DC3 Science Team Meeting, 25-28 February 2013

Biomass Burning Studies during DC3

Bernadett Weinzierl
with contributions from many groups

DLR

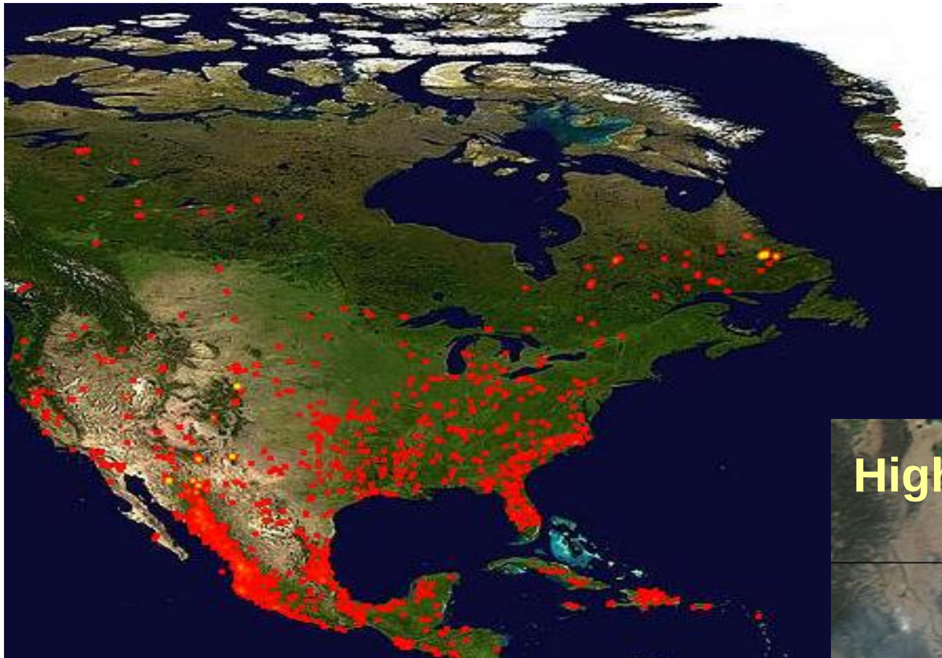
Outline of this presentation

- **General overview** on biomass burning during DC3
- **Case studies** (biomass burning aerosol close to the source):

  11 June 2012 & 22 June 2012
- **Long-range transport** of biomass burning aerosol
- Summary of **preliminary findings**
- **Topics** addressed by individual groups
- **Gaps**

Intensive fires during DC 3

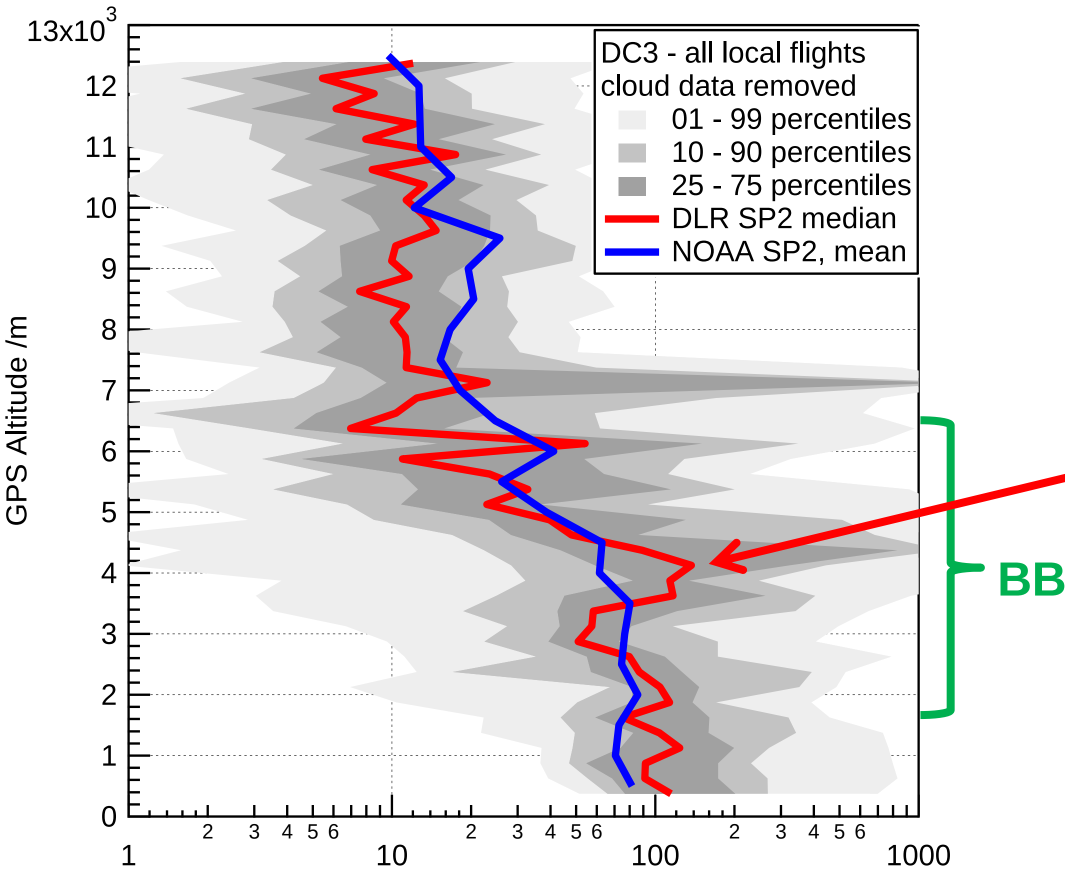
9 June – 18 June 2012



http://rapidfire.sci.gsfc.nasa.gov/imagery/firemaps/firemap.2012161-2012170.2048x1024.jpg

(NASA Earthobservatory)

Vertical profiles of rBC mass concentration outside of clouds



DC8/G-V (18 May – 22 June):
Accidental sampling of biomass burning plumes (except for 22 June 2012)

Falcon (29 May – 14 June):
Chasing biomass burning plumes as an objective

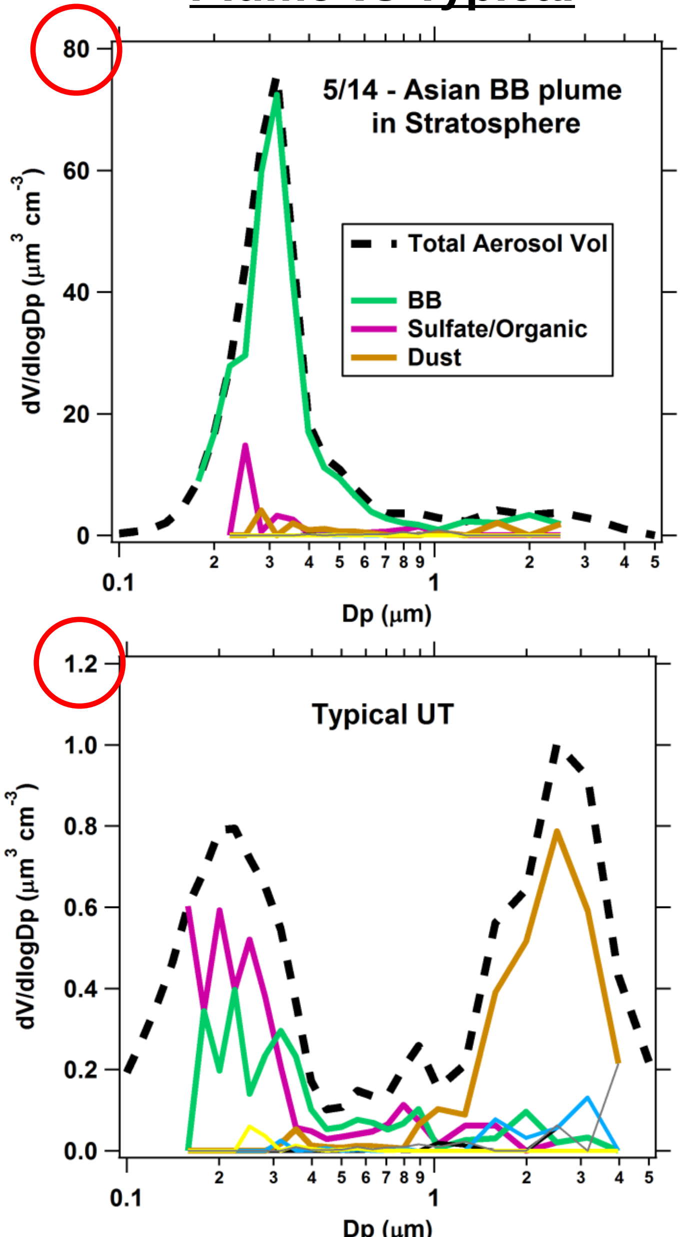
preliminary data
NOAA SP2: Milos Markovic, Shuka Schwarz, Anne Perring, Dave Fahey
DLR SP2: Bernadett Weinzierl, Katharina Heimerl

DLR

preliminary data
PALMS group: Karl Froyd, Jin Liao

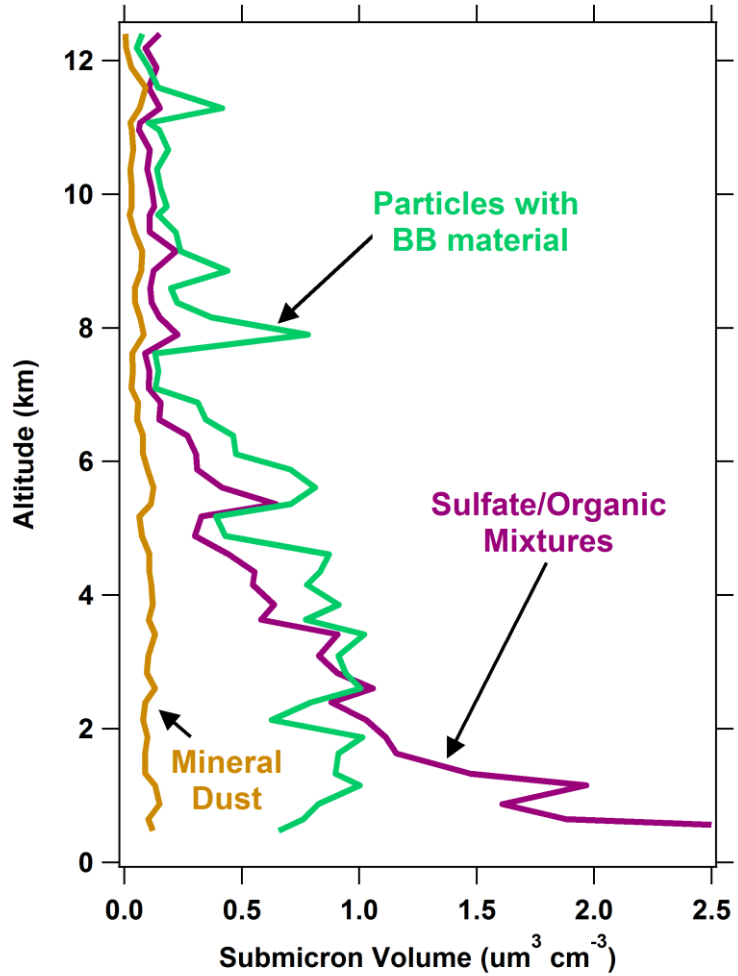
DC3 – dominant particle types

Plume vs Typical



Average Vertical Profile

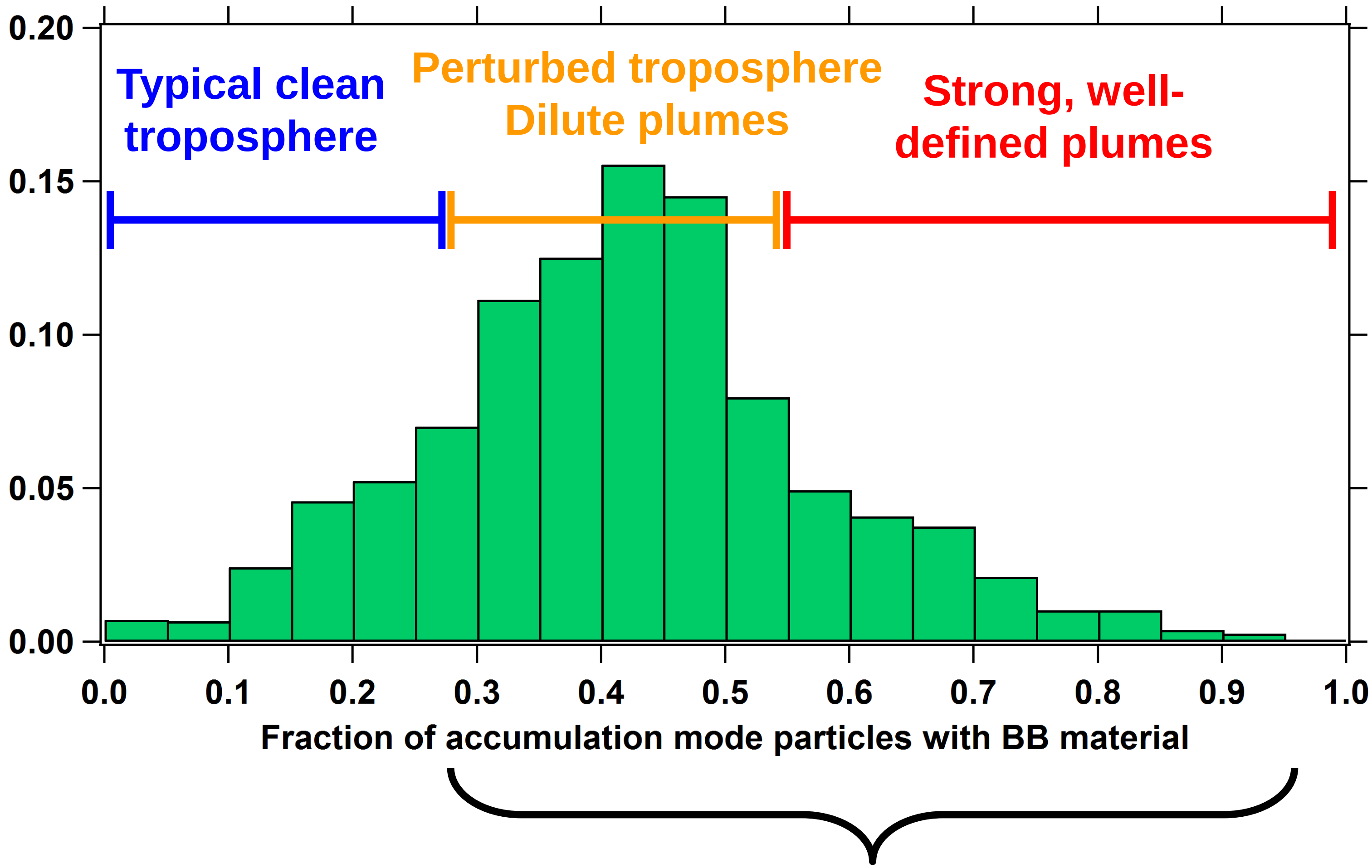
cloud-free air, all KS flights



Particles with BB material typically dominated the Free Troposphere

Frequency of Biomass Burning Particles

(cloud-free, all KS flights)



