Evolution of Biomass Burning Aerosols Optical Properties in the Near Field

A. J. Sedlacek and L. Kleinman (BNL)

Pat Arnott (U. Nevada)
D. Chand (PNNL)
E. Fortner (Aerodyne, Research)
A. Freedman (Aerodyne Research)
T. Onasch (Aerodyne Research)
S. R. Springston (BNL)
S. Smith (BNL)

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Radiative Forcing by BB Aerosols Remains Uncertain

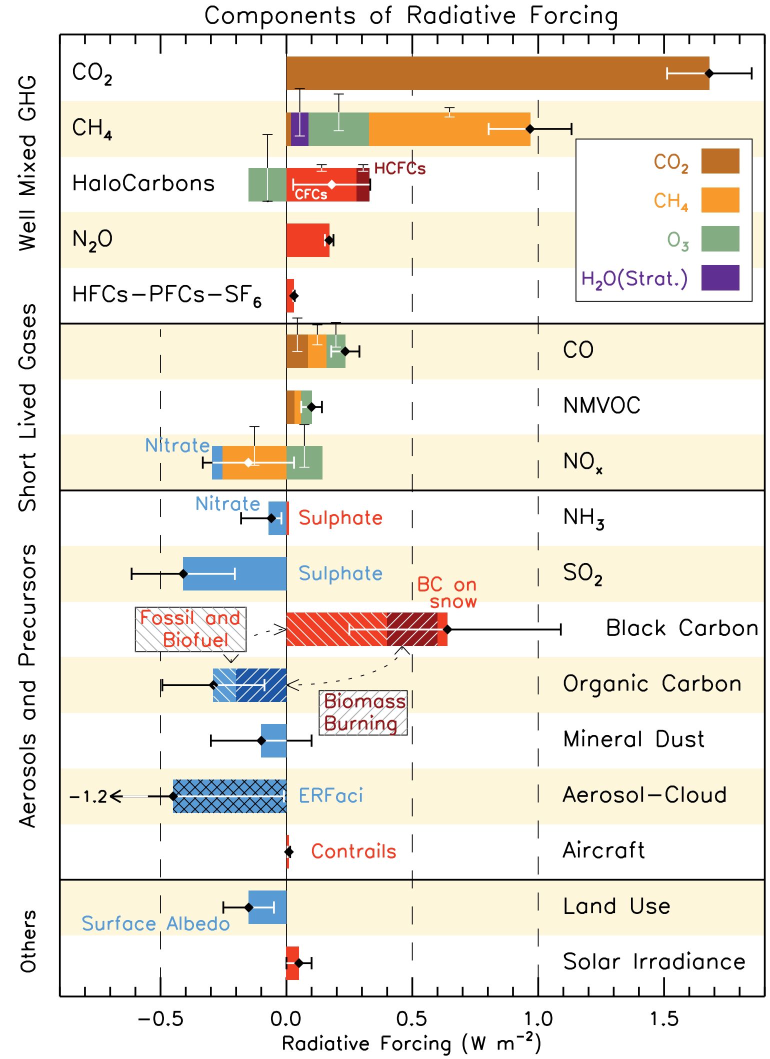
- Black carbon exerts positive aerosol forcing (warming) - second only to CO_2
- BB is a significant source of brown carbon (BrC)
  - Exhibits pronounced λ dependence in absorption
  - Role as CCN (in contrast to nascent BC)
- Estimated total climate forcing due to BB:

  -0.11 (-0.46 to +0.15) W m^{-2} (Bond et al. 2013)

  Uncertainly reflects knowledge gaps in BC-cloud interactions & BC interactions with co-emitted organic carbon

POA dominate

BC dominate



IPCC Fifth Assessment Report: Climate Change 2013, Ch: 8, p 698

Biomass Burn Observation Project (BBOP)

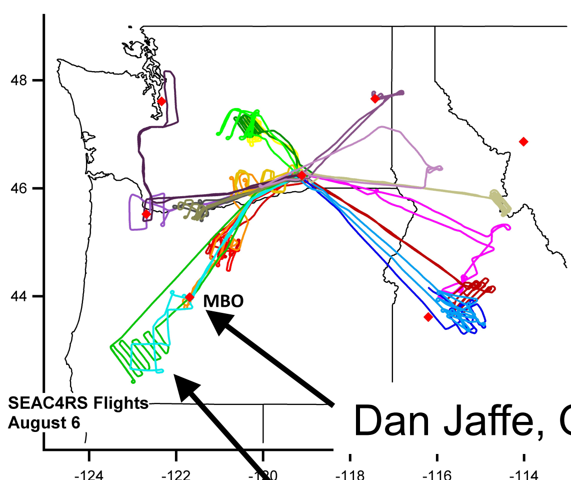
Scientific Challenge:

To understand and quantify the role of BB in aerosol forcing (heating/cooling)

*Investigate the **evolution** of chemical, hydroscopic, microphysical, and optical properties of biomass burn aerosols in the near field*

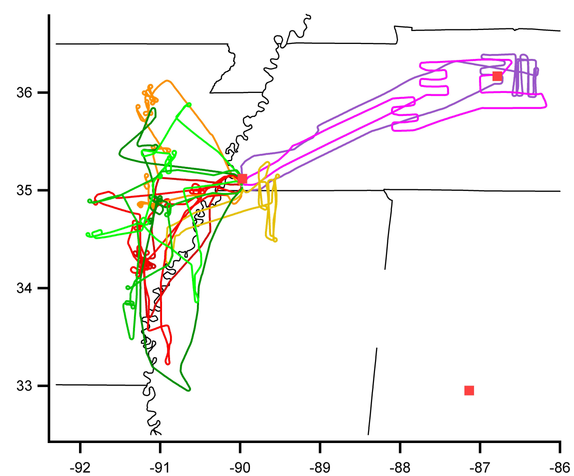
Wildland Fires: Shrub, Forest
Urban: Seattle (3), Portland (2), Spokane (2)
MBO (3)
SEAC4RS: Joint mission Aug., 6

Prescribed Agricultural burns:
rice, soybean, sorghum
Urban: Nashville (2), Memphis (2)

