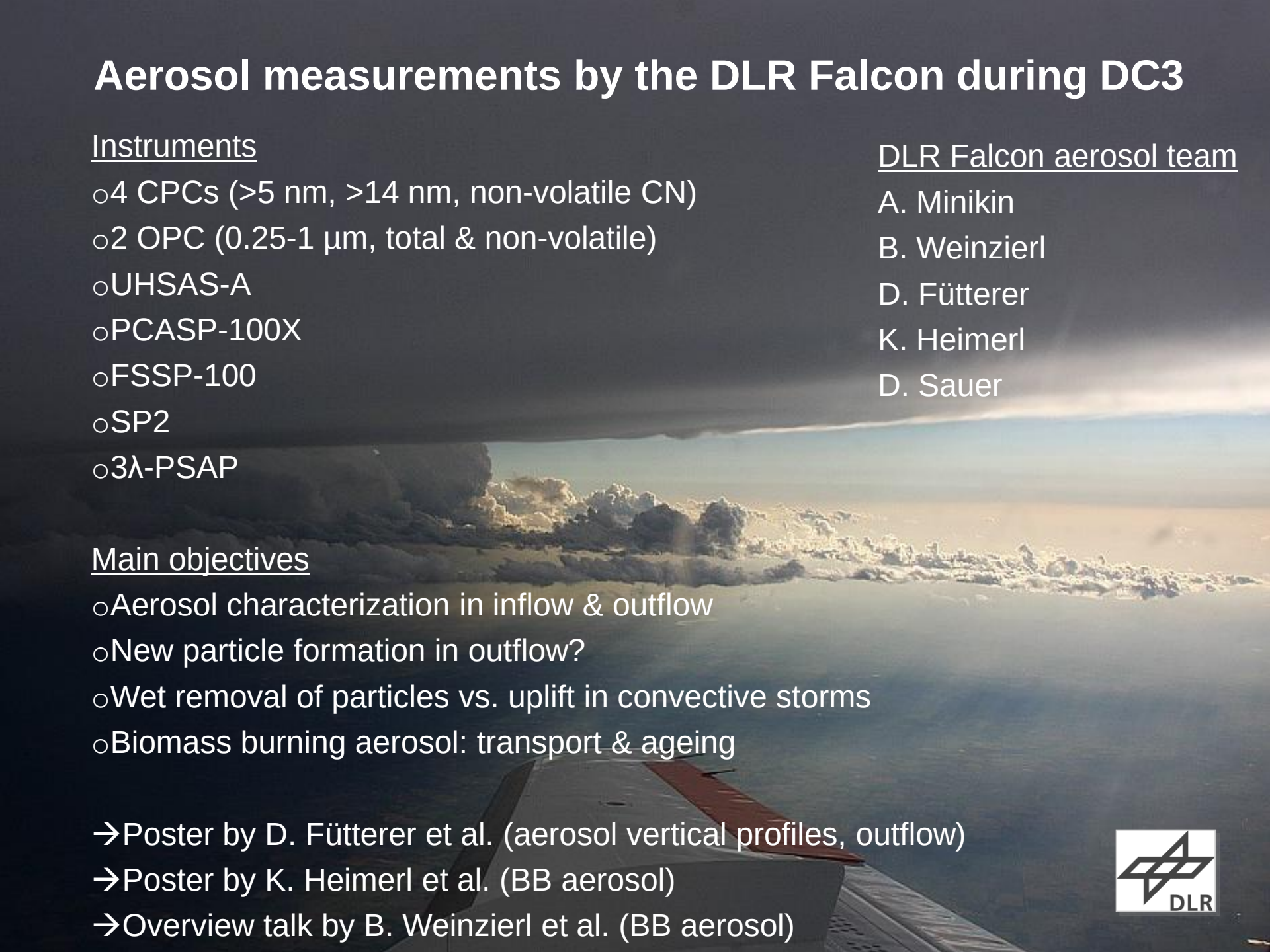
Aerosol measurements by the DLR Falcon during DC3



Instruments

- 4 CPCs (>5 nm, >14 nm, non-volatile CN)
- 2 OPC (0.25-1 µm, total & non-volatile)
- UHSAS-A
- PCASP-100X
- FSSP-100
- SP2
- 3λ-PSAP

DLR Falcon aerosol team

A. Minikin

B. Weinzierl

D. Fütterer

K. Heimerl

D. Sauer

Main objectives

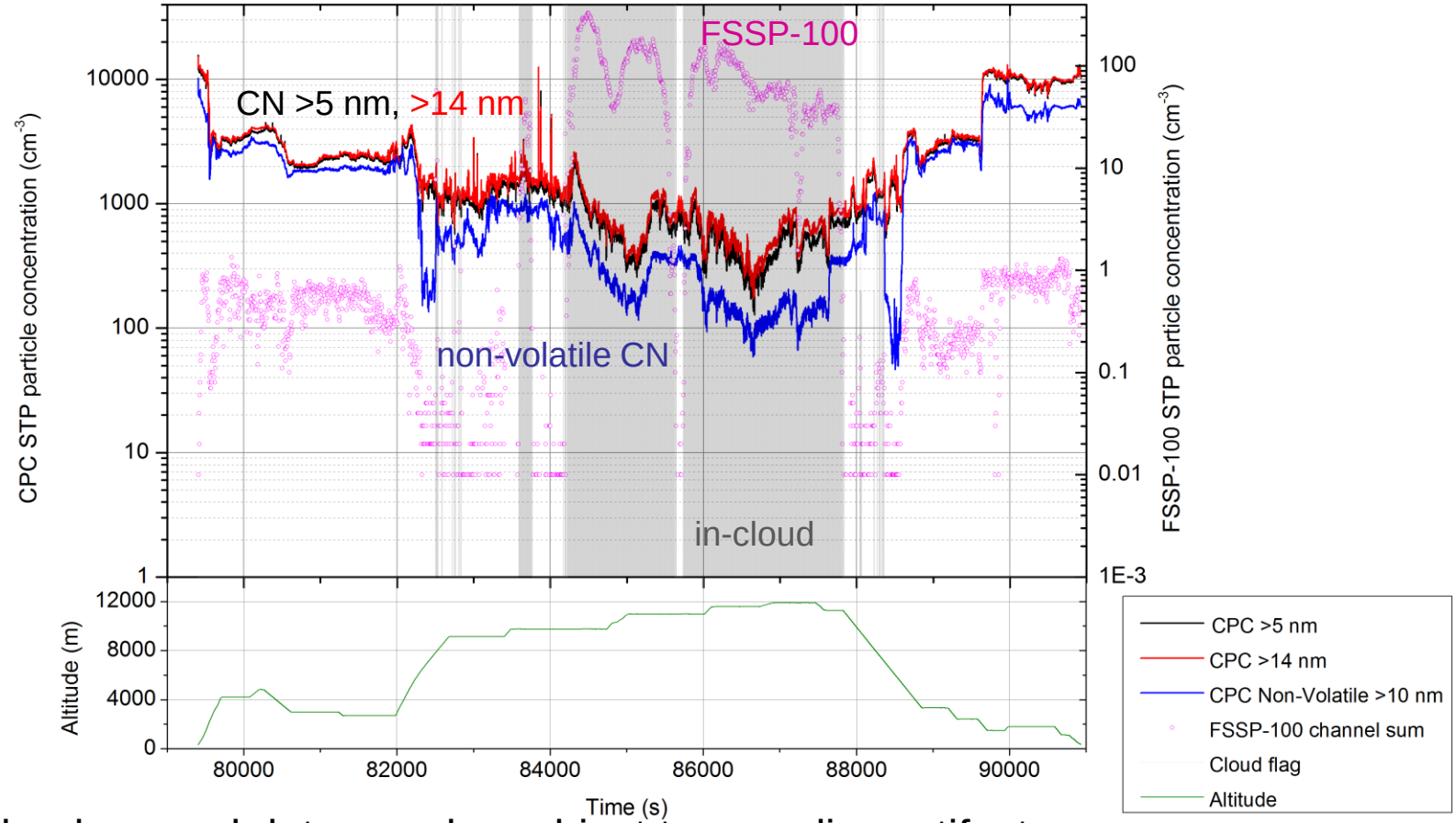
- Aerosol characterization in inflow & outflow
- New particle formation in outflow?
- Wet removal of particles vs. uplift in convective storms
- Biomass burning aerosol: transport & ageing

→Poster by D. Fütterer et al. (aerosol vertical profiles, outflow)

→Poster by K. Heimerl et al. (BB aerosol)

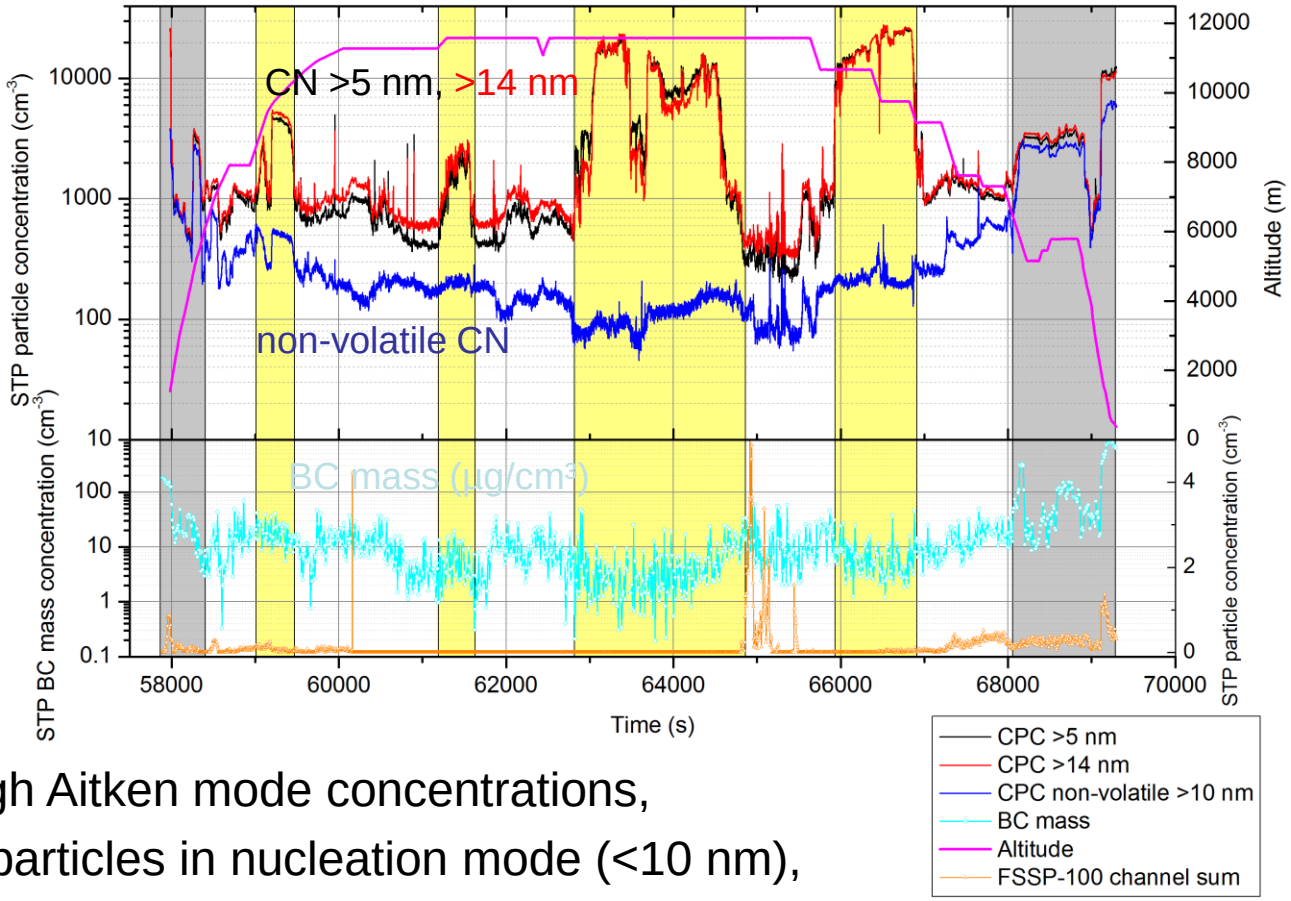
→Overview talk by B. Weinzierl et al. (BB aerosol)

Aerosol observations in fresh outflow



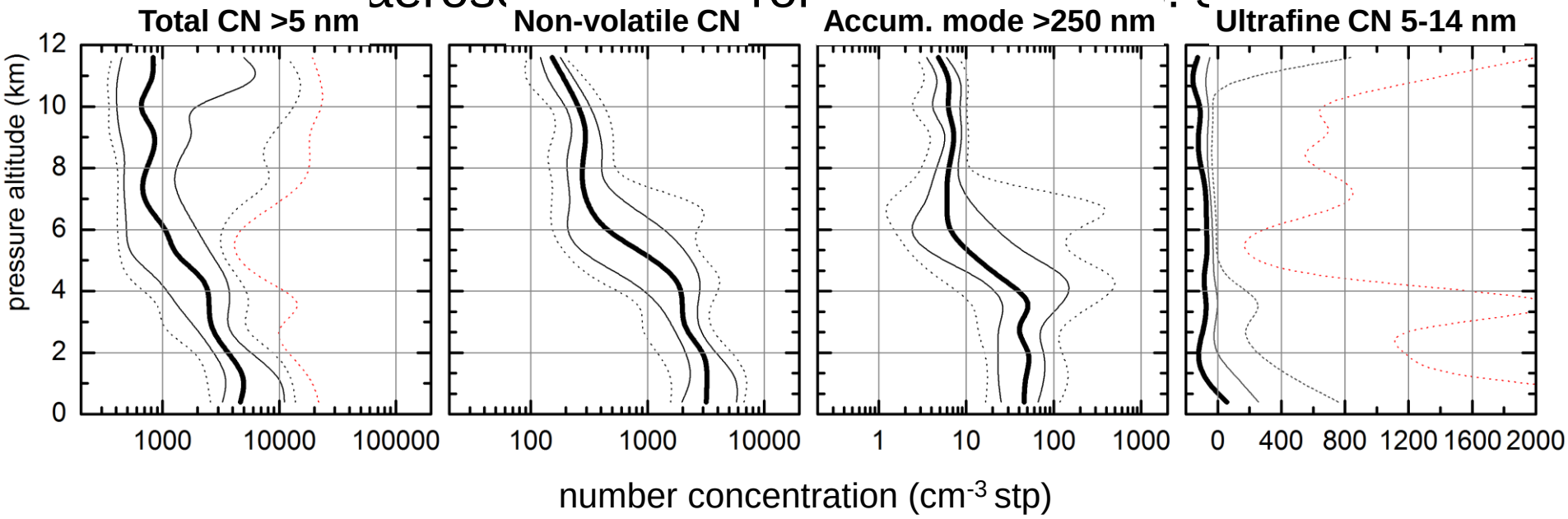
- in-cloud aerosol data may be subject to sampling artifacts, but concentrations in the anvil are in general lower than outside anvil
- no observations of ongoing new particle formation near the storm cell
- no obvious strong (wet) removal of aerosol in fresh outflow as seen previously

