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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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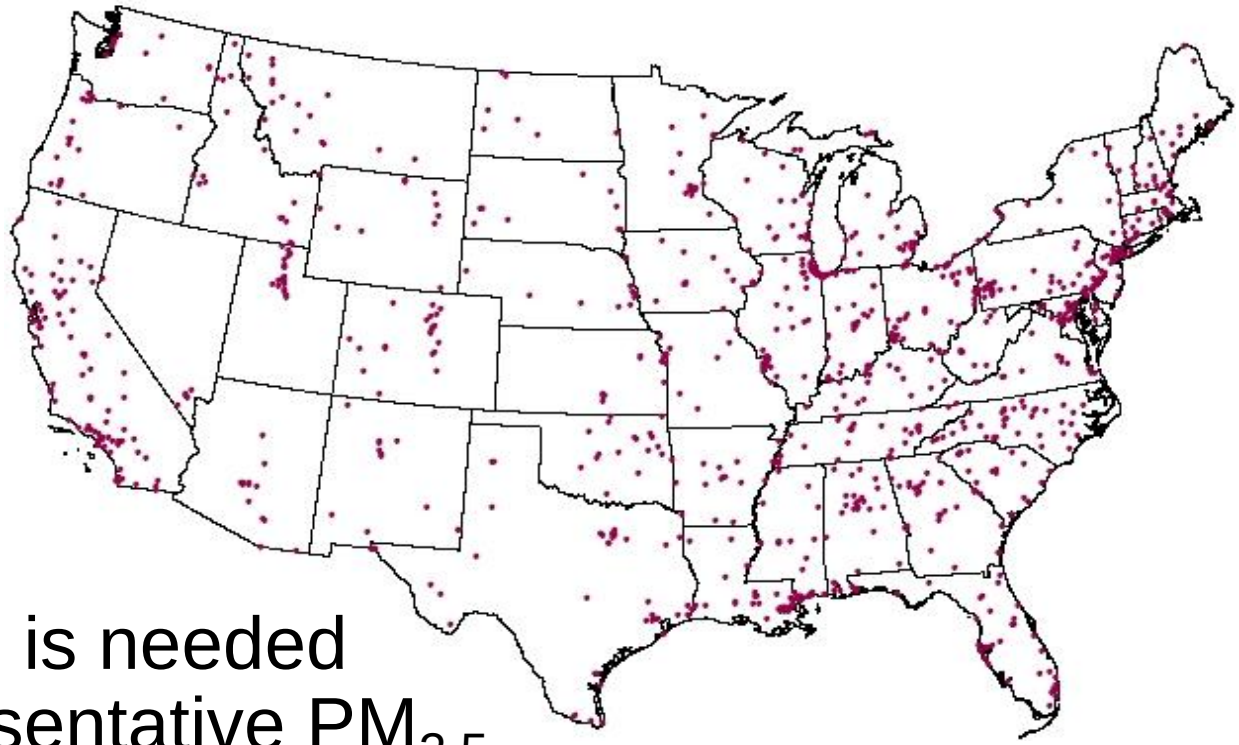
Project Overview

