AERONET Aerosol Measurements in Latin America and the Caribbean (LAC)

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SAMLAC Training

November 13, 2018

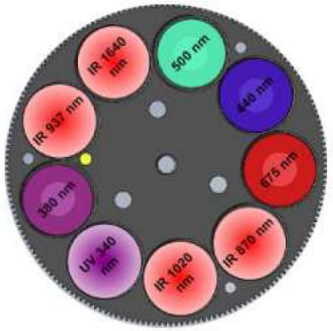
Key Aerosol Sources

- Wind driven dust from deserts and arid land
- Sea salt from wind and wave action
- Emissions from urban and industrial sources (e.g., fossil fuel combustion)
- Smoke from biomass burning (e.g., forests, shrubs, grass)
- Volcanic eruptions and biogenic sources

Photo credits (top to bottom): Daniel Jamen Bryant; Dee Golden; Kenn W. Kiser; Daniel Yara; Jane M. Sawyer; Rick Hoblitt/USGS; center: AERONET

Aerosol Robotic Network (AERONET)

http://aeronet.gsfc.nasa.gov



- Aerosol Remote Sensing Using Sun/Sky Scanning Radiometers
  - Measure light intensity from UV to Vis to NIR (8-10 wavelengths)
  - Aerosol Optical Depth (Direct Sun or Direct Moon)
  - Inferred Aerosol Properties (Direct Sun and Sky Radiances)

- Widely Used by the Aerosol Community
  - Aerosol Characterization and Climatology
  - Satellite and Model Evaluation
  - Model Assimilation
  - Synergism with other Earth Science data sets

V3 AOD Data Quality Levels

Level 1.0 – Minimally screened

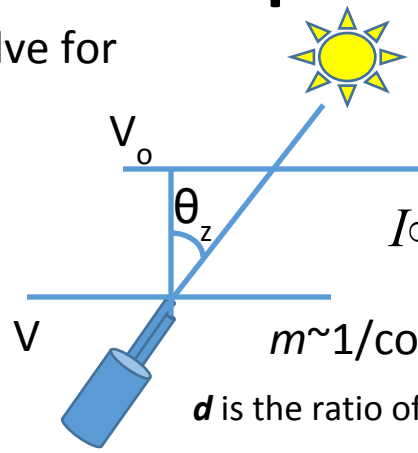
Level 1.5 – Cloud Screened & Quality Controlled

Level 2.0 – Quality assured

Aerosol Optical Depth

From Beer-Lambert-Bouguer Law, solve for the optical depth or $\tau(\lambda)_{Total}$:

$$\tau(\lambda)_{Total} = \frac{d^2}{m}\ln\left(\frac{V_o(\lambda)}{V(\lambda)}\right)$$



**Cloud-free measurements

$I \infty V$ for Sun photometer

d is the ratio of the average to the actual Earth-Sun distance

Determine Aerosol Optical Depth (AOD) :

$$\tau(\lambda)_{Aerosol} = \tau(\lambda)_{Total} - \tau(\lambda)_{Rayleigh} - \tau(\lambda)_{H20} - \tau(\lambda)_{O3} - \tau(\lambda)_{NO2} - \tau(\lambda)_{CO2} - \tau(\lambda)_{CH4}$$

Field Instrument AOD Uncertainty = **±0.01 (Vis-NIR) to ±0.02 (UV)**

Reference instruments calibrated by Langley technique have AOD uncertainty ±0.003 to ±0.007

Approximate aerosol size:

Ångstrom Exponent

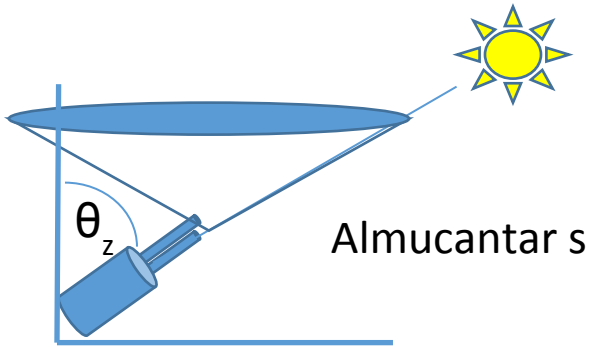
$$\alpha = -\frac{\ln(\tau(\lambda))}{\ln(\lambda)}$$

Fine mode fraction of AOD

$$\eta(\lambda) = \frac{\tau_f(\lambda)}{\tau_f(\lambda) + \tau_c(\lambda)}$$

Aerosol Characteristics

Almucantar inversion [Dubovik and King, 2000; Dubovik et al., 2000, 2002, 2006]:



Almucantar sky scan

Assumptions

1. Plane parallel atmosphere
2. Homogenously distributed particles
3. Randomly oriented spheroids
4. Surface characterization
5. Optically effective columnar properties
6. Same refractive index applied to fine and coarse modes of size distribution

Volume Size Distribution ($\mu m^3/\mu m^2$)

$$dV(r)/d\ln r$$

Single Scattering Albedo (SSA)

$$\omega_o = \frac{\tau_{scat}}{\tau_{ext}}$$

Estimated SSA Uncertainty= **±0.03** for AOD_{440nm} >0.4

Further transformations give other parameters:

Absorption AOD

$$\tau_{abs} = \tau_{ext}(1-\omega_o)$$

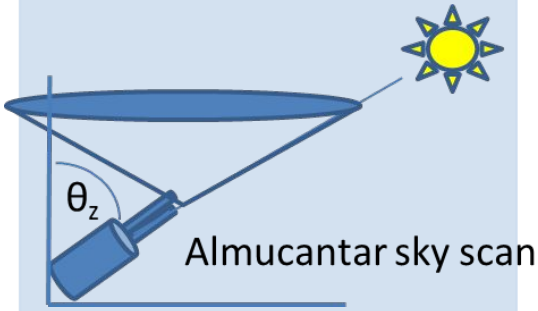
Absorption Ångstrom Exponent (AAE)

$$\alpha_{abs} = -\frac{\ln(\tau_{abs}(\lambda))}{\ln(\lambda)}$$

Standardization

Measurements

- Cimel radiometers
- Direct sun measurements (every 3 to 15 minutes)
- Sky scans performed hourly (e.g., almucantar, principal plane)

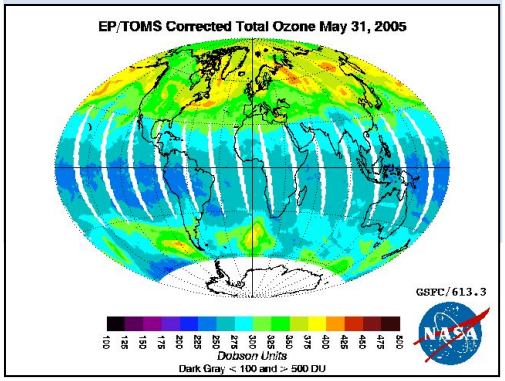


Calibration

- Langley calibration technique for reference instruments
- Calibration transfer from reference to field instruments
- Integrating sphere calibrated by NIST light source for sky measurements

Processing

- Known techniques for computing aerosol properties
- Implementing EOS data sets (e.g., NCEP reanalysis fields, OMI NO_2, TOMS O_3)
- Processed and freely available on web site in near real time



Aerosol Robotic Network (AERONET)

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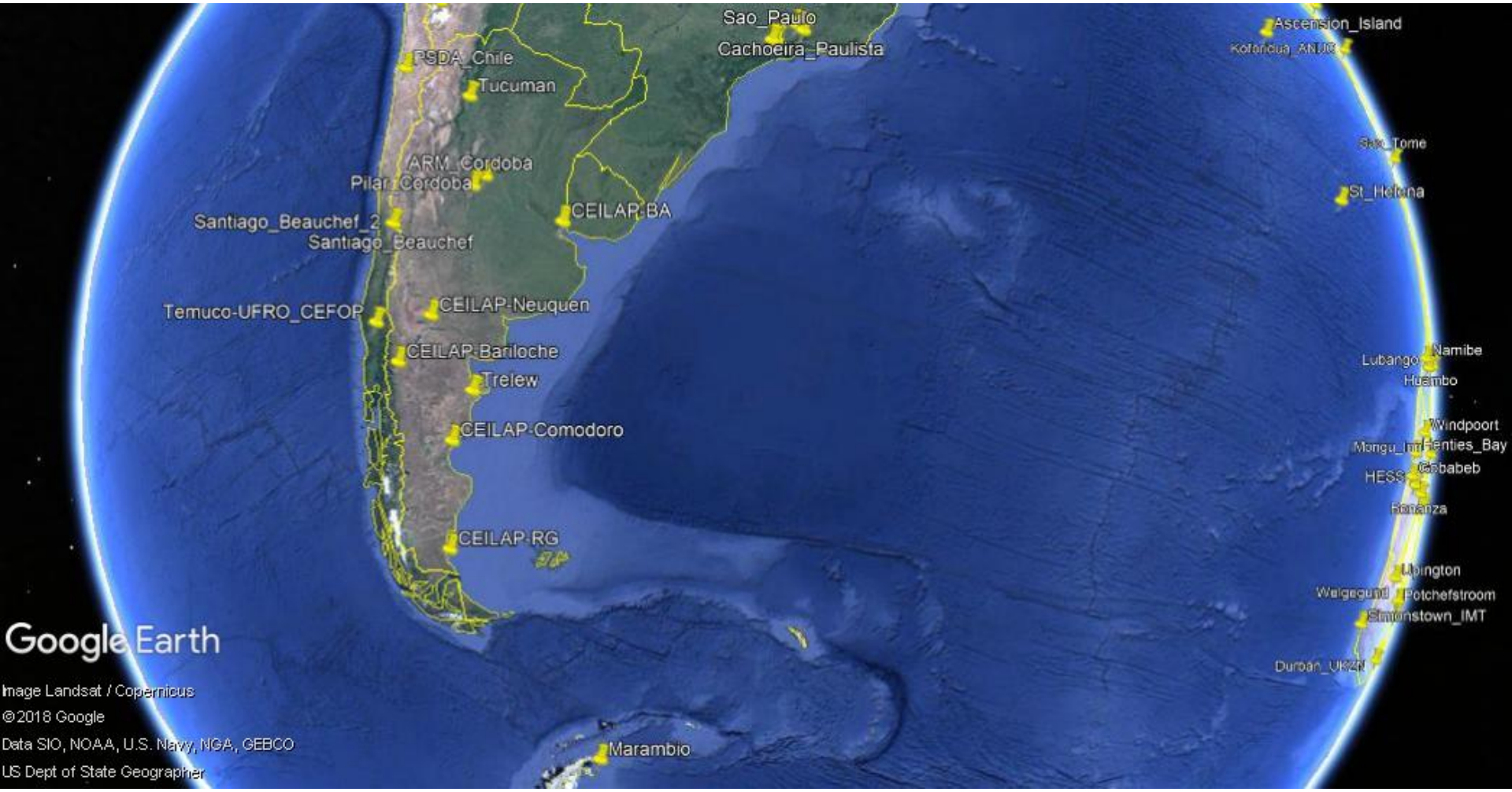
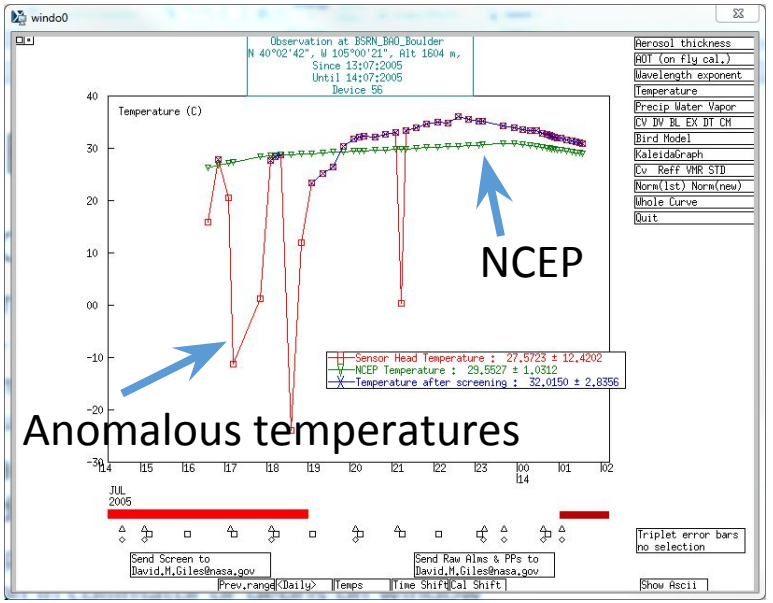
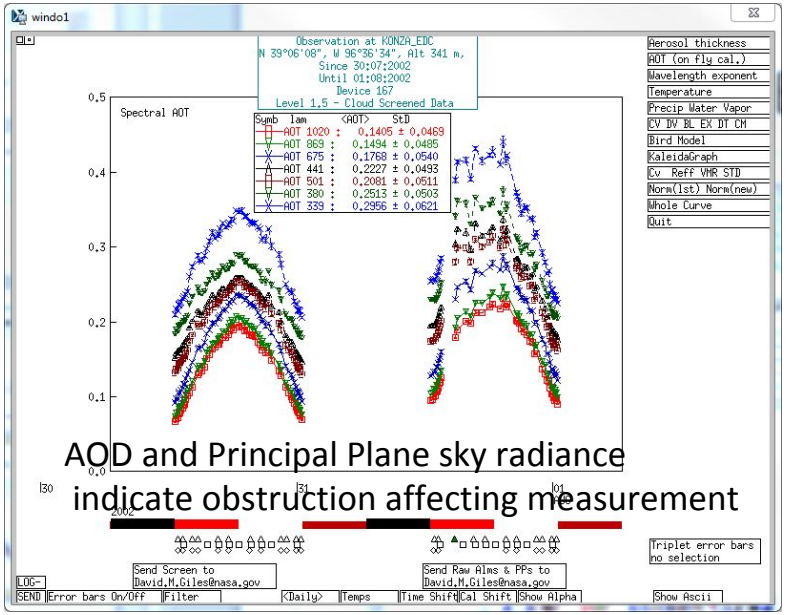


