Long-Range Transport of Agricultural Smoke to Houston, TX: Effects on Aerosol Optical Depths

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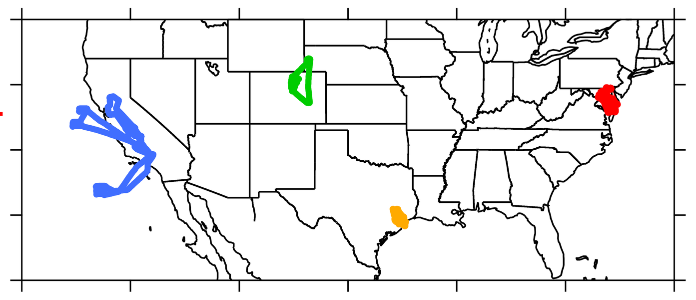
DISCOVER-AQ

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.

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

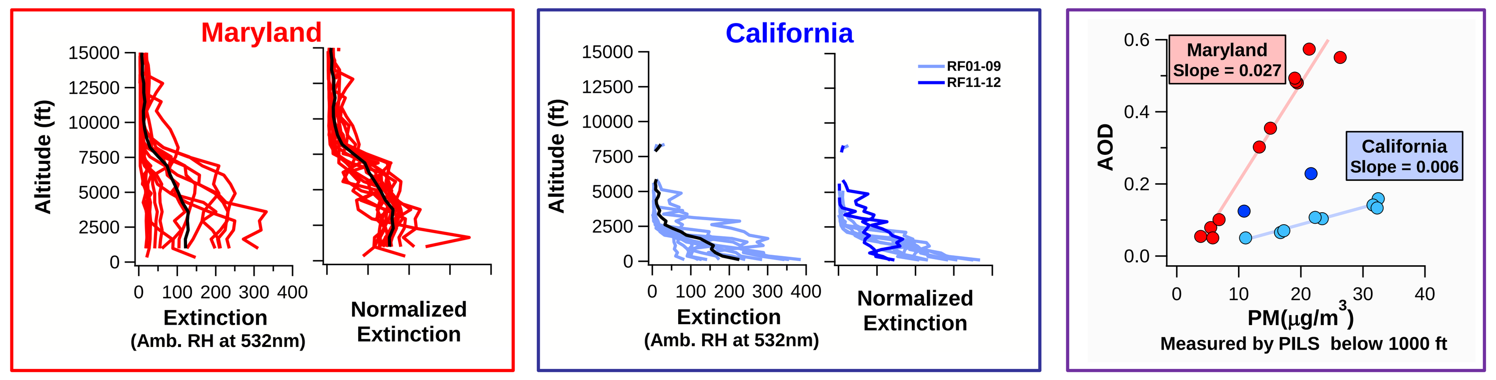


Results from Previous Campaigns

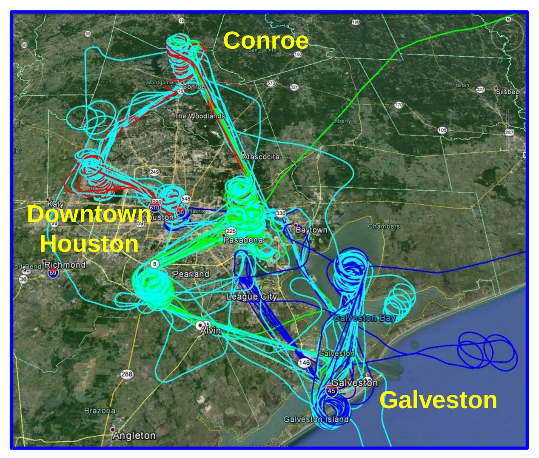
Maryland
- aerosol was composed of a mixture of organics and ammonium sulfate
- aerosol present in a well-mixed deep haze layer (~ 7500 ft)

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.



