative regional control programs. Model simulations were made for several strategies directed at reducing NO_x emissions from power plants and other large NO_x sources. The results of these runs were analyzed and reported to the EPA and members of the Ozone Transport Commission. Additional Phase III runs will be made in FY-1995.

During FY-1994, work began on ROM simulations to support the EPA review of the ozone NAAQS. Because several of the possible new forms of NAAQS involve seasonal averages, it is necessary to perform model applications for periods longer than typical multiday high-ozone episodes. In response to this need, ROM was run for a full 3-month summer season using meteorological conditions from June through August 1987 and emissions for 1990. Emissions for a 2007 future-baseline scenario are being prepared for simulation in FY-1995. Control strategy simulations will also be made next year. The results will be used to assess alternative control pathways for attaining possible new NAAQS and for direct input to the cost/benefit regulatory impact analysis, which is associated with the NAAQS review process.

2.8.1.2 Surface Coal Mine Study

Section 234(a) of the 1990 CAAA requires the EPA Administrator to 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 response to these requirements, an extensive field study of emissions from fugitive dust sources was conducted at the Cordero mine, south of Gillette, Wyoming, in the 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 on an intensive schedule for 60 days. Field personnel took detailed observations of all operations at the mine during this period in order to determine hourly emission estimates. The study was successful in compiling a unique database that has the necessary quality required to test the predictive accuracy of the dispersion model (Cowherd *et al.*, 1994; U.S. Environmental Protection Agency, 1994a).

In Phase II of the study, an objective model evaluation protocol is being developed. In the study, the performance of the existing ISC model is compared with a new version of the model with improved modeling techniques. These include a new area source algorithm applicable to ground-level releases, a new particulate matter dry-deposition algorithm, and a pit-retention algorithm. Several source characterization techniques for modeling these fugitive sources are also being examined. Due to the sensitive nature of the issues involved, considerable negotiations are required among industry, State, and the EPA regional office groups.

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 and supplement B (U.S. Environmental Protection Agency, 1987), lists the air quality models for estimating ambient air concentrations due to sources of air pollution. During the summer of 1994, final reviews and clearances were completed on a draft Notice of Proposed Rulemaking, entitled supplement C, to augment the available guidance in several areas. The proposal includes incorporating improved algorithms for treatment of area sources and dry deposition in the Industrial Source Complex (ISC2) model; adopting a solar radiation/delta-T (SRDT) method for estimating atmospheric stability categories; adopting a new screening approach for assessing annual nitrogen dioxide impacts; and adding SLAB (Ermak, 1990) and HGSYSTEM (Witlox, 1991) as alternative dense gas air dispersion models.

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 (TTN), was created to foster technology transfer among all users of regulatory air quality models. The SCRAM BBS is a mechanism for providing technical support for air modeling activities. Users experiencing problems with regulatory models can leave messages on the BBS or call designated telephone numbers to obtain assistance.

SCRAM BBS publishes *SCRAM NEWS*, which provides articles on new features and models added to the BBS, tips on using models, and discussions of issues related to modeling guidance. Division meteorologists contributed articles and announcements relating to models and to model revisions that are on the SCRAM BBS.

During FY-1994, several activities were accomplished by the SCRAM Systems Operator. A restructuring of the information on TTN improved the SCRAM BBS to the standards of the other subject areas. This entailed shifting SCRAM files to a SCRAM subdirectory. Each model or subject area was then given a separate directory for ease of file tracking. Also, formal SCRAM documentation was created on the structure and file configuration. This documentation is useful in the daily functions of the SCRAM Systems Operator and facilitates expansion of menus as well as isolating and resolving problems.

2.8.2.3 Model Clearinghouse

The FY-1994 activities for the Model Clearinghouse included the following:

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

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

3. Documenting Clearinghouse decisions and discussions.

4. Summarizing Clearinghouse activities at various meetings.

5. Issuing an internal summary report of FY-1994 activities.

6. Entering FY-1994 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 63 modeling referrals to the Model Clearinghouse from the Regional Offices during FY-1994. These included 12 regulatory modeling problems, each of which required a written response, and 51 referrals, each of which required an oral response. 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 1993, a Clearinghouse report was prepared and distributed to the Regional Offices; the report informed Clearinghouse users about issues and responses that occurred during FY-1993.

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-1994, one sensitive case arose involving a proposed method to objectively identify nearby sources for inclusion in a modeling emission inventory. 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 1249 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-1994; (2) FY-1989 through FY-1994 Clearinghouse memoranda; and (3) FY-1989 through FY-1993 Model Clearinghouse reports.

2.8.2.4 Guidance for Modeling Air Toxic Releases at Superfund Sites

Evaluating the air exposure pathway at Superfund sites is an integral part of several regulatory programs, which use air dispersion models to assess the potential risk associated with existing and proposed emissions and for contingency analyses. Through consultation with the EPA Air/Superfund Coordinators and the regional modeling contacts, special modeling requirements for these sites were identified and a guidance document will be issued in FY-1995. This document is intended to augment the primary EPA guidance document (Title 40, Code of Federal Regulations, 1994); as such it will elaborate on modeling issues particularly related to Superfund sites.

Another useful tool for preliminary screening for impacts from Superfund sources is the upgraded TSCREEN model (U.S. Environmental Protection Agency, 1994b). This user-friendly interactive model contains information on estimated emission rates for several typical release scenarios at these sites. Each release scenario is then coupled with a screening level dispersion model according to release density and duration. As described in the user's guide, four dispersion models are imbedded in TSCREEN: the SCREEN2 and PUFF dispersion models, which are used for buoyant continuous and instantaneous releases, respectively; and the Relief Valve Discharge and the Britter and McQuaid models, which are used for scenarios with denser-than-air, pressurized and spill releases, respectively.

2.8.2.5 New Modeling Techniques

With increased emphasis on indirect exposure modeling for hazardous waste combustors and small particles such as PM-10, enhancements were needed for the Industrial Source Complex (ISC2) model to accurately estimate and model dry deposition. The existing deposition algorithm in ISC2 was designed for treating large particles. During the last three years, work has focused on assembling databases and testing dry deposition velocity techniques (U.S. Environmental Protection Agency, 1994c). Division scientists recommended consideration of an algorithm from ADOM for estimating the deposition velocities for particulates. Evaluation results suggested the algorithm would substantially improve the characterization of particulate dry deposition in comparison to the algorithm available in ISC2. The deposition algorithm was incorporated into a revised ISC2 model, which will be the focus of a proposal to revise the Guideline on Air Quality Models (Revised) (Title 40, Code of Federal Regulations, 1994).

