



Overview of Comprehensive Pole-to-Pole Airborne Survey of Greenhouse Gases



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²Harvard University

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⁴Rosenstiel School of Marine and Atmospheric Sciences

⁵National Science Foundation

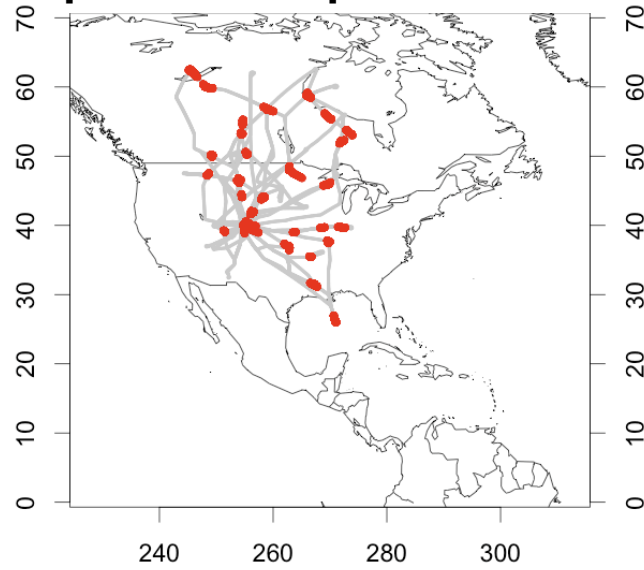
HIPPO Instrumentation

Harvard/Aerodyne—HAIS QCLS	CO₂, CH₄, CO, N₂O (1 Hz)
NCAR A02	O₂/N₂, CO₂ (1 Hz)
Harvard OMS CO ₂	CO₂ (1 Hz)
NOAA CSD O ₃	O₃ (1 Hz)
NOAA GMD O ₃ , H ₂ O	O₃, H₂O (1 Hz)
NCAR RAF CO	CO (1 Hz)
NOAA-GMD UCATS and PANTHER GCs	CO, CH₄, N₂O, CFCs, HCFCs, SF₆, CH₃Br, CH₃Cl, H₂ (70 – 200 s)
Whole Air Samples: Nwas (NOAA-GMD), AWAS (Miami), MEDUSA (NCAR/Scripps)	O₂/N₂, N₂/Ar, CO₂, CH₄, CO, N₂O, SF₆, H₂, COS, CS₂, halocarbons , solvents, reactive HCs, marine species, ...
VCSEL Princeton/SWS	H₂O (1 Hz)
NOAA SP2	Black Carbon mass (1 Hz)
MTP, wing stores	T, P, winds, aerosols, cloud water

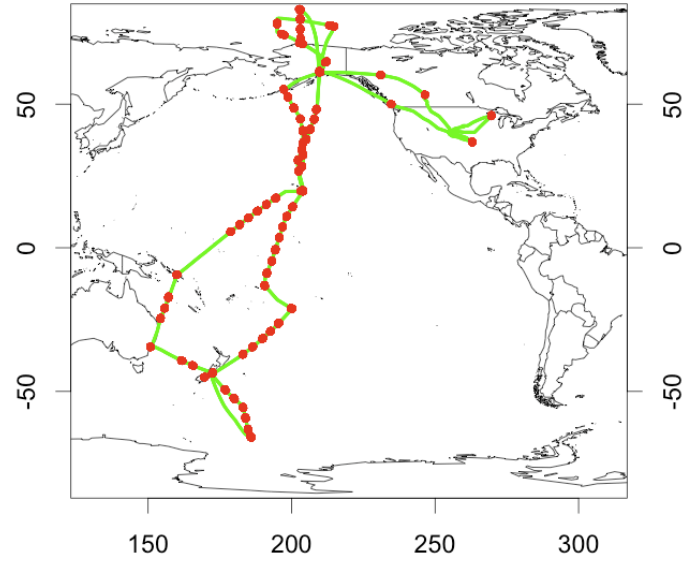
Multiple measurements: *Red symbols* ≥ 3, *Blue* = 2; *sampling rates in ()*.

HIPPO itinerary

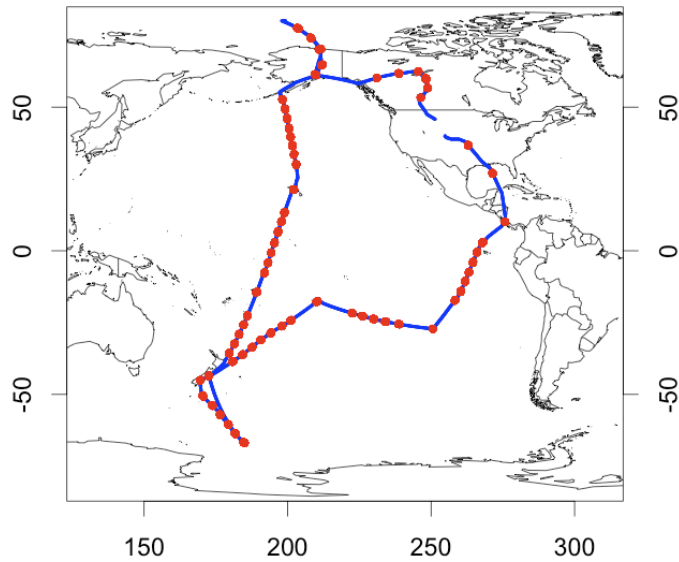
preHIPPO Apr-Jun 2008



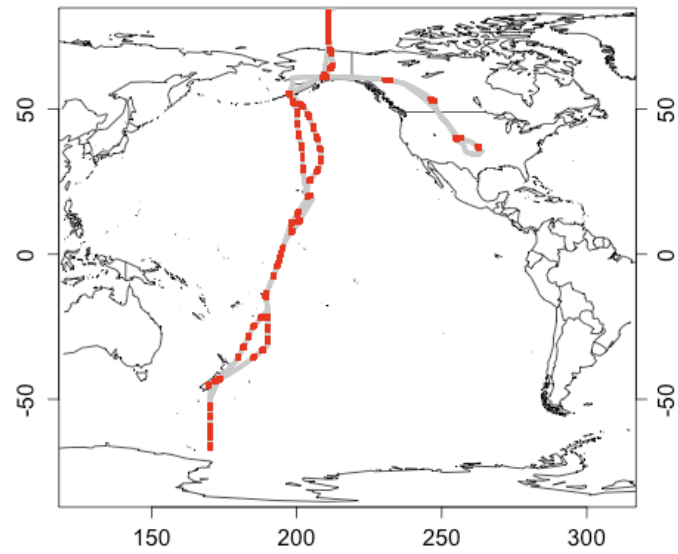
HIPPO_2 Nov 2009



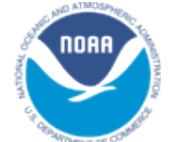
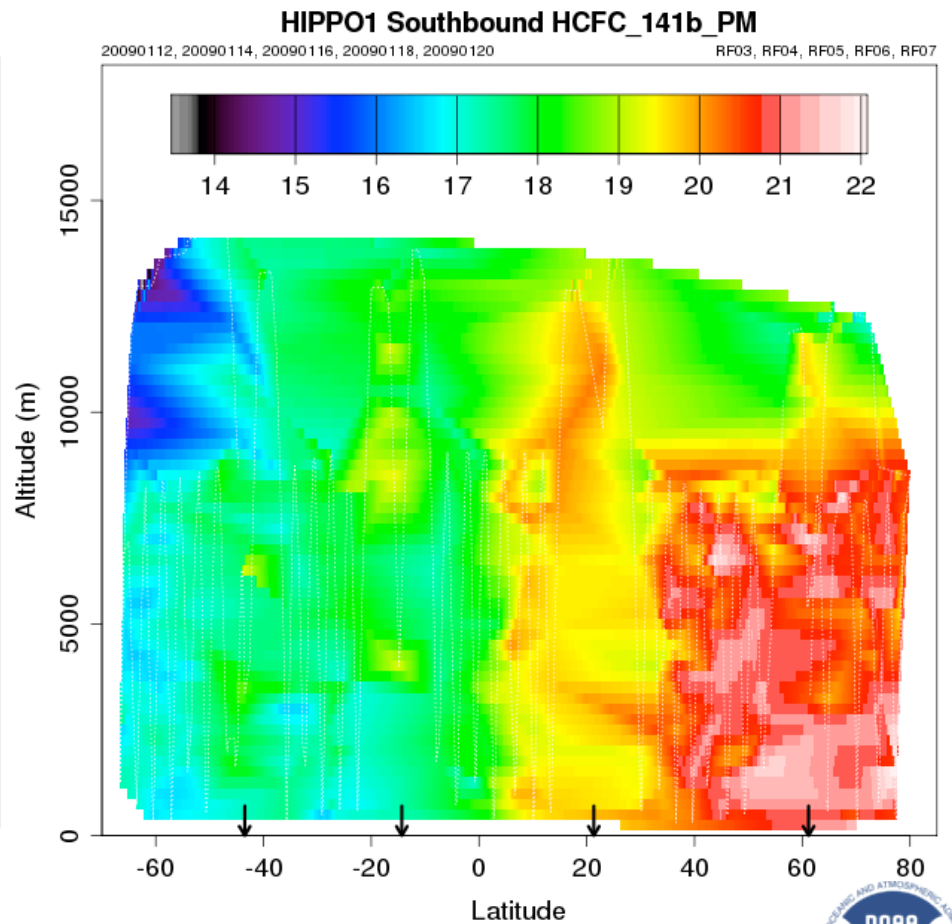
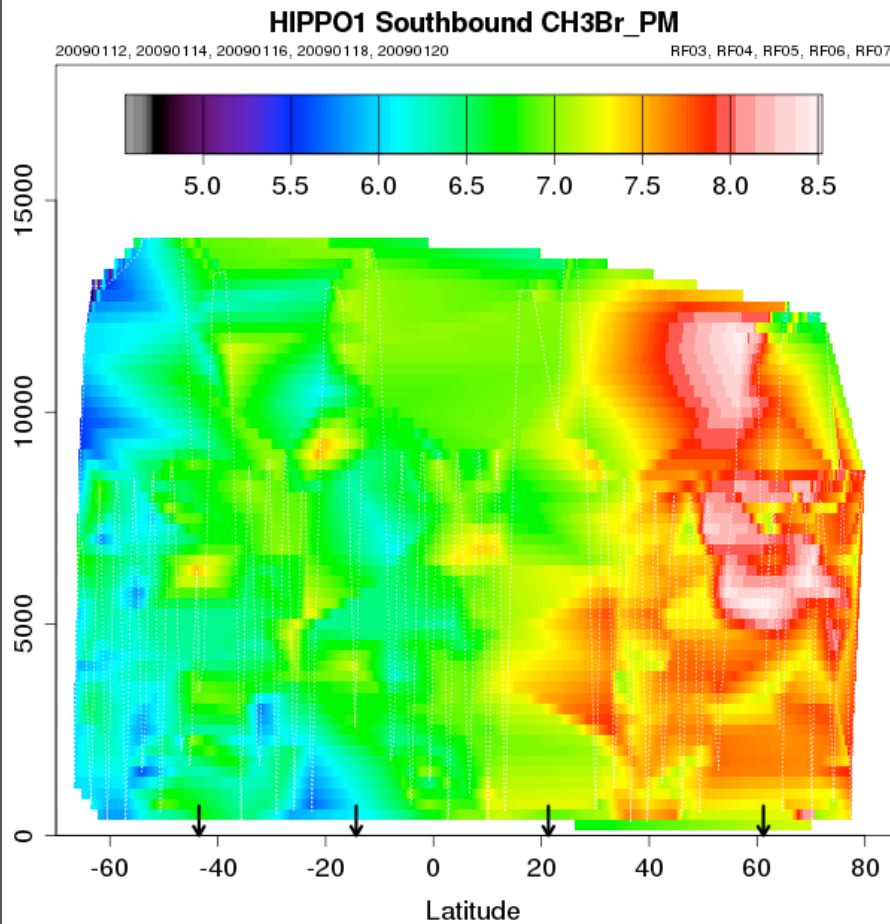
HIPPO_1 Jan 2009



