Boundary Layer Ambient Aerosols on Ascension Island during LASIC: Biomass Burning Season

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AMF1 on Ascension Island (ASI)

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Earth & Environmental Sciences

ASR Atmospheric System Research

ARM Climate Research Facility

U.S. Department of Energy

NNSA National Nuclear Security Administration

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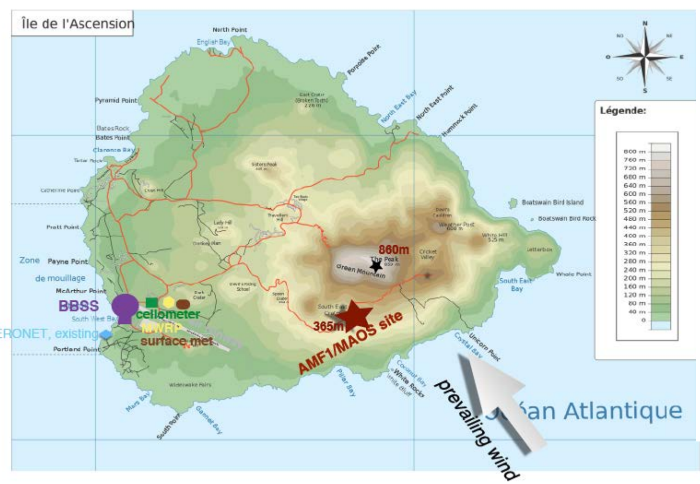
Layered Atlantic Smoke Interactions with Clouds (LASIC)

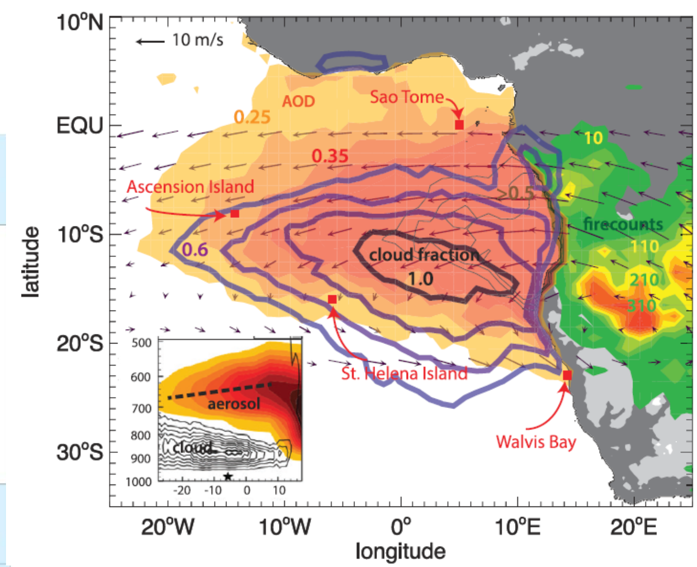
- **PI: Paquita Zuidema** (Thurs. Plenary and Breakout)
- **Southern Africa and Biomass Burning (BB)**
  - Largest source of BB Emissions Globally
  - Land Clearing Wood and Grassland Fires
  - BB Season is from June to November

- **LASIC Measurements**
  - Ascension Island in the Southern Atlantic Ocean
  - June 2016 – Oct. 2017
  - Two Southern African BB Seasons

