NOAA Technical Memorandum ERL ARL-160

FISCAL YEAR 1985 SUMMARY REPORT OF NOAA METEOROLOGY DIVISION SUPPORT TO THE ENVIRONMENTAL PROTECTION AGENCY

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

C.William Verity Secretary

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Environmental Research Laboratories

Vernon E. Derr, Director

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PREFACE

This document presents for Fiscal Year 1985 a summary of the research and operational efforts and accomplishments of the Meteorology Division (MD) working under interagency agreement EPA DW13931239-01-0 between the 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 Meteorology Division is part of the Air Resources Laboratory and serves at the vehicle for implementing the agreement with the EPA, which funds the research efforts in air pollution meteorology. The MD conducts research activities inhouse and through contract and cooperative agreements for the Atmospheric Sciences Research Laboratory (ASRL) and other EPA groups. With a staff consisting of NOAA, EPA, and Public Health Service Commissioned Corps (PHS) personnel, consultation on all meteorological aspects of the air pollution control program to many EPA offices, including the Office of Air Quality Planning and Standards (OAQPS) and Regional Offices. The primary groups within the MD are the Atmospheric Modeling Branch, Fluid Modeling Branch, Data Management Branch, Terrain Effects Branch, Environmental Operations Branch, and Air Policy Support Branch. The staff is listed in Appendix A, B-1, and B-2.

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

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ABSTRACT

The Meteorology Division provided meteorological research and support to the Environmental Protection Agency. Basic meteorological support consisted of the application of dispersion models, and the conduct of dispersion studies and model evaluations. The primary research effort was the development and evaluation of air quality simulation models using numerical and physical techniques supported by field studies. Modeling emphasis was on the dispersion of photochemical oxidants and particulate matter on urban and regional scales, dispersion in complex terrain, and atmospheric processes related to the acid deposition problem.

Highlights during FY-1985 included evaluation of the dividing streamline height concept for flow over and around terrain features; completion of the VALMET and MELSAR models for use in specific terrain situations; development of a preliminary version of the Regional Acid Deposition Model (RADM); completion of a mesoscale acid precipitation study; conduct of a field study of the transport and transformation of acidic compounds by non-precipitating cumulus convective processes; and completion of a position paper on the research status and needs on diffusion in atmospheric boundary layers. Work underway in other areas of air pollution meteorology and modeling is also described.

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1. INTRODUCTION

During Fiscal Year 1985, the Meteorology Division (MD) continued to provide meteorological research and support to the Environmental Protection Agency (EPA). The primary effort of the Division was to conduct research in the basic processes affecting the dispersion of atmospheric pollutants and to model the dispersion on all temporal and spatial scales. The major modeling emphasis was on oxidant dispersion on the urban and regional scales, particulates dispersion on the regional scale, dispersion in complex terrain, and acid precipitation related processes. Work on the study and modeling of boundary layer processes continued. Physical modeling experiments were conducted in the Fluid Modeling Facility on the flow in complex terrain, building downwash, and the effects of automobile wakes. Participation was begun in the Integrated Air Cancer Program, and on the use of dispersion models on the North Slope of Alaska. The research effort is described in Sections 2.1, 2.2, 2.3, 2.4, and 2.5. Section 2.1 also discusses the Division's participation in several major international activities.

Meteorological support was provided to various EPA offices, including the Office of Air Quality Planning and Standards (OAQPS) and the Regional offices. This work is discussed in Sections 2.6 and 2.7.

2. PROGRAM REVIEW

2.1 Office of the Director

2.1.1 American Meteorology Society Steering Committee

Since 1979 the Meteorology Division and the American Meteorological Society (AMS) have collaborated in an effort to improve the scientific basis of air quality modeling. Under a cooperative agreement, this joint effort has occurred in topical workshops and model evaluation exercises. The AMS established a Steering Committee to oversee the agreement.

2.1.1.1 Workshop on Dispersion in Complex Terrain

During May 17-20, 1983, the AMS Steering Committee conducted a workshop in Keystone, Colorado on dispersion in complex terrain. The purpose of the workshop was to encourage atmospheric scientists working in the area of complex terrain dispersion modeling to exchange information on atmospheric processes in mountainous terrain and to make recommendations regarding both the present application of air quality models to complex terrain settings and the research necessary to meet future needs.

A workshop report was completed which contains a summary of the state-of-the- science review concerning phenomena of importance, physical modeling capabilities, and mathematical modeling capabilities. The report concludes with recommendations on the use of present science and with suggestions for future research and development needs. The latter two categories include comments on current research efforts and suggestions for improving present screening models and utilizing physical modeling techniques (Egan, 1985).

2.1.1.2 Complex Terrain Model Evaluation

The EPA Office of Air Quality Planning and Standards undertook an independent review of eight complex terrain dispersion models. In the first phase of the review process, a contractor calculated and tabulated a uniform set of statistics for the eight models to provide reviewers with a consistent set of measures for evaluating model performance. Three Meteorology Division scientists evaluated each model using scientific and technical information obtained from the User's Guides and the statistical performance data developed by the contractor.

These scientific reviews were summarized by the AMS Steering Committee and published in a report (White et al., 1985). The Committee members mirrored the reactions of the reviewers in being disappointed in the technical quality of the models, and in concluding that a massive statistical analysis is not the best way to analyze model performance. The reviewers and the Committee members concluded that future evaluations should stress understanding of the physics of the models and examination of their performance in specific case studies.

2.1.1.3 International Workshop on Model Uncertainty

Under a separate cooperative agreement, the American Meteorological Society conducted a workshop in September 1983 which was jointly funded by the U.S. Environmental Protection Agency and the Canadian provincial and federal governments. The workshop focused on sources and evaluation of uncertainty in long-range transport models. This effort was an outgrowth of the modeling activities performed in previous years under the United States/Canadian Memorandum of Intent on Transboundary Air Pollution (Schiermeir and Misra, 1983).

Workshop participants from the United States, Canada, England, Denmark, and Norway joined in the attempt to identify and quantify uncertainty in long-range transport model predictions. An AMS publication is being prepared containing the complete documentation of the workshop including recent developments in model evaluation and sensitivity analysis, and reports of the Eulerian and Lagrangian working groups. In the meantime, an article summarizing the findings and recommendations was accepted for publication (Demerjian, 1985).

2.1.2 NATO/CCMS Participation

2.1.2.1 Membership on NATO/CCMS Panel 2

The Meteorology Division Director served as a member of Panel 2 on Air Quality Modeling of the NATO Committee on Challenges of Modern Society (CCMS) which focused on current international developments in air quality modeling. Members of Panel 2 shared information about a large number of air pollution transport models and performed detailed comparisons of the effectiveness of a selected number of them. Under the auspices of the NATO/CCMS Pilot Study on Air Pollution Control Strategies and Impact Modeling, the Panel's work in this area influenced regional European cooperation and served as an impetus for efforts in transboundary air pollution abatement by the European Economic Community (EEC) and by the Organization for Economic Cooperation and Development (OECD). In October 1984, a paper was presented at the NATO/CCMS International Workshop on CCMS Air Pollution Pilot Studies (Schiermeier, 1984). The workshop was held in Lindau, Federal Republic of Germany, and represented the final meeting of the Panel 2 on Air Quality Modeling. A final report is being prepared describing the activities of the Pilot Study on Air Pollution Control Strategies and Impact Modeling.

2.1.2.2 NATO/CCMS International Technical Meeting

The Meteorology Division Director serves as a member of the Steering Committee for the NATO/CCMS International Technical Meetings (ITM) on Air Pollution Modeling and Its Application. The organization of a yearly symposium dealing with air pollution modeling and its application is one of the main activities within the NATO/CCMS Pilot Study on Air Pollution Control Strategies and Impact Modeling. The meetings are held annually in different NATO member countries; the normal rotation is for the ITM to be held in North America every third year with the two intervening ITMs to be held in European countries.

The Division Director served as International Conference Chairman for the 15th NATO/CCMS International Technical Meeting and presented a paper (Schiermeier et al., 1985). The meeting was held in St. Louis, Missouri in April 1985, with participants from Australia and Japan, as well as from Europe and North America. All of the technical papers and discussions will be published.

2.1.3 US/USSR Environmental Working Group

During FY-1985 the EPA Administrator assumed co-chairmanship of the US/USSR Joint Committee on Cooperation in the Field of Environmental Protection, with the intent of reinvigorating this exchange program in an effort to expand communications and establish better working relationships between the two countries. The Meteorology Division Director was asked to serve as the United States Coordinator for Modeling Activities under the Working Group 02.01-10 on Air Pollution Modeling, Instrumentation, and Measurement

Methodology. In this capacity, he is responsible for coordinating reciprocal visits between the two countries for the purpose of working together on selected modeling activities.

During a May 1985 visit to research institutes in Leningrad, Vilnius, and Moscow, a protocol was negotiated and signed by the Co-Chairmen of the Working Group. Although several prospective areas for joint research are outlined in the protocol, the main area of interest for the Meteorology Division is the exchange of information and visits in the area of complex terrain dispersion model development and evaluation.

2.1.4 National Acid Precipitation Assessment Program

The national effort aimed at seeking solutions to the acidic deposition problem is centered in the interagency National Acid Precipitation Assessment Program (NAPAP). The Meteorology Division performs research under the NAPAP Atmospheric Processes Task Group C. This is discussed in Section 2.2.1.

The Meteorology Division Director served as Chairman of the NAPAP Atmospheric Processes Task Group C, and established the interagency research plans and budgets for FY-87 in concert with the NAPAP Task Force and the nine remaining Task Groups. Also, the Chairman was responsible for monitoring the ongoing FY-85 research activities performed by NOAA, EPA, Department of Energy (DOE), and Tennessee Valley Authority (TVA), and for updating the FY-86 interagency research plans.

During January and February 1985, an Acid Deposition Symposium was sponsored by the Rocky Mountain States Section of the Air Pollution Control Association. The Task Group C Chairman served as Chairman of the Atmospheric Processes Session in which presentations centered on development of Eulerian and Lagrangian long-range transport models and on the use of these models to permitting and other regulatory applications. The focus of the symposium was on the western areas of the United States where the potential exists for increased acidic deposition due to development of natural resources.

The Task Group C Chairman also served on the NAPAP Committee for Dry Deposition Research, the NAPAP Design Committee for Model Evaluation Field Study, and the EPA Acid Deposition Atmospheric Sciences Guidance Group.

2.1.5 NOAA Air Quality Working Group

The Meteorology Division Director served on an Air Quality Working Group charged with composing a NOAA Air Quality Document and Mission Statement. The intent of this document is to more clearly define NOAA's responsibilities in the fields of atmospheric quality.

2.1.6 Visibility Research

The objectives of the program are to investigate regional visibility levels and sources of impact, to improve and standardize visibility monitoring technology, and to provide a point of communications between government agencies and the private sector on visibility research. In FY-1985 the primary emphasis was on the operation of, and preliminary data analysis for, a seven-station visibility monitoring network in the Mojave Desert in southern California. This monitoring was conducted for the Department of Defense whose concern is the degradation of their ability to test defense systems in the desert caused by reduced air clarity. The title of this program is Research on Operations Limiting Visual Extinction (RESOLVE).

Nearly two years of monitoring was completed August 30, 1985. Preliminary analysis of portions of the data suggested several interesting results. Multi-variate statistical analysis suggests that sulfate aerosol must share its traditional role as major contributor to visibility impacts with organic aerosol. Sulfur aerosol size distributions indicate much of the sulfur is in an ultrafine mode (diameter less than 0.15 microns), which is optically unimportant. The data analysis and reporting effort for the RESOLVE is expected to continue for another two years.

Efforts began in FY-1985 to develop standardized performance specifications for visibility measurement techniques. There are three general categories of visibility measurement thought to be required for visibility monitoring. The characteristics of a scene viewed at a distance are monitored to document the scene-specific visibility. Optical properties of the atmosphere are monitored for a scene-independent measure of visual air quality. Aerosol characteristics are determined to associate atmospheric optical properties with the responsible pollutants. In order to make these measurements meaningful in terms of human perception of visual clarity, instrumental visibility measures must be made with certain physical characteristics (e.g., optical wavelength) and with certain minimum requirements (e.g., sensitivity, precision, etc.). Preliminary work to establish performance specifications for contrast measurements started in FY-1985, and will be intensified and expanded to include other techniques in subsequent years. When combined with the performance testing of specific monitoring techniques, in three years this program is expected to provide documented guidance to those wishing to perform visibility monitoring.

Advanced visibility monitoring techniques, including a long path length transmissometer, are being co-developed with the National Park Service. This and other second generation visibility monitoring instrumentation are being evaluated to determine their feasibility for routine use.

The Meteorologist in charge of this program is also involved with a number of other visibility research programs, including the five-year SCENES visibility monitoring program in the desert southwest; the interagency program to monitor visibility in federal visibility-protected areas; the Interagency Monitoring of Protected Visual Environments (IMPROVE) program; and the multi-state PANORAMAS visibility monitoring program in the Pacific Northwest. In each of these the Meteorologist serves on the technical steering or advisory committee.

2.2 Atmospheric Modeling Branch

The Atmospheric Modeling Branch develops, evaluates and validates analytical, statistical, and numerical models used to describe the relationships between air pollutant source emissions and resultant air quality, to estimate the distribution of air quality, and to describe and predict the state of the planetary boundary layer. Model scales range from local to global. Studies are conducted to describe the physical processes affecting the transport, diffusion, transformation, and removal of pollutants in and from the atmosphere.

2.2.1 Acid Deposition Studies

2.2.1.1 Development of an Eulerian Acid Deposition Model

A comprehensive Regional Acid Deposition Model (RADM) is being developed at the National Center for Atmospheric Research (NCAR) through funding provided primarily by the EPA with cooperative funding by the National Science Foundation. Administrative and technical direction is provided by the Meteorology Division. The project was initiated in the Spring of 1983. The principal objective is to develop an Eulerian model suitable for assessing nonlinear source-receptor relations. The initial task was the construction of a modeling framework integrating an existing and evolving mesoscale meteorological model with a new transport and chemical transformation model. All components of this modeling system are expected to include state-of-the-art representations of the relevant physical and chemical processes. Much of the required research and development is based on contributions from a broad cross section of the scientific community. The rationale and approach to the modeling effort are contained in two companion NCAR reports (National Center for Atmospheric Research, 1983a and b).

During FY-1985, Version I of the RADM (National Center for Atmospheric Research, 1985), containing first-generation submodels of gas phase and aqueous phase chemistry with simple parameterizations of subgrid-scale cloud processes and dry deposition of pollutants, was completed. This version of RADM and the basic technical approach to the modeling program received favorable peer review in March 1985. The model is currently being subjected to extensive sensitivity tests and evaluation against Oxidation and Scavenging Characteristics of April Rains (OSCAR) experimental chemistry data. A draft report of the sensitivity studies was received and a formal progress report documenting the evaluation of the model against OSCAR data will be available in 1986. Other significant accomplishments of the RADM program are:

- The computer program for the mesoscale meteorological model was rewritten with as much as a factor of three gain in execution speed.
- Studies of the mesoscale meteorological model determined that the existing synoptic network and observational frequency are not adequate for accurate calculation of long-range transport during episodic events.

- A first complete examination of the OSCAR experimental chemical data was documented.
- A new approach to source receptor analysis for Eulerian models using specific carrier frequencies as signals from individual source was developed.
- Work was begun on the construction of an engineering model representation of the RADM. This model will be capable of being executed on a VAX-class computer with a fast-turn-around analysis of control options.
- Sensitivity studies of the RADM are being applied to the design of a field program to evaluate regional acid deposition models.

MCAR has initiated development and/or integration of second-generation submodels for chemistry, precipitation scavenging and dry deposition for Version II of RADM. These submodels, being developed by NCAR, Pacific Northwest Laboratory (PNL), and Argonne National Laboratory (ANL), respectively, are expected to be completed and integrated into a preliminary operational version of RADM II by the end of calendar year 1986. Both EADM and the engineering model are expected to be used operationally in the 1987 National Acid Precipitation Assessment Program.

2.2.1.2 Regional Acid Deposition Model Evaluation

In support of the National Acid Precipitation Assessment Program (NAPAP), a concept plan was developed for the evaluation of the RADM (Environmental Protection Agency, 1985c). The focus of the concept plan is on the requirements for a credible evaluation and development of a field study to support the evaluation of the RADM. A major goal is to have a first evaluation of the RADM in time for the 1989 NAPAP assessments. The model evaluation concept plan was developed in several stages. In May 1985 a workshop of the US/Canadian Technical Committee on Model Evaluation was held. In June 1985 a White Paper was produced and circulated stating the need for an evaluation, what components it might contain, and the need for a field study in support of a credible evaluation. In July a preliminary concept was produced to provide the basis for a U.S./Canadian workshop on model evaluation in Toronto in early August. The concept document was revised at the Toronto workshop and the Canadians officially became associated with the development of a model evaluation plan and field study. In September 1985 the concept plan was peer reviewed under the auspices of NAPAP.

As part of the concept plan development, special design studies were carried out for the siting of a surface network for monitoring ambient concentrations and wet chemistry in the northeastern United States to support model evaluation requirements. A relatively new geostatistical technique, Kriging, was used in the design study, with additional guidance from preliminary results of the International Sulfur Deposition Model Evaluation study and preliminary runs of the Regional Oxidant Model. The surface network design is being closely coordinated with the Monitoring Task Group of NAPAP. Also model evaluation planning is being coordinated with the other government agencies in NAPAP.

2.2.1.3 Mesoscale Study for Acid Deposition

The purposes of this program are to determine the effect of emissions, from a large urban-industrial area on the wet acidic deposition downwind from the source; to determine the importance of local primary sulfate emissions, and to examine the chemical, transport and deposition processes on a finer scale than is done in the Regional Acid Deposition Modeling Program. Three field programs were conducted in the Philadelphia area: an exploratory study in the fall of 1983 that sampled two storms; a two-month study in the spring of 1984 that sampled nine storms; and a study in the spring of 1985 that sampled one storm with slightly different meteorological characteristics from the 1984 series. The instrumentation for the spring 1985 study included aircraft flights and sequential samplers for determination of the ionic concentrations of all species that were measured in previous experiments and in addition for hydrogen peroxide. A summary paper of the 1983 and 1984 measurement campaigns was prepared (Patrinos, 1985).

Meteorological fields for the 1983-1984 experiments will be available soon. The case studies will be simulated using the Sulfur Transport Eulerian Model (STEM II) (Carmichael and Peters, 1984) which was modified to include the chemical mechanism of Atkinson, Lloyd and Winges (1982), and aqueous-phase reactions as well.

The model will be used to simulate the cases observed during the Philadelphia mesoscale field experiments. Meteorological fields for the spring 1985 experiment were prepared using the Mesoscale Atmospheric Simulation System (Kaplan et al., 1982). The mesoscale modeling program also includes the development of a transport, transformation, and removal model which can be used for application in assessing the mesoscale effects of control strategies for amelioration of the effects attributed to acid deposition.

2.2.1.4 Air Trajectory Tracking Using Fluorescent Dye Particles

A technique to track free tropospheric pollutant transport was developed as part of the NAPAP and was discussed in the FY-1984 annual report (Viebrock and Poole-Kober, 1985). This technique was utilized in the cloud venting experiment (VENTEX-1985) field study conducted in and around the Lexington, Kentucky area in August 1985 (see Section 2.2.1.5). The airborne two-wavelength ALPHA-1 lidar system developed and operated by SRI International, Inc. was modified to track the movement and to characterize the dispersion of a cloud of non-toxic fluorescent dye particles (FDP) in various release scenarios. The ALPHA-1 has two independent receivers that measure the elastically backscattered radiation at 1.06 mm and 0.53 mm. The fluorescent particles used in the FDP-tracer experiments were transparent organic resin particles containing a dye with a fluorescent orange color (dominant wavelength 0.59 mm), that is produced by converting energy absorbed at the green wavelength (0.53 mm) of ALPHA-1. During daytime, fluorescence can be excited by solar energy as well as by laser light. However, because of the large energy density of the laser pulse, the laser-induced fluorescent light is larger than that induced by the sun. Initial field tests were conducted in conjunction with the Cross Appalachian Tracer Experiment (CAPTEX '83). The technique proved capable of providing detailed range resolution of both a cloud of FDP particles and the background aerosol distribution, the latter for obtaining concurrent information on atmospheric stratification. This program is described in Ching et al. (1984), and Uthe et al. (1985a and b).

During VENTEX-85, this system was utilized to perform studies of exchange processes by cumulus convective cloud elements. FDP was released slightly above cloud tips and tracked by the airborne lidar system. Preliminary analyses of these data suggest rapid distortion and entrainment of the FDP cloud near the cumulus element. However, a portion of the FDP moved off into the clear air region between cumulus clouds and remained relatively undisturbed for about an hour or so.

Long-distance tracking of FDP was facilitated by an additional airborne lidar system operated by the EPA's Environmental Monitoring Support Laboratory (EMSL) and modified in a manner similar to that of the ALPHA-1 system. In that effort, the FDP cloud was released at dusk above the mixed layer and tracked by two aircraft deployed in tandem or leap-frog sequence. This operational mode was followed successfully for eight hours until scavenging of the FDP by a rain cloud terminated the tracking mission. Future plans include the study of mountain impaction in a flow visualization application of this system.

