3D-AQS

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1. INTRODUCTION – THE MANAGEMENT/POLICY ISSUE FOR $PM_{2.5}$

Airborne particulate matter smaller than 2.5 μm ($PM_{2.5}$) is one of the major air pollutants monitored and regulated by U.S. Environmental Protection Agency (EPA) as mandated by the Clean Air Act. Elevated $PM_{2.5}$ levels have been linked to decreases in lung function and to increased hospitalization due to exacerbation of respiratory or cardiovascular diseases and premature death from cardiopulmonary causes and cancer [1]. High $PM_{2.5}$ concentrations are also responsible for reduced visibility throughout national parks and wilderness areas, often referred to as regional haze.

We have documented that NASA remote sensing data can greatly enhance EPA's monitoring networks through the correlation of aerosol optical depth (AOD) and $PM_{2.5}$ [2-6]. We have recently been funded by NASA with significant support from NOAA and the USEPA to integrate remote sensing data into the EPA Air Quality Systems. This paper will outline the work to be done under this project. The work focuses on the synergistic needs that exist between air quality forecasting, assessments, and public health tracking through the use of multi-scale NASA aerosol data streams to define influences on ambient $PM_{2.5}$ concentration. We will integrate NASA's unique atmospheric scientific data into EPA's decision support monitoring networks, expanding EPA's 1 and 2-dimensional air quality networks into a 3-D air quality system (3D-AQS) through integration of satellite and lidar data. Two primary EPA support networks will be enhanced as parts of 3D-AQS: EPA's Air Quality System/AirQuest air quality regulatory databases and the AIRNow real-time monitoring and forecasting system. We will also support EPA's contribution to the Center for Disease Control's (CDC) National Environmental Public Health Tracking Network and the National Oceanic and Atmospheric Administration (NOAA) Air Quality Mapping System. These systems are decision support systems (DSS). The NASA data and scientific resources that will be integrated are MODIS, OMI, CALIPSO, AERONET, AIRS, MPLNET, as well as GOES, REALM and ground-based University of Maryland, Baltimore County (UMBC) resources.

2. DECISION SUPPORT USER COMMUNITY AND TOOLS

Listed below are the DSS that will be enhanced with NASA data and resources.

2.1 AirQuest/Air Quality System (Ambient Air Monitoring)

EPA's Air Quality System (AQS) supports both AirQuest and AIRNow-DMC, decision-support tools that consolidate data from the national network of air quality monitors into centralized databases which are then used by policymakers for developing new air pollutant rules, monitoring municipality compliance to current air quality standards, determining regulatory accountability, and helping $PM_{2.5}$ pollution forecasting. These monitoring networks represent an extensive system of *in-situ* point measurements, collected in the AQS DSS, yet they do not form a continuous view of the horizontal or vertical spatial scale of pollutants. The addition of NASA and NOAA satellite data would greatly enhance this DSS by adding "continuous" data surfaces of aerosol extinction and AOD for the entire U.S. This expanded coverage would not only help to identify local and regional sources of particulates but also the role of intercontinental and transboundary transport on U.S. air quality. The satellite and lidar data that will make up 3D-AQS will be incorporated into AirQuest, a complementary system to the AQS, designed to accommodate new and multi-dimensional datasets, such as health and geospatial datasets for use by EPA and State/Local air agencies.

2.2 AIRNow ($PM_{2.5}$ Next Day Forecast)

National air quality forecasts and near real-time data visualization of ozone concentrations for major US metropolitan areas have been provided to the public by a partnership between the EPA and state and local agencies through the AIRNow website (U.S. EPA 2005a) since 1997. Forecasts of $PM_{2.5}$ were started in 2003 and numerical forecasts of $PM_{2.5}$ will be available in the east by 2009 and nationally by 2014. These forecasts rely on surface based pollutant measurements. However, large regions of the U.S. are devoid of surface monitors. In addition, pollution aloft may not be detected by AIRNow ground monitors and these polluted airmasses can migrate and mix with surface air far downwind, leading to increases in pollutant concentration at the ground in areas without local sources..

2.3 NOAA's Air Quality Mapping System (AQMS)

NESDIS plans to enhance its support by developing an Air Quality Mapping System (AQMS) system that blends different NASA and NOAA satellite-based products of air quality and optimize information for forecast guidance. NOAA is interested in partnerships that can help overcome challenges associated with developing this AQMS system to achieve its air quality goals.