LASIC
LAYERED ATLANTIC SMOKE INTERACTIONS WITH CLOUDS
2016-2017

ARM
CLIMATE RESEARCH FACILITY





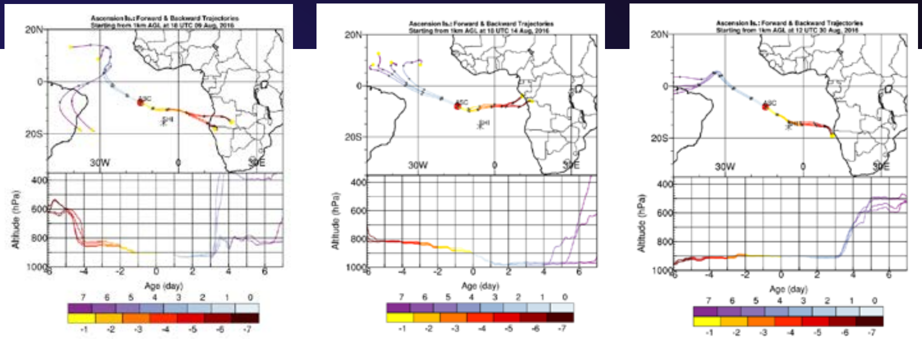
P. Zuidema, BAMS, 2016

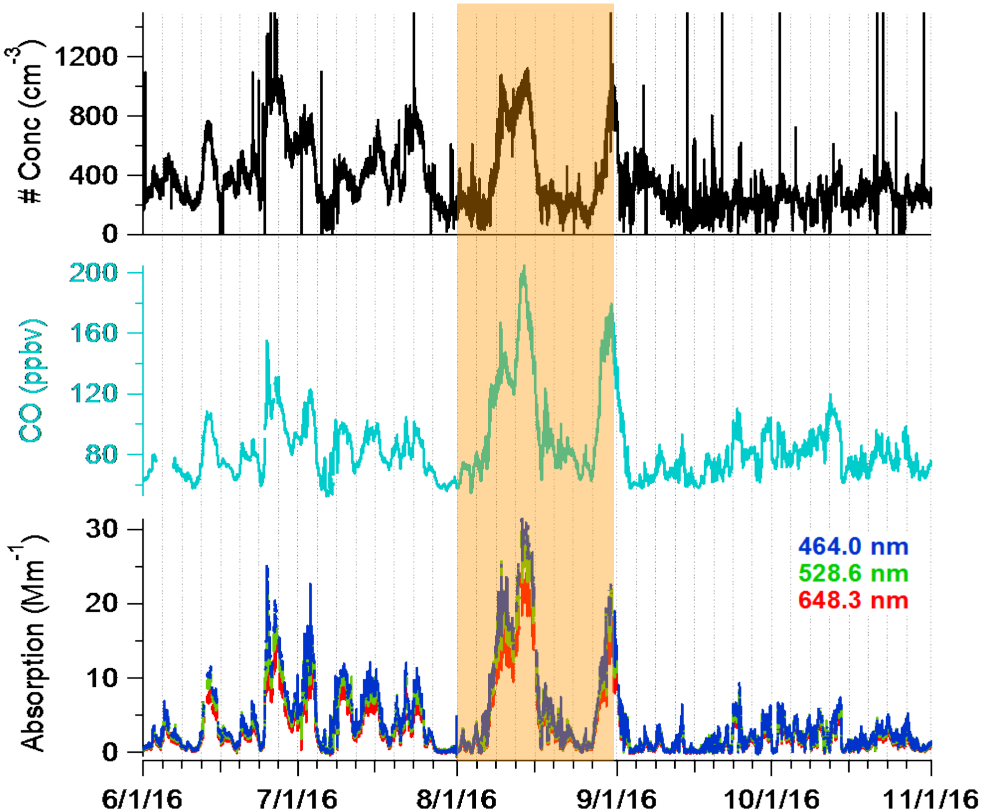
ARM Mobile Facility (AMF1 with AOS and MAOS) at LASIC

- **Aerosols and Trace Gases in the Aerosol Observing System (AOS) and Mobile AOS (MAOS)**
  - Surface: Particle number, size, optical properties, refractory Carbon (rC) content, non-refractory chemical composition, hygroscopicity and water uptake properties, Nitrogen Oxides, Combustion tracers (CO, SO_2), Ozone, Volatile Organic Compounds
  - Column: Sunphotometer
- **Atmospheric Profiling**
  - Microwave, High Frequency, and 3-Channel Radiometers
- **Clouds**
  - Lidar, Cloud Radars (K- and W-band), Total Sky Imager, Ceilometer
- **Radiometers**
- **Surface Meteorology**