2.2.1.5 Vertical Transport and Chemical Transformation Processes Due to Non-Precipitating Convective Clouds

Non-precipitating cumulus convective clouds enhance vertical transport and chemical transformation of acidic materials. Venting experiments (VENTEX) and theoretical studies were conducted to quantify and parameterize these processes. Field study efforts were conducted by PNL in the Lexington, Kentucky area in the summer of 1983 and boundary layer experiments were conducted by ANL in Oklahoma. This was followed by a major field study effort in the Lexington area by PNL, ANL, and Research Triangle Institute (RTI) in 1984 (Viebrock and Poole-Kober, 1985) and in 1985 by PNL, ANL, and SRI International, Inc. (VENTEX-85).

VENTEX-85 concentrated on data collection during July and August. An instrumented aircraft equipped with a real time HOOH monitor was installed and deployed as part of the overall measurement program. Vertical profiles and horizontal structure data were successfully obtained in the boundary layer and in the cloud layer. In addition, SF_6 tracer studies and FDP (see previous section) tracking were conducted to study the vertical exchange processes associated with the cumulus convection.

Preliminary results from these studies support the contention that: 1) boundary layer pollutants are vented above the boundary layer by non-precipitating convective cumulus clouds, 2) cloud layer air is vigorously exchanged with the mixed layer by the cloud processes, 3) HOOH is produced as a result of in-cloud chemistry, 4)

SO_2 is oxidized to sulfuric acid in these clouds and becomes acid aerosol after cloud evaporation, 5) nitrate aerosols apparently are converted to nitric acid within the cloud droplets and reappear in the atmosphere as nitric acid vapor after cloud dissipation, and 6) ammonia gas concentrations decreased sharply with increasing altitude.

2.2.1.6 Parameterizations of Dry Deposition for RADM

Dry deposition field studies were conducted by ANL as an integral part of the NAPAP program on acid deposition, transport, and modeling. A major fraction of acidic pollutants are deposited during non-precipitating events, with the rate of such deposition being dependent on land use, meteorological factors, and chemical species. ANL conducted field experiments and theoretical investigations to develop parameterizations of deposition velocities of acidifying substances. Micrometeorological measurements of fluxes of SO_2, sulfate, ozone, and NO were made in FY-1985 over midwestern grasslands and agricultural crops in Pennsylvania. These data sets augment the existing data bases collected in previous years. Also, dry deposition experiments were conducted by ANL in West Germany as part of an international transport and deposition study in the Black Forest area.

In the spring of 1984, a dry deposition computer module was developed for sulfur compounds for applications in the RADM. From the recent field experiments and other independent studies, a dry deposition module for NO_x is being developed and the existing SO_x parameterization upgraded. Theoretical analyses (Wesley and Hart, 1985) were conducted to evaluate the experimental "noise" of the eddy correlation measurement technique for determining the chemical fluxes and the modeling biases or subgrid scale, non-linear effects introduced when the dry deposition parameterization schemes, based on detailed land use, are coupled with such RADM scale values of boundary layer parameters as surface roughness, friction velocity, and heat fluxes. A model sensitivity study of RADM for subgrid scale land-use variation in deposition velocity of SO_2, sulfate and HNO_3 was conducted (Walcek et al., 1985).

2.2.1.7 International Sulfur Deposition Model Evaluation

A joint program to evaluate regional sulfur deposition models is being conducted in cooperation with the Canadian Government. Predictions of 1980 seasonal and annual SO_2 and sulfate ambient concentrations and wet/dry deposition amounts were made for 66 receptor sites in eastern North America using three statistical, six Lagrangian and one Eulerian models. The Regional Lagrangian Model for Air Pollution (RELMAP) was one of these models. The model results are being compared to each other and with wet deposition for eastern North America.

A standardized set of model input data was generated so that the models could be evaluated on common ground. This data set consisted of 1000- and 850-mb wind velocities, 12-hr precipitation amounts, climatological mixing heights, and stratified SO_2 emission rates (Clark, 1985).

The evaluation data set was complied using measurements of seasonal and annual sulfur wet deposition amounts calculated from data collected at sites regionally representative of the United States and Canada (Voldner et al., 1984). Thirty-two annual and 38 to 49 seasonal evaluation sites were used in the evaluation.

Preliminary model evaluation results for seven of the models indicate that they all predict the maximum sulfur wet deposition amounts over the vicinity of northern West Virginia. On the other hand, the maximum observed sulfur wet deposition amounts were in the vicinity of western Lake Erie, 300 km to the northwest. Correlations of observations and predictions were generally highest in spring (0.56 to 0.77) and lowest in autumn (0.09 to 0.42).

2.2.1.8 Trends in SO_2 Emissions and Ambient Concentration in the Northwest

Trends in seasonally adjusted monthly power plants SO_2 emissions and trends in monthly average ambient SO_2 concentrations were compared for the period 1975-1982 across 21 northeastern states and the District of Columbia (Pollack and Burton, 1985). Due to the recession of the late 1970's, power plants used less energy. Therefore, power plant emissions, comprising nearly 75% of the nation's total annual SO_2 emissions, decreased by up to 30% for some states. Coincidentally, for more than half the states, there was a downward trend in the ambient concentrations.

Correlations of the seasonally adjusted emissions and ambient concentrations were calculated at the local, state, and regional levels. In general, higher correlations were observed in those states with higher levels of emissions. In the six-state region of the Ohio Valley, the correlation between the seasonally adjusted emissions and ambient concentrations was 0.75.

2.2.1.9 Lagrangian Modeling of Sulfur Transport and Deposition

During FY-1985 ANL continued to develop the Advanced Statistical Trajectory Regional Air Pollution (ASTRAP) model. ANL used the model to achieve a better understanding of the transport and deposition of sulfur compounds. By using the ASTRAP model, these topics were addressed: 1) typical transport distances of SO_2 and sulfate, 2) uncertainties in model source-receptor relationships (for the 1985 NAPAP Assessment), 3) climatological variability of transport and deposition of air pollutants (Shannon, 1984), 4) deposition patterns of biogenic sulfur compounds, and 5) sulfur fluxes across the Atlantic and Gulf of Mexico coasts. In addition, ANL participated in the International Sulfur Deposition Model Evaluation Program, generated source-receptor matrices for a six-year period (1976-1981), and produced the ASTRAP Model User's Guide (Shannon, 1985).

2.2.2 Photochemical Modeling

2.2.2.1 Regional Oxidant Model (ROM)

The first generation Regional Oxidant Model (ROM) was used in a preliminary assessment of the effects of proposed hydrocarbon and NO_x emissions on ozone concentrations in the northeastern United States (Lamb, 1985). For this study, two model simulations were performed using meteorological conditions observed during August 3-4, 1979. The first simulation, or base case, used the 1979 Northeast Corridor Regional Modeling Project (NECRMP) emissions inventory to establish all hydrocarbon and NO_x emission rates. The second simulation, or control case, used the same emissions inventory modifying the emission rates in accordance with baseline projections for 1987 contained in the State Implementation Plans (SIPS).

Comparisons of the ozone predicted by the model in the base and control cases showed that ozone levels were lower everywhere in the control case than in the base case, with larger percentage reductions occurring in urban and suburban areas than in rural and more remote regions. The model results also showed that peak ozone concentrations generally were reduced by much larger margins than spatial average concentrations were reduced.

2.2.2.2 Regional Oxidant Model Chemical Kinetic Mechanism Development

Systems Applications, Inc. delivered a "compressed" version of the Carbon- Bond-Extended (CBM-X) chemical kinetic mechanism for use in the ROM. The compressed version, CBM-RR, contains 70 reactions (compared to 183 in CBM-X) and 28 chemical species (compared to 72 in CBM-X). Despite the considerable reduction in detail from the full mechanism, the CBM-RR should perform comparably to CBM-X for ambient simulations. Limited testing of both mechanisms on smog chamber data shows good agreement between them. CBM-RR contains eight reactive hydrocarbon classes, including an explicit treatment of isoprene, a biogenic organic compound. The size of the CBM-RR chemical mechanism is more comparable to the size of the first generation ROM chemical kinetic mechanism (Demerjian chemistry: 36 reactions, 23 species) than is CBM-X. Integration of the full CBM-X mechanism into the ROM would have resulted in a model requiring prohibitive computer time resources to run. The CMB-RR mechanism is being integrated into the second generation ROM and preliminary testing of the full model should begin by early FY-1986.

Current estimates show the amount of time the ROM spends in solving the chemistry alone is about 90% of the total time requirements of the model. Clearly, any time-saving steps taken in the chemistry solution procedure should contribute significantly to a reduction in the total time requirements in the ROM. Several techniques are being tested as minor adjustments to the original chemical solution scheme. They show promise toward reducing the time requirements with minimal loss of accuracy in the solution. These include monitoring the fractional rate of change in the primary species, NO, as an indicator of when to tighten or loosen an adjustment error tolerance parameter, and establishing a 10-sec lower bound value on the modelcomputed chemistry time step.

2.2.2.3 First Generation ROM Evaluation

The protocol document for performing an evaluation of the ROM using the Northeast Regional Oxidant Study (NEROS) data base was completed (Schere and Fabrick, 1985). It presents an outline of the analysis steps needed for the ambient and simulated concentration data bases in the model performance evaluation. As an initial test of these evaluation guidelines, the first generation ROM results for the August 3-4, 1979 test episode will be analyzed against ambient data for that period. Air quality data from approximately 25 Ontario air monitoring stations were acquired and will be integrated into the ambient data base containing data from about 200 United States surface monitoring sites. Emphasis in this evaluation will be placed on surface level ozone concentrations.

2.2.2.4 3-D Grid Model Application in Japan

In a cooperative project with the National Institute of Environmental Sciences (NIES) of Japan under sponsorship of the U.S. National Research Council, a scientist from NIES worked in the Atmospheric Modeling Branch for one year setting up an application of the Urban Airshed Model (UAM) to the Tokyo Metropolitan area. This application of the UAM, a complex 3-D gridded photochemical air quality simulation model, is of interest to both countries, because of the density of ozone precursor emissions in the Tokyo area and the complex terrain features included in the model domain. Much of the research involved in this model application was toward the determination of an accurate, mass-consistent flow field for use with the model. The Tokyo special study meteorological data base contains about 70 surface-based wind monitors and 19 upper-air sounding locations to be used in the flow field determination. The most promising wind fields were obtained with an updated version of the ATMOS1 wind interpolation model. At present ATMOS1 is relatively expensive to operate, although a new version was obtained that is purported to be much more efficient. UAM model simulations using the ATMOS1-generated wind fields for Tokyo will be performed in Japan.

2.2.2.5 Operation Manuals for the Urban Airshed Model

Detailed operation manuals for the UAM were published (Ames et al., 1985a and b). The manuals present a general view of the model as well as detailed operating instructions for the user. The model is available from the National Technical Information Service on magnetic tape (Ames et al., 1985c). The UAM is a 3-D gridded photochemical air quality model designed to calculate the concentrations of both reactive and inert air pollutants on urban scales through simulation of the relevant physical and chemical processes that take place in smog-prone urban atmospheres. The User's Manual includes discussions of all of the files needed to run the model, the data preparation programs that produce each file, the input formats and data preparation methods, samples of input and output, and information flow diagrams that illustrate the job-stream control on any computer. The Systems Manual describes the system from a programmer's point of view, including descriptions of all subroutines and how they fit together, run-time core allocation techniques, internal methods of segment handling by using secondary storage, and detailed structure definitions of all files in the system.

2.2.3 Boundary Layer Studies

2.2.3.1 Vertical Turbulent Velocity Characteristics

Various statistical, objective and spectral analyses were made of vertical velocity fluctuations obtained in the lower and middle portions of the convective boundary layer (CBL) in St. Louis, Missouri. The most notable difference in the vertical velocity moments was in the variance, which was 50% greater above the urban area compared to surrounding rural locations. Statistics for the positive and negative velocities revealed greater vertical transport and power spectra indicating there was greater turbulent energy production across a wide frequency range over the city. Conditional sampling results showed the mean and peak widths of downdrafts generally exceeded corresponding values for updrafts. The mean and peak sizes of eddies were slightly larger over the urban area, but the differences were not statistically significant. The peak widths of updrafts and downdrafts were comparable to the CBL depth. Results were encouraging for the applicability of convective similarity scaling in the urban CBL, as normalized vertical velocity statistics were the same for both urban and rural areas (Godowitch, 1985).

2.2.3.2 Subgrid Scale Ozone Deposition Study

Analyses are underway to investigate the deposition of ozone from turbulence measurements obtained on low level aircraft flights during the NEROS field program. The flight design consisted of horizontal runs above relatively flat agricultural ridges and valleys to the northwest. On two days the flight pattern was performed repeatedly during the daytime.

Regional air quality model grid cells typically encompass areas containing a variety of land use, vegetation, and terrain features. Dry deposition is usually parameterized by summing the weighted contribution of each land use based on its fractional area within a grid. However, this treatment of pollutant deposition needs to be substantiated with experimental measurements. The objective of this in-house research is to determine the temporal and spatial variations of ozone deposition from these wide area measurements and to compare these results with concurrent point measurements on a tower in a soybean field.

Preliminary results of the eddy correlation measurements reveal the daytime ozone flux is negative (toward the surface), but it generally decreases with height from the 5-m tower level to the aircraft altitude of 150 m. Spectral and cross-spectral analyses with a Fast Fourier Transform package were performed with the filtered time series of ozone and vertical velocity fluctuations from the aircraft. Waves greater than 8 k were eliminated from the filtered data set. The peaks in the vertical velocity and ozone spectra were at about the same wavelength. The ozone variance is effected by instrument noise at high frequencies, however, the co-variance between ozone and vertical velocity is not impacted seriously. Results of the aircraft runs over the cropland in uniform terrain versus the forested ridges and valley region will be evaluated to determine if there are statistically significant differences in ozone deposition. An important aspect of the analyses will be to assess the contribution of longer waves not associated with convective turbulence. Results from the filtered data will be compared to those from linearly detrended time series.

2.2.3.3 Diffusion Meteorology Research

A position paper on the status of and needs for continuing research in the atmospheric boundary layer was prepared (Briggs and Binkowski, 1985). This paper reviews what is known about the behavior of the atmospheric boundary layer during stable, neutral, and convective conditions. For neutral conditions, that is under cloudy skies with brisk winds, the major gap in knowledge is the structure of the upper third of the turbulent mixing layer. For stable conditions, the influence of even a slight terrain slope can have a major effect upon the depth of active surface based mixing. The influence of fair weather cumulus on the structure and behavior of the convective boundary layer is being studied, but more efforts are needed. The paper recommends a series of smaller field studies of the atmospheric boundary layer under varied stability conditions. Such studies would be over a carefully chosen set of representative sites, with modest slopes and land cover typical of the eastern woodlands, farmland, and urban-suburban area. Tracers could be released during some of these studies and plume measurements made. There is an especially strong need for vertical and lateral profiles from near the source to at least 100 km from the source. The paper concludes that a modest, but steady, effort of measurement, analysis, and evaluation is much better than one or two large studies with little follow-up in data analysis. The paper also recommends that newer models of diffusion be compared with the current operational models using high quality experimental data. When such comparisons are made, improvements of the operational models can then be more effectively carried out.

2.2.4 Model Development and Evaluation

2.2.4.1 Pollution Episodic Model - Version 2

The Pollution Episodic Model (PEM), an urban-scale model, was modified with new options, designated PEM-2, and designed to predict 1-hour average ground-level concentrations and deposition fluxes of one or two gaseous or particulate pollutants on an urban scale for a single day. The model accounts for the effects of dry deposition, gravitational settling, and a first-order chemical transformation. The Gaussian plume algorithms for point sources were derived from analytical solutions of a gradient transfer model to determine deposition and settling of each pollutant species, while concentrations from area sources are calculated by numerical integration of the point source algorithms. The horizontal and vertical dispersion coefficients in PEM-2 are determined from Briggs' urban equations derived from St. Louis tracer data. New options include the selection of the standard plume rise equations or Briggs' new plume rise/plume penetration expressions, buoyancy-induced dispersion, and final or gradual plume rise treatment. A user guide will document the methodologies, contains instructions for execution, and test case input/output examples.

An evaluation of PEM-2 was performed using emissions, meteorology, and pollutant measurements obtained during the one month 1982 Philadelphia Aerosol Field Study (PAFS). The model's concentrations were statistically and graphically compared to the 12 and 24-hour concentration measurements of fine and coarse total particulate mass, fine sulfate, and sulfur dioxide at six monitoring sites. The particulate concentrations were simulated closely by the model, however, the background concentrations far exceeded the local contributions and dominated the evaluation. A final report containing the complete results in the form of tables and graphs will be completed in FY-1986.

2.2.4.2 Lagrangian Modeling of Particulate Matter

The Regional Lagrangian Model for Air Pollution (RELMAP), formerly the Eastern North American Model for Air Pollution (ENAMAP), was expanded to consider the transport and deposition of inhalable particulate matter. Highly parameterized wet and dry deposition modules were incorporated into RELMAP. Interim emission inventories of particles with diameters less than 2.5 and from 2.5 to 10.0 m were created from the Version 4.0 NAPAP Emissions Inventory. These emissions, as well as Version 4.0 SO_2 and primary sulfate emissions, were gridded for input to the model.

The first draft of the RELMAP User's Guide was completed. The user's guide discusses the technical and computer aspects of the model and provides users with application instructions, sample results, and model evaluation results.

2.2.4.3 Model Evaluation Procedures

Critical reviews of past and more "traditional" approaches to model evaluation were carried out over the past year (White et al., 1985; Dennis, 1985a; and Dennis and Irwin, 1985). The importance of graphical analyses to the understanding of the evaluation results was emphasized in the review of complex terrain model evaluation for the AMS (White et al., 1985) and at the DOE Workshop on Model Evaluation (Dennis and Irwin, 1985). A number of the recommendations for use of graphical displays were accepted and acted upon by the OAQPS (Cox and Moss, 1985).

A major conclusion of the assessment of past model evaluations is the need for understanding the purpose of the evaluation and the importance of providing diagnostic analyses as part of an evaluation. A procedure new to air quality model evaluation and expressly for diagnostics purposes was developed and presented at the DOE workshop (Dennis and Irwin, 1985). The procedure uses a simple model as a non-linear filter of the data in order to stratify both the observed and model predicted data with respect to dominant physical/meteorological processes. The simple model tested was a theoretical reconstruction of the plume centerline concentration profiles as a function of distance downwind. This technique provided a demonstrably improved diagnosis of model behavior and improved understanding of model behavior with respect to the observations.

2.2.4.4 Complex Terrain Model Performance Evaluation

A scientific review was conducted of a set of eight complex terrain dispersion models. These models were COMPLEX I, COMPLEX II, COMPLEX PFM, 4141, PLUME5, RTDM, SHORTZ and IMPACT. The first seven models listed were Gaussian type models; the eighth, IMPACT, was a deterministic finite difference numerical grid diffusion model. TRC Environmental Consultants, Inc. calculated and tabulated a uniform set of performance statistics for these models using the Cinder Cone and Westvaco Luke Mill data bases (Wackter and Londergan, 1984).

Subsequently, the TRC performance statistics, analyses, and evaluation were reviewed by members of the Atmospheric Modeling Branch and an independent assessment of each of the models, as well as their performance, was made (Ching, 1985; Dennis, 1985b). They found that while the TRC effort produced a useful set of statistical products, their analyses were too limited to provide a thorough evaluation of the scientific merits of these models. For example, the sensitivity test and model component diagnostic studies performed were inadequate. Therefore, additional sets of model comparisons and diagnostic analyses were conducted to compliment the TRC study in an effort to compare the different model predictions relative to the methodology adopted by individual models in handling the more important and sensitive model components. It was shown that model prediction differences and errors can be as much a function of inadequate model methodologies as the formulation of the basic model components.

Additionally, each model's approach to parameterizing plume rise, dispersion, transport, terrain adjustment, and mixed layer heights was examined. The treatment of terrain features and the stability dependency of flow over terrain and its potential importance to complex terrain modeling was studied in greatest detail. It was found that terrain adjustment and transport was treated quite differently by all the models in this set; in combination with other model components, it was concluded that large differences in model predictions is expected. The incorporation of potential flow concepts, and Froude number scaling, and the use of a critical dividing streamline height by some models is clearly an important improvement.

2.2.4.5 Field Validation for Exposure Assessment Models

A method to estimate the strength of inaccessible sources will be examined in a model sensitivity study. The method uses a line source of known emission rate of a tracer along with measurements of the tracer and of the material emitted from the inaccessible area source. The ratio of the measured concentrations will be used to estimate the pollutant source strength. In field experiments the line source is in reality a rapidly moving point source. The uncertainty involved in this approximation as well as sensitivity to the meteorological conditions will be investigated in this project. Work will begin early in FY-1986.

