**National Oceanic and Atmospheric Administration**
**Office of Oceanic and Atmospheric Research**
**Air Resources Laboratory**

# Strategic Plan for Atmospheric Transport and Dispersion (Plume) Research and Development 2011-2016

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## Background

Since its formation in 1948, the National Oceanic and Atmospheric Administration's (NOAA) Air Resources Laboratory (ARL) has made significant national and international contributions to developing and applying understanding and models of atmospheric transport and dispersion (ATD). This refers to movement of airborne substances, typically gases or aerosols. ARL currently performs four types of ATD activities: 1) improves the understanding of relevant characteristics of the atmosphere, 2) develops ATD models and associated tools, 3) conducts field studies to inform model development, and 4) and provides ATD predictions for selected customers. Examples of this work include: 1) studies of meteorological characteristics of the planetary boundary layer (PBL) and of transport in urban areas; 2) providing the Hybrid Single-Particle Lagrangian Integrated Trajectory[1] (HYSPLIT) transport and dispersion model to multiple government agencies, including the National Weather Service (NWS); 3) studies of atmospheric tracer dispersion; and 4) providing plume predictions for the Department of Energy's (DOE) Idaho National Laboratory and Nevada National Security Site.

## Scope of this Plan

This plan describes the ARL research and development (R&D) to support emergency response and other event-specific applications of ATD models. This plan includes development of tools for all users, including DOE customers, but it does not include ARL's routine ATD prediction services for DOE. However, ARL uses insights and feedback from those services to inform its R&D activities.

Some of ARL's ATD activities also support air quality applications, including modeling of biomass burning smoke and ecologically active chemicals (e.g., mercury, dioxins). The primary description of those activities is in ARL's strategic plan for air quality.

## Statement of Need

Understanding and predicting atmospheric transport and dispersion is essential for protecting the health and welfare of the public and emergency response personnel when harmful substances are released into the air in significant quantities. The Federal National Response Framework, approved by the President in January, 2008, assigns NOAA ATD prediction responsibilities for smoke and radioactive and hazardous materials, maintenance and development of HYSPLIT, and coordination with the World Meteorological Organization on international incidents. ARL develops many of NOAA's capabilities for these services.

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[1]This model uses meteorological fields (e.g., wind) and information about emissions sources to estimate the path and/or concentration of airborne materials. HYSPLIT can work with meteorological fields from observations or different models, allowing the use of the information that is most appropriate to the application.

Needs for ATD or “plume” understanding and tools are continually evolving, driven by demands for more accurate predictions, estimates of uncertainties, finer spatial resolution, easier-to-use tools, and tools to address evolving risks. For instance, in 2008 GAO[2] recommended that the Secretary of Homeland Security "work with the federal plume modeling community to accelerate research and development to address plume model deficiencies in urban areas and improve federal modeling and assessment capabilities. Such efforts should include improvements to meteorological information, plume models, and data sets to evaluate plume models." ARL’s research and development (R&D) addresses each of these areas, as well as ATD decision support tools.

## ARL’s Mission and Goals

The mission of ARL’s ATD R&D is to provide scientific information and tools to improve prediction of atmospheric dispersion of harmful materials to protect public health and the environment and to minimize economic impacts. “Harmful materials” could include chemicals, radiological releases, windblown dust, volcanic ash, and wildfire smoke.

ARL’s ATD R&D goals are the following:

- Improve the quality of ATD predictions and assessments, including estimation of uncertainties; and
- Improve decision-makers' understanding of predictions, assessments, and associated uncertainties.

Included implicitly is the transfer of ARL-developed capabilities to operations/applications within NOAA and at other agencies and organizations.

## Benefits

This work supports the mitigation and/or avoidance of health, economic, and societal impacts of harmful airborne materials through better decision-making. Decisions influenced by ATD predictions include the deployment of emergency response resources, evacuation of the public, issuance of health advisories, identification of sources, and routing of vehicles.

