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Project Summary

Developments in National Weather Service Meteorological Data Collection Programs as Related to EPA Air Pollution Models

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During the next decade, the National Weather Service (NWS) will be upgrading its meteorological instrumentation and data dissemination procedures. Because these changes will affect the operation of the U.S. Environmental Protection Agency's (EPA) air pollution models, this project has been undertaken to report on proposed changes and to recommend how to make optimal use of the new NWS data products. New instrumentation will include automated surface observation systems, next generation radar, and remote profilers. Data dissemination is being upgraded with an automated weather interactive processing system, the conversion of data tapes to an element format, and the introduction of data formats that are compatible with personal computers. Complete descriptions of existing and new formats that are applicable to EPA air pollution models are given in the Appendices. To maximize the usefulness of NWS meteorological data, the following actions are recommended: (1) adapt the EPA meteorological processors to read the new data formats and upgrade them to incorporate advances in diffusion meteorology; (2) encourage the collection of meteorological data specific to diffusion modeling and investigate the feasibility of collecting some of these data at NWS sites; (3) improve the handling and formatting of NWS data for regional-scale models; and (4) maintain active communication with the National Climatic Data Center (NCDC).

This Project Summary was developed by EPA's Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

One of the principal inputs to an air pollution model is meteorological data. Collecting and archiving the data pose a challenge to those involved in diffusion modeling. The Nuclear Regulatory Commission (NRC) and the Environmental Protection Agency (EPA) have addressed this problem of meteorological data quite differently. The NRC requires that nuclear installations collect comprehensive meteorological data, including temperature differences, hourly average winds, and turbulence fluctuations. These measurements are usually taken on masts at heights ranging from 30 to 100 m. In some localities, such as near a large body of water, multiple meteorological masts are required. In contrast, EPA regulates a greater number and many more types of sources than the NRC. Because it is impractical for every potential emitter of air pollution to operate a comprehensive on-site meteorological monitoring program, EPA has traditionally relied on meteorological data collected by the National Weather Service (NWS). EPA's models use simplistic characterizations of diffusion meteorology using only a few measured NWS meteorological variables. For example, the rate of dispersion is determined by a Pasquill stability class as estimated from routine observations of wind speed, cloud cover, and ceiling height. Hourly estimates of plume rise, dilution, and transport direction are based on a single 2-minute average wind value reported by an observer on the hour.

During the past few years, the NWS has started to modernize its meteorological instrumentation and data dissemination systems, and EPA has begun efforts to use additional meteorological information to characterize diffusion. Upgrades in new instrumentation will include automated surface observation stations (ASOS), next generation radar (NEXRAD), and remote profilers. Data dissemination will be improved with the operation of an automated weather interactive processing system (AWIPS) and perhaps with a modern climatological data distribution system (NOAANET). The focus of this project is to assess how these changes in NWS meteorological data will affect EPA air pollution models. In particular, this project is intended to inform model users and developers on likely changes and to recommend upgrades in meteorological processors in order to effectively accommodate data from new instruments and in different formats.

Current Requirements

Air pollution models in EPA can be broken down into two basic areas: UNAMAP models and regional models. In general, UNAMAP models are used by the public for regulatory modeling. It is estimated that several hundred organizations in the United States use UNAMAP models. Regional models tend to be larger and more complicated than UNAMAP models. They are either used for research and development or for planning emission reduction strategies across several states. Models such as the regional model for acid deposition (RADM) and the regional oxidant model (ROM) are being used in making important policy decisions. Both types of models depend on NWS meteorological data.

UNAMAP stands for the User's Network for the Applied Modeling of Air Pollution. It began in 1973 to provide the EPA modeling community ready access to models for estimating air quality impact from proposed and existing sources of air pollution. The latest version of UNAMAP, version 6, was released in 1986 and contains over 24 models and meteorological processors.

The UNAMAP models listed in Table 1 are either short-term or long-term models. Short-term models use hourly meteorological data to estimate air pollution concentrations for time periods ranging from 1 hour to 1 day. Long-term models use climatological frequency distributions of wind speed, wind direction, and stability class to estimate air pollutant concentrations for seasonal or yearly periods.

As shown in Table 1, many of the UNAMAP models use meteorological data in special formats as available from the National Climatic Data Center (NCDC) in Asheville, North Carolina. The four currently-used data formats are summarized in Table 2.