2.2.5 Technical Assistance to the People's Republic of China (PRC)

A Meteorologist provided technical assistance to the People's Republic of China (PRC) through the sponsorship of the United Nations World Health Organization (WHO). This project consisted of reviewing their environmental monitoring and research programs, providing lectures on measurement principles and practices, and reviewing state-of-the-art sampling technology and current dispersion concepts and models, with emphasis on dispersion in complex terrain and on regional scale problems associated with coal-fired power plants. The primary host was the Atmospheric and Environmental Research and Monitoring Center, the major research arm of the PRC Ministry of Water Resources and Electric Power. This branch of government has the overall responsibility for meeting China's projected goal of quadrupling its electric power output by 2000 AD from its base year of 1980.

2.2.6 Support of Airshed Model Use by State Air Pollution Agencies

Technical assistance in the use of the Urban Airshed Model, a 3-D gridded urban photochemical model, was provided to the New York Department of Environmental Conservation and the Colorado Air Pollution Control Division. The New York application is part of the Oxidant Modeling for the New York Metropolitan Area Project (OMNYMAP). The purpose is to enable the States to determine strategies for attainment of the National Ambient Air Quality Standard (NAAQS) for ozone. The focus of the technical support is to provide guidance for the development and implementation of air pollutant/meteorological input methodologies and modeling protocol, particularly the meteorological processor developed by the Environmental Operations Branch. The OMNYMAP is providing a useful test of the meteorological processor because of the quality of the Northeast Corridor Regional Modeling Project data and availability of aircraft soundings of pollutants. For summer conditions the importance of mechanical mixing was shown.

2.3 Fluid Modeling Branch

The Fluid Modeling Branch conducts physical modeling studies of air flow and pollutant dispersion in such complex flow situations as in complex terrain; and near buildings, near roadways, and near storage piles. The Branch operates the Fluid Modeling Facility consisting of large and small wind tunnels and a large water channel/towing tank. The meteorological 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 simulation of transport and dispersion in the neutral atmospheric boundary layer. The towing tank has an overall length of 35 m with a test section 25 m long, 2.4 m wide, and 1.2 m high. It has a speed range of 0.1 to 1 m/s and the towing carriage a range of 1 to 50 cm/s. It is generally used for simulation of strongly stable flow.

2.3.1 Complex Terrain Studies

In conjunction with the complex terrain model development project, the Fluid Modeling Branch conducted two separate modeling studies. The first study attempted to characterize the effects of stability on the horizontal and vertical deflections of streamlines around an isolated hill. A large set of streamline trajectories over an axisymmetric hill was measured using the stratified towing tank. Three-dimensional coordinates of the streamlines (86 independent trajectories) were determined through stereographic analysis of photographs of dye streak lines released at a matrix of source positions (heights and lateral offsets from the hill/flow centerline), and at stabilities ranging from strongly stable to neutral (Froude numbers of 0.6, 1.0, 2.0, and ∞). A mathematical model using linear theory and a Fast Fourier Transform Technique to predict these streamline trajectories also was evaluated. The model predicted adequately in neutral flow and displayed correct trends with increasing stability. However, in the stratified flows, the model underpredicted lateral deflections and overpredicted vertical deflections. A report on this work will be published. (Snyder, Thompson and Shipman, 1985).

The second study examined the conditions under which flushing of a valley between two ridges will occur, i.e., to answer the question of when a stable cross wind will sweep the valley clean and/or when the flow will separate from the top and thus form a nearly stagnant region in the valley beneath. This study was conducted as a cooperative project with the Los Alamos National Laboratory and as an extension of earlier work (Lee et al., 1984). The first phase of a series of towing-tank studies examined the effect of Froude number (characterizing the stability of the cross wind) and the separation distance between the pair of ridges, where the maximum slope of the valley sidewalls was quite steep (40°). Unexpected results strongly suggested further studies with valley sidewalls of smaller slope.

A wind tunnel demonstration study on Good-Engineering-Practice (GEP) stack height was conducted in response to a request from the EPA Office of Air Quality Planning and Standards under a Federal Appeals Court Mandate requiring the revision of the stack height regulations. The site chosen for this demonstration study was the Clinch River Power Plant in southwestern Virginia. A 1:1920 scale model of surrounding terrain was constructed and measurements were made to describe the simulated atmospheric boundary layer structure, plume-dispersion characteristics in the boundary layer, and the maximum ground-level concentration (glc) of effluent downstream from the source, both in the presence of all significant terrain surrounding the plant and in the absence of "nearby" upwind terrain. Analysis of the maximum glc showed that, in this case, a stack height of 326 m met the GEP criteria under 50% plant-load conditions, i.e., the nearby upwind terrain effected an increase of 40% in the maximum ground-level concentration. The results were published (Snyder and Lawson, 1985). Related work on measurements of terrain amplification factors over generic hill shapes (two- and three-dimensional) was prepared for presentation (Lawson and Snyder, 1985).

Reports on previous towing-tank and wind-tunnel measurements of flow fields and concentration distributions resulting from sources in complex terrain were prepared. The basic, but controversial, paper on dividing-streamline heights was published (Snyder et al., 1985) after more than two years of correspondence with the journal (and referees) and additional experiments on the upstream influence of two-dimensional hills in towing tanks. The reason for the controversy was that the results cast doubt upon the validity of previous laboratory experiments. The results of the additional experiments were presented at the Oxford Workshop on Wind Tunnel Modeling of Atmospheric Diffusion (Thompson and Snyder, 1984). A journal article describing surface concentrations resulting from plume impingement under neutral and strongly stratified flow conditions was published (Snyder and Hunt, 1984). Also, a paper describing the flow fields and plume deformations around moderately steep hills of triangular cross section and varying crosswind aspect ratios was submitted for publication (Snyder and Britter, 1985).

2.3.2 Wind Tunnel Studies

A cooperative project with the Los Alamos National Laboratory to investigate the Monte Carlo simulation of two-particle relative diffusion using Eulerian statistics was concluded. Detailed measurements of flow characteristics downstream of a turbulence generating grid in the wind tunnel were used as a basis for the calculation of particle diffusion. Results of these calculations were compared with total diffusion measured by a hydrocarbon tracer technique and with relative diffusion determined from analysis of instantaneous photographs of smoke plumes. Comparisons between a one-particle diffusion model and the two-particle model showed that the two-particle model provided a more accurate description of plume meandering and relative diffusion (Lee et al., 1985).

Under a cooperative agreement with North Carolina State University, the final phase of a wind tunnel study was conducted to examine the effectiveness of screens (windbreaks) in reducing wing speeds on the surfaces of storage piles. A variety of screen types, placements, shapes and sizes were tested for two typical storage pile shapes (conical and flat-topped oval shapes). Simple mathematical models relating wind speed to particle uptake were used as engineering tools to assess the overall effectiveness of the screens in reducing fugitive dust emissions. In general, the study demonstrated that even moderate sized windbreaks showed large reductions in fugitive dust emissions with 90% reductions being fairly typical (Billman, 1985; Billman and Arya, 1985). Previous work under this cooperative agreement on flow and dispersion in the wakes of three-dimensional low hills was published (Arya and Gadiyaram, 1985).

Under an agreement with Oak Ridge National Laboratory, a detailed series of wind tunnel measurements was conducted to examine the flow fields and concentration patterns resulting from sources upwind of a series of ramps (followed by plateau) of various slopes and crosswind aspect ratios. Data reports and preliminary analyses were completed, and a paper is being prepared for publication.

2.4 Data Management Branch

The Data Management Branch coordinates all ADP activities within the Meteorology Division, including the design, procurement, and implementation of data base management, computer systems analysis, and ADP studies. The Branch provides data management and programming services that are done primarily through ADP service contracts.

2.4.1 Regional Oxidant Model Testing and Application

The Regional Oxidant Model was applied to a series of test problems whose exact solutions are known. The predicted concentrations were compared with the true values to obtain a measure of the accuracy of the numerical algorithms that comprise the model's governing equations. The kinetics algorithm produced exact solutions of the chemical rate equations over the full range of species concentrations that are likely to be encountered in applications. In simulations of the advection of clouds of chemically reactive compounds, the kinetics and transport algorithms jointly reproduce the correct shapes and motions of clouds and predicted the peak concentration in the cloud to within 10% of the true value over 48-hour simulation times. In applications to continuous finite line sources in steady, spatially variable flows, the combined algorithms produced plumes with negligible pseudo-diffusion. In general, it was found that ozone is among the species simulated best while compounds such as nitrous and nitric acid, alkyl nitrate and related nitrogen containing species are simulated poorest. The predicted concentrations of free radical species are of intermediate accuracy. Evidence also was found that errors in plume concentration can be amplified when a plume crosses a second source. The zone of enhanced error tends to be confined to the vicinity of the second source.

The ROM was applied to demonstrate its usefulness in studying the effects of proposed urban control strategies on rural ozone concentrations. Meteorological data were prepared for August 3-4, 1979. The 1979 Northeast Corridor Regional Modeling Project hydrocarbon and NO_x emissions were used for the base case and adjusted on a county-by-county-basis for the control case to provide an emission inventory which reflects State compliance with the 1987 State Implementation Plans. The first generation ROM was executed with constant thickness layers, nondivergent winds, and the Demerjian chemistry.

The resulting analysis focused on aggregate effects rather than concentration at one or several specific sites. All grid cells were designated as either urban, suburban, rural or wilderness. Diurnal variation in median concentrations for each class was studied as well as overall impact of the control strategy. Maximum hourly averaged ozone was reduced by about 35% in urban and suburban locations in contrast to approximately 20% reduction in predicted peak ozone in rural areas. The emission control reduced peak concentration significantly more than it reduced the median or mean concentration values. Differences in the diurnal pattern of the land use classes indicate that three or more days are necessary for the regional air mass as a whole to become considerably burdened by precursor emissions.

In preparation for execution of the first generation ROM for a two-week scenario, raw meteorological and surface air monitoring data were collected and reviewed from July 23 to August 16, 1980. Data for the initial nine days were processed through the complete series of ROM processors to produce verified input data for execution of ROM. Quality control procedures included automated range checks and verification of specific physical relationships within the entire data set. A more subjective review of temporal and spatial features was performed by graphical analysis. ROM executions for base case and emission control strategy application are in progress.

2.4.2 Regional Lagrangian Sulfur Deposition Model Application

The RELMAP was modified to use a latitude-longitude based grid system with one degree resolution. The model was executed in a monthly mode for all of 1980. Monthly, seasonal, and annual means and variance of observed/predicted concentrations and depositions were computed. The overall annual correlation coefficient was 0.614. The hourly gridded data were submitted as part of the International Sulfur Deposition Model Evaluation (see Section 2.2.1.7).

A precipitation processor was developed to transform the standard National Climatic Center Deck 488 precipitation data recorded in station order into the hourly synoptic form required by the regional models. Canadian hourly and daily precipitation data were also merged with the U.S. data and then gridded for model input. The meteorological data processor was modified to conform with the latitude-longitude grid system and new emissions processors were written to select and grid emissions from the NAPAP emissions inventory.

2.4.3 Emission Inventory Preparation

A preliminary particle size discriminate emissions inventory was prepared for initial testing of the RELMAP. Particle size data were abstracted from Draft Source Category Reports being prepared as part of the inhalable particulate matter (PM_{10}) emission factor program. Percentage factors for size range of <2.5 μm, 2.5 - 6.0 μm, 6.0 - 10.0 μm, and >10 μm for uncontrolled and controlled processes are applied to the NAPAP total suspended particulate emissions reported by source classification code.

The NAPAP version 4 emissions inventory was reviewed extensively and further processed through the Regional Model Data Handling System (RMDHS) to produce the hourly, gridded emissions input data for the ROM. RMDHS also breaks the Volatile Organic Compound (VOC) emissions into the reactivity classes required for the Demerjian chemistry mechanism in ROM.

2.4.4 Miscellaneous Activities

The Air Resources Laboratory's Branching Atmospheric Trajectory (BAT) model was enhanced to produce overlays of geographical features on trajectory maps. Forward and backward meteorological data were processed for 1980 through 1983. BAT was applied for April through October 1982 and 1983 for several sites to assist Maine's Air Bureau in a critical ozone analysis.

The enhancement, testing, and documentation of the Meteorological Processor for Dispersion Analysis (MPDA) was completed. The MPDA provides alternative methods for preparing National Weather Service (NWS) hourly surface observations, NWS twice-daily radiosonde reports, and user-supplied field data.

A parameterization of mixing depth statistics and analysis of the structure of the turbulent boundary layer during the convective period was completed for the Tennessee Plume Study data. Temporal variation of the standard deviations of the vertical velocity was examined. It was found, that in the mean, the magnitude of the turbulent intensity decreased in the upper half of the convective mixed layer relatively earlier in the afternoon, than in the lower half. This suggests that convective similarity parameterization concepts may be limited only in the early afternoon. These preliminary findings have important ramifications to pollutant dispersion modeling.

2.5 Terrain Effects Branch

The Terrain Effects Branch conducts research studies into the effects of complex irregular terrain and man-made surface features on ambient pollutant dispersion, on both an intramural and extramural basis; establishes mathematical relationships among air quality, meteorological parameters, and physical processes affecting the air quality; and conducts research in the areas of air pollution climatology and acidic deposition.

2.5.1 Dispersion Model Development for Sources in Complex Terrain

Initiated in 1980, the Complex Terrain Model Development (CTMD) Program, with Environmental Research and Technology, Inc., as prime contractor, is designed to produce improved atmospheric dispersion models with defined reliability for large sources located in complex mountainous terrain. The initial effort was planned to focus on stable plume impaction on terrain obstacles. The model development approach produced by the Fluid Modeling Facility, and atmospheric dispersion experiment results. Through FY-1984 comprehensive tracer experiments were conducted in three distinctive terrain settings and three milestone reports were published (Lavery et al., 1982; Strimaitis et al., 1983; Lavery et al., 1983). During FY-1985 the fourth milestone report was published (Straimitis et al., 1985) and the fifth will be published in FY-1986 (DiCristofaro et al., 1985).

The Complex Terrain Diffusion Model (CTDM), which is under development, has as its central feature the concept of the dividing streamline height in which the effluent in the approach flow above the critical height (the "lift" component of the model) passes over the terrain obstacle and the effluent below (the "wrap" component) passes round the side(s) of the obstacle. The dividing streamline height is determined essentially as the height at which the kinetic energy of the approach flow is just sufficient to surmount the obstacle. Both model components include mathematical expressions for adjustments to pertinent dispersion features as the flow is modified in interacting with the terrain.

The CTDM was tested with various quantities of on-site meteorological data. Results suggest that 5-minute simulations improved the correspondence between measured and calculated concentrations for some hours, but did not substantially change the overall performance statistics. Simulations using degraded meteorological data (except wind directions) demonstrated clearly that on-site measurements of turbulence intensities near release heights and detailed vertical profiles of wind and temperature were essential for accurately calculating concentrations even at the topographically simplest of our experiment settings, an isolated, nearly symmetric, 100-m high hill.

Meteorological conditions were analyzed for the ten highest observed concentrations for each of two tracers at each of the three field locations. At the three-dimensional small hill, the highest concentrations were observed most often on the windward side of the terrain when the tracers were emitted near the calculated dividing streamline height. At a long ridge (across the flow), practically a two-dimensional ridge, the highest concentrations occurred when tracers were released below the dividing streamline height. Streamline analyses indicated that the flow below the critical height was blocked by the ridge, thus enhancing impingement on the lower windward side of the ridge. At both of these small-scale sites, tracers released above the critical height tended to flow up and over the terrain, and higher concentrations occurred near the top or on the lee sides of the terrain. In the irregular complex terrain downwind of an existing power plant, located in both of the small-scale sites. For such general applications of the model, hills are simulated as ellipsoids.

The CTMD was exercised for a limited number of tracer experiments and the results compared with those for other well-known models: Valley and Complex I & II. For some experiments, the CTDM was clearly superior and for others the differences were small. Some of the reasons for differences in performance were diagnosed and provided the basis for modifying the CTDM.

The current phase of the CTDM Program, focusing on plume impingement, is due for completion near the end of FY-1986, culminating in an operational, fully-documented model of plume impingement under stable conditions.

2.5.2 Plume Dispersion in the Wake of Surface Obstacles

An in-house building wake effects research project to evaluate the overall effects of building wakes on plume dispersion downwind is continuing. Data is being collected in the Fluid Modeling Facility, available field data is being reviewed and methods for estimating dispersion downwind of isolated buildings is being evaluated. The applicability of fluid modeling studies of potential applications will be addressed. Velocity and concentration measurements from a surface release are being evaluated to delineate the effect of building scale, building orientation, wind speed, and boundary layer characteristics on their non-dimensional distributions. Additional data collections and analyses will continue during FY-1986.

Under a cooperative agreement with North Carolina State University, methodologies for analyzing videotaped images of smoke plumes were developed as a practical method of describing the short-time scale phenomena of building wake effects on plume dispersion. By systematically varying flow parameters in the controlled environment of the Fluid Modeling Facility, the relation between the transient characteristics of the dispersion process as determined from analysis of the video images can be evaluated against steady-state measurements from conventional instrumentation.

2.5.3 Stack Height Remand Task Force

A Meteorologist participated as a member of the Stack Height Remand Task Force upon request from the EPA Office of Air Quality Planning and Standards. The task force addressed issues related to the EPA regulations on Good-Engineering-Practice (GEP) stack heights from a case which was remanded by the U.S. First Circuit Court of Appeals. The Meteorologist provided technical review and information to OAQPS and attended task force workgroup meetings. A report on peak groundlevel concentrations due to building downwash relative to peak concentrations under atmospheric dispersion processes was prepared (Huber and Pooler, 1985). Additional discussion may be found in Section 2.7.2.5.

2.5.4 Green River Ambient Model Development Program

The Green River Ambient Model Development Program was completed with delivery to two initial air quality models: VALMET and MELSAR. The VALMET model is a two-dimensional model designed for application when pollutants are carried in locally developed circulations within a deep valley flow decoupled from the prevailing flow above the valley. The model was constructed to include parameterizations of the major physical processes that act to disperse pollution during morning transition periods. The MELSAR model was designed for application to mesoscale transport of air pollutants over the complex terrain region of the Green River Oil Shale Formation of Colorado, Utah, and Wyoming. The model is a Lagrangian puff model for long source to receptor distances (1 to 24). The transport winds were computed from measured upper-air and surface weather data using a mass-consistent three dimensional flow model. Specific adjustments were made to account for the effects of terrain features and stable atmospheric conditions. However, there is a continued need for model evaluation and improvement since both models are initial working versions for very complicated situations. The VALMET model was described fully with a user's guide in the final report (Whiteman and Allwine, 1985). The MELSAR model also was described fully in the final report (Allwine and Whiteman, 1985a and b). A limited evaluation of the VALMET model was presented by Whiteman, et al., (1984).

2.5.5 Complex Terrain Data Base Documentation

A computer data base of meteorological and tracer gas observations from Small Hill Impaction Study #2 was completed and placed on magnetic tape. This 1982 study was performed at Hogback Ridge near Farmington, New Mexico employing procedures similar to those used at the 1980 Small Hill Impaction Study #1, at Cinder Cone Butte, Idaho. Documentation of the Hogback Ridge data base is contained in a report (Truppi, 1985), which describes the data tape files of meteorological measurements and tracer concentrations. The data base is made available by tape copies or by interactive computer access.

A computer data base of meteorological and tracer gas observations from the preliminary full scale plume study conducted at the Tracy Power Plant near Reno, Nevada, during November 1983, was completed and placed on magnetic tape. These data will be combined with data from the full scale plume study conducted during August 1984 at the Tracy Power Plant and made available.

Climatological summaries in the form of vertical profiles of wind and temperature from six years of twice-daily radiosonde observations recorded at ten National Weather Service stations located in the Rocky Mountain and Great Basin regions of the western United States were prepared (Truppi, 1984). Seasonal and diurnal patterns were presented showing terrain influences at each radiosonde site characteristic of early morning and late afternoon conditions. Although these patterns were related to the particular valley-ridge topography at each site, terrain influences might be estimated or extrapolated to nearby regions where data may be required for atmospheric modeling applications.

2.5.6 Comprehensive Field Study Plan

During FY-1984 a contract was awarded for a comprehensive field study plan to relate pollutant sources leading to acidic deposition and to determine the requirements for, and costs of, a major field study (McNaughton et al., 1985; Stewart et al., 1985).

The Comprehensive Design Plan recommends that a sensitive receptor area be chosen for relatively intensive measurements, with a much coarser network over a large area that includes the limited receptor area. The initial receptor area recommended is one of about 300-km diameter centered over the Adirondacks region of upstate New York. This area would be monitored for gaseous and aerosol pollutants, as well as precipitation for laboratory analysis, on about a 40-km × 40-k grid. Nine additional upper air sounding sites would be installed in and around the area. Intensive measurement periods of 2 to 4 weeks per season would be carried out, during which the meteorological measurements would be augmented by doubling the frequency of upper air soundings, by use of indirect measurement systems to obtain detailed wind profiles on a continuous basis, by use of Lidar to obtain profiles of aerosol backscatter, and by use of several weather radars to provide a three dimensional view of precipitation patterns. Four aircraft would be extensively instrumented to measure patterns of pollutant distributions above the ground, and to perform various special sampling missions in support of particular experimental scenarios. Three insert gaseous tracers would be released for 24-hour periods every third day from distant areas that are known to be significant sources of acidic precursor emissions. The tracer releases would be made from about half a dozen sources within each area, so as to approximate the distribution of pollutant emissions, both horizontally and vertically. For planning purposes, a one-year program was estimated to be over one-hundred million dollars. Because of this high cost, it was further recommended that a phased approach be followed, e.g., the adequacy of tracer releases distributed over a few sources within a source region to represent emissions from the entire region should be investigated with limited field and modeling studies; the feasibility of empirically determining total pollutant deposition over a limited area by a mass balance determination should be assessed by means of short-time experiments; and instrument development should be completed to determine if promising sampling methods can be used in mobile sampling platforms.