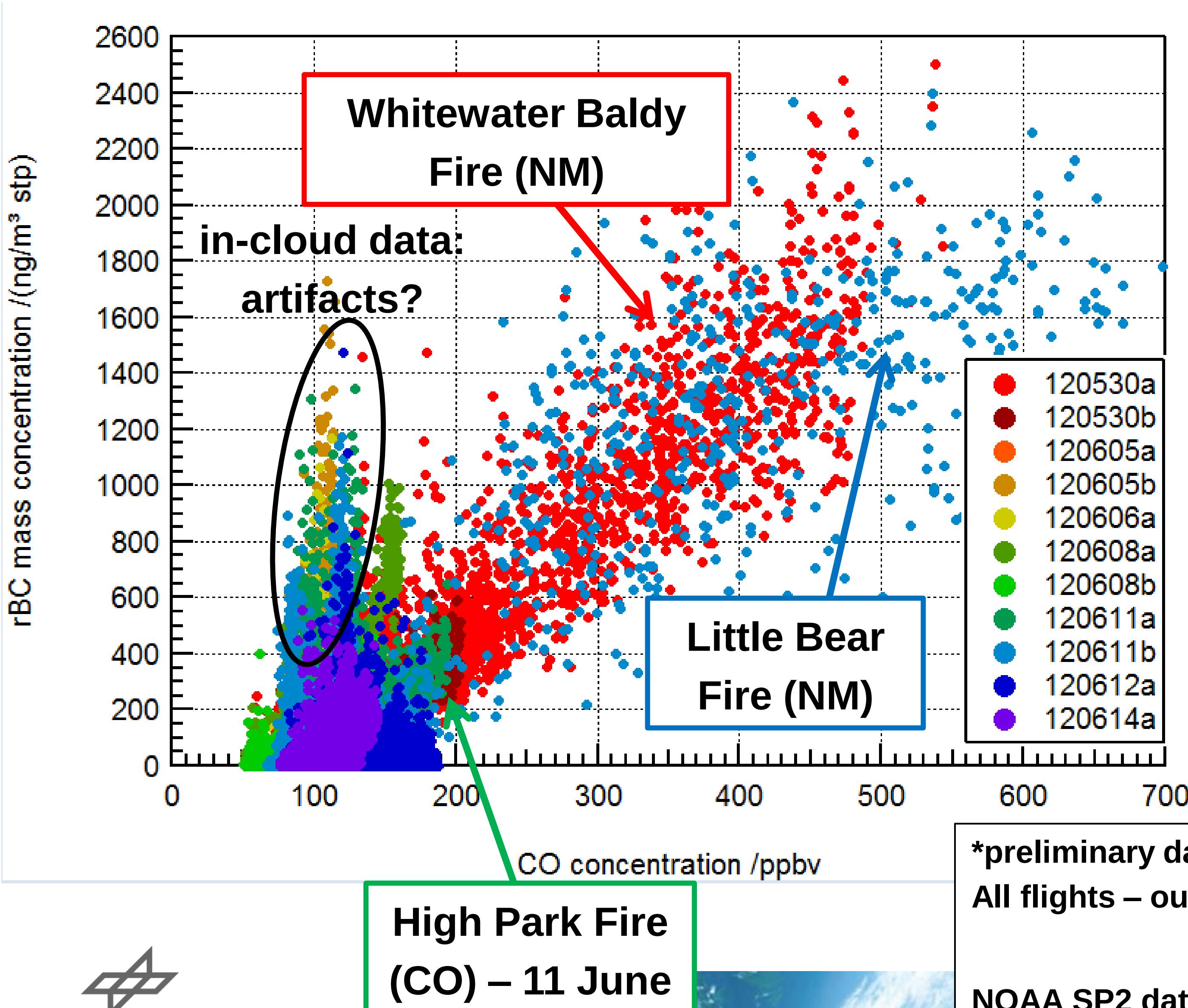
Majority of DC-8 flight time:

***Moderate-to-High* BB influence on aerosol**

preliminary data

PALMS group: Karl Froyd, Jin Liao

rBC – CO ratios

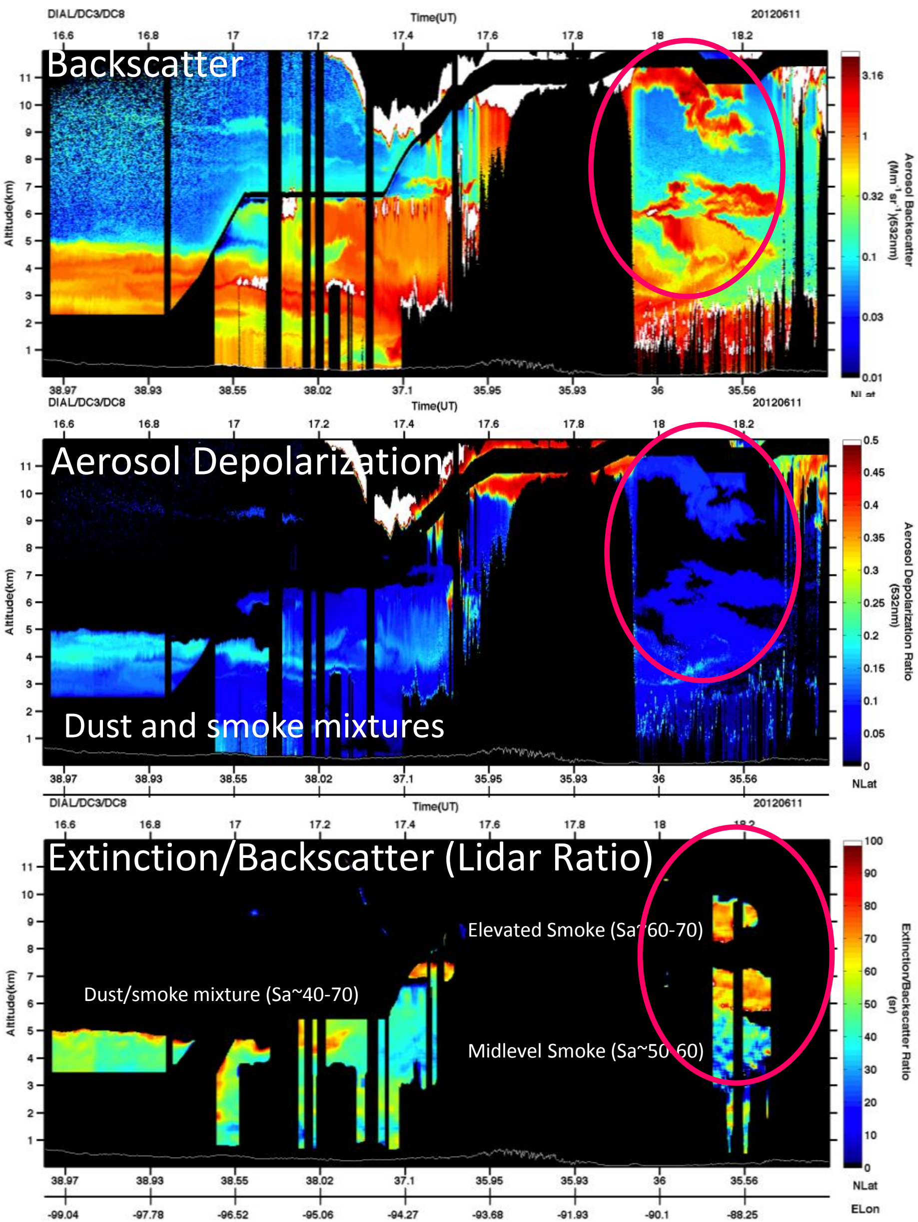


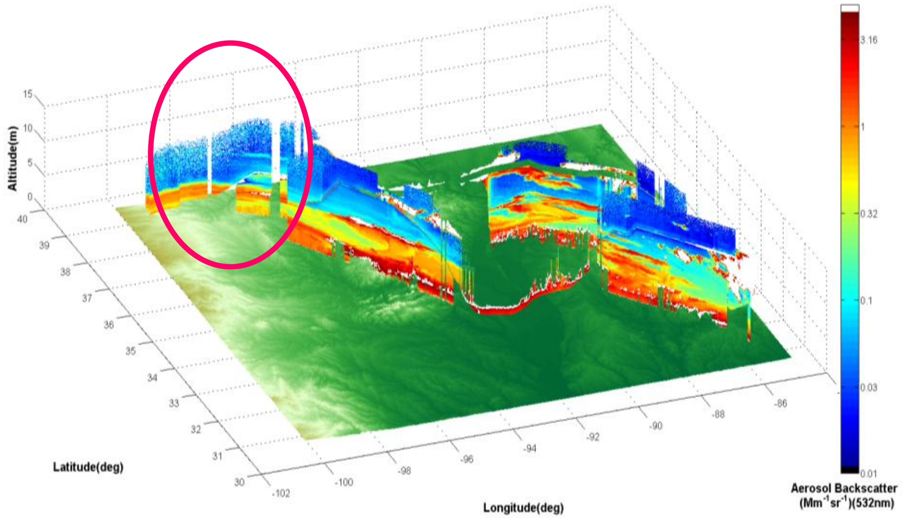
preliminary data

All flights – outside of clouds:

	intercept	slope
NOAA SP2 data:	**-262**	**2.77**
DLR SP2 data:	**-233**	**2.66**

The 11 June 2012 – High Park CO & New Mexico Fires



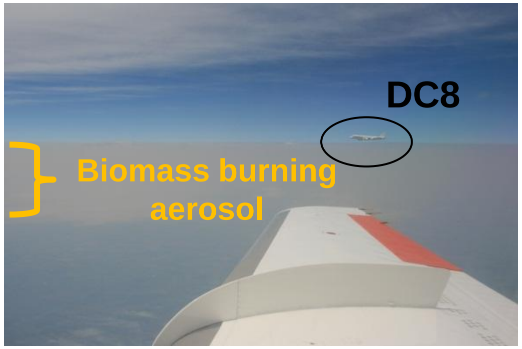


- Biomass burning aerosol mixed with a certain fraction of dust
- Note the vertical extent of smoke that is mixed within cirrus clouds

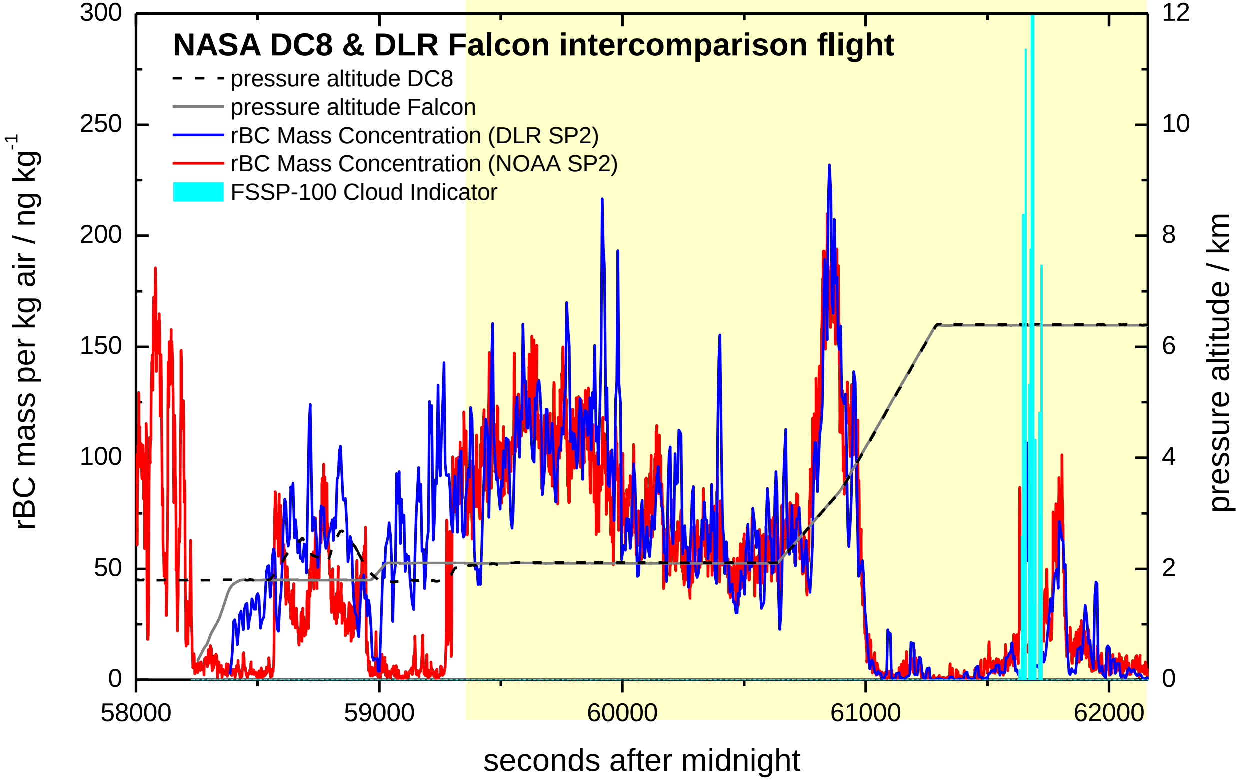
preliminary data
NASA HSRL group:
Johnathan W. Hair, Carolyn F. Butler, Marta A. Fenn

DC3 2012: DC8-Falcon intercomparison flight on 11 June 2012

High Park Fire



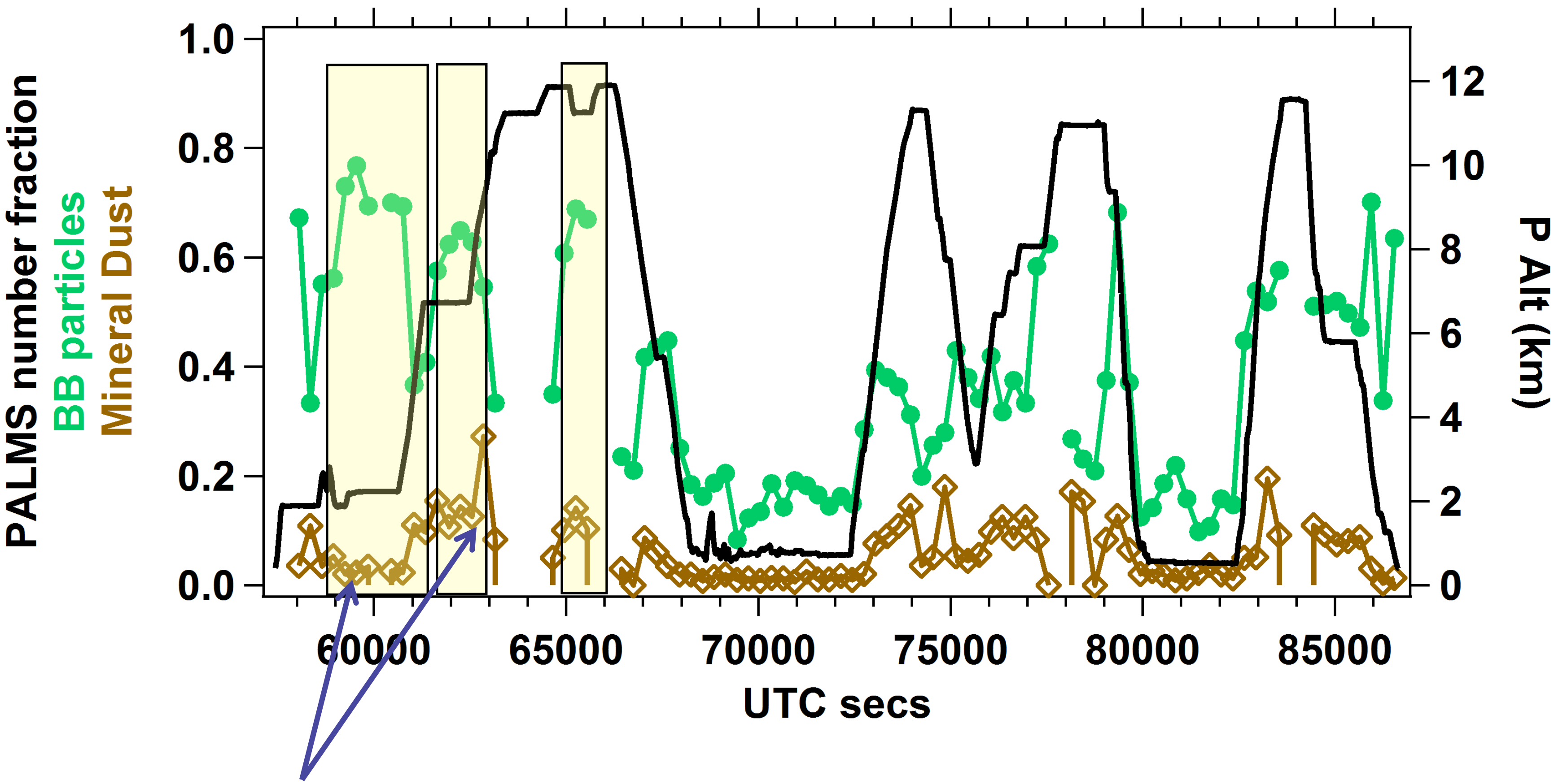
wing-by-wing sequence:
59400 – 62160 UTC



preliminary data
NOAA SP2: Milos Markovic, Shuka Schwarz, Anne Perring, Dave Fahey
DLR SP2: Bernadett Weinzierl, Katharina Heimerl