2016 Biomass Burning Season

- **June – October, 2016**
  - 5 months of 1 minute data
  - Submicron aerosol (<1 µm diameter)
  - Largest plumes in August
  - Backtrajectory analysis for the three plumes in August (Adebiyi/U. Miami)
- **Aerosol Number, CO, and Particulate Absorption**
  - Similar trends in the time series
- **3 Wavelength Absorption**
  - Spans the visible range
  - Signals reach 30 Mm^{-1} in August
  - Peak Biomass Burning season in Southern Africa





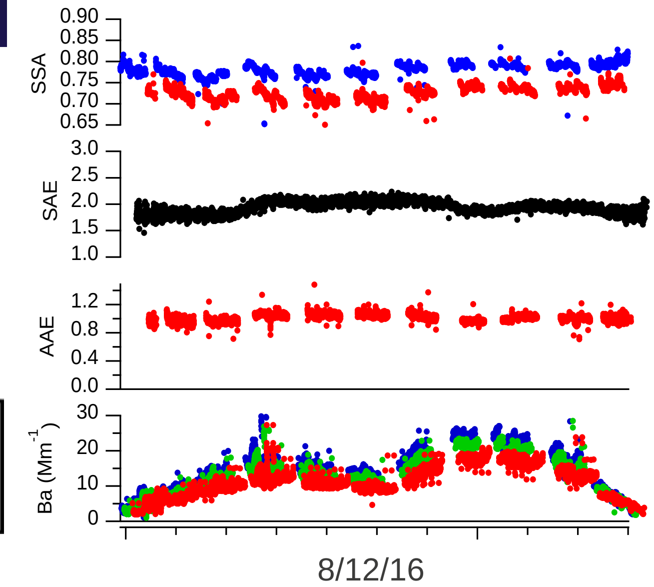
LASIC August Biomass Burning Plume Optical Properties

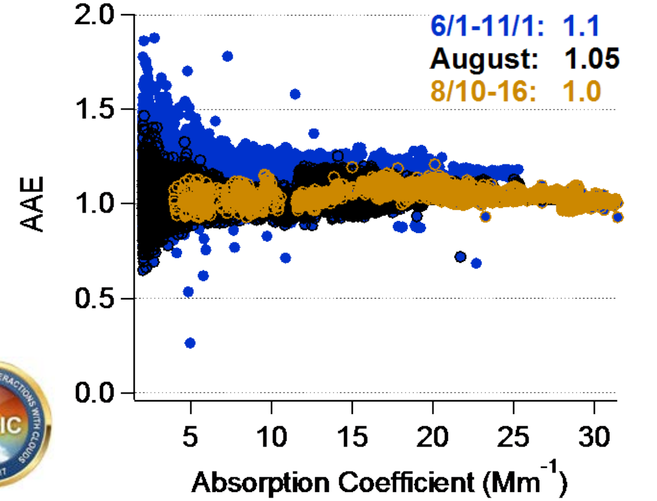
- **South African Biomass Burning Plume**
  - Plumes detected that correlate with column (e.g. AERONET data) – *Zuidema et al., GRL submitted*
- **Optical Properties**
  - **Absorption Angstrom Exponent (AAE: 464/648 nm)**

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

    - Indicator for chemical composition
    - Values ~1 indicate refractory carbon while >1 indicate absorbing organics (absorption in the UV)
    - Organics and refractory Carbon dominate the submicron mass
  - **Low Single Scatter Albedo (SSA)**
    - Comparison within measurement uncertainties (Biomass Burning/breakout)
    - ~0.78 at 464 nm
    - ~0.72 at 648 nm