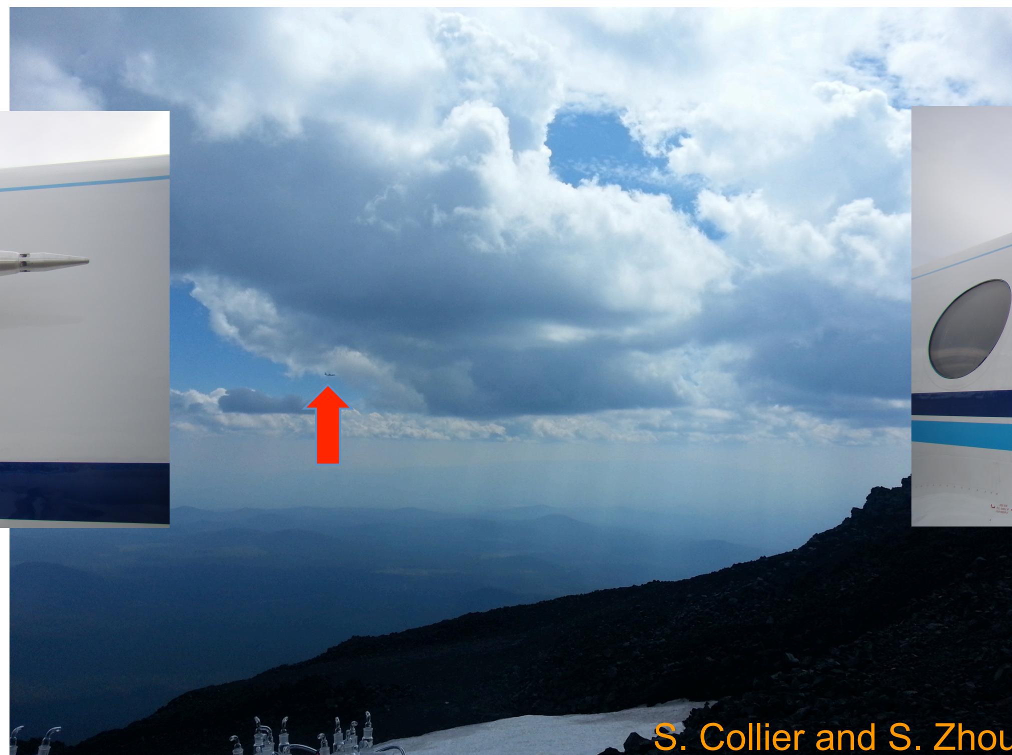


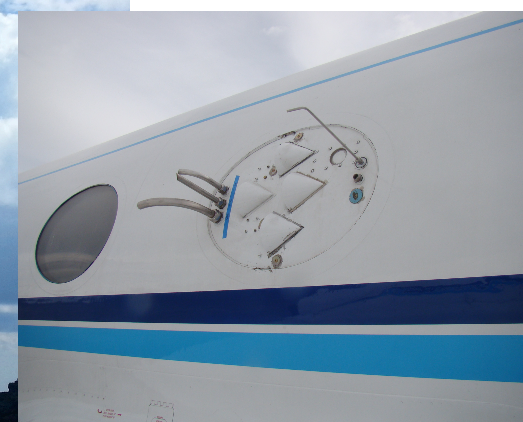
Dan Jaffe, Qi Zhang

B. Yokelson, R. Ferrare, R. Kahn, C. Ichoku



Gulfstream-1 (G-1) Platform





BBOP Instrument Suite

This field campaign will leverage the capabilities of several new instruments or instrument combinations that have not been previously used in aircraft.

Microphysical Properties:

- SP-AMS (chemical composition)
- FIMS (10 – 300 nm @1 Hz)
- Microscopy (TEM)
- SP2 (rBC conc. & mixing state)
- Dual column CCN
- UHSAS/PCSAP
- Particle counter

Trace gas

- PTRMS (VOCs)
- H_2O, CH_4, N_2O, NO, NO_2, NO_y, CO, CO_2, O_3 and SO_2

Optical Properties

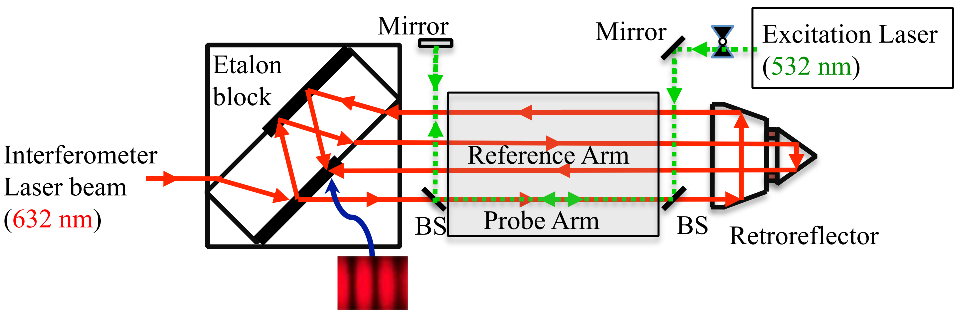
- 3-λ nephelometer (scat; 450, 550, & 700 nm)
- 3-λ PSAP (abs; 461, 523, & 648 nm)
- 1-λ PAS (abs & scat; 355 nm)
- 1-λ PTI (abs; 532 nm)
- 1-λ CAPS (ext; 628 nm)

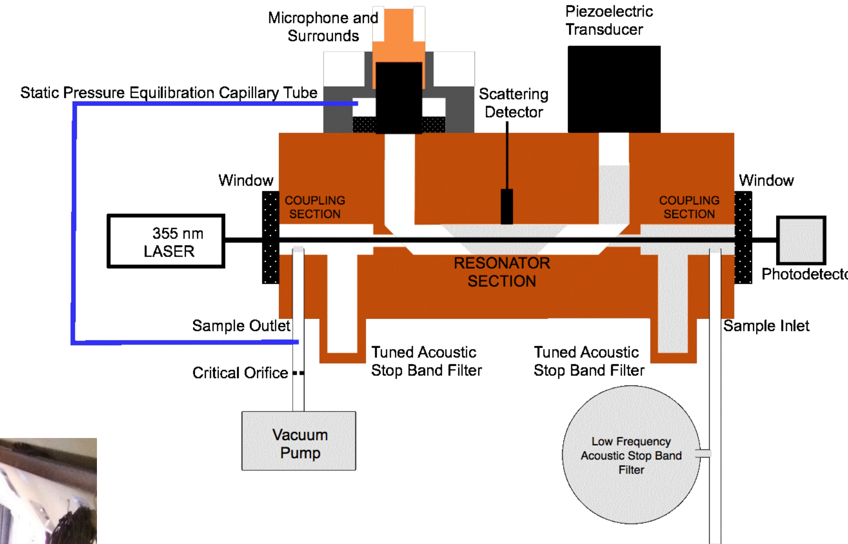
Radiation

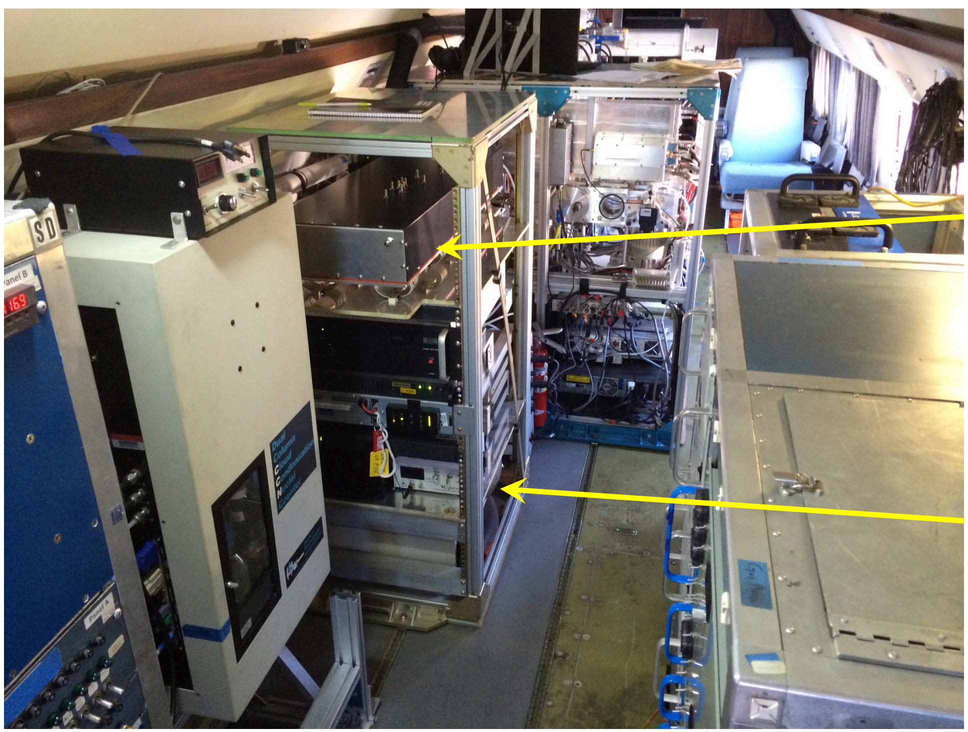
- SW, Upwelling hemispheric, spectral
- SW, Upwelling hemispheric, broadband
- IR. Surface Temperature
- SW, Down-welling hemispheric, broadband, global and diffuse
- SW, Down-welling hemispheric, broadband, diffuse

