Improve EPA’s Air Quality Index Maps with NASA Satellite Data

AirNow Satellite Data Processor (ASDP) Project Update

John E. White
U.S. Environmental Protection Agency

2012 NASA Health and Air Quality Applications Program Review

September 19th, 2012
What is AirNow?

AirNow is the national framework for acquiring and distributing air quality information

- Collects, quality assures, and transfers real-time and forecasted air quality information to the public
- Gathers data provided by 130 federal, state, and local air quality agencies
- Issues weather/air quality news stories
- Partners with national media and other agencies
- Provides air quality education and outreach

America’s “go to” resource for current and forecasted air quality information
ASDP Project Objectives

- Improve operational air quality maps currently in AirNow and make them available 24 hrs a day every day
- Provide satellite data products in AirNow-Tech
- Improve tools for air quality forecasting

Without satellite data, no contouring is possible in the hatched areas
Project Background

• **Satellite data:**
  – A variety of satellite products can be used for the ASDP.
  – ASDP using MODIS (Terra/Aqua -- passes over each region twice daily)
  – Team has developed sophisticated algorithms to estimate 24-hour ground-level PM$_{2.5}$ concentrations based on Aerosol Optical Depth (AOD) and GEOS-Chem simulations
  – Estimates are dependent on data availability (e.g., no satellite data are available in areas with significant cloud cover or bright surfaces)

• **Ground observations:**
  – Using hourly observations from AirNow to calculate PM$_{2.5}$ 24-hour averages
  – Point data are interpolated using kriging method

• **Fused map product:**
  – Ground observations are fused with satellite estimates
  – Fusion employs an algorithm that assigns relative weights to each observation and estimate according to the data’s uncertainty at that point
  – Satellite weight + ground observation weight = 1 at any given point
Project Background

- Spatial coverage of current AirNow maps is limited
- There are significant data gaps resulting in over 36 million American (~40% of the area) not covered by a monitoring network
- Satellite data, specifically AOD can provide information to “fill-in” these gaps

Example: New Mexico and Mexican Fires 5/24/2012

Current continuous AirNow PM$_{2.5}$ monitoring sites

Satellite data captures the smoke and observed aerosols not in the AirNow data.
• Philip Dickerson, EPA, Research Triangle Park, NC
• John E. White, EPA, Research Triangle Park, NC
• James J. Szykman, EPA/NASA LaRC, Langley, VA
• Allen Chu, UMBC, Baltimore, MD
• Shobha Kondragunta, NOAA/NESDIS, Washington D.C.
• Randall Martin, Dalhousie University, Nova Scotia, Canada
• Sonoma Technology, Inc. (STI), EPA Contractor, Petaluma, CA
• Center for Technology and Government at the University Albany (CTG), EPA Sub contractor, Albany, NY
Key Partnerships

• Dalhousie University
  - Developed algorithms to estimate surface PM$_{2.5}$ concentrations from AOD

• NOAA NESDIS Satellite Applications and Research (NOAA/NESDIS/STAR)
  - Infusing satellite Data into Environmental Applications (IDEA)
  - Agreed to run the algorithms developed by Dalhousie University
  - Provide to AirNow DMC on an operational basis as part of IDEA processing

• Center for Technology and Government at the University Albany (CTG)
  - Perform a socioeconomic benefits analysis of adding NASA satellite data to AirNow (now in progress)
Preliminary Results: Smoke and No Monitors (Dakotas)

May 16th, 2012

MODIS True Color and AirNow Observations

AOD and AirNow Observations

Smoke and aerosols
Preliminary Results: Smoke and No Monitors (Dakotas)

- Smoke in Dakotas (MODIS and AOD)
- Limited Air Quality Monitors
- ASDP Product adds information (Moderate)
- Next Steps: How good is this information (from both a scientific and socio-economic perspective)
Preliminary Results: Isolated Unhealthy for Sensitive Groups

- High AOD (smoke?) in central Indiana
- Large USG area due to interpolation
- ASDP constrains the monitor influences
Accomplishments/Outcomes

• Developed the ASDP modules
  - Data selection and weighting and uncertainty
  - Data fusion and Testing
  - Dalhousie reduced relative errors in estimating surface PM$_{2.5}$ from satellite data from 50%-100% to <50% for most of North America
  - Dalhousie also eliminated the need for an online calculation of the AOD/PM$_{2.5}$ ratio (submitted journal article on method)