Aerosol observations in `aged“ outflow (~24 hours age)



- very high Aitken mode concentrations,
  but no particles in nucleation mode (<10 nm),
  embedded in very thin cirrus (not shown)
  → new particle formation must have happened before
- no observations of vertical uplift of BL particles
  (non-volatile CN & BC mass remain low in aged outflow)

Vertical aerosol profiles from Falcon flights: statistics

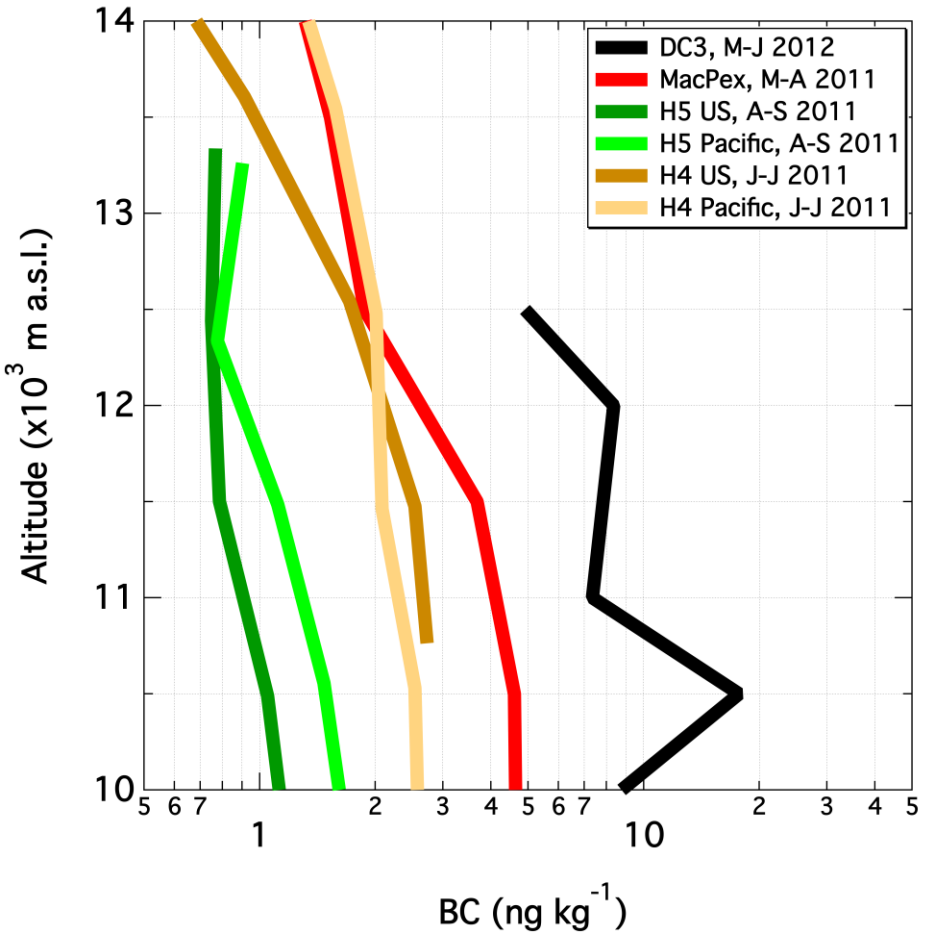


Median, 10-, 25-, 75-, 90-, 99-percentiles, based on 800 m altitude binning, out-of-cloud data only

- high BL concentrations, sometimes also including BB aerosol (→ inflow)
- maximum of non-volatile and larger particles in some flights at 3-7 km altitude (→ BB plumes)
- high variability of Aitken mode particles (CN) > 7 km altitude (→ outflow + background)
- occasional very high CN (→ „aged“ outflow) but NPF not directly observed

NOAA SP2 GROUP – BC MEASUREMENTS

- The graph shows vertical distribution of BC in UT/LS during DC3 and several previous campaigns.
- Significantly higher MMR of BC was observed during DC3 perhaps due to convective processes in the region.
- For more info on our measurements/analysis please see Milos Markovic's poster and Bernadett Weinzierl's overview talk on BB.

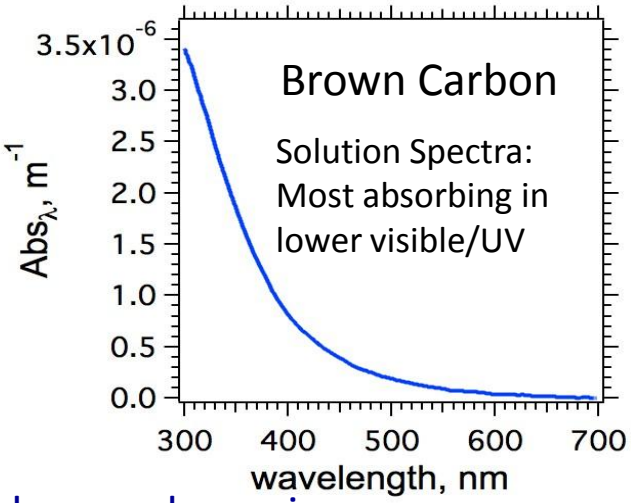


Markovic, M. Z., Perring, A. E., Gao, R. S., Watts, L. A., Holloway, J. S., Fahey, D. W. , Schwarz, J. P.

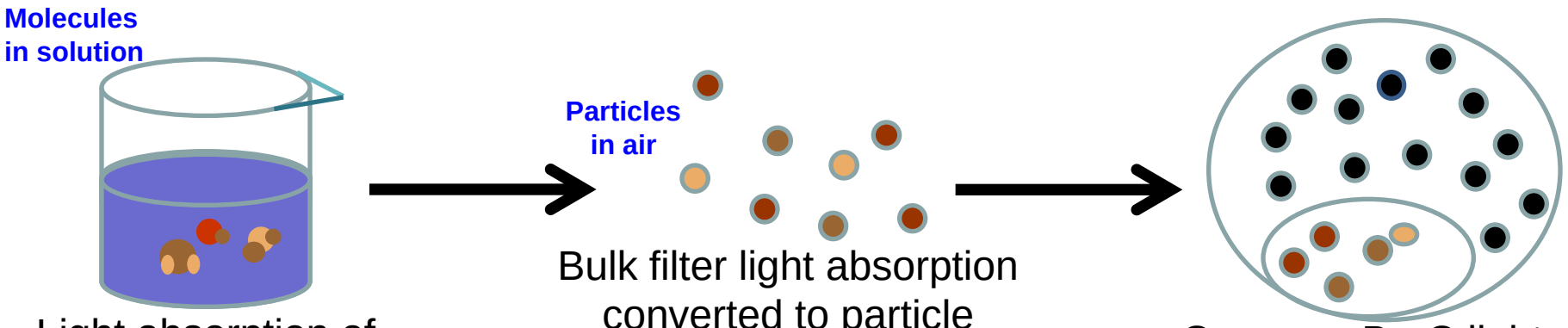
Vertical Profiles of Brown vs Black Carbon

J. Liu, R. Weber, J. Dibb, E. Scheuer, G. Diskin et al.

1. Extract UNH filters in water, then methanol. Measure extract light absorption spectra 300-900nm via long path spectrophotometer



2. Use size resolved ground-based data (MOUDI) and Mie theory to convert solution light absorption by chromophores to light absorption by ambient aerosol.
   - Apply result to DC3 bulk filters. Assumes aged aerosol; chromophores in accumulation mode.
3. Estimate pure BC light absorption by: 7.5 m^2/g * SP2 BC @ 550nm and Ångstrom exp. = 1 for b_{ap} at 365nm



Light absorption of solution

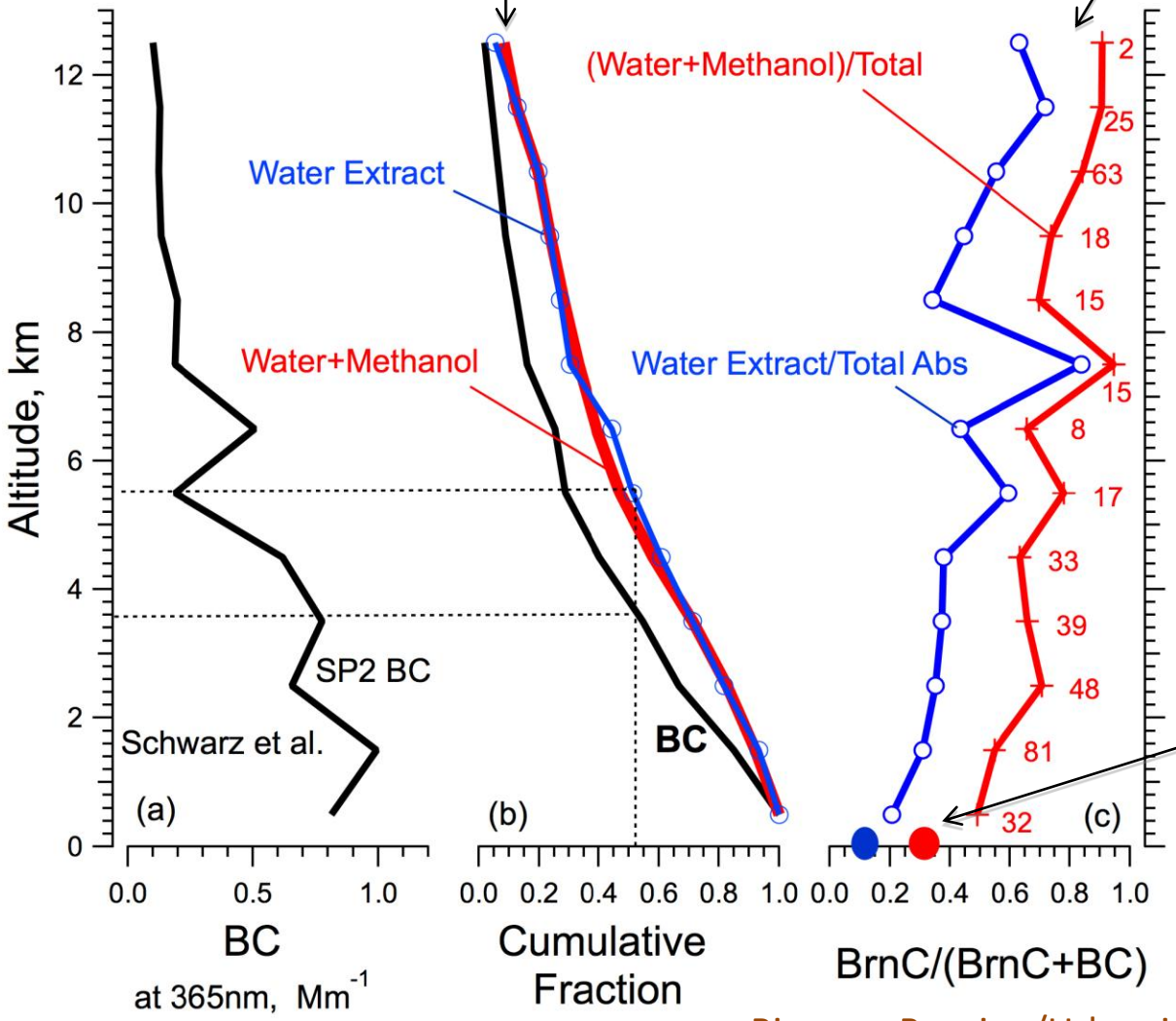
Bulk filter light absorption converted to particle absorption via Mie theory

Compare BrnC light absorption to BC

Brown vs Black Carbon Vertical Profiles @ 365 nm

~ 50% of BC absorption at 3.5km asl vs 5.5km for BrnC

BrnC increasing fraction of total light absorption at higher alt.



