IBBI Interdisciplinary Biomass Burning Initiative

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Biomass Burning Observation Project (BBOP): Near Field Evolution of BB Emissions

A. J. Sedlacek, L. Kleinman, K. Adachi, P. Buseck, T. Onasch, Q. Zhang, et al.

ASR Atmospheric System Research

ARM CLIMATE RESEARCH FACILITY

<u>B</u>iomass <u>B</u>urn (BB) <u>O</u>bservation <u>P</u>roject: BBOP

<u>Scientific Objective:</u>

To understand and quantify the role of BB aerosols in climate forcing by investigating the *<u>near-field</u>* evolution of their optical, chemical, hygroscopic, and microphysical properties.

Key Results

Rapid near-field changes observed in:

- Aerosol chemical properties
- Aerosol microphysical properties
- Aerosol optical properties

Dependence on burn conditions

Identification of 3 types of BBOA

Tar balls represent large contribution

Gulfstream-1 (G-1) Platform

Chemical & Physical Particulate Measurements

NR-PM: SP-AMS, TEM

rBC: SP2, **SP-AMS**, TEM

Size: UHSAS, PCASP, FIMS

Optical Measurements

Extinction: 1-λ **CAPS PMex (630 nm)**

Scattering: 3-λ Nephelometer (450, 550, 700 nm)
1-λ **PAS (355 nm)**

Absorption: 1-λ **PAS (355 nm)**
1-λ **PTI (532 nm)**
3-λ PSAP (462, 523, 648 nm)

Trace Gas Measurements

VOCs: PTRMS

CO_2, CO, O_3, SO_2, N_2O, NO, NO_2, NO_y

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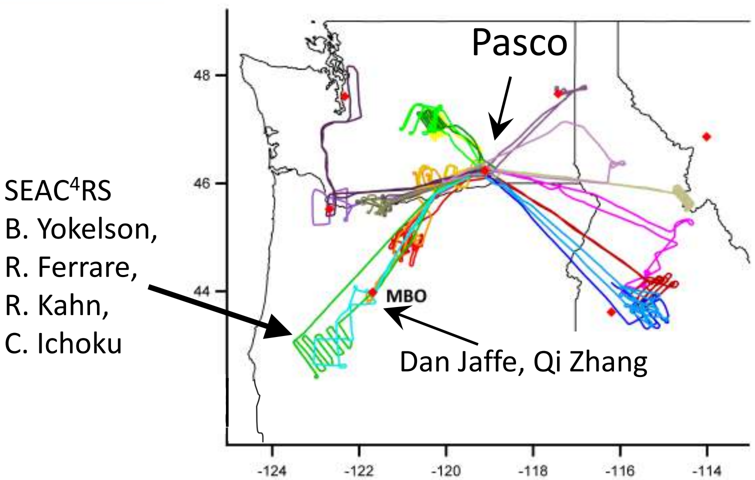
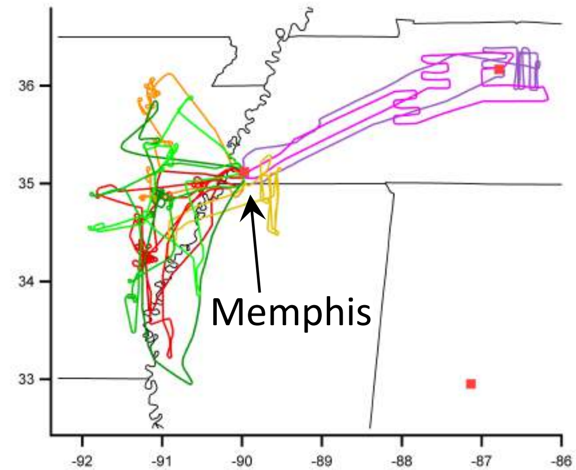
120 flight hours – Mix of Sources





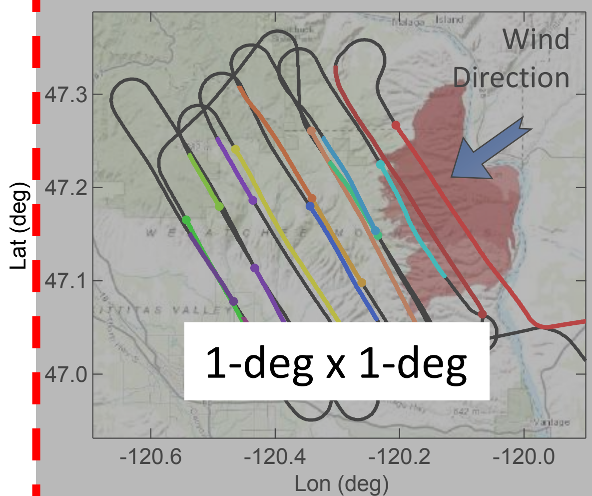
WildFires: (17 fires)
Shrub, Forest
MBO (3 flights)
SEAC4RS: Joint mission Aug., 6

Agricultural Burns: (> 24 burns)
cotton, rice, soybean, sorghum

Urban: Seattle, Portland, Spokane, Nashville, Memphis

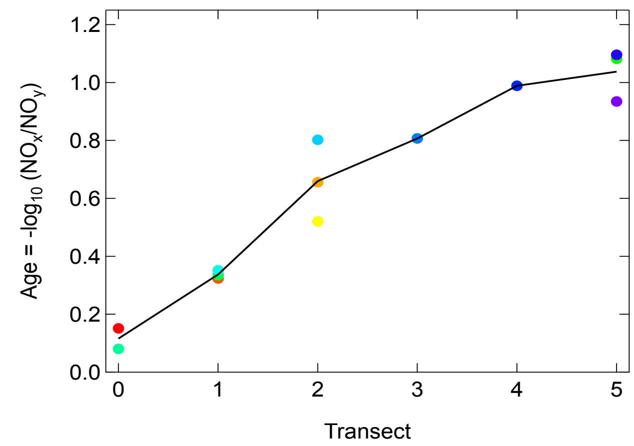
Near-Field Changes in Aerosol Properties

