Aerosol Chemistry and Processing at Mt. Bachelor Summit during the Biomass Burning Observation Project (BBOP): Influences from Wildfire Plumes

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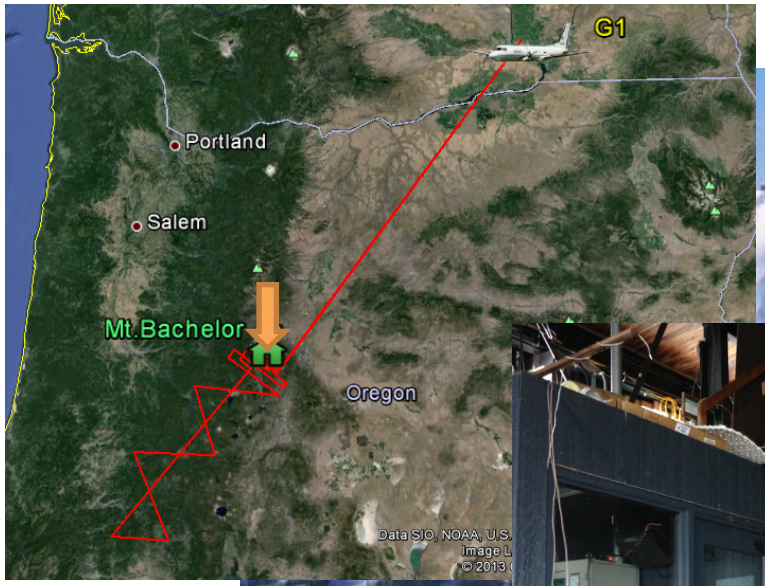
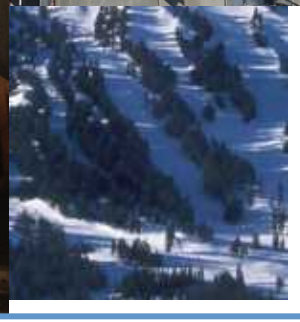
ASR Atmospheric System Research

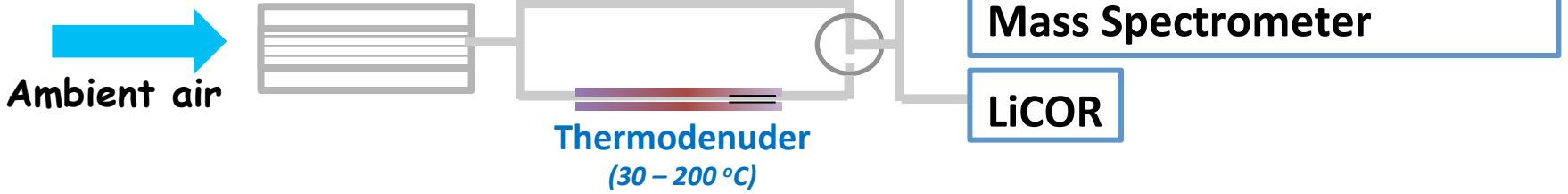
Mt. Bachelor Observatory (MBO), Oregon, 2.7 km a.s.l.

- The only high elevation/free trop. research site in western U.S.
- Continuous observations of CO, O_3, aerosols and Hg since 2004;
- Frequent detection of Asian pollution and biomass burning plumes;
- In summer 2013 added a High-Resolution Aerosol Mass Spectrometer

Mt. Bachelor Observatory (MBO), Oregon, 2.7 km a.s.l.







- Aerosol light extinction, EC/OC, BC
- O_3, CO, CO_2, NO_x, NO_y, VOCs, PAN
- Meteorological data
- Mercury …

