Solutions Network Formulation Report

Integration of OMI and TES Aerosol Products into the EPA Regional Planning Organizations' FASTNET Aerosol Tracking and Analysis Tool

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1. Candidate Solution Constituents

a. Title: Integration of OMI and TES Aerosol Products into the EPA Regional Planning Organizations' FASTNET Aerosol Tracking and Analysis Tool

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c. Identified Partners: U.S. Environmental Protection Agency Regional Planning Organizations: CAPITA (Center for Air Pollution Impact and Trend Analysis); Cooperative Institute for Research in the Atmosphere

d. Specific DST/DSS: CAPITA FASTNET (Fast Aerosol Sensing Tools for Natural Event Tracking)

e. Alignment with National Application: Air Quality

f. NASA Research Results – Table 1:

Mission	Sensors/Models	Data Product
Aura	OMI (Ozone Monitoring Instrument)	• OMAERUV (aerosol extinction and absorption optical depth) • OMNO2 (nitrogen dioxide total and tropospheric columns) • OMSO2 (sulfur dioxide total column - not yet available)
Aura	TES (Tropospheric Emission Spectrometer)	• TL2NO2L (nitrogen dioxide limb observations – not yet available)

g. Benefit to Society: Improved accuracy in air quality monitoring; better crisis/natural disaster effect mitigation; better air pollution source identification; more accurate prediction of air pollution episodes; improved testing accuracy for atmospheric model outputs

2. Abstract

Every year, more than 280 million visitors tour our Nation's most treasured parks and wilderness areas. Unfortunately, many visitors are unable to see the spectacular vistas they expect because of white or brown haze in the air. Most of this haze is not natural; it is air pollution, carried by the wind often hundreds of miles from its origin. Some of the pollutants have been linked to serious health problems, such as asthma and other lung disorders, and even premature death. In addition, nitrates and sulfates contribute to acid rain formation, which contaminates rivers and lakes and erodes buildings and historical monuments.

The U.S. Environmental Protection Agency RPOs (Regional Planning Organizations) have been tasked with monitoring and determining the nature and origin of haze in Class I scenic areas, and finding ways to reduce haze in order to improve visibility in these areas. The RPOs have developed an Internet-based air quality DST (Decision Support Tool) called FASTNET (Fast Aerosol Sensing Tools for Natural Event

Tracking). While FASTNET incorporates a few satellite datasets, most of the data utilized by this DST comes from ground-based instrument networks. The problem is that in many areas the sensors are sparsely located, with long distances between them, causing difficulties in tracking haze over the United States, determining its source, and analyzing its content. Satellite data could help to fill in the data gaps and to supplement and verify ground-recorded air quality data.

Although satellite data are now being used for air quality research applications, such data are not routinely used for environmental decision support, in part because of limited resources, difficulties with interdisciplinary data interpretation, and the need for advanced inter-agency partnerships. As a result, the validation and verification of satellite data for air quality operational system applications has been limited

This candidate solution evaluates the usefulness of OMI (Ozone Monitoring Instrument) and TES (Tropospheric Emission Spectrometer) air quality data for the RPOs by comparing OMI and TES data with ground-based data that are acquired during identified episodes of air pollution. The air quality data from OMI and TES are of different spectral ranges than data from satellites currently included in FASTNET, giving them potential advantages over the existing satellites. If the OMI and TES data are shown to be useful to the RPOs, they would then be integrated into the FASTNET DST for use on an operational basis.

3. Detailed Description of Candidate Solution

a. Purpose/Scope

Every year, our Nation's most treasured parks and wilderness areas draw more than 280 million visitors. Unfortunately, many visitors are unable to see the spectacular vistas they expect. During much of the year, a veil of white or brown haze hangs in the air. Much of this haze is not natural—it is air pollution, carried by the wind often hundreds of miles from its origin. This haze substantially reduces the visibility range. In eastern parks, the average visual range has decreased from 90 miles to 15–25 miles; in the West, visual range has decreased from 140 miles to 35–90 miles. Some of the pollutants that form haze have also been linked to serious health problems and environmental damage. Exposure to very small particles in the air has been linked with increased respiratory illness, decreased lung function, and even premature death. In addition, particles such as nitrates and sulfates contribute to acid rain formation, which makes lakes, rivers, and streams unsuitable for many fish and erodes buildings, historical monuments, and paint on cars.

