Biomass Burn Observation Project (BBOP)

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ARM
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ASR Atmospheric System Research

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ASU
University of Arkansas
DRI Desert Research Institute
Aerodyne Research Inc.
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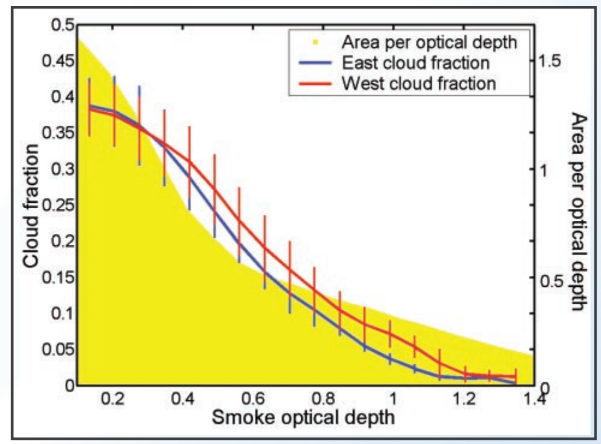
Biomass Burn Observation Project - Motivation

Aerosols from biomass burning perturb Earth's climate through

- Direct Effect (scattering and absorption)
- Indirect Effect (cloud formation and precipitation)
- Semi-direct Effect (evaporation of cloud drops)

Direct Effect
(Akagi et al., 2012)

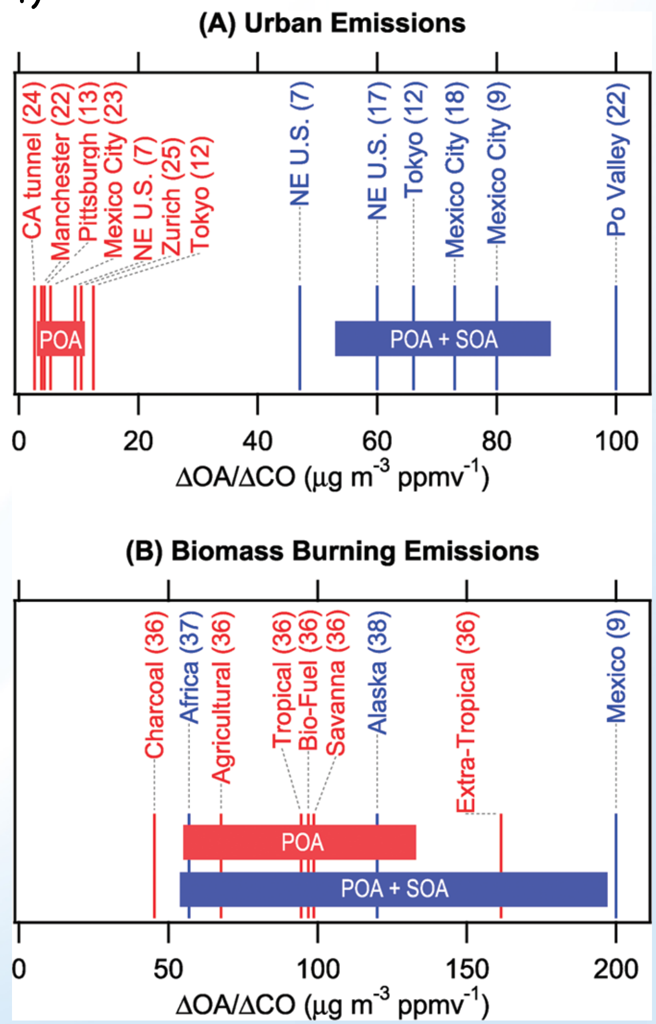
Indirect Effect
(pyrocumulus)
[Photo: B. Inaglory]



Semi-direct
(Koren et al. 2004)

Biomass Burn Observation Project – Motivation

- Biomass burning estimated to account for ~60% of carbonaceous particles (Bond et al., 2004)
- Primary organic aerosol (POA) from BB comprises largest component of POA mass emissions in northern temperate latitudes (de Gouw & Jimenez 2009)
- IMPROVE network suggests that major fraction of aerosol mass and year-to-year variability is due to emissions from fires (Park et al. 2007)