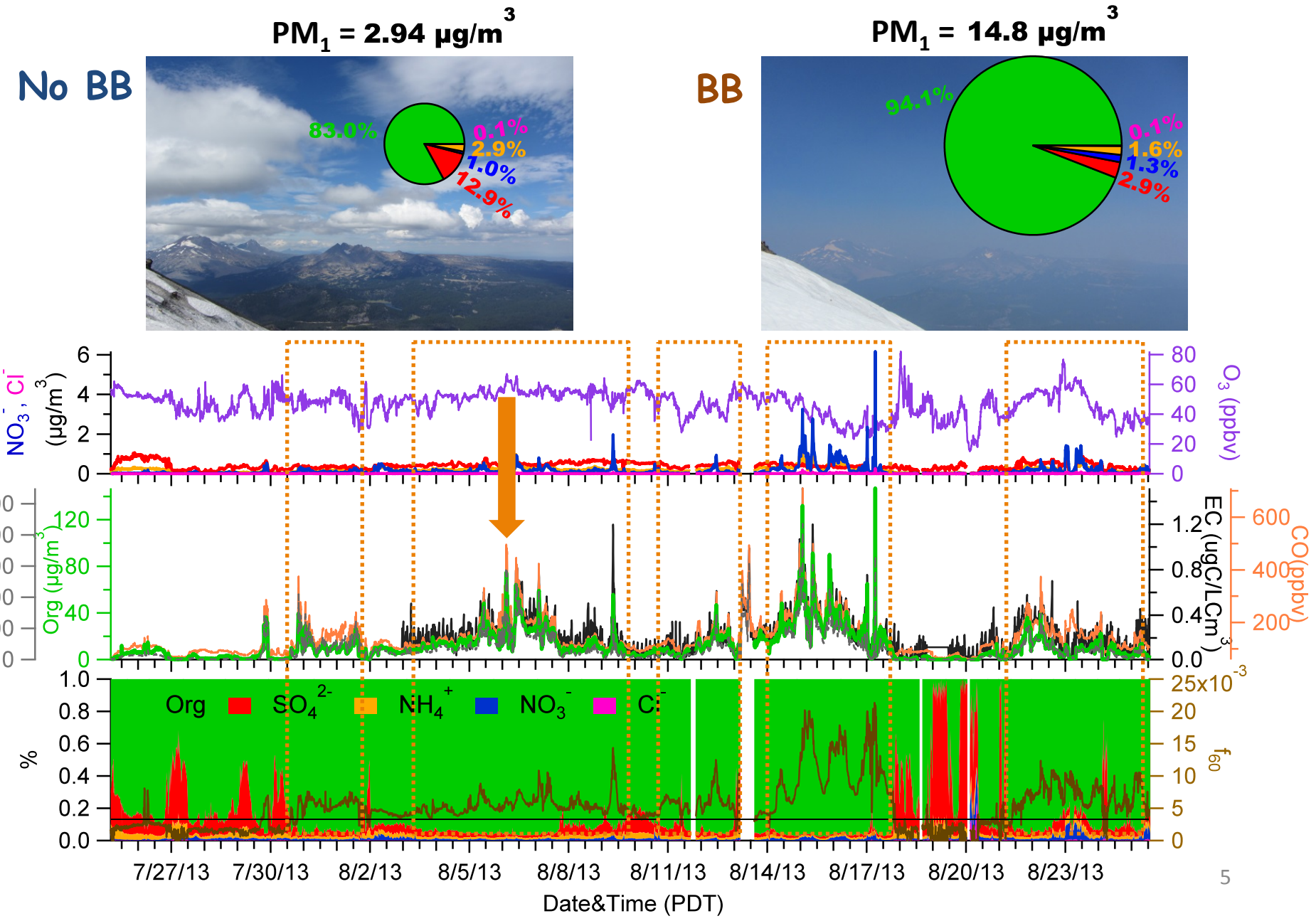
Past Studies on Fires, PM and O_3

View from Mt. Bachelor of the Sisters fire on 9/19/2012. Up to 9 ppmv and 1000 µg/m^3 PM_1 seen at MBO.

- **MBO is an ideal location to study wildfire plumes due to frequent fires in the PNW and N. Calif.**
- **9 publications with MBO data on the relationships between PM, O_3 and a variety of wildfire tracers;**
- **Large uncertainties remain about primary and secondary aerosol production, ozone production and radiative effects of smoke plumes.**

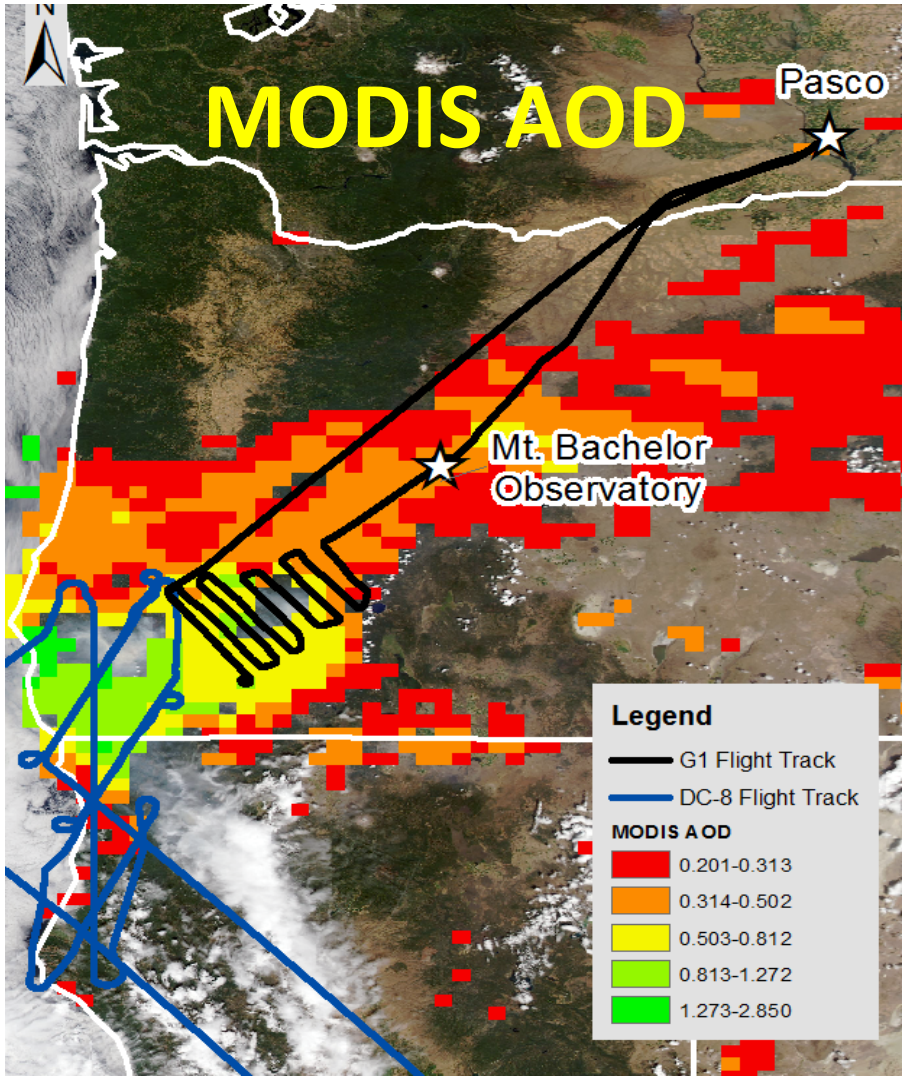
Past work by Jaffe's group has demonstrated large variability in emissions and chemistry from fire to fire. Why? What are the controlling factors?

