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Summary Report of Air Quality Modeling Research Activities for 2006

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Summary Report of Air Quality Modeling Research Activities for 2006

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Notice

The research presented here was performed under the Memorandum of Understanding and Memorandum of Agreement between the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Commerce's (DOC's) National Oceanic and Atmospheric Administration (NOAA). It has been subjected to EPA and NOAA peer and administrative review and has been approved for publication as a joint EPA-NOAA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Abstract

Through a Memorandum of Understanding (MOU) and Memorandum of Agreement (MOA) between the Department of Commerce (DOC) and U.S. Environmental Protection Agency (EPA), the Atmospheric Sciences Modeling Division (ASMD) of National Oceanic and Atmospheric Administration's (NOAA's) Air Resources Laboratory (ARL) develops advanced modeling and decision support systems for effective forecasting and management of the Nation's air quality. As a division within the EPA organizational structure, ASMD is known as the Atmospheric Modeling Division (AMD). The Division is responsible for providing a sound scientific and technical basis for regulatory policies to improve ambient air quality. The models developed by the Division are being used by EPA, NOAA, and the air pollution community in understanding and forecasting not only the magnitude of the air pollution problem, but also in developing emission control policies and regulations. This report summarizes research and operational activities of the Division for the year 2006.

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Chapter 1
Introduction

September 2005 marked the 50th Anniversary of the collaboration between the U.S. Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) and the U.S. Environmental Protection Agency (EPA), and their predecessor agencies on air quality modeling research and its application. The relationship between NOAA and EPA began when the Air Pollution Unit of the Public Health Service, which later became part of the EPA, requested the Weather Bureau to provide it with meteorological expertise. Thus, a special Weather Bureau air pollution unit was formed in 1955 and integrated with the Public Health Service. It was located in Cincinnati, Ohio, until it moved in 1969 to Raleigh, North Carolina. Now called the NOAA Atmospheric Sciences Modeling Division (ASMD), it works within the framework of the Memorandum of Understanding and Memorandum of Agreement between the U.S. Department of Commerce and EPA. These agreements are implemented through long-term Interagency Agreements DW13938483 and DW13948634 between EPA and NOAA.

The Division is organized into five research branches:

- Atmospheric Model Development Branch
- Model Evaluation and Applications Research Branch
- Air-Surface Processes Modeling Branch
- Air Quality Forecasting Research Branch
- Applied Modeling Branch

The first four branches listed above comprise the Atmospheric Modeling Division (AMD) of the National Exposure Research Laboratory of the Office of Research and Development (ORD) within EPA's organizational structure. The fifth branch listed is part of the Air Quality Assessment Division of the Office of Air Quality Planning and Standards (OAQPS) within EPA's organizational structure. Throughout this report, these NOAA-EPA branches will be collectively referred to as "the Division." A listing of employees and division and branch descriptions are located in the appendix along with a listing of awards and publications.

The Division's role within the source-to-outcome continuum is to conduct research that improves the Agency's understanding of the linkages from source to exposure, as depicted in Figure 1-1[1]. Through its research branches, the Division provides atmospheric sciences expertise, air quality forecasting support, and technical guidance on the meteorological and air quality modeling aspects of air quality management to various EPA offices, including OAQPS Regional Offices, state and local pollution control agencies, and other federal agencies.

The Division provides this technical support and expertise using an interdisciplinary approach emphasizing integration and partnership with EPA and public and private research communities. Specific research and development activities are conducted in-house and externally via contracts and cooperative agreements.

In 2006, the Division completed a major strategic planning process begun in 2002. Six outcome-oriented theme areas were identified:

- Providing scientifically-advanced models and tools to support environmental policy decisions
- Evaluating the impact of regulatory policies on air quality and ecosystems
- Linking sources to human exposure
- Linking sources to ecosystem exposure
- Providing air quality forecast guidance for health advisories
- Understanding the relationships between climate change and air quality.

Research tasks were developed within each theme area, considering these questions:

- Over the next 2-3 years, who are the major clients and what are their needs?
- What research investments are needed to further the science in a way that helps the client(s)? How will we lead or influence the science in this area?
- What personnel expertise, resources, and partners are needed to do this work?

[1] Exposure Science Research: A Conceptual Framework, November 2006 Draft by EPA's National Exposure Research Laboratory.

- Does the proposed work fall within the current scope and plans of existing projects, or would people resources need to be shifted from other projects to make this happen?

The result is a research strategy to meet user needs built around six major theme areas and supported by the five branches of the Division, as depicted in Figure 1-2. The Division's Applied Modeling Branch in turn supports these research and development-focused branches by facilitating the transition of atmospheric modeling systems and other research tools to regulatory applications.

This report summarizes research and operational activities of the Division for the year 2006. It includes descriptions of research and operational efforts in air pollution meteorology, meteorology and air quality model development, model evaluation and applications, and air pollution abatement and compliance programs. The report is organized by the major program themes presented in Figure 1-2.

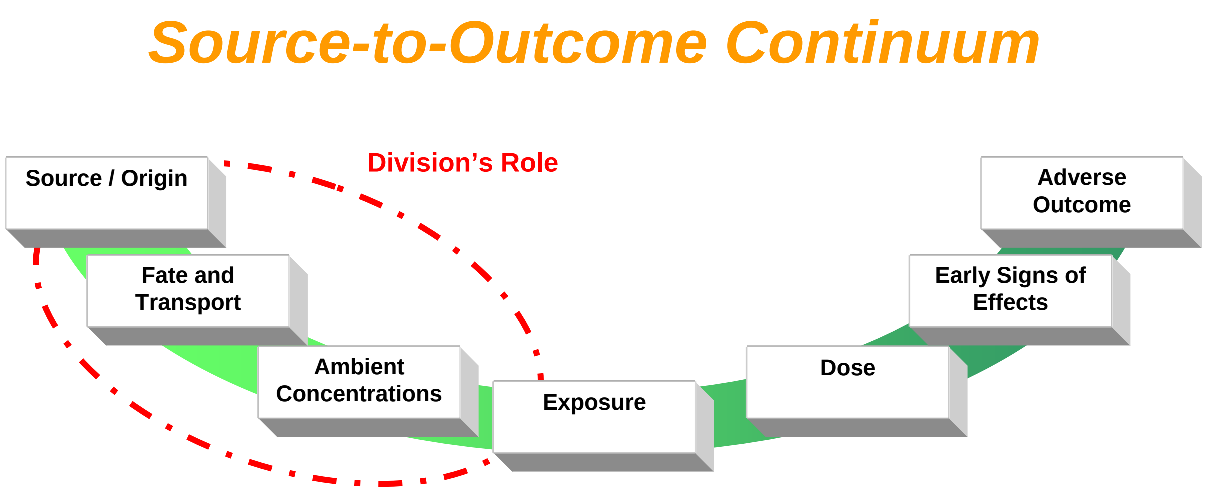

Figure 1-1. The Division's role in the Source-Exposure-Dose-Effects Continuum.

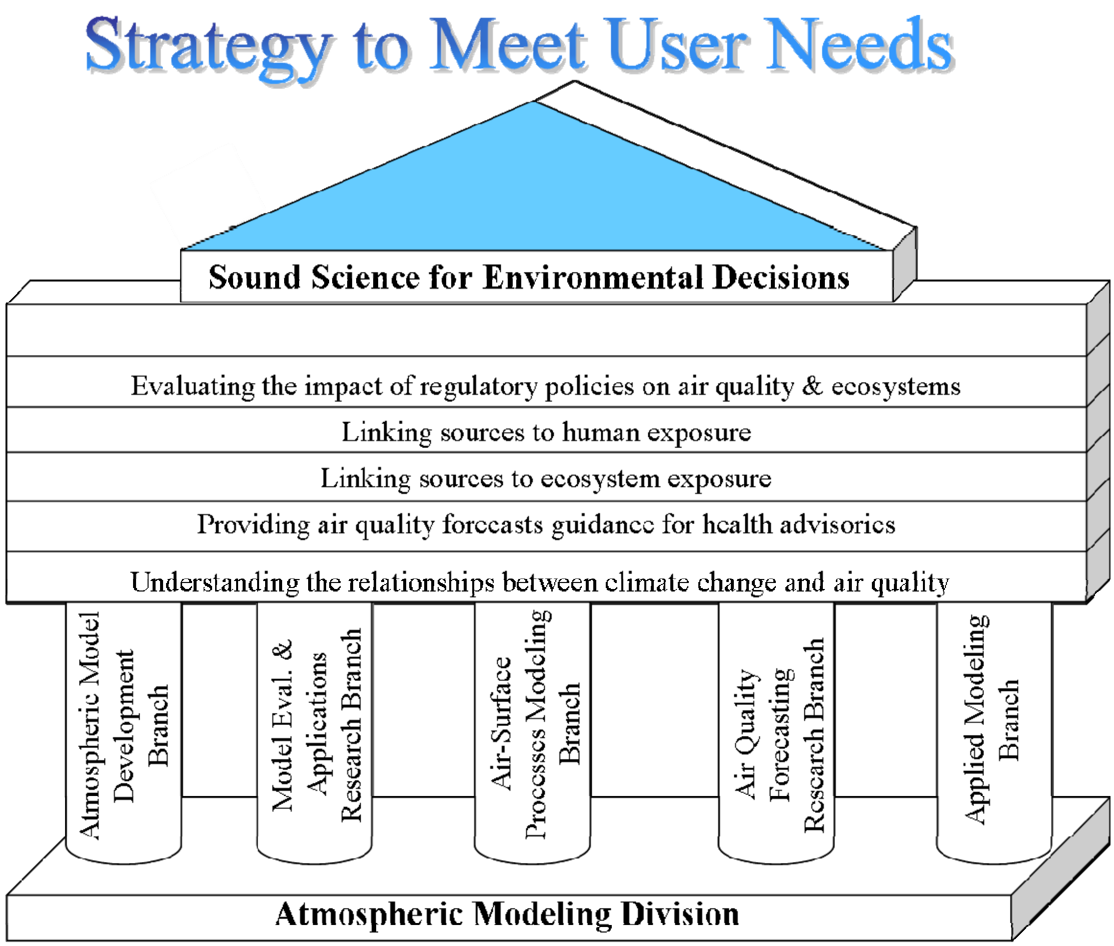

Figure 1-2. Strategy to meet user needs.