2.8.3 Additional Support Activities

2.8.3.1 Technology Transfer

For many years information on the application of atmospheric dispersion models was disseminated to the public by contract instructors through the Air Pollution Training Institute. In FY-1994, Division staff taught the course to more than 150 students linked via satellite at 47 down-link sites. Course contents included the background information on dispersion models; on-site meteorological data processing; tutorial demonstrations of the SCREEN2, ISC2, TSCREEN, VISCREEN, CTDM, and CTSCREEN models; modeling approaches for hazardous/toxic air pollutants; and new modeling approaches. Students received assignments and the instructor reviewed the responses. Phone links were used for student questions and responses.

2.8.3.2 AMS/EPA Regulatory Model Improvement Committee

The AMS and 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 ISC model because of its wide use in regulatory applications. Improvements are expected in the areas of dispersion, plume rise, complex terrain, and surface-layer parameterizations.

The committee completed a preliminary version 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; a 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. The preliminary version of the model is undergoing a developmental evaluation to identify design and coding revisions that may need to be made before the model is coded in final form.

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 Forest Service (FS) signed a Memorandum of Understanding 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 protected forests and parks (Federal Class I areas). The Memorandum established an interagency work group comprised of technical staff representing NPS, FWS, FS, OAQPS, 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 the EPA modeling guideline (U.S. Environmental Protection Agency, 1992b).

During FY-1994, the work group sponsored a demonstration assessment of drafted recommendations (U.S. Environmental Protection Agency, 1993) for use while effort continues in the development of more comprehensive modeling techniques. The demonstration assessment would identify and summarize the decisions made, would record and summarize the resolution process for these decisions, and would provide a written record of the resources used to complete this effort. The objective was to learn by experience where the difficulties were in the process of conducting such an analysis and, when possible, to provide a means for resolving these difficulties. In the assessment, a case study was conducted to apply the interim modeling systems. These interim recommendations provided an approach from existing off-the-shelf-techniques to assess distant source impacts in satisfaction of the regulations associated with the EPA Prevention of Significant Deterioration program. The study was completed during the summer of 1994 and the report summarizing the experiences is being prepared. Basically, it was determined that the interim modeling systems are best implemented on a workstation computer environment to provide adequate storage and execution speed. It was also noted that the study required cooperation between several Federal and State agencies involving many case-specific decisions. This coordination was recognized to be critical to the successful completion of the analysis.

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APPENDIX A: ACRONYMS

Acid-MODES	Acid Models Operational and Diagnostic Evaluation Study
ADOM	Acid Deposition and Oxidant Model
AERMIC	AMS/EPA Regulatory Model Improvement Committee
AERMOD	Improved ISCST2 Model
AMS	American Meteorological Society
ARL	Air Resources Laboratory
ARO	Army Research Office
AQM	Air Quality Model
ASMD	Atmospheric Sciences Modeling Division
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
CHARR	Chemical Hazards of Atmospheric Releases Research
COMPDEP	COMPlex terrain DEPosition model
COMSTM	COMprehensive Sulfur Tracking Model
CPU	Central Processing Unit
CREME	Cooperative REgional Model Evaluation project
DOE	Department of Energy
EMEFS	Eulerian Model Evaluation Field Study
EMEP	European Monitoring and Evaluation Program
EPA	Environmental Protection Agency
EUROTRAC	EUROpean experiment on the TRAnsport and transformation of trace atmospheric Constituents
FDDA	Four Dimensional Data Assimilation
FIFE	First ISLSCP Field Experiment
FREDS	Flexible Regional Emissions Data System
FS	Forest Service
FTP	file transfer protocol
FWS	Fish and Wildlife Service
GCM	General Circulation Model
GEMAP	Geocoded Emission Modeling And Projection system
glc	ground level concentration
HAPEM	Hazardous Air Pollutant Exposure Model
HAPEM-MS	Hazardous Air Pollutant Exposure Model-Mobile Source
HGSYSTEM	Dispersion models for ideal gases and hydrogen fluoride
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
MCHISRS	Model ClearingHouse Information Storage and Retrieval System
MESOPUFF	MESOscale Lagrangian PUFF dispersion model
MM4/5	Mesoscale Meteorological Model - version 4/version 5
Models-3	Third generation air quality modeling system
MOHAVE	Measurement Of Haze And Visual Effects
MPP	massively parallel processor
NAAQS	National Ambient Air Quality Standards
NADP	National Acid Deposition Program
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
NDDN	National Dry Deposition Network
NESC	National Environmental Supercomputing Center (EPA)
NESCAUM	NorthEast States for Coordinated Air Use Management
NMC	National Meteorological Center
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NRC	National Research Council
NWS	National Weather Service
OAQPS	Office of Air Quality Planning and Standards (EPA)
PBL	Planetary Boundary Layer
PERF	Petroleum industry Environmental Research Forum
PM	Particulate Matter
pNEM/CO	probabililistic National Ambient Air Quality Exposure Model applied to Carbon Monoxide
PVM	Parallel Virtual Machine
QA	Quality Assurance
RADM	Regional Acid Deposition Model
RADM/EM	RADM Engineering Model
RAMS	Regional Atmospheric Modeling System
RAOB	RAdiosonde OBservations
RELMAP	REgional Lagrangian Model for Air Pollution
RMSE	Root Mean Square Error
ROM	Regional Oxidant Model
RPM	Regional Particulate Model
SAMSON	Solar And Meteorological Surface Observation Network
SARMAP	SJVAQS/AUSPEX Regional Modeling Adaptation Project
SBUV	Solar Backscatter Ultra Violet
SCRAM BBS	Support Center for Regulatory Air quality Models Bulletin Board System
SDTF	Spray Drift Task Force
SLAB	Atmospheric dispersion model for denser-than-air releases
SOS	Southern Oxidant Study
STAPPA	State and Territorial Air Pollution Program Administrators

STF	liquified gaseous fuels Spills Test Facility (DOE)
STM	Sulfate Tracking Model
SVOC	Semi-Volatile Organic Compounds
TOMS	Total Ozone Mapping Spectrometer
TSCREEN	Air dispersion screening model
TSEM	Tagged Species Engineering Model
TTN	Technology Transfer Network (OAQPS)
TVA	Tennessee Valley Authority
UAM	Urban Airshed Model
UAMMET	Urban Airshed Model METeorological module
UCFM	Unitree Central File Manager
USWRP	United States Weather Research Program
VOC	Volatile Organic Compounds
WESTAR	WEstern STates Air Resources council
WRADM	Window RADM
WTI	Waste Technology Industries

APPENDIX B: PUBLICATIONS

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APPENDIX C: PRESENTATIONS

Alapaty, K., F.S. Binkowski, and S.J. Roselle. Development and application of a windowed version of the regional acid deposition model. Presentation at the A&WMA International Conference Regional Photochemical Measurement and Modeling Studies, San Diego, CA, November 9, 1993.

