Black carbon aerosol vertical profiles repeatedly measured from the polar southern to the polar northern hemisphere

HIAPER Pole-to-Pole Observations (HIPPO) of Carbon Cycle and Greenhouse Gases Study

Supported by NSF, NOAA, and NASA

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Outline

1. Overview of the HIPPO Dataset
2. Single Particle Soot Photometer
3. HIPPO BC Results
4. Future analyses

HIPPO: What

CO_2	CH_4	CO	N_2O
O_2/N_2	O_3	CFCs	HCFCs
SF_6	CH_3Br	PAN	CH_3Cl
H_2	H_2O	N_2/Ar	COS
CS_2	T	P	Winds

Reactive hydrocarbons

Marine species

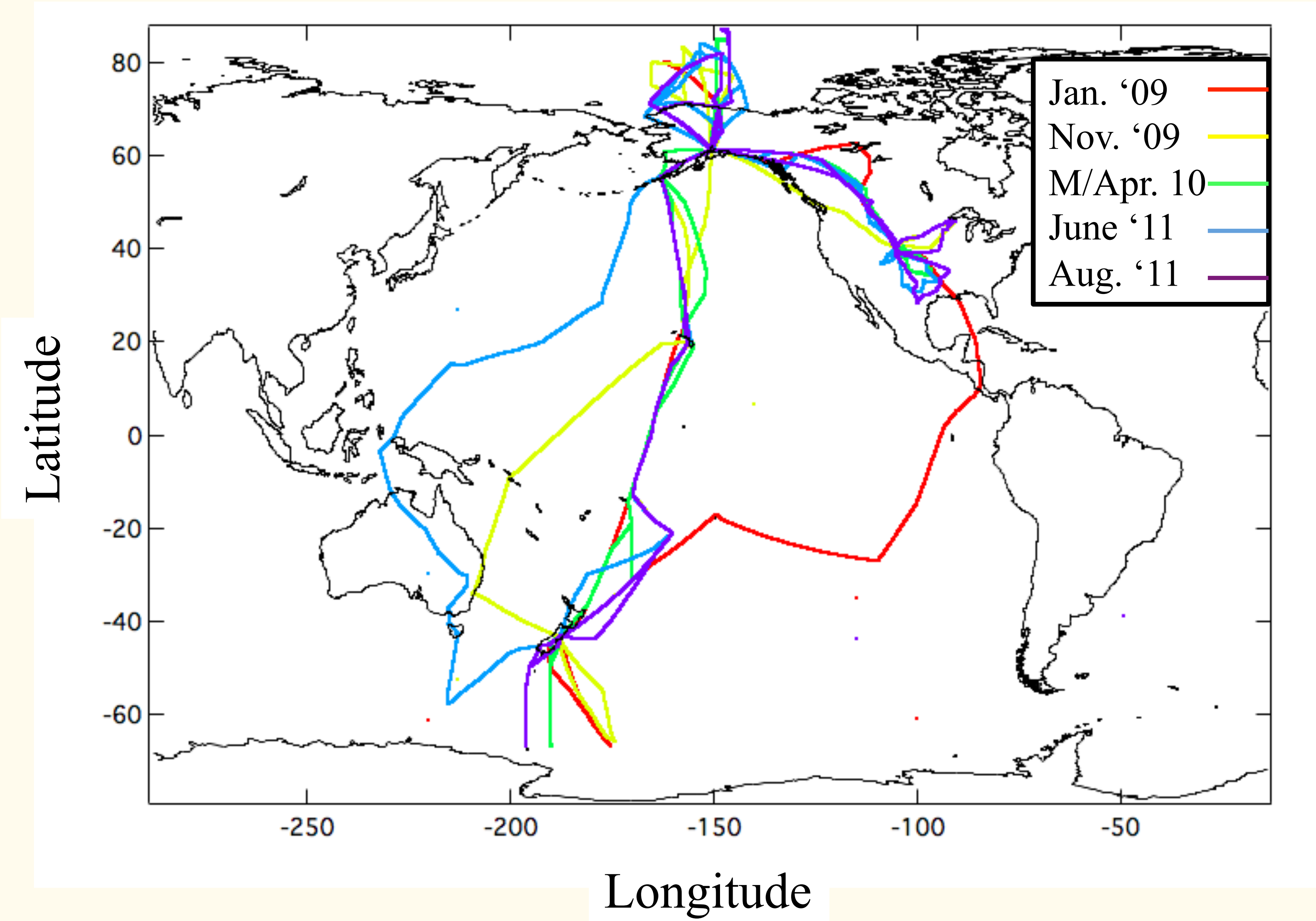
Isotopes of CO_2

Aerosol

Cloud water

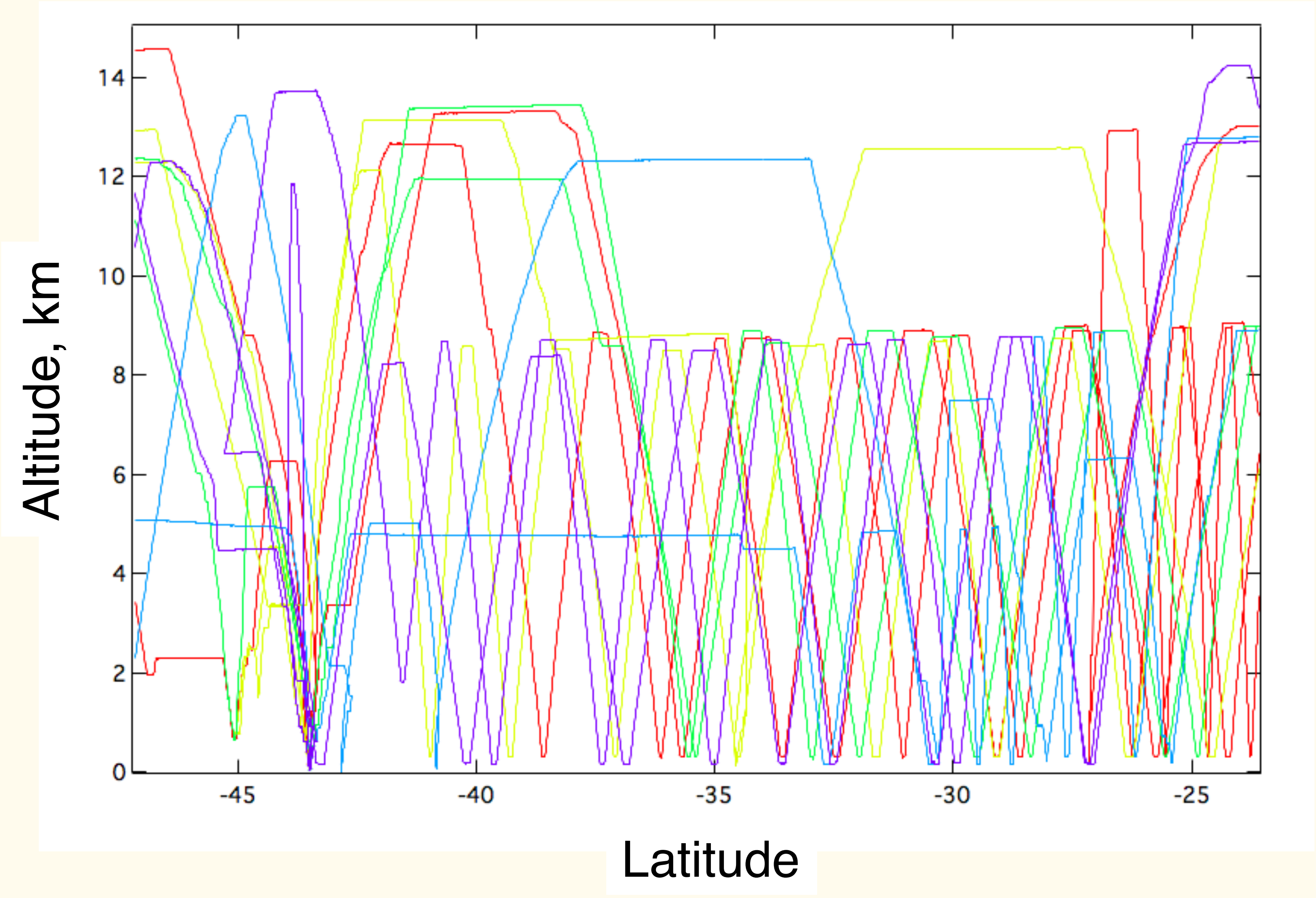
BC Aerosol

HIPPO: Where

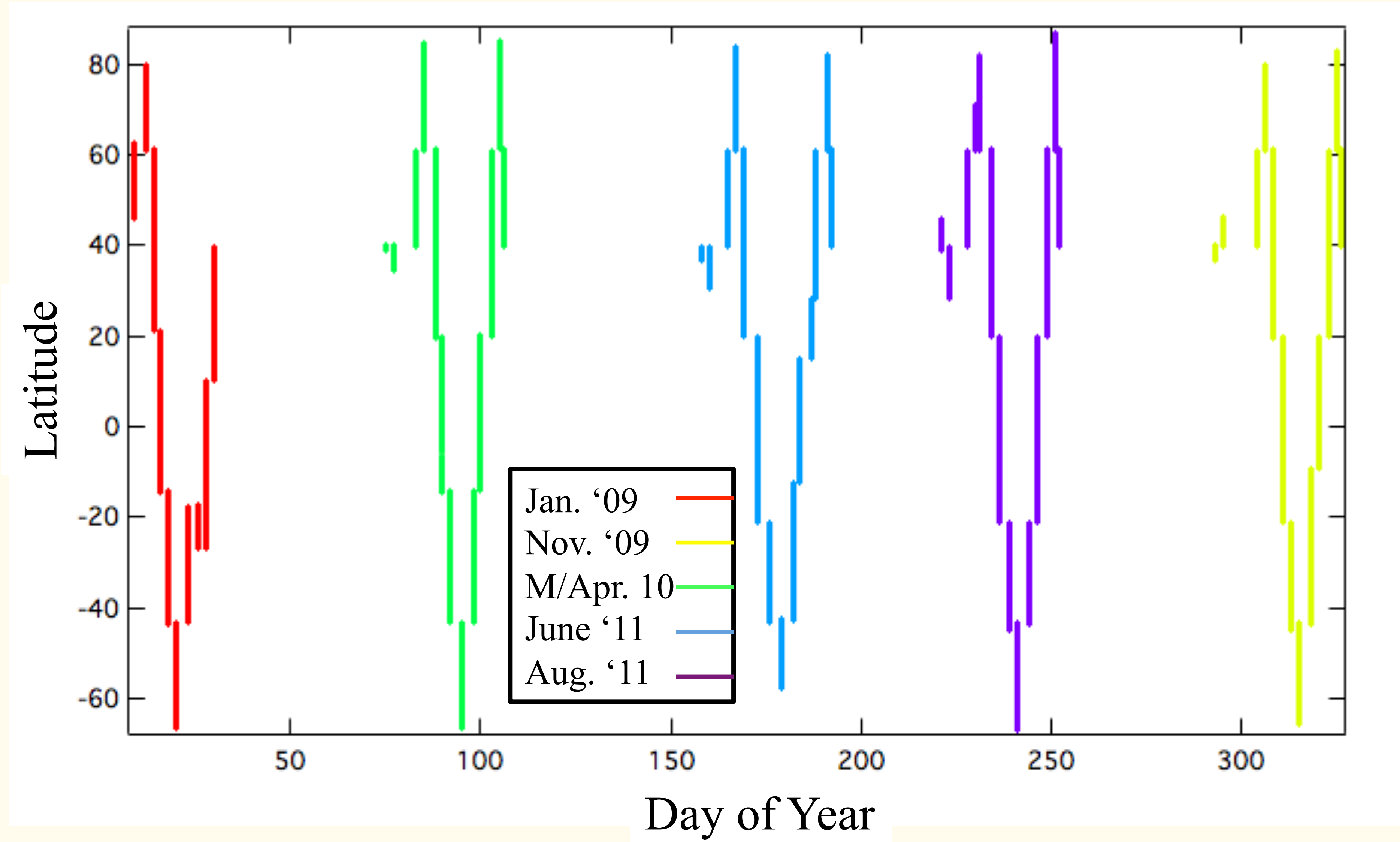


Latitude
80
60
40
20
0
-20
-40
-60
-250
-200
-150
-100
-50
Longitude
Jan. '09
Nov. '09
M/Apr. 10
June '11
Aug. '11