Colockum Tarps Fire

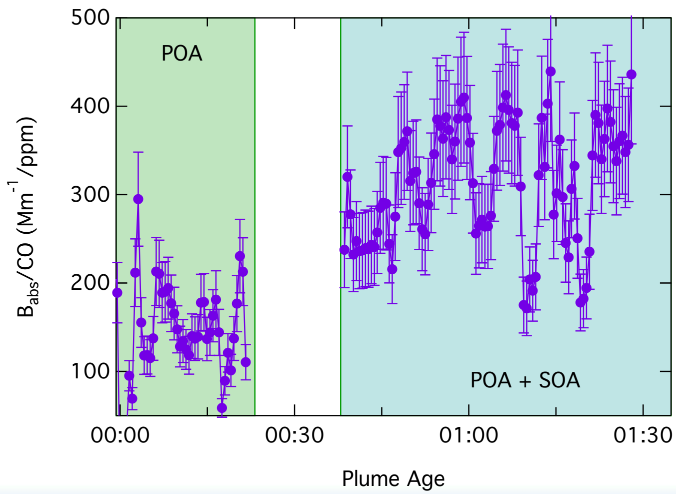


Challenge: far-field modeling based on near-field measurement

Rapid Chemistry Occurring

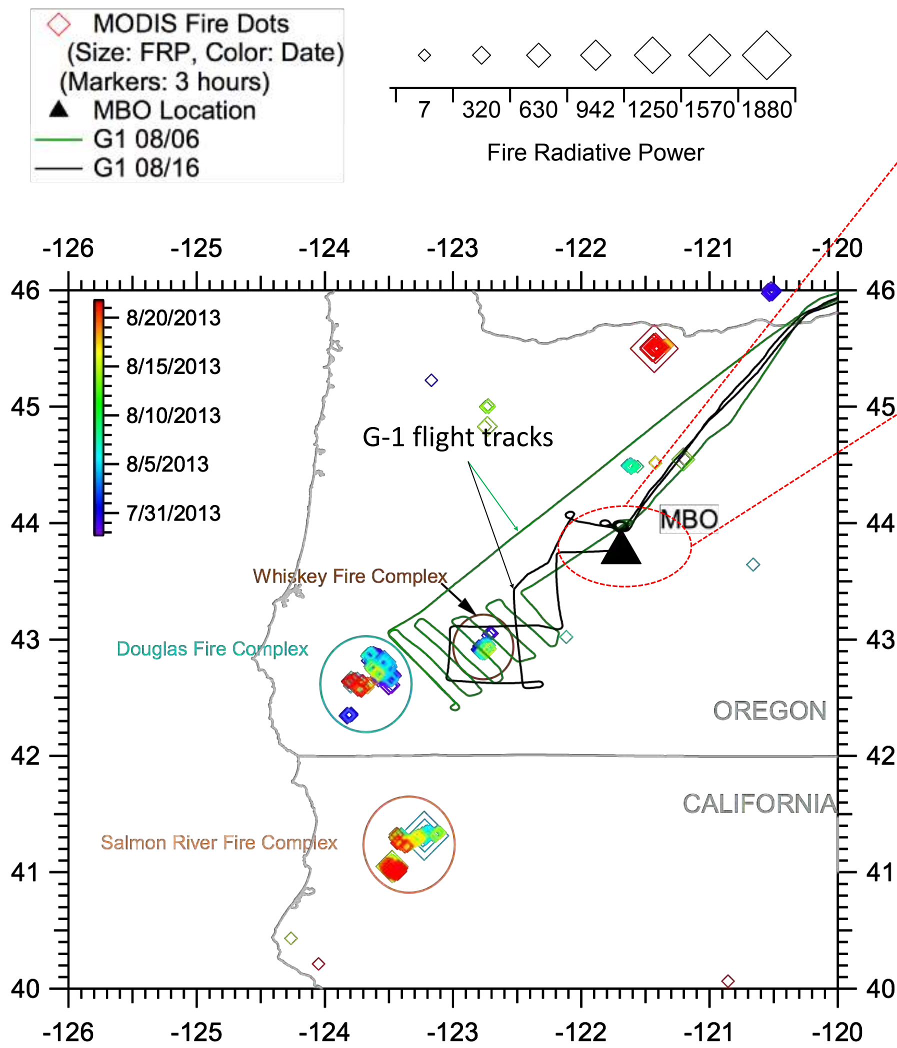


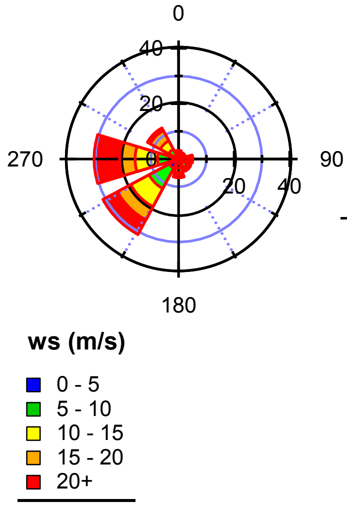
Rapid Increase in Light Absorption

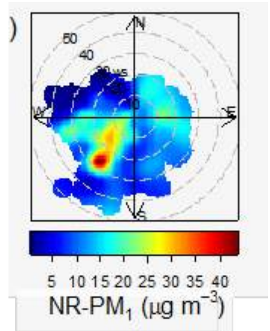


λ = 355 nm

Aerosol Measurements at Fixed Site (July 25 – Aug. 25, 2013)







MBO: Transported (6 – 48 hrs/Regional)

G1: Near Field (< 1 - 10 hrs)