Alkezweeny, A.J., J.L. Stith, F.S. Binkowski, J.E. Pleim, and J.K.S. Ching. Aircraft measurement of CO_2, O_3, water vapor, and aerosol fluxes and turbulence over Lake Michigan. Presentation at the A&WMA International Conference Regional Photochemical Measurement and Modeling Studies, San Diego, CA, November 9, 1993.

Atkinson, D.G. EPA's SCREEN2 model. Lecture via satellite to participants in the Air Pollution Technical Institute, Raleigh, NC, September 20, 1994.

Atkinson, D.G. EPA's SCRAM BBS. The WRPLOT utility program - tutorial. Lecture via satellite to participants in the Air Pollution Technical Institute, Raleigh, NC, September 20, 1994.

Bailey, D.T. Meteorological data - processors and on-site measurements. Lecture via satellite to participants in the Air Pollution Technical Institute, Raleigh, NC, September 20, 1994.

Benjey, W.G. Emission processing, Models-3, and GEMAP. Presentation at the First Models-3 Science Design Workshop, Research Triangle Park, NC, August 9, 1994.

Benjey, W.G. Emission data processing issues and status. Presentation at the Second Models-3 Science Design Workshop, Research Triangle Park, NC, September 13, 1994.

Binkowski, F.S. The role of relative humidity in the size dependent dry deposition of sulfate in an Eulerian air quality model. Presentation at the 1993 Annual Meeting of the American Association for Aerosol Research Conference, Oak Brook, Illinois, October 12, 1993.

Binkowski, F.S., and U. Shankar. The role of size dependent dry deposition of sulfate aerosol in a three-dimensional air quality model. Presentation at the U.S. EPA/A&WMA International Symposium Measurement of Toxic and Related Pollutants, Durham, NC, May 3, 1994.

Binkowski, F.S., and U. Shankar. Development of an algorithm for the interaction of a distribution of aerosol particles with cloud water for use in a three-dimensional Eulerian air quality model. Presentation at the Fourth International Aerosol Conference, Los Angeles, CA, August 31, 1994.

Briggs, G.A. Conceptual model and site meteorology for planning dense gas experiments at the STF. Presentation at the CHARR Steering Committee Meeting, Washington, DC, October 7, 1993.

Briggs, G.A. Some problems of decoupled stable boundary layers. Presentation at ARO/ARL Workshop on Turbulence and Diffusion in the Stable Boundary Layer, Tempe, AZ, January 12, 1994.

Briggs, G.A. Dense gas diffusion theory, results of the 1993 CHARR experiments, and feasibility of very stable, rough surface dense gas experiments in the field and in wind tunnels. Presentation at the CHARR/PERF Work Group Meeting for Planning of the Joint 1995 Field Experiments at DOE Nevada Spill Test Facility, Research Triangle Park, NC, July 7, 1994.

Bullock, O.R., Jr. Evaluation of MM4/FDDA simulations using independent observations of wind, temperature, and humidity. Presentation at the MM5 Mesoscale Modeling Systems User's Workshop, National Center for Atmospheric Research, Boulder, CO, October 28, 1993.

Byun, D.W. Models-3 air quality model prototype science concept development. Presentation at the A&WMA International Conference Regional Photochemical Measurement and Modeling Studies, San Diego, CA, November 10, 1993.

Byun, D.W. Influence of the vertical resolution of a regional model in the prediction of diurnal ozone concentration. Presentation at the A&WMA International Conference Regional Photochemical Measurement and Modeling Studies, San Diego, CA, November 11, 1993.

Byun, D.W. U.S. EPA's Models-3 air quality model development project. Presentation at Special Seminar on the Direction of Air Quality Modeling Research, Kangweon University, Chuncheon, Korea, July 13, 1994.

Chiaramonti, D. (Energetics Department, University of Florence, Italy). An Eulerian approach to atmospheric flows in complex orography: numerical simulation of the RUSVAL experiment. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, June 27, 1994.

Ching, J.K.S. Modeling photochemical reaction products. Panel presentation at the A&WMA International Conference Regional Photochemical Air Quality Measurement and Modeling Studies, San Diego, CA, November 10, 1993.

Ching, J.K.S. U.S. EPA air and water quality modeling: a visual feast of environmental modeling simulations. Presentation at EUROTRAC 1994 Symposium, Garmisch-Partenkirchen, Germany, April 12, 1994.

Ching, J.K.S. Air quality modeling and forecast with case study. Presentation at the 1994 International Symposium on the Development of the Environmental Monitoring Program and Index System, Taipei, Taiwan, June 1, 1994.

Coats, C., and D.W. Byun. Model engineering concepts for air quality models in an integrated environmental modeling system. Presentation at the A&WMA International Conference Regional Photochemical Measurement and Modeling Studies, San Diego, CA, November 10, 1993.

Dennis, R.L. Regulatory and assessment modeling. Presentation at NOAA NMC/ARL Meeting on Modeling Research Directions, Washington DC, October 18, 1993.

Dennis, R.L. RADM evaluation results related to photochemistry. Seminar presented at the NOAA Aeronomy Laboratory, Boulder, CO, October 20, 1993.

Dennis, R.L. EPA's high performance computing program. Presentation at the Research Consortium Executive Conference on Federal High Performance Computing and Communications Program, Fairfax, VA, November 3, 1993.

Dennis, R.L. The next generation of integrated air quality modeling: EPA's Models-3. Presentation at the A&WMA International Conference Regional Photochemical Measurements and Modeling Studies, San Diego, CA, November 8, 1993.

Dennis, R.L. The linking of RADM to water quality and watershed models. Presentation at the Watershed, Estuarine, and Large Lakes Modeling Workshop, Bay City, MI, April 19, 1994.

Dennis, R.L. EPA's next generation modeling system: Models-3. Seminar presented at the California Institute of Technology, Pasadena, CA, May 11, 1994.

Dennis, R.L. On the coupled use of photochemical grid models and observation-based approaches. Presentation at the Fourth US/FRG/EC Workshop on Photochemical Ozone Problem and Its Control: On Urban, Regional, and Global Scale, Charleston, SC, June 14, 1994.

Dennis, R.L., and J.E. Pleim. Comparison of modeled nitrogen chemistry with measurements in the mixed layer. Presentation at the A&WMA International Conference Regional Photochemical Air Quality Measurement and Modeling Studies, San Diego, CA, November 11, 1993.

Edgerton, E., and J.F. Clarke. Ozone deposition across the eastern United States. Presentation at the A&WMA International Conference Regional Photochemical Measurement and Modeling Studies, San Diego, CA, November 9, 1993.

