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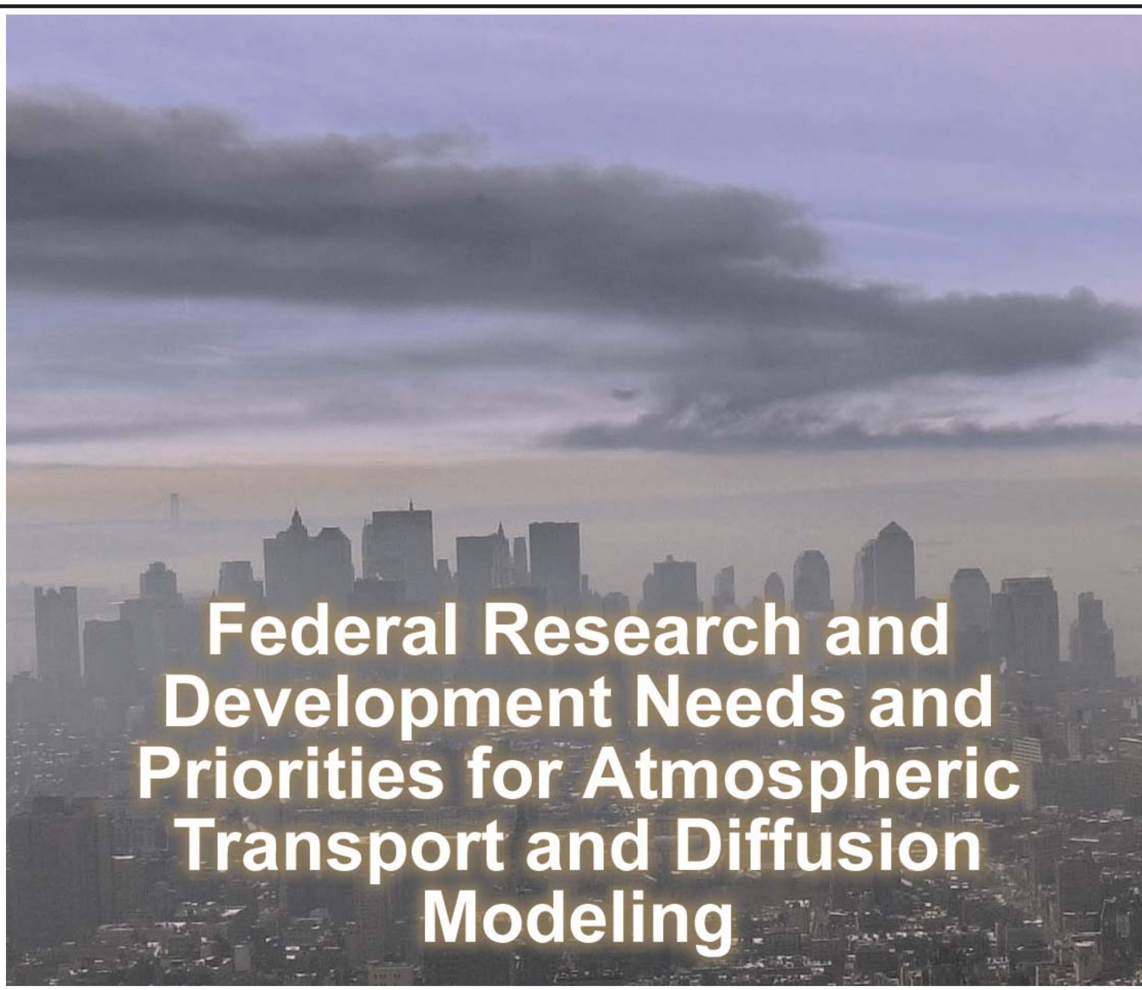

JOINT ACTION GROUP FOR ATMOSPHERIC TRANSPORT AND DIFFUSION MODELING (RESEARCH AND DEVELOPMENT PLAN)

