NOAA Technical Memorandum ERL ARL-188

FISCAL YEAR 1990 SUMMARY REPORT OF NOAA ATMOSPHERIC SCIENCES MODELING DIVISION SUPPORT TO THE U.S. ENVIRONMENTAL PROTECTION AGENCY

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

Robert A. Mosbacher
Secretary

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

John A. Knauss
Under Secretary for Oceans and Atmosphere/Administrator

Environmental Research Laboratories

Joseph O. Fletcher
Director

NOTICE

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PREFACE

This document summarizes the Fiscal Year 1990 research and operational efforts and accomplishments of the Atmospheric Sciences Modeling Division (ASMD) working under interagency agreement EPA DW13934799-01 between the U.S. Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA). The summary includes descriptions of research and operational efforts in air pollution meteorology, air pollution control activities, and abatement and compliance programs.

Established in 1955, the Division is part of the Air Resources Laboratory and serves as the vehicle for implementing the agreement with the EPA, which funds the research efforts in air pollution meteorology. The ASMD conducts research activities in-house and through contract and cooperative agreements for the Atmospheric Research and Exposure Assessment Laboratory and other EPA groups. With a staff consisting of NOAA, EPA, and Public Health Service (PHS) Commissioned Corps personnel, the ASMD provides technical information, observational and forecasting support, and consulting on all meteorological aspects of the air pollution control program to many EPA offices, including the Office of Air Quality Planning and Standards (OAQPS) and Regional Offices. The primary groups within the ASMD are the Atmospheric Model Development Branch, Fluid Modeling Branch, Modeling Systems Analysis Branch, Global Processes Research Branch, Applied Modeling Research Branch, and Air Policy Support Branch. The staff is listed in Appendix E. Publications and other professional activities are listed in Appendixes A, B, C, and D.

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

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FISCAL YEAR 1990 SUMMARY REPORT OF NOAA ATMOSPHERIC SCIENCES MODELING DIVISION SUPPORT TO THE U.S. ENVIRONMENTAL PROTECTION AGENCY

ABSTRACT. During FY-1990, the Atmospheric Sciences Modeling Division provided meteorological research and operational support to the U.S. Environmental Protection Agency. Basic meteorological operational support consisted of applying dispersion models and conducting 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 the transport, transformation, and deposition of acidic materials. Highlights included expansion of the Regional Acid Deposition Model/Engineering Model family to consist of the Tagged Species Engineering Model, the Non-Depleting Model, and the Sulfate Tracking Model; completion of the Acid-MODES field study; completion of the RADM2.1 evaluation; completion of the atmospheric processes section of the National Acid Precipitation Assessment Program 1990 Integrated Assessment; conduct of the first field study to examine the transport and entrainment processes of convective clouds; development of a Regional Oxidant Model-Urban Airshed Model interface program; conduct of an international sodar intercomparison experiment; incorporation of building wake dispersion in numerical models; conduct of wind-tunnel simulations of stack-tip downwash; and initiation of the publication of *SCRAM NEWS*.

1. INTRODUCTION

In Fiscal Year 1990, the Atmospheric Sciences Modeling Division (ASMD) continued its commitment for providing goal-oriented, high-quality research and development and operational support to the U.S. Environmental Protection Agency (EPA). Using an interdisciplinary approach emphasizing integration and close cooperation with the EPA and the public and private research communities, the Division's primary efforts were studying the basic processes affecting dispersion of atmospheric pollutants, modeling pollutant dispersion on all temporal and spatial scales, and studying the effects of global climate change on regional climate and air quality. The technology and research products developed by the Division are transferred to the public and private, national and international user communities. Section 2.1 discusses the Division participation in major international activities, while Sections 2.2 through 2.5 outline the Division research activities in support of the short- and long-term needs of the EPA and the environmental community. Sections 2.6 and 2.7 discuss Division support to the EPA operational programs and to the general air quality model user community.

2. PROGRAM REVIEW

2.1 Office of the Director

The Office of the Director provides direction, supervision, program management, and administrative support in performing the Atmospheric Sciences Modeling Division's mission and achieving its goals of advancing the state of the atmospheric sciences and enhancing the protection of the environment.

2.1.1 American Meteorological Society Steering Committee

Beginning in 1979, the Division established a cooperative agreement with the American Meteorological Society (AMS) to improve the scientific bases of air quality modeling. Under this agreement, the AMS maintains a Steering Committee on Scientific Assessment of Air Quality Models to (1) provide scientific reviews of various types of air quality dispersion models; (2) assist in developing a more complete understanding of uncertainty as it affects different aspects of air quality modeling; (3) respond to specific requests regarding scientific aspects of the Division's air quality modeling practices; and (4) plan and conduct scientific workshops in an attempt to advance the state of regulatory dispersion modeling.

2.1.1.1 Air Quality Modeling Uncertainty

To better understand modeling uncertainty, the AMS Steering Committee addressed the role of inherent uncertainty in evaluating dispersion models, and in 1988 prepared an unpublished assessment. The assessment is being revised to reflect new developments in uncertainty evaluation, and will be published in FY-1991. The assessment concludes that deviations between predicted model ensemble-averages and individual realizations are due to a combination of concentration random variability, model errors, uncertainties in model inputs, and measurement error. Recommendations are made to deal with large random variabilities in evaluating model physics. The assessment is being prepared for publication as a journal article.

2.1.1.2 Scientific Criteria for Model Evaluation

The AMS Steering Committee began to address two topical issues concerning regulatory dispersion modeling: (1) developing objective, defined scientific criteria with which to evaluate the performance of newly-developed regional dispersion models (oxidant, particulate, acid aerosol, and acid deposition); and (2) providing a means of specifying the quality of predictions from dispersion model output, similar to specifying in advance the required quality of measured field data. This effort will build upon a previous report by the EPA Science Advisory Board regarding use of mathematical models for regulatory assessment and decision making (U.S. Environmental Protection Agency, 1989a).

2.1.2 Interdepartmental Meteorological Committee

The Division Director serves as a representative to the Interdepartmental Committee for Meteorological Services and Supporting Research (ICMSSR). The Committee, composed of representatives from 15 Federal government agencies, was formed in 1964 under Public Law 87-843 to provide the Congress and the Executive Branch with a coordinated plan for government meteorological services and for research and development programs that directly support and improve these services.

The Division was involved in preparing three ICMSSR published reports. One, the annual Federal plan for meteorological services and supporting research (U.S. Department of Commerce, 1990b) provides the Executive Branch and the Congress a useful summary of coordinated Federal meteorological services and research activities. Two, the Federal Meteorological Requirements - 2000 study (to be published in FY-1991) will summarize requirements for meteorological services and supporting research to the year 2000 by addressing agency interdependence, mutual needs, and opportunities for further interagency coordination. Three, the Federal compendium lists government organizations and facilities that support applied research, experimentation, test and evaluation activities having a current or potential relationship to automated weather information systems (U.S. Department of Commerce, 1990a).

2.1.3 NATO/CCMS Steering Committee

The Division Director serves as one of two United States representatives on the Steering Committee for International Technical Meetings (ITMs) on Air Pollution Modeling and Its Application, sponsored by the North Atlantic Treaty Organization Committee on Challenges of Modern Society (NATO/CCMS). A primary activity within the NATO/CCMS pilot study on Air Pollution Control Strategies and Impact Modeling is organizing a symposium every 18 months that deals with various aspects of air pollution dispersion modeling. The meetings are rotated among different NATO members, with every third ITM held in North America and the two intervening ITMs held in European countries.

The Division Director helped organize the 18th NATO/CCMS International Technical Meeting held in Vancouver, British Columbia, Canada, during May 1990, and served as session chairman. A conference summary was submitted for publication (van Dop et al., 1990) and the proceedings will be published. The Steering Committee selected Ierápetra, Crete, Greece, as the site for the 19th International Technical Meeting to be held during September 1991.

2.1.4 United States/Japan Environmental Agreement

The Division Director serves as the United States Co-Chairman of the Air Pollution Meteorology Panel under the United States/Japan Agreement on Cooperation in the Field of Environment. The purpose of this 1975 agreement is to facilitate, through mutual visits and reciprocal assignments of personnel, the exchange of scientific and regulatory research results pertaining to control of air pollution. Under this agreement, a Division scientist spent six months at the Institute for Pollution and Resources in Tsukuba, Japan, conducting cooperative research on building wake dispersion.

2.1.5 US/USSR Joint Environmental Committee

The Division Director serves as the United States Co-Chairman of the US/USSR Working Group 02.01-10 on Air Pollution Modeling, Instrumentation, and Measurement Methodology, and as Co-Leader of the US/USSR Project 02.01-11 on Air Pollution Modeling and Standard Setting. The purpose of the 1972 agreement forming the US/USSR Joint Committee on Cooperation in the Field of Environmental Protection is to promote, through mutual visits and reciprocal assignments of personnel, the sharing of scientific and regulatory research results related to the control of air pollution.

During May 1990, a delegation of six NOAA and EPA scientists participated in Working Group and Project meetings at the following locations: Voeikov Main Geophysical Observatory in Leningrad; Institute for Atmospheric Optics in Tomsk; Institute for Organic Chemistry in Novosibirsk; Moscow State University in Moscow; and Environmental Protection Committee Headquarters in Novgorod, USSR. Discussions were held regarding joint progress in mass spectroscopy of chemical compounds; regional and complex terrain dispersion modeling; fluid modeling of terrain irregularities; results of roadway automotive exhaust field studies; remote sensing of atmospheric parameters; and the use of modeling techniques in establishing regulatory standards for pollutant emissions. A protocol was signed outlining future exchanges of scientific information and planning the next Working Group Meeting to be held during March 1991 in the United States. Another Project was formed under the Working Group, bringing the total to four:

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

FY-1990 accomplishments also included a working visit from November 1989 through April 1990 by two Soviet experts in remote sensing to the EPA Environmental Monitoring Systems Laboratory in Las Vegas, NV; a December 1989 visit to the Voeikov Main Geophysical Observatory by an EPA expert in pollution monitoring for regulatory enforcement and an April 1990 reciprocal visit to the EPA Office of Air Quality Planning and Standards in Durham, NC, by a Soviet scientist with similar expertise; a February 1990 visit by a Soviet scientist to the National Acid Precipitation Assessment Program (NAPAP) conference in Hilton Head Island, SC; and an August 1990 visit to Moscow and Leningrad by the Director of NAPAP. The Division Director also participated in the January 1990 meeting of the US/USSR Joint Committee in Washington, DC.

Plans were made for three scientists from the Soviet Institute of Organic Chemistry to visit the National Institute of Standards and Technology during March 1991 to exchange spectroscopic data bank information; for an EPA regulatory scientist to visit the Main Geophysical Observatory in December 1990; for five Soviet scientists to participate in a workshop on regulatory aspects of air pollution modeling in Durham, NC, during March 1991; for a journal article on complex terrain dispersion modeling to be co-authored by United States and Soviet scientists; and for a 1990 symposium to be held in the Soviet Union to report on results of three joint roadway automotive exhaust field studies conducted in Research Triangle Park, NC (1987), Leningrad, USSR (1988), and Vilnius, Lithuania (1989).

2.1.6 Eulerian Modeling Bilateral Steering Committee

The Division Director was appointed as the United States Co-Chairman of the Eulerian Modeling Bilateral Steering Committee (EMBSC). This committee is composed of representatives from the Canadian Atmospheric Environment Service, the Ontario Ministry of the Environment, the Electric Power Research Institute, and the U.S. Environmental Protection Agency. The committee coordinated the evaluation of the Canadian Acid Deposition and Oxidant Model (ADOM) and the United States Regional Acid Deposition Model (RADM) in preparation for their use in the NAPAP 1990 Integrated Assessment. After completing this effort, the committee will focus on future requirements for regional dispersion model development, evaluation, and application.

2.2 Atmospheric Model Development Branch

The Atmospheric Model Development Branch develops, evaluates, and validates analytical and numerical models used to describe the physical and chemical processes impacting the transport, dispersion, transformation, and removal of atmospheric pollutants, and integrates these models into comprehensive air quality modeling systems on local to regional scales.

2.2.1 Acid Deposition Studies

2.2.1.1 Development of the Regional Acid Deposition Model (RADM)

The Regional Acid Deposition Model (RADM) was developed into a modeling system consisting of (1) RADM, a comprehensive Eulerian model with three-dimensional transport, gas- and aqueous-phase chemistry, and wet and dry removal processes covering a 2800 km by 3040 km domain with 80-km resolution; (2) a meteorological driver with four-dimensional data assimilation; and (3) several special processors collectively known as the RADM Engineering Model (RADM/EM) family. RADM and RADM/EM are described and documented in the NAPAP State-of-Science/Technology Report No. 3 (Binkowski et al., 1990). The RADM/EM family members use archived RADM output files along with the same meteorological input files used by RADM for the particular cases. The chemistry of these members is restricted to the oxidation of sulfur dioxide to sulfate in both gas and aqueous processes. Values of hydroxyl and hydroperoxy radicals are read from the RADM archive files, and the chemical system for sulfur oxidation and production and loss of hydrogen peroxide is solved. Predicted values for corresponding species from RADM and RADM/EM are nearly identical. Except for some isolated grid cells with very small concentrations, the relative differences between RADM and RADM/EM wet and dry sulfur deposition fields are 1% or less.

Developmental work continued on the nested RADM, which covers an 800 km by 800 km subdomain with 26.7-km resolution; an operational version is expected within FY-1991. Also, a windowed version of RADM was developed. This version covers a 720 km by 720 km subdomain with 80-km resolution, and can be used for studies that require extra detail in output information and for prototyping new process modules. The windowed version uses archived RADM history files for boundary and initial conditions and the same meteorological fields used for the original RADM simulation. The windowed version runs on the EPA VAX* computer cluster at Research Triangle Park, NC.

2.2.1.2 RADM Engineering Models (EMs)

Three members of the RADM/EM family are the Tagged Species Engineering Model (TSEM), the Non-Depleting Model (NDM), and the Sulfate Tracking Model (STM). TSEM allows source-receptor relationships to be established between selected sources of sulfur dioxide and deposition at all receptors in the domain. Four species can be tracked: tagged and untagged sulfur dioxide, and tagged and untagged sulfate. For example, emissions from all of the Ohio Valley electric generating plants can be tagged and the percentage contribution of these emissions to wet and dry deposition anywhere in the RADM domain can be found. Also, TSEM can be used to determine the relative contribution of United States and Canadian sources to deposition in the RADM domain. NDM was developed to test the sensitivity of wet sulfate deposition to the depletion of hydrogen peroxide during aqueous chemistry calculations. RADM was designed with a closed-reactor concept, that is, the concentrations of the various species are set at the beginning of the aqueous chemistry calculation and then the hydrogen peroxide is depleted during the calculation. NDM, conceptually, maintains the hydrogen peroxide at the initial concentration throughout the aqueous chemistry calculation. This EM version was used during the NAPAP 1990 Integrated Assessment to determine the role of nonlinearity in the response of acid deposition to emission reductions. STM was developed for use in the analysis of nonlinearity to examine the fate of sulfate from aqueous- and gas-phase oxidation of sulfur dioxide.

2.2.1.3 RADM Meteorological Driver

The meteorological driver used by RADM, consisting of the Penn State/NCAR Mesoscale Meteorological Model Version 4 (MM4) (Anthes et al., 1987) integrated with the Four-Dimensional Data Assimilation (FDDA) algorithm (Stauffer and Seaman, 1990), was operated under contract. During FY-1990, Division personnel were trained to operate the meteorological driver. The MM4/FDDA driver was run on the CRAY X-MP** supercomputer located at the National Center for Atmospheric Research (NCAR) in Boulder, CO. On October 1, 1990, NCAR's CRAY X-MP was taken off-line and all computing was transferred to NCAR's CRAY Y-MP**; thus, the MM4/FDDA driver was modified to operate in the UNICOS command language used by all CRAY Y-MP systems. To reduce the processing delays that resulted from operating the MM4/FDDA driver on a remote computing system, work was begun to allow the Division to

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**CRAY X-MP and CRAY Y-MP are trademarks of Cray Research, Inc.

operate the driver on the CRAY Y-MP located at the North Carolina Supercomputing Center (NCSC) in Research Triangle Park, NC. A successful benchmark test at NCSC of the MM4/FDDA core module showed perfect alignment with a previous run performed at NCAR. It was determined, however, that the MM4/FDDA preprocessor modules (those that process data for the core module) must remain on the NCAR computing system until a graphics hardware disparity is resolved.

The skill of MM4/FDDA in predicting cloud and precipitation is being examined. A program that uses computer graphic visualization of gridded satellite and radar data was developed and formatted to compare observations with the corresponding MM4 cloud and precipitation fields in time-motion format. Initial results for the first half of September 1988 show that MM4 precipitation simulations are in qualitative agreement with the observations. Eleven months of radar and satellite data were collected during the Acid Models Operational and Diagnostic Evaluation Study (Acid-MODES) field study to evaluate MM4/FDDA performance.

2.2.1.4 RADM Aggregation Methodology

Regional model development activities, including those in the RADM program, have focused on explicit treatment of physical and chemical processes in episodic models. Because long-term impact estimates are required for acid deposition assessment, a method of aggregating deposition fields from thirty 3-day episodic RADM simulations to produce seasonal and annual averages of acid deposition was developed (Samson et al., 1990), peer reviewed, and applied in the NAPAP 1990 Integrated Assessment. The research program was expanded in FY-1990 to address aggregation of ambient concentrations of fine particles, primarily sulfate, for use with a system for predicting visibility frequency distributions from RADM episodic predictions. The work is being conducted under a cooperative agreement with the University of Michigan.

2.2.1.5 Acid Models Operational and Diagnostic Evaluation Study (Acid-MODES)

A major 2-year field program to collect data to evaluate regional acid deposition models, primarily RADM, was completed in May 1990. The Acid Models Operational and Diagnostic Evaluation Study (Acid-MODES) program, during the second year of data collection, consisted of a 32-station surface monitoring network to support diagnostic and operational evaluation, and a 6-week spring intensive aircraft sampling period for diagnostic evaluation.

The surface network was coordinated with other networks sponsored by the Electric Power Research Institute (EPRI); the Ontario Ministry of the Environment (OME); the Atmospheric Environment Service of Canada (AES); and the Florida Electric Power Coordinating Group (FCG). Together, more than 75 sites were distributed throughout eastern North America. Twenty-four-hour integrated aerometric samples from each Acid-MODES site were analyzed for gaseous SO_2, HNO_3, and NH_3, and particulate sulfate, nitrate, and ammonium. Precipitation samples collected daily were analyzed for conductivity, pH, sulfate, nitrate, ammonium, Cl^-, Na^+, Ca^{2+}, and Mg^{2+}. Collocated sampling at the Penn State Scotia Range, PA, and at Egbert, Ontario, provided information on inter- and intranetwork variability. The Acid-MODES network also measured ozone hourly at 13 sites. All data from this network were or will be archived in the Eulerian Model Evaluation Field Study (EMEFS) database. The surface data from August 25 through September 27, 1988, were quality checked.

The summer 1988 and spring 1990 intensive field studies provide the observational basis for a diagnostic evaluation of RADM and other similar models. In these studies, measurements were made using instrumented aircraft. During the first study, from August 20 to September 27, 1988, sampling was performed by the Fraunhofer Research Institute Hawker-Siddley 125 instrumented jet (Werhahn et al., 1990), the NOAA Air Resources Laboratory instrumented Beechcraft King Air, and the Battelle Memorial Institute Gulfstream-1 (G-1) (Spicer et al., 1989). The second study, from April 20 through May 25, 1990, used the King Air and the G-1 aircraft. Unique flight patterns were designed to obtain data to (1) test the models' abilities to predict the horizontal and vertical gradients and patterns in and downwind of the major Midwestern source region; (2) evaluate the clear-air chemistry model predictions; (3) test the models' abilities to predict gradients arising from regional source distributions; (4) test the models' abilities to characterize synoptic-scale frontal dynamics with respect to buildup and cleanout of pollutant concentrations; and (5) test the aqueous-phase chemistry component of the scavenging module. These aircraft continuously sampled SO_2, NO, NO_2, NO_y, ozone, H_2O_2, wind, temperature, moisture, radiation, pressure, altitude, and location. Sulfate and nitrate were collected on filter packs; PAN and VOCs were also collected. The aircraft were equipped to collect cloud water samples.

Data from both studies are of known and documented quality, with the accuracy for all pollutants sampled better than $\pm 15\%$. Relative precision from ground and side-by-side parallel flight legs for most of the pollutants sampled also easily improved on the goal of $\pm 15\%$ required for the model evaluation. The static and performance quality assurance programs were performed under a rigid set of protocols specified in the design plans (Dennis and Laulainen, 1988; Laulainen et al., 1990). The data from the summer 1988 study are archived, and the spring 1990 data will be archived in FY-1991.

2.2.1.6 RADM Evaluation Studies

The NAPAP phase of the RADM evaluation, part of a larger effort to evaluate regional Eulerian acidic deposition models, was finished. Model evaluation comparisons and interpretation for the 33-day period from August 25 to September 27, 1988, were completed and reviewed by the Model Evaluation Team and the External Review Panel, both part of the Eulerian Model Evaluation Field Study, and external NAPAP reviewers. Evaluation comparisons for annual averages also were completed and reviewed. Results are documented in the NAPAP State-of-Science/Technology Report No. 5 (Dennis et al., 1990a, 1990b), delivered to NAPAP in September 1990.

Three versions of RADM were evaluated: RADM2.1 (the NAPAP assessment version), RADM2.5/6-layer, and RADM2.5/15-layer. The NAPAP evaluation focused on RADM2.1 because it was used in the assessment. The 33-day averages of SO_2 and HNO_3 were biased high by 40%-60% and 30%-40%, respectively; most of this bias was due to large overpredictions at night. Sulfate aerosol was underpredicted by 35%-40%, so the overall sulfur budget showed little bias. The 33-day average precipitation concentrations of SO_4^{2-} were overpredicted at low concentrations and underpredicted at high concentrations, while the 33-day average precipitation concentrations of NO_3^- were underpredicted by 20%-40%. The correlation coefficients between observations and RADM2.1 predictions of day-to-day changes in surface concentrations ranged from 0.4 to 0.9, with the secondary pollutants, SO_4^{2-} and HNO_3, being predicted more accurately than the primary pollutant, SO_2. RADM predictions for thirty 3-day cases were statistically weighted to derive annual average estimates representative of the 1982-85 period. The annual average RADM2.1 predictions of wet sulfate deposition showed little bias, with a slope of 0.94 and a correlation coefficient of 0.60. Comparisons of RADM2.1 sulfur dry deposition predictions with empirically derived estimates of sulfur dry deposition showed that 84% of the site comparisons were within ±50%. RADM performed much better than the linear model, where 70% of the comparisons differed by more than a factor of 2.

To augment the RADM evaluation, bounding analyses were carried out to assess the risk of using RADM, with its shortcomings, for the NAPAP assessment. The bounding analyses estimated how broadly the model predictions could range as a function of anticipated corrections of biases. Based on all evaluation information and bounding analyses, the interpretation team judged that the biases exhibited by the model were not extreme enough to preclude using RADM2.1 for assessing sulfur deposition for the NAPAP assessment.

The predictive skills of RADM were tested against measurements made by specially instrumented aircraft in the Acid-MODES intensive study during August and September, 1988, according to a protocol for diagnostic evaluation of RADM (Dennis and Laulainen, 1988). Although several versions of RADM were developed, these studies emphasized the results of testing RADM2.5, in which the vertical structure is resolved using 15 layers. A critical test of the zigzag-type horizontal transects (ZIPPER) and the vertical up-and-down sawtooth transects (CURTAIN) occurred during the fair-weather conditions of August 31, 1988. The test results showed the model's ability to resolve horizontal patterns and gradients as well as the vertical cross section of primary and secondary acidic pollutant species in the mixed layer over the major source region for sulfur and nitrogen emissions. The overall results were satisfactory for SO_2 and NO_y. Preliminary analyses of data from the Frontal Passage flights on September 2, 6, and 8, 1988, were performed to test the model's ability to simulate conditions associated with a synoptic front representing a major scavenging event. Horizontal transects in and above the mixed layer over 1000-km distances were flown parallel to a cold front before, during, and after pollutant buildup. Finally, data from a set of flights on September 1, 1988, are being studied to characterize the diurnal behavior of the primary and secondary species over approximately four RADM cells and to provide the means to judge the performance of the gas-phase chemistry and the daytime mixing aspects of RADM. Individually, each type of flight pattern was designed to emphasize model performance for various conditions controlled by different sets of processes. Collectively, these tests provided a powerful set of tools for evaluating the model's skill. Results of these tests were presented at the February 1990 NAPAP International Conference in Hilton Head Island, SC.

2.2.1.7 ANATEX Model Evaluation Study (AMES)

In this study sponsored by the EPA, the NOAA, and the U.S. Air Force, the performances of 11 atmospheric transport and diffusion models were assessed using quantifiable measures based on comparisons of ensemble mean concentrations and plume widths as well as trajectory errors expressed as a function of transport time (Clark and Cohn, 1990). The Across North America Tracer EXperiment (ANATEX) provided a unique data set with which to evaluate long-range transport and diffusion simulations (up to 3000 km) and establish a range of uncertainty for various model genres (Draxler and Heffter, 1989).

The multiple-layer Lagrangian models were generally the best at simulating transport of the tracers, while the Eulerian models were the best at simulating the ensemble concentration frequency distributions. After 0.5 day of transport, trajectory errors ranged from 100 km to 400 km; after 2.5 days, the errors ranged from 300 km to 800 km. Beyond 2.5 days, errors for four Lagrangian models plateaued, while errors for the other models continued to increase, peaking at nearly 1100 km after 3.5 days. Of the three single-layer models, one performed as well as any other model in simulating transport; the other two single-layer models performed worse. Thus, a slight difference in the method of calculating single-layer transport vectors can yield a significant difference in model performance. For 6 of the 11 models, the greatest errors in transport speed and location tended to occur when the tracer was intercepted by cyclones and/or fronts.

The ensemble mean concentrations along three bands of sites 1000 km to 2300 km downwind from the release sites were nearly always overpredicted by the single-layer Lagrangian models, in some cases by as much as a factor of 5; overpredictions by a factor of 3 were common. The two Eulerian models tended to underpredict these ensemble means by about 40%, especially along the nearest band. Finally, the multiple-layer Lagrangian models tended to underpredict the ensemble means for the tracer released from Montana, but tended to overpredict the ensemble means for the tracer released from Minnesota.

Horizontal spreading of the tracer plumes beyond the 1000 km transport distance occurred at a rate of 30% to 60% per 600 km. Generally, the models replicated this spreading rate, although there was a wide range of plume widths. The plume widths of the Eulerian models tended to be the greatest, which partially explained their tendency to underpredict mean concentrations. In most cases, the plume widths of the Lagrangian models were equivalent to or less than the actual plume widths; for some models, plume widths were much less, by a factor of 2 or 3.

2.2.1.8 RADM Applications for the NAPAP 1990 Integrated Assessment

A significant application of RADM2.1/6-layer and RADM/EM was completed for the NAPAP 1990 Integrated Assessment. This work enhanced the scientific understanding of the atmospheric transport and transformation processes; provided guidance on important assessment questions; and provided specific answers for the assessment.

For subregions with the largest concentrations of SO_2 emissions, it was determined that more than 50% of the local annual sulfur deposition is due to local emission sources and that many source regions are responsible for deposition in a receptor region. The nonproportional (nonlinear) response of annual sulfur deposition to changes in emissions is due to oxidant limitation. For eastern North America, oxidant limitation results in the absolute percentage reduction in total (wet plus dry) annual sulfur deposition being 10% less than if the system were linear. For emission reductions typical of those proposed for the Clean Air Act Amendments of 1990, the absolute percentage reduction is expected to be 20% less than if the system were strictly proportional; half of the less-than-proportional response would be due to oxidant limitation, and half would be due to source-receptor relationships. It was also found that controlling anthropogenic NO_x and/or VOC emissions in addition to SO_2 emissions did not alter the pattern and extent of estimated changes in annual sulfur deposition significantly.

Although the geographic impact of emission trading is poorly defined, it was found that trading could reduce the protection for lakes and streams in the southern United States and upper-midwestern United States, but could benefit acidic lakes and streams in the northeastern United States. Further, the importance of possible geographic differences in the deposition reduction pattern decreases as the overall emission reduction increases. The importance is probably marginal at the level of emission reduction proposed for the Clean Air Act Amendments of 1990. For the NAPAP 1990 Integrated Assessment, acidic deposition results for 1985, 2000, 2010, and 2030 were provided for the four main NAPAP Illustrative Future Scenarios: Scenario S1, no new emission reduction legislation beyond that mandated before 1990; Scenario S3, only a 12-million-ton reduction of SO_2 by the year 2000; Scenario S4, only a 10-million-ton reduction of SO_2 by 2000; and Scenario S5, only an 8-million-ton reduction of SO_2 by 2000.

2.2.1.9 Acid Deposition Studies

Several acid deposition studies were initiated in FY-1990. In the first effort, a program was developed to enhance and apply an inferential approach (Hicks et al., 1985) for estimating dry deposition for the National Dry Deposition Network (NDDN). The approach uses ambient concentration data, meteorological and land use/vegetation data, and a theoretical and empirical model of deposition processes to estimate dry deposition. The inferential approach showed a strong sensitivity to site vegetation characteristics. As a result, a program was initiated to provide detailed analysis of land use characteristics and types and of biological activities of vegetation species.

In another study, an inference technique was developed (Eder and Dennis, 1990) that allows estimation of the annual and monthly dry deposition of Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+}. Conceptually, this technique is based on the premise that precipitation efficiently scavenges aerosols, causing a strong correlation between concentrations within precipitation and surface-level air. Empirically, it is based on the linear relationship exhibited between the measured surface-level air and precipitation concentrations at 23 stations in Ontario, Canada, for the period 1983-85. Correlations ranged from 0.513 for K^{+} to 0.946 for Mg^{2+}. Because of the stochastic nature of such an approach, the assumptions inherent in the concept of precipitation scavenging, and therefore in this inference technique, must be carefully considered. Under such assumptions, annual and monthly dry deposition of alkaline aerosols can be estimated at many locations across North America where precipitation concentrations are measured routinely.

In a third study, the spatial and temporal variability of SO_4^{2-} precipitation concentrations over the eastern United States for the period 1981-86 was examined using principal component analysis (Eder, 1989). Seven contiguous subregions were delineated using Kaiser's Varimax orthogonal rotation, each displaying statistically unique SO_4^{2-} concentration characteristics. Accounting for 74.2% of the total variance, these seven statistically significant modes of variability corresponded well with major SO_x emission patterns. The time series associated with each subregion showed a general seasonality in which periods of high concentrations were more likely during the summer than during the winter. The seasonal cycle was more prevalent in subregions that contained few major emissions, and was less prevalent and often obscured by perturbations in subregions that contained predominantly major emissions.

2.2.1.10 Cloud Processes Studies

Under a Cooperative Agreement with the University of North Dakota, the first of two field studies to investigate the transport and entrainment processes of convective clouds was conducted during August 1990. The study, based in central Illinois, was accomplished using a specially equipped Citation jet. The aircraft was equipped with an atmospheric sampling system and a unique "pointer" system to provide air parcel position change information on a real-time basis; this allowed the aircraft to return to the "same" air parcel for repeat sampling. Experiments conducted on 13 separate days should provide high-quality information on cloud-top entrainment and detrainment processes, mass flux through the anvil of a thunderstorm, and vertical exchange at the base of these clouds.

A methodology to estimate the vertical pollutant mass flux between the mixed layer and cloud layers using an ensemble of nonprecipitating cumulus clouds was developed (Vukovich and Ching, 1990). Using standard meteorological data, the semiempirical approach determines the existence of the cloud ensemble, estimates the cloud amount at cloud base, and establishes the vertical distribution of the convective cloud amount attributed to a cloud population.

2.2.2 Photochemical Modeling

2.2.2.1 Regional Oxidant Model (ROM)

The Regional Oxidant Model (ROM) was developed to provide a scientifically credible basis for simulating the regional transport and collective fate of emissions from all sources in the northeastern United States, and to serve as a tool for developing regional emission control policies for attaining the primary ozone standard in the most cost-effective way. ROM was applied to the southeastern United States for regional analyses, and was used to investigate the effect of emission controls on concentrations averaged over longer periods, in anticipation of a secondary ozone standard designed to protect welfare interests (e.g., forests, crops, and materials).

During FY-1990, the ROM program emphasized the application of the second-generation model, ROM2.1 (Young et al., 1989), in the Regional Ozone Modeling for Northeast Transport (ROMNET) study in the northeastern United States; the evaluation of ROM2.1 on several 1985 episodes; and the development of an upgraded version, ROM2.2, for use in upcoming applications in the southeastern and midwestern United States. Also, the sensitivity of simulated ozone concentrations to natural-source emissions, the generation of regional wind fields, and innovative computational techniques were studied. An interface program was written and tested that allows the Urban Airshed Model (UAM) to be driven with inputs from the ROM system.

2.2.2.2 Development and Testing of ROM2.2

In anticipation of other model applications, work was begun on a new set of enhancements to the second-generation ROM system. The updated system, ROM2.2, includes several major changes in meteorological processes. First, the well-mixed boundary layer is allowed to develop to a fully extended state over a 3- to 4-h period, starting at sunrise. Previously, a fully mixed boundary layer became established shortly after sunrise. Second, the wind flow in the first model layer during nighttime inversion periods is calculated using ROM's standard diagnostic wind field interpolation scheme. Previously, a shallow-water equation model predicted the wind flow in this inversion layer. However, past applications showed that this flow model produced results uncharacteristic of the low transport speeds expected in ROM's layer 1. Further, the ROM2.2 expanded spatial domains are too large to allow assumption of domain-wide homogeneity of surface inversions. Third, ROM 2.2 also includes significant modifications to the turbulence representation over urban areas and the vertical cumulus cloud flux parameterization.

Other changes planned for ROM2.2 include model initialization at midnight (instead of noon), upgrades to the Biogenic Emissions Inventory System (BEIS) (including a new solar radiation algorithm), newly revised rate constants for the PAN production and destruction reactions, and the integration of the B-matrix calculations into the core model itself. The first applications of ROM2.2 are expected to begin in FY-1991 with simulations for the southeastern and midwestern United States.

2.2.2.3 Sensitivity of Regional Ozone Modeling to Biogenic Hydrocarbons

Research efforts using ROM to assess the effects of biogenic hydrocarbon emissions on the formation of regional-scale ozone began in FY-1989 and continued in FY-1990. One study of the northeastern United States (Roselle and Schere, 1990) examined the response of O_3 to the removal of all biogenic emissions and to the removal of anthropogenic hydrocarbons. Ozone was found to be influenced significantly by biogenic emissions. The degree of significance varied spatially over the modeled area, depending upon the geographic distribution of emissions. In rural environments with large NO_x sources, the presence of biogenic hydrocarbons caused high predicted levels of O_3. A second study of the northeastern United

States was initiated to quantify how uncertainties in biogenic emission estimates affect O_3 production. Nine ROM simulations are being examined, including (1) a base case and two control strategy cases at the reference level of biogenic emissions, (2) the same set of three cases with biogenic emissions increased by a factor of 3, and (3) the same set with biogenic emissions decreased by a factor of 3. Analysis of results from these simulations will continue in FY-1991.

2.2.2.4 Evaluation of ROM

ROM model evaluation activities in FY-1990 centered on an operational evaluation of ROM2.1 in the northeastern United States and on diagnostic testing designed to probe the accuracy of the model's numerical solution algorithms (Pierce et al., 1990b). In the operational evaluation, model estimates for ozone were compared with ambient measurements collected on 26 days during the summer of 1985, the base simulation period for the ROMNET program, in the northeastern United States. Observed and simulated maximum daytime concentrations agreed, on average, to within 2 ppb, or 1.4%. The model tended to underestimate at the higher extremes of the frequency distribution; at the 95th-percentile level, the underestimation was 6.6%. Estimated and observed spatial patterns of 3-day maximum ozone concentrations generally showed good agreement. ROM2.1 improved noticeably over ROM2.0 with regard to modeling the orientation of high-ozone plumes in the Northeast Corridor.

In the diagnostic testing, the model was subjected to extremely sharp concentration gradients (steeper than those observed in the ambient atmosphere). In a 48-h simulation, the model results deviated by as much as 18% from mass conservation based on the total initial mass value. However, when the tests were repeated with more realistic concentration gradients, the mass conservation was nearly perfect. Nevertheless, a mass-correcting algorithm is being considered for the horizontal transport solution scheme. ROM exercises planned for FY-1991 include operational evaluations for the southeastern and midwestern United States applications for base year 1988; a diagnostic evaluation of the ROM's transport component using the CAPTEX database; and the initiation of a model intercomparison project involving ROM, RADM, and the NOAA Aeronomy Laboratory (AL) Oxidant Model.

2.2.2.5 A Nested Regional Oxidant/Urban Airshed Modeling Framework

The development and testing of a one-way nesting framework for the Urban Airshed Model (UAM), exhibiting a fine-mesh grid and urban-scale domain within the coarser grid and larger domain of ROM, were completed. Approaches outlined by Godowitch and Schere (1989) were implemented to allow a wide array of ROM gridded outputs--predicted concentrations, winds and other meteorological parameters, biogenic emissions, and surface geophysical parameters--to be used as inputs for algorithms in the ROM-UAM interface programs. These approaches for resolving the ROM gridded data onto UAM's horizontal and vertical framework were encoded into seven interface computer programs that link the two model systems. A retrieval program developed specifically for this effort extracts the gridded parameters from the

ROM database and creates the formatted data files needed to exercise the interface programs. Each interface program generates an output file that can be input directly into either a UAM preprocessor or the model simulation program.

During the interface program development, a series of UAM test runs was conducted to investigate the sensitivity of predicted ozone concentrations to differences in the methodologies and procedures for nesting. Results revealed that nesting 17 of 23 species from the ROM concentration file was sufficient for specifying initial and boundary conditions in UAM. State and local agencies will run the interface programs when applying the UAM system in emission control strategy simulations for ozone reduction. A user's guide (Tang et al., 1990), issued as Volume V of a new set of UAM user's manuals, describes the technical approaches and provides instructions and test data for exercising the computer codes.

2.2.2.6 Generation of Probabilistic Wind Fields for ROM

Research on the generation of "probabilistic" wind fields for use with ROM continued during FY-1990. From a set of wind observations, ensembles of possible wind fields are created that conform to the physical laws of momentum and energy conservation, and agree with measurements at observation times and locations. The differences between the wind fields represent the stochastic nature of the atmosphere and the uncertainties generated from the sparseness of the data and inherent errors in the measurements. A method of assigning a probability of occurrence to each member field was developed. Three methods of assessing the inherent uncertainties in the wind fields are being investigated. In the first, the stochastic component of the turbulent energy spectrum of the wind field drives the wind field variations; the second method involves errors in wind measurements used in the ROM wind field generator at low wind speeds; and the third method is a combination of the first two. When the probabilistic wind fields are used with ROM, the resulting pollutant concentration fields are probabilistic rather than deterministic (deterministic concentration fields result from using a single wind field). The use of ROM in this stochastic sense will be explored during FY-1991.

2.2.2.7 Development of ROM Multi-Processor Computing Capabilities

ROM and other large regional-scale Eulerian models require extensive computational resources. A disparity between the growth rate of model size and relative computational power and speed motivated a study to determine the feasibility of building a custom digital hardware device that could be attached to a minicomputer to accelerate the execution speed of ROM and other large air quality models for applications work. The feasibility study showed that the optimum computer architecture for ROM should be designed around a system of loosely coupled parallel processors. A prototype device based on the feasibility study was constructed through a cooperative agreement. The specific architecture decided upon for the prototype uses the host machine to calculate the horizontal transport portion of the model while the microprocessors solve the chemical and flux portions. The chemical calculations can account for nearly

90% of the model's computational time. The resulting version of ROM, Regional Oxidant Model Multi-Processor (ROMMP), demonstrated peak performance speed 11 times faster than that of the VAX single-processor model version, with an average performance speed 7.5 times faster (Roberts and Young, 1990).

In another ROM parallel processing effort, the operational production code of ROM2.1 on the EPA's IBM 3090* system was modified to operate in a parallel mode on that system's six central processing units (CPUs), using a new parallel version of the IBM FORTRAN compiler. The model domain was divided row-wise into six sections for distributing the computational burden among the CPUs. This IBM-parallel implementation of ROM effected a speed-up varying from 2.4 to 4 times that of the single-processor version of the code; the speed-up is highly dependent on the total machine load and the operating system configuration at run time. Plans for FY-1991 involve transferring the ROM2.2 code to the CRAY supercomputer at the North Carolina Supercomputing Center (NCSC) and adapting it to a parallel environment on that machine for research simulations.

2.2.2.8 Development of a Third-Generation Urban Airshed Model System

An intensive 2-year effort commenced to upgrade the current UAM system. The model simulation program's computer code was upgraded to conform with updated FORTRAN standards and structured coding techniques, which also makes it more easily adaptable to different computer systems. Also underway is an assessment of the scientific merits of the model's simulation methods for processes such as vertical diffusion, pollutant dry deposition, and chemical kinetics. The 13 preprocessor programs that generate all the input files for UAM are being consolidated into a smaller, more coherent group of algorithms with updated methodologies for processing available routine data into gridded fields of meteorological parameters and pollutant concentrations.

2.2.3 Aerosol Modeling Program

This program's objective is to develop and evaluate atmospheric modeling systems that address the physical and chemical processes of aerosol emissions, transport, chemistry, and removal on both urban and regional scales. The modeling tools are used primarily to assist in promulgating air quality standards for fine particles, visibility, and acid aerosols.

2.2.3.1 Regional Fine-Particle Network

A network of 35 cyclonic-separator samplers operated synchronously with the Acid-MODES network during 6-week periods in summer and autumn 1988 and winter 1989 and during the period from July 1989 through May 1990. Total fine-particle mass and fine-particle mass loadings of at least eight elements--including sulfur, calcium, magnesium, and chlorine--were determined from each of the approximately 12,000 24-hour samples. These measurements will provide the bases for evaluating regional models

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*IBM and 3090 are a registered trademark and a trademark, respectively, of International Business Machines Corporation.

for fine-particle concentrations and estimating upwind boundary conditions for urban particle models. A personal computer (PC) data retrieval system that creates Lotus* spreadsheet files of user-defined database subsets was developed, as was a PC-based mapping program to generate daily concentration maps from these data files. The sampling and analysis protocols and sample analyses will be documented in a FY-1991 report.

2.2.3.2 Regional Particulate Modeling

During FY-1990, there were two new contributions to the Regional Particulate Model (RPM) program. First, the windowed version of RADM was enhanced with an updated version of the Model for an Aerosol Reacting System (MARS) (Saxena et al., 1986). The updates include new values of equilibrium constants and binary activity coefficients as well as enhanced numerical algorithms for solving the mathematical equations. A study of the sensitivity of the aerosol inorganic chemistry to ammonia emissions is underway. Second, the Modal Aerosol Dynamics (MAD) model (Whitby, 1990) was completed. This method of representing aerosol size distributions assumes that atmospheric aerosols are well characterized by two lognormal distributions, and is based on the method of moments using the zeroth, third, and sixth moments of the aerosol number distribution. Appropriate rate equations for the moments of the two size distributions were added to a special version of RADM/EM; these equations account for aerosol growth, shrinkage, and coagulation. After the initial developmental stage, the MAD model will be completely integrated into the RADM system via the windowed version. The final stage will be a particulate model that includes gas-to-particle conversion and aerosol dynamics in addition to the present features of the RADM system.

During FY-1990, a technique for estimating dry-deposition fluxes for particulate matter was developed that accounts for the particle-size-dependent effects of Brownian motion, inertial impaction, and gravitational settling. This technique is based on the works of Sehmel and Hodgson (1974, 1978) and Slinn (1982). The results from the sensitivity testing of this technique in a regional-scale modeling application were presented at an international scientific symposium (Bullock, 1990).

2.2.4 Boundary-Layer Diffusion Research

A journal article is being prepared that discusses diffusion in convective conditions and includes the results of data analyses from the CONvective Dispersion Observed with Remote Sensors (CONDORS) experiment (Eberhard et al., 1988), which produced the most extensive set of field measurements available for daytime diffusion of passive tracers. The results are given in more than 150 figures, showing meteorological timelines and tower/rawinsonde profiles, growth of diffusion coefficients, the effect of averaging time, comparisons of lidar-detected oil fog and SF_6 concentrations, and comparisons of crosswind integrated concentrations of oil fog and SF_6 plus radar-detected chaff. There are also comparisons of both lateral and vertical distributions of oil fog, chaff, and wind direction measurements. The most important

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figures, given for all 16 experiments, use nondimensional convective scaling to compare (1) crosswind integrated concentrations versus height and distance for oil fog and chaff with (2) results of laboratory and numerical modeling experiments. The CONDORS results confirm the prevalence of non-Gaussian vertical plume behaviors, which were suggested by laboratory tank experiments in the 1970s.

2.2.5 Technical Support

2.2.5.1 Regional Ozone Modeling for Northeast Transport (ROMNET) Program

ROMNET, a major 3-year (FY-1988 through FY-1990) program, used ROM to assess the effects of region-wide VOC and NO_x emission control strategies in the northeastern United States on region-wide ozone distribution, and to estimate future-year boundary conditions for urban models. Results of the future-year simulations for base cases and emission control strategies will be provided to State and local air pollution control agencies so that they can estimate initial and inflow boundary conditions when using urban air quality models. Meteorological scenarios from episodic periods in 1980, 1983, 1985, and 1988 were used along with the projected emission inventories for 1995 and 2005. During FY-1990, work focused on performing the ROM air quality simulations. An episode spanning July 2-17, 1988, was chosen as the primary episode for evaluating various emission control strategy scenarios in which anthropogenic hydrocarbon and/or NO_x reductions were effected. Full analysis of ROMNET results will not be available until FY-1991, but preliminary results showed the region-wide effectiveness of NO_x reductions in lowering ozone concentrations. However, in the major urban source areas of New York and, to a lesser extent, Washington-Baltimore, NO_x reductions led to local ozone increases. Hydrocarbon reductions appeared to be more effective at reducing ozone concentrations in those areas.

2.2.5.2 Modeling Advisory Committee

The California Air Resources Board (ARB) initiated a Modeling Center within its Technical Support Group in Sacramento to coordinate all regulatory air quality modeling activities within the State and to develop and test tools needed for air quality modeling. A Modeling Advisory Committee (MAC) was established to review and comment on the Center's programs and activities and to provide ongoing expert opinion on a variety of modeling subjects, including model evaluation, model application, and uncertainty in the modeling process. The Committee is composed of members from the scientific community selected by ARB officials for fixed terms of membership. One representative from the Division is serving a renewed 3-year term on the MAC. During FY-1990, MAC meetings focused on model performance standards and evaluation protocols, technical guidance on photochemical modeling, and incremental reactivity.

2.2.5.3 Urban Airshed Model (UAM)

Two Division representatives serve on working groups providing technical assistance to the EPA on two UAM projects. The first project is SCOPE, in which the New York State Department of Environmental Conservation is attempting to interface ROM and UAM. The working group associated with SCOPE is providing wind fields and initial- and boundary-condition concentrations from ROM for a limited number of single-day UAM simulations. This project is being coordinated with the more extensive Division effort to interface these two models. The second project is the development of guidance for regulatory applications of UAM. The working group associated with this project is formulating a guidance document to be published in FY-1991.

2.2.5.4 Southeast Oxidant Study (SOS)

Planning for a multiyear Southeast Oxidant Study (SOS) of the generation and control of ozone and photochemical processes in the southeastern United States continued in FY-1990; a consortium of Southeastern universities is coordinating the study. Recent evidence indicates that the traditional policy of controlling hydrocarbon emissions to improve the ozone problem is not very effective in the Southeast, perhaps due to the abundance of natural hydrocarbons from the region's forests and vegetation. Plans were made for a Southeast Regional Oxidant Network (SERON) program and a Southern Oxidant Research Program (SORP). The SERON program is a long-term data collection effort over the region. SORP is subdivided into several components, including an intensive field effort in selected urban airsheds within the Southeast, an emissions and effects study, and a hydrocarbon measurement methods development program. In addition to the measurement programs, there will be modeling studies on the regional and urban scales. The first field campaigns are expected to begin during FY-1991.

2.2.5.5 National Acid Precipitation Assessment Program (NAPAP)

A Division scientist serves as chairman of NAPAP Task Group III, Atmospheric Transport and Modeling. During FY-1990, this group provided support to the NAPAP Office of the Director regarding the atmospheric processes component of the NAPAP 1990 Integrated Assessment. Task Group III helped structure the definition and use of major scenarios of future emission changes and helped supply RADM deposition and air quality results for use by the effects task groups. Also, specific RADM analyses were developed for the 1990 assessment. Other support included providing the NAPAP Office of the Director with State-of-Science/Technology Reports No. 3 (Binkowski et al., 1990); No. 4 (Chang et al., 1990); and No. 5, Part 1 (Dennis et al., 1990a) and Part 2 (Dennis et al., 1990b).

2.2.5.6 Eulerian Model Evaluation Field Study (EMEFS) Project

The Eulerian Model Evaluation Field Study (EMEFS) project is a multiagency-sponsored program for obtaining a database and evaluating regional-scale acid deposition models, including RADM and the Acid Deposition and Oxidant Model (ADOM). Data are obtained from the EPA Acid-MODES study, the Electric Power Research Institute (EPRI) Operational Evaluation Network (OEN), the Canadian Atmospheric Environment Service (AES) Canadian Air Pollution Monitoring Network (CAPMoN), the Ontario Ministry of the Environment (OME) Acid Precipitation in Ontario Study (APIOS) network, and the Florida Electric Power Coordinating Group (FCG) Florida Acid Deposition Program. The Program Management Group that oversees this project includes representatives of the sponsors and consists of four teams: the Operations Measurements Team (OMT), the Diagnostic Measurements Team (DMT), the Emissions Inventory Team (EIT), and the Model Evaluation Team (MET). The DMT and the MET are chaired by Division scientists.

2.2.5.7 Methane Emissions Inventory Development

A Division scientist served on an advisory committee established in FY-1990 to evaluate methods for estimating methane emissions from production and distribution areas. The committee focused on assessing the feasibility of estimating methane emissions and examined several methods, including the use of tracers and engineering approaches. The results of this effort--estimates of methane emissions for the United States and, eventually, for the world--will be used in global warming studies.

2.2.5.8 Atmospheric Deposition of Toxic Pollutants to North American Watersheds

Using the REgional Lagrangian Model of Air Pollution (RELMAP), a set of 10 annual uniform-emission, source-receptor matrices was derived to estimate atmospheric deposition of toxic pollutants for the Chesapeake Bay Watershed. The set of matrices applies to a specific group of chemically inert pollutants with similar dry and wet atmospheric removal rates. With these matrices and user-compiled emission rates, annual fields of mean concentrations and wet/dry deposition amounts can be constructed. This modeling work will be expanded in FY-1991 to address deposition across other North American watersheds.

2.3 Fluid Modeling Branch

The Fluid Modeling Branch conducts physical modeling studies of fluid flow and pollutant dispersion in complex flow situations, including flow and dispersion in complex terrain, near and around obstacles, and at coastal outflows. The Branch operates the Fluid Modeling Facility, consisting of large and small wind tunnels, a large water channel/towing tank, and a convection tank. The large wind tunnel has an overall length of 38 m with a test section 18.3 m long, 3.7 m wide, and 2.1 m high. It has an airflow speed range of 0.5 to 10 m/s and is generally used for simulating transport and dispersion in the neutral atmospheric boundary layer. The towing tank has an overall length of 35 m with a test section 25 m long, 2.4 m wide, and 1.2 m high. It has a speed range of 0.1 to 1 m/s, and the towing carriage has a range of 1 to 50 cm/s. Generally, it is used for simulation of strongly stable flow and salt water of variable concentration is used to establish density gradients in the tank. A convection tank measuring 1.2 m on each side and containing water to a depth of 0.5 m is used to study the convective boundary layer and to study flow and dispersion under convective conditions.

2.3.1 Stack-Tip Downwash

Downwash of neutrally buoyant effluent in the immediate lee side of a circular stack was modeled using a wind-tunnel simulation. The goals of the research were to obtain sufficient data to evaluate the accuracy of the formula used in atmospheric diffusion models to assess plume downwash, to suggest improvements to the formula, and to provide an algorithm to predict downwind pollutant concentration distributions when downwash occurs.

The range of Reynolds numbers typically encountered in the field required that simulations be conducted in both subcritical and supercritical flow regimes. In the subcritical regime, the boundary layer separates on the upwind side of the cylinder, creating a large negative pressure on the downwind side that tends to draw the effluent plume into the wake of the stack. In the supercritical regime, the boundary layer becomes turbulent, which delays separation and reduces the magnitude and extent of the low-pressure region on the lee side, thus reducing the tendency to draw effluent into the wake. The criterion demarcating these two flow regimes is the critical Reynolds number, Re_c. The value of Re_c is a function of the scale and intensity of turbulence in the approach flow, the roughness of the cylinder, and possibly the aspect ratio of the cylinder.

In the laboratory simulation, it was not possible to match the highest Reynolds numbers to be found in the field. Instead, a grid was used to create turbulence of known intensity and scale; by delaying separation on the cylinder surface, this turbulence reduced the Re_c value or, equivalently, allowed simulation of the higher-Reynolds-number regime. This turbulence also provided a semblance of the atmospheric turbulence that might be expected in the flow approaching a full-scale stack.

In the subcritical flow regime, the onset of downwash--defined as the point at which the concentration at the location one diameter down from the top of the stack was 1% of the in-stack concentrations--began at an effluent-to-wind-speed ratio (W/U) of 1.5. Measurable concentrations were observed to 7 diameters down from the stack top at $W/U = 0.3$. Plume centroids remained essentially level with downwind distance for $0.75 \leq W/U \leq 2.0$. At $W/U = 0.3$, the plume centroid descended nearly 2.5 diameters over its travel 30 diameters downwind. This last point contrasted sharply with several mathematical models that purportedly account for plume downwash. They calculate a downwash amount, subtract that from the stack height, then treat the plume rise as if the identical plume were emitted from the shorter stack.

In the supercritical regime, the onset of downwash occurred at $W/U = 1.1$. The flow was more nearly two-dimensional, so measurable concentrations were observed to only 4 diameters down from the top when $W/U = 0.3$. The plume centroids rose with downwind distance except when $W/U = 0.3$, where the centroid was essentially level.

Empirical expressions were provided for vertical plume widths in both flow regimes, for lateral plume widths in the supercritical regime, and for plume centroids in the supercritical regime; the centroids in the subcritical regime were too complex to be fitted by simple expressions. The commonly used downwash formula was found to be too conservative, and simple equations were recommended to replace it for the two flow regimes. It is also worth noting that both lateral and vertical concentration distributions tended toward Gaussian shape with downwind distance; by 30 diameters downwind, virtually all the distributions could be fitted with Gaussian curves. A journal article was prepared and submitted for publication (Snyder and Lawson, 1990).

2.3.2 Building Amplification Factors

An extensive set of measurements of concentration patterns in the vicinity of buildings was collected in a wind-tunnel study. Sources were placed at a matrix of positions (locations and heights) upwind, over the roof, and downwind of buildings of various shapes. The concentration patterns can be characterized most simply in terms of building amplification factors (ratios of maximum surface concentrations in the presence of the buildings to the maximum observed from sources in flat terrain) and distances to the maximum concentrations. These data are being analyzed and a journal article is in preparation.

2.3.3 Dispersion Around Buildings

During a study of dispersion around buildings, a set of wind-tunnel concentration distributions resulting from diffusion in the near-wake of a cubical building was compared with the predictions of several simple models. The Huber-Snyder model (Huber and Snyder, 1976) provided very good agreement with the observed ground-level centerline concentrations, but underpredicted lateral plume spread. The Ferrara-Cagnetti model (Hosker and Pendergrass, 1986) provided better agreement with observed plume spreads, but underpredicted observed concentrations. Based on observations of transport speed in the wake of similar obstacles, a simple modification to the Ferrara-Cagnetti model was suggested that improved concentration predictions while providing reasonable estimates of plume spread. Results of this study were presented at the Ninth Symposium on Turbulence and Diffusion in Roskilde, Denmark.

2.3.4 Flow and Dispersion in Complex Terrain

A series of experiments was run in the stratified towing tank to further elucidate the concept of the dividing-streamline height. Recent theoretical work (Smith, 1989) suggested that strongly stratified flows around hills elongated in the streamwise direction would display streamline lifting over the tops of the hills, which directly contradicts the dividing-streamline concept. The towing-tank results invalidated the theoretical ideas by showing that the dividing-streamline concept was valid for these hills as well as for axisymmetric hills and hills elongated in the crosswind direction.

In a prior year, a paper describing streamline patterns over a three-dimensional hill was submitted for journal publication. The paper compared numerical solutions of the linearized equations of motion for an inviscid fluid of infinite depth with experimental data acquired in the stratified towing tank. A referee of the paper suggested that similar computations should be done in a fluid of finite depth for more direct comparisons with the experimental results. During FY-1990, considerable effort was put into further theory development, extensive additional numerical computations, and paper revisions (Thompson et al., 1990). The comparisons showed that the depth of the tank was sufficient to model an unbounded atmosphere.

2.4 Modeling Systems Analysis Branch

The Modeling Systems Analysis Branch supports the Division Branches by providing computer programming and systems analysis needed in the development of mathematical and statistical models. The Branch is the focal point for modeling software design and systems analysis in compliance with stated Agency quality control and assurance requirements. The Branch operates the Facility for Advanced Research Model Operation and Analysis (Research Modeling Facility) to provide expertise in the application and interpretation of advanced dispersion models and to establish definitive scientific standards for model evaluation and policy analysis that are consistent with standards followed in the research and model development efforts.

2.4.1 Regional Oxidant Model (ROM) Applications

Activities in FY-1990 involved extensive ROM applications. Numerous model runs were made to support the ROMNET program. Additional simulations were made to support an evaluation of ROM2.1; an assessment of ozone concentrations in Shenandoah National Park for the National Park Service; and an analysis of ozone sensitivity to natural emissions of nonmethane hydrocarbons (NMHC) and NO_x.

For the ROMNET program, 25 emission control strategies were examined. Model simulations centered on a 2-week period in July 1988 for which ozone concentrations above 300 ppb were predicted. Various combinations of VOC and NO_x control strategies were examined to determine the emission levels required to attain the ozone standard of 120 ppb. Even with the emission controls proposed for the Clean Air Act Amendments of 1990, predicted ozone levels would violate the standard near many urban areas in the northeastern United States. A combination of stringent VOC and NO_x emission controls would be required to reach attainment. These results contrast somewhat with those of Trainer et al. (1987) and Chameides et al. (1988), who suggest that NO_x-only controls are preferred for lowering ozone concentrations. However, ROMNET simulations showed that NO_x-only controls could be detrimental, increasing peak ozone concentrations, compared to VOC-only controls, particularly near such NO_x-rich areas as New York City, NY, and Washington, DC. The results from the ROMNET simulations will be used to coordinate ozone attainment programs in the northeastern United States.

Partially in support of ROMNET, Pierce et al. (1990b) reported on an operational evaluation of ROM2.1 using surface measurements of ozone obtained in 1985, the base year of the emission inventory. Modeled and observed peak daytime concentrations agreed, on average, to within 2 ppb (77 ppb versus 79 ppb). The model tended to underestimate at the higher extremes of the frequency distribution and overestimate at the lower extremes. Interestingly, the evaluation provided an assessment of ROM's ability to estimate boundary conditions for UAM. Near the New York City Metropolitan Area, estimated and observed boundary conditions agreed to within 4 ppb (57 ppb versus 61 ppb). However, model performance sometimes deteriorated during periods of such rapidly changing mesoscale wind flow conditions as squall lines. Future ROM evaluations can benefit from more rural ozone monitoring sites and from additional measurements of NO_x, isoprene, formaldehyde, nitric acid, and other chemical species.

In a sensitivity study for the National Park Service (Milich et al., 1990), anthropogenic emissions within 100 km of the boundary of Shenandoah National Park were excluded from model simulations to assess how these emissions affect ozone concentrations. Simulations performed for the July 1988 episode showed that the anthropogenic emissions seem to have a modest effect on the Park's ozone concentrations. This implies that important contributors to elevated ozone levels within the Park include long-range transport of ozone and NO_x combined with high levels of biogenic NMHC emissions.

Other model simulations were undertaken to examine the sensitivity of ROM to biogenic NMHC emissions (Roselle and Schere, 1990; Roselle et al., 1990) and to lightning-generated and soil NO_x emissions. These results are being analyzed.

2.4.2 Regional Acid Deposition Model (RADM) Applications Support

During FY-1990, the system for generating emission scenarios for RADM Engineering Model (RADM/EM) executions was modified to produce emissions for the 6-layer and 15-layer versions of RADM. Numerous anthropogenic emission data sets were generated and quality assured to support model applications. These included data sets for (1) 30 days in base year 1985 and future years 2010 and 2030; (2) evaluation of interstate and intrastate trading as part of the Clean Air Act policy analysis; (3) geographic areas targeted for nonproportionality analysis; (4) a 33-day model evaluation period with integrated hourly emissions for the 130 major sources in the United States and Canada; and (5) evaluation of sulfur reduction strategies. Biogenic emission estimates were produced for all applications.

A significant application of RADM2.1/6-layer and RADM/EM was completed for the NAPAP 1990 Integrated Assessment. This effort involved completing approximately 150 RADM runs on the National Center for Atmospheric Research (NCAR) CRAY X-MP and more than 1000 RADM/EM runs on the EPA National Computer Center (NCC) IBM 3090. More than 30,000 files were generated. The work focused on four major areas of investigation: (1) the source attribution and cross-boundary flux of sulfur deposition; (2) the degree and extent of the influence of nonlinearity (oxidant limitation) on sulfur deposition and ambient air concentrations, including diagnosis of conversion pathway budgets; (3) the sensitivity of annual deposition and air quality to emission changes, which differed in magnitude, pattern, and sources; and (4) the deposition and air quality changes estimated for the NAPAP Illustrative Future Scenarios. Most of the RADM and all of the RADM/EM estimates and analyses were in terms of annual averages. More than simply an operational accomplishment, this successful effort with RADM represents a major achievement in using an Eulerian framework model to produce results on an averaging-time scale appropriate for the NAPAP assessment and linkages to effects modeling.

2.4.3 Natural Emissions

The Biogenic Emissions Inventory System (BEIS) was developed (Pierce et al., 1990a) to improve the specification of natural emissions in regional and urban-scale air pollution models. BEIS combines features of the Lamb et al. (1987) and Novak and Reagan (1986) methodologies and includes a simple leaf energy balance model (Gates and Papian, 1971) for estimating leaf temperature and solar radiation profiles in forest canopies. BEIS was incorporated into ROM, RADM, and UAM. In addition, a personal computer version of BEIS was developed for estimating hourly biogenic NMHC emissions for any county in the contiguous United States (Pierce and Waldruff, 1990).

Also, work was started to expand the specification of natural NO_x emissions with the development of an algorithm to include soil NO_x emission factors (Placet et al., 1990). Further, a method was developed to estimate lightning-generated NO_x emissions using data from the State University of New York at Albany lightning detection network. Computed emissions for 1988 in the northeastern United States show that lightning-generated NO_x emissions are small compared to anthropogenic emissions. However, additional study is planned for the southern United States where lightning is more frequent and anthropogenic emissions are lower.

2.4.4 Visualization

A new visualization tool, the RADM/ROM Visualization Program (RRVP), was designed for use in displaying ROM and RADM results. RRVP runs on a dedicated Silicon Graphics workstation and produces time-series representations of air pollution model inputs and results or any other gridded data in color and in 2-D or rubber-sheet 3-D. The results can be stored on optical disks and subsequently transferred to video tape directly using a video cassette recorder (VCR). This program was used to make several video tapes for reviewing ROM species concentrations and for analyzing lightning-strike frequency and its contributions to regional NO_x emissions and ozone formation. This ability to construct video outputs of regional model inputs and predictions significantly enhances interpretive capabilities.

A different approach, the Interactive Volume Modeling (IVM) program, was used to visualize and analyze data that have considerable three-dimensional structure. IVM also runs on a Silicon Graphics workstation and interactively shows a 3-D representation of a gridded data set. The user can rotate the data in any direction, peel off layers to reveal the inner structure, make slices through the data in any plane, and calculate volumes or engineering values. Color video can be created from the workstation screen without previously storing an image. Other possibilities for using this program are being explored, including running a probe along an aircraft flight path and comparing air concentration measurements with 3-D model predictions.

2.4.5 Research on Optimal Use of Supercomputer Environments

In April 1990, a cooperative agreement with the North Carolina Supercomputing Center was initiated for research and training on the optimal use of supercomputers for regional model research and applications. The goal of this effort is to improve the performance of critical numerical algorithms in regional air quality simulation models through vectorization, parallelization, and restructuring of code. A combination of scalar and vector optimization and the migration of the RADM code from a CRAY X-MP to a CRAY Y-MP reduced the execution time for a 5-day RADM run from 4.3 to 1.6 CPU hours. Work is underway to implement parallel versions of the RADM and ROM codes and to develop a visualization framework that will enable research scientists to analyze model results directly with sophisticated graphical analysis tools. The agreement further provides (1) basic user support and training in the use of high-performance computing technology, (2) an Executive Seminar Series to keep management informed about the benefits of supercomputing, (3) a mechanism for remote users to access high-performance resources to develop prototypes for potential supercomputing applications, and (4) a procedure for producing a formal benchmark suite and documentation to support the procurement of two supercomputers.

2.5 Global Processes Research Branch

The Global Processes Research Branch performs and directs research to obtain qualitative and quantitative predictions of regional climate and air quality changes caused by global climate fluctuations for use in evaluating the sensitivities and responses of major environmental systems to climate change. The Branch also studies the effects of irregular terrain on pollutant dispersion and establishes mathematical relationships among air quality, meteorological variables, and physical processes affecting air quality.

2.5.1 Global Climate Change Program

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

Results from General Circulation Models (GCMs), including output from recent simulations by the Geophysical Fluid Dynamics Laboratory (GFDL) at a higher resolution (2.22° latitude by 3.75° longitude), have shown a pattern of midcontinent drying during the growing season. These results were compared with observed data. The most recent observed episode of growing season dryness in the North American midcontinent occurred in 1988. Forty years of historical data were examined for spring and summer drought situations similar to 1988's, and it was found that only 1988 exhibited the pronounced large-scale June drying. This event is important because the GCMs indicate an earlier onset of spring and summer due to climate change.

As part of the climate scenario development effort, a gridded precipitation database for the United States and Canada was used to examine rainfall variation over coniferous forests from Lake Winnipeg to north of Lake Huron and south to central Minnesota, Wisconsin, and Michigan. An investigation of weather-tree relationships showed that wet, cool seasons favor good deciduous growth and dry, warm seasons favor conifers. Under a cooperative agreement with the University of Illinois at Champaign, IL, Richman (1989) prepared a paper on this work.

As part of the research effort on the impact of climate change, the gridded 700-mb geopotential height data provided by the NOAA National Weather Service Climate Analysis Center were analyzed using cluster analysis and a Markov process. Upper-level patterns associated with air pollution events are being identified, and relationships with regional precipitation features are being established. The next step will be a comparison with the GFDL GCM results for the current climate.

In another effort, theoretical research focused on extreme climate events. This research showed that these events are more sensitive to changes in variability than to changes in the mean. The relative sensitivity increases as the event becomes more extreme. Under a cooperative agreement with NCAR, Katz and Brown (1989) presented the results of this work.

An effort is underway to compare the winds of the recent past with winds for the future predicted by GCMs, because winds are an important forcing mechanism for most of the continental United States near-shore ocean currents. Historical wind data are available from the Comprehensive Ocean-Atmosphere Data Set (COADS), which contains monthly wind data at a 2° spatial resolution for the world oceans for the years 1854 to 1979. Time series of monthly winds from 1950 to 1979 for about 30 grids off the coast of the continental United States were examined. To select a future-climate simulation, the simulated winds were compared with the historical wind observations. Results showed that wind and pressure fields from the GFDL climate simulation compared favorably with the COADS data, so this was accepted as a future-climate scenario.

2.5.2 Complex Terrain Dispersion Modeling

The research effort to develop the Complex Terrain Dispersion Model PLus algorithms for Unstable Situations (CTDMPLUS) was completed in FY-1989 (Perry et al., 1989). Model performance was analyzed in FY-1990 using a previously unavailable field study database. Although individual components of CTDMPLUS were thoroughly tested and evaluated over the last few years, this analysis represented the first effort to examine model performance with a full year of the hourly meteorological data that are typically available for regulatory applications of the model. Comparing the highest 25 hourly observations with the highest 25 CTDMPLUS predictions showed a tendency for the model to overpredict, on average, by a factor of 2. Similar results were found for 3-h and 24-h average predictions. Most of the overpredictions occurred in stable conditions. For hours of daytime convective conditions, the model was only sightly biased toward overprediction. Final performance results will be published in FY-1991.

Because of the demanding meteorological input requirements of CTDMPLUS, a screening version of the model, CTSCREEN, was developed that does not require meteorological data. This screening version provides users an excellent planning and analysis tool for determining likely problem pollutant sources and the location of their greatest impact. CTSCREEN is being tested and evaluated relative to CTDMPLUS. Performance results and a CTSCREEN user's guide will be published in FY-1991.

2.5.3 Integrated Air Cancer Program

In 1985, a long-term integrated air cancer research program was initiated to investigate the toxicity of airborne pollutants. The first phase of this program was to evaluate the chemical composition and mutagenicity of woodsmoke. The transport and diffusion of woodsmoke in an urban setting was studied and the results of these experiments were published in FY-1990 (Eskridge et al., 1990).

A second experiment was conducted in Roanoke, VA, in the winter of 1988-89, using a 50-m tower instrumented with two sonic anemometers, two propeller and vane anemometers, and two delta T systems. Roanoke Valley, a pooling valley, is expected to behave quite differently from the Boise River Valley in Idaho, where the first experiment was conducted in the winter of 1986-87. Data resulting from the eight Roanoke meteorological and tracer experiments were analyzed, and these results and data are being prepared for publication.

2.6 Applied Modeling Research Branch

The Applied Modeling Research Branch investigates and develops applied numerical simulation models of sources, transport, fate, and mitigation of pollutants in microenvironments. Databases are assembled and used for model development and research on flow characterization and dispersion modeling. Research is coordinated with other agencies and researchers.

2.6.1 Dispersion Downwind of Isolated Buildings

Using results from tracer dispersion experiments conducted in the Fluid Modeling Facility wind tunnel, Irwin et al. (1990) evaluated how well a finite line source model simulated dispersion from a continuous, nonreactive, nondepositing, point-source release centered at ground level on the leeward side of a building. The model estimated the average concentrations at surface receptors within the cavity and wake region of the building. The vertical dispersion effects were simulated using an empirical estimate of the nondimensional crosswind integrated concentrations as a function of scaled distance downwind from the building. This approach allowed incorporation of the results from many experiments. The dispersion induced by the building was assumed to result from a superposition of two dispersive processes: the process induced by the building and the process that would have occurred had the building not been present. All simulations were for buildings oriented perpendicular to the predominant wind flow. Standard models were used for the finite line source equation and the characterization of the lateral dispersion.

The model included two unique aspects. The first was the method used to characterize the length of the line source. The emission from the point source was simulated as being emitted from a continuous line source, using $q = Q/L$ (mass per unit length per unit time), where Q is the point-source emission rate and L is the length of the line source. The length L was set equal to W for $W/H < 4$, where W is the building width and H is the building height; for $W/H \geq 4$, L was held constant at $4H$. The second unique aspect was the method used to characterize the nondimensional crosswind integrated concentration. Empirical data from several wind-tunnel experiments were used to calculate these concentrations according to the equation $C_y = X_y UH/Q$ (see Figs. 1 and 2), where X_y is the crosswind integrated concentration and U is the wind speed at building height H. The lines shown in the figures are empirical fits to the data, given by the following expressions:

$$C_y = a\left(\frac{X}{H}\right)^b \qquad a = 5\left(\frac{W}{H}\right)^{-0.7} \qquad b = \frac{\ln(0.45) - \ln(a)}{\ln(100)} ,$$

where X is the distance in the alongwind direction. As Figure 1 shows, more empirical data are needed for W/H values greater than 2 at downwind distances less than $X/H = 10$. Figure 2 shows the variation of C_y as seen in wind-tunnel simulations, where the downwind distance was fixed at $X/H = 10$ and W/H was varied from 1 to 18. The empirical fit, shown as a solid line, closely follows the decrease in C_y as the building width-to-height aspect ratio increases. Beyond $W/H = 10$ there is an apparent increase in C_y, which may be an artifact of interaction between the modeled building and the side walls of the wind tunnel. More data are needed to confirm the adequacy of the simple power-law fit used to describe how C_y varies as a function of downwind distance and building width-to-height aspect ratio.

Experimental results suggest that, given data from a suitable series of wind-tunnel tracer studies, the characterization of C_y could be expanded to show the functional dependence of C_y on wind orientation to the building, source location, and receptor height. The model provides a basis for developing an applied model to characterize the concentration at surface receptors of nonreactive, nondepositing releases of pollutants near isolated buildings.

2.6.2 Puff Model Simulation of Building Wake Dispersion

Based on results from wind-tunnel experiments (Huber, 1988; Huber and Arya, 1989), a study was done to evaluate the use of a puff model for calculating pollutant concentration fluctuations downwind of buildings. A puff model formulation can provide estimates of the mean and standard deviation of the concentrations in the building wake. Fluctuations in the spatial-temporal scales of the shed vortices and meander in the plume can be related to the scales of the mean velocity and the building. The study compared the cross-stream distribution for a series of video images with the concentration distribution computed with a Gaussian puff model. Also, the study compared averaged concentrations from the puff model with averaged tracer concentrations.

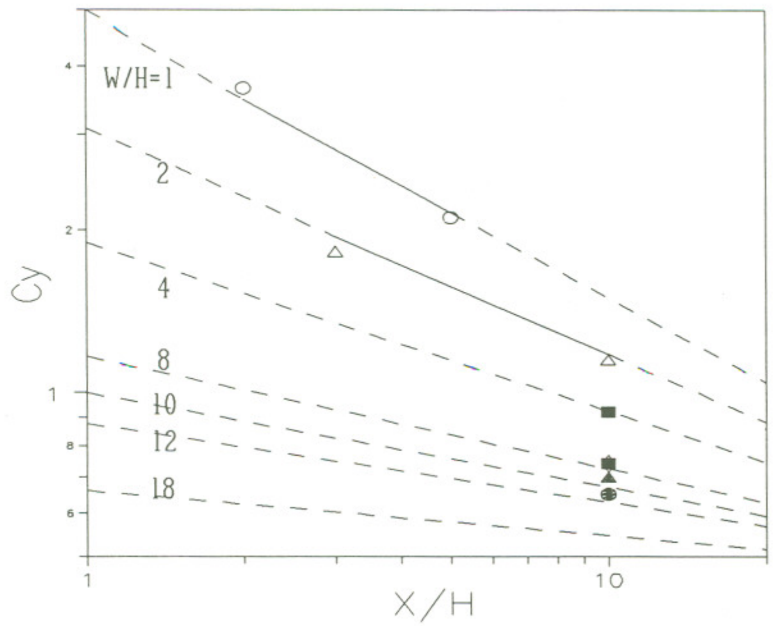

Figure 1.--Nondimensional crosswind integrated concentrations for several building width-to-height ratios (*W/H*) as a function of scaled downwind distance (*X/H*), where *X* is the distance in the alongwind direction. Lines are modeled values.

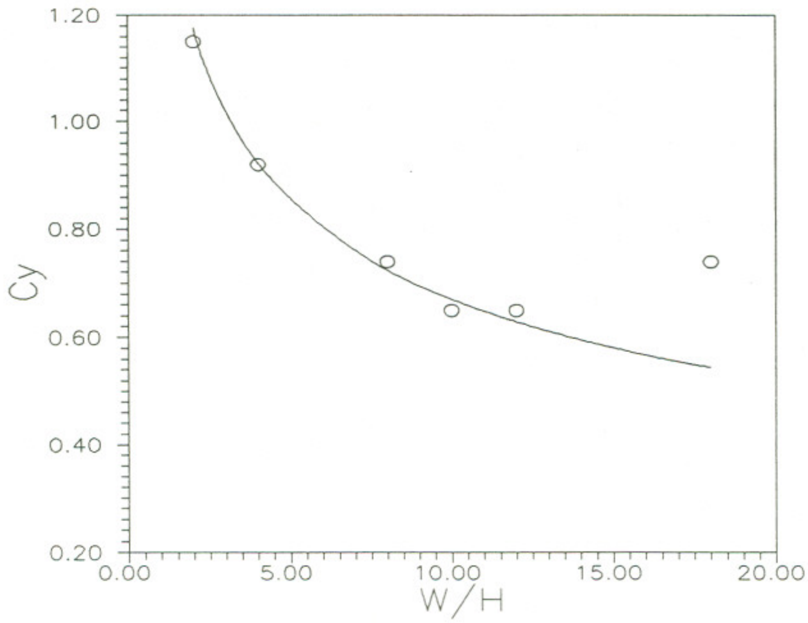

Figure 2.--Nondimensional crosswind integrated concentrations for several building width-to-height ratios (*W/H*) at scaled downwind distance $X/H = 10$, where *X* is the distance in the along-wind direction. Solid line is modeled values.

The study was performed using INPUFF (Petersen and Lavdas, 1986) because this model was adaptable to simulating concentrations in the building wake, where rapid puff release rates were necessary. Analysis of the video image data suggested that vortex shedding in the lee of a building can be simulated by puffs that are released at three ground-level positions, in sequence along the leeward edge of the building. The puff release location oscillates between the center of the leeward edge and positions 0.8*H* on either side of the center, where *H* is building height.

Figures 3 and 4 compare the cross-stream profiles of mean values across the plume at $X/H = 3$ and $X/H = 10$, respectively, where *X* is the distance in the alongwind direction. The video image data and the puff model estimates were normalized to match the tracer value at $Y/H = 0$, where *Y* is the distance in the crosswind direction. Once normalized, the spatial and temporal distributions of the video data should be a valid measure of concentration. The model and tracer concentrations are made nondimensional using UH^2/Q, where *U* is the approach velocity at building height and *Q* is the emission rate. Because the source is near the building where the mean wind is reduced in comparison to the free stream approach flow, some compensation for this effect must be made in the model concentration estimates. The model input includes a puff advective velocity that applies to the effective plume dilution at some distance downwind of the building (e.g., $X/H = 15$). Thus, to allow comparison with wind-tunnel tracer concentrations that are affected by this reduced wind, a modified model velocity is used:

$$\frac{U_{(\mathrm{atH})}}{U_{(\mathrm{modified})}} = 0.95 + 6.42(X/H)^{-1.77} \qquad \text{for } 3 < X/H < 15 .$$

Figure 5 compares the model and tracer concentrations along the centerline. The comparison at distances beyond $X/H = 10$ could be improved by incorporating dispersion parameters specific to conditions found in the wind tunnel for the Pasquill-Gifford dispersion parameters. Figures 3, 4, and 5 all show that the mean profiles for the puff model compare well to measurements.

The puff model simulated many features of the larger-scale variation observed in the building wake flow, but did not simulate the short-term peaks. This could be overcome by adding an empirically determined factor for the relatively short-term peaks. However, this feature would not be necessary for most applications where average concentrations over several minutes are needed. These comparisons indicate that a four-puff-per-cycle model can be used to simulate the characteristics of building wake dispersion. The puff model also has the special feature for simulating the effects of meander and rapidly changing conditions for emissions and meteorology. The building wake formulations developed in the puff model are based on analysis of the video image data from wind-tunnel studies.

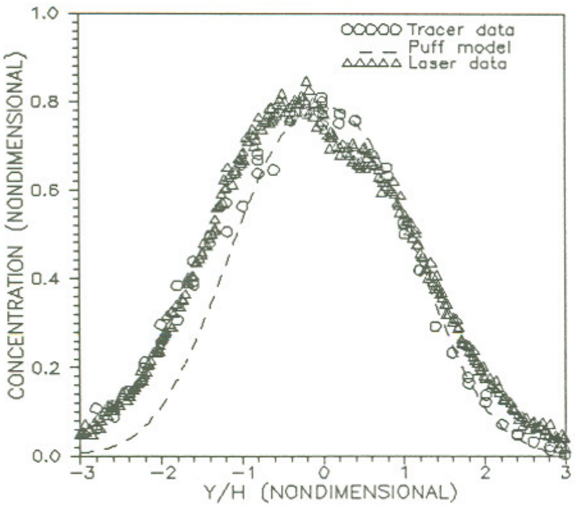

Figure 3.--Nondimensional lateral concentration at 3 building heights downwind ($X/H = 3$) for a rectangular block described by $W/H = 2$. W and H are building width and height, respectively, and X and Y are the distance in the alongwind and crosswind directions, respectively.

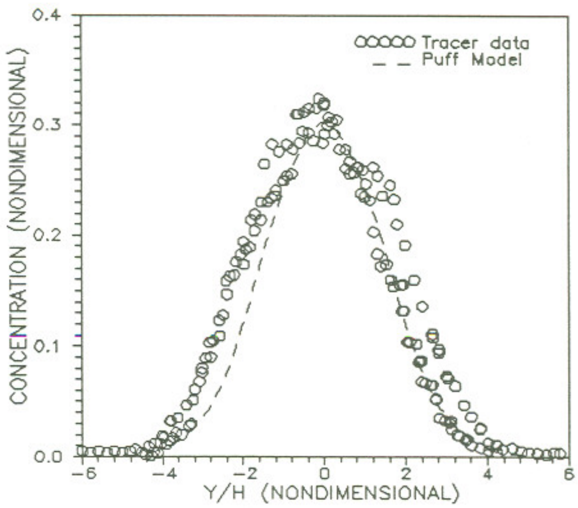

Figure 4.--Nondimensional lateral concentration at 10 building heights downwind ($X/H = 10$) for a rectangular block described by $W/H = 2$. W and H are building width and height, respectively, and X and Y are the distance in the alongwind and crosswind directions, respectively.

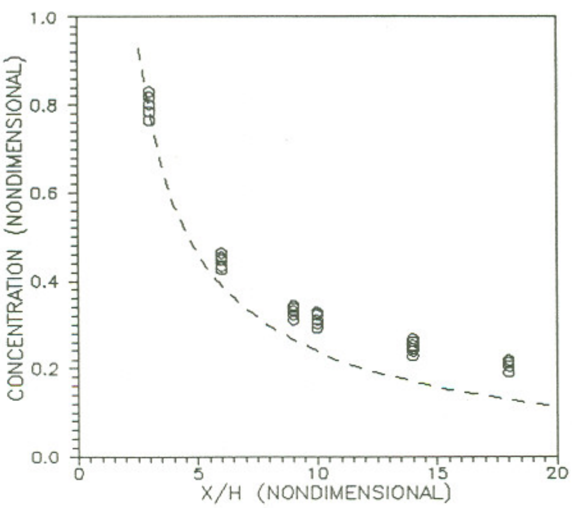

Figure 5.--Nondimensional centerline concentration for tracer data (circles) and model results (dashed line) for a rectangular block described by $W/H = 2$. W and H are building width and height, respectively, and X is the distance in the alongwind direction.

2.6.3 Building Effects Studies

Research is being conducted in the Fluid Modeling Facility to develop and apply video image analysis techniques to the study of smoke plumes near wind-tunnel modeled buildings. Video image analyses are especially useful for studying the temporal-spatial plume distributions in ways not obtainable from traditional point-tracer measurements. Two techniques were used. The first uses smoke illuminated by a floodlight. Each smoke picture represents a two-dimensional view of smoke-scattered light integrated through the third dimension. The digitized luminance value, called image intensity, represents an indirect measure of the smoke particle concentration through the field of view. A journal article summarizing analyses for this technique was finished (Huber et al., 1990). The second technique uses smoke illuminated with a thin sheet of laser light. The image intensity for the laser sheets represents point concentrations. A project report was completed (Rajala and Trotter, 1990), and a paper summarizing analyses for the laser-sheet-lighted technique is being prepared.

An additional wind-tunnel study of stably stratified flow around a model building was conducted in Japan during a six-month fellowship program at the Institute for Pollution and Resources with the Agency of Industrial Science and Technology. This study was designed to compliment similar studies of neutrally stratified flow that had been conducted in the Fluid Modeling Facility wind tunnel. Data from tracer concentration mappings and video image recordings of laser-sheet-lighted smoke patterns were collected. Preliminary analyses show that the effect of stratification, which influences the region of flow separation on the building surfaces, was greater than anticipated. Data analysis is continuing and a journal article is being prepared.

2.6.4 Sonic Anemometer Measurement Within a Room

In preparation for future research on the characterization of indoor pollutant concentration values, the feasibility of using a small (5-cm path-length) sonic anemometer for measurement and characterization of velocity fluctuations within rooms was investigated (Irwin and Paumier, 1990). This experiment was conducted with doors and windows closed and the forced-air circulation system turned on. Measurements were taken at three heights (floor, middle, and ceiling) in two rooms, one square and one rectangular. Data were recorded for 10-min periods at each sampling location.

Figure 6 was constructed to investigate whether the variance of the velocity fluctuations might be related to the mean speed or to the location within the room. The figure shows the standard deviation of the velocity fluctuations, averaged at each sampling location over the three flow components, versus the computed average speed. The largest variances are observed near the ceiling, where the flow from the floor vents was disrupted by the barrier presented by the ceiling. Disregarding these values, there was no significant correlation between the variance of the velocity fluctuations and the average speed, nor does there appear to be a location dependence. Except within the corners or above the vents, the flow was nearly isotropic, with speeds on the order of 15 cm/s and an average standard deviation of 6.7 cm/s.

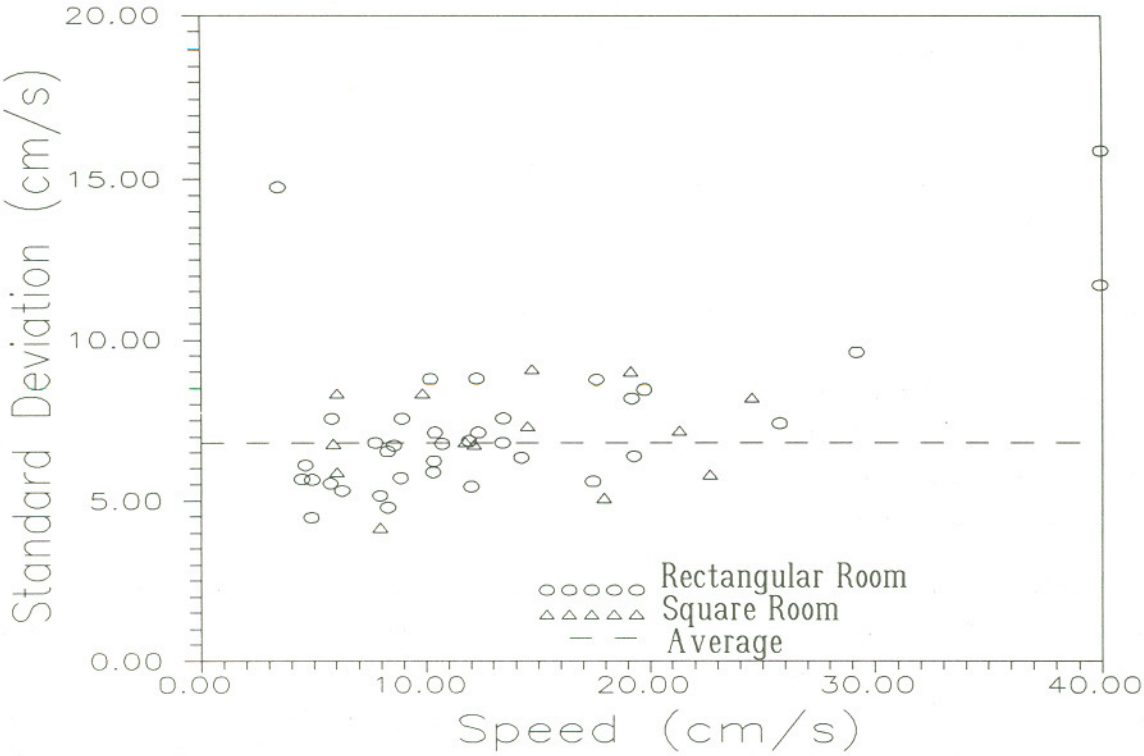

Figure 6.--Average standard deviation of velocity components versus flow speed at each sampling location. The average standard deviation of 6.7 cm/s was computed ignoring the three sampling locations where the flow was forced to turn, resulting in very large standard deviations.

Approximately 10% to 20% of the measured component velocities were below the threshold of the instrument's uncertainty. Given the frequent occurrence of very low speeds--even in these experiments, where the circulation was constantly forced--the accuracy of the instrument restricts the situations in which useful measurements are possible. The experiment showed that the instrument can yield useful measurements where the flow is on the order of 20 cm/s or more.

2.6.5 Sonic Anemometer Flow Distortion Coefficients

The use of sonic anemometers for measuring fluxes is being examined from the standpoint of developing flow distortion coefficients. Wind-tunnel measurements were made with four different types of sonic anemometers, both in a relatively smooth flow and in a uniform field of grid-generated turbulence. This experiment was designed to determine the sonic anemometers' responses to the smooth flow typical of most wind tunnels and to the turbulent flow encountered in the atmosphere, and to determine the response characteristics of the four anemometers. This information was used to evaluate various correction schemes being applied to sonic anemometer data.

The longitudinal and vertical turbulent intensities were measured in the wind tunnel with and without the turbulence grid in the volume swept out by the sonic anemometers. The turbulence grid produces a desired scale and intensity of turbulence by equating the dissipation rate of the tunnel turbulence to that typical in the atmospheric surface layer. This experiment showed that a well-characterized tunnel that inhibits acoustic reflections can be used to develop response functions for sonic anemometers, and that the generation of turbulence is unnecessary. The implications for flux measurements are being examined.

2.6.6 Acoustic Doppler Sounders

The International Sodar Intercomparison Experiment (ISIE) was conducted over a continuous 21-day period during September 1988. The concurrent operation of the sodars provided a unique opportunity to evaluate the statistical comparison of conventional in situ or point measurements with volume-average measurements of the first and second moments of the wind. The research is focused on using bias and comparability statistics to compare the simultaneous in situ and volume-average speed and direction at various heights. The results so far indicate that, for 20-min averaging and a spatial separation of 700 m, the effects of meteorology are small and instrument effects dominate. Wind direction is an exception, where the comparison is poor due to high wind direction variability during the averaging period. These variable directions do not always occur with light winds, making the selection of a cut-off speed for useful comparisons difficult. Time series analysis of the sodar measurements indicated that a 20-min average is adequate for stable boundary layer comparisons. Using time periods shorter than 20 minutes would exclude some of the energy-containing eddies from the time series analyses, which could significantly contaminate the statistics of the comparison.

2.7 Air Policy Support Branch

The Air Policy Support Branch supports activities of the EPA Office of Air Quality Planning and Standards (OAQPS). The Branch's general responsibilities include (1) evaluating, modifying, and improving atmospheric dispersion and related models to ensure adequacy, appropriateness, and consistency with established scientific principles and Agency policy; (2) preparing guidance on applying and evaluating models and simulation techniques that are used to assess, develop, or revise national, regional, state, and local air pollution control strategies for attainment and maintenance of National Ambient Air Quality Standards (NAAQS); and (3) providing meteorological assistance and consultation to support the OAQPS in developing and enforcing Federal regulations and standards and assisting the EPA Regional Offices.

2.7.1 Modeling Studies

2.7.1.1 Regional Ozone Modeling for Northeast Transport (ROMNET) Program

The Regional Ozone Modeling for Northeast Transport (ROMNET) program was initiated by the EPA and State and local agencies in the northeastern United States, as part of a joint effort to address the problem of regional transport in developing effective and equitable control programs for attaining the ozone NAAQS in this region. The specific goals of ROMNET were

1. to evaluate the relative effectiveness of different control strategies on regional ozone levels in the northeastern United States;

2. to provide quantitative estimates of ozone and precursor concentrations transported between urban areas following the application of regional control measures; and

3. to provide procedures and guidance for incorporating ozone and precursor transport in future State Implementation Plan (SIP) development.

The EPA and State decision makers will use the findings in guiding ozone-policy development and planning for potential regional control programs and in evaluating urban-area-specific strategies. The urban-scale analyses were conducted by the States as part of the SIP process. The program's results and guidance will enable States to quantify changes in future levels of ozone and precursor transport expected to follow implementation of nationwide Federal measures, local control programs in upwind cities, and potential regional strategies. The major technical activities of ROMNET that were performed to meet the program goals included

1. applying the Regional Oxidant Model (ROM) to evaluate the relative effectiveness of emission control strategies;

2. developing the Gridded Model Information Support System that contains an archive for ROM input/output databases and provides a user-friendly avenue for State agencies to retrieve these databases to use in SIP development; and

3. developing the ROM-Urban Airshed Model (UAM) Interface Program System that translates ROM input/output databases into the form needed to drive UAM and provides a means to incorporate ozone and precursor transport in urban analyses.

The technical components of ROMNET were completed and a final report is being prepared.

During ROMNET, control scenarios were designed and applied to address five strategic issues. These issues and the general conclusions drawn from analyses of model simulations are provided below.

Issue #1: What are the relative benefits of VOC versus NO_x controls in reducing ozone levels across the region?

- NO_x controls are more effective than VOC controls (beyond existing programs) in many areas of the northeastern United States.

- The efficacy of NO_x versus VOC control varies from city to city and in some cities from day to day.

- Unlike VOC control, in some cities NO_x control can be counterproductive, resulting in increased ozone levels.

Issue #2: What is the impact of reducing regional transport on Northeast Corridor ozone levels?

- The impact of controls outside the Corridor on ozone levels inside the Corridor is minor, given the control programs and control measures in effect prior to the proposed Clean Air Act Amendments of 1990.

- Following the application of stringent controls in the Corridor, upwind controls may determine whether the NAAQS is met throughout the Corridor.

Issue #3: What levels of VOC and/or NO_x emission reductions are necessary to reduce predicted ozone concentrations in the northeastern United States to below 125 ppb?

- Reducing ozone to the level of the NAAQS or below is possible in the northeastern United States with the application of stringent control measures.

- The magnitude of emission reductions required varies from city to city.

- The greatest amount of emission reduction is needed in the New York City urban area, with VOC reduction of 91% from 1985 base emission levels, maximum technology mobile-source NO_x tailpipe standards, and reactivity reduction measures.

Issue #4: How effective are potential reactivity-based strategies in reducing regional ozone levels?

- Reactivity-based measures are most effective in areas where VOC controls produce the largest reduction in ozone levels. However, maximum technology VOC controls are more effective than the reactivity-reduction measures.

- In those areas, the most benefit occurs near the city where population is greatest, with diminishing benefit farther downwind.

Issue #5: How does the large uncertainty in biogenic emissions alter conclusions regarding the effectiveness of control measures?

- Although the uncertainty in biogenic emissions is large, model predictions are closest to observed values when "best estimate" biogenic emission rates are used.

- If biogenic emissions were near the high end of the uncertainty range, then most of the Northeast Corridor would require emission reductions beyond the stringent measures required to reduce peak ozone to below 125 ppb, according to calculations with "best estimate" biogenics.

- If biogenic emissions were near the low end of the uncertainty range, then measures in the proposed Clean Air Act Amendments of 1990 would be insufficient to reduce ozone to less than 125 ppb during a severe ozone episode throughout the Corridor by 2005.

2.7.1.2 Dense-Gas Model Performance Evaluation

As part of an ongoing program to evaluate several categories of air quality simulation models, a study was completed to evaluate the performance of models used in determining the impact of routine (nonaccidental) atmospheric releases of toxic dense gases. The study began with archiving three databases for this evaluation: the Desert Tortoise ammonia releases, the Goldfish hydrogen fluoride releases, and the Burro liquefied natural gas releases. Seven models were evaluated, including two public (DEGADIS and SLAB) and five proprietary (AIRTOX, CHARM, FOCUS, SAFEMODE, and TRACE). Model performance was evaluated by comparing observed and predicted concentrations as well as cloud half-widths, using statistical measures recommended by the AMS. Statistical tests were applied to assess prediction bias and scatter for each model and each field program. None of the models demonstrated good performance consistently for all three experimental programs, but information was gained on the state-of-science in dense-gas dispersion modeling. A report will be published in FY-1991.

2.7.1.3 Evaluation of Area-Source Algorithms

An evaluation was completed of dispersion modeling techniques available for estimating ambient concentrations produced by emissions from Superfund sites contaminated with toxic pollutants (U.S. Environmental Protection Agency, 1989b). The study focused on the application of area-source dispersion algorithms to Superfund emission sources. These sources are characterized by low-level releases with little buoyancy and are different from scenarios treated by traditional Gaussian dispersion models. Five short-term and three long-term area-source models were tested in several applications using one field database to compare the magnitude of concentration predictions and determine whether concentration estimates are consistent with mathematical and physical principles. Generally, the short-term models employing algorithms based on the line-source method, as in the FDM and PAL models, provide an adequate treatment for near-ground area sources. The results for long-term models showed that the algorithms in the ISCLT and CDM models, although different from the short-term-model algorithms, generally provide adequate treatment for area sources.

2.7.2 Modeling Guidance

2.7.2.1 Revisions to the Guideline on Air Quality Models

A regulatory package was prepared that contains (1) proposed revisions (known as Supplement B) to the Guideline on Air Quality Models (Revised) (U.S. Environmental Protection Agency, 1987), (2) the Summary of Public Comments and EPA Responses on the Fourth Conference on Air Quality Modeling, and (3) a *Federal Register* notice seeking public comments on Supplement B. Following Office of Management and Budget review of this package, the Fifth Conference on Air Quality Modeling will be announced as the public hearing on Supplement B. The proposal includes adding to the modeling guideline the new refined complex terrain model CTDMPLUS and the screening model CTSCREEN; new techniques for modeling CO concentrations at roadway intersections; an air emissions and dispersion modeling system for airports; updated screening techniques for stationary sources (SCREEN) and visibility impairment (VISCREEN); and on-site meteorological program guidance. Based on the public comments received, no further action is being proposed concerning point-source modeling for ozone precursors and regional-scale models.

2.7.2.2 Support Center for Regulatory Air Models (SCRAM)--*SCRAM NEWS*

In May 1989, the Support Center for Regulatory Air Models Bulletin Board System (SCRAM BBS) was created to foster technology transfer among all users of regulatory air models. In FY-1990, this effort was augmented by publishing the first two issues of *SCRAM NEWS,* which is directed to the modeling community in general and the SCRAM BBS users in particular. The circulation of the last issue exceeded 1600 copies.

SCRAM NEWS provides articles on new features and models added to the BBS, tips on using the models, and discussions of issues related to modeling guidance. Division meteorologists contributed 10 articles. Five articles announced the release of models through the SCRAM BBS. One of these articles discussed the release of the Complex Terrain Dispersion Model PLus algorithms for Unstable Situations (CTDMPLUS) and briefly described the model's history and features, how to obtain user's guides, and who to contact with questions about the model and its applications. An article on Meteorological Data Guidance described guidance documents that are available, ways to communicate user needs and concerns, and mechanisms to resolve issues. A regular full-page column, "Model Clearinghouse Notes," discussed Model Clearinghouse decisions of particular interest to modelers. Finally, three articles assisted users in more effectively and efficiently applying the Industrial Source Complex Short Term (ISCST) and Long Term (ISCLT) models on personal computers. Of these three, the first addressed using DOS redirection commands to input data files into the models; the second discussed avoiding (or resolving) problems frequently encountered when using binary meteorological data files with ISCST; and the third described changing the "wake option switch" implementation in both ISCST and ISCLT.

2.7.2.3 User's Guides on the SCRAM BBS

Originally, users could download air quality models from the SCRAM BBS in a matter of minutes, but needed to order user's guides from the National Technical Information Service (NTIS). In FY-1990, a project was conducted to provide abridged user's guides on the SCRAM BBS for five regulatory air quality models. The user's guides are in WordPerfect format. Because figures are difficult to reproduce in machine-readable form, they were eliminated and the text was reworded where necessary. Also, since a test case and the model code are included in the model file on the SCRAM BBS, these elements were deleted from the user's guides. In the longer user's guides, additional technical discussion was deleted to keep the file sizes to about 80KB and to reduce downloading times.

User's guides for the following models are now available on the SCRAM BBS:

- MPTER, a regulatory model for estimating concentrations of nonreactive pollutants from point sources for averaging times from 1 hour to 1 year.
- RAM (second edition), a regulatory model for estimating concentrations of nonreactive pollutants from point and area sources in urban environments for averaging times from 1 hour to 1 year.
- CDM-2.0, a regulatory model for estimating annual and seasonal average concentrations of nonreactive pollutants from point and area sources.
- CALINE-3, a regulatory model for estimating concentrations of carbon monoxide near transportation facilities for an averaging time of approximately 1 hour.
- ISC (revised second edition, Volume I), a regulatory model for estimating concentrations of nonreactive pollutants from industrial sources for averaging times from 1 hour to 1 year. ISC treats sources as combinations of point, area, and volume sources. ISCST and ISCLT share the same user's guide.

2.7.2.4 Model Clearinghouse

The FY-1990 activities for the Model Clearinghouse included the following:

1. Responding to EPA Regional Office requests to review nonguideline models proposed for use.
2. Reviewing draft and formally submitted *Federal Register* actions.
3. Documenting Clearinghouse decisions and discussions.
4. Summarizing Clearinghouse activities at various meetings.
5. Issuing an internal summary report of FY-1989 activities.
6. Entering FY-1990 records into a computerized database.
7. Providing direct modem access for the Regional Offices to the computerized database.
8. Disseminating Clearinghouse memoranda and reports to the public through a bulletin board system.

There were 103 modeling referrals to the Model Clearinghouse from the Regional Offices during FY-1990. These included 23 regulatory modeling problems, each of which required a written response, 67 referrals, each of which required an oral response, and 13 referrals where discussions took place without Clearinghouse recommendations being requested. Requests for assistance, either written or by telephone, came from the 10 Regional Offices, indicating that there is an awareness of and a desire for Clearinghouse support throughout the Agency.

In FY-1990, the Clearinghouse conducted or participated in coordination and information exchange activities with the Regional Offices. In October 1989, a Clearinghouse report was prepared and distributed to the Regional Offices; the report informed Clearinghouse users about issues and responses that occurred during FY-1989.

The Clearinghouse continued its policy of sending copies of its written responses and incoming requests to the Regional Offices, keeping them informed of decisions affecting their modeling activities. Also during FY-1990, the Clearinghouse continued its policy of attaching to each response an updated list of Clearinghouse memoranda issued during the fiscal year, to help the Regional Offices maintain complete records.

The Model Clearinghouse also continued its policy of seeking advance opinions from the Regional Offices on particularly sensitive issues with national implications. During FY-1990, one such case arose. The proposed Clearinghouse response was discussed in some detail at the 1990 Regional/State Modelers Workshop before the response was finalized.

In FY-1987, the Clearinghouse installed a PC software system, the Model Clearinghouse Information Storage and Retrieval System (MCHISRS), for storing key information on each Clearinghouse referral. The software allows the user to search the MCHISRS database electronically to find records with like characteristics and to consider the consistency aspects of new referrals. There are approximately 800 referrals in the database, including those from FY-1990. A mechanism was developed during FY-1990 that gives the Regional Offices direct access to the national consistency determination precedents for reference.

In FY-1990, Agency memoranda and Clearinghouse reports became available to the public through the SCRAM BBS. The bulletin board includes three types of information: (1) selected historical memoranda on generic/recurring issues generated by the Clearinghouse from FY-1981 through FY-1990; (2) FY-1989 and FY-1990 Clearinghouse memoranda; and (3) the FY-1989 Model Clearinghouse report.

2.7.2.5 Treatment, Storage, and Disposal Facility (TSDF) Analyses

A screening procedure was developed for estimating maximum annual average ground-level concentrations from hazardous constituent emissions from TSDF point sources. This procedure allows a user to determine whether risk levels may be exceeded and whether more detailed analyses may be required. It consists of a family of curves for three generic point-source heights (5 m, 10 m, and 15 m) that yield χ/Q values versus distance, where χ is concentration and Q is pollutant emission rate. These curves were derived by applying the ISCLT model for 15 locations throughout the United States representing differing climatological regimes, and then using the worst-case predictions to derive the χ/Q curves. The procedure will be incorporated into the TSDF guidance documents.

2.7.2.6 Urban Airshed Modeling Guidance

Work supported the development of a draft guidance document for applying UAM, a photochemical grid model, for the development of SIPs. Under Title I of the proposed Clean Air Act Amendments of 1990, photochemical modeling is required for cities with severe and extreme ozone pollution. Also under Title I, development of a comprehensive modeling program is required for ozone attainment demonstration for SIP submittals. The guidance document will ensure consistent application of the modeling program among the EPA Regional Offices and State agencies conducting photochemical modeling studies. The guidance provides information on the procedures for conducting a modeling study program, which include (1) developing a modeling protocol; (2) evaluating meteorological and air quality data needs for the modeling; (3) conducting diagnostic model testing; (4) evaluating model performance; and (5) demonstrating attainment using the modeling results. The document will be published in FY-1991.

2.7.2.7 TSCREEN--An Air Toxics Screening Model

Continued involvement continued in Superfund toxic/hazardous pollutant impact activities created a need for guidance on appropriate screening models. Consequently, the TSCREEN model was developed (U.S. Environmental Protection Agency, 1990b). This personal computer program guides the user through a set of logical decision processes for executing release scenarios described in U.S. Environmental Protection Agency (1988). Many of the 18 scenarios described are applicable to Superfund sites. Based on the information supplied by the user, TSCREEN chooses and executes one of three embedded screening models: (1) SCREEN, for neutral and buoyant continuous releases; (2) RVD, for dense-gas releases; and (3) PUFF, for instantaneous releases. Default values, valid ranges of input variables, extensive help menus, a chemical database library, and a method of easily viewing and saving the modeling results are additional TSCREEN attributes designed to help the user. TSCREEN will be available for distribution through the SCRAM BBS.

2.7.3 Additional Support Activities

2.7.3.1 Regional/State Modelers Workshop

Modelers held their annual workshop on April 23-27, 1990, in Denver, CO; the 30 attendees represented the 10 EPA Regions, the OAQPS, the ASMD, 7 States, and 2 County agencies. Work groups reported on such ongoing projects as complex terrain, highway intersection modeling, air toxics, and model developments. Experts from the NOAA, National Park Service (NPS), U.S. Forest Service (USFS), and National Center for Atmospheric Research (NCAR) presented their agencies' modeling activities. A field trip to the NOAA 300-m instrumented tower east of Boulder, CO, provided an opportunity to observe various profilers in situ. Two members of the AMS Steering Committee discussed advances in turbulence theory, emphasizing how these developments could be used in regulatory modeling situations. In addition, Division personnel participated in five modeling-related workshops at the Regional Offices.

2.7.3.2 Urban Airshed Modeling Workshop

Assistance is being provided in conducting nationwide workshops on the application of UAM. This includes providing technical descriptions of model processors and input data requirements, and conducting hands-on demonstrations of the ROM-UAM Interface Program System. The first workshop was conducted for EPA Region I States in August 1990. Additional workshops are planned for Region V in January 1991, Region VI in February 1991, and Region IV in April 1991.

2.7.3.3 EPA Office of Solid Waste Seminars

The EPA Office of Solid Waste was assisted in the preparation and presentation of nine 3-day seminars on incineration and alternative treatment of energetic compounds to minimize effects to air, soil, and water supplies. The seminars, held throughout the country, were designed to assist writers of EPA permits for waste-handling units, especially those for waste propellants, explosives, and pyrotechnics (PEP). The audience also included manufacturers, handlers, users, consultants, and the general public with an interest in PEP. The lecture outline, abbreviated script, and visual aids that were used to present an overview of items to consider in air assessment constitute Document 7 in the seminar publication series (U.S. Environmental Protection Agency, 1990a).

2.7.3.4 Regulatory Work Groups

Meteorologists provide technical assistance and consultation by participating in various regulatory work groups and task forces. As experts on models, databases, and interpretation of results, they help generate sound technical positions and options on key issues facing policymakers. In FY-1990, Division meteorologists served on the Work Group to Revise the Modeling Guideline; the Technology Transfer Work Group; the Visibility SIP Work Group; the On-Site Meteorological Data Work Group (Chairman); the Valley Stagnation Work Group; the Stack Height Remand Task Force; the NO_2 PSD Increment Work Group; the Open Burning/Open Detonation Technical Steering Committee; and the Emissions/Modeling Work Group for Implementation of Title I of the proposed Clean Air Act Amendments of 1990.

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APPENDIX A: PUBLICATIONS (continued)

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Vukovich, F.M., and J.K.S. Ching. A semi-empirical approach to estimate vertical transport by nonprecipitating convective clouds on a regional scale. *Atmospheric Environment* **24A:**2153-2168 (1990).

APPENDIX B: PRESENTATIONS

Binkowski, F.S., D.W. Byun, R.L. Dennis, and J.S. Chang. Sensitivity of nonlinearity to changes in the emissions of NO_x and VOC. Poster session presented at the NAPAP State of Science/Technology Assessment International Conference, Hilton Head Island, SC, February 11-16, 1990.

Briggs, G.A. Experiments on flushing of pooled dense gas by crosswinds. Seminar presented at North Carolina State University, Raleigh, NC, December 4, 1989.

Castro, I.P. (University of Surrey, Guildford, England). Effects of stratification on obstacle wakes. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, September 17, 1990.

Ching, J.K.S., J. Chang, C. Spicer, and E. Schaller. Investigation of RADM performance using aircraft measurements. Poster session presented at the NAPAP State of Science/Technology Assessment International Conference, Hilton Head Island, SC, February 11-16, 1990.

Clark, T.L. Multi-model evaluation of transport and diffusion across North America. Presentation at the International Conference on Acidic Deposition: Its Nature and Impacts, Glasgow, Scotland, September 19, 1990.

Clark, T.L. ANATEX model evaluation study: Protocol and results. NOAA/ARL seminar, Silver Spring, MD, April 30, 1990.

Clark, T.L. The performance of 11 models in simulating wintertime transport and diffusion up to 2300 km. AREAL seminar, Research Triangle Park, NC, March 29, 1990.

Dennis, R.L. Key findings for atmospheric processes. Presentation at the NAPAP Final Task Force Meeting and Public Briefing, Washington, DC, September 5-6, 1990.

Dennis, R.L. RADM evaluation. Presentation at the NAPAP International Conference, Hilton Head Island, SC, February 11-16, 1990.

Dennis, R.L. State-of-Science/Technology Report 5, Evaluation of regional acidic deposition models. Presentation at the NAPAP State of Science/Technology Assessment International Conference, Hilton Head Island, SC, February 11-16, 1990.

Dicke, J.L. An overview of items to consider in air assessment. EPA Seminar on Incineration and Alternative Treatment of Energetic Compounds to Minimize Effects to Air, Soil and Water Supplies, Kansas City, MO, June 27, 1990.

Dicke, J.L. An overview of items to consider in air assessment. EPA Seminar on Incineration and Alternative Treatment of Energetic Compounds to Minimize Effects to Air, Soil and Water Supplies, Dallas, TX, May 2, 1990.

Doll, D.C. Overview of biogenic emissions inventory system for UAM and applications of the ROM/UAM interface programming system. EPA Urban Airshed Model Demonstration Workshop, New York, NY, August 28-29, 1990.

Doll, D.C. Episode selection for final ROM simulations. Briefing to the Modeling Committee of the Regional Ozone Modeling for Northeast Transport (ROMNET) project, Philadelphia, PA, November 15, 1989.

Gaynor, J.E., C.B. Baker, and J.C. Kaimal. The international sodar experiment. Presentation at the Fifth Symposium on Acoustic Remote Sensing of the Atmosphere and Oceans, New Delhi, India, February 6-9, 1990.