- 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

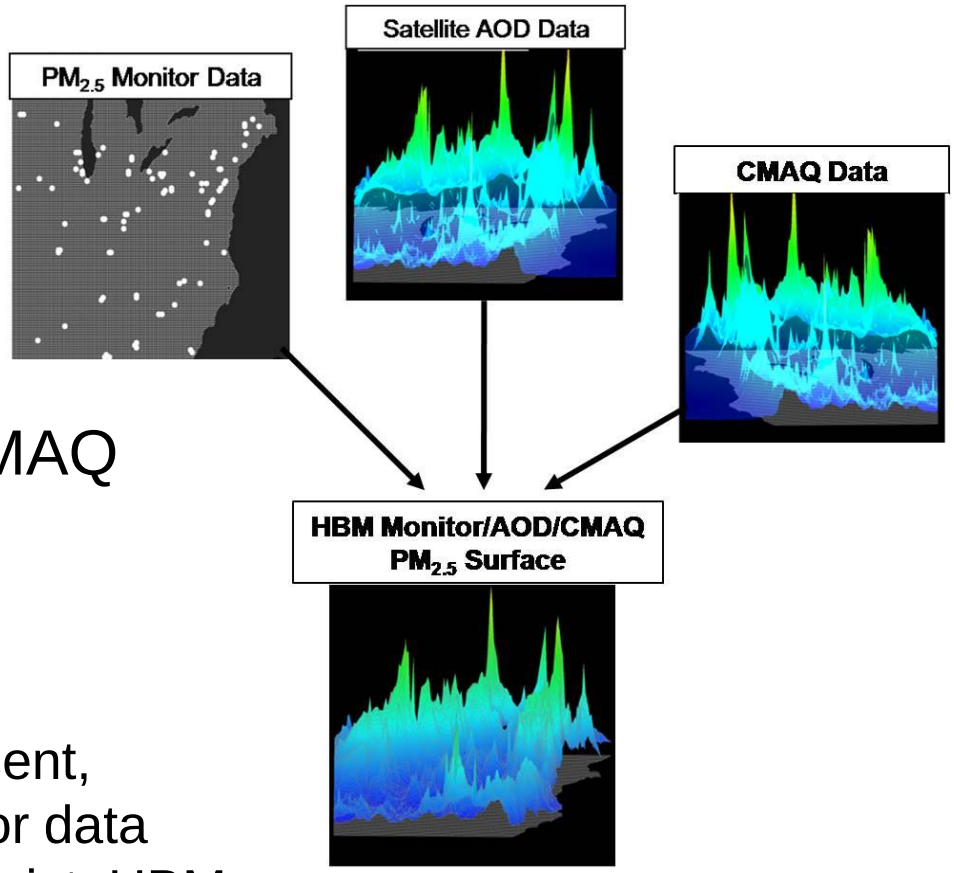
Project Motivation

- 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



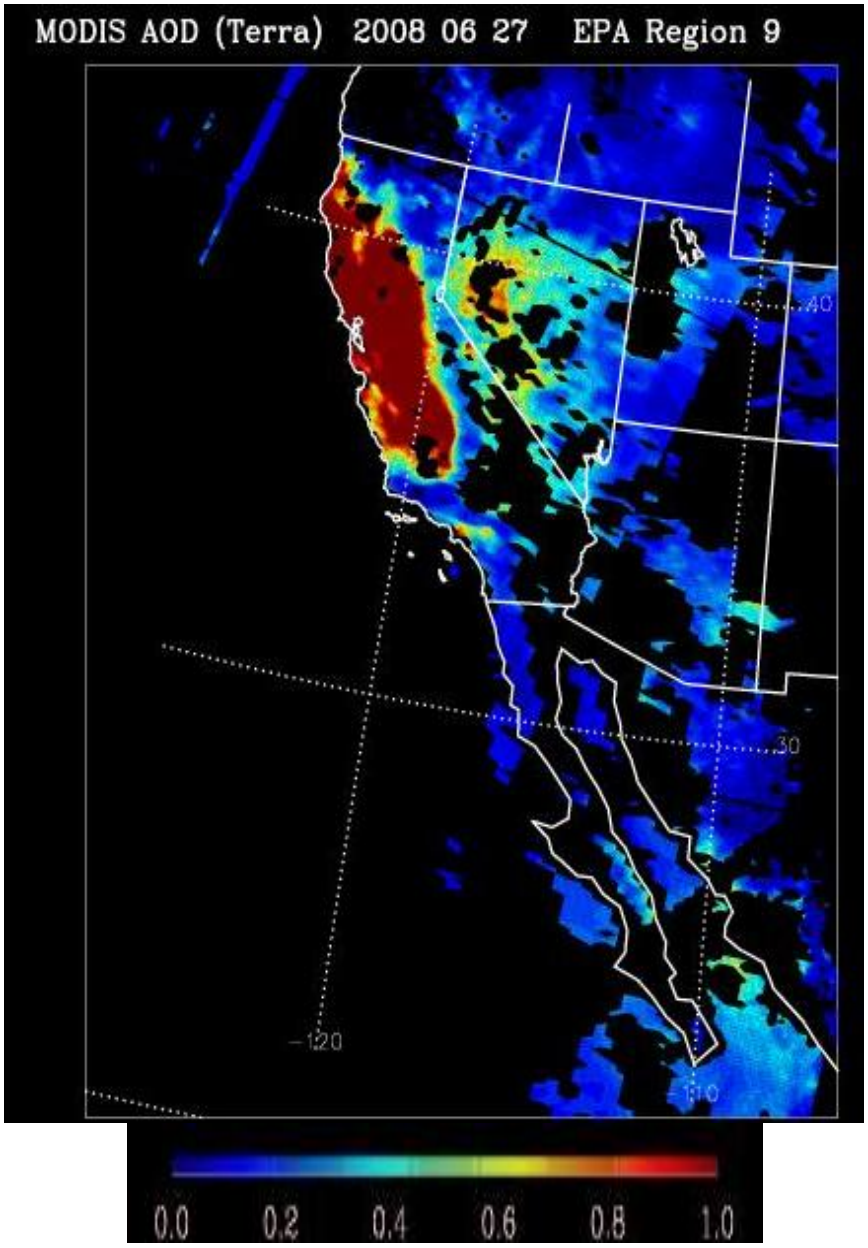
Approach

- 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:

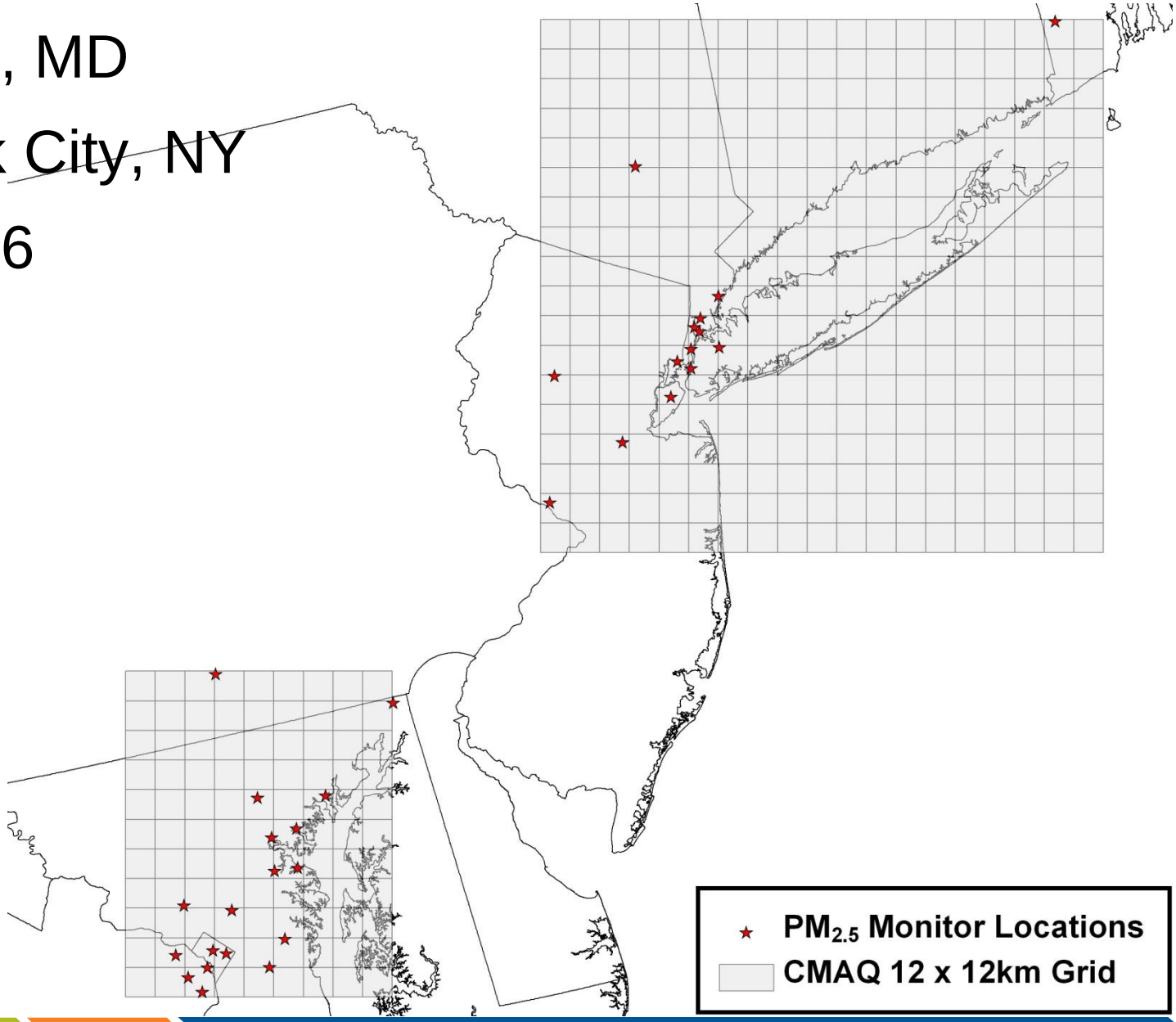
- Information in areas where monitors do not exist
- Captures spatial distribution of $PM_{2.5}$ field
- Measured value so it reflects actual concentrations of $PM_{2.5}$ in atmosphere (unlike CMAQ model)