Biomass Burn Observation Project – Challenge

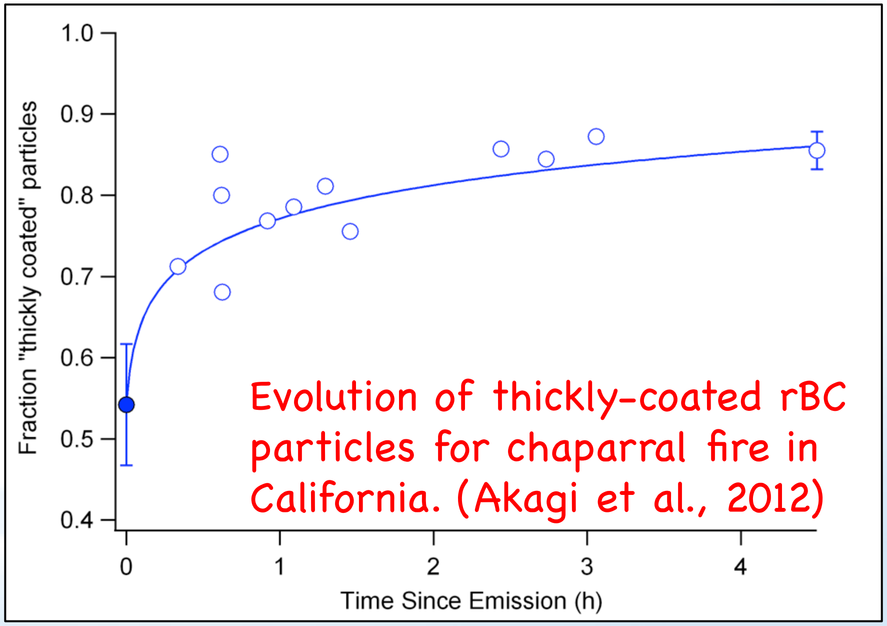
- Wildfires are sporadic and unpredictable
- Lifetime of wildfires (especially prescribed burns)
- Spatial inhomogeneity of fires (dynamic mix of flaming/smoldering)



- Wide variety of aerosol types dependent on phase of fire:
  - Flaming: primarily BC
  - Smoldering: POA (including BrC), SOA, BC, tar balls, etc.
- Where to stage for field campaign

Biomass Burn Observation Project – Unique Focus

- Most field studies have focused on tropical region (ABLE, BIBLE, PACE-5, SCAR-B, SAFARI92, SAFARI2000, TRACE-A)
- Fewer, smaller scale, aircraft-based field measurements carried out in U.S. (Yokelson)
  - ➤ Infrequent occurrence of fires contributes to the paucity of studies
- Still fewer studies have focused on the near-field evolution of BB aerosols (e.g., Akagi et al., 2012)



Evolution of thickly-coated rBC particles for chaparral fire in California. (Akagi et al., 2012)

Biomass Burn Observation Project – Key Objectives

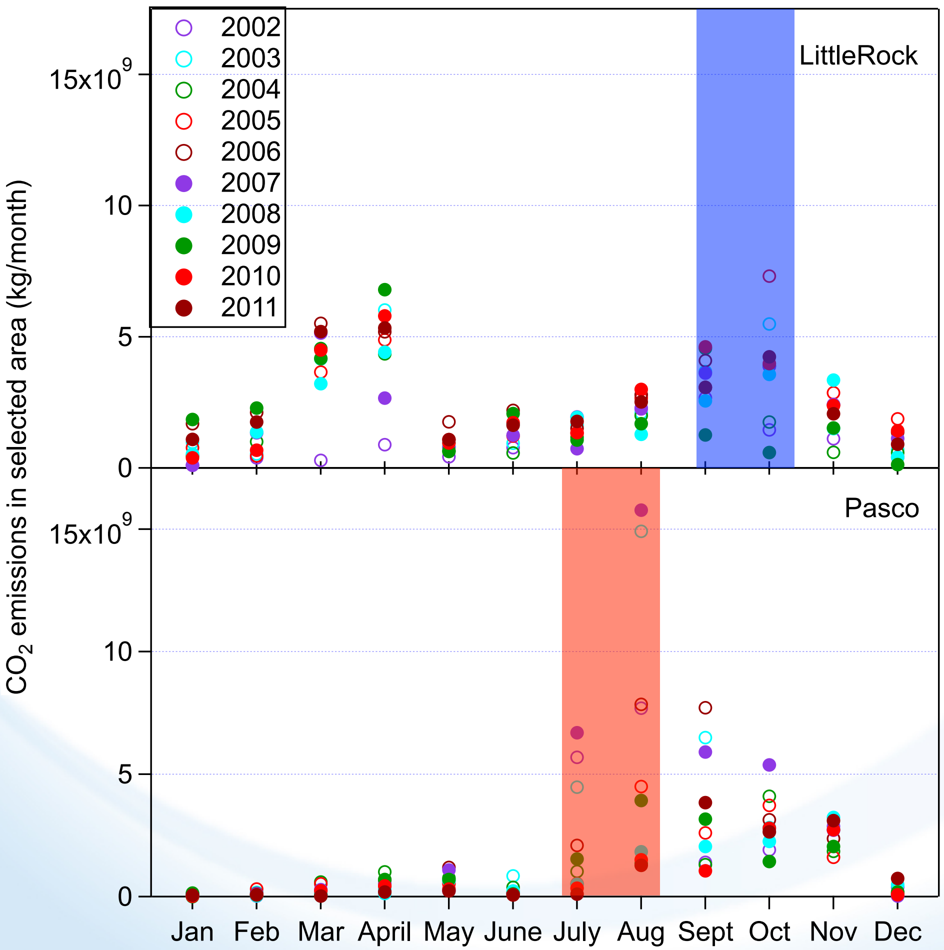
Quantify the downwind time evolution of microphysical, morphological, chemical, hygroscopic, and optical properties of aerosols generated by biomass burning

