NOAA Technical Memorandum ERL ARL-213

FISCAL YEAR 1995 SUMMARY REPORT OF THE NOAA ATMOSPHERIC SCIENCES MODELING DIVISION SUPPORT TO THE U.S. ENVIRONMENTAL PROTECTION AGENCY

Evelyn M. Poole-Kober
Herbert J. Viebrock
(Editors)

Air Resources Laboratory
Silver Spring, Maryland
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noaa NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION / Environmental Research Laboratories

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UNITED STATES DEPARTMENT OF COMMERCE

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Secretary

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

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NOTICE

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PREFACE

This document summarizes the Fiscal Year 1995 research and operational activities of the Atmospheric Sciences Modeling Division (ASMD), Air Resources Laboratory, working under Interagency Agreements EPA DW13937039, DW13935457, and DW13937252 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 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 National Exposure Research Laboratory and other EPA groups. With a staff consisting of NOAA, EPA, and Public Health Service Commissioned Corps personnel, ASMD also 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. The primary groups within ASMD are the Atmospheric Model Development Branch, Fluid Modeling Branch, Modeling Systems Analysis Branch, Applied Modeling Research Branch, and Air Policy Support Branch. The staff is listed in Appendix G. 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), U.S. Environmental Protection Agency, Research Triangle Park, NC 27711.

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FISCAL YEAR 1995 SUMMARY REPORT OF THE NOAA ATMOSPHERIC SCIENCES MODELING DIVISION SUPPORT TO THE U.S. ENVIRONMENTAL PROTECTION AGENCY

ABSTRACT. During Fiscal Year 1995, the Atmospheric Sciences Modeling Division provided meteorological research and operational support to the U.S. Environmental Protection Agency. Operational activities consisted of the application of dispersion models, conduct of dispersion studies and model evaluations, and provision of advice and guidance. The research efforts emphasized the development and evaluation of air quality models using numerical and physical techniques supported by field studies, and conduct of studies under the High Performance Computing and Communications program. These efforts included the continued evaluation and application of ROM and RADM; development of Models-3; development of the RELMAP Mercury Model and RELMAP Dioxin Model; conduct of dense-gas dispersion and dry-deposition field studies; conduct of water channel studies of buoyant thermals in the atmosphere; data analysis of particle resuspension mass transport variability; examination of meteorology and acid aerosol concentration relationships; and statistical analysis of the global distribution of total column ozone.

1. INTRODUCTION

In Fiscal Year 1995, 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 developing multi-media model frameworks in a high computing and communications environment. 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 2.5 outline the Division research activities in support of the short- and long-term needs of the EPA and the environmental community. Section 2.6 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.

2.1.1 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.

2.1.1.1 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 (Gryning and Millan, 1995). The Division Director will serve as conference chairman of the 21st NATO/CCMS International Technical Meeting to be held in Baltimore, Maryland, during November 6-10, 1995; the proceedings will be published in 1996 by Plenum Press. The NATO/CCMS Scientific Committee selected Clermont-Ferrand, France, as the site for the 22nd International Technical Meeting to be held during June 1997.

2.1.1.2 Coastal Urban Air Pollution Study

The Division Director serves as the United States representative on the International Oversight Committee for the NATO/CCMS Pilot Study on Urban Pollutant Dispersion near Coastal Areas. This pilot study, sponsored by Greece, originated in a workshop held in Athens during February 1992. The purpose is to understand the causes of high air pollution episodes in coastal urban areas and to devise strategies to mitigate pollution problems caused by vehicular and industrial emissions in these areas. A NATO/CCMS advanced research workshop was held during May 1993 to design a reference experiment in a coastal urban area to collect relevant ambient measurements and emissions for use in evaluation of existing urban dispersion models and understanding the atmospheric boundary layer at the interface of land and water. A workshop summary was published (Melas *et al.*, 1995). The final meeting of the pilot study will be held in Baltimore, Maryland, during November 1995.

2.1.2 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-1995, interaction was maintained through correspondence and exchange of research findings.

2.1.3 United States/Russia Joint Environmental Committee

The Division Director serves as the United States Co-Chairman of the United States/Russia Working Group 02.01-10 on Air Pollution Modeling, Instrumentation, and Measurement Methodology, and as Co-Leader of the United States/Russia Project 02.01-11 on Air Pollution Modeling and Standard Setting. The purpose of the 1972 Nixon-Podgorny Agreement forming the US/USSR Joint Committee on Cooperation in the Field of Environmental Protection was 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. Activities under this agreement were extended to also comply with the 1993 Gore-Chernomyrdin Agreement forming the United States/Russia Commission on Economic and Technological Cooperation. There are four Projects under Working Group 02.01-10:

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

Progress under this Working Group continued during FY-1995. Activities included a July 1995 Working Group meeting at the Main Geophysical Observatory in St. Petersburg, Russia, 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 Characterization Research Division 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

United States and Russian complex terrain models (Genikhovich and Schiermeier, 1995).

2.1.4 Meteorological Coordinating Committees

2.1.4.1 Federal Meteorological Committee

The Division Director serves as the agency representative on the Federal Committee for Meteorological Services and Supporting Research (FCMSSR). The Committee is composed of representatives from 14 Federal government agencies and is chaired by the Under Secretary of Commerce for Oceans and Atmosphere, who is also the NOAA Administrator. FCMSSR was established in 1964 with high-level agency representation to provide policy guidance to the Federal Coordinator for Meteorology, and to resolve agency differences that arise during coordination of meteorological activities and the preparation of Federal plans in general.

2.1.4.2 Interdepartmental Meteorological Committee

The Division Director also serves as the agency representative on the Interdepartmental Committee for Meteorological Services and Supporting Research (ICMSSR). The Committee, composed of representatives from 14 Federal government agencies, was formed in 1964 under Public Law 87-843 and OMB Circular A-62 to provide the Executive Branch and the Congress with a coordinated, multi-agency plan for government meteorological services and for those research and development programs that directly support and improve these services. The Committee prepared the annual *Federal Plan for Meteorological Services and Supporting Research* (U.S. Department of Commerce, 1995). A Division scientist serves on the ICMSSR Working Group for Atmospheric Transport and Diffusion. Four other Division scientists served on an ICMSSR panel to develop a *National Agenda for Meteorological Services and Supporting Research* (U.S. Department of Commerce, in preparation).

2.1.5 United States Weather Research Program

The Division Director serves as the 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.

2.1.6 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.

2.1.7 OSTP/NSTC Committee on Information and Communications

The Division Director serves as the alternate agency member to the Committee on Information and Communications (CIC), of the National Science and Technology Council, Office of Science and Technology Policy. The mission of the Committee is to "accelerate the evolution of existing technology and nurture innovation that will enable universal, accessible, and affordable application of information technology to enable America's economic and national security in the 21st century" (U.S. Office of Science and Technology Policy, 1995). The Committee serves as the National Coordination Office for the High Performance Computing and Communications (HPCC) program in which this Division has a major role.

The CIC has prepared a strategic implementation plan that outlines six strategic focus areas to guide Federal research and technology investments in information and communications (U.S. Office of Science and Technology Policy, 1995). These areas are global-scale information infrastructure technologies; high performance/scalable systems; high confidence systems; virtual environments; user-centered interfaces and tools; and human resources and education.

2.1.8 Standing Air Simulation Work Group

The Division Director serves as the Agency Office of Research and Development (ORD) representative to the Standing Air Simulation Work Group (SASWG), which serves as a forum for issues relating to air quality simulation modeling of criteria and other air pollutants from point, area, and mobile sources. Its scope encompasses policies, procedures, programs, model development, and model application. The work group fosters consensus between the agency and State and local air pollution control programs through semi-annual meetings of members representing all levels of enforcement.

2.1.9 AMS Glossary of Meteorology

The Division is participating in multi-agency funding of updating and revising the Glossary of Meteorology by the American Meteorological Society (AMS). Under sponsorship of the National Science Foundation (NSF), AMS will review the existing entries in the 1959 edition of the Glossary and revise and update the listings resulting in a potential doubling of the number of entries. The new Glossary will be published in both print and CD-ROM format.

2.1.10 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 such programs with EMEP as the modeling studies of the Modeling Synthesizing Center West (MSC-W) at the Norwegian Meteorological Institute in Oslo, Norway.

2.1.11 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 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-1995 emphasized bringing the retrospective assessment to completion and developing a quick look at the prospective. Regarding the retrospective assessment, work targeted transfer to effects researchers 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). Regarding the prospective assessment, available model predictions from previous studies were supplied for the quick-look analyses.

2.1.12 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 in determining 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-1995 focused on development of a 20-km resolution modeling domain that covers most of the Chesapeake Bay airshed, with GIS links to the watershed model, and creation of RADM predictions of the estimated effect potential oxidant-related controls and feasible controls due to the 1990 CAAA would have on the nitrogen deposition to the Chesapeake watershed basins and to the Bay.

2.1.13 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 completion of a conceptual design for a CAMRAQ Comprehensive Modeling System that will allow interoperability with EPA's Third Generation Modeling System, Models-3, as well as explore the development of community standards.

2.1.14 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. RADM application studies in support of the EPA Congressionally-mandated reports helped to evaluate the effectiveness of the acidic deposition control program of CAAA Title IV and helped determine the reduction in emissions that are associated with deposition rates needed to prevent adverse effects.

2.1.15 North American Research Strategy for Tropospheric Ozone

The North American Research Strategy for Tropospheric Ozone (NARSTO) is a research program with the goal of addressing outstanding issues regarding the understanding and management of tropospheric ozone and aimed at coordinating the collaborative research among all North American organizations performing and sponsoring tropospheric ozone studies. Sponsors include the private sector and State, Provincial and Federal governments of the United States, Canada, and Mexico. NARSTO was formally established in FY-1995. The Subcommittee on Air Quality Research of the Committee on Environment and Natural Resources (CENR) within the National Science and Technology Council will facilitate the coordination of NARSTO Federal research activities. Four technical teams have been established: Analysis and Assessment; Observations; Modeling and Chemistry; and Emissions. The first major goal of NARSTO is to produce in 1998 a scientific assessment of the state of tropospheric ozone science.

During FY-1995, a Division scientist was chosen to co-chair the NARSTO Modeling and Chemistry Team. Work in FY-1995 saw the formation of the Modeling and Chemistry Team and development of a draft implementation plan for the 1995 NARSTO Planning Workshop. The draft implementation plan proposed near-term activities for the modeling and chemistry team with a strong emphasis on providing analyses in support of the NARSTO 1998 assessment.

2.1.16 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 was also a member of the 1995 Nashville/Middle Tennessee Ozone Study Planning Team. An experimental design was produced in FY-1995 (Tennessee Valley Authority, 1995). The Division scientist was a mentor for one of the aircraft experiments in the design plan and participated in the on-site aircraft experiment planning during the 1995 summer field campaign.

2.1.17 International Task Force on Forecasting Environmental Change

A Division Scientist is a member of the International Task Force on Forecasting Environmental Change, addressing the methodological and philosophical problems of forecasting under the expectation of significant structural changes in the behavior of physical, chemical or biological systems. The second of three planned workshops was held at the International Institute for Applied Systems Analysis, Laxenburg, Austria, in July 1994, and a concept and outline of a monograph was developed. Work is now progressing on individual chapters for the monograph to prepare for the third workshop in FY-1996.

2.1.18 RADM Application Studies

Efforts during FY-1995 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 and given high priority are (1) the feasibility of deposition standards; and (2) the impact on deposition of trading NO_x emission reductions for SO_2 allocations. RADM applications supported an EPA report to the Congress (U.S. Environmental Protection Agency, in preparation). This report was reviewed by EPA's Science Advisory Board and received extensive public comment. It will be completed and released to the Congress and public in October 1995.

Other applications are in progress, principally for the Chesapeake Bay coastal estuary. The EPA Region 3 Office and the Chesapeake Bay Program Office need nitrogen deposition and source attribution information to address the atmospheric component of loading of nitrogen to the Chesapeake Bay. Estimates of the airshed affecting the Bay were completed and reviewed. In FY-1995, a 20-km version of RADM, which more accurately depicts deposition gradients and deposition to the water surfaces of the Bay, was adapted for Chesapeake Bay applications and a linkage to the watershed model was established. Using the 20-km RADM, estimates of the nitrogen deposition reductions that would be expected from ozone-driven regional and national nitrogen oxide emission reductions possible under the 1990 CAAA were developed and made available to the Chesapeake Bay Program's water quality model. This work is to provide technical input to discussions in 1997 regarding renewal of the Bay Agreement by the Bay States and EPA. A RADM study was initiated during FY-1995 to estimate source region responsibility for the nitrogen deposition to the different water basins of the Bay as part of a cost analysis of air controls relative to their ability to reduce nitrogen load to the Bay.

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/resuspension of atmospheric pollutants on local, urban, and regional scales. These are comprehensive air quality modeling systems that incorporate state-of-science formulations describing physical and chemical processes.

2.2.1 Regional Acid Deposition Studies

Studies to understand model bias due to the limited horizontal and vertical grid resolution of the Regional Acid Deposition Model (RADM) 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 the PBL to predict surface deposition fluxes correctly (Byun and Dennis, 1995).

The hypothesis that increased resolution can reduce the biases in the model using 15- and 30-layer versions of RADM was examined. In general, the 15-layer model results provide similar geographical patterns as the 30-layer model, but the former shows smaller dynamic range of diurnal ozone variations. The 30-layer model predicts higher daily maximum ozone and lower daily minimum ozone than the 15-layer model; thus, reducing model biases in general in rural cells. The lower daily minimum ozone in a model with higher vertical resolution is expected because the NO_x emissions intensity into the lowest model layer nearly doubles; thus, enhancing the NO-O_3 titration process at night. The increased daily maximum is caused by the higher NO_x that ultimately leads to more O_3 production downwind of the sources. To understand the nonlinear response of the photochemical ozone production in more detail, an in-depth study with the integrated reaction rates and mass budget analyses is underway. The findings should help modelers in setting up an Eulerian air quality model at optimal vertical resolution, considering both scientific accuracy and computational efficiency.

2.2.2 Dry Deposition Studies

The dry deposition measurement system was deployed to two field sites during the 1995 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 set of meteorological, vegetation, and chemical measurements to support modeling activities, micro-meteorological research activities, and quality assurance (QA).

The system was deployed at the Sand Mountain experimental farm (pasture grass) in Alabama during the spring and at Keysburg (soybean crop) in Kentucky during the summer and fall, collecting over 3 gigabytes of data over a 7-month period. Initial data evaluation showed excellent performance of the system at both sites. The Keysburg site was part of the Southern Oxidant Study.

The operation at the Keysburg site covers the complete growth cycle of a soybean crop from germination to harvest. The reaction of the Bowen ratio and ozone flux to plant growth is shown in Figure 1 by the leaf area index (LAI) and drought period. The data will be used to evaluate the inferential dry deposition model and the RADM dry deposition module. During 1996, the system will be deployed at sites in northern Pennsylvania as part of the NARSTO-NorthEast study, and at a forest site in North Carolina.

2.2.3 Meteorological Modeling Studies

2.2.3.1 Mesoscale Meteorology Modeling for Air Quality Applications

The Penn State/NCAR Mesoscale Model has continued to be the primary tool for providing meteorological input data for air quality modeling studies, with generation 4 (MM4) being used in concert with RADM. Recent refinements to this modeling system include the incorporation of the Kain-Fritsch deep convection cloud model and the Betts-Miller shallow convection cloud model. Also, an additional output file containing many two-dimensional fields (e.g. sensible and latent heat flux, PBL height, cloud cover, etc...) is routinely produced for analysis and use in air quality models. A new cloud cover algorithm was developed and implemented, which restricts the tendency of the model to produce overcast conditions in afternoon convective boundary layers. The effects of four-dimensional data-assimilation (FDDA) of water vapor mixing ratio on cloud cover was also examined. It was determined that surface and boundary layer nudging of mixing ratio tended to result in overestimation of PBL mixing ratio. This had the effect of greatly overestimating afternoon cloudiness. Thus, this problem was corrected through both the implementation of a new cloud cover algorithm and by not using FDDA of mixing ratio within the PBL. Hopefully, any loss of responsiveness to the ambient low-level moisture fields due to not using PBL moisture nudging will be made up by the

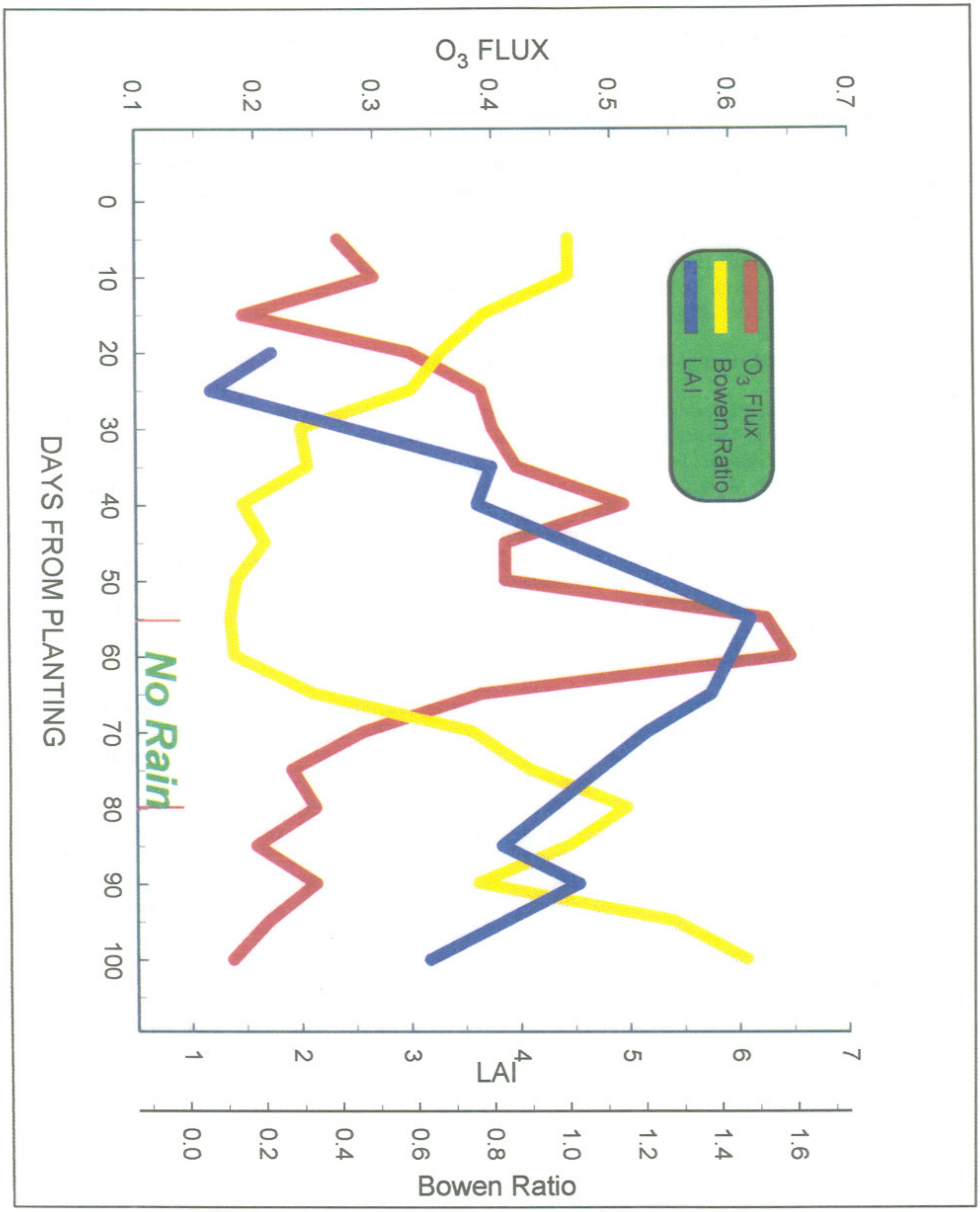

Figure 1. Variation with time of ozone flux, Bowen ratio, and leaf area index (LAI) at the Keysburg, Kentucky, site during 1995 soybean growing season.

addition of a more sophisticated surface model, which explicitly simulates soil moisture and vegetative transpiration, as described in the next section.

