Biomass burning plumes observed with the DLR Falcon research aircraft during DC3 – first results

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DLR-Falcon @ DC3

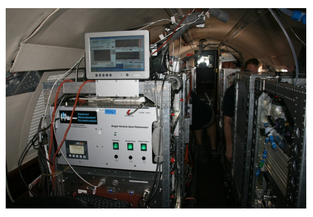
The DLR Falcon stayed in Salina/Kansas from May 28th to June 16th 2012 and conducted 13 research flights.

Date 2012	Falcon flight route	Flight time	Flight's main objectives, remarks
26-May	Keflavik-Kangerlussuaq	2:35	**Transfer flight**, pollution plume in MT
	Kangerlussuaq-Gander	3:50	**Transfer flight**, no special remarks
27-May	Gander-Syracuse	3:15	**Transfer flight**, pollution/BB plume in UT
	Syracuse-Salina	3:05	**Transfer flight**, no special remarks
29-May F#1	Salina-Lubbock	3:20	**BL air**, low level BB plume (New Mexico/N. Texas)
F#2	Lubbock-Salina	1:45	**Fresh MCS outflow** (N. Oklahoma), anvil penetration together with G-V and DC-8, only low NO in anvil observed
30-May F#3	Salina-Ardmore	3:10	**BL air** & inflow region, BB plume above BL (New Mexico/N. Texas), high CO
F#4	Ardmore-Lubbock	2:40	**Fresh supercell outflow** (N. Texas), anvil penetration
5-June F#5	Salina-Wichita Falls	3:10	**Aged outflow** (KS-CO boarder), NO enhanced, **fresh and aged MCV outflow and inflow** (boarder TX-OK)
F#6	Wichita Falls-Salina	2:55	**Fresh and aged MCV outflow** (downwind and upwind, boarder TX-OK), anvil penetration
6-June F#7	Salina-Salina	3:10	**Fresh squall line outflow**, anvil penetration (boarder SE-Wyoming/NE-Colorado), coordination planned with G-V and DC-8, but Falcon diverted, Falcon triggered flash
8-June F#8	Salina-Salina	3:25	**Aged outflow** (Kansas), NO enhanced, MT BB plume
F#9	Salina-Salina	2:50	**Aged outflow** (Kansas), NO enhanced, MT BB plume
11-June F#10	Salina-Oklahoma City	3:25	**DC-8 intercomp., fresh and aged MCS outflow** (SW-Missouri/NW-Arkansas), anvil penetration, high NO, BB plume, high CO
F#11	Oklahoma City-Salina	2:50	**Fresh and aged MCS outflow** (SW-Missouri /NW-Arkansas), anvil penetration, high NO
12-June F#12	Salina-Salina	3:25	**Fresh squall line outflow**, anvil penetration (boarder SE-Colorado/ SW-Kansas), high NO
14-June F#13	Salina-Salina	2:45	**Aged outflow** (Kansas/Missouri), MT BB plume
17-June	Salina-Syracuse	2:40	**Transfer flight**, BB plume in MT/UT (elevated CO)
17-June	Syracuse-Gander	2:40	**Transfer flight**, BB plume in MT/UT (elevated CO)
18-June	Gander-Kangerlussuaq	3:30	**Transfer flight**, BB plume in MT/UT (elevated CO)

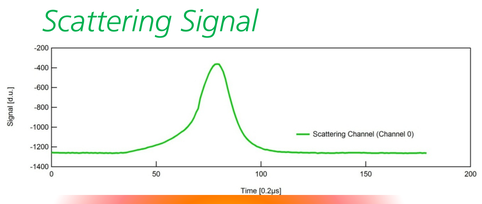
- As the 2012 wildfire season in the U.S. was one of the worst in the past decade, the DLR Falcon detected biomass burning during nearly every flight.
- Most of the biomass burning plumes were found between 2 and 7 km altitude, but in some cases extended smoke layers were also present in the UT (9-13 km), and in the outflow of thunderstorms.

