Using NASA Satellite Aerosol Optical Depth Data to Create Representative PM$_{2.5}$ Fields for Use in Human Health and Epidemiology Studies in Support of State and National Environmental Public Health Tracking Programs

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Project Overview

• ROSES 2010 Earth Science Applications Feasibility Studies: Public Health

• Received funding August 18, 2011

• 2-year period of performance

• Co-Investigators:
  – Stephanie Weber, Battelle
  – Dr. John Braggio, Maryland Dept of Health and Mental Hygiene
  – Thomas Talbot, New York State Dept of Health

• Collaborators:
  – Eric Hall, National Exposure Research Laboratory, USEPA
  – Fred Dimmick, retired USEPA
Project Motivation

• Studies that analyze human health effects of exposure to atmospheric PM$_{2.5}$ use measurements from USEPA’s national ground-based monitor network

• PM$_{2.5}$ network has significant gaps in coverage

• Traditional methods that interpolate gaps in monitor data (e.g., kriging) may not capture spatial trends

• A new approach is needed to provide representative PM$_{2.5}$ fields for health studies
**Approach**

- Combine PM$_{2.5}$ monitor network data, NASA satellite aerosol optical depth (AOD), and CMAQ air quality model predictions to make a single dataset

- Addition of AOD data is expected to create more temporally and spatially representative PM$_{2.5}$ concentration field compared to only monitor data and/or CMAQ

- Use EPA/Battelle Hierarchical Bayesian model (HBM) to combine datasets
  - In areas where monitors are present, HBM gives most weight to monitor data
  - In areas where monitors do not exist, HBM will use estimates of surface PM$_{2.5}$ concentration from AOD
  - In areas where no AOD data are available, HBM will use CMAQ
Aerosol Optical Depth (AOD)

- AOD is a measure of scattering and absorption of visible light in vertical column between TOA and Earth’s surface.
- AOD is proportional to PM$_{2.5}$ concentration; high AOD corresponds to high PM$_{2.5}$.
- Values range 0-1.
- Project will use AOD measured by MODIS on Terra and Aqua satellites.
Benefits of Using Satellite AOD:

- Information in areas where monitors do not exist
- Captures spatial distribution of PM$_{2.5}$ field
- Measured value so it reflects actual concentrations of PM$_{2.5}$ in atmosphere (unlike CMAQ model)

Challenges and Risks:

- AOD represents particles in vertical column of atmosphere, not at surface
  - Statistical correlation studies widely accepted to estimate surface PM$_{2.5}$ concentration from AOD
- CMAQ output is not an observation (higher uncertainty)
- 12×12 km spatial resolution of combined datasets (set by CMAQ output) may be too coarse for use in health studies
  - EPA recommends CMAQ 12×12 km for EPHT program datasets
Approximate Study Regions

- Baltimore, MD
- New York City, NY
- 2004-2006
Experimental Design

• Download and prepare datasets:
  – PM$_{2.5}$ monitor data: USEPA’s Air Quality System (AQS)
  – MODIS AOD data: NASA LAADS; convert to PM$_{2.5}$ surface concentrations using season- and location-dependent relationships in Zhang et al., 2009
  – CMAQ model output: provided by USEPA

• Use HBM to create combined PM$_{2.5}$ datasets: “CMAQ-HBM” and “AOD-HBM”

• Compare PM$_{2.5}$ datasets to health outcome datasets:
  – Asthma visits to ED
  – Acute MI
  – Ischemic heat disease
  – Heart rhythm and conduction disturbances
  – Cerebrovascular disease
  – Peripheral artery disease
  – Heart failure

<table>
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<tr>
<th>PM$_{2.5}$ Analysis Datasets</th>
<th>PM$_{2.5}$ Concentration Data Sources</th>
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<td>PM$_{2.5}$ Monitors</td>
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<td>“Monitors”</td>
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Statistical Analyses

1. Determine accuracy of estimated PM$_{2.5}$ datasets (“CMAQ,” “CMAQ-HBM,” “AOD,” “AOD-HBM”) in relation to “Monitors”
   - 2004-2006 data
   - Does addition of AOD increase accuracy of combined PM$_{2.5}$ dataset?

2. Estimate impact of short-term variations in PM$_{2.5}$ concentrations on health outcomes
   - 2004-2005 data
   - Case-crossover analyses using all 5 PM$_{2.5}$ analysis datasets
     - Comparison of results to Haley et al., 2009 will determine if addition of AOD increases correlation with health outcomes for NYC
Statistical Analyses

3. Determine which estimated PM$_{2.5}$ dataset is most accurate for predicting health outcomes
   - Use results from Stage 2 with logistic regression models to predict health outcomes for 2006
   - *Does addition of AOD increase accuracy of combined PM$_{2.5}$ dataset?*

4. Determine effects of spatial variations in PM$_{2.5}$ across metropolitan scale on health outcomes
   - 2004-2006 data
   - Same as Stage 2 but add spatial location in case-crossover analysis
   - Separate impacts of high PM$_{2.5}$ (downtown) from low PM$_{2.5}$ (rural)
Public Health End-User Programs

If results of feasibility study show value in using HBM to create combined PM$_{2.5}$ datasets including AOD, we will provide results to state/national environmental tracking programs:

- **Maryland Environmental Public Health Tracking (EPHT) Program**
  - Dr. Clifford S. Mitchell, Director of Infectious Disease and Environmental Administration, MDHMH

- **National Environmental Public Health Tracking Network**
  - Dr. Judy Qualters, Chief of Environmental Health Tracking Branch, CDC

- **USEPA Advanced Monitoring Initiative (AMI) for the Baltimore PM$_{2.5}$ Community of Practice (CoP)**
  - Dr. Cynthia Stahl, Environmental Scientist, USEPA Region 3
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  – Stephanie Weber, Battelle
  – Dr. John Braggio, Maryland Dept of Health and Mental Hygiene
  – Thomas Talbot, New York State Dept of Health
  – Eric Hall, USEPA
  – Fred Dimmick, retired USEPA
Example: Correlation between MODIS AOD and PM$_{2.5}$ for Baltimore

\[ y = 26.9 \times + 8.2 \]
\[ r = 0.77 \]

Baltimore, Maryland
2005
Example: Correlation between MODIS AOD and PM$_{2.5}$ for May 2007 in U.S.

- Correlation varies by:
  - Region and season
  - Vertical aerosol distribution and properties
  - Meteorological conditions such as relative humidity and boundary layer height

- AOD retrievals are less accurate over bright surfaces such as desert or snow

Image generated by Giovanni, NASA GES DISC