Gillani, N.V., W. White, C. Spicer, and J.K.S. Ching. Reconciliation of a reactive urban emissions and ambient concentrations: approaches and assessment. Presentation at the A&WMA International Conference Regional Photochemical Measurement and Modeling Studies, San Diego, CA, November 12, 1993.

Gillette, D.A. Preliminary results of the Lake Owens Dust Experiment. Presentation at Annual Meeting of US/Russian Working Group VIII, Ashville, NC, October 25, 1993.

Gillette, D.A. The fetch effect in wind erosion. Seminar presented at the Department of Geology, Duke University, Durham, NC, November 9, 1993.

Gillette, D.A. Owens Lake surface crust dynamics. Presentation to the Owens Lake Advisory Group, Independence, CA, December 9, 1993.

Gillette, D.A. Causes of the fetch effect in wind erosion. Presentation at the Workshop on the Response of Eolian Processes to Global Change, Zzyzx, California, March 26, 1994.

Gillette, D.A. Aral Sea/Owens Lake wind erosion problems. Invited talk at NATO Advanced Research Workshop, Tashkent, Uzbekistan, May 4, 1994.

Gillette, D.A. Disaggregation of soils in wind erosion. Presentation at the Fourth Annual Friends of the Jornada Symposium, Las Cruces, NM, May 19, 1994.

Gillette, D.A., and T. Ley. North-South line of sand and dust flux measurements. Presentation at the Lake Owens Dust Experiment Workshop, Boulder, CO, July 19, 1994.

Glen, W.G., and M.P. Zelenka. Trends in CO exposure for Denver using a population based exposure model. Poster presentation at the Fourth Conference of the International Society for Exposure Analysis, Research Triangle Park, North Carolina, September 19, 1994.

Godowitch, J.M. Intercomparison results of UAM versions with different meteorological drivers. Presentation at the Fourth US/FRG/EC Workshop on Photochemical Ozone Problem and Its Control: On Urban, Regional, and Global Scale, Charleston, SC, June 14, 1994.

Godowitch, J.M. Photochemical urban airshed modeling using diagnostic and diagnostic meteorological fields. Presentation at the 87th Annual Meeting of the Air & Waste Management Association, Cincinnati, OH, June 22, 1994.

Groisman, P.Y. (State Hydrological Institute, St. Petersburg, Russia). Variability and trends of total precipitation and snowfall over the United States and Canada. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, March 14, 1994.

Hanna, A., F.S. Binkowski, and U. Shankar. Comparison of visibility algorithms using a three-dimensional Eulerian aerosol model. Presentation at the International Specialty Conference Aerosols & Atmospheric Optics: Radiation Balance and Visual Air Quality, Snowbird UT, September 27, 1994.

Hanna, A., U. Shankar, and F.S. Binkowski. Analysis of regional visibility in the United States using aerosol models. Presentation at the A&WMA International Conference Regional Photochemical Measurement and Modeling Studies, San Diego, CA, November 10, 1993.

Harada, H., and H. Mishima. (Fluid Dynamics and Heat Transfer Laboratory, Mitsubishi Heavy Industries, Nagasaki, Japan). Wind-tunnel and computer modeling of LNG dispersion. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, April 22, 1994.

Herbert, G., and D.A. Gillette. Dust and sand flux source relationships: North-South wind profiles; the fetch effect. Presentation at the Lake Owens Dust Experiment Workshop, Boulder, CO, July 19, 1994.

Hunt, J.C.R. (U.K. Meteorological Office, Bracknell, England). Developments in turbulent diffusion concepts and modeling and in European harmonization of practical dispersion models. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, February 18, 1994.

Irwin, J.S. Class I pollution impact assessments. The conference briefing to the Federal Advisory Committee Act (FACA) Subcommittee for New Source Review (NSR), July 18, 1994.

Irwin, J.S. New modeling approaches and additional modeling topics (Regional scale model - Interagency Workgroup on Air Quality Modeling). Lecture via satellite to participants in the Air Pollution Technical Institute, Raleigh, NC, September 22, 1994.

Law, P.L., P.J. Lioy, M.P. Zelenka, T. McCurdy, and A.H. Huber. Validation of the probabilistic National Ambient Air Quality Exposure Model applied to Carbon Monoxide (pNEM/CO) using Denver personal exposure monitoring data for carbon monoxide. Poster presentation at the Fourth Conference of the International Society for Exposure Analysis, Research Triangle Park, NC, September 20, (1994).

LeDuc, S.K. Technical aspects of career in physical science. Presentation at the Expanding Your Horizons Research Triangle Science & Mathematics Partnership Meeting, University of North Carolina at Chapel Hill, Chapel Hill, NC, May 10, 1994.

Lee, C.B., and D.W. Byun. Meteorological factors influencing daily maximum ozone concentration in a regional air quality model. Presentation at the A&WMA International Conference Regional Photochemical Measurement and Modeling Studies, San Diego, CA, November 12, 1993.

Lee, R.F. Introduction to ISC2 models (components and tutorial). Lecture via satellite to participants in the Air Pollution Technical Institute, Raleigh, NC, September 20, 1994.

Lee, R.F. The ISC2 models (guidance on applications). Lecture via satellite to participants in the Air Pollution Technical Institute, Raleigh, NC, September 21, 1994.

Lee, R.F. The ISC2 models (tutorial and exercises). Lecture via satellite to participants in the Air Pollution Technical Institute, Raleigh, NC, September 21, 1994.

Lee, R.F. New modeling approaches and additional modeling topics (new dispersion algorithms - AERMOD). Lecture via satellite to participants in the Air Pollution Technical Institute, Raleigh, NC, September 22, 1994.

Mathur, R., A.F. Hanna, K.L. Schere, and R.L. Dennis. On the intercomparison of two regional photochemical models. Presentation at the A&WMA International Conference Regional Photochemical Air Quality Measurement and Modeling Studies, San Diego, CA, November 12, 1993.

Nicholson, K. (Harwell Laboratories, Didcot, Oxfordshire, England). Atmospheric surface exchange of particles. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, November 1, 1993.

Novak, J.H. Technology-based decision support for air pollution assessment. Presentation at Environmental Computing & Information Technology '94, Washington, DC, June 9, 1994.

Novak, J.H. Access to the EPA High Performance Computing Resources for Environmental Decision Support. Presentation at the Decision Support Tools Workshop, Seattle, WA, June 29, 1994.

Novak, J.H. EPA's High Performance Computing and Communications program. Presentation at the 2nd International Visualization Workshop, Cleveland, OH, August 31, 1994.

Novak, J.H. EPA's High Performance Computing and Communications program and budget. Presentation to the High Performance Computing and Communications Information Subcommittee of the National Science & Technology Council, Washington, DC, September 9, 1994.