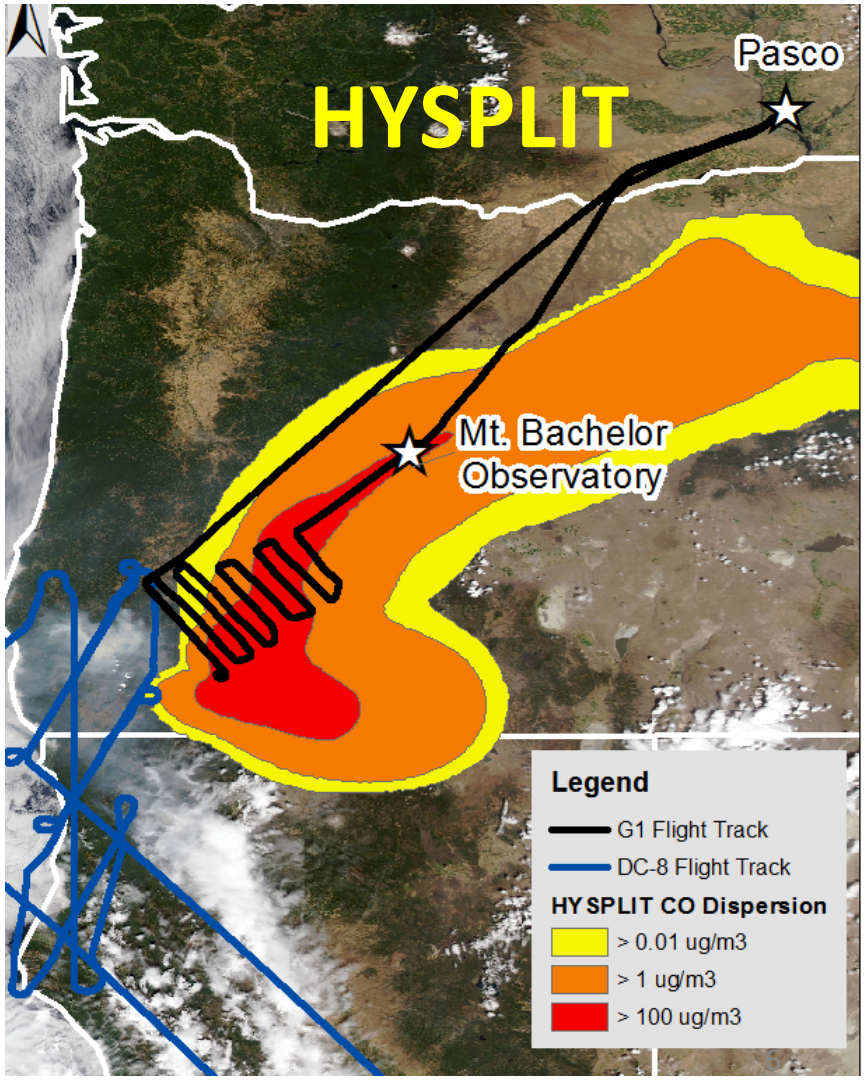
Aerosol Temporal Variations: 7/15 – 8/25, 2013



Whiskey Complex Fire, Aug. 6, 2013

Overlay of G1 and DC8 flight tracks, with MODIS AOD (left) and HYSPLIT Dispersion model (right)





Modified Combustion Efficiency (MCE)

$$\frac{\Delta CO_2}{\Delta CO + \Delta CO_2}$$

Smoldering combustion:
CO, CH4, OVOC, OC, etc.

Flaming combustion:
NO, CO2, EC, etc.

smoldering
MCE ~ 0.80

wildland fires vary along spectrum over time

flaming
MCE ~ 1.00

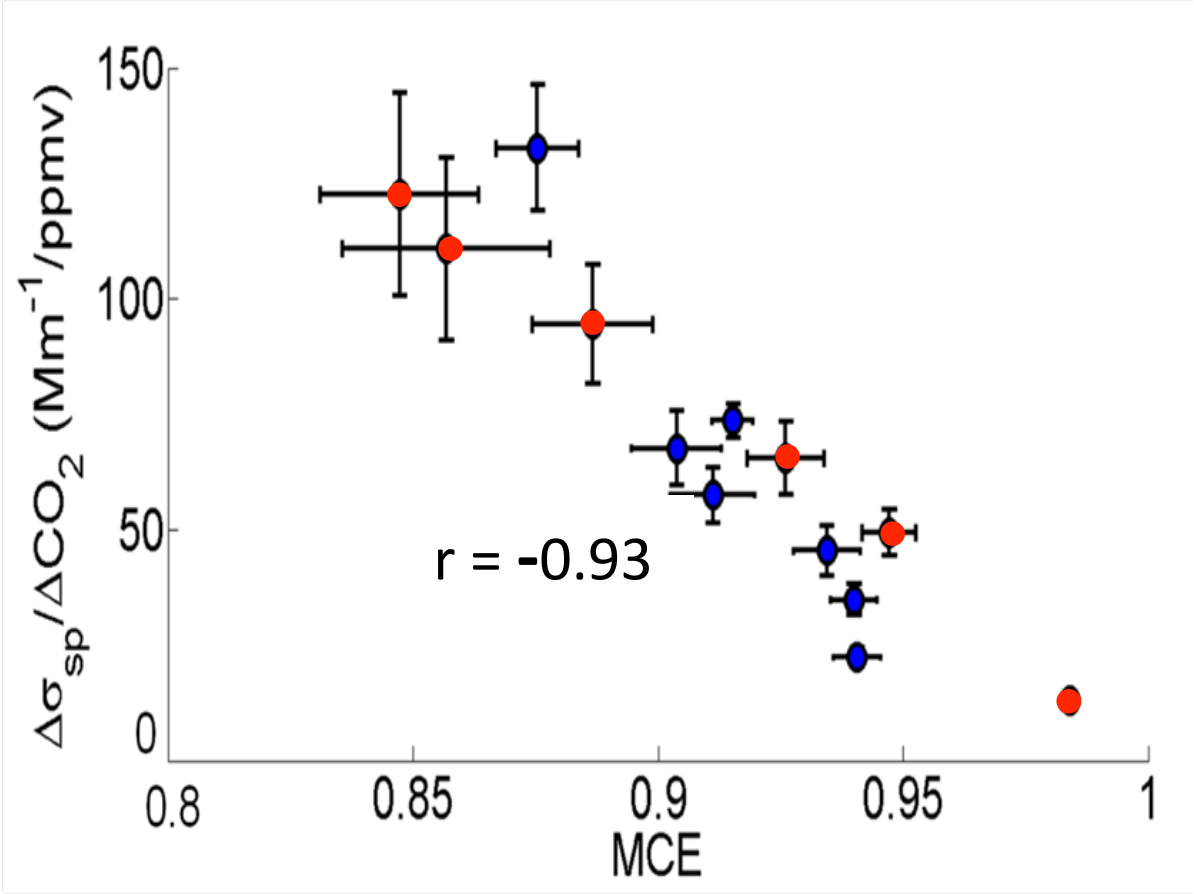
Plume Identification & MCE Calculation

Method (Wigder, Jaffe et al.):