DLR

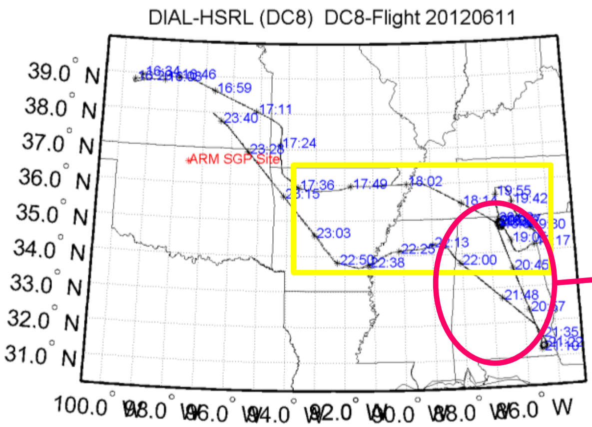
The 11 June 2012 – High Park CO & New Mexico Fires

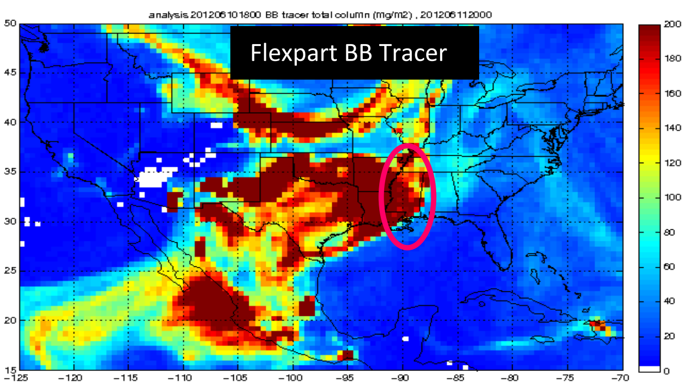


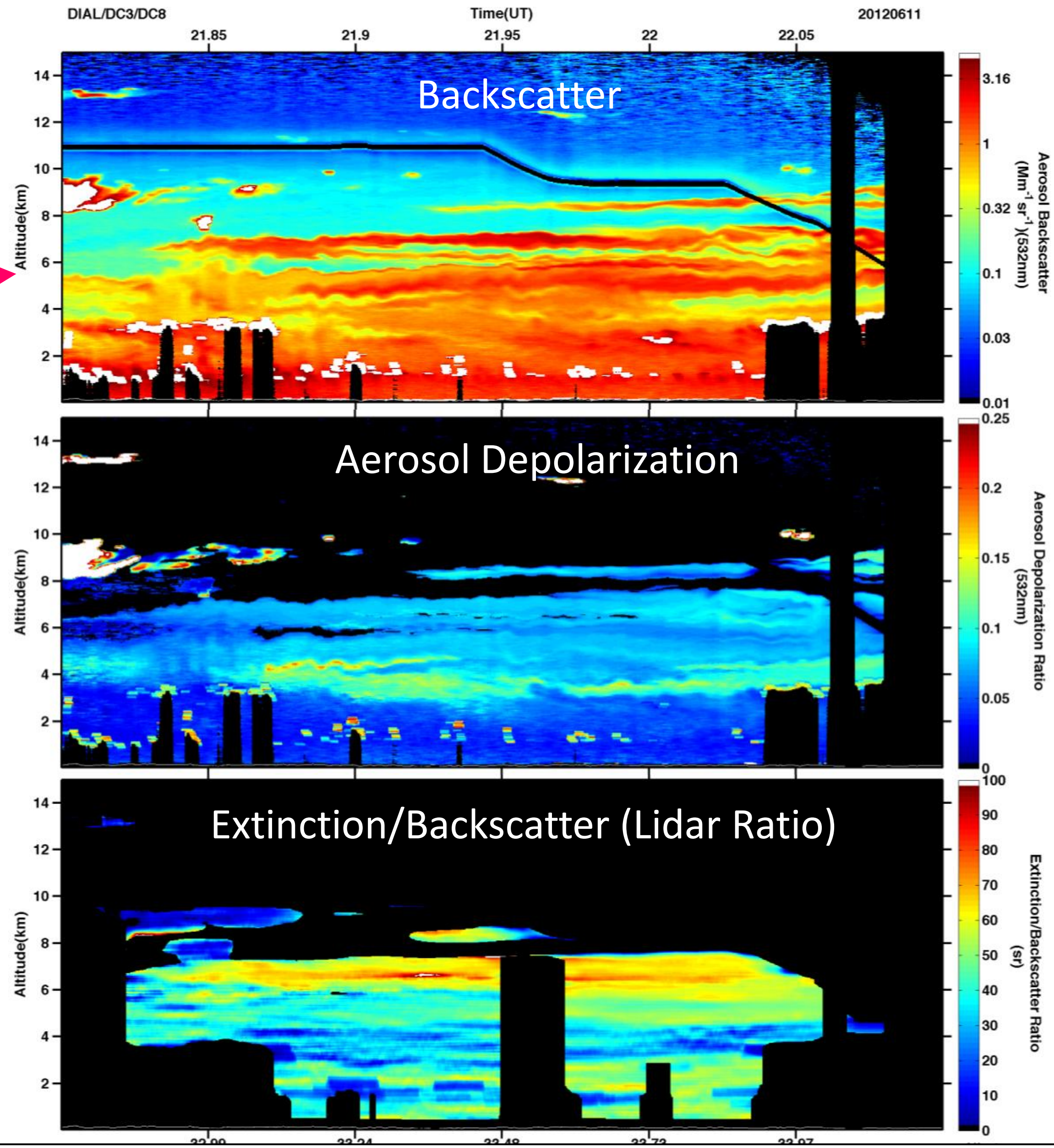
Consistent with HSRL: higher dust fraction in the upper part of the BB plume

preliminary data
PALMS group: Karl Froyd, Jin Liao

New Mexico Fires – 11 June 2012







Comments

1. Observed throughout in SE US region
2. Mix of smoke and dust
3. Depolarization higher than High Park Smoke plume
4. Possibly some mixing of smoke into BL

preliminary data

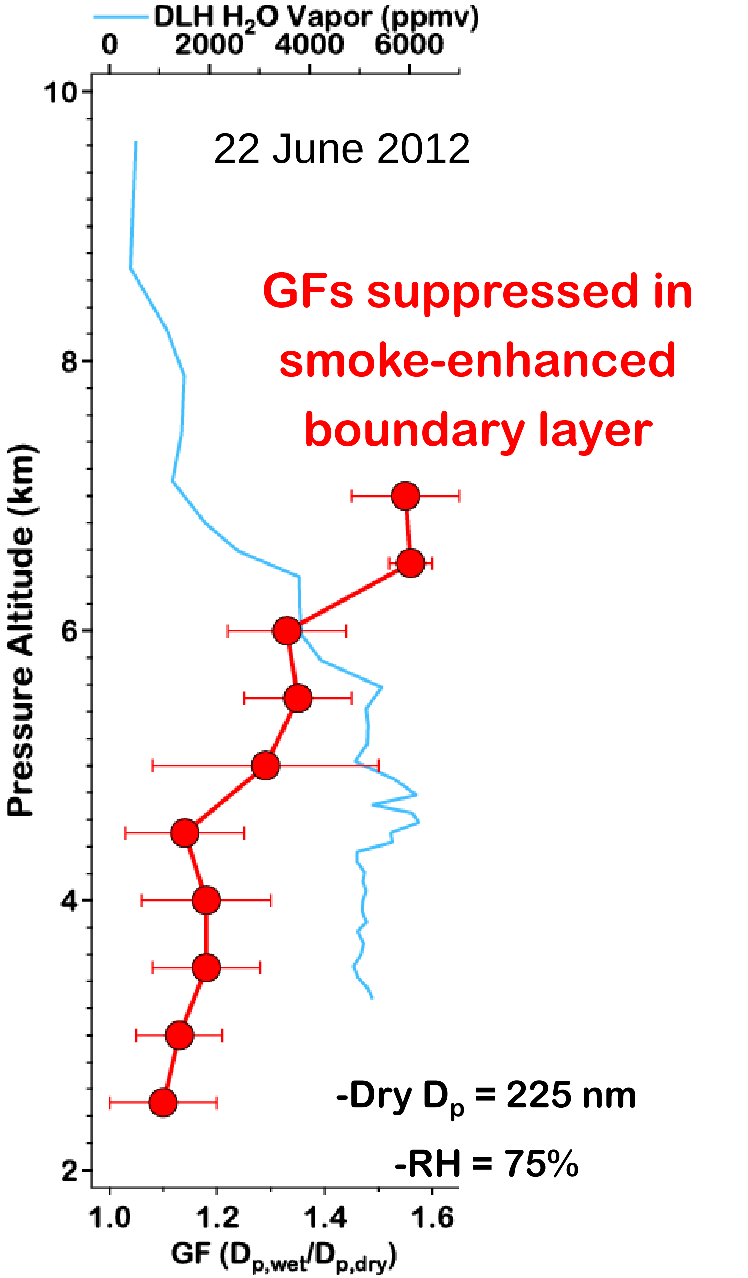
NASA HSRL group: Johnathan W. Hair, Carolyn F. Butler, Marta A. Fenn

The 22 June case

Photograph: Jim Crawford

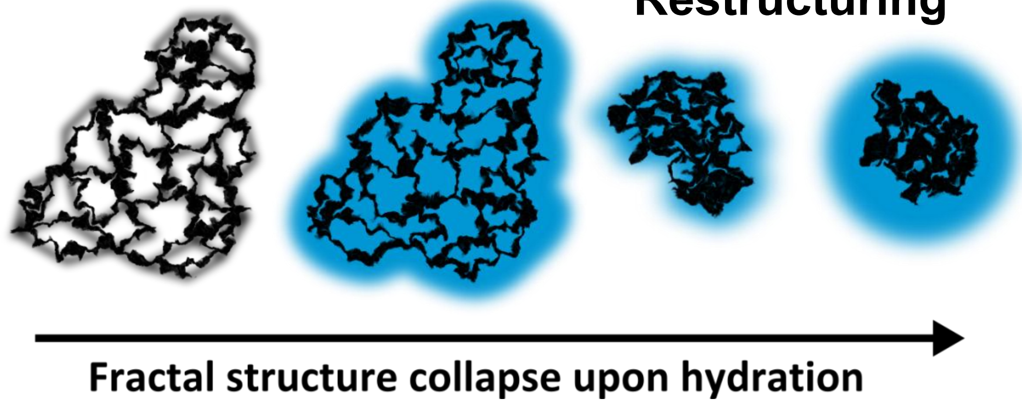
-Aerosol Hygroscopicity During RF18 (DC-8) / Colorado / Smoke Flight

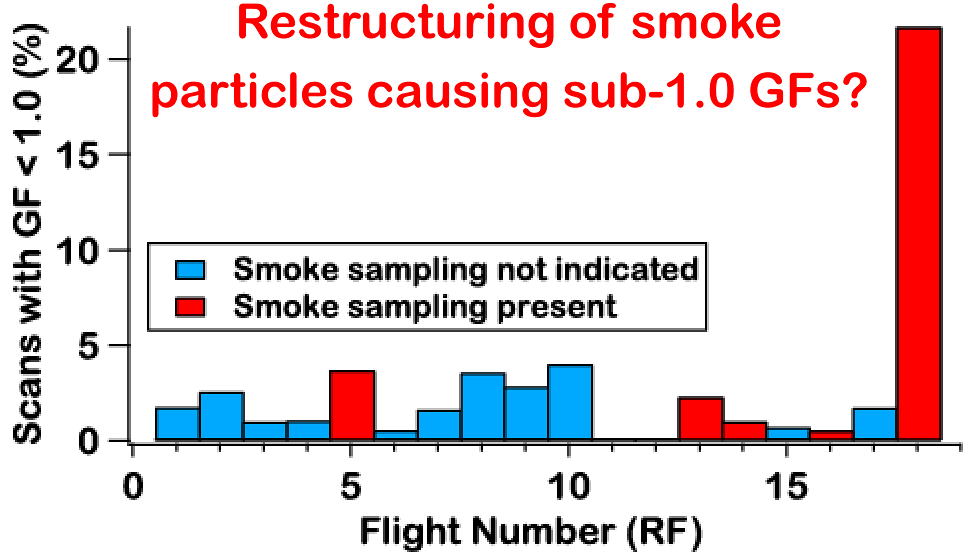
DC-8 / Taylor Shingler and Armin Sorooshian / University of Arizona



Instrument: Differential Aerosol Sizing and Hygroscopicity Spectrometer Probe (DASH-SP) → Growth Factor (GF) = $\frac{D_{p,wet}}{D_{p,dry}}$

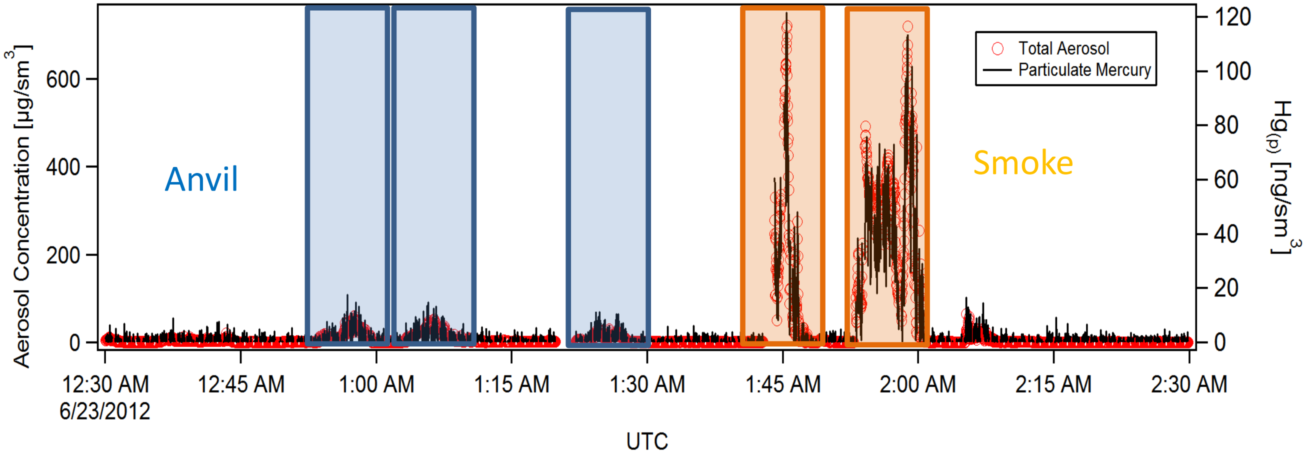
"Restructuring"