HIPPO_3 Apr 2010



HIPPO1 (SB) NOAA PANTHER CH₃Br & HCFC-141b

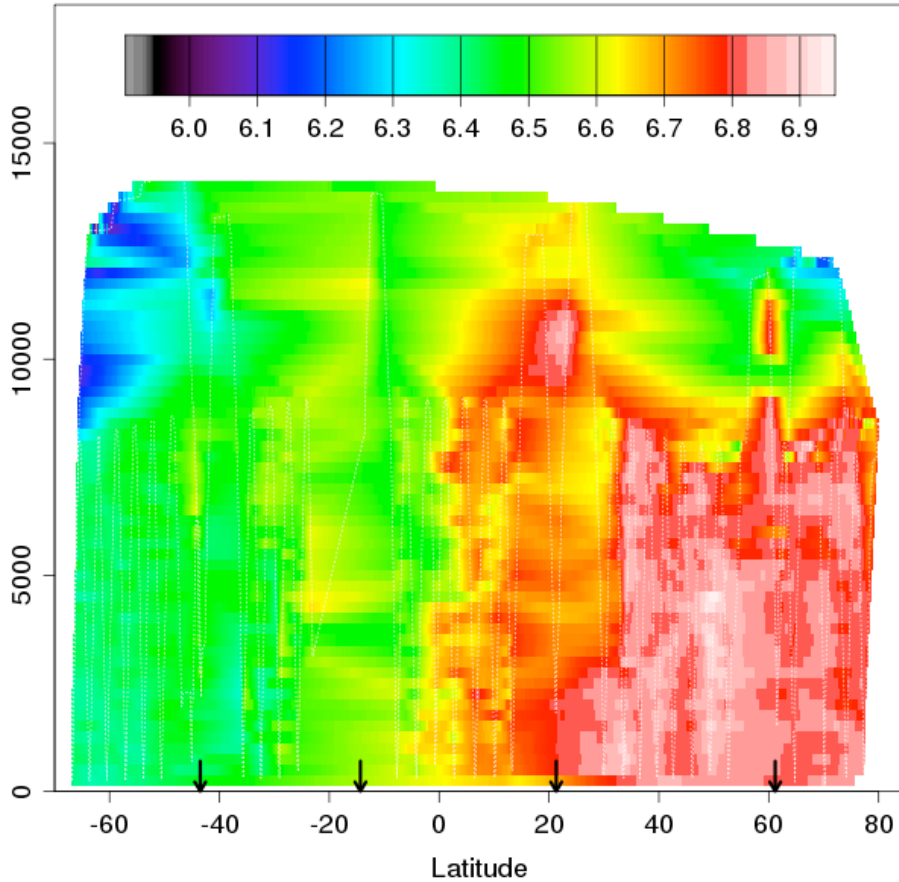


HIPPO1 (SB) NOAA SF₆ & CO₂

HIPPO1 Southbound SF₆_UGC

20090112, 20090114, 20090116, 20090118, 20090120

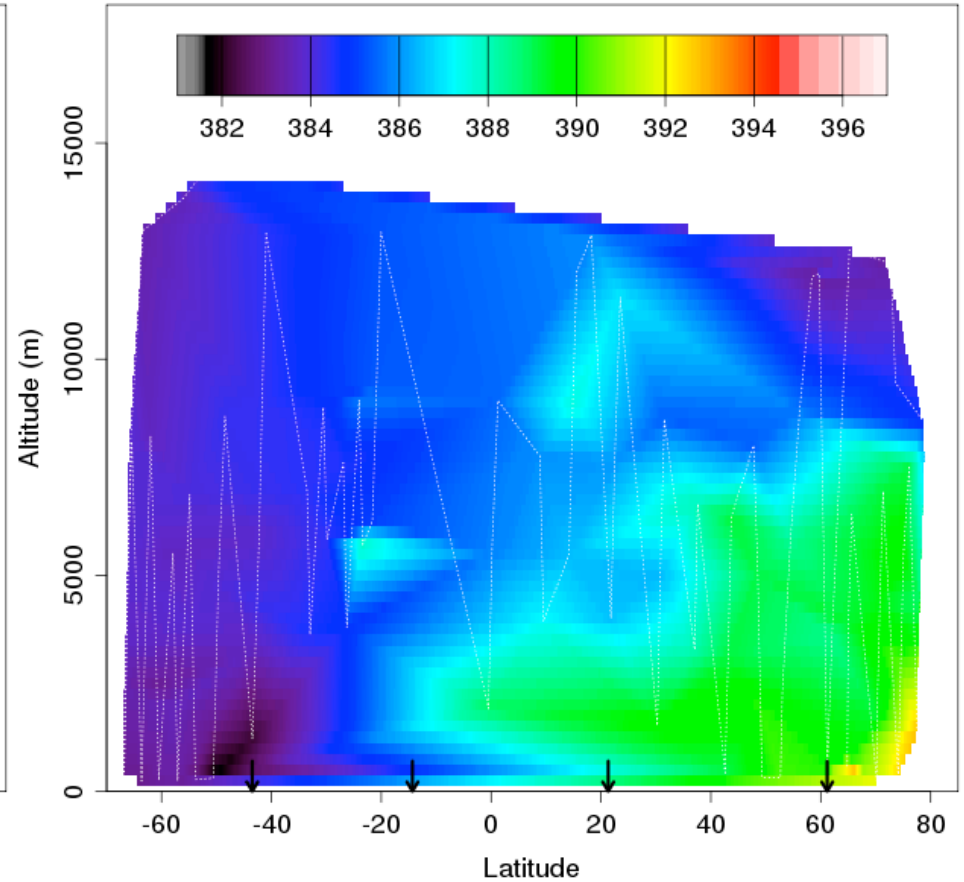
RF03, RF04, RF05, RF06, RF07



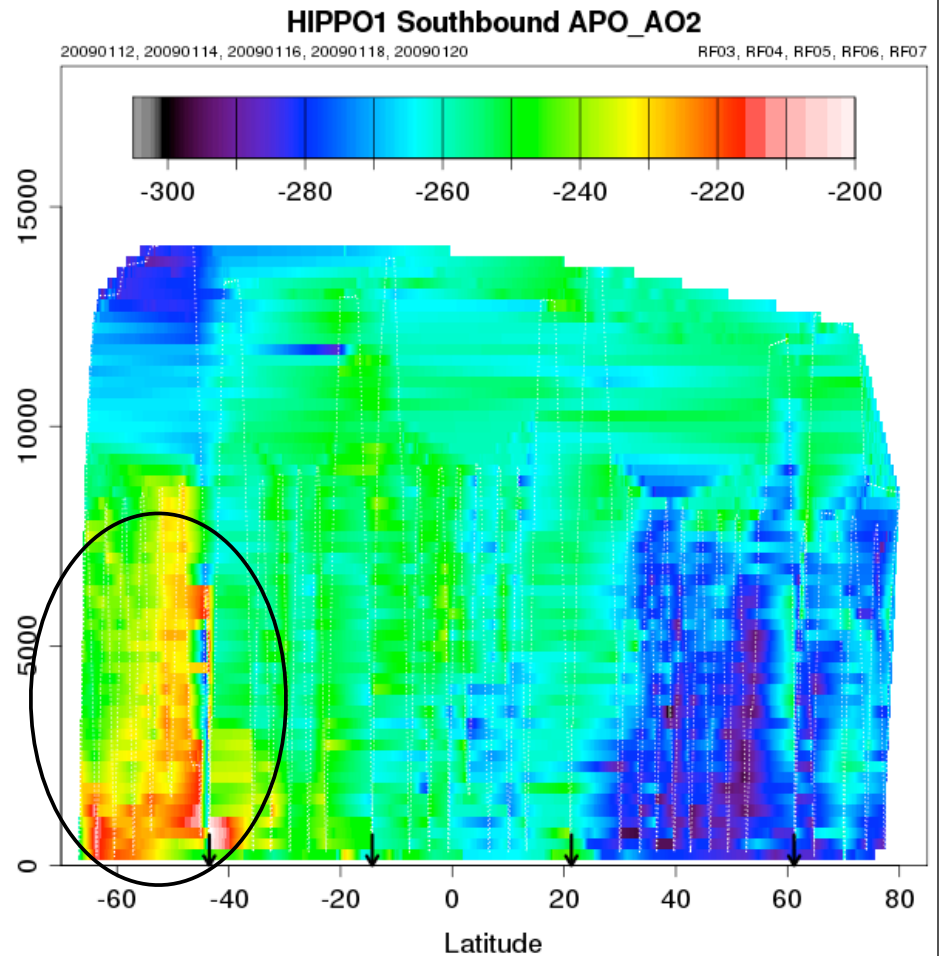
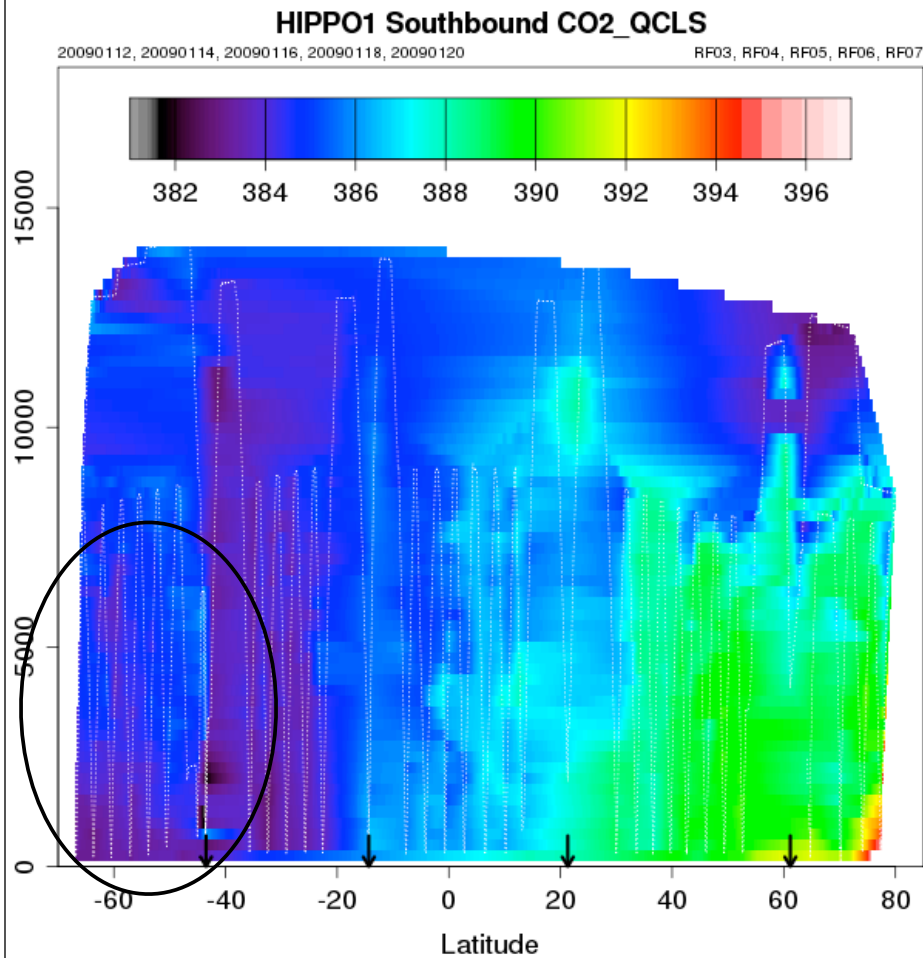
HIPPO1 Southbound CO₂_CCG