FCM-R23-2004
Washington, DC
September 2004

Front Cover Graphic: On Friday, February 21, 2003, a fuel barge that was unloading fuel at a storage facility on Staten Island exploded. The barge was unloading 4 million gallons of unleaded gasoline. Smoke and flames climbed hundreds of feet into the air. A plume of smoke originating from the fire was carried over lower Manhattan and was captured in this photograph by Gregory Bull (AP Photo)

FEDERAL COMMITTEE FOR
METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH

WORKING GROUP FOR
ENVIRONMENTAL SUPPORT TO HOMELAND SECURITY

JOINT ACTION GROUP FOR ATMOSPHERIC TRANSPORT AND DIFFUSION
MODELING (RESEARCH AND DEVELOPMENT PLAN) (JAG/ATD(R&DP))

Federal Research and Development Needs and Priorities for Atmospheric Transport and Diffusion Modeling

FCM-R23-2004

September 2004

Office of the Federal Coordinator
for Meteorological Services and
Supporting Research (OFCM)
8455 Colesville Rd, Suite 1500
Silver Spring, MD 20910

FOREWORD

In August 2002, the Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM) published the comprehensive report, *Atmospheric Modeling of Releases from Weapons of Mass Destruction: Response by Federal Agencies in Support of Homeland Security*. This publication, prepared by the OFCM's Joint Action Group for the Selection and Evaluation of Atmospheric Transport and Diffusion Models (JAG/SEATD), provided a comprehensive summary of Federal capability to provide atmospheric transport and diffusion (ATD) modeling support and has become a valuable resource in support of the homeland security/defense missions.

The JAG/SEATD report also made a number of recommendations for future work, regarding ATD modeling support, which was endorsed by both the Interdepartmental Committee for Meteorological Services and Supporting Research (ICMSSR) and the Federal Committee for Meteorological Services and Supporting Research (FCMSSR). Among the recommendations was the need to address the research and development required to advance the state-of-the science of ATD modeling in support of critical homeland security/homeland defense activities.

In October 2003, the OFCM established the Joint Action Group for Atmospheric Transport and Diffusion Modeling (Research and Development Plan) (JAG/ATD(R&DP)) to address this recommendation head on. Each agency that participated in the JAG/ATD(R&DP) shared the common goal to: Identify the most pressing research needs facing the Federal ATD modeling community as it strives to support the homeland security mission and to recommend a strategy that will eventually satisfy those needs.

This report, *Federal Research Needs and Priorities for Atmospheric Transport and Diffusion Modeling,* represents a commitment by each of the responsible Federal agencies in the OFCM Federal coordinating infrastructure to work in a collaborative and synergistic way to address this critical homeland security issue, and the report's recommendations are the result of careful deliberation by the members and are based on their collective skills, experiences, and vision.

The next step is for the participating agencies to work together in a collaborative and cooperative manner to incorporate these recommendations into agency plans and programs in order to improve Federal ATD modeling capabilities. The completion of this task in a timely and coordinated manner is vitally important to the Nation. Close coordination with the academic and private organizations will also be required, and the user community must be involved in the process from start to finish.

I wish to extend my deepest appreciation to the JAG members, alternates, technical advisors, and subject-matter experts who brought unprecedented knowledge and experience to the table and who demonstrated outstanding teamwork in developing this report. I am also deeply grateful for the outstanding leadership of the JAG cochairs, Dr. Walter Bach and Ms. Nancy Suski. The quality and comprehensiveness of the report reflects highly on the insight, professionalism, and dedication of all the participants and the report provides a solid foundation for future R&D efforts, regarding environmental support to homeland security.

Samuel P. Williamson
Federal Coordinator for Meteorological Services
and Supporting Research

September 23, 2004

MEMORANDUM FOR: Mr. Samuel P. Williamson
Federal Coordinator for Meteorology

FROM: Cochairpersons

SUBJECT: Federal Atmospheric Transport and Diffusion Modeling Research and Development Plan

The Joint Action Group for Atmospheric Transport and Diffusion Modeling (Research and Development Plan) (JAG/ATD (R&DP)) has completed the tasks assigned in the JAG/ATD (R&DP) Terms of Reference. We are pleased to provide the subject report, titled: *Federal Research and Development Needs and Priorities for Atmospheric Transport and Diffusion Modeling*.