Zhou et al., ACP 2017

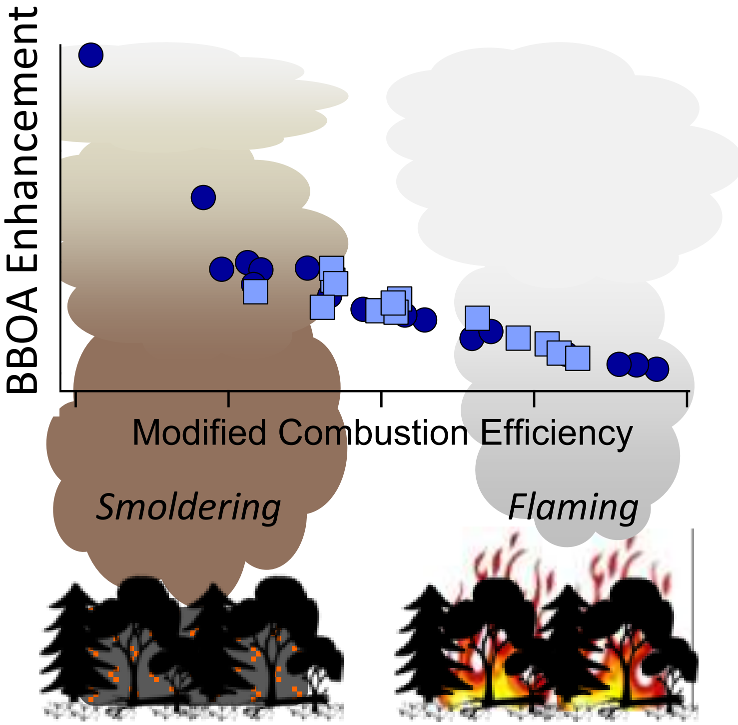
Collier et al., ES&T, 2016

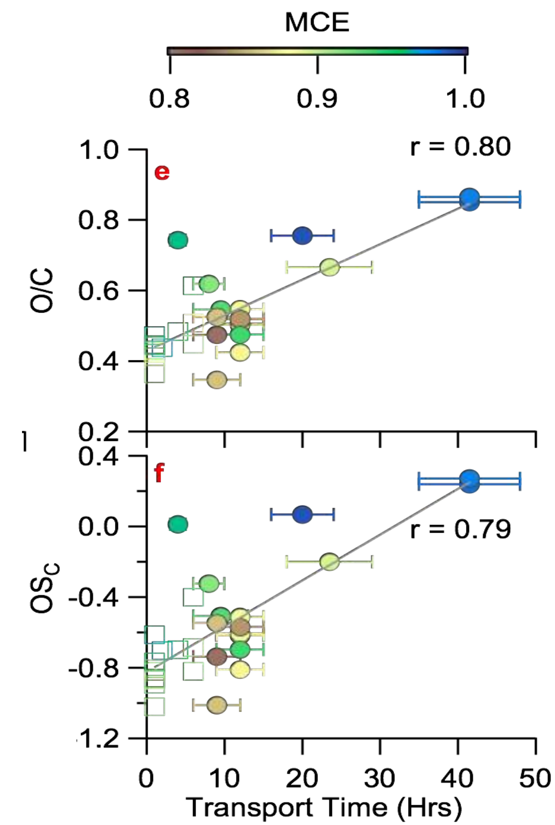
Regional BBOA Enhancement Driven by Burn Efficiency
BBOA Chemistry is Driven by Atmospheric Aging

Collier et al., ES&T, 2016

OA enhancement = $\Delta Org/\Delta(CO+CO_2)$

MCE = $\Delta CO_2/\Delta(CO+CO_2)$



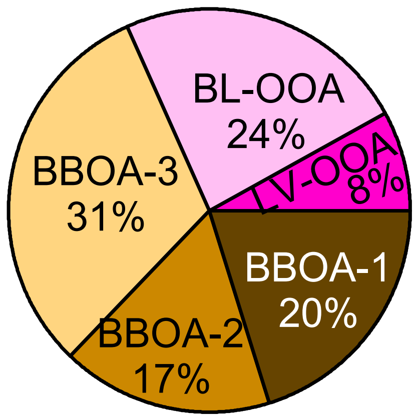


Low MCE → greater POA and oxygenated VOCs emissions (greater SOA formation)

MBO and G1 data overlap → Aging has little influence on BBOA enhancement

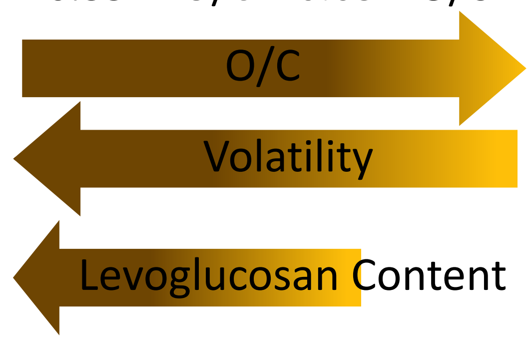
Three Types of Biomass Burn Organics (BBOA)

$\Sigma_{BBOA} \approx 70\%$ of OA mass

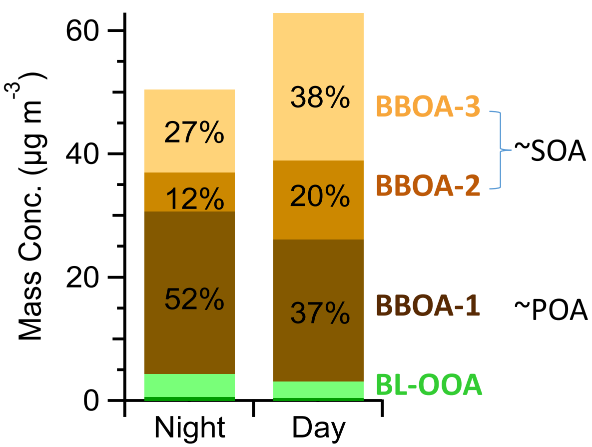


Three types of BBOA

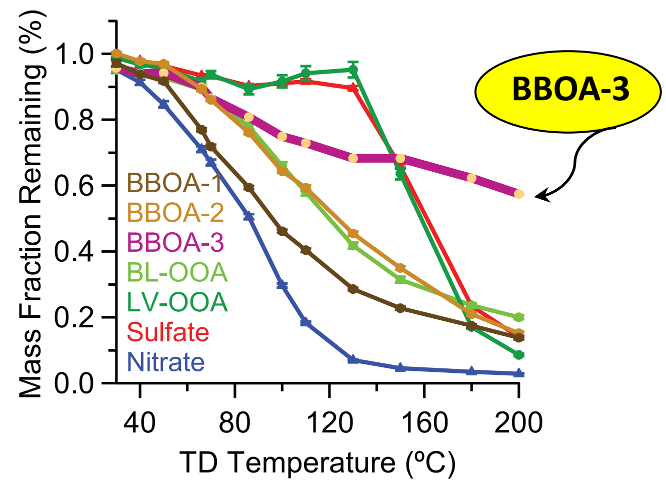
Fresh	Aged	Aged
BBOA-1	**BBOA-2**	**BBOA-3**
O/C = 0.35	O/C = 0.65	O/C = 1.06



