Carbonyl Sulfide: Hippo *vs.* other observations

S. Montzka
B. Miller
F. Moore
E. Atlas
C. Sweeney and NOAA's Carbon Cycle Group
L. Miller
D. Nance
B. Hall
J. Elkins

…all those people making the HIPPO mission possible…

…the many people involved with NOAA flask sampling

NOAA, CIRES, NSF

Thanks also to T. Campos (additional pfps)

Can Carbonyl Sulfide (COS) provide useful information about carbon fluxes?

Sinks: Vegetative uptake and soil uptake (via carbonic anhydrase), hydroxyl radical

Sources: Oceans, oxidation of DMS & CS_2, anthropogenic (direct and indirect), biomass burning

Observed seasonality in the hemispheres:

In the SH—oceanic production enhanced in Austral summer

In the NH—uptake by land in Boreal summer

Observed gradients over the North American continent:

–consistent with a strong summertime, land-based sink

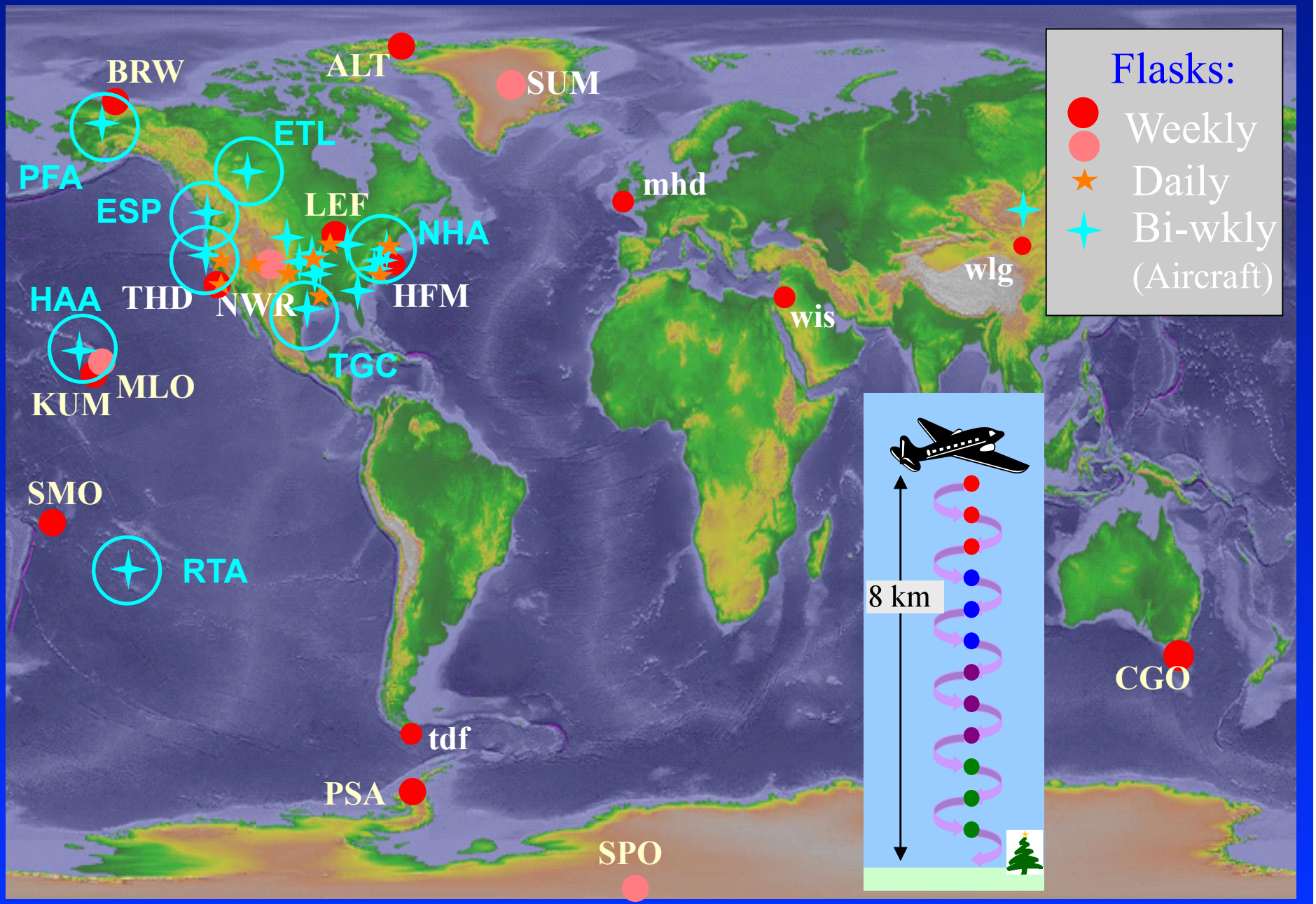
–consistent with the uptake being dominated by GPP

Many questions remain:

Relative loss: vegetation *vs.* soils?