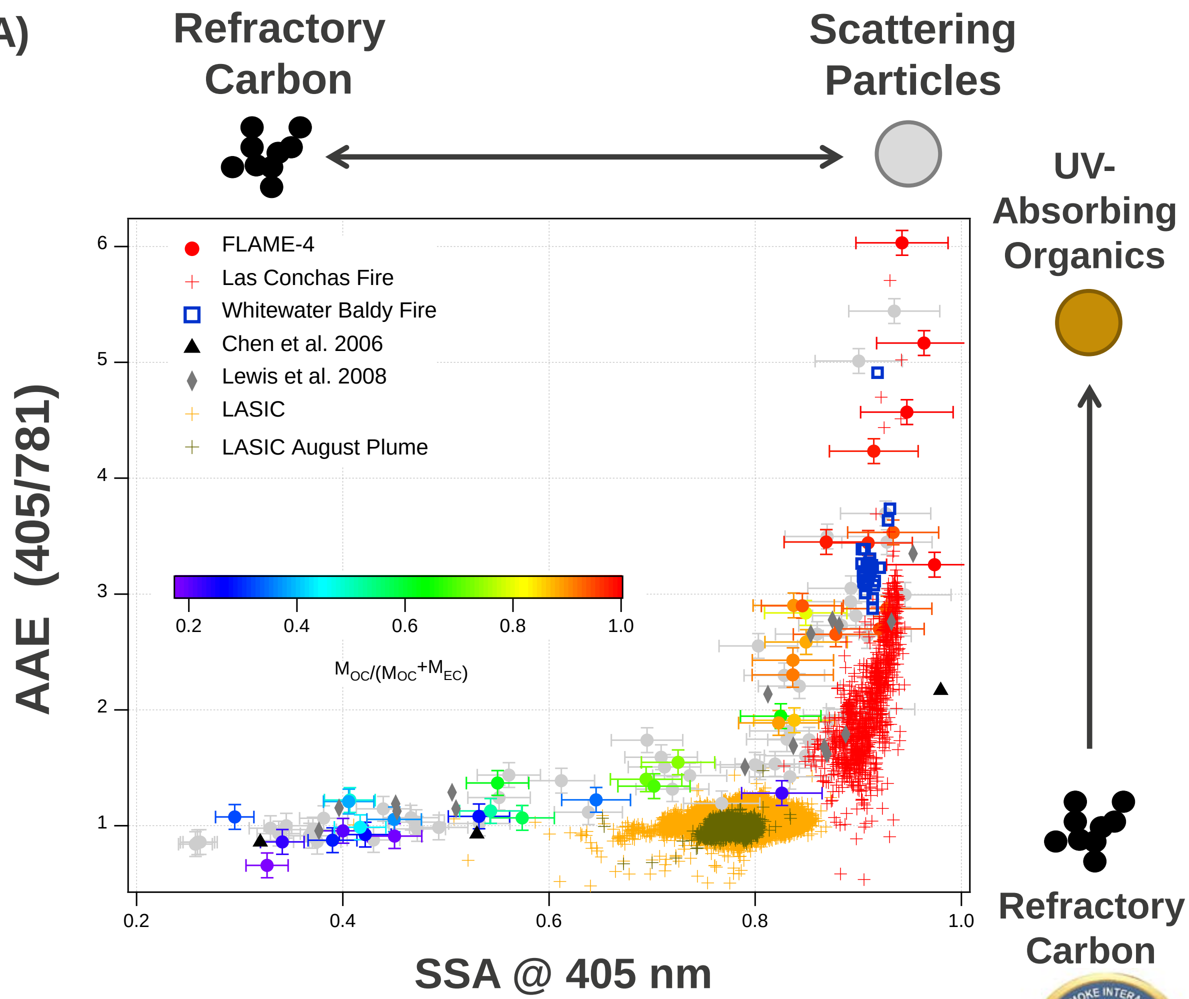
$$SSA = \frac{\beta_{sca}}{(\beta_{sca} + \beta_{abs})}$$





LASIC Biomass Burning Organic Aerosol Comparison to Laboratory and Near-field Biomass Burning Data

