Three Dimensional Air Quality System (3D-AQS)

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Outline

• NASA 3D-AQS overview
• Current and future 3D-AQS data sets
• Case examples
Why are we interested in measuring air quality data in 3D?

• Regional haze and regional scale events
• Long and medium distance transport
• Clean Air Interstate Rule
• Improved modeling
• Regulatory accountability

Satellite sensors can provide horizontal data coverage, ground and space-based lidar can measure aerosols in the vertical dimension.

Yet, it is difficult to access these data…
Overview of NASA 3D-AQS Project

- **Integrate** NASA satellite sensor and lidar data into EPA’s air quality data systems: AQS/AirQuest, IDEA

- Provide greater *accessibility* and *usability* of satellite and lidar data to users of these systems

- Enable monitoring in *horizontal* and *vertical* dimensions for forecasting and retrospective analysis
Progress

- Formation and interaction with end user committee
- Completed benchmark report
- Determined priority datasets and sent to AirQuest (QA in progress):
  - MODIS AOD and PM$_{2.5}$ monitor matched data
  - MODIS AOD on CMAQ grid
- Started development of 3D visualization methods
- Transferring IDEA to operational NOAA environment:
  http://www.orbit.nesdis.noaa.gov/smcd/spb/aq/
- Created website and 2 page flyer: http://alg.umbc.edu/3D-AQS/
NASA 3D Air Quality System Timeline

Near-term Actions
- Benchmark demonstration at EPA on November 5
- Inclusion of new datasets (based on end user input) into AirQuest
- Prepare and finalize documentation (articles)
- Validate new IDEA site
- Implementation of 3D visualization and data output

Long-term Actions (2008-2009)
- Complete 3D data integration and visualization
- Conduct additional assessment of satellite data with EPA data
- Complete data integration and transition to operations
**Decision-Support Tools**

**AIRNow/AQS-EPA/NOAA**
- Increase synoptic data for PM$_{2.5}$ forecasters

**AQS/AIRQuest (EPA)**
- Multi-dimensional aerosol related data and analyses:
  - Assess general state of air quality and trends
  - Assess progress of SIPs and compliance
  - Waivers to air standards
  - Air quality rule development

**NEPHTN-PHASE (CDC)**
- Produce better AQ maps through statistical models

**Value & Benefits to Citizens & Society**

- Increase accuracy in AQ forecast: reduce poor air quality health impacts.
- Increase knowledge in causes or poor air quality – leading to improvements in AQ and confidence in government.
- Improved prevention initiative targeting.
3D-AQS integrates disparate datasets - our vision
NASA 3D-AQS Project: Purpose

- Integrate NASA satellite and lidar data into EPA’s air quality data systems:
  - AQS
  - AirQuest
  - IDEA

- Provide greater accessibility and usability of NASA satellite and lidar data to their users

- Provide remote sensing data in horizontal and vertical dimensions to facilitate air quality forecasting and retrospective analysis
NASA 3D-AQS Project: Current Initiatives

• Sent first datasets to AirQuest – QA in progress:
  – MODIS and GOES AOD matched to surface PM$_{2.5}$ monitor data
  – MODIS AOD matched to CMAQ 12×12 and 36×36 km$^2$ grids

• Developing 3D visualization methods for remote sensing data

• Transferring IDEA content to operational NOAA site

• Prioritizing next datasets for inclusion in AirQuest, based on input from End Users:
  1. Ground-based lidar
  2. OMI tropospheric NO$_2$
  3. OMI-derived tropospheric O$_3$
  4. CALIPSO aerosol extinction profile
  5. MISR AOD
Daily posts

NASA satellite images, EPA data, etc.

Daily posts from 3.5 years
~ 35,000 visitors per month, including universities, EPA, NASA, NOAA, & States, and general public
http://alg.umbc.edu/REALM
MODIS aerosol optical depth, with aerosol trajectory forecast

GOES aerosol optical depth, with aerosol trajectory forecast
Direction of changes to the website

IDEA* → “3D-IDEA”

* Infusing satellite Data into Environmental Applications
Current Datasets Sent to AirQuest

- MODIS and GOES AOD matched to ground-based PM$_{2.5}$ monitors
  - MODIS - fully incorporated
  - GOES/GASP - fully incorporated
Current Datasets Sent to AirQuest

- MODIS AOD matched to 12 km and 36 km CMAQ grids
  - test dataset prepared with MODIS AOD data regridded to a 36 km CMAQ grid for entire U.S. and a 12 km grid for the eastern U.S. domain
Current Datasets Sent to AirQuest