A number of areas were investigated in the preliminary study of uncertainties. Because source modulation was suggested as a direct empirical method to determine source contributions, a modeling study was performed to assess the detectability of the signal in sulfur dioxide and sulfate concentrations resulting from modulating emissions from a number of sources in western New York. It was concluded that the signal would be very weak, and would probably be undetected against the much greater variability due to large-scale weather effects. Sample data from prior studies were examined to assess the adequacy of networks to measure the true horizontal distributions of pollutants. A station spacing of up to 500 km would provide a reasonable indication of sulfate distributions, whereas for sulfur dioxide, the required station spacing is less than 100 km. Calculations to simulate a mass balance study indicate that such an experiment would likely be inconclusive, because of variations of instrumental measurements. Analyses of long-range tracer data indicate that a sampler spacing of several hundred kilometers would be adequate for determining long-range trajectories most of the time; however, the frequency with which releases might be detected at a sampling point decreases monotonically with distance, and thus the greater the source-receptor separation, the longer the period of record required to adequately assess the impact of a source on a receptor, even for the inert substances considered.

The results of the analysis of uncertainties were included in modifications to the design plan as appropriate.

2.5.7 Integrated Air Cancer Program

A long-term research program to investigate the toxicity of airborne pollutants was initiated. The first phase of this research program is a study of the chemical composition and mutagenicity of woodsmoke. MD is studying the transport and diffusion of woodsmoke in urban areas to determine the relative effect of nearby sources on the chemical samples taken at a single site and to determine how woodsmoke diffuses.

During the 1984 and 1985 winter field experiments in Raleigh three meteorological towers were set up in the Quail Hollow area. Towers were located at the Quail Hollow and Lakemont swimming clubs and at Eastgate Park. Towers at Lakemont swimming club and Eastgate Park were instrumented at 3 m and 10 m with

Climatronic cup and vane anemometers, while a R.M. Young anemometer (starting speed at 0.35 m/sec) was deployed at 10 meters on the tower at the Quail Hollow site. Data was stored on cassette tape using Campbell data loggers.

The meteorological network was not operational until February 1985. During the period from February until the network was closed down in April 1985, there were only a few nights with stable conditions conducive to high woodsmoke concentrations. Analysis of these cases showed that the anemometers used were sensitive enough to describe either the transport of pollutants or the atmospheric turbulence which diffuses the pollutants. To rectify the inadequacy of the instrumentation, the MD evaluated available anemometers and procured two sonic anemometers which can accurately measure wind flow speed down to 0.01 m/sec; two R.M. Young bivanes which can have starting speeds of 0.25 m/sec; two R.M. Young Del T systems; one fast response temperature sensor, which when coupled with a sonic anemometer allows direct measurement of heat fluxes; and a programmable data logger to process the data from the two sonics and fast response temperature probe. This new instrumentation should be capable of resolving nighttime stable flow in suburban areas in the next field experiment.

During the Raleigh field experiment meteorological forecasts were provided each workday for that night and the following night. Each forecast provided expected wind direction, wind speed, temperature range, dew point, probability of precipitation, and a forecast scale of expected woodsmoke concentration during each twelve-hour period. Experience indicates that woodsmoke concentrations in Raleigh depend not only on meterological conditions but also on the day of the week and the month (i.e., people seem to use their fireplaces and/or woodstoves more frequently in November and December, and on weekends).

A cooperative agreement was implemented with Washington State University to investigate a number of tracer gases and analysis techniques to allow the release, sample and analysis of four different tracer gases. The four tracer gases that will be used are SF_6, CF3Br, Freon-14, and Freon-21. The Freon 14 and 21 gases were found to be absorbed by the plastic syringes used on the automotic syringe samplers. A test of the tracer gases using automatic bag samplers found that they were not absorbed by the bags. Sufficient automatic bag samplers to perform the experiments are available.

A numerical modeling study was performed to estimate the width of the tracer plumes under various initial dispersion scenarios simulating emission of woodsmoke from houses. The study indicates the plumes are narrow and may be difficult to locate, and that sampling networks will have to be designed with care.

2.5.8 Cooperative Experiment with People's Republic of China

In October and November 1984, Division personnel participated in the U.S. EPA and the Chinese Academy of Science of the People's Republic of China series of tracer experiments in the Beijing-Tianjin area of China. SF_6 tracer gas was released from the 300-m meteorological tower after cold fronts had passed through and a strong northwest wind was transporting the plume towards Tianjin, approximately 150 km downwind. Automatic syringe samplers were set up on arcs 70, 100, and 150 km from the release point. A helicopter took grab samples and continuous samples along arcs at 40 and 70 kms. The data analysis has not been completed because of difficulties the Chinese Investigator has encountered in traveling to the U.S.

2.5.9 Analysis of Acid Deposition Data

Statistical techniques, including Kriging, were used to analyze spatial patterns of wet deposition data from Canada and the United States, collected from 1980 through 1983. Maps of concentration and deposition of SO_4, NO_3, and H ions were prepared and examined to see if any significant temporal trends were evident. Comparison of maps, including confidence levels, shows that no statistically significant change in spatial pattern took place during the study period. Examples of the results produced using this technique are shown in Figures 1 and 2.

2.5.10 Dispersion Modeling in the Arctic

Under a cooperative agreement with Washington State University, a research program was initiated to evaluate Gaussian air pollution dispersion models for use on Alaska's North Slope and similar areas. The research is to address whether meteorological conditions on the North Slope of Alaska are so different from those

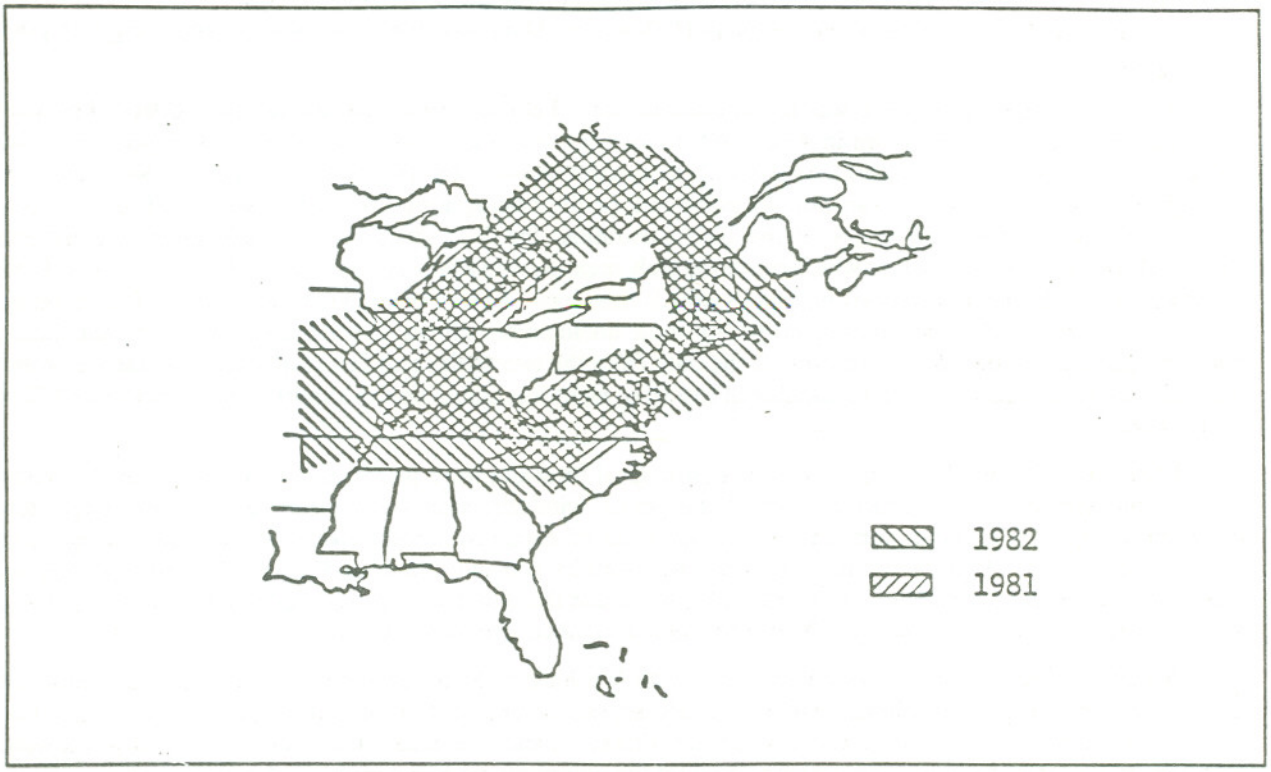

Figure 1: Hydrogen ion concentrations for 0.05 mg/l confidence regions.

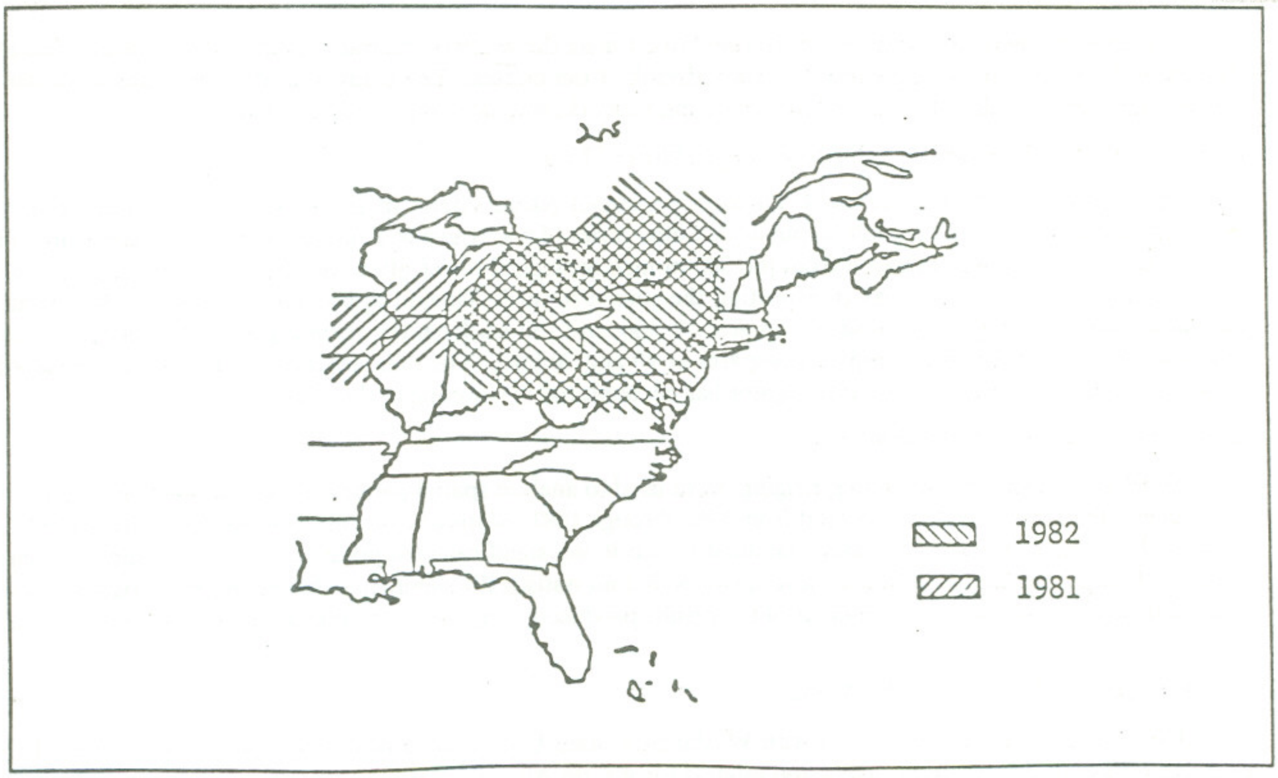

Figure 2: Nitrate concentrations for 2.0 mg/l confidence regions.

in more temperate climates, where conventional dispersion models are commonly used for regulatory purposes, as to result in misleading (significantly inaccurate) regulatory decisions. It is anticipated that the research will address this question by reference to the climatology of the atmospheric boundary layer in the Arctic. Should additional data be necessary to address the program, a field study will be conducted to evaluate some aspects of the Arctic boundary layer.

2.6 Environmental Operations Branch

The Environmental Operations Branch improves, adapts, and evaluates new and existing air quality dispersion models, makes them available for use, and consults with users on their proper application. The research work of the branch consists of two major projects: model availability and evaluation; and improving characterizations of dispersion meteorology.

2.6.1 Model Availability and Evaluation

2.6.1.1 Air Quality and Effects Modeling

A plant injury mathematical model, developed previously to model acute and chronic leaf injury data, was developed further by Larsen and Heck (1984) to model National Crop Loss Assessment Network (NCLAN) data. Percent crop yield reduction was estimated as a function of a new parameter, the effective mean O_3 concentration:

$$m_e = [(\Sigma\, c_h^{-1/v})/n]^{-v} ,$$

where c_h is the hourly average ambient O_3 concentration for each daytime hour (9:00 A.M. - 4:00 P.M.) of data available at an air sampling site for summer (June 1-August 31), n is the total number of such available hours, and v is an exposure time-concentration parameter (-0.376).

The overall purpose of air pollution control is to reduce or eliminate such adverse effects as plant injury or crop reduction. In order to study and to control such adverse effects efficiently, air quality parameters are needed that correlate closely with the effects, as does the above effective mean concentration.

Ambient air quality data can often be characterized by two parameters of the lognormal distribution, the geometric mean and the standard geometric deviation, but some ambient data are far from lognormal. Larsen and Heck (1985) suggest that even though an air quality data set is not lognormal, the effects of the ambient concentrations can be characterized with an effective geometric mean, m_{gae}, and an effective standard geometric deviation, S_{gae} calculated from the effective and arithmetic means:

$$m_{gae} = (m_e m_a^{1/v})^{1/(1+1/v)} \qquad \text{and}$$

$$s_{gae} = \exp([2\,\ln\,(m_a/m_{gae})]^{0.5}) ,$$

where exp indicates that e, 2.718, is raised to the power in parentheses. These two effective parameters can be used to characterize air quality at a site, in terms of its expected effects on plants, and to compare these parameters and the expected plant effects from site to site.

2.6.1.2 Model Evaluation

For the past several years, the performance of the RAM, an urban air quality simulation model (Turner and Novak, 1978a and b), was examined using measurements of SO_2 at 13 locations in the St. Louis area, collected as part of the Regional Air Pollution Study (RAPS). Papers by Turner and Irwin (1985) and Turner et al. (1985) reviewed the performance of the RAM in estimating the highest and second-highest SO_2 concentration values for averaging times of 1, 3, and 24 hours. The model had little bias as revealed by these studies.

Succeeding analyses, Rao et al. (1985a and b) suggest there is a bias to underestimate SO_2 concentration values during unstable conditions and to overestimate concentration values during low wind speed (less than 2 m/s) stable conditions. It is suspected that this bias may, in part, relate to an inability of the model to properly characterize the diffuse emissions now partitioned in the data base as area source emissions. The objective of this recent investigation is to improve upon the previously employed methodologies through the use of specific statistical analysis techniques in the quantitative evaluation of the performance of models. To this end, extreme value statistics are employed to determine the model's capability in simulating the tails of the observed concentrations cumulative distribution. Also, the resampling or bootstrap technique is applied to develop nonparametric confidence intervals for each percentile value of the concentrations distribution. These techniques enable the assessment of the model's behavior both on a paired (observed and predicted value at the same time and location is considered as a pair) and unpaired basis. In this way, model performance from the scientific and regulatory or operational viewpoints can be evaluated.

Both the RAM and the Climatological Dispersion Model (CDM) employ versions of the narrow plume hypothesis to simulate diffusion from area source emissions. The study by Irwin and Brown (1985), using the CDM and the RAPS SO_2 data base, noted that simulation results are quite sensitive to the size of the grid square used to specify the area source emissions. Although the area source emissions constituted only 3.5% of the total area and point source emissions, estimated annual concentrations from area sources ranged from 14 to 67% of the total concentrations estimated at the 13 sites. The median estimated impact from area sources was 32%. These results suggest that modeling results from urban air quality simulation models are strongly affected by the detail to which the area source emissions are specified. The area source inventories are estimated from seasonal fuel and gas usage estimates, partitioned to specific areas by population estimates. Hence, the area-source emissions are those in which we are least confident.

2.6.1.3 Concentration Statistics by Wind Direction

In an evaluation of the urban air quality simulation model, RAM, using hourly SO_2 concentrations measured at 13 sites during the 1976 Regional Air Pollution Study conducted in St. Louis, Missouri, bias with stability was noted (Turner and Irwin, 1985). A possible cause of the calculated maximum values during stable conditions was that all but the largest 196 point sources were included in the area source part of the emission inventory. Measured maxima occurred over a variety of conditions from unstable to stable.

Five statistics, maximum, second highest, median, mean, and minimum concentration (both modeled and measured) were calculated for each wind direction for each of the 13 sites. Various displays of these statistics were used to explore the validity of the speculation regarding source types.

The impetus for this analysis was to see if there was any evidence of measured concentrations resulting from point sources that were not in the inventory (Turner, 1985). However, the depictions appeared to offer no concrete conclusions on this point. Although the many spikes that appear in the measured concentration diagrams may result from many point sources, they may just as easily result from measured winds occurring near the general direction of the upwind source such that 10 to 15 spikes over a 20° to 25° azimuth range may result from the same source.

Obvious difficulties are that the most representative wind measurement at a monitoring site may still not represent the actual direction of transport of air arriving at that site, and that pollutant trajectories are seldom straight lines. In spite of these shortcomings, it would appear that organization of data by observed wind direction, and the calculation and graphical display of particular statistics for each direction may be useful. A specific application might be during air quality data collection in an emissions inventory study. By examining graphical output for significant sources, especially those near the monitoring site, steps could be taken to insure their inclusion in the emissions inventory.

Such analysis would also be useful when combined with receptor modeling. Although it is desirable, but not necessary to collect data continuous in time, wind direction measurements at the monitoring site are necessary for the time period of each air quality measurement. This requires air quality sampling over short time periods (generally not longer than an hour) for ease in relating a wind direction to the air quality measurement.

The study also indicated that statistics in large quantity, such as 360 values per site, can be made more manageable through the use of graphical presentations. Such presentations enable the viewer to assimilate the important and discard the unimportant as the graphs are examined. The variability or scatter, which dominates model and measured concentrations, also is visually apparent.

2.6.1.4 Estimation of Emission Rates of Significance

Following the 1984 disaster at Bhopal, India, the EPA Office of Research and Development asked that, given significant concentration levels for a number of potential air pollutants, emission rates be calculated that would result in the peak concentrations observed at Bhopal, at two distances for several different meteorological scenarios.

For releases that take place over at least 20 to 30 minutes, a continuous plume model can be used to estimate peak concentrations at distances up to 1 km from the source. For short releases, a puff model could be employed. The concentration normalized for emission rate, C/Q, is given for two distances and four conditions in the table. The factor of 10 (for adverse) is used to approximate the extreme from the ensemble of very stable conditions.

Table 1. C/Q (s m^{-3}) for different atmospheric conditions.

Condition (u, σ_a, σ_e)	Downwind Distance, km 0.1	1.0
UNSTABLE (2, 30, 35)	7.7×10^{-5}	1.5×10^{-6}
TYPICAL (5, 10, 10)	2.8×10^{-4}	4.6×10^{-6}
VERY STABLE (0.5, 1.3, 1)	6.3×10^{-1}	2.4×10^{-2}
ADVERSE (10 times very stable)	6.3	2.4×10^{-1}

u in m s^{-1}, σ_a and σ_e in degrees.

Emissions can be calculated from

$$Q = C / (C/Q)$$

where C is the significant concentration of a particular pollutant and C/Q is for a particular atmospheric condition and distance. If the particular pollutant is emitted at the rate Q, the significant concentration C can be expected to occur at the specified distance for this atmospheric condition.