The new generation Mesoscale Model (MM5) is now in an operational state. The main advances over MM4 are that it can be run in a non-hydrostatic mode and that it has improved nesting capabilities allowing up to nine nested sub-domains. Both of these upgrades are essential for extending modeling down to urban scales. Therefore, current and future meteorology modeling for air quality applications will mainly involve MM5. The modifications to MM4 described above and in the next section apply equally well to MM5 since the PBL, FDDA, and cloud cover portions of the model were essentially unchanged in the transition from MM4 to MM5.

2.2.3.2 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 Asymmetric Convective Model (ACM), which was originally 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. Pleim and Xiu (1995) described an evaluation study using a one-dimensional prototype applied to several studies, the Wangara Experiment (Clarke et. al., 1971), First ISLSCP Field Experiment (FIFE) 1987, and FIFE 1989.

Refinement of the surface model continued and involved changes to several of the resistance parameterizations to be more consistent with published modeling techniques and laboratory studies. Also, advanced FDDA techniques for indirect nudging of soil moisture were developed and implemented. The surface/PBL model with soil moisture nudging was incorporated into the MM4, replacing the existing high resolution PBL model. New techniques were developed for gridding and aggregating vegetation and land-use related parameters needed by the surface model. The resulting modified MM4 system was tested through comparison with surface flux and PBL observations measured by the dry-deposition measurement system at Bondville, Illinois, during the summer of 1994. Modeled dry-deposition velocities were also compared to measurements made at this site (see Section 2.2.7.5). These comparison studies were reported by Pleim *et al.* (1995). The surface and PBL modifications are being incorporated into the MM5. Testing and evaluation of these modeling techniques will continue through comparison with other field experiments, particularly the 1995 Keysburg, Kentucky, field experiment.

2.2.3.3 Dynamic Meteorological Modeling on Urban-Scale Domains

A hydrostatic, mesoscale meteorological model (MMM) (Ulrickson and Mass, 1990), which simulates the evolution of the three-dimensional (3-D) flow, thermal, and moisture fields generated from differential surface heating/cooling and terrain irregularities, was exercised to generate meteorological parameter fields to drive photochemical grid-model simulations in selected fine grid domains encompassing major metropolitan areas. The dynamic MMM also exhibits a four-dimensional data-assimilation (FDDA) technique for incorporating available observed surface- and/or upper-air wind and temperature data through objectively-analyzed, weighted 3-D parameter fields into the numerical calculations (Douglas, 1992).

A bulk Richardson number approach (Pleim and Xiu, 1995) was inserted in the model to derive time-varying gridded-mixing heights, an essential input parameter for the photochemical grid-model simulations. The approach utilizes the modeled wind and temperature profiles to derive the hourly mixing height fields over the entire diurnal cycle. Hourly vertical eddy diffusivity coefficient fields are also generated from the MMM simulations for use in photochemical modeling.

Godowitch and Vukovich (1994) described the results of dynamically generated data sets and diagnostically created meteorological inputs employed in a series of simulations of a revised version of the Urban Airshed Model (UAM). Further cooperative work was performed to assess the impact on the wind fields by the FDDA technique with different temporal and spatial densities of observations (Uno, 1995). In addition, model simulations are planned with a refined version, which allows for the specification of spatial fields of the surface geophysical parameters to provide a better representation of various land use subsurface features in the model. Results of this effort will be reported.

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; thereby, serving as a basis for developing regional emission control policies for attaining the primary ozone standard in the most cost-effective way. FY-1995 was a transitional year for ROM research, as development activities for the multi-scale Models-3 increased. Eventually, Models-3 will replace ROM as the primary research model for regional and urban ozone studies. ROM research activities this year emphasized model intercomparison with RADM and evaluation.

2.2.4.2 Development of Wind Fields for ROM

A project comparing ROM predictions using both diagnostic and prognostic meteorological drivers was completed. A journal article describing the results was published (Alapaty *et al.*, 1995). The hourly profiles of data from each vertical column of the MM4 prognostic model 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.

2.2.4.3 Development and Evaluation of a Refined Urban Airshed Model

The research and evaluation effort continued with a revised version of the Urban Airshed Model (UAM), an Eulerian photochemical grid model. The refined UAM exhibits scientific upgrades, which include a more recent 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 described by Godowitch and Vukovich (1994).

In support of the plume-in-grid effort, simulations of UAM and a Lagrangian reactive plume model (LRPM) are underway with NO_x emissions from a single major point source. Using UAM, a range of grid cell sizes from 2 km to 30 km is being employed within a domain to investigate the impact of grid resolution on the maximum ozone and other oxidants generated downwind of the point source. Common inputs are being applied to both models to allow for a comparison of the results. Preliminary results indicate a broad plume and lower-peak ozone within the downwind plume for the coarser grid sizes due to the initial overdilution of the point emissions. With the finer grid sizes of 2 or 4 km, the evolution of ozone in the plume was captured rather well with the near-source ozone deficit becoming an ozone bulge downwind. A comparison revealed a lower-peak ozone concentration in the LRPM simulations. Further work is planned to examine the roles of the dispersion techniques in these modeling approaches on photochemical species.

2.2.4.4 ROM Matrix of Emission Reduction Scenarios

Work to compare various combinations of anthropogenic NO_x and VOC emission reductions concluded in FY-1995. A series of model simulations was described by 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 between the 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 buildup 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 buildup of regional scale O_3.

2.2.5 Aerosol Modeling Program

The objectives of this effort are to develop, enhance, and evaluate scientifically-credible atmospheric modeling systems that are capable of addressing environmental issues associated with aerosols, and that incorporate all the known major physical and chemical processes affecting the concentration distribution, chemical composition, and physical characteristics of atmospheric aerosols. Processes modeled include emissions, formation, transport, chemistry, and removal on both urban and regional scales. This program provides assistance in the form of modeling support to and tools for activities on promulgation of primary and secondary air quality standards for fine particles to protect human health (acid aerosols) and welfare (visibility and material damage).

In other applications, particle models will be adapted to investigate the transport and fate of semi-volatile toxic compounds. The development of Eulerian and Lagrangian framework models will incorporate various levels of sophistication of aerosol chemistry and dynamics. In addition, either coupled urban and regional scale models or window and nested regional scale models will provide relative loadings between urban and regional sources. Modeling particulates will be an integral component of the Models-3 air quality modeling system.

2.2.5.1 Regional Particulate Modeling

The Regional Particulate Model (RPM) is an expansion of RADM. The added capabilities include aerosol chemistry and size distributions. Two size ranges are considered (Whitby, 1978); the size range associated with source emissions and particle production processes designated the nuclei mode, and the size range associated with longer term residence in the atmosphere designated the accumulation mode.

The effort during FY-1995 centered on increasing the number of chemical species included in the aerosol particles. To do this, all particles are assumed to have identical chemical characteristics. The additional species added to the system are nitrate and organic carbon (Binkowski and Shankar, 1995). Thus, the particles now consist of sulfate, ammonium, water, nitrate, and organic species in either an aqueous solution or a solid particle, depending on whether the relative humidity is greater or less than the relative humidity required for crystallization. The water algorithm was expanded to include ammonium nitrate. A new aerosol equilibrium code was developed, which can calculate the amount of sulfate, nitrate, ammonium, and water in the aerosol particles. This code is undergoing intensive testing. Preliminary evaluation indicates that the code is adequate for the aerosol system under study.

The issue of the uncertainty in ammonia emissions was attacked by a series of numerical experiments in which the ammonia concentrations were increased by a factor of two and the sulfur emissions reduced by a factor of one-half. Results from these experiments show that for the case of unmodified sulfur emissions and a factor of ten increase in ammonia, there was a slight increase in atmospheric sulfate due to cloud processing. This occurred because the increased ammonia decreased the acidity, which allowed aqueous oxidation mechanisms that are pH limited to produce more sulfate in the cloud water. This also resulted in a substantial increase in sulfate dry deposition. This integrated air quality modeling system contains components of RPM, including a custom visualization package that allows easy access to model output.

2.2.5.2 Aggregation Research

One of the most reliable regional air quality models for estimating changes in ambient air concentrations of fine particulate matter is RADM. However, this model requires massive human and computer resources for each policy and/or meteorological situation. The benefit analyses proposed for the CAAA of 1990 require annual time scales. Unfortunately, most Eulerian models like RADM challenge the practical limits of computer resources as well as the ability to collect the pertinent input data. As a result, application of such models to determine the long-term relationship between changing emission patterns and ambient air concentrations is limited. To circumvent this problem, an aggregation method, initially developed for acid-deposition applications, was modified and applied to a limited number of RADM simulations to provide estimates of long-term (annual) ambient air concentrations of fine particulate matter.

The aggregation method is based on the premise that at any given location ambient air concentrations of fine particulate matter are governed by a finite number of different, though recurring, meteorological regimes. If a series of concentration patterns representative of these different meteorological regimes can be identified, they can be aggregated to produce reasonable estimates of annual averages. Because the amount of fine particulate data is limited, this analysis will employ an extinction coefficient (b_{ext}) estimated from midday human observations of visible range at 73 locations throughout the eastern two-thirds of the United States for the period 1979-1990. The analysis will examine the statistical significance of the differences in b_{ext} between these meteorological categories and determine whether such an approach will be successful for the aggregation of fine particulate simulations.

2.2.5.3 Toxics Air-Aerosol 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 (Ching et al., accepted for publication) is being developed to predict wet and dry deposition of airborne semi-volatile organic toxic compounds (VOCs) applicable on a regional scale.

An initial application of this model for toxic compound exposure assessment was planned using the herbicide atrazine as the modeled pollutant. Because atrazine is one of the toxic compounds that is the subject of study by the Lake Michigan Mass Balance Project (LMMBP), the Division was asked to provide estimates of the atmospheric deposition pattern and total atmospheric loading of atrazine to Lake Michigan through the use of available air emission data and state-of-the-science semi-volatile air transport and diffusion models. The LMMBP is attempting to estimate the future concentrations of various toxic compounds in Lake Michigan given present-day levels of atmospheric and tributary loadings. Using atmospheric model estimates of sulfate, nitrate, and organic particulate loading and various meteorological variables, a modeling strategy was developed where the gas/particle partitioning of semi-volatile atrazine can be modeled to estimate its concentration and deposition patterns over Lake Michigan. Actual model application is due to begin in FY-1996.

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 atmospheric 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, multi-media 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.* (1995), 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 continued during FY-1995.

The RELMAP Mercury Model was adapted to allow an exchange of air between the surface-based mixed layer and the free atmosphere above. Assumptions about the chemical and physical form of the air emissions from various source types were also modified based on new information obtained. The updated RELMAP Mercury Model was applied to calculate 1989 monthly mean air concentrations and wet and dry deposition amounts of mercury across 40-km grid cells covering the lower 48 States. Division personnel participated with the EPA researchers throughout the United States in the interpretation of these results, which will be integrated with results obtained for other environmental media and reported.

A special version of RELMAP was also developed for the simulation of atmospheric arsenic, cadmium, lead, and 17 separate dioxin/furan congeners. This version was used to provide estimates of average annual concentration and wet and dry deposition attributable to the air emissions from electric utility boilers. Human exposure to dioxin and furan compounds has traditionally been quantified in terms of a summed toxic equivalent (TEQ) to 2,3,7,8-tetrachlorodibenzo-*p*-dioxin, the most toxic of all dioxin/furan congeners. However, the various congeners of dioxin and furan each have different vapor pressures and gas/particle mass partitioning ratios in the atmosphere. Thus, a scientifically credible treatment of the transport and deposition of total dioxin toxicity required that each congener be modeled explicitly. Once exposures to each of the 17 congeners are estimated by RELMAP, TEQ is calculated based on prescribed toxic equivalency factors for each congener.

2.2.6.2 Dioxin Modeling for the National Center for Environmental Assessment

To provide the National Center for Environmental Assessment nationwide estimates of exposure to atmospheric dioxin and furan compounds, modifications were made to the RELMAP Dioxin Model to allow the simulation of air emissions from a variety of source types and to incorporate the latest scientific methods for estimating dry gaseous deposition of dioxin and furan compounds to vegetated surfaces. This version of the model will be used during FY-1996 to provide estimates of the average concentration and total wet and dry deposition of 17 separate congeners over the continental United States.

2.2.6.3 South Florida Mercury Study

A coordinated pilot study was proposed and subjected to scientific peer review to determine the scientific certainties and the measurement data qualities necessary for a credible source attribution of atmospheric mercury deposition to the Everglades. During August of 1995, the data collection phase of this pilot study was conducted. The key features of this study are (1) obtaining data on the chemical and physical forms of mercury emitted from industrial activities in south Florida; (2) obtaining data on the emission of other elements whose deposition may be correlated with mercury deposition; (3) using automated semi-continuous ambient air mercury monitors; (4) collecting and analyzing individual rain events at multiple locations for subsequent analysis of mercury and other trace metals; (5) collecting wet- and dry-deposition samples at 12-hour or less intervals at a background site upwind of suspected sources; (6) using special upper-air sounding devices to provide additional data to analyze air parcel movements and convective rainfall during the study; and (7) using data collected in these studies in dispersion, deposition, and receptor models to estimate the impact of urban and regional emissions and extractions from the global background reservoir on mercury exposures at downwind receptor locations.

2.2.6.4 Mercury Modeling for the NorthEast States Coordinated for Air Use Management

The NorthEast States Coordinated for Air Use Management (NESCAUM) sponsored the development and modification of the RELMAP Mercury Model. The model determines the source types of atmospheric mercury most responsible for exposures at various locations within the northeastern United States. It was modified so that the concentrations and wet and dry depositions attributable to each source type in the model can be determined. This version of the model will be applied for a variety of emission scenarios during FY-1996.

2.2.7 Models-3 Advanced Air Quality Modeling

The Models-3 project seeks to develop a comprehensive air quality modeling system that integrates high performance computing capabilities with flexible and explicit process modules that are amenable to modification, revision, and a wide-range of applications. The Models-3 system integrates not only traditional air quality modules but also the data preprocessing and postprocessing steps into a complete and efficient simulation system (Byun *et al.*, 1995a: Ching *et al.*, 1995). The goals of the Models-3 project are to (1) develop a state-of-the-art air quality modeling system capable of handling multi-pollutant 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), multi-scale interactions (e.g., multi-level 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.

2.2.7.1 Models-3 Prototypes

Because of the complexity of comprehensive air quality models (AQMs) and rapidly changing HPCC technology, an evolutionary prototyping approach is being applied for the development of the initial operational version (IOV) of Models-3. Evolutionary prototyping is a combination of research prototyping and incremental development. It focuses on well understood science components and those parts of the system framework that are crucial for the proof of concept. The prototype is then reviewed and tested by scientists to better understand the remaining requirements. The system is implemented in subsets to incorporate additional research progress. Problems found at this stage are addressed before proceeding to the next iteration. Each succeeding version of the prototype then addresses a more complex air quality problem.

The objective of the AQM prototyping in Models-3 is to test the following science and system concepts: (1) the ability to address multiple air quality issues, such as regional and urban oxidant and acid deposition problems; (2) modular and interchangeable science implementations using standard input/output interfaces; (3) key algorithms for high-performance platforms and distributed computing; and (4) consistent implementation of model science across the system. From the prototyping efforts, a better detailed understanding of how to incorporate new developments in both atmospheric and computer sciences into the Models-3 air quality modeling framework is acquired. The requirements of the IOV are divided into two categories: (1) the minimum requirements, which specify the minimum acceptable functionality for an operational Models-3 system and the minimum hardware and system software necessary for system development and operation; and (2) the targeted capabilities, which describe the capabilities to be included in the IOV in addition to those on the minimum requirements list (Byun *et al.*, 1995b).

To take advantage of extensive experience using those models, RADM and its associated Engineering Models were chosen to be benchmarks to compare with the Models-3 prototypes. The prototypes generally satisfy many of the Model-3 concepts. They demonstrate the need for optimized chemistry solvers to speed up the detailed chemistry model. The vectorized RADM prototype is a reasonably efficient code, but the computational complexity of the generalized solver is much higher than the original hand-tooled RADM solver.

A generalized coordinate AQM prototype was developed that allows transformation among various vertical coordinates and transformation among various horizontal coordinates, especially map projections, by simple changes in a few scaling parameters, boundary conditions, map origin, and orientation. One advantage of the generalized coordinate system is that a single chemistry transport model (CTM) can adapt to any of the coordinate systems commonly used in meteorological modeling.

Also, one- and two-way nesting prototypes were developed. A nested model may have a coarse grid that covers the entire domain of interest, with a fine grid covering the neighborhood of the urban area nested in it. The prototypes are used to study key science issues related with the scale-dependent atmospheric-dynamics hydrostatic and nonhydrostatic assumptions both in meteorological models and CTMs.

2.2.7.2 Investigation of Numerical Solvers for Chemical Kinetics

A version of the sparse matrix vectorized Gear (SMVGEAR) was incorporated in both the Models-3 prototype and the Urban Airshed Model, Version V (UAM-V). The Gear algorithm (Gear, 1971), upon which SMVGEAR is based, is generally recognized as the most accurate solver for "stiff" systems of ordinary differential equations that arise in modeling photochemical kinetics. Unfortunately, previous implementations of the algorithm have been too CPU intensive for incorporation in three-dimensional photochemical models such as Models-3 and UAM-V.

