Adventures with CO_2 at the Mt. Bachelor Observatory

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Mt. Bachelor, Oregon, (MBO) 2.8 km asl

- ❖ **The only high elevation/free trop research site on west coast of U.S.**
- ❖ **Continuous observations of CO, O_3 and aerosols since 2004;**
- ❖ **Frequent detection of Asian pollution and biomass burning plumes;**
- ❖ **More than 40 papers since 2004 on O_3, PM. Hg, LRT, wildfires, etc.**
- ❖ **Key goal: Identify importance of background sources on US air quality.**

National Science Foundation
WHERE DISCOVERIES BEGIN

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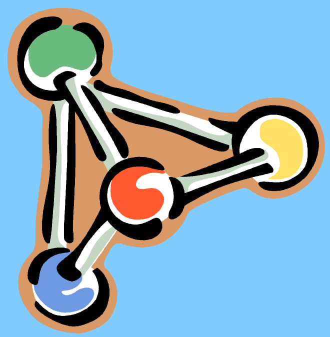
Chemical measurements at MBO



Continuous (most since 2004):

- CO and CO_2 Cavity Ring Down Spectroscopy
- O_3: UV spectroscopy
- Aerosol scattering (continuous PM1, PM2.5)
- Aerosol absorption (climate relevance)

Campaigns:

- NOx/NOy: Chemiluminescence spectroscopy
- Peroxyacetyl nitrate (PAN): Gas chromatography, CIMS
- Mercury (Hg): Cold vapor atomic fluorescence (CVAFS)
- Hydrocarbons: Gas chromatography/mass spec.
- Acids (H_2SO_4, HNO_3): Ion chromatography, CIMS
- Aerosol chemistry: X-ray fluorescence, AMS (Zhang UCD)
- Aerosol size distribution (UFPs)

Multiple measurements are essential to understand the sources and chemical processing!

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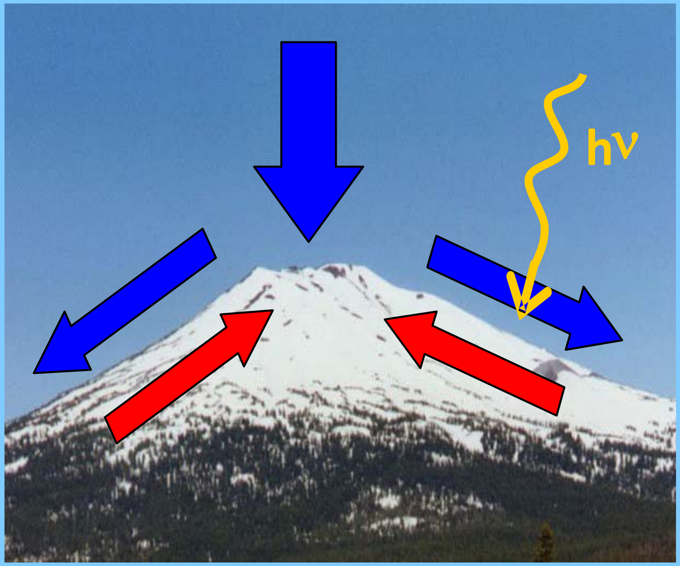
Diurnal circulation pattern at Mt. Bachelor



Day: upslope flow brings modified BL air to summit. This air is more humid and usually low in O_3.

Night: downslope flows brings Free Tropospheric (FT) air to the summit. This air is dry and usually high in O_3.

ID of Free Tropospheric Air

- **Time of day.**
- **Water vapor mixing ratio**
- **Chairlift soundings, observations of NOx (Weiss 2006, 2007; Fischer 2009; 2010; Reidmiller 2011)**

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Collaboration with NOAA-GMD

- **Prior to 2012 CO measurements with a Thermo 48CTL;**
- **Starting in April 2012, we installed a CRDS from Picarro for higher precision CO, CO_2 and WV.**
- **NOAA (Kofler) has provided invaluable support for maintenance and calibration of the Picarro.**
- **GMD flask samples started in October 2011, now doing <u>daily</u> samples at 12Z, which is most likely time for free trop air.**
- **Picarro calibrations performed every 8 hours using three different NOAA-GMD calibration gas standards.**