2.4 National Environmental Public Health Tracking Network (NEPHTN)

Through this project we will work with the existing CDC Public Health Air Surveillance Evaluation (PHASE) project to demonstate the use of NASA science data to support the National Environmental Public Health Tracking Network (NEPHTN) (CDC 2002), currently being developed by the CDC. We propose to use the NASA aerosol related data sets within a spatial prediction model to generate "continuous" ambient air quality data surfaces of $PM_{2.5}$ for the eastern U.S. These maps will then be used by the public health community to assess associations with important health outcomes for the purpose of informing the Nation's public health system.

2.5 Infusing satellite Data into Environmental Applications (IDEA)

IDEA is a 2-D near real-time system and website that integrates MODIS AOD, EPA $PM_{2.5}$ concentrations, meteorological data, and models for use by EPA and state and local forecasters in monitoring and predicting $PM_{2.5}$ concentrations for public notification IDEA was developed in a cooperative project between NOAA, EPA and NASA to provide real-time views of AOD from MODIS, compare these with the EPA AIRNow ground monitors, include trajectory information for forecast guidance, and provide a brief analysis for the public.We intend to migrate IDEA to an operational environment. At the same time, IDEA will further evolve into a fully three-dimensional tool, including analysis of transport of aerosols in the atmosphere using lidar data from the proponents and from new satellite sensors.

2.6 U.S. Air Quality Weblog (The Smog Blog)

The U.S. Air Quality weblog [7] provides daily interpretation of regional aerosol vertical distribution by coupling MODIS AOD, GOES AOD, and surface $PM_{2.5}$ concentrations with UMBC lidar measurements over the Baltimore-Washington corridor. The site also summarizes air quality throughout the U.S. using satellite, lidar, and ground-based air quality inputs. The weblog will be used as a testbed for new 3-D data visualization techniques and as a means to communicate to EPA managers and others about the use of integrated datasets in near real-time.

3. NASA AND NOAA RESEARCH TO SUPPORT EPA DECISION SUPPORT TOOLS

3.1 MOderate Resolution Imaging Spectroradiometers (MODIS)

MODIS onboard both EOS-Terra (10:30 a.m. equator crossing time) and EOS-Aqua (1:30 p.m. equator crossing time) satellites are capable of deriving aerosol loading independent of vertical distribution via the scattering of light by aerosol particles in the visible wavelength. As a calibrated and well-documented product, MODIS AOD standard products (10 x 10 km^2) will serve as the base layer of satellite data for 3D-AQS. Finer resolution products (4 x 4 km^2 and 1 x 1 km^2) will be produced to enhance the spatially resolved AOD data in key regions (such as northeastern US) and in specific urban areas (e.g., New York, Chicago, Houston, etc.).

3.2 GOES Aerosol and Smoke Product (GASP)

MODIS has shown that the integrated aerosol optical depth product is central to mapping the spatial extent and movement of $PM_{2.5}$ aerosols; however, MODIS only retrieves AOD from once-daily daylight overpasses of both the Terra and Aqua satellites. The visible channel on the GOES platforms have been used to derive a daytime aerosol optical depth product called GASP [8,9]. As a new application, we will use GASP in a coordinated and systematic fashion with MODIS in 3D-AQS. We will use the MODIS morning and afternoon overpasses to calibrate ("vicariously") the GASP AOD product. We will use these results to guide planning for use of data from the Advanced Baseline Imager on GOES-R (which will have multiple visible and infrared channels) so that a high time resolution product is available by the beginning of the next decade.

3.3 AErosol RObotic NETwork (AERONET)

Ground-based sunphotometer measurements made by the AERONET provide the ground truth of AOD (every 15 minutes) as well as the inferral of single scattering albedo and aerosol size distributions from hourly almucantar measurements.

3.4 Ozone Monitoring Instrument (OMI)

OMI on the Aura Spacecraft will be utilized to determine the single scattering albedo of the aerosol column from OMI's ultraviolet aerosol absorption index (AAI) [10]. This allows determination for the first time of aerosol speciation related parameters from spaceborne optical sensors and particularly the predominance of aerosol black carbon in the aerosol makeup.

3.5 Cloud Aerosol Lidar with Orthogonal Polarization (CALIOP)

CALIOP on the Cloud-Aerosol Lidar and Infrared Pathfinder Spaceborne Observations (CALIPSO) Mission will provide a revolutionary ability to determine the placement of aerosols within the vertical column. As members of the CALIPSO science team, we have early access to CALIOP data. CALIOP allows us to determine where in the vertical important aerosol features lie.

3.6 The Regional East Aerosol Lidar Mesonet (REALM) and Micropulse Lidar Network (MPLNET)

In addition to the overpasses of CALIPSO and its lidar, CALIOP, daily observations of vertical profiles of aerosol backscatter and extinction are made by the lidars in the REALM [11] and the Micropulse Lidar Network (MPLNET) [12]. REALM measurements of aerosol profiles in the U.S. within the framework of 3D-AQS.