BBOA Photochemical Aging



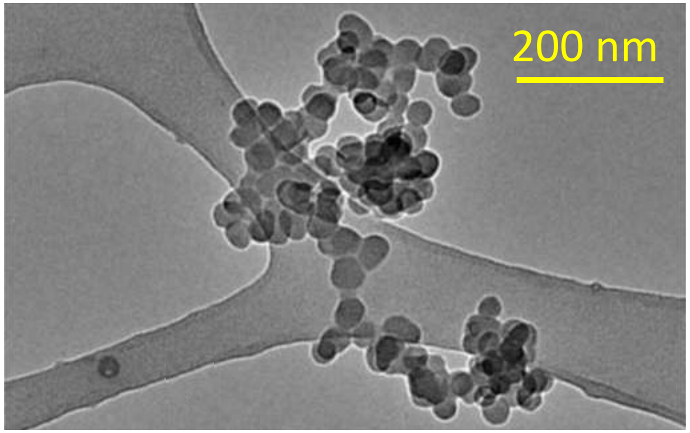
BBOA-3 has very low volatility



Zhou et al., ACP 2017

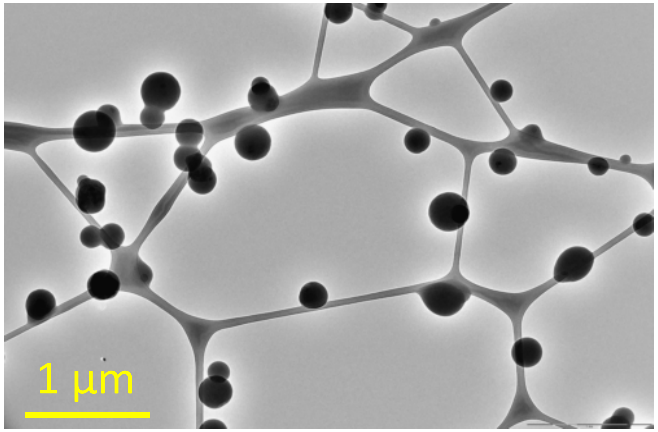
Types of Spherical Carbonaceous Solids

Soot



Pawlyta and Hercman Ann. Soc. Geo. Pol. 2016

Tar balls (BrC particles)



BBOP

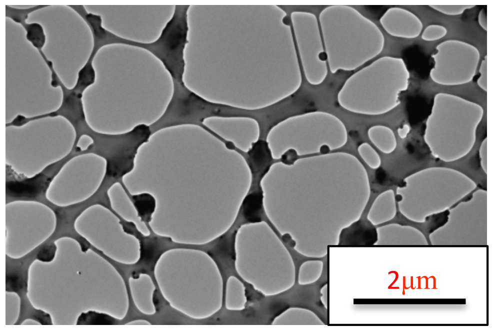
Tar Balls (TBs)

- Spherical shape
- Particle diameter between 200 - 500 nm
- High viscosity
- Lack of crystallinity and absence of graphitic fine structure
- Composed primarily of carbon and oxgyen
- Low volatility
- Recognized through TEM and SEM

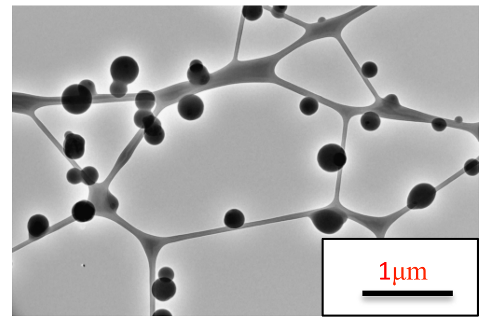
Formation and Evolution of Tar Balls

BBOP demonstrated that Tar balls are extremely processed primary particles.

0 h

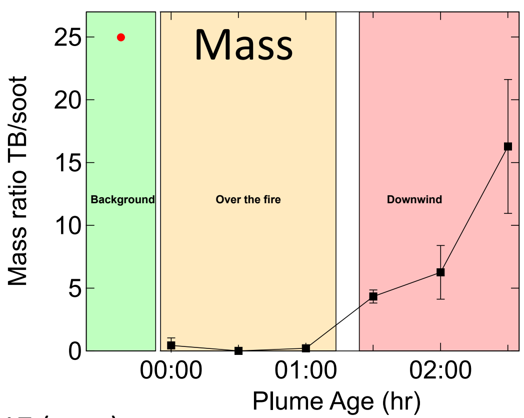


2.5 h

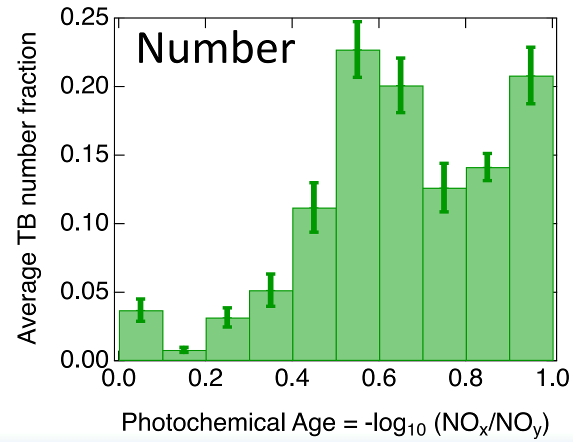


Tar ball formation need not involve rapid heating as suggested in laboratory studies.

Flight: July 30, 2013



All BBOP wildfires



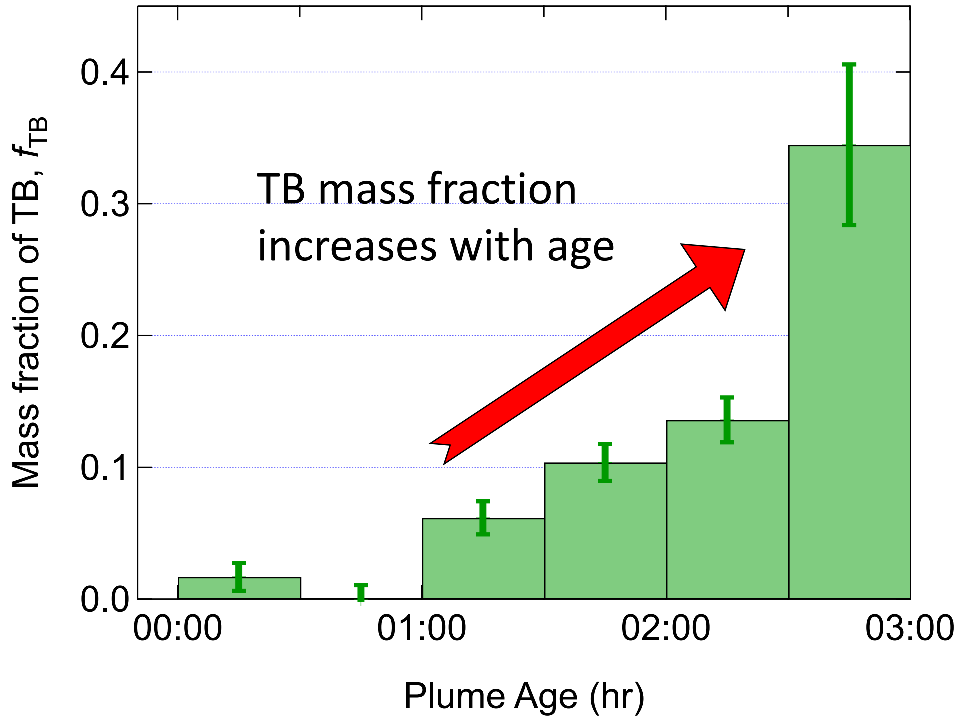
Sedlacek et al., 2017 (prep)