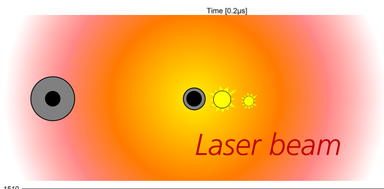
Methods:
The Single Particle Soot Photometer (SP2)

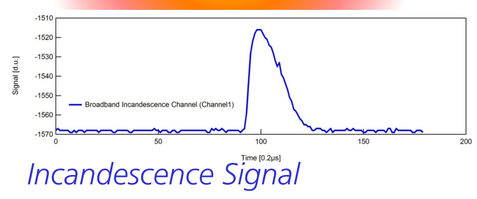
The SP2 measures the refractory black carbon (rBC) mass of single particles and their coating thickness.



Scattering Signal







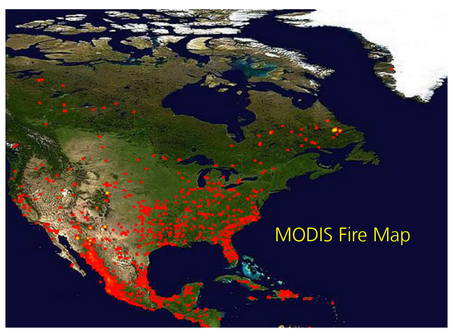
Incandescence Signal

- Particles are brought into an intense laser beam, where absorbing particles heat up and lose their coating
- When heated particles reach their incandescence temperature, they evaporate
- The heated particles emit thermal radiation in the visible spectrum
- The emitted thermal radiation is proportional to the mass of the refractory black carbon core
- The scattering signal is recorded simultaneously, which makes it possible to determine the particle's mixing state

Biomass Burning Plumes measured during local Falcon flights during DC3

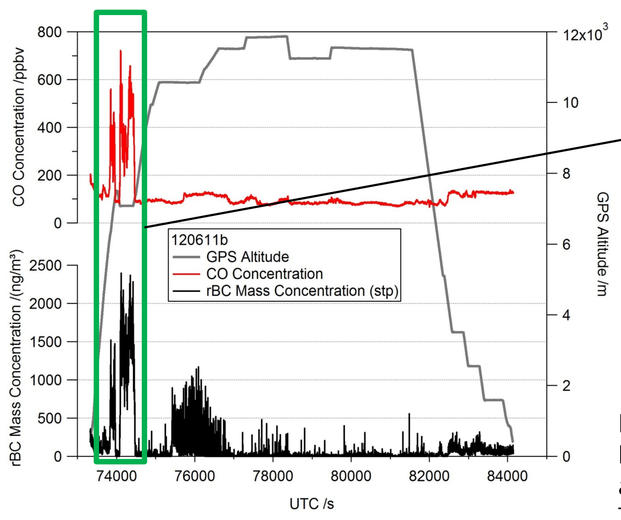
Scientific Goals:

- Statistics and characterization of the biomass burning plumes during DC3 (BC/CO; microphysical state; aging; impact of biomass burning on vertical profiles; determine plume age by back trajectories)
- Compare biomass burning contribution to upper tropospheric BC with aviation impact
- Assess the global contribution of biomass burning to transport of black carbon into the upper troposphere with global models

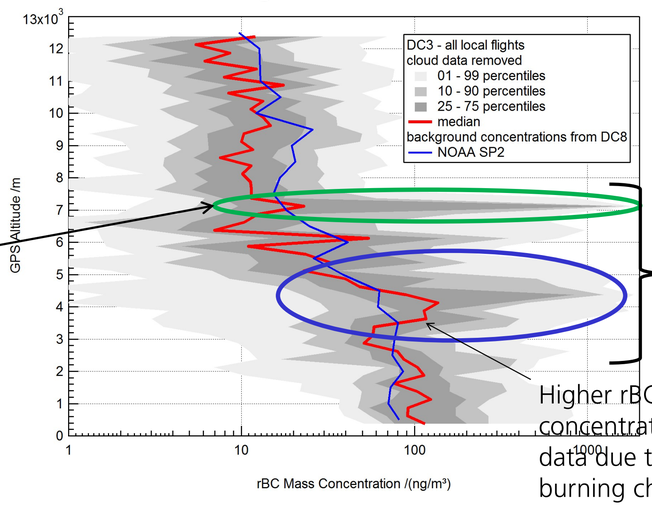


- The 2012 wildfire season was one of the worst in the past decade.
- The DLR Falcon encountered biomass burning plumes during nearly every local flight.