IV. CASE STUDY FROM THE INTEX-NE STUDY PERIOD.

In the summer of 2004, a rare winter-like high-latitude jet stream plunged into the eastern half of the US, resulting in a big trough east of the Rocky Mountains. This pattern brought a wet east coast summer and corresponding low insolation, cool weather and low ozone. This summer also had large forest fires in Alaska with more than 4 million acres of forest burned, resulting in significant $PM_{2.5}$ transport into the continental U.S. This period will be analysed in detail in a future paper, but it is illustrative of what 3D-AQS can bring to the understanding of air quality.

Figure 1 is a composite image with three days of MODIS AOD images from the IDEA site, lidar observations from the UW and UMBC lidars from REALM, GASP imagery, and AIRS CO columns from North America. This period was analysed in detail on the IDEA site and on the US Air Quality weblog, and presented at a recent AMS meeting [13]. These data sources easily identified smoke-rich air moving southward on July 17 covering the entire state of Minnesota, and farther down to Kansas and Oklahoma on July 18. The smoke plume stretched from coastal Louisiana and Texas to Quebec on July 19 by the high- and low-pressure systems in control over the western and eastern U.S. On July 20, the smoke plume was broken up, when passing the Appalachian Mountain, into two aerosol masses, one lingering in the south and one continuing to move to the east. Along the passage of the smoke plume, the REALM surface-based lidars recorded the vertical distribution of smoke at UW-Madison, New York City (CCNY), Chebogue Point, Nova Scotia (Dalhousie University) and at UMBC. The smoke subsided as it moved from north to south from 6 km into the boundary layer (clearly seen from the lidar measurements at UW-Madison and UMBC) and from the increased EPA $PM_{2.5}$ mass concentration peaking at 60 $\mu g\ m^{-3}$ on July 22 in Baltimore. It is this type of event which forces air quality managers to react since this level is at a threshold for EPA regulatory actions. The AIRS CO retrievals demonstrate the similar evolution of the smoke event as shown by MODIS AOD. The AIRS CO products are valuable to provide supportive evidence of smoke produced by combustion. Our conclusion from the IDEA and REALM data is that a significant portion of the AOD seen in the images was due to smoke generated in Alaska. From the MODIS AOD and AIRS CO products, it is certain that a significant fraction of aerosol abundance was smoke from Alaska, showing not only that long-range transport aerosols can impact local air quality but that we are able, with the combination of tools shown here, to understand the fraction of aerosol from local sources and from long range transport.

These results are consistent with the conclusions of NOAA/EPA forecasters working on this case and showed that their model was not incorrect by a factor of two, but rather their model missed a transient source of $PM_{2.5}$ which added nearly 50% of the aerosol mass to the US East Coast during this period [14]. EPA regulators can use this integrated analysis to understand cities that may or may not be out of compliance due to transported PM. Adding satellite and 3-D profiling sources enable better air quality decisionmaking.

5. References

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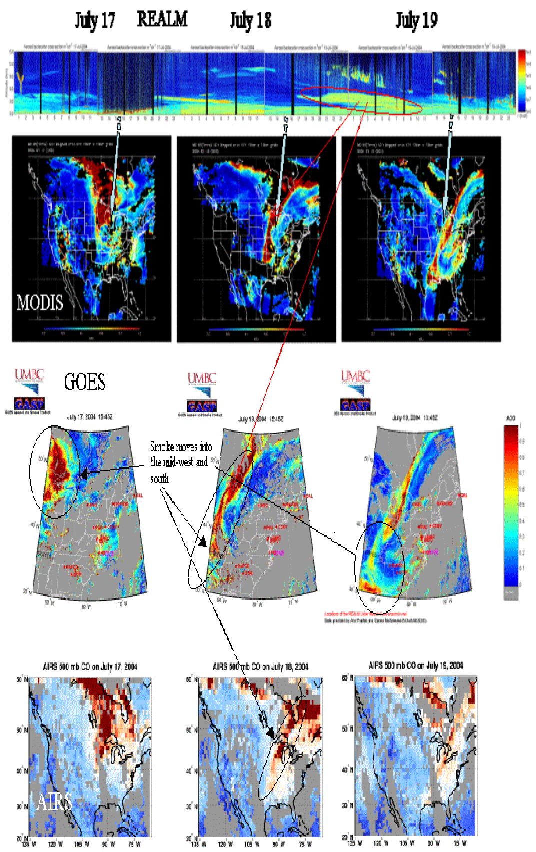

Figure 1. Example of 3D-AQS data sources: (top) REALM U. Wisconsin lidar for July 17-19