2.6.2 Improving Characterizations of Dispersion Meteorology

2.6.2.1 Meteorological Processor

During FY-1985 work continued on developing a meteorological processor for use in diffusion modeling. The FORTRAN-coded program and associated user's guide are the results of work in three areas: consultation with experts on techniques to be employed; fabrication and testing of algorithms for use in the meteorological processor; and performance evaluation of the processor with field data. Conclusions reached by an international workgroup (scientists from Denmark, The Netherlands, Norway and the United States) are summarized in a report (Irwin et al., 1985), and two symposium papers (Holtslag et al., 1985; Sivertsen et al., 1985). The report outlines the schemes for processing the available meteorological data in order to specify the surface fluxes and mixing height, as well as the profiles of wind, temperature and turbulence within the mixed layer. Suggestions are made for how such meteorological data could be used to estimate the ground-level concentrations from non-buoyant point source emissions over the first 5 to 10 km transport downwind. The performance of these schemes are demonstrated in the two symposium papers using meteorological and tracer data collected in The Netherlands, Denmark, and Norway. It is shown that the transport and diffusion of air pollution can be related directly to the turbulent state of the Atmospheric Boundary Layer (ABL). The ABL is partitioned into several regions based on scaling arguments. For the different scaling regions of the atmosphere, methods are demonstrated for modeling the diffusion using available tracer data. The turbulence, and thus the diffusion, is best explained and modeled in the surface layer of the atmosphere. Releases within the unstable mixed layer are approximated adequately. Some success is demonstrated for modeling tracer concentration values in the stable local scaling layer, and in the near-neutral layer. At the same symposium results were presented of a preliminary evaluation of the performance of the meteorological processor (Irwin, 1985). Mean monthly patterns of the diurnal variation of the wind, temperature and turbulence over the lower 300 m were computed, using as input to the processor the hourly National Weather Service reports from Augusta, Georgia and the twice daily radiosonde reports from Athens, Georgia (160 km northwest of Augusta). These computed monthly patterns were compared with patterns developed from data collected on the 365 m WJBT-TV meteorological mast located 11 km southwest of Augusta. Comparisons for June 1976 suggested the turbulence and temperature patterns were approximated adequately by the processor; but the wind characterization was not properly characterizing the magnitude and timing of the wind maximum that typically occurred at 300 m at 0100 LST. Currently the effort is focusing on acquiring field data from past programs for use in further evaluating the meteorological processor.

2.6.2.2 Data Archive for Meteorological Air Tracer Field Data

During FY-1985 an effort was initiated to develop and test a means for archiving invaluable data sets in a timely fashion before the necessary supporting information about the data was lost permanently. While the intent was to develop a means for preserving these data and making these data more readily available, it was not the goal of this project to design a data base management system. It was anticipated that no one fixed format could possibly cope with the variety of data collected during typical large-scale micrometeorological and tracer diffusion field studies. The envisioned need was a procedure for storing the data that was sufficiently flexible to encompass a variety of data types and formats. To accomplish this, a survey was made of field data available from studies conducted prior to 1980 (Woodruff and Glantz, 1985). Based on the findings of the survey, it was determined that the archived data should include descriptive information as well as the data values. The entries in the descriptive portion of the archive would include, among other items, a data fact summary, a description of the experiment, and special information regarding the data. The archived data were described using a structure called a data map (Droppo and Watson, 1985). The data map allows the data to be entered in original formats, while providing the user with a machine-readable pathway for accessing the diverse data formats. Standard words were used for mapping variables and their units within the various data sets. This feature allows global scanning of data sets for specific variables. The data archive procedures were demonstrated using the Minnesota 1973 micrometeorological field data and the Hanford 1964 tracer diffusion field data (Woodruff et al., 1985; Glantz et al., 1985).

2.6.2.3 A Field Comparison of *In-Situ* Meteorological Sensors

During the first three weeks of September 1982, an experiment was conducted at NOAA's Boulder Atmospheric Observatory to assess the ability of *in-situ* and remote sensors to measure the mean and turbulent properties of the lower atmosphere. The experiment was conducted in response to the need for comparative data from which scientists could evaluate the accuracy, field precision, and general performance of some of the more commonly used meteorological instruments that measure atmospheric turbulence. A summary of the evaluation of measurements by four Doppler sodars of wind speed, wind direction, and the vertical component of turbulence (Kaimal et al., 1984) was included in last year's annual report (Viebrock and Poole-Kober, 1985).

Measurements of wind speed, wind direction, and the vertical wind component from five conventional *in-situ* meteorological systems were compared with similar measurements from a fast-response sonic anemometer (Kaimal et al., 1985). The systems tested were an orthogonal three-axis propeller anemometer, a light bivane and cup anemometer, a bivane propeller anemometer, a light cup and vane with a vertical propeller, and a vane-mounted propeller anemometer with a vertical propeller.

The results of the experiment can be summarized as follows:

1. Mean wind speed measurements seem the most reliable. They are subject to little, if any, overspeeding from the cup anemometers. However, mean wind direction measurements show scatter as measured by comparability (the root mean square difference between the value from the test sensor and the value from the reference sensor) of about 5°, larger than expected.

2. Standard deviations σ_{ϕ} and $\sigma\phi$ are measured with reasonable accuracy, having a scatter of ± 3° in σ_{θ} and ± 2° in σ_{ϕ}.
3. When transfer functions for the vertical velocity, w, are compared, a clear difference emerges between the bivanes and the propellers. The bivanes tended to overestimate w but also responded to wavelengths as short as 4.4 m. The propellers did not overestimate w, but neither did they respond well to wavelengths shorter than 32 m. Intermittent stoppage of the propeller was probably responsible for the drop in spectral levels observed in the light wind stable case. The response to ϕ is the same as for w.

2.6.2.4 Comparison of Three Methods for Calculating the Standard Deviation of the Wind Direction

To realistically estimate concentrations from air pollutant sources using air quality simulation models, it is important to represent the atmospheric physics as closely as possible. Therefore, the Meteorology Division has advocated the use of fluctuation statistics to estimate atmospheric dispersion (Turner, 1979; Irwin, 1983).

Since wind direction is a circular function with a crossover point between 360° and 0°, standard statistical methods for calculating the standard deviation of wind azimuth cannot be used directly.

If all instantaneous values over the time period, for which the standard deviation is calculated, were retained until the end of the period, a straight forward method can be used to account for the crossover (Irwin, 1980). A variation of this procedure, but still requiring hundreds of computer storage locations was suggested by Nelson (1984).

Three other methods (Verrall and Williams, 1982; Ackermann, 1983; Yamartino, 1984) overcome the above storage requirements if the on-line processor can determine the trigonometric functions, sine and cosine, of each instantaneous value and add these values to accumulators. The Verrall-Williams method requires five sums; the Ackerman method requires six sums; and the Yarmartino method requires three sums.

Tests of the three methods using data collected on the Boulder Atmospheric Observatory tower indicated that all three methods gave standard deviations of the wind azimuth with errors less than 0.5 degrees. Standard deviation ranged from 3.5 to 21.7 degrees.

Since the values of these real data were restricted to quite small values, some synthetic data, including large standard deviations, were used to test the methods. The results indicated that even for large values of the standard deviation, the Yamartino method gave results with errors less than 1.2 degrees and less than or equal to 1.5%. Also, the approximation of the mean wind direction by the arc tangent of the mean sines and mean cosines also gives excellent results; errors are less than 1° for distributions with a standard deviation of less than 75°. Distributions having a standard deviation greater than 75° are approaching circular distributions and for these, mean wind direction has little meaning.

2.6.2.5 Balloon Marker System

The results of Phase I of the development of an adjustable buoyancy balloon tracer of atmospheric motion were reported (Zak et al., 1985). The adjustable balloon tracer is a research tool which allows one to electronically track atmospheric flows in both the horizontal and the vertical, including the weak, sustained vertical motion associated with meso- and synoptic-scale atmospheric disturbances. The design goals for the balloon tracer specify a lifetime ≥ 3 days, tracking range ≥ 1000 km, a ceiling altitude ≥ 500 mb (5.5 km), and the capability to respond to mean vertical flows as low as 1 cm/s. The balloon tracer also must measure and telemeter selected meteorological variables, be sufficiently inexpensive to permit use in significant numbers, and be serviced by a ground system capable of handling several balloon tracers at a time. The balloon tracer has applications throughout the atmospheric sciences, but the immediate motivation for this effort is to provide a means to evaluate the accuracy of air pollution transport models for the eastern United States. The authors (Zak et al., 1985) proposed a generic design for such a system, subjected that design to theoretical analysis, constructed a prototype, and conducted a series of tests with the prototype to evaluate the concept. They conclude that a system meeting the design goals is feasible, and are proceeding to build that system in Phase II of this project.

2.7 Air Policy Support Branch

The Air Policy Support Branch (APSB) supports activities of the EPA Office of Air Quality Planning and Standards. General responsibilities include: (1) evaluating, modifying and improving atmospheric dispersion and related models to ensure adequacy, appropriateness and consistency with Agency policy and established scientific principles; (2) preparing guidance on applying and evaluating models and simulation techniques that are used to assess, develop or revise national, regional and local air pollution control strategies for attainment/maintenance of ambient air quality standards; and (3) providing meteorological assistance and consultation to support OAQPS's broad responsibilities for development and enforcement of Federal regulations and standards and assistance to the Regional Offices. The meteorologists are typically involved in interdisciplinary team efforts that include engineers, chemists, statisticians, computer specialists and other technical staff. Thus, it should be noted that most of the projects discussed required team effort and other technical staff.

2.7.1 Modeling Studies

2.7.1.1 Oxidant Modeling of the New York Metropolitan Area Project

The Oxidant Modeling of the New York Metropolitan Area Project (OMNYMAP) is a program to apply the Urban Airshed Photochemical Model to the New York Metropolitan Area (portions of New Jersey, New York, and Connecticut) in order to evaluate hydrocarbon emission control strategies necessary for attainment of the ozone National Ambient Air Quality Standard (NAAQS) in this area. The program is being conducted by the New York State Department of Environmental Conservation (NYSDEC) and the Connecticut Department of Environmental Protection under separate cooperative agreements with the EPA. During FY-1985 the air quality and meteorological data bases and a copy of the Airshed model were provided to the grantees. A 240 km (E-W) by 192 km (N-S) modeling domain was selected which covers the major emissions source areas and downwind areas of expected maximum impact during a single day's transport time. A grid resolution of 8×8 km was selected for all simulations. The participants in the program agreed to target five days, July 16, 21, and 22 and August 6 and 8, 1980, for analysis. These days were chosen using the following criteria: (a) maximum ozone in the region was in excess of 200 ppb; (b) aircraft measurements were available for specifying upwind boundary conditions; and (c) upper air data were available for specifying wind fields and mixing heights. Peak ozone concentrations on these days occurred over Connecticut, although exceedances of the NAAQS were measured in all three States.

Efforts to prepare the air quality and meteorological input data proceeded in two stages. The first stage was the development of specific methods for processing the vast amount of available ambient data required by Airshed. During a two-day workshop in June 1985 these procedures were reviewed and subsequently used by NYSDEC in the second stage to process the available data generating the inputs for the first day scheduled for model simulation, July 21, 1980.

Progress was slow on the compilation of the emissions data from New York, New Jersey, and Connecticut into the gridded, speciated, hourly inventory required for input to Airshed. The base case inventory is to be complete in early FY-1986 followed by the base case simulations. Subsequently, future year inventories and control strategies will be developed and simulated with the model. Evaluation of the strategies is to be complete by the end of FY-1986.

2.7.1.2 Regional Ozone Impact Analyses

During FY-1985 substantial progress was made toward coordinating the efforts of various groups addressing issues associated with rural ozone concentrations. Working sessions have identified both short- and long-term modeling needs to support the regulatory programs. These programs are: review of the NAAQS for ozone, development of regulations under Resource Conservation and Recovery Act (RCRA) for Treatment, Storage, and Disposal Facilities (TSDF) handling Volatile Organic Compounds (VOC) containing hazardous wastes, and Prevention of Significant Deterioration (PSD) for major new stationary VOC sources. Collectively, these programs involve the examination of the effects of urban area and single source VOC/NO_x control programs on ozone levels in rural areas. Primary interest is in assessing the benefits of various control strategies in terms of welfare effects, particularly agricultural crop damage. Given the urgency that exists for rural ozone model applications to support regulatory decision-making, there is a need for the development, testing, and evaluation of regional scale models. Several approaches are being explored for using two available regional ozone models, ROM and RTM-III, for regulatory applications. One problem yet to be resolved is how to translate the results of simulations with these episodic models into needed long-term, seasonal information.

Thus far, several initial investigations were performed with the first generation versions of both models. RTM-III was applied to a portion of the upper Midwest to ascertain whether the identity of urban plumes could be resolved by reducing the grid scale from 80 to 20 km since resolution of urban plumes is critical for the types of analyses desired. The results indicate that only plumes from the largest urban areas in the modeling domain, such as St. Louis and Chicago, could be detected. As part of the developmental work on ROM, the model was applied to a two-day episode. Urban plumes were clearly visible in the simulation results. This model also was run for an example control strategy in order to provide a test case for designing actual scenarios. Further applications of ROM and RTM-III are planned to evaluate various control strategy options.

2.7.1.3 Long-Range Transport Model Performance Evaluation

Considerable progress was made by ANL under an interagency agreement to evaluate the performance of eight short-term, long-range transport models, i.e., ARRPA-1, MESOPLUME, MESOPUFF, MESOPUFF-II, MSPUFF, MTDDIS, RADM, and RTM-II. The two evaluation data bases (Barr Ferber/Oklahoma and Savannah River Plant) were expanded in terms of geographic domain, additional surface and upper air meteorological data acquired, and the data bases archived on the ANL computer. Also, each of the eight models was installed on the ANL computer and verified to be operating properly by means of a benchmark test case provided by the model developer and one data set from each of the two evaluation data bases.

By the end of FY-1985, seven of the eight models were run with one Oklahoma tracer release data set. An examination of the results indicates that MESOPUFF predicts the fastest plume transport followed by MESOPUFF-II, RTM-II, and then RADM. In general, the model predictions lag the time of the observed peak by 2 to 4 hours. Comparisons of predicted and observed concentrations paired in time and space are expected to be poor for this data set due to the time lag phenomenon. However, on an unpaired basis, a preliminary analysis indicates that the peak predictions for all models are within a factor of three of the observed peak at 100 km from the source.

A method to evaluate the capability of the models to predict the observed ground pattern irrespective of the location of the predictions (and perhaps the time of prediction) is being developed by ANL. This method will be used to supplement the model performance evaluation that utilizes AMS suggested statistical procedures (Fox, 1981). It is anticipated that all models will be run through the evaluation data sets, including the generation of the AMS statistics, the results analyzed, and a final report prepared.

2.7.1.4 Particulate Matter Impact Due to Surface Coal Mines

Most air quality dispersion models which are used to predict particulate concentrations in the vicinity of surface coal mines assume emissions are released at grade level. However, many dust-producing operations occur inside the pit, sometimes at depths of many hundreds of feet below grade. Therefore, it is reasonable to suspect that only a fraction of the fugitive dust generated at the pit floor escapes to the surface. This tendency for particulate matter to remain inside the pit is called pit retention.

Under a contract, Air Sciences, Inc. conducted a field study in 1983 at four Western surface coal mines. Smoke puffs were released at the bottom of the pits, the motion of the smoke puffs was videotaped, and meteorological data were collected both in and out of the mine pits during the smoke release. Using these data, TRC Environmental Consultants, under a contract, calculated values of escape fraction (that portion of the dust emitted in the pit that leaves the pit) using published particle size distributions for related industrial activities. Results showed that the escape fraction is greater for unstable and neutral conditions than for stable conditions, suggesting that stable atmospheres may suppress vertical motion causing particulate matter to be retained in the mine pits (U.S. Environmental Protection Agency, 1985d). Also, the standard deviation of horizontal wind direction inside a pit is always greater than outside the pit. The degree to which the in-pit standard deviation exceeds the out-of-pit value increases with wind speed, but does not appear related to the Pasquill-Gifford stability class.

In FY-1985, TRC Environmental Consultants incorporated other physical and meteorological parameters into the original escape fraction equation. Four alternative equations were derived and evaluated by comparing values of escape fraction computed using the alternative equations with values of escape fraction inferred from the smoke release data. Each of the four alternatives was coded into a FORTRAN algorithm and tested in the ISC model with input data from a hypothetical surface coal mine. These results must be evaluated against monitored field data before any definitive conclusion can be reached about the choice of the best escape fraction equation/algorithm. The project report on FY-1985 activities is undergoing review.

2.7.1.5 Evaluation and Sensitivity Analysis of Coastal Fumigation Models

This study consists of an evaluation of two shoreline fumigation models, a sensitivity analysis which confirms the importance of the proper characterization of the Thermal Internal Boundary Layer (TIBL), and a separate evaluation of the TIBL height equations. The two models which are evaluated in the study are the CRSTER Shoreline Fumigation Model (CSFM) and the Misra Shoreline Fumigation Model (MSFM). The CSFM is a modification of the Lyons and Cole (1973) approach coded into a version of the CRSTER air quality model. The MSFM is a model developed by P. K. Misra (1980).

The two-year comprehensive Naticoke, Canada power plant study was used for evaluation purposes. Thirteen test cases were selected based on the criteria of daytime on-shore flow and sufficient land-water temperature difference. The statistical procedures used in the report include the use of scatterplots, variances, total root mean square error, systematic root mean square error, and the index of agreement. The initial evaluation indicates that the MSFM model performs better than the CSFM base model. This conclusion is based to a substantial extent on the comparatively high index of agreement values for the MSFM model.

Two modifications to the MSFM were tested as well. The first is an empirical modification based on work by Deardorff and Willis (1982) and Kerman (1983). The second is "downdraft modification" proposed by Misra (1981). Neither of these modifications gave better results than the unaltered MSFM.

A sensitivity analysis of the various model input parameters was conducted. The parameters considered included convective velocity scaling, buoyancy flux, Brunt-Vaisalla frequency, and the TIBL parameterizations. The TIBL parameterization was found to be the most sensitive variable. This supports the claim that proper TIBL parameterization is the key to coastal dispersion modeling. Lastly, an evaluation of the TIBL height equations was carried out. Six TIBL models were identified from the literature and compared using two TIBL experimental data bases. The formulation of Weisman (1976) gave the best results in this study. The final report from the contractor at North Carolina State University is being prepared.

2.7.2 Modeling Guidance

2.7.2.1 Interim Procedures for Evaluating Air Quality Models--Experience with the Procedures

In FY-1984 a document (U.S. Environmental Protection Agency, 1984a) was prepared to provide a general framework for deciding whether a proposed model, not specifically recommended in the "Guideline on Air Quality Models" (U.S. Environmental Protection Agency, 1978), was acceptable on a case-by-case basis for a specific application. In FY-1985, a companion report (U.S. Environmental Protection Agency, 1985b) summarized and intercompared the details of five major regulatory cases for which the guidance provided in the Interim Procedures was implemented in evaluating candidate models. In two of the cases, the evaluations were completed and the appropriate model was determined. In three of the cases, the data base collections and/or the final analyses have not been completed.

Each of the five cases involved major point sources of SO_2. In all cases the major regulatory concern was to determine the emission limit that would result in attainment of the NAAQS within a few kilometers of the plants. Most of the cases involved power plants and/or industrial facilities located in complex terrain where short-term impact on nearby terrain is the critical source-receptor relationship.

Although the scope of model problems was limited, the analysis showed that the basic principles or framework underlying the Interim Procedures is sound and workable in application. The concept of using the results from a prenegotiated protocol for the performance evaluation was shown to be an appropriate and workable primary basis for objectively deciding on the best model. Similarly, "up-front" negotiation on what constitutes an acceptable data base network, while often difficult to accomplish because of conflicting viewpoints, was established as an acceptable way of promoting objectivity in the evaluation.

The experience pointed up the need to emphasize the importance of preliminary estimates of ambient concentration levels from the proposed and the reference models in order to provide a better linkage between source-receptor relationships and the contents of the performance evaluation protocol; and to better define the requisite data base network. The experience also pointed up the need to build in some safeguards in the application of the chosen model, should that model be shown to underpredict concentrations. This is particularly a problem if an emission limit derived from the model application might result in violations of the NAAQS. The method used in more recent regulatory cases generally involves the use of adjustment factors to correct for possible underprediction. This technique is not particularly appealing and the development of more innovative and scientifically defensible schemes was recommended.

Finally, analysis of the case studies showed that the credibility of the performance evaluation is greatly enhanced by the availability of continuous on-site measurements of the requisite model input data. This includes the measurement of meteorological parameters, as well as designation of pre-specified backup data sources for missing data periods. The provision for continuous in-stack measurement of emissions and accurate stack parameter data is also very important.

2.7.2.2 Guideline on Air Quality Models (Revised)

Following incorporation of minor comments from the Office of Management and Budget, the draft revised guideline on air quality models was made available for public comment through a Federal Register notice on December 7, 1984. Public interest in the guideline has been very high; almost 1000 copies have been distributed. A later notice on December 20 announced the Third Conference on Air Quality Modeling (see next section) which served as a forum for public review and comment on the proposed revisions to the guideline. The public comment period closed April 1, 1985, although an additional 30 days were allowed for receipt of written rebuttal and supplementary information. Over 450 comments have been extracted from the record. Division staff summarized the comments, provided many of the responses and coordinated the preparation of the overall response document. The draft document was sent for review to members of the Work Group to Revise the Modeling Guideline. The final version will be made part of the public record. The revised guideline, reflecting appropriate changes, is scheduled for promulgation in FY-1986.