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Army Research Office

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EXECUTIVE SUMMARY

Atmospheric transport and diffusion (ATD) modeling is a challenging and dynamic field of research, and the Federal agencies have played a critical role in applying advances in the field to satisfy pressing national needs. Federal resources have proven to be vitally important to these efforts because ATD models typically must describe atmospheric processes in the most changeable and complex part of the atmosphere. For homeland security applications, the end-user's need for timely and accurate ATD information in the urban environment is one of the most pressing national needs.

In October 2001, the Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM) established the interagency Working Group for Environmental Support to Homeland Security (WG/ESHS) at the request of the Federal Committee for Meteorological Services and Supporting Research (FCMSSR). In January 2002, the WG/ESHS formed the Joint Action Group for the Selection and Evaluation of Atmospheric Transport and Diffusion Models (JAG/SEATD) to study the nonproprietary atmospheric transport and diffusion (ATD) modeling systems in use by federally funded operations centers. In August 2002, the JAG/SEATD's definitive report was published, and its recommendations were endorsed by FCMSSR.

Among the recommendations was the need to further study the research and development (R&D) requirements related to ATD modeling. In October 2003, the Joint Action Group for Atmospheric Transport and Diffusion Modeling (Research and Development Plan) (JAG/ATD(R&DP)) was formed under the WG/ESHS and charged to:

- Develop a methodology for characterizing and prioritizing the research and technical needs, and for linking those needs to stated operational requirements.
- Consult with subject-matter experts as required (based on the needs of the JAG members).
- Identify the tools required for transitioning successful research results into operations through interagency cooperative efforts like observational and modeling test beds, field and urban studies/experiments, and a common model evaluation methodology.
- Develop a comprehensive plan that documents the research and technical needs of the ATD modeling and operational communities. The plan should prioritize the most pressing R&D needs and provide a roadmap to address those needs within the OFCM coordinating infrastructure. Expanded feedback on the plan was solicited during the 8th Annual George Mason University Conference on Atmospheric Transport and Dispersion Modeling on July 14, 2004, and the OFCM Urban Meteorology Forum, *Challenges in Urban Meteorology: A Forum for Users and Providers,* on September 21-23, 2004, which included participation from the academic, public, and private sectors.

This report is the culmination of the JAG/ATD(R&DP)'s efforts. The report describes the research and development needs, based on user-community needs, and recommends a

number of strategies to address those needs in order to provide a reliable capability to use atmospheric transport and diffusion as an instrument of local and national emergency response or planning. The principal topics addressed by the report include:

- A discussion of user needs for *consequence assessment systems* (a general name for typical applications in which ATD models are employed, including but not limited to emergency response/recovery and preparedness planning applications).
- Interpretation of the ATD modeling capabilities required to support what users need from their consequence assessment systems.
- Analysis of the gaps between the required capabilities and current Federal ATD modeling capabilities (requirements pull), plus opportunities for new and emerging science and technology to fulfill user needs better in the future (technology push).
- Strategies to fill the gaps and provide improved capability through an interrelated set of coordinated R&D activities implemented by Federal agencies with ATD modeling programs or related research, development, or technology transition programs.
- Prioritized recommendations for implementing the R&D strategies.

User's Needs

The emergency preparedness and response environment includes a number of activities during which consequence assessment of an airborne hazard is relevant. Planning activities start in anticipation of a specific incident to help everyone prepare to respond. Response activity begins when an incident occurs. Response activity then transitions into recovery activity. Incidents that involve the release of an airborne hazardous material can range from a relatively straightforward situation that that can be handled by local responders to a complex situation that involves elements of all three activities described and requires resources from many different organizations; i.e., incidents of national significance.