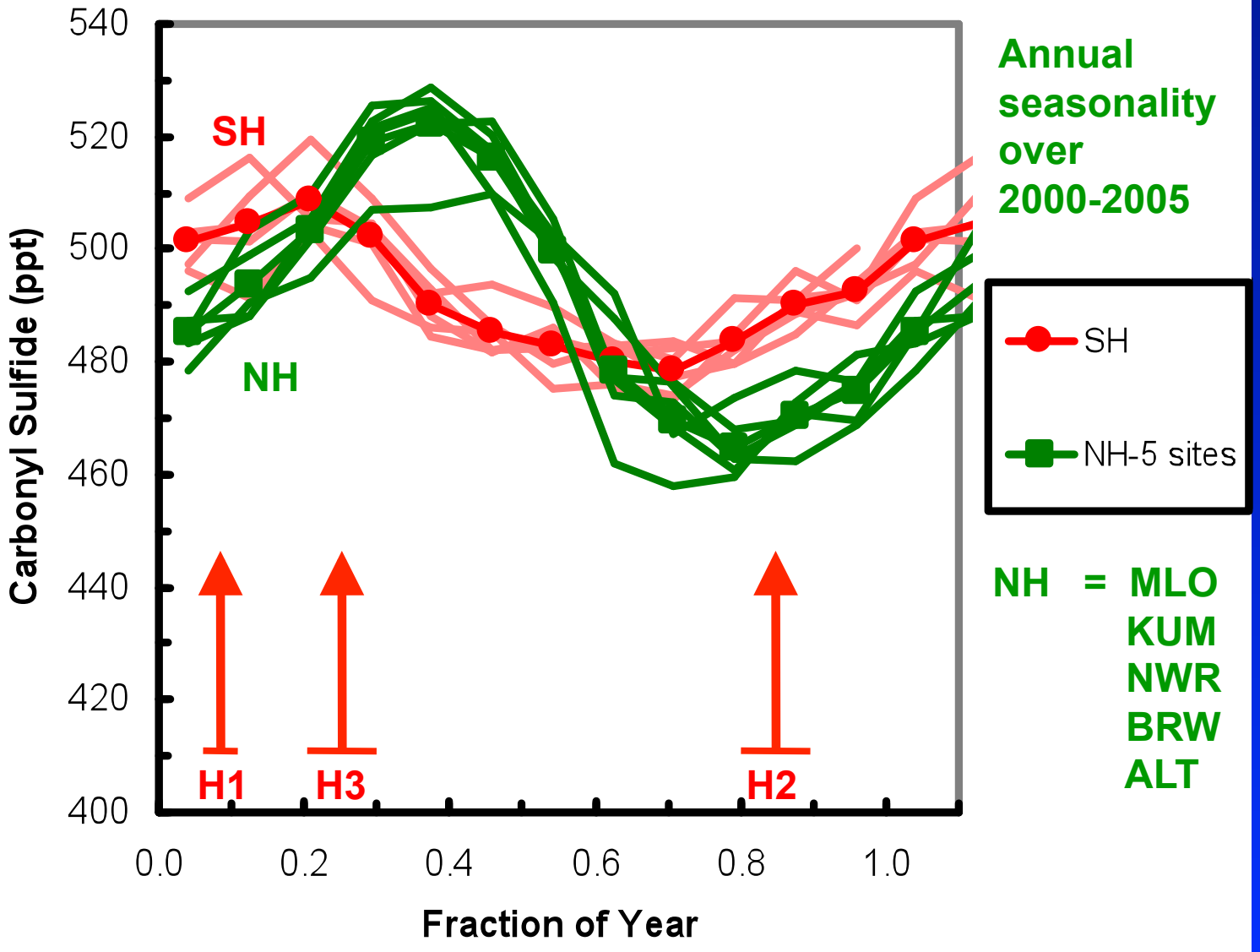
Large additional COS sources needed?