- Significant enhancement in CO and aerosol scattering (σ_{sp})
- R^2 of CO/CO_2 > =0.85
- Distinct plume in CO and CO_2 that begins and ends at approximately the same concentration (to minimize impact of change in background)
- Fire source identified using satellite imagery and model
- calculate transport time using HYSPLIT trajectories

Plume #	Plume Period (PDT)	Duration (hr)	MCE	Suggested Origin	Approx. Transport hrs
18	2013/8/05 09:50 – 11:10	1.3	0.93	SW OR & NW CA	14-34
19	2013/8/13 05:20 – 09:40	4.3	0.95	N CA	24-30
20	2013/8/13 09:40 – 12:00	2.3	0.85	N CA	24-30
21	2013/8/15 00:20 – 02:35	2.3	0.89	N CA	10-12
22	2013/8/15 05:00 – 07:05	2.1	0.86	N CA	10-12
23	2013/8/21 17:30 – 22:30	5.0	0.98	SW OR & NW CA	25-45

Influence of Modified Combustion Efficiency (MCE) on Pollutant Enhancements in Wildland Fire Plumes (Wigder, Jaffe et al., in prep.)



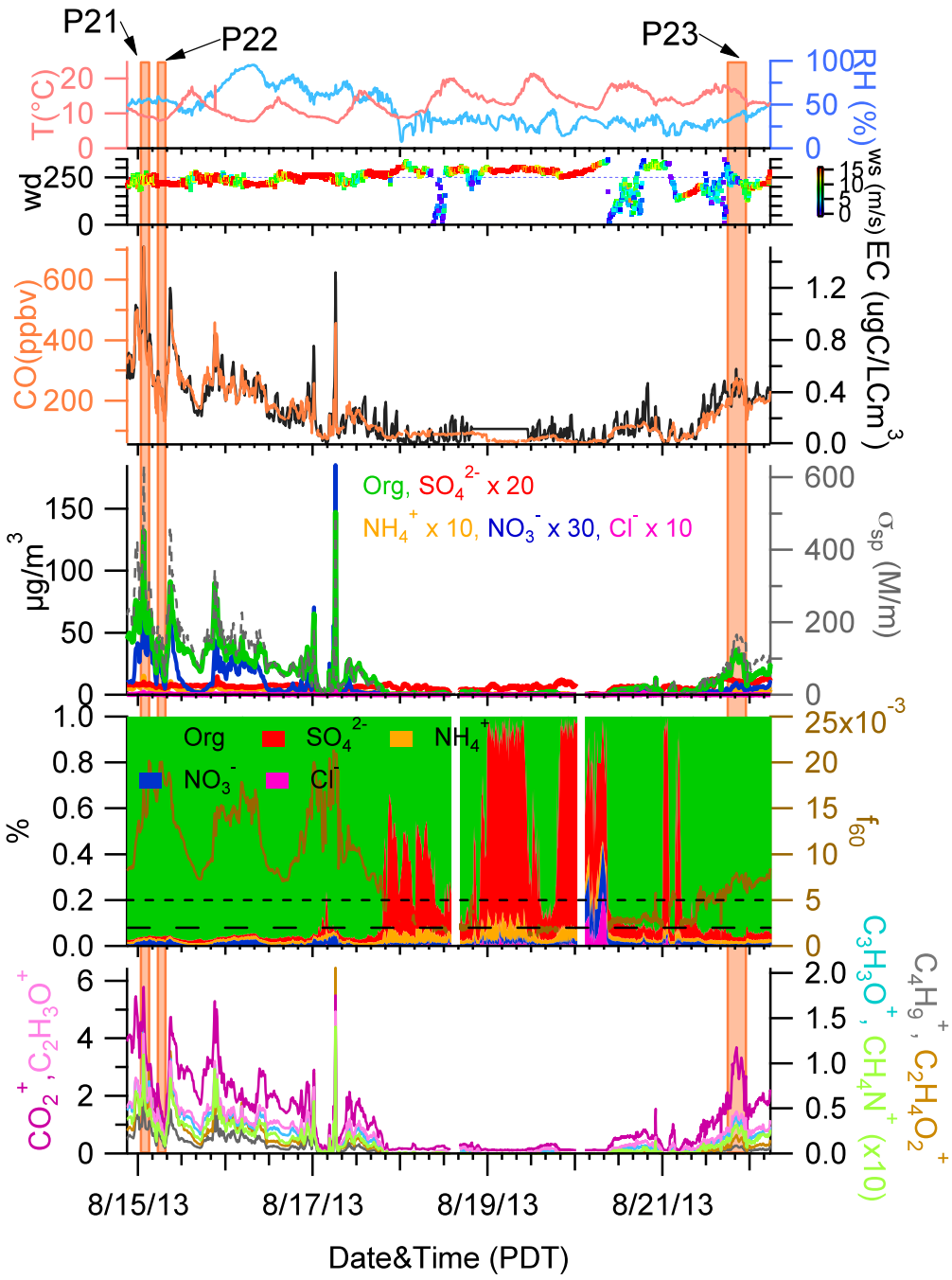
Low MCE: more smoldering combustion

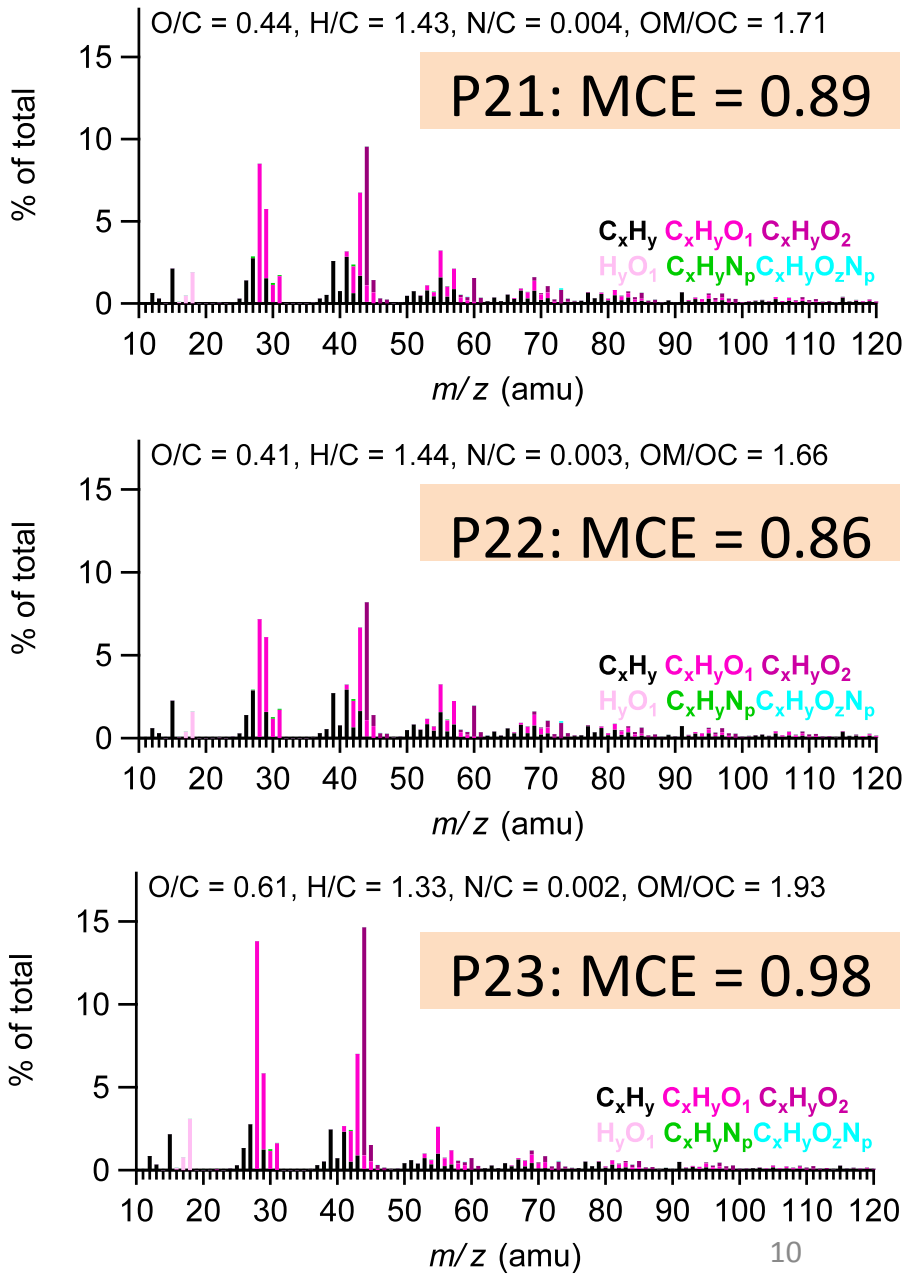
High MCE: more flaming combustion

Aged fire plumes (1-2 days) at MBO from 2012-2013 shows negative correlation between aerosol scattering enhancement ratio ($\Delta\sigma_{sp}/\Delta CO_2$) and MCE due to:

1) Greater primary emissions of aerosols at low MCE
2) Greater SOA formation at low MCE due to greater emissions of oxygenated VOCs