Users recognize that ATD models of the consequence assessment system are imprecise. They desire—and create—ways to work with the limitations of the information. Models give little or no expressions of probability and uncertainty, so they are insufficient to help many users make sound decisions. This fact imposes two complementary demands on model development. First, we must provide a reasonable measure of the uncertainty in a prediction or its probability distribution, and then secondly, we must communicate the implications of quantifying the uncertainty in ways the users can apply**.**

Research Needs

Advances in current ATD modeling are likely to come from improvements in meteorological model predictions and from measurements at the scales of interest. The former are closely related to better representations of atmospheric boundary layer (ABL) processes by improved parameterizations, initial conditions, boundary conditions, and representations in complex, especially urban, environments. As existing modeling and observing capabilities are improved, the realization that the ATD process is partly stochastic, rather than entirely deterministic, will enable uncertainties in the modeling process to be quantified. The modeler must then learn with the user how to communicate this uncertainty information to the user in ways that are relevant to the user's decisions.

Models and data must come together and complement one another. Techniques to localize and/or quantify source characteristics by fusing information from concentration sensors, ATD models, and other measurements are lacking or untested. To meet user requirements for timely modeling predictions, faster methods are needed to determine the quality of observed data, merge the acceptable data into modeling frameworks, and estimate concentrations rapidly across several scales of motion. Finally, to ensure the quality of the model estimates and provide the benchmark for improvements, the skill of the prediction and its robustness need to be assessed on a continuing basis.

To advance the state-of-the-science in ATD modeling, we must meet these R&D needs:

- Bridge the gap from mesoscale to microscale/urban scale.
- Improve characterizations of surface boundary conditions in model parameterizations and in input data sets (initial conditions and boundary conditions). In particular, better methods are needed to obtain, maintain, and apply land cover data for urban and surrounding environments.
- Test and refine the physical basis for sub-grid-scale parameterizations.
- Characterize dispersion in complex environments.
- Develop methods and technologies for improving ensemble construction and interpretation.
- Develop and test techniques to better estimate wet and dry deposition and chemical interactions.
- Improve tracer materials and measurement technology.
- Improve boundary layer atmospheric measurement capability.
- Improve and evaluate data acceptance and assimilation techniques for both initial conditions and boundary conditions.
- Develop physics-based evaluation metrics that recognize the fundamentally different sources for variations in observed and model-predicted values of downwind hazard concentration.

A tabular summary of these needs and priorities follows.

Table ES-1. Summary Table of R&D Needs with Prioritization Factors

R&D Need	Time Sensitivity	Short-Term Gain	Overall Level of Effort	Lead Time	Ultimate Gain Potential
Bridge the modeling gap	near term	average	moderate	average	exceptional
Characterization of surface conditions & input data sets	near term	average	high	average	exceptional
Test and refine physical basis for sub-grid-scale parameterizations	longer term	average	moderate	average	exceptional
Characterize dispersion in complex environments	immediate	average	high	average	high
Improve ensemble construction and interpretation	immediate	minimal	high	short	exceptional
Techniques to better estimate wet and dry deposition	near term	average	moderate	average	high
Physical and high-resolution computational models	near term	average	moderate	average	exceptional
Improve tracer materials and measurement technology	immediate	high	moderate	short	exceptional
Improve boundary-layer measurement technology	immediate	high	high	short	exceptional
Improve and evaluate sensor-fusion techniques	immediate	high	moderate	moderate	high
Data QA/QC for model fit and data assimilation	immediate	average	moderate	moderate	high
Develop physics-based model evaluation methods	near term	high	low	average	exceptional

Research and Development Strategies

The JAG identified two capstone goals for the R&D plan: *quantifying uncertainty* and *interpreting the implications of this uncertainty to users*. The JAG then identified six program elements needed to support the capstone goals. To achieve the goals, it is essential that the elements of the strategy be sustained, evaluated, and allowed to evolve as the knowledge base grows and the capabilities for ATD modeling improve.