Tar Ball Mass Fraction

High Tar ball *number fractions* (>50%) have been reported in previous studies.

However, there are uncertainties due to loss of other (volatile) particles during analysis.

- BBOP yielded the first determination of Tar ball *mass fraction* in a wildfire plume.
- This is the quantity models need.



Tar balls could help resolve discrepancies between retrieval and inventory comparisons.

Sedlacek et al., 2017 (prep)

Constraint on Optical Properties of Tar Balls

Previous reported values of TB refractive index:

- m = 1.67 – 0.27i (Alexander et al., 2008)
- m = 1.84 – 0.21i (Hoffer et al., 2015)
- m = 1.56 – 0.02i (Hand et al., 2005)
- m = 1.80 – 0.007i (Chakrabarty et al., 2010)
- m = 1.75 – 0.002i (Chakrabarty et a., 2010)

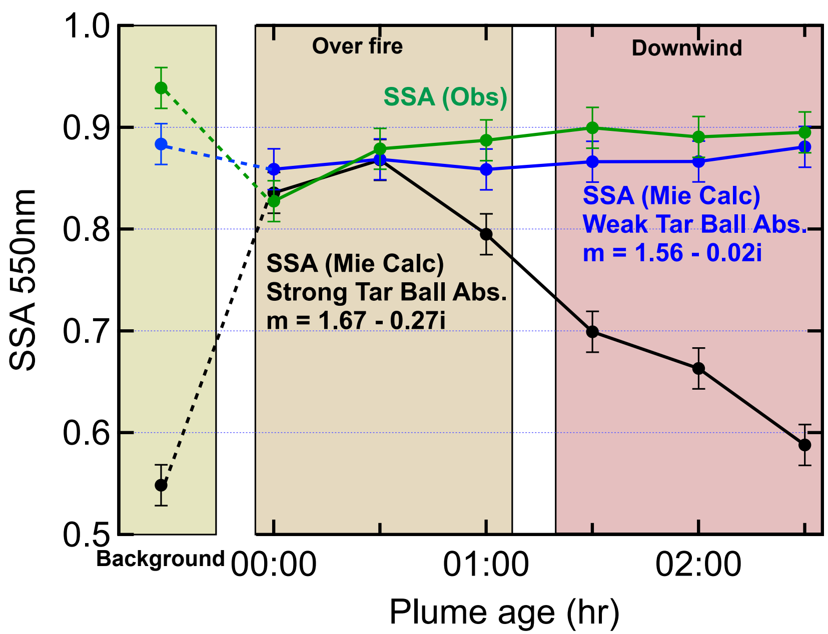
100x range in imaginary component

Single Scattering Albedo (SSA)

$$SSA = \frac{\text{Scattering}}{\text{Scattering + Absorption}}$$

Nephelometer → Scattering

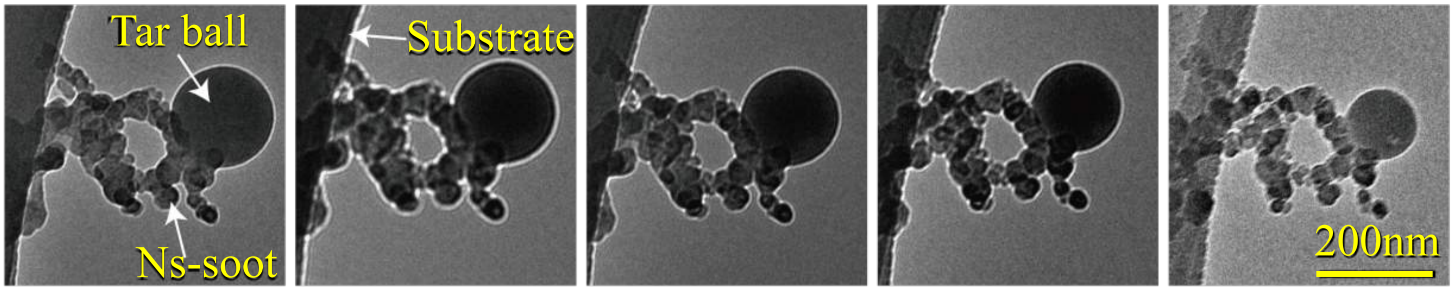
Photothermal Interferometer → Absorption



m=1.56 – 0.02i, based on SSA consistency between calculations and BBOP field measurements.