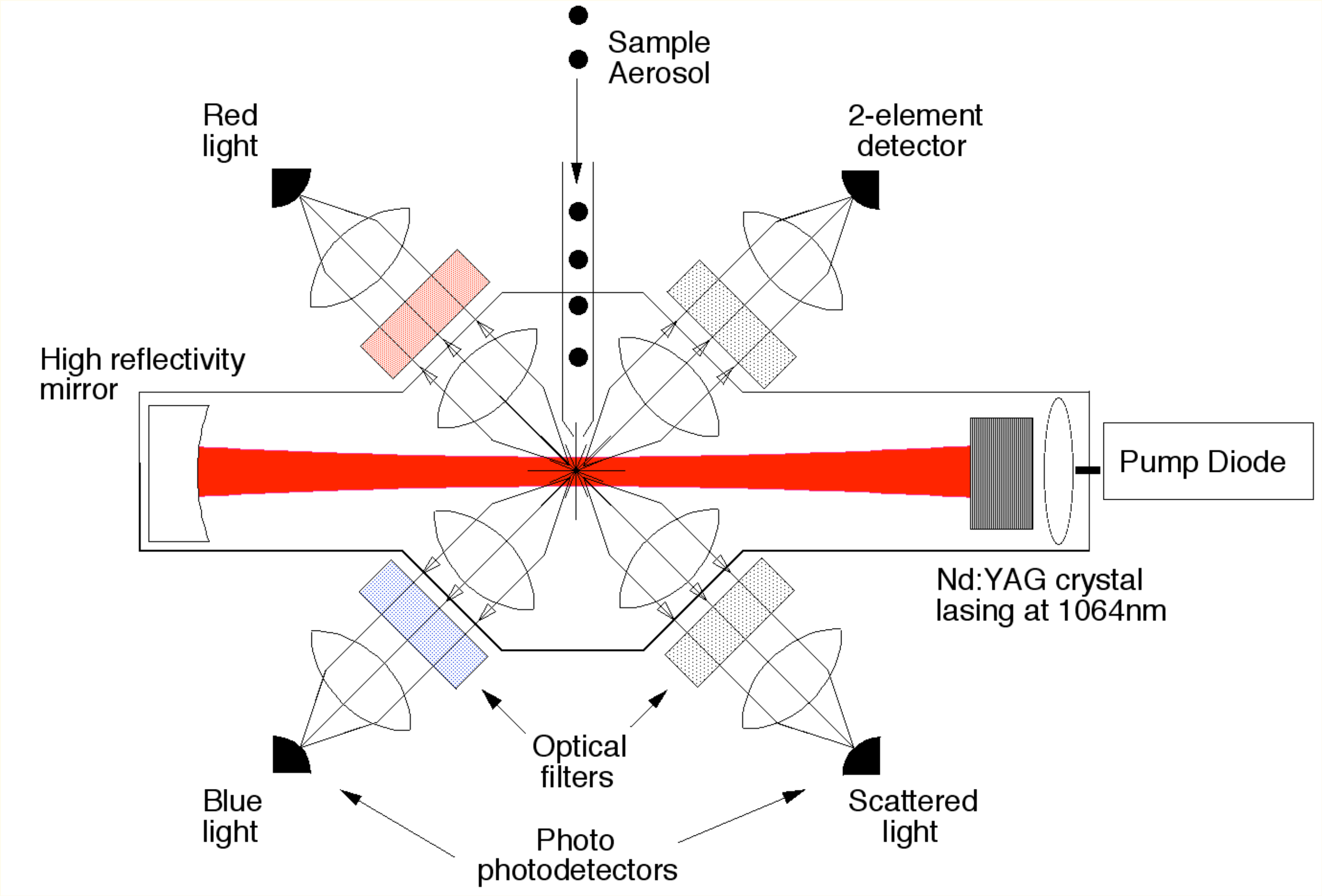
HIPPO: Vertical Coverage



HIPPO: Seasons



Single-Particle Soot Photometer (SP2)



BC detection ~70 - 600 nm Volume Equivalent Diameter
Scattering = 150 - 800 nm diameter
Sampling < 1/4 l/m

Concept demonstrated at Research Electro Optics, Inc. Instrument refined, developed and produced by Droplet Measurement Technology, Inc.