20090112, 20090114, 20090116, 20090118, 20090120

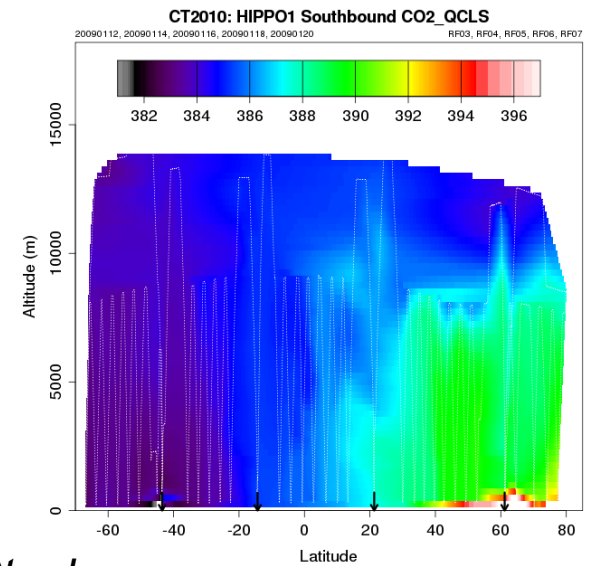
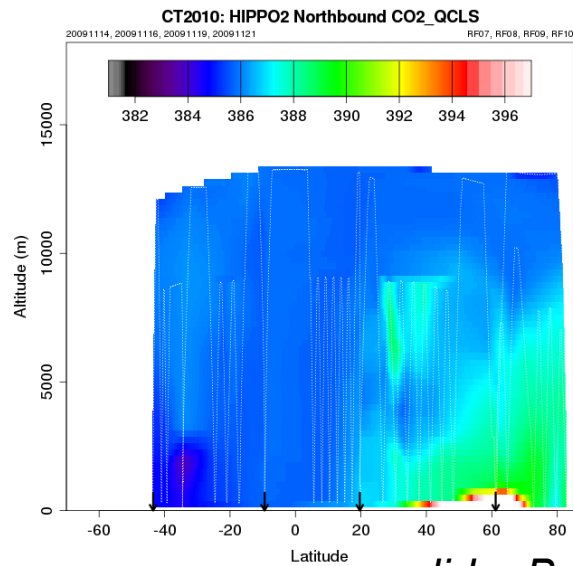
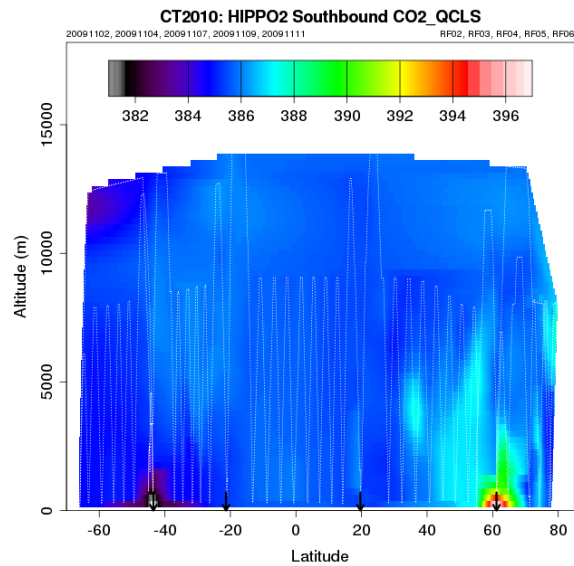
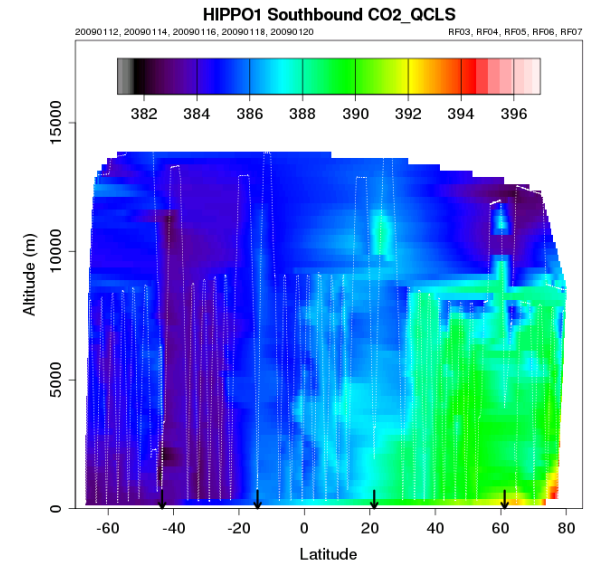
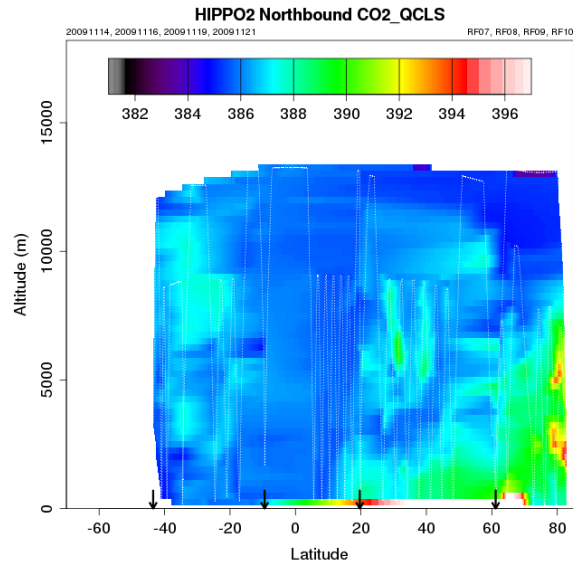
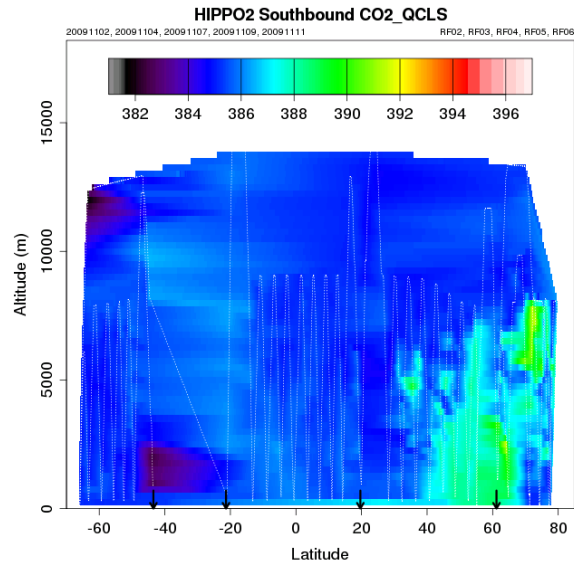
RF03, RF04, RF05, RF06, RF07



HIPPO1 (SB): Uptake of CO₂ and source of O₂ in Southern Ocean.