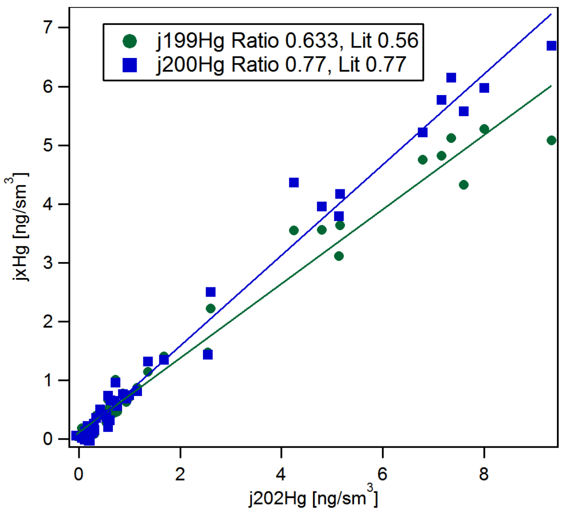


June 22 : Mercury detection

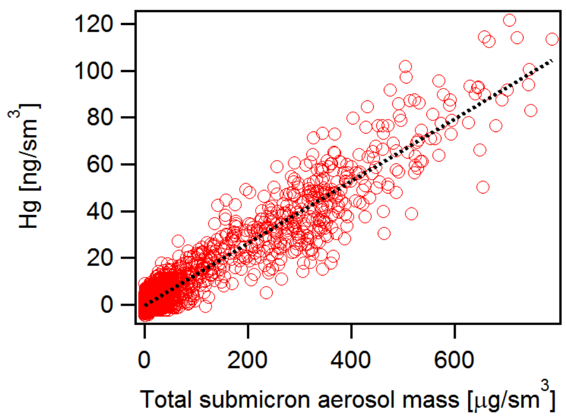
preliminary data
AMS group: Pedro Campuzano Jost, Doug Day, Brett Palm, Amber Ortega, Patrick Hayes and Jose Luis Jimenez



>100 ng/sm³ of particulate mercury in the smoke, about 10 ng/sm³ made it to the anvil at 33 kft



Despite the high organic signal at m/z 202, the isotopic ratios found in the HR fitting of the mass spectra are consistent with mercury

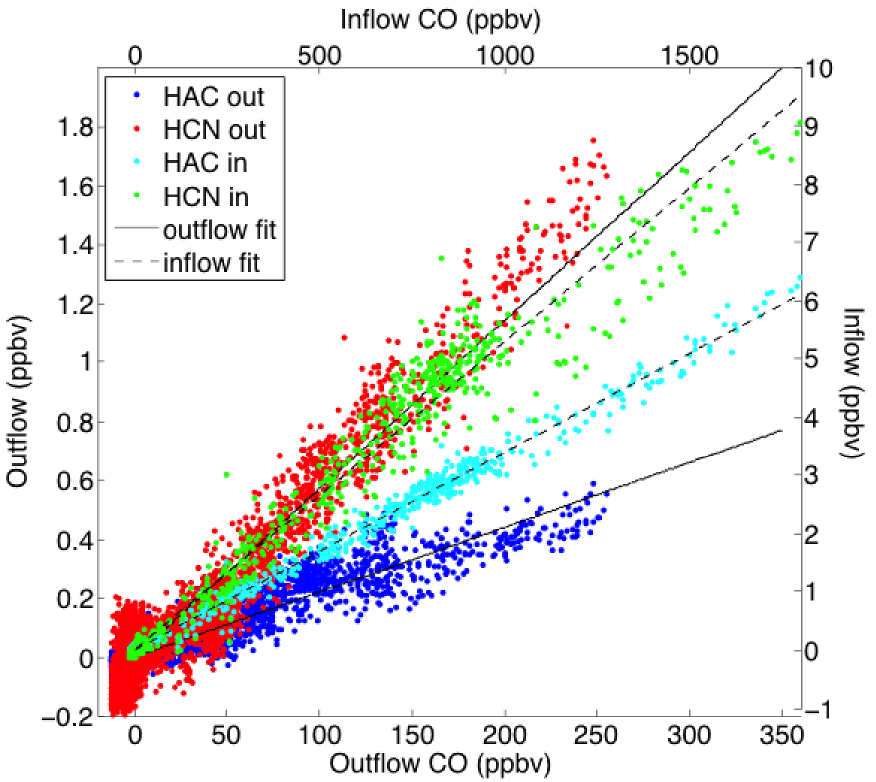


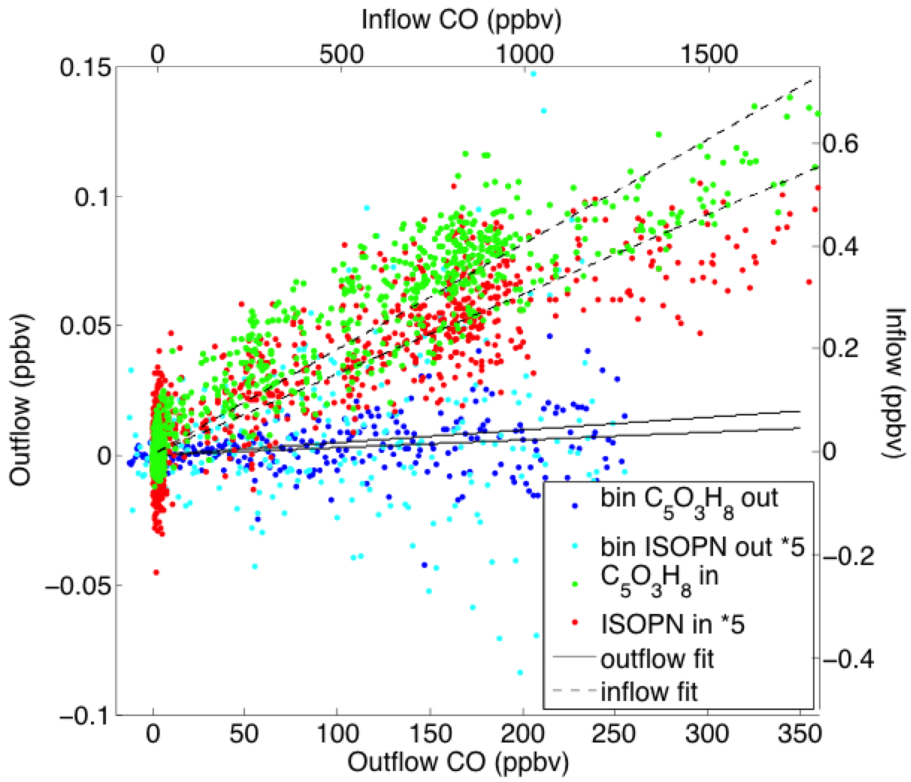
While the overall Hg sensitivity of the AMS needs to be better calibrated, a preliminary analysis leads to about ~100 ppm overall abundance in fresh BBOA

The extent of Hg evaporation in the inlet is unknown, and the overall ionization sensitivity for Hg is probably lower than assumed, so this are lower, conservative estimates.

So this suggests that biomass burning might be a larger source of particulate Hg than currently thought

Cloud processing of fire emissions: 2012 June 22



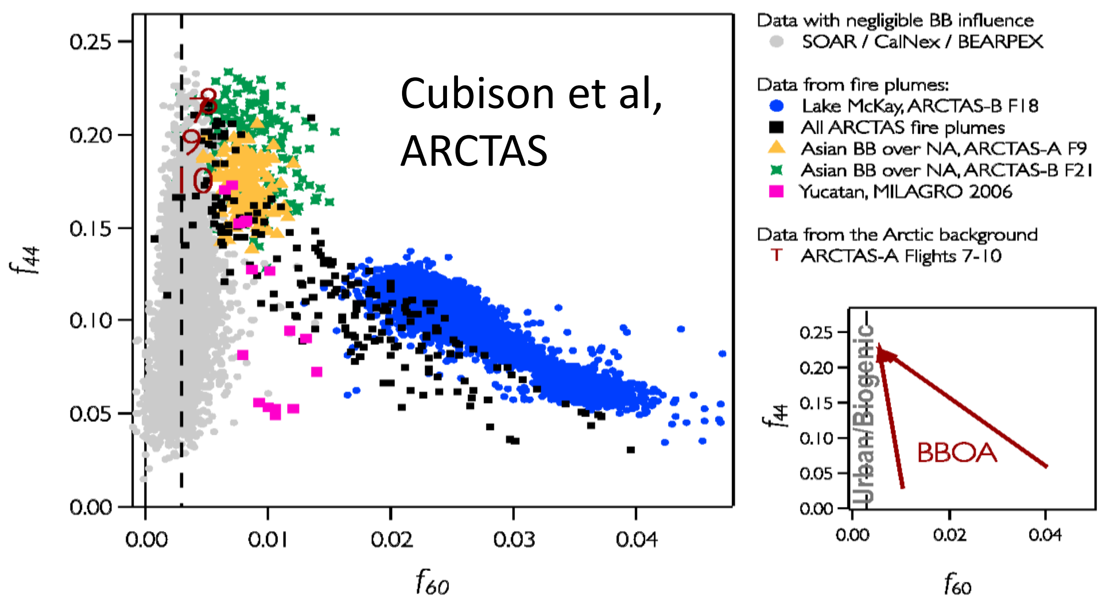


•Species measured by the Caltech-CIMS show **varied levels of removal by cloud processing**, as predicted by their different Henry's Law coefficients.

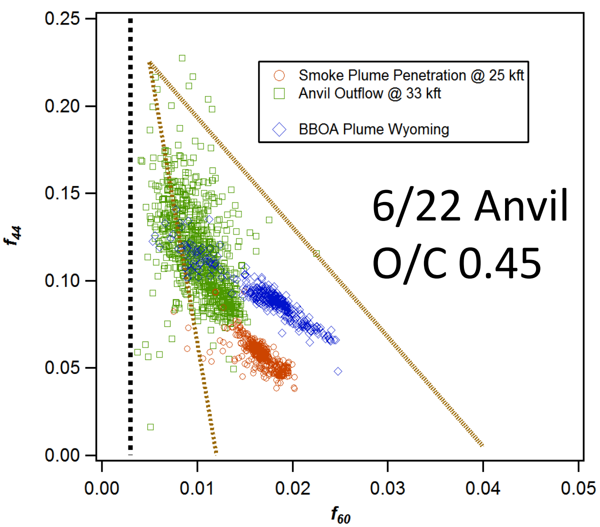
preliminary data

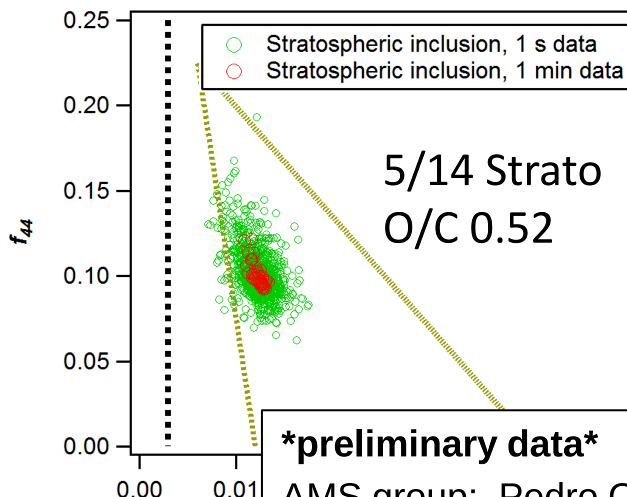
Jason St. Clair, John Crounse, Paul Wennberg

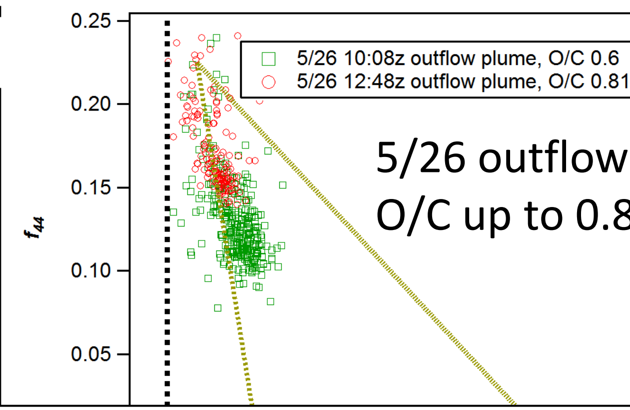
Different degrees of BBOA oxidation



The f_{44}/f_{60} triangle tries to visualize BBOA aging, as the initial levoglucosan content gets slowly oxidized.
On the 6/22 flight, the ingested smoke in the anvil was **almost as aged by the convection in a few minutes as the BBOA coming from Siberia** via stratospheric transport that was sampled on 5/14
Above background values of f_{60} were found on most flights. For outflow flights, very high degrees of oxidation were observed, often associated with acidic sulfate; if these were only 24-48 h old airmasses, this would be consistent with **much faster aging than typically assumed.**