Influence of MCE on Aerosol Chemistry

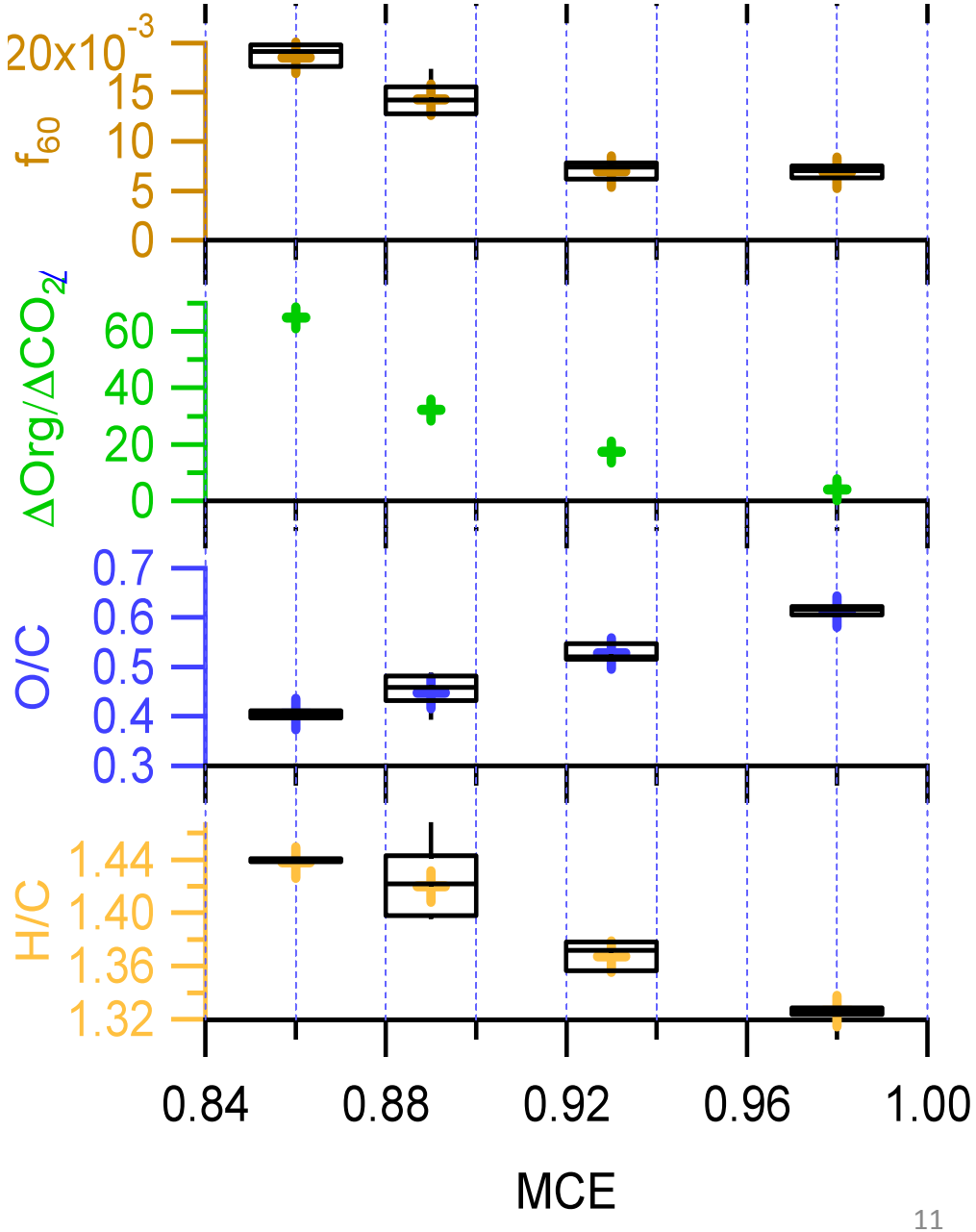




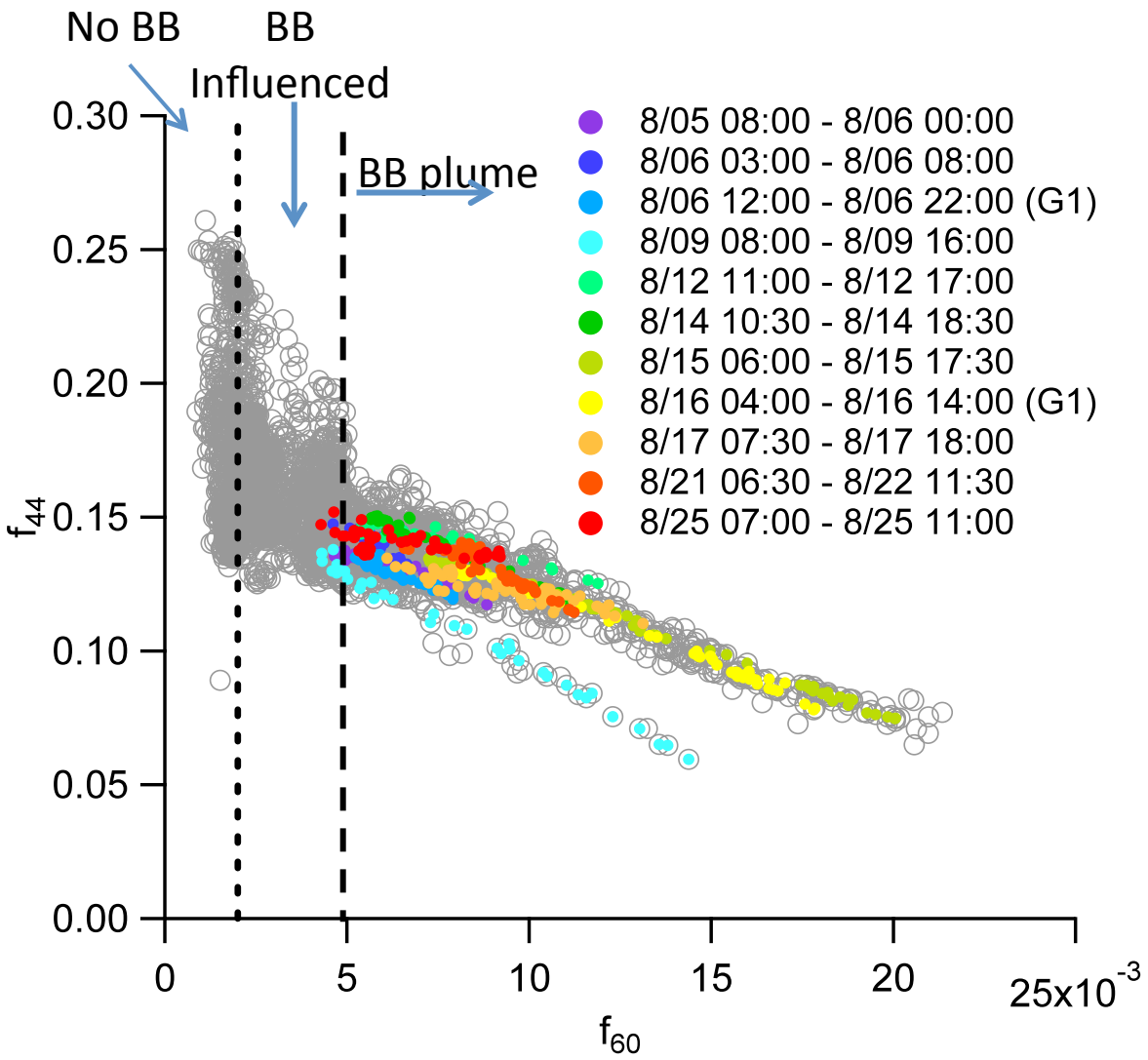