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CO_2 Goals

- **Characterize the boundary layer and free tropospheric distribution**
- **Use CO_2 as tracer of atmospheric processes;**
- **Use CO_2 with other tracers (e.g. CO) to gauge combustion efficiency and source type.**
- **Use the MBO data to constrain continental inflow of CO_2, CH_4 and other gases.**

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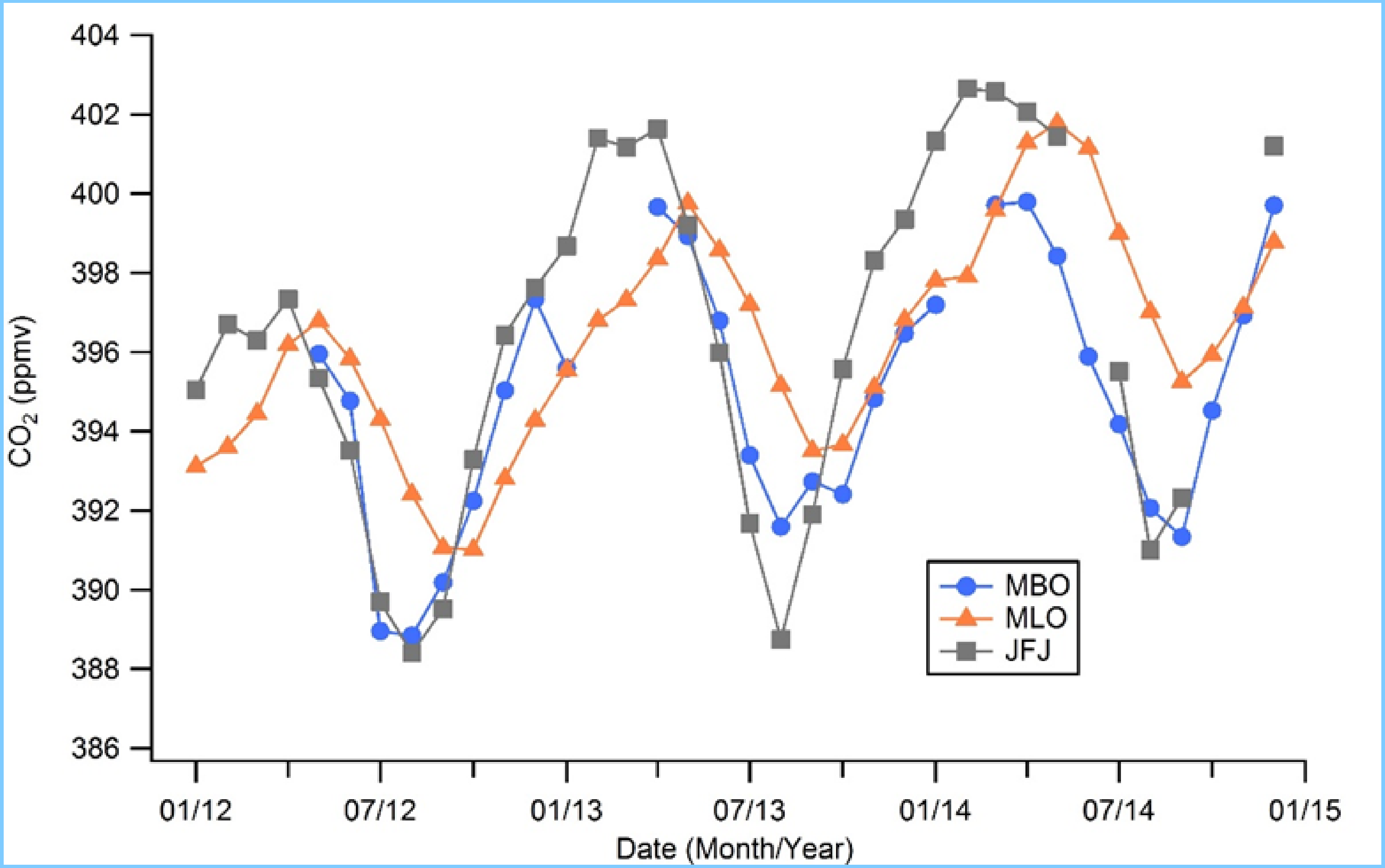
Monthly mean CO_2