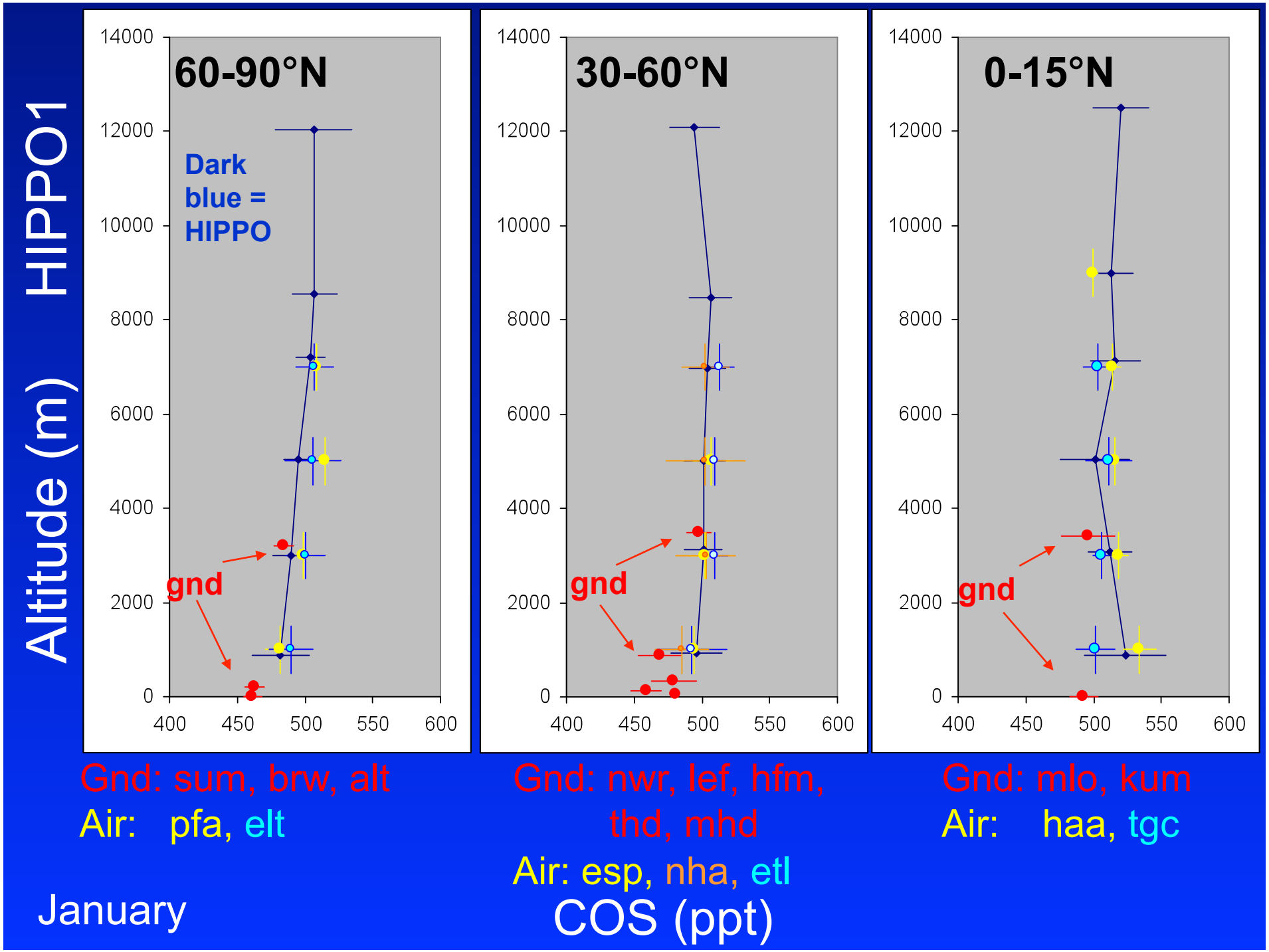
NOAA's Cooperative Flask Sampling Network