Two of the UNAMAP models, MESOPUFF-2 and PLUVUE-2, are regional models. They require more data than the other UNAMAP models. MESOPUFF-2 requires surface and upper-air data from many locations within an area. Its meteorological preprocessor, MESOPAC, accepts data in the TD-1440 and TD-9689 formats. PLUVUE-2 has similar data requirements except it does not have a preprocessor for manipulating meteorological data into a specific format.

Other regional models used by EPA include RELMAP, ROM, and RADM. Most of these models are undergoing research and development, and their meteorological processors can be updated as new and improved meteorological data become available. Their data needs currently are similar to MESOPUFF except that RELMAP requires precipitation amounts for one degree latitude by one degree longitude areas. RADM estimates precipitation amounts using its own dynamic prognostic meteorological model because adequate precipitation data do not exist for objective analysis.

Proposed NWS Revisions

The NWS is modernizing its observational systems and data dissemination procedures. Existing NWS instrumentation has not been significantly modified for 25 years and is rapidly approaching obsolescence. Furthermore, the current observational process is quite labor-intensive and requires a large expenditure of funds. Technology now exists for automated measurements of surface and upper-air weather variables. In addition, the advantages of Doppler radar have been clearly demonstrated, especially for severe weather application. These new systems will generate additional data that will require enhanced data handling capabilities. The current AFOS system uses 1970s technology and is overburdened in its data handling and processing requirements. Also, the NCDC is striving to meet the needs of new data formats and the increased amount of data that will be collected in the near future.

Advances are taking place in surface observations, upper-air observations and radar. Current surface observation platforms will be replaced by an ASOS The upper-air rawinsonde system will be supplemented by remote profilers Radars are being replaced by Doppler radar in the NEXRAD project.

The NWS plans for ASOS to be in operation by the early 1990s. ASOS will be implemented in one of two levels basic or unmanned. In the unmanned level, ASOS systems will be installed at sites which currently do not have a meteorological observation system ASOS will therefore provide extensive surface meteorological measurements at locations where very little or no information has been available. In the basic level of service, ASOS will be installed at existing weather reporting stations. Initially, however, on-site observers will augment the system by reporting additional cloud information and special remarks. At some locations where an observer is available less than 24 hours a day, ASOS will run in an unmanned mode when the observer is not available. In all, about 1500 ASOS sites are planned for the next 10 years.

ASOS uses recent advances in meteorological instrumentation. A laser ceilometer will replace the current 25 year-old rotating beam ceilometer. The laser ceilometer can measure cloud bases through precipitation and can detect cloud layers up to 12,000 feet Visibility measurements will be taken with a forward-looking visibility meter. Wi

Table 1. *Meteorological Requirements for UNAMAP (Version 6) Models*

Model	Averaging Time	Meteorological processor	Format
BLP	Hourly	RAMMET	TD-1440/9689
RAM	Hourly	RAMMET	TD-1440/9689
ISCST	Hourly	RAMMET	TD-1440/9689
MPTER	Hourly	RAMMET	TD-1440/9689
CRSTER	Hourly	RAMMET	TD-1440/9689
MPTDS	Hourly	RAMMET	TD-1440/9689
COMPLEXI	Hourly	RAMMET*	TD-1440/9689
CALINE-3	Hourly	None	Unique
INPUFF	Hourly	None	Unique
PEM-2	Hourly	None	Unique
PLUVUE-2	Hourly	None	Unique
HIWAY-2	Hourly	None	Unique
PAL-2	Hourly	None	Unique
APRAC-3	Hourly	None	Unique
PBM	Hourly	PBMMET	TD-1440/9689
MESOPUFF-2	Hourly	READ56/MESOPAC	TD-1440/5600
TUPOS	Hourly	MPDA	TD-1440/5600/onsite
SHORTZ	Hourly	METZ	TD-1440/9689/onsite
PTPLU-2	Hourly	None	none-required
CDM-2	Long-term	None	STAR
ISCLT	Long-term	None	STAR
VALLEY**	Long-term	None	STAR
LONGZ	Long-term	None	STAR

**RAMMET is a generic name for EPA short-term meteorological processors.*
***Can also predict 24-hour average concentrations.*

the eventual automation of ASOS, a laser weather identifier is being developed. The current design employs a light-emitting diode weather identifier (LEDWI). The LEDWI can discriminate between rain, snow, and drizzle and can estimate their intensities. However, it cannot discriminate between hail and ice pellets. Other instruments being updated include the hygrothermometer and the windvane.