2.7.2.3 Third Conference on Air Quality Modeling

The meteorology staff was involved in developing and ensuring logistical support for the Third Conference on Air Quality Modeling which was held on January 29-31, 1985 in Washington, DC. The Conference served as a forum to present the results of research activities in air quality dispersion modeling, and the status of plume model validation, evaluation and development programs. The conference also served as a forum to receive public comment on the draft "Guideline on Air Quality Models (Revised)," which was released for public review and comment in December 1984. Over 190 individuals attended the conference and there were 22 speakers. The Conference proceedings were transcribed as part of the rule-making docket for the revised modeling guideline.

Providing technical support for the EPA position at the Third Conference on Air Quality Modeling were two papers presented at the Fourth Joint Conference of Applications of Air Pollution Meteorology on October 16-19, 1984 in Portland, Oregon. These papers presented an opportunity for scientific discussion of the technical bases for several of the modeling recommendations. One paper presented a summary of studies conducted to assess the effects of several suggested changes on the rural model estimates (Lee et al., 1984). The other paper reviewed several alternatives for modeling in elevated terrain and compared the impact on estimated concentrations of using alternative schemes (Wilson and Tikvart, 1984).

2.7.2.4 Revising Regulatory Air Quality Models

Several models recommended by the EPA are being revised to reflect improvements in modeling techniques and to improve technical consistency among these models. The models being revised are MPTER, CDM, CRSTER, ISC, and RAM. The changes include consistent formulations of plume rise; treatment of terrain (where appropriate); buoyancy-induced dispersion; revised wind profile exponents; consistent treatment of mixing height; addition to CRSTER and ISC of the urban dispersion coefficients now in the RAM model; several minor changes suggested in the public comments received on the modeling guideline; and an improved downwash algorithm for the ISC model developed for the American Petroleum Institute. Moreover, there will be an option switch in each model to cause defaults to those model settings recommended in the forthcoming revised Guideline on Air Quality Models. Most of the changes are being accomplished under contract. The addition of urban dispersion coefficients to CRSTER and ISC was completed and the revised model code provided to the EPA Regional Offices in January 1985 as an interim product of this project.

2.7.2.5 Technical Support and Guidance for the EPA 1985 Stack Height Regulation

During FY-1985 the 1981 technical support document/guideline was substantially revised to conform to the final EPA regulation on stack heights, promulgated in July 1985. The new publication (U.S. Environmental Protection Agency, 1985a) incorporates a number of new aspects including current regulatory requirements for demonstrating Good-Engineering-Practice stack height; results from recent studies and tests on the applicability of the refined GEP formula, HG = HB + 1.5L, where L is the lesser of the height or width of the building; how to treat portions of terrain that may induce wake eddies or downwash in a fluid model simulation; and how to apply air quality modeling when there is high terrain, multiple source impacts or venting from multiple flues. The guidance on determining GEP stack height credit in complex terrain was completely changed because the U.S. Court of Appeals reversed EPA's previous position that such credit could be allowed in order to avoid plume impaction. In addition, the new regulation imposes a test against the NAAQS and/or PSD increments to determine whether, in fact, the height given by the GEP formula is actually necessary, or maybe excessive, to avoid air quality violations. Several hundred public comments were generated by the proposal. Technical responses were provided to about one hundred comments which were incorporated in the summary of comments and responses document for the record. Meteorologist members of the Stack Height Remand Task Force served on public hearing panels, attended management option selection meetings, provided technical input to Task Force meetings and contributed technical modeling analyses showing the effects that adopting certain approaches would have on ambient concentrations. The implementation phase of the regulation has begun. The States are required to carry out GEP stack height assessments for all sources emitting more than 5000 tons/year of SO_2 (no de minimis limits for other pollutants have yet been set) and, where revised emission limits based on GEP stack height are required, revised State Implementation Plans must be submitted to the EPA for approval.

2.7.2.6 National Air Audit System: Program Effectiveness in Modeling

Over the past several years the EPA has been delegating many of its functions to the State and local agencies, including the responsibility, and sometimes the final authority, for conducting the requisite air quality dispersion modeling associated with permits and State Implementation Plans. With these delegations the EPA has taken on an oversight role of the State/local agency actions. This is accomplished through annual audits of the State/local agency actions. In each audit a series of questions is asked to determine how well the agency is carrying out its responsibilities. Specific questions are designed to determine the State/local agencies' capabilities to perform dispersion modeling as well as to determine how well the individual modeling analyses were performed.

During FY-1985 meteorologists were involved in several ways in the National Air Audit program. In the first activity, they provided detailed comments on the National Air Audit System FY-1984 National Report (U.S. Environmental Protection Agency, 1984b). This report summarizes the audits conducted during FY-1984, and covers modeling analyses done by the States/local agencies during FY-1983. A major concern expressed on the early drafts of the report was the lack of recognition of the varying demand for sophisticated air quality dispersion modeling among the States/ local agencies, i.e., it was implied that all areas of the country need to be equally capable of performing dispersion modeling. Another concern was that the findings and implied corrective actions were confused with factual material. Some of the findings seemed to unduly imply that the EPA was remiss in communicating information and guidance on modeling to the State/local agencies. Through the suggested clarifications and restatements, the final report is much more accurate and clear.

In the second activity, meteorologists were involved in designing specific questions for the FY-1985 audits. The questions were designed to determine the agencies' personnel resources and facilities (hardware and software) to carry out modeling responsibilities; the number of modeling analyses of various types that the individual agencies conducted during FY-1984; the number and nature of modeling analyses where departures from original guidance occurred during FY-1984; and the extent to which the State/local agencies required industry to perform the requisite modeling analyses (vs. the State/local agencies performing the analyses themselves).

In the third activity, FY-1984 audit questions on the State/local agency modeling of new sources/PSD sources were reviewed and changes recommended. It was suggested that, in addition to establishing what models were employed, the audits should attempt to establish what model options, e.g., gradual plume rise, urban/rural dispersion, etc., were used.

Finally, recommendations were provided to correct State/local agency deficiencies noted in the FY-1985 audit as well as input to and review of FY-1986/87 audit questions.

2.7.2.7 Model Clearinghouse

The FY-1985 activities for the Model Clearinghouse included responding to the EPA Regional Office requests for review of non-guideline models proposed for use; reviewing State Implementation Plan submissions; documenting Clearinghouse decisions and discussions; summarizing Clearinghouse activities at various meetings; and issuing periodic information (newsletter) on models and data base usage.

During FY-1985 the Model Clearinghouse handled 94 modeling questions. It also conducted or participated in coordination and information exchanges with the Regional Offices, including distribution of an annual report covering FY-1984 activities. Copies of Clearinghouse written responses were sent to the Regional Offices. Advance opinions are sought from the Regional Offices on sensitive issues with national implications. In FY-1985 one such case involved the correction of model estimates to standard temperature and pressure. It was decided not to begin a nationwide policy of correcting model estimates.

2.7.3 Additional Support Activities

Meteorologists have provided technical support for the development and implementation of the Model Evaluation Support System (MESS). This system provides a structure for data bases to be used in in-house model evaluation studies. Technical support was provided in the development of the system, and in the selection and installation of data bases, including those from the Clifty Creek power plant in Indiana, the Muskingum River power plant in Ohio, a special study at the Westvaco Luke Mill power plant in West Virginia, and a subset of the Electric Power Research Institute field study at the Kincaid power plant in Illinois. The support includes involvement in several model performance evaluation studies using these data bases, two of which were published (Cox and Moss, 1985; Cox et.al., 1985).

Also, Meteorologists serve on a number of short-duration task groups, formed to develop or revise existing regulations and programs or to generate sound technical options and potential positions on key issues facing policymakers. Current memberships include: (1) the Work Group to Revise the Modeling Guideline; (2) The Visibility SIP Development Work Group (until May 1985): (3) The Visibility Task Force (until April 1985); (4) the Stack Height Remand Task Force; (5) the Eastern Fine Particle/Visibility Work Group (until March 1985); (6) the Emissions Trading Policy Work Group; and (7) the OMNYMAP Technical Review Committee.

3. REFERENCES

Ackermann, G. R. Means and standard deviations of horizontal wind components. *Journal of Climate and Applied Meteorology* 22: 959-961 (1983).

Allwine, K. J., and C. D. Whiteman. Green River air quality model development: A mesoscale air quality model for complex terrain. Volume 1. Overview, technical description and user's guide. EPA/600/8-85/017a, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 142 pp. (1985a).

Allwine, K. J., and C. D. Whiteman. Green River air quality model development - MELSAR: A mesoscale air quality model for complex terrain. Volume 2. Appendices. EPA/600/8-85/017b, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 368 pp. (1985b).

Ames, J., T. C. Myers, L. E. Reid, D. C. Whitney, S. H. Golding, S. R. Hayes, and S. D. Reynolds. SAI Airshed model operations manuals. Volume I - User's manual. EPA/600/8-85/007a (PB85-191567), Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 350 pp. (1985a).

Ames, J., S. R. Hayes, T. C. Myers, and D. C. Whitney. SAI Airshed model operation manuals. Volume II - Systems manual. EPA/600/8-85/007b (PB85-191575), Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 236 pp. (1985b).

Ames, J., T. C. Myers, L. E. Reid, D. C. Whitney, S. H. Golding, S. R. Hayes, and S. D. Reynolds. SAI Airshed model source code and sample input/output data magnetic computer tape. Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, (1985c).

Arya, S. P. S., and P. S. Gadiyaram. An experimental study of flow and dispersion in the wakes of three-dimensional low hills. First International Conference on Atmospheric Sciences and Applications to Air Quality, May 20-24, 1985, Seoul, Korea. To be published in *Atmospheric Environment* (1985).

Atkinson R., A. C. Lloyd, and L. Winges. An updated chemical mechanism for hydrocarbons/NO_x/SO_2 photooxidations suitable for inclusion in atmospheric simulation models. *Atmospheric Environment* 16: 1341-1355 (1982).

Billman, B. J. Windbreak effectiveness for storage-pile fugitive-dust control: a wind tunnel study. Master of Science Thesis, Department of Marine, Earth and Atmospheric Science, North Carolina State University, Raleigh, NC, 96 pp. (1985).

Billman, B. J., and S. P. S. Arya. Windbreak effectiveness for storage-pile fugitive-dust control: a wind tunnel study. EPA/600/3-85/059, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 96 pp. (1985).

Briggs, G. A., and F. S. Binkowski. Research on diffusion in atmospheric boundary layers: A position paper on status and needs. EPA/600/3-85/072, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 226 pp. (1985).

Carmichael, G. R., and L. K. Peters. An Eulerian transport/chemistry/removal model for SO_2 and sulfate. I. Model development. *Atmospheric Environment* 18: 937-951 (1984).

Ching. J. K. S. Review of complex terrain model performance. Summary of complex terrain model evaluation. EPA/600/3-85/060, Atmospheric Science Research Laboratory, Research Triangle Park, NC, pp. 9-60 (1985).

Ching, J. K. S., E. E. Uthe, B. M. Morley, and W. Viezee. Observational study of transport in the free troposphere. Preprints, Fourth Joint Conference on Application of Air Pollution Meteorology, October 16-19, 1984, Portland, Oregon. American Meteorological Society, Boston, MA, pp. 154-157 (1984).

Clark, T. L. Sulfur deposition modeling with the NAPAP emissions inventory. First Annual Acid Deposition Emissions Inventory Symposium. EPA/600/9-85/015, Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, pp. 88-92 (1985).

Cox, W. M., and G. K. Moss. Evaluation of rural air quality simulation models. Addendum A: Muskingum River data base. EPA-450/4-83-003a, Office of Air Quality Planning and Standards, Research Triangle Park, NC, 166 pp. (1985).

Cox, W. M., G. K. Moss, J. A. Tikvart, and E. Baldridge. Evaluation of rural air quality simulation models. Addendum B: Graphical display of model performance using the Clifty Creek data base. EPA-450/4-83-003b, Office of Air Quality Planning and Standards, Research Triangle Park, NC, 57 pp. (1985).

Deardorff, J. W., and G. E. Willis. Ground-level concentration due to fumigation into an entraining mixed layer. *Atmospheric Environment* 16: 1159-1170 (1982).

Demerjian, K. L. Quantifying uncertainty in long-range transport models. *Bulletin of the American Meteorological Society* (in press) (1985).

Dennis, R. L. Issues, design and interpretation of performance evaluations: ensuring the emperor has clothes. Proceedings, 15th International Technical Meeting on Air Pollution Modeling and Its Applications, St. Louis, Missouri, April 1985. NATO/CCMS (1985a).

Dennis, R. L. Review of complex terrain model performance. Summary of complex terrain model evaluation. EPA/600/3-85/060, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, pp. 61-112 (1985b).

Dennis, R. L., and J. S. Irwin. Current views of model performance evaluation. Proceedings, DOE/AMS Air Pollution Model Evaluation Workshop, Vol. 1: Participants and Invited Speakers' Papers. A. H. Weber and A. J. Garrett (eds.), October 1984, Kiawah, SC. Report No. DP-1701-1, E. I. du Pont de Nemours and Co., Savannah River Laboratory, Aiken, SC, and American Meteorological Society, Boston, MA, paper no. 1-3 (1985).

DiCristofaro, D. C., D. G. Strimaitis, B. R. Greene, R. J. Yamartino, A. Venkatram, D. A. Goden, T. F. Lavery, and B. A. Egan. EPA complex terrain model development: Fifth milestone report - 1985. EPA/600/3-85/069, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 277 pp. (1985).

Droppo, J. G., Jr. and C. R. Watson. Introduction to micrometeorological and tracer data archive procedures. EPA/600/3-85/053, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 58 pp. (1985).

Egan, B. A. Dispersion in complex terrain - a report of a workshop held at Keystone, Colorado, May 17-20, 1983. EPA/600/9-85/031, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 67 pp. (1985).

Fox, D. G. Judging air quality model performance. *Bulletin of the American Meteorological Society* 62: 599-609 (1981).

Glantz, C. S., R. K. Woodruff, and J. G. Droppo. The Hanford 1964 atmospheric boundary layer experiment. Micrometeorological and tracer data archive. EPA/600/3-85/055, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 24 pp. (1985).

Godowitch, J. M. Characteristics of vertical turbulent velocities in the Urban convective boundary layer. *Boundary Layer Meteorology* (submitted) (1985).

Holtslag, A. A. M, S. E. Gryning, J. S. Irwin, and B. Sivertsen. Parameterization of the atmospheric boundary layer for air pollution dispersion models. Proceedings, 15th International Technical Meeting on Air Pollution Modeling and Its Application. St. Louis, Missouri, April 1985. NATO/CCMS (1985).

Huber, A. H., and F. Pooler, Jr. Comments on peak ground-level concentrations due to peak concentrations under atmospheric dispersion processes. Office of Air Quality Planning and Standards, Research Triangle Park, NC, 34 pp. (1985).

Irwin, J. S. Dispersion estimate suggestion #9: Processing of wind data. (document for internal distribution) Environmental Applications Branch, Meteorology and Assessment Division, Environmental Sciences Research Laboratory, Research Triangle Park, NC, (1980).

Irwin, J. S. Estimating and plume dispersion: A comparison of several sigma schemes. *Journal of Climate and Applied Meteorology* 22: 92-114 (1983).

Irwin, J. S. Modeling the diurnal variation of meteorological variables within the boundary layer - preliminary comparison results. Proceedings, 15th International Technical Meeting on Air Pollution Modeling and Its Application. St. Louis, Missouri, April 1985. NATO/CCMS (1985).

Irwin, J. S., and T. M. Brown. A sensitivity analysis of the treatment of area sources by the Climatological Dispersion Model. *Journal of Air Pollution Control Association* 35: 359-364 (1985).

Irwin, J. S., S. E. Gryning, A. A. M. Holtslag, and B. Sivertsen. Atmospheric diffusion modeling based on boundary layer parameterization. Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 53 pp. (1985).

Kaimal, J. C., J. E. Gaynor, P. L. Finkelstein, M. E. Graves, and T. J. Lockhart. An evaluation of wind measurements by four doppler sodars. EPA-600/3-84-111 (PB85-115301), Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 110 pp. (1984).

Kaimal, J. C., J. E. Gaynor, P. L. Finkelstein, M. E. Graves, and T. J. Lockhart. A field comparison of *in situ* meteorological sensors. EPA/600/3-85/057 (PB85-196988), Atmospheric Sciences Research Laboratory Research Triangle Park, NC, 107 pp. (1985).

Kaplan, M. L., J. W. Zack, V. C. Wong, and J. J. Tucillo. Initial results from a mesoscale atmospheric simulation system and comparisons with the AVE-SESEME I data set. *Monthly Weather Review* 110: 1564-1590 (1982).

Kerman, B. R. Response to ground-level concentrations due to fumigation into an entraining mixed layer. *Atmospheric Environment* 17: 1030-1032 (1983).

Lamb, R. G. Application of the first generation regional oxidant model to an assessment of the effect of proposal emissions reductions on episodic ozone levels in the northeastern United States. EPA Internal Report, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 120 pp. (1985).

Larsen, R. I., and W. W. Heck. An air quality data analysis system for interrelating effects, standards, and needed source reductions: Part 8. An effective mean O_3 crop reduction mathematical model. *Journal of the Air Pollution Control Association* 34: 1023-1034 (1984).

Larsen, R. I., and W. W. Heck. An air quality data analysis system for interrelating effects, standards, and needed source reductions: Part 9. Calculating effective ambient air quality parameters. *Journal of the Air Pollution Control Association* (in press) (1985).

Lavery, T. F., A. Bass, D. G. Strimaitis, A. Venkatram, B. R. Greene, P. J. Drivas, and B. A. Egan. EPA complex terrain model development: First milestone report - 1981. EPA-600/3-82-036, Environmental Sciences Research Laboratory, Research Triangle Park, NC, 305 pp. (1982).

Lavery, T. F., D. G. Strimaitis, A. Venkatram, B. R. Greene, D. C. DiCristofaro, and B. A. Egan. EPA complex terrain model development: Third milestone report - 1983. EPA-600/3-83-101, Environmental Sciences Research Laboratory, Research Triangle Park, NC, 271 pp. (1983).

Lawson, R. E., Jr., and W. H. Snyder. Stack heights and locations in complex terrain. Preprint, 7th Symposium on Turbulence and Diffusion, November 12-15, 1985, Boulder, Colorado. American Meteorological Society, Boston, MA, pp. 223-226 (1985).

Lee, J. T., S. Barr, R. E. Lawson, Jr., W. H. Snyder, and G. L. Marsh. Towing tank studies of stratified flow over ridges and valleys. Preprints, Third Conference on Mountain Meteorology, Portland, Oregon. American Meteorological Society, Boston, MA, pp. 37-41 (1984).

Lee, J. T., G. L. Stone, R. E. Lawson, Jr., and M. S. Shipman. Monte Carlo simulation of two-particle relative diffusion using Eulerian statistics. *Atmospheric Environment* (submitted) (1985).

Lee, R. F., J. L. Dicke, D. A. Wilson, and J. A. Tikvart. Evaluating the effects on concentration estimates of technical changes to regulatory air quality models. Preprints, Fourth Joint Conference on Applications of Air Pollution Meteorology, October 16-19, 1984, Portland, Oregon. American Meteorological Society, Boston, MA, pp. 91-94 (1984).

Lyons, W. A., and H. S. Cole. Fumigation and plume trapping on the shores of Lake Michigan during stable on-shore flow. *Journal of Applied Meteorology* 21: 494-510 (1973).

McNaughton, D. J., N. E. Bowne, R. J. Londergan, D. L. Shearer, D. A. Stewart, G. A. Moore, J. E. Langstaff, M. K. Liu, S. M. Greenfield, S. E. Schwartz, and D. H. Stedman. Comprehensive experimental design plan to relate pollutant sources to acidic deposition. Report prepared under EPA Contract 68-02-4081 by TRC Environmental Consultants, Inc., East Hartford, CT, 202 pp. (1985).

Misra, P. K. Dispersion from tall stacks into a shoreline environment. *Atmospheric Environment* 14: 396-400 (1980).

Misra, P. K. Dispersion of non-buoyant particles inside a convective boundary layer. *Atmospheric Environment* 16: 239-243 (1981).

National Center for Atmospheric Research. Regional acid deposition: Design and management plan for a comprehensive modeling system. NCAR-TN-215+PPR, National Center for Atmospheric Research, Boulder, CO, 33 pp. (1983a).

National Center for Atmospheric Research. Regional acid deposition: Models and physical processes. NCAR-TN-214+STR, National Center for Atmospheric Research, Boulder, CO, 386 pp. (1983b).

National Center for Atmospheric Research. The NCAR Eulerian acid deposition model. NCAR-TN-256+STR, National Center for Atmospheric Research, Boulder, CO, 178 pp. (1985).

Nelson, E. W. A simple and accurate method for calculation of the standard deviation of the horizontal wind direction. *Journal of the Air Pollution Control Association* 34: 1139-1140 (1984).

Patrinos, A. A. N. The impact of urban and industrial emissions on mesoscale precipitation quality. *Journal of the Air Pollution Control Association* 35: 719-727 (1985).

Pollack, A. K., and C. S. Burton. Trends in sulfur dioxide emissions from the electric utility industry and ambient sulfur dioxide concentrations in the northeastern United States 1975-1982. EPA/600/3-85/035, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 142 pp. (1985).