BC Data Products

Primary Product

Single particle

1. BC mass content

2. Non-BC content?

3. Dry optical size

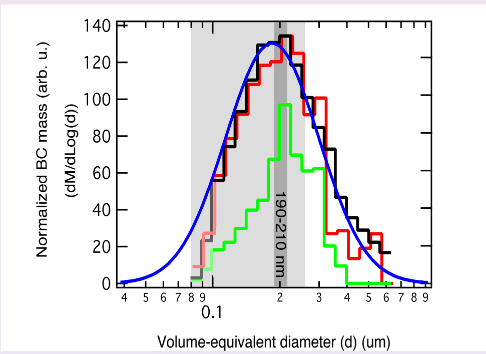
Derived Product

Single particle

1. BC mass content
2. Non-BC content?
3. Dry optical size

Accumulation mode BC Mass loading

Mass size distributions



Quantitative estimate of mixing state

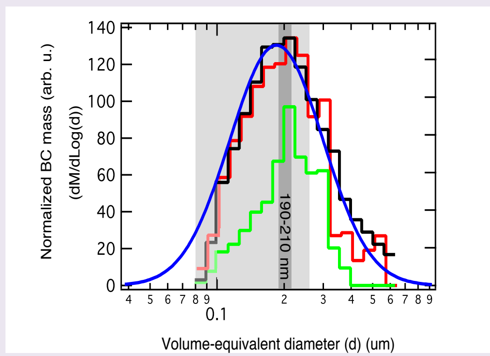
- Via Mie Theory -

- Coating thickness
- Absorption enhancement

Derived Product | Caveats

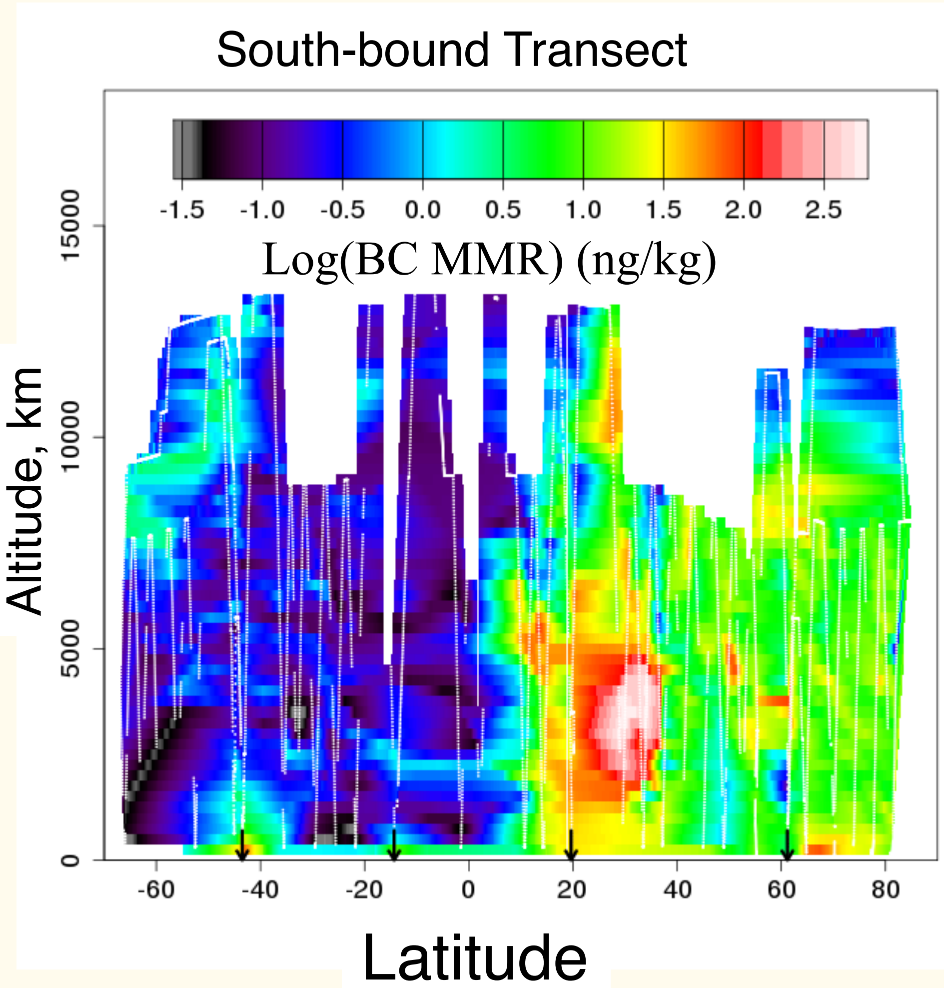
Single particle

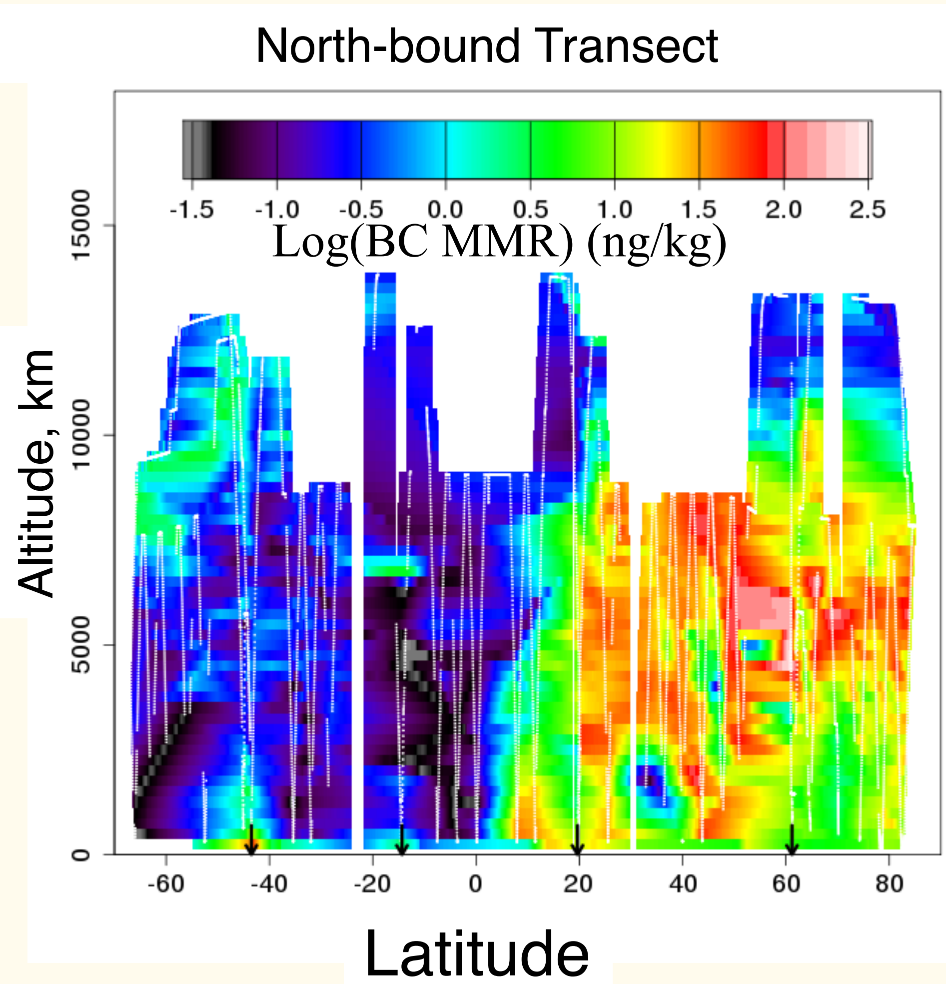
1. BC mass content
2. Non-BC content?
3. Dry optical size

Derived Product	Caveats
Accumulation mode BC Mass loading	25% absolute uncertainty ~70- 600 nm diameter
Mass size distributions 	Good statistics required (time scale depends on BC load)
Quantitative estimate of mixing state	Sensitivity estimated at 25 nm thickness
- Via Mie Theory - • Coating thickness • Absorption enhancement	Only for a narrow range BC mass, largely unvalidated, some supporting evidence.

