Biomass Burning and Black Carbon Aerosol from African Sources

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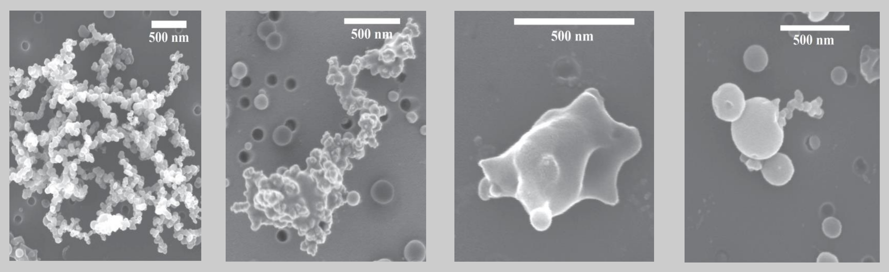
Climate Impacts of Biomass Burning (BB) Emissions and Black Carbon (BC) Aerosol

- Biomasss Burning: Large source of Carbon to the atmosphere
  - Particles: Black Carbon (BC), Organic Carbon (OC), Brown Carbon (light-absorbing in the visible and UV)
  - Gases: CO, CO_2
  - Largest BC source globally

- BB is the largest source of BC globally
  - BC: most light absorbing particle in the visible region
  - 6-9 Tg/yr with up to ~0.6 W m^{-2} warming - *(IPCC, 5AR)*
  - 2nd most important in global warming, most uncertain, underestimated - *(Bond, JGR, 2013)*
  - Expected to increase in the future due to increased drought and extreme events

- BC directly warms the atmosphere, OC cools
  - Mixtures in BB with complex climate impacts (indirect effects: clouds, precipitation)
  - BB emissions age in time – changing properties of the aerosol (physical, optical, chemical)
  - BC from BB has enhanced absorption due to coatings
  - *(S. Liu, GRL, 2014; D. Liu, Nat Geo, 2017)*

SEM Images of 4 Types of BC in BB



China et al., Nat. Commun., 2013

Layered Atlantic Smoke Interactions with Clouds (LASIC) Campaign

- Southern Africa: Largest BB source
  - Fuels: Land clearing wood and grassland fires
  - BB Season peaks from June – November