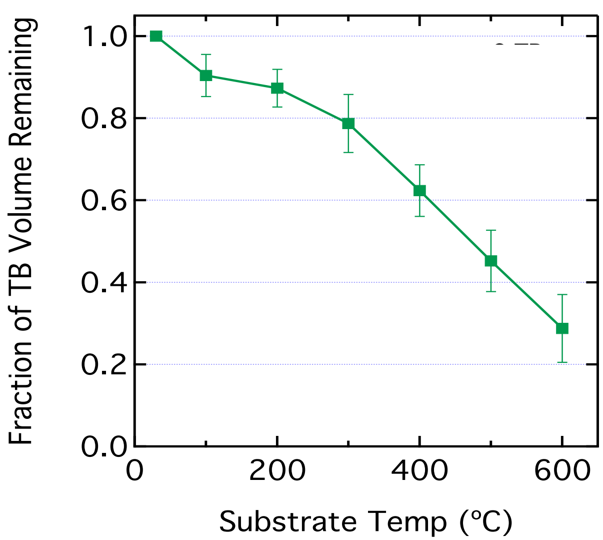
Refractory Properties of Tar Balls

Tar balls resistant to heating

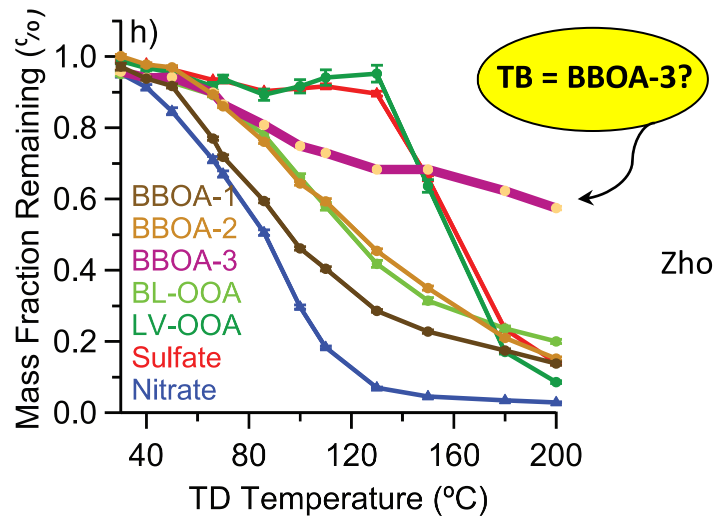


25 C 150 C 300 C 450 C 600 C

Adachi et al., 2017 (in review)



Sedlacek et al., 2017 (prep)



Zhou et al., 2016

Are Tar Balls = BBOA-3 ?

Closing Thoughts

Near-field measurements of optical properties → validity in models

- Can models based on near-field measurements be applied to the far field?

Dependence of aerosol properties on combustion → improved model estimation

BBOA-1, BBOA-2, BBOA-3 (= TB?) → different classes of light-absorbing aerosol

- Current models assume *non-absorbing* OA.
- How spectral classes of *absorbing* OA are required for accurate modeling?

Tar Balls are a major component of some wildfires → model incorporation

- Implications for budgets and closure (top-down/bottom-up comparisons).
- Are TBs "Dark Matter" not detected by current *in situ* instruments?
- Are laboratory-generated TBs the same as ambient TBs?

Big Thanks to all that made BBOP a success!

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J. Thomlinson
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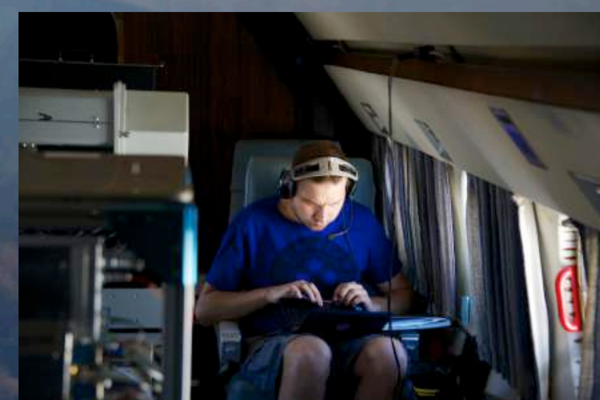
B. Yokelson
Q. Zhang
S. Zhou



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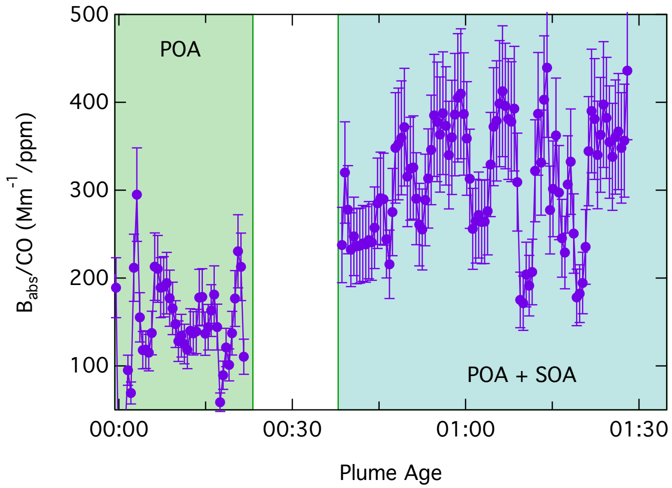
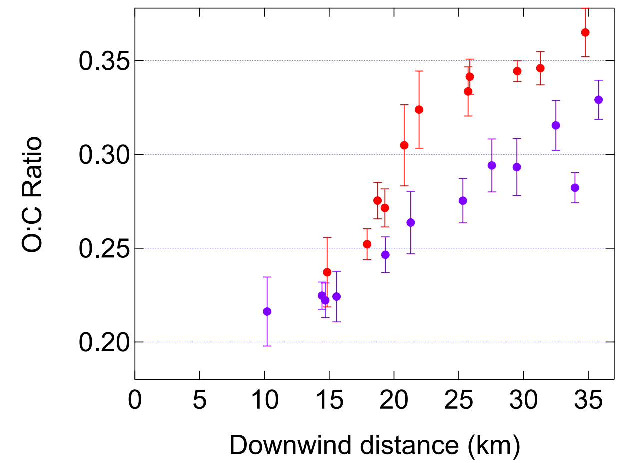
Atmospheric System Research