Curtains

HIPPO 3: March/April 2010

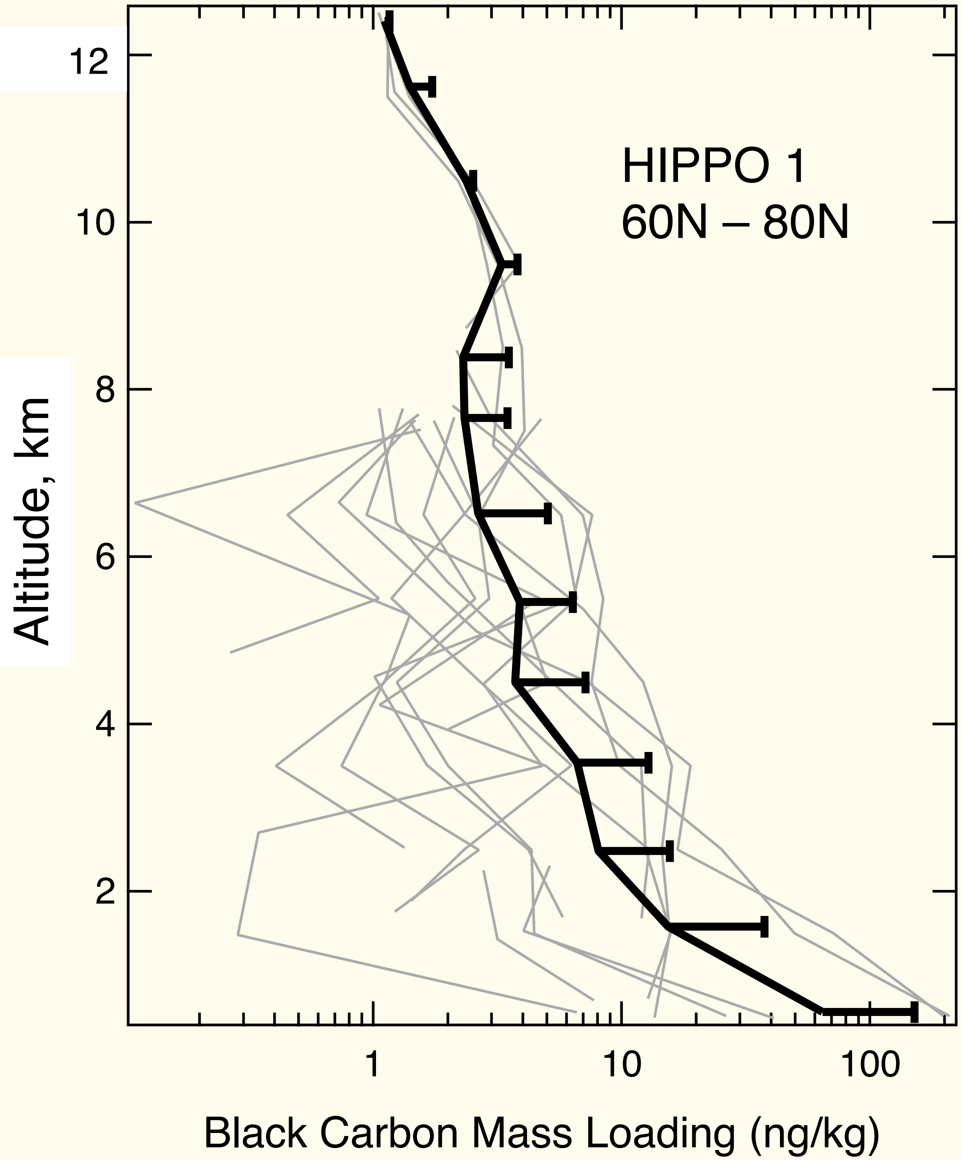




Curtain plots courtesy of Britt Stephens, NCAR

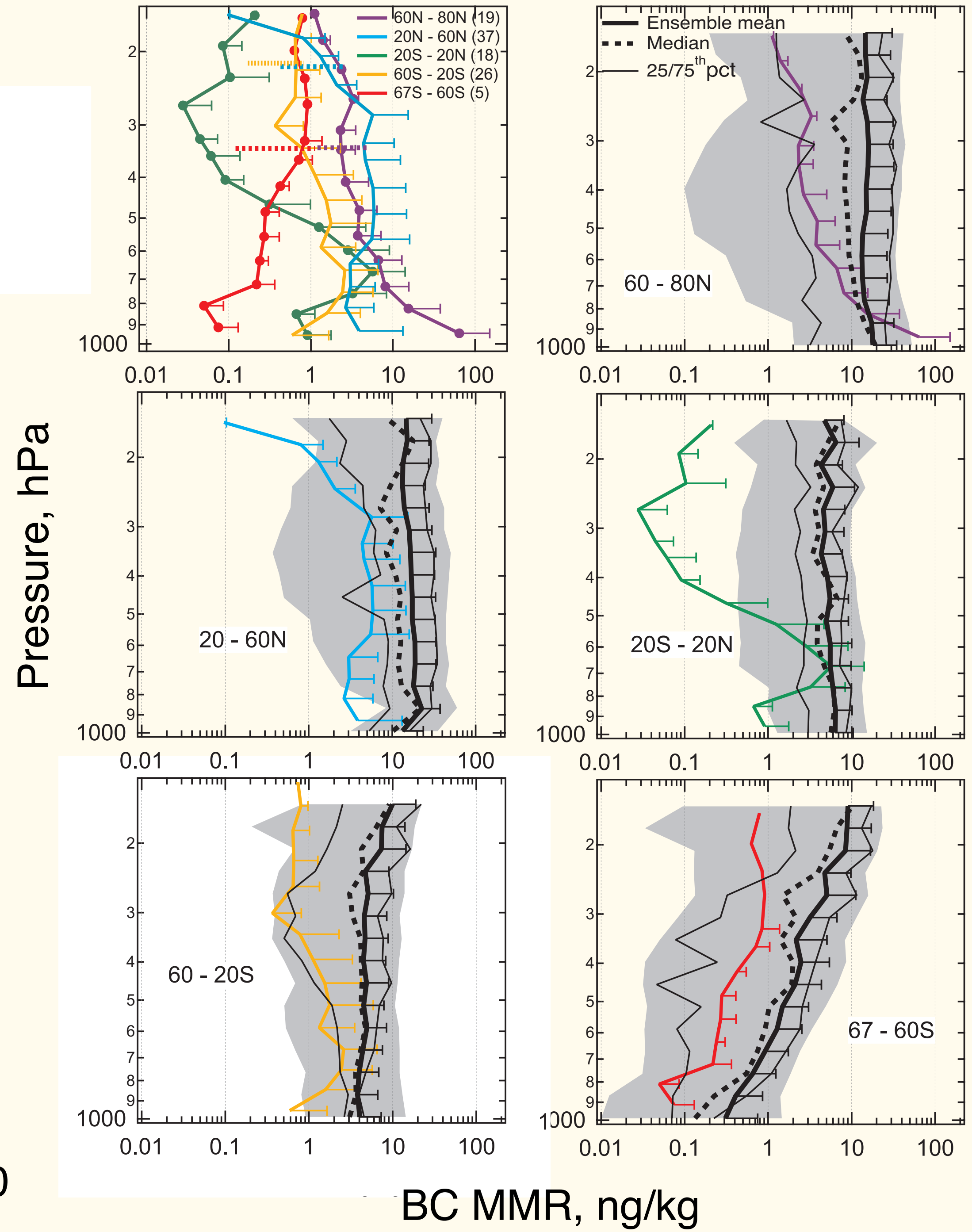
Analysis approach

- Each vertical ascent/ descent treated as an independent profile measurement: statistics based on inter-profile variability.
- Whiskers represent standard deviation at each altitude/ pressure bin
- ~1km resolution



AeroCom

- 14 global models from AeroCom suite compared to observations.
- Colored profiles are SP2- measured zonal averages
- Models overestimate BC mass loads by a factory 5, on average.
- Insufficient removal of BC identified as a likely source of the bias.