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

$PM_{2.5}$ Analysis Datasets	$PM_{2.5}$ Concentration Data Sources		
	$PM_{2.5}$ Monitors	Satellite AOD	CMAQ Model
"Monitors"			
"AOD"			
"CMAQ"			
"CMAQ-HBM"			
"AOD-HBM"			

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

Acknowledgements

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- John Haynes and Sue Estes
- Co-Investigators and Collaborators:
  - Stephanie Weber, Battelle
  - Dr. John Braggio, Maryland Dept of Health and Mental Hygiene
  - Thomas Talbot, New York State Dept of Health
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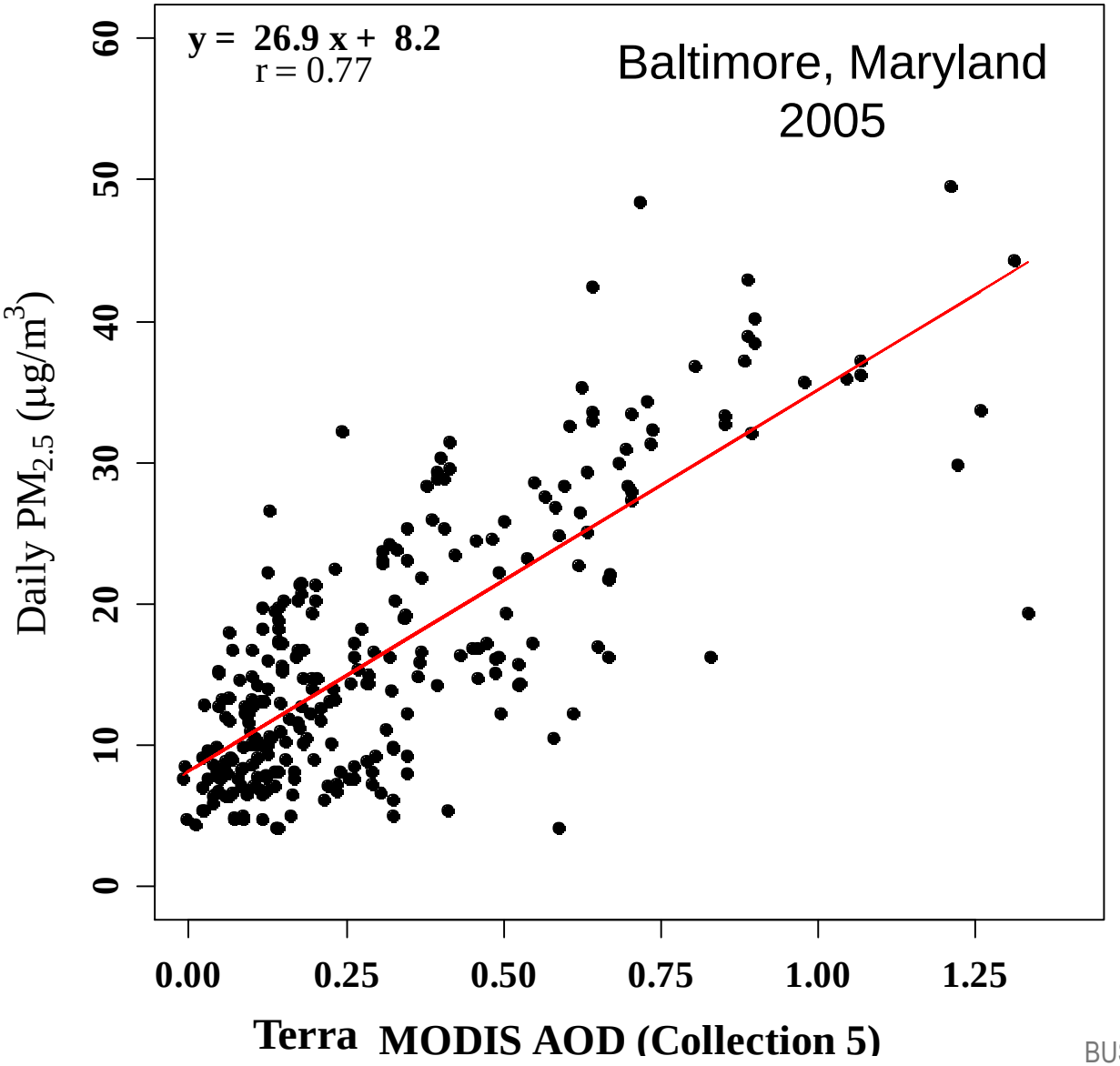
Example: Correlation between MODIS AOD and $PM_{2.5}$ for Baltimore



Example: Correlation between MODIS AOD and $PM_{2.5}$ for May 2007 in U.S.