The SMVGEAR algorithm developed by Jacobson and Turco (1994) incorporates new computational techniques that both reduce the number of computations required in the Gear algorithm and substantially improve the vectorization of those computations. This new implementation now makes the Gear algorithm a viable chemical solver in three-dimensional models that are run on computers with vector capabilities. For example, in the test cases that have been run thus far on a Cray C-90 supercomputer, SMVGEAR is on the order of 50% to 60% faster than the standard solver used in the UAM-V, and about 45% faster than the standard RADM solver incorporated in the Models-3 prototype. Because of the high degree of vectorization in SMVGEAR, its use will likely be limited to computer platforms with vector processing capabilities. Nevertheless, it can still be used as a benchmark to evaluate the accuracy of other solvers, and used in intensive modeling studies whenever supercomputing resources are available.

Finally, SMVGEAR was installed with a generalized mechanism reader in UAM-V and the Models-3 prototype. The generalized mechanism reader greatly facilitates changing or replacing chemical mechanisms used in these two models since the algorithm is structured to receive the mechanism as a model input rather than have the mechanism hard-coded within the solver as is usually done.

2.2.7.3 Plume-in-Grid Development for a Multi-Scale Eulerian Air Quality Modeling System

An effort is underway to develop a plume-in-grid capability for the Models-3 air quality model to realistically treat the subgrid scale physical and chemical processes impacting pollutant species contained in plumes emitted from major elevated point sources. Two principal modeling components are being developed to deal with the relevant processes at the proper spatial and temporal scales for pollutant plumes. A plume dynamics model (PDM) was designed to provide the position and dimensions of individual plume sections by simulating plume rise, plume growth, and plume transport (Godowitch *et al.*, 1995).

A Lagrangian reactive plume modeling (LRPM) approach, which simulates the relevant processes in a moving array of adjacent cells representing a plume vertical cross-section, will serve as the key plume-in-grid module. The LRPM is being adapted and incorporated into the Models-3 chemical transport module (CTM) to simulate the processes governing reactive pollutants in the multiple plume sections released from selected major point sources situated in the Eulerian grid domain. The output information generated by PDM, as well as concentration and parameter fields available in CTM, will be employed to drive the Lagrangian plume module during the subgrid scale phase of each pollutant plume. Testing will be conducted to identify the physical and chemical criteria for the eventual transfer of a plume pollutant mass to the grid system at the proper time and location. The prototype plume-in-grid approach will be subjected to an evaluation as part of the greater Models-3 effort with a forthcoming data set obtained during Southern Oxidant Study's Nashville 1995 field experiment.

2.2.7.4 Photolytic Rates

Current procedures for computing photolysis rates in air quality models are being re-examined as part of the Models-3 project. One common method uses multi-dimensional tables for representing broad ranges of photolysis rates in relation to zenith angle, height, and other critical parameters. With this procedure, an interpolation scheme is used to determine the photolysis rate from the table based on current conditions. The problem with this approach is that it ignores spatial variations in surface albedo, aerosol concentrations, and total ozone column data, and it can only crudely represent the effects of clouds. The starting point for the re-examination is the photolysis rate processor from RADM (Madronich, 1987).

This processor was updated to include the most recent absorption cross-section and quantum-yield measurement data. Enhancements were also made to allow the generation of photolysis rates for RADM2 (Stockwell *et al.*, 1990), Carbon Bond IV (CB-IV) (Gery *et al.*, 1989), and the University of California's Statewide Air Pollution Research Center (SAPRC) chemical mechanisms (Carter, 1990) with increased vertical resolution. The processor is being extended to produce hourly, gridded photolysis rates based on modeled and observed cloud cover, modeled meteorological profiles, total ozone column data, and aerosol distributions. The processor will be included in Models-3 for sensitivity testing and evaluation.

2.2.7.5 Development of New Dry Deposition Model

A new dry deposition model is being developed in conjunction with the development of improved surface and PBL modeling for the MM4 and MM5 meteorology models (see Section 2.2.3.2). The new surface model in the mesoscale meteorology models parameterizes evapotranspiration as part of the surface moisture flux. A key feature of this model is its parameterization of stomatal and canopy resistance as functions of solar radiation, root zone soil moisture, air temperature, and vapor pressure deficit. Because stomatal processes are also key aspects of dry deposition modeling for such gaseous pollutants as ozone, SO_2, PAN, and H_2O_2, the new dry deposition model being developed will use bulk stomatal resistance and the aerodynamic resistance from the meteorological surface model. The result will be a model that is simpler, more consistent with the meteorological simulation, and probably better than stand alone dry deposition models.

The other surface resistances that are needed for a complete dry deposition model are computed according to the dry deposition module in the Acid Deposition and Oxidant Model (ADOM). The dry deposition module was originally developed by Pleim *et al.* (1984) and evaluated and modified by Padro *et al.* (1991). The results of the prototype of this model were compared to observed dry deposition velocities from the Bondville, Illinois, field study and reported by Pleim *et al.* (1995).

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 northeast United States database. The American Petroleum Institute, Electric Power Research Institute, and 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 share the needed model data for ROM input to the project contractor team. Both model evaluations and diagnostic/sensitivity analyses are being performed. During FY-1995, model evaluations were conducted using the LMOS database. The UAM-IV and UAM-V models performed comparably for ozone when upwind boundary conditions were specified from observational data. When ROM was used to specify upwind boundary conditions, the performance of UAM-IV was degraded because of ROM's ozone underpredictions upwind of Chicago, Illinois. Plans were begun for northeastern United States model evaluations.

2.2.8.2 Southern Oxidant Study

FY-1995 was the fifth year of the multi-year 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. The focus of activities within SOS was on preparing for and carrying out a major field study in and around Nashville, Tennessee. The principal objective was to study the physical and chemical interaction of power plant plumes and the Nashville urban plume with the regional environment. Besides intensive measurements obtained at the surface, observations aloft were also made by several aircraft, including the NOAA/ARL Twin Otter and NOAA/AL P3. Data obtained in the Nashville study will be used to better understand the photochemical processes occurring in this region and assist in evaluating air quality models.

Activities for a centralized data archive for SOS, to be located in Research Triangle Park, North Carolina, began in earnest. A relational database is being developed for the archival and retrieval of air quality, meteorological, emissions, and miscellaneous data collected as part of SOS. The database will house surface, tower, tethersonde, and aircraft measurements collected during regional and urban intensives and from regional surface ozone and intermediate chemistry networks. In addition, gridded data of typical summer-time emissions will be included in the database.

2.2.8.3 Interagency Work Group on Air Quality Modeling

The Interagency Work Group on Air Quality Modeling (IWAQM) was formed in FY-1991 through a Memorandum of Understanding between the EPA, the U.S. Forest Service, the U.S. Fish and Wildlife Service, and the National Park Service. The IWAQM seeks to develop the modeling tools needed to conduct assessments of 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.

This past year, a model development effort involved the creation of one year (1990) of modeled meteorology and the testing and incorporation of such data into advanced regional-scale dispersion models. IWAQM undertook this project to improve the accuracy and resolution of meteorology information needed to develop the dispersion modeling tools for non-local source-impact analyses. These data were produced with MM4-FDDA using a Cray Y-MP computing system at the EPA National Environmental Supercomputing Center (NESC). Three-dimensional meteorology fields were produced for the domain that included the continental United States, southern Canada, and northern Mexico. This set of gridded data was produced on an hourly basis at a horizontal resolution of 80 km, at 15 vertical levels, and also at the mandatory levels. The total size of the output data files from this project is over 20.5 gigabytes. These simulated meteorological fields are now available in CD-ROM format.

2.2.8.4 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 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 also are participating in the continental NARSTO plan. During FY-1995, two Division representatives were involved in chairing key planning committees for the continental NARSTO program and in helping develop and refine the research agenda. 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.

2.2.8.5 NARSTO-NorthEast

A major field study, NARSTO-NorthEast (NE), was begun during the summer of 1995 to collect data in the northeastern United States to provide new insights into the photochemical ozone problem, including regional transport of ozone and its precursors. Additional surface monitoring stations were set up to measure ozone, nitrogen oxides, and hydrocarbons upwind and far downwind of the major East Coast urban areas. These stations supplement the data of the existing EPA/State Photochemical Assessment Monitoring Stations (PAMS) in the urban areas. In addition, the meteorological network in the Northeast was augmented during the study with additional rawinsonde releases and the deployment of several radar profilers with Radio Acoustics Sounding System (RASS) systems.

Two aircraft were also used to obtain measurements aloft during ozone episode conditions. The study is expected to continue through 1997, with analysis and modeling components starting up during FY-1996. Resources for NARSTO-NE derive from both public and private sources, with the utility industry providing funds for the non-PAMS measurements and the EPA and States providing PAMS support. One Division member serves on the NARSTO-NE Executive Steering Committee and as chair of the Data Management Committee.

2.2.8.6 Support for the EPA/Office of Air Quality Planning and Standards Ozone Programs

The EPA Office of Air Quality Planning and Standards (OAQPS) formed the PAMS Data Analysis Workgroup that is responsible for developing strategies for the analysis of the PAMS data. This will lead to interpretations of the data sets useful to scientists and policy makers. The PAMS network of monitoring stations represents a very large investment by the Federal and State governments in collecting long-term monitoring data on ozone, nitrogen oxides, and hydrocarbons. One Division member participates on the Data Analysis Workgroup.

OAQPS also formed an Ozone NAAQS Control Strategies Workgroup that is charged with providing guidance on implementation plans for assessment of the existing ozone ambient air quality standard and planning for implementation of a new primary standard for ozone within several years. One Division member serves on this Workgroup.

2.2.8.7 Total Column Ozone

The global distribution of total column ozone continues to attract great international attention as concerns over reduced ozone abundance escalate. The spatial and temporal distribution of ozone is poorly understood. To assess anthropogenic changes to date and to better understand how ozone abundance may respond to future perturbations require a better understanding of its natural intra- and inter-annual variability and the processes that contribute to this variability.

Accordingly, an analysis was undertaken to develop a better understanding of these natural variations across all spatial and temporal scales. This was achieved through the application of multi-variate statistical techniques, including rotated principal component analysis and spectral density analysis, to the total column ozone data derived from the satellite borne Total Ozone Mapping Spectrometer (TOMS) Version 6.0 for the period 1984 through 1989. The main objective of principal component analysis is to identify, through a reduction in data, the characteristic, recurring, and independent modes of variation across all potential spatial and temporal scales (Eder, 1993). This technique is ideal for application to the TOMS data set where the total number of observations exceeds 3 million.

Utilization of Kaiser's varimax orthogonal rotation has allowed delineation of homogeneous subregions that experience unique total ozone characteristics. The first rotated principal component (RPC) defines an area encompassing much of the Southern Hemisphere (SH). The time series and spectra analysis of this component reveal a strong annual cycle (maximum spectral power at $f = 0.01720$, corresponding to a periodicity of $(2\pi/f) =$ 365.33 days) that peaks during the austral Spring (September and October) of each year and falls to a broader minimum during the period of February through May. The second RPC defines a comparable area comprising much of the Northern Hemisphere (NH); however, the poleward extent of this NH subregion is limited to roughly 35° N, resulting in a more narrow subregion. This difference is likely attributable to the extensive land masses found in the NH, which play a large role in perturbing the Arctic circumpolar vortex; hence, the hemispheric scale circulation patterns. The time series and spectral analysis of this subregion likewise indicate a strong annual cycle; however, its peak is much more broad and occurs during the period of March through July. The minimum tends to occur during December and January.

The third RPC defines an area that is fairly symmetrical about the equator, dominating between 10° N and 10° S. This subregion coincides well with a region associated with the Quasi-Biennial Oscillation (QBO) of the tropical winds in the lower stratosphere, where dominance of the NH and SH annual variability is replaced with QBO dominated variance. This association is confirmed by the spectral density analysis, which reaches a maximum power at $f = 0.00860$, corresponding to a periodicity of 731 days (roughly two-years). The fourth RPC defines an area in the SH from New Guinea in the Western Pacific to central South America. This area coincides well with that impacted by the El Nino — Southern Oscillation, which is the likely driving force.

The fifth and sixth RPCs are both associated with subregions where a strong semi-annual variance dominates. The fifth subregion defines a region from the western Indian Ocean into the western Pacific Ocean. It is strongest north of the Australian Continent over Indonesia and appears to be associated with the Equatorial Semi-Annual Oscillation, which is physically driven by the negative temperature effect of ozone photochemistry associated with the semi-annual modulation of the temperature field. This component has a very strong semi-annual cycle, with maximum spectral power at $f = 0.03440$, corresponding to a periodicity of 182.67 days. Similarly, the sixth subregion, which defines an area in central Asia, may be related to the Polar Semi-Annual Oscillation, which is driven by two processes: the photochemical production of ozone and dynamical transport from the equatorial regions of maximum ozone production. This subregion also has a strong periodicity of roughly 182 days.

The seventh RPC is somewhat different from the first six RPCs in that it is not contiguous, but rather a compilation of three separate subregions, that are nonetheless driven by the same physical process, namely, Baroclinic Waves associated with the polar jet stream. Each of these three areas are associated with favored areas of tropospheric jet stream cores, principally, the Aleutian coast, the Canadian North Atlantic Coastal region, and eastern Siberia/Asia.

2.3 Fluid Modeling Branch

The Fluid Modeling Branch conducts laboratory simulations of atmospheric flow and pollutant dispersion in and around complex terrain and other obstacles, and in the convective boundary layer; dense-gas plumes; and pollutant dispersion in other complex flow situations that are not easily handled by mathematical models. 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 0.4 m is used to study the convective boundary layer and flow and dispersion under convective conditions. Another activity of the Branch is the study of resuspension mechanics and wind erosion, primarily through experimental field measurements.

2.3.1 Plume Penetration of Elevated Inversions

This project attempts to simulate the penetration of highly buoyant plumes into an elevated inversion above the convective boundary layer using the convection tank. Much effort was expended this year in developing a new technique to measure concentration fields downwind of the source within the tank using dyes that fluoresce when illuminated with laser light. Considerable progress was made in (1) relocating the convection tank to a larger room to accommodate the new technique; (2) acquiring a post-doctoral assistant under a cooperative agreement with The Pennsylvania State University, University Park, Pennsylvania, to develop the technique; (3) establishing a thin light sheet with uniform intensity using a combination of a parabolic mirror and a rapidly scanning mirror driven by a galvanometer; (4) finding a dye with fluorescent properties matched to the laser and video camera, and exhibiting negligible photo-dissociation, temperature dependence, and attenuation characteristics; (5) acquiring analysis software for processing the video images obtained; and (6) developing a hardware/software system to automate the entire experimental process, so that all experimental conditions may be precisely duplicated. The automated system is especially important, as numerous repetitions of the experiments are anticipated to be necessary to obtain meaningful ensemble averages.

2.3.2 Model of Pollutant Dispersion in the Vicinity of a Building

In the third 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 underwent further refinement and evaluation by comparison with numerous wind-tunnel and field data sets. The distance-dependent plume rise incorporated in the model was described in a conference presentation (Genikhovich and Snyder, 1995), and a final report describing the model and comparing its predictions with the various data sets was prepared (Genikhovich, 1995).

2.3.3 Roughness Array Tests for Design of Field Experiments

Wind-tunnel tests on roughness arrays were conducted in conjunction with the PERF (Petroleum Environmental Research Forum) program in preparation for a series of field experiments to be conducted in the summer of 1995 with releases of carbon dioxide at the Liquified Gaseous Fuels Spill Test Facility, a smooth desert site near Las Vegas, Nevada. The main objective of the field tests was to simulate dense-gas releases over *rough* surfaces, so the designers needed to roughen the smooth desert floor using elements that were inexpensive and easy to construct, transport, install, remove, and store. As opposed to the construction of thousands of roughness elements to be deployed in the field, the wind tunnel provided an economical method to test a number of arrays in a simulated atmospheric boundary layer. The objective was to determine the most effective array for generating the largest roughness length z_0 while minimizing the "cost" in terms of element height, width, and number required.

Four different geometries of roughness arrays were tested. In all cases, the individual elements were rectangular plates placed perpendicular to the wind, and in alternate rows the elements were staggered rather than aligned with one another. The width-to-height ratio of the plates was varied from 1 to 4, and two different spacings between the elements, 8 and 12 plate heights, were tested. In conclusion, the most effective array was that with a width-to-height ratio of 4 and spacing-to-height ratio of 12. It was found to generate a roughness-length-to-plate-height ratio of 1/14, which is regarded as quite effective in comparison with generally quoted values of 1/20 to 1/40. This final array was also tested under a different wind direction. The results were documented in a data report (Snyder, 1995) and used by the designers of the field experiments.

2.3.4 Dense-Gas Dispersion

Under a cooperative agreement with North Carolina State University, Raleigh, North Carolina, wind-tunnel tests were conducted to examine the behavior of a dense-gas plume released within an array of large roughness elements using the final array tested in Section 2.3.3. Dense-gas releases typically form vertically thin but horizontally wide plumes that "hug" the ground surface. The question to be examined here was: Does this dense-gas layer effectively form a "vapor blanket" over the roughness elements and thus shield the boundary layer from the effects of the surface roughness? The tests involved the release of carbon dioxide from a small area source (Britter and Snyder, 1988) under low-wind-speed conditions in the wind tunnel to measure the flow structure and mean and fluctuating concentrations within the plumes downwind of the source. A data report was prepared (Zhu, 1995), and the data are being analyzed for preparation of a master's thesis.

2.3.5 Surface Coal Mines

An extensive database on the transient concentrations within and steady-state concentrations downwind of surface coal mines was obtained in FY-1993 (Thompson, 1993) using the meteorological wind tunnel. Turbulent velocity measurements made with a hot-wire anemometer on the centerplane for two of the mine configurations were included in the study. Because of modeling constraints, the settling of particles cannot be modeled at the wind-tunnel scale and all dispersion measurements were made with a neutral tracer gas. To extend the results of the wind-tunnel study to particles with a settling velocity, a two-dimensional particle trajectory model was developed to track particles released within a rectangular shaped hole. The model computes the trajectory of each released particle by calculating a random turbulent velocity based on the measured rms value, which is added to the mean velocity. This total velocity advanced the particle through a prescribed time step. The local velocities were interpolated from the four surrounding grid-point measurements. The particle may be reflected or deposited if the path crosses a boundary and is tracked until it is deposited or escapes the mine and passes the downwind mine lip. A residence time can be determined by releasing a large number of particles at a fixed position within the mine, using the turbulent velocity field to advect them within and from the mine and averaging their escape times. The results of computations for particles with no settling velocity were compared to those for the neutral gas releases in the wind-tunnel experiments.