Chapter 2
Providing Scientifically-Advanced Models and Tools to Support Environmental Policy Decisions

Introduction

Air quality management in the U.S. is implemented for criteria pollutants through the National Ambient Air Quality Standards (NAAQS). The states must submit state implementation plans (SIPs) for areas that do not meet the NAAQS, demonstrating how additional emissions controls will bring their areas into compliance with the NAAQS. The principal tools that EPA and the states use to demonstrate this compliance are air quality simulation models. Current NAAQS exist for tropospheric ozone (O_3), fine particulate matter ($PM_{2.5}$), coarse particulate matter (PM_{10}), and other criteria pollutants. EPA performs a review of each NAAQS every 5 years, and proposes changes if the most current science on health and ecological effects suggest changing the standards. In 2006, EPA revised the standards for daily average $PM_{2.5}$ from 65 to 35 $\mu g/m^3$, and dropped the annual average standard for PM_{10}, leaving only the daily standard of 150 $\mu g/m^3$. When areas of the country are designated as exceeding the NAAQS for a particular pollutant, the states have at least three years to submit a SIP, including a modeling demonstration illustrating how they intend to mitigate emissions to achieve compliance with the standards.

In addition to the NAAQS for the criteria pollutants, EPA and the states also study mitigation strategies for other types of pollutants, such as hazardous air pollutants (HAPS, or air toxics) and global pollutants, such as mercury. While there are a range of air quality policy-related issues that are tracked separately for individual pollutants, chemistry, and sources involved in producing these air quality conditions are inter-related. Therefore, a multi-pollutant model is needed that can simulate the atmospheric processes and emission source inputs that contribute to all of these chemical species and conditions. The Division develops, evaluates, applies, and refines such models. The principal modeling platform, the Community Multiscale Air Quality (CMAQ) modeling system, includes components for meteorology, emissions, air quality, and analysis with visualization (see Figure 2-1).

Research Description

The principal elements of the modeling program are **Model Development** and **Model Evaluation**. These elements are inter-related, as model evaluation provides information for improving the models, models are improved through research and development, improved models are re-evaluated, and improved models are then available for regulatory application. Hence, the development and evaluation of the models form an iterative process.

Through the **Model Development** program element, the Division develops and improves the CMAQ air quality model for a variety of spatial (urban through continental) and temporal (days to years) scales and for a variety of pollutants (O_3, PM, air toxics, mercury, visibility, acid deposition). The multi-pollutant model approach permits the testing of emissions control strategy impacts on the target pollutant, as well as collateral impacts on other pollutants.

Focus areas of model development include the following:

- Turbulence and diffusion within the planetary boundary layer in the meteorological and air quality models
- Data assimilation
- Consistent linkage of the meteorology model with the air quality and emissions models
- Source emissions modeling including biogenic, wildfire, dust, ammonia, and other anthropogenic emissions
- Gas- and aqueous-phase chemistry
- Aerosol chemistry, physics and thermodynamics
- Sub-grid parameterization and modeling techniques
- Numerical advection and other solution techniques
- Code parallelization and efficiency.

Integrating meteorology and chemistry modeling is a new program priority to provide feedback from air quality parameters (e.g., aerosols) that affect meteorological parameters (e.g., radiation). Developmental areas are guided by the model evaluation results and by model sensitivity and uncertainty tests. New CMAQ model versions are released for public access roughly on a 1-2 year frequency. Workgroups have been formed to focus around these research topics:

- Atmospheric Chemistry and Aerosols
- Two-way interactive Meteorology-Chemical Transport Modeling
- Weather Research and Forecast Model
- Air Toxics Modeling

Through the **Model Evaluation** program element, the Division evaluates the models to characterize the accuracy of model predictions and to identify improvements needed in model processes or model inputs. This requires comparisons against observational data. Different CMAQ simulations (e.g., different model versions, different chemical mechanisms, different vertical layer structuring) are compared to identify the impact of model changes or options on model performance. Uncertainties in meteorological predictions and emission estimates are considered to help identify where improvements are needed. Regulatory Applications of CMAQ are evaluated by comparing model-predicted changes in ozone and aerosols to changes in emission precursors. Model evaluation is conducted through workgroups dealing with these issues:

- Operational evaluations supporting the CMAQ model releases
- Model diagnostics (chemistry, meteorology)
- Model dynamics (i.e., tracking simulated and observed changes in air quality over time)
- Probabilistic evaluation (exploring limits to the deterministic use of model predictions)
- Spatial and temporal analyses of modeled and observed air pollutants

Through these efforts, the Division facilitates the transition of research to the regulatory community.

Accomplishments

During FY-2006, the Division released several new versions of the CMAQ model system to the model user community. CMAQv4.5, released in October 2005, included several advancements in $PM_{2.5}$ modeling capabilities. New to this version of the model were sea-salt aerosol emissions from wind and wave action, along with thermodynamic equilibrium for the phase partitioning of these aerosols in the fine mode (0-2.5 μm diameter). Figure 2-2 illustrates the treatment of particulate matter in the CMAQ model. Chemical reactions involving chlorine were added to the gas-phase chemistry of the CMAQ model as well. This model release also included a carbon source apportionment version of the model, in which explicit tracers are added from various emissions source sectors to track the incremental contributions of these sectors to primary carbon aerosol.

CMAQv4.5 was used to simulate a full year (2001) over the continental U.S. using 36-km grid size in the horizontal and 14 vertical layers extending to 100 mb. Model results for O_3 were compared with data from EPA's Air Quality System network data; model results for $PM_{2.5}$ were compared with data from several surface-based monitoring networks.

CMAQv4.5.1, released in March 2006, extended model capabilities to simulate atmospheric mercury (Hg) concentrations and deposition. The additional processes included elemental mercury (Hg^0), reactive gaseous mercury (RGM), and particulate mercury (Hg(p)) emissions, as well as the chemical reaction pathways to transform Hg^0 into RGM. When deposited in water bodies, RGM produces toxic forms of methylated Hg, which can enter the food chain through ingestion by fish. While the Division had been using research versions of CMAQ-Hg for several years, this was the first time these capabilities were included in a public release version of the model. The Division is participating in the North American Mercury Model Intercomparison Study, a collaboration among several groups in the U.S. and Canada, to compare the results of different atmospheric models for Hg.

CMAQv4.6, released in September 2006, contained several improvements to the chemistry and turbulent diffusion modules. The Carbon Bond 2005 (CB05) chemical kinetic mechanism was added to the model. The new CB05 mechanism, containing 52 species and 156 reactions, provides an extended inorganic reaction set and better representations of O_3 and $PM_{2.5}$ precursor species compared with the previous version. In addition, the latest data on the reaction efficiency of the N_2O_5 hydrolysis reaction was incorporated into CMAQ. This heterogeneous reaction is important in the production of HNO_3 and particulate NO_3. The CMAQ model was also extended to include new hazardous air pollutants (air toxics) including several toxic metals (beryllium, cadmium, lead, manganese, nickel, and chromium) and diesel exhaust components. A new turbulent diffusion module was developed to include both local and non-local components of convective turbulence for mixing of pollutants in the planetary boundary layer. CMAQv4.6 was evaluated by simulating one month in each season of 2001 on a continental U.S. domain (36-km grid cells) and nested eastern U.S. domain (12-km grid cells), using both 14 and 34 vertical layers. Figure 2-3 provides information on July 2001 performance of CMAQ for $PM_{2.5}$ components. Note that the results show reasonably good performance for inorganic species and under predictions for organic aerosols. Note also that, about 25% of the $PM_{2.5}$ mass is classified as other (i.e., unknown constituents) in both observations and model predictions.

In FY 2006, CMAQ model evaluations included more detailed analyses of model performance based on different synoptic weather patterns, chemical mechanisms, vertical resolution, and chemical boundary conditions. These analyses have shown that chemical boundary conditions, the depth of the model's first layer, and the representation of clouds in the model play roles in over predictions of ozone at low observed concentrations. More detailed analyses of the contribution of individual aerosol species to the total $PM_{2.5}$ have identified that the PM "other" category is contributing substantially to over predictions of $PM_{2.5}$ during the fall and winter, suggesting uncertainty in the primary $PM_{2.5}$ emission inventory. Source apportionment or process analysis diagnostic methods have also identified biases in the emissions inventory inputs to the CMAQ model for several primary $PM_{2.5}$ sources.

New advancements in diagnostic evaluation methods have also been emerging. For example, the analysis of CMAQ's particulate NO_3 predictions effectively informed model developers of issues in the chemistry, which were addressed, in part, in the CMAQv4.6 release. In addition, a new metric has been developed to estimate the change in aerosol NO_3 with changes in gaseous SO_2 and NH_3 emissions in the winter. The recent NO_x emissions reductions from eastern U.S. coal-fired power plants present a unique opportunity to assess model response to emissions changes. CMAQ was used to apply these NO_x emission changes to simulate ambient O_3 concentrations. A new probabilistic model evaluation project was begun to explore CMAQ model prediction sensitivities to model physics and chemistry options, and ultimately develop an ensemble of CMAQ predictions.

Next Steps

Over the next several years, science and technology advancements planned for the CMAQ model system include emissions modeling and additional model system evaluation. These are some of the planned milestones:

FY-2007

- Incorporate Weather Research and Forecast (WRF) meteorological model into CMAQ modeling system as a new meteorological driver

FY-2008:

- Release and evaluate new version of CMAQ model system that will include improved simulations of aerosol processes, especially secondary organic aerosol production
- Develop prototype of two-way integrated meteorology/chemistry simulation model based on WRF and CMAQ models

FY-2009

- Add fugitive wind-blown dust emission module to CMAQ modeling system

Impacts and Transition of Research to Applications

The Division releases versions of the CMAQ model and associated programs to the public through the ORD-supported Community Modeling and Analysis System (CMAS) Center. The Center also provides user support and training. The community air quality modeling concept, the CMAQ model in particular, have seen growing acceptance since the model was first released in 1998. An annual CMAQ model-users workshop now attracts over 200 people each year from North America, Europe, and Asia.

EPA's Office of Air Quality Planning and Standards (OAQPS) and the states use the CMAQ model for assessments in national air quality rulemaking and in their State Implementation Plans (SIPs), respectively. OAQPS has used the CMAQ model to assess the potential effectiveness of the Clean Air Interstate Rule and the Clean Air Mercury Rule as a part of EPA's rule making process. The states, through their Regional Planning Organizations, are using the CMAQ model for visibility assessments in support of the Regional Haze Rule and for upcoming SIP assessments for O_3 and $PM_{2.5}$. The CMAQ model is also being used in Canada, the U.K., Spain, Eastern European Countries, China, Korea, and many other nations in programs to improve regional air quality management. NOAA's National Weather Service, in a collaborative project with EPA, is using the CMAQ model to make publicly-available short-term (next-day) forecasts of ozone air quality across the eastern U.S. (See Chapter 6).