Capture and Use Existing Data Sets. This element focuses on assembling the available (open access) data sets from the many years of ATD experiments and model testing into a modern data format. The data are in various forms and available on many types of storage media. Both the data and the expertise of the participating scientists are at risk of being lost. These rich data files are the only source of concentration data which can currently be used to quantify uncertainty in ATD models.

Model Evaluation Standards. Procedures for evaluating the performance of ATD modeling systems are not standardized across the Federal agencies or ATD model user communities. Further, the existing procedures may not fully deal with the complexities introduced by comparing calculations and observations having different inherent space and time averaging. Without common reference standards, model development and implementation tends to remain "stovepiped" within the developing agency, while other development efforts are discounted or go unused.

Bridge the Modeling Gap. Top-down modeling (large to small scale) and bottom-up modeling (small to larger scales) do not merge across scales from 50 meters to 5 kilometers in realistic environments. This fact points to a fundamental lack of knowledge of how to model the processes at these scales. In all models, there is an element of turbulence carried in the smallest scales and the unresolved processes. Although there is perpetual optimism that higher-resolution models will give better results, current operational experience does not substantiate the optimism.

Improved Measurement Capabilities. Measurements are fundamental to advancing the realism of a science-based description or prediction. In ATD modeling, improving the capability to measure concentrations of tracers and atmospheric variables (e.g., wind velocity, turbulence, temperature) *at the scales of ATD model use* is essential to R&D leading to better ATD models. Quantifying the uncertainty in model variables requires in situ and/or remote measurements at the modeled scales. Most applications of ATD models are at much finer scales than are the available data, especially in populated areas. To develop better parameterizations, measurements are needed to understand processes not resolved within models. Measurements are also needed to help bridge the model gap. Tracer measurement capabilities are needed to provide data for quantifying the uncertainty in ATD model predictions.

Local/Regional Siting of Instrumentation. Each locality has a unique morphology. Many localities want to provide a network of instruments, within budget limitations, that will reasonably represent wind and turbulence fields needed for ATD concentration fields in emergency conditions. No one plan fits all these sites. Strategies are needed to make reliable recommendations through a combination of modeling exercises, optimization processes, and experience in other areas.

ATD Test Beds. Most ATD model studies come in defined field campaigns operated to maximize the probability of success. Within this context, benign, simple, and non-taxing weather conditions were preferred although terrain conditions may have been complex. Controlled tracer releases are sampled and atmospheric measurements are made as densely as capabilities and resources permit. As accidental releases and terrorist incidents are not scheduled, little is known about performance of ATD models under daily conditions. Recently, fledgling infrastructures for routine ATD forecasting based on model and local information, such as NOAA's DCNet, have developed in several urban areas. The JAG proposes a strategy of establishing test beds in appropriate areas across the country to address and test ATD models, model needs, and model capabilities on a continuing basis. By operating and performing evaluations continuously, by testing new ideas and instruments, and by interacting regularly with users, an ATD test bed becomes a crucible in which ATD modeling is made robust and refined from an art into a demonstrated and verified operational capability. The initial number of test bed installations should be limited so that operational procedures can be developed and refined without squandering scarce resources. Once the prototyping lessons have been learned, the set of installations could expand to cover more locations of priority interest, with each additional location chosen to represent different challenges from those already in place or being installed.