Maiden Deployments of 355 nm PAS and 2-Generation 532 nm PTI

In situ measurement of aerosol light absorption is expected to important in BB events due to large loadings (scattering) and high OA/BC ratios.





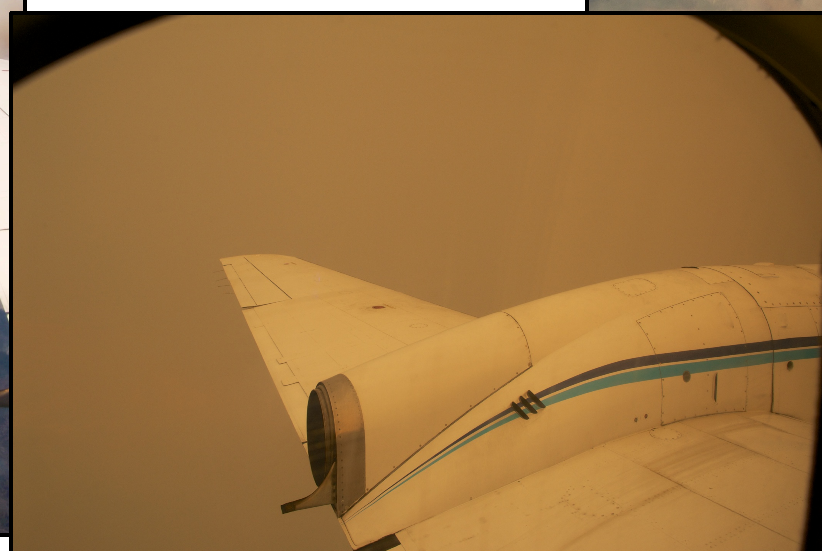


PTI (Sedlacek)

PAS (Arnott)

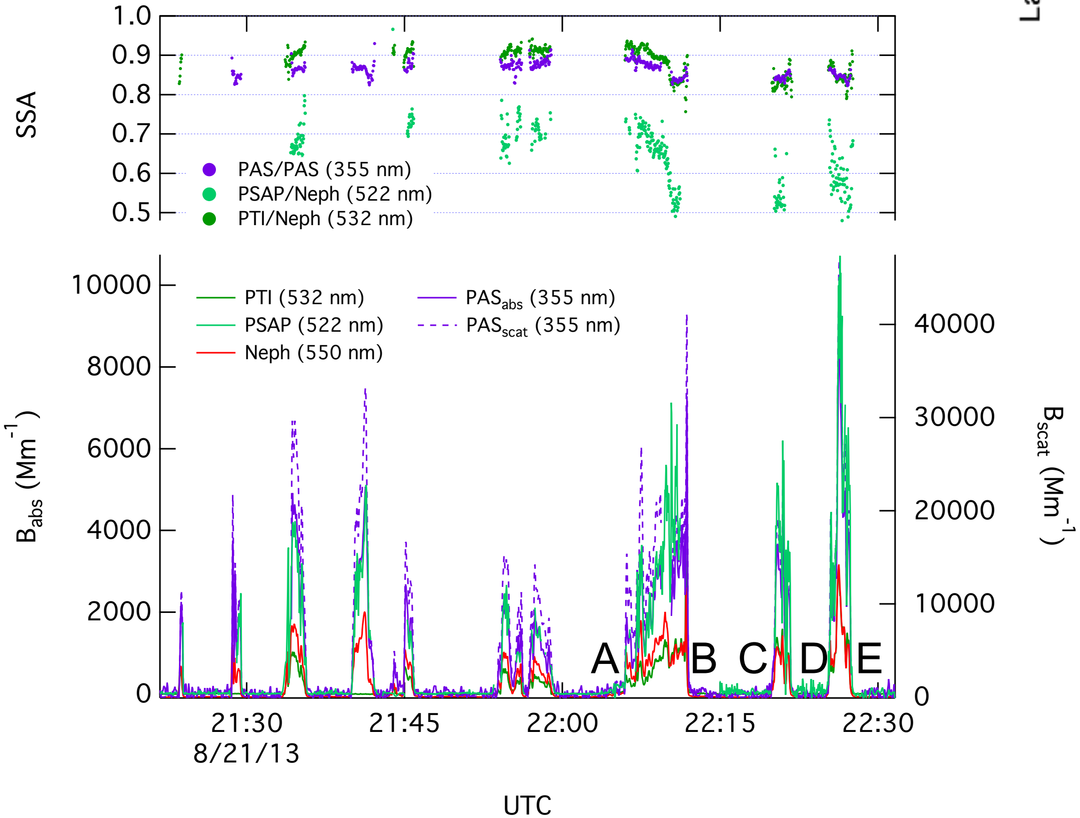
"Government Flats" 0 – 2.5 hour Evolution