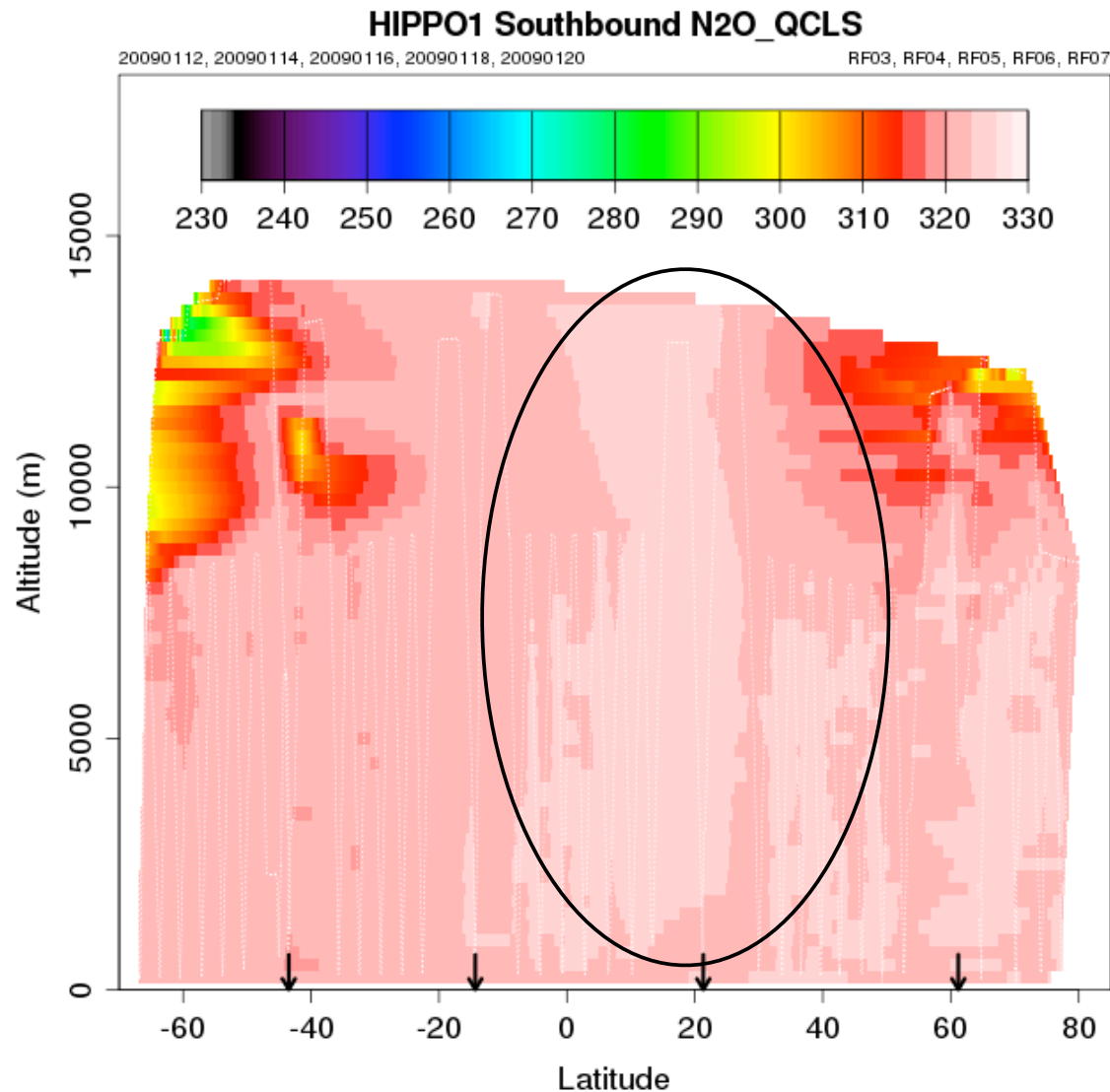


HIPPO 1 and 2 and NOAA CarbonTracker Comparisons

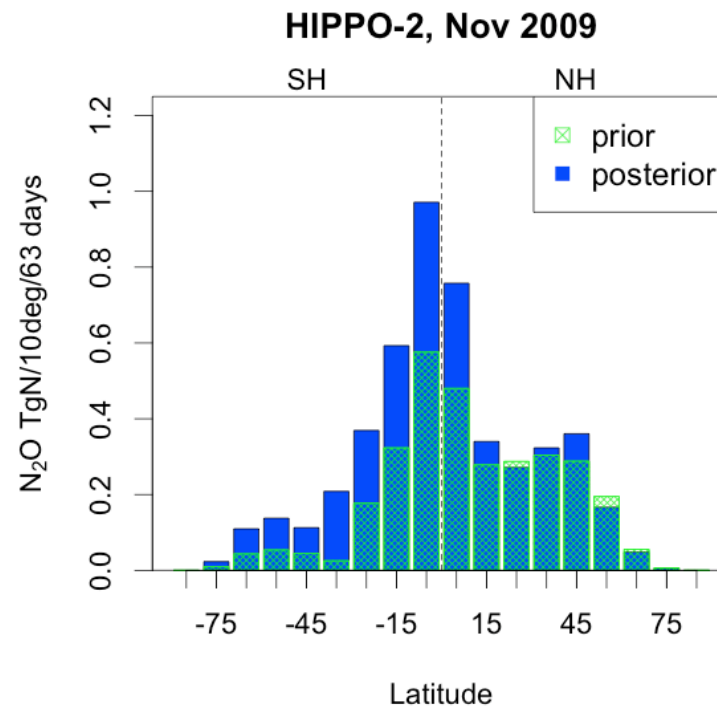
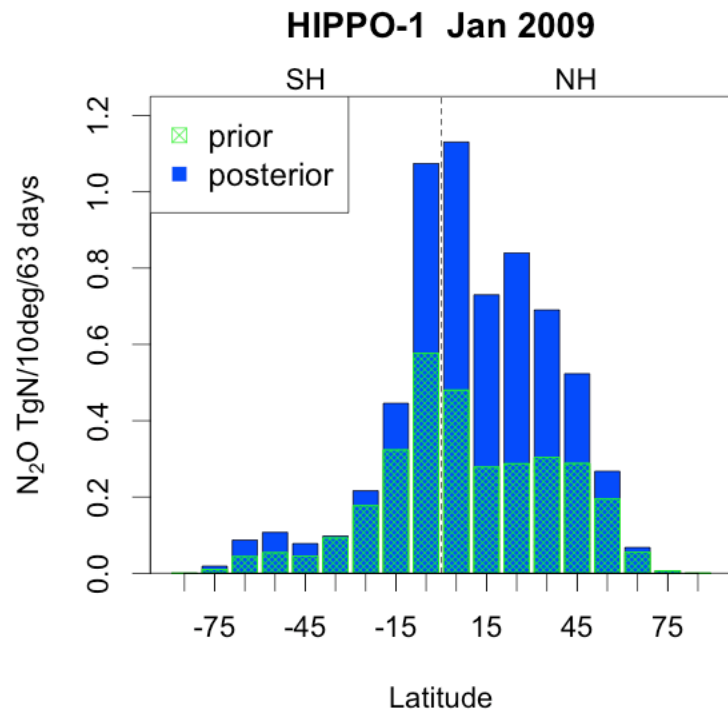


slide: B. Stephens

HIPPO1 (SB) High Resolution N₂O shows tropical source from convection



Global Distribution of N₂O emissions: HIPPO cross sections, ACTM Model



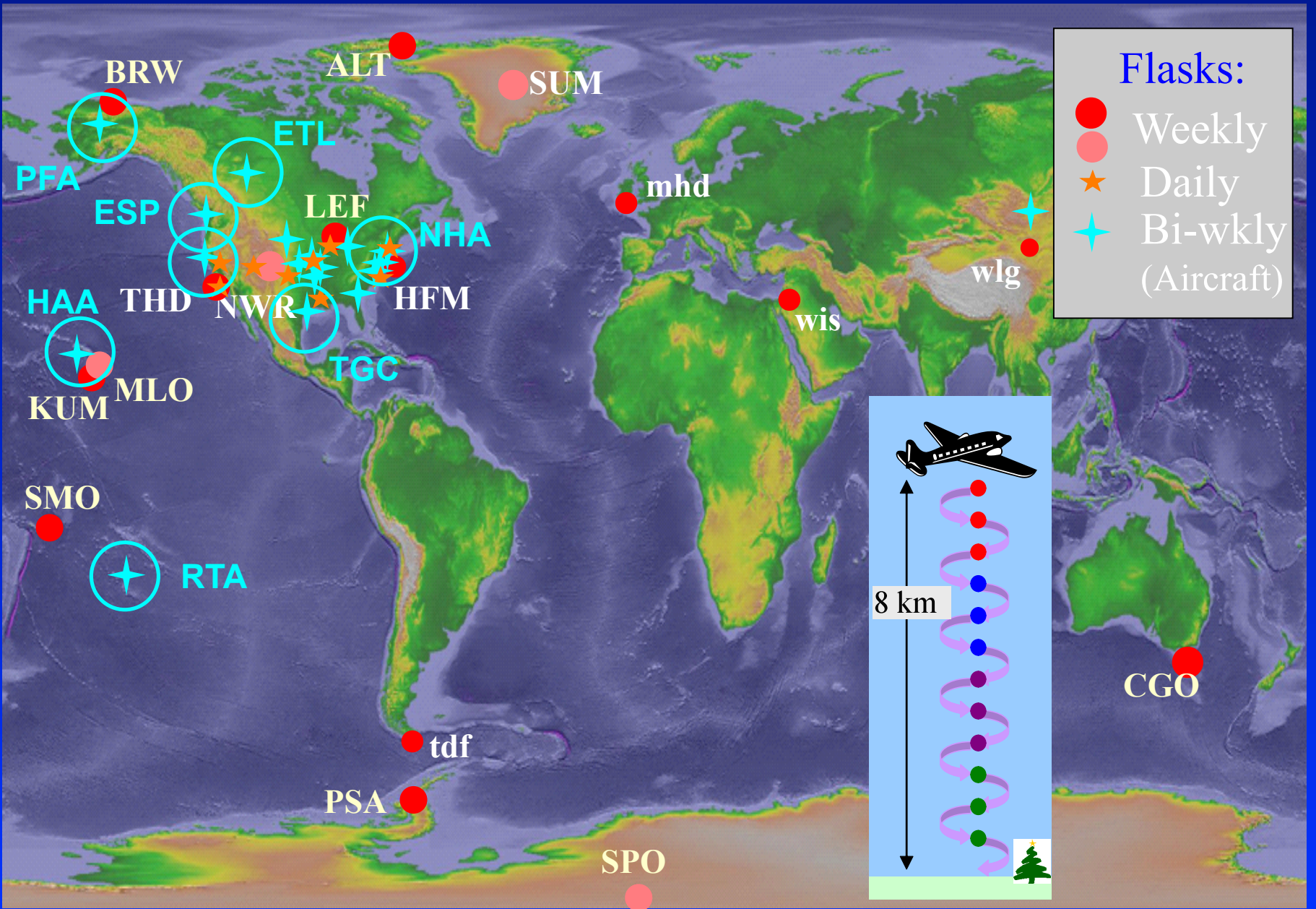
Global Totals (Tg N in N₂O, over 63 days)

6.4	Posterior	4.8
3.2	Prior	3.15

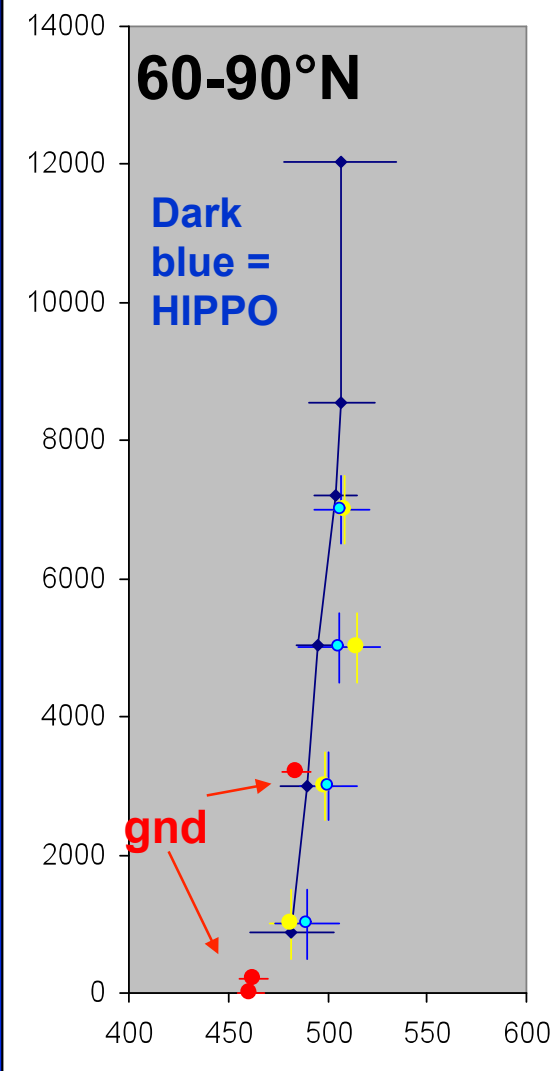
Eric Kort (Harvard); Prabir Patra, Kentaro Ishijima (JAMSTEC)

Kort et al., 2011, GRL, in review.

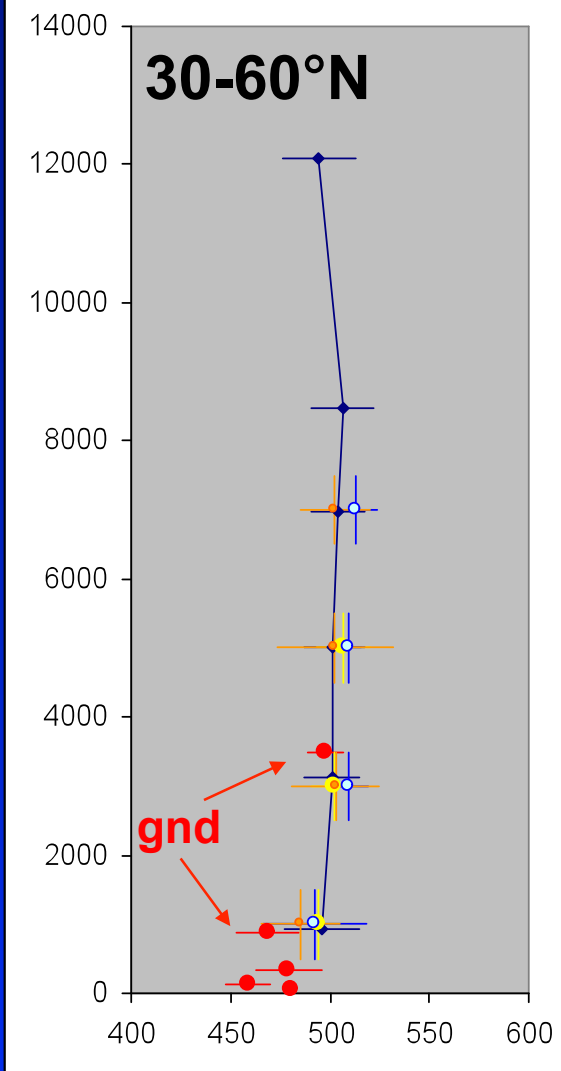
NOAA's Cooperative Flask Sampling Network