Influence of MCE on Aerosol Chemistry

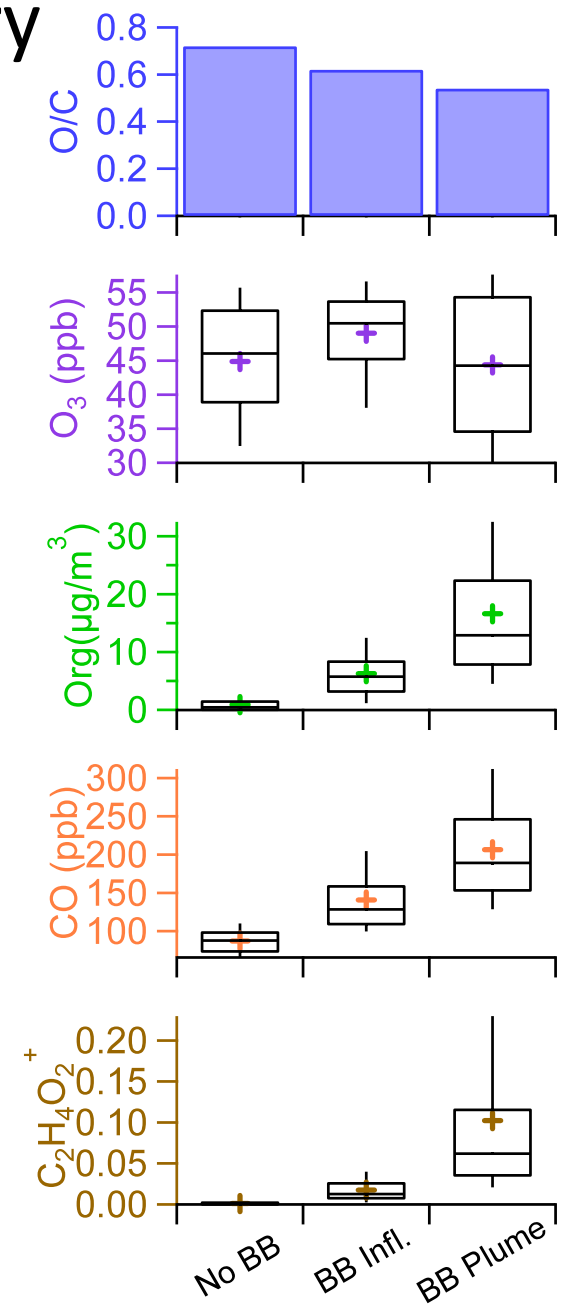
$C_2H_4O_2^+$ (*m/z* = 60) is an AMS tracer ion for BBOA