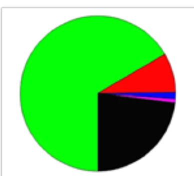
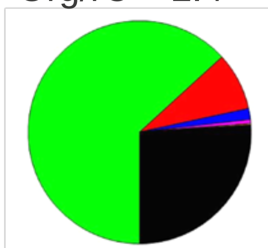
- **X: Single Scatter Albedo (SSA)**
  - Values from 0 - 1
  - Bare refractory Carbon ~ 0.4
  - Scattering Organics ~ 1.0 (non-absorbing)
- **Y: Absorption Angstrom Exponent (AAE)**
  - Refractory Carbon ~ 1.0 (λ independent)
  - Absorbing organics > 1 (higher in the UV)
- **Ambient US Forest Fires**
  - SSA ~ 0.85 – 0.95
  - AAE ~ 1 – 4
- **LASIC**
  - Lower SSA (0.81 ± 0.03) and AAE (1.04 ± 0.10)
  - Refractory Carbon dominates, no evidence for organic absorption



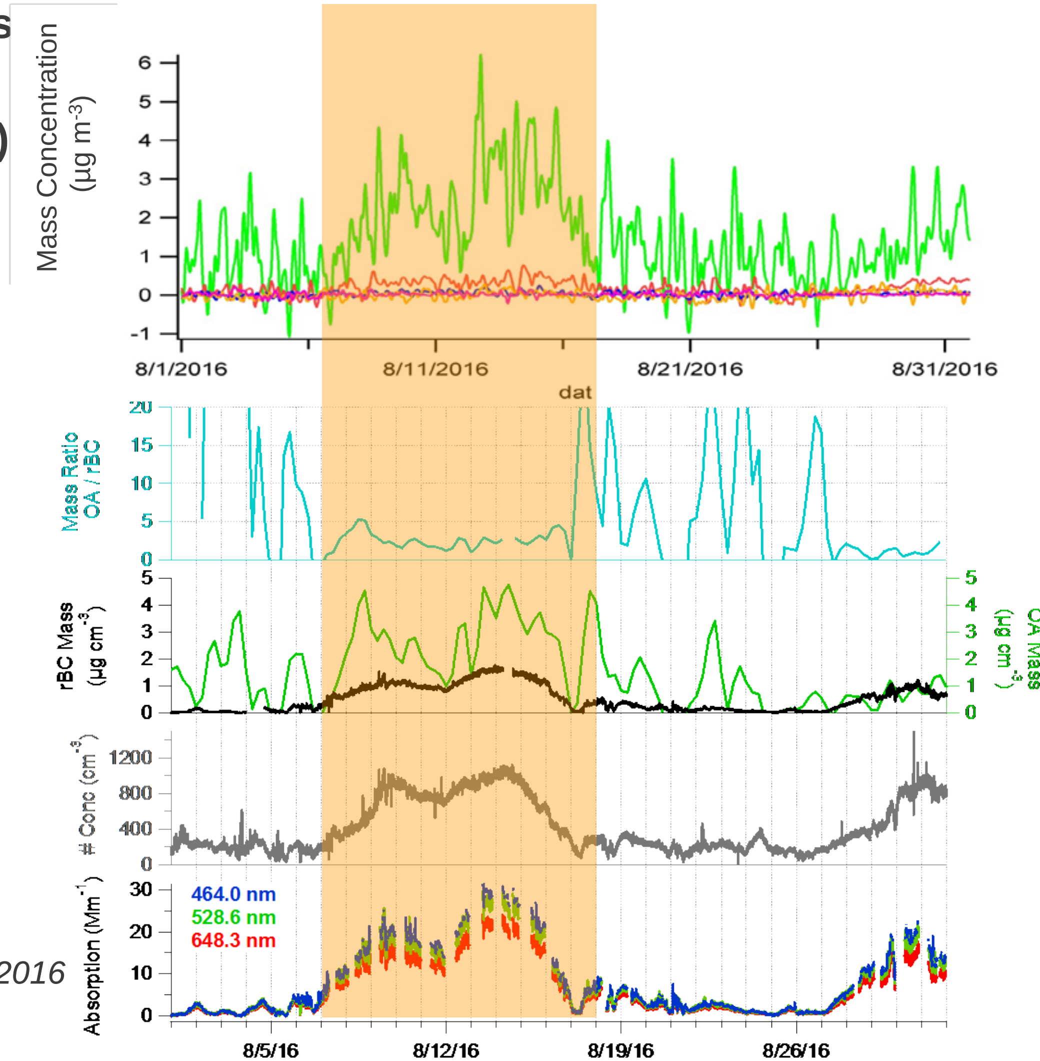
S. Liu, A.C. Aiken, et al., GRL,2014

LASIC Biomass Burning Plume Chemical Composition

- **Non-Refractory Submicron Aerosol Mass**
  – Dominated by Organics
- **Total (non-refractory +refractory Carbon)**

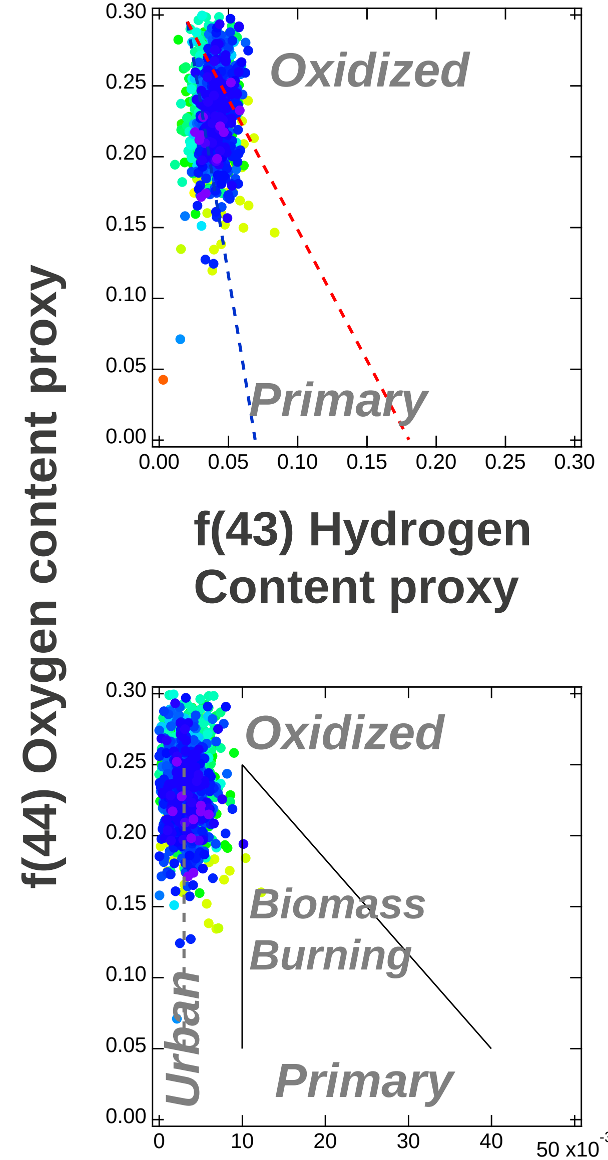
August	**8/7 – 17 Plume**
2.2 µg m^{-3}	3.9 µg m^{-3}
Org/rC = 3.0	Org/rC = 2.4
	
Organics = 67.0%	**Organics = 63.2%**
Sulfate = 8.59%	**Sulfate = 8.39%**
Nitrate = 1.37%	**Nitrate = 1.61%**
Chloride = 0.78%	**Chloride = 0.58%**
Ammonium = -0.01%	**Ammonium = 0.20%**
rC = 22.3%	**rC = 26.0%**

