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The Effects of Long-Range Transport of Agricultural Smoke on AOD in Houston, TX

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Motivation

Measuring surface level particulate concentrations remains a challenge for Earth-observing satellites due to:
1) variability in aerosol vertical distribution, and
2) the effects of aerosol composition and hygroscopicity on optical properties.

The correlation between aerosol optical depth (AOD) measured by satellites and ground-level aerosol loading (PM2.5) can be hindered by the presence of pollution in the free troposphere. **During September 2013 transported smoke from agricultural fires was transported to Houston, TX increasing aerosol optical depths in the region. This aged smoke can be compared to fresher smoke measured:**

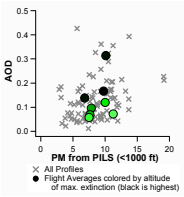
- during SEAC⁴RS - eight agricultural smoke plumes
- over Georgia during a DISCOVER-AQ transit flight

Conclusions & Future Work

Transported smoke measured during four flights (Sept. 4, 6, 13 and 14)
- No smoke measured at ground level
- AOD-to-PM higher than expected

Aerosol aging:
- Increases SSA due to secondary aerosol formation
- Increases smoke hygroscopicity by 45% (and thus increases AOD more than fresh smoke would)

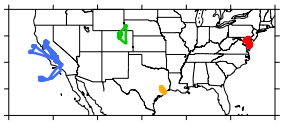
Agricultural Fires:
- lower modified combustion efficiencies than other types of fires (smoldering fires) resulting in high particulate emissions & lower SSA



DISCOVER-AQ

DISCOVER-AQ (Deriving Information on Surface conditions from Column and Vertically Resolved Observations Relevant to Air Quality) is a multi-year project aimed at understanding the variables that affect remote sensing measurements in U.S. urban areas. Four campaigns were performed in regions with differing aerosol composition and meteorology:

Baltimore & Washington, DC, Summer 2011
San Joaquin Valley, CA, Winter 2012
Houston, TX, Summer 2012
Denver, CO, Summer 2013



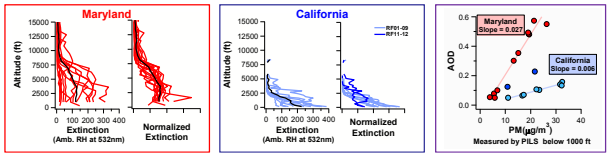
Measurements made by the NASA P-3B:
- Trace gas measurements
- Aerosol measurements including:
  - Optical Properties (Nephelometer & PSAP)
  - Size (UHSAS, SMPS & APS)
  - Composition (PILS) & Hygroscopicity

Results from Previous Campaigns

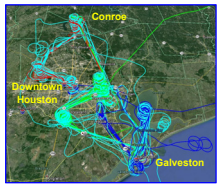
Maryland
- aerosol was composed of a mixture of organics and ammonium sulfate
- aerosol present in a well-mixed deep haze layer (~7500 ft)

California
- primarily ammonium nitrate aerosol
- contained in a very shallow boundary layer (~2000 ft) except for the last two flights

AOD-to-PM
- The AOD-to-PM correlation is dependent on the height of the haze layer (boundary + residual) with Maryland having a higher ratio than measured during California.



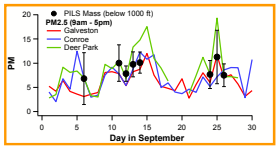
DISCOVER-AQ Texas

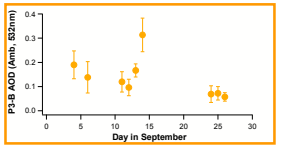


9 Flights between Sept. 4th and 26th, 2013
- P-3B aircraft
  - Repetitive flight plans - 24 spirals (1,000-15,000 ft above ground level) over 8 ground sites
  - In situ measurements of aerosols & trace gases
    - Aerosol number concentration, scattering, absorption, size & composition (by SP2 and PILS; particle into liquid sampler)
- B-200 aircraft (30,000 ft)
  - High Resolution Spectral Lidar (HSRL)

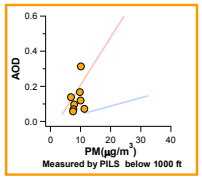
Sampling of agricultural fires during transit flight