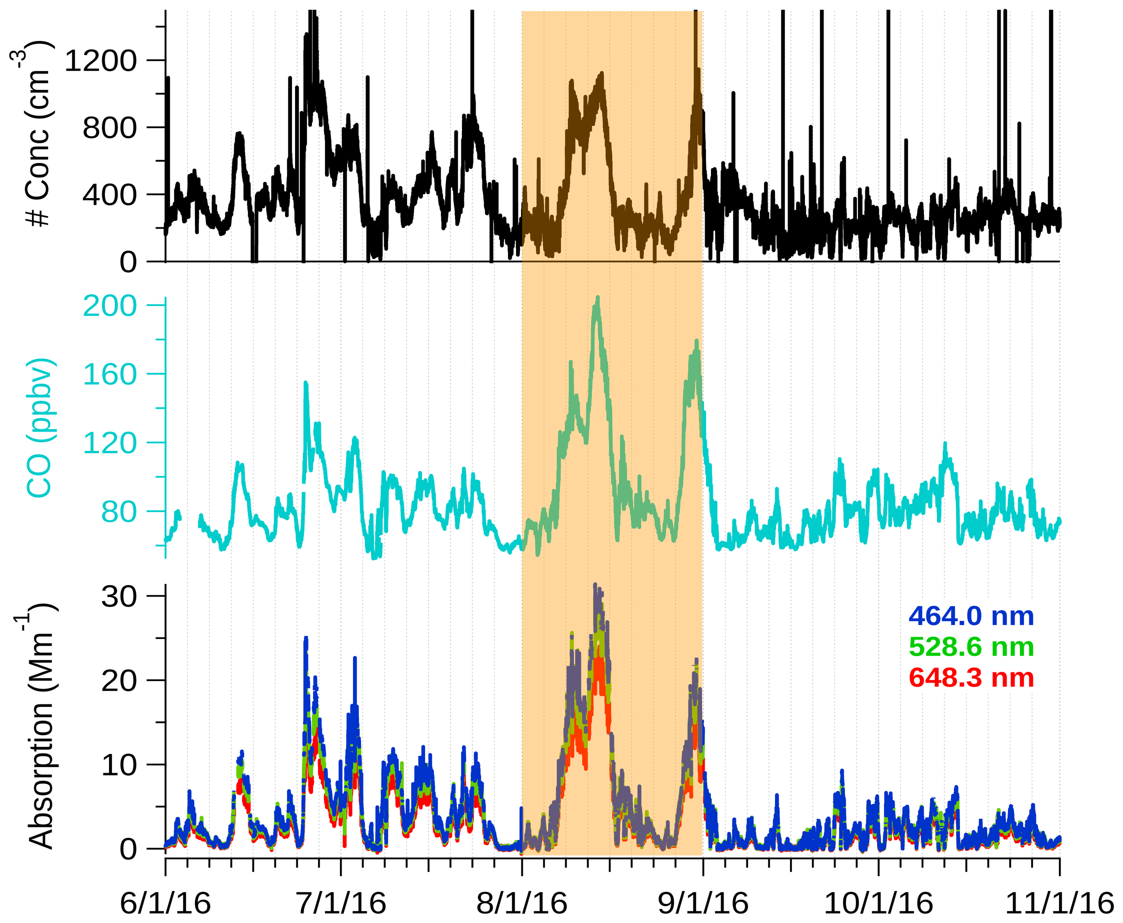
- LASIC Measurements
  - Ascension Island is in the Southern Atlantic Ocean
  - June 2016 – October 2017
  - Sample 2 Southern African BB Seasons
  - PI: Paquita Zuidema

- AMF1 Aerosol Observing System (AOS) and Mobile AOS (MAOS): *In situ* aerosol measurements at the surface
  - Particulate: number, size, optical properties, Black Carbon (BC) content, non-refractory chemical composition, hygroscopicity and water uptake
  - Trace Gas: Nitrogen Oxides, Combustion tracers (CO, SO_2), Ozone, Volatile Organic Compounds (VOCs)

(Zuidema, BAMS, 2016)

AMF1 AOS and MAOS LASIC 2016 Preliminary Results

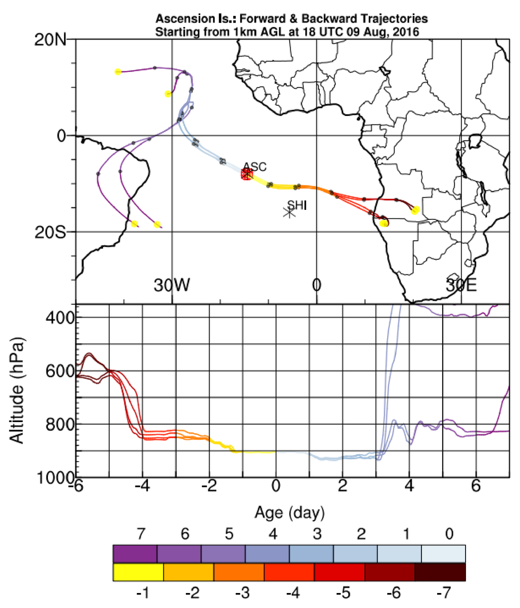
- June – October, 2016 (1st BB season data)
  - 5 months of 1 minute data
  - Submicron aerosol (<1 μm diameter)
  - Aerosol number, CO, and particulate absorption in the visible range have similar time series trends