McClure et al 2015-
AAQR Mtn top special issue

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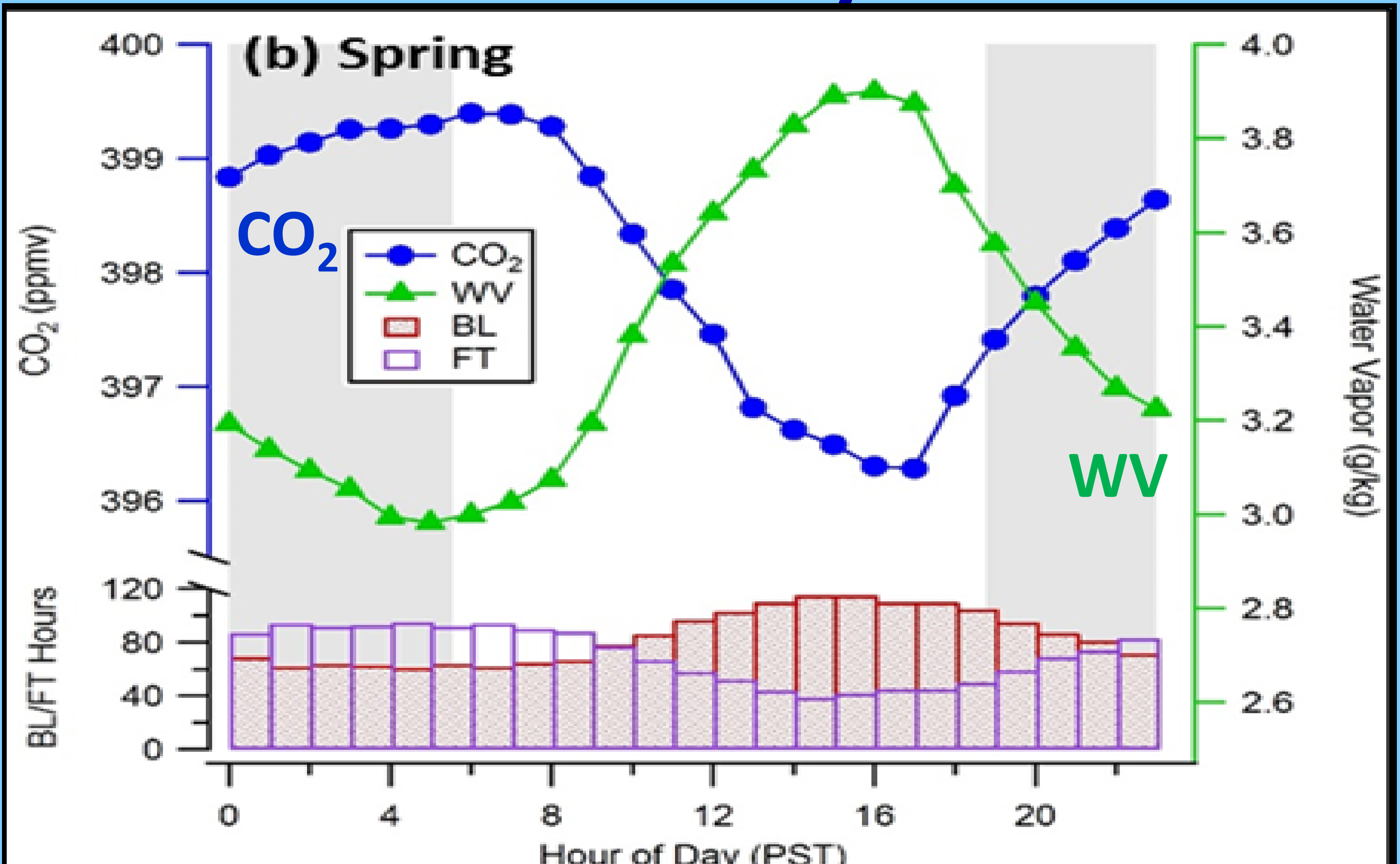
Diurnal cycle