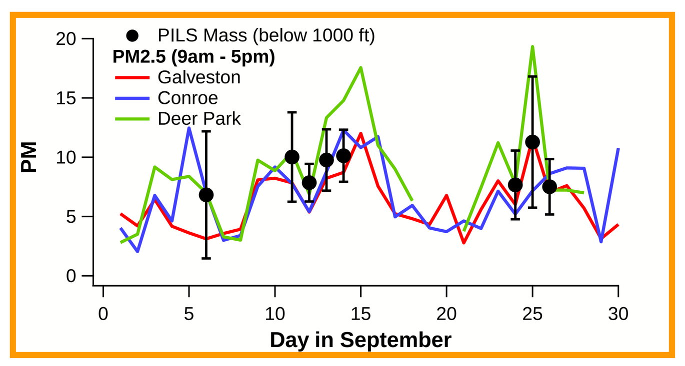
DISCOVER-AQ Texas

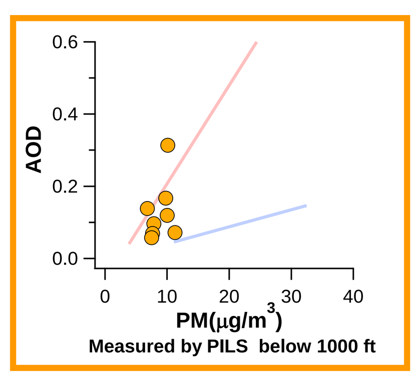


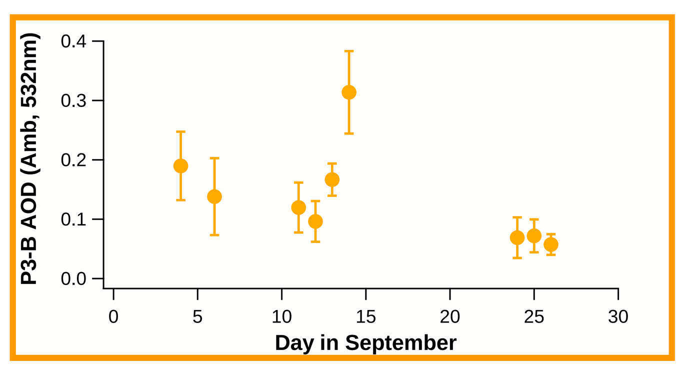
9 Flights between Sept. 4th and 26th, 2013
- P-3B aircraft
  - 24 spirals (1,000-15,000 ft above ground levels) over 8 ground sites
  - In situ measurements of aerosols & trace gases
    - Aerosol number concentration, scattering, absorption, size & composition (by SP2 and PILS; particle into liquid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

Sampling of agricultural fires during transit flight

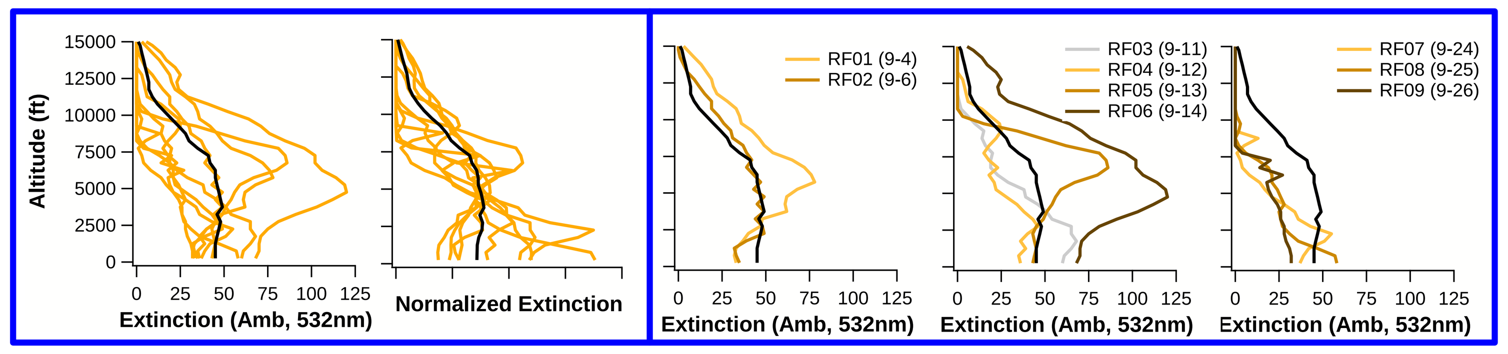
No correlation between ambient AOD and particulate mass during DAQ-TX
- Ambient AOD (measured by the P3) varied between 0.06 (Sept 26th) & 0.32 (Sept. 14th)
- Flight day particulate mass was less variable (6-11 μg/m³)