AERONET Version 3: AOD

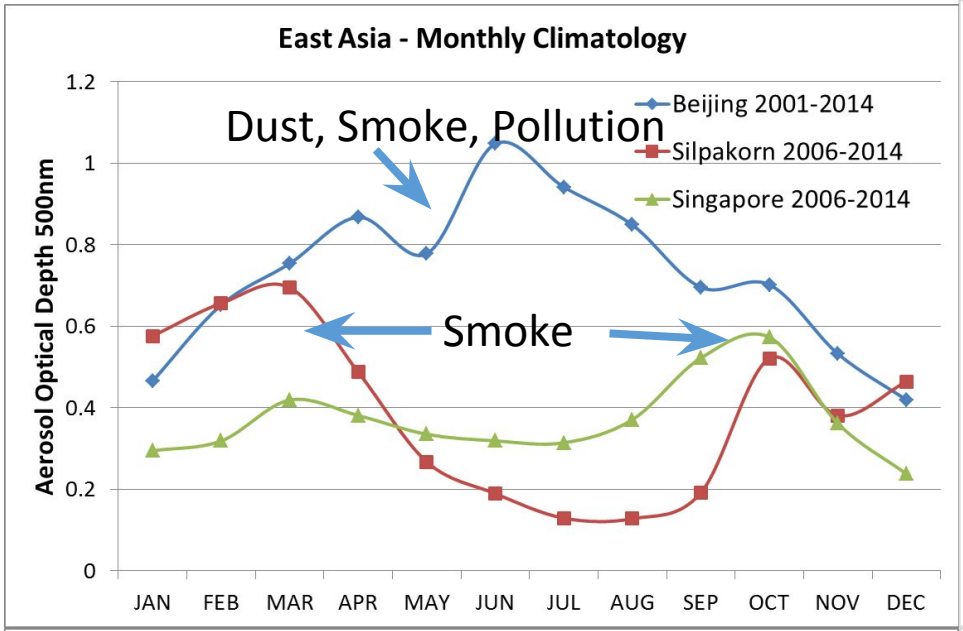
- V3 Level 1.0: Unscreened data (NRT)
  - **Applies new temperature characterizations**
  - **Updated coordinates and elevation**
  - Applies NO2 OMI L3 climatology (2004-2013)
  - Applies updated absorption coefficients (Literature/HITRAN)
- **V3 Level 1.5:** Based on Level 1.0 (NRT)
  - **Improved cloud screening**
  - **New quality controls applied**
- **V3 Level 2.0**: Based on Level 1.5 with pre- and post-calibration and temperature characterization applied
  - Level 2.0 data quality confirmed during post-field calibration evaluation and released 30 days afterwards to allow for updates to ancillary databases
  - **Significantly improves timeliness of Level 2.0 data availability**