2.3.6 Open Burning and Detonation

In conjunction with the Open Burning/Open Detonation Project of the Strategic Environmental Research and Development Program (SERDP), a laboratory study of the rise through the atmosphere of buoyant thermals produced by open burning and detonation is underway at the Fluid Modeling Facility. The U.S. government has over 400,000 tons of munitions to be disposed and is currently detonating them in quantities of 2.5 tons or less as permitted by the EPA. To evaluate the effects of detonating larger quantities (up to 25 tons has been requested), a new dispersion model is under development. This laboratory study will provide a fundamental database and an empirical description of the physical processes involved for inclusion in the dispersion model.

The rise of a buoyant thermal in the atmosphere is simulated in the laboratory by the fall of a dense volume of fluid, containing a blue dye, through a water tank. The dense volume of fluid is initially held at the tank's water surface in a hemispherical cup; the cup is quickly rotated to release the fluid and instantaneously create a "thermal" at the water surface. As the thermal falls, it is videotaped with the camera positioned to obtain simultaneous front and side views by using a mirror. An example of a frame from an experiment is shown in Figure 2. Selected frames of the videotape are

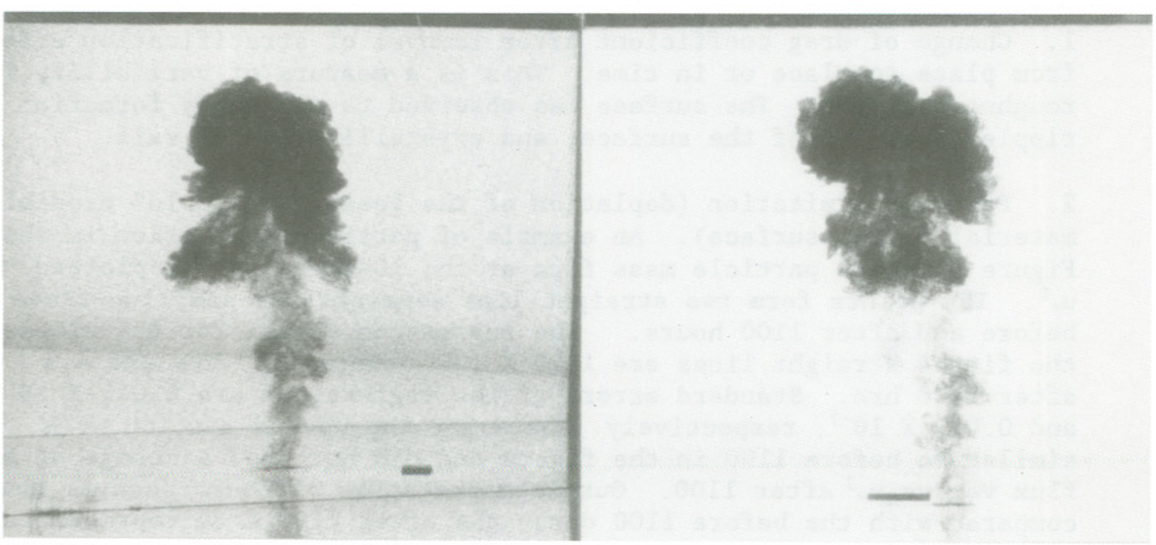

Figure 2. Front and side views of open burning and detonation experiment in the water channel/towing tank (photo inverted to show simulated thermal rising).

digitized and analyzed to determine the depth and size of the thermal as a function of time. By filling the tank with two layers of water of different density (fresh water above a slightly saline mixture), the elevated inversion above the convective boundary layer is simulated. The fraction of the thermal that penetrates the inversion is observed.

2.3.7 Investigation of Resuspension Mechanics and Wind Erosion

Analysis of data on the variability of resuspension mass transport was the principal activity in the NOAA sponsored investigation of resuspension mechanics and wind erosion. Measurements taken during 1993 and 1994 on Owens Lake, California, were analyzed to determine the mechanisms causing variability of resuspension mass transport. The data showed that the horizontal mass flux increases with the cube of the friction velocity (u_*). The data showed this relationship for all heights sampled and for all sediment textures tested. For sandy-textured sediment at all u_* during erosion and for all textures for $u_* > 50$ cm s^{-1}, the shapes of the vertical profiles of airborne particle mass flux were constant. Using this result, the scientists chose a line of measurement sites on the northeast side of Owens Lake having a sandy surface sediment texture and used measurements of mass flux at the height of 10 cm as a surrogate for total mass transport.

Variability in sand flux for 17 stations located on an approximately 4-km line of instruments set at 326° was observed during wind erosion episodes in 1993 and 1994. Data were selected for winds that lined up with the instrument line and whose mean speed U differed by less than 1.7% along the line at a four-meter height. Four mechanisms caused large scale differences in the mass flux profiles. In order of importance, the mechanisms are:

1. Change of drag coefficient after removal of stratification effects from place to place or in time. This is a measure of variability in roughness height. The surface was observed to change by formation of ripples, heaving of the surface, and crystallization of salt.

2. Particle limitation (depletion of the loose "available" erodible material on the surface). An example of particle limitation is shown in Figure 3, where particle mass flux at the 10-cm height is plotted versus u_*^3. The points form two straight-line segments for sampling times before and after 1100 hours. The regression values for the slopes of the fitted straight lines are 1.20×10^{-7} before 1100 hrs and 4.3×10^{-8} after 1100 hrs. Standard errors of the regressions are 0.046×10^{-7} and 0.017×10^{-7}, respectively. Data for the upwind station were similar to before 1100 in the figure and did not show a change of mass flux versus u_*^3 after 1100. Our interpretation of these data is that, compared with the before 1100 data, the after 1100 data represent a time when particle availability was limited for erosion at the site. Although the slope of mass flux versus u_*^3 changes in the middle of a wind erosion episode, the linear relationship between mass flux and u_*^3 remains.

3. Variation of threshold friction velocity, which can change by formation and destruction of salt cementation on the surface and by the transport of coarser or finer particles onto the surface.

4. The Owens effect, where u_* /U increases with U, is caused by increase of the aerodynamic roughness height. This is an effect of the dense layer close to the surface that contains airborne particles.

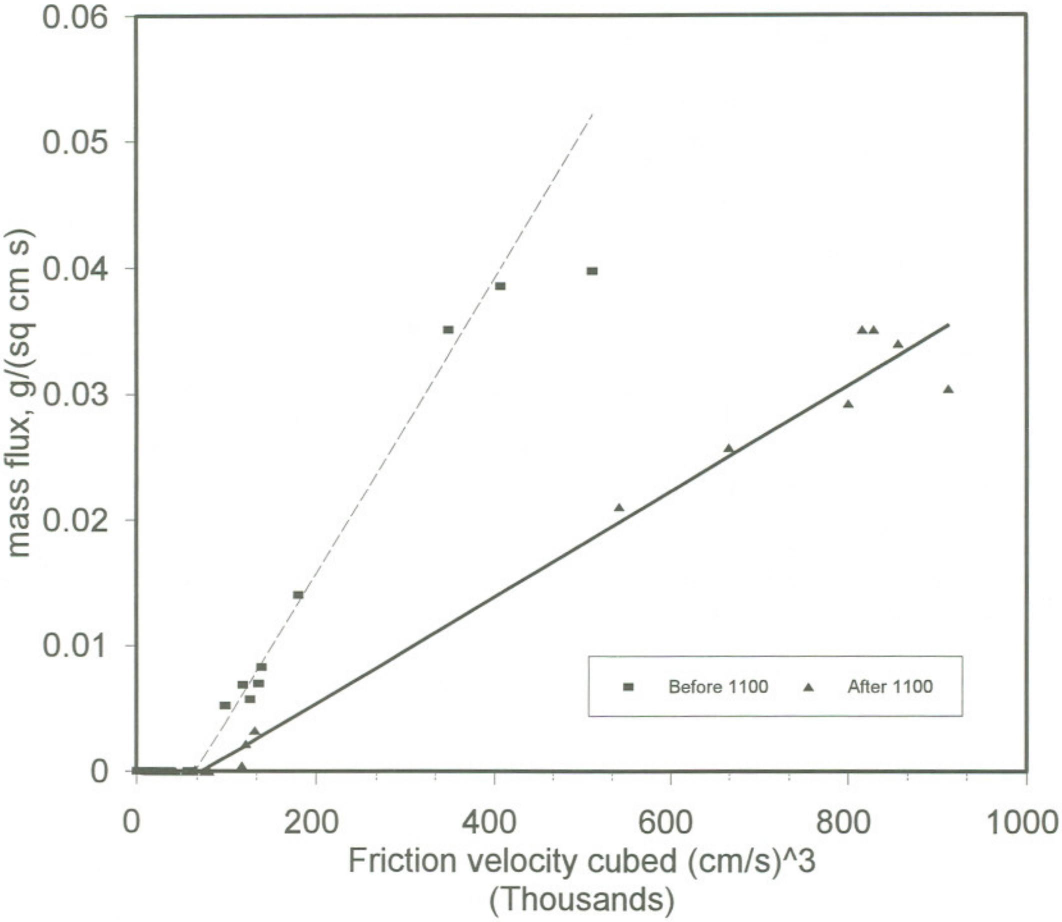

Figure 3. Twenty-minute mass fluxes versus u_*^3 before and after 1100 hours.

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

While the Division has shifted its research emphasis away from ROM towards the next-generation regional air quality model (Models-3), ROM continues to be widely used in the regulatory community. It provides boundary conditions for UAM applications, and it calculates regional ozone levels in support of provisions under CAA. Three papers related to the sensitivity of ROM to uncertainties in meteorological and emission inputs were published by Olerud *et al.* (1995) and Pierce *et al.* (1995a; 1995b).

A set of ROM simulations made during FY-1994 continued to generate much interest in the regulatory community. These model runs were designed to test the effect of a new biogenic emissions system (Geron *et al.*, 1994) on ozone calculations. The new emissions, which form the basis for the Biogenic Emissions Inventory System (BEIS2), 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. Of particular concern from this simulation was that the calculated ozone with the new emissions inventory did not compare as well to measured routine surface observations as the previous version of the model. This has raised a slew of research questions. 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? Does the new inventory change the direction of emission control requirements for ozone attainment in the eastern United States? If ozone was predicted fairly well with the old inventory, why then does a scientifically improved inventory produce less satisfactory results? These questions are being examined more closely using ROM.

2.4.2 Southern Oxidant Study

A Division scientist continued to serve as a scientific liaison for emissions research to the Southern Oxidant Study (SOS), and participated in an isoprene flux experiment in Oak Ridge, Tennessee, during summer 1995. Research groups from the NOAA Atmospheric Turbulence and Diffusion Division (ATDD), National Center for Atmospheric Research (NCAR), Washington State University, Pullman, Washington, and the EPA National Risk Management Research Laboratory collaborated during this experiment, which was part of the SOS Nashville field study. The three-week experiment included a variety of measurements: leaf cuvettes, within-canopy isoprene concentrations, flux estimates above the deciduous forest canopy using eddy correlation and gradient measurements, a tethersonde that was flown with six canisters up to two kilometers in height, and boundary layer flights above the study site by the NOAA Twin Otter aircraft. The data from this experiment will be the most comprehensive set available for evaluating isoprene fluxes.

2.4.3 Biogenic Emissions

The Division continues to take an active role in promoting the use of biogenic emissions in air quality simulation models. A new methodology was released that incorporates new emission factors and an updated land use inventory (Geron *et al.*, 1994). The system, called the Biogenic Emissions Inventory System (BEIS2), was incorporated into ROM, RADM, and UAM. The FORTRAN source code and land use data were made available over the Internet (anonymous ftp monsoon.rtpnc.epa.gov, or URL: http://www.epa.gov/asmdnerl/).

To develop an improved understanding of NO_x emission fluxes from soils, the Division began work with North Carolina State University, Raleigh, North Carolina. To date, work includes a number of chamber-based measurements (Aneja *et al.*, 1995); plans for an intercomparison experiment (Aneja, 1994); and execution of a field experiment in the summer of 1995. The 1995 experiment, which included researchers from North Carolina State University, National Aeronautics and Space Administration (NASA), Argonne National Laboratory, and National Center for Atmospheric Research (NCAR), involved extensive chamber measurements over a fertilized corn field in eastern North Carolina. Micrometeorological measurements were taken, and Argonne National Laboratory calculated $NO/NO_2/O_3$ flux estimates. Preliminary data indicate significant fluxes of NO from the fertilized soil that were rapidly converted to NO_2 in the presence of O_3. A more comprehensive intercomparison experiment with chamber measurements and chemical fluxes is planned for the summer of 1996 and will possibly include the University of Maryland, and NOAA Divisions at Oak Ridge, Tennessee, and Silver Spring, Maryland. This comparison experiment is needed because current 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 will improve our ability to model tropospheric ozone.

A Division scientist is also a co-chair of a biogenic emissions committee sponsored by the STAPPA/ALAPCO/EPA Emission Inventory Improvement Plan (EIIP). The role of this committee is to develop a consistent and improved methodology for estimating biogenic emissions related to the CAA. A draft preferred methods document for estimating biogenic emissions was circulated for review and comment for possible release in FY-1996. The Division was also a participant in a International Global Atmospheric Chemistry (IGAC) committee that published an approach for estimating global biogenic VOC emissions (Guenther *et al.*, 1995).

2.4.4 High Performance Computing and Communications Program

The High Performance Computing and Communications (HPCC) program is part of a larger multi-agency 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 to 1) build advanced capabilities to address multi-pollutant and multi-media 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.

2.4.4.1 Framework for Air Quality Modeling and Decision Support

The formal system requirements and design of Models-3, a flexible software system designed to facilitate the development and use of environmental assessment tools, was completed. The initial version of Models-3 focuses on urban to regional scale air quality simulation of ground-level ozone, acid deposition, visibility, and fine particulate matter. The Models-3 framework provides an interface between the user and operational models, between the scientist and models under development, and between the hardware and model software. This allows the user to perform a wide range of environmental tasks, from regulatory and policy analysis to understanding the interactions of atmospheric chemistry and physics, while rapidly adapting to new technology. Models-3 is intended to serve as a framework for continual use and advancement of environmental assessment tools. The next challenge is to extend the system to handle integrated cross-media assessments.

2.4.4.2 High Performance Cross-Media Modeling Workshop

A High Performance Cross-Media Modeling Workshop was held in Research Triangle Park, North Carolina, on January 30-31, 1995. The purpose of the workshop was to explore a variety of key issues related to modeling framework, computing infrastructure, and common data and algorithm needs to facilitate cross-media (air and water) modeling to address complex environmental issues.

2.4.4.3 Emission Data for Models-3

Modification and testing of the Geocoded Emission Modeling and Projection (GEMAP) system (Wilkinson *et al.*, 1994), sometimes called Emission Modeling System-95, was begun and partially completed. GEMAP is a non-proprietary software system written in SAS programming language and incorporates an ArcInfo(R) geographic information system[1]. It will serve as an integral part of the initial Models-3 air quality modeling system.

An input processor was developed for GEMAP, which allows it to read emission inventory data in either the 1985 NAPAP emission inventory format or 1990 EPA interim emission inventory format. This capability will be used for the joint EPA-State Emission Inventory Improvement Program (SAEWG and U.S. Environmental Protection Agency, 1993). The input processor also receives needed meteorological data for emission modeling from the meteorology model (MM5), performs automated and user-defined quality control on input data, and serves as the principal link to the Models-3 study manager interface. In addition, an output processor was developed to perform quality control on internal emission processing procedures and output data, translate output data to the NetCDF format used by the Models-3 system, and provide data to the plume rise and chemical transport model portions of the system.

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

The capabilities of GEMAP were increased by adding BEIS2 (Geron *et al.*, 1994); adding the RADM2 chemical speciation mechanism in addition to Carbon Bond IV and University of California's State Air Pollution Research Center (SAPRC) mechanisms (Lurmann, 1991); and streamlining the GEMAP code to improve execution times and decrease file storage space needs. Work is underway to install and optimize the performance of Mobile 5a, the EPA mobile source emission estimation model.

2.4.4.4 Computing Infrastructure and Parallel Algorithm Research

The HPCC program acquired a Cray T3D with 128 processors and 8 gigabytes of memory to support parallel algorithm research and applications throughout the agency. A heterogeneous C90/T3D version of the Models-3 RADM was implemented with the chemistry solver, the most intensive computing component, executing on the T3D and the rest of the model executing on the C90. Message passing with the Parallel Virtual Machine (PVM) is used to synchronize the input/output (I/O) file. Output concentrations after 4 advection cycles from C90/T3D executions using 4, 8, 16, and 32 processors agreed to 7 significant digits. However, performance of the C90/T3D version is severely limited because the C90 executable gets swamped out of memory when waiting to receive PVM messages from the T3D or for I/O operations to complete. Considering the large work load on the C90, the only way to get reasonable performance with the heterogeneous C90/T3D approach would be to use a system call to lock the C90 executable in memory, making it immune to swamping. The entire RADM code is being ported to the T3D to eliminate the C90 bottlenecks.

2.4.4.5 Visualization and Analysis Tools

The primary focus of this effort was to produce visualization/analysis modules that plug into and operate within the Models-3 framework. A public domain interactive 3-D visualization package, originally developed at the University of Wisconsin, Madison, Wisconsin, was adapted for use within Models-3. Input data readers were developed for MM4 and MM5 outputs; high- and low-resolution RADM and RADM emission files; NetCDF/Models-3 files; and ROM, RADM, UAM, and RELMAP concentration output files. This provides the capability to make isosurfaces, volume rendering, contour lines, slices, etc., and animate the three-dimensional (3-D) displays in real time. Two-dimensional displays of color tiles, contours and 3-D mesh plots, box and whisker plots, time-series plots, and bar charts are also available in Models-3 through the package for analysis and visualization of environmental data developed at MCNC, Research Triangle Park, North Carolina. A visualization technique was developed to help policy makers assess the relative efficiency of VOC versus NO_x emission controls for ROM emission control strategy executions. An 11-minute video was created to promote a better understanding of the benefits of cross-media modeling. The video displayed results of a preliminary cross-media assessment of nitrogen pollution in the Chesapeake Bay and surrounding area.

2.4.4.6 Technology Transfer

A cooperative agreement was awarded to conduct research to facilitate the transfer to users of the advanced air quality models planned for inclusion in Models-3. This included using the World-Wide Web for widespread delivery of the first Models-3 prototype, UAMGUIDES, to a broad spectrum of users and platforms (URL: http://www.iceis.mcnc.org/uamguides/index.html). In turn, the users of UAMGUIDES provided input to influence the research and development of Models-3. A workshop was held March 22, 1995, which was broadcast from North Carolina State University both by satellite and Internet using Multicast backBONE. Curriculum needs for future users of advanced air quality models were outlined. From that outline, modules were identified to be developed and tested on the World-Wide Web. One module is for tropospheric ozone chemistry. Tools were also developed to enhance decision making functions for inclusion in Models-3 (Loughlin *et al.*, 1995; Loughlin and Ranjithan, 1995).