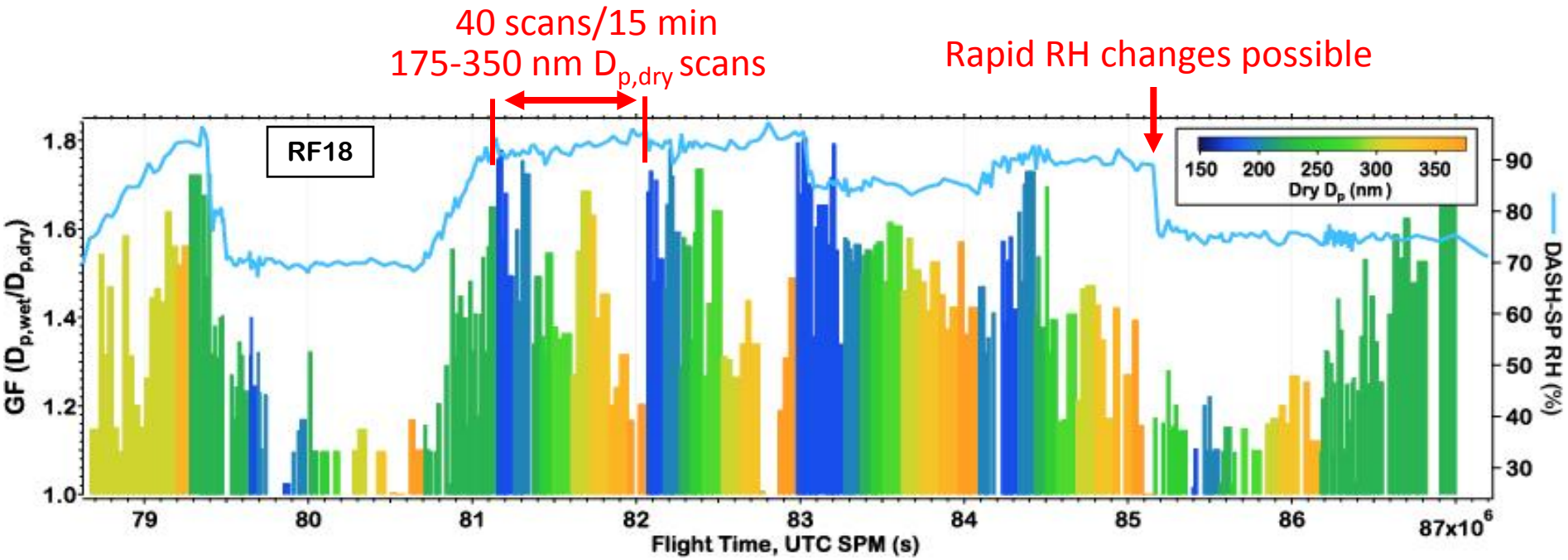
Rural GA surface site

Biomass Burning/Urban impacts excluded via CO

Differential Aerosol Sizing and Hygroscopicity Spectrometer Probe (DASH-SP)

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

- Overview of the DASH-SP instrument on DC-8
  - Size-resolved aerosol Growth Factors (GF = $D_{p,wet}/D_{p,dry}$)
  - Dried particles size selected between dry D_p of ~175-350 nm and humidified to a set RH (up to ~95%)
  - Able to scan at < 5 s when aerosol concentrations are sufficiently high (i.e. boundary layer)



- Current DC3 interests for the DASH-SP include:
  - GF sensitivity to convective transport and cloud/aqueous processing
  - GF response to source emissions (smoke, biogenics, etc…)
  - Possible “restructuring” of smoke particles
  - High altitude GF characteristics
  - Investigation of composition/hygroscopicity relationships and comparison of water uptake in sub- and super-saturated regimes: evaluation of current model parameterizations of aerosol water-uptake (e.g. ‘kappa’)

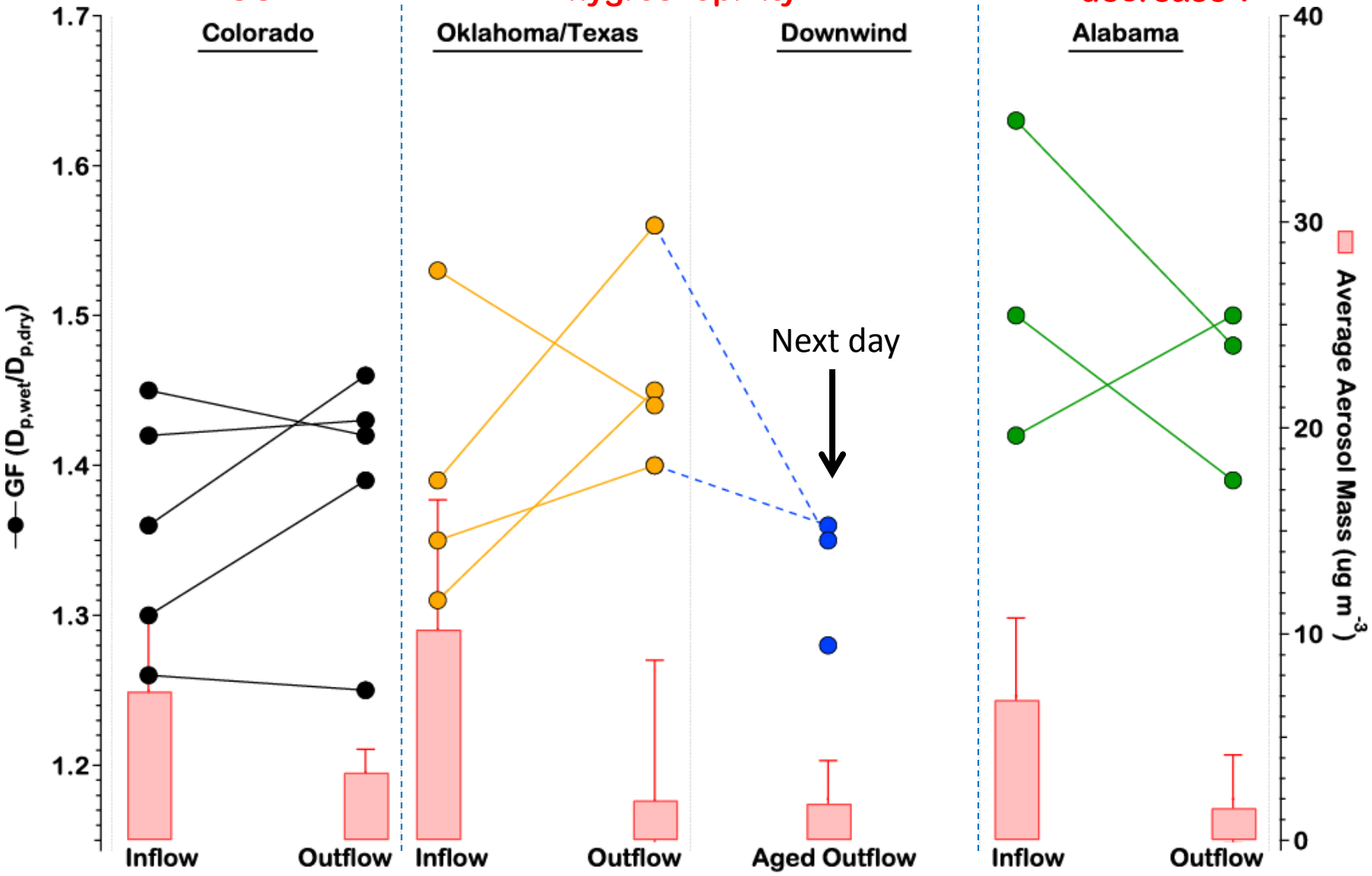
Inflow-Outflow Comparisons of GF at an RH of ~85% & $D_{p,dry}$ of ~225 nm

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

Smoke influence suppressing GFs in CO?

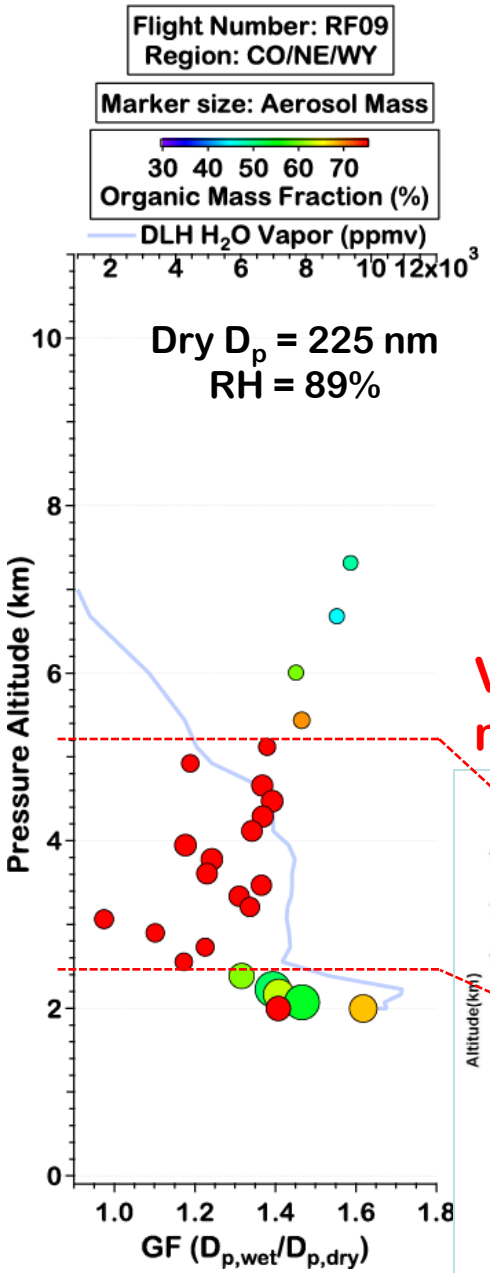
Effects of convective outflow aging on hygroscopicity?

Why do some GFs increase after convection while some decrease ?



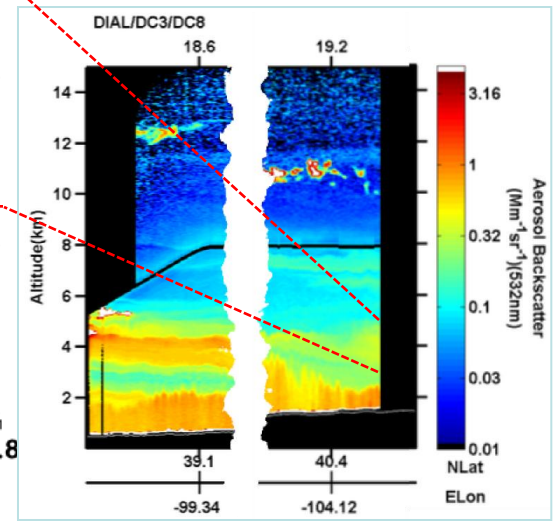
Growth Factor Results During Spirals: Snapshot from Two Flights

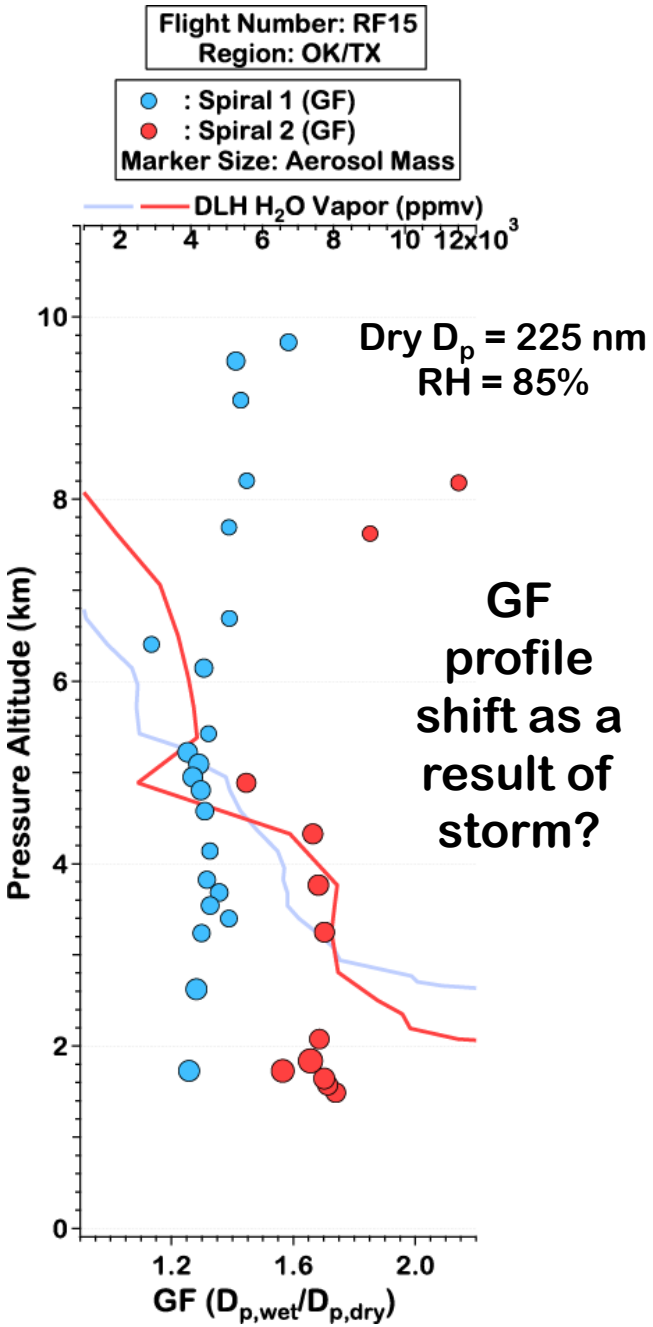
DC-8 / Taylor Shingler and Armin Sorooshian / University of Arizona



We are examining the role of composition and different air masses in explaining variations in vertical GF structure during spirals.

Variation in GFs by air mass in a vertical profile





GF profile shift as a result of storm?