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Wildfires

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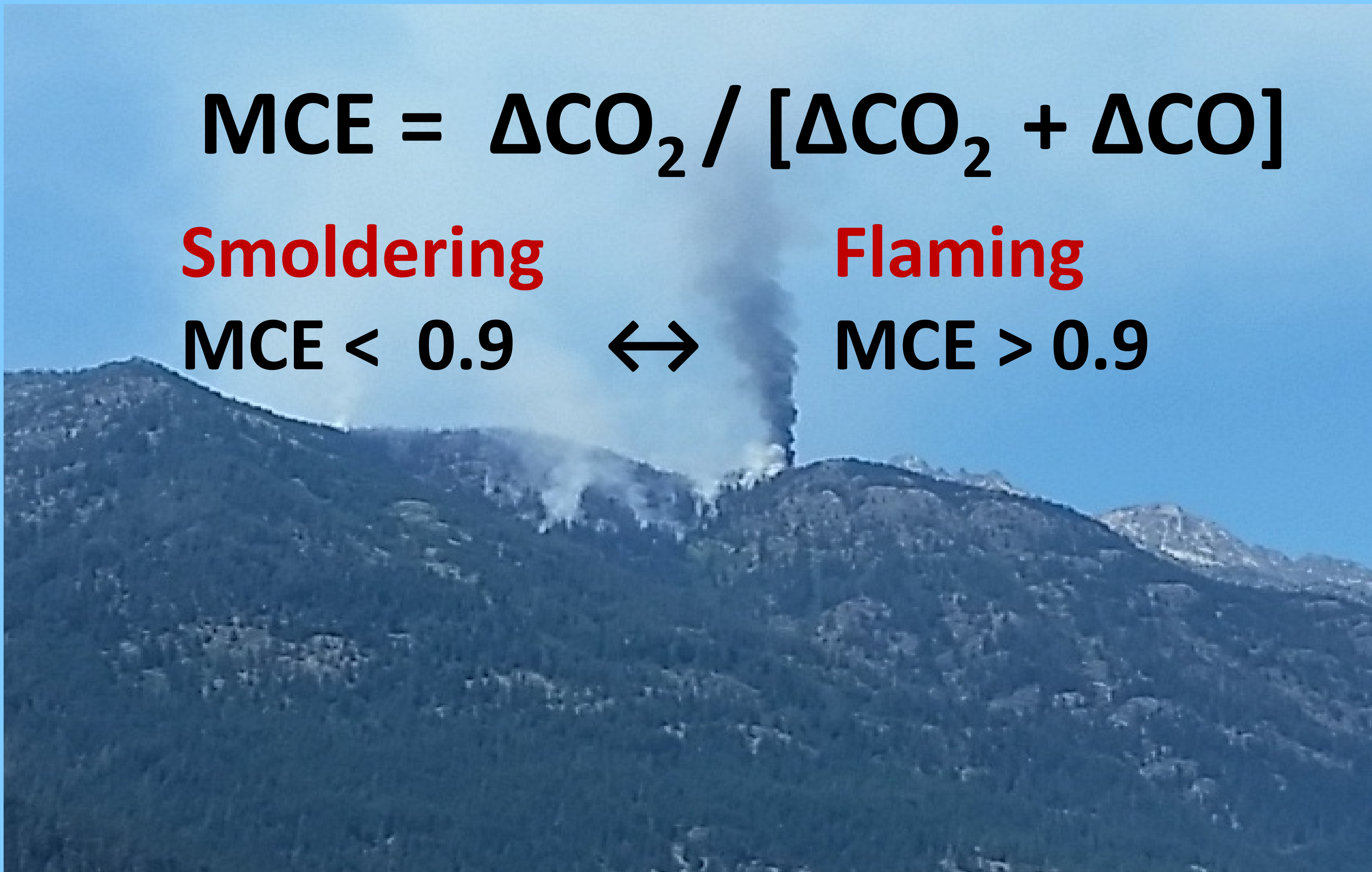
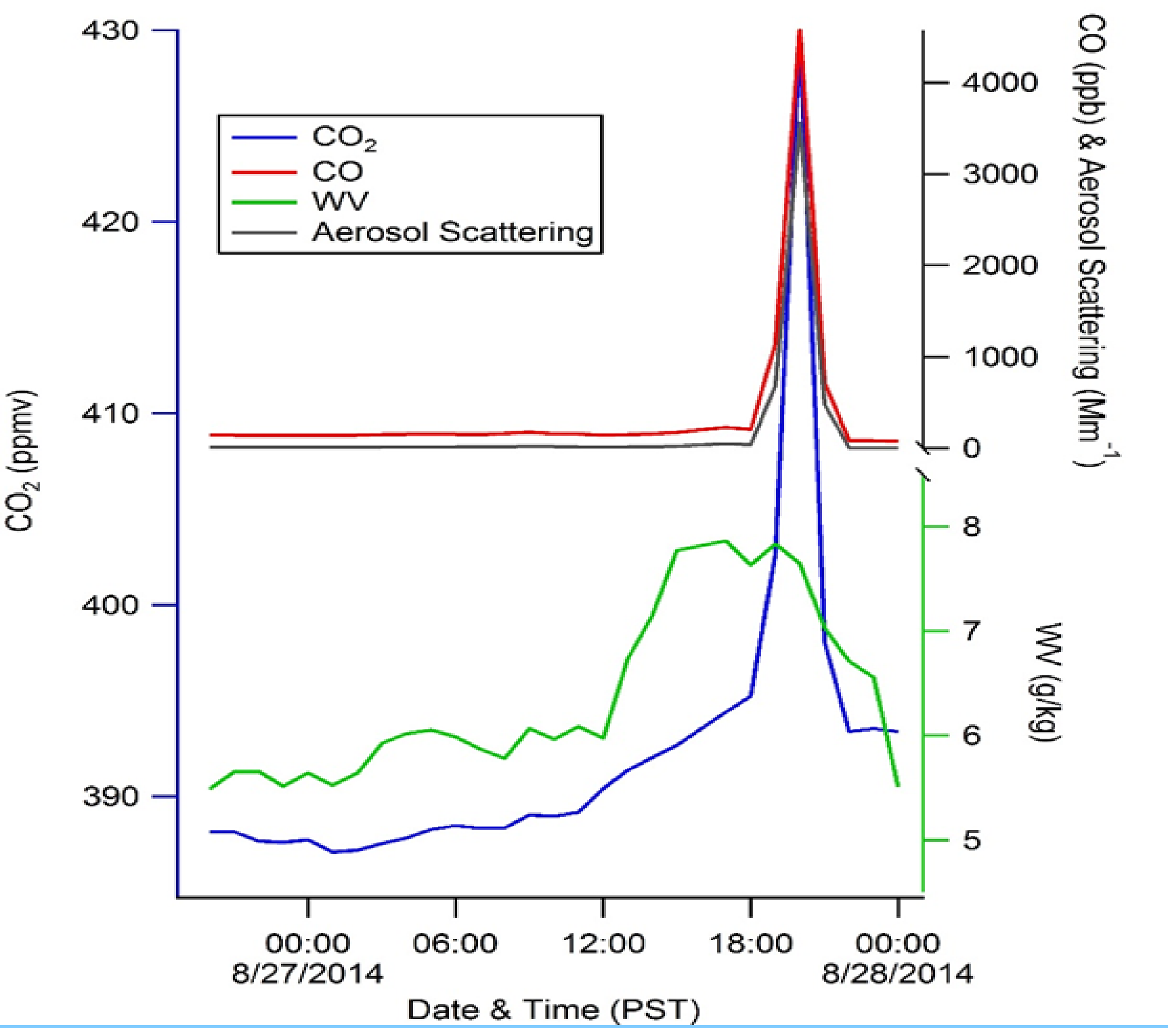
Modified Combustion Efficiency (MCE)