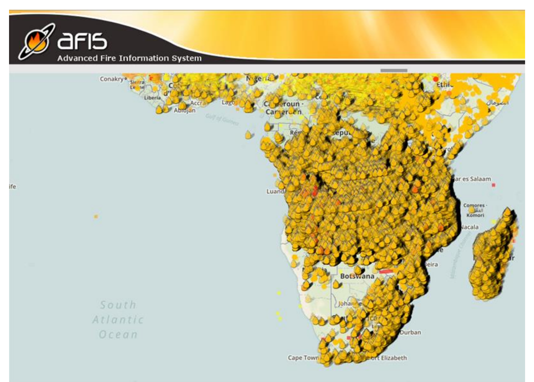


Biomass Burning

- Largest plumes of the season arrive at ASI in August 2016
  - Submicron number concentration of ~1000 #/cc
  - Absorption Coefficients reach 30 Mm^{-1}

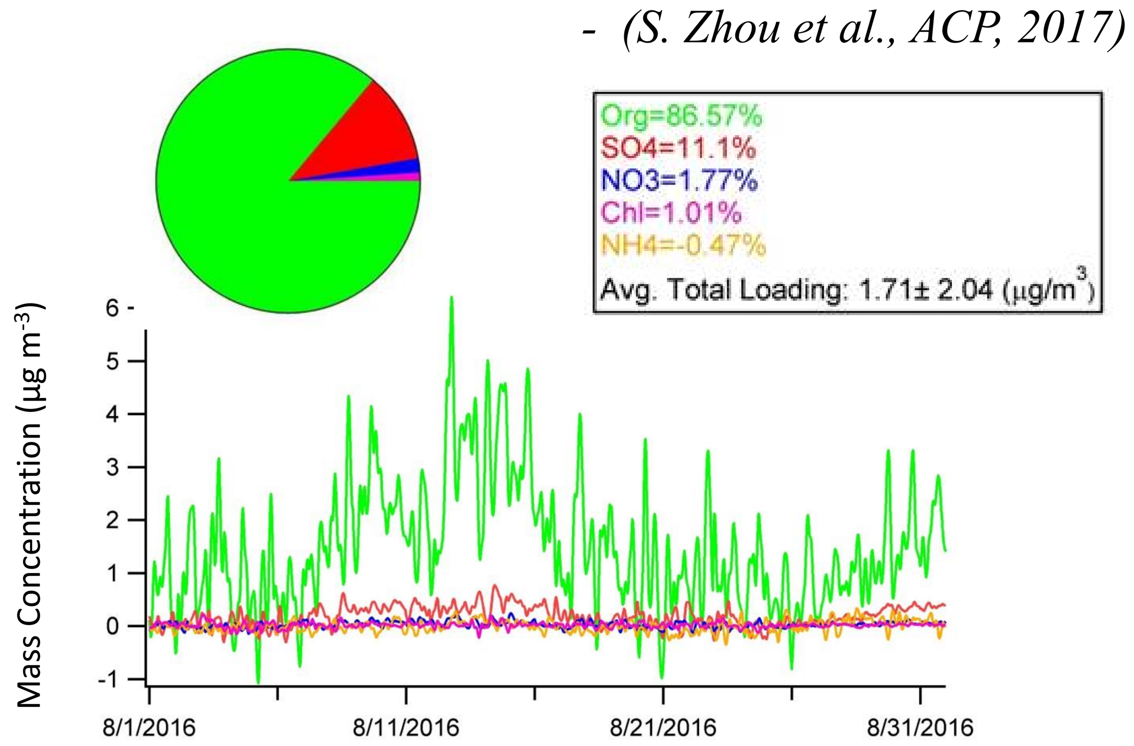
- Back trajectory analysis - *(A. Adebiy, Q J Roy Meteor Soc, 2016)*
  - Southern African sources (e.g., Namibia, Angola) with ~ 1 week atmospheric transportation time
- Active fires from August 6 – 17 (MODIS / VIIRS) show numerous fires across the region