The effects of all of these efforts will be to better inform the public on current air quality conditions (forecasting applications) to help them make decisions on health-related exposures to air pollution, and to better inform policy makers (air quality model assessments) to guide them in the best long-term emissions control decisions to reduce air pollution.

The part of the Division organizationally associated with OAQPS oversees and facilitates the process of transitioning tools to regulatory applications, thus providing the foundation for scientifically sound regulatory decisions.

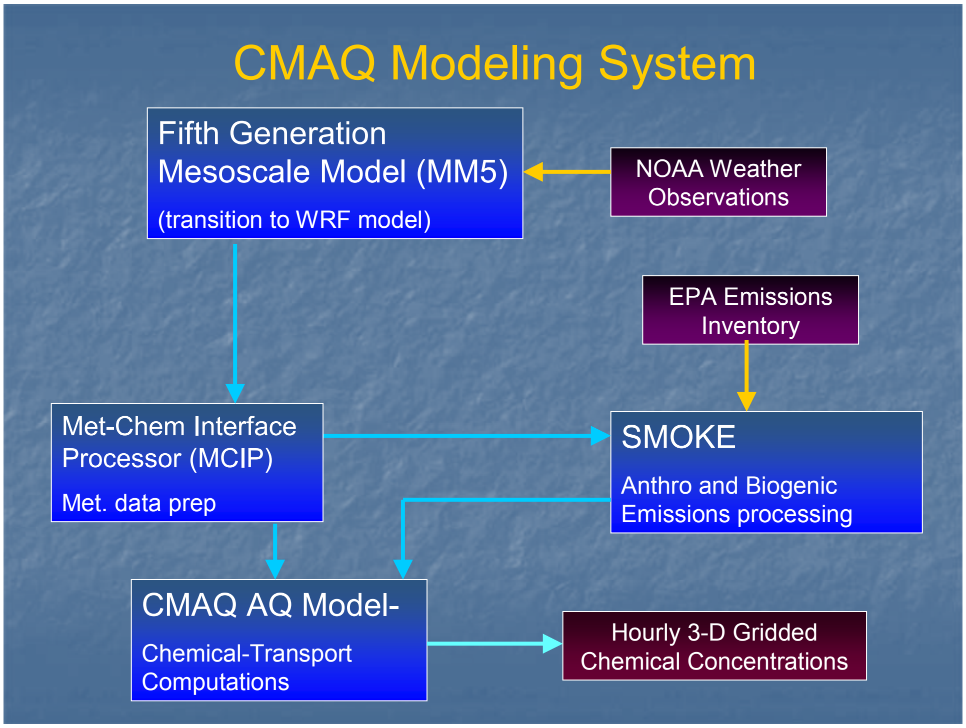

Figure 2-1. Schematic of CMAQ modeling system, including meteorology, emissions, and air quality models.

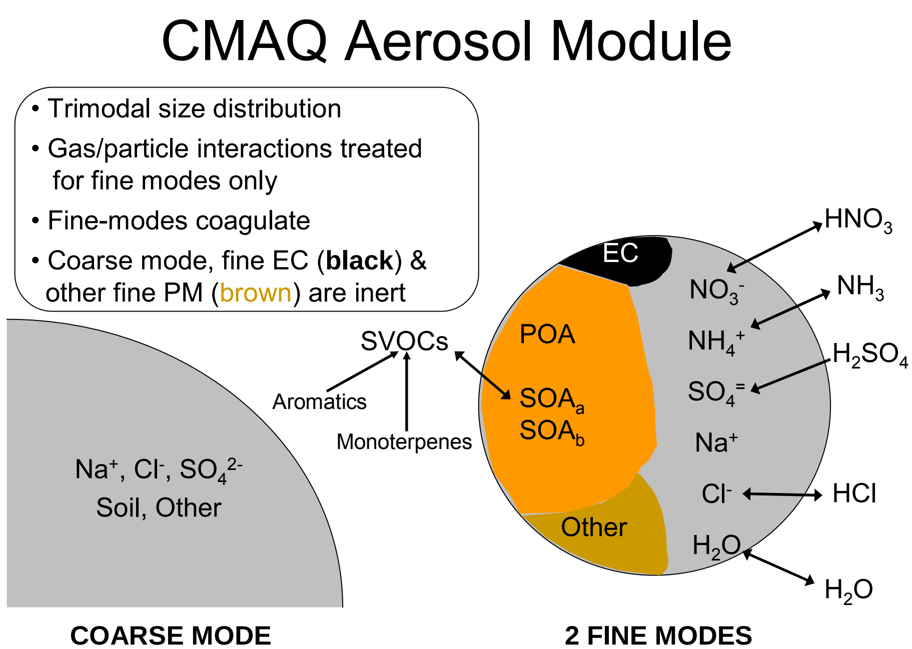

Figure 2-2. Schematic of particulate matter/aerosol module in CMAQ model.

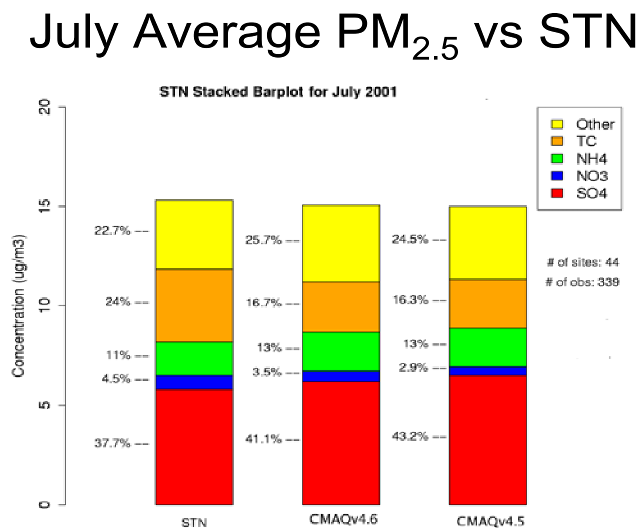

Figure 2-3. Comparisons of monthly average $PM_{2.5}$ species components observed at eastern U.S. STN sites with comparable results from CMAQv4.5 and CMAQv4.6 (from eastern U.S. simulation with 12-km grids).

Chapter 3
Evaluating the Impact of Regulatory Policies on Air Quality and Ecosystems

Introduction

The majority of the criteria pollutants are transported across state boundaries, complicating the non-attainment issue. Recent EPA rulemakings have recognized that this transport must be considered in meeting NAAQS, requiring a regional perspective when developing strategies for air pollution non-attainment.

In 1998, EPA finalized a rule known as the "NO_x SIP Call," requiring 22 states and the District of Columbia to submit SIPs that address the regional transport of ground-level ozone. The actions directed by these plans include reducing emissions of nitrogen oxides (NO_x), a precursor to ozone formation, thereby decreasing the formation and transport of ozone across state boundaries.

The recent Clean Air Rules are a suite of actions designed to improve air quality. Three of the rules specifically address the transport of pollution across state borders. The Clean Air Interstate Rule (CAIR) will permanently cap emissions of sulfur dioxide and nitrogen oxides from utilities in the eastern United States. When fully implemented in 2015, CAIR will reduce SO_2 emissions in these states by over 70 percent and NO_x emissions by over 60 percent from their 2003 levels. The Clean Air Mercury Rule (CAMR) will build on the CAIR to reduce mercury emissions from coal-fired power plants. The Non-Road Diesel Rule will reduce emissions from future non-road diesel engines by changing the way diesel engines function to remove emissions and the way diesel fuel is refined to remove sulfur.

Deposition of atmospheric nitrogen, sulfur, and mercury to land and water surfaces contributes significant loadings to receiving water bodies, affecting ecosystems health. For example, atmospheric deposition of nitrogen accounts for about 30% of the nitrogen coming into the Chesapeake Bay. CAA regulations, including the NO_x SIP Call, CAIR, and CAMR are expected to reduce atmospheric deposition of these pollutants.

Research Description

Given the significant costs associated with these rules and control measures, it is important to demonstrate their effectiveness. The Division has demonstrated reductions in observed and modeled ozone concentrations resulting from actions of the NO_x SIP Call. Research will continue to develop ways to systematically track and periodically assess our progress in attaining national, state, and local air quality goals - particularly those related to criteria pollutants regulated under the NAAQS and the Clean Air Rules.

Research under this Theme area falls into two categories:

- Evaluating changes in ambient pollutant concentrations and atmospheric deposition due to the implementation of emission reductions
- Investigating relationships between emissions, ambient pollutant concentrations, human exposure, and human health endpoints.

The major research questions addressed by this research include the following:

- Did our control strategies result in the anticipated emission reductions?
- Did our models accurately predict the changes in pollutant concentrations and atmospheric deposition due to the control strategies?
- What are the human and ecosystem health consequences of these reductions?

This research will support the accountability program to develop tools and techniques for assessing the effectiveness of control strategies. The CMAQ model will be used to characterize air quality before and after the implementation of a target regulation and to evaluate relationships between changes in emissions and pollutant concentrations or atmospheric deposition. Various scenarios will be modeled to estimate the anthropogenic contribution to total ambient concentrations and the impact of not promulgating the regulation. Methods will also be developed to differentiate changes attributable to emission reductions from those resulting from other factors, such as weather and annual and seasonal variations.

Research will initially focus on NO_x and SO_2 where emissions monitoring data are available. Later, research will investigate using other sources of information (e.g., remote sensing, surrogate measures) to evaluate pollutants such as particulate matter and mercury where emissions data are sparse or uncertain.

In addition, the relationship between meteorology and the regional-scale transport of pollutants will be investigated. Specifically, the effect of a target regulation on downwind concentrations will be assessed. Trajectory analysis, using NOAA's HYSPLIT model, will be performed to investigate the transport of primary and secondary pollutants from their source to downwind regions, as illustrated in Figure 3-1. Source regions responsible for atmospheric deposition to water bodies downwind will be investigated using similar methods.

Methods to statistically combine modeled and observed data will be developed to improve the characterization of air quality and deposition. These enriched air quality concentration and deposition maps will be used to improve and track pollutant control programs and their impact on ecosystem and human health. The enriched surface maps will also be used with exposure models to estimate the probability that a population will be exposed to an atmospheric pollutant.