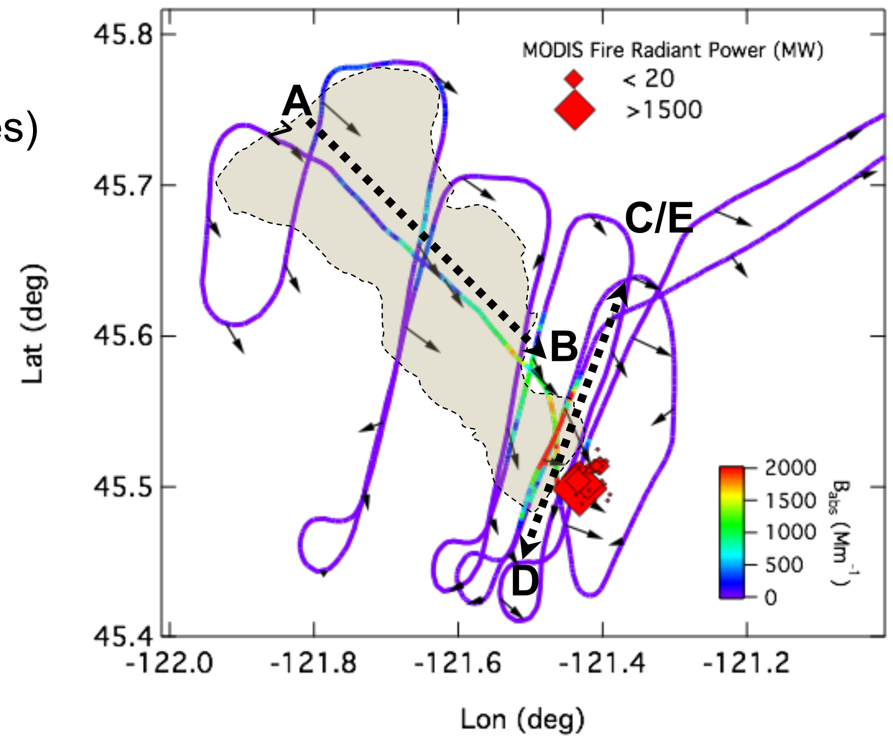
Targeted on 2013-08-21



Government Flats Flight Path

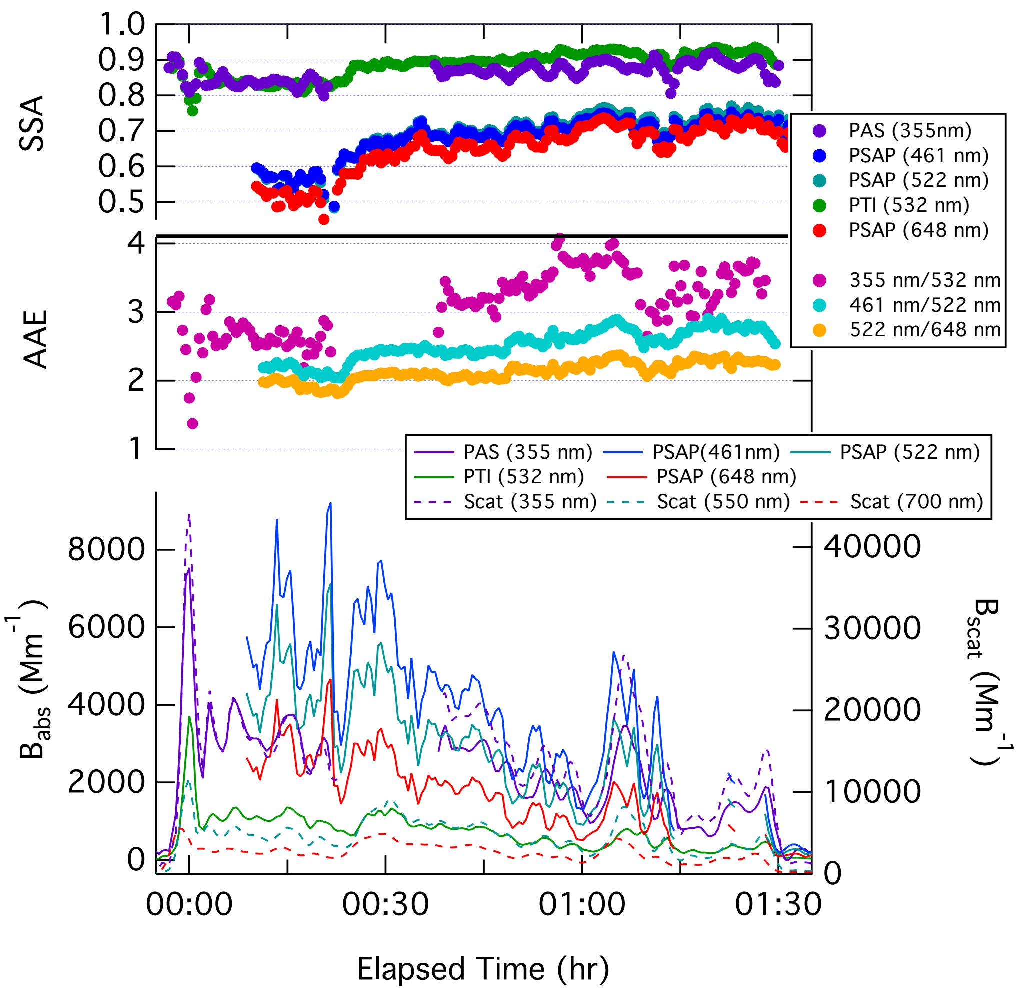
24-hrs fire increased by > 2800 acres (4.4 sq. mi)
Eventually consumed over 11,500 acres (18 sq. miles)
Fuel: softwoods (pine and fir) and grass