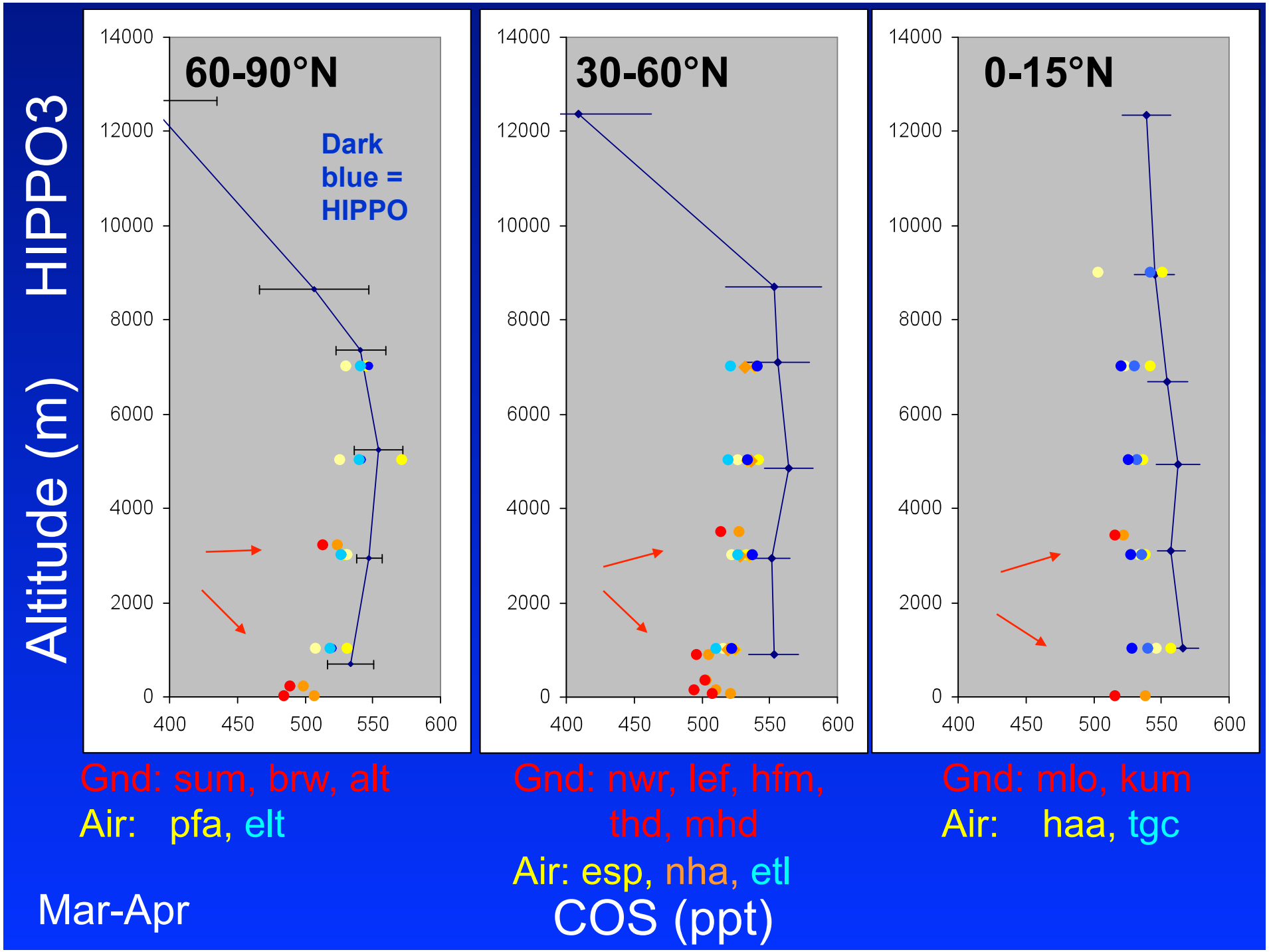


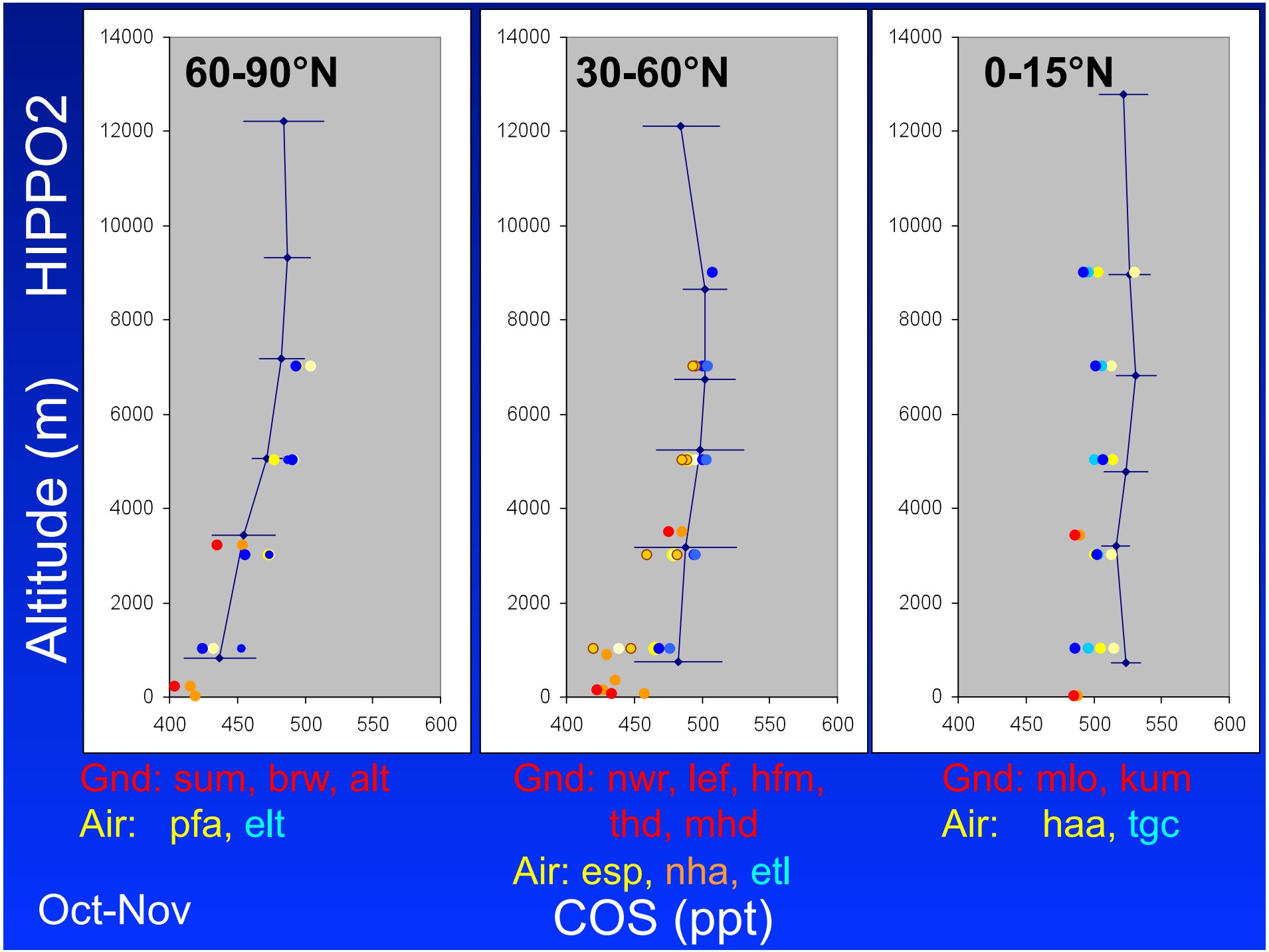
Seasonality in hemispheric means—marine/high alt. NH sites