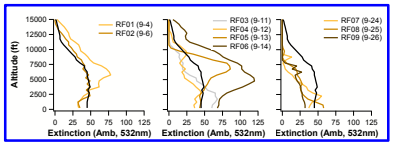
Smoke Transport



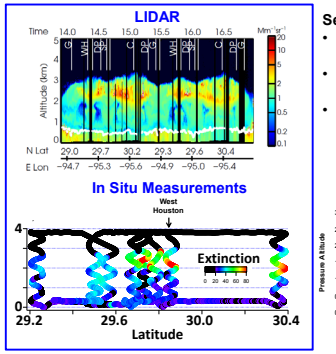


AOD-to-PM2.5:
Flight day particulate mass varied between 6 & 11 μg/m³ (top left)
Ambient AOD (measured by the P-3B) was more variable (top right): between 0.06 (Sept 26th) & 0.32 (Sept. 14th)
No correlation between ambient AOD and particulate mass (right)

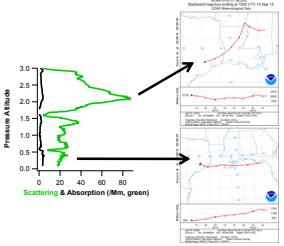




Vertical profile variability:
- Boundary layer – low loadings of 30-70/Mm
- 2,500-10,000 ft – transported smoke caused increased aerosol loadings for September 13-14



September 13th
- Smoke measured by both the HSRL and in situ measurements
- Highest loadings in the north of the flight region
- Back trajectory for layer aloft from a region of agricultural fires



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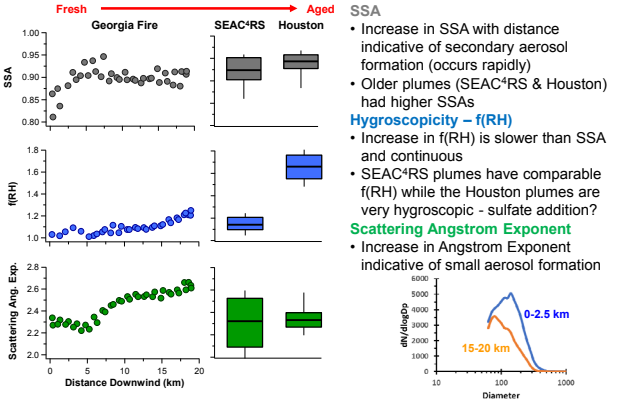
Smoke Properties

Aged agricultural smoke plumes measured over Houston can be compared to:
- Fresh agricultural smoke plumes encountered during SEAC⁴RS
- An agricultural fire sampled extensively in Georgia during a transit flight (below)

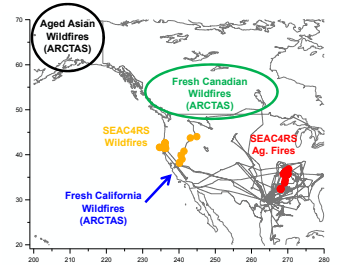


SSA
- Increase in SSA with distance indicative of secondary aerosol formation (occurs rapidly)
- Older plumes (SEAC⁴RS & Houston) had higher SSAs

Hygroscopicity – f(RH)
- Increase in f(RH) is slower than SSA and continuous
- SEAC⁴RS plumes have comparable f(RH) while the Houston plumes are very hygroscopic - sulfate addition?

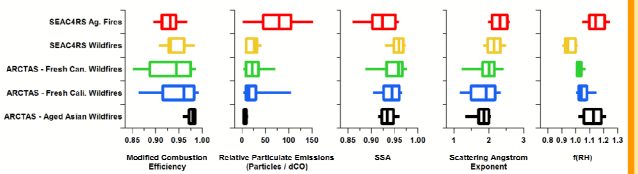
Scattering Angstrom Exponent
- Increase in Angstrom Exponent indicative of small aerosol formation

SEAC⁴RS & ARCTAS Biomass Burning



SEAC⁴RS Fire Plumes
- Preliminary identification by Bob Yokelson including western U.S. wildfires and agricultural fires in the southeast.
- Additional identification to follow for more aged plumes downwind of the Rim fire.

ARCTAS Fire Plumes
- 495 plumes identified by Hecobian et al. (ACP, 2011)
- Aged Asian wildfires sampled over Alaska
- Fresh Canadian and California wildfires



Agricultural Fires (in comparison to wildfires)
- lower modified combustion efficiencies → smoldering fires
  - MCE = $(\Delta CO_2)/(\Delta CO+\Delta CO_2)$
- high particulate emissions & lower single scattering albedo

Western Wildfires (in comparison to ARCTAS fires)
- highest single scattering albedos
- f(RH) less than 1 → indicative of soot restructuring