$$MCE = \Delta CO_2 / [\Delta CO_2 + \Delta CO]$$

Smoldering		**Flaming**
$MCE < 0.9$	$\leftrightarrow$	$MCE > 0.9$

Fire plume seen in BL
Aug 28, 2014



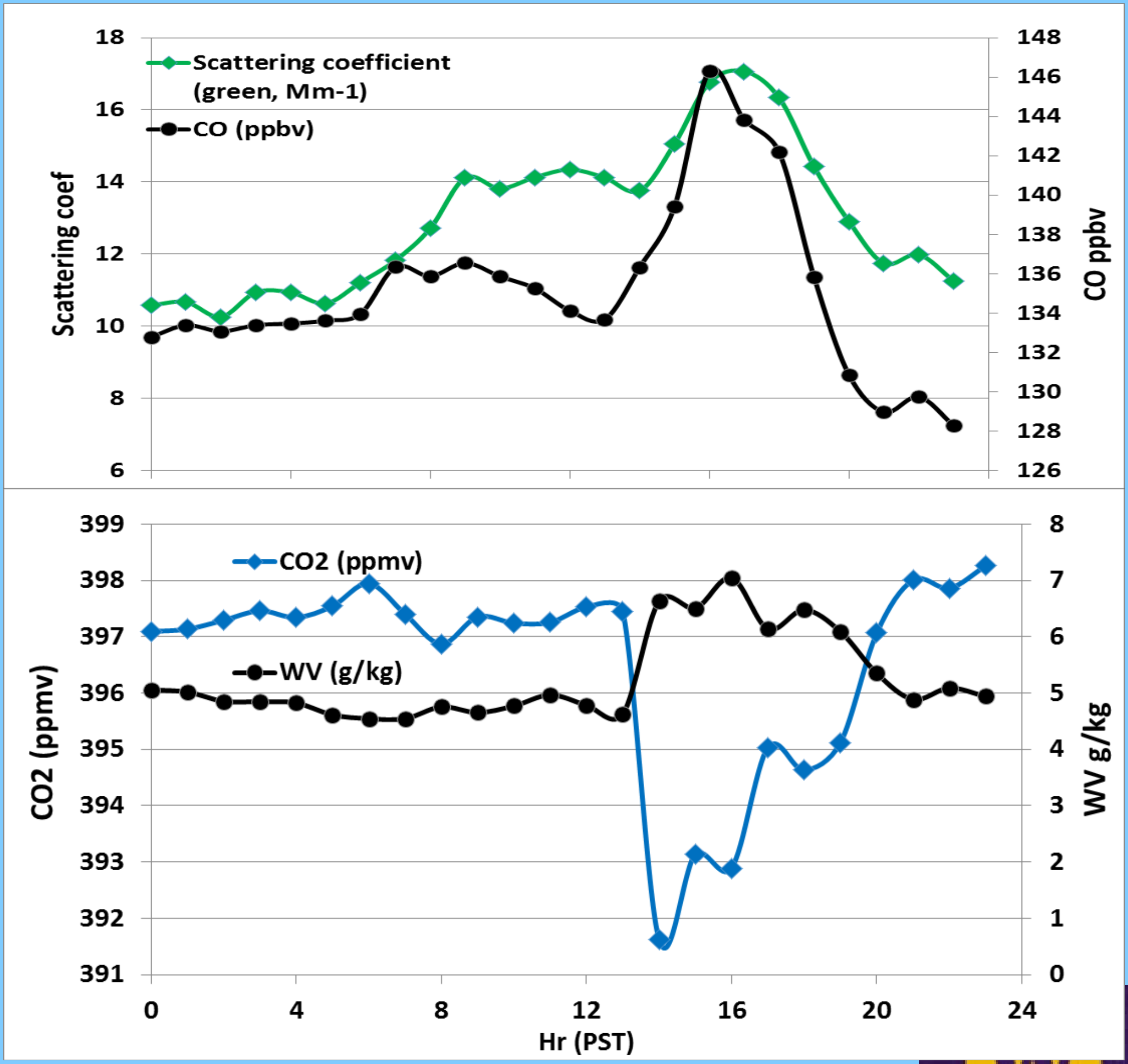
ΔCO = 4490 ppbv

ΔCO_2 = 38 ppmv

MCE = 0.89

Predominantly smoldering combustion

Fire plume seen in BL
May 9, 2013



ΔCO = 20 ppbv

ΔCO_2 = -5.8 ppmv

MCE = ??

Plume too small to reliably calc MCE

Uncertainty in MCE

$$\delta M =$$

$$M^* ((\delta(A+B)/(A+B))^2 + (\delta A/A)^2 - 2(\delta A^2)/(A(A+B)))^{1/2}$$

where M=MCE; A= ΔCO_2, B=ΔCO, and δ refers to the uncertainty of the corresponding terms.

Bottom line: Larger plumes, smaller uncertainty

Briggs et al 2016 (submitted)