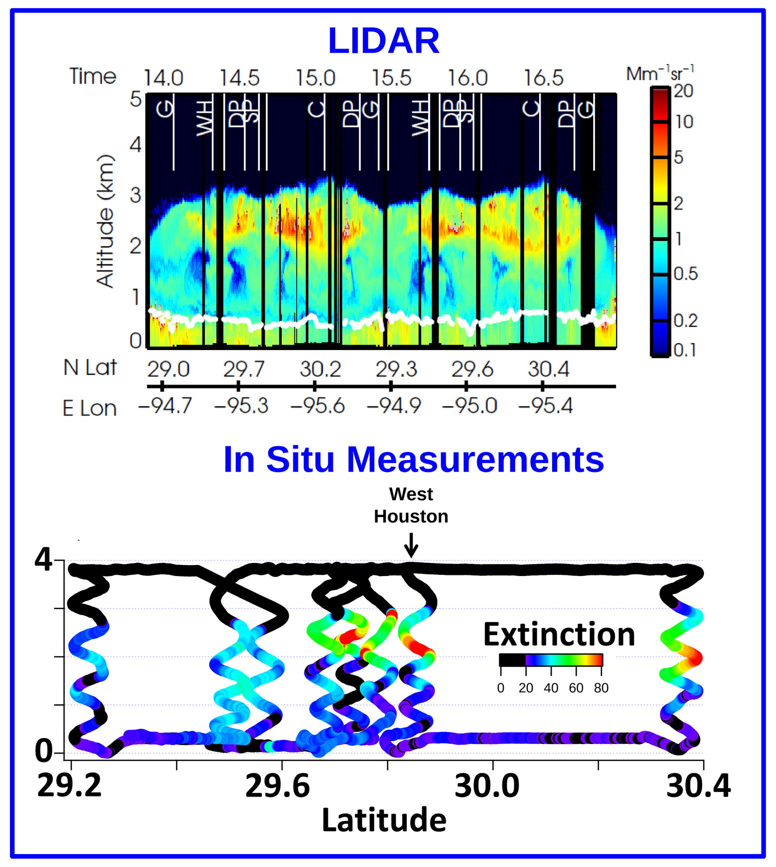




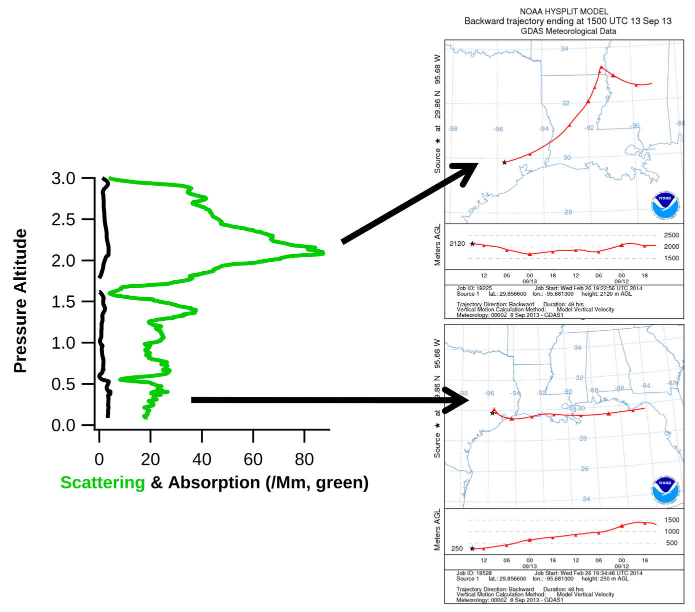
Smoke Transport



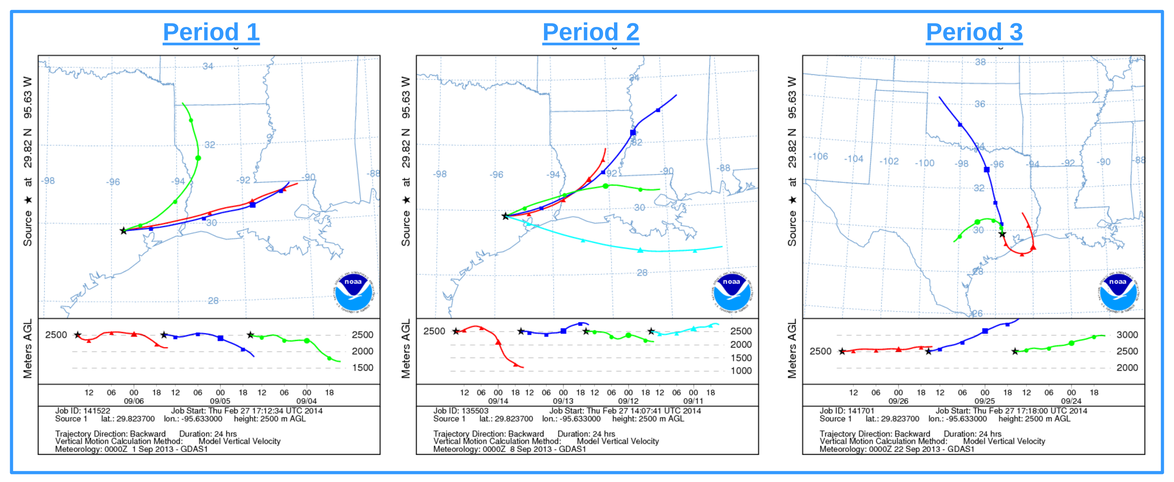
Vertical profiles of extinction during DISCOVER-AQ-Texas varied amongst flights
- Boundary layer – low loadings of 30-70/Mm
- 2,500-10,000 ft – transported smoke caused increased aerosol loadings for September 13-14



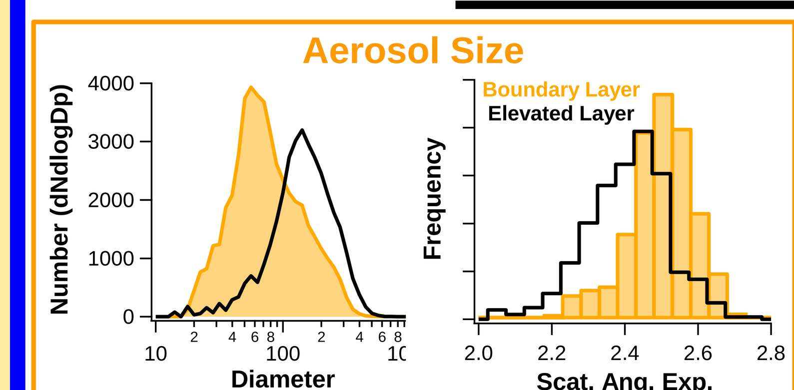