Olerud, D.T., A. Hanna, T.E. Pierce, and K.L. Schere. Sensitivity of the Regional Oxidant Model to meteorological parameters. Presentation at the A&WMA International Conference Regional Photochemical Air Quality Measurement and Modeling Studies, San Diego, CA, November 8, 1993.

Olerud, D.T., and K.L. Schere. On the calculation of near-surface air pollution concentrations using the Regional Oxidant Model. Presentation at the A&WMA International Conference Regional Photochemical Air Quality Measurement and Modeling Studies, San Diego, CA, November 10, 1993.

Perry, S.G. A simple screening technique for estimating impacts from area sources and other low-level sources. Presentation at the Annual Meeting of the USEPA Air/Superfund Coordination Committee, Raleigh, NC, February 9, 1994.

Perry, S.G. Overview of the Atmospheric Sciences Modeling Division research activities of 1993-1994. Presentation at the Annual Regional/State/ Local Modelers Workshop, Kansas City, MO, May 23, 1994.

Perry, S.G. Model development for applications to surface coal-mining operations. Presentation to the PM-10 Modeling Subcommittee at the USEPA Annual Regional Modelers Workshop, Kansas City, MO, May 26, 1994.

Perry, S.G. Technical description of the AMS/EPA Regulatory Model Improvement Committee model (AERMOD). Presentation at the USEPA Annual Regional Modelers Workshop, Kansas City, Mo, May 26, 1994.

Pierce, T.E. Refined estimates of biogenic hydrocarbon emissions for Atlanta. Presentation at the A&WMA International Conference Regional Photochemical Measurement and Modeling Studies, San Diego, CA, November 10, 1993.

Pierce, T.E. Sensitivity of the Regional Oxidant Model to an assortment of emission scenarios. Presentation at the A&WMA International Conference Regional Photochemical Measurement and Modeling Studies, San Diego, CA, November 10, 1993.

Pierce, T.E. Estimating biogenic emissions for the 1995 Nashville field study. Presentation at the Southern Oxidant Study Planning Meeting on Emission Inventories, Nashville, TN, March 25, 1994.

Pierce, T.E. Biogenic emission inventory needs for air quality simulation modeling. Presentation at the Working Group on Biogenic Emissions Research, Estes Park, CO, May 13, 1994.

Pierce, T.E. Development of the second generation of the Biogenic Emissions Inventory System (BEIS-2). Presentation at the Fourth US/FRG/EC Workshop on the Photochemical Ozone Problem and its Control: On Urban, Regional, and Global Scale, Charleston, SC, June 15, 1994.

Pierce, T.E. Incorporation of biogenic emissions and upgraded land use data in the interim operational version of Models-3. Presentation at the Workshop on Models-3, Research Triangle Park, NC, August 8, 1994.

Pierce, T.E. Development of biogenic emission inventories for State Implementation Plans. Satellite video presentation to state and regional agencies on emission inventory procedures, television studio at North Carolina State University, Raleigh, NC, August 17, 1994.

Pierce, T.E. Effect of BEIS2 on the Regional Oxidant Model. Briefing to Office of Air Quality Planning and Standards, Research Triangle Park, NC, September 21, 1994.

Pierce, T.E., K.L. Schere, and D.T. Olerud. Sensitivity of the Regional Oxidant Model to an assortment of emission tests. Presentation at the A&WMA International Conference Regional Photochemical Air Quality Measurement and Modeling Studies, San Diego, CA, November 11, 1993.

Pitchford, M.L., and M. Green. Analyses of sulfur aerosol size distributions for a 40-day period in summer 1992 at Meadview, AZ. Presentation at the International Specialty Conference Aerosols & Atmospheric Optics: Radiation Balance and Visual Air Quality, Snowbird, UT, September 27, 1994.

Pleim, J.E., F.S. Binkowski, J.K.S. Ching, and R.L. Dennis. Interpretive analysis of modeled nitrogen chemistry. Presentation at the A&WMA International Conference Regional Photochemical Air Quality Measurement and Modeling Studies, San Diego, CA, November 9, 1993.

Possiel, N.C. Impact of NO_x-oriented control strategies on ozone in the Northeast — Comparison of results for two meteorological episodes. Presentations to the ROMNET2 Emission/Control Strategy and Modeling Technical Committee, Sturbridge, MA, September 14, 1994.

Possiel, N.C. Impact of alternative regional NO_x-oriented control strategies on ozone concentrations in the Ozone Transport Region. Invited presentation at the Fall 1994 Meeting of the Ozone Transport Commission, Newport, RI, September 27, 1994.

Roselle, S.J. Predicted response of regional ozone to across-the-board reductions in anthropogenic VOC and NO_x emissions. Presentation at the Fourth US/FRG/EC Workshop on Photochemical Ozone Problem and Its Control: On Urban, Regional, and Global Scale, Charleston, SC, June 16, 1994.

Roselle, S.J. Nonhydrostatic chemical transport model. Presentation at the Second Models-3 Science Design Workshop, Research Triangle Park, NC, September 13, 1994.

Roselle, S.J. Air quality observational databases. Presentation at the Second Models-3 Science Design Workshop, Research Triangle Park, NC, September 14, 1994.

Roselle, S.J., and K.L. Schere. Modeled response of photochemical oxidants to systematic reductions in anthropogenic VOC and NO_x emissions. Presentation at the A&WMA International Conference Regional Photochemical Measurement and Modeling Studies, San Diego, CA, November 10, 1993.

Sampson, A., P. Dougherty, and E.J. Cooter. Regional variation in loblolly pine production response to climate change in the southeastern United States. Presentation at the International Society for Ecological Modelling, Knoxville, TN, August 7-11, 1994.

Schere, K.L. Comparative appraisal of different (photochemical measurement/modeling) study approaches. Panel presentation at the A&WMA International Conference Regional Photochemical Air Quality Measurement and Modeling Studies, San Diego, CA, November 9, 1993.

Schere, K.L. Planning large scale measurement and modeling studies: perspectives, accomplishments, lessons and recommendations. Panel presentation at the A&WMA International Conference Regional Photochemical Air Quality Measurement and Modeling Studies, San Diego, CA, November 11, 1993.

Schere, K.L. NARSTO overview. Presentation at the Fourth US/FRG/EC Workshop on Photochemical Ozone Problem and Its Control: On Urban, Regional, and Global Scale, Charleston, SC, June 14, 1994.

Schere, K.L. NARSTO overview. Presentation to the Ozone Transport Commission Modeling Committee, Washington, DC, August 2, 1994.

Schere, K.L. NARSTO overview. Presentation at the Standing Air Simulation Work Group Meeting, San Diego, CA, September 29, 1994.

Schiermeier, F.A. Atmospheric Characterization and Modeling Division technical assistance modeling activities for indirect exposure. Presentation at the Standing Air Simulation Work Group Meeting, Point Clear, AL, October 22, 1993.