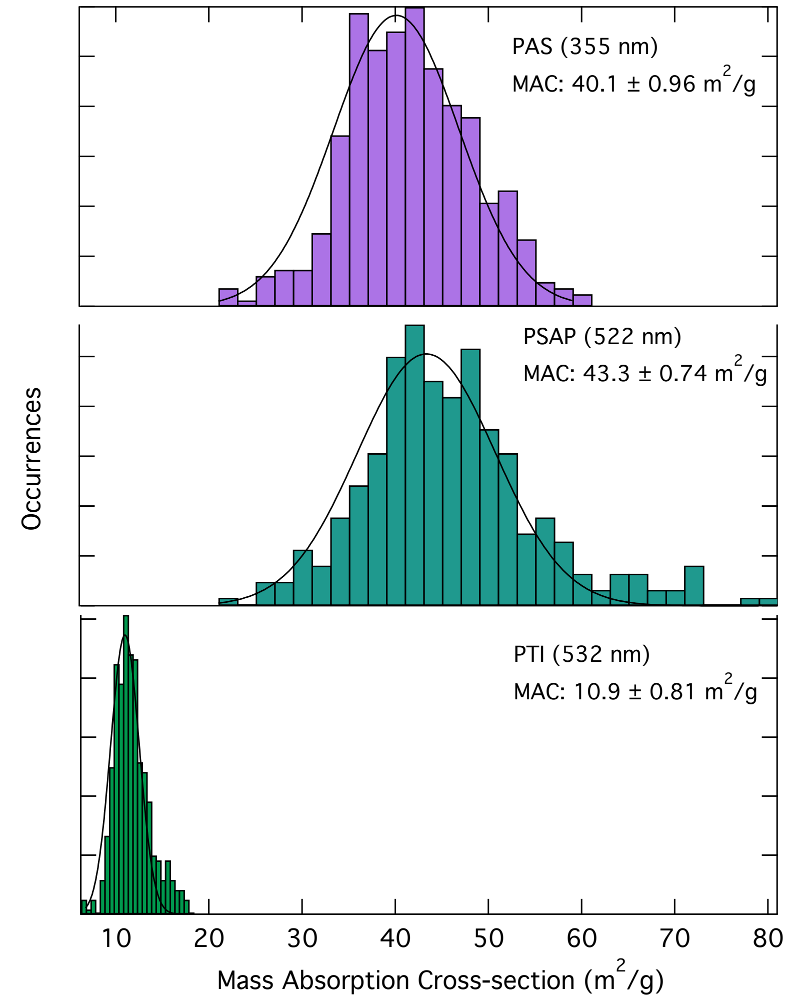




Rapid Evolution of BB Optical Properties

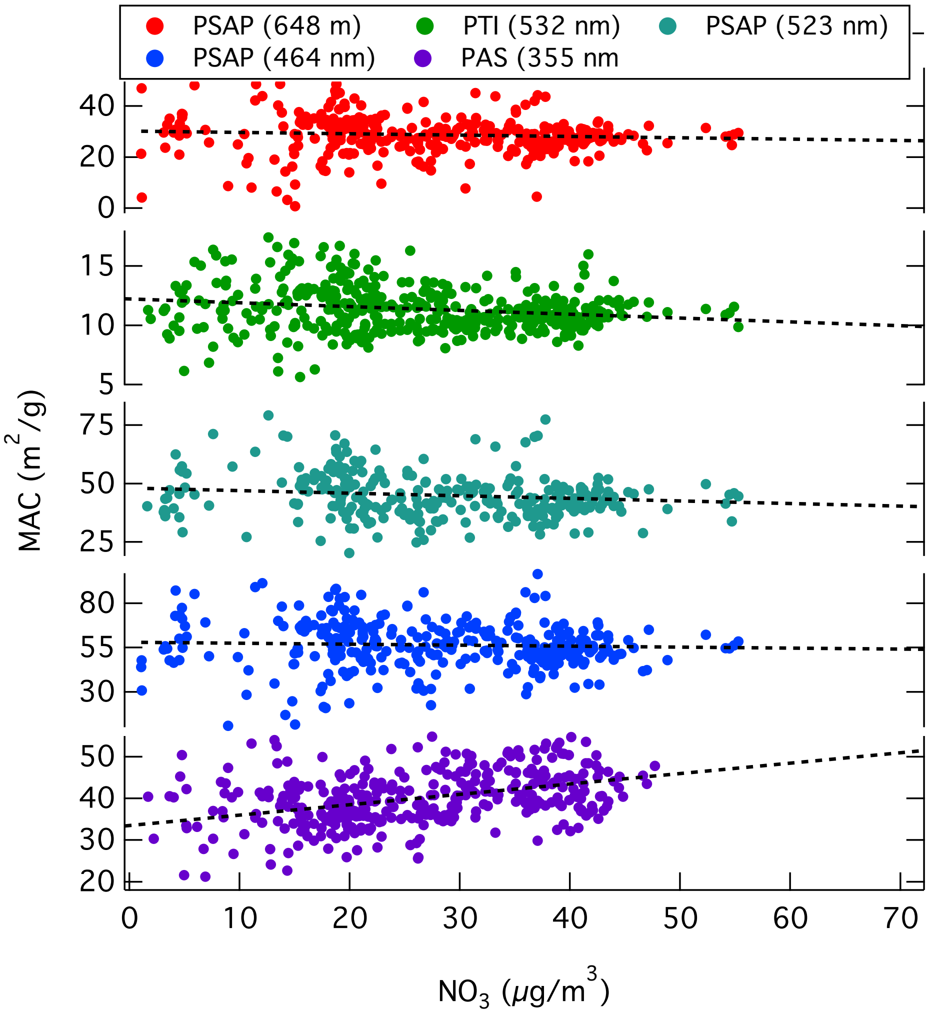
Use wind speed to estimate plume age

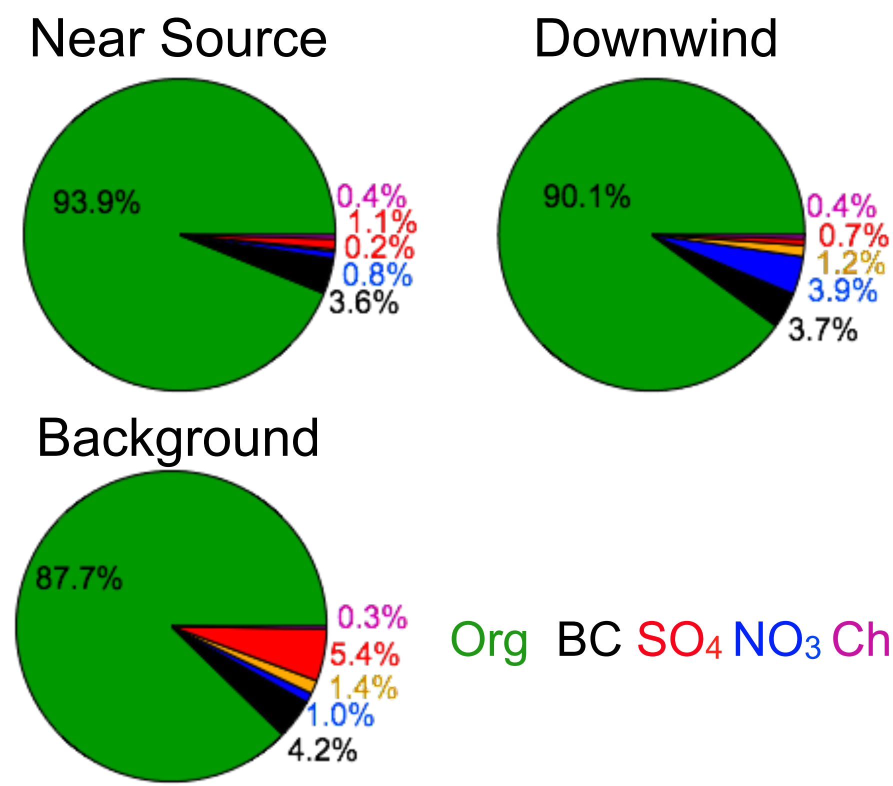




BC mass provided by SP-AMS

Evidence for Brown Carbon (BrC)