Use the time sequences of observations to constrain processes and parameterizations in a Lagrangian model of aerosol evolution

Incorporate time evolution information into a radiative transfer model for determining forcing per unit carbon burned.

Biomass Burn Observation Project – Where to Stage

Monthly BB CO emissions were examined for Little Rock (AR) and Pasco (WA). Based on MODIS fire products and FINNv1 emission inventory (Wiedinmyer et al., 2011)



Little Rock: September/October

Pasco: July/August

Biomass Burn Observation Project – 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
- FIMS
- Microscopy (TEM)
- SP2
- Dual column CCN
- UHSAS/PCSAP
- Particle counter

Optical Properties
- 3-λ nephelometer
- 3-λ PSAP
- 1-λ PAS (355 nm)
- 1-λ PTI (532 nm)
- 1-λ CAPS (extinction, 628 nm)

Trace gas
- PTRMS
- H_2O, CH_4, N_2O, NO, NO2, NOy, CO, CO_2, O_3 and SO_2

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

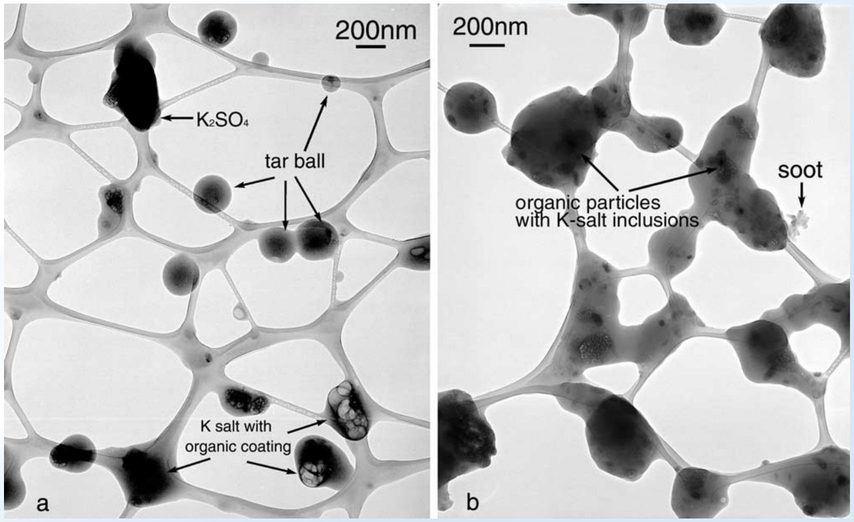
BBOP- Microphysical Properties

Impacts of chemical composition/particle morphology on BC radiative forcing:

- SP-AMS (Soot Particle Aerosol Mass Spectrometer):
  - chemical composition of non-refractory material associated with rBC
- SP2 (single particle soot photometer):
  - using lagtime methodology probe particle morphology
- Microscopy (TEM):
  - chemical composition and particle morphology

Probe the evolution of size distribution:

- FIMS (Fast Integrated Mobility Spectrometer):
  - Range: 15 nm – 300 nm
  - Time response: 1-Hz



TEM images of smoke aerosols from Timbavati fire, South Africa, 2000

(Li et al, 2003)