Surface stations only

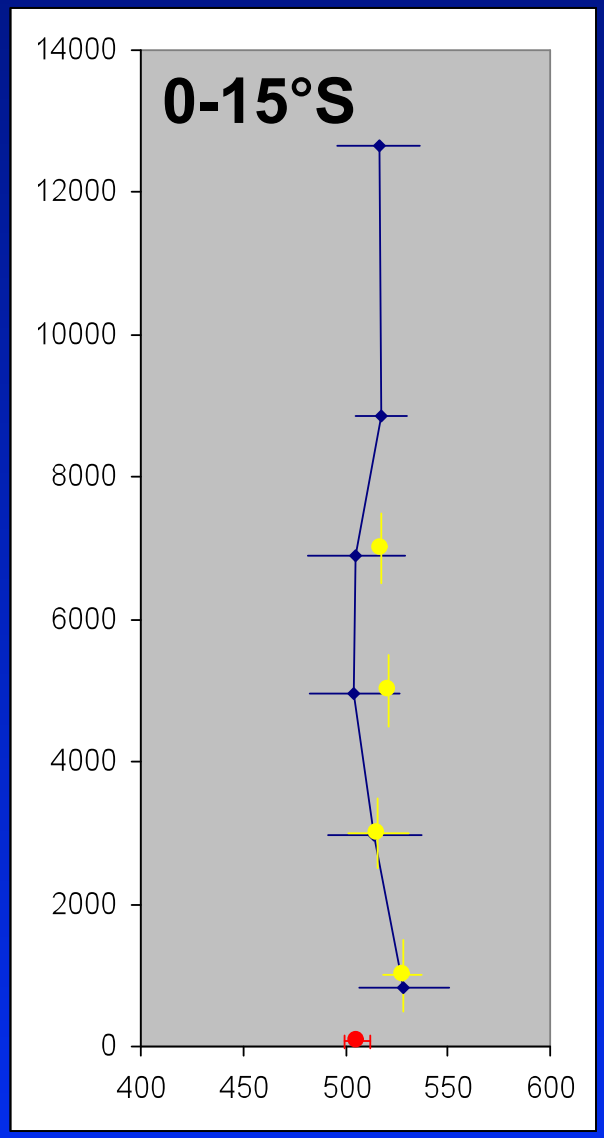


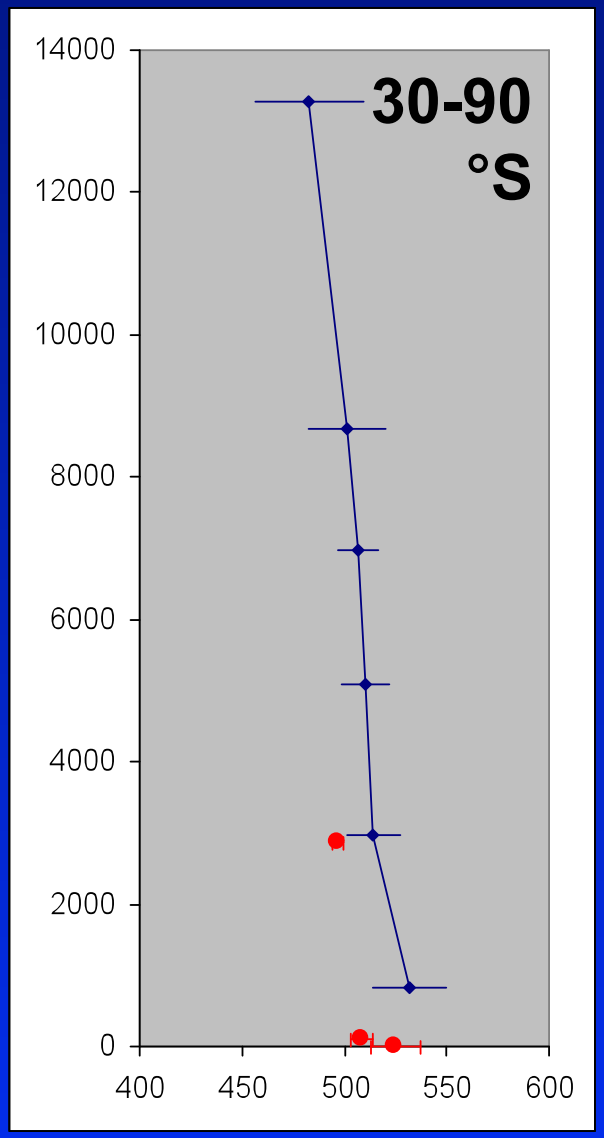

Altitude (m) HIPPO1
60-90°N
30-60°N
0-15°N
Dark blue = HIPPO
gnd
14000
12000
10000
8000
6000
4000
2000
0
400
450
500
550
600
Gnd: sum, brw, alt
Air: pfa, elt
Gnd: nwr, lef, hfm, thd, mhd
Air: esp, nha, etl
Gnd: mlo, kum
Air: haa, tgc
January
COS (ppt)


HIPPO3
Altitude (m)
60-90°N
30-60°N
0-15°N
Dark blue = HIPPO
14000
12000
10000
8000
6000
4000
2000
0
400
450
500
550
600
Gnd: sum, brw, alt
Air: pfa, elt
Gnd: nwr, lef, hfm, thd, mhd
Air: esp, nha, etl
Gnd: mlo, kum
Air: haa, tgc
Mar-Apr
COS (ppt)