By improving ATD models, the meteorological predictions that drive ATD models (e.g., through wind predictions), and the ability of decision-makers to generate and understand predictions, ARL’s unique expertise improves the ability of emergency managers to protect the safety of first responders and the public and minimizes economic losses (e.g., damage to aircraft flying

[2]GAO, 2008. First Responders' Ability to Detect and Model Hazardous Releases in Urban Areas is Significantly Limited. GAO-08-180 Homeland Security.

through plumes of volcanic ash). These benefits occur through ARL's meteorological and ATD research, ARL's development of HYSPLIT and related tools, and ARL's own specialized ATD prediction services for DOE. The results of ARL's R&D are applied by NWS; other U.S., state, local, and international agencies; universities; and the private sector. For instance, thousands of people have downloaded HYSPLIT or have utilized web-based HYSPLIT services. Also, multiple Federal agencies rely on HYSPLIT and ARL's tracer field studies to support their ATD needs.

## Partnerships and the Transition of Research and Development to Applications

ARL has strong collaborative relationships with a number of organizations around the world and works closely with partners on a number of topics. For instance, ARL shares HYSPLIT source code with partners, and universities share HYSPLIT improvements with ARL. NOAA's National Ocean Service (NOS) is integrating its chemical database and models of chemical spills with HYSPLIT. Also, ARL works with other research organizations on studying wind flows and ATD in urban areas.

A number of organizations coordinate ATD activities, in some cases for specialized applications. ARL works with or through the Office of the Federal Coordinator for Meteorology (OFCM) on general ATD coordination, the World Meteorological Organization (WMO) on radioactive releases, and the International Civil Aviation Organization (ICAO) on predicting volcanic ash plumes.

A strength of ARL's work is the broad and effective transition of R&D to applications. Avenues for this transition include:

- providing HYSPLIT transport and dispersion model upgrades to the NWS National Centers for Environmental Prediction (NCEP), where the model is run for homeland security, radiological, and volcanic ash events, and daily for predicting biomass burning smoke plumes;
- providing a web-based interface that enables NWS forecast offices to run HYSPLIT and display results for local events;
- providing web-based HYSPLIT downloads and simulations to thousands of customers worldwide (http://www.ready.noaa.gov/);
- HYSPLIT training sessions and materials;
- sharing mesonet measurements, both to directly support operational forecasting, and to generate 3-D wind fields for dispersion modeling;
- publishing articles and other information, such as chemical tracer measurement data, that contributes to improved forecasts; and,
- providing dispersion support and related tools to DOE operational facilities in Idaho and Nevada.

## Priorities for ARL ATD Research and Development

ARL has considered the need for ATD information and tools, development trends in the ATD community, and ARL's areas of expertise. Based on all of that information, ARL has identified several high-priority areas for its ATD R&D:

- boundary-layer characterization and meteorological predictions--this is an essential driver for dispersion models;
- dispersion modeling;
- decision support tools; and,
- dispersion model evaluation.

For each of the priority areas, ARL has identified the work it will pursue over the next 5 years; these are described below. Except where indicated, these plans assume existing funding levels.

### (1) Boundary Layer Characterization and Predictions

Accurate characterization and prediction of the meteorological characteristics of the boundary layer are fundamental to successfully simulating the transport and dispersion of hazardous substances. ARL will focus on reducing errors in analyses and predictions of winds and turbulence in the planetary boundary layer (PBL). ARL will develop or modify a suite of PBL modeling options that extends from simple observation interpolation to high-resolution prognostic forecasts with an estimate of mesoscale forecast uncertainty to be available for ATD predictions. Within this topic, ARL is focusing on three subtopics:

- *Urban boundary layer* - Most of the population lives in or near urban areas. However, meteorological models and measurement networks often poorly characterize winds and PBL structure in urban areas. ARL will conduct measurement studies (e.g., of heat fluxes and wind profiles) and analysis to improve the understanding of the urban and suburban boundary layer.
- *Prognostic mesoscale modeling* - The accuracy of mesoscale predictions is often a significant issue in ATD predictions. ARL will support improved meteorological predictions for ATD applications by evaluating the use of high resolution models, improving the parameterization of the land and PBL (e.g., by applying insights from ARL's and other groups' field studies), and exploring approaches to account for uncertainties and utilize observations.
- *Diagnostic wind modeling based on observations* - Diagnostic wind models are important for ATD predictions because they can often provide more accurate meteorological estimates than prognostic models for the time from the beginning of the release of materials up until the current time, especially in areas with adequate observations. ARL will investigate the use and improvement of diagnostic models for ATD applications.