Schiermeier, F.A. Risk assessment of WTI hazardous waste incinerator. Presentation at the Standing Air Simulation Work Group Meeting, St. Louis, MO, April 15, 1994.

Schiermeier, F.A. Opening address and plans for Working Group research activities. Presentation at the Seventeenth US/Russia Working Group Meeting on Air Pollution Modeling, Instrumentation, and Measurement Methodology, St. Petersburg, Russia, June 27, 1994.

Schiermeier, F.A. Endocrine disrupters. Seminar presented at Main Geophysical Observatory, St. Petersburg, Russia, July 1, 1994.

Schiermeier, F.A. Overview of Atmospheric Characterization and Modeling Division Research Programs. Presentation to the delegation of Office of Programs, University Corporation for Atmospheric Research, Research Triangle Park, NC, September 20, 1994.

Schwede, D.B. Overview of the COMPDEP model. Presentation at the Annual Meeting of the USEPA Air/Superfund Coordination Committee, Raleigh, NC, February 10, 1994.

Schwede, D.B. Improvements in indirect exposure assessment modeling: a model for estimating air concentrations and deposition. Presentation at the 87th Annual Meeting of the Air & Waste Management Association, Cincinnati, OH, June 23, 1994.

Shankar, U., and F.S. Binkowski. Sulfate aerosol wet deposition in a three-dimensional eulerian air quality modeling framework. Presentation at the Fourth International Aerosol Conference, Los Angeles, CA, September 5, 1994.

Snyder, W.H. Flow fields and plume downwash in the vicinity of buildings — A wind tunnel study. Invited presentation to the Department of Mechanical and Aerospace Engineering, North Carolina State University, Raleigh, NC, October 14, 1993.

Snyder, W.H. Simulation of top-down and bottom-up diffusion in a convection tank. Presentation to Review Panel of Strategic Environmental Research and Development Program, Fort Belvoir, MD, July 13, 1994.

Stout, J. (North Carolina State University, Raleigh, NC). The motion of large and heavy particles in geophysical flows. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, May 27, 1994.

Touma, J.S. Ongoing activities for indirect exposure modeling and current modeling issues. Teleconference briefing at the Superfund Incineration/ Indirect Exposure Risk Assessment Meeting, Dallas, TX, October 28, 1993.

Touma, J.S. An expert interface to implement volume V of the National Technical Guidance Document Series. Presentation at the Annual Meeting of the USEPA Air/Superfund Coordination Committee, Raleigh, NC, February 9, 1994.

Touma, J.S. Status of revised volume V - procedures for air dispersion modeling at Superfund sites, and a revised TSCREEN model. Presentation at the Annual Meeting of the USEPA Air/Superfund Coordination Committee, Raleigh, NC, February 10, 1994.

Touma, J.S. Development of new deposition algorithm. Presentation at the Annual Regional/State/Local Modelers Workshop, Kansas City, MO, May 24, 1994.

Touma, J.S. The development of the Expert Interface (ExInter) program. Presentation at the Regional Air/Superfund Coordinators Meeting, Cincinnati, OH, July 27, 1994.

Touma, J.S. A status of supplement C to the Guideline on Air Quality Models (Revised) with emphasis on the deposition algorithm. Presentation to the Regional Air/Superfund Coordinators Meeting, Cincinnati, OH, July 27, 1994.

Touma, J.S. Surface coal mine study, Clean Air Act Section 234: fugitive dust. Briefing for the Director, Technical Support Division, Office of Air Quality Planning and Standards, Research Triangle Park, NC, August 17, 1994.

Touma, J.S. Where to get information on EPA's air quality models. Presentation at the Air Toxics Clean Air Act Section 112 Implementation Workshop, Durham, NC, August 30, 1994.

Touma, J.S. Transport and dispersion of air pollutants. Lecture via satellite to participants in the Air Pollution Technical Institute, Research Triangle Park, NC, September 20, 1994.

Touma, J.S. Modeling hazardous/toxic air pollutants (modeling guidance including contingency planning). Lecture via satellite to participants in the Air Pollution Technical Institute, Raleigh, NC, September 21, 1994.

Touma, J.S. Modeling hazardous/toxic air pollutants (TSCREEN tutorial with example). Lecture via satellite to participants in the Air Pollution Technical Institute, Raleigh, NC, September 21, 1994.

Xiu, A., and J.E. Pleim. Implementation and experimentation of an advanced land-surface/PBL model in the Penn State/NCAR mesoscale model (MM4). Presentation at the A&WMA International Conference Regional Photochemical Air Quality Measurement and Modeling Studies, San Diego, CA, November 11, 1993.

Young, J.O. Gas-phase chemistry solvers in air quality models. Presentation at the Southeastern-Atlantic Section of SIAM, Winston-Salem, NC, March 26, 1994.

Young, J.O. Optimizing an air quality model's algorithms for the Cray Y-MP and the MasPar MP-1. Presentation at the 14th World Congress of the International Association for Mathematics and Computers in Simulation, Atlanta, GA, July 11, 1994.

Young, J.O. Gas-phase chemistry solvers in air quality models. Presentation at the International Federation for Information Processing, Technical Committee 2, Working Group 2.5, Raleigh, NC, October 24, 1994.

Zhang, Y.Q. (North Carolina State University, Raleigh, NC). Numerical simulation of flow and dispersion around buildings. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, October 21, 1993.

Zhang, Y.Q., A. Lansari, W.G. Glen, and J.J. Streicher. Exposure to uncombusted fuels inside a residence with an attached garage. Poster presentation at the Fourth Conference of the International Society for Exposure Analysis, Research Triangle Park, NC, September 19, 1994.

Zelenka, Michael P. Meteorology effects on potential exposures to acid aerosols. Poster presentation at the Fourth Conference of the International Society for Exposure Analysis, Research Triangle Park, NC, September 20, 1994.

APPENDIX D: WORKSHOPS

CHARR (Chemical Hazards of Atmospheric Releases Research) Steering Committee Meeting, Washington, D.C., October 6-7, 1993.

G.A. Briggs
W.B. Petersen

WEstern STates Air Resources (WESTAR) Modeling Meeting Telephone Conference Call Briefing, October 11, 1993

J.S. Irwin
R.F. Lee
D.A. Wilson

US/Russia Working Group 02.08-10 Meeting on Influence of Environmental Changes on Climate, Asheville, NC, October 24-25, 1993.

F.A. Schiermeier

NAPAP Workshop on Determining Deposition, Easton, MD, November 2-3, 1993.

R.L. Dennis

STAPPA/ALAPCO/EPA Workshop on the Emissions Inventory Improvement Program, Research Triangle Park, NC, November 16-18, 1993,

T.E. Pierce.