2.4.4.7 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.

2.4.4.8 Division World-Wide Web Home Page

The Division created a Home Page for the World-Wide Web. This page includes an overview of the Division's mission; a staff directory with phone numbers and addresses; a map of the Research Triangle Park, North Carolina, area; a list of division publications; the FY-1994 annual report; monthly highlights; and links to sites that provide computer models and databases. The Division's URL address is http://www.epa.gov/asmdnerl/. The Internet anonymous ftp site (monsoon.rtpnc.epa.gov) includes databases and air quality simulation modeling programs developed or supported by the Division. Computer files are available for the following: acid deposition modeling, photochemical oxidant (smog) modeling, hazardous release modeling, particulate modeling, toxic modeling, emissions modeling (biogenic and anthropogenic), and associated meteorological models and data.

2.4.5 National Agenda for Meteorological Services and Supporting Research

Four Division members serve on ICMSSR panel to develop a *National Agenda for Meteorological Services and Supporting Research* (U.S. Department of Commerce, in preparation) based on input from the Federal agencies and private sector and coordinated by the Office of the Federal Coordinator for Meteorology. The document, which included ten initiatives, was not released in FY-1995. Input from the private sector was to be incorporated prior to acceptance for release.

2.4.6 Visibility

A visibility effort involved writing a report (U.S. Environmental Protection Agency, 1995b) in response to provisions of Section 169B(a) of the 1990 CAAA that call for production of interim findings of available visibility related research and information. The report addressed findings in four areas: expansion of current visibility related monitoring in class I areas; assessment of current sources of visibility impairing pollution and clean air corridors; adaptation of regional air quality models for the assessment of visibility; and studies of atmospheric chemistry and physics of visibility. Current and future research was also discussed.

Another visibility effort involved using the National Weather Service observations of visual range to estimate light extinction coefficients for the midday (Husar and Wilson, 1993) for the period of 1979-1990. Each day was assigned to one of 20 meteorological categories (Brook *et al.*, 1994). A summer intern developed maps depicting spatial correlations of the light extinction coefficient for the meteorological categories. Other statistics were also developed for the meteorological categories.

2.5 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 and conducts research to develop and improve human exposure predictive models, focusing principally on urban environments where exposures are high. Databases are assembled and used for model development and research on flow characterization, dispersion modeling, and human exposure. Research is coordinated with other agencies and researchers.

2.5.1 AMS/EPA Regulatory Model Improvement Committee

In 1991, the AMS and EPA initiated a formal collaboration to accelerate the inclusion of advances in atmospheric boundary layer understanding into the EPA regulatory models. In 1994, the AMS/EPA Regulatory Model Improvement Committee (AERMIC) completed the first version of the AERMIC Model (AERMOD) and its meteorological preprocessor (AERMET). AERMOD is a steady-state plume-based model designed for estimating near-field impacts from a variety of industrial source types. In developing AERMOD over the past four years, AERMIC followed certain design criteria (goals) to yield a model with desirable regulatory attributes. These model attributes are to be 1) robust in estimating regulatory design concentrations (i.e. provide reasonable concentration estimates over a wide range of conditions with minimal discontinuities); 2) easily implemented with reasonable input requirements and computer resource needs; 3) based on up-to-date science that captures the essential physical processes while remaining fundamentally simple; and 4) easily revised as the science evolves.

The AERMIC work group completed development of AERMAP, the terrain preprocessor for AERMOD. AERMAP uses gridded terrain data (e.g., USGS Digital Elevation Mapping data) to model terrain influence on the atmospheric flow. Additionally, AERMIC completed a major part of the developmental evaluation of AERMOD that included comparisons of model estimates with measurements from a variety of field studies. The purpose of the evaluation is primarily diagnostic, i.e., to identify and correct problems in the model as it is being developed.

AERMOD was compared with the Prairie Grass passive surface release (rural) data (Barad, 1958), Kincaid elevated, buoyant release (rural) data (Liu and Moore, 1984), and Indianapolis elevated, buoyant release (urban) data (Murray and Bowne, 1988). The comparisons are described in a paper by Lee *et al.* (1995). In summary, for surface releases, AERMOD has a slight tendency to underpredict the highest concentrations in both convective and stable conditions; for both urban and rural elevated releases, AERMOD exhibited insignificant bias in convective conditions and again only a slight tendency toward underprediction in stable conditions. A technical description of the model as well as a discussion of the model performance were presented to the public at the *Sixth Modeling Conference on Air Quality Modeling* in Washington, DC, in August, 1995. Comments from the public will be considered during the final stages of model development.

2.5.2 Modeling Pesticide Applications

2.5.2.1 Modeling Spray Drift from the Application of Agricultural Pesticides

In FY-1995, Division scientists continued their involvement in a research effort to develop methodologies for evaluating the drift of airborne pesticides from agricultural applications. Because of the wide variety of application scenarios (i.e., droplet distributions, aircraft turbulence, pesticide characteristics, surface characteristics, and meteorology) resulting in significant uncertainty of the magnitude of off-site drift and deposition, development of practical modeling tools for use by the EPA and pesticide manufacturers is the focus of this project.

Through a cooperative research and development agreement with the agricultural chemical industry's Spray Drift Task Force, a draft screening level assessment method was developed and designed specifically for aerial spray applications. This screening model is the first tier of a proposed three-tier approach for evaluating off-site deposition and the extent of buffer zones needed to protect sensitive aquatic and terrestrial habitats from undesired exposures. The EPA Office of Pesticide Programs is responsible for determining how newly proposed pesticides can be applied safely. The three-tier approach will provide them with a better tool for evaluating these new products before registering them for general use. Tier one requires only basic information about the pesticide and its application. With conservative assumptions about the environment and assumed reasonable application practices, tier one provides a practical, yet conservative, screening of potential impacts. Tiers two and three require additional specific information about the pesticide and the scenarios under which pesticide will be applied and provide improved impact estimates based on more refined application scenarios. All three tiers are based on the same empirically confirmed model.

The AGDRIFT model (Teske, 1994) is the kernel of the approach. AGDRIFT predicts the motion of spray material released from aircraft, including the mean position of the material and the variance about the mean as a result of both aircraft-generated and ambient turbulent fluctuations. It uses a Lagrangian approach to track the behavior of each spray nozzle stream through the assumed flow and turbulence field using trajectory equations of motion and then solving them exactly at each step. The model tracks the material until it deposits on the surface or is carried aloft beyond the domain of interest.

The proposed screening level assessment method was built into a Microsoft® Windows™-based personal computer program[2] and a draft version of the method will be made available to the Office of Pesticide Programs. Development of the higher tiers of the method and model evaluation effort will also continue in FY-1996. The tier-one approach is described by Bird *et al.* (1995). Additionally, analysis of historical aerial spray drift databases and their relationship to the results of field studies performed by the Spray Drift Task Force are in Bird *et al.* (accepted for publication).

2.5.2.2 Modeling Deposition of Mosquito Adulticide

At the request of the EPA Office of Pesticide Programs, an analysis of the likely deposition downwind of a neighborhood application by truck of mosquito adulticide was performed using the INPUFF Lagrangian model (Petersen and Lavdas, 1986). Eight scenarios involving variations in meteorology, application area, and spray equipment were modeled. Deposition in a pond or small lake adjacent and downwind of the neighborhood was found to be in the range of about 5 to 30 percent of the application rate. Deposition in a pond immediately downwind of the treated area was found to be sensitive to the number, N, of upwind streets (swaths) treated for $N < 5$ (with majority of impact from first few swaths), but relatively insensitive to additional swaths for $N > 5$. Increased wind speed decreased concentration over the pond but increased the deposition velocity.

For the droplet range of 4 to 30 microns, typical for these applications, and a wind speed increase from 1 to 2.2 ms^{-1}, the deposition showed a moderate increase because the wind speed effects on deposition velocity more than compensated for the effects on concentration. This increase was more pronounced on the small end of the droplet range. In general, wind speed and atmospheric stability, application area and type of equipment, and associated droplet size distribution all have important influences on downwind deposition from a mosquito adulticide application.

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[2]Microsoft is a registered trademark of the Microsoft Corporation. Windows is a trademark of Microsoft Corporation.

2.5.3 Ground-Based Remote Sensor QA/QC Development

This project addresses the development of quality assurance (QA) and quality control (QC) guidance for ground-based remote sensors (sodars, wind profiling radars, and radio acoustic sounding systems) for use in regulatory monitoring. This includes revisions to the *Quality Assurance Handbook for Air Pollution Monitoring Systems, Volume IV: Meteorological Measurements* (U.S. Environmental Protection Agency, 1995d). The Ground-Based Remote Sensor Characterization Study was conducted in April 1995 at the Boulder Atmospheric Observatory in Boulder, Colorado. The results will be used for developing guidance on issues such as siting, installation, acceptance testing, calibration, auditing, routine operation and maintenance, tear-down, refurbishment, and expected accuracy as a function of atmospheric conditions and sensor configuration. A technical report and a conference paper are being prepared, which will summarize the data acquired during the experiment.

2.5.4 Ultraviolet-B Study

A cooperative agreement was awarded to the Department of Marine, Earth and Atmospheric Sciences, North Carolina State University, Raleigh, North Carolina, to investigate the effects of clouds and haze on ultraviolet-B (V-B) radiation received at the earth's surface. The study examined data acquired from a spectrophotometer, and global and UV-B pyranometers in Research Triangle Park, North Carolina. Data from the nearby National Weather Service station located at the Raleigh-Durham International Airport were also included in the analysis. Results show that clouds have both an attenuating effect on UV-B radiation in the long term (more than an hour) as well as a magnifying effect in the short term (less than an hour) (Estupiñán *et al.*, 1995).

2.5.5 Strategic Environmental Research and Development Program

The Strategic Environmental Research and Development Program (SERDP) is a multi-agency project, whose goal is to eliminate the estimated 400,000 tons of warfare munitions. The stockpile is distributed throughout the country at more than 200 Department of Defense (DOD) and Department of Energy (DOE) installations. The demilitarization of the U.S. armed forces has led to an increase in the stockpile. Many of the materials are old, unstable, and unsafe. The most common disposal methods in use today are open burning (OB) and open detonation (OD). OB/OD activities are a relatively simple and cost effective means for stockpile reduction. However, these activities can generate air pollutants. Any facility that intends to use OB/OD disposal methods must meet permit requirements under subpart X of Part 264 of the *Resource Conservation and Recovery Act* (RCRA).

SERDP funded the EPA to develop an OB/OD air pollution dispersion model and mobile meteorological observing platform, which will be used to acquire the necessary data for obtaining a RCRA permit. NOAA Environmental Technology Laboratory and ASMD are responsible for the development of a mobile meteorological platform and the OB/OD dispersion model.

A workshop on OB/OD atmospheric dispersion modeling and monitoring was conducted at the Environmental Technology Laboratory in Boulder, Colorado, on

February 15 and 16, 1995. The purpose of the workshop was to present and discuss the strengths and weaknesses of a strawman plan for an OB/OD atmospheric modeling and monitoring system. Major topics of discussion included regulatory permitting requirements, short- and long-range dispersion models of OB/OD plumes, source characterization of the OB/OD, mobile meteorological measurement platform, and model and measurement platform evaluation and testing.

2.5.6 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-1995. The model, ISC-COMPDEP (Industrial Source Complex - COMPlex terrain DEPosition), was further enhanced and tested. The enhanced version is ISCST3 (Industrial Source Complex - Short Term) (U.S. Environmental Protection Agency, 1995f). The meteorological preprocessors, PCRAMMET, (U.S. Environmental Protection Agency, 1995c) and MPRM (Meteorological Processor for Regulatory Models) (Irwin and Paumier, 1990), were updated to be compatible with ISCST3. Further sensitivity testing of ISCST3 was performed.

Investigations continued into the possibility of incorporating a gas deposition algorithm into ISCST3. Building on the model evaluation work done in FY-1994, diagnostic evaluations were performed to identify which model components are important for particular chemicals and land-use types. The diagnostic work showed that the model performance could be improved by using a better formulation for ground resistance and better minimum stomatal resistance estimates. Results from both the model evaluation and diagnostic studies were presented in Moore *et al.* (1995).

2.5.7 Improvements in the CTDMPLUS Stratified Flow Algorithm

An improved version of the stratified flow algorithm found in the Complex Terrain Dispersion Model (CTDMPLUS) (Perry, 1992) was tested for inclusion into the CTDMPLUS and INPUFF (INtegrated PUFF Model) (Petersen and Lavdas, 1986). The new flow algorithm uses an improved mathematical formulation for the flow and avoids some approximations that were made in the earlier version. The streamline patterns predicted by the new flow algorithm were compared against fluid modeling studies and show a better match. The new flow algorithm is being implemented into CTDMPLUS and its effect on ground level concentrations is being examined by comparing results with previous model evaluations.

2.5.8 Ultraviolet Radiation Monitoring Network

The EPA ultraviolet (UV) radiation monitoring network consists of five sites (four urban areas and one background site). The first network site at Research Triangle Park, North Carolina, began operation in the fall of 1992. Two more sites are to be added to the original five that were operational by the end of 1994. The monitoring network is intended to provide the scientific basis for the UV Exposure Index; to verify the predictions of potential human UV exposure; to assess and improve algorithms for predicting the UV flux, accounting for pollutants and other factors in populated areas; and to provide high-quality, spectrally-resolved UV radiation measurements that can be convolved with a variety of human health or biological action curves. The total column ozone and spectrally resolved UV data were formatted for archiving in a relational database.

2.5.9 Modeling Acid Aerosols

To better understand the effects that exposure to acid aerosols have on humans, epidemiologic air pollution studies were conducted characterizing the spatial and temporal distribution of acid aerosols. To fully understand the processes responsible for the spatial and temporal distribution of acid aerosols, a rigorous analysis of local and regional meteorology and its effect on H^+ concentrations was required. There were few studies that included a comprehensive analysis on the effects of meteorology on acid aerosol concentrations. Therefore, an examination of the relationships between meteorological parameters and their effects on acid aerosol concentrations was undertaken (Zelenka, accepted for publication). Ambient air samples of strong acid aerosol (H^+) 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 air temperature, dew point temperature, pressure, wind speed and direction, and mixing height. The analysis yielded important information about the synoptic scale and mesoscale meteorological parameters, which coincided with acid aerosol episodes. A clear association was shown between episodic events of elevated ambient H^+ concentrations and the synoptic pattern whereby an anticyclone sets up to the east of the mid-Atlantic states.

2.5.10 Alternative Fuels Exposure Modeling

Concentrations of evaporated (noncombusted) fuel species from an automobile's fuel system in residential and attached garage may represent a significant component of total human exposure to these chemicals. Hot soak (cool down) and resting loss phase (constant temperature, pseudo steady state) are components of evaporative emissions applicable to attached garage vehicle use scenarios. Each phase proceeds under the composite effects of temperature gradients and/or vapor redistribution, and evaporation canister outgassing hysteresis. A model paradigm of evaporative emissions during the hot soak and resting phase parking scenario must first succeed in isolating the functional dependence of emissions on temperature and vapor distribution gradients separately. Extended isothermal equilibration tests at 75 °F (≃24 °C) and 94 °F (≃34 °C) were conducted on a 1988 General Motors Corsica fuel system in sealed housing for evaporative determination (SHED) using pure methanol fuel (M100). An initial condition of evaporation canister breakthrough loading was chosen to avoid hysteresis effects and assure experimental repeatability. Hot flame ion detection analysis of air samples from SHED were performed during several 6-hour experiments.

A time and temperature dependent model was developed assuming that evaporation rate is proportional to a finite mass of fuel available for evaporation and diffusion from the fuel system. Regression of model parameters was optimized using Quasi-Newton methods subject to a temperature-weighted least squares loss function.

This study found that the hot soak emissions process, with concurrent thermal and non-equilibrated fuel system vapor concentration gradients, is unlikely to stabilize within a nominal one-hour period. Evaporation canister discharge contributes to both hot soak and resting loss phases of vehicle use scenarios. Insofar as canister outgassing contributes to resting loss, those losses are not constant; the experimental repeatability of any of the stationary evaporative loss process (diurnal, hot soak, or resting) may depend on the initial condition of the canister, due to hysteresis effects. Vapor redistribution within the fuel system is an important component of evaporative emissions, and the effective time constant characterizing this process is generally much greater than one hour (Streicher, in press; Lansari *et al.*, in press).

2.5.11 Hazardous Air Pollution Human Exposure Models

The Hazardous Air Pollutant Exposure Model for Mobile Sources (HAPEM-MS) was used to show the effect that emission controls have had in reducing CO exposures in recent years. The HAPEM-MS calculates exposures on a seasonal basis, for different demographic groups, for each hour of the day, for a single calendar year. The HAPEM-MS is important to the EPA Office of Mobile Sources for evaluating human exposures to motor vehicles. This work shows that reductions in both ambient concentrations of CO and average personal exposure in Denver, Colorado, occurred over the last 10 years. Reductions in mobile source emissions are the primary reason for these reductions. This research was the basis for a larger study relating meteorological variables and trends in motor vehicle emissions to urban carbon monoxide concentrations (Glen *et al.*, accepted for publication).

Developmental work and background investigations were also performed on HAPEM-MS. A literature review of indoor/outdoor ratios for benzene/toluene/ethylbenzene/xylene, CO, and air exchange tracer concentrations was obtained, including temporal changes with monitored meteorology and SF_6 tracer measurements. Also, an investigation into additional meteorological parameters for choosing activity patterns from the three-city database was performed. No significant correlation was found between the meteorological parameters chosen and relationships to human activity patterns. Finally, a comparison of model outputs for the latest version of HAPEM-MS with outputs from the latest version of the probabilistic National ambient air quality Exposure Model for CO (pNEM/CO) was performed. These results are not yet available.

OAQPS uses pNEM/CO in its on-going assessment of the National Ambient Air Quality Standards (NAAQS). The model has received limited evaluation, and an independent external review group, the Clean Air Science Advisory Committee, recommended that pNEM/CO be formally evaluated by independent analysis. To this end, an in-depth evaluation of the model was performed (Law *et al.*, accepted for publication). It was found that the model underestimates personal exposures of individuals with high exposures to CO.

2.5.12 Interactive Multi-Layer Source-Receptor Trajectory Module

A two- and a half-year project to develop a multi-layer wind trajectory model useful for relating exposure concentrations to distant sources was started. The work will be performed under a competitive cooperation agreement and the products will be used to support the need to include an identification of source contributions for human exposure assessments. This work is proceeding based on the original Washington University CAPITA (Center for Air Pollution and Trend Analysis) Monte Carlo model for simulation of regional scale transport.