September 13th
- Smoke measured by both the HSRL and in situ measurements
- Highest loadings in the north of the flight region
- Back trajectory for layer aloft from a region of agricultural fires

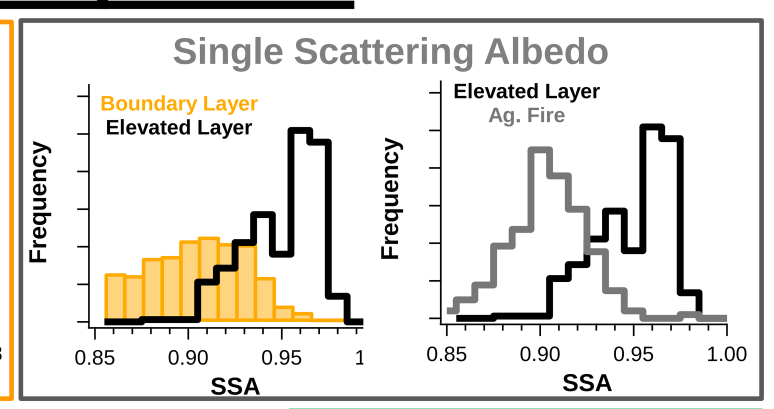


Differences in Back Trajectories
- Boundary layer – low loadings of 30-70/Mm
- 2,500-10,000 ft – transported smoke caused increased aerosol loadings for September 13-14