BBOP: Aerosol Optical and Chemical Properties

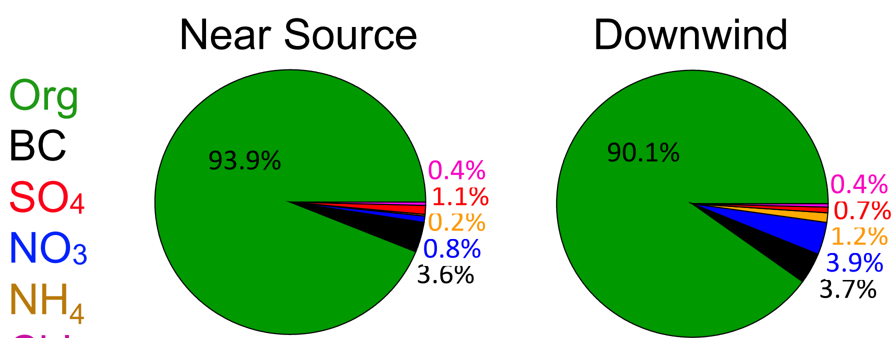
BrC Absorption Increase with Age



OA Oxidation Increase with Age: SOA



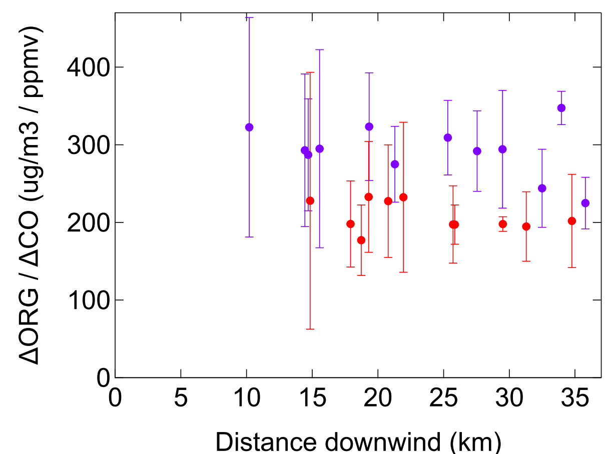
Particulate Nitrate Increase with Age



NO_3 = 0.8% NO_3 = 3.9% (5x)

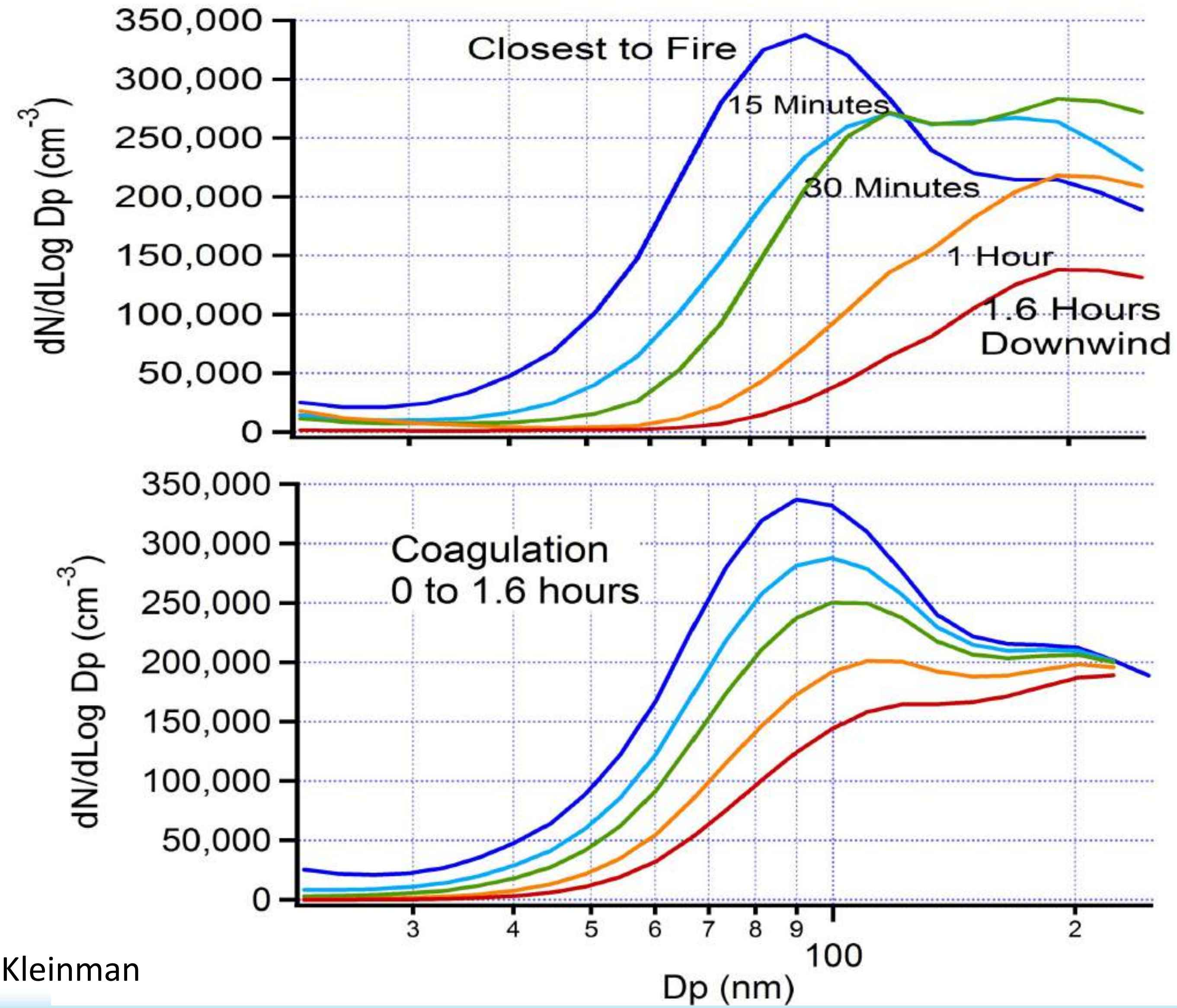
Sedlacek, Arnott, Onasch

ΔOrg/ΔCO Constant despite Chemistry



Kleinman, Onasch

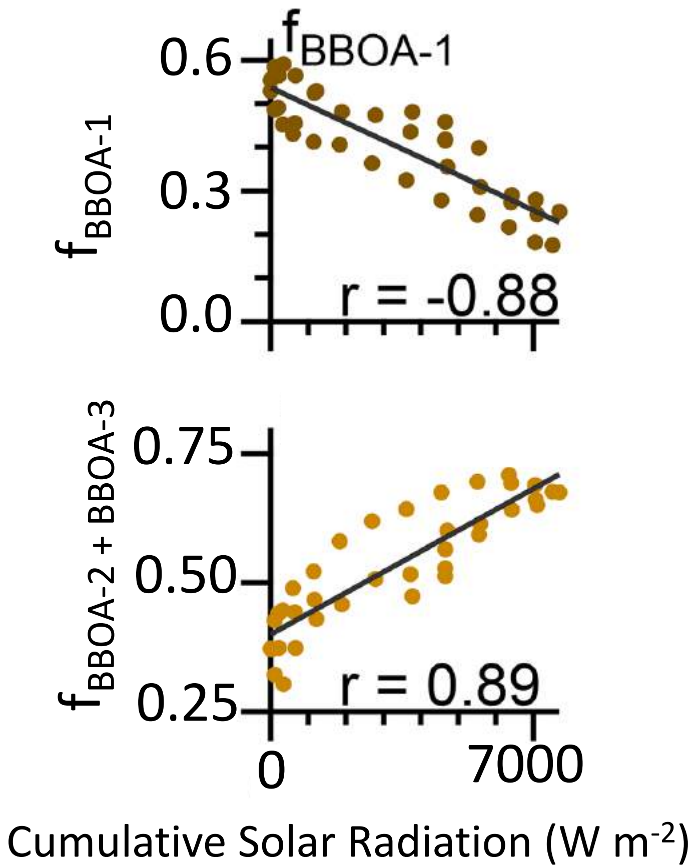
Coagulation Near Source Drives Particle Growth