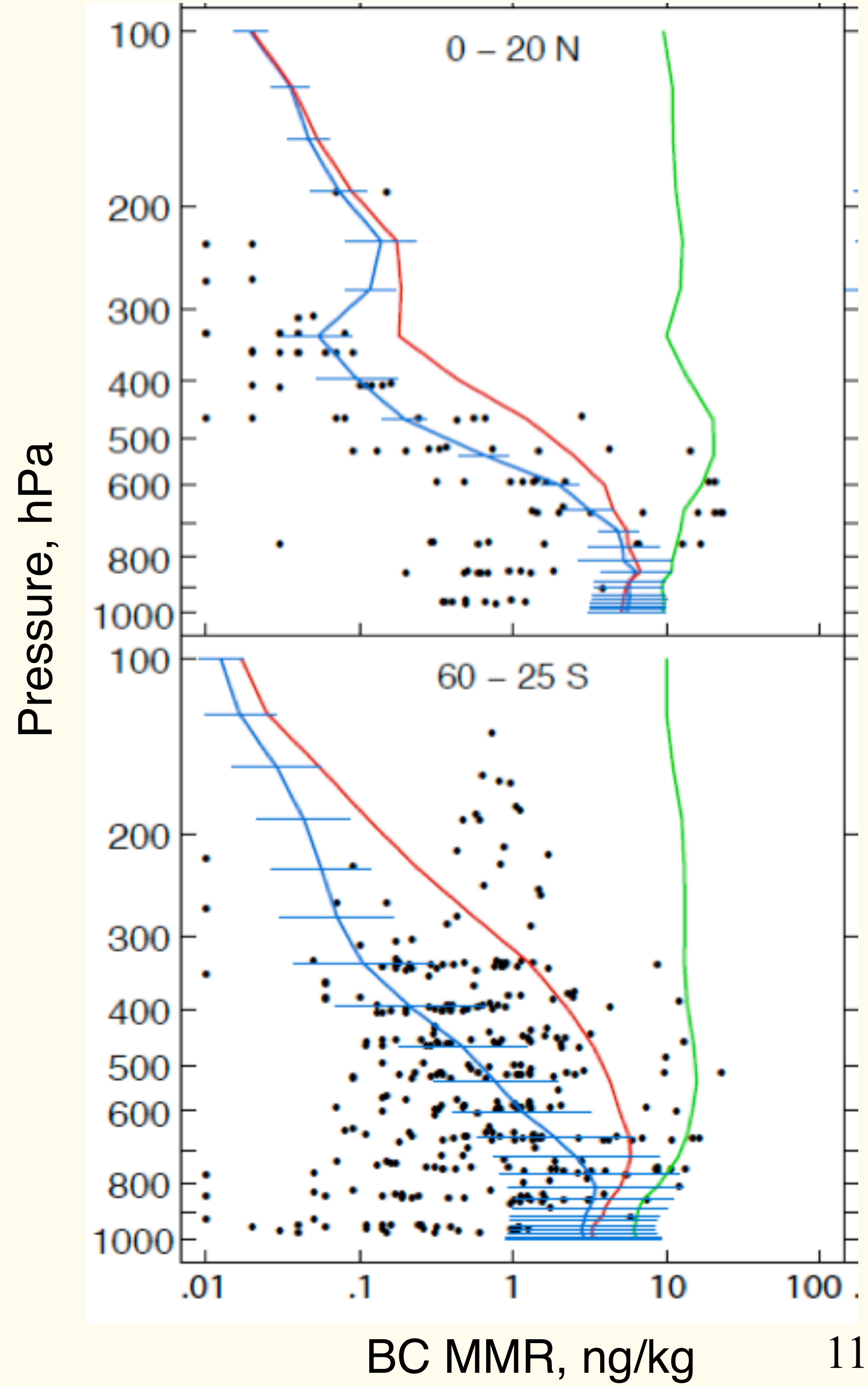
Schwarz et al., GRL 2010

BC Removal

HIPPO 1 only

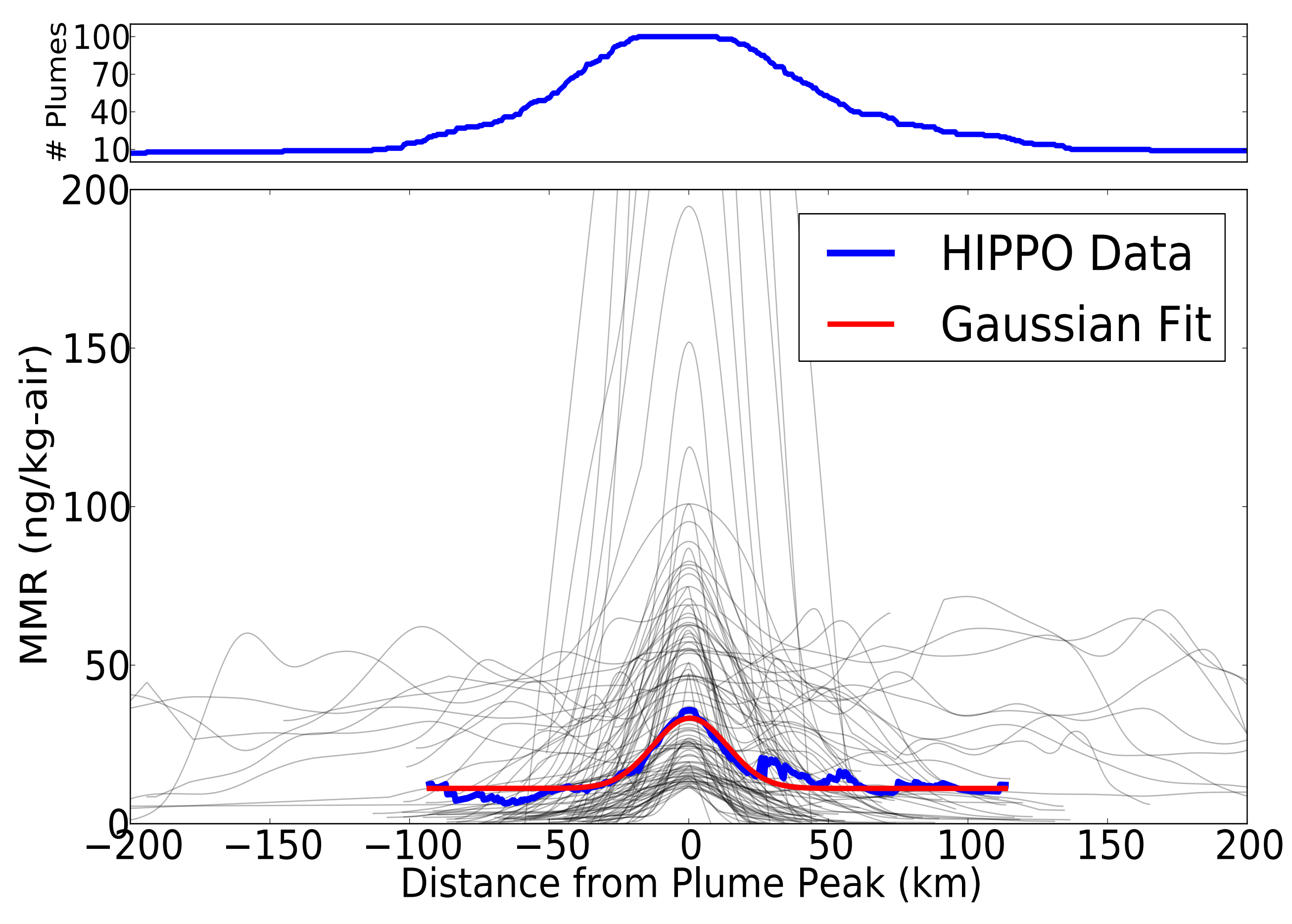
- Measured BC (1 km vertical bins) shown by black dots.
- Vertical lines GFDL-AM3 model with reanalysis winds
- Green: $F_{scav} = 0.01$ for all snow.
- Red: $F_{scav} = 0.01$ for Wegener-Bergeron-Findeisen snow, 0.3 for freezing/riming
- Blue: $F_{scav} = 0.3$ for all snow.
- All rain: $F_{scav} = 0.3$
- All convective precipitation: $F_{scav} = 0.4$