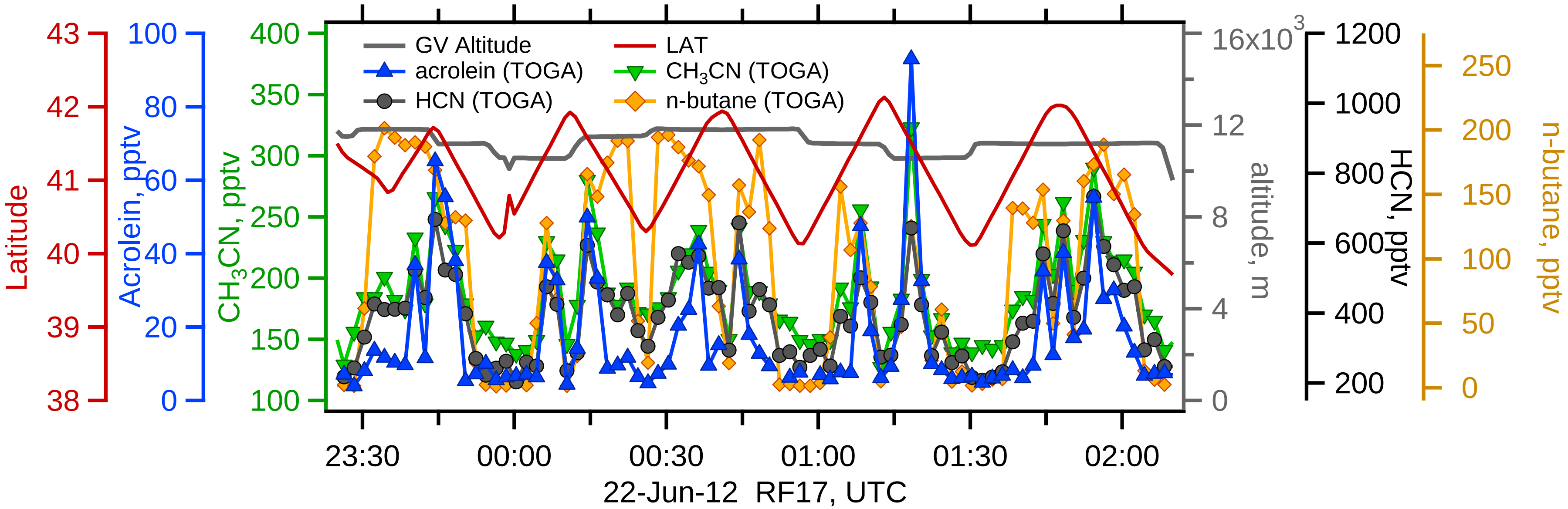


preliminary data

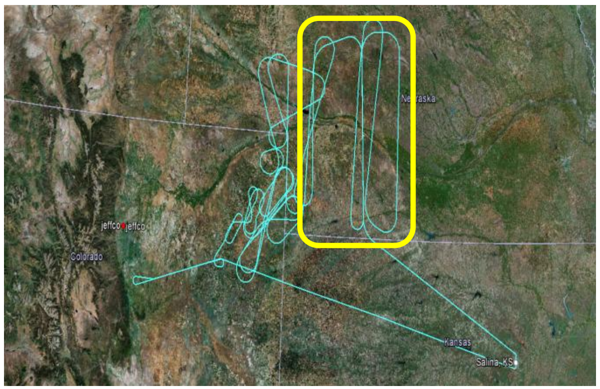
AMS group: Pedro Campuzano Jost, Doug Day, Brett Palm, Amber Ortega, Patrick Hayes and Jose Luis Jimenez

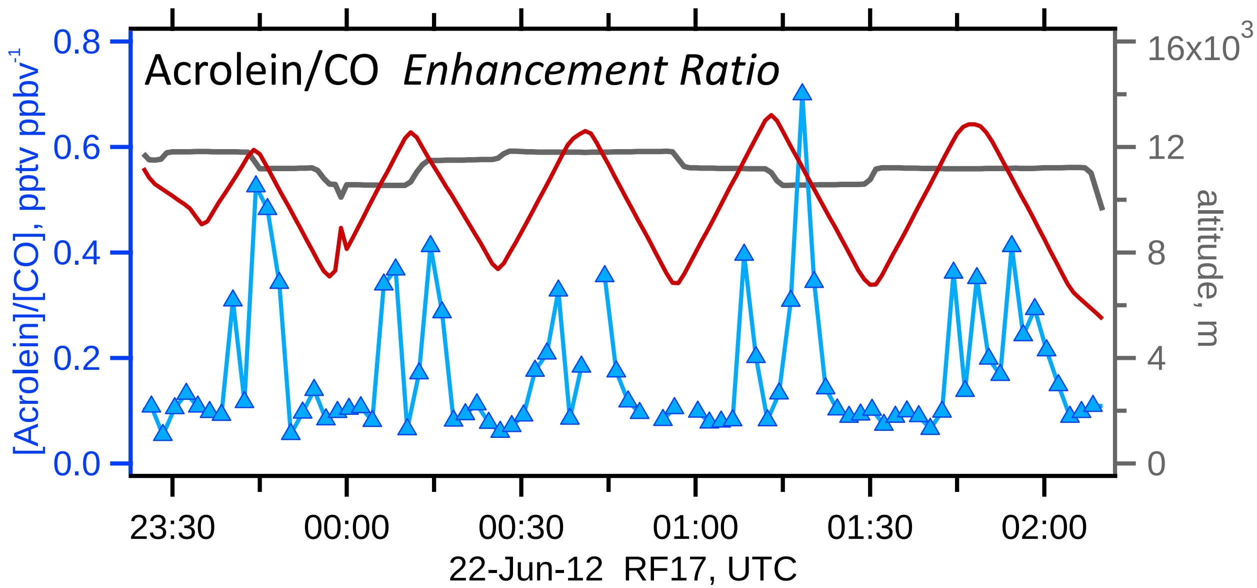
TOGA (GV), June 22 High Park Fire

High Park Fire observed tracers: HCN, CH_3CN, acrolein (k_{OH} = 2.1 x 10^{-11} cm^3 $molecule^{-1}$ s^{-1})



GV flight track



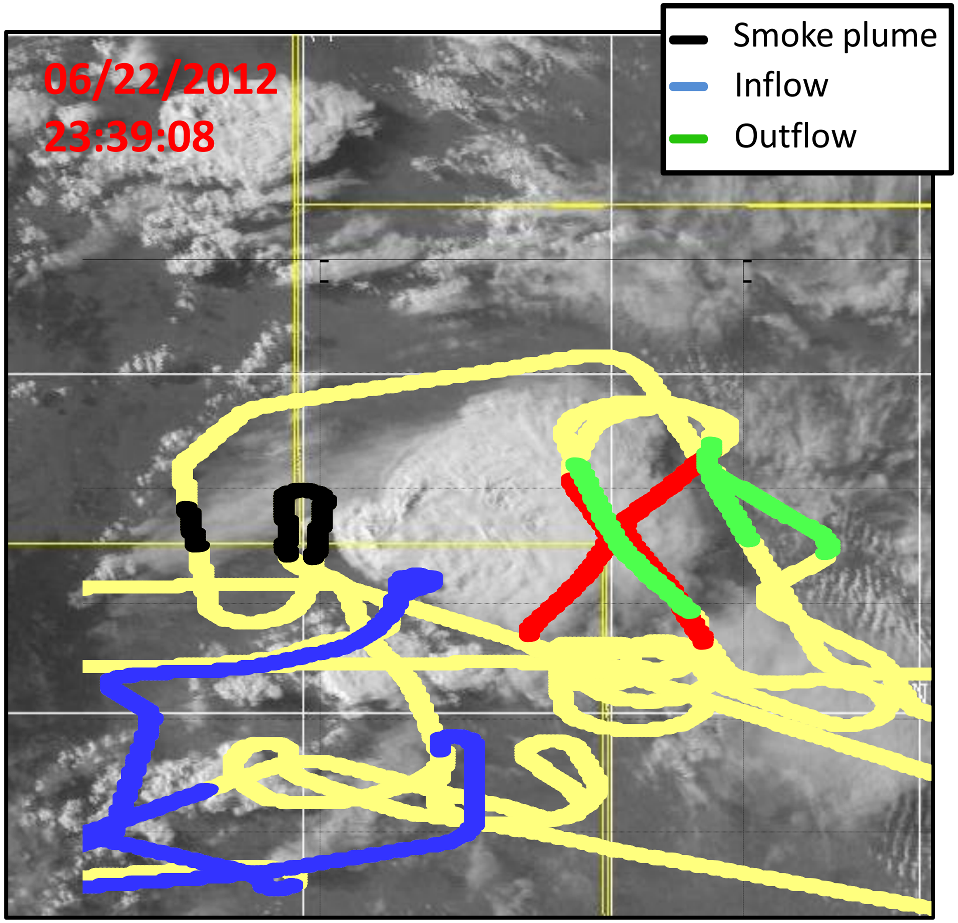


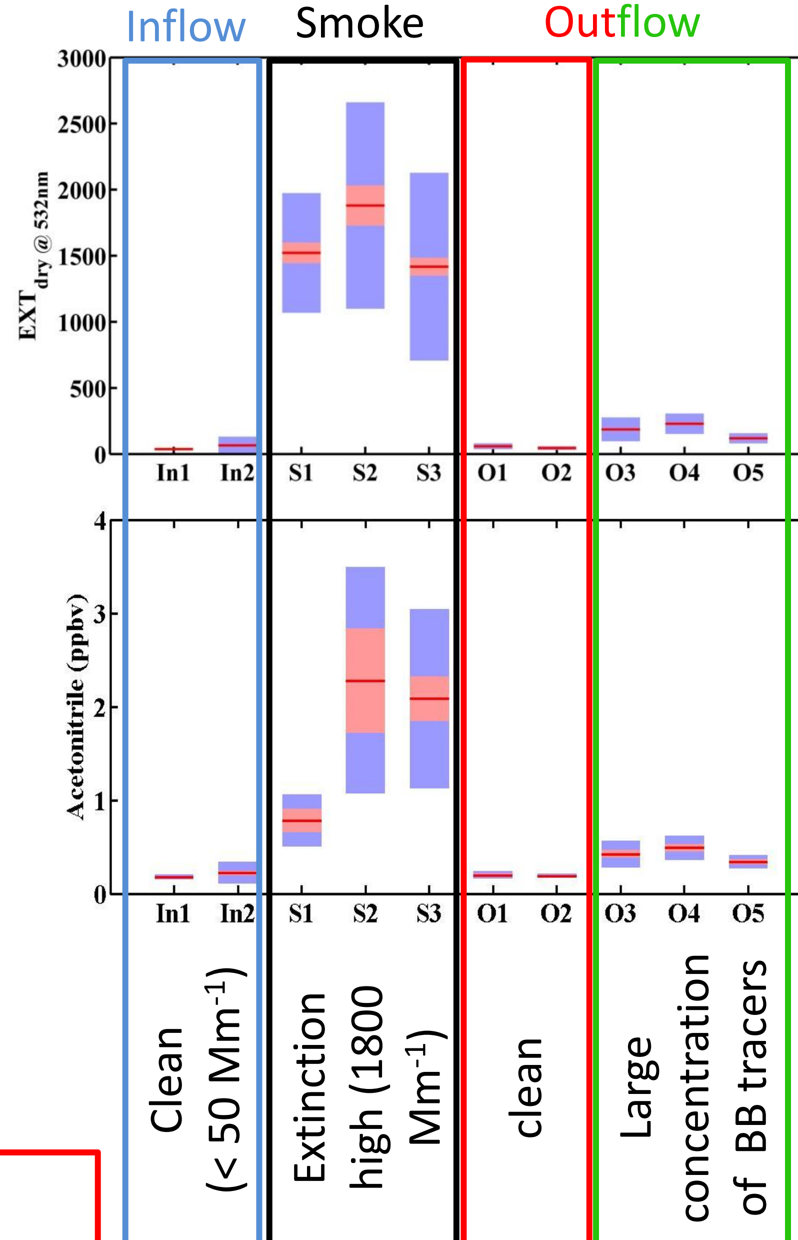
NCAR NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

UNIVERSITY OF MIAMI

TOGA group: Eric Apel, Dan Riemer, Rebecca Hornbrook, Alan Hills

Biomass burning





Timing issue or stratosphere influence (Palms meteoric evidence)

BB aerosol entrained in the cloud

preliminary data

Suzanne Crumeyrolle and the LARGE & Avocet Team

Biomass burning ONLY

<u>3 smoke periods</u> :

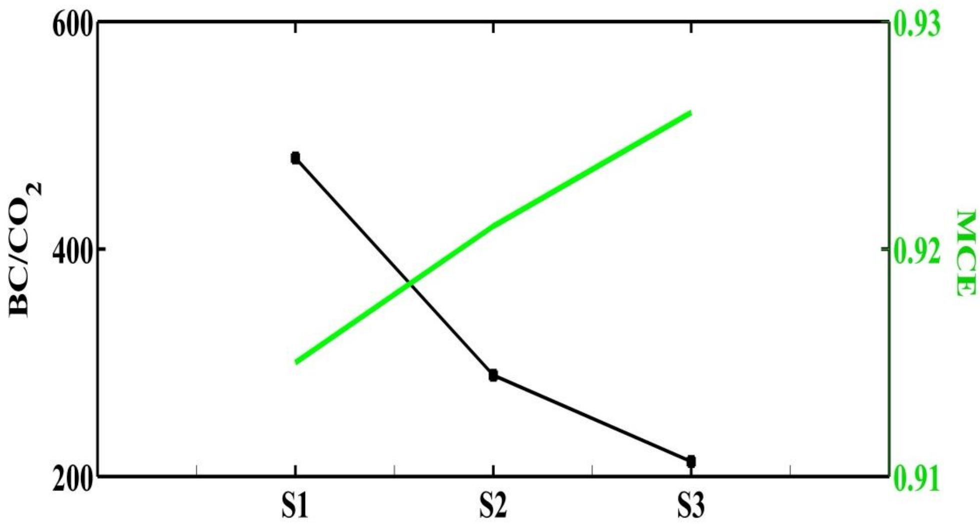
- 1 in clear sky (~ 2 min : 20:44 to 20:46 UTC)
- 2 in Cloud vicinity (~ 9 min : 1:44 to 1:46 UTC & 1:53 to 2:00 UTC)

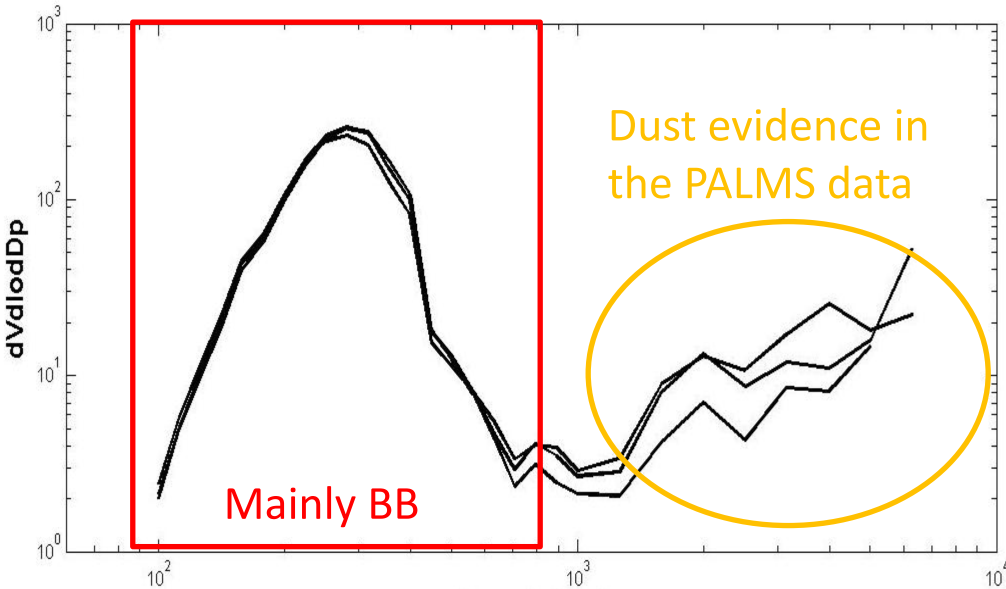
<u>Modified combustion efficiency</u> (MCE: calculated from CO and CO2) gives an indication of fire type : MCE increased from S1-S3 (more complete combustion)

- BC mass and BC/CO_2 decreased
- Size distributions are similar during the 3 periods
- fRH similar and low (~ 1.17)

➔ Work in progress

	AMS Mass (ug/m³)	BC (ng/m³)	Ext (Mm⁻¹)	SSA
S1	264	3372	1520	0.94
S2	357	3998	1880	0.93
S3	317	1670	1420	0.93