Rao, S. T., G. Sistla, V. Pagnotti, W. B. Petersen, J. S. Irwin, and D. B. Turner. Evaluation of the performance of RAM with the Regional Air Pollution Study data base. *Atmospheric Environment* 19: 229-245 (1985a).

Rao, S. T., G. Sistla, V. Pagnotti, W. B. Petersen, J. S. Irwin, and D. B. Turner. Resampling and extreme value statistics in air quality model performance evaluation. *Atmospheric Environment* (in press) (1985b).

Schere, K. L. and A. J. Fabrick. EPA Regional Oxidant Model: Description and evaluation plan. EPA/600/3-85/067, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 92 pp. (1985).

Schiermeier, F. A. Dispersion modeling - recent innovations and current techniques. Presentation, International Workshop on CCMS Air Pollution Pilot Studies. Lindau, Federal Republic of Germany, October 1984. NATO/CCMS (1984).

Schiermeier, F. A., T. F. Lavery, and D. C. DiCristofaro. Meteorological events that produced the highest ground-level concentrations during complex terrain field experiments. Proceedings, 15th International Technical Meeting on Air Pollution Modeling and Its Application, St. Louis, Missouri, April 1985. NATO/CCMS (1985).

Schiermeier, F. A., and P. K. Misra. Evaluation of eight linear regional-scale sulfur models by the Regional Modeling Subgroup of the United States/Canadian Memorandum of Intent Work Group 2. Proceedings, International Specialty Conference on the Meteorology of Acidic Deposition, Hartford, Connecticut, October 1983. Air Pollution Control Association, Pittsburgh, PA, 16 pp. (1983).

Shannon, J. D. Climatological variability in modeling of long-term regional transport and deposition of air pollutants. Preprints, Fourth Joint Conference on Application of Air Pollution Meteorology, October 16-19, 1984, Portland, Oregon. American Meteorological Society, Boston, MA, pp. 178-181 (1984).

Shannon, J. D. User's Guide for the Advanced Statistical Trajectory Regional Air Pollution (ASTRAP) Model. Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 83 pp. (1985).

Sivertsen, B., S. E. Gryning, A. A. Holtslag, and J. S. Irwin. Atmospheric dispersion modeling based upon boundary layer parameterization. Proceedings, 15th International Technical Meeting on Air Pollution Modeling and Its Application, St. Louis, Missouri, April 1985. NATO/CCMS (1985).

Snyder, W. H., and R. E. Britter. A wind tunnel study of dispersion from sources upwind of three-dimensional hills. *Atmospheric Environment* (submitted) (1985).

Snyder, W. H., and J. C. R. Hunt. Turbulent diffusion from a point source in stratified and neutral flows around a three-dimensional hill; Part II. Laboratory measurements of surface concentrations. *Atmospheric Environment* 18: 1969-2002 (1984).

Snyder, W. H. and R. E. Lawson, Jr. Fluid modeling demonstration of good-engineering-practice stack height in complex terrain. EPA/600/3-85/022, Atmospheric Sciences Laboratory, Research Triangle Park, NC, 89 pp. (1985).

Snyder, W. H., R. S. Thompson, R. E. Eskridge, R. E. Lawson, Jr., I. P. Castro, J. T. Lee, J. C. R. Hunt, and Y. Ogawa. The structure of strongly stratified flow over hills: Dividing-streamline concept. *Journal of Fluid Mechanics* 152: 249-288 (1985).

Snyder, W. H., R. S. Thompson, and M. S. Shipman. Streamline trajectories in neutral and stratified flow over a three-dimensional hill. EPA complex terrain model development: Fifth milestone report - 1985, EPA/600/3-85/069, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, pp. 241-277 (1985).

Stewart, D. A., J. E. Langstaff, G. E. Moore, S. M. Greenfield, M-K. Liu, D. J. McNaughton, N. E. Bowne, R. Kaleen, and M. K. Anderson. Comprehensive field study plan to relate pollutant sources to acidic deposition: a preliminary study of uncertainties. Report prepared under EPA Contract 68-02-4081 by TRC Environmental Consultants, East Hartford, CT, 223 pp. (1985).

Strimaitis, D. G., A. Venkatram, B. R. Greene, S. Hanna, S. Heisler, T. F. Lavery, A. Bass, and B. A. Egan. EPA complex terrain model development; Second milestone report - 1982. EPA-600/3-83-015, Environmental Sciences Research Laboratory, Research Triangle Park, NC, 375 pp. (1983).

Strimaitis, D. G., T. F. Lavery, A. Venkatram, D. C., DiCristofaro, B. R. Greene, and B. A. Egan. EPA complex terrain model development; Fourth milestone report - 1984. EPA-600/3-84-110, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 319 pp. (1985).

Thompson, R. S., and W. H. Snyder. Fluid modeling of blocking and upstream influences of stable flow over two-dimensional hills. Proceedings, Workshop on Wind/Water Tunnel Dispersion Modeling, September 1984. Oxford, England, 5 pp. (1984).

Truppi, L. E. Diurnal and seasonal patterns of temperature and wind flow in the planetary boundary layer for ten locations in complex terrain. Preprints, Third Conference on Mountain Meteorology, October 16-19, 1984, Portland, Oregon. American Meteorological Society, Boston, MA, pp. 73-76 (1984).

Truppi, L. E. EPA complex terrain model development: Description of a computer data base from small hill impaction study no. 2, Hogback Ridge, New Mexico. EPA/600/3-86/002, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 86 pp. (1985).

Turner, D. B. Atmospheric dispersion modeling - A critical review. *Journal of the Air Pollution Control Association* 29: 502-519 (1979).

Turner, D. B. Concentration statistics by wind direction for 1976 St. Louis SO_2 measurements and model estimates. Proceedings, 15th International Technical Meeting on Air Pollution Modeling and Its Application, St. Louis, Missouri, April 1985. NATO/CCMS (1985).

Turner, D. B., and J. S. Irwin. The relation of urban model performance to stability. In: C. De Wispeleare (ed.), *Air Pollution Modeling and Its Application IV*, Plenum Publishing Corp., New York, NY, pp. 721-732 (1985).

Turner, D. B., J. S. Irwin, and A. D. Busse. Comparison of RAM model estimates with 1976 St. Louis RAPS measurement of sulfur dioxide. *Atmospheric Environment* 19: 247-253 (1985).

Turner, D. B., and J. H. Novak. User's Guide for RAM. Volume I. Algorithm description and use. EPA-600/8-78-016a, Environmental Sciences Research Laboratory, Research Triangle Park, NC, 60 pp. (1978a).

Turner, D. B., and J. H. Novak. User's Guide for RAM. Volume II. Data preparation and listings. EPA-600/8-78-016b, Environmental Sciences Research Laboratory, Research Triangle Park, NC, 222 pp. (1978b).

U.S. Environmental Protection Agency. Guideline on air quality models. EPA-450/2-78-027, Office of Air Quality Planning and Standards, Research Triangle Park, NC, 84 pp. (1978).

U.S. Environmental Protection Agency. Interim procedures for evaluating air quality models (Revised). EPA-450/4-84-003, Office of Air Quality Planning and Standards, Research Triangle Park, NC, 144 pp. (1984a).

U.S. Environmental Protection Agency. National air audit system FY-1984 national report. EPA-450/2-84-009, Office of Air Quality Planning and Standards, Research Triangle Park, NC, 117 pp. (1984b).

U.S. Environmental Protection Agency. Guideline for determination of good-engineering-practice stack height (Revised). EPA-450/4-80-023r, Office of Air Quality Planning and Standards, Research Triangle Park, NC, 102 pp. (1985a).

U.S. Environmental Protection Agency. Interim procedures for evaluating air quality models: Experience with implementation. EPA-450/4-85-006, Office of Air Quality Planning and Standards, Research Triangle Park, NC, 116 pp. (1985b).

U.S. Environmental Protection Agency. Performance evaluations of acid deposition models concept plan. (to be published as an EPA technical report.) (1985c).

U.S. Environmental Protection Agency. Dispersion of airborne particulates in surface coal mines: Data analysis. EPA-450/4-85-001, Office of Air Quality Planning Standards, Research Triangle Park, NC, 81 pp. (1985d).

Uthe, E. E., W. Viezee, and B. M. Morley. Airborne lidar monitoring of fluorescent dye particles as a tracer to characterize transport and dispersion: A feasibility study. EPA/600/3-85/009, Atmospheric Science Research Laboratory, Research Triangle Park, NC, 120 pp. (1985a).

Uthe, E. E., W. Viezee, B. M. Morley, and J. K. S. Ching. Airborne lidar tracking of fluorescent dye tracers for atmospheric transport and diffusion studies. *Bulletin of American Meteorological Society* 66: 1255-1262 (1985b).

Verrall, K. A., and R. L. Williams. A method for estimating the standard deviation of wind direction. *Journal of Applied Meteorology* 21: 1922-1925 (1982).

Viebrock, H. J., and E. M. Poole-Kober. Fiscal Year 1984 Summary Report of NOAA Meteorology Division Support to the Environmental Protection Agency. NOAA Technical Memorandum, ERL/ARL-139, Silver Spring, MD, 57 pp. (1985).

Voldner, E. C., A. Sirois, and T. L. Clark. Data screening and calculations procedures for the North American precipitation chemistry data to be used in the international sulfur deposition model evaluation. Proceedings, APCA Specialty Conference on Quality Assurance in Air Pollution Measurements, Boulder, Colorado, October 1984. Air Pollution Control Association, Pittsburgh, PA (1984).

Wackter, D. J., and R. J. Londergan. Evaluation of complex terrain air quality models. EPA-450/4-84-017, Office of Air Quality Planning and Standards, Research Triangle Park, NC, 244 pp. (1984).

Walcek, C. J., R. A. Brost, J. S. Chang, and M. L. Wesely. Regional SO_2, sulfate, and HNO_3 deposition velocities computed using representative land use and meteorological information. *Atmospheric Environment* (in press) (1985).

Weisman, B. On the criteria for the occurrence of fumigation on land from a large lake - A reply. *Atmospheric Environment* 12: 172-173 (1976).

Wesely, M. L., and R. L. Hart. Variability of short term eddy-correlation estimates of mass exchange. Preprints, Conference on Forest Environmental Measurements, October 23-28, 1984, Oak Ridge, Tennessee (1984).

White, F. D., J. K. S. Ching, R. L. Dennis, and W. H. Snyder. Summary of complex terrain model evaluation. EPA/600/3-85/060, Atmospheric Science Research Laboratory, Research Triangle Park, NC, 124 pp. (1985).

Whiteman, C. D., A. H. Huber, R. W. Fisher, and B. D. Zak. Atmospheric tracer experiments in a deep narrow valley. Preprints, Fourth Joint Conference on Applications of Air Pollution Meteorology, October 16-19, 1984, Portland, Oregon. American Meteorological Society, Boston, MA, J1-J4 (1984).

Whiteman, C. D., and K. J. Allwine. Green River air quality model development. VALMET - A valley air pollution model. EPA/600/3-85/064, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 176 pp. (1985).

Wilson, D. A., and J. A. Tikvart. An analysis of alternatives for modeling in elevated terrain less than stack height. Preprints, Fourth Joint Conference on Applications of Air Pollution Meteorology and Third Conference on Mountain Meteorology, October 16-19, 1984, Portland, Oregon. American Meteorological Society, Boston, MA, J13-J16 (1984).

Woodruff, R. K., J. G. Droppo, and C. S. Glantz. The Minnesota 1973 atmospheric boundary layer experiment. Micrometeorological and tracer data archive. EPA/600/3-85/054, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 21 pp. (1985).

Woodruff, R. K., and C. S. Glantz. Survey of meteorological and tracer data for demonstrating a data archive. EPA-600/3-85-052, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 51 pp. (1985).

Yamartino, R. J. A comparison of several "single-pass" estimators of the standard deviation of wind direction. *Journal of Climate and Applied Meteorology* 23: 1362-1366 (1984).

Zak, B. D., H. W. Church, A. L. Jensen, G. T. Gay, and M. D. Ivey. Development of an adjustable buoyancy balloon tracer of atmospheric motion: Phase I. Systems design and demonstration of feasibility. EPA/600/3-85/027 (PB85-185817), Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 163 pp. (1985).

APPENDIX A: METEOROLOGY DIVISION PUBLICATIONS

Allwine, K. J., and C. D. Whiteman. Green River air quality model development. MELSAR - A mesoscale air quality model for complex terrain. Volume 1. Overview, technical description and user's guide. EPA/600/8-85/017a, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 142 pp. (1985).

Allwine, K. J., and C. D. Whiteman. Green River air quality model development. MELSAR - A mesoscale air quality model for complex terrain. Volume 2. Appendices. EPA/600/8-85/017b, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 368 pp. (1985).

Ames, J., S. R. Hayes, T. C. Myers, and D. C. Whitney. SAI Airshed operations manuals. Volume II -- Systems Manual. EPA/600/8-85/007b, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 236 pp. (1985).

Ames, J., T. C. Myers, L. E. Reid, D. C. Whitney, S. H. Golding, S. R. Hayes, and S. D. Reynolds. SAI Airshed model. Source code and sample input/output data magnetic computer tape. Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, (1985).

Ames, J., T. C. Myers, L. E. Reid, D. C. Whitney, S. H. Golding, S. R. Hayes, and S. D. Reynolds. SAI Airshed model operations manuals. Volume I -- User's Manual. EPA/600/8-85/007a, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 350 pp. (1985).

Billman, B. J., and S. P. S. Arya. Windbreak effectiveness for storage-pile fugitive-dust control. A wind tunnel study. EPA/600/3-85/059, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 96 pp. (1985).

Ching, J. K. S. Review of complex terrain model performance. Summary of complex terrain model evaluation. EPA/600/3-85/060, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, pp. 9-60 (1985).

Ching, J. K. S., E. E. Uthe, B. M. Morley, and W. Viezee. Observational study of transport in the free troposphere. Preprints, Fourth Joint Conference on Application of Air Pollution Meteorology, October 15-19, 1984, Portland, Oregon. American Meteorological Society, Boston, MA, pp. 154-157 (1984).

Ching, J. K. S., S. T. Shipley, E. V. Browell, and D. A. Brewer. Cumulus cloud venting of mixed layer ozone. In: C. S. Zerefos (ed.), *Atmospheric Ozone*, D. Reidel Publisher, pp. 745-749 (1985).

Clark, T. L. Sulfur deposition modeling with the NAPAP emission inventory. Proceedings: First Annual Acid Deposition Emission Inventory Symposium. EPA/600/9-85/015, Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, pp. 88-92 (1984).

Clark, T. L., G. J. Ferber, J. L. Heffter, and R. R. Draxler. Cross-Appalachian tracer experiment (CAPTEX '83). Preprints, Fourth Joint Conference on Applications of Air Pollution Meteorology, October 16-19, 1984, Portland, Oregon. American Meteorological Society, Boston, MA, pp. 158-161 (1984).

Clarke, J. F. (Project Officer). The NCAR Eulerian acid deposition model. NCAR-TN-256+STR, National Center for Atmospheric Research, Boulder, CO, 178 pp. (1985).

Clarke, J. F., and G. Griffing. Aircraft observations of extreme ozone concentrations near thunderstorms. *Atmospheric Environment* 19: 1175-1179 (1985).

Clarke, J. F., J. K. S. Ching, T. L. Clark, and N. C. Possiel. Regional-scale pollutant transport studies in the northeastern United States. In: C. De Wispelaere (ed.), *Air Pollution Modeling and Its Application IV*, Plenum Publishing Corporation, New York, NY, pp. 529-540 (1985).

Coulter, R. L, M. L. Wesely, K. H. Underwood, and T. J. Martin. Surface heat flux derived from sodar amplitude and frequency data: A comparison. Proceedings, 2nd International Symposium on Acoustic Sensing of Atmosphere and Oceans, Rome, Italy, August/September 1983. Instituto di fisca del 'Atmosfera, Consiglio Nazionale delle Ricerche. XXXVI pp. 1-18 (1984).

Dabberdt, W. F., W. Viezee, and H. B. Singh. Conceptual design for a Gulf Coast oxidant transport and transformation experiment. EPA/600/9-85/008, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 84 pp. (1985).

Dennis, R. L., and J. S. Irwin. Current views of model performance evaluation. Proceedings, DOE/AMS Air Pollution Model Evaluation Workshop, Vol. 1: Participants and Invited Speakers Papers. A. H. Weber and A. J. Garret (eds.), October 1984, Kiawah, SC, Report No. DP-1701-1. E. I. du Pont de Nemours and Co., Savannah River Laboratory, Aiken, SC, and American Meteorology Society, Boston, MA, paper no. 1-3 (1984).

Dennis, R. L. Review of complex terrain model performance. Summary of complex terrain model evaluation. EPA/600/3-85/060, Atmospheric Science Research Laboratory, Research Triangle Park, NC, pp. 61-112 (1985).

Doll, D., J., Kaneshiro, and J. K. S. Ching. Parameterization of subsurface heating for soil and concrete using net radiation data. *Boundary Layer Meteorology* 32: 351-372 (1985).

Downton, M. W., and R. L. Dennis. Evaluation of urban air quality models for regulatory use: refinement of an approach. *Journal of Climate and Applied Meteorology* 24: 161-173 (1985).

Droppo, J. G., Jr., and C. R. Watson. Introduction to micrometeorological and tracer data archive procedures. EPA/600/3-85/053, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 58 pp. (1985).

Eskridge, R. E., and S. T. Rao. Reply. *Journal of Climate and Applied Meteorology* 24: 1006-1007 (1985).

Glantz, C. S., R. K. Woodruff, and J. G. Droppo. The Hanford 1964 atmospheric boundary layer experiment. Micrometeorological and tracer data archive. EPA/600/3-85/055, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 124 pp. (1985).

Godowitch, J. M., and J. K. S. Ching. Turbulence parameters impacting dispersion in urban convective boundary layer. Preprints, Fourth Joint Conference on Applications of Air Pollution Meteorology, October 16-19, 1984, Portland, Oregon. American Meteorological Society, Boston, MA, pp. 8-11 (1984).

Godowitch, J. M., J. K. S. Ching, and J. F. Clarke. Evolution of the nocturnal inversion layer at an urban and a non-urban location. *Journal of Climate and Applied Meteorology* 24: 791-804 (1985).

Huber, A. H. Evaluation of a method for estimating pollution concentrations down-wind of obstacles and buildings. *Atmospheric Environment* 18: 2313-2339 (1984).

Irwin, J. S. Atmospheric diffusion modeling based on boundary layer parameterization. EPA-600/3-85-056, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 53 pp. (1985).

Irwin, J. S., and T. Brown. A sensitivity analysis of the treatment of area-sources by the climatological dispersion model. *Journal of the Air Pollution Control Association* 35: 359-364 (1985).

Jerskey, T. N., L. E. Reid, J. H. Seinfeld, and F. Gelbard. Continued research in mesoscale air pollution simulation modeling. Volume VII. Mathematical modeling of urban aerosol dynamics. EPA-600/3-84-095c, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 203 pp. (1984).

Kaimal, J. C., J. E. Gaynor, P. L. Finkelstein, M. E. Graves, and T. J. Lockhart. An evaluation of wind measurements by four doppler sodars. EPA-600/3-84-111, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 110 pp. (1985).

Kaimal, J. C., J. E. Gaynor, and P. L. Finkelstein. A field comparison of *in situ* meteorological sensors. EPA/600/3-85/057, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 107 pp. (1985).

Killus, J. P., J. P. Meyer, D. R. Durran, G. E. Anderson, and T. N. Jerskey. Continued research in mesoscale air pollution simulation modeling. Volume V. Refinements in numerical analysis, transport, and pollutant removal. EPA-600/3-84-095a, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 238 pp. (1984).

Lamb, R. G. Application of the first-generation regional oxidant model to an assessment of the effects of proposed 1987 emissions reductions on episodic ozone levels in the northeastern United States. EPA Internal Report, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 120 pp. (1985).

Lamb, R. G., and G. F. Laniak. A regional-scale (1000 KM) model of photochemical air pollution. Part 3. Tests of the numerical algorithms. EPA/600/3-85/037, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 264 pp. (1985).

Lamb, R. G., D. R. Durran, L. E. Reid, W. R. Shu, and J. H. Seinfeld. Continued research in mesoscale air pollution simulation modeling. Volume VI. Further studies in the modeling of microscale phenomena. EPA-600/3-84-095b, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 307 pp. (1984).

Lamb, V. R., and R. E. Britter. Shallow water flow over an isolated obstacle. *Journal of Fluid Mechanics* 147: 291-313 (1984).

Larsen, R. I. An air quality data analysis system for interrelating effects, standards, and needed source reductions: Part 8. An effective mean O_3 crop reduction mathematical model. *Journal of the Air Pollution Control Association* 34: 1023-1034 (1984).

Lee, J. T., S. Barr, R. E. Lawson, Jr., W. H. Snyder, and G. L. Marsh. Towing tank studies of stratified flow over ridges and valleys. Preprints, Third Conference on Mountain Meteorology, October 16-19, 1984, Portland, Oregon. American Meteorological Society, Boston, MA, pp. 37-41 (1984).