$$f_{60} = \frac{\text{Signal}_{m/z=60}}{\text{overall OA mass}}$$

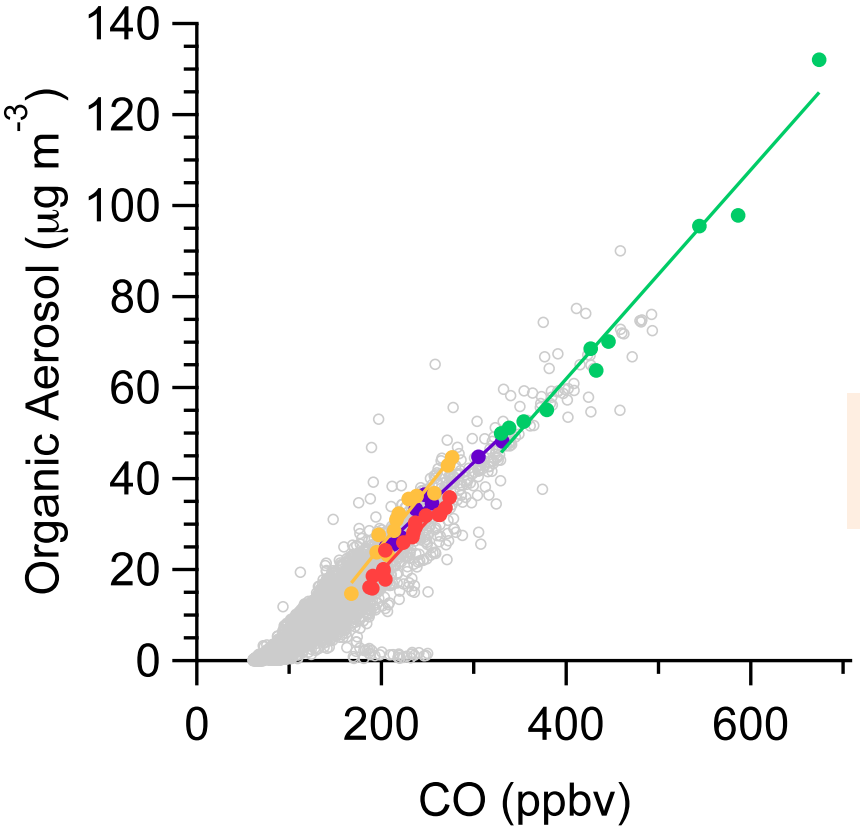


Influence of BB on Aerosol Chemistry



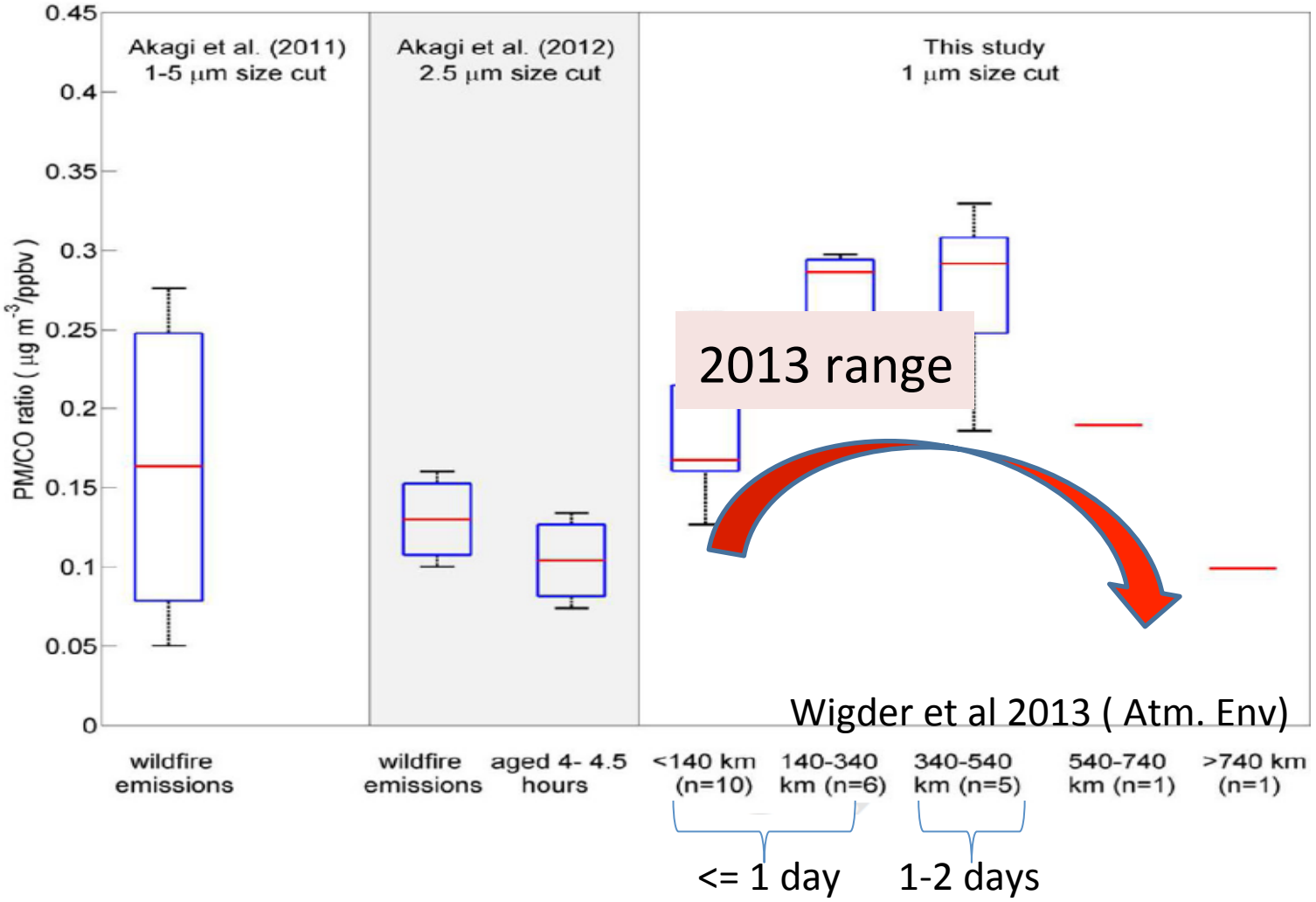


PM enhancement ($\Delta PM_1/\Delta CO$) in BB Plumes



	ΔOrg/ΔCO (μg m^{-3} ppb^{-1})	Transport time (hr)	MCE
P18	0.19	14 - 34	0.93
P21	0.23	10 - 12	0.89
P22	0.25	10 - 12	0.86
P23	0.22	25 - 45	0.98
Fresh plume (G1)	~ 0.17		

PM enhancement ($\Delta PM_1/\Delta CO$)

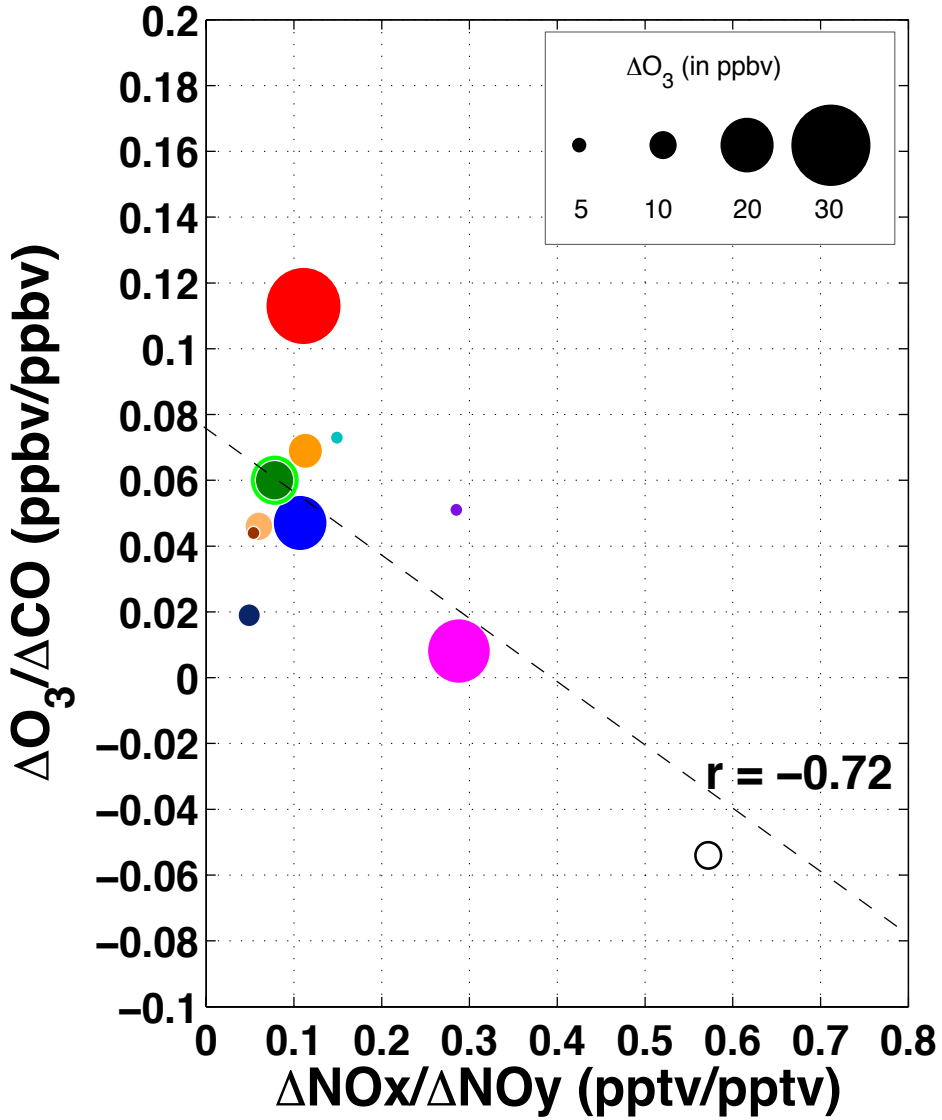


- 32 fire plumes observed in 2004-2011
- $\Delta PM_1/\Delta CO$ ratio varied from 0.06-0.42 $\mu g/m^3$ ppb^{-1}
- Initial emissions → Near-field → More distant transport

Conclusions

- Wild fire plumes were frequently observe at Mt. Bachelor summit
- Wild fire plumes characteristics
  - > 90% of PM is organic
  - Variable MCE
  - MCE correlates well with $\Delta PM/\Delta CO_2$, O/C
- Significant ↑of $\Delta PM/\Delta CO$ 1-2 days downwind compared to at sources → indicating SOA formation .

Ozone enhancement in wildfire plumes at the Mount Bachelor Observatory: Role of NOx (Baylon, Jaffe et al., in preparation)



- Analysis of more than 20 fire plumes at MBO in 2012-2013.
- Negative correlation between $\Delta O_3/\Delta CO$ and $\Delta NOx/\Delta NOy$ enh. ratios. This shows that degree of oxidation is a primary determinant of O_3 production.
- Size of markers proportional to absolute ozone enh. (ΔO_3). This shows that even if $\Delta O_3/\Delta CO$ is low, ΔO_3 may still be significant if CO enhancement is large.