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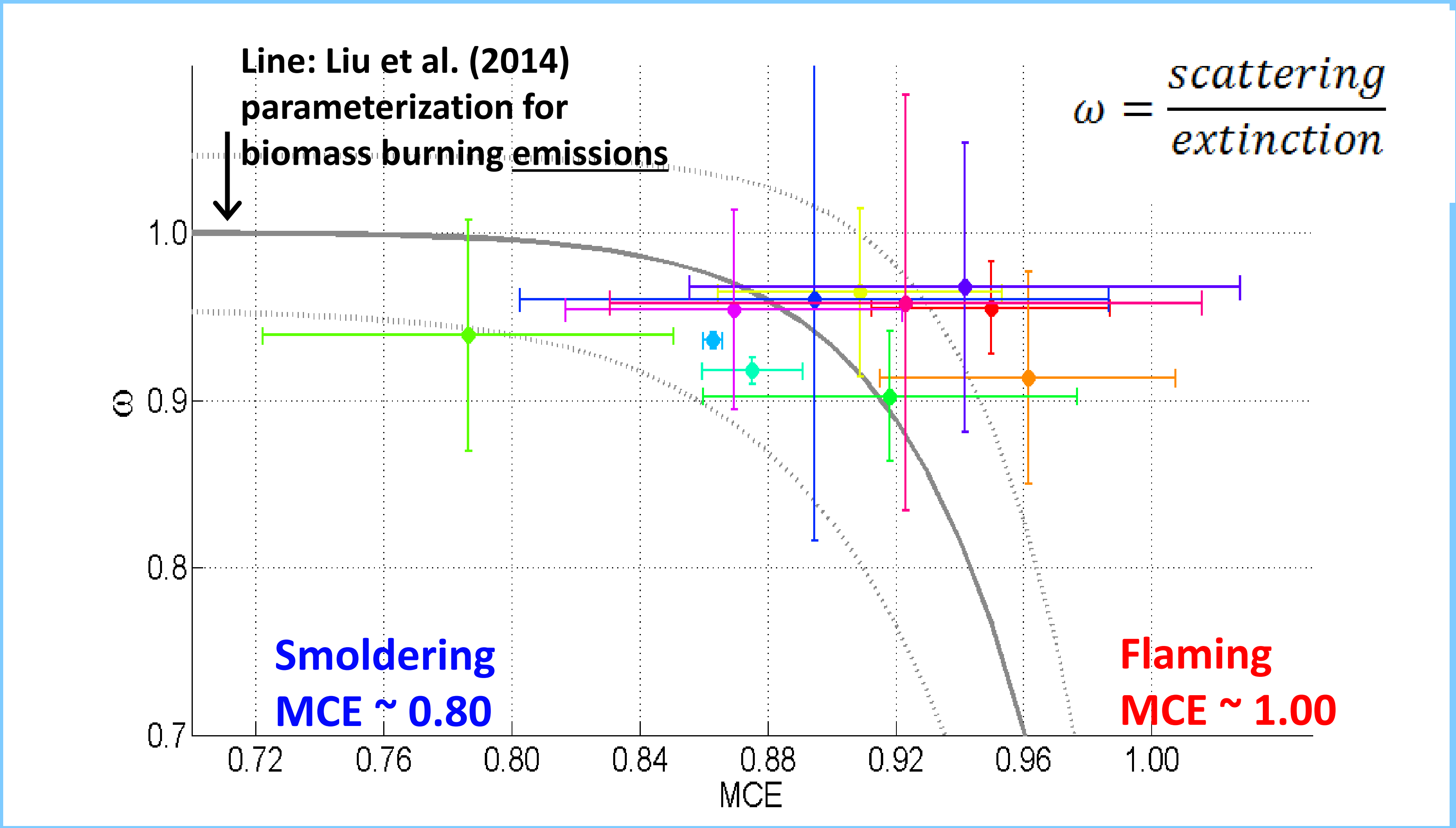
Single Scattering Albedo (ω-532 nm) vs MCE for fire plumes seen at MBO



- Bars show uncertainty in both SSA and MCE.
- Obs do not show a drop in SSA with MCE. (Briggs et al 2016-submitted)

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Summary

- **MBO is an excellent site to observe free tropospheric inflow into North America, Asian and wildfire plumes. Observations of CO_2, CH_4, etc can give information on NA boundary conditions and help constrain global fluxes;**
- **At MBO, CO_2 has a pronounced diurnal cycle with higher concentrations in nighttime/free tropospheric air;**
- **CO and CO_2 can also given information on combustion efficiency (MCE) in fire plumes, but consideration must be given to understand the background variations and the resulting uncertainties.**
- **Our observations in fire plume indicate that SSA is relatively insensitive to MCE, in contrast to lab studies;**
- **Many plumes have higher POC/CO_2 compared to the emission ratios, suggesting secondary organic aerosol production.**

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