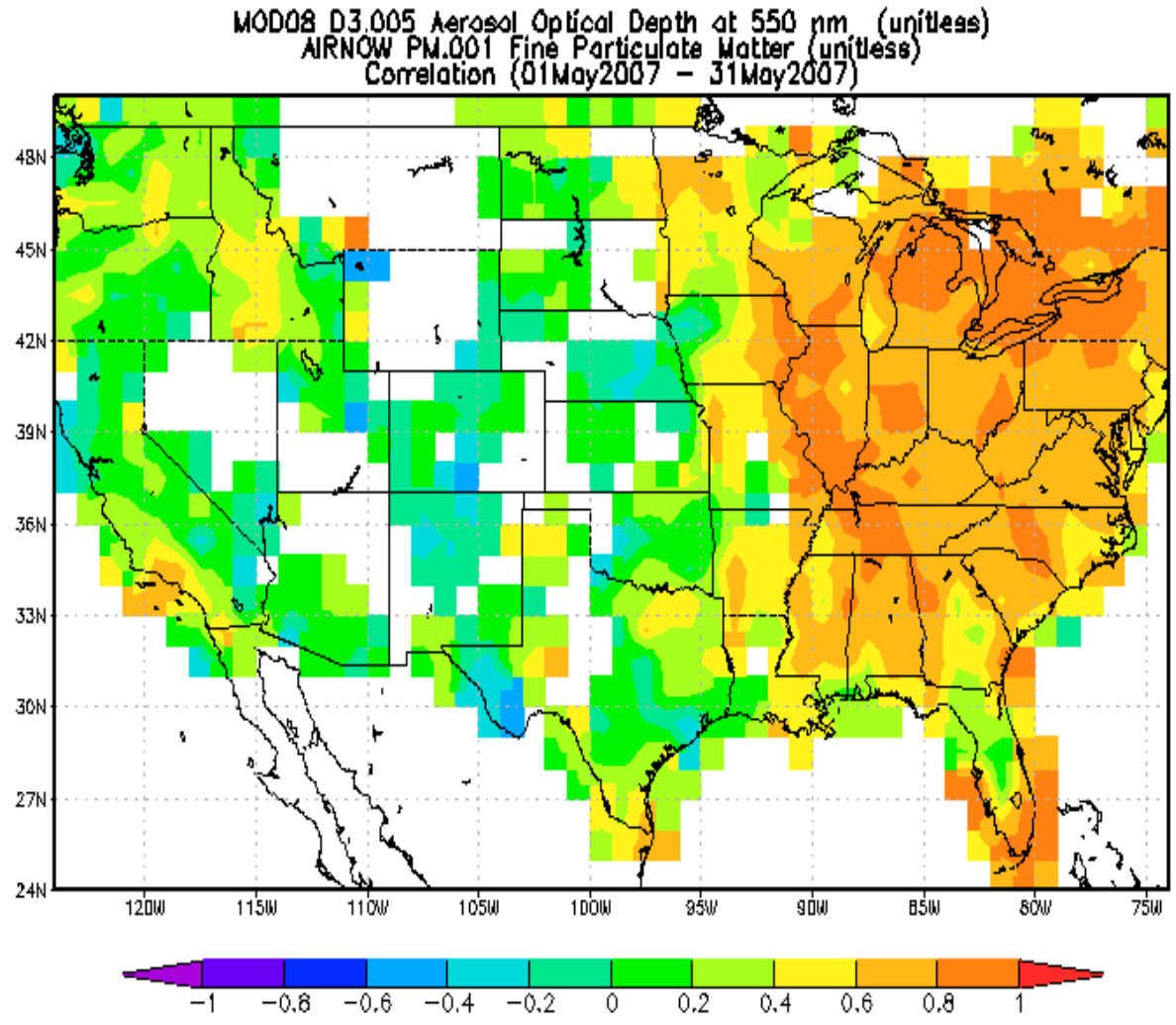


Image generated by Giovanni , NASA GES DISC

- 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