- **Preliminary (PMF) Analysis**
  - Most of the Organics are Aged/Oxidized
  - Aged Biomass Burning - *S. Zhou et al., ACPD 2016*
- **Bulk Chemical Information**
  – Refractory Carbon and Organics dominate



Organic Aerosol in LASIC Biomass Burning Plumes

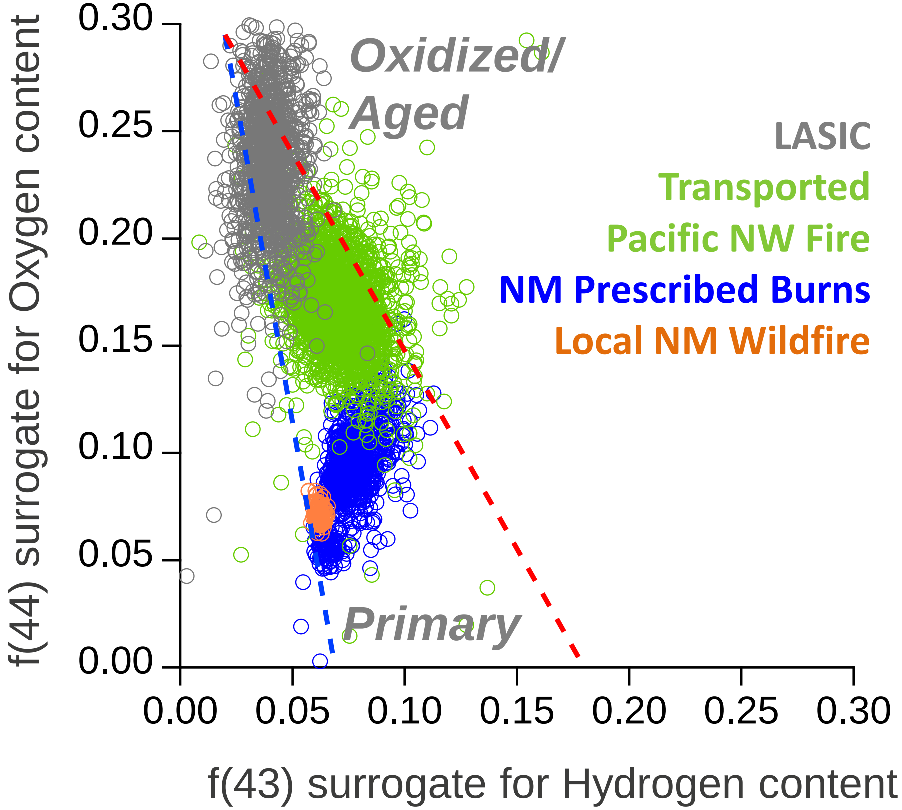
- **Non-refractory Organic Aerosol is the largest chemical component**
  - Over half of the PM_1 mass
  - Measured by aerosol mass spectrometry
  - Can determine more information from mass spectral signatures and tracer ions
- **Organics are highly oxygenated**
  - f(44: Oxygen content) vs f(43: Hydrogen content)
    - *Ng et al., ACP, 2011*
  - Don't exhibit primary hydrocarbon-like content
  - Resemble low volatility oxygenated organics
- **No evidence of primary biomass burning ion**
  - f(60) Levoglucosan fragment ion
    - *Cubison et al., ACP, 2011*