Altitude (m) HIPPO1

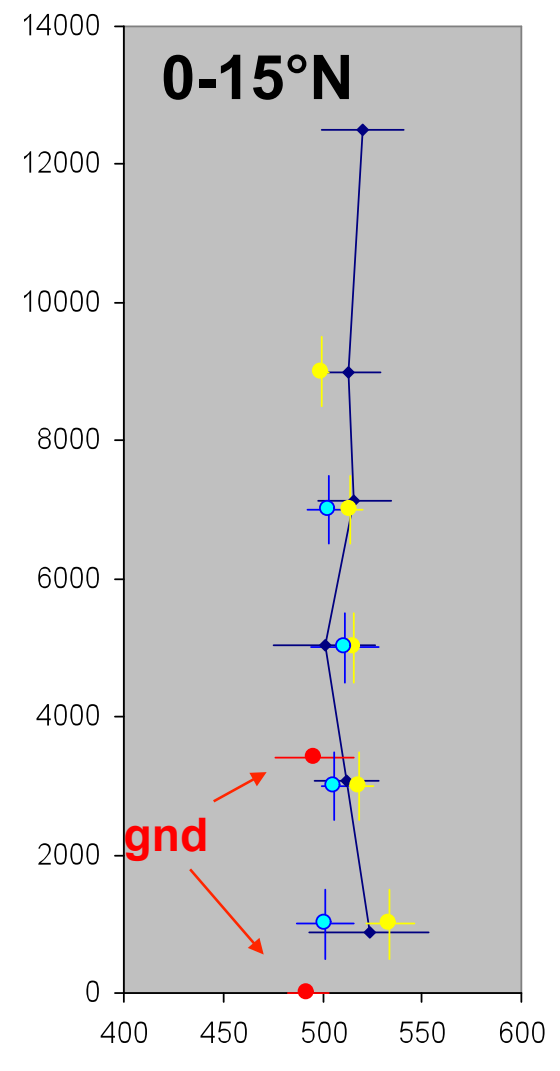


Gnd: sum, brw, alt
Air: pfa, elt



Gnd: nwr, lef, hfm,
thd, mhd

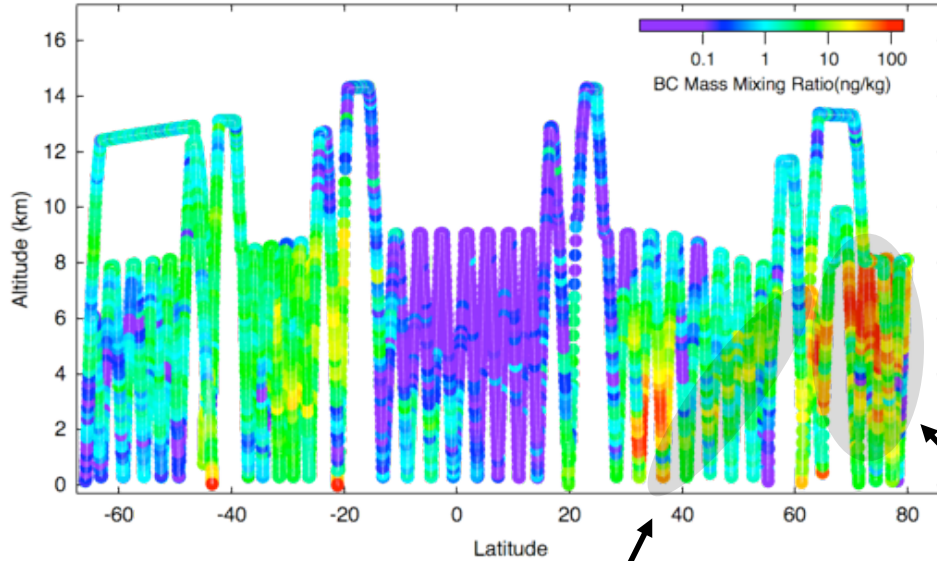
Air: esp, nha, etl
COS (ppt)



Gnd: mlo, kum
Air: haa, tgc

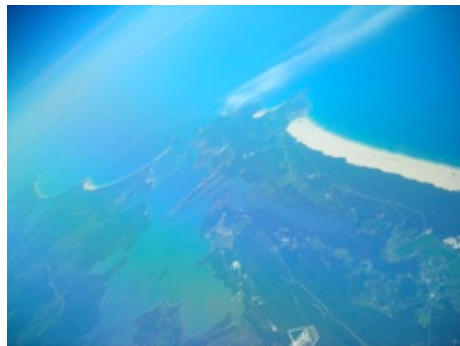
January

2-11 November 2009, Southbound



Warm Conveyor Belt

- Long-range biomass burning plumes observed in southern hemisphere from Africa and South America
- Very low BC loadings in the deep tropics



Long-range biomass burning plumes

HIPPO-2 NOVEMBER 2009

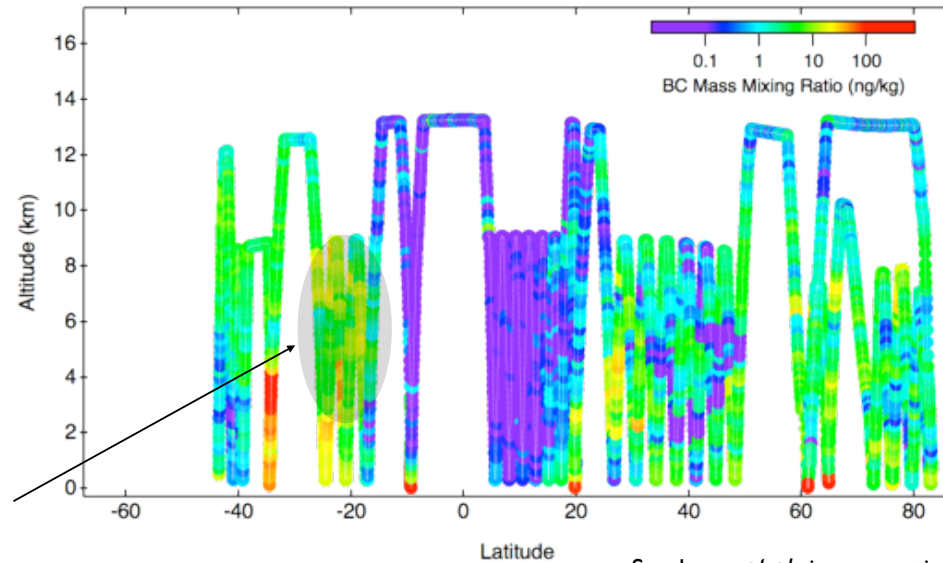


Photo: E. Kort

- High loadings of BC observed in the Arctic; well stratified plumes from Asia, Europe, and North America
- BC as a tracer of isentropic transport

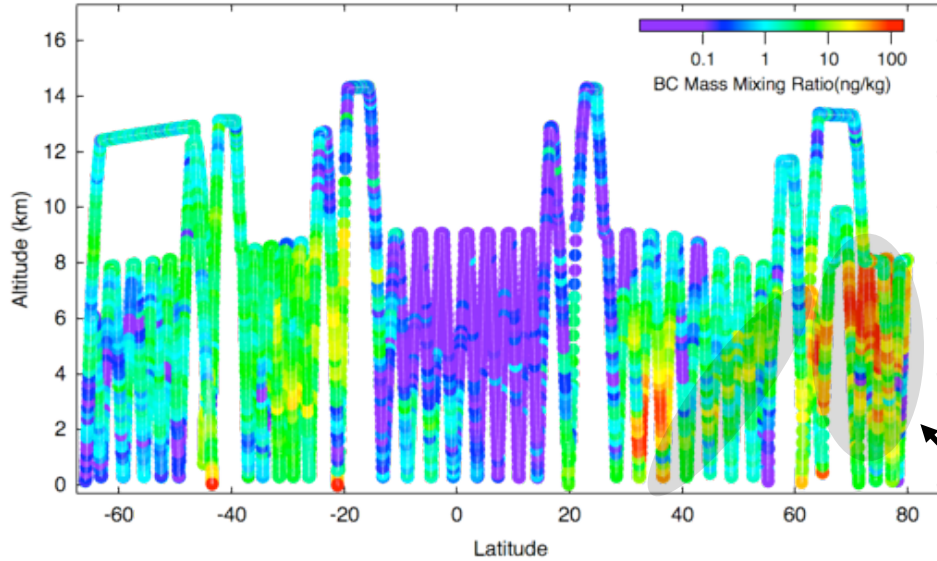
Asian and North American pollution

14-21 November 2009, Northbound



Spackman *et al.*, in preparation

2-11 November 2009, Southbound



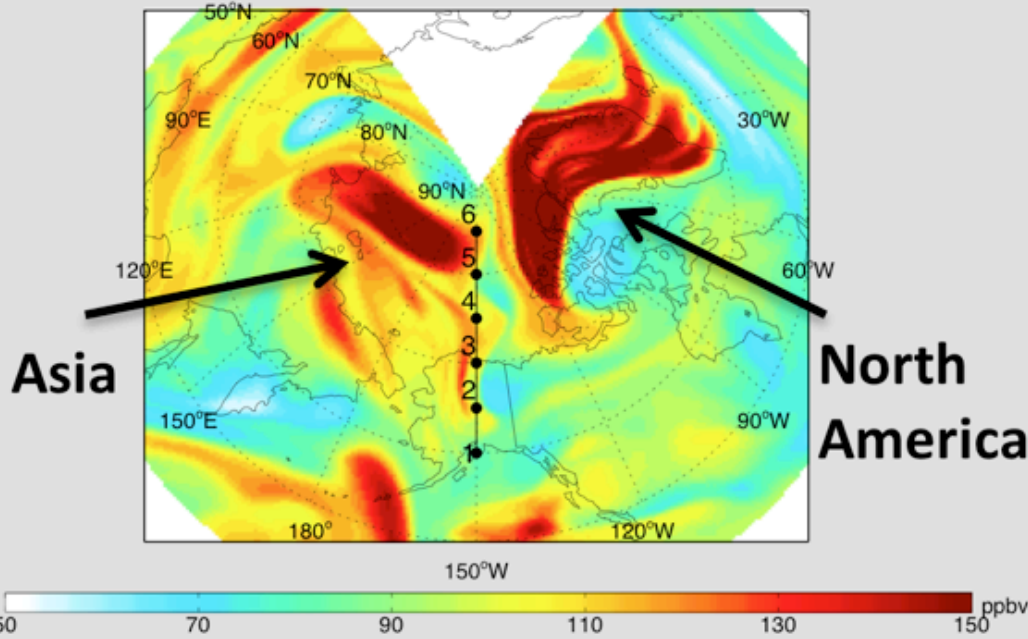
HIPPO-2 NOVEMBER 2009



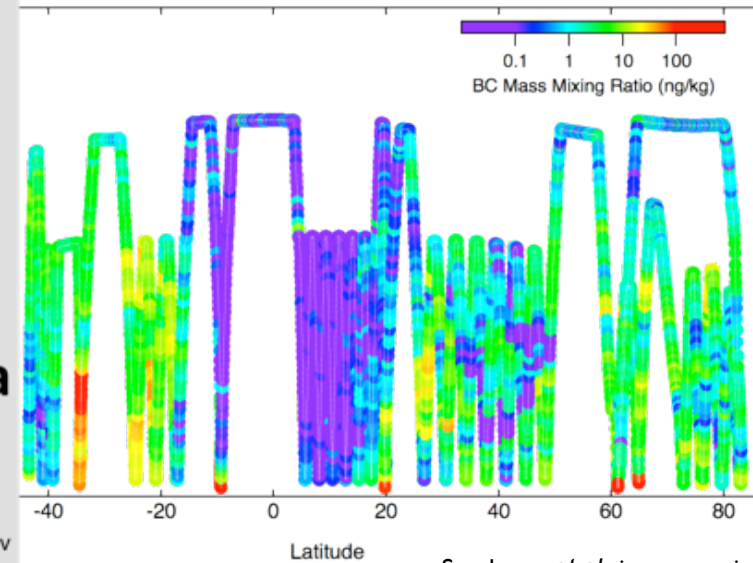
- High loadings of BC observed in the Arctic; well stratified plumes from Asia, Europe, and North America
- BC as a tracer of isentropic transport