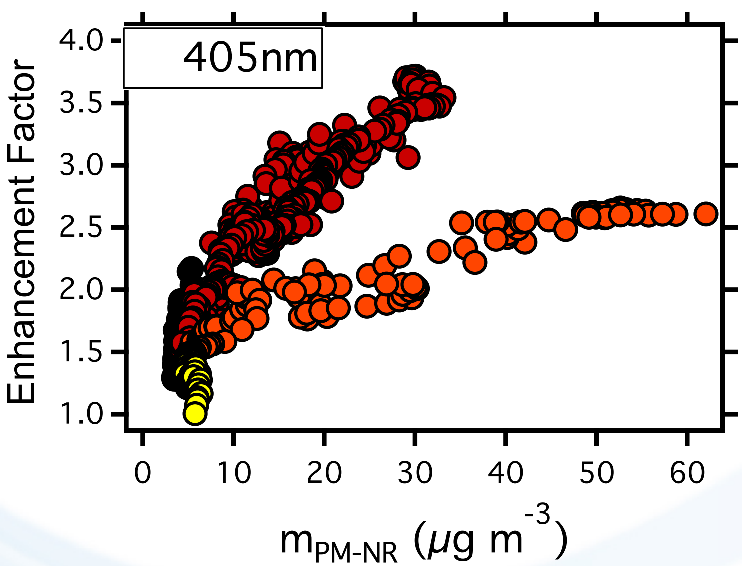
BBOP- Optical Properties

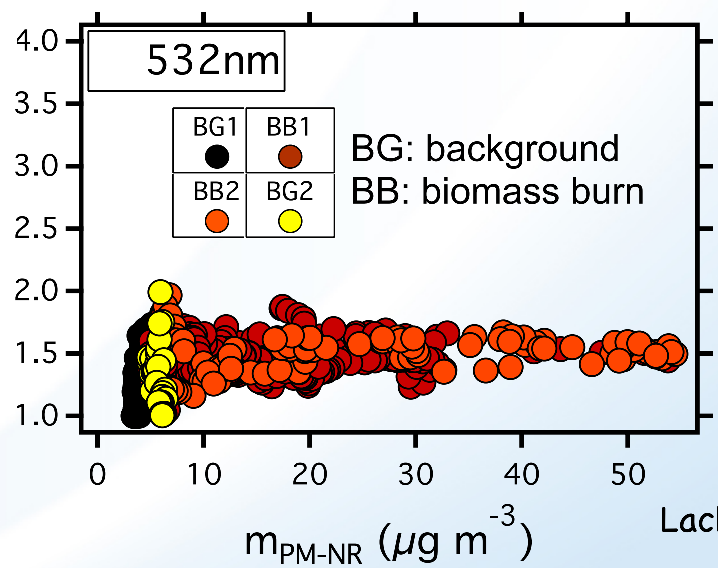
Black Carbon Closure Study:

- 3-λ nephelometer (λ=700, 550, & 450 nm)
- 3-λ PSAP (Particle Soot Absorption Photometer; absorption; λ=650, 527, 450 nm)
- 1-λ PTI (photothermal interferometry; absorption; λ=532 nm)
- 1-λ CAPS (Cavity Attenuated Phase Shift; extinction; λ=628 nm)

Brown Carbon:

- 1-λ PAS (Photoacoustic Spectroscopy; absorption/scattering; λ=355 nm





Lack, et al., 2012

BC and BrC contributions separated by wavelength dependence

BBOP- SOA Formation Rates/Evolution of CCN Activity

Investigation into SOA Formation Rates:

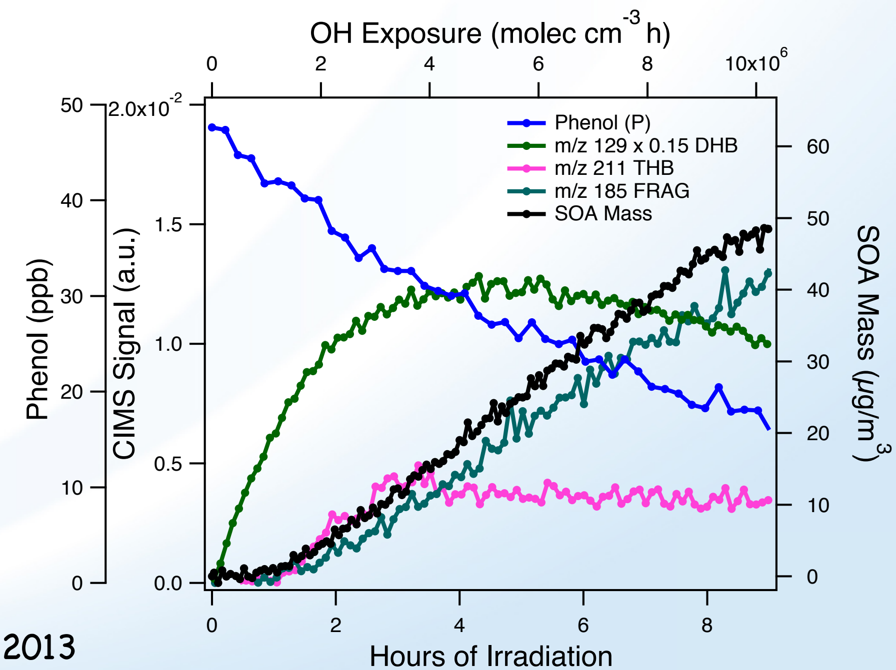
AMS (High-Resolution Aerosol Mass Spectrometry): organic aerosols
PTRMS (Proton Transfer Reaction Mass Spectrometry): trace VOCs
CO_2: ratio of OA to excess CO or CO_2 information on SOA formation rates
NOx/NOy: photochemical age

Investigation of evolution of CCN activity:

Dual-column CCN (Cloud Condensation Nuclei counter): 0.4% and 1.0% SS
AMS (High-Resolution Aerosol Mass Spectrometry): organic aerosols

Trace Gas Measurement:

H_2O, CH_4, N_2O, NO, NO2, NOy,
CO, CO_2, O_3 and SO_2



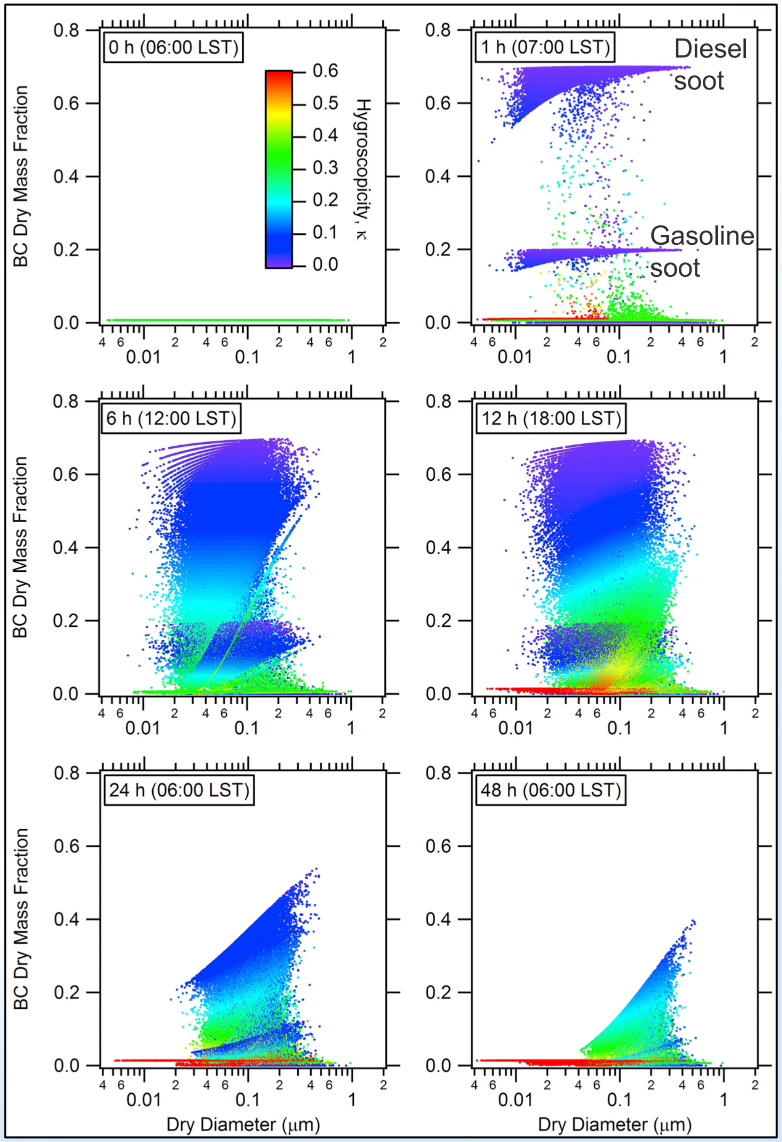
Lee et al., ACPD 2013

BBOP- Modeling

Quasi-Lagrangian observations within and outside of fire plumes will be interpreted with the comprehensive sectional aerosol box model MOSAIC. (Zaveri et al., 2008)