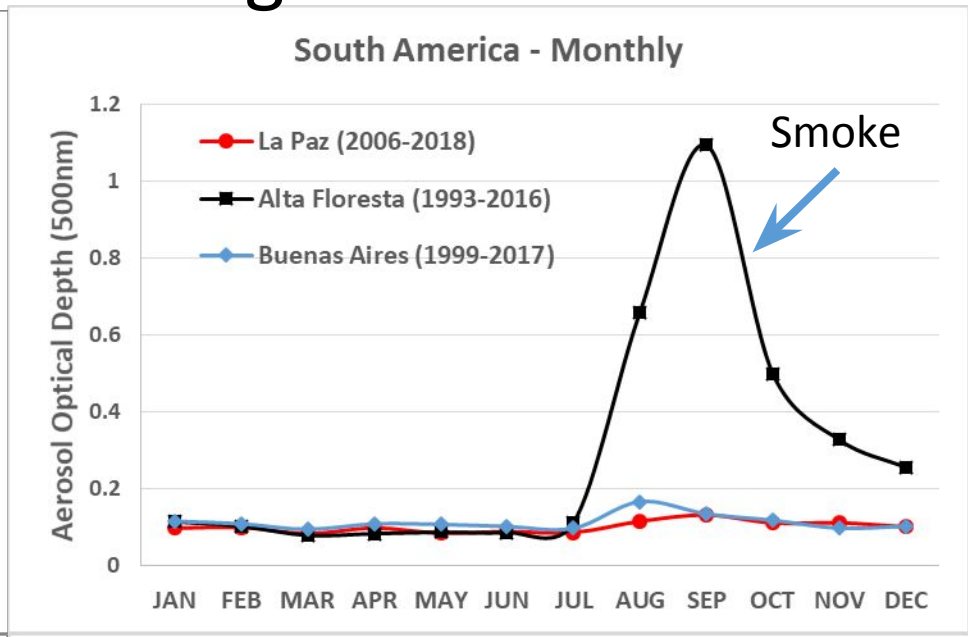


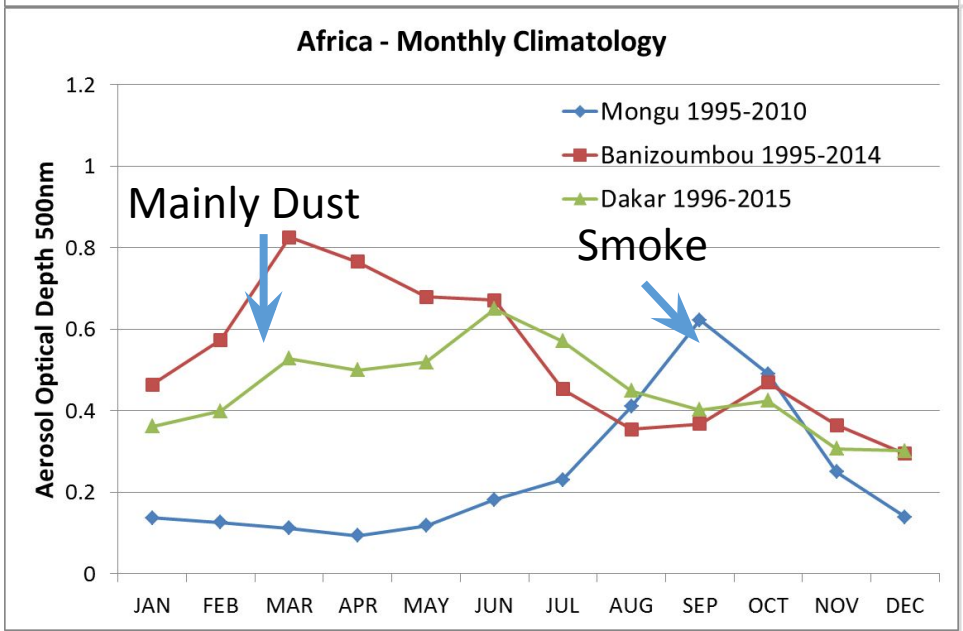


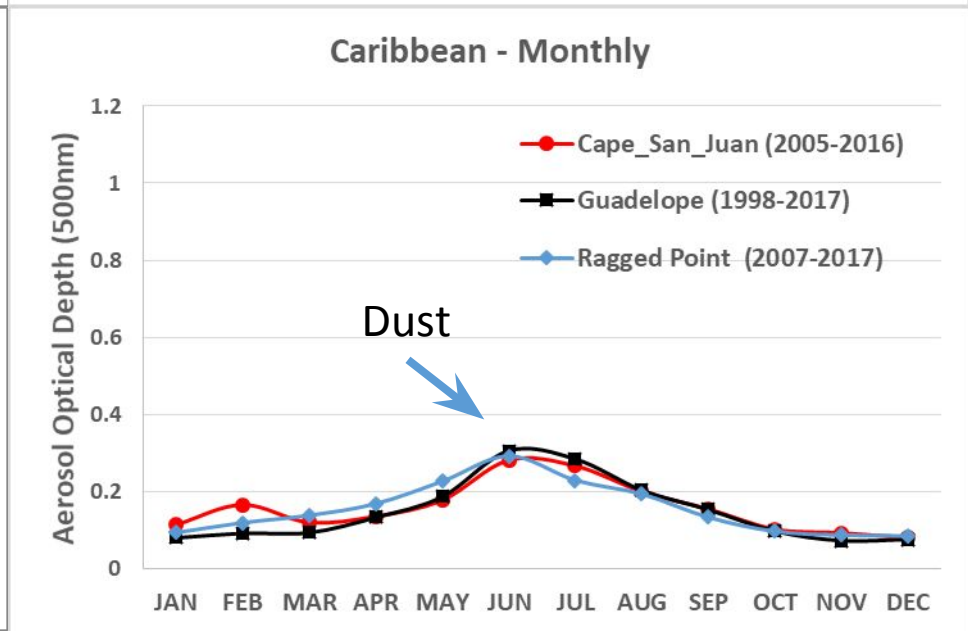
❖ *Giles et al. 2018, Atmos. Meas. Tech.*