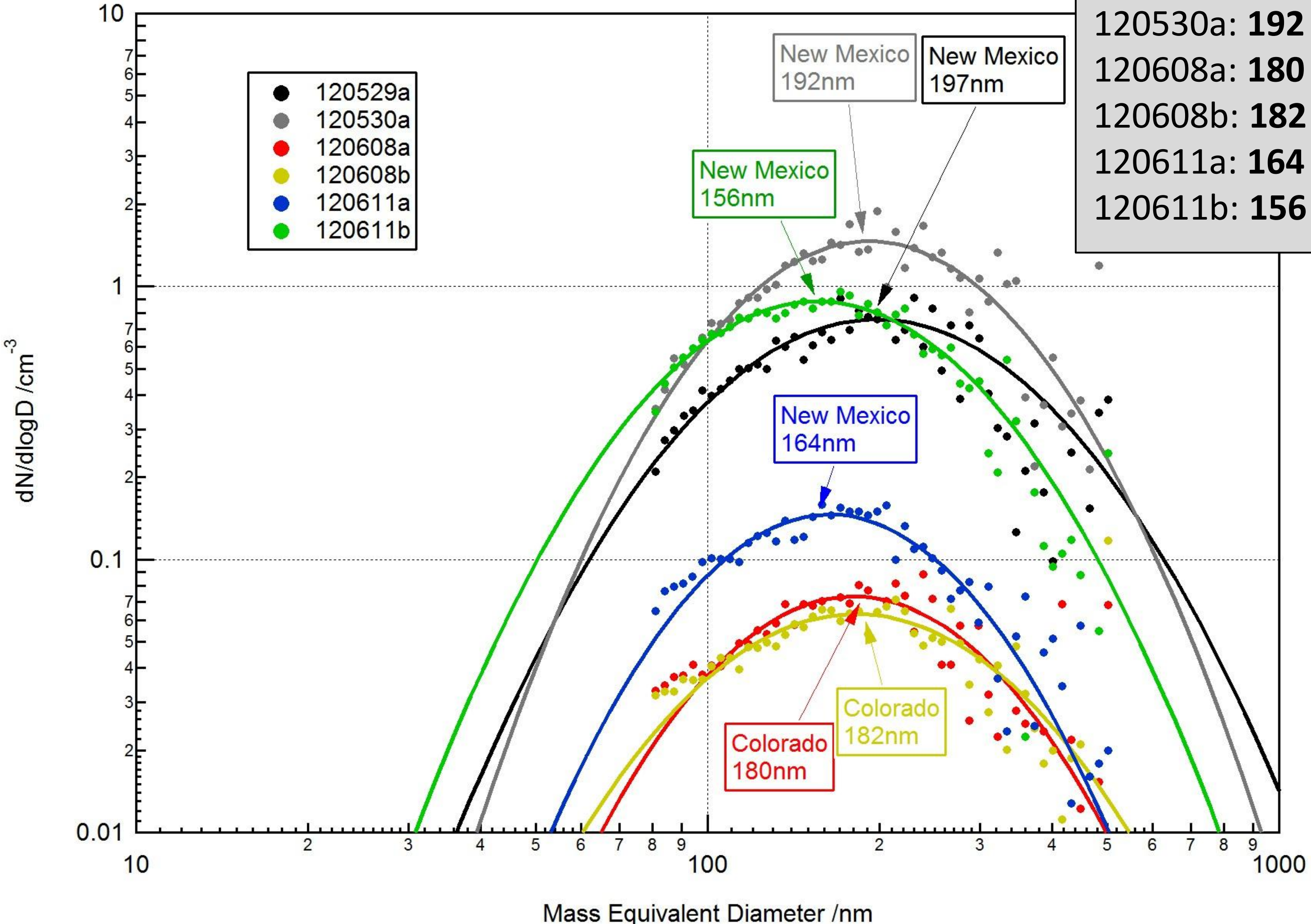




preliminary data
Suzanne Crumeyrolle and the LARGE & Avocet Team

Mass size distributions in different BB plumes

120529a: **197 nm** (New Mexico)
120530a: **192 nm** (New Mexico)
120608a: **180 nm** (southern Colorado)
120608b: **182 nm** (southern Colorado)
120611a: **164 nm** (New Mexico)
120611b: **156 nm** (New Mexico)

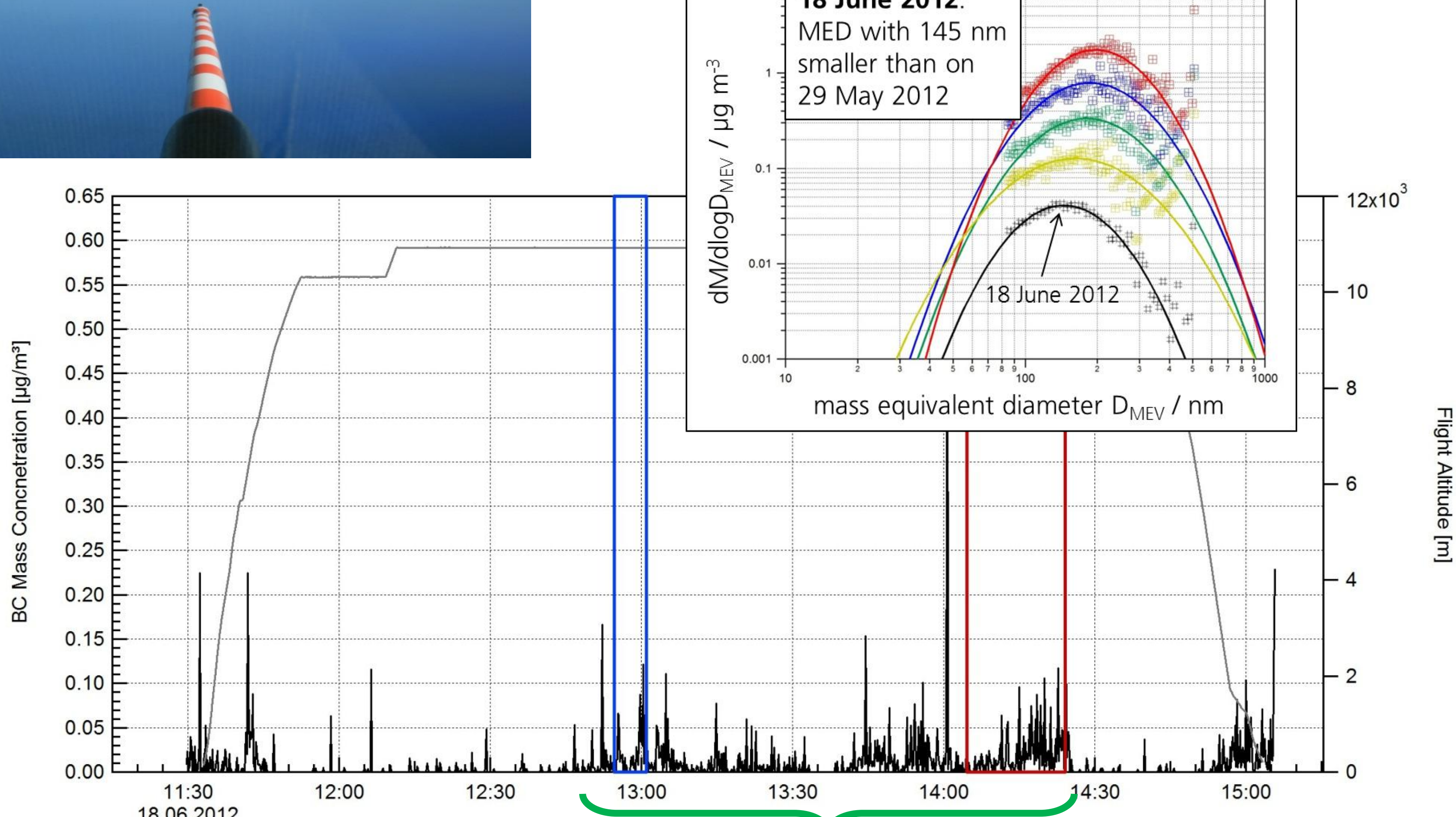


preliminary data
DLR SP2: Bernadett Weinzierl, Katharina Heimerl

DLR

Do we see size-dependent wet removal of BC?

…similar to the observations by Moteki et al. (2012)?



2 hours of flight time ~ 1500 km

preliminary data

DLR SP2: Bernadett Weinzierl, Katharina Heimerl

Summary of preliminary findings

- BB aerosol dominant in the free troposphere mainly between 2-6 km, but also observed at higher altitudes
- BB plumes contained a certain fraction of dust
- Observation of sub-1.0 GFs due to restructuring of smoke particles (fractural structure collapse upon hydration)?
- BB might be a larger source of particulate Hg than currently thought
- Observation of entrainment on 22 June 2012?
- Observation of size dependent wet removal of BC in the UT?

Wildfires – Air Quality – Health

G. Pfister, D. Edwards NCAR/NESL/ACD
P. Reddy, J. Mitchell Colorado Dept. of Public Health and Environment
Y. Liu, M. Strickland Emory University, Atlanta, GA

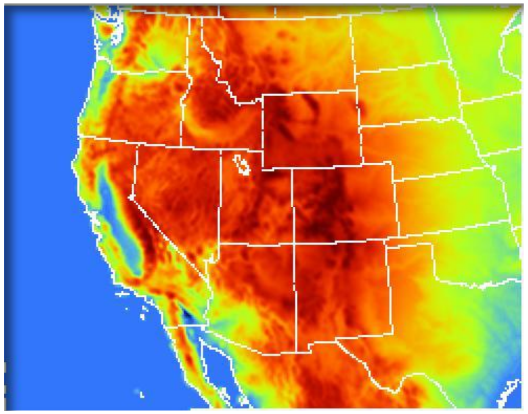
- Establish impacts of wildfires on Human health
  - Epidemiological analysis
  - Bring together air quality managers, health authorities and academic and agency scientists

- Quantify fire impact on AQ
  - Support Exceedance Demonstration

➔ WRF-Chem Modeling Analysis of Colorado Wildfires in June-July 2012

Modeling & Data

G. Pfister, D. Edwards NCAR/NESL/ACD
P. Reddy, J. Mitchell Colorado Dept. of Public Health and Environment
Y. Liu, M. Strickland Emory University, Atlanta, GA

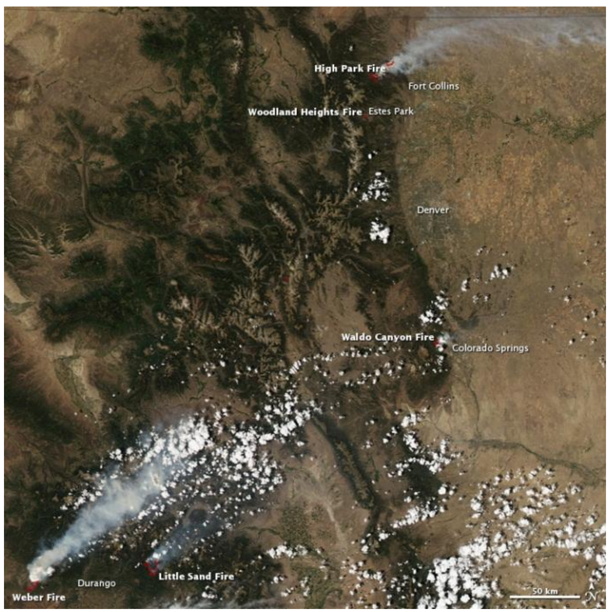


- WRF-Chem: 12 x 12 km^2 Western U.S.
- Different Setups:
  - WRF-Chem free running
  - Analysis nudging
  - DART/WRF
- MOZART gas phase chemistry & MAM or GOCART aerosol scheme
- Emissions:
  - Anthropogenic : EPA NEI projections for 2011; CDPHE inventory
  - Fire Emissions: NCAR FINN V1; online plumerise
  - Biogenic: MEGAN online
- Chemical IC and BC from global MOZART-4 forecasts
- Data Sets: EPA Surface Network, CASTNET, Satellite (MODIS AOD, MOPITT CO, IASI CO and O3, OMI NO2, MISR Plumerise), DC-3