Fan et al., *submitted JGR 2012*



Plume Length Scales

- 100 plumes from 400 vertical profiles in HIPPO 1 – 3
- Some mixing of vertical/ horizontal length scales.
- Median plume length scale is 115 km
- Plumes contain ~60% of all remote BC mass

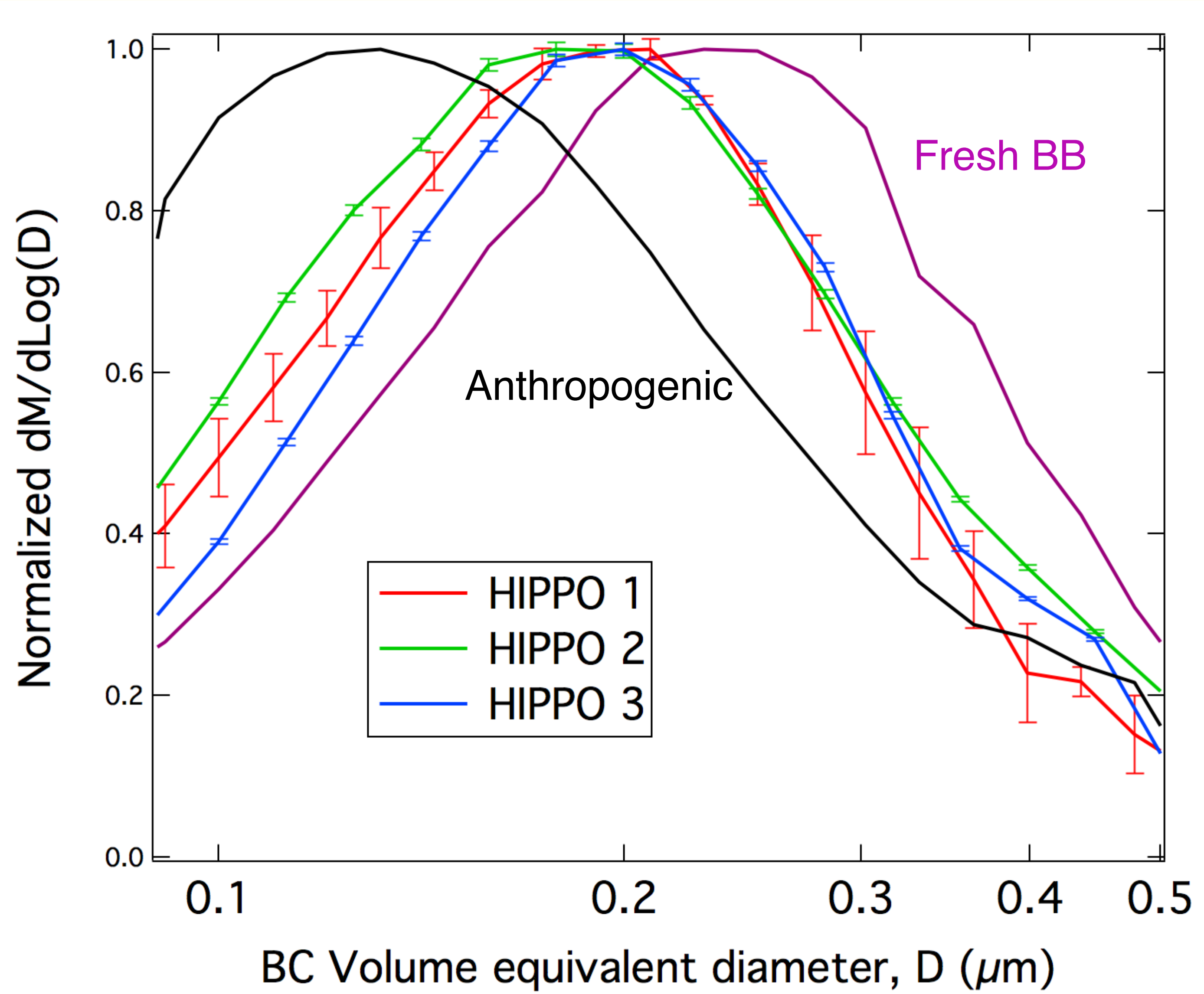


Weigum et al., *accepted* GRL, 2012

BC Mass Size Distributions

- Greatly reduced variability in remote air masses – simplifies treatment, provides model constraint