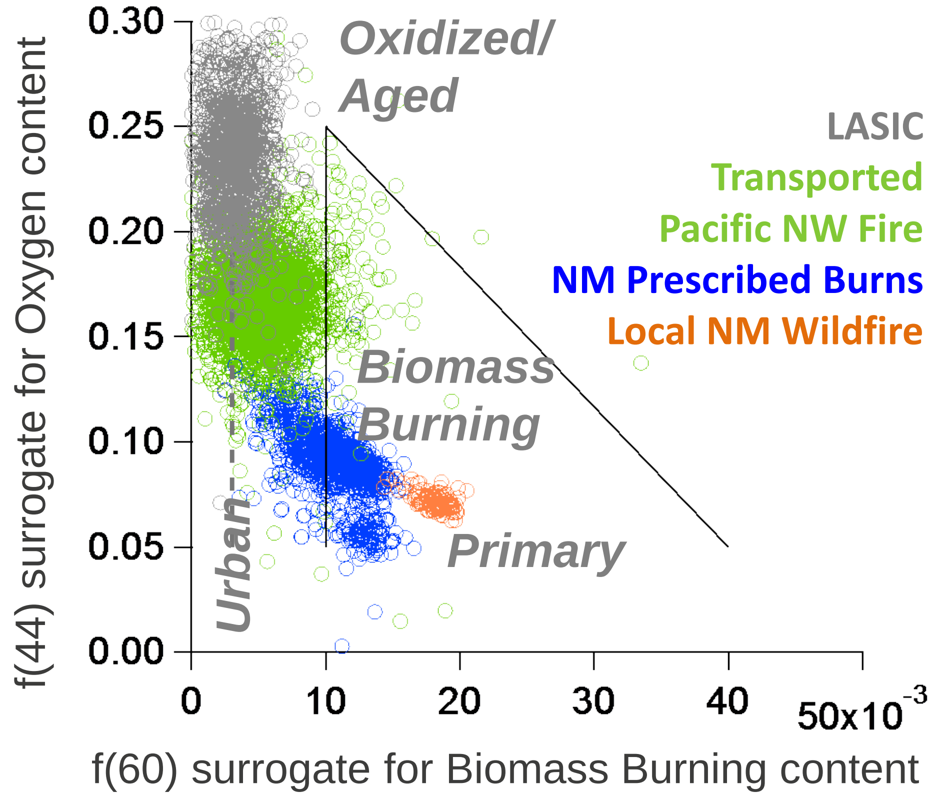


f(43) Hydrogen Content proxy

f(60) Biomass Burning marker (Levoglucosan)

LASIC Biomass Burning Organic Aerosol Comparison to 2017 US Wildfire Data

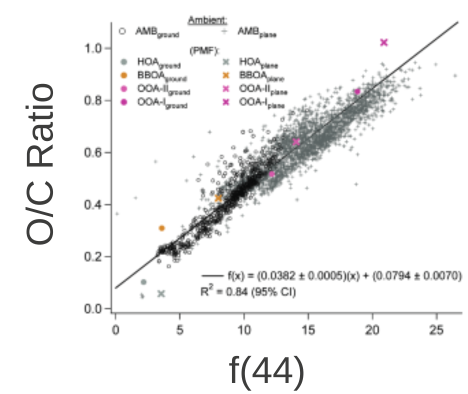




- **LASIC Elemental Analysis Approximation**

  - Aiken et al., ES&T, 2008

  - **O/C = 0.98 ± 0.12**
  - **OM/OC = 2.41 ± 0.16**



Summary and Future Work

- **South African Biomass Burning Plume Analysis**
  - Significant aerosol number and mass concentrations within the Boundary Layer measured by the ARM Aerosol Observing System (AOS)
  - Organics and refractory Carbon dominate the submicron mass
    - Organics are highly oxygenated (aged/low volatility) with no significant primary ions/tracers
    - AAE indicates most absorption is from refractory Carbon (lack of UV absorption from Organics)
- **Continued and Future work**
  - In depth comparison of Biomass Burning season aerosol with background conditions
  - Comparison with NASA-ORACLES and ATom (aging and differences in source emissions)
  - Mass closure studies, e.g. size distribution analysis
  - Gas-phase tracer and precursor analysis
  - Positive Matrix Factorization of Organic Aerosol
- **Continued need for *in situ* aerosol data**
  - Sample regional and source-specific differences
  - Capture dynamic processes and uncertainties
  - Closure studies

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