Flight 120611b on June 11th: Plume with highest CO and rBC mass concentrations during DC3

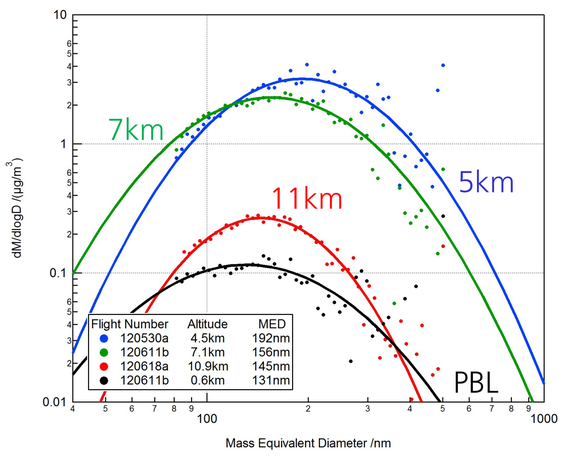


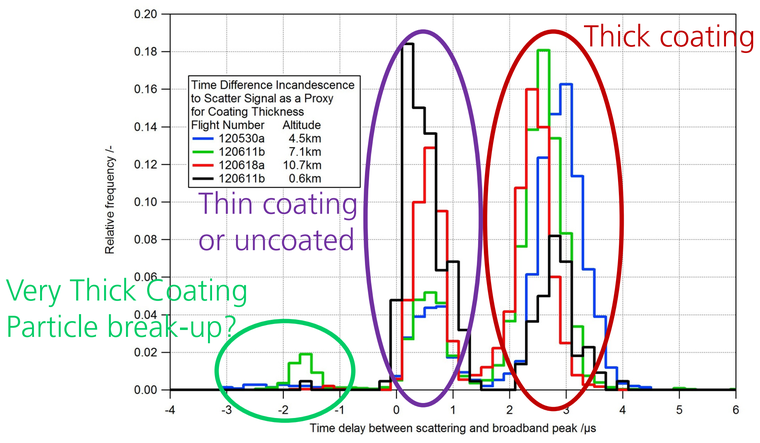
Refractory black carbon mass concentrations measured during DC3



Most biomass burning plumes were found at altitudes between 2 and 7 km. During transfer, an extensive biomass burning layer was also found at 11km altitude.
The peak in concentration at 4km is dominated by two biomass plume chasing flights (May 29th and 30th), which have no influence on the NOAA background profile.

Properties of biomass burning plumes observed during DC3





- The Biomass Burning Plumes at 4 and 7 km altitude show similar concentrations but different MEDs and mixing states, probably due to originating from different sources. All plumes show higher fractions of thickly coated particles than the boundary layer sample.
  - ➢ How representable are these plumes for the overall picture of biomass burning?
- The Biomass Burning Plume at 11km, measured during the transfer flight Gander-Kangerlussuaq over Canada on May 18th, has the lowest MED of the three plumes and the highest fraction of thinly coated particles.
  - ➢ Is this an effect of size-dependent wet removal? (as described in Moteki et al. 2012)

Summary

- During DC3 numerous biomass burning plumes originating from wildfires in Texas, New Mexico, Colorado, and Mexico were investigated. Layers were mostly found at altitudes between 2 and 7 km, but in some cases extended smoke layers were also present in the upper troposphere between 9 and 13 km altitude, and in the outflow of thunderstorms.
- All biomass burning layer examples here show a higher fraction of thickly coated particles than found in the boundary layer. In case of the June 11th plume, signatures of particle break-up were found.
- Black carbon (BC) mass concentrations (size range: 70 nm - ~500 nm) in the biomass burning plumes ranged between 0.1 and 2 µg m^{-3}. Peak CO concentrations were as high as 700 nmol mol^{-1}.

Next Analysis Steps

- Compare all biomass burning plumes the Falcon encountered during DC3 to get a more complete picture.
- Characterize the meteorology along trajectories to investigate the processes which transport biomass burning layers into the upper troposphere

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Literature: Moteki, N., et al. (2012), Size dependence of wet removal of black carbon aerosols during transport from the boundary layer to the free troposphere, Geophys. Res. Lett., 39, L13802, doi:10.1029/2012GL052034.

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