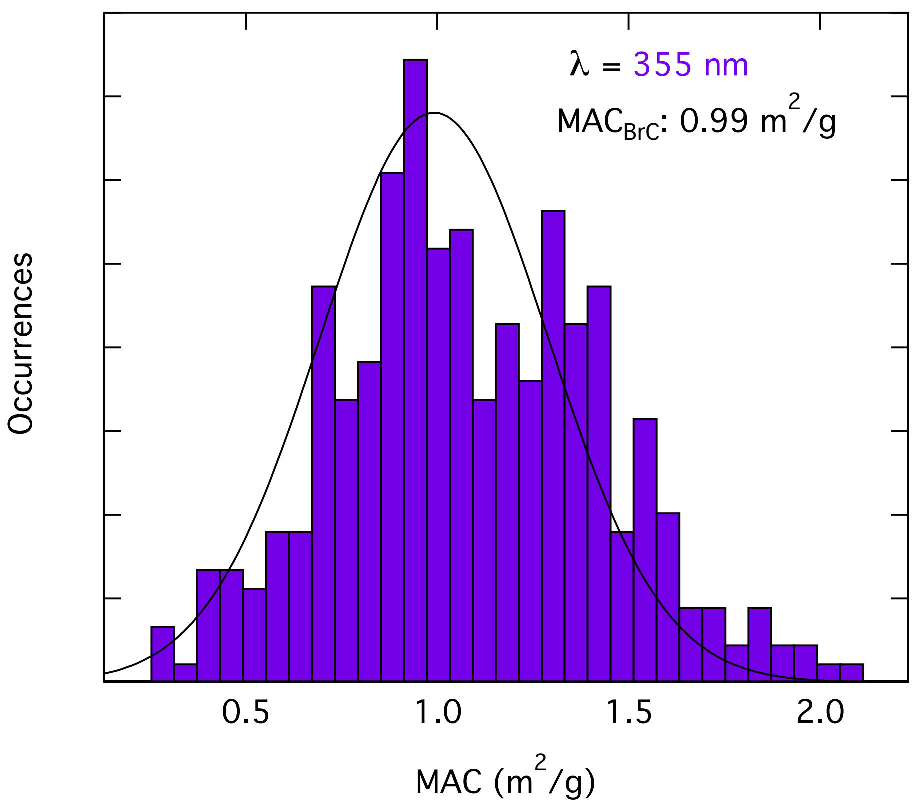


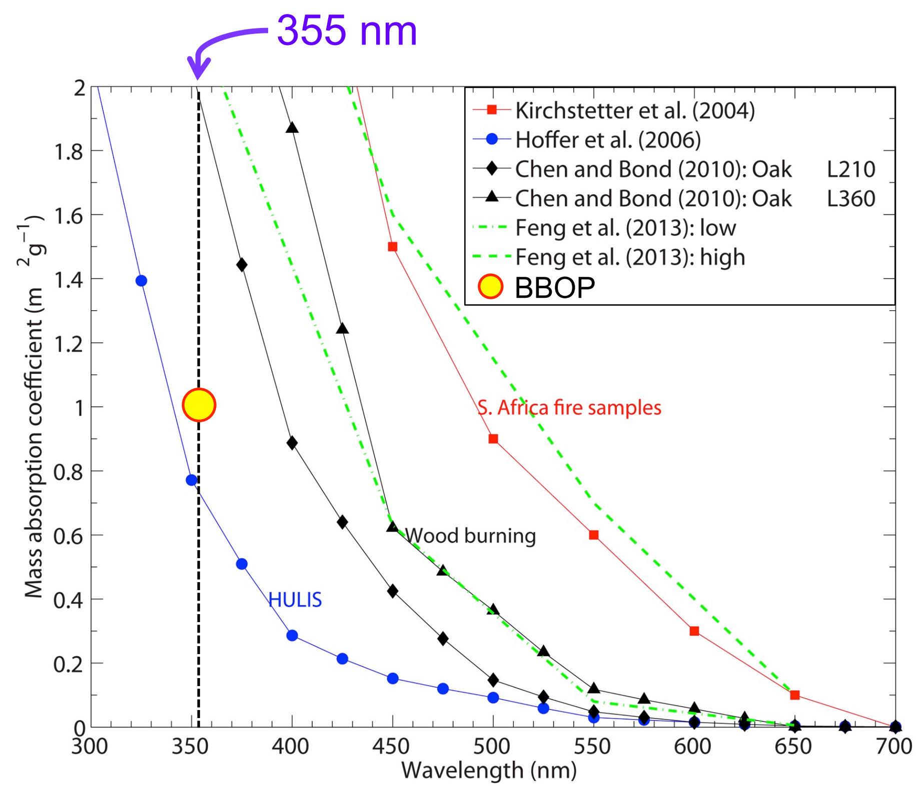


Organic dominates aerosol mass
Nitrate increases with age plume age
UV absorption increases with nitrate

Estimating BrC Mass Absorption Cross-Section (MAC_{BrC})

- Assume negligible BrC absorption at λ = 532 nm
- Use B_{abs} (BC, 532 nm) for estimate of B_{abs} (BC, 355 nm)
- B_{abs} (BrC, 355 nm) = B_{abs} (total, 355 nm) - B_{abs} (BC, 355 nm)
- OA loading from SP-AMS

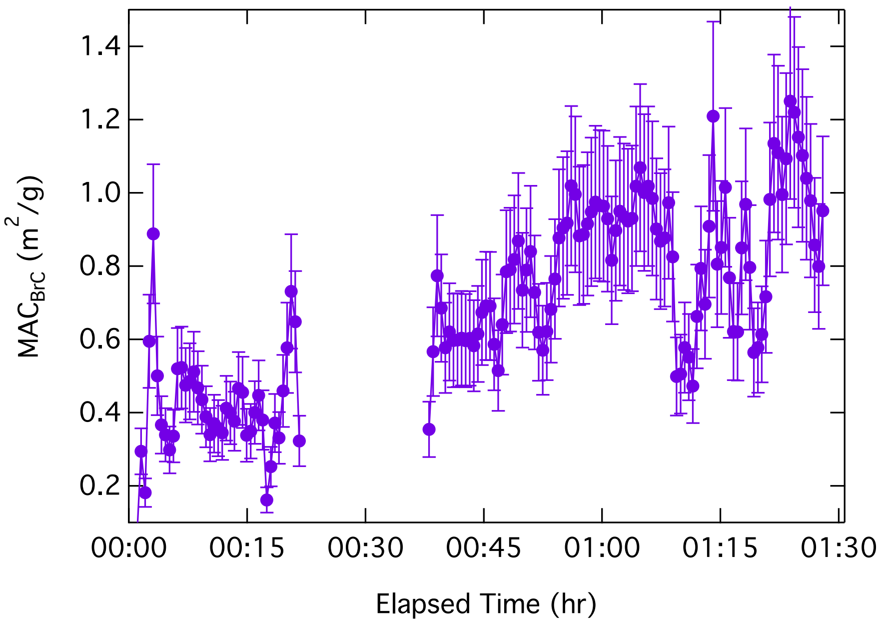


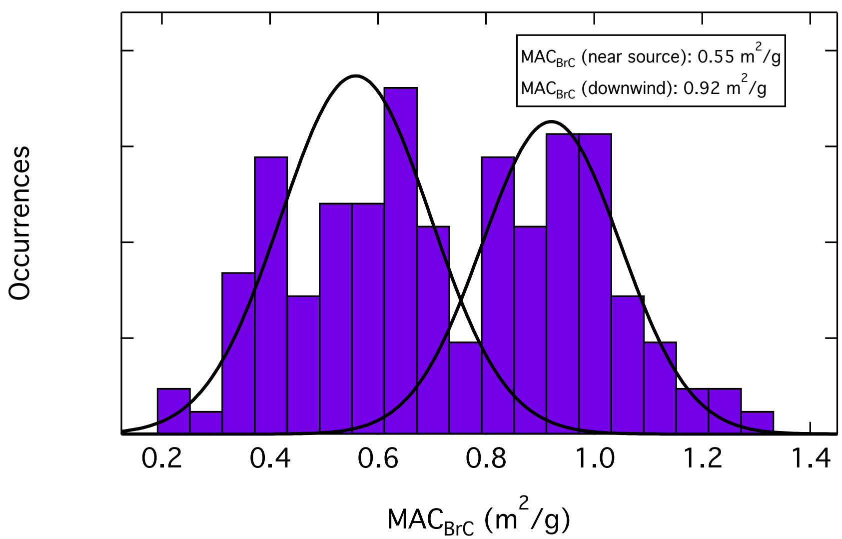


Plot courtesy of Y. Feng (ANL)

Assumes that all ORG contributes to BrC absorption

Does the MAC_{BrC} Evolve?