G. Pfister, D. Edwards , P. Reddy, J. Mitchell, Y. Liu, M. Strickland

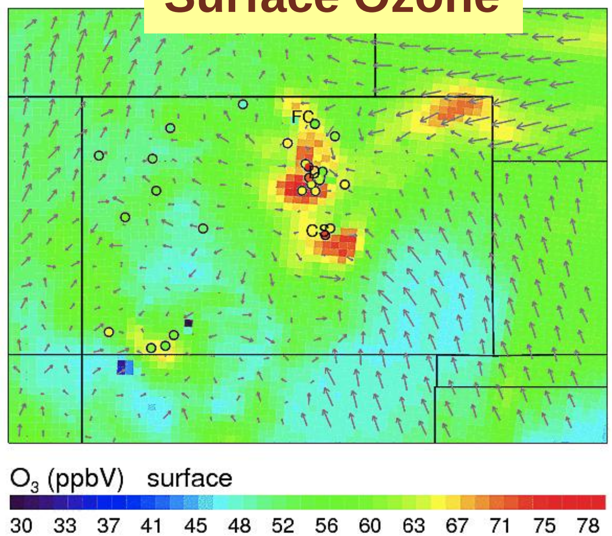
Example - Widespread Fire Activity

24 June

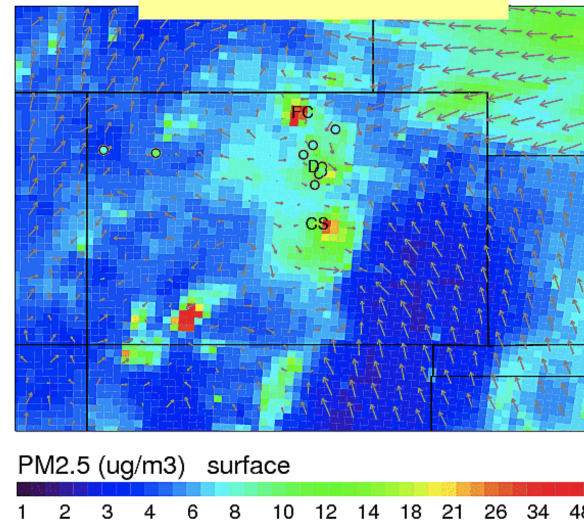


MODIS Aqua

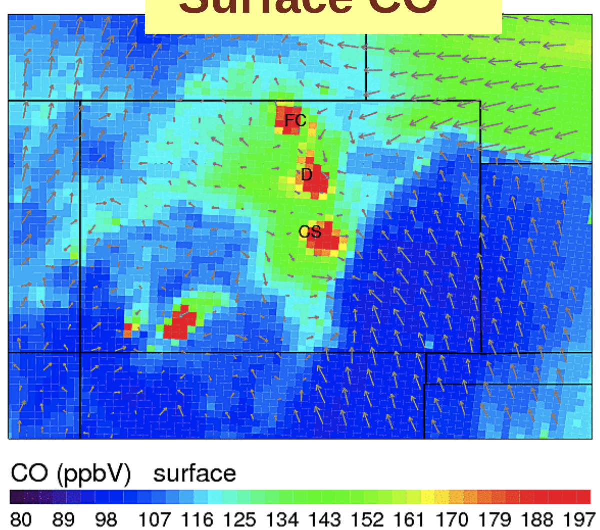
Surface Ozone



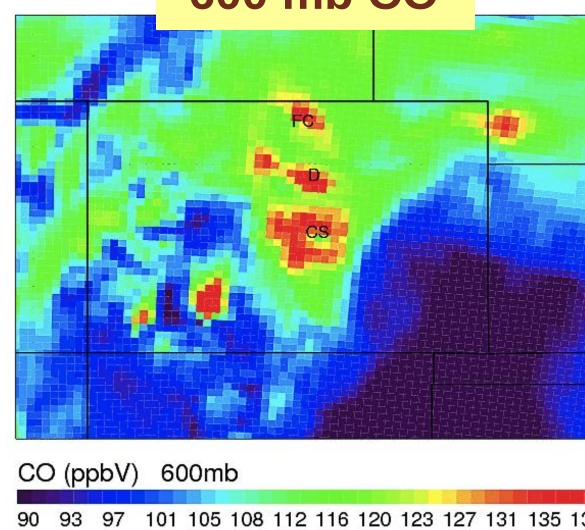
Surface PM2.5



Surface CO

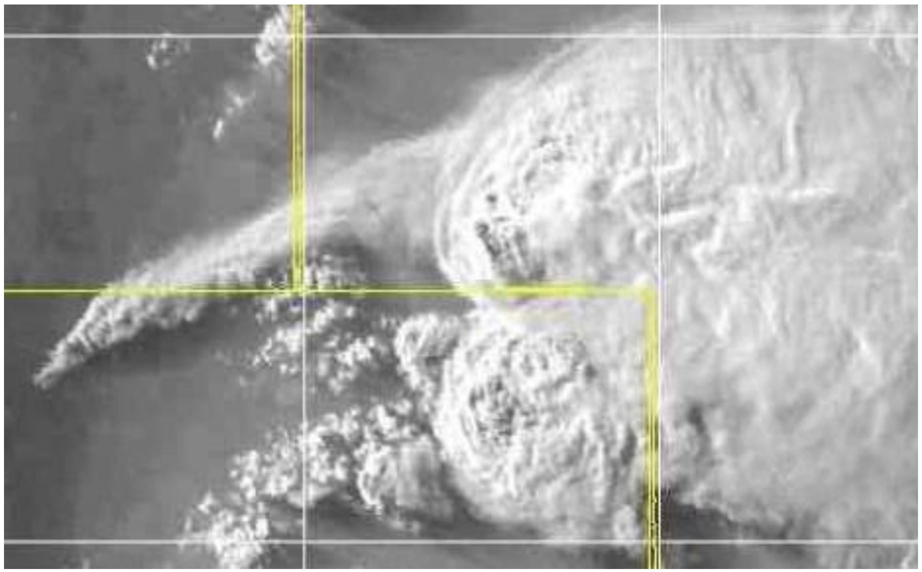


600 mb CO

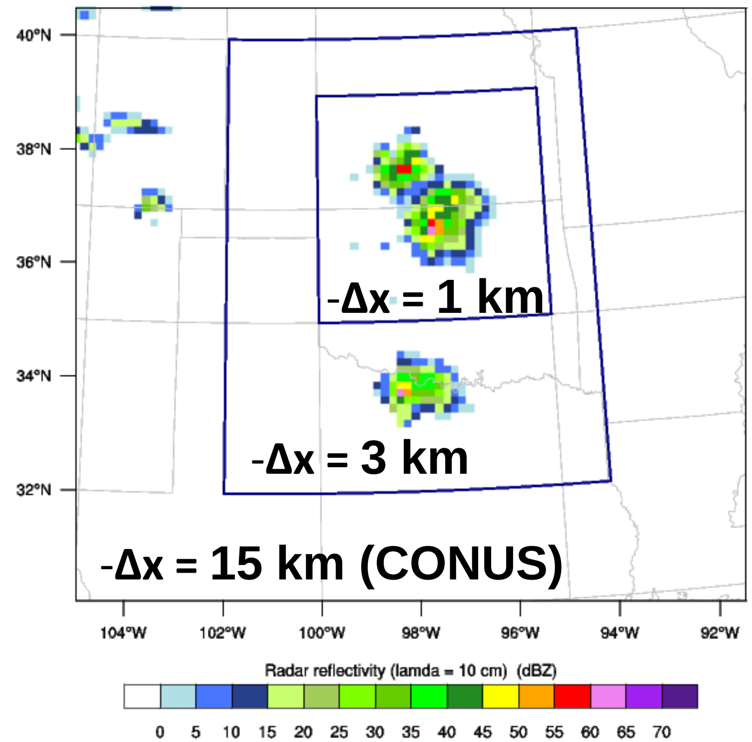


High-Resolution WRF-Chem Simulations of June 22 Case
(Bela, Barth)

Simulate June 22 NE CO storm (interaction with High Park Fire)



Domains (ex. for May 29 storm)



Science Questions:

- How well does WRF-Chem represent fire plume rise and emissions?
- How much smoke is ingested by the storm?
- How is smoke transported / chemically transformed within storm?

Further research/scientific questions

Christine Wiedinmyer:

- I am currently working on emissions from open biomass burning, and have emission estimates from fires during the DC3 mission.
- → I am happy to share the emission estimates with anyone interested, and I appreciate any and all feedback.

Further research/scientific questions

Taylor Shingler and Armin Sorooshian:

- Is particle restructuring evident in biomass burning plumes during DC3?
- How do biomass burning particle water-uptake properties change as a function of age during DC3 events?
- How well do current model parameterizations for water-uptake predict observed biomass burning aerosol hygroscopic properties?

PALMS group (Froyd, Liao et al.)

The PALMS group is not planning to lead a BB paper for DC3, but they are happy to support other projects.

- How to best estimate plume age or origin (either through trajectories or chemically), and particularly, the age of the dilute 'background' BB aerosol that was prevalent during DC3?
- It would be interesting to find a case where BB aerosol were lofted by convection.

DLR

Further research/scientific questions

Suzanne Crumeyrolle and the LARGE & Avocet Team:

- Oxidation/ageing of the BB aerosol in the cloud free atmosphere
- Outflow characterization : BB influence on particle microphysical, optical and chemical properties
- Interactions aerosol/cloud :
    - Is the cloud formation linked to the smoke plume presence ?
    - Evidence of high IWC in this cloud

➔ Simulation of the case would be needed : Anybody interested ?

Further research/scientific questions

DLR/NOAA SP2 groups:

- How do **microphysical properties of biomass burning** (BB) **vary** between sources, events, and as a function of aging?
- How does BB affect the **vertical and spatial distributions of BC** in the DC3 sample region?
- Do we see **differences** between **mid-tropospheric and upper tropospheric BB** plumes?
- What is the relationship/variabiltity in the **BC/delta-CO relationship** from different BB events?
- What is the **injection height** associated with the BB plumes observed and **how often do upper tropospheric BB occur**?
- Contribution of **BB and aviation soot** to UT aerosol composition
- (How do internal mixtures with BB BC interact with water vapor?) (NOAA)

Further research/scientific questions

Hornbrook and the Toga group:

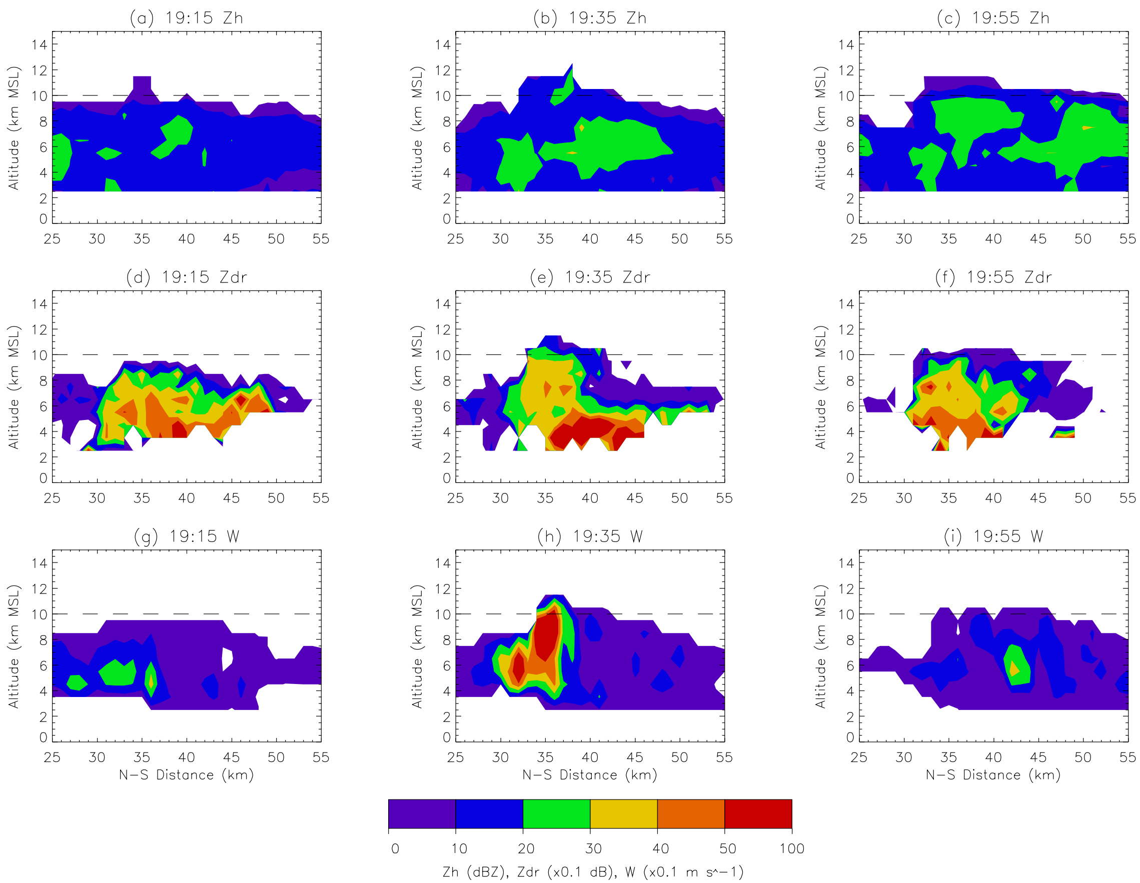
- Various fire tracer measurements, including the alkene and acrolein measurements, that we observed with TOGA during DC3, particularly on 22-June
- Investigate differences in the northern v. southern portions of the **outflow from the 22-June storm** to investigate any differences in the primarily **anthropogenically-influenced** outflow air versus the air that is highly **affected** by the **High Park fire smoke plume**.

Sebastian Schmidt et al.:

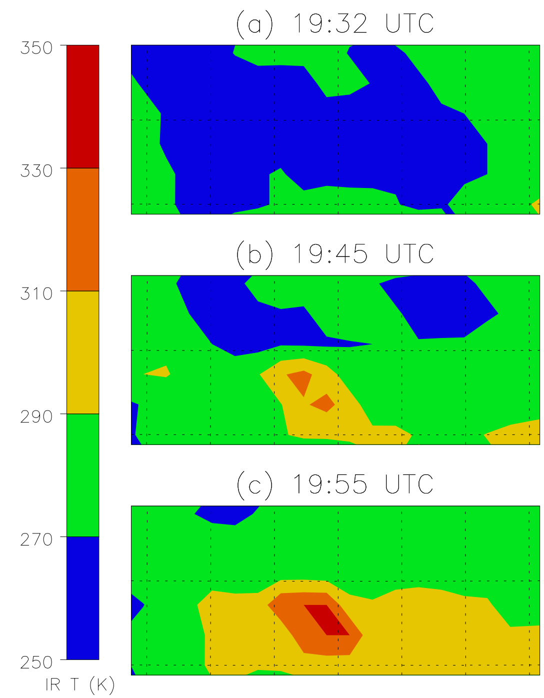
- Determine aerosol radiative forcing of fire plumes from SSFR and HSRL measurements.
- Retrieve aerosol single scattering albedo and compare with direct measurements.

DLR

Pyrocumuli above three Colorado forest fires (Hewlett Gulch, High Park, and Waldo Canyon) electrified and produced small intracloud discharges whenever the smoke plumes grew to high altitudes (over 10 km MSL). This normally occurred during periods of explosive wildfire growth. This suggests an application for lightning observations in pyrocumulus clouds.



DC3 radars observed Hewlett Gulch plume electrification. Strong updrafts in the plume led to subsequent electrification at high altitudes.



GOES shortwave IR hot spot, indicating fire intensification, occurs as the Hewlett plume electrifies

Timothy Lang

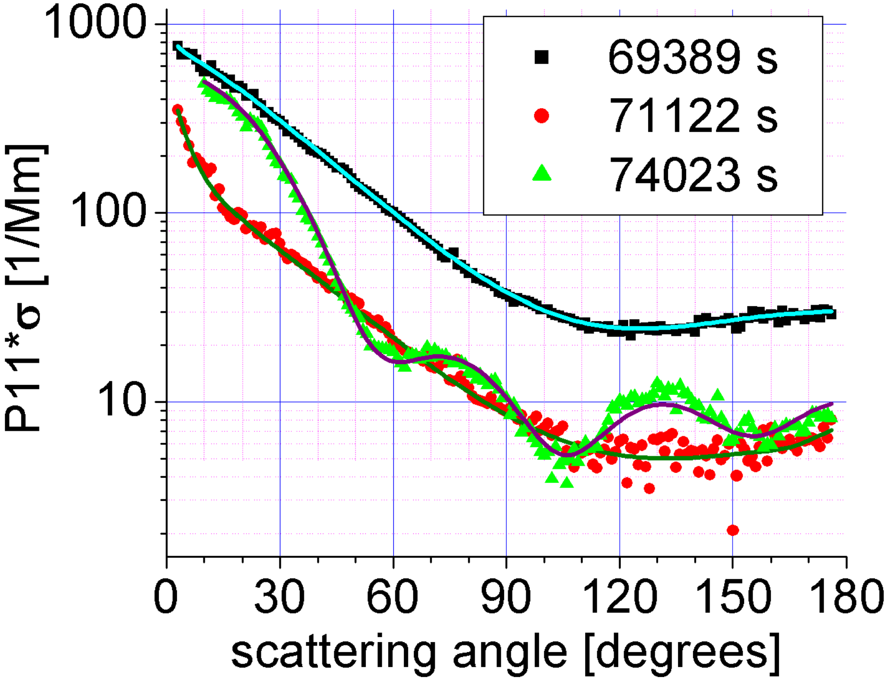
Further research/scientific questions

Timothy Lang and CSU/MSFC:

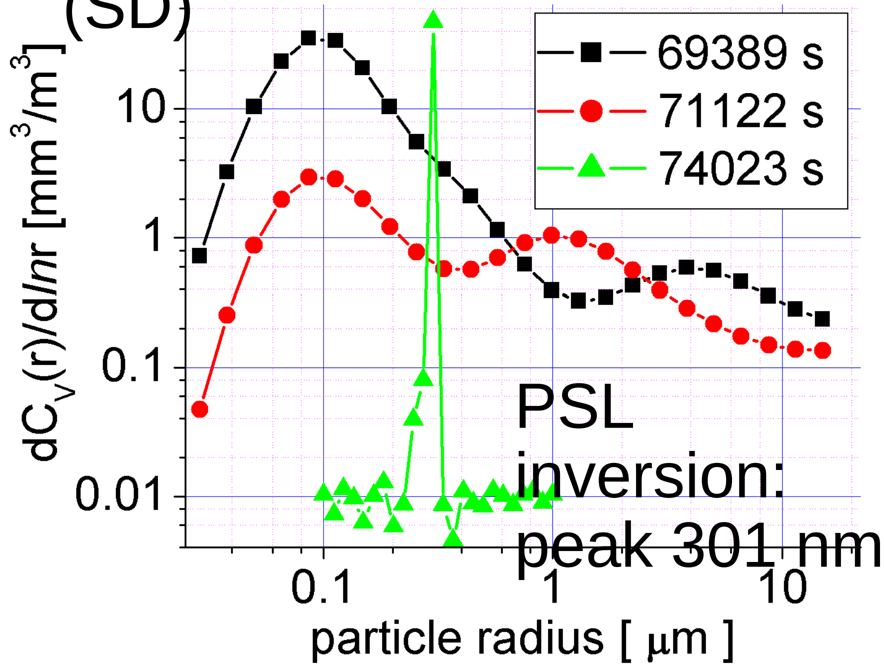
- Use DC3 Colorado radar data to compare the microphysical and kinematic structures of storms ingesting **smoke against those of storms in cleaner air**. Follow up with a larger regional analysis of smoky/clean convection using the newly upgraded polarimetric NEXRADs. Compare with model and satellite analyses.
- Do smoke-affected **anvils persist longer** than unaffected ones, which would have potentially important downstream energy/water-cycle impacts?
- What are the **impacts of smoke aerosols on cold-phase** microphysical processes?
- Can **lightning** in pyrocumulus be used to identify rapidly growing wildfires?
- What role do **smoke aerosols** play in causing **anomalous electrification** of thunderstorms?