• Surveyed AirNow-Tech users

• Created a sub-committee of AirNow stakeholders
  - Evaluation and feedback of products

• Developed a project website: aspd.airnowtech.org

• Outreach award for additional videos (in progress)

• Award for socio-economic evaluation (in progress)
  - Draft literature review in progress
  - Face-to-face interviews w/ state, local, EPA regional, public health officials
  - Analyze benefits of AirNow and the addition of NASA satellite data

• Established a real-time operational data feed at NOAA
Accomplishments/Outcomes

Operational ASDP Project website:
aspd.airnowtech.org
## Schedule/Milestones

<table>
<thead>
<tr>
<th>Task</th>
<th>PY2010</th>
<th>PY2011</th>
<th>PY2012</th>
<th>PY2013</th>
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<tbody>
<tr>
<td><strong>Derivation of satellite-based surface PM$_{2.5}$</strong></td>
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<td>Preliminary gridded monthly AOD/PM$_{2.5}$ ratios and error estimates</td>
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<td>Grided monthly AOD/PM$_{2.5}$ ratios and error estimates</td>
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<td>Report on the necessary steps for creating an hourly satellite-estimated surface PM$_{2.5}$ product</td>
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<td>Baseline study on the relationship between AOD and PM$_{2.5}$ using high spectral resolution LIDAR</td>
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<td>Comparison of MODIS and GOES AOD to develop regional uncertainty factors</td>
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<td>Journal article on daily satellite-based estimate of ground-level PM$_{2.5}$</td>
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<tr>
<td><strong>Derivation of satellite-based surface NO$_2$ concentrations</strong></td>
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<td>Monthly gridded climatology of the relationship between tropospheric NO$_2$ column and surface NO$_2$ concentration</td>
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<td>Report on other progress and recommendations related to the inference of NO$_2$ from satellite observations</td>
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<td><strong>Creation of AirNow Satellite Data Processor</strong></td>
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<td>Selection and initial evaluation of data fusion techniques</td>
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<td>Research and development of a prototype data fusion software system to researched and selected data fusion techniques</td>
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<td>Development of a community and project website to display preliminary results as a mechanism for feedback</td>
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<tr>
<td>Developing the ASDP modules, including data selection, weighting and uncertainty, data fusion, and testing applications</td>
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### KEY

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<td>Green</td>
<td>Completed</td>
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<td>Yellow</td>
<td>Progress Started</td>
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<tr>
<td>Orange</td>
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<td>Satellite data in AirNow-Tech</td>
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<td>Proof-of-concept website for AirNow-Tech using open-source GIS tools combined with a web services to display NASA satellite data, and AirNow</td>
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<td>AirNow Satellite Data Processor Documentation</td>
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<td>Functional Specification Document</td>
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<td>Initial User's Guide</td>
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<td>Socioeconomic Analysis</td>
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<td>Professional Communication</td>
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<td>13th Conference on Atmospheric Chemistry AMS Annual Meeting</td>
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<td>AGU Fall Meeting</td>
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<td>Integrated Annual Progress Report</td>
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### KEY

- **Color**
  - Green: Completed
  - Yellow: Progress Started
  - Orange: Task to begin in the next Project Year

- **Status**
  - O: On Track
  - X: Behind Schedule
Upcoming Plans

- **AirNow Satellite Data Processor**
  - Integrate ASDP in AirNow Information Mapping System (IMS) and continue to evaluate and test the results
  - Finalize a peer-reviewed journal article on the method
  - Bring satellite products into AirNow-Tech (AirNow Navigator)
  - Work with NASA to gain access to a better web service with higher resolution that is more reliable and is standards compliant
    - NASA developers are evaluating options (e.g. creating tiles in both projections vs. on-the-fly generation vs. a hybrid scheme)

- **Socioeconomic Evaluation**

- **Outreach Videos**
  - Remote Sensing and Air Quality, description of the method used to estimate PM$_{2.5}$ surface concentration from AOD, and a case study evaluation

- **Some Investigation...**
  - Jim Szykman looking into the use of Dave Holland/EPA approach of a downscaler to fuse satellite data with PM$_{2.5}$ surface concentrations and PM$_{2.5}$ BlueSky model predictions
  - Use of VIIRS and GASP to replace MODIS AOD
  - Use of an Empirical Bayesian Kriging Interpolation method
Project Risks/Challenges