The Rapid Radiative Transfer Model will be used to translate the observed optical properties into radiative forcing. (Mlawer et al., 1997)

Evolution of BC mass fraction as f(dry diameter)



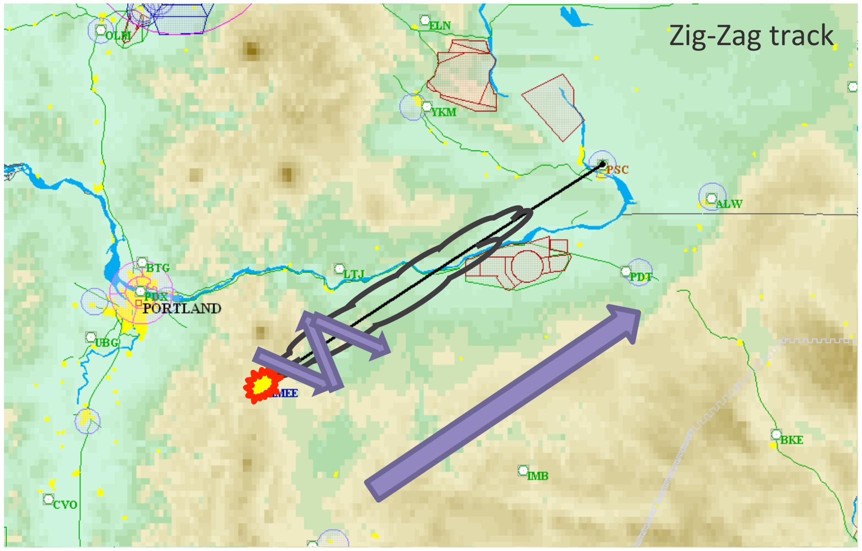
Zaveri et al. 2010

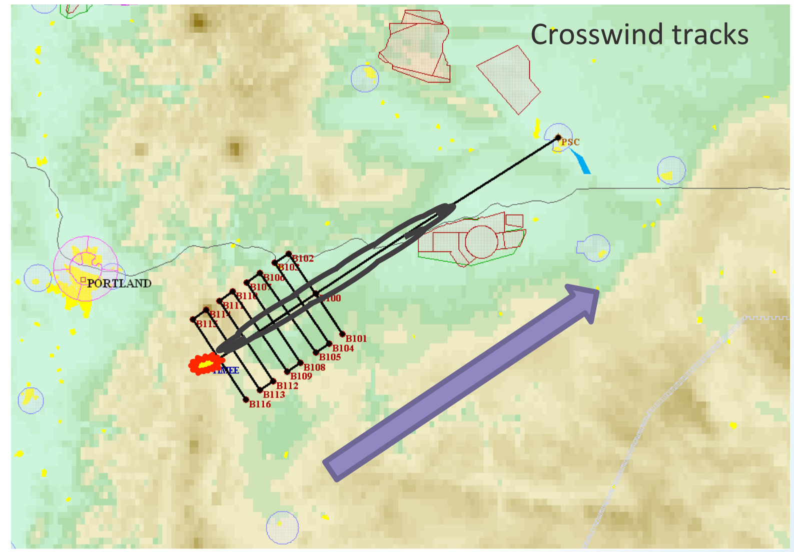
BBOP Platform: AAF Gulfstreeam-I

120 flight hours

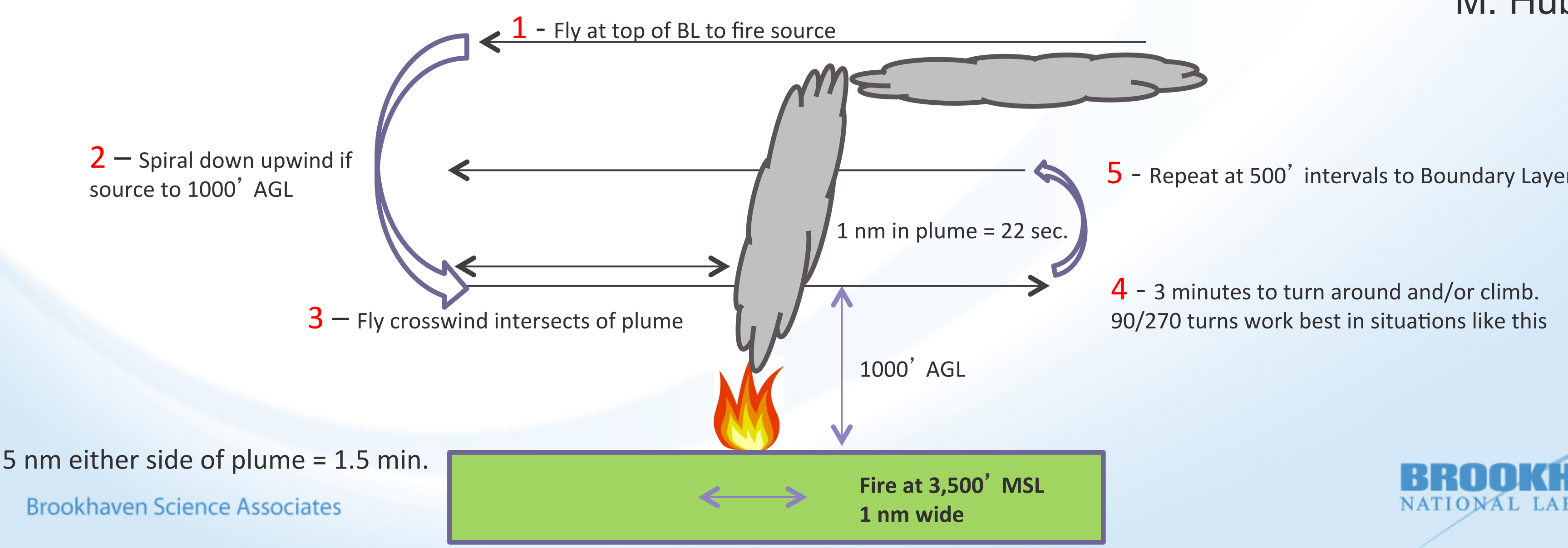
BBOP- Platform: Sampling Patterns

Discussions recently initiated - No patterns finalized or rejected