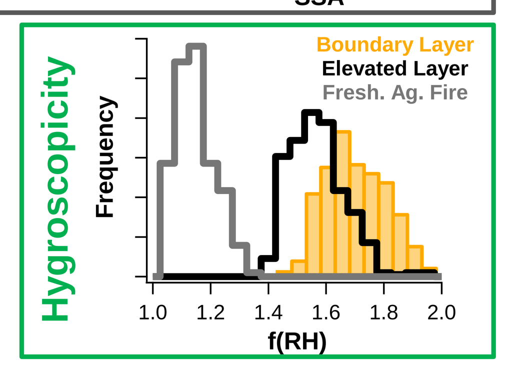


Smoke Properties



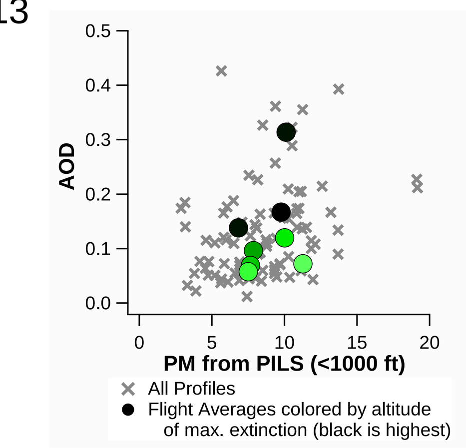


Aerosol Size – smoke was larger than fresher aerosol measured in the boundary layer
Single Scattering Albedo – smoke had a higher SSA than the boundary layer and fresh agricultural fires indicating secondary aerosol formation
Hygroscopicity – fresh smoke had an average f(RH) of 1.1 while the aged smoke averaged 1.5



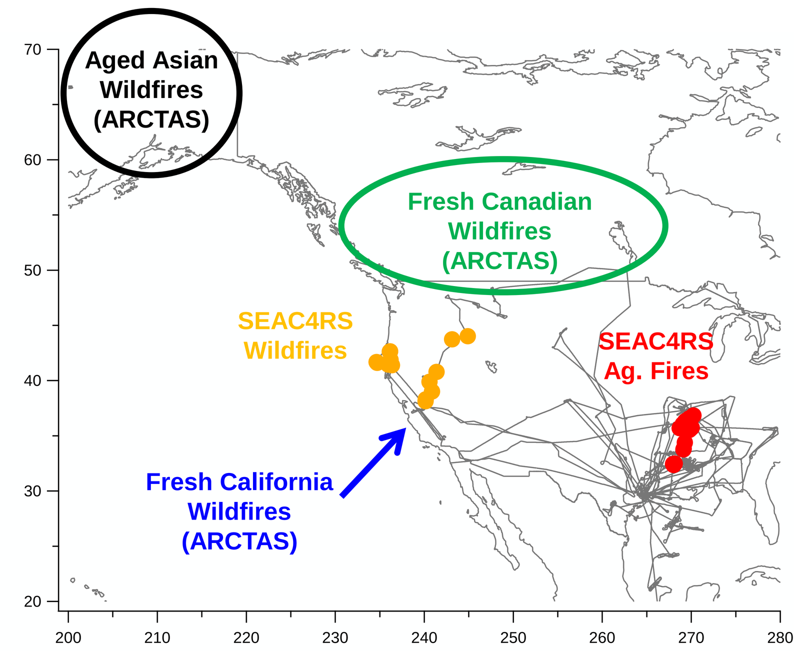
Conclusions & Future Work

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 was aged agricultural smoke from the Mississippi River Valley
- Aerosol aging increases smoke hygroscopicity by 36%
  - f(RH) of 1.5 for aged smoke / 1.1 for fresh smoke
  - and thus increases AOD more than fresh smoke would