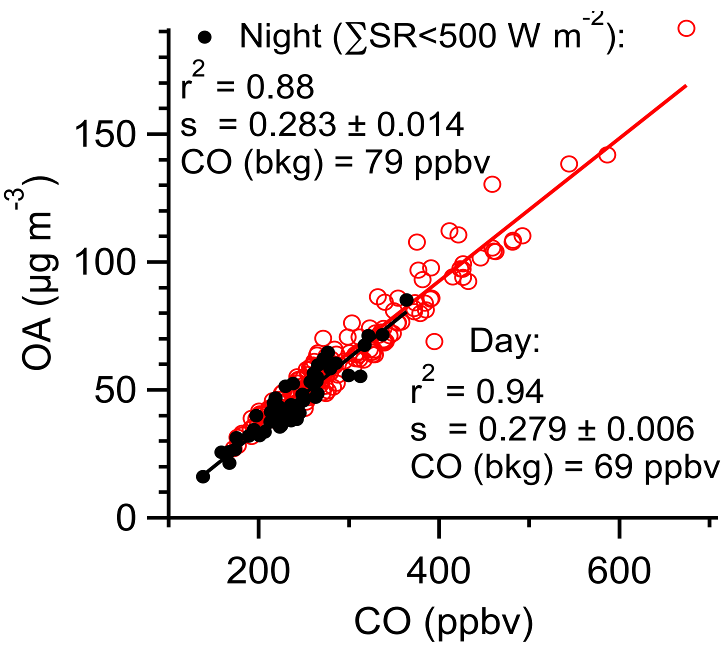
Wang and Kleinman

BBOA Evolution in Regional Air Masses

- BBOA-1 =primary
- BBOA-2 & BBOA-3 = more aged, secondary



No net OA mass enhancement due to photochemical aging

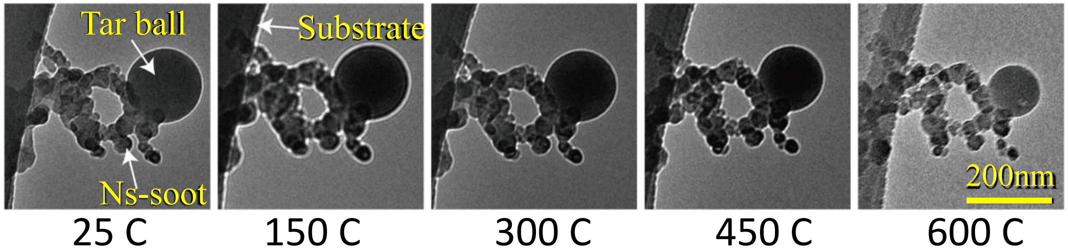


- Evidence of BBOA photochemical aging
- Photochemical production of BB SOA.
- Offsetting SOA formation and POA evaporation
  ~ constant OA/CO with aging

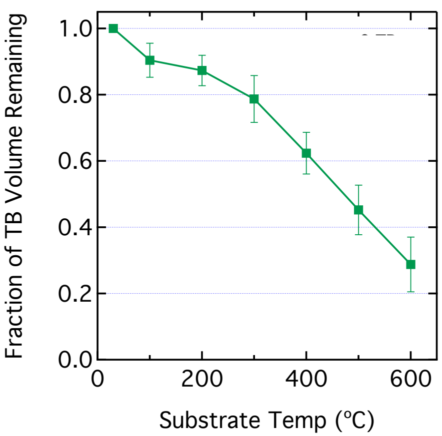
Refractory Properties of Tar Balls

Field Measurements

TBs resistant to heating



Adachi et al., 2017 (in prep)



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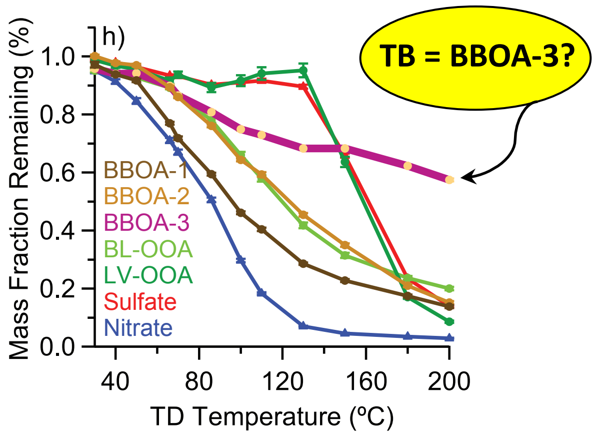


Zhou et al., 2016

Are TBs a low-volatility PMF factor?

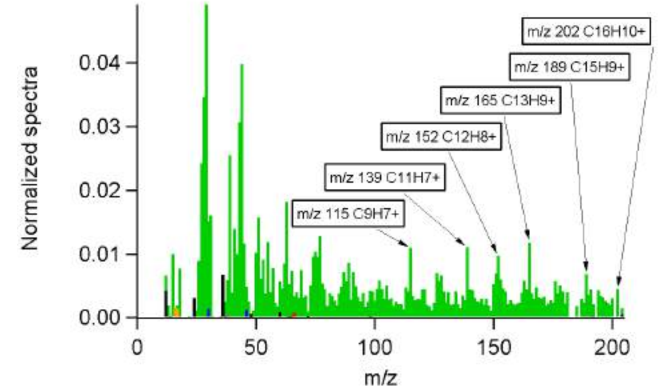
Laboratory Studies

AERODYNE RESEARCH, Inc.

Pyrolysis of pine twigs

Lab-generated TBs similar

AMS shows unsaturated hydrocarbons



Are lab-generated TBs the same as ambient?