PI-Neph Data Products

Directly Measured:

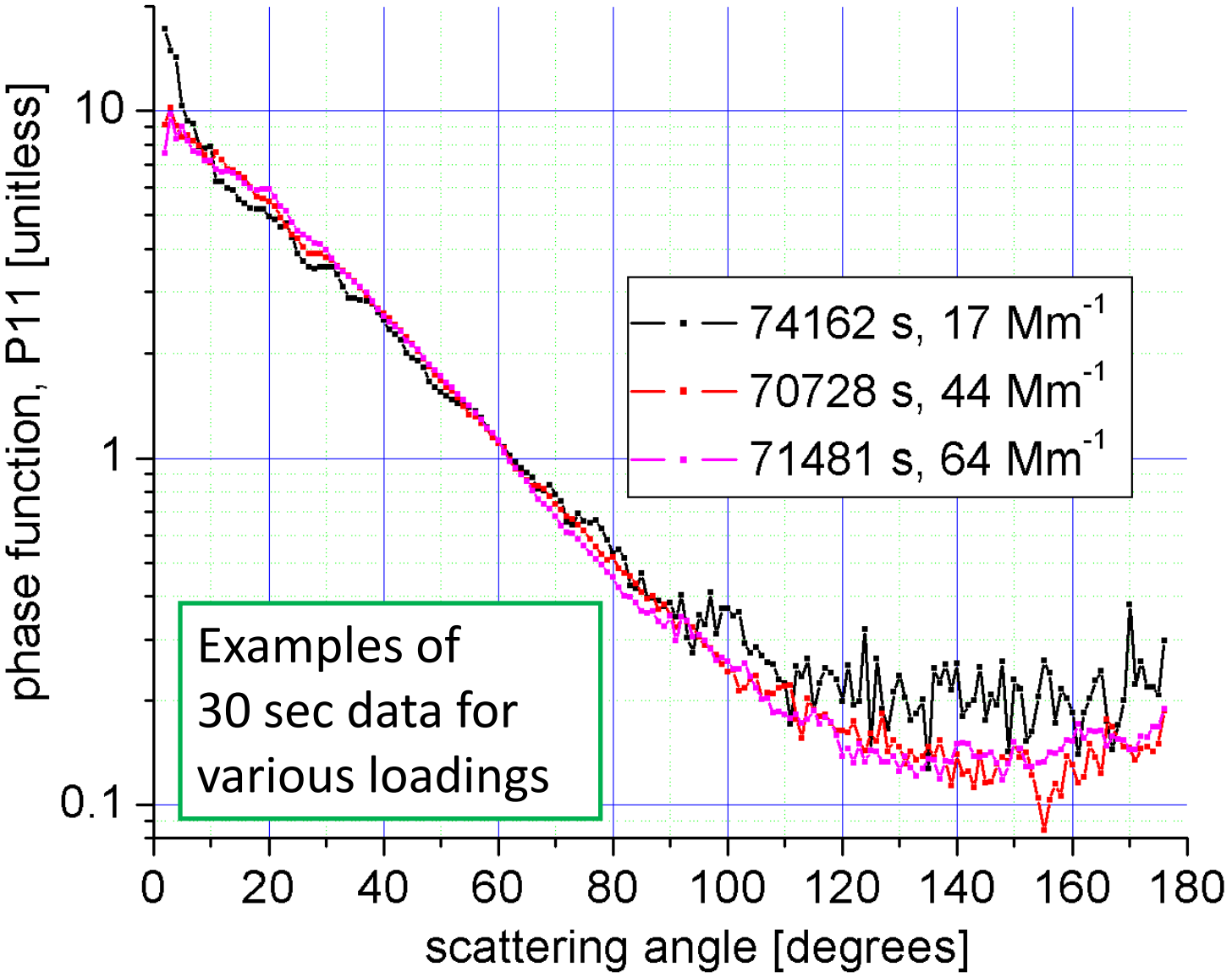
- Phase function, P11
- Degree of linear polarization, P12
- Scattering angle range 2 to 176 deg
- Volume scattering coefficient: 5 to 1000 1/Mm
- Asymmetry factor
- Lidar ratio estimate by extrapolation to 180 deg

Retrieval Products

- Size distribution, 24 bins, AERONET type
- Index of refraction

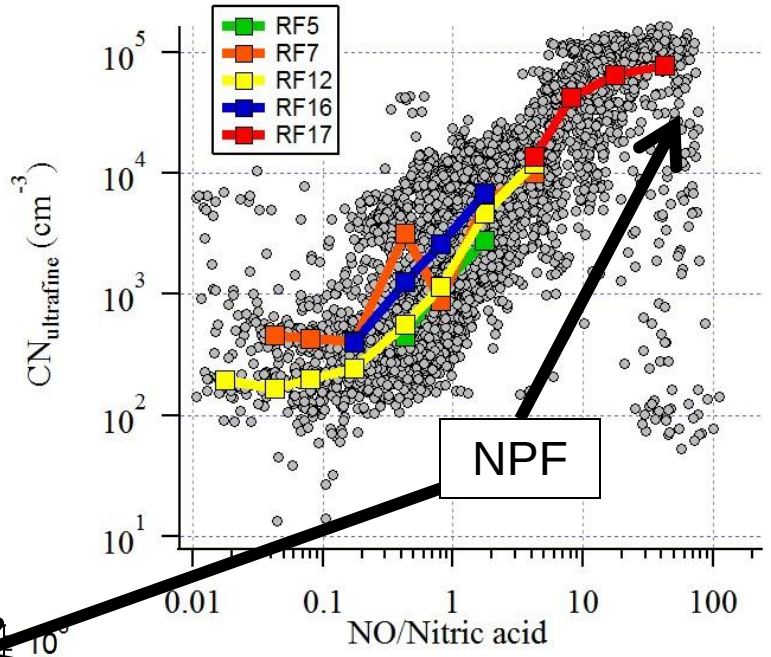
(real part is more accurate than imaginary part)

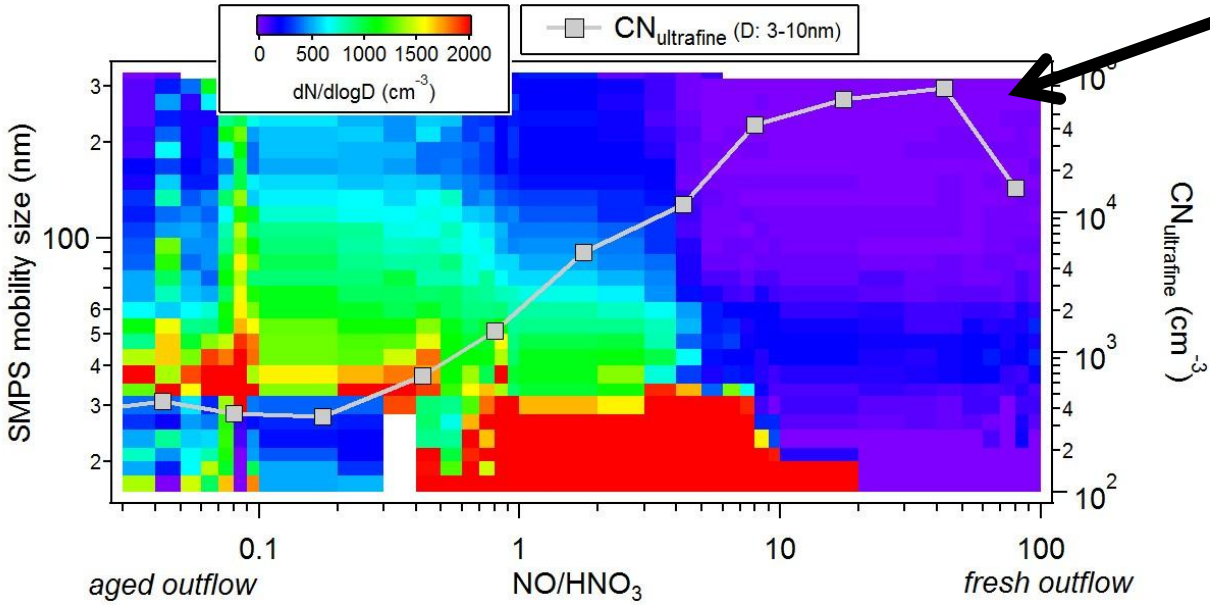
DC3 Phase Functions



New Particle Formation/Growth in Outflow

- Combination of 5 outflow flights covers wide range of convective age
- New particle formation (NPF) was observed only in fresh outflow, concentrations decreased with age



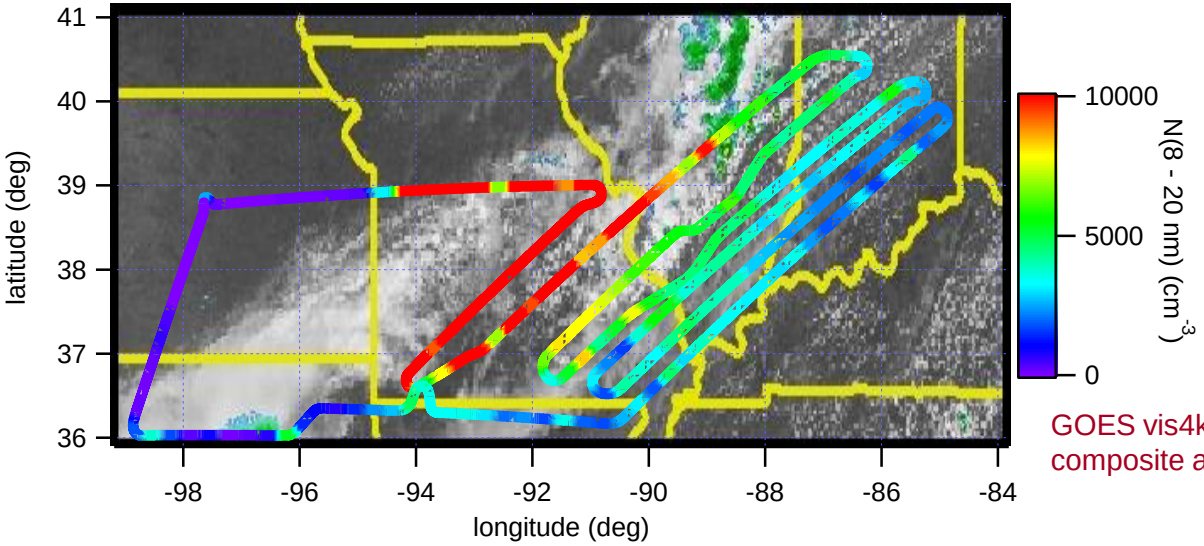


- particles grow during aging, yielding sizes that are likely CCN active and contribute to AOD

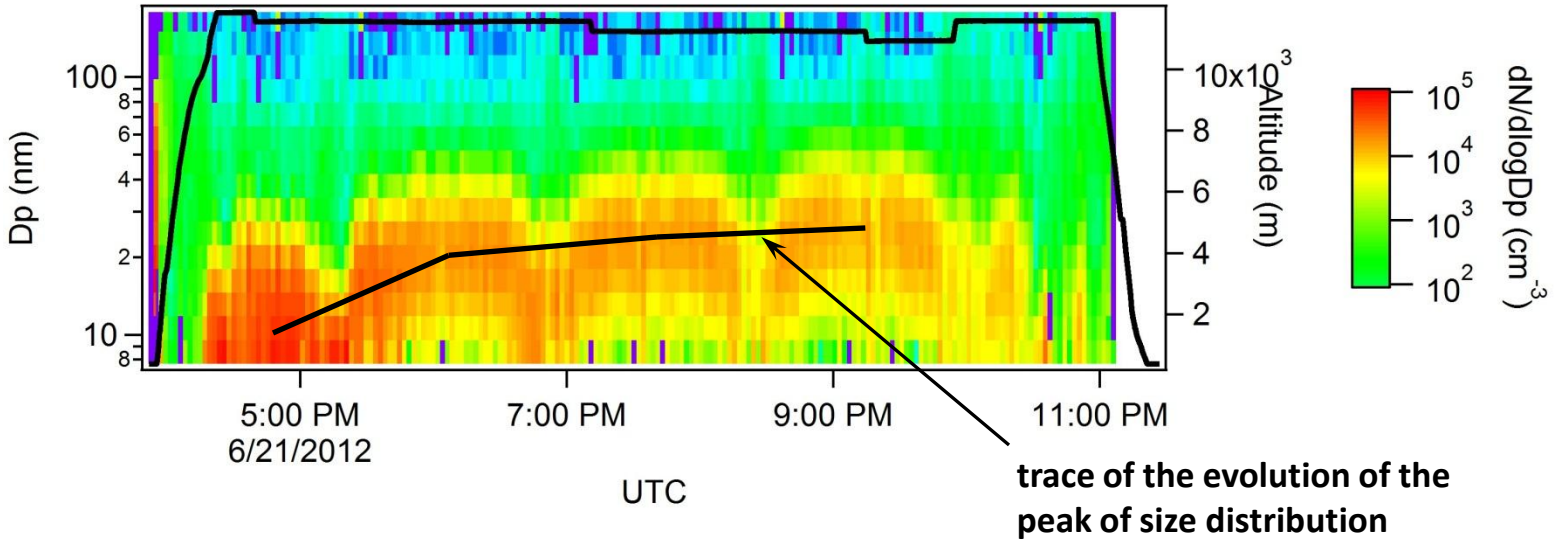
21 June: New particle formation and growth in outflow of a Mesoscale Convective System

What is the role of deep convection on **aerosol formation, transformations, and transport**?