Examine A→B transect introduced earlier

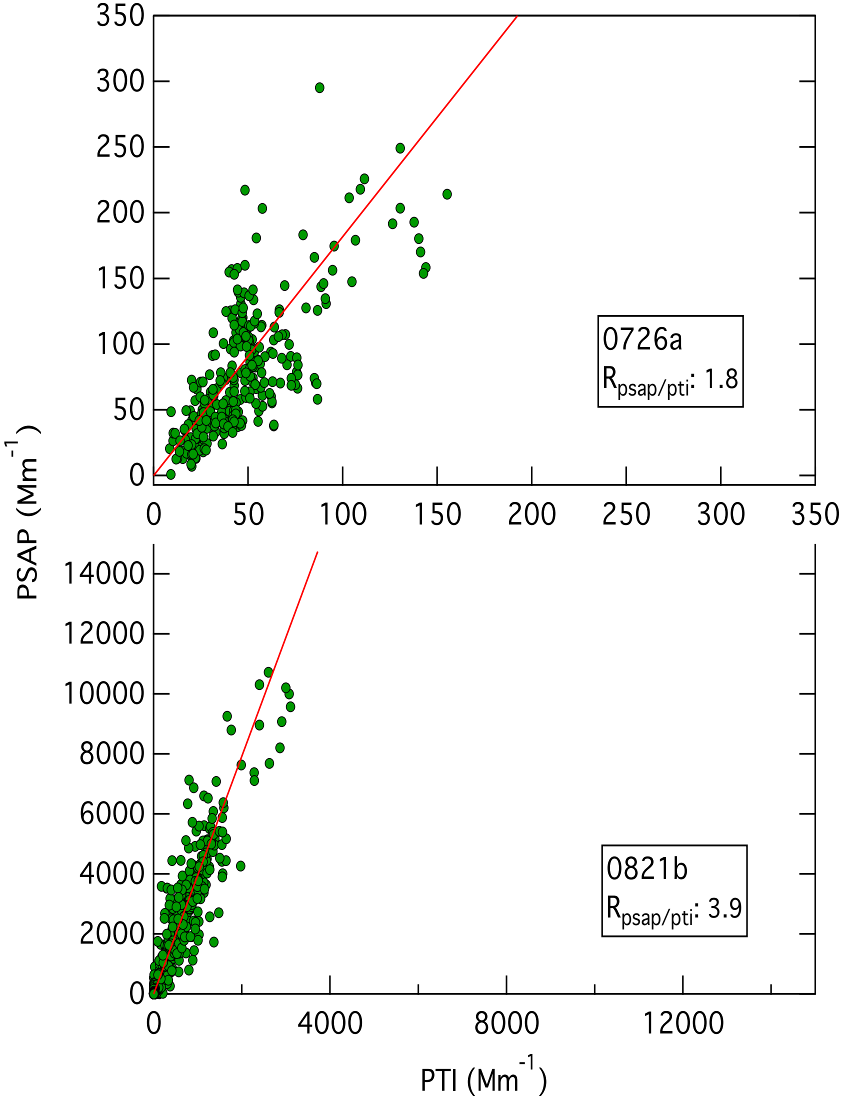
Assumption: All OA is BrC (unlikely)

Preliminary analysis suggests that the MAC_{BrC} increases downwind of the fire

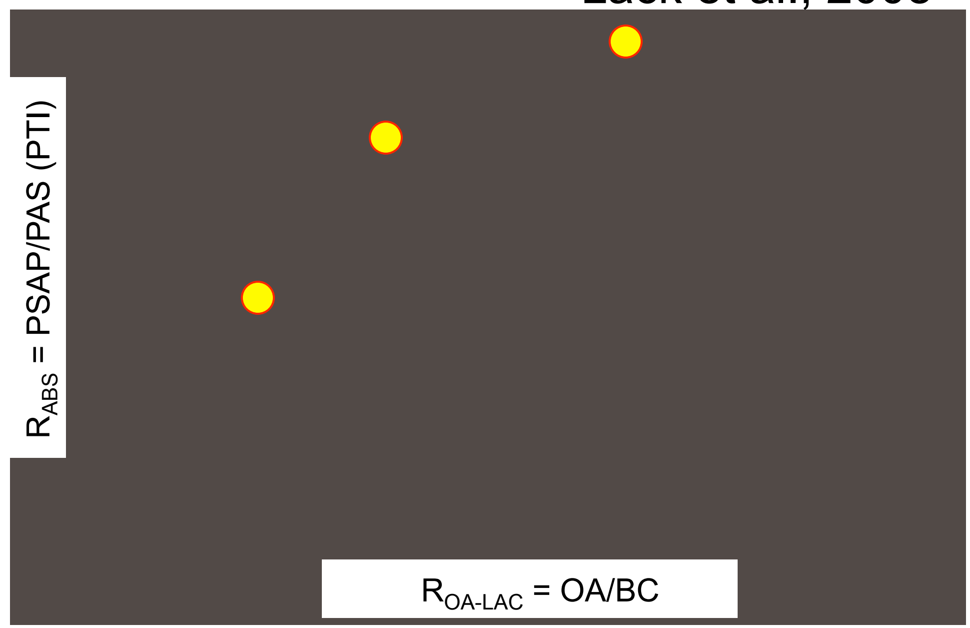
Limiting BrC to oxidized OA -

- Larger MAC_{BrC}
- Suppress change in MAC_{BrC}

Extreme Environment of BB Enhances Bias in PSAP



Lack et al., 2008



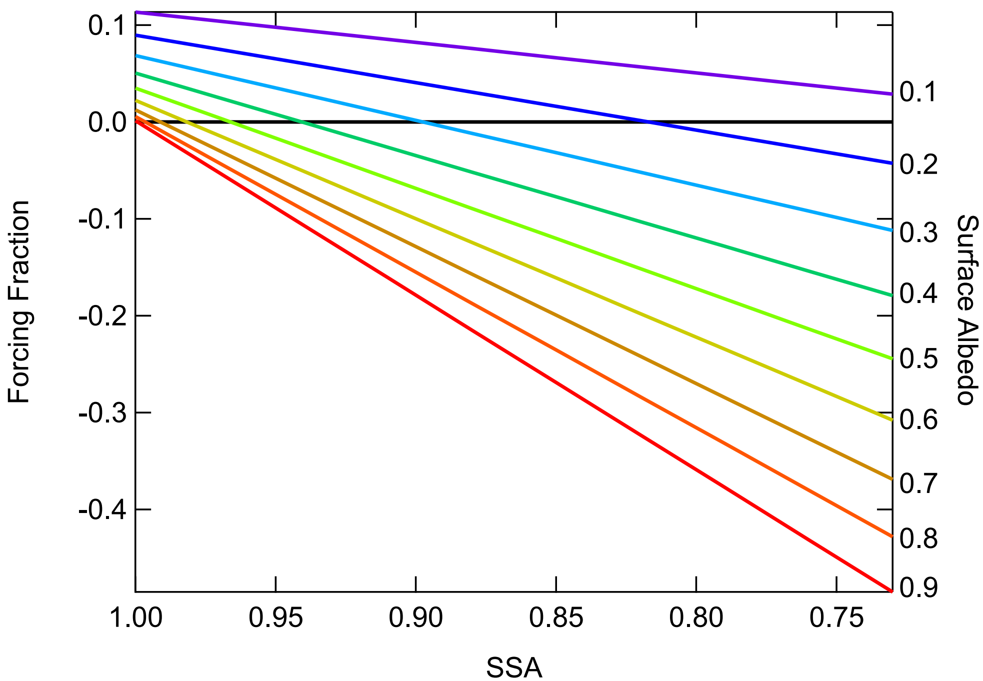
Lack et al.,(2008) dataset does not contain significant sampling of biomass burning aerosol.

How Quickly do BB Aerosols Evolve to Negative Forcers?