2.5.13 Sulfur Dioxide Fumigation in Mae Moh Valley, Thailand

A study was initiated and conducted during FY-1994 in support of the EPA Environmental Action Team assisting the Royal Thai Government in the air pollution emergency at the Mae Moh Power Station in northern Thailand. A single-beam monostatiac sodar, radar wind profiler, RASS, and in situ sensors mounted on a 100-m tower were used to acquire meteorological data. During FY-1995, these data were used to examine the atmospheric processes, which are responsible for fumigation of high concentrations of sulfur dioxide to the surface on a near daily basis during this cool season (Crescenti and Gaynor, 1995, and Crescenti et al., 1994). CALPUFF version 1.0 (Scire *et al.*, 1990) was used to investigate modeling of pollution in the Mae Moh Valley. A gridded fumigation scheme was incorporated into CALPUFF, enabling the simulation of the spacial and temporal concentration of sulfur dioxide within the valley. Comparisons of time series of model versus measured hourly concentrations were generally good. The project has provided the Royal Thai Government scientifically sound advice on the nature of surface- and upper-air meteorology over the Mae Moh Power Plant; the possibility to forecast a potential for an air pollution emergency; and the modeling approach needed to assess potential concentration levels and time period for an air pollution emergency. The database resulting from this project is very valuable for future model studies of plume fumigation.

2.5.14 Statistical Modules and Advanced Mathematical Analysis Tools Developed for an Innovative Multi-Pollutant Human Exposure Model

A two-year project to model human exposure to air pollutants was begun. This innovative project includes both a field sampling and a data analysis component. This project responds to the need for improved methodologies for estimating the exposures of the population for use in its risk assessments. The project seeks to address this need directly by developing a new exposure assessment methodology with a solid statistical framework. The goal is to develop a multi-pollutant model of exposures, which will combine the latest research on human time/activity patterns; concentration levels for numerous indoor and outdoor locations; air exchange rates for calculating indoor intrusion of ambient pollutants; spatial mapping of ambient pollution concentrations; meteorological effects on the distribution of pollutants; and emissions from specific sources with the calculation of exposure scenarios using rigorous mathematical and statistical techniques. Nine months of 5-minute measurements of both indoor and outdoor concentrations for CO, ozone, and $PM_{2.5}$ (including the PAHs bound to those particles) were collected at a site in the San Francisco Bay Area. Ultimately, over a full year of such data will be collected. During the first year, activity focused on getting the new instrumentation working at this special site and developing a plan for gathering data from all Bay Area ambient monitoring stations. During the second year, activities will focus on research related to meteorological factors and ambient site characterization for developing models of temporal and spatial distributions of human exposures.

2.5.15 Chemical Hazards of Atmospheric Releases Research

As authorized by the 1990 CAAA, the Chemical Hazards Atmospheric Releases Research (CHARR) program began studies on dispersion of dense (heavier-than-air) gases with a series of CO_2 releases at the Spills Test Facility, Nevada Test Site, in July 1993. Further experiments under the CHARR program at this site were carried out in September 1995 with a strong emphasis on low wind speed and stable conditions. The overall value of the program was greatly enhanced by a collaboration with the Petroleum Industry Research Forum (PERF), which sponsored a series of releases in August 1995 at the site, using the same instrumentation array. Since PERF's main interest is modeling of accidental release scenarios within industrial settings of very large roughness, part of the program was done with artificial roughening of the desert floor to as much as 1000 times its natural roughness length.

In part, the 1993 experiments were a test of real-time, infrared CO_2 sensors with 37 of the sensors positioned on 9 towers at one arc 40 m from the source, and most of the sensors collocated with bag samplers so that time integrated concentrations could be compared. These comparisons, as well as mass flux checks against the known release rate, were for the most part very satisfactory (Egami *et al.*, 1995; Briggs, 1995). Therefore, it was decided to expand usage of the CO_2 sensors to 80 units in 1995, positioned on four arcs at 25, 50, 100 and 225 m from the source. For the first three arcs, some sensors were deployed on five-level towers 4.8 to 10 m high, three towers per arc.

The PERF roughness array had two components. All PERF experiments used a 120 by 330 m, 6600-element Uniform Roughness Array (URA) developed in the Division wind tunnel in Research Triangle Park, North Carolina; these flat-baffle elements were 0.8 m wide by 0.2 m high, on 2.4 m spacing. A row of turbulence-generating spires 5 m high was placed at the upwind end to accelerate boundary-layer development, a technique long used in wind tunnels. The first series of PERF experiments also used a 40 x 85 m array of 2.4 by 2.4 m baffles centered on the source; this Equivalent Roughness Pattern (ERP) was developed to simulate the dispersive effect of an industrial complex (the field scale was 6 to 10 times smaller than full-scale, but very much larger than wind tunnel scales). Both the URA and the ERP were removed for the CHARR smooth desert experiments; the roughness lengths associated with the ERP, URA, and smooth desert were 200, 12, and 0.2 mm.

Five meteorological towers with 25 prop-vanes, 10 sonic anemometers, temperature, and radiation measurements provided ample meteorological measurements. About 72 releases of CO_2 were picked up on at least several arcs during the August-September 1995 experiments; two-thirds of these were 20 second puffs, while the remaining were long enough to be considered continuous releases. Half the releases were made with the URA roughness and the remainder were evenly split between the ERP, URA, and smooth desert configurations.

2.6 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.

2.6.1 Modeling Studies

2.6.1.1 Regional Ozone Modeling for Regulatory Applications

Two ozone modeling efforts involved ROM. The first modeling effort was ROM simulations performed to support the Ozone Transport Commission in the development of emission control strategies to reduce ozone levels in the northeastern United States. This work involved ROM simulations to assess the effectiveness of a low emissions vehicle program and controls on major source of nitrogen oxides. Simulations were made to evaluate the benefits of these controls in reducing ozone in the Northeast, and of applying these controls across the entire eastern United States versus the Northeast only. The results indicate that there are significant additional benefits to the Northeast of controls applied outside this region although the greatest benefits occur from controls applied within the Northeast. This effort will be expanded in FY-1996 to assess the impact of potential new national, regional, and subregional control strategies within the eastern United States. In addition to ROM, UAM-V will be used in this study. UAM-V has enhanced features including plume-in-grid treatment, multiple nested grids, and increased vertical resolution compared to ROM.

The second modeling effort involved ROM applications to support the review by the EPA of the ozone National Ambient Air Quality Standard (NAAQS). Using meteorological data from the summer of 1987, simulations covering a 92-day period were completed for an emission scenario forecast to 2007. The results were used to identify areas in the eastern United States where ozone levels would be expected to exceed the current 1-hr ozone NAAQS and potential new 8-hr NAAQS, after the implementation of controls required by the 1990 CAAA. Additional simulations were completed to identify the local emission reductions that might be necessary to attain these standards. The results are being used by the EPA in the cost/benefit analysis that is required in the agency's review of NAAQS. During FY-1996, additional modeling will be performed to compare the benefits of local versus regional strategies for attaining alternative standards.

2.6.1.2 Surface Coal Mine Study

Section 234(a) of the CAAA requires the EPA to analyze the accuracy of the Industrial Source Complex (ISC) dispersion model in predicting the effect on air quality of fugitive dust emissions from mining activities at large surface coal mines. In response to these requirements, an extensive model evaluation study of emissions from fugitive dust sources was conducted.

Phase I of the study involved the collection of meteorological and air quality data at the Cordero mine, south of Gillette, Wyoming, in the Powder River Basin. 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 to determine hourly emission estimates. The study was successful in compiling a unique database that consists of 30 days of meteorological data, air quality data and source activity data, with the necessary quality required to test the predictive accuracy of the ISC dispersion model.

In Phase II of the study, an objective model evaluation protocol was developed, after extensive negotiations among the mining industry, State of Wyoming, and EPA. The protocol lists in detail all the scientific model input assumptions as well as the statistical performance and acceptable test criteria. In this study, the performance of the ISC model is being compared with an enhanced version of the model that includes improved modeling techniques. These improvements include a new area source algorithm applicable for ground-level releases, a new particulate-matter dry-deposition algorithm, and a fugitive-source algorithm to estimate the amount of particulate matter that can escape from a large surface mine pit.

Several source characterization techniques for modeling these fugitive sources were also examined (Hardikar et al., 1995; Cowherd *et al.*, 1995; U.S. Environmental Protection Agency, 1994). Preliminary results show that, in general, the enhancements to the ISC model have resulted in improved model performance, i.e., the enhanced ISC model, coupled with revised emission factors performed better than the standard ISC model with the standard AP-42 emission factors. A draft report was prepared.

2.6.2 Modeling Guidance

2.6.2.1 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 1995, final reviews, clearances, and formal promulgation were completed on supplement C, to augment the available guidance in several areas. This supplement included incorporation of improved algorithms for treatment of dispersion from area sources and characterization of dry particulate deposition during transport downwind. A new solar radiation and temperature difference method was approved for use in determining Pasquill stability categories with on-site meteorological instrumentation. A new screening approach for assessing annual nitrogen dioxide impacts was added based on the work of Chu and Meyer (1991). Also, two alternative dense-gas air-dispersion models were added for consideration: SLAB (Ermak, 1990) and HGSYSTEM (Witlox, 1991).

2.6.2.2 Support Center for Regulatory Air Models

During FY-1995, several activities were accomplished in the Support Center for Regulatory Air Models (SCRAM). A restructuring of the SCRAM BBS was tested and completed. Among the changes was a new SCRAM main menu, which more appropriately groups items of similar purpose. The top of the main menu highlights the EPA models; the core of the SCRAM BBS. Within this new area, the models, user's guides, and model change bulletins were brought together for easy access and less confusion. In addition, the *Guideline on Air Quality Models* with supplement C, including new and revised dispersion models and related documentation, were uploaded to the SCRAM BBS. This action affected several models/programs including SCREEN, ISC, PCRAMMET, and MPRM. A new area was created on the main SCRAM menu entitled *Sixth Modeling Conference* to facilitate the release of conference materials prior to and following the conference, which was held in August 1995.

2.6.2.3 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. Air dispersion models are used as a vital tool in assessing the potential risks associated with existing and proposed emissions and for contingency analyses. Through consultation with the EPA Air/Superfund Coordinators and Regional Modeling Contacts, all special modeling requirements for these sites were identified and a guidance document to address these modeling needs was developed (Touma *et al.*, 1995; Touma, 1995; U.S. Environmental Protection Agency, 1995a). This latter EPA report, which is one of a five-volume series dealing with air pathway assessment of hazardous air releases from Superfund sites, is intended for use by a diverse audience including the EPA and State agency staffs, and contractors and field personnel for designing, conducting, and evaluating air dispersion modeling analyses. The document discusses the approach to model selection and major components for modeling analysis to understand how the treatment of each component directly affects the predicted concentrations. These include meteorology (windspeed and direction, atmospheric stability, etc.), terrain, urban/rural classification, averaging time, etc. The document also addresses how modeling results can be summarized and interpreted by the user.

2.6.2.4 Sixth Modeling Conference

As required by Section 320 of the Clean Air Act, a formal conference is held every three years for the purpose of providing review of air quality modeling methods. The sixth of these conferences was held in Washington, D.C., August 9 and 10, 1995, with over 100 people in attendance. A primary focus of this conference was a review of work accomplished by the AMS/EPA Regulatory Model Improvement Committee (AERMIC) and by the Interagency Work Group on Air Quality Modeling (IWAQM). The focus of AERMIC is to fabricate a Gaussian plume model having modern boundary layer parameterizations. The focus of IWAQM is to fabricate a meteorological and puff modeling system for use in local and mesoscale modeling assessments. Presentations included descriptions of the projects, the technical basis of work, how the modeling techniques differ from more commonly used modeling algorithms, and the status and results obtained so far in the two programs.

2.6.3 Additional Support Activities

2.6.3.1 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 formulated and recommended changes in the scientific components of regulatory air models and participated in the evaluation and implementation of these new methodologies. The initial focus was on the Industrial Source Complex (ISC) model because of its wide use in regulatory applications. Improvements were expected in the areas of dispersion, plume rise, complex terrain, and surface-layer parameterizations.

The committee completed a beta version of the revised model, now called AERMOD, along with a meteorological preprocessor (AERMET). Both AERMOD and AERMET were made available for public testing. A developmental evaluation was conducted continuously as a part of the model development, with encouraging results. An internal technical review was completed and an external beta test is underway, which will help define possible changes for consideration to the modeling system.

2.6.3.2 Interagency Work Group on Air Quality Models

In October 1991, the EPA, National Park Service (NPS), U.S. Fish and Wildlife Service (FWS), and U.S. 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 the NPS, FWS, FS, and EPA. The objective of the work group is to foster the development of mutually acceptable techniques for characterization of these impacts and assist in the development of rulemaking to adopt acceptable models according to the EPA *Guideline on Air Quality Modeling (Revised)* (U.S. Environmental Protection Agency, 1987).

During FY-1995, the work group sponsored the completion of a Lagrangian puff modeling system entitled CALPUFF (U.S. Environmental Protection Agency, 1995e). CALPUFF's meteorological processor includes a diagnostic wind model, which provides an initial guess wind field adjusted for kinematic effects of terrain, slope flows, terrain blocking effects, and three-dimensional divergent minimization. Provisions were made to allow for the incorporation of winds as might be developed by a hydrodynamic mesoscale meteorological modeling system. CALPUFF provides a variety of dispersion characterization options to allow tailoring of the dispersion characterization to particular situations. Options included are either time-dependent dispersion parameters or distance-dependent Pasquill-Gifford dispersion parameters; dry- and wet-particulate deposition; partial buoyant plume penetration into elevated capping inversions; plume rise characterization for forest fires; plume impaction on isolated hills, and first-order chemical transformation during transport downwind. The creation of the setup files to run the entire modeling system is facilitated by a user-friendly windows application interface. Each subsystem interface has on-line context sensitive help and access to the entire user's guide electronically. The latest versions of user interfaces, code, and user's guides are available on the SCRAM BBS.

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APPENDIX A: ACRONYMS

ACM	Asymmetric Convective Model
ADOM	Acid Deposition and Oxidant Model
AERMIC	AMS/EPA Regulatory Model Improvement Committee
AERMAP	AERMOD terrain preprocessor
AIRMET	AERMOD meteorological preprocessor
AERMOD	Improved ISCST2 Model
AGDRIFT	AGricultural spray DRIFT model
AMS	American Meteorological Society
AQM	Air Quality Model
ASMD	Atmospheric Sciences Modeling Division (NOAA)
ATDD	Atmospheric Turbulence and Diffusion Division (NOAA)
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
CENR	Committee on Environment and Natural Resources
CHARR	Chemical Hazards of Atmospheric Releases Research
CIC	Committee on Information and Communications (NSTC)
CIRES	Cooperative Institute for Research in Environmental Sciences
CREME	Cooperative REgional Model Evaluation project
CTDMPLUS	Complex Terrain Dispersion Model PLus algorithms for Unstable Situations
CTM	Chemistry Transport Model
DOE	Department of Energy
EIIP	Emission Inventory Improvement System
EMEP	European Monitoring and Evaluation Program
EPA	Environmental Protection Agency
ERP	Equivalent Roughness Pattern
EUROTRAC	EUROpean experiment on the TRAnsport and transformation of trace atmospheric Constituents
FCMSSR	Federal Committee for Meteorological Services and Supporting research
FDDA	Four Dimensional Data Assimilation
FIFE	First ISLSCP Field Experiment
FREDS	Flexible Regional Emissions Data System
FS	Forest Service
FWS	Fish and Wildlife Service
FY	Fiscal Year
GEMAP	Geocoded Emission Modeling and Projection
GIS	Geographical Information System
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

IAMSLIC	International Association of Marine Sciences and Library Information Centers
ICMSSR	Interdepartmental Committee for Meteorological Services and Supporting Research
IGAC	International Global Atmospheric Chemistry committee
INPUFF	INtegrated PUFF model
IOV	Initial Operating Version
ISC2	Industrial Source Complex model - version 2
ISCST3	Industrial Source Complex Short-Term model - version 3
ISC-COMPDEP	Industrial Source Complex-COMPlex terrain DEPosition model
ITM	International Technical Meeting
IWAQM	Interagency Work Group on Air Quality Models
LAI	Leaf Area Index
LMMBP	Lake Michigan Mass Balance Project
LMOS	Lake Michigan Ozone Study
LRPM	Lagrangian Reactive Plume Model
MESOPUFF	MESOscale Lagrangian PUFF dispersion model
MM4/5	Mesoscale Meteorological Model - version 4/version 5
MMM	Mesoscale Meteorological Model
Models-3	Third generation air quality modeling system
MPRM	Meteorological Processor for Regulatory Models
MSC-W	Modeling Synthesizing Center - West
NAAQS	National Ambient Air Quality Standards
NAPAP	National Acid Precipitation Assessment Program
NARSTO	North American Research Strategy for Tropospheric Ozone
NARSTO-NE	NARSTO-NorthEast
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NATO/CCMS	North Atlantic Treaty Organization/Committee on Challenges of Modern Society
NBS	National Bureau of Standards
NCAR	National Center for Atmospheric Research
NDDN	National Dry Deposition Network
NERL	National Exposure Research Laboratory (EPA)
NESC	National Environmental Supercomputing Center (EPA)
NESCAUM	NorthEast States for Coordinated Air Use Management
NH	Northern Hemisphere
NMC	National Meteorological Center
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NRC	National Research Council
NSF	National Science Foundation
NWS	National Weather Service
OAQPS	Office of Air Quality Planning and Standards (EPA)
OB/OD	Open Burning/Open Detonation
OMB	Office of Management and Budget
ORD	Office of Research and Development (EPA)
OSTP/NSTC	Office of Science and Technology Policy/National Science and Technology Council
PAMS	Photochemical Assessment Monitoring Stations
PBL	Planetary Boundary Layer
PCRAMMET	Personal Computer version of the ISC meteorological processor

PDM	Plume Dynamics Model
PERF	Petroleum Environmental Research Forum
PM	Particulate Matter
pNEM/CO	probabilistic National ambient air quality Exposure Model applied to Carbon Monoxide
PVM	Parallel Virtual Machine
QA	Quality Assurance
QC	Quality Control
QBO	Quasi-Biennial Oscillation
RADM	Regional Acid Deposition Model
RCRA	Resource Conservation and Recovery Act
RASS	Radio Acoustic Sounding System
RELMAP	REgional Lagrangian Model for Air Pollution
RMS	Root Mean Square
ROM	Regional Oxidant Model
RPC	Rotated Principal Component
RPM	Regional Particulate Model
SAEWG	Standing Air Emission Work Group
SAIL	Southeast Affiliate of IAMSLIC Libraries
SAPRC	Statewide Air Pollution Research Center chemical mechanisms University of California
SARMAP	SJVAQS/AUSPEX Regional Modeling Adaptation Project
SASWG	Standing Air Simulation Work Group
SCRAM BBS	Support Center for Regulatory Air quality Models Bulletin Board System
SERDP	Strategic Environmental Research and Development Program
SH	Southern Hemisphere
SHED	Sealed Housing for Evaporative Determination
SLAB	Atmospheric dispersion model for denser-than-air releases
SMVGEAR	Sparse Matrix Vectorized GEAR
SOS	Southern Oxidant Study
SVOC	Semi-Volatile Organic Compound
TEQ	Toxic EQuivalent
TOMS	Total Ozone Mapping Spectrometer
UAM	Urban Airshed Model
UAMGUIDES	Urban Airshed Model with Graphical User Interface and DEcision Support
UAMMET	Urban Airshed Model METeorological module
URA	Uniform Roughness Area
URL	Uniform Resource Locator
USGS	U.S. Geological Survey
USWRP	U.S. Weather Research Program
UV	Ultraviolet
VOC	Volatile Organic Compound
WWW	World-Wide Web

APPENDIX B: PUBLICATIONS

Alapaty, K., D.T. Olerud, Jr., K.L. Schere, and A.F. Hanna. Sensitivity of Regional Oxidant Model predictions to prognostic and diagnostic meteorological fields. *Journal of Applied Meteorology* 34:1787-1801 (1995).