GV SMPS concentration of 8 – 20 nm diameter aerosol

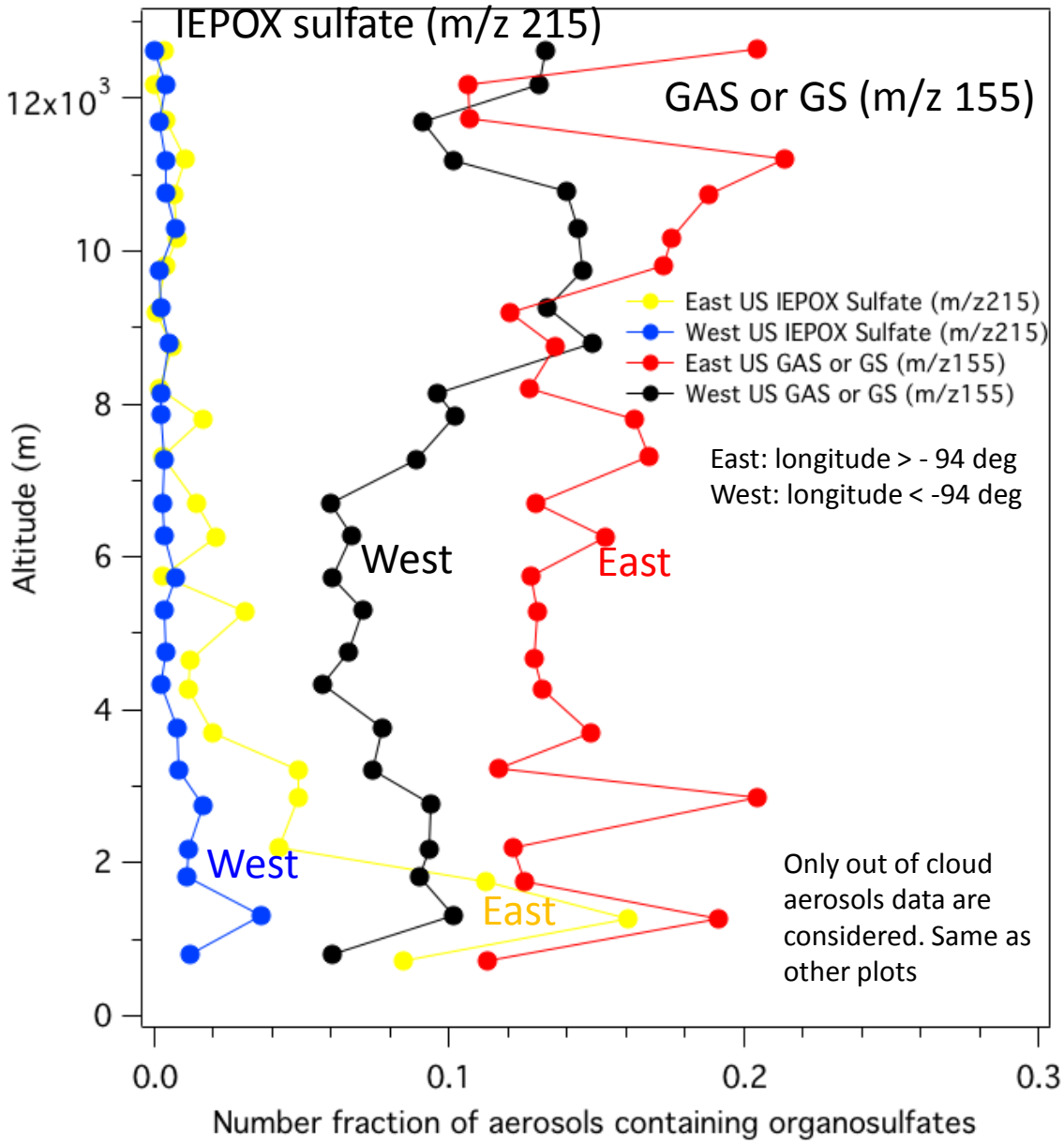


GOES vis4km and nexrad composite at 18:00 GMT



trace of the evolution of the peak of size distribution

Vertical distributions of organosulfates during DC3

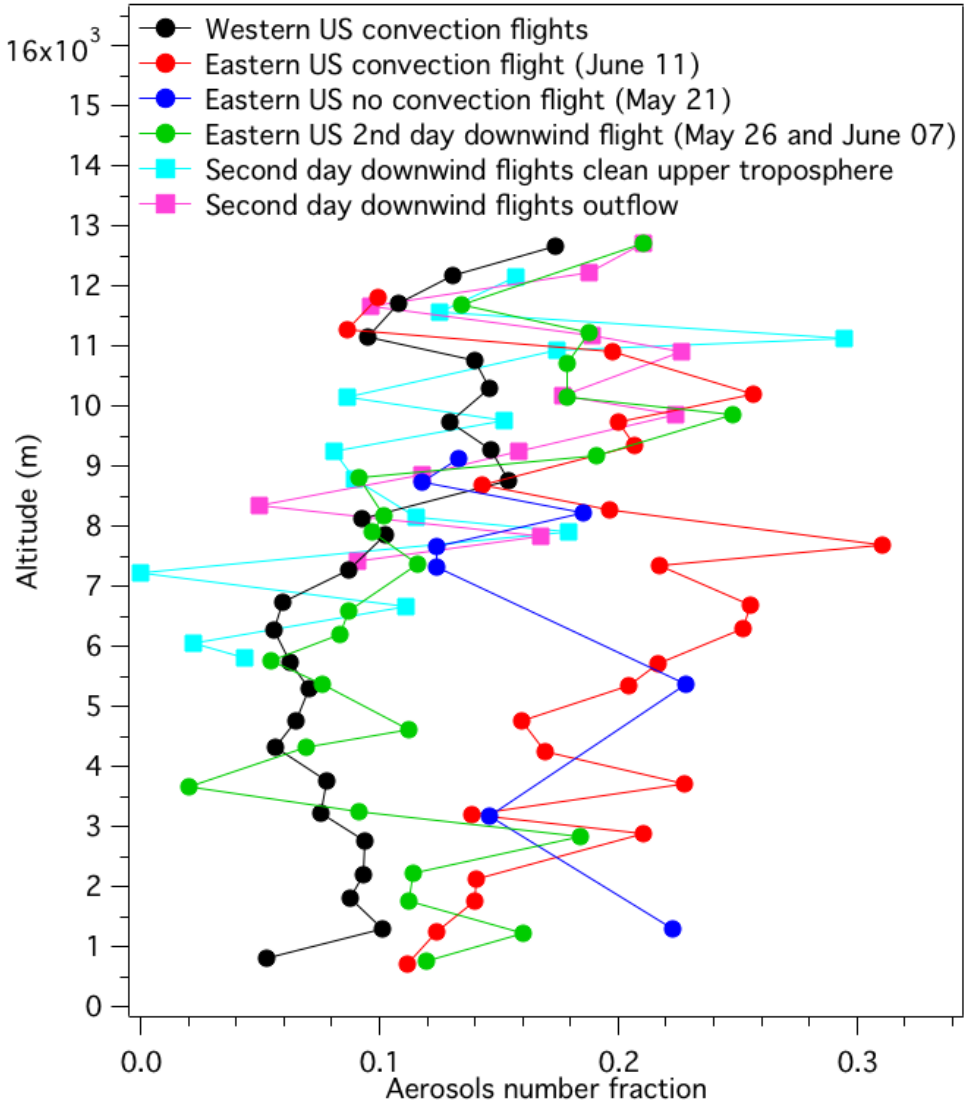


•IEPOX sulfate aerosols were concentrated near the ground in the eastern US where isoprene emissions were high.

•Generally, GAS or GS is more ubiquitous than IEPOX sulfate: more aerosols (10%-20%) containing GAS or GS than IEPOX sulfate; number fraction of aerosols containing GAS or GS do not decrease with altitude.

•More aerosols containing organosulfates in the eastern US compared to the western US.

Convection influence on organosulfate (GAS or GS)



Black: Western US convection flights → Enhancement from 9 - 11 km (anvil height) indicates **convection may promote formation of GAS or GS**

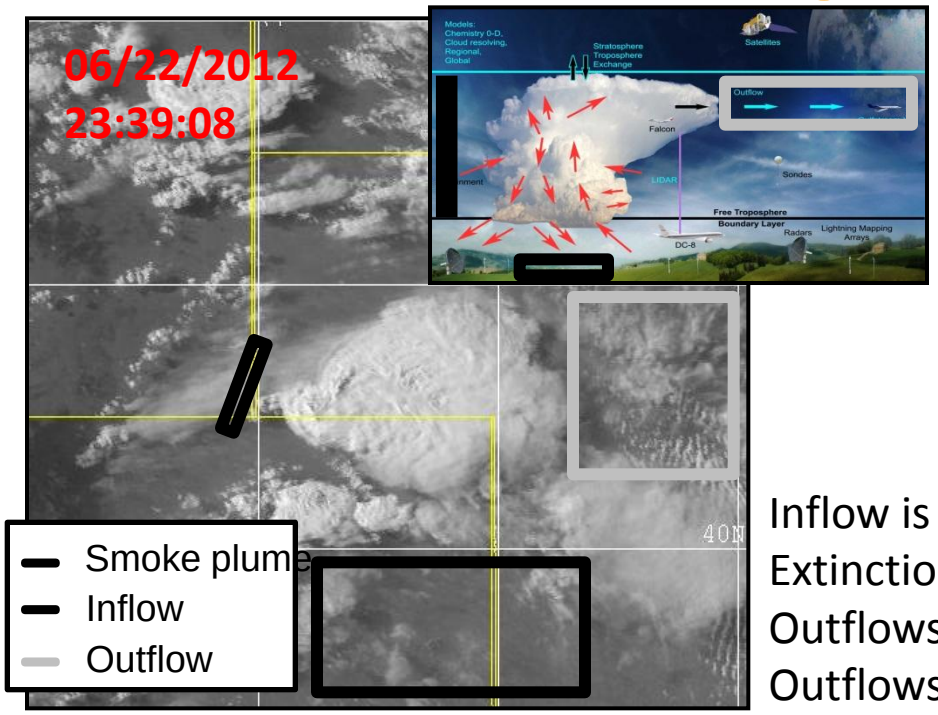
Red: Eastern US flight (affected by convections in Alabama areas June 11) → Enhancement in the mid and upper troposphere (6-11 km)

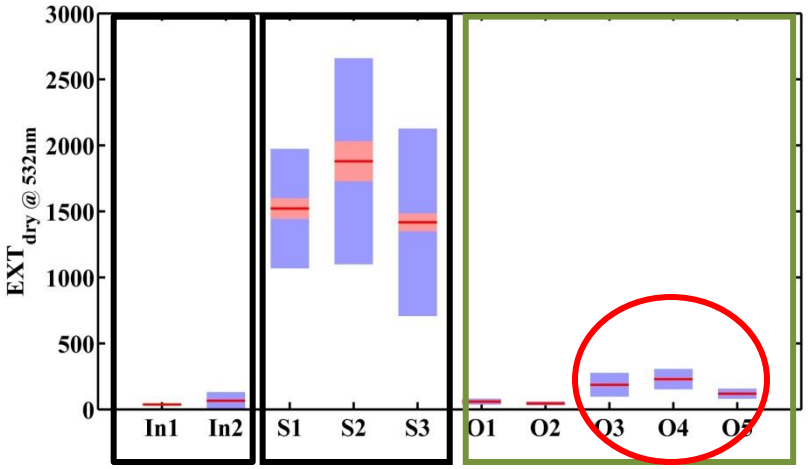
Blue: Eastern US flight (no convection May 21) Decreased with altitude

Green: Flights to Eastern US (second day downwind from May 25 storm in Texas/Oklahoma and June 06 storm in Colorado) at low altitude 0-3 km: similar to that in eastern US; in mid and upper troposphere 3-9 km: similar to that in western US; stratosphere >9 km: not transported from western storms the day before

Analysis using trace gases as outflow indicators also shows that **GAS or GS was enhanced in the outflow** compared to clean upper troposphere from 9-11 km.

Biomass burning and cloud interactions

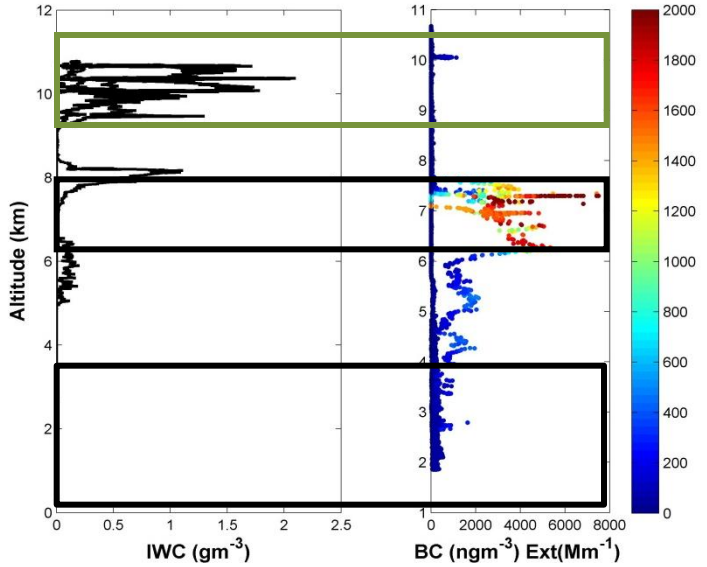




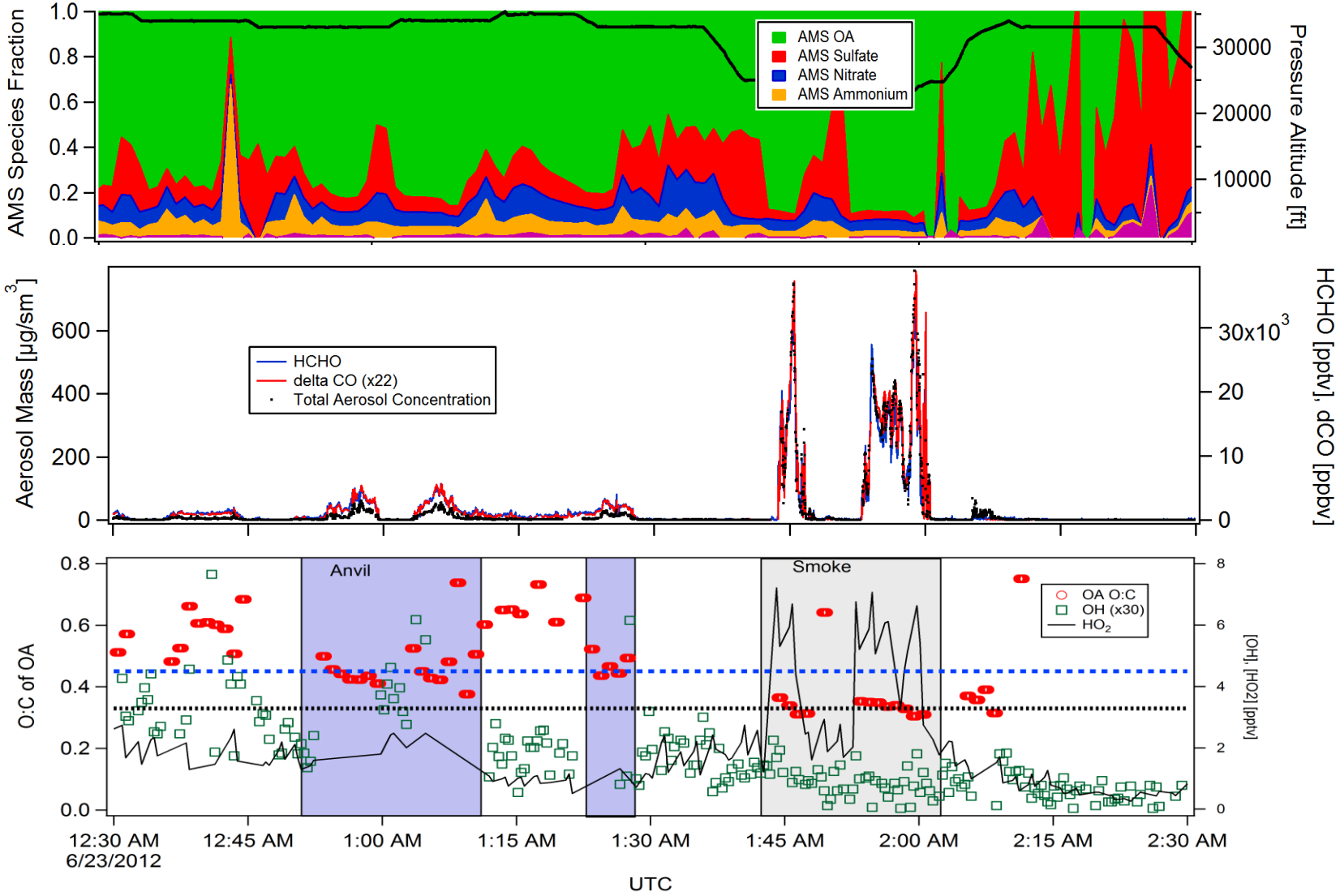
Inflow is clean (< 50 Mm^{-1})
Extinction in the smoke plume is extremely high (1800 Mm^{-1}
Outflows 1-2 : No evidences of smoke air masses
Outflows 3-5 : Large concentration of smoke tracers