Accomplishments

In FY 2006, substantial progress was made in comparing the ozone levels before and after the implementation of the NO_x SIP Call (see Figure 3-2 for example). The analysis of NO_x emissions data from Electric Generating Units (EGUs) indicated that utility NO_x emissions at both the source and at downwind monitors were reduced substantially by May 2004 because of the implementation of the NO_x SIP Call.

The influence of meteorology was assessed by analyzing ozone and meteorological data collected at the CASTNET sites, a national monitoring network for data on dry acidic deposition and rural, ground-level ozone, and controlling for meteorology in CMAQ model runs. In addition to reduced NO_x emissions, the changes in the meteorologically-adjusted ozone concentrations between the pre- and post- NO_x SIP Call periods indicated that the NO_x SIP Call resulted in a reduction to the secondary formation of ozone at sites downwind from the reduced emissions. The results from the trajectory analysis supported this potential source-receptor relationship and revealed that NO_x and ozone can be transported hundreds of kilometers from their sources aloft via the nocturnal jet stream. The results of this investigation indicated that emission controls on EGUs in the Midwest have contributed toward the improvement of ozone air quality in downwind regions, especially east and northeast of the Ohio River Valley.

Next Steps

Research conducted under this Theme Area will evaluate changes in pollutant concentrations resulting from regulatory actions and investigate relationships among sources of emissions, pollutant concentrations, atmospheric deposition, and human and ecosystem health. The following major milestones are planned:

FY-2008

- Develop methods to quantify the impact of the NO_x SIP Call on ambient ozone concentrations and atmospheric transport of pollutants, including impacts of not implementing the regulation and quantifying the anthropogenic contribution.

FY-2009

- Develop methods to quantify the probability of ozone exposure above exceedance levels to populations before and after the NO_x SIP call was implemented.
- Conduct a prototype risk assessment to examine the health impact of simulated emission scenarios.

FY-2010

- Develop approaches for characterizing the magnitude of changes in hospital admissions in New York State resulting from the NO_x SIP Call.

FY-2012

- Apply prototype ambient concentration tracking method to evaluate impact of the CAIR on ambient and deposition concentrations.
- Apply prototype deposition approach to evaluate impact of CAIR on ecological exposure endpoints in major water bodies.

Impacts and Transition of Research to Applications

Quantifying the improvement in air quality and human and ecological health brought about by costly regulations is critical in evaluating whether these actions are making the difference originally anticipated. This research will evaluate the impact and effectiveness of specific regulatory actions. Methods developed for these evaluations will also provide a framework for assessing future regulatory actions. These methods will include

- data combination techniques
- model evaluations for different regulatory and emission scenarios
- approaches for tracking trends embedded within spatial and temporal signals and confounded by factors such as meteorology
- evaluation of the impacts of regulatory actions on human and ecological exposure and health.

This effort transitions research to applications by demonstrating the use of CMAQ, HYSPLIT, and various statistical techniques to evaluate the impact of regulations implemented to improve air quality.

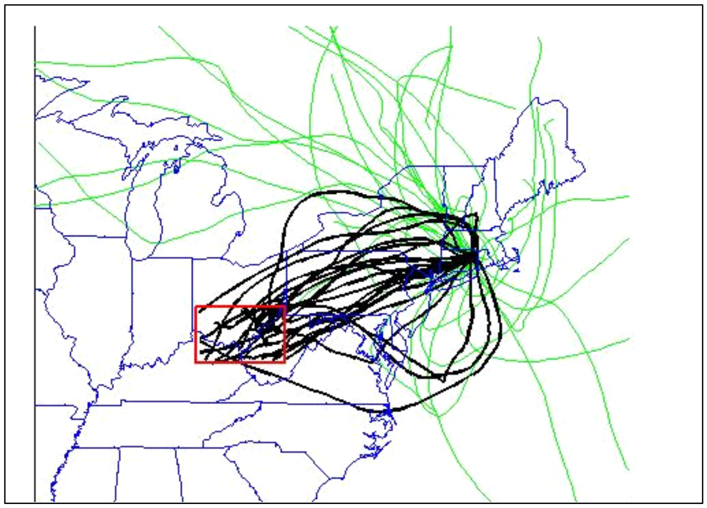

Figure 3-1. Back trajectories show Ohio River Valley as source region for high ozone levels at a site in the northeast (green trajectories indicate source regions of low ozone days and black trajectories indicate source regions of high ozone days) during the 2002 summer.

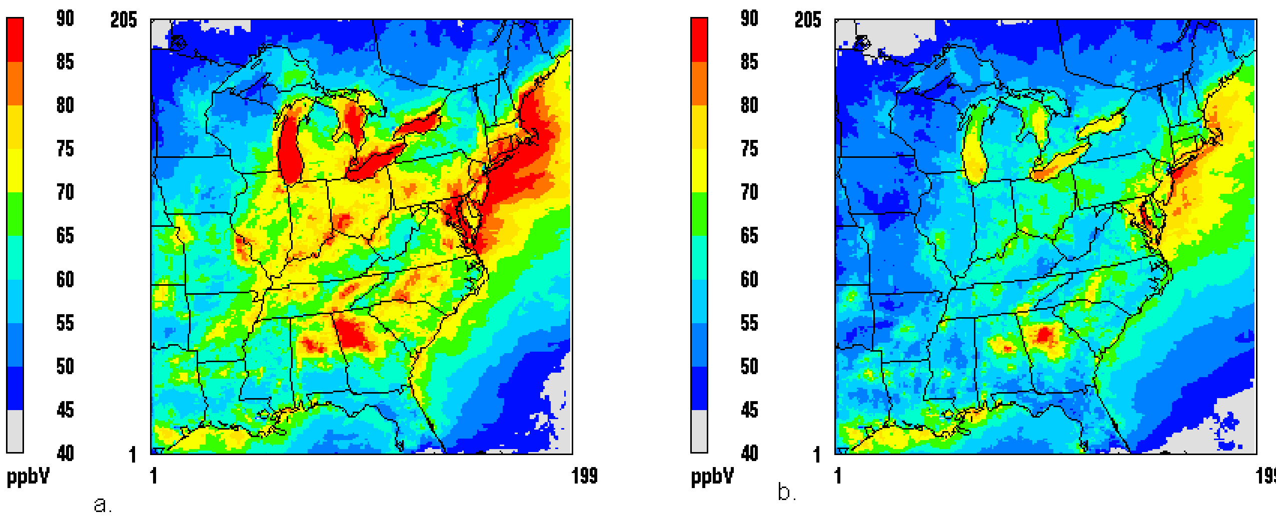

Figure 3-2. NO_x SIP Call evaluation showing daily maximum 8-hr ozone concentrations at 95th percentile for (a) summer 2002, and (b) summer 2004.

Chapter 4

Linking Sources to Human Exposure

Introduction

The Clean Air Act requires EPA to assess which hazardous air pollutants pose the greatest risk to humans in the United States, and to develop strategies for controlling harmful concentrations of these compounds. These assessments typically involve the application of different models depending on program objectives – national, regional, urban, or locale scale (Figure 4-1). Performing these assessments requires a link between ambient air quality and human exposure models. The Division conducts research to build this link by combining the features of grid-based, regional-scale, chemical transport models and urban-scale, dispersion models. This research facilitates the use of air quality model concentrations in human exposure models, which historically have relied upon monitored concentrations at a central site.

For exposure assessments, air quality modeling should include local-scale features, long-range transport, photochemistry, and deposition to provide the best estimates of air concentrations. Generally speaking, there are two major types of air quality models: source-based gaussian dispersion models and grid-based chemical transport models. Chemical transport models, such as the CMAQ model, can provide estimates of photochemically formed pollutants typically at 12-km grid dimensions, but not local-level details. CMAQ provides volume-average concentration values for each grid cell in the modeling domain for given conditions. Emissions are assumed to be instantaneously well-mixed within the grid cell in which they are emitted. While grid-based models are the platform of choice for this simulation of chemically-reactive airborne pollutants, there are various dispersion models (such as AERMOD[2]) that have been developed to simulate the fate of airborne pollutants that are relatively chemically inert.

Research Description

To incorporate the salient features of both modeling approaches, the Division has been testing a hybrid approach that combines results from a regional grid model with a local plume model. The regional grid model provides the regional background concentrations and urban-scale photochemistry, and the local plume dispersion model provides the air concentrations due to local emission sources. The results of both model simulations are combined to provide the total ambient air concentrations for use in exposure models. The advantage of using this modeling approach is that it incorporates the spatial and temporal variation of air pollution within a study area in lieu of dense ambient monitoring networks. This hybrid approach is currently being explored in several studies, including the air quality and exposure study in Detroit and the accountability study in New Haven, CT.

The goal of this research theme is to reduce uncertainties in quantifying the link between sources of atmospheric pollution and human exposure. The Division's work in this theme is broken into the following research tasks:

- Multi-scale modeling of toxic air pollutants
- Near-roadway modeling
- Homeland security support

Accomplishments

The CMAQ modeling system has been modified to include HAPS, and its results have been coupled with the near-field dispersion model AERMOD to account for urban-scale gradients of air toxics. In addition, outputs from this coupled system have been successfully linked to the Stochastic Human Exposure and Dose Simulation (SHEDS) exposure model and the Hazardous Air Pollutant Exposure Model (HAPEM). This research has been performed in collaboration with scientists from NERL's Human Exposure and Atmospheric Sciences Division (HEASD) and OAR's Office of Air Quality Planning and Standards (OAQPS).

During FY-2006, the Division embarked upon the Near-Roadway and School Infiltration Research Initiative. The overall goal of this EPA ORD-sponsored effort is to examine the contribution of roadway air pollutants to sensitive populations living near roadways. As part of this initiative, the Division started a numerical and physical modeling study to examine the impact of typical road configurations on downwind concentration patterns. The road configurations being studied include noise barriers, road cuts, and elevated highways. This study was motivated by a lack of parameterizations in current roadway dispersion models. To complement work in the meteorological wind tunnel, the Quick Urban Industrial Complex (QUIC) model is being applied to help in developing parameterizations and to explore field monitoring in Raleigh, NC, and Las Vegas, NV.

Because of a decrease in funding, research related to Homeland Security received less attention in FY-2006 than in previous years. A 1:400 scale model of midtown Manhattan has been constructed for insertion in the meteorological wind tunnel, when and if resources allow.

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[2] Cimorelli, A.J., S.G. Perry, A. Venkatram, J.C. Weil, R.J. Paine, R.B. Wilson, R.F. Lee, W.D. Peters, and R.W. Brode. AERMOD: A Dispersion Model for Industrial Source Applications. Part I: General Model Formulation and Boundary Layer Characterization. *Journal of Applied Meteorology,* 44, 682–693 (2005).

