15 Minutes about satellite aerosol products (from VIIRS)

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In this talk

- Basics of aerosol measurement from space
- Some results presented at a recent NOAA-sponsored meeting on satellite air quality applications
  - Satellite aerosol products and air quality—what can they do and not do?
- 3 minutes about VIIRS satellite aerosol products
  - Structure of VIIRS aerosol products
  - VIIRS Cal/Val status and outlook
  - Current data sources
- Resources to learn more
The basics part 1

• Satellites measure radiation leaving Earth’s atmosphere
• Particles in the atmosphere scatter and absorb radiation
• Satellites measure at multiple wavelengths and angles to constrain aerosol properties
• This constraint is not achieved without some assumptions:
  – Partial information about particle optical properties required
  – Land surface reflectance has a certain spectral profile
The basics part 2

• The property to which satellites are most sensitive is aerosol optical depth (AOD)
  – Integrated value from surface to top of atmosphere

• To convert AOD to mass, you must know:
  – Particle size distribution
  – Particle extinction efficiency
  – How to account for humidity effects

• Or you can take surface measurements and work it out empirically...
Using AOD to estimate PM2.5 – the optimistic outlook

This slide is from Sundar Christopher’s talk at the VIIRS AQ meeting. The figures are from Hoff and Christopher (JAWMA 2009) and related papers.
Using AOD to estimate PM2.5 – the optimistic outlook

If the dot isn’t red, then AOD explains less than 57% of variation in surface PM2.5.

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Using AOD to estimate PM2.5 – the pessimistic outlook

This is from work by Travis Toth and Jianglong Zhang at North Dakota (in review at JGR). The comparison is between two years (2008-2009) of EPA PM2.5 data from surface monitors, and MODIS and MISR optical depth data. These results are after application of significant QA filtering to MODIS and MISR data.
Conditions for success of Empirical AOD-to-PM conversion

• Calibration case (AOD and trusted PM) and prediction case (AOD only) must both:
  – Have aerosol mass concentrated at the surface
    • Plume aloft will break correlation
  – Have same boundary layer height
    • This varies seasonally and can be weather-dependent
  – Have same mix of aerosol sources
    • You cannot extrapolate from normal conditions to exceptional events
    • Humidity effects can throw off correlation
Within these conditions, you can use AOD as a proxy

- Lee et al. ACP 2011
  - New England domain; dense PM surface network
  - Use satellite AOD to extrapolate
    - Within the domain
    - Within the same day
    - Calibrated by all surface PM data
  - Applied method to 99 days in 2003
  - Tested by cross-validation (excluding sites from regression, and testing predicted vs observed at those sites)
    - 20% error in predicted (SE/mean)

This figure from Lee et al. compares predictions based on daily regression of AOD vs PM at multiple sites in New England to PM observations at stations excluded from the regressions.
Aerosol in CONUS is not reliably surface concentrated

- Aerosol mass is rarely more than 50% at the surface, and often less than 25%

It is a lot to ask for the surface concentration to equal the column when the surface is <30% of the column mass.
A model-based approach can overcome these problems

• The approach used by Randall Martin, Aaron van Donkelaar, and colleagues uses GEOS-CHEM to model the vertical distribution of aerosol and estimate the PM2.5/AOD ratio

• This accounts for well, assuming GEOS-CHEM has a reliable description of local/regional/long-range sources

• Van Donkelaar et al. (2010), *Environmental Health Perspectives* 118:847-855.
Assimilation of AOD into the model captures the most dynamic information

- from Saide et al. (2013), *ACP* 13:10425-10444
VIIRS aerosol product status

• VIIRS aerosol EDR is validated (stage 1) as of this summer
  – Data quality results from this validation apply to data from 1/23/2013 forward (no older data available at this time)
• VIIRS product data quality similar to MODIS under good observing conditions
• At this writing, VIIRS outstanding issues are
  – High AOD values (AOD > 2.0) excluded
  – snow/ice clearing
  – No retrieval over bright surfaces
VIIRS aerosol data products (1)

- **Aerosol Optical Thickness (AOT)**
  - for 11 wavelengths (10 M bands + 550 nm)

- **APSP (Aerosol Particle Size Parameter)**
  - Ångström Exponent derived from AOTs at M2 (445 nm) and M5 (672 nm) over land, and M7 (865 nm) and M10 (1610 nm) over ocean
  - qualitative measure of particle size
  - over-land product is not recommended!

- **Suspended Matter (SM)**
  - classification of aerosol type (dust, smoke, sea salt, volcanic ash) and smoke concentration
  - currently, derived from VIIRS Cloud Mask (volcanic ash) and aerosol model identified by the aerosol algorithm

- **Only day time data**
- **Only over dark land and non-sunglint ocean**
VIIRS aerosol data products (2)

At NOAA Comprehensive Large Array-data Stewardship System (CLASS):

• **Intermediate Product (IP)**
  - 0.75-km pixel
    - AOT, APSP, AMI (Aerosol Model Information)
      - land: single aerosol model
      - ocean: indexes of fine and coarse modes and fine mode fraction
    - quality flags

• **Environmental Data Record (EDR)**
  - 6 km aggregated from 8x8 IPs filtered by quality flags
    - granule with 96 x 400 EDR cells
    - AOT, APSP, quality flags
  - 0.75 km
    - SM

At NOAA/NESDIS/STAR:

• **Gridded 550-nm AOT EDR**
  - regular equal angle grid: 0.25°x0.25° (~28x28 km)
  - only high quality AOT EDR is used
Resources

• NOAA VIIRS Air Quality Workshop: http://alg.umbc.edu/aqpg/viirs_workshop/
  – Many useful talks, special notice to talk by Rohit Mathur (EPA) on satellite products and AQ models

• VIIRS aerosol user’s guide and fully revised ATBD (technical description): http://www.star.nesdis.noaa.gov/smcd/emb/viirs_aerosol/documents.php

• Two peer-reviewed publications
  – Jackson et al. JGR 2013
  – Liu et al. JGR in review
References


