LIDAR and Satellite Monitoring of Ambient Particulate Matter
MANE-VU and Midwest-EPO Meeting
Timonium, MD July 10-11, 2007

MODIS 29 April 2007
Data from NASA GSFC and University of Wisconsin
The same plume in the vertical

This is why ground monitors in FL did not set off alarms

CALIPSO - A satellite lidar

(more on this later.....)
Measuring Carbon Optically

- I'm going to disappoint you, it can't be done.
- Current data and why EPA is interested in satellite and lidar data for aerosols
- Quick overview of existing satellite data
- Quick overview of lidar
- Status of 3D-AQS project
- How you can access these data and provide input to 3D-AQS
Why are we interested in measuring air quality data in 3D?

- Regional haze and regional scale events
- Long and medium range transport
- Clean Air Interstate Rule
- Improved modeling and validation of models
- Regulatory accountability
- Health endpoints?

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

"At this point, we are ants on a two dimensional world...."
Current Datasets: Ambient Air Monitoring for Aerosols

- “True” measure of air quality
  - Varying temporal scales (hourly, daily, 1 in 3 days)
  - Sparse networks spatially
- Ground-based concentration in mass units ($\mu g / m^3$)
- Monitors usually sited in urban or rural areas only, e.g.,
  - Urban FRM network
  - IMPROVE in Class I areas
- Used for forecasting and historical analysis (including compliance)
- Decision support systems include:
  - AQS / AirQuest (http://www.epa.gov/ttn/airs/airsaqs/)
  - AIRNow (http://www.airnow.gov)
Some key air quality satellite sensors
MODIS Direct: http://eosdb.ssec.wisc.edu/modisdirect/
IDEA: http://idea.ssec.wisc.edu/

MODIS Terra, October 10, 2006
MODIS Direct and IDEA run by UW-SSEC
UMBC data can all be found at http://alg.umbc.edu
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
Elastic Lidar Facility (ELF)

Atmosphere
Smoke, Haze, Dust, Clouds, Aerosols

Nd:YAG 532, 1064 nm

14” Schmidt-Cassegrain Telescope

Transmitter

Receiver

APD
PMT
http://alg.umbc.edu/REALM
NASA Three-Dimensional Air Quality System (3D-AQS) Project

- Integrate NASA satellite sensor and lidar data operationally into EPA’s air quality data systems: AQS/AirQuest, AirNow
- Provide greater accessibility and usability of satellite and lidar data to all users of these systems: IDEA, Smog Blog, REALM
- Develop visualization tools in horizontal and vertical dimensions for forecasting and retrospective analysis
Integrated System Solutions for 3-D AQS Impacting Air Quality & Public Health

**Value & Benefits to Citizens & Society**

**Partnership Area**

**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

**Observations**
- Terra/Aqua
- MODIS
- AIRS
- LIDAR
- REALM
- MPLNet
- GOES
- GASP
- Aura
- OMI
- CALIOP
- CALIPSO
- AERONET
- 3D-AQS
- IDEA
- USAQ Weblog

**Models**
- NOAA
- Hysplit
- LaRC modified IMPACT trajectory model

**Inputs**
- NASA/NOAA/EPA/UMBC/CIMSS/BMI

**Outputs**
- EPA/NOAA/CDC

**Outcomes**
- 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
Baltimore, MD Summer 2004

- Aug 10: Normal haze
- Aug 24: Transferred haze
- July 9: High altitude smoke
- July 21: Mixed down smoke
- Aug 10: Normal haze
- Aug 24: Transferred haze
Sulfate transport to Maryland
24 August 2004

August 24, 2004

Optical Depth

PM$_{2.5}$ (ug/m$^3$)

- Hourly PM$_{2.5}$
- Daily Average PM$_{2.5}$
- MODIS AOD
- Lidar OD Total Column
- Lidar OD Below Boundary Layer
Alaskan Smoke over Maryland
9 July 2004

10 July 2004, am
(12 hrs later)
Direction of changes to the website

IDEA* → “3D-IDEA”

* Infusing satellite Data into Environmental Applications
Progress of 3D-AQS Project

Progress

• Determined priority datasets:
  • MODIS AOD and PM$_{2.5}$ monitor matched data
  • GASP AOD, AERONET AOD, LIDAR profiles and AOD
• Porting historical MODIS AOD-PM$_{2.5}$ matched station data to AirQuest
• Started development of finer resolution AOD data (5x5km and 2x2 km)
• Started development of 3D visualization methods
• Transferring IDEA to operational NOAA environment
• Formation and interaction with end user committee

Timeline

• 2007-08: Evaluation of other sensors (OMI, AIRS) for integration into AirQuest. Implementation of 3D visualization and data output.
• 2008-09: Complete data integration and transition to operations
3D-AQS Needs Input

- End user input needed
  - Input sought through end user committee
  - Email always welcome: engelcoxj@battelle.org

- Type of input needed
  - Data types of interest
  - Level of processing and format required
  - Type and style of visualization
  - Temporal and spatial needs

- Better data accessibility = more use and demand for environmental information = greater understanding of our atmosphere
OMI Images of Aerosol Absorption Optical Depth

@6km
a - July 7

@6km
b - July 8

POSSIBLE OC/EC Contributions:

OMI Aerosol Absorption Optical Depth (Torres, 2006)
Raman Hygroscopic Growth (Rogers, 2007)
Questions?
Backup
OMI - CALIPSO Synergy

~ 2 km

N(z)
MODIS Terra Aerosol Optical Depth July 6-9

Mean Aerosol Optical Depth is about 0.7 - 1.0
Correcting to 550 nm
∴ \( \omega = 0.7 - 0.79 \) very low for smoke aerosol

Source: Giovanni (NASA)
UMBC Elastic Lidar Facility

Atmosphere
Smoke, Haze, Dust, Clouds, Aerosols

June 14 – December 8, 2006
480 hours of operation
29 CALIPSO overpasses ≤ 300 km
(225 hours of operation)
July 7 – 9, 2006 Smoke layer - UMBC
July 9, 2006

CALIPSO and ELF Comparison
Aerosol Backscatter Coefficient

\[ \beta_{532} \text{[km}^{-1}\text{sr}^{-1}] \]

ALTITUDE [km]

\[ 0 \quad 2 \quad 4 \quad 6 \quad 8 \quad 10 \]

CALIPSO @ 7:15 UTC
ELF @ 7:15 UTC
ELF @ 6:20 UTC
ELF @ 5:25 UTC
Mean AAOD = 0.15
Correcting to 550 nm
∴ ω = 0.84 - 0.89 more realistic for smoke