➔ Inflow is not necessarily limited to the boundary layer
➔O2 & O3 are located exactly in the same location : time difference is the time needed for the particles to get in the outflow

BB aerosol impact on the cloud dynamics :
IWC profile shows 2 layers highly concentrated :
•8 km just above the BB layer, IWC > 1 g/m^3
•10km (outflows altitude), IWC > 1.5 g/m^3



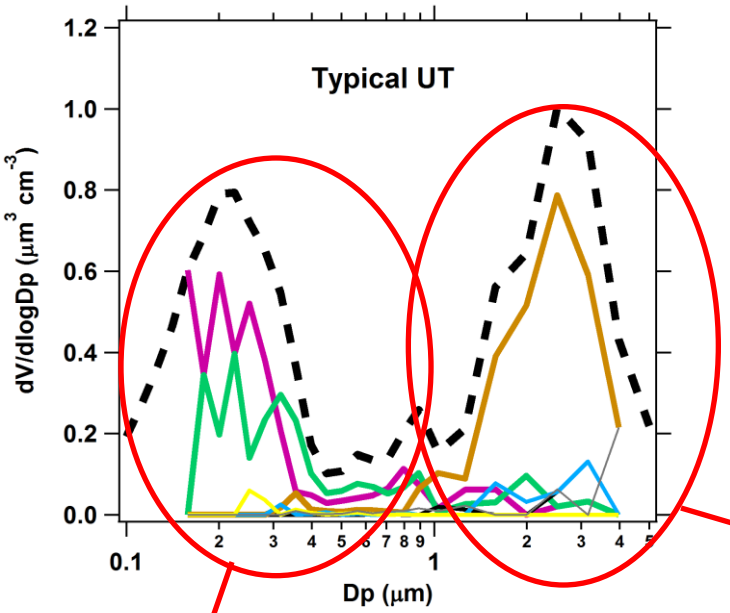
Convective Transport from the FT: RF18 (6/22)



- About 50% of aerosol mass relative to the tracers is transported from the FT to the Anvil
- While some OA is lost in relation to inorganics, the remainder has been significantly oxidized (O:C 0.3 -> 0.45) despite the short time scales, mechanism unclear

PALMS single particle composition + LARGE size distributions

Karl Froyd
Jin Liao

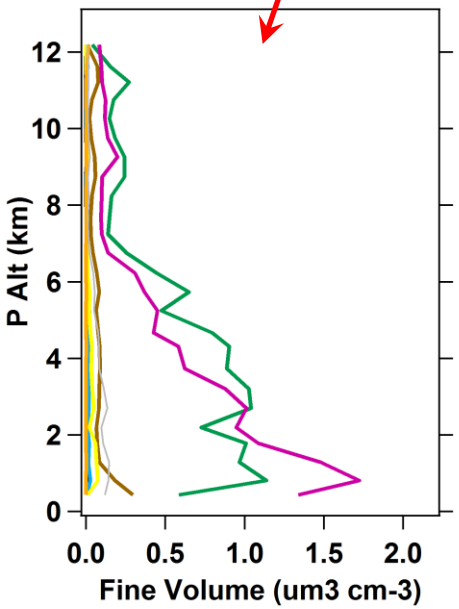


Sulfate-Organic mixture
Biomass Burning
} **Dominate Submicron**

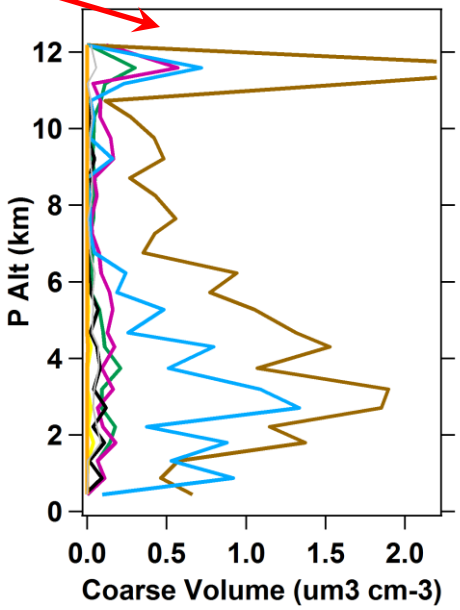
Mineral Dust
} **Dominates Supermicron**

Sea Salt
EC
Meteoric
Oil Combustion

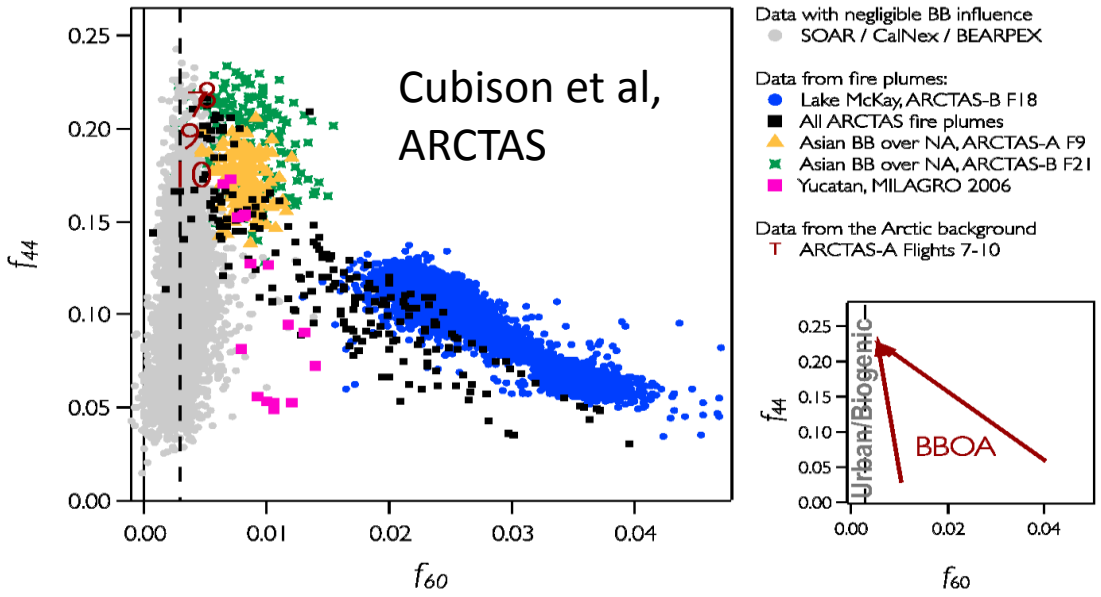
Apportion aerosol volume – Western US



- US & Asian Biomass Burning plumes: strongly impacted aerosol properties throughout DC3
- Submicron and Supermicron: similar contributions to volume
- Aerosol vol does not drop off above BL, constant up to ~6 km (see also DIAL). ???
- Dust and Sea Salt (or dry lakebed salt) significant throughout troposphere.



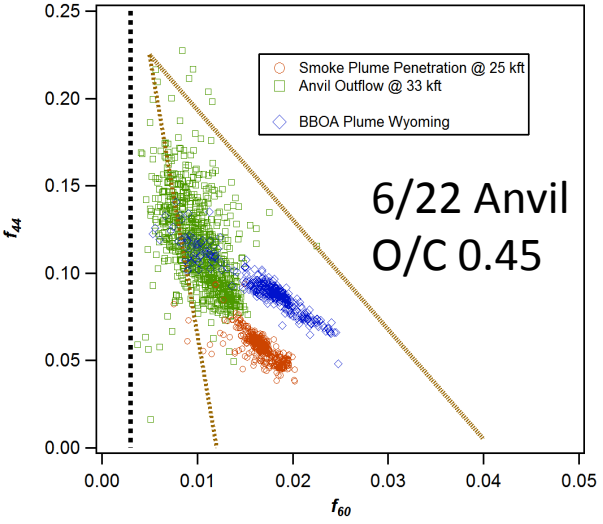
Different degrees of BBOA

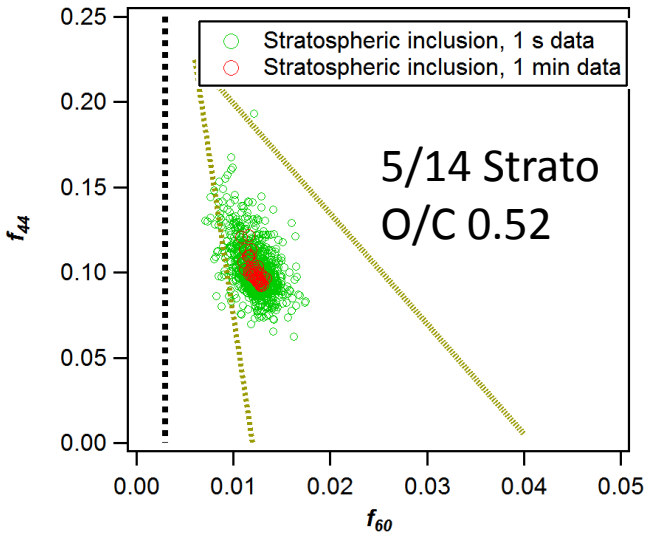


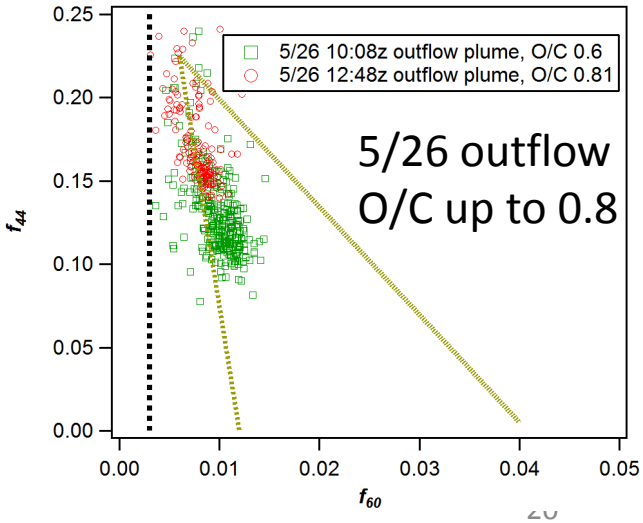
The f_{44}/f_{60} triangle tries to visualize BBOA aging, as the initial levoglucosan content gets slowly oxidized.

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.



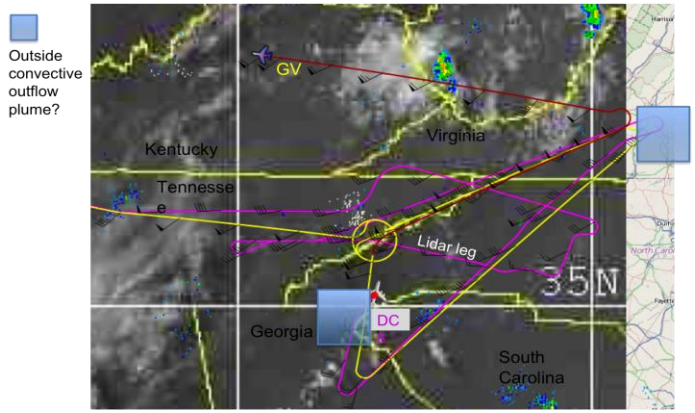




PALMS – Aerosol composition in (cloud-free) outflow

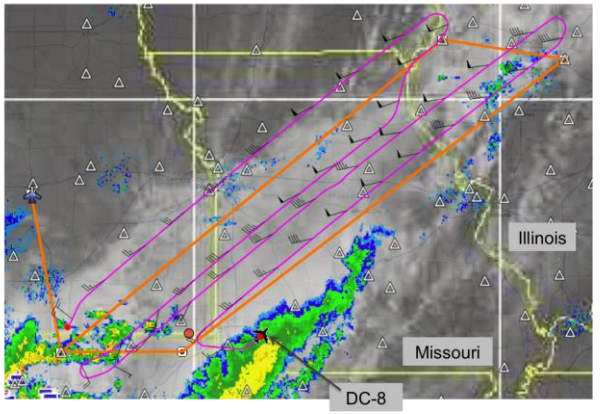
Karl Froyd
Jin Liao

May 30 - Outflow from previous day TX storms

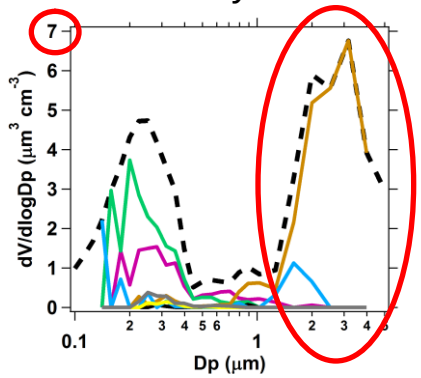


- Most aerosol measurements are artifact-ridden inside anvil cirrus
- Identify cloud-free outflow using gas phase tracers: Alkanes, NOx/HNO3, MeOH