NorthEast States for Coordinated Air Use Management (NESCAUM), Grafton, VT, November 18-19, 1993.

J.S. Irwin

Air Directors Meeting for EPA Region 3 States, Washington, DC, November 30, 1993.

J.S. Irwin

NATO/CCMS Pilot Study Workshop on Air Pollution Transport and Diffusion Over Coastal Urban Areas, Valencia, Spain, December 2-3, 1993.

F.A. Schiermeier

WEstern STates Air Resources (WESTAR) Prevention of Significant Deterioration Increment Tracking Workshop, Denver, CO, December 8-9, 1993.

J.S. Irwin

Workshop on Planning 1994 CHARR Experiments, Desert Research Institute, Reno, NV, December 9-10, 1993.

G.A. Briggs
W.B. Petersen

ARO/ARL Workshop on Turbulence and Diffusion in the Stable Boundary Layer, Tempe, AZ, January 11-13, 1994.

G.A. Briggs

ARL Tropospheric Ozone Research Planning Workshop, Silver Spring, MD, January 18, 1994.

R.L. Dennis
K.L. Schere

U.S. Forest Service National Climate Change Scenario Task Force Meeting, Ft. Collins, CO, January 18-19, 1994.

E.J. Cooter

NADP/EPA Trends Analysis Workshop, Research Triangle Park, NC, February 9-10, 1994.

S.K. LeDuc

U.S. Forest Service Southern Global Change Program All-Hands Meeting, New Orleans, LA, March 1-2, 1994.

E.J. Cooter

Board on Atmospheric Sciences and Climate, Climate Research Committee, GEWEX (Global Energy and Water cycle EXperiment) Panel, National Academy of Sciences, Washington, DC, March 3-4, 1994.

S.K. LeDuc

Second Urban Airshed Modeling Workshop, Atlanta, Ga, March 9-11, 1994.

J.M. Godowitch

Plume-in-Grid Model Evaluation Workshop, Atlanta, GA, March 10-11, 1994.

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

Workshop on NO_x Emissions from Soils, Raleigh, NC, March 14-15, 1994.

T.E. Pierce.

Data Management Workshop at MCNC, Research Triangle Park, NC, March 15, 1994.

W.G. Benjey
D.W. Byun
J.K.S. Ching
R.L. Dennis
J.H. Novak

Expert Panel on Mercury Atmospheric Processes, Tampa, FL, March 16-18, 1994.

O.R. Bullock, Jr.

Methyl-Mercury and Human Health Workshop, Bethesda, MD, March 22-23, 1994.

J.K.S. Ching

North American Research Strategy for Tropospheric Ozone (NARSTO) Planning Workshop, Boulder, CO, April 4-6, 1994.

K.L. Schere

Quarterly Workshop of the Spray Drift Task Force, Washington, DC, April 12-13, 1994.

S.G. Perry

Watershed, Estuarine, and Large Lakes Modeling Workshop, Bay City, MI, April 18-20, 1994.

R.L. Dennis

Fourth Annual Southeast Affiliate of IAMSLIC Libraries (SAIL) Workshop, National Marine Fisheries Service, Panama City Beach, FL, May 4-6, 1994.

E.M. Poole-Kober

Workshop on Development of the North American Research Strategy for Tropospheric Ozone, Dallas, TX, May 10, 1994.

R.L. Dennis

Working Group on Biogenic Emissions Research, Estes Park, CO, May 13, 1994.

T.E. Pierce

Models-3 Status Meeting with CAMRAQ, MCNC, Research Triangle Park, NC, May 17, 1994.

W.G. Benjey
D.W. Byun
R.L. Dennis
J.H. Novak

Advanced Modeling Technology Transfer Workshop, Research Triangle Park, NC, May 17-19, 1994.

N.C. Possiel

Technology Transfer Workshop at MCNC, Research Triangle Park, NC, May 18-19, 1994.

S.K. LeDuc
J.H. Novak

Regional, State, and Local Modelers Workshop, Kansas City, MO, May 23-27, 1994.

D.T. Bailey
C.T. Coulter
J.S. Irwin
S.G. Perry
J.S. Touma

EPA Spill Test Research Planning Meeting, Research Triangle Park, NC, May 24-25, 1994.

G.A. Briggs

Eulerian Model Evaluation Field Study: Joint Meeting of the Model Evaluation Team and External Review Panel, Niagara-on-the-Lake, Ontario, May 25-27, 1994.

D.W. Byun
J.K.S. Ching
R.L. Dennis
J.E. Pleim

North American Research Strategy for Tropospheric Ozone (NARSTO) Workshop, Boulder, CO, June 6-8, 1994.

K.L. Schere

University Corporation for Atmospheric Research, NOAA Postdoctoral Program in Climate and Global Change Summer Institute, Steamboat Springs, CO, June 13-17, 1994.

S.K. LeDuc

Fourth US/FRG/EC Workshop on Photochemical Ozone Problem and Its Control: On Urban, Regional, and Global Scale, Charleston, SC, June 13-17, 1994.

D.W. Byun
J.K.S. Ching
R.L. Dennis
J.M. Godowitch
T.E. Pierce
S.J. Roselle
K.L. Schere

US/Russian Working Group 02.01-10 Meeting on Air Pollution Modeling, Instrumentation, and Measurement Methodology, St. Petersburg, Russia, June 27-July 1, 1994.

F.A. Schiermeier

Agricultural Pesticide Spray Drift Task Force Airblast Drift Peer-Review Workshop, Washington, D.C., June 28-29, 1994.

S.G. Perry
W.B. Petersen

Workshop on Atmospheric Loadings to Coastal Areas: Resolving Existing Uncertainties, Baltimore, MD, June 29-30, 1994.

R.L. Dennis

CHARR/PERF Work Group Meeting for Planning of the Joint 1995 Field Experiments at DOE Nevada Spill Test Facility, Research Triangle Park, NC, July 7, 1994.

G.A. Briggs
W.B. Petersen
W.H. Snyder

U.S.EPA/U.S. Agricultural Research Service/Spray Drift Task Force Joint Workshop on Agricultural Pesticide Spray Drift Issues, Research Triangle Park, NC, July 20, 1994.

S.G. Perry

Office of Federal Coordinator for Meteorology, National Agenda Panel Meeting, Rockville, MD, July 27, 1994.

S.K. LeDuc

First Models-3 Science Design Workshop, Research Triangle Park, NC, August 8-11, 1994.

W.G. Benjey
F.S. Binkowski
O.R. Bullock, Jr.
D.W. Byun
J.K.S. Ching
R.L. Dennis
J.M. Godowitch
J.H. Novak
T.E. Pierce
J.E. Pleim
S.J. Roselle
J.O. Young

National Center for Atmospheric Research/GEWEX (Global Energy and Water Cycle Experiment) Cloud System Study Workshop on Boundary Layer Clouds, Boulder, CO, August 16-18, 1994.