Next Steps

During the next few years, the Division is expected to build in the areas of near-roadway modeling and linkage of air quality models with human exposure models to assess human health. Planned milestones include the following:

FY-2008

- Characterization of near roadway dispersion

FY-2009

- CMAQ model system release and evaluation, including concurrent multi-pollutant modeling capability (O_3, PM, air toxics, Hg)

FY-2010

- Development of line source algorithms for near-field and hybrid models

FY-2012

- Improved CMAQ modeling system for use in urban-scale applications.

Impacts and Transition of Research to Applications

The Division conducts research to link ambient air quality and human exposure models. Application of these linked models helps policy-makers to develop control strategies targeting those hazardous air pollutants identified as posing the greatest risk to humans.

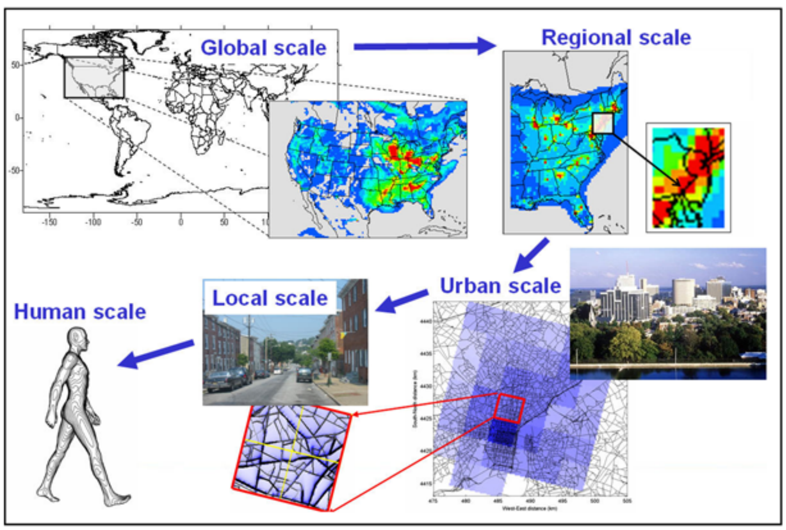

Figure 4-1. Multiple scales in air quality modeling.

Chapter 5
Linking Sources to Ecosystem Exposure

Introduction

Ecosystems provide resources and services that contribute to our social and economic welfare. A long-term goal of environmental management is to achieve sustainable ecological resources through a comprehensive assessment of current and projected ecosystem health. Such an assessment must include identification of the major threats (in the form of specific stressors) to ecosystem health, the source of those stressors, and how they move through the environment. This is fundamentally a problem of multimedia pollution.

The overall objective of this work is to develop the atmospheric components of multimedia modeling and assessment tools to allow better management and protection of ecosystems and their associated resources and services. The Division is developing a suite of linked models, tools, and technology to provide long-range ecological forecasts and a scientific basis for decision-making to protect aquatic ecosystems. This research supports EPA's expanded definition of air quality management that includes ecosystem protection in regulatory assessments of air pollution regulations, i.e., setting of secondary NAAQS. It also supports EPA's renewed emphasis on linking sources to exposure in a multi-pollutant context and developing capabilities for ecosystem risk assessment.

The interaction between the atmosphere and the underlying surface is increasingly being recognized as an important factor in multimedia issues. Atmospheric deposition is an important source of ecosystem stressors, in particular for acidification, eutrophication of coastal estuaries due to excess nitrogen, and bioaccumulation of mercury. Critical load is the amount of deposition above which natural resources can be negatively affected and is intended as a protective threshold. The National Academy of Sciences (NAS) has recommended that EPA consider a critical load approach to ecosystem management.[3] In support of this recommendation, the Division conducts research to provide the most accurate atmospheric deposition estimates possible.

The Clean Water Act administered by the EPA requires states to develop Total Maximum Daily Load limits (TMDLs), the maximum amount of a pollutant that a body of water can receive while still meeting water quality standards. While the atmosphere is an important contributor to stressors such as excess nutrients, atmospheric deposition is seldom considered in the development of TMDLs. The Division's research has been improving our understanding of the atmospheric contribution of stressors to TMDLs.

Research Description

For this research theme, the Division has identified research areas that have the greatest potential to reduce critical uncertainties in atmospheric deposition, assess program accountability, and link atmospheric deposition to ecosystem resources and services.

Specific research tasks are grouped under one of the following research program elements:

- Air-Surface Research and Development
- Multimedia Applications
- Multimedia Tool Development

Through the **Air-Surface Research and Development** program element, the Division develops and advances air-surface exchange modules for CMAQ and advances the linkage between CMAQ and the underlying land-use categories to facilitate improved interactions with ecosystem models. The Division also develops and advances air-surface exchange modules for monitoring network operations using an inferential method for dry deposition, focusing primarily on sulfur, nitrogen, and mercury species. Bi-directional air-surface exchange process is a new feature of this program element.

Focus areas of **Air-Surface Research and Development** include the following:

- Dry deposition of fine particles

[3] Committee on Air Quality Management in the United States, National Research council. 2004. Air Quality Management in the United States. Washington, DC: National Academy of Sciences.

- Uni-directional deposition of gases
- Bi-directional flux (air-surface exchange) of ammonia
- Bi-directional flux of mercury
- Land-surface interface within the CMAQ system to support bi-directional fluxes
- Land-use specific flux determination by CMAQ for linkage with ecosystem models
- Dry deposition and bi-directional flux module adaptations for network operations

Through the **Multimedia Applications** program element, the Division develops and improves linkages between air and water models and connections to ecosystem resources and services through participation with partners in multimedia assessments. National coverage of deposition estimates is an important output for these efforts (see Figure 5-1).

Focus areas of **Multimedia Applications** include the following:

- Chesapeake Bay 2007/2008 Re-evaluation and 2010 TMDL assessment
- Tampa Bay assessment
- Coastal air-water model linkage development to address water quality issues
- Gulf of Mexico studies

Through the **Multimedia Tool Development** program element, the Division develops tools for specialized multimedia analyses and applications involving atmospheric models. The need for specialized tools is especially pertinent to bringing atmospheric components together with watershed components for multimedia management analyses. Most off-the-shelf tools do not address the specialized needs or applications encountered in analyzing data from a multimedia perspective. Significant effort is often required to analyze observations and model results and provide them in a form required to support management decisions.

Focus areas of multimedia tool development include the following:

- Allocation of spatial data to a CMAQ-useable gridded form
- Watershed deposition tool to overlay gridded CMAQ output onto a selected set of watershed segment polygons
- Updating CMAQ visualization tools to be based on Java

Accomplishments

The Division collaborated with Canadian colleagues to compare their respective models that estimate dry deposition for network operations, the Routine Deposition Model (RDM) for Canada and the Multi-Layer Model (MLM) for EPA's Clean Air Status and Trends Network (CASTNET). Required input data for each model were measured at the same monitoring site in Canada. These measured concentrations agreed quite well with each other. However, there were large differences in the deposition velocities calculated by MLM and RDM due to different assumptions about how to parameterize the dry deposition velocities. These differences are now being investigated.

An evaluation of the MLM for estimating dry deposition used in CASTNET pointed to areas for model improvement. In response, the Division developed the Multilayer Biochemical Model (MLBC) as a replacement for the MLM mode, and made progress towards implementing the MLBC for network operations.

The Division partnered with the Chesapeake Bay Program Office to provide a series of CMAQ estimates of future atmospheric nitrogen deposition out to 2020 simulating growth and implementation of new air regulations. The new regulations include the Clean Air Interstate Rule (CAIR) the Clean Air Mercury Rule (CAMR) and the Clean Air Visibility Rule (CAVR). Figure 5-1 shows the 2001 base-case nitrogen deposition against which the future scenarios are compared. A significant decrease in nitrogen deposition from NO_x emission reductions is expected, but the growth in ammonia emissions erodes these benefits.

The Division used CMAQ to estimate the relative contribution of NO_x emissions from mobile sources, power plants, and industry to nitrogen deposition in the Chesapeake Bay watershed. The Division also investigated uncertainties in the CMAQ model for estimating dry deposition of nitrogen to the Chesapeake Bay watershed, specifically examining the uncertainty in the efficiency of the N_2O_5 hydrolysis reaction that produces nitric acid and uncertainty in the deposition rate for ammonia. After reviewing the results, the uncertainties in the dry deposition estimates provided to the Chesapeake Bay watershed modeling team were deemed to be within acceptable bounds. An analysis of ammonia sources and sinks with CMAQ showed that the uncertainty in ammonia dry deposition rate can significantly affect the area of influence of a region of high ammonia emissions.

The Division completed the evaluation of CMAQ-UCD, a sectional version of CMAQ with code developed at the University of California, Davis (UCD) that incorporates sea salt influences. Model estimates compared well with the Bay Regional Air Chemistry Experiment (BRACE) aircraft data. The finding that almost half the total nitrate budget in Tampa Bay is associated with coarse particle sea salt also agreed with the observations. These comparisons set the stage for the Tampa Bay assessment to be completed in FY 2007.

The Watershed Deposition Tool (WDT) is designed to allow users to read seasonally- or annually-averaged CMAQ files in native format, and calculate a weighted-average deposition or change in deposition for selected watershed hydrologic units. The Division made improvements to the WDT, adding the capability to export GIS Shape files and to continue from the point of exit from a previous work session. The revised WDT received favorable reviews. Public release of the revised WDT is planned for spring 2007.

Next Steps

Over the next several years, advancements are planned for the multi-media theme area to investigate more sophisticated futures scenarios for air-water linkages and to adapt the CMAQ modeling system, to calculate bi-directional exchange of ammonia and mercury and to more closely couple to ecosystems models. Some of the planned milestones are:

FY-2007

- Release of MLBCNet to the public, coordinated by EPA's Clean Air Markets Division (CAMD) of the Office of Air Programs
- Additional Chesapeake Bay scenarios commissioned by the Bay Program. Source responsibility calculations re-evaluated
- Completion of the Tampa Bay Assessment for the Tampa Bay National Estuary Program
- Bi-directional NH_3 flux algorithms incorporated into CMAQ
- Release of the Watershed Deposition Tool to the public
- Spatial Allocator configured to grid the new National Land Cover Data (NLCD) to CMAQ grids

FY-2008

- Chesapeake Bay futures scenarios simulated with 12-km grid cell sizes for the eastern US
- Bi-directional NH_3 flux version of CMAQ run for Chesapeake Bay sensitivity
- New mosaic land-use interface incorporated in CMAQ for better communication with ecosystem models
- Bi-directional Hg flux paradigm defined

FY-2009

- Chesapeake Bay scenarios run with mercury in addition to sulfur and nitrogen
- Advanced land-surface layer to support bi-directional flux calculations incorporated in a science version of CMAQ
- Preliminary regional air-water model linkage pilot study completed for nitrogen and mercury

Impacts and Transition of Research to Applications

The Clean Air Status and Trends Network (CASTNET) monitors concentration and dry deposition at sites across the country to assess long-term trends in air quality, dry deposition, and environmental protection resulting from regulatory policies and emission reductions required under the Clean Air Act. CASTNET is considered the primary source for estimates of dry acidic deposition and is vital to the Agency's efforts in the protection of terrestrial and aquatic ecosystems. The Division's development of an improved model (MLBC) for dry deposition estimates is a key component of CASTNET's success.