Asian and North American pollution

CO MIXING RATIO
300 hPa (9.2 km) 20091102 22:30Z



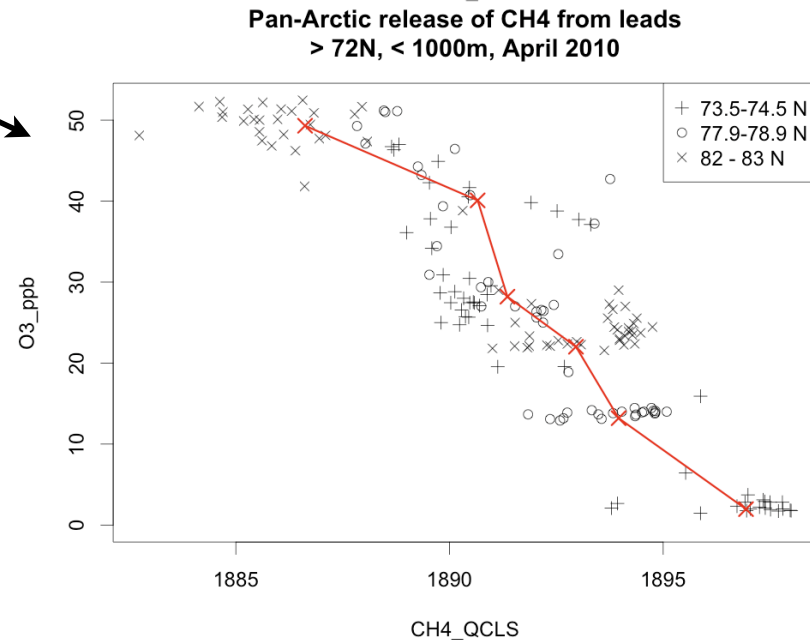
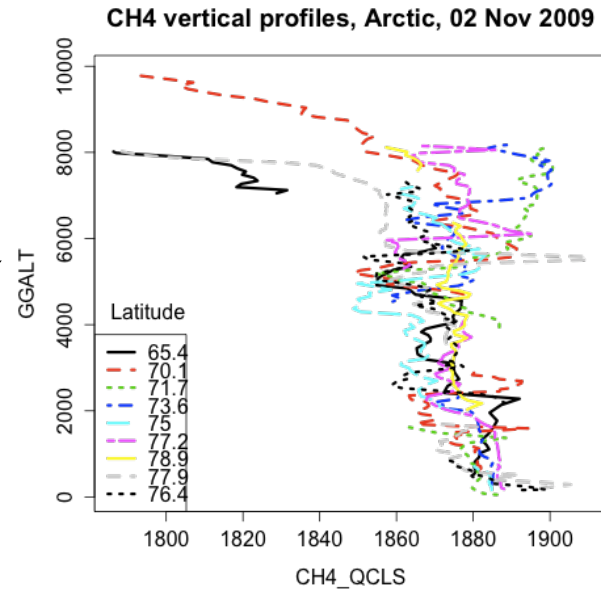
14-21 November 2009, Northbound



Spackman *et al.*, in preparation

Methane release from sea leads

- HIPPO2: We found that the ocean releases CH₄ to the air when it is not ice-covered. This is unexpected and indicates that reduction in ice cover has by itself probably increased CH₄ flux to the atmosphere even in the absence of a change in CH₄ release rates from clathrates.
- HIPPO3: Low O₃ in the presence of high CH₄ over sea leads.
- HIPPO was also a carbon cycle (not just CO₂) mission, and this result for CH₄ may change our understanding of Arctic sources.



Summary of HIPPO/1-3

- First snapshot of complete troposphere for many GHGs and black carbon.
- Summertime uptake of CO₂ and sources for O₂ at high southern latitudes. NOAA's CarbonTracker does a good job of reproducing this result for CO₂.
- Fine scale variability observed for N₂O at altitude from Asian Sources over NH
- Comparisons of NOAA ground based/small aircraft to HIPPO COS show consistent gradients-sources and sinks, but small differences noted in mixing ratios.
- Models predict higher black carbon levels, Asian and N. American Sources seen.
- High source of boundary layer CH₄ around sea leads.

HIPPO Science Team:

Harvard University: (QCLS, OMS) S. C. Wofsy, B. C. Daube, R. Jimenez, E. Kort, J. V. Pittman, S. Park, R. Commane, Bin Xiang, G. Santoni; (GEOS-CHEM) D. Jacob, J. Fisher, C. Pickett-Heaps, H. Wang, K. Wecht, Q.-Q. Wang;

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NOAA ESRL and CIRES: J. W. Elkins, D. W. Fahey, R. S. Gao, F. Moore, S. A. Montzka, J. P. Schwarz, D. Hurst, B. Miller, C. Sweeney, S. Oltmans, D. Nance, E. Hints, G. Dutton, L. A. Watts, J. R. Spackman, K. H. Rosenlof, E. A. Ray;

Princeton: M. Zondlo, Minghui Diao

JPL: M. J. Mahoney; (AIRS) M. Chahine, E. Olsen;

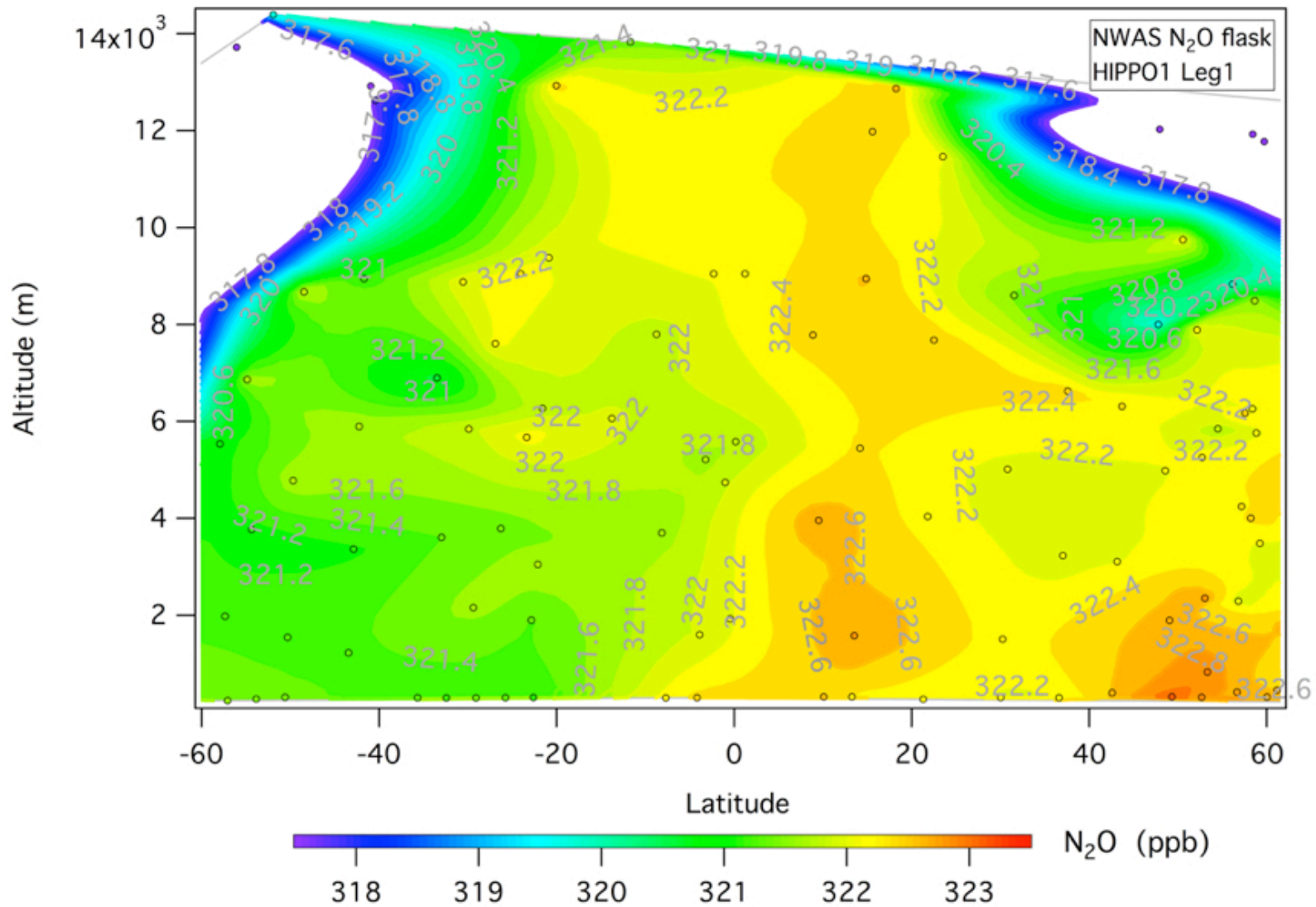
UCSD/Scripps: R. Keeling, J. Bent;

U. Miami: E. L. Atlas, R. Lueb;

Cooperating modeling groups: ACTM P. Patra, K. Ishijima; GEMS-MACC R. Engelen; (GEOS-Chem, U. Toronto) R. Nassar, D. B. Jones, (TM3/TM5): Sara Mikaloff-Fletcher