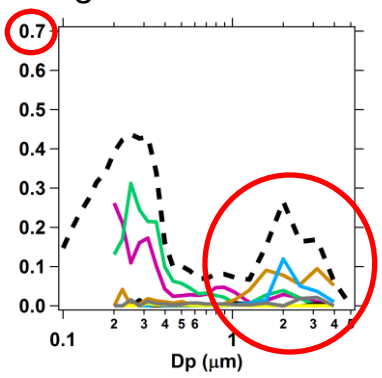
Jun 21 – Dissipating MCS



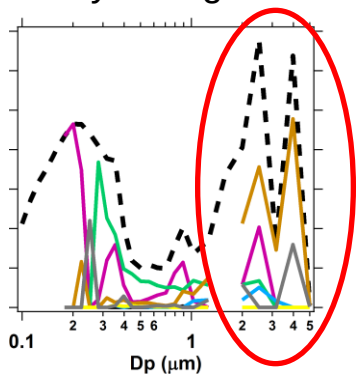
Previous Day Inflow



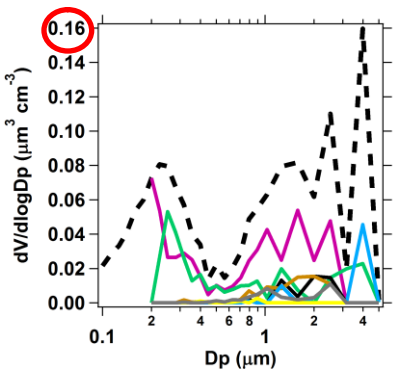
Aged UT Outflow



Nearby Background UT



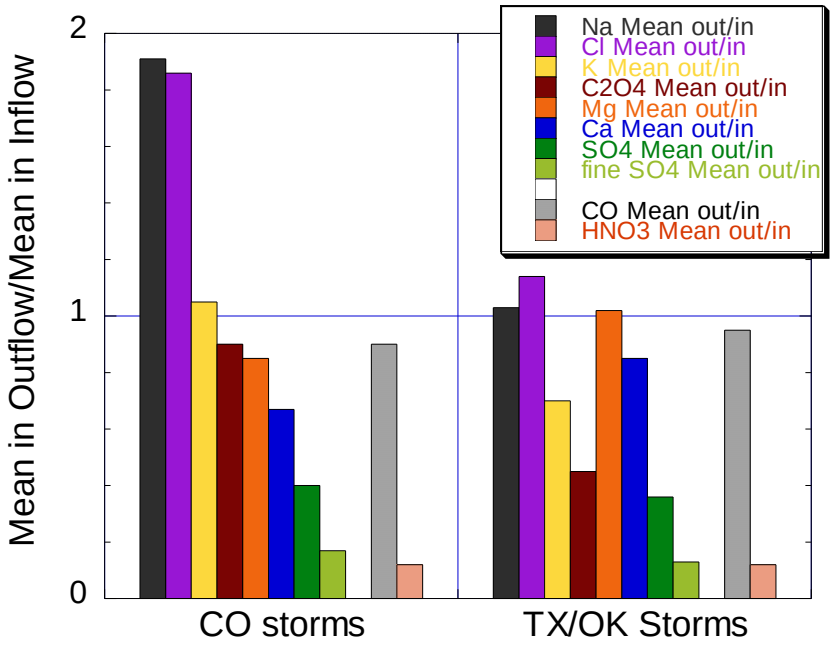
Fresh UT Outflow

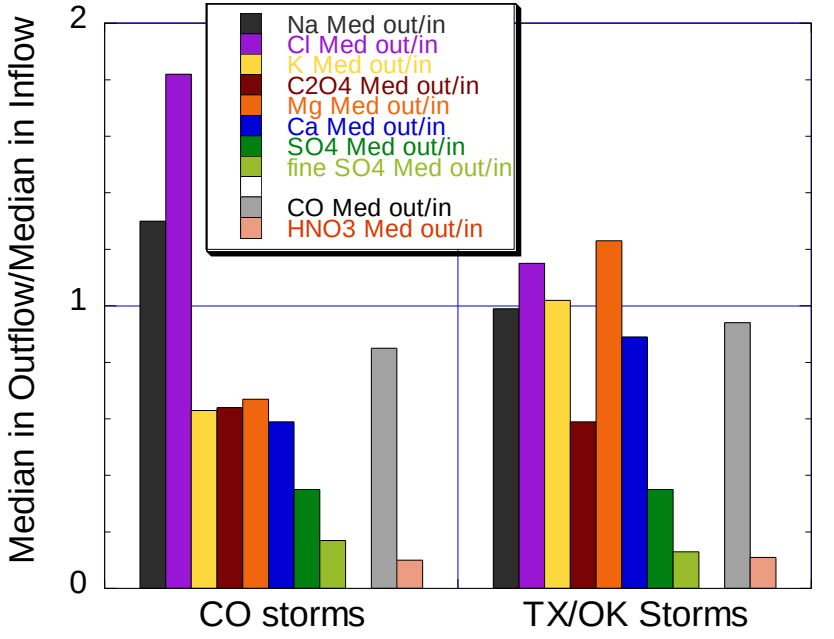


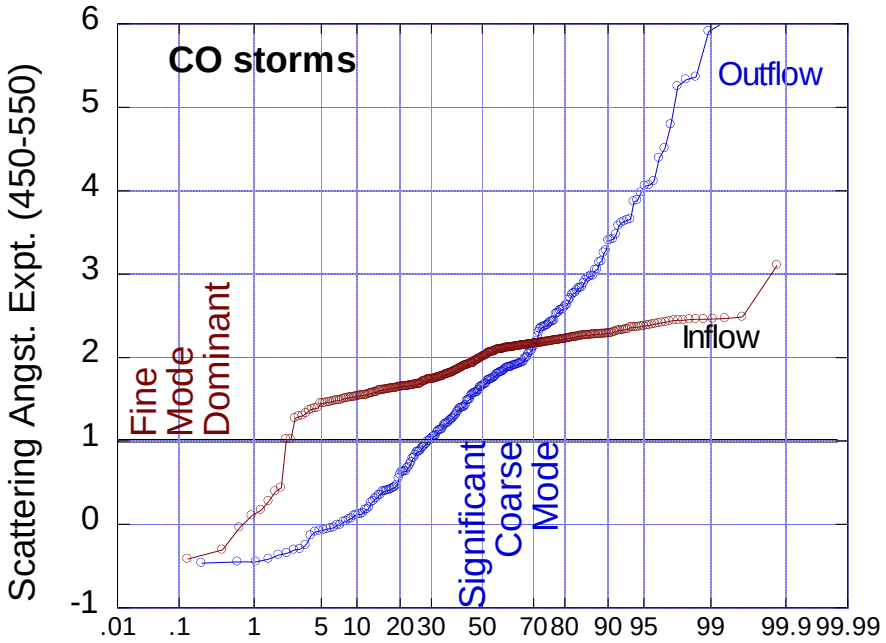
- Inflow → Outflow: ~x5 decrease in aerosol mass
- Coarse aerosol mostly Dust
- Less Dust in Outflow vs UT background
- No obvious composition-dependent removal in submicron aerosol

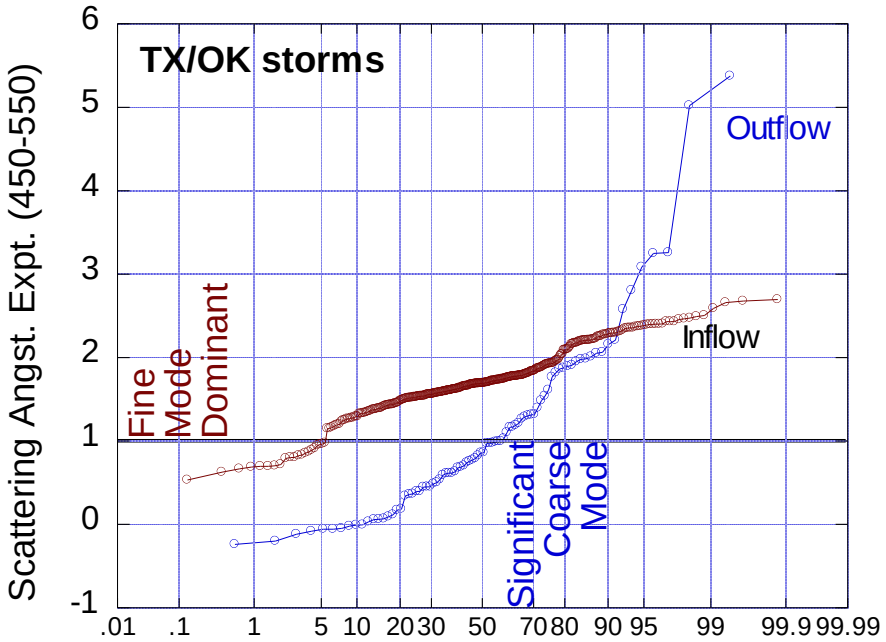
Sulfate-Organic
Biomass Burning
Mineral Dust
Sea Salt

- Efficient aerosol removal: Very low volume (x5-10 lower than typical background UT)
- Aerosol growth through cloud processing: Coarse aerosol are mostly Sulfate-Organic, not Dust


Mean in Outflow/Mean in Inflow
2
1
0
Na Mean out/in
Cl Mean out/in
K Mean out/in
C2O4 Mean out/in
Mg Mean out/in
Ca Mean out/in
SO4 Mean out/in
fine SO4 Mean out/in
CO Mean out/in
HNO3 Mean out/in
CO storms
TX/OK Storms


Median in Outflow/Median in Inflow
2
1
0
Na Med out/in
Cl Med out/in
K Med out/in
C2O4 Med out/in
Mg Med out/in
Ca Med out/in
SO4 Med out/in
fine SO4 Med out/in
CO Med out/in
HNO3 Med out/in
CO storms
TX/OK Storms


CO storms
Scattering Angst. Expt. (450-550)
6
5
4
3
2
1
0
-1
Outflow
Inflow
Fine Mode Dominant
Significant Coarse Mode
.01
.1
1
5
10
20
30
50
70
80
90
95
99
99.9
99.99


TX/OK storms
Scattering Angst. Expt. (450-550)
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3
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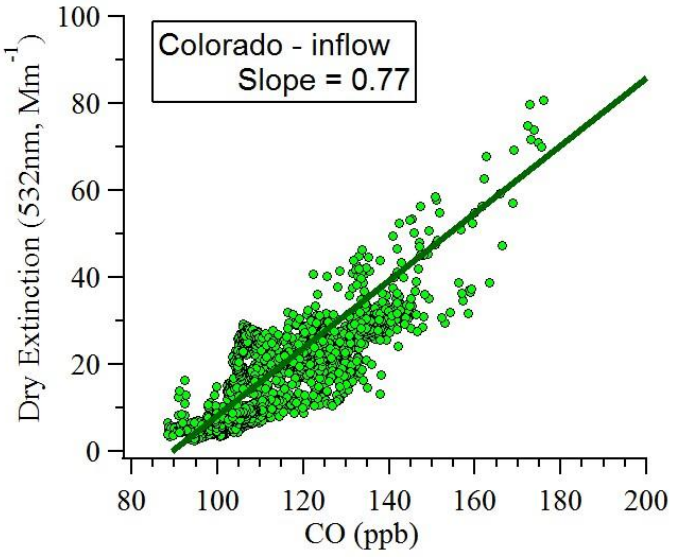
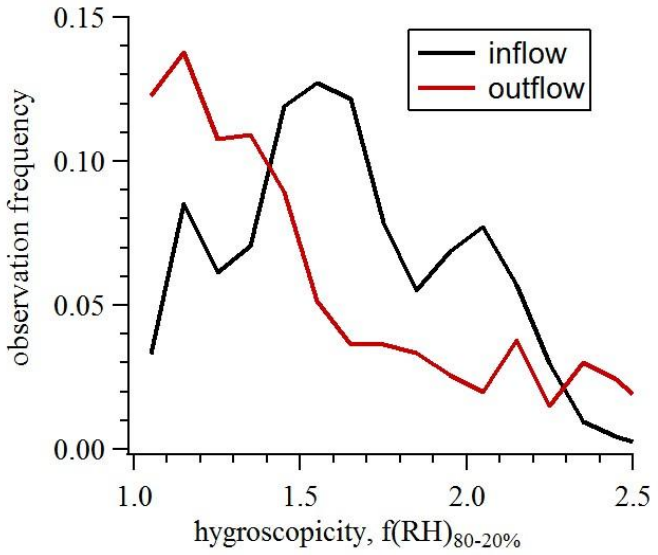
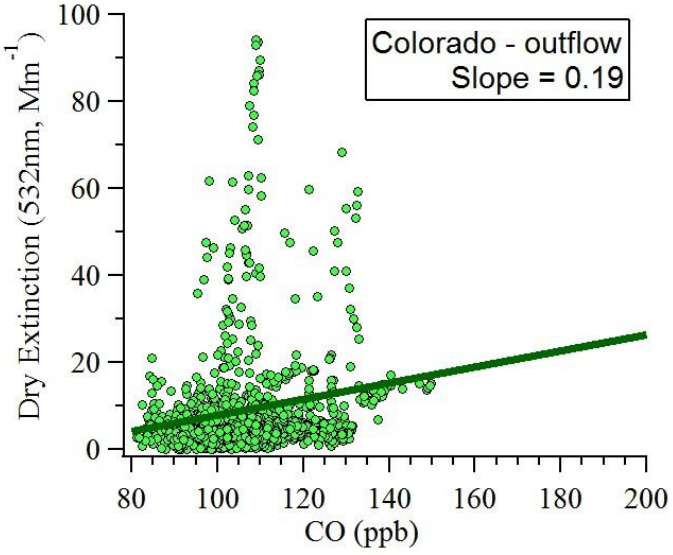
1
0
-1
Outflow
Inflow
Fine Mode Dominant
Significant Coarse Mode
.01
.1
1
5
10
20
30
50
70
80
90
95
99
99.9
99.99