Multi-Annual Monthly Climatology
Aerosol Loading

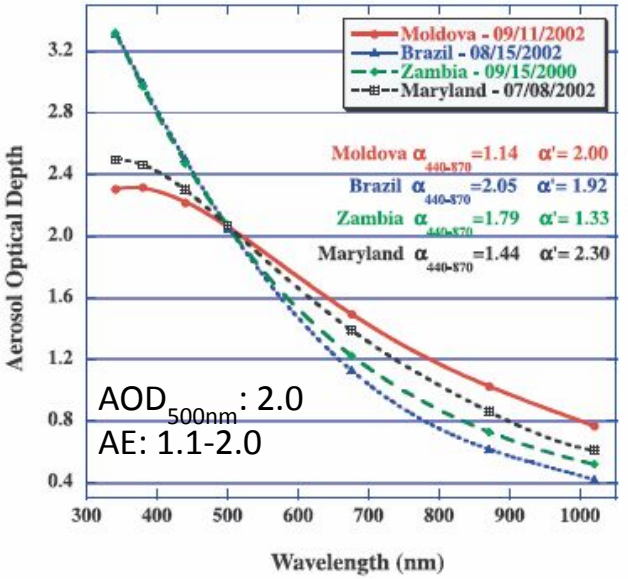




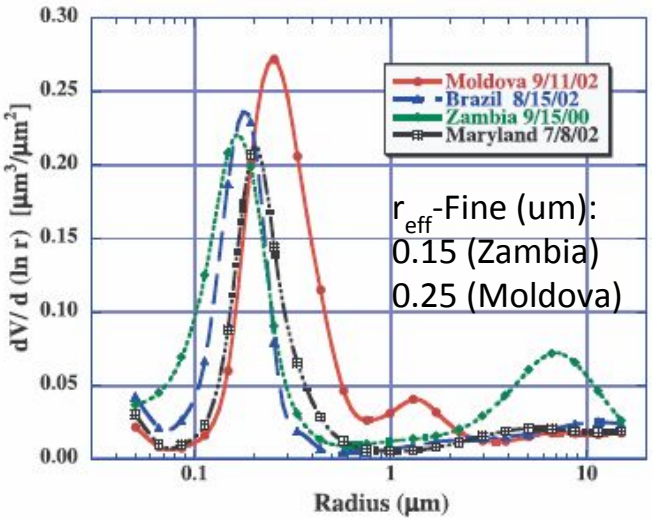




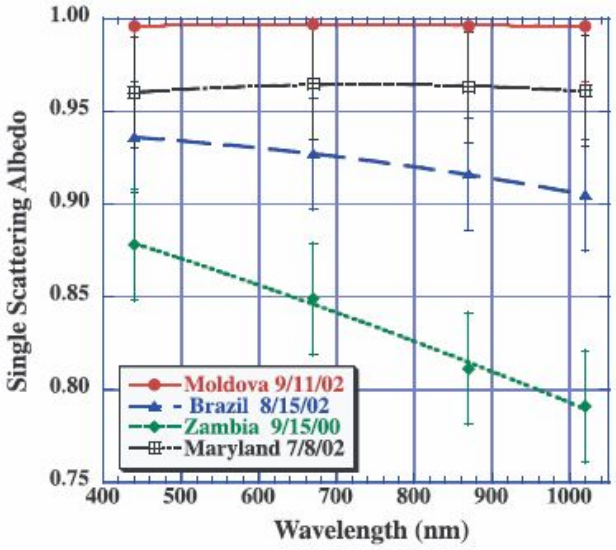
Variations of Biomass Burning Smoke



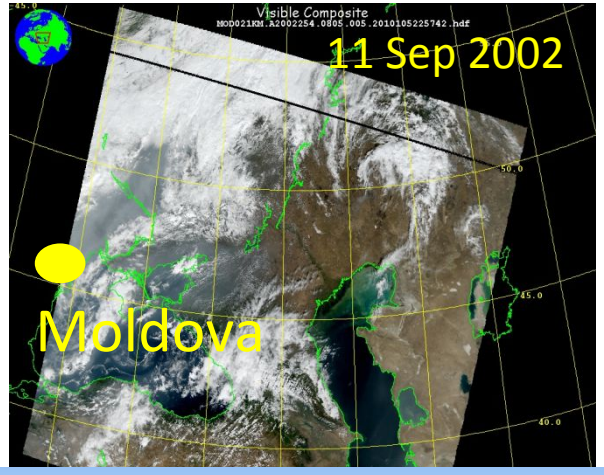
Aerosol optical depth spectra from 340 nm to 1020 nm for the four smoke events studied.