Extra Slides

NOAA CCGG data confirms the high N₂O, but 1/2

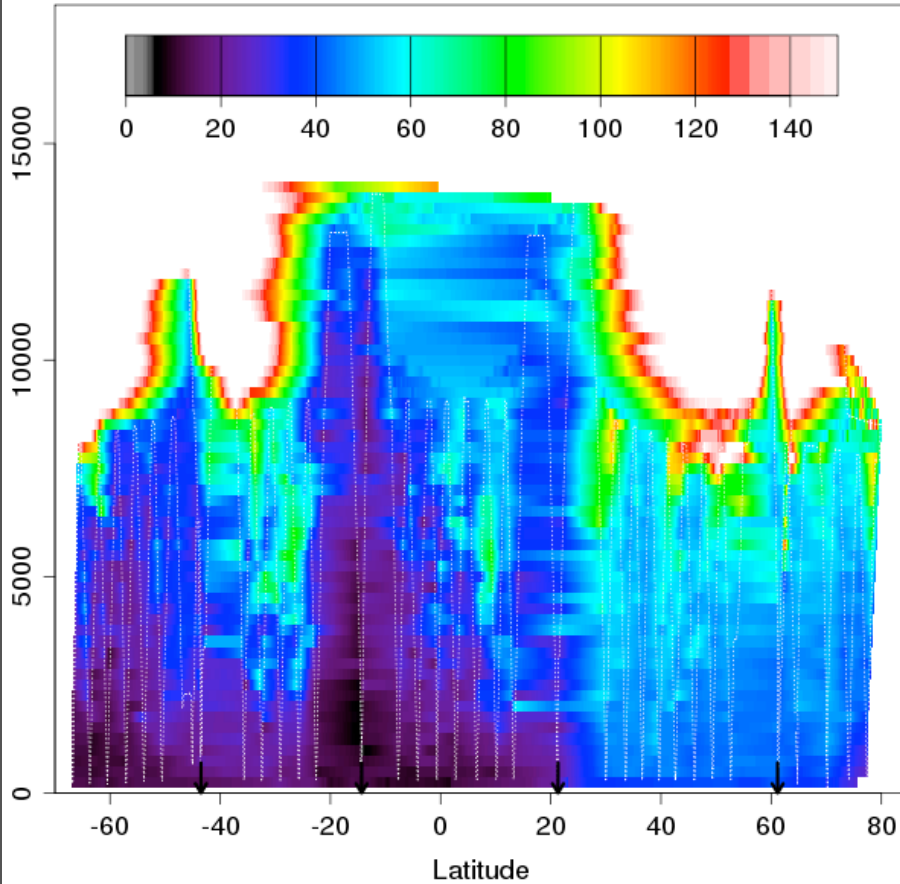


HIPPO1 (SB) NOAA UCATS O₃ & H₂O

HIPPO1 Southbound O₃_UO3_trop

20090112, 20090114, 20090116, 20090118, 20090120

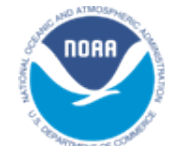
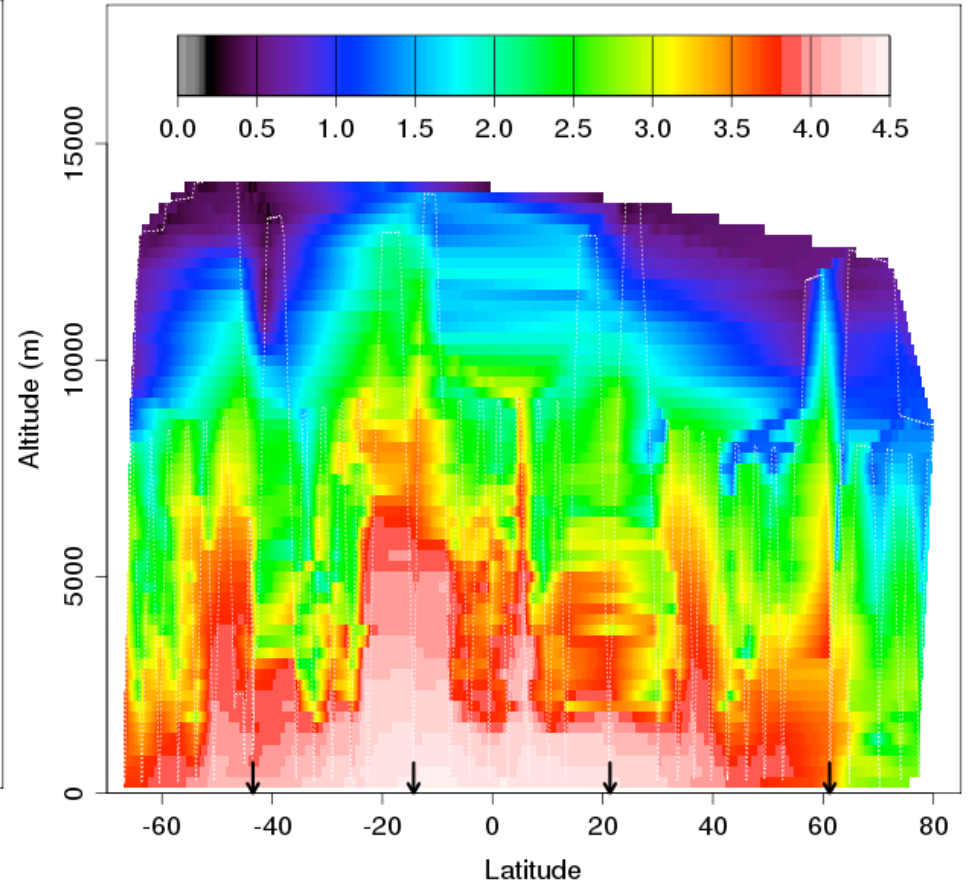
RF03, RF04, RF05, RF06, RF07



HIPPO1 Southbound H₂O_UWV (Log)

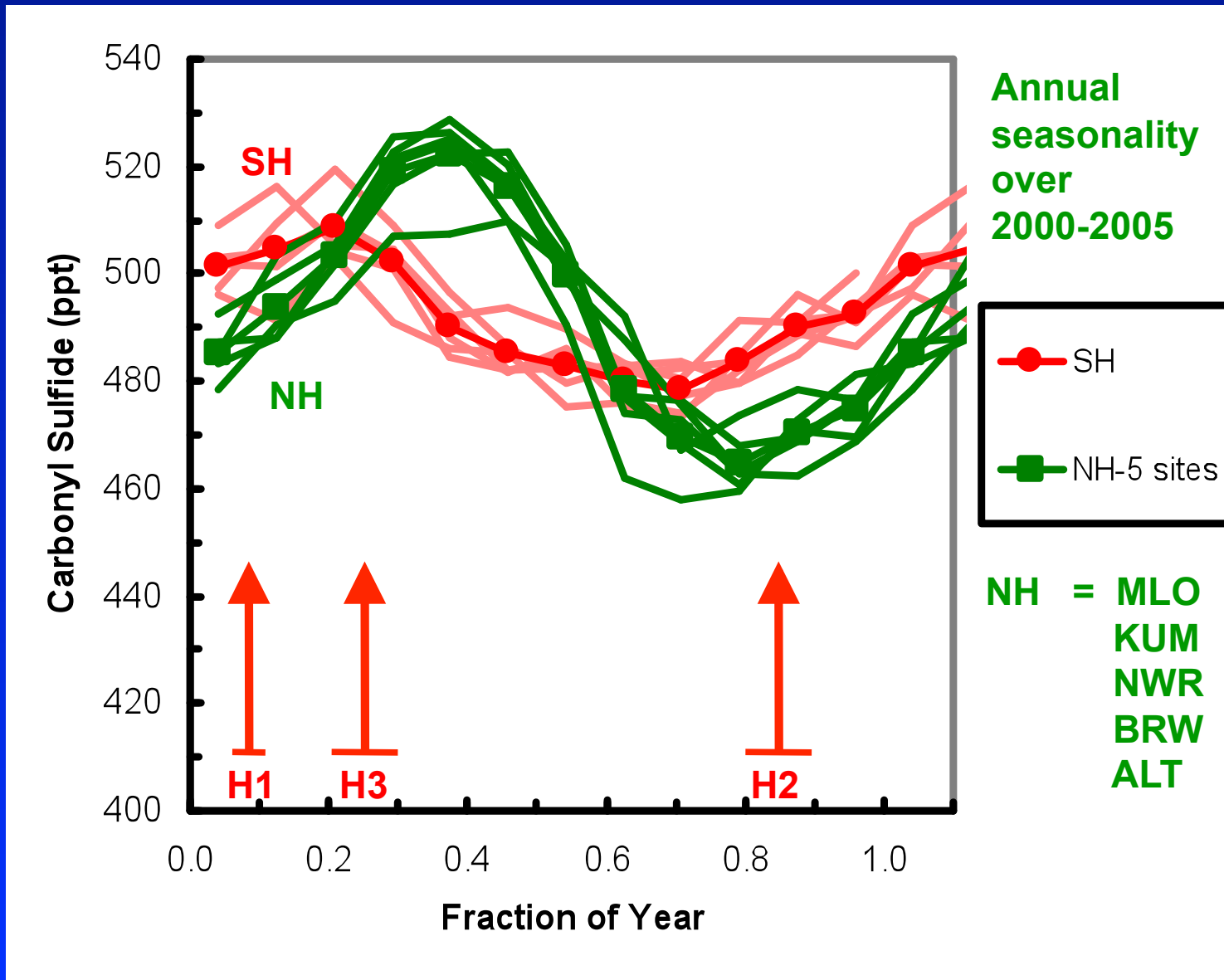
20090112, 20090114, 20090116, 20090118, 20090120

RF03, RF04, RF05, RF06, RF07



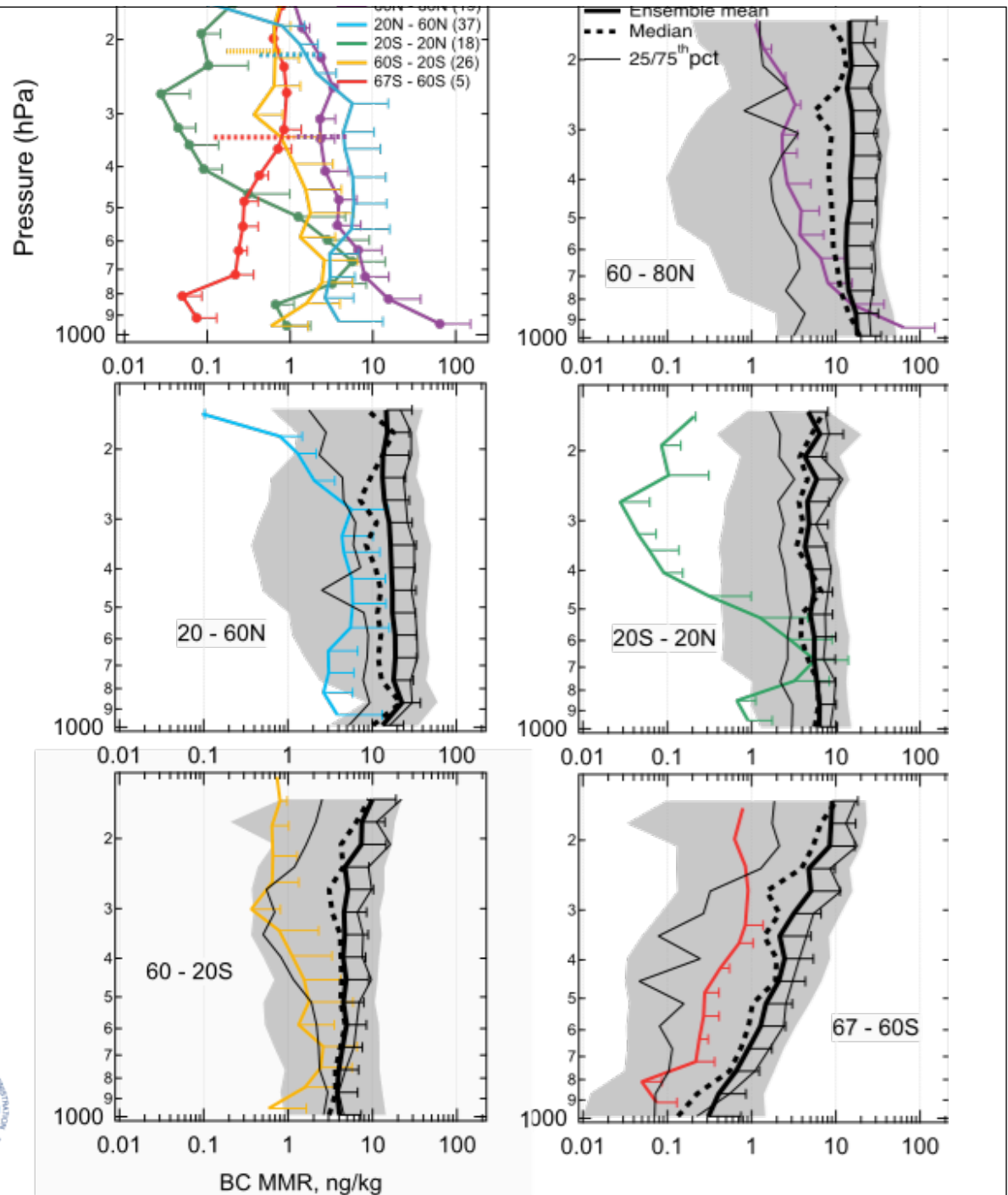
Seasonality in hemispheric means—marine/high alt. NH sites

Surface stations only



Model/Measurement Comparison

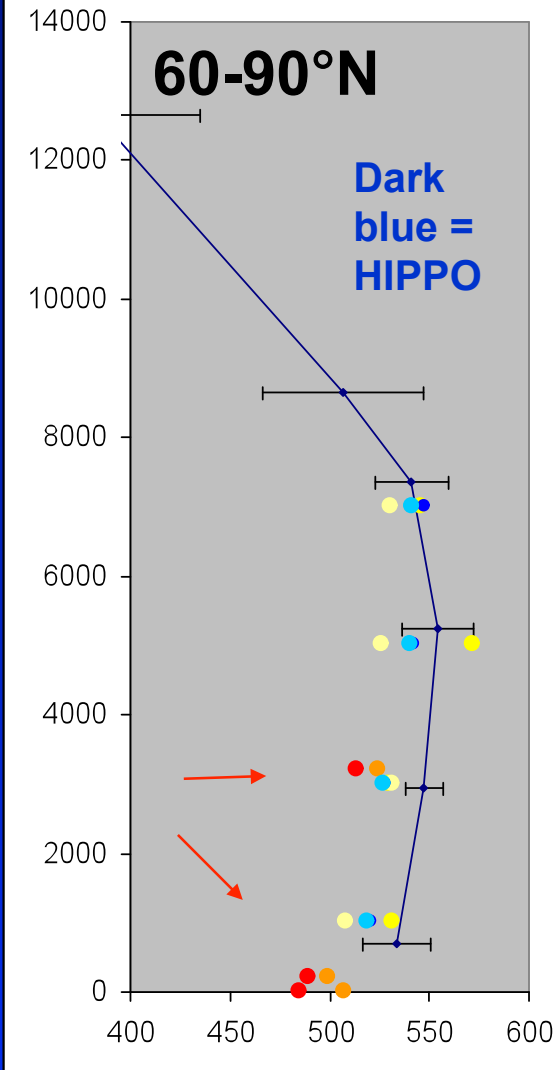
- 14 global models from AEROCOM suite compared to observations.
- Grey region represents model range.
- Colored profiles are SP2-measured zonal averages
- **Models overestimate BC mass loads by a factor of 5, on average.**
- **Insufficient removal** of BC identified as a likely source of the bias.