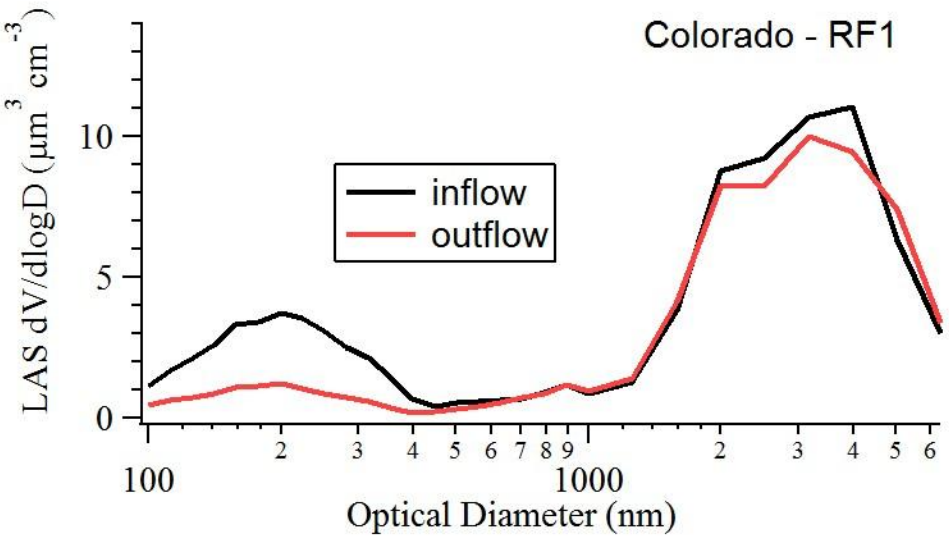
Aerosol Convective Transport during DC3



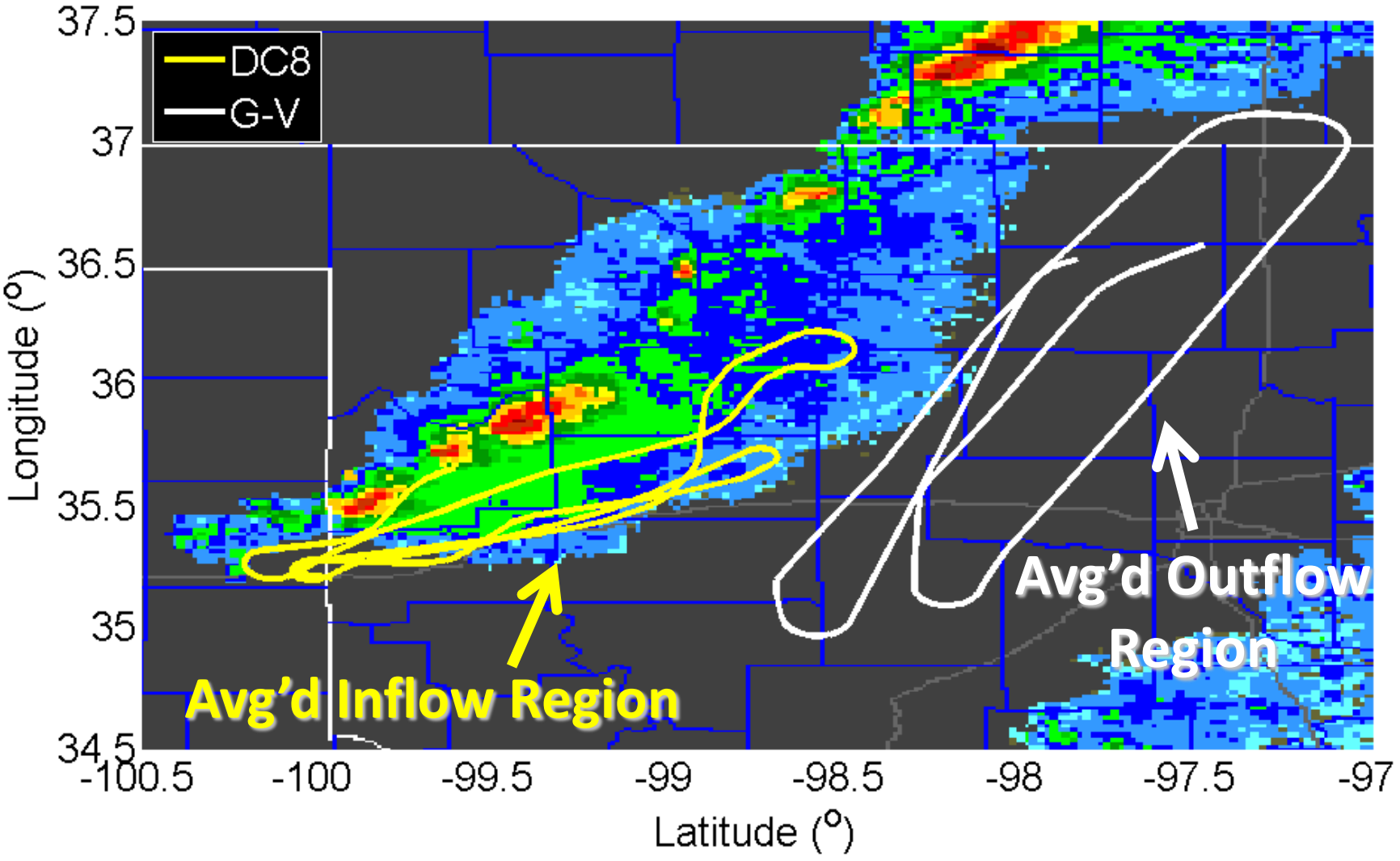
- Comparison of extinction coefficient yields 25 % transport to outflow for Colorado
- Aerosol in outflow is less hygroscopic
- super-micron aerosol (dust) is transported more efficiently





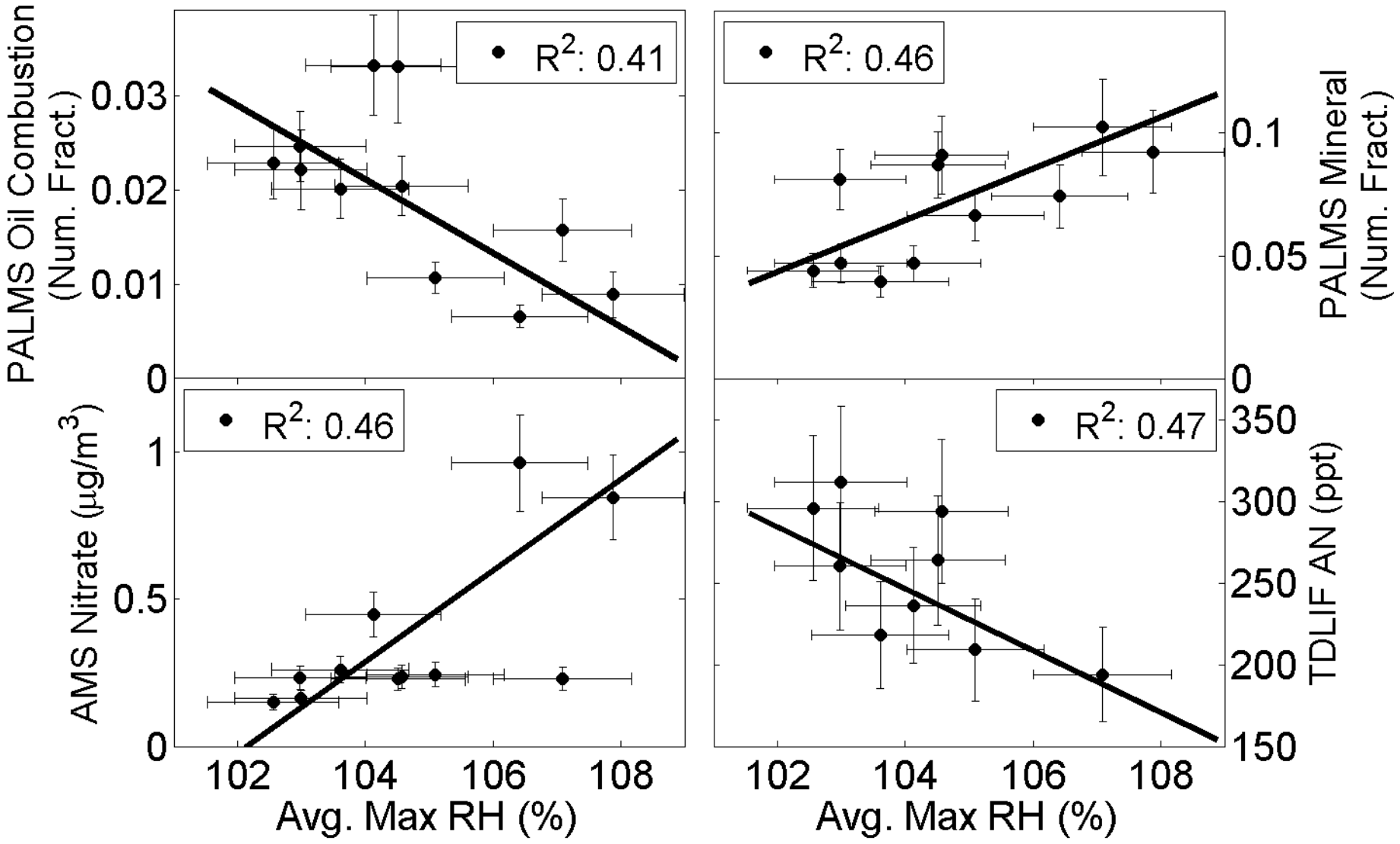


Effects of Inflow Air Quality on Ice Supersaturation in Convective Outflows



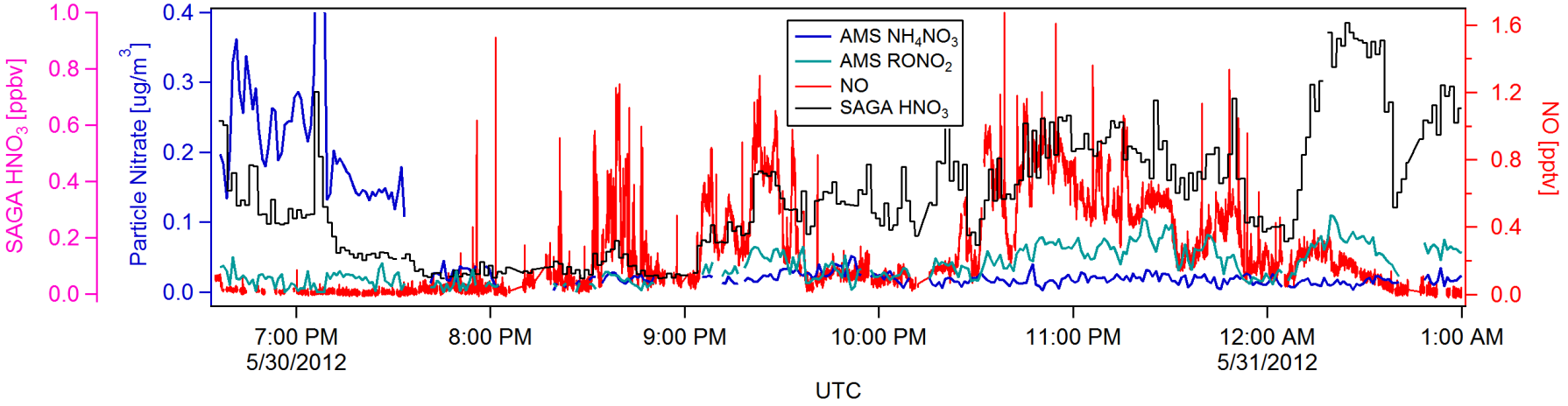
Josh DiGangi, Mark Zondlo

Inflow Species vs. Outflow Max ISSR RH



Goal: case studies of polluted and non-polluted inflow and differences in cirrus properties (e.g. aerosol composition, tracers, rate of uplift, level of detrainment)

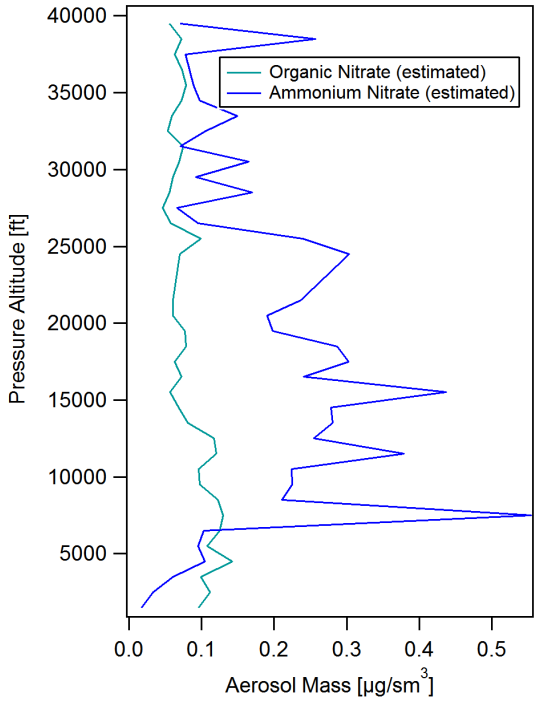
Nitrate Chemistry in the outflow



Both active convection flights and outflow show a modest increase in aerosol nitrate relative to other species (typically about 0.1 µg/sm^3). It is always associated with NO outflow, but it correlates very weakly with NO concentrations. Hence, it is unclear if this nitrate is formed in the convection or if it is the result of less efficient scavenging of nitrate

In most cases, this seems to be organic nitrate, as identified by the NO^+/NO_2^+ ion ratio in the AMS. This organic nitrate was not present in the inflow (although plenty of organic nitrate was observed in some of our lower altitude sampling). Note that the classification as organic nitrate is still tentative and interferences from other nitrates or nitric acid, for that matter, are possible.

Several flights showed also enhancements of ammonium nitrate, however in all of these there were inorganic nitrate sources in the inflow or it was a Day 2 flight with ill-defined inflow chemistry.



Campaign Averages of both types of nitrate