M. Hubbell



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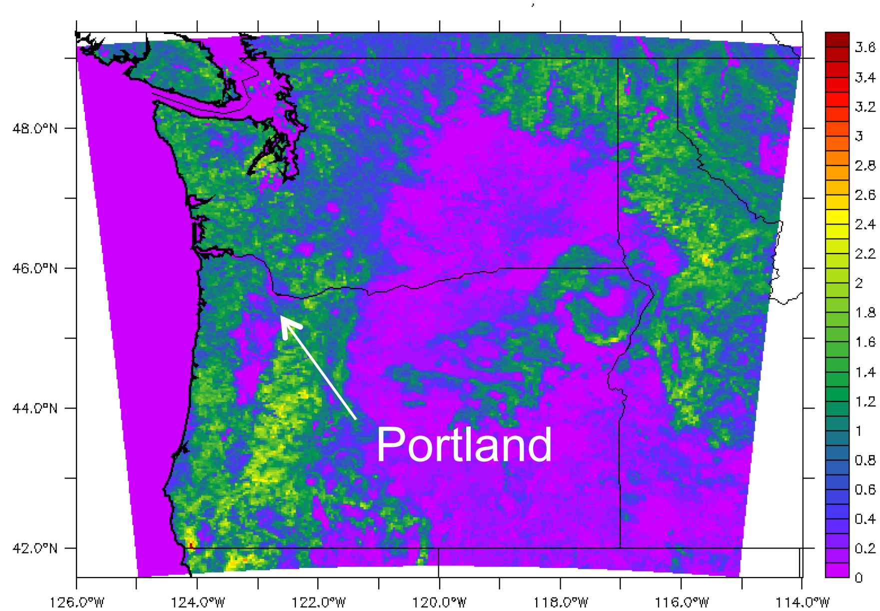
BBOP: What?! No fires!

Plan 'B"

Urban flights for A-B interactions

Comparison of Portland Plume (terpene forest) with Sacramento plume (isoprene forest: CARES)



Terpene emission rate, 02 UTC July 04. A MEAGEN-WrfChem calculation by J. Fast

Collaborate with the Southern Oxidants and Aerosol Study (SOAS) & Southeast Nexus (SENEX).