Lee, R. F., J. L. Dicke, D. A. Wilson, and J. A. Tikvart. Evaluating the effects on concentration estimates of technical changes to regulatory models. Preprints, Fourth Joint Conference on Applications of Air Pollution Meteorology, October 16-19, 1984, Portland, Oregon. American Meteorological Society, Boston, MA, pp. 91-94 (1984).

Novak, J. H. Emission inventory applications to regional acid deposition modeling. Proceedings: First Annual Acid Deposition Emission Inventory Symposium. EPA/600/9-85/015, Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, pp. 93-94 (1985).

Patrinos, A. A. N. The impact of urban and industrial emissions on mesoscale precipitation quality. *Journal of the Air Pollution Control Association* 35: 719-727 (1985).

Patrinos, A. A. N., and M. J. Leach. Evaluation of two numerical integrator schemes. EPA-600/3-84-112, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 36 pp. (1985).

Petersen, W. B. An evaluation of INPUFF with the MATS data base. Proceedings, DOE/AMS Air Pollution Model Evaluation Workshop, Vol. I: Participants and Invited Speakers Papers. In: A. H. Weber and A. J. Garret (eds.), October 1984, Kiawah, SC. Report No. DP-1701-1. E. I. du Pont de Nemours and Co., Savannah River Laboratory, Aiken, SC, and American Meteorological Society, Boston, MA, pp. 3-8 (1984).

Petersen, W. B., and J. S. Irwin. Climatological variability in maximum concentrations. Preprints, Fourth Joint Conference on Applications of Air Pollution Meteorology, October 16-19, 1984, Portland, Oregon. American Meteorological Society, Boston, MA, pp. 99-102 (1984).

Petersen, W. B., and J. S. Irwin. Climatological variability in maximum concentrations. *Atmospheric Environment* 19: 739-742 (1985).

Petersen, W. B., J. A. Catalano, T. Chico, and T. S. Yuen. INPUFF-A single source gaussian puff dispersion algorithm user's guide. EPA-600/8-84-027, Environmental Sciences Research Laboratory, Research Triangle Park, NC, 110 pp. (1984).

Pitchford, M., and A. Pitchford. Analysis of regional visibility in the Southwest using principal component and back trajectory techniques. *Atmospheric Environment* 19: 1301-1316 (1985).

Pollack, A. K., and C. S. Burton. Trends in sulfur dioxide emissions from the electric utility industry and ambient sulfur dioxide concentrations in the northeastern United States, 1975-1982. EPA/600/3-85/035, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 145 pp. (1985).

Rao, S. T., G. Sistla, V. Pagnotti, W. B. Petersen, J. S. Irwin, and D. B. Turner. Evaluation of the performance of RAM with the regional air pollution study data base. *Atmospheric Environment* 19: 229-253 (1985).

Rao, S. T., G. Sistla, V. Pagnotti, W. B. Petersen, J. S. Irwin, and D. B. Turner. Resampling and extreme value statistics in air quality model. *Atmospheric Environment* 19: 1503-1518 (1985).

Ritter, J. A., and D. H. Stedman. The vertical redistribution of a pollutant tracer due to cumulus convection. EPA/600/3-85/010, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 157 pp. (1985).

Schere, K. L., and A. J. Fabrick. EPA regional oxidant model: description and evaluation plan. EPA/600/3-85/067, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 92 pp. (1985).

Schiermeier, F. A. Scientific assessment document on status of complex terrain dispersion models for EPA regulatory application. EPA-600/3-84-103, Environmental Sciences Research Laboratory, Research Triangle Park, NC, 122 pp. (1984).

Schiermeier, F. A., A. H. Huber, C. D. Whiteman, and K. J. Allwine. The Green River ambient model assessment program. In: C. DeWispelaere (ed.), *Air Pollution Modeling and Its Application IV*, Plenum Publishing Corporation, New York, NY, pp. 435-451 (1985).

Schiermeier, F. A., T. F. Lavery, D. G. Strimaitis, A. Venkatram, B. R. Greene, and B. Egan. EPA model development for stable plume impingement on elevated terrain obstacles. In: C. DeWispelaere (ed.), *Air Pollution Modeling and Its Application IV*, Plenum Publishing Corporation, New York, NY, pp. 637-647 (1985).

Shannon, J. D. Climatological variability in modeling of long-term regional transport and deposition of air pollutants. Preprints, Fourth Joint Conference on Applications of Air Pollution Meteorology, October 16-19, 1984, Portland, Oregon. American Meteorological Society, Boston, MA, pp. 178-181 (1984).

Shannon, J. O. Simulation modeling of atmospheric deposition of sulfur from biogenic and anthropogenic emissions. Proceedings, APCA International Specialty Conference on the Environmental Impact of Natural Emissions, Research Triangle Park, NC, March 1984. Air Pollution Control Association, Pittsburgh, PA, pp. 318-325 (1984).

Shannon, J. D. User's guide for the advanced statistical trajectory regional air pollution (ASTRAP) model. EPA-600/8-85-016, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 83 pp. (1985).

Snyder, W. H. Fluid modeling of pollutant transport and diffusion in stably stratified flows over complex terrain. In: Milton Van Dyke, et al. (eds.), *Annual Review of Fluid Mechanics*, Volume 17, Annual Reviews, Inc., Palo Alto, CA, pp. 239-266 (1985).

Snyder, W. H. Review of complex terrain model performance. Summary of complex terrain model evaluation. EPA/600/3-85/060, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, pp. 113-124 (1985).

Snyder, W. H., and J. C. R. Hunt. Turbulent diffusion from a point source in stratified and neutral flows around a three-dimensional hill; Part II. Laboratory measurements of surface concentrations. *Atmospheric Environment* 18: 1969-2002 (1984).

Snyder, W. H., and R. E. Lawson, Jr. Stable plume dispersion over an isolated hill: Releases above the dividing-streamline height. EPA complex terrain model development: Fourth Milestone Report - 1984. EPA-600/3-84-110, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, pp. 233-268 (1985).

Snyder, W. H., and R. E. Lawson, Jr. Fluid modeling demonstration of good-engineering-practice stack height in complex terrain. EPA/600/3-85/022, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 89 pp. (1985).

Snyder, W. H., R. S. Thomspon, R. E. Eskridge, and R. E. Lawson, Jr. The structure of strongly stratified flow over hills: dividing-streamline concept. *Journal of Fluid Mechanics* 152: 249-288 (1985).

Strimaitis, D. G., T. F. Lavery, A. Venkatram, D. C. DiCristofaro, B. R. Greene, and B. A. Egan. EPA complex terrain model development: Fourth Milestone Report - 1984. EPA-600/3-84-110, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 319 pp. (1984).

Thompson, R. S., and W. H. Snyder. Air pollution and terrain aerodynamics: a review of fluid modeling studies at the EPA Fluid Modeling Facility. *Journal of Wind Engineering and Industrial Aerodynamics* 21: 1-19 (1985).

Truppi, L. E. Diurnal and seasonal patterns of temperature and wind flow in the planetary boundary layer for ten locations in complex terrain. Preprints, Third Conference on Mountain Meteorology, October 16-19, 1984, Portland, Oregon. American Meteorological Society, Boston, MA, pp. 73-76 (1984).

Turner, D. B. Proposed pragmatic methods for estimating plume rise and plume penetration through atmospheric layers. *Atmospheric Environment* 19: 1215-1218 (1985).

Turner, D. B., and J. S. Irwin. The relation of urban model performance to stability. In: C. DeWispelaere (ed.), *Air Pollution Modeling and Its Application IV*, Plenum Publishing Corporation, New York, NY, pp. 721-732 (1985).

Turner, D. B., J. S. Irwin, and A. D. Busse. Comparison of RAM model estimates with 1976 St. Louis RAPS measurements of sulfur dioxide. *Atmospheric Environment* 19: 247-253 (1985).

Uthe, E. F., W. Viezee, and B. M. Morley. Airborne lidar monitoring of fluorescent dye particles as a tracer to characterize transport and dispersion. A Feasibility study. EPA/600/3-85/009, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 120 pp. (1985).

Vaughan, W. M. Transport of pollutants in plumes and PEPES. A study of pollutants in power plant plumes, urban and industrial plumes, and persistent elevated pollution episodes. EPA/600/3-85/033, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 67 pp. (1985).

Viebrock, H. J., and E. M. Poole-Kober. Fiscal year 1984 summary report of NOAA Meteorology Division support to the Environmental Protection Agency. NOAA-TM-ERL-ARL-139, Silver Spring, MD, 57 pp. (1985).

Voldener, E. C., A. Sirois, and T. L. Clark. Data screening and calculation procedures for the North American precipitation chemistry data to be used in the international sulfur deposition model evaluation. Proceedings, APCA Specialty Conference on Quality Assurance in Air Pollution Measurements, Boulder, Colorado, October 1984. Air Pollution Control Association, Pittsburgh, PA (1984).

Wesely, M. L., and R. L. Hart. Variability of short term eddy-correlation estimates of mass exchange. Proceedings, Forest Environment Measurement Conference, Oak Ridge, Tennessee, October 1984.

White, F. D., J. K. S. Ching, R. I. Dennis, and W. H. Snyder. Summary of complex terrain model evaluation. EPA/600/3-85/060, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 124 pp. (1985).

Whiteman, C. D., A. H. Huber, and R. W. Fisher. Atmospheric tracer experiments in a deep narrow valley. Preprints, Fourth Joint Conference on Applications of Air Pollution Meteorology, October 16-19, 1984, Portland, Oregon. American Meteorological Society, Boston, MA, pp. 1-4 (1984).

Whiteman, C. D., and K. J. Allwine. Green River air quality model development. VALMET - A valley air pollution model. EPA/600/3-85/064, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 176 pp. (1985).

Wilson, D. A., and J. A. Tikvart. An analysis of alternatives for modeling in elevated terrain less than stack height. Preprints, Fourth Joint Conference on Applications of Air Pollution Meteorology, October 16-19, 1984, Portland, Oregon. American Meteorology Society, Boston, MA, pp. 13-16 (1984).

Woodruff, R. K., and C. S. Glantz. Survey of meteorological and tracer data for demonstrating a data archive. EPA/600/3-85/052, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 163 pp. (1985).

Woodruff, R. K., J. S. Droppo, and C. S. Glantz. The Minnesota 1973 atmospheric boundary layer experiment. Micrometeorological and tracer data archive. EPA/600/3-85/054, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 21 pp. (1985).

Zak, B. D., H. W. Church, A. L. Jensen, G. T. Gay, and M. D. Ivey. Development of an adjustable buoyancy balloon tracer of atmospheric motion. Phase I. Systems design and demonstration of feasibility. EPA/600/3-85/027, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, 153 pp. (1985).

APPENDIX B-1. PRESENTATIONS

Binkowski, F. S. "Modeling the planetary boundary layer", lecture series presented to the Meteorology Division, Durham, NC, June-August, 1985.

Briggs, G. A. "Air quality management and modeling", graduate course, Duke University, Durham, NC, Fall 1985.

Ching, J. K. S. "Air quality research modeling program of the U.S. EPA and the People's Republic of China", seminar presented at the Hong Kong Environmental Protection Agency, Hong Kong, November 2, 1984.

Clark, T. L. "International sulfur deposition model evaluation", poster session, The International Symposium on Acidic Precipitation, Muskoka, Ontario, Canada, September 15-20, 1985.

Cowley, S. J. (Visitor). "The evaluation of an unsteady translating nonlinear Rossby wave critical layer", University College, London, seminar at North Carolina State University, Raleigh, NC, August 26, 1985.

Dennis, R. L. "Model evaluation needs for dry deposition monitoring", presentation at Third Annual Meeting of the National Acid Precipitation Assessment Program, Omni Hotel, Baltimore, MD, May 1-2, 1985.

Dicke, J. L. "Model applications in a regulatory setting", briefing for Japanese visiting scientists representing the Meteorological Institute of Japan, Japan Environmental Agency and the Association of Meteorology, Durham, NC, December 1984.

______"Revised guideline on air quality models", briefing at the Third Conference on Air Quality Modeling, U.S. Environmental Protection Agency, Washington, DC, Docket A-80-46, January 29, 1985.

______"Fundamentals of air pollution meteorology", invited lecture during Air Pollution Training Institute Course #452, U.S. Environmental Protection Agency, Research Triangle Park, NC, February 1985.

______"Influence of topography on meteorology", invited lecture during Air Pollution Training Institute Course #452, U.S. Environmental Protection Agency, Research Triangle Park, NC, February 1985.

Frost, W. B. (Visitor). "Water channel modeling of atmospheric dispersion of toxic release", University of Tennessee Space Institute, seminar at the Fluid Modeling Facility, Research Triangle Park, NC, September 12, 1985.

Hunt, J. C. R. (Visitor). "Air flow over hills", Department of Applied Mathematics and Theoretical Physics, University of Cambridge, England, seminar at the Meteorology Division, Durham, NC, July 1, 1985.

______"Vorticity and vortex dynamics in complex turbulent flows", seminar at North Carolina State University, Raleigh, NC, July 2, 1985.

Hunt, J. C. R. (Visitor). Dispersion from sources in recirculation regions", seminar at the Fluid Modeling Facility, Research Triangle Park, NC, July 3, 1985.

Lamb, R. G. "Applications of first generation oxidant model to the assessment of the effects of proposed 1987 emissions reduction on episodic ozone levels in the northeastern United States", seminar at the U.S. EPA Office of Air Quality Planning and Standards, Durham, NC, July 5, 1985.

Ohba, R. (Visitor). "Wind tunnel modeling of stratified flow and katabatic wind over hills", Nagasaki Technical Institute, Mitsubishi Heavy Industries, Nagasaki, Japan, seminar at the Fluid Modeling Facility, Research Triangle Park, NC, May 1985.

Schere, K. L. "Regional oxidant modeling in the northeast United States", presentation at the 15th International Technical Meeting on Air Pollution Modeling and Its Applications, St. Louis, MO, NATO/CCMS, April 15-19, 1985.

Snyder, W. H. "EPA Fluid Modeling Facility", presentation to U.S./Japan Scientific Exchange Agreement Meeting, Meteorology Division, Durham, NC, November 29, 1984.

______"Physical modeling of transport and dispersion", presentation at U.S. EPA/ASRL Modeling and Analysis Workshop, North Carolina State University, Raleigh, NC, April 9, 1985.

______"EPA Fluid Modeling Facility", presentation to Grace Heritage High School, Fluid Modeling Facility, Research Triangle Park, NC, September 19, 1985.

APPENDIX B-2. WORKSHOPS

This section lists the workshops in which Meteorology Division personnel participated and the names of the Division participants.

1. VENTEX-84 Data Analysis Workshop, Research Triangle Institute, Research Triangle Park, NC, December 19, 1984.

   J. K. S. Ching
   J. F. Clarke

2. Joint U.S./Canada Workshop on Statistical Analyses for the ISDME Study, Meteorology Division, Durham, NC, June 24-27, 1985.

   T. L. Clark
   R. L. Dennis

3. Joint U.S./Canada Workshop on Design Plan for Evaluation of Regional Acid Deposition Models, U.S. Environmental Protection Agency, Research Triangle Park, NC, May 14-15, 1985.

   J. F. Clarke
   R. L. Dennis

4. Joint U.S./Canada Workshop on Evaluation of Regional Acid Deposition Models, Toronto, Canada, August 7-9, 1985.

   J. K. S. Ching
   J. F. Clarke
   R. L. Dennis
   J. H. Novak

5. DOE/AMS Air Pollution Model Evaluation Workshop, Kiawah, SC, October 1984.

   R. L. Dennis
   W. B. Petersen

6. Region V/State Modelers Workshop, U.S. Environmental Protection Agency, Chicago, IL, 1985.

   J. L. Dicke

7. Region IV/State Modelers Workshop, U.S. Environmental Protection Agency, Atlanta, GA, 1985.

   J. L. Dicke

8. Region VI/State Modelers Workshop, U.S. Environmental Protection Agency, Dallas, TX, 1985.

   J. L. Dicke
   D. A. Wilson

9. Regional Office Annual Workshop, Southern Pines, NC, 1985.

   J. L. Dicke

10. Workshop for U.S./Canada Cooperative Interaction on Regional Emissions Inventories, U.S. Environmental Protection Agency, Research Triangle Park, NC, December 5, 1984.

    J. F. Clarke
    J. H. Novak

11. Oxidant Modeling for the New York Metropolitan Area Project (OMNYMAP) Workshop, U.S. Environmental Protection Agency, Research Triangle Park, NC, 1985.

    N. C. Possiel

12. Modeling and Analysis Workshop, North Carolina State University, Raleigh, NC, April 9, 1985.

    W. H. Snyder

13. International Workshop on CCMS Air Pollution Pilot Studies, Lindau, Federal Republic of Germany, October 2-4, 1984.

    F. A. Schiermeier

APPENDIX C. VISITING SCIENTISTS

1. S. K. Hati, Design Engineer
   Development Consultants, Inc.
   Calcutta, India

Spent two years with the Meteorology Division to work on the application of dynamic programming and other mathematical methods of operations research to the problem of probabilistic modeling of air pollution and the use of models for developing optimal methods of air pollution control.

2. J. C. R. Hunt, Lecturer
   Department of Applied Mathematics and Theoretical Physics
   University of Cambridge
   Cambridge, England

Spent two weeks at the Fluid Modeling Facility conducting visualization studies of flow around block-shaped buildings and discussing complex terrain modeling efforts.

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

Spent one month at the Fluid Modeling Facility conducting towing tank studies on flushing of valleys under stable stratified cross flows.

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

Spent one week at the Fluid Modeling Facility conducting preliminary flow visualization experiments on ocean outfall project (in preparation for extensive quantitative tests in FY-86).

5. J. W. Rottman, Senior Research Associate
   Department of Marine, Earth and Atmospheric Sciences
   North Carolina State University
   Raleigh, NC

Spent eleven months at the Fluid Modeling Facility under a cooperative agreement with North Carolina State University conducting theoretical and experimental studies on projects: (1) turbulence in stratified flow behind a grid, (2) pollutant transport and dispersion in complex terrain using the Navier-Stokes model of Mason and Sykes.

6. S. Wakamatsu, Senior Research Scientist
   National Institute for Environmental Studies
   Tokyo, Japan

Spent one year with the Meteorology Division to apply the Photochemical Box Model to the Greater Tokyo Region.

APPENDIX D. METEOROLOGY DIVISION STAFF - FISCAL YEAR 1985

All personnel are assigned to the Environmental Protection Agency from the National Oceanic and Atmospheric Administration, except those designated (EPA) = Environmental Protection Agency employees or (PHS) = Public Health Services Commissioned Corps personnel.

Office of the Director

Francis A. Schiermeier, Meteorologist, Director
Herbert Viebrock, Meteorologist, Assistant to the Director
Dr. Kenneth Demerjian, Physical Scientist
Marc Pitchford, Meteorologist (Las Vegas, NV)
Evelyn M. Poole-Kober, Technical Information Clerk
Joan Emory, Secretary

Atmospheric Modeling Branch

Dr. John F. Clarke, Meteorologist, Chief
Dr. Francis Binkowski, Meteorologist
Dr. Gary Briggs, Meteorologist
Terry Clark, Meteorologist
Dr. Jason Ching, Meteorologist
Dr. Robin Dennis, Physical Scientist
Brian Eder, Meteorologist
James Godowitch, Meteorologist
Dr. Robert Lamb, Meteorologist
Kenneth Schere, Meteorologist
Bess Flowers (PT) (EPA), Secretary (until June 1985)

Fluid Modeling Branch

Dr. William H. Snyder, Physical Scientist, Chief
Lewis Knight, Electronics Technician
Robert Lawson, Physical Scientist
Michael Schneider, Engineering Aid
Joseph Smith, Mechanical Engineering Technician
Ralph Soller, Meteorological Technician
Roger Thompson (PHS), Environmental Engineer
Anna Cook (PT), Clerk-Typist

Data Management Branch

Joan H. Novak, Computer Systems Analyst, Chief
William Amos (EPA), Computer Programmer
Adrian Busse, Computer Specialist
Dale Coventry, Computer Systems Analyst
Alfreida Rankins, Computer Programmer
James Reagan (PHS), Statistician
John Rudisill, Meteorological Technician
Barbara Hinton (PT) (EPA), Secretary

Terrain Effects Branch

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

Environmental Operations Branch

D. Bruce Turner, Meteorologist, Chief
Alan Cimorelli, Meteorologist (Philadelphia, PA) (until November 1984)
Valentine Descamps, Meteorologist (Boston, MA)
Richard Fisher, Meteorologist (Fort Collins, CO) (until June 1985)
Mark Garrison, Meteorologist (Philadelphia, PA) (since August 1985)
John Irwin, Meteorologist
Dr. Ralph Larsen (PHS), Environmental Engineer
Lewis Nagler, Meteorologist (Atlanta, GA)
William Petersen, Meteorologist
Thomas Pierce, Jr., Meteorologist
Everett Quesnell, Meteorological Technician
Ray Young, Physical Science Aid
Sylvia Coltrane (PT), Secretary

Air Policy Support Branch

James L. Dicke, Meteorologist, Chief
Russell Lee, Meteorologist
Normal Possiel, Jr., Meteorologist
Jawad Touma, Meteorologist
Dean Wilson, Meteorologist