Most air pollution monitoring is performed using ground-based sensor networks. Sensors are sparsely located in some regions. The low density of sensors causes difficulties in tracking air pollution events over long distances, in identifying their sources, and in accurately determining their content. Satellites have the potential capacity to fill in data gaps in areas with few ground-based sensors and to enhance and verify air quality measurements in regions possessing ground-based sensors. Although satellite data are now being used for air quality research applications, such data are not routinely used for environmental decision support, in part because of limited resources, difficulties with interdisciplinary data interpretation, and the need for advanced interagency partnerships. As a result, the validation and verification of satellite data for air quality operational system applications has been limited (Engel-Cox et al., 2004a).

This study examines the use of air quality products from the OMI (Ozone Monitoring Instrument) and TES (Tropospheric Emission Spectrometer) sensors onboard the Aura satellite to enhance the FASTNET (Fast Aerosol Sensing Tools for Natural Event Tracking) DST (decision support tool). This candidate solution explores how the integration of OMI and TES air quality data into FASTNET could be used to enhance the monitoring of air quality parameters in near-real-time and be used as a DST for the mitigation of environmental- and health-related concerns.

b. Identified Partners

The EPA (U.S. Environmental Protection Agency) enacted the RHR (Regional Haze Rule) in 1999 as a result of actions originating with the Clean Air Act, which Congress amended in 1977 to protect visibility in areas of scenic importance defined as Class I areas (EPA, 1997, 1999a, 1999b, 2005). The EPA established five RPOs (Regional Planning Organizations) to enforce the RHR. The RPOs are tasked with monitoring, analyzing, and finding ways to reduce haze in scenic areas across the United States. The RPOs use an Internet-based DST called FASTNET that compiles air quality data from many ground-based sensor networks and from a few satellites. FASTNET was developed and is supported by personnel at CAPITA (Center for Air Pollution Impact and Trend Analysis) and by the RPOs (CAPITA, 2006).

Correspondence has been initiated with members of three of the five EPA RPOs: the Midwest Regional Planning Organization, the Western Regional Planning Organization, and the Mid-Atlantic/Northeast Visibility Union. Correspondence has also taken place with members of CAPITA.

The FASTNET input datasets include historical and near-real-time ground-based data from a variety of sensor networks, satellite data, surface weather parameters, and aerosol model outputs. Satellite data are from MODIS (Moderate Resolution Imaging Spectroradiometer), TOMS (Total Ozone Mapping Spectrometer), SeaWiFS (Sea-viewing Wide Field-of-view Sensor), and GOES (Geostationary Operational Environmental Satellite). Another source of historical ground-based air quality data is an information portal called VIEWS (Visibility Information Exchange Web System). VIEWS inputs include particulate density and species data from urban and suburban sites as well as aerosol extinction coefficient, fine particle speciation, and visibility data that were collected at Interagency Monitoring of Protected Visual Environments Network sites in national parks and rural recreation areas (VIEWS, 2006; IMPROVE, 2006).

FASTNET is accessible through DataFed.net, a distributed Web-based computing environment for accessing, processing, and rendering real-time and retrospective air quality data (DataFed, 2006; Husar et al., 2005). The DataFed network has access to more than 50 datasets, of which FASTNET has direct access to more than 14. FASTNET also contains links to the DataFed data catalog, to the five RPOs, to the VIEWS datasets, to CAPITA (CAPITA, 2006), and to the Cooperative Institute for Research in the Atmosphere, which maintains VIEWS (VIEWS, 2006).

Another informational input to FASTNET is the NAAPS (Navy Aerosol Analysis and Prediction System) model. This model is generated by the Global Aerosol Model of the Naval Research Laboratory. NAAPS outputs are expressed as surface concentration and vertical optical thickness. Data parameters include dust concentration; mixed dust, smoke, and sulfate aerosol optical thickness; smoke concentration; and sulfate concentration. Another accessible tool is the WRF (Weather Research and Forecasting) Model developed by the National Oceanic and Atmospheric Administration. The WRF Model generates imagery that displays forecasts for ozone, nitrogen oxides, and fine particulates (UCAR, 2006).

The RPOs have identified four critical air quality applications for which remote sensing satellite technology could be used: (1) detection of particulate matter less than 2.5 microns in diameter (PM 2.5), such as dust and smoke; (2) particulate matter between 2.5 and 10 microns in size (PM 10), including some forms of dust; (3) nitrogen oxides (NO_x); and (4) sulfur oxides (SO_x). For remote sensing satellite data to be useful for the specified RPO applications, the data should meet the following five criteria: (1) near-real-time acquisition, (2) daily and possibly bi-daily data availability, (3) horizontal resolution of 10–40 km or better, (4) vertical resolution of surface or total column, and (5) availability as imagery and numeric formats.

The RPOs use FASTNET outputs to track the movement of air pollution events and to trace them backwards in time to identify the sources. They analyze the content of air pollution and predict upcoming episodes.