J.E. Pleim

Society of Environmental Toxicology and Chemistry Ecological Risk Assessment Modeling Systems Workshop, Pellston, MI, August 23-28, 1994.

J.S. Irwin

Air Toxics Clean Air Act Section 112 Implementation Workshop, Durham, NC, August 29-31, 1994.

J.S. Touma

Grand Canyon Visibility Transport Commission, Meteorology Subcommittee, Flagstaff, AZ, August 30-31, 1994.

S.K. LeDuc

Geocoded Emission Modeling and Projection (GEMAP) System Advanced Training Workshop, Research Triangle Park, NC, August 29-September 1, 1994.

W.G. Benjey
A.R. Torian

Second Models-3 Science Design Workshop, Research Triangle Park, NC, September 13-14, 1994.

W.G. Benjey
F.S. Binkowski
O.R. Bullock, Jr.
D.W. Byun
J.K.S. Ching
R.L. Dennis
J.M. Godowitch
S.K. LeDuc
J.H. Novak
T.E. Pierce
J.E. Pleim
S.J. Roselle
J.O. Young

National Institute of Statistical Science Workshop on Spatial Statistics, University of North Carolina at Chapel Hill, Chapel Hill, NC, September 21, 1994.

S.K. LeDuc

APPENDIX E: VISITING SCIENTISTS

1. Ms. Pamela Blakley
   U.S. EPA Region 5
   Chicago, IL

Ms. Blakley visited the Fluid Modeling Facility on June 2, 1994, to discuss the wind tunnel modeling study being performed to assess the impact potential for terrain induced downwash at the Waste Technologies Industries incinerator in East Liverpool, OH.

2. Dr. R.E. Britter
   Department of Engineering
   University of Cambridge
   Cambridge, England

Dr. Britter spent three days at the Fluid Modeling Facility discussing problems of mutual interest in the area of dense-gas modeling and met with Division personnel to discuss the dense-gas experiments planned for the CHARR and PERF programs and related work in Europe.

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

Dr. Dayan, visiting from August 16, 1993 through July 31, 1994, developed and demonstrated a method of integrating air pollution model output with monitoring data for exposure assessment.

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

Dr. Genikhovich spent his second 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 Fluid Modeling Facility staff continued development and evaluation of a model to handle the downwash of pollutants from sources in the vicinity of buildings.

5. Mr. Makoto Harada and Mr. Mishima Hiroyuki
   Mitsubishi Heavy Industries Ltd.
   Nagasaki, Japan

Mr. Harada and Mr. Hiroyuki visited the Division on April 22, 1994, to discuss complex terrain modeling and dense-gas experiments (CHARR program).

6. Gary Herbert
Climate Monitoring and Diagnostics Laboratory
National Oceanic and Atmospheric Administration
Boulder, CO

Mr. Herbert spent two days at the Fluid Modeling Facility in August 1994, discussing logistics and strategies to conduct measurements of dust fluxes at Owens Lake, California.

7. 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 UAM and RADM. He implemented windowing capability in 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 preprocessor codes to run on a workstation. Dr. Lee applied the model to the Far East and used window ing capability to study local effects on urban and regional air pollution before returning to Kangweon National University.

8. Dr. David Miller
Department of Natural Resources Management
University of Connecticut
Storrs, CT

Dr. Miller spent August 23, 1994, reviewing recent model developments in canopy edge flow and demonstrating his PC-based canopy model. He is working with the Division in a cooperative agreement to advance the understanding of pesticide spray drift from orchard airblast applications. Dr. Miller is nationally recognized for his work in forest meteorology and the effects on flow and turbulence near the edge of plant canopies.

9. Dr. Bob Olson and Dr. Dennis Garvey
U.S. Army Research Laboratory
White Sands Missile Range, NM

Drs. Bob Olson and Dennis Garvey visited the Division on September 7, 1994, to discuss open burn/open detonation modeling work. They have been involved in similar work for the Army.

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

Dr. Selvam spent May to August 1994, with the Division. He conducted numerical simulation modeling research of wind and pollution in building microenvironments. Dr. Selvam was a NOAA/NRC Research Fellow.

11. Dr. Jeffery C. Weil
National Center for Atmospheric Research
Boulder, CO

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

Drs. Weil and Venkatram spent two 3-day periods (November 8-10, 1993; June 6-8,1994) in Research Triangle Park, NC, working with the AMS/EPA Regulatory Model Improvement Committee (AERMIC) on its continuing efforts to develop an enhanced model for applications presently modeled with the Industrial Source Complex Model.

APPENDIX F: ATMOSPHERIC SCIENCES MODELING DIVISION STAFF FY-1994

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) (until January 1994)
Dr. Robin L. Dennis, Physical Scientist
Dr. Basil Dimitriades (EPA), Physical Scientist
Dr. Peter L. Finkelstein, Physical Scientist
Bruce W. Gay, Jr. (EPA), Supv. Chemist
Dr. Marc L. Pitchford, Meteorologist (Las Vegas, NV) (until October 1994)
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 (until February 1994)
Dr. John F. Clarke, Meteorologist
James M. Godowitch, Meteorologist
Dr. Jonathan A. Pleim, Physical Scientist
Shawn J. Roselle, Meteorologist
Kenneth L. Schere, Meteorologist
Kelly M. Davis, Secretary

Fluid Modeling Branch

Dr. William H. Snyder, Supv. Physical Scientist, Chief
Dr. Dale A. Gillette, Physical Scientist
Lewis A. Knight, Electronics Technician
Robert E. Lawson, Jr., Physical Scientist
Roger S. Thompson (PHS), Environmental Engineer
Pamela V. Bagley, Secretary

Modeling Systems Analysis Branch

Joan H. Novak, Supv. Computer Specialist, Chief
Dr. William G. Benjey, Physical Scientist
Dale H. Coventry, Computer Specialist (until May 1994)
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 (until September 1994)

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) (until January 1994)
Donna B. Schwede, Physical Scientist
Dr. Steven G. Perry, Meteorologist
Katherine A. Scott, Secretary (since April 1994)

Human Exposure Modeling Branch

Dr. Alan H. Huber, Supv. Physical Scientist, Chief
Gennaro H. Crescenti, Physical Scientist
John J. Streicher, Physical Scientist
Brian D. Templeman, Meteorologist (Boulder, CO) (until September 1994)
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
Dennis Doll (EPA), Environmental Scientist
Norman C. Possiel, Jr., Meteorologist
Jawad S. Touma, Meteorologist
Dean A. Wilson, Meteorologist (until May 1994)
Brenda P. Cannady (EPA), Secretary