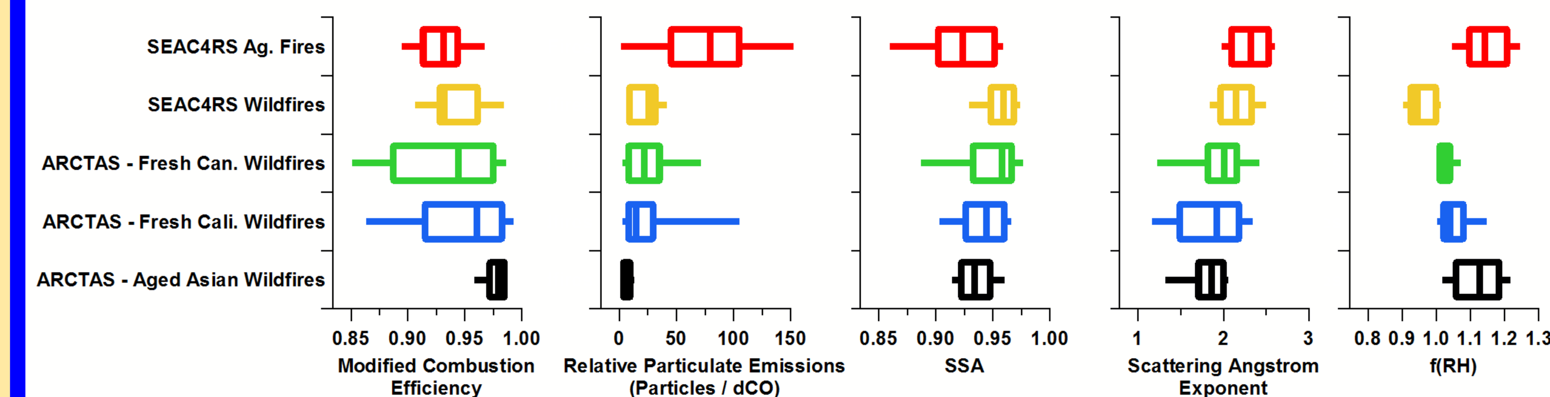
Future work will look at AERONET and ground-based $PM_{2.5}$ measurements in order to study:
- the frequency of these long-range transport events
- the spatial extent of smoke transport in the southeast U.S.

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.

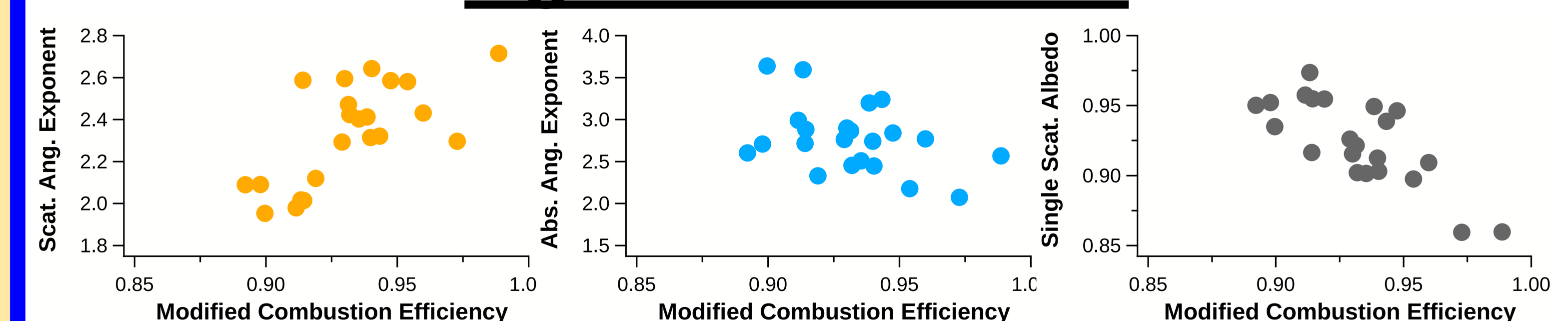
ARCTAS Fire Plumes
- 495 plumes identified by Hecobian et al. (ACP, 2011)
- Aged Asian wildfires sampled over Alaska
- Fresh Canadian and California wildfires



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

Agricultural Fires



Changes in aerosol intensive properties with flame conditions (MCE)
- Flaming conditions (high MCE) gives:
  - higher scattering angstrom exponent (smaller aerosol)
  - lower absorption angstrom exponent (less organic coating)
  - lower single scattering albedo (darker smoke)

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We also wish to thank the entire SEAC4RS science team.