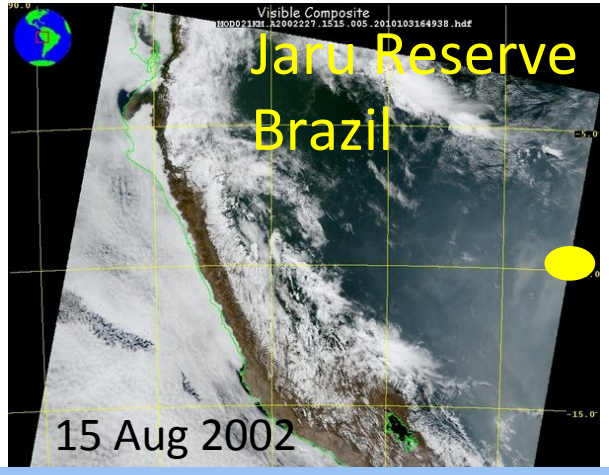


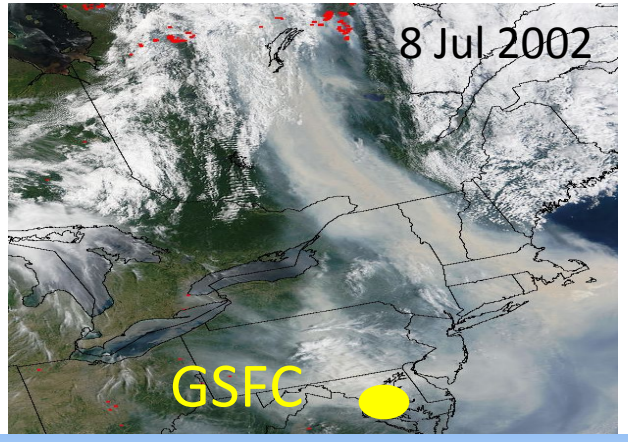
Aerosol volume size distributions retrieved from AERONET measurements



Aerosol single scattering albedo retrieved from AERONET measurements. The error bars show the 0.03 uncertainty (estimated) in retrieved SSA.







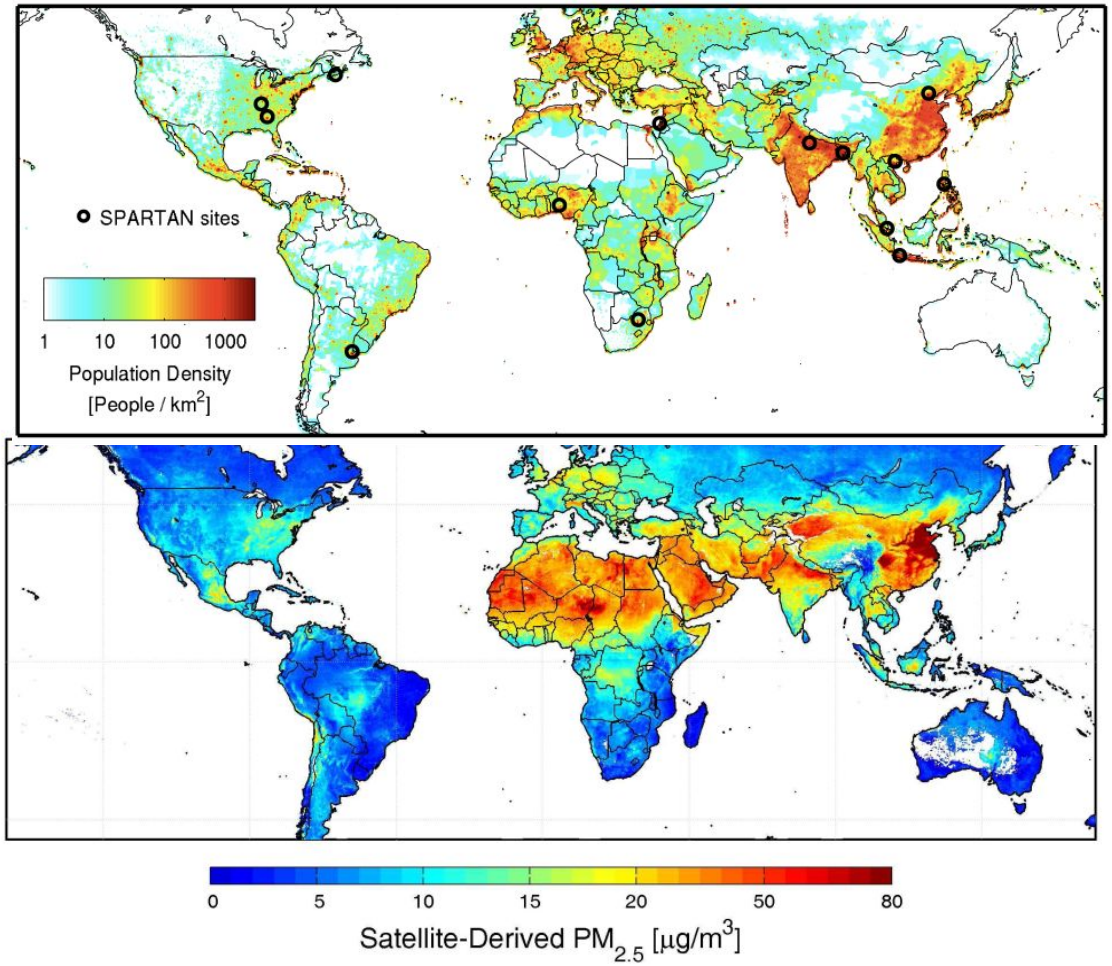
Eck, T. F., et al. (2003), High aerosol optical depth biomass burning events: A comparison of optical properties for different source regions, Geophys. Res. Lett., 30(20), 2035.