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APPENDIX C: PRESENTATIONS

Benjey, W.G. Recent and ongoing toxic emission inventory compilation in the United States. Presentation at the Global Emission Inventory Activity Workshop, Gothenburg, Sweden, July 2, 1995.

Benjey, W.G. Processing of emission inventory data for air quality modeling with the Models-3 system. Presentation at the Global Emission Inventory Activity Workshop, Gothenburg, Sweden, July 3, 1995.

Binkowski, F.S. Modeling aerosol characteristics over eastern North America. Presentation at the AWMA International Specialty Conference Particulate Matter: Health and Regulatory Issues, Pittsburgh, PA, April 5, 1995.

Binkowski, F.S. Development and application of a three-dimensional regional particulate model. Invited presentation at the National Public Health Institute, Division of Environmental Health, Kuopio, Finland, September 25, 1995.

Binkowski, F.S., and U. Shankar. Prediction of aerosol characteristics over eastern North America using a three-dimensional Eulerian model. Presentation at the 1995 European Aerosol Conference, Helsinki, Finland, September 19, 1995.

Binkowski, F.S., and U. Shankar. The sensitivity of aerosol ammonium deposition to the uncertainties in ammonia emissions over North America. Presentation at the International Conference on Atmospheric Ammonia: Emission, Deposition and Environmental Impacts, Culham, Oxford, UK. October 3, 1995.

Briggs, G.A. Wind tunnel/laboratory studies to support Petroleum Environmental Research Forum (PERF) project on dense gas diffusion with large roughness and obstacles, low wind speed and stable conditions. Presentation at a meeting of PERF (EPA-Petroleum Industry), Research Triangle Park, NC, November 29, 1994.

Bullock, O.R., Jr. Regional-scale atmospheric modeling for the Mercury Study Report to Congress. Briefing for the Assistant Administrator for Research and Development, U.S. Environmental Protection Agency, Washington, DC, January 10, 1995.

Bullock, O.R., Jr. Atmospheric modeling strategy for the proposed South Florida Atmospheric Mercury Study. Presentation at a meeting between the Assistant Administrator for Research and Development and Administrator for Region IV, U.S. Environmental Protection Agency, Atlanta, GA, January 23, 1995.

Bullock, O.R., Jr. Long-range transport modeling of air pollution at the EPA National Exposure Research Laboratory. Presentation at the EPA STAPPA/ALAPCO Risk Assessment Workshop, Research Triangle Park, NC, May 2, 1995.

Byun, D.W. Emerging high performance computational multi-pollution, multiple-scale emissions based modeling system. Presentation at the AWMA International Specialty Conference Particulate Matter: Health and Regulatory Issues, Pittsburgh, PA, April 6, 1995.

Castro, I.P. (University of Surrey, England). Relaxing boundary layers behind separated regions. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, August 25, 1995.

Ching, J.K.S. Overview: modeling of fine particulates on regional and urban scales. Presentation at the AWMA International Specialty Conference Particulate Matter: Health and Regulatory Issues, Pittsburgh, PA, April 5, 1995.

Ching, J.K.S. Models-3 overview. Presentation at the Sixth Modeling Conference, Washington, DC, August 9, 1995.

Ching, J.K.S., and J.E. Pleim. Evaluation of PBL schemes using the First ISLSCP Field Experiment (FIFE) data. Presentation at the 11th Symposium on Boundary Layers and Turbulence of the American Meteorological Society Charlotte, NC, March 28, 1995.

Ching, J.K.S., J.E. Pleim, and J.S. Irwin. Diagnostic evaluation of predicted mixing height and cloud fields from the MM4-FDDA Meteorological Model. Poster presentation at the International Union of Geodesy and Geophysics, Boulder, CO, July 3, 1995.

Cooter, E.J. Climate 101: introduction to climatology for weather and climate applications managers for resource management. Presentation at National Advanced Resource Technology Center, Marana, AZ, March 20, 1995.

Cooter, E.J., A. Sampson, and P. Dougherty. Effects of initial stand and site conditions on simulated NPP in *Pinus taeda L.* Presentation at the Annual Ecological Society of America Meeting, Snowbird, UT, July 31, 1995.

Cooter, E.J., and D.B. Schwede. An overview of work utilizing math and science for career choices. Presentation at the Expanding Your Horizons Conference attended by seventh grade girls, Raleigh, NC, March 14, 1995.

Coulter, C.T., and J.S. Touma. Proposed revisions to EPA's guideline on air quality models. Paper No. 95-WA-75A. Presentation at the 88th Annual Meeting of the Air & Waste Management Association, San Antonio, TX, June 20, 1995.

Cowherd, C., A.K. Caughron, and J.S. Touma. Development of a time-resolved emission inventory for a western surface coal mine. Paper No. 95-TA-38.03. Presentation at the 88th Annual Meeting of the Air & Waste Management Association, San Antonio, TX, June 19, 1995.

Dennis, R.L. Overview of simulation in the improvement of environmental management. Invited presentation at the Conference on Environmental Impact Prediction, North Carolina Supercomputing Center, Research Triangle Park, NC, October 6, 1994.

Dennis, R.L. Using the Regional Acid Deposition Model to determine atmospheric nitrogen loading to coastal estuaries. Presentation at the 15th Annual Meeting of the Society of Environmental Toxicology and Chemistry, Denver, CO, November 2, 1994.

Dennis, R.L. EPA's Chesapeake Bay multi-media modeling. Presentation for the EPA Senior Leadership Council, Washington Information Center, Washington, DC, December 6, 1994.

Dennis, R.L. Regional modeling with the Regional Acid Deposition Model. Presentation to the NRC Committee on Research and Peer Review in EPA, Research Triangle Park, NC, May 1, 1995.

Dennis, R.L. Regional air quality modeling at the U.S. EPA for multi-pollutant and cross-media assessments. Invited presentation at the WMO International Conference on Meteorological and Hydrological Technology and Its Management--METEOHYTEC 21, Geneva, Switzerland, May 26, 1995.

Dennis, R.L. Sources of atmospheric nitrogen deposition to U.S. Atlantic coastal estuaries and ocean waters as estimated by the Regional Acid Deposition Model. Invited presentation at the Gordon Research Conference on Estuarine & Coastal Processes, Plymouth State College, Plymouth, NH, June 20, 1995.

Dennis, R.L. Estimating the regional extent of pollutant impacts using the Eulerian model RADM. Presentation at the International Joint Commission's 1995 Biennial Meeting, Duluth, MN, September 24, 1995.

Eltgroth, M.W., J.S. Touma, and D. Yeh. Systematic method for determining a hazardous air pollutant release scenario and model input. Poster for International Conference and Workshop on Modeling and Mitigating the Consequences of Accidental Releases of Hazardous Materials, New Orleans, LA, September 27, 1995.

Ferrier, A. (Georgia Institute of Technology, Atlanta, GA). Procedures toward the recovery of concentration information obtained from planar laser-induced fluorescence images. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, June 2, 1995.

Genikhovich, E.L. (Main Geophysical Observatory, St. Petersburg, Russia). Comparison of American and Russian screen-type models. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, November 15, 1995.

Huber, A.H. Characterization of human exposure to MTBE. Presentation at the EPA Workshop to Provide Guidance on the Feasibility and Design of Epidemiologic Studies Among Population Exposed to MTBE, Research Triangle Park, NC, April 14, 1995.

LeDuc, S.K. Computer-based tools to assist in air quality modeling (technology transfer). Lecture via satellite and Internet to State Air Offices through the Air Pollution Technical Institute, Raleigh, NC, March 22, 1995.

Lee, R.F., and J.S. Irwin. A methodology for a comparative evaluation of two air quality models. Third Workshop on Harmonisation Within Atmospheric Dispersion Modelling for Regulatory Purposes, Mol, Belgium, November 22, 1994.

Nieuwstadt, F.T.M. (University of Delft, Netherlands). Drag reduction by Riblets in a turbulent boundary layer under adverse pressure gradient. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, August 18, 1995.

Novak, J.H. EPA's HPCC program: grand challenge tools for state and industrial use. Presentation at the RCI North American Annual Membership Executive Conference, Herndon, VA, November 2, 1994.

Novak, J.H. EPA's program accomplishments for the HPCC program. Presentation at the HPCC Panel, Supercomputing '94 Conference, Washington, DC, November 16, 1994.

Novak, J.H. Integrating quality assurance for development of EPA's Models-3. Presentation at the North Carolina Quality Assurance Discussion Group, Research Triangle Park, NC, March 8, 1995.

Novak, J.H. Computer-based tools to assist air quality modeling (air quality modeling systems - short & long term needs). Lecture via satellite and Internet to State Air Offices through the Air Pollution Technical Institute, Raleigh, NC, March 22, 1995.

Novak, J.H. Plans and activities supporting the long term modeling vision. Lecture via satellite and Internet to State Air Offices through the Air Pollution Technical Institute, Raleigh, NC, March 22, 1995.

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, August 11, 1995.

Novak, J.H. Computer-based tools for State environmental management. Presentation at the EPA Technology Exposition, Washington, DC, December 6, 1995.

Novak, J.H. New technologies for data sharing and air quality management. Presentation at the Joint Plenary Session of the SAEWG, SASWG, and SAMWG, Philadelphia, PA, April 21, 1995.

Ohba, M. (Tokyo Institute of Polytechnics, Japan). Study on measurement techniques of concentration fluctuations in wakes of model stack and building using high-speed video images. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, September 7, 1995.

Ohba, R. (Mitsubishi Heavy Industries, Nagasaki, Japan). Prediction of gas diffusion in thermally stratified flow over mountainous terrain. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, December 16, 1994.

Okabayashi, K. (Mitsubishi Heavy Industries, Nagasaki, Japan). An example of numerical simulation of building wake diffusion under wind direction fluctuations. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, September 25, 1995.

Perry, S.G. AERMOD dispersion model: model description and evaluation. Presentation at the USEPA Regional and State Modelers Workshop, Region 2, New York, NY, May 8, 1995.

Perry, S.G. Current research activities of the Atmospheric Sciences Modeling Division. Presentation at USEPA Regional and State Modelers Workshop, New York, NY, May 10, 1995.

Perry, S.G. Overview of orchard-airblast spray-drift research program. Presentation at Pesticides Research Program Review, Research Triangle Park, NC, May 24, 1995.

Perry, S.G. AERMOD dispersion model: evaluation results. Presentation at the Sixth Conference on Air Quality Modeling, Washington, DC, August 9, 1995.

Pierce, T.E. Sensitivity of the Regional Oxidant Model to isoprene emission uncertainties. Presentation at the Data Analysis Workshop for the Oak Ridge Isoprene Field Experiment, Pullman, Washington, December 16, 1994.

Pierce, T.E. Looking at the sky. Millbrook Elementary School, Kindergarten class, Raleigh, NC, January 9, 1995.

Pierce, T.E. Use of alternate biogenic emission inventories in ozone models. Invited talk to the Modeling Ozone Cooperative Project, Washington, DC, February 23, 1995.

Pierce, T.E. Proposed improvement to biogenic emissions methodologies. Presentation at the Emissions Inventory Improvement Plan Workshop, Morrisville, NC, May 11, 1995.

Pierce, T.E. Development of a preferred methods document for estimating biogenic emissions. Presentation at the Plenary Session of the AWMA Conference on Emission Inventories, Raleigh, NC, November 2, 1994.

Pierce, T.E. Advances in biogenic emission modeling in the United States. Presentation at the Canadian Workshop on Biogenic Hydrocarbon Emissions, Environment Canada, Ottawa, Canada, November 16, 1994.

Pleim, J.E. Development and model description of a land-surface/PBL model within a Mesoscale Meteorological Model. Presentation at the International Union of Geodesy and Geophysics, Boulder, CO, July 4, 1995.

Schatzmann, M. (University of Hamburg, Germany). Building effects on heavy gas jet dispersion. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, September 25, 1995.

Schere, K.L. What we are learning from air quality observations and modeling. Presentation at the MIT Symposium on Effective Technology for Reducing Vehicle Emissions, Dedham, MA, July 19, 1995.

Schere, K.L. NARSTO overview to the plenary session. Presentation at the Standing Air Simulation Work Group Meeting, Philadelphia, PA, April 21, 1995.

Schiermeier, F.A. Overview of Atmospheric Characterization and Modeling Division research programs. Presentation to delegation of the Singapore National Science and Technology Board, Research Triangle Park, NC, November 10, 1994.

Schiermeier, F.A. Overview of Atmospheric Sciences Modeling Division. Presentation at the NOAA/ARL Science Management Review, Silver Spring, MD, December 1, 1994.

Schiermeier, F.A. Opening address and plans for Working Group research activities. Presentation at the Eighteenth United States/Russia Working Group Meeting on Air Pollution Modeling, Instrumentation, and Measurement Methodology, St. Petersburg, Russia, July 3, 1995.

Schiermeier, F.A. Effects of ORD Budget Adjustments on Program Office Support. Presentation at the Standing Air Simulation Work Group Meeting, San Antonio, TX, September 16, 1995.

Schiermeier, F.A., and E.J. Cooter. Climate data and analysis for the New England Forest Health Monitoring Project. Poster presented at the CIA/NOAA Joint United States/Russian Ecological/Environmental Seminar, Washington, DC, May 16, 1995.

Shankar, U., A.F. Hanna, C.J. Coats, Jr., S.R. Thorpe, and F.S. Binkowski. An integrated aerosol model to predict regional visibility with output visualization. Presentation at the Fourteenth Annual Meeting of the American Association for Aerosol Research, Pittsburgh, October 10, 1995.

Sickles, J.E., J. Fisherman, F. Vukovich, V. Brackett, B.K. Eder, S.N. LeDuc, M. Bolstad, and L. Truppi. Visualization of satellite-based global tropospheric ozone data. Presentation at the Third International Environmental Visualization Exposition, Research Triangle Park, NC, June 26, 1995.

Streicher, J.J. Isothermal automobile fuel system vapor emission following evaporation canister breakthrough. Presentation at the Engineering Solutions to Indoor Air Quality Problems Conference, Research Triangle Park, NC, July 24, 1995.

Thompson, R.S. Random-walk modeling of particle dispersion in surface coal mines. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, February 2, 1995.

Touma, J.S. Developments in EPA's air dispersion modeling for hazardous/toxic releases. Paper No. 95-WA-54B.04. Presentation at the 88th Annual Meeting of the Air & Waste Management Association, San Antonio, TX, June 22, 1995.

Touma, J.S., M.W. Eltgroth, T.K. Paik, and E.D. Chikhliwala. Expert interface for air emissions from Superfund sites. Paper No. 95-TP-55.02. Presentation at the 88th Annual Meeting of the Air & Waste Management Association, San Antonio, TX, June 21, 1995.

Touma, J.S., M.W. Eltgroth, and S.M. Templeman. Procedures for air dispersion modeling at Superfund sites. Paper No. 95-TP-55.03. Presentation at the 88th Annual Meeting of the Air & Waste Management Association, San Antonio, TX, June 21, 1995.

Tsutsumi, J. (University of Ryukyu, Japan). Large eddy simulation of indoor and outdoor turbulent air flow: 3-D model of natural ventilation within a room, and 1-D and 2-D models of the urban atmosphere. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, September 7, 1995.

Walter, G.L. Southern Oxidant Study data archive WWW interface. Presentation at the NOAA World-Wide Web Workshop, Bethesda, MD, June 15, 1995.

APPENDIX D: WORKSHOPS

SOS Aircraft Planning Workshop for 1995 Nashville Field Study, Atlanta, GA, October 14, 1994.

R.L. Dennis

SOS Planning Workshop to Prepare Aircraft Experiments for 1995 Nashville Field Study, Boulder, CO, November 14-17, 1994.

R.L. Dennis

Mercury Research Coordination Workshop, West Palm Beach, FL, November 15-17, 1994.

O.R. Bullock, Jr.

Canadian Workshop on Biogenic Hydrocarbon Emissions, Environment Canada, Ottawa, Canada, November 16, 1994.

T.E. Pierce

Third Workshop on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes, Mol, Belgium, November 22-24, 1994.

R.F. Lee

Seminar on Evaluation of Models of Heavy Gas Dispersion, Mol, Belgium, November 25, 1994.

R.F. Lee

PERF Workshop for Planning Field Experiments and Wind-Tunnel Measurements of Dense-Gas Dispersion over Large Roughness Elements, Research Triangle Park, NC, November 29-30, 1994.

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

The Continuing Education Symposium, Environmental Air Regulations, Sampling, Analysis and Modeling, Pittsburgh, PA, December 3, 1994.

J.S. Touma

Workshop on Advanced Air Quality Systems at Carnegie Mellon University, Pittsburgh, PA, December 5-8, 1994.

W.G. Benjey
D.W. Byun
J.K.S. Ching
J.H. Novak
G.L. Walter
J.O. Young

Data Analysis Workshop for the Southern Oxidant Study's Oak Ridge Isoprene Field Experiment, Pullman, WA, December 16, 1994.

T.E. Pierce

EPA/NERL Workshop to Develop Laboratory Strategy for Multi-Media Modeling, Environmental Research Laboratory, Athens, GA, December 20-21, 1994.

R.L. Dennis
A.H. Huber
F.A. Schiermeier

Workshop on Systems Software and Tools, Pasadena, California, January 10-12, 1995.

G.L. Walter

SOS Data Analysis Workshop and Annual Meeting, Raleigh, NC, January 10-13 1995.

J.K.S. Ching
J.M. Godowitch
T.E. Pierce
S.J. Roselle
K.L. Schere

Air/Superfund Coordinators Meeting, Las Vegas, NV, January 24-26, 1995.

J. S. Touma

EPA Mercury Study Peer Review Workshop, Cincinnati, OH, January 25-26, 1995.