Schwarz, et al., *GRL*, 2010

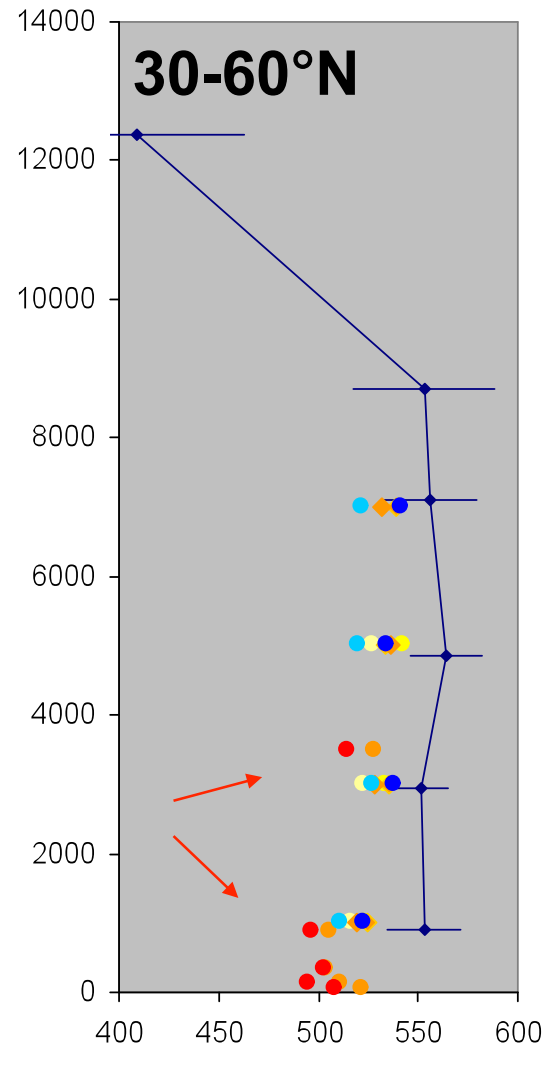


Altitude (m) HIPPO3



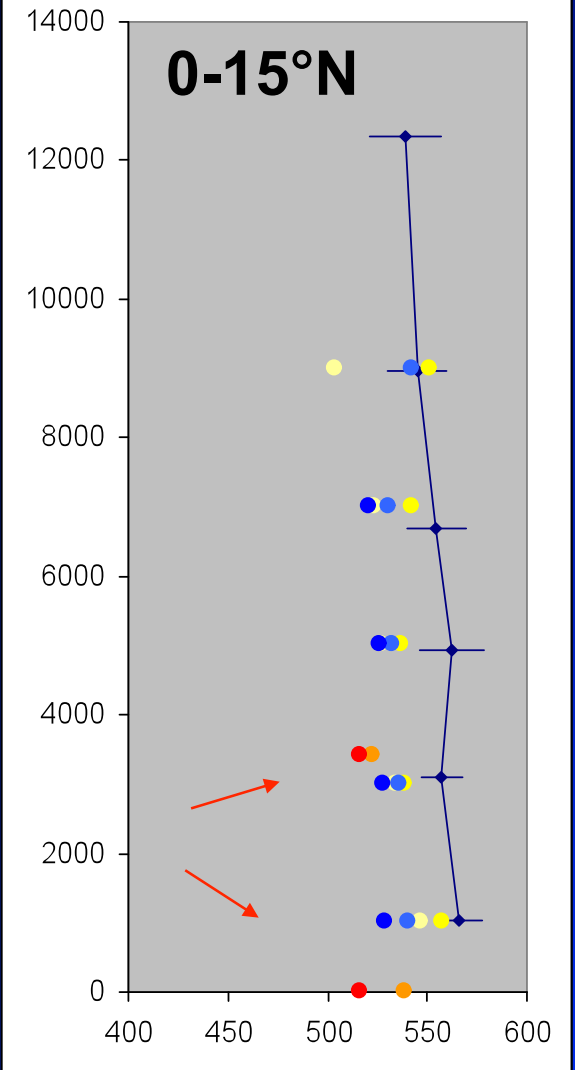
Gnd: sum, brw, alt
Air: pfa, elt

Mar-Apr



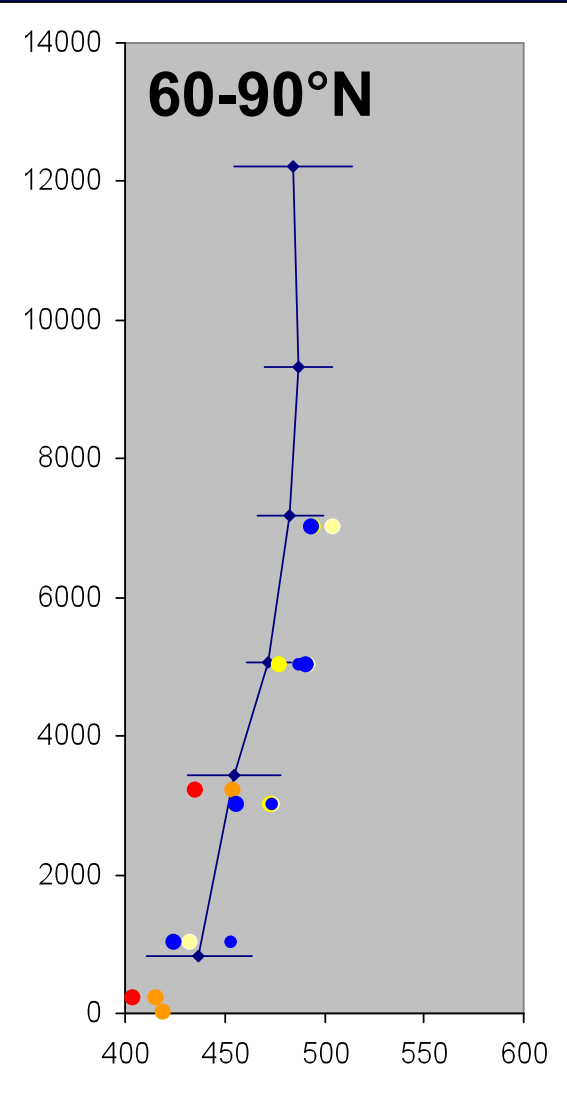
Gnd: nwr, lef, hfm,
thd, mhd

Air: esp, nha, etl
COS (ppt)



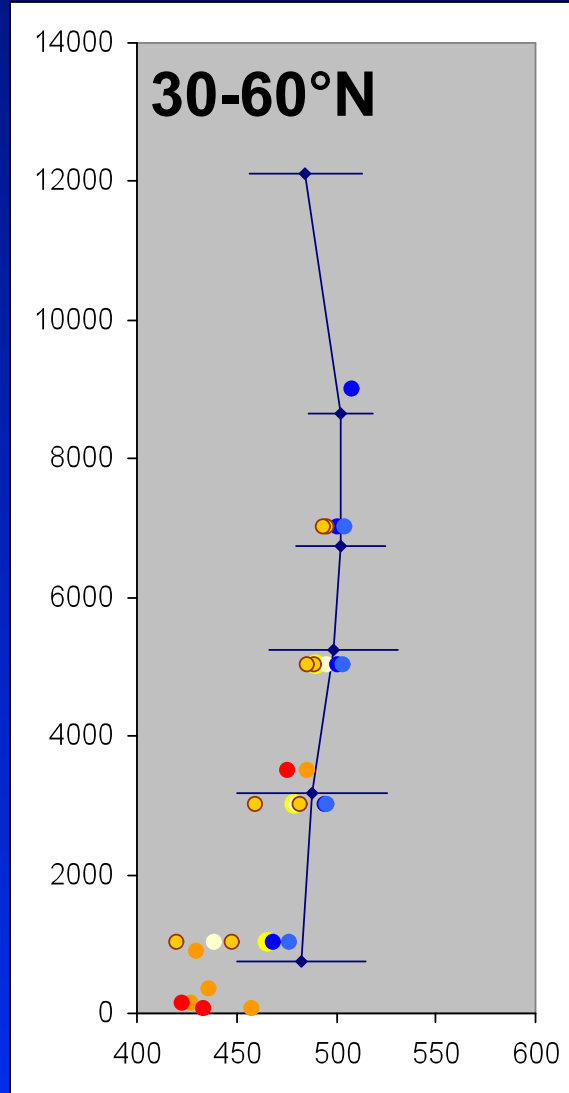
Gnd: mlo, kum
Air: haa, tgc

Altitude (m) HIPPO2



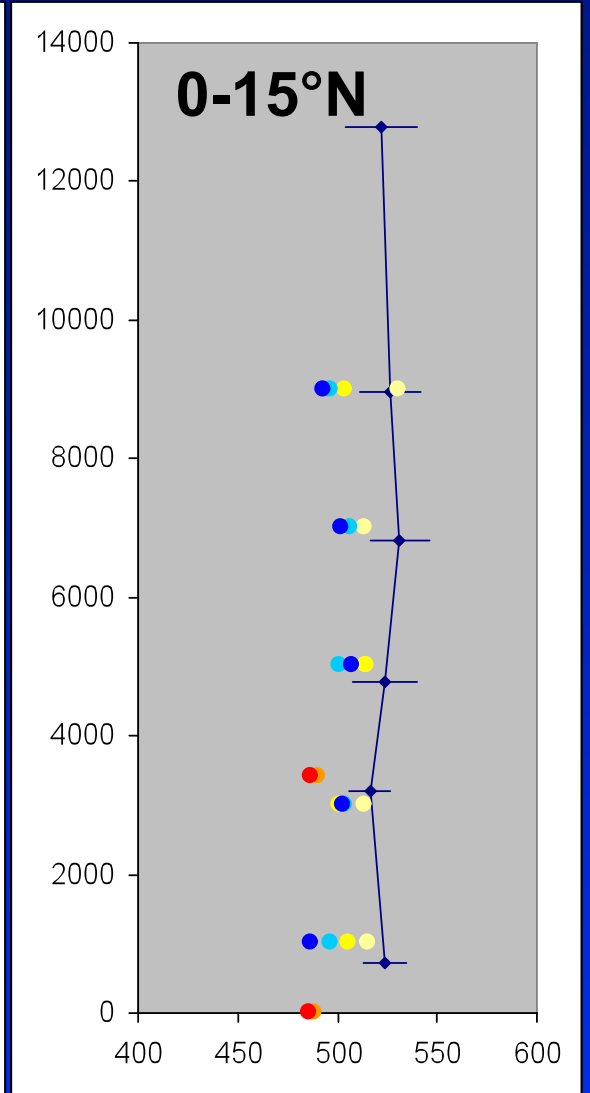
Gnd: sum, brw, alt
Air: pfa, elt

Oct-Nov



Gnd: nwr, lef, hfm,
thd, mhd

Air: esp, nha, etl
COS (ppt)



Gnd: mlo, kum
Air: haa, tgc