The major connection between the atmosphere and ecosystems is through air-surface exchange, which includes deposition, and for some pollutants also includes a bi-directional flux. Significant ecosystem stressors that result from air-surface exchange include acidifying deposition of nitrogen and sulfur, neutralizing deposition of base cations, and eutrophying deposition of reduced and oxidized nitrogen. EPA program offices such as Office of Water and Office of Air and Radiation and states use this information to support their policy decisions affecting TMDLs, atmospheric emissions, and coastal management.

Estimates of the expected changes in atmospheric deposition to the Chesapeake Bay watershed contribute significant information on nitrogen loading that is used by the Chesapeake Bay Program to manage the Chesapeake Bay. This supports the Chesapeake Bay Program's commitment to reducing nitrogen loads in the Chesapeake Bay by 2010 with the help of reductions in atmospheric deposition. In addition, this work provides an important test bed for linking atmospheric models with watershed models and is a flagship of multimedia planning and benefits assessment for a coastal estuary.

Air deposition reductions are a key element of the Tampa Bay TMDL implementation strategy required by the Clean Water Act. This work will significantly reduce the uncertainty in the estimates of nitrogen loading due to atmospheric deposition to Tampa Bay watershed basins and bay segments used in the Tampa Bay TMDL. The model-estimated effect of court-ordered nitrogen oxide (NO_x) emissions reductions from two electric generating plants adjacent to the bay will provide Tampa the best estimate of nitrogen deposition reductions across the bay and the watershed attributable to known NO_x emission reductions expected to occur by 2010. The model-estimated effects of deposition reductions due to the recent clean air rules will assess whether these rules are keeping up with or out-pacing the effects of growth.

Addressing multimedia issues often requires working with multiple types of models and data sets. Proper software tools allow environmental scientists and managers to perform their work with less effort and allow them to develop insights that they might have missed. The software tools developed by this project are for community use, but will allow EPA and the states to conduct their work more effectively and efficiently and provide for a more complete multimedia approach. These tools will allow new users to be able to take advantage of the results of the more advanced air quality models for multimedia applications. The tools will also allow ecosystem and watershed managers to take atmospheric deposition into account in their planning.

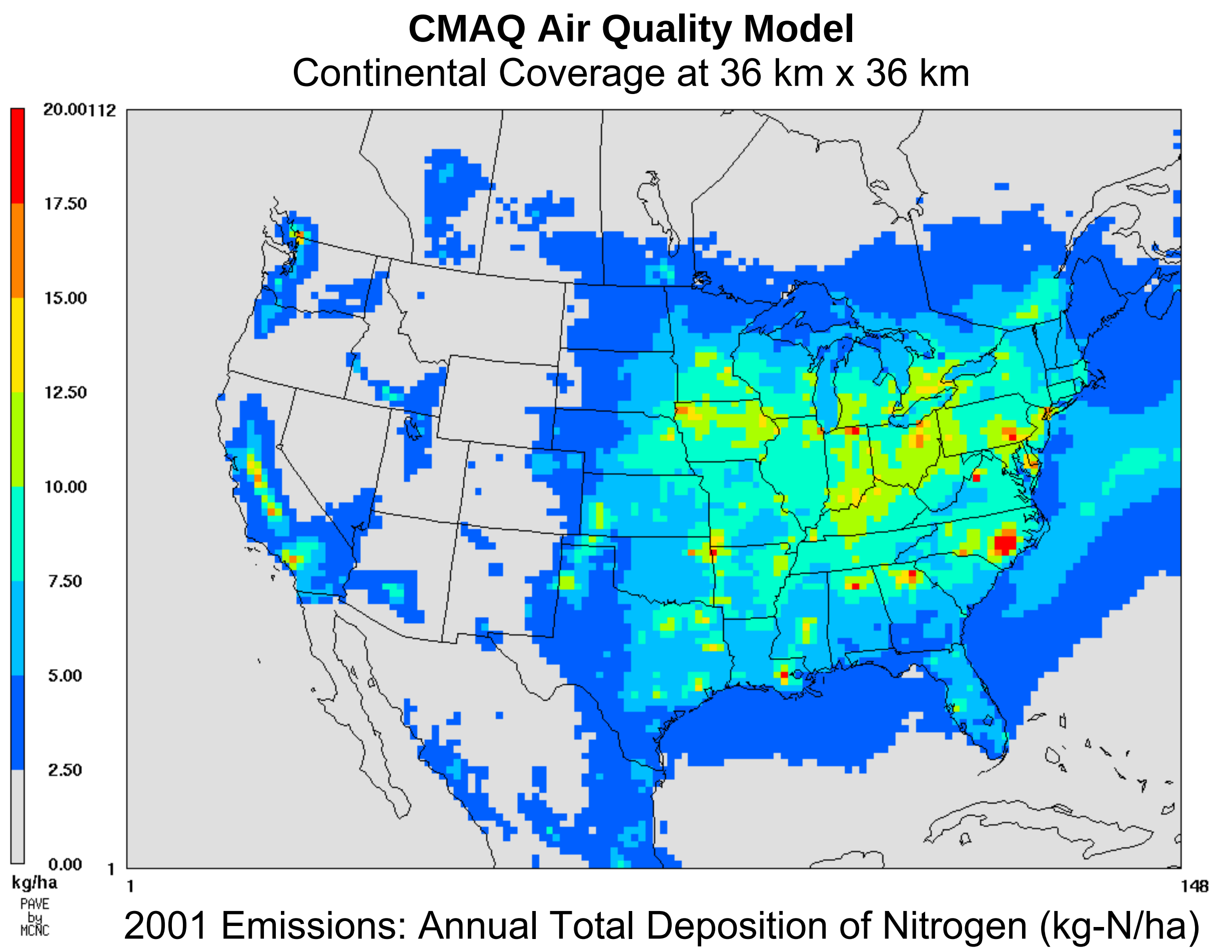

Figure 5-1. CMAQ annual average (wet plus dry and oxidized plus reduced) nitrogen deposition (in kg-N/ha) across the U.S. based on 3 years of differing meteorology - one dry, one wet, and one average precipitation year - across the Eastern U.S.

Chapter 6
Providing Air Quality Forecast Guidance for Health Advisories

Introduction

An increasing number of clinical and epidemiological studies have associated adverse health effects in humans with exposure to ambient O_3 and fine particulate matter (particles with diameter less than 2.5 µm, also called $PM_{2.5}$). As a result, local air quality agencies need accurate forecasts of atmospheric pollutant concentrations to alert the sensitive populations on the onset, severity, and duration of unhealthy air, and to encourage the public and industry to reduce emissions-producing activities. The ability to forecast local and regional air pollution events is challenging since the processes governing the production and accumulation of ozone and fine particulate matter are complex and non-linear. Comprehensive atmospheric models provide a scientifically-sound tool for providing air quality forecast guidance. These models represent as much detail as possible the various dynamical, physical, and chemical processes regulating the atmospheric transport and fate of pollutants. The Division develops, applies, evaluates, and improves such models to provide robust tools to forecast the day-to-day variability in air pollutant concentrations. The principal modeling platform is the CMAQ modeling system linked with the North American Mesoscale (NAM) model, NOAA/National Weather Service's operational weather prediction model.

Research Description

In 2003, EPA and NOAA signed a Memorandum of Agreement to collaborate on the design and implementation of a system to produce daily air quality modeling forecast information. The Division has linked together NOAA's operational NAM-meteorological model and EPA's CMAQ model to form the core of this forecast system. The preliminary system provided ground-level ozone predictions over the Northeastern United States. Through an on-going collaborative program of phased development and testing with the National Weather Service, the Division is expanding the system's capability. As of August 31, 2005, the operational domain was extended over the entire eastern United States. In 2006, the domain coverage for experimental O_3 predictions was expanded to cover the entire continental United States (figure 6-1), and the Division began developmental testing for $PM_{2.5}$ forecasts over the continental United States. Over the next few years, the Division will expand the operational model domain to the continental U.S., and will add $PM_{2.5}$ to the model forecast capability. The Division has already begun developmental testing of both of these capabilities.

NOAA is supporting the basic infrastructure for air quality forecasting, with NOAA-EPA/AMD personnel providing much of that support. The Division

- Contributes to the CMAQ model improvements through comprehensive diagnostic analyses of model forecasts
- Builds an air quality forecast database at EPA/RTP consisting of the daily meteorological, emissions, and air quality outputs from the NAM-CMAQ forecast system
- Improves the accuracy of predicted pollutant distributions through development and application of bias-adjustment methods to correct model errors in forecasts either in real-time or in post-process
- Makes these data available to the air quality management community and the general public
- Provides value-added analyses of the data contained in this long-term database (e.g., reanalysis or data fusion with observations to create long-term archive of ambient air quality and deposition surfaces for linkage with exposure studies, analysis of long-term spatial and temporal trends in ambient air quality and deposition, exploring relationships between ambient concentrations and meteorological conditions).

Accomplishments

During FY-2006, several major changes were implemented in the air quality forecast modeling system:

- In 2006, the Eta model was replaced by the Weather Research and Forecasting Non-hydrostatic Mesoscale Model (WRF-NMM) as the operational North American Mesoscale meteorological model. To reflect this change, modifications were introduced in the air quality forecast system to link CMAQ with the new version of the NAM.

- Since the coordinate systems used in the WRF-NMM are different from those used in CMAQ, the initial linkage between the models was based on interpolation of meteorological data from the WRF-NMM coordinate structure to that used in CMAQ – a method known as "loose coupling." To reduce errors associated with this loose coupling, the interface between the WRF-NMM model and CMAQ was modified so that the two models would use the same vertical coordinate systems for their calculations. The updated system provides a more accurate representation of the 3-dimensional (3-D) meteorological fields. Efforts are underway to also include consistent coupling between the horizontal coordinate and grid system between the two models.