ASOS will have the capability of storing data on-site and will connect with the existing data dissemination network. Current plans are for hourly data summaries to be stored on-site for 30 days and 1-minute data to be stored up to 8 hours. Eventually, the data from ASOS will be disseminated via the AWIPS and archived at the NCDC.

Table 2. *Meteorological Data Formats Used with UNAMAP (Version 6) Models*

NCDC Format Identifier	Description
TD-1440	Hourly surface observations
TD-5600	Twice-daily rawinsonde observations
TD-9689	Twice-daily mixing height estimates
TD-9773	STAR data--joint frequency distributions of wind speed, wind direction, stability class

Despite its advantages, ASOS poses potential shortcomings for air pollution models. At unmanned sites, cloud information will be available only to 12,000 feet. Current EPA meteorological processors require opaque cloud cover for stability estimates. However, the ASOS program office intends to maintain observers at primary locations so that certain information such as the upper-level cloud cover can be reported. Unfortunately, current plans by the NWS state that hourly values of meteorological variables will be based on only 2-minute data averages collected on the hour. Since data will be sampled every minute, true hourly averages (especially of winds) could be obtained at little additional cost. However, this averaging and archival of hourly data requires a commitment of funds that currently does not exist.

Since World War II, rawinsondes have been used to measure the vertical structure of wind, temperature, moisture, and pressure in the atmosphere. Although the system is well established, some minor improvements are being implemented. Microprocessors are being installed at each rawinsonde site which will automate data collection and perform many of the quality assurance checks. This should result in greater data capture and improved data quality. The microprocessors coupled with a redesign in the rawinsonde package will yield more frequent measurements. Instead of 60 seconds, data will be archived for every 30 seconds of ascent, thus providing improved resolution of vertical measurements. Also, data measured every six seconds will be archived at each site for up to six months.

For years, rawinsondes have not provided upper-air data in a temporal and spatial resolution desired by numerical weather prediction and air pollution modelers. Currently, upper-air data are available every 12 hours and only at selected stations. The profiler system is designed to fill in these temporal and spatial data gaps for weather forecasting purposes.

The profiler is a ground-based remote sensing system designed to measure wind, temperature, and moisture profiles above a given site during all weather conditions. It consists of two subsystems: a wind profiler and a thermodynamic profiler. The wind profiler is a UHF (frequency currently established at 405 MHz) clear-air radar which is sensitive to backscatter from radio refractive-index irregularities caused by turbulence. Winds with the profiler are determined from Doppler shifts of the backscattered signal. The thermodynamic profiler used for measuring temperature and moisture consists of six channels of a radiometer which measures thermally emitted electromagnetic energy.

Like the ASOS program, the profiler network poses some potential problems for air pollution modelers. The lower limit of measurement for the 405 MHz wind profiler is 0.5 km. This limitation would be a detriment to boundary layer models which require lower-level winds. The NWS has indicated that it is considering to collocate acoustic Doppler sounders along with the wind profilers to provide lower-level winds. However, these plans require further investigation. With the thermodynamic profiler, temperature and moisture data will be measured up from the surface, but the accuracy of these measurements will decrease with height. Satellite sensing data is expected to augment this data at upper levels. Preliminary tests of the radiometric measurements indicate that while the temperature and moisture profiles are averaged quite accurately, the radiometer fails to detect rapid changes in these parameters. Research is continuing on how to integrate information from the wind profiler and other data sources to the temperature and moisture readings. Therefore, while it will be beneficial to have hourly vertical profiles of temperature and winds, much work remains to be accomplished with the profiler to obtain the data in sufficient vertical resolution for air pollution modeling.

Another advanced system planned for deployment in the 1990s is NEXRAD. Like ASOS, it is the culmination of years of research in an effort to modernize instrument systems. NEXRAD is a Doppler radar which provides increased range and resolution of reflectivity patterns. It also can estimate wind velocities within precipitating clouds. While its primary purpose is for severe storm detection and tracking, its gridded precipitation estimates should assist in regional-scale air pollution modeling.

The NCDC each day handles hundreds of requests for data. Six staff meteorologists interact with users to determine the data needs for each user. The number of data requests and the amount of data continue to grow at a staggering pace. The center handles over 20,000 requests for data per year. It also has to maintain a tape library of over 30,000 magnetic tapes which grows weekly. Because of this huge amount of data, NCDC has started to modernize its operation.