Inversions of DEVOTE R04 data

30s scattering data and fits



inverted size distributions (SD)



UTC [s]	σ [Mm^{-1}]	SSA	n	k
69389	100	0.94	1.39	0.005
71122	25	0.86	1.60	0.023
74023	47	0.915	1.636	0.028

AERONET style, 25 size bins
1^{st} and 2^{nd}: biomass burning (?)
3^{rd}: PSL, NIST < r > = (300±5)nm
n_{web}-$n_{retrieved}$ = 0.037 = Δn

n_{web}: http://refractiveindex.info/?group=PLASTICS&material=PS

$\Delta n_{required}$ = 0.02 Mishchenko, et al, JQSRT, 2004

Further research/scientific questions

Dolgos and PI-Neph Group:

- What is the **range of variability of phase function** (P11) and degree of linear polarization (P12) of biomass burning.
- From the PI-Neph data of P11 and P12 we will retrieve **size distribution** and **refractive index** of aerosol with an algorithm that is adapted from AERONET.
- We will want to **add absorption information** to the input of the retrieval to better **constrain the imaginary refractive index**.
- How good is the comparison of retrieval results with conventional size distribution measurements for biomass burning aerosol?
- What is the **estimated lidar ratio** from dry in situ measurements up to 176 degrees? Extrapolations with AERONET type fits.

Gaps

- „Satellite perspective“ on biomass burning aerosol:
  - Detection of biomass burning plumes with satellites, comparison with modelling
  - Can BC outflow be detected from satellite images?

- Where is all the BC in the UT coming from? Is it all biomass burning?

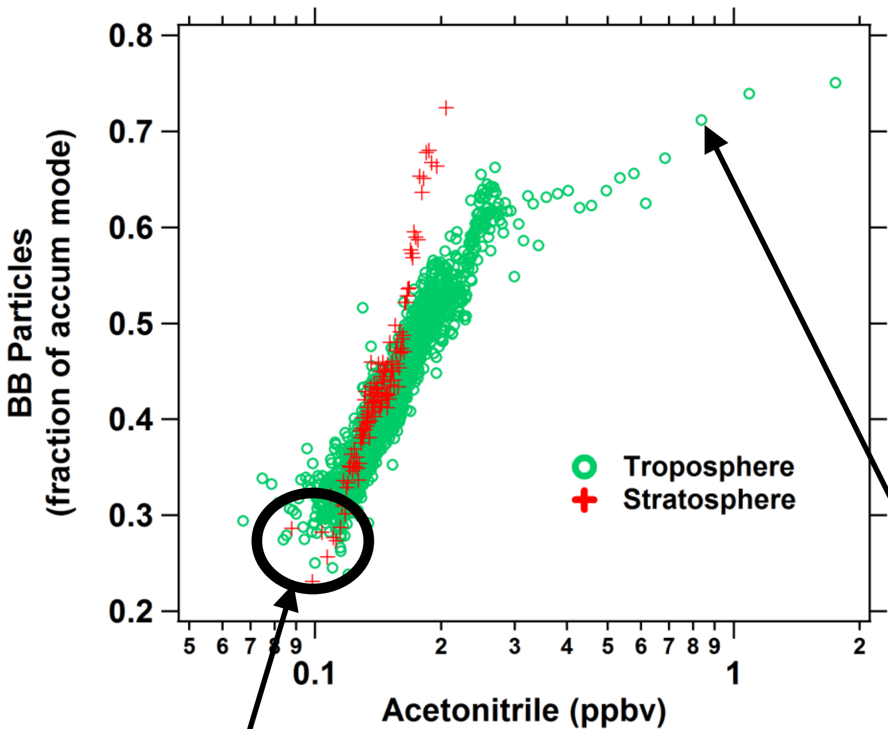
Backup

Karl Froyd
Jin Liao

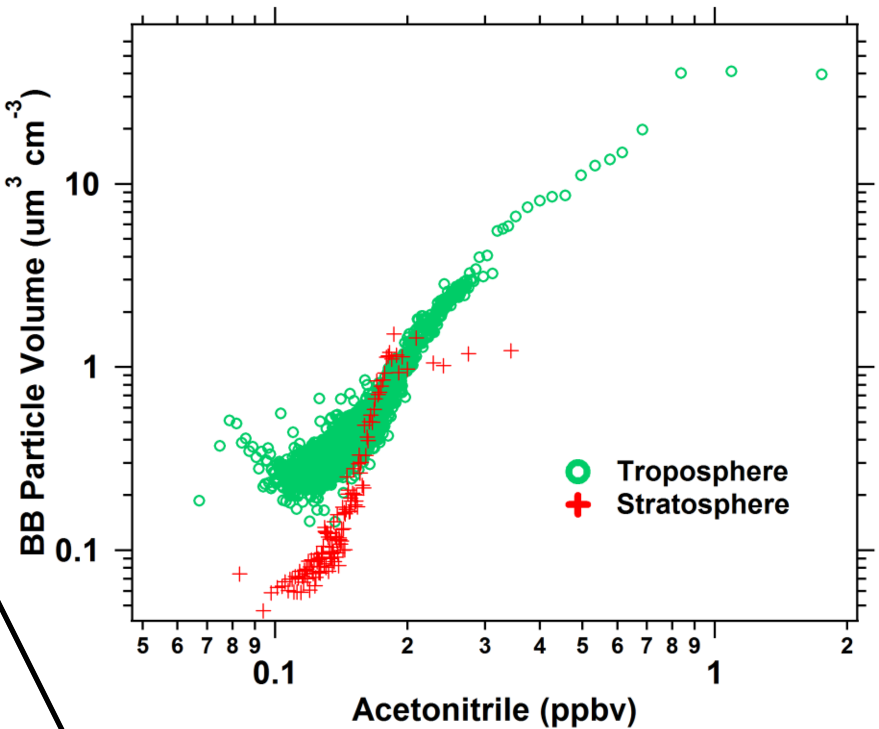
PALMS - Biomass Burning Particle Tracer

"BB particle" = mostly OC mass, trace EC and inorganics

Correlates with Acetonitrile



Combine with size distribution instruments to get BB Particle Volume



Typical clean UT air

~25% of accumulation mode aerosol contain BB material

In strong plumes

75% of accumulation mode aerosol contain BB material.

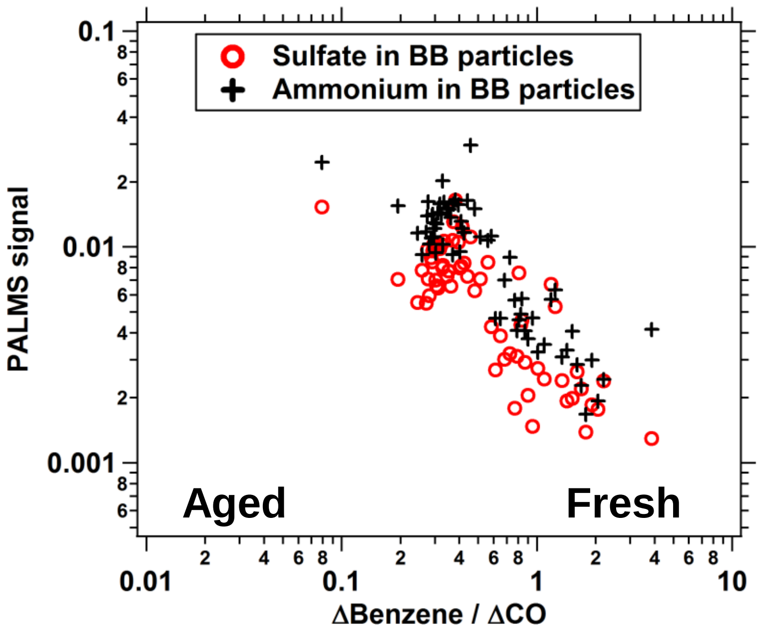
(The rest is Dust, EC, Other)

An Attempt at BB plume Aging – preliminary!

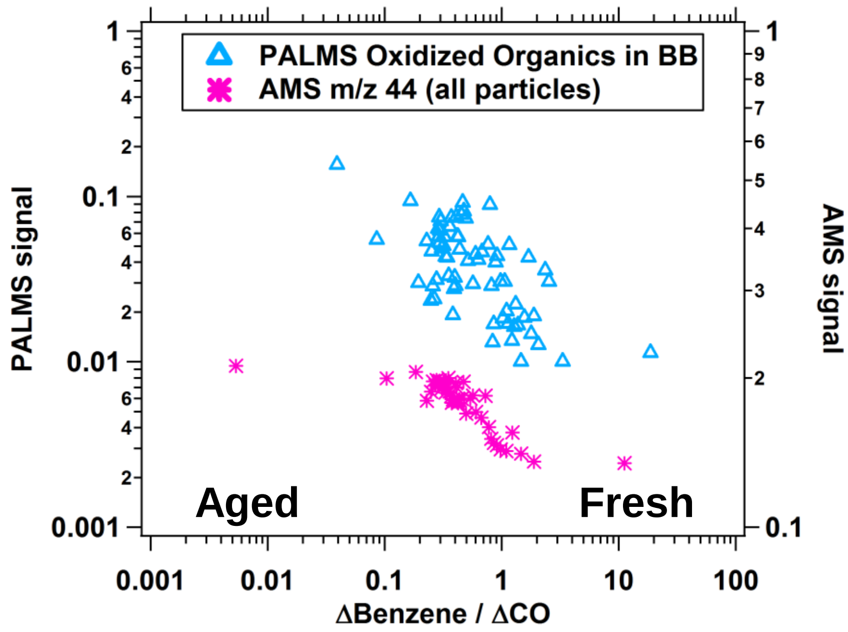
Most DC3 Benzene was from BB

Use Benzene loss as photochemical clock

Look within defined plumes, look just at BB particles



Secondary species increase with time



Organic material becomes more oxidized

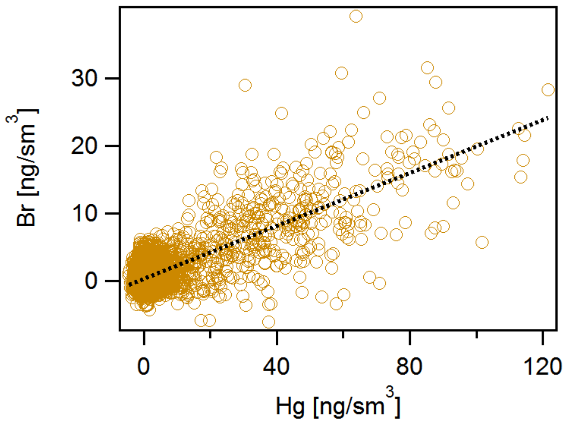
Caveats:

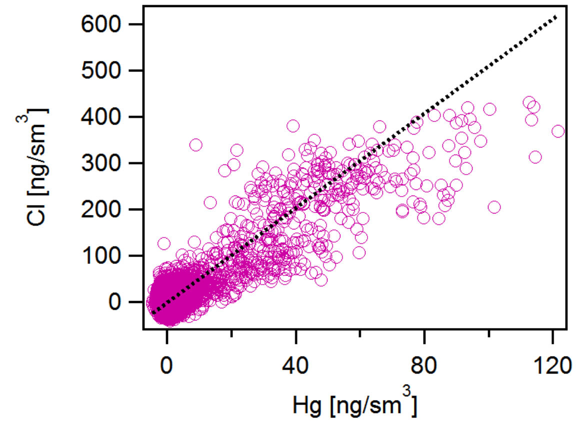
- Assumes same emissions factors for different fires (Asia vs US, fuel types, etc)
- Cloud processing will affect all these

preliminary data

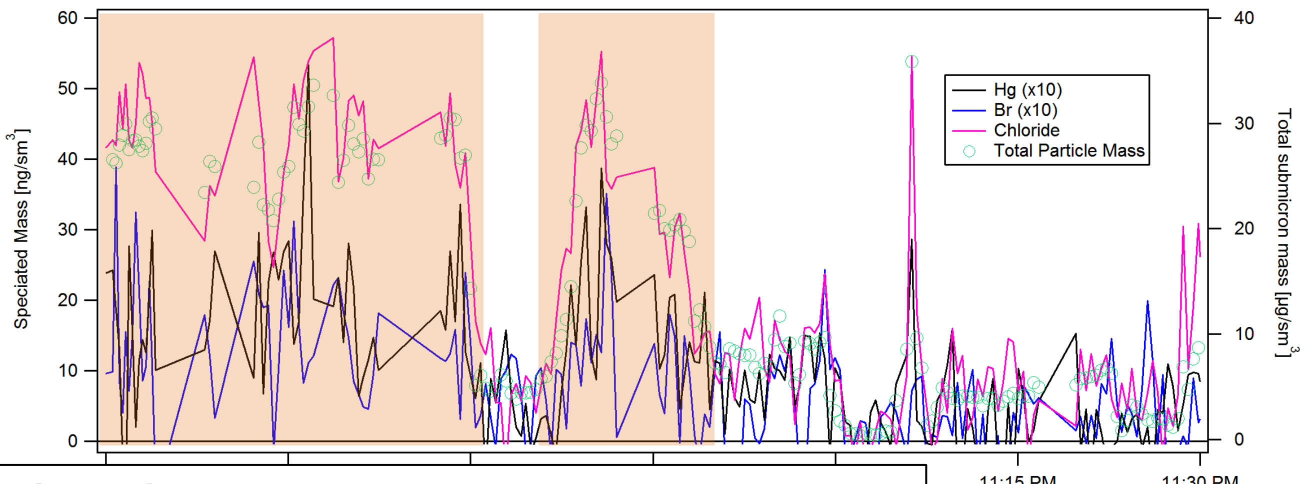
PALMS group: Karl Froyd, Jin Liao

Hg/X chemistry and the 5/14 Flight





While particulate mercury has often been associated with $HgBr_2$, and bromine was indeed detected during the 6/22 flight, with realistic calibration factors a 1:2 stoichiometry cannot be achieved, so part of the mercury might be bound otherwise (ie there is plenty of chloride present)



The stratospherically transported BBOA detected on the 5/14 flight showed traces of both mercury and bromide (barely above DL).

The ratio of Hg/Total Mass is consistent with the one found for the 6/22 flight

preliminary data

AMS group: Pedro Campuzano Jost, Doug Day, Brett Palm, Amber Ortega, Patrick Hayes and Jose Luis Jimenez