HIPPO2
Altitude (m)
60-90°N
30-60°N
0-15°N
14000
12000
10000
8000
6000
4000
2000
0
400
450
500
550
600
Gnd: sum, brw, alt
Air: pfa, elt
Gnd: nwr, lef, hfm, thd, mhd
Air: esp, nha, etl
Gnd: mlo, kum
Air: haa, tgc
Oct-Nov
COS (ppt)

HIPPO 1, SH





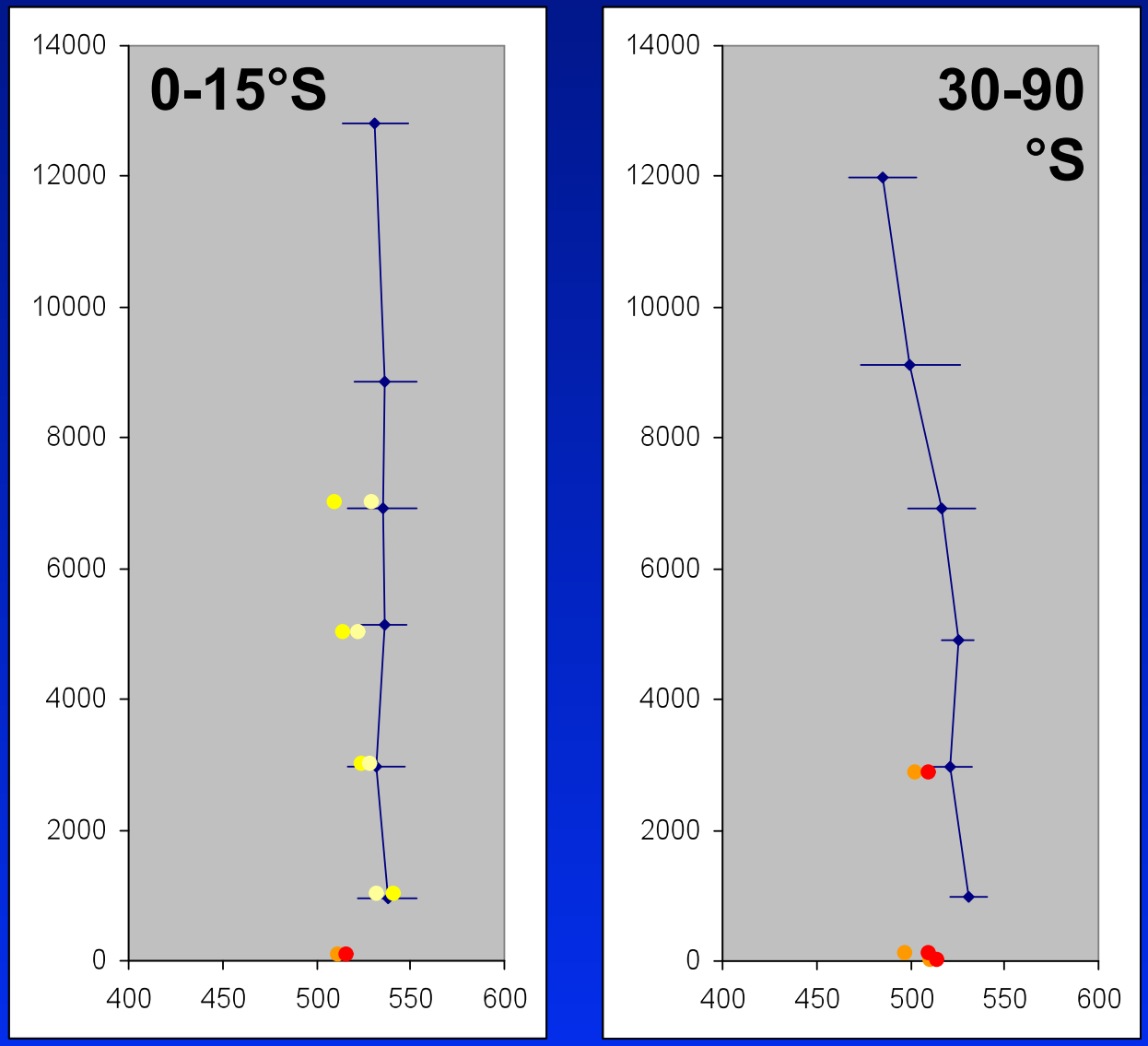
Gnd: SMO
Air: RTA

Gnd: SPO, CGO, PSA

Jan

COS (ppt)

HIPPO 3, SH