AERONET
New Instrumentation/Enhancements

- Improved solar tracking reducing triplet variance
- Greater control over instrument measurement scenarios (e.g., **CCS and Hybrid**)
- **Lunar measurements**
  - 1st to 3rd quarter lunar phase (waxing to waning gibbous)
  - Processing for lunar measurements (e.g., ROLO, Tom Stone)
- Development toward attachment for CO2 measurements (Emily Wilson)
- Synergism with MPLNET, PANDORA, SPARTAN, and in situ measurements

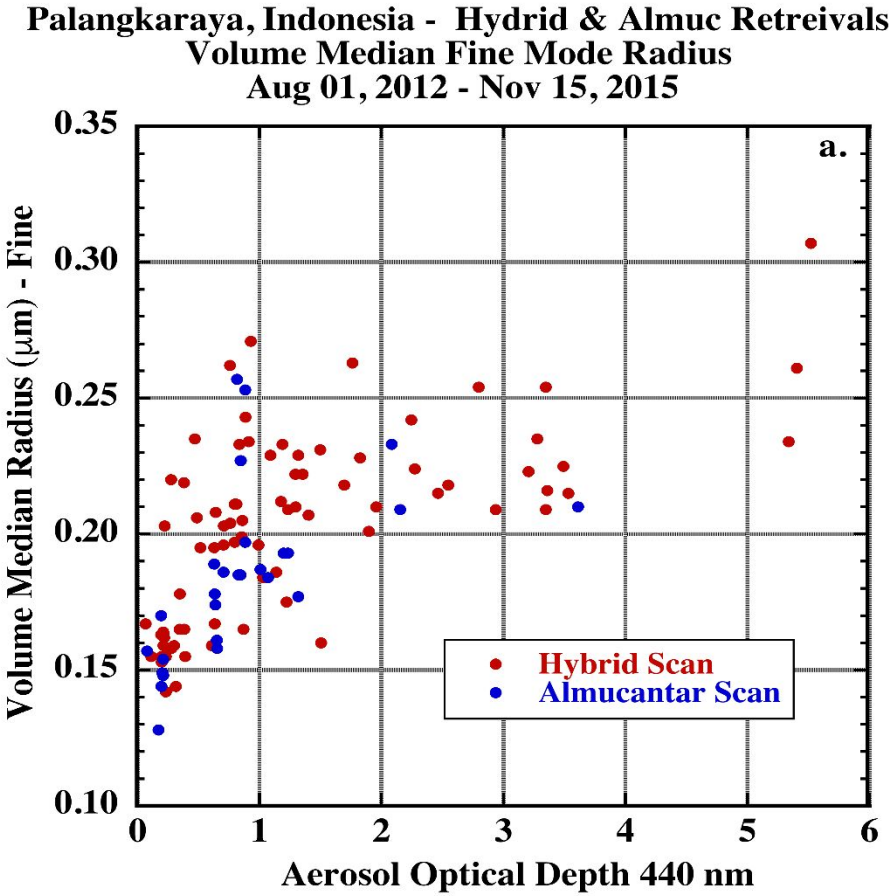
SPARTAN –Surface Particulate Matter Network

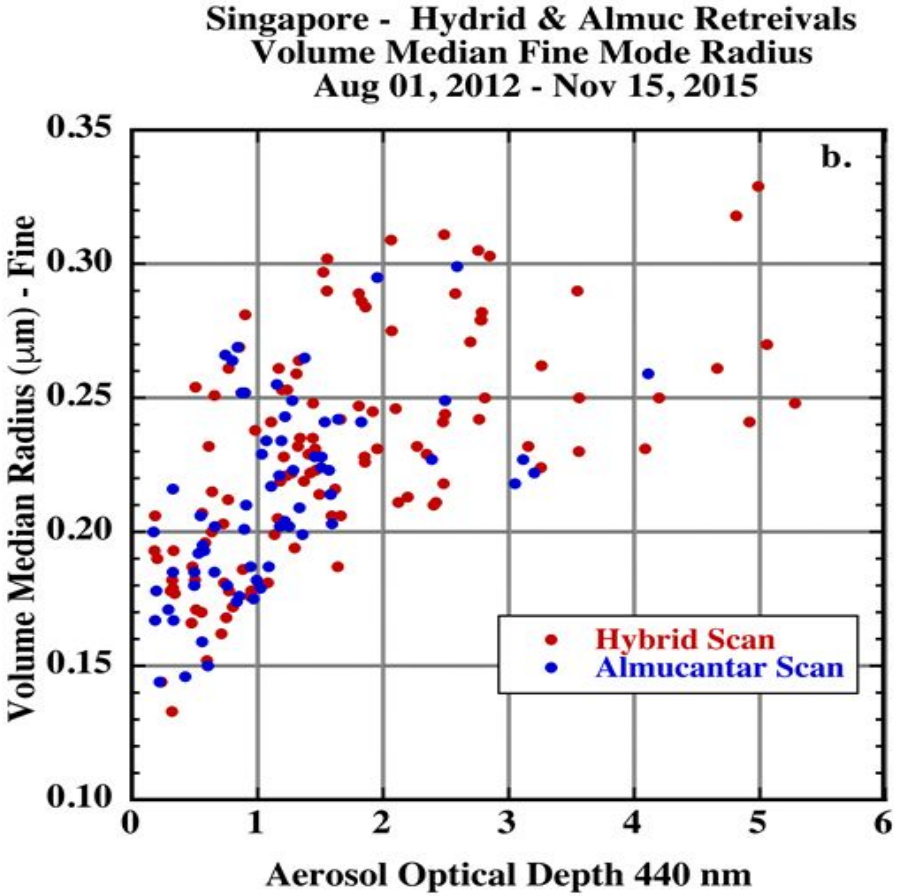
$PM_{2.5}$ and AERONET to relate satellite AOD to ground-level $PM_{2.5}$
http://spartan-network.org/