### (2) Dispersion Modeling

The HYSPLIT model is the core of ARL's transport, dispersion, and deposition modeling capability. When provided with the appropriate meteorological fields, HYSPLIT can be applied to scales ranging from a kilometer to global. ARL R&D on HYSPLIT will focus on the following subtopics:

- *General HYSPLIT improvements* - Priorities include improving the computational performance, better representation of winds and turbulence on fine scales, and predicting dispersion in stable conditions.
- *Linking HYSPLIT and ALOHA/CAMEO* - An effort is underway to develop an integrated system that combines HYSPLIT and the Areal Locations of Hazardous Atmospheres/Computer-Aided Management of Emergency Operations (ALOHA/CAMEO) model, which was developed by NOAA NOS as a short-range tool for hazardous chemical releases. This effort will provide a seamless ATD modeling system for short- and long-range applications.
- *In-line dispersion modeling* - ARL will explore development of a version of the dispersion model that runs in-line with the prognostic meteorological model. This allows the dispersion model to access the meteorological fields at a much higher frequency than is available in the output files, improving the quality of fine-scale predictions.
- *Estimating uncertainties* - Dispersion predictions have significant uncertainties, including source terms, meteorological fields, and ATD representations. Estimating the effect of these uncertainties on plume predictions can provide valuable information for decision-makers. ARL will investigate approaches for estimating ATD uncertainties, such as generating representative ensemble members for ATD applications.
- *Special dispersion applications* - The HYSPLIT modeling system special applications, such as volcanic ash, semi-volatile compounds (e.g., dioxins), and smoke forecasting, have specialized components for estimating source strength and also have unique displays for model output. Other specialized applications may be developed in the future.

### (3) Decision Support Tools

The ability to quickly and accurately model dispersing plumes and assimilate available information is critical to reliable decision making in situations requiring rapid responses. To improve capabilities in this area, ARL will pursue the following subtopics:

- *Communication of uncertainty* - Uncertainties in ATD predictions need to be communicated to decision makers in a manner that is quickly and easily understood, but there is no generally accepted approach for communicating uncertainties in dispersion predictions--information which could have a significant impact on protective actions. ARL will evaluate the sources of uncertainty in plume predictions and investigate methods to display the uncertainty that will not be confusing to decision makers.
- *Streamlining user input, plume product display, training, and quality assurance* - ARL needs to keep up with technological advances in computer displays, networking, and interfaces.

Although a model may be technically sound, supporting capabilities such as user interfaces and display of results also have a significant impact on value to customers. For instance, in an emergency response environment it is critical that the user interface minimizes the amount of detail that a user has to supply manually while still producing an accurate simulation. ARL is developing software tools that simplify the configuration of simulations, enable easy manipulation of outputs, and display information relevant to customers. As examples, ARL is incorporating pre-configured release scenarios into the user interface and utilizing Google Maps and Google Earth for displaying results. Customer organizations also expect training materials and software quality assurance documentation for ARL products. ARL has an effective training program and documentation for HYSPLIT, but further effort will be required in this area to meet evolving expectations.

**(4) Dispersion Model Evaluation**

Model evaluation is crucial for improving models and gaining confidence in the models. ATD models are typically evaluated by comparison of model output to measured tracer samples from field studies, such as those available in the online Data Archive of Tracer Experiments and Meteorology (http://www.arl.noaa.gov/DATEM.php). In a typical tracer study, a gaseous compound is released and then its concentrations at different locations are measured. However, field studies designed to evaluate and improve dispersion prediction capabilities are relatively rare. In NOAA, tracer work has been primarily funded by other agencies. In recent years, funding has been limited, but there are still funding opportunities from ARL's partners such as the Departments of Defense and Homeland Security. Work supported by external funding will, of course, focus on topics important to the partners but will also address issues of direct relevance to NOAA's mission:

- *Tracer technologies* - ARL is in the forefront of tracer dispersion research, but current tracers have three problems: they are expensive, require significant effort to use, and are often strong greenhouse gases. Research on alternative tracers is needed and may require the development of new measurement technology. No funding is currently available for this work.
- *Tracer field studies* - Tracer field studies provide essential data for evaluating and improving ATD models. Further studies and analysis are needed to better characterize transport in urban areas, stable boundary layers, complex terrain, and various meteorological and release scenarios. Any funding for these activities will likely come from external partners.
- *Improved model evaluation methods* - Simple pairwise comparisons of observed and modeled concentrations fail to account for the differences in uncertainty in observed and modeled concentrations and therefore often lead to misleading results. Further research is needed to devise new statistical methods that recognize different sources of variability related to observed and modeled concentrations.