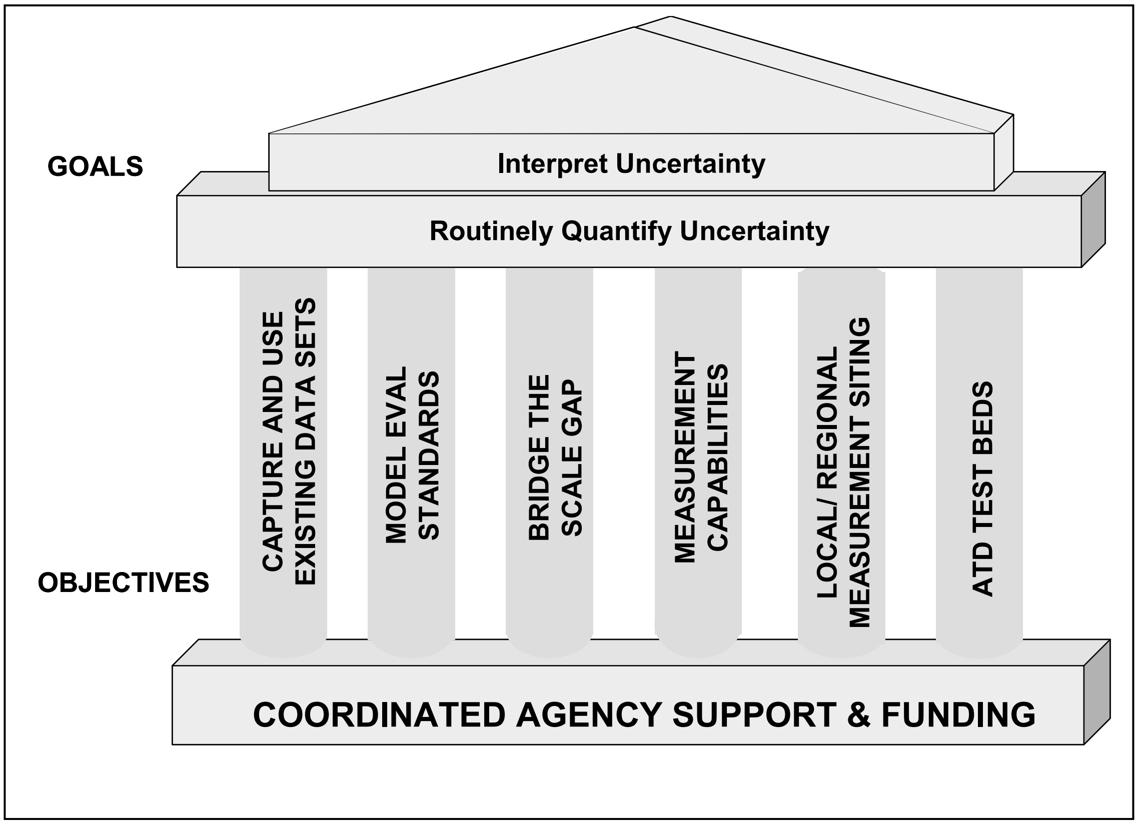

Figure ES-1. Six R&D objectives need to be achieved to support the ultimate goals of quantifying uncertainty and communicating its implications to users.

Recommendations

The recommendations are intended to support and guide Federal agency efforts to prioritize and obtain the necessary resources for their most pressing research needs. Additionally, they were developed to encourage multiagency collaboration and cooperation on shared objectives while helping to facilitate the participation from the academic and private sectors and the coordination of Federal activities with state, regional, and local governmental agencies.

The R&D elements will require a robust, coordinated effort by the multiple Federal agencies engaged in research, development, or application of ATD modeling systems. No one agency holds all the capabilities needed to affect the recommended course of action. Shared responsibilities, shared vision, and shared resources are essential to success. Without the resource base and sustained direction that a well-coordinated Federal effort can provide, the R&D needs cannot be met within time horizons consistent with national policy priorities.

Implementing recommendations are provided for the following seven areas:

- Quantify model uncertainties and interpret their implications to users.
- Capture and use existing data sets.
- Implement ATD test beds.
- Develop standards for evaluating modeling system performance.
- Improve the spatial and temporal scale interactions between meteorological and ATD models.
- Improve measurement technologies.
- Design and conduct special studies and experiments.

Implementing the recommendations will require a sustained effort over more than a decade. Some of the implementing actions will produce returns in the near term—within the next 2 years. Other actions will provide some benefits at intervals along the way, even though the most significant benefits may require a decade or more to be realized. Many of the limitations in capability identified in the report, however, are systemic, resulting from a lack of coordinated effort across agencies and agency programs, but they can be successfully overcome with the commitment and coordination of resources and facilities, particularly the agency teams of individuals dedicated to advancing the operational state-of-the-science of ATD modeling.