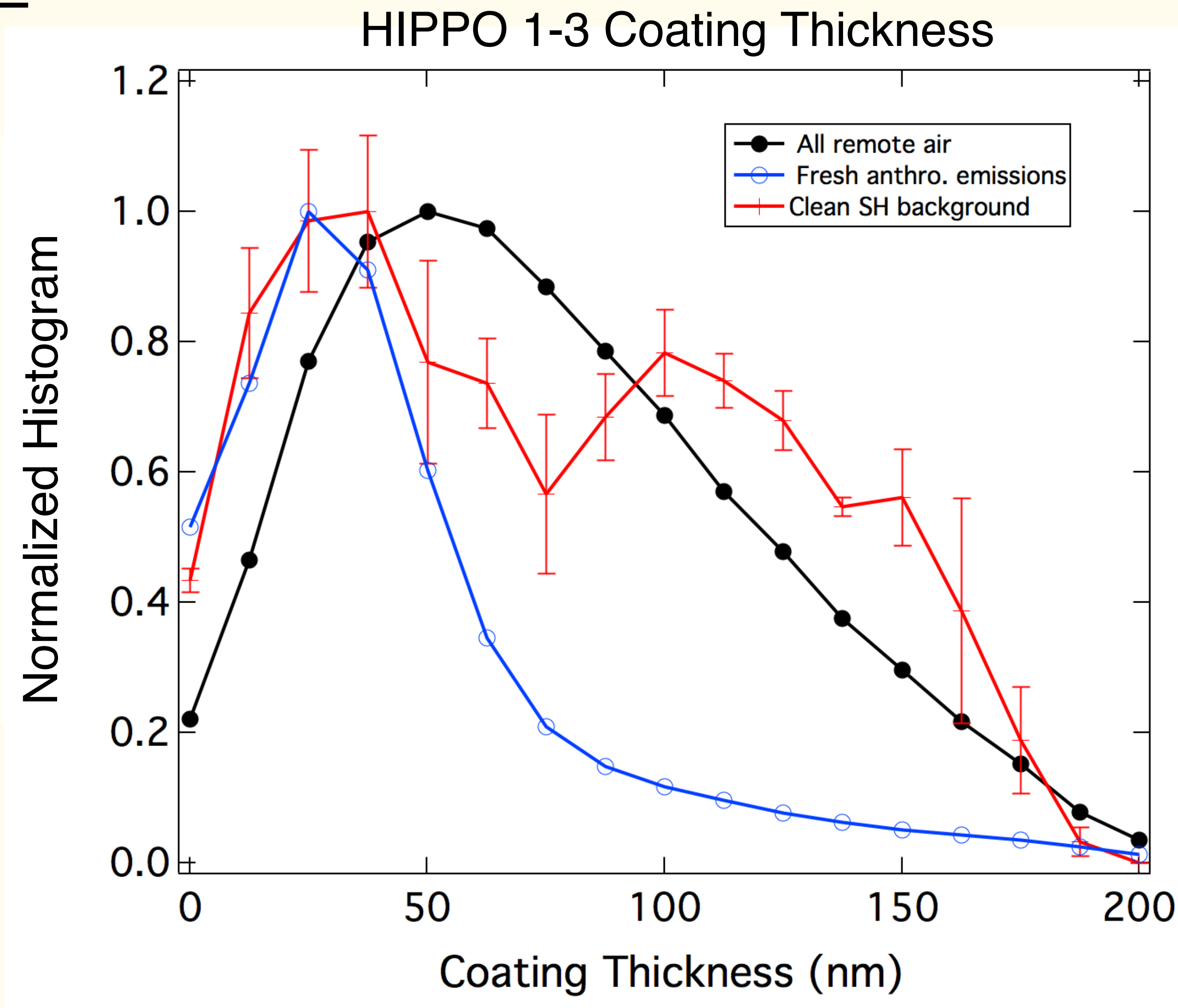
- A good estimate of a "general remote" BC size distribution is: 182 nm mass median diameter, σ = 1.64



Schwarz et al., *in preparation*

Dry Coatings

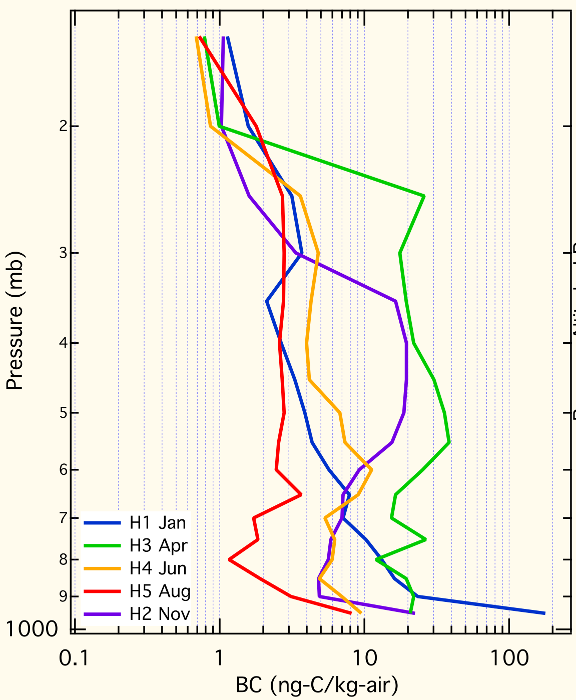
- BC cores of 150-180nm
- Optical size/BC mass interpreted with Mie theory for coating thickness
- Bimodal distribution in coating thickness associated with clean SH air
- Results generally consistent with expectations.



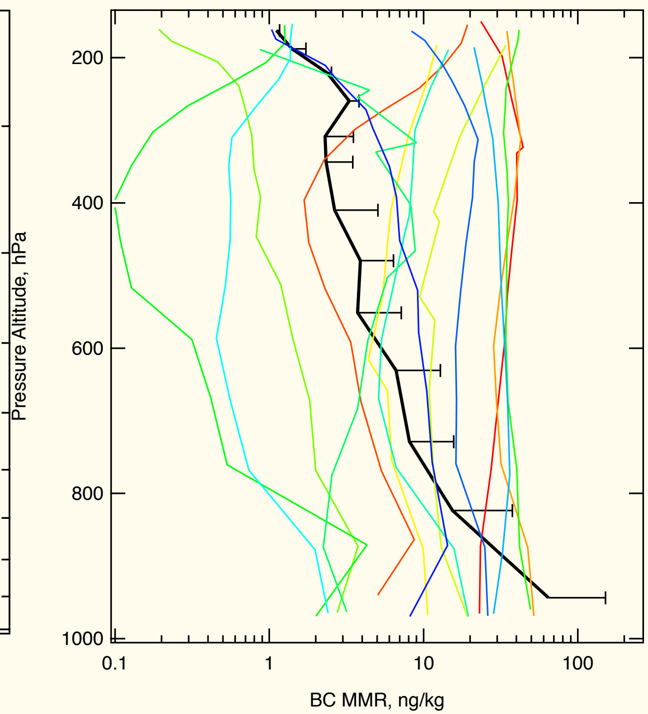
Future Analysis

- Full 5-HIPPO AeroCom/ Measurement BC intercomparison
- Individual model comparisons

5-HIPPO 60-85N



HIPPO-1 60-80N



Collaborations

Carslaw Group – Leeds
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Jacob Group - Harvard
S. Fan – NOAA GFDL
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Comments/questions?