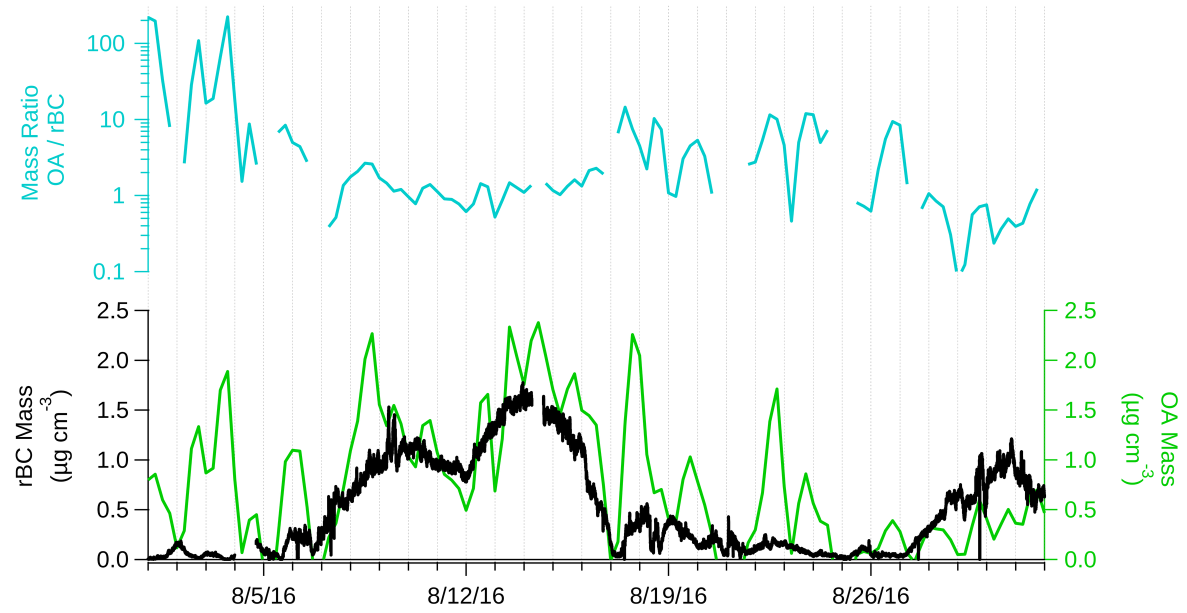
https://southernafrica.afis.co.za

- Non-refractory submicron aerosol mass is dominated by Organics (OA) in August during the peak BB season
  - Preliminary PMF analysis of the OA (not shown) indicates the OA to be aged/oxidized with minimal fresh BB (BBOA) similar to previous (aged BB) from Mt. Bachelor, CA - *(S. Zhou et al., ACP, 2017)*

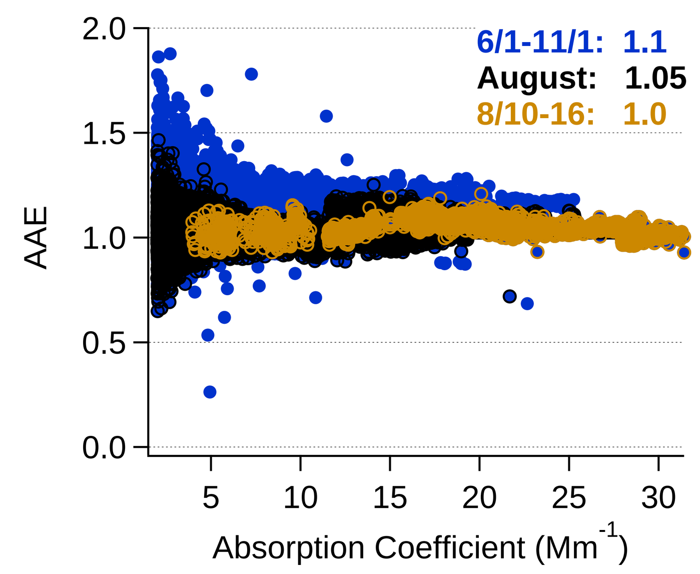


Plume Analysis

- Submicron bulk chemical aerosol
  - OA and rBC dominate the submicron mass and have similar mass concentrations with OA/rBC ~ 1 in the plumes