Study anthropogenic - biogenic interactions that foster production of SOA

Investigate season variations in biogenic emissions and properties of anthropogenic and biogenic aerosol

BBOP: Collaborations

Satellite Analysis of Biomass Burning: Charles Ichoku and Ralph Kahn

Mount Bachelor Observatory (MBO; 43.98-N, 121.69-W, 2763 m asl)

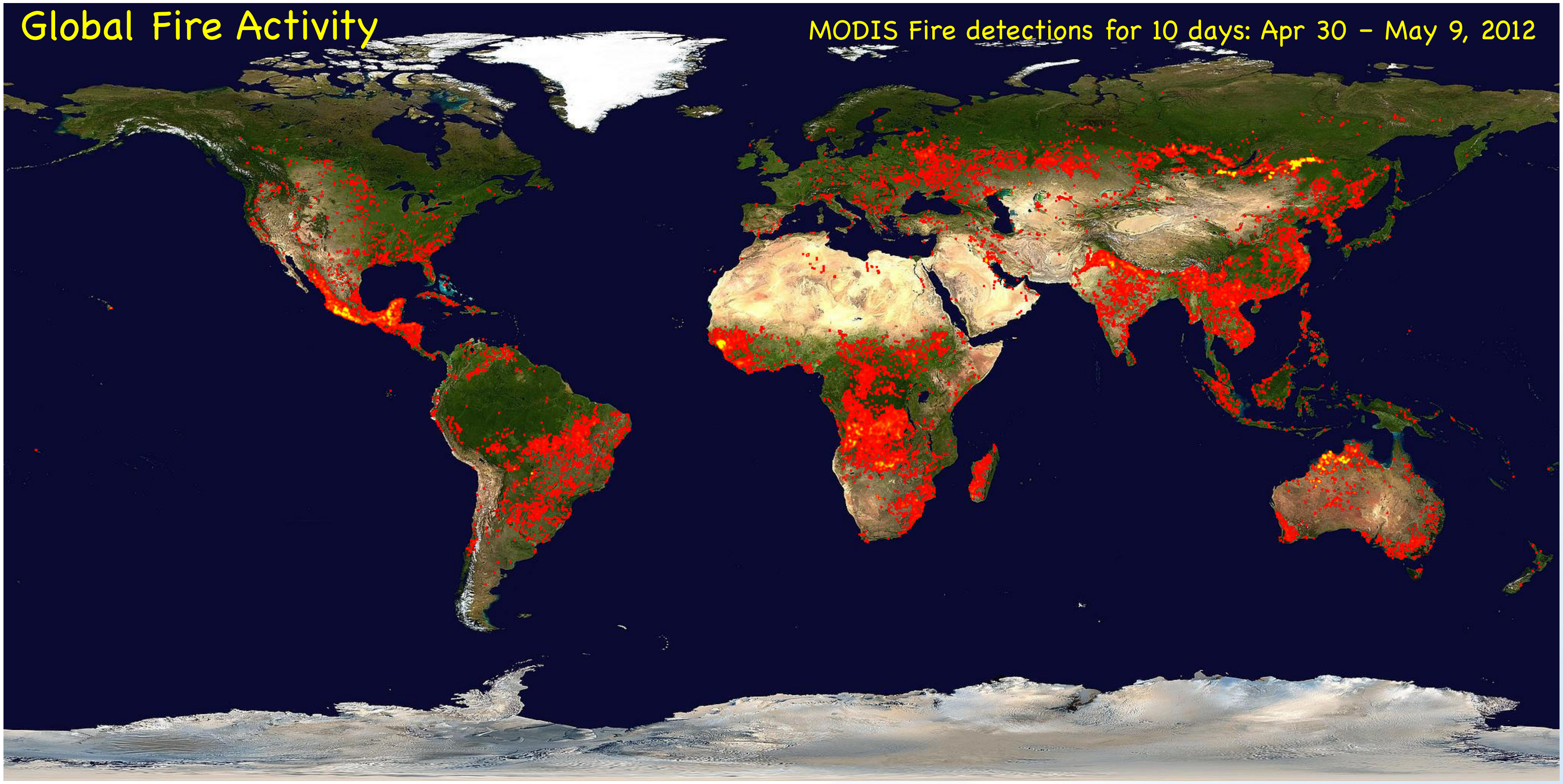
- Dr. Dan Jaffe
- Couple ground and aircraft measurements
- Historical emission measurements in the July – Sept. time frame

SOAS/SENEX (Plan 'B')

- Examine changes in biomass emissions between the SOAS/SENEX deployment (mid-June to July) and BBOP (late Sept. to October)

Discussions with SEAC^{4}RS (Southeast Asia Composition, Cloud, Climate Coupling Regional Study) team on potential combined flight opportunities (DC-8/ER-2)

Summary



C. Ichoku and R. Kahn