Modernization activities at NCDC include an increased use of Personal Computers (PCs) and the introduction of the element format. Several data formats are available on floppy diskette. These include TD-1440 surface data, TD-3280 surface data, TD-9689 mixing height data, and TD-9773 STAR data. As PCs gain favor among the air pollution modeling community, the sale of floppy diskettes by NCDC will likely grow.

Thus far, the new element formats (TD-3280 and TD-6200) have not been used in EPA air pollution modeling. Although they have been available since 1984, changes in computer codes for EPA meteorological processors take time and money. However, discussions with NCDC have revealed that obtaining the same data in TD-3280 format instead of TD-1440 reduces costs by about 40 percent. NCDC is basically set up on a cost reimbursable basis -- they charge what it costs them to generate the data. Because data are stored in the element format, it is advantageous to obtain the data in the new format.

The advent of new observational systems in the NWS presents additional challenges to NCDC. NCDC has made some effort on establishing formats for NEXRAD and profilers. Archiving data for NEXRAD will be a problem because of the amount of gridded data. The amount of data consists of gridded values (for 1 km by 2 km areas) every 5-15 minutes for up to 25 variables. Clearly, this is a large amount of data and needs to be maintained in a logical manner. Because profilers are still undergoing development, their data are being stored by NOAA's Environmental Research Laboratory in Boulder, Colorado. Eventually, the profiler data need to be added to the national archive, but no arrangements for archiving the data have yet been made.

Summary and Recommendations

This project began as an attempt to understand how data formats from the National Climatic Data Center (NCDC) were changing and how these changes would impact EPA's meteorological processors. While investigating these changes, we learned of new advances in meteorological instrumentation and data dissemination which potentially can benefit EPA's air pollution models.

For EPA to best accommodate the planned changes to NWS observation and data dissemination programs and the planned changes to NCDC's data formats, we offer the following recommendations:

(1) *Recognizing that EPA's meteorological processors will need to be modified to handle new NCDC data formats, they should also be upgraded to incorporate our more advanced knowledge of diffusion meteorology.* This upgrade could also serve as a catalyst for incorporating more advanced modeling techniques into air pollution models. It should be noted that such efforts have begun with the development of the Meteorological Processor for Diffusion Analysis (MPDA) and the Turbulence Profile Sigmas (TUPOS) model.

(2) *EPA should encourage the collection of meteorological data specific to diffusion modeling and should investigate the feasibility of collecting some of these data at NWS sites.* As recommended by an expert panel in 1981, additional meteorological variables such as horizontal fluctuations of wind direction ($\sigma\theta$), harmonic mean wind speeds, low-level temperature gradients, and total solar radiation should be collected for air pollution modeling. It is promising to note that EPA recently provided guidance for collecting some of these variables at on-site measurement programs. Not all air pollution modeling applicants, however, will have access to an extensive meteorological monitoring program and will have to depend on NWS data. Therefore, EPA should actively coordinate NWS meteorological data collection programs through the Office of the Federal Coordinator. In particular, it is advisable that EPA maintain vigorous participation in the Working Groups for Automated Surface Observations, Profiler Systems, and Radar Meteorological Observations. Perhaps with funding from appropriate organizations and cooperation with the NWS, additional meteorological data for diffusion modeling can be collected at NWS sites.

(3) *The formatting and handling of meteorological data for regional-scale models should be improved.* Regional-scale models require vast amounts of surface, upper-air, and satellite data. Because these models operate sequentially, data must be sorted by hour. Unfortunately, NCDC data are sorted by station and not by hour. Consequently, much effort goes into generating a data set in the appropriate format. Two options which could be investigated include the development of a new NCDC data format and direct access and storage of NWS observations by EPA.

(4) *The Environmental Operations Branch (EOB) should maintain active communication with NCDC.* In performing this study, it became quite apparent that NCDC is willing to be responsive to the needs of the air pollution modeling community. By improving communication with NCDC, EOB can more effectively inform users about changes in data formats. One possibility is to develop a users' guide describing meteorological data requirements for UNAMAP models. The guide would also provide information on how to order meteorological data from NCDC, and it could serve as a valuable reference manual for NCDC meteorologists when dealing with air pollution modeling clients.