Sun photometer
3-λ nephelometer
Filter sampler-PM2.5, PM10

Hybrid and Almucantar Sky Scan Retrievals





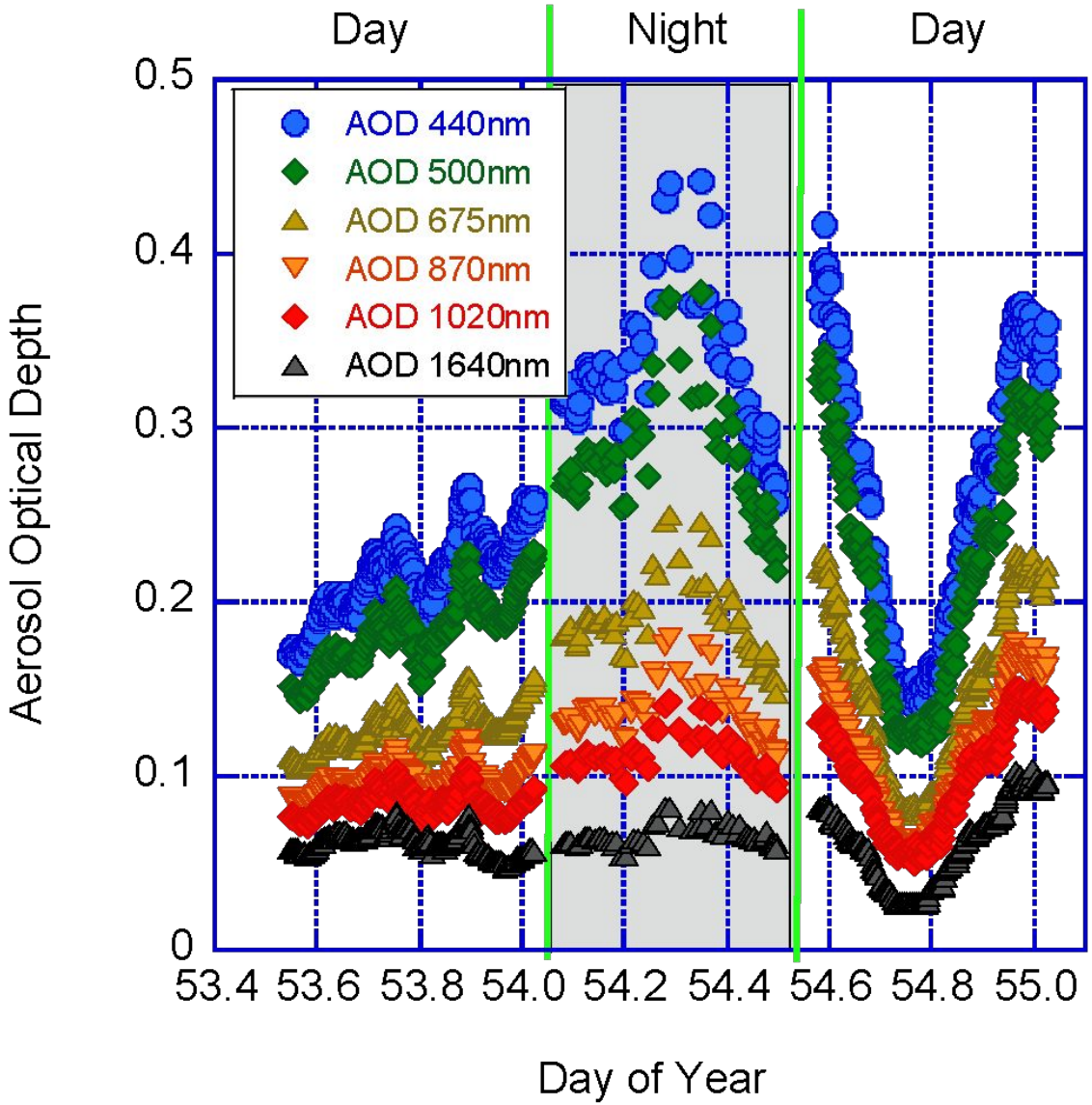
Hybrid Scan results in many more retrievals at AOD> 2 at 440 nm since Hybrid scans can be made at mid-day with low Solar Zenith Angle (SZA). Almucantar scans require SZA > 50 degrees – this results in insufficient signal to measure 440 nm AOD when AOD is very high

- *Eck et al. 2018, in preparation*

Provisional Lunar AOD

Kanpur, India 22–23 February 2016

- Under evaluation
  - Instrument nighttime performance
  - Lunar calibration and corrections
  - Cloud screening and quality controls



AERONET Data Applications

- Aerosol climatology – seasonal variability
- Aerosol Inversions
- Data Synergy (MPLNET)
- Atmospheric correction and evaluation (MODIS, MISR, VIIRS, OMI, ASVRN, etc.)
- Comparison to remote sensing and in situ sensors at the surface and on aircraft (SolRadNet, LARGE, PANDORA)
- Applications to air quality (SPARTAN, IMPROVE)
- Verification of aerosol transport models (GOCART, NAAPS, ICAP, MERRA)
- Utilization of aerosols in numerical weather (NCEP, ECMWF, UKMET)

http://aeronet.gsfc.nasa.gov

V3 AOD, SDA, and inversions