- MISR AOD, matched to PM monitors
  - tested, full historical dataset being developed by NASA JPL

- Ground-based LIDAR data
  - in development

9 view angles at Earth surface with 14-bit pushbroom cameras
7 minutes to view each scene from all 9 angles
275 m spatial resolution per pixel
~400-km swath width
Calibrated measurements of the intensity of reflected sunlight
4 spectral bands at each angle:
  - 446 nm ± 21 nm
  - 658 nm ± 15 nm
  - 672 nm ± 11 nm
  - 968 nm ± 20 nm

Polar ELF

0.5
Altitude (km) 3

15:00 Time (UTC) 00:00
## Future Datasets

### 3D-AQS End User Rankings of Remote Sensing Datasets

<table>
<thead>
<tr>
<th>Ranking</th>
<th>Pollutant</th>
<th>Sensor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Particulate Matter (PM$_{2.5}$)</td>
<td>ground-based LIDAR</td>
</tr>
<tr>
<td>2</td>
<td>Nitrogen Dioxide (NO$_2$)</td>
<td>OMI</td>
</tr>
<tr>
<td>3</td>
<td>Tropospheric Ozone (O$_3$)</td>
<td>OMI-derived</td>
</tr>
<tr>
<td>4</td>
<td>Particulate Matter (PM$_{2.5}$)</td>
<td>CALIOP</td>
</tr>
<tr>
<td>5</td>
<td>Sulfur Dioxide (SO$_2$)</td>
<td>OMI</td>
</tr>
<tr>
<td>6</td>
<td>Particulate Matter (PM$_{2.5}$)</td>
<td>MISR</td>
</tr>
<tr>
<td>7</td>
<td>Carbon Monoxide (CO)</td>
<td>AIRS</td>
</tr>
<tr>
<td>8</td>
<td>Carbon Monoxide (CO)</td>
<td>MOPITT</td>
</tr>
</tbody>
</table>
Baltimore/Washington, DC Case Study
(5 Surface Monitoring Sites)

AirQuest/3D-AQS data can be used to evaluate specific pollution events...

Data:
- PM$_{2.5}$ (1 hr)
- PM$_{2.5}$ (24 hr)
- Sulfate
- MODIS AOD
- GASP AOD
- AERONET AOD
- LIDAR AOD
  - Total Column
  - Below PBL

July 9-14, 2004

Graph showing data for PM$_{2.5}$ and AOD from July 9 to July 14, 2004.
Baltimore/Washington, DC Case Study (cont.)

... or for relationship and trend analysis at specific sites or for specific regions

Daily PM2.5 vs. MODIS AOD
Summer 2004 and 2005

- $y = 27.4 \times 9.2$
- $R^2 = 0.43$

- $y = 28 \times 8.6$
- $R^2 = 0.57$

Hourly PM2.5 vs. ELF AOD
Baltimore, MD - Summer 2004

- $y = 48.8 \times 6.7$
- $R^2 = 0.43$

- $y = 30.7 \times 7.9$
- $R^2 = 0.4$
National MODIS AOD and PM$_{2.5}$ Case Study

• 2-year (2005 and 2006) comparison of v.4.0.1 and v.5.2.6 MODIS AOD data to surface PM$_{2.5}$ concentration measurements across the US by EPA Region

• v.5.2.6 AOD more highly correlated with surface PM$_{2.5}$ than v.4.0.1 AOD, and thus v.5.2.6 AOD data are more accurate
National MODIS AOD and PM$_{2.5}$ Case Study (cont.)

- v.4.0.1 AOD coverage is approximately 40% greater nationwide than v.5.2.6 AOD, due to differences in the cloud screening algorithms.
- v.5.2.6 AOD are more accurate, but v.4.0.1 AOD have greater coverage.
• MODIS AOD are more highly correlated with surface PM$_{2.5}$ concentration measurements in the summer compared to the winter months.

• v.4.0.1 and v.5.2.6 AOD are more accurate in the summer and less accurate in the winter.
3D-AQS Remote Sensing Data: Conclusions

- Satellite aerosol optical depth data matched to monitors and on CMAQ grid now available in AirQuest
- Applications include:
  - Location specific evaluation of satellite data versus EPA monitored data
  - Supplemental monitoring at increased spatial and temporal scales
  - Air quality model evaluation
  - Back trajectory studies to evaluate pollutant transport for CAIR
- New datasets available over next 18 months
Questions?