Optically-thin limit (Chylek and Wong, 1995)

Forcing Fraction

$$\Delta F \approx \frac{-S_o T^2}{2}(1 - A_c)\tau[2\beta\omega(1-R)^2 - 4R(1-\omega)]$$



S_o: solar flux (ToA)
T: atmospheric transmittance
$(1-A_c)$: albedo in non-cloud covered areas
R: mean surface reflectance
β: mean upscatter fraction (0.14)
τ: extinction optical depth
ω: single scattering albedo

Surface albedo very important on forcing estimate
Pre-burn albedo: 0.15 – 0.4
Burn albedo: ~ 0.05

Smoke aerosols quickly evolve to become negative forcers (< 2 hrs)

Summary

Rapid evolution of BB aerosol optical properties

AAE values suggest presence of brown carbon (BrC)

MAC_{BC} dependence on NO_3 concentration observed at 355 nm only

Estimate of MAC_{BrC} (355 nm): 1 ± 0.04 m^2/g (Assumes all ORG is BrC)

Evolution of MAC_{BrC} in the near field

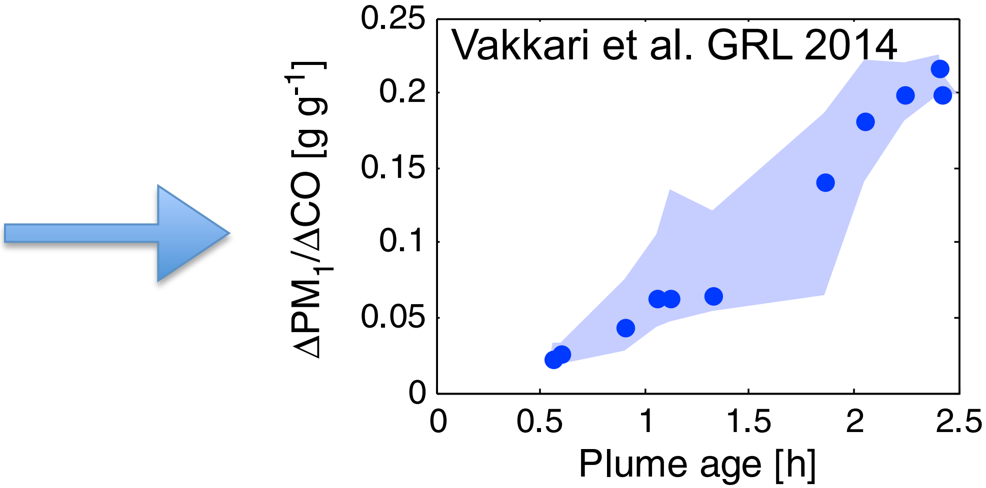
PSAP exhibits measurement bias on OA/BC ratio that consistent with previous study (Lack et al., 2008)

Radiative forcing in the optically-thin limit:

In situ measurements suggest BB quickly become negative forcers

PSAP suggest that this transition takes much longer

Rapid aerosol evolution also observed in independent study



Big Thanks to all that made BBOP a success!

P. Arnott
K. A
P. B
D. C
S. C
J. C
P. D
A. F
J. H
D. J
C. K
E. L
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Backup Slides

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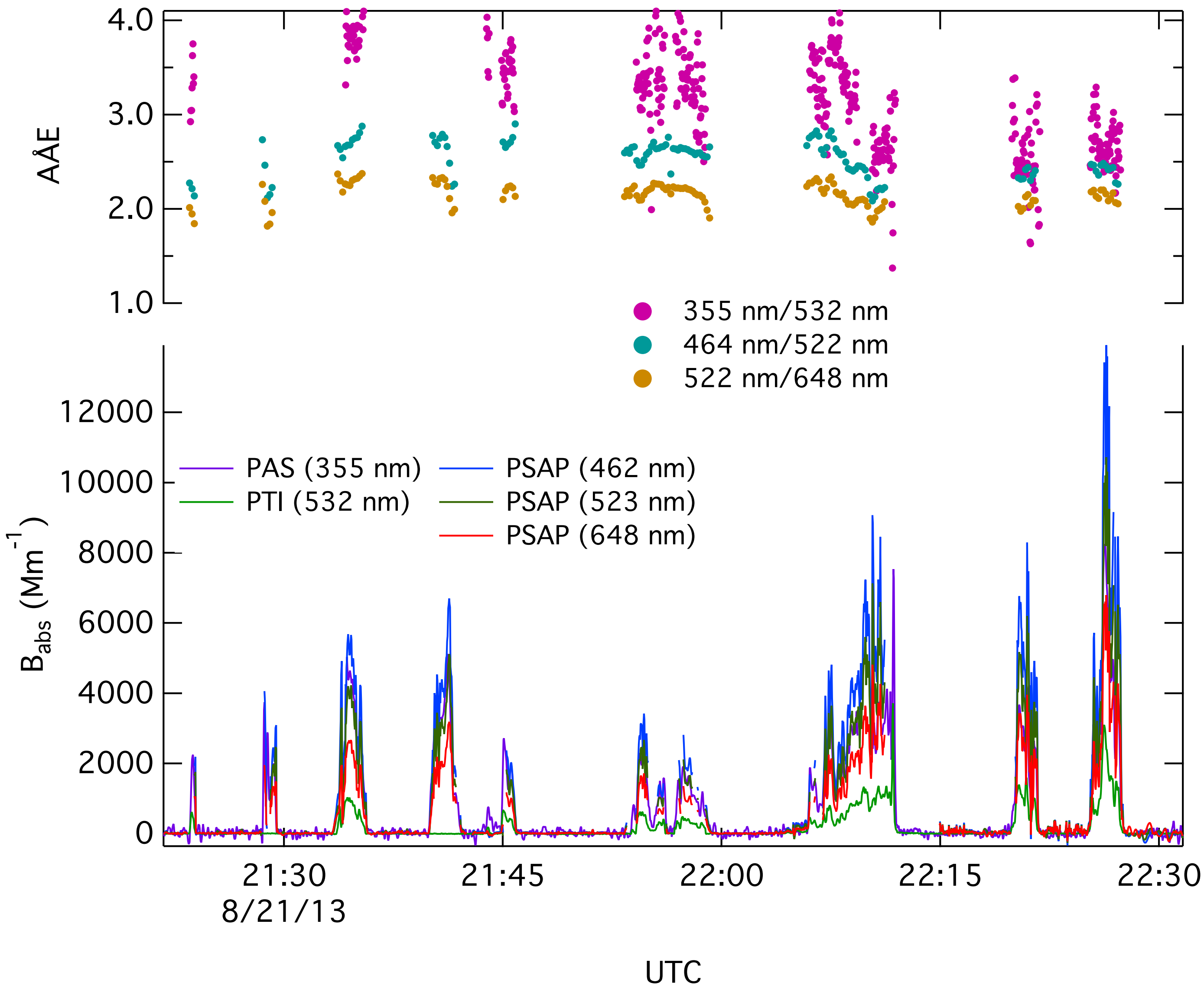

AÅE
4.0
3.0
2.0
1.0
355 nm/532 nm
464 nm/522 nm
522 nm/648 nm
B_abs (Mm^-1)
12000
10000
8000
6000
4000
2000
0
PAS (355 nm)
PTI (532 nm)
PSAP (462 nm)
PSAP (523 nm)
PSAP (648 nm)
21:30
8/21/13
21:45
22:00
22:15
22:30
UTC

Intensive Optical Properties