O.R. Bullock, Jr.

High Performance Multi-Media Modeling Workshop, Research Triangle Park, NC, January 30-31, 1995.

J.H. Novak

Great Lakes Agricultural Profile Steering Committee Planning Meeting, Ann Arbor, Michigan, January 31, 1995.

W.G. Benjey

South Florida Atmospheric Mercury Study Data Quality Objectives Workshop, Research Triangle Park, NC, January 31 - February 2, 1995.

O.R. Bullock, Jr.

Work Group on General Transport and Regional Strategies, Durham, NC, February 6-7, 1995.

N.C. Possiel

Ozone Transport Commission Meeting, Wilmington, DE, February 13-14, 1995.

N.C. Possiel

North American Research Strategy for Tropospheric Ozone Planning Workshop, Washington, DC, February 15-16, 1995.

R.L. Dennis

Open Burn/Open Detonation Dispersion Modeling Workshop, NOAA Environmental Technology Laboratory, Boulder, Co, February 15-16, 1995

G.A. Briggs
G.H. Crescenti
J.S. Irwin
W.B. Petersen
W.H. Snyder

NARSTO-NorthEast Participants Workshop, Silver Spring, MD, February 15-16, 1995.

D.T. Bailey
K.L. Schere

Region VI Annual States Modeling Meeting Telephone Conference, Dallas, TX, March 2, 1995.

J.S. Touma

Spring Conference of the Librarians' Association at the University of North Carolina at Chapel Hill, Chapel Hill, NC, March 6, 1995.

E.M. Poole-Kober

Emission Inventory Improvement Program Steering Committee and Data Management Committee Planning Meeting, Research Triangle Park, NC, March 8-9, 1995.

W.G. Benjey

SOS Aircraft Planning Workshop for 1995 Nashville Field Study, Nashville, TN, March 15-16, 1995.

R.L. Dennis

Conference of the NOAA/EPA/NBS/USGS Librarians, Denver, CO, April 3-5, 1995.

E.M. Poole-Kober

Workshop to Provide Guidance on the Feasibility and Design of Epidemiologic Studies Among Populations Exposed to MTBE, Health Effects Research Laboratory, Research Triangle Park, NC, April 4, 1995.

A.H. Huber
M.P. Zelenka

PERF Technical Advisory Committee Meeting, Research Triangle Park, NC, April 12-13, 1995.

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

UNC/SAMI Program Review, Department of Environmental Sciences and Engineering, School of Public Health, University of North Carolina at Chapel Hill, Chapel Hill, NC, April 27, 1995.

J.S. Irwin

EPA/STAPPA/ALAPCO Risk Assessment Workshop, National Institute of Environmental Health Sciences, Research Triangle Park, NC, May 1-3, 1995.

A.H. Huber
J.S. Irwin
M.P. Zelenka

Fifth Annual Southeast Affiliate of IAMSLIC Libraries (SAIL) Workshop, Beaufort, NC, May 3-5, 1995.

E.M. Poole-Kober

Regional and State Modelers Workshop, New York, NY, May 8-12, 1995.

D.G. Atkinson
D.T. Bailey
J.S. Irwin
R.F. Lee
S.G. Perry
J.S. Touma

SAIC/SDC Staff Meeting on Models-3 Project, Arlington, VA, May 9-10, 1995.

D.W. Byun
J.K.S. Ching

STAPPA/ALAPCO/EPA Workshop on the Emissions Inventory Improvement Plan, Morrisville, NC, May 11, 1995.

T.E. Pierce

Pesticides Research Program Review, National Environmental Research Laboratory, Research Triangle Park, NC, May 24-25, 1995.

A.H. Huber
S.G. Perry
W.B. Petersen

PERF Technical Advisory Committee Meeting, Research Triangle Park, NC, May 31, 1995.

G.A. Briggs
W.H. Snyder

Ozone Transport Commission, Providence, RI, June 13, 1995.

N.C. Possiel

North American Research Strategy for Tropospheric Ozone, Core Team Planning Workshop, Albany, NY, June 7-8, 1995.

R.L. Dennis

EPA Large Lake Research Station GEOWAMS Workshop, Grosse Ile, MI, June 13, 1995.

O.R. Bullock, Jr.

Lake Michigan Mass Balance Atmospheric Modeling Workshop, Southgate, MI, June 14-15, 1995.

O.R. Bullock, Jr.
W.B. Petersen

OAR Internet/MOSAIC Workshop, Bethesda, MD, June 15, 1995.

G.L. Walter

International Environmental Visualization Exposition, Research Triangle Park, NC, June 26-28, 1995

O.R. Bullock, Jr.
D.W. Byun
J.K.S. Ching
G.L. Gipson

Global Emission Inventory Activity Workshop, Gothenburg, Sweden, July 1-3, 1995.

W.G. Benjey

United States/Russian Working Group 02.01-10 Meeting on Air Pollution Modeling, Instrumentation, and Measurement Methodology, St. Petersburg, Russia, July 3-7, 1995.

F.A. Schiermeier

ASTM 1995 Johnson Conference Performance Evaluation of Atmospheric Dispersion Models, Johnson, VT, July 9-12, 1995.

J.S. Irwin

The Computing and Atmospheric Sciences Workshop (CAS'95), Washington, DC, July 13-14, 1995.

D.W. Byun
J.K.S. Ching

Air/Superfund Coordinators Meeting, Denver, CO, July 25-28, 1995.

J.S. Touma

EPA Sixth Modeling Conference, Washington, DC, August 9-10, 1995.

J.S. Irwin
R.F. Lee

Developmental Meeting on Operations/Implementation Plan for NARSTO program on Analysis and Assessment, Palo Alto, CA, August 22-24, 1995.

K.L. Schere

Institute for Sustainable Communities Workshop on Nizhnii Tagil (Russia) Environment Project, Research Triangle Park, NC, September 1, 1995.

J.S. Irwin
R.F. Lee
S.G. Perry
W.B. Petersen
F.A. Schiermeier

Third Urban Airshed Modeling Workshop, Arlington, VA, September 12-13, 1995.

J.M. Godowitch
K.L. Schere

Advances in Source and Dispersion Modeling/Explosions, BLEVES, Fires, CCPS, USEPA, and six other sponsors, New Orleans, LA, September 26, 1995.

G.A. Briggs

APPENDIX E: VISITING SCIENTISTS

1. Professor S.P. Banerjec
   Director In Charge
   India School of Mines
   Dhanbad, India 82604

Professor Banerjec visited on November 18, 1994, to collaborate with a Division member on methods for modeling fugitive particulate matter from open pit surface coal mines.

2. Ms. Rona Birnbaum
   Messrs. Ravi Srivastava and Nick Mangis
   Acid Rain Division
   U.S. Environmental Protection Agency
   Washington, DC

Ms. Birnbaum and Messrs. Srivastava and Mangis visited the Division on September 21-22, 1995, to become acquainted with Models-3 development. They were interested in using the Models-3 framework and science modules for air quality modeling. The visit was part of the Technology Transfer of Models-3.

3. Professor I.P. Castro
   University of Surrey
   Guildford, England

Professor Castro visited the Fluid Modeling Facility on August 25, 1995, for discussions on collaborative work on wind-tunnel modeling of dense-gas dispersion.

4. Dr. Ron Cionco
   White Sands Missle Range
   White Sands, NM

Dr. Cionco visited the Fluid Modeling Facility on June 9, 1995, to discuss measurements of flow around buildings.

5. Mr. A. Ferrier
Georgia Institute of Technology
Atlanta, GA

Mr. Ferrier visited the Fluid Modeling Facility on June 2, 1995, to discuss video-image analysis of planar laser-induced fluorescent images of plume in the convection tank.

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

Dr. Genikhovich spent his third full year at the Fluid Modeling Facility (FMF) as a Senior Research Associate under the NOAA/National Research Council Resident Research Associateship Program. He and the FMF staff continued development and evaluation of a model to handle the downwash of pollutants from sources in the vicinity of buildings. A final report was prepared describing the model and evaluating its performance against wind-tunnel and field measurements.

7. Dr. Seven-Erik Gryning
Meteorology and Wind Energy Division
Riso National Laboratory
DK-4000 Roskilde, Denmark

Dr. Gryning visited the Division on May 22, 1995, to assist in planning the 21st NATO/CCMS International Technical Meeting on Air Pollution Modelling and Its Application.

8. Mr. Milan Machac
Ministry of the Environment of the Czech Republic
Department of Ostrava
Prague, Czech Republic

Mr. Machac visited on August 23, 1995, as part of a visit to the EPA for discussions on Air Monitoring/Modeling.

9. Professor F.T.M. Nieuwstadt
University of Delft
Delft, Netherlands

Professor Nieuwstadt visited the Fluid Modeling Facility on August 18, 1995, to discuss collaborative work on particle-image velocimetry in the convection tank.

10. Professor M. Ohba
Tokyo Institute of Polytechnics
Tokyo, Japan

Professor J. Tsutsumi
University of Ryukyu
Ryukyu, Japan

Professors Ohba and Tsutsumi visited the Fluid Modeling Facility on September 7, 1995, to discuss future collaborative work on wind-tunnel modeling of atmospheric dispersion.

11. Dr. R. Ohba and Mr. M. Harada
Mitsubishi Heavy Industries
Nagasaki, Japan

Dr. Y. Aoyagi
Osaka Gas
Osaka, Japan

Drs. Ohba and Aoyagi, and Mr. Harada visited the Fluid Modeling Facility on December 16, 1994, to discuss wind-tunnel modeling of dense-gas dispersion.

12. Dr. R. Ohba and Mr. M. Harada
Mitsubishi Heavy Industries
Nagasakis, Japan

Drs. Ohba and Harada visited on December 6, 1994, to discuss dense gas research at the U.S. Environmental Protection Agency.

13. Messrs. Jeong-Gyoo Park and Kun-Il Jang
Meteorological Research Institute
Korea Meteorological Administration
Seoul, Korea

Messrs. Park and Jang visited the Division on August 29, 1995. These meteorologists work with government laboratories in Korea. They have an interest in U.S. research on database work and how the data is handled in different formats.

14. Dr. Vassily A. Poddubny
Ural Department of Russian Academy of Sciences
Ekaterinburg, Russia

Dr. Poddubny visited on September 1, 1995, to discuss the use of the EPA models for analysis of emissions in Russian cities and industrial areas.

15. Professor M. Schatzmann
University of Hamburg
Hamburg, Germany

Professor M. Schatzmann visited the Fluid Modeling Facility on September 25, 1995, for discussions of wind-tunnel modeling of dense-gas dispersion.

16. Dr. J.C. Weil
Cooperative Institute for Research in Environmental Sciences (CIRES)
University of Colorado
Boulder, CO

Dr. Weil visited the Fluid Modeling Facility on several occasions (November 14-18, 1994, and June 5, 8 and 9, 1995) under a cooperative agreement to study plume penetration of elevated inversions in the convection tank.

17. Dr. J.C. Weil
Cooperative Institute for Research in Environmental Sciences (CIRES)
University of Colorado
Boulder, CO

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

Drs. Weil and Venkatram visited December 6-12, 1994, to participate in the AERMIC Workgroup Meeting held in Raleigh, NC.

APPENDIX F: UNDERGRADUATE AND GRADUATE STUDENTS AND POSTDOCTORAL RESEARCHERS

1. Ms. Meredith Blackwelder
   University of North Carolina at Chapel Hill
   Chapel Hill, NC

Ms. Blackwelder, a junior at the University of North Carolina at Chapel Hill, was a participant in the Order of the Bell Tower Extern Program, which matches students with alumni for the opportunity to explore careers and learn more about their field of interest during Spring Break. Ms. Blackwelder spent part of 1995 Spring Break working in the ASMD Library with an alumna and editing the FY-1994 annual report.

2. Ms. Jianfeng (Deborah) Ding
   Department of Marine, Earth, and Atmospheric Sciences
   North Carolina State University
   Raleigh, NC

Ms. Ding is a master of science candidate beginning her second year at the Fluid Modeling Facility where she is conducting research on the intermittency of turbulence within a dense-gas plume and its possible transition to a laminar state at small Reynolds numbers.

3. Mr. Terek Geter
   Howard University
   Washington, DC

Mr. Geter, a student at Howard University, was a participant in the University of North Carolina at Chapel Hill's Summer Pre-Graduate Research Experience program during summer 1995. For 10 weeks, Mr. Geter worked with an assigned mentor on a project examining personal human activity and hourly CO air concentrations in support of a human exposure project for the San Francisco Bay Area.

4. Ms. Marie Jenkins
   Tennessee State University
   Department of Civil Engineering
   Nashville, TN

Ms. Jenkins participated in the EPA Minority Academic Institution Summer Fellows Program for 10 weeks in the summer of 1995. She tested an advanced flow module for modeling streamline deflections over an isolated hill against fluid modeling data and wrote a report representing the results. The new flow module replaces an earlier version that showed deficiencies in the treatment of wind speed shear and density stratification and the convergence routines.

5. Dr. Poug Law
   Rutgers State University
   Environmental and Occupational Health Sciences Institute
   Piscataway, NJ

Dr. Law, postdoctoral researcher, worked with the Division's human exposure researchers during 1994 through July 1995. He completed an evaluation of personal exposure to CO using the probabalistic National Exposure Model (pNEM) and co-authored a paper for publication.

6. Dr. Jie Lu
   The Pennsylvania State University
   University Park, PA

Dr. Lu, postdoctoral researcher, started his second year at the Fluid Modeling Facility where he is studying plume penetration of elevated inversions in the convection tank in collaboration with Drs. Jeffery C. Weil, CIRES, University of Colorado, Boulder, CO, and John Wyngaard, The Pennsylvania State University, University Park, PA.

7. Ms. Felicia Vestal
   Tennessee State University
   Nashville, TN

Ms. Vestal participated in the EPA Minority Academic Institution Summer Fellows Program for 10 weeks in the summer of 1995. She worked on developing an analysis of RADM simulations and co-authored *Aggregation of Selected RADM Simulations to Estimate Annual Ambient Air Concentrations of Fine Particulate Matter* to be presented at a conference.

8. Ms. Nikki Williams
   Spelman College
   Atlanta, GA

Ms. Williams, a rising senior at Spelman College, was a participant in the University of North Carolina (UNC) at Chapel Hill's Summer Pre-Graduate Research Experience program during summer 1995. For 10 weeks, Ms. Williams worked on comparing chemistry solvers used in air quality models. At the end of her tenure, Ms. Williams authored a brief unpublished technical note and presented a poster, *Comparison of Two Stiff ODE Solvers Used in Atmospheric Chemistry Models*, along with the other participants, at UNC.

9. Ms. Yu-Ling Wu
Department of Marine, Earth, and Atmospheric Sciences
North Carolina State University
Raleigh, NC

Ms Wu, a graduate student at North Carolina State University, worked on the plume-in-grid effort as a part of the Models-3 project by applying and testing a plume dynamics model designed to determine plume rise, and the transport and diffusion of a plume released at regular intervals from a major elevated point source. The results on downwind plume locations and plume dimension (horizontal and vertical) information are needed by a Lagrangian photochemical plume module embedded in a Eulerian grid model.

10. Mr. Guwei Zhu
Department of Marine, Earth, and Atmospheric Sciences
North Carolina State University
Raleigh, NC

Mr. Zhu is a master of science candidate completing his second year at the Fluid Modeling Facility where he is conducting research on the behavior of dense gases released from point sources over large roughness elements.

APPENDIX G: ATMOSPHERIC SCIENCES MODELING DIVISION STAFF

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, Supervisory Meteorologist, Director
Herbert J. Viebrock, Meteorologist, Assistant to the Director
Dr. Robin L. Dennis, Physical Scientist*
Dr. Basil Dimitriades (EPA), Physical Scientist
Dr. Peter L. Finkelstein, Physical Scientist
Bruce W. Gay, Jr. (EPA), Program Manager
Evelyn M. Poole-Kober, Technical Editor
Barbara R. Hinton (EPA), Secretary
B. Ann Warnick, Secretary

Atmospheric Model Development Branch

Dr. Jason K.S. Ching, Supervisory Meteorologist, Chief
Dr. Francis S. Binkowski, Meteorologist
O. Russell Bullock, Jr., Meteorologist
Dr. Daewon W. Byun, Physical Scientist
Dr. John F. Clarke, Meteorologist
Dr. Brian K. Eder, Meteorologist
James M. Godowitch, Meteorologist
Dr. Jonathan A. Pleim, Physical Scientist
Shawn J. Roselle, Meteorologist
Kenneth L. Schere, Meteorologist
Tanya L. McDuffie, Secretary (since November 1994)

Fluid Modeling Branch

Dr. William H. Snyder, Supervisory Physical Scientist, Chief
Dr. Dale A. Gillette, Physical Scientist
Lewis A. Knight, Electronic Technician (until April 1995)
Robert E. Lawson, Jr., Physical Scientist
Lt. Cdr. Roger S. Thompson (PHS), Environmental Engineer
Pamela V. Bagley, Secretary (until July 1995)

Modeling Systems Analysis Branch

Joan H. Novak, Supervisory Computer Specialist, Chief
Dr. William G. Benjey, Physical Scientist
Dr. Sharon K. LeDuc, Physical Scientist

Modeling Systems Analysis Branch Cont'd

Thomas E. Pierce, Meteorologist
John H. Rudisill, III, Equipment Specialist
Alfreida R. Torian, Computer Specialist
Gary L. Walter, Computer Scientist
Dr. Jeffrey O. Young, Mathematician
Kelly M. Davis, Secretary

Applied Modeling Research Branch

William B. Petersen, Supervisory Physical Scientist, Chief**
Dr. Gary A. Briggs, Meteorologist
Dr. Ellen J. Cooter, Meteorologist
Gennaro A. Crescenti, Physical Scientist†
Dr. Alan H. Huber, Physical Scientist**†
Dr. Steven G. Perry, Meteorologist
Donna B. Schwede, Physical Scientist**
John J. Streicher, Physical Scientist†
Lawrence E. Truppi, Meteorologist
Dr. Michael P. Zelenka, Meteorologist
E. Francis Horvath (EPA), Secretary
Katherine A. Scott, Secretary (until May 1995)
Sherry A. Brown, Secretary (since August 1995)

Air Policy Support Branch

John S. Irwin, Supervisory Meteorologist, Chief
Dennis A. Atkinson, Meteorologist
Dr. Desmond T. Bailey, Meteorologist
Russell F. Lee, Meteorologist
Brian L. Orndorff, Meteorologist
Norman C. Possiel, Jr., Meteorologist**
Jawad S. Touma, Meteorologist**

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*Finalist, Annual Smithsonian Computer World Award (Environmental Category).
**U.S. Environmental Protection Agency Bronze Medal.
†U.S. National Oceanic and Atmospheric Administration Bronze Medal.