The FASTNET outputs can be displayed as single images, animated movies over a selected time period, or layers on a GIS (geographic information system). Statistical analysis can be performed on the data. Output data can be visualized as time charts, site maps, site data, point data, or grid data. The VIEWS software is capable of providing data summaries, graphic back trajectories, relevant GIS data, and trend analyses.

The RPOs report their analysis of regional haze and air quality to the EPA Office of Air Quality Planning and Standards.

c. NASA Earth-science Research Results

Aura was launched in July 2004 and has a 6-year design life. The satellite, part of the "A-train," is in a sun-synchronous polar orbit crossing the equator at 1:45 PM. The orbit has a period of 100 minutes and a repeat cycle of 16 days.

OMI is a hyperspectral push-broom imager onboard Aura with 740 channels over a spectral range of 0.27–0.50 μm. The nominal ground resolution is 13 x 24 km, which can be zoomed to 13 x 13 km for detecting and tracking urban-scale pollution sources. Temporal resolution is once per day. OMI data products currently available include NO_2 total and tropospheric columns, ozone total column, and cloud pressure and fraction. Of particular interest is the aerosol product containing extinction and absorption optical depth, which has recently become available (Ahmad et al., 2005; GSFC, 2006). Another product not yet available is SO_2.

TES is a high-resolution, infrared-imaging, Fourier transform spectrometer onboard Aura with spectral coverage of 3.2 to 15.4 μm and the capability to make both limb and nadir measurements. In the limb mode, the height resolution is approximately 5 km with coverage from 0 to 34 km, and the horizontal resolution is 53 x 169 km. In the nadir mode, the horizontal resolution is 5.3 x 8.5 km. Temporal resolution is once every 2 days. The product of interest is NO_2 volume mixing ratio and vertical resolution (limb mode).

The OMI and TES data are in HDF-EOS5 format.

d. Proposed Configuration's Measurements and Models

OMI possesses an important advantage over the sensors currently included in FASTNET: its spectral range extends from visible to ultraviolet wavelengths, whereas the MODIS, SeaWiFS, and GOES operate at visible and infrared but not at ultraviolet. TOMS records only in the ultraviolet range. OMI, with its simultaneous visible and ultraviolet measurement capability, can be used to calculate Aerosol Indices that distinguish between absorbing aerosols (such as dust and smoke) and nonabsorbing aerosols (such as sulfates), and between dust and smoke if the smoke aerosol optical thickness is less than 2 (Stammes, 2002). The MODIS, TOMS, SeaWiFS, and GOES sensors lack this capability. However, MODIS has proven to be useful for certain air quality applications (Engel-Cox et al., 2004b).

NASA satellite data may be invaluable for filling in the gaps in regions with few or no ground-based monitors, thereby enhancing the RPOs' ability to perform quantitative analysis of the interstate transport of haze, emissions monitoring, and validation and verification of air quality models. OMI is expected to be able to distinguish between absorbing and nonabsorbing aerosols and between dust and smoke in some circumstances, significantly aiding the RPOs in analyzing the content and sources of haze events. In certain natural disasters, ground-based sensors can be disabled or destroyed, as happened during Hurricane Katrina. Satellite data may provide the only air quality information available for portions of the Louisiana and Mississippi Gulf Coast during the aftermath of Katrina.

The OMI and TES data will need to be transformed into a format compatible with FASTNET. Because FASTNET is already capable of accepting certain satellite datasets, this transformation should be straightforward.

The Aura mission, launched in July 2004, has a design life of 6 years. The aerosol product (aerosol extinction and absorption optical depth) became available in March 2005, and the NO_2 product became available in September 2004. The OMI SO_2 product and the TES NO_2 limb product are not yet available. Because of instrument lifetime concerns, the acquisition of TES limb data has been suspended during nominal Global Survey operations since April 10, 2005. TES can be operated in the limb mode for special requests, but no historical NO_2 limb data exists. However, the effect on the candidate solution is minor because OMI is the primary instrument and TES is of secondary importance.

4. Programmatic and Societal Benefits

This solution aligns with the Air Quality National Application by integrating NASA satellite air quality data into a DST used by the EPA RPOs for monitoring and analyzing haze in scenic Class I areas. The addition of NASA satellite data could result in improved accuracy in air quality monitoring and air pollution source identification. Crisis and natural disaster effects could be more efficiently mitigated with the aid of satellite air quality data, particularly if the ground-based sensors are disabled. Finally, prediction of air pollution episodes could be improved, and the accuracy of atmospheric model outputs could be tested.

5. References

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