• Technical Risks
  - Loss of satellite a big one
  - Team is looking into using data from VIIRS and GASP (in preparation for GOES-R)
  - ASDP can fuse gridded data from any source (satellites, numerical models, other)

• Stakeholder Support/Buy-in
  - Engaged them early to help with the evaluation of the product
  - Received great feedback (product changes/availability)
  - Creating outreach section of Project website (case studies, meeting minutes, presentations)

• Operational Challenges
  - Satellite algorithms are running in a research capacity at NOAA NESDIS as part of IDEA
    - Lost data feed recently for 1+ months because of facility move (came back online 9/14/12-will try to get data backfilled for AirNow community)
  - Not much we can do since NOAA has agreed to run for us (without receiving funding support)

• Management Issues (none to report)
  - Dalhousie has been excellent team member and has stayed in constant communication and delivered products on time and on budget.
Application Readiness Level

- **2009 - Project started at ARL 2**
- **August 2011 – ARL 4**
- **July 2012 – ARL 7**
  - ASDP running at AirNow Data Management Center
  - Testing/evaluation being done in operational mode
- **Project will end at ARL 8**
Project Budget

- **Project Funding Obligated to Date - $996,018.00**
  - Base Funding Summary $260,594 (FY10), $267,676 (FY11- received late), $272,691 (FY12)
  - Supplemental Awards
    - Outreach videos ($9,844 FY12)
    - Socio-economic Study ($185,213 FY12)
- **Final Year – FY13**
  - $9,930 for Outreach Videos just received by EPA in mid-August
  - Awaiting base funding $228,500
  - EPA will modify inter-agency agreement once remaining funding is received (necessary step to put funds on contract)
Thank you

John E. White -- EPA AirNow
(919) 541-2306, white.johne@epa.gov
Data Flow and Processing for ASDP (Working Draft)

IDEA (NOAA)

Process:
\[ PM_{2.5} = \text{AOD} \times F(\text{date}) \]
\[ PM_{2.5 \text{unc}} = F(\text{date}, PM_{2.5}) \times PM_{2.5} \]
Input: HDF5/NetCDF (static)
Output: NetCDF
Format: CMAQ
Resolution: 4 km

AOD: PM_{2.5}
Format: HDF5/netCDF
Number: 365
Contents: 30-day average
Resolution: 4 km
Size: < 1.0 GB for all files

Uncertainty in Total PM_{2.5}
Format: HDF5/netCDF
Number: 365
Contents: 30-day average
Resolution: 4 km
Size: < 1.0 GB for all files

AIRNow DMC (STI)

Process: ASDP (see attached)
Input: Sat. PM_{2.5}
Sat. Unc
AIRNow Obs
Output: Maps (jpg, png)
KML
Text Files (.csv)

FTP – Push or Pull 2 NetCDF files
Time: TBD

If interested, we could send KML output for display on IDEA website

Key
Data
System
Process

Processed currently at Dalhousie University; want to move to IDEA
1. Based on the date, read the associated AOD:PM_{2.5} and uncertainty files
2. Acquire the satellite AOD: Terra or Aqua
3. Apply the appropriate ratio to AOD
4. Determine the uncertainty
5. Produce NetCDF data file
6. Save to FTP location (for either AIRNowDMC to grab or push to AIRNowDMC)
NASA satellite data needed to improve AIRNow (America’s public air quality information system)

Data Types:
- Images (e.g. PNG, GIF, JPEG, TIFF)
- KML

Access: WMS
Attributes: OGC Standard

Example of Selected Organizations
- Federal, State, Local, and Tribal Air Quality and Health Agencies (~200+)
  - Washington D.C. COG
  - LADCO
  - South Coast AQMD (Los Angeles, CA)
  - EPA Region 9 Air Resources Board
- Emergency Responders
  - U.S. Park Service
  - U.S. Forest Service
  - BP Oil Spill Response
- Weather Service Providers (~75)
  - Weather Channel
  - CNN
  - USA Today
  - WeatherBug
  - Mobile Application Developers (~20)
  - Challenge Grant
  - University Researchers (~30)
  - UMBC
  - USC
  - Vanderbilt
  - UC Davis
  - International Collaborators
    - Canada
    - Mexico

“I study satellite pictures and I like to compare AIRNow maps to what is going on in the US using satellite pictures.”

Air Monitoring Manager, Local Air Quality Management District (AQMD)