- Aerosol Optical Properties
  - Absorption Angstrom Exponent (AAE)
    - Values ~1 indicate most of the absorbance is from BC
    - Higher observed values would indicate BrC
    - *(Saleh R. et al., Nat Geo, 2014)*



$$\frac{\beta_{\lambda}}{\beta_{\lambda_0}} = \left(\frac{\lambda}{\lambda_0}\right)^{-AE}$$

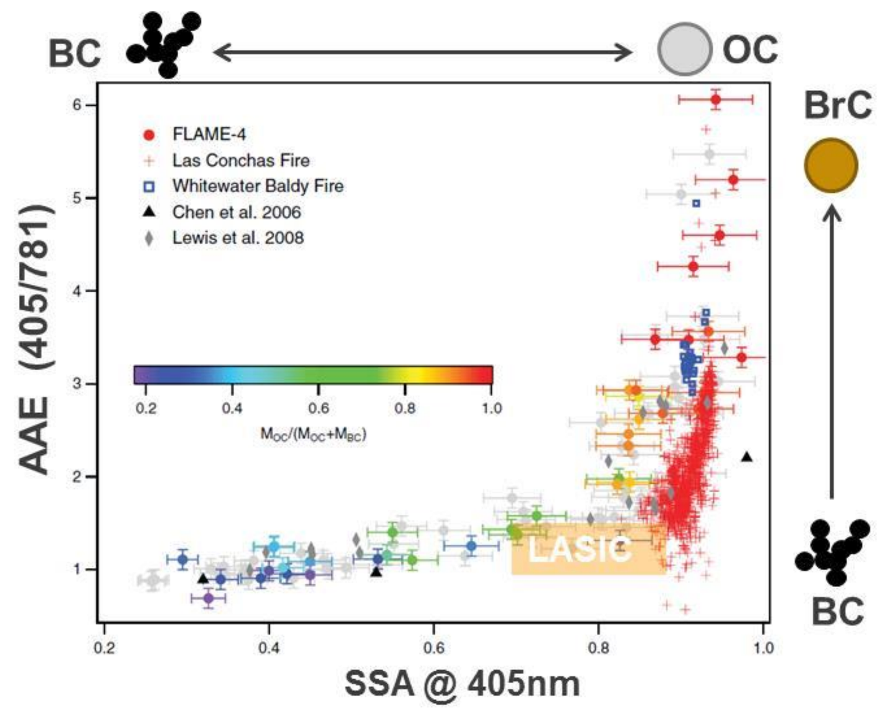
$$SSA = \frac{\beta_{sca}}{(\beta_{sca} + \beta_{abs})}$$

- Single Scatter Albedo (SSA; not shown)
  - Values ≤0.85 indicate a mixture (internal/external)
  - Lower in the plumes (higher BC fraction)
  - Is the fuel (likely grasses/savannas) more flaming?
  - High BC per total aerosol mass

Comparison with Laboratory BB and US Wildfires

- Laboratory BB data (shown in color based on OC Mass Ratio)
  - Sampled flaming to smoldering conditions with a large range of fuels, including African grasses
  - Dominant trend for near-field emissions, optical properties of the aerosol depend on fire conditions - *(S. Liu et al., GRL, 2014)*

- Ambient BB from SW US Forest Fires
  - Las Conchas and Whitewater Baldy in New Mexico
  - Aged from < 1 day to < 4 days



- Preliminary LASIC BB plumes (aged ~1 week)
  - lower SSA and AAE than SW US BB plumes
  - BrC not observed by AMF1 AOS

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