Lawson, R.E., Jr. Concentration distributions in the near-wake of a building. Presentation at the Ninth Symposium on Turbulence and Diffusion, Riso, Roskilde, Denmark, April 30-May 3, 1990.

LeDuc, S.K. Large scale atmospheric flow and surface climate for impact assessment. Seminar presented at the University of North Carolina at Chapel Hill, Department of Geography, Chapel Hill, NC, September 7, 1990.

LeDuc, S.K. Climate change. Invited speaker at Altrusa, Raleigh, NC, February 19, 1990.

LeDuc, S.K. Climate change. Invited speaker at Daniels Middle School, Raleigh, NC, November 13, 1989.

Nappo, C.J. (Atmospheric Turbulence and Diffusion Division, NOAA, Oak Ridge, TN). Gravity waves and turbulence in the planetary boundary layer. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, June 13, 1990.

Novak, J.H. Graphics developments and computer resource issues. Presentation at the Peer Review session of the Regional Oxidant Modeling Program, U.S. Environmental Protection Agency, Research Triangle Park, NC, June 13, 1990.

Novak, J.H. Biogenic emissions. Presentation at the NESCAUM Symposium on the Role and Importance of Nitrogen Oxides Emissions Controls in Ozone Attainment Strategies for Eastern North America, Boston, MA, May 30-June 1, 1990.

Novak, J.H. Scientific visualization--A computing tool for the 1990's. Presentation to the U.S. Environmental Protection Agency, Research Triangle Park, NC, January 23, 1990.

Ohba, R. (Mitsubishi Heavy Industries, Nagasaki, Japan). Numerical and fluid modeling predictions of diffusion around Cinder Cone Butte: Comparison with field data. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, May 10, 1990.

Pierce T.E. Model-predicted ozone transport patterns in the northeastern United States. Video presentation at the 18th International Technical Meeting of NATO/CCMS on Air Pollution Modeling and its Application, University of British Columbia, Vancouver, B.C., Canada, May 15, 1990.

Possiel, N.C. OAQPS/ORD plans to utilize ROM in the Midwest. Briefing for the State Air Pollution Control Directors, Chicago, IL, May 10, 1990.

Possiel, N.C. Results of "Phase 2" ROMNET control strategies. Briefing for the Deputy Assistant Administrator and Staff, Headquarters, U.S. Environmental Protection Agency, Washington, DC, April 17, 1990.

Possiel, N.C. Implications for VOC control strategies of Clean Air Act proposals based on modeling results from ROMNET. Briefing for the Assistant Administrator and Staff, Headquarters, U.S. Environmental Protection Agency, Washington, DC, November 7, 1989.

Possiel, N.C., and W.M. Cox. The relative effectiveness of NO_x and VOC strategies in reducing Northeast ozone concentrations. Presentation at the NESCAUM Symposium on the Role and Importance of Nitrogen Oxides Emissions Controls in Ozone Attainment Strategies for Eastern North America, Boston, MA, May 30-June 1, 1990.

Roberts, A., and D. Rich (Research Triangle Institute). ROMMP: ROM Multi-Processor, An air quality simulation model based on loosely-coupled parallel processors. Seminar presented at the Environmental Research Center Annex, U.S. Environmental Protection Agency, Research Triangle Park, NC, October 26, 1989.

Samson, P.J., and R.L. Dennis. State-of-Science/Technology Report 4, Regional acidic deposition model aggregation and application. Presentation at the NAPAP State of Science/Technology Assessment International Conference, Hilton Head Island, SC, February 11-16, 1990.

Schaller, E., J.S. Chang, J. Pleim, J. Boatman, J.K.S. Ching, and C. Spicer. Intercomparison of measured and modeled late summer trace gas concentration over northeastern Pennsylvania. Poster session presented at the NAPAP State of Science/Technology Assessment International Conference, Hilton Head Island, SC, February 11-16, 1990.

Schatzmann, M. (Meteorologisches Institut, Universitat Hamburg, Federal Republic of Germany). Heavy gas dispersion modeling for risk assessment applications. Seminar presented at the Fluid Modeling Facility, Research Triangle Park, NC, May 23, 1990.

Schere, K.L. EPA ROM applications in the southeast U.S. and modeling activities within the SERON program. Briefing for the State Air Program Directors, U.S. EPA Region IV, Atlanta, GA, September 26, 1990.

Schere, K.L. Regional Oxidant Modeling Program. Presentations at the Peer Review sessions of the Regional Oxidant Modeling Program, U.S. Environmental Protection Agency, Research Triangle Park, NC, June 12-13, 1990.

Schere, K.L. Urban and regional ozone modeling. Invited presentation at the International Workshop on Modeling and Simulation of Atmospheric Dynamics and Pollution, Cuernavaca, Mexico, March 13, 1990.

Schere, K.L. Ozone non-attainment--Modeling studies and needs. Presentation to EPA/AREAL Management Review, Research Triangle Park, NC, March 7, 1990.

Schere, K.L. Meteorological data Q/A and diagnostic tests with grid models. Presentation to the Lake Michigan Ozone Study Team, Chicago, IL, December 12, 1989.

Schere, K.L. Wind field modeling for photochemical models. Presentation to the Lake Michigan Ozone Study Team, Chicago, IL, December 12, 1989.

Schiermeier, F.A. Enhanced version of the EPA Complex Terrain Dispersion Model (CTDMPLUS). Presentation at the Fourteenth US/USSR Working Group Meeting on Air Pollution Modeling, Instrumentation, and Measurement Methodology, Main Geophysical Observatory, Leningrad, USSR, May 28, 1990.

Schiermeier, F.A. Report on plans and implementation of Working Group 02.01-10 on Air Pollution Modeling, Instrumentation, and Measurement Methodology. Presentation at the Twelfth Meeting of the US/USSR Joint Committee on Cooperation in the Field of Environmental Protection, Washington, DC, January 9, 1990.

Schiermeier, F.A. Implementation of Working Group 02.01-10 on Air Pollution Modeling, Instrumentation, and Measurement Methodology. Briefing for the Administrator, Headquarters, U.S. Environmental Protection Agency, Washington, DC, December 13, 1989.

Schiermeier, F.A. Upgrade of the Urban Airshed Model for state implementation plans. Presented at the Standing Air Simulation Work Group meeting, New Orleans, LA, October 13, 1989.

Spicer, C.W., J. Chang, J.K.S. Ching, R.L. Dennis, E. Schaller, T. Kelly, K. Busness, R. Lee, C. Lindsey, and J. Anderson. Diagnostic evaluation of RADM performance during a period of frontal passage using aircraft measurements. Poster session presented at the NAPAP State of Science/Technology Assessment International Conference, Hilton Head Island, SC, February 11-16, 1990.

Touma, J.S. Modeling activities concerning evaluation of area source algorithms and development of TSCREEN. EPA Air Superfund Technical Advisory Committee Meetings, Boston, MA, June 18, 1990.

Touma, J.S. Modeling activities concerning evaluation of area source algorithms and development of TSCREEN. EPA Air Superfund Technical Advisory Committee Meetings, Dallas, TX, March 6, 1990.

Touma, J.S. Modeling activities concerning evaluation of area source algorithms and development of TSCREEN. EPA Air Superfund Technical Advisory Committee Meetings, San Francisco, CA, October 17, 1989.

APPENDIX C: WORKSHOPS

Southern Oxidant Research Program for Oxidant Non-attainment Workshop, Research Triangle Park, NC, November 28-29, 1989.

K.L. Schere

Model Evaluation Team Interpretation Workshop for RADM Evaluation, Research Triangle Park, NC, November 28-30, 1989.

R.L. Dennis

External Review Panel Meeting for RADM Evaluation, Research Triangle Park, NC, December 1, 1989.

R.L. Dennis

Second US-Dutch Expert Workshop on UV-B Measurements, Exposure and Effects, Winston-Salem, NC, December 10-14, 1989.

C.B. Baker

CES Subcommittee on Atmospheric Research Workshop on Strategic Plan for Weather Research, Washington, DC, December 15, 1989.

F.A. Schiermeier

Great Lakes Mass Balance Planning Meeting, Ann Arbor, MI, January 16-17, 1990.

J.F. Clarke

U.S. EPA Advisory Group on Aircraft Measurements (AGAM) Workshop, Albany, NY, February 20-21, 1990.

J.K.S. Ching

NOAA Technical Exchange Conference on National Weather Service Restructuring and Modernization Activities, Columbia, MD, February 25-28, 1990.

J.K.S. Ching

Great Lakes Mass Balance Workshop, Barrie, Ontario, Canada, March 7-9, 1990.

J.F. Clarke

International Workshop on Modeling and Simulation of Atmospheric Dynamics and Pollution, Cuernavaca, Mexico, March 12-16, 1990.

K.L. Schere

EPA Region III State Air Quality Modelers Workshop, State College, PA, March 13-16, 1990.

S.G. Perry

International Workshop on Methane Emissions from Natural Gas Systems, Coal Mining and Waste Management Systems, Washington, DC, April 9-11, 1990.

J.K.S. Ching

Urban Airshed Model Guidance Workshop, Tiburon, CA, April 16-19, 1990.

K.L. Schere

Terrestrial CO_2 Workshop for NOAA Climate and Global Change Program, ATDD, Oak Ridge, TN, April 18-19, 1990.

C.B. Baker

Regional/State Modelers Workshop, U.S. Environmental Protection Agency, Denver, CO, April 23-27, 1990.

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

NAPAP Integrated Assessment Planning Workshop, Washington, DC, May 1-2, 1990.

R.L. Dennis

Incineration and Alternative Treatment of Energetic Compounds to Minimize Effects to Air, Soil and Water Supplies, U.S. Environmental Protection Agency Seminar, Dallas, TX, May 1-3, 1990.

J.L. Dicke

ROSE Workshop on Modeling and Measurements Plan, Boulder, CO, May 15, 1990.

K.L. Schere

A Technical Exchange of the Transport and Diffusion Working Group on Federal Agencies' Response to Hazardous Incidents and Releases, Las Cruces, NM, May 22-24, 1990.

R.E. Lawson, Jr.

Fourteenth US/USSR Working Group 02.01-10 Meeting on Air Pollution Modeling, Instrumentation, and Measurement Methodology, Leningrad, USSR, May 28-June 1, 1990.

F.A. Schiermeier
W.H. Snyder

U.S./Federal Republic of Germany Biennial Workshop on the Photochemical Oxidant Problem and Its Control, Chapel Hill, NC, June 5-7, 1990.

R.L. Dennis
N.C. Possiel, Jr.
K.L. Schere

Hanford Dose Reconstruction Project Workshop, Hanford, WA, June 12-13, 1990.

W.B. Petersen

NOAA/EPA Oxidant Research Workshop, Livingston, AL, June 14-15, 1990.

J.F. Clarke
T.E. Pierce
F.A. Schiermeier

Model Evaluation Team Interpretation Workshop for RADM Evaluation, Research Triangle Park, NC, June 21-22, 1990.

R.L. Dennis

Incineration and Alternative Treatment of Energetic Compounds to Minimize Effects to Air, Soil and Water Supplies, U.S. Environmental Protection Agency Seminar, Kansas City, MO, June 26-28, 1990.

J.L. Dicke

Consortium for International Earth Science Information Network (CIESIN) Task Force Committee, Stratospheric Ozone Depletion, Washington, DC, July 14-18, 1990.

C.B. Baker

APPENDIX C: WORKSHOPS (concluded)

Regional Office Annual Workshop, U.S. Environmental Protection Agency, Greensboro, NC, July 23, 1990.

J.L. Dicke
D.C. Doll
N.C. Possiel, Jr.
J.S. Touma
D.A. Wilson

U.S. EPA Advisory Group on Aircraft Measurements (AGAM) Workshop, Albany, NY, August 13-15, 1990.

J.K.S. Ching

Diagnostic Measurements Team Meeting, Toronto, Ontario, Canada, August 19-22, 1990.

J.K.S. Ching

VOC Reactivity Workshop, U.S. Environmental Protection Agency, Research Triangle Park, NC, August 21, 1990.

K.L. Schere

Bureau Meeting and Steering Body Meeting, European Monitoring and Evaluation Program (EMEP), Geneva, Switzerland, August 27-30, 1990.

R.L. Dennis

Urban Airshed Model Demonstration Workshop, U.S. Environmental Protection Agency, New York, NY, August 28-30, 1990

D.C. Doll

Human Exposure Modeling Workshop Meeting, Las Vegas, NV, September 16-21, 1990.

J.S. Irwin
W.B. Petersen

APPENDIX D: VISITING SCIENTISTS

1. E.Yu. Bezuglaya
   Chief of Laboratory
   Main Geophysical Observatory
   Leningrad, USSR

E.Yu. Bezuglaya spent 2 weeks at the Atmospheric Sciences Modeling Division and the EPA Office of Air Quality Planning and Standards developing a statistical analysis methodology and assessing United States versus Soviet Union air quality trends. This work was performed under the US/USSR Working Group 02.01-10, Project 02.01-14.

2. I.P. Castro, Reader
   Department of Mechanical Engineering
   University of Surrey
   Guildford, Surrey, England

I.P. Castro spent 6 weeks at the Fluid Modeling Facility under a cooperative agreement with North Carolina State University. He conducted experiments in the towing tank to examine the structure of stratified flow over hills, in order to determine the effects of hill shape and slope on wave-breaking aloft and on the dividing-streamline height. He also conducted experiments in the small wind tunnel to test the feasibility of using a pulsed-wire shear-stress probe within the roughness elements of a rough-wall boundary layer. Finally, he ran a numerical model for comparison with results from stratified flow experiments in the towing tank.

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

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

APPENDIX E: ATMOSPHERIC SCIENCES MODELING DIVISION STAFF FISCAL YEAR 1990

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

Office of the Director

Francis A. Schiermeier, Meteorologist, Director
Herbert J. Viebrock, Meteorologist, Assistant to the Director
Marc L. Pitchford, Meteorologist (Las Vegas, NV)
Evelyn M. Poole-Kober, Technical Publications Editor
Joan K. Emory, Secretary

Atmospheric Model Development Branch

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

Fluid Modeling Branch

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

Modeling Systems Analysis Branch

Joan H. Novak, Computer Systems Analyst, Chief
William E. Amos (EPA), Computer Programmer
Dr. William G. Benjey, Physical Scientist (since September 1990)
Dale H. Coventry, Computer Systems Analyst
Thomas E. Pierce, Jr., Meteorologist
Alfreida D. Rankins, Computer Programmer
James A. Reagan (PHS), Statistician
John H. Rudisill, III, Computer Specialist
Barbara R. Hinton (EPA), Secretary

Global Processes Research Branch

Dr. Peter L. Finkelstein, Meteorologist, Chief
Dr. Ellen J. Cooter, Meteorologist (since May 1990)
Brian K. Eder, Meteorologist
Dr. Robert E. Eskridge, Meteorologist (until August 1990)
Dr. Sharon K. LeDuc, Statistician
Dr. Steven G. Perry, Meteorologist
Dr. Francis Pooler, Jr., Meteorologist (until April 1990)
Lawrence E. Truppi, Meteorologist
Hazel D. Hevenor (EPA), Secretary (until August 1990)
Ella L. King (EPA), Secretary (since August 1990)

Applied Modeling Research Branch

John S. Irwin, Meteorologist, Chief
Dr. C. Bruce Baker, Meteorologist
Todd A. Ellsworth, Meteorologist (Philadelphia, PA)(since September 1990)
Dr. Alan H. Huber, Meteorologist
Lewis H. Nagler, Meteorologist (Atlanta, GA)
William B. Petersen, Meteorologist
Everett L. Quesnell, Meteorological Technician
Brian D. Templeman, Meteorologist (since September 1990)
Dana L. Bailey, Secretary (since March 1990)

Air Policy Support Branch

James L. Dicke, Meteorologist, Chief
Dennis G. Atkinson, Meteorologist (since August 1990)
Dr. Desmond T. Bailey, Meteorologist (since May 1990)
Thomas N. Braverman (EPA), Environmental Engineer
Carl T. Culter (EPA), Environmental Protection Specialist
Dennis C. Doll, Meteorologist
Russell F. Lee, Meteorologist
Norman C. Possiel, Jr., Meteorologist
Jawad S. Touma, Meteorologist
Dean A. Wilson, Meteorologist
Brenda P. Cannady (EPA), Secretary

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