- The emission inventories used by the Air Quality Forecast system were updated to represent the 2006 conditions. Continuous Emission Monitoring (CEM) data from 2004 were used to generate a base year of emission estimates for NO_x and SO_2 from Electric Generating Units. For other pollutants and non-Electric Generating Units, base year 2001 emissions were used. Annual Energy Outlook data from the Department of Energy was used to project energy-related emissions from the base year to 2006. Vehicle Miles Traveled projected out to 2006, along with updated 2006 fleet information, were used to estimate mobile source emissions. The emissions inventory was also augmented with updated emission information from some states.

- Diagnostic tracers were added to CMAQ to track and quantify the influence of lateral boundary conditions specified for O_3. Analysis of simulated tracer distributions indicated that the simulated surface-level background O_3 is highly dependent on lateral boundary conditions specified in the free troposphere. Additional analyses of the 3-D O_3 and diagnostic tracer fields with extensive ozonesonde measurements from the 2006 INTEX Ozonesonde Network Study are underway.

Extensive evaluation of archived forecasts results from the summer of 2004 were also conducted through comparisons with a variety of measurements from surface sites as well as aircraft deployed during the 2004 International Consortium for Atmospheric Research on Transport and Transformation field study.

Continuous evaluation of particulate matter forecasts results from the developmental simulations was performed through detailed comparisons with measurements from a variety of surface networks. Performance characteristics for $PM_{2.5}$ forecast over an entire year were investigated with emphasis on understanding seasonal biases. A detailed comparison of $PM_{2.5}$ and constituent concentrations forecasts with measurements from different surface networks was conducted to characterize model performance during the winter-time.

The Division developed and tested a method to characterize real-time emissions from wildfires using satellite information from the Hazard Mapping System to detect the location of fires. The Division also developed a method to estimate the emissions of gaseous and particulate matter constituents from these fires for input to CMAQ. Initial testing indicates the new wildfire estimates improved CMAQ model performance for both O_3 and $PM_{2.5}$ in regions impacted by pollution plumes from the fires.

Next Steps

FY-2007

- Continue populating the air quality data archive at EPA/RTP with WRF-NMM-CMAQ daily air quality forecasts and meteorological data for 2007
- Conduct initial testing of WRF-NMM-CMAQ linkage on the native WRF model E-Grid structure
- Development and evaluation of post-processing bias-adjustment techniques to achieve improved model forecasts

FY-2008

- Analysis and evaluation of developmental PM forecast simulations over the Continental United States

FY-2009

- Experimental testing of daily PM forecast simulations (with NOAA/National Weather Service)
- Improved methods to specify lateral chemical boundary conditions for forecast applications through linkage with global models

Impacts and Transition of Research to Applications

Since early 2003, the Division has worked with NOAA's National Weather Service to develop and deploy a model-based national air quality forecast guidance system, which currently operates at the National Weather Service. Hourly ozone forecasts through midnight of the following day are available online, providing information on the onset, severity, and duration of poor air quality to more than 290 million people across the country. Local and state air quality forecasters use this tool to create daily air quality outlooks and issue air quality alerts, using EPA's health-based Air Quality Index.

Analysis of model forecasts of air quality will allow EPA and NOAA researchers to continuously assess and improve model performance. Forecast guidance products have also been used for in-field guidance for flight planning during specialized field campaigns such as the 2004 International Consortium for Atmospheric Transport and Transformation and the 2006 Texas Air Quality Study. Detailed post-mission analyses of model forecast results with extensive measurements from these field campaigns have also provided diagnostic information on model performance, helping improve the science in CMAQ.

EPA's archive of the forecast products provides a rich repository of daily air quality information that can potentially be used for to understand long-term trends in air quality, the effectiveness of emission control programs in reducing population exposure, and relationships between air pollution and human health.

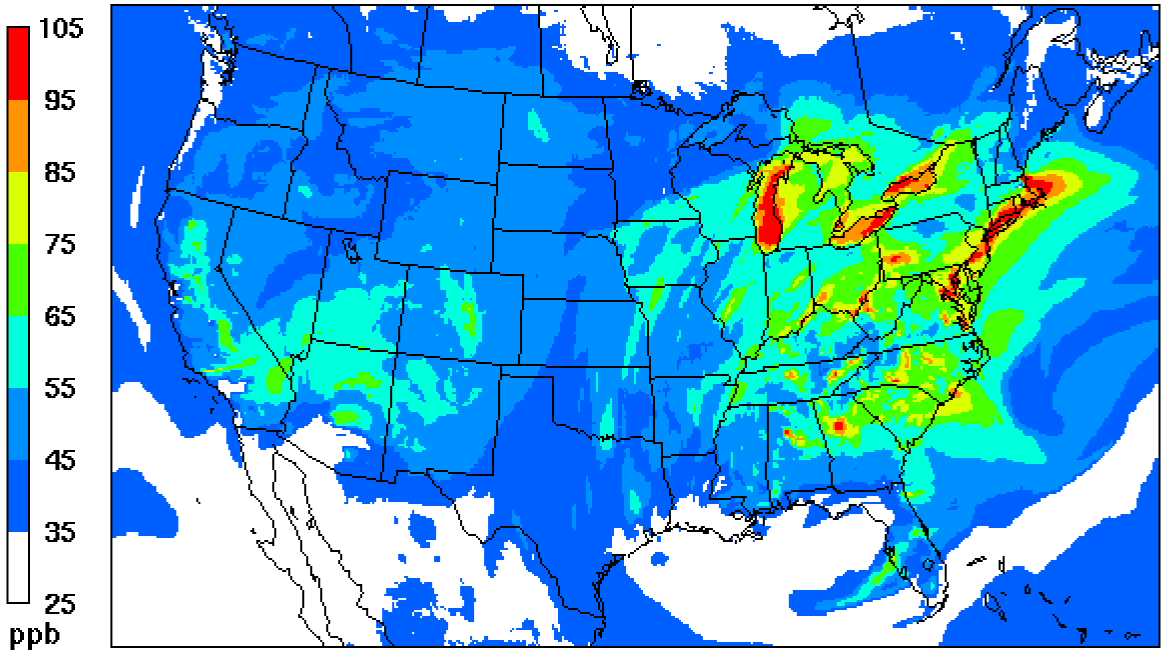

Figure 6-1. Forecast surface-level 8-hour maximum O_3 concentrations on August 1, 2006.

Chapter 7
Understanding the Relationships between Climate Change and Air Quality

Introduction

It is well-known that meteorology has a strong influence on ozone and aerosol variability, both spatially and temporally. Meteorology over many decades includes variations on synoptic, seasonal, and interannual time scales. In addition to the long-term, interannual variability, research suggests the presence of an increasing trend in temperature over the past century and this trend is projected to continue into the future. It is important to understand potential impacts from climate change on air quality compared with projected improvements in air quality stemming from regulatory programs. In addition to understanding the responses of air quality to potential climate change, the air quality influences on climate must also be understood. For example, sulfate aerosols can have a cooling effect on the atmosphere through radiation scattering; thus, emission controls resulting in substantial decreases in sulfate concentrations are likely to affect climate change. Using modeling tools that can simulate these interactions between climate and air quality, key goals of this theme area are to improve our understanding of the impacts of changing climate in the future for air quality and to identify potential influences on climate from major changes in aerosol loadings.

Research Description

The focus of the Climate Impacts on Regional Air Quality (CIRAQ) project is characterizing potential effects of climate change on regional air quality between now and 2050. The results from the CIRAQ project have been generated using a coupled global-to-regional downscaled modeling approach. Modeling results suggest that a mid-range climate scenario fifty years into the future could introduce a moderate increase in ozone and a decrease in aerosols in the Eastern United States; however, future emission scenarios would introduce a much larger difference that has an uncertain direction in both magnitude and direction. The CIRAQ project will investigate future emission scenarios and test model sensitivity to estimate the range of emissions and the resulting impacts on air quality. The results from the first series of simulations will contribute to the 2007 U.S. EPA national air quality assessment report; the emission scenario tests will contribute to the 2010 EPA national air quality assessment report. Results of CIRAQ will support two of the Synthesis and Assessment reports planned for the Climate Change Science Program (CCSP), a multi-agency program aimed at improving our understanding of the science of climate change and its potential impacts.

In addition to the series of simulations and analyses developed under the current CIRAQ project, future research plans include additional downscaled regional climate simulations using the NOAA Geophysical Fluid Dynamics Laboratory (GFDL) global scale models. GFDLs global models are regularly scientifically updated, and together with the Division's regional-scale models would provide an advanced global to regional scale modeling tool for this research. Preliminary linkages and tests are underway, and current planning under the NOAA air quality and climate programs may provide additional support for this effort.

The Weather, Research and Forecasting (WRF) model, a new generation mesoscale weather model, will be used to produce meteorology for CMAQ air quality simulations. The WRF-CMAQ model will provide direct feedbacks from aerosols in CMAQ to radiation predictions in WRF. The Division will use this integrated modeling tool to conduct sensitivity simulations to evaluate the potential impact of future air quality programs on regional climate. For example, large-scale reductions in sulfate concentrations may contribute to warming in the United States.

Accomplishments

During the next three years, the CIRAQ project members have collaborated with Pacific Northwest National Laboratory (PNNL) and Harvard University to develop and evaluate a series of 10 years of current and 10 years of future (2050) down-scaled regional climate simulations. Dr. Ruby Lueng (PNNL) led the effort to generate the downscaled climate scenarios.

Approximately four terabytes of regional climate model output (i.e., a large volume of data) was transferred and archived within the Division.

A series of scientific papers has been prepared by the Division to evaluate these simulations for current time periods and characterize the differences from the current to future year predictions.

During 2006, 5 years of current and 5 years of future (2050) air quality simulations were developed using these downscaled regional climate simulations.

Next Steps

FY-2008

- Development of air quality emission scenarios for 2050 time period (in collaboration with the National Risk Management Research Laboratory)

FY-2009

- Completion of 5 years of CMAQ simulations with future emission scenarios

FY-2010

- Development of manuscript and written contributions to the 2010 national air quality assessment report (led by EPA's National Center for Environmental Assessment)

FY-2011

- Test linkages with the GFDL global-scale climate and chemical transport models.

Impacts and Transition of Research to Applications

Air quality planning procedures rely on present meteorological conditions when developing future emission control strategies. The research conducted under this theme area will help for future years identify the uncertainty introduced when future climate influences are not included in the analysis. Modeling tools including WRF-CMAQ and global model linkages developed in this research will be made available for use in air quality management to consider climate variability and trends. Sensitivity studies will provide an additional assessment of the role of short-lived pollutants on the radiative budget.

Appendix A
Division Staff Roster

Office of the Director
S. T. Rao, Director
Patricia McGhee, Assistant to the Director
Veronica Freeman-Green, Secretary
Sherry Brown, Support Specialist
Val Garcia, Deputy Director
Linda Green, Budget Analyst
John Irwin (contractor)
David Mobley (EPA), Associate Director
Bill Peterson (contractor)
Dev Roy, (EPA) Post-Doc
Jeff West, QA Manager

Atmospheric Model Development Branch
Ken Schere, Chief
Shirley Long (SEEP), Secretary
Prakash Bhave
Russ Bullock
Simon Clegg (visiting scientist)
Rob Gilliam
Jim Godowitch
Alan Huber
Bill Hutzell (EPA)
Deborah Luecken (EPA)
Tanya Otte
Jon Pleim
Adam Reff (EPA), Post-Doc
Shawn Roselle
Golam Sarwar (EPA)
John Streicher
David Wong
Jeff Young
Yang Zhang (ORISE, Oak Ridge Science and Education Program)

Model Evaluation and Application Research Branch
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Melanie Ratteray (SEEP), Secretary
Wyat Appel
Jerry Davis (ORISE)
Brian Eder
Kristen Foley (EPA), Post-Doc
Steve Howard
Sergey Napelenok
Chris Nolte
Rob Pinder
Jenise Swall
Alfreida Torian
Gary Walter

Air-Surface Processes Modeling Branch
Tom Pierce, Chief
Jane Coleman (SEEP, Senior Environmental Employee Program), Secretary
Bill Benjey
Jason Ching
Ellen Cooter
Robin Dennis
Vlad Isakov
George Pouliot
Donna Schwede
George Bowker, Fluid Modeling Facility
David Heist, Fluid Modeling Facility
Steve Perry, Fluid Modeling Facility
Ashok Patel (SEEP), Fluid Modeling Facility
John Rose (SEEP), Fluid Modeling Facility

Air Quality Forecasting Research Branch
Rohit Mathur, Chief
Ann Marie Carlton
Dale Gillette
Jerry Herwehe
Daiwen Kang (contractor)
Hsin-mu Lin (contractor)
Daniel Tong (contractor)
Shaocai Yu (contractor)

Applied Modeling Branch
Mark Evangelista, Chief
Dennis Atkinson
Desmond Bailey
Pat Dolwick
Rich Mason
Brian Orndorff
Joe Touma

Appendix B
Division and Branch Descriptions

Division

The Division implements the Memorandum of Understanding (MOU) and Memorandum of Agreement (MOA) between the Department of Commerce (DOC) and the Environmental Protection Agency (EPA). In this capacity the Division develops and evaluates predictive atmospheric models on all spatial and temporal scales for forecasting the Nation's air quality, and for assessing changes in air quality and air pollutant exposures, as affected by changes in ecosystem management and regulatory decisions. The Division is responsible for providing a sound scientific and technical basis for regulatory policies to improve ambient air quality. The models developed by the Division are being used by EPA, NOAA, and the air pollution community in understanding and forecasting not only the magnitude of the air pollution problem, but also in developing emission control policies and regulations. Established in 1955, the Division serves as the vehicle for implementing the agreements between NOAA and EPA, which funds the research efforts.

The Division conducts atmospheric research in-house and through contract and cooperative agreements with other agencies, academia, and the private sector. With a staff of NOAA and EPA scientists, the Division provides technical information, observational and forecasting support, and consulting on all meteorological and modeling aspects of the air pollution control program. In addition to facilitating research in the fields of air pollution meteorology and atmospheric modeling, The Division interacts extensively with academic and other scientific institutions in the U.S. and abroad to help support NOAA's and EPA's mission-oriented efforts as well as to ensure that the environmental community has the benefit of the highest quality peer-reviewed science in dealing with air pollution problems.

Atmospheric Model Development Branch

The Atmospheric Model Development Branch (AMDB) develops, tests, and refines analytical, statistical, and numerical models used to describe and assess relationships between air pollutant source emissions and resultant air quality, deposition, and pollutant exposures to humans and ecosystems. The models are applicable to spatial scales ranging from local/urban and mesoscale through regional, including linkage with global models. AMDB is a key advocate in the meteorological modeling community for air quality applications. AMDB adapts and extends meteorological models to couple effectively with chemical-transport models to create comprehensive air quality modeling systems, including the capability for two-way communication and feedback between the models. AMDB conducts studies to describe the atmospheric processes affecting the transport, diffusion, transformation, and removal of pollutants in and from the atmosphere using theoretical approaches as well as from analyses of monitoring and field study data. The AMDB converts these and other study results into models for simulating the relevant physical and chemical processes and for characterizing pollutant transport and fate in the atmosphere. AMDB conducts model exercises to assess the sensitivity and uncertainty associated with model input databases and applications results. AMDB's modeling research is designed to produce tools to serve the nation's need for science-based air quality decision-support systems.

Model Evaluation and Application Research Branch

The Model Evaluation and Applications Branch (MEARB) develops and applies advanced methods for evaluating the performance of models in reproducing the observed air quality. MEARB provides routine and high performance computing support needed by the Division in the development, evaluation, and application of environmental models. The Branch applies the Division's models to important environmental problems, providing scientific guidance on their use in air quality decision making. The Branch fosters the application of new computational techniques and tools to environmental simulation modeling and contributes to the interagency Information Technology Research and Development program.

Air-Surface Processes Modeling Branch

The Air-Surface Processes Modeling Branch (APMB) performs process-based modeling research for the Division's atmospheric pollutant models, with a focus on three research themes: (1) emissions modeling, (2) deposition onto sensitive ecosystems, and (3) linkage of air quality with human exposure. APMB's emissions modeling effort (with a special emphasis on natural sources such as wind-blown fugitive dust, wildfires, and biogenic emissions) helps ensure that meteorologically influenced emissions are properly considered in air quality models. APMB's deposition research uses state-of-the-art trace gas flux measurements to develop tools for assessing nutrient loadings and ecosystem vulnerability. APMB's urban-scale modeling program (which includes collection and integration of experimental data from its Fluid Modeling

Facility is focused on building “hot-spot” air toxic analysis algorithms and linkages to human exposure models.

Air Quality Forecasting Research Branch

The Air Quality Forecasting Research Branch (AQFRB) fosters collaborations between NOAA and EPA in developing, applying, and evaluating comprehensive models for operational use for providing short-term air quality forecast guidance. Through the continuous application of the linked meteorological and chemistry-transport models and analysis of its predictions, AQFRB develops diagnostic information on model performance to guide further development and enhancement of physical and chemical process representations in the models. AQFRB also works on extending the utility of the daily air quality forecast model data being produced by NOAA’s National Weather Service (NWS) as part of the NOAA-EPA collaboration in air quality forecasting, to EPA mission-oriented activities. These include developing and maintaining a long-term database of air quality modeling results (ozone and PM2.5), performing periodic analysis and assessments using the data, and making the air quality database available and accessible to States, Regions, RPO’s and others to use as input data for regional/local scale air quality modeling for policy/regulatory purposes.

Applied Modeling Branch

The Applied Modeling Branch (AMB) evaluates, modifies, and improves atmospheric modeling systems and simulation techniques to ensure appropriateness and consistency with established scientific principles. The Branch evaluates the effect of meteorological conditions on air quality and on the environmental decisions that are based upon air quality assessments and simulations.

Appendix C
Awards and Recognition

Distinguished Career Award

- Dale Gillette - For Outstanding Theoretical and Empirical Contributions - International Conference on Aeolian Research

NOAA Silver Medal

- Ken Schere, Jon Pleim, George Pouliot, Tanya Otte, and Jeff Young - CMAQ Air Quality Forecast Team

EPA Bronze Medals

- David Mobley and Jeff West - NARSTO Emission Inventory Assessment
- Joe Touma and Rich Mason - 2002 National Air Toxics Assessment
- Mark Evangelista and Desmond Bailey - Modeling guidance for the Best Available Retrofit Technology Rule

EPA Administrator's Award for Excellence

- Pat Dolwick - Economic Analysis Tool Development Team

EPA Special Act/Time Off Awards

- David Mobley, Adam Reff, Golam Sarwar, and Prakash Bhave - SPECIATE Update
- Deborah Luecken - CB05 Development
- George Bowker - Sand Flux Modeling Papers
- Dev Roy - Remote Sensing Support and Analysis
- Bill Hutzell - Addition of toxic species to CMAQ

NERL Special Achievement Awards

- Ken Schere - Goal 2: Promote High-Performing Organization
- Robin Dennis - Goal 3: Leadership in the Environmental Research Community
- Prakash Bhave - Goal 4: Science Integration - Inter-divisional-laboratory research
- Alice Gilliland and Vlad Isakov - Goal 5: Identifying and Addressing Future Issues
- Jeff West - Quality Assurance Award
- David Heist and Steve Perry - Health and Safety Award

NOAA CIYA/Special Act/Time-Off Awards

- Wyat Appel - Testing new evaluation methods to better account for the nature of the data and model
- Sherry Brown - Analysis and resolution of NOAA property records and issues
- Russ Bullock - Facilitating a major collaborative intercomparison of models and model simulation results for atmospheric mercury
- Ellen Cooter - Programmatic and technical support to the CIRAQ program
- Mark Evangelista - Program and policy support for model applications
- Veronica Freeman-Green - Provided exemplary support in budget, human resources, and purchasing
- Val Garcia and Linda Green - Resolution of long-standing billing issues associated with the IAG
- Rob Gilliam - Evaluating the meteorological model used for CIRAQ
- Jim Godowitch - Analysis on the effectiveness of major reductions in NO_x emissions on ozone concentrations
- Rohit Mathur - Transition of NOAA-EPA Air Quality Forecast System to the WRF-NMM system
- Trish McGhee - Exemplary support to the Division
- Chris Nolte - Completing CMAQ simulations to study air quality sensitivities to future climate scenarios as part of CIRAQ (Congressional APM)
- Tom Pierce - Development of research program in linking sources to human exposure
- Evelyn Poole-Kober - Analysis and reconciliation of NOAA and EPA peer review database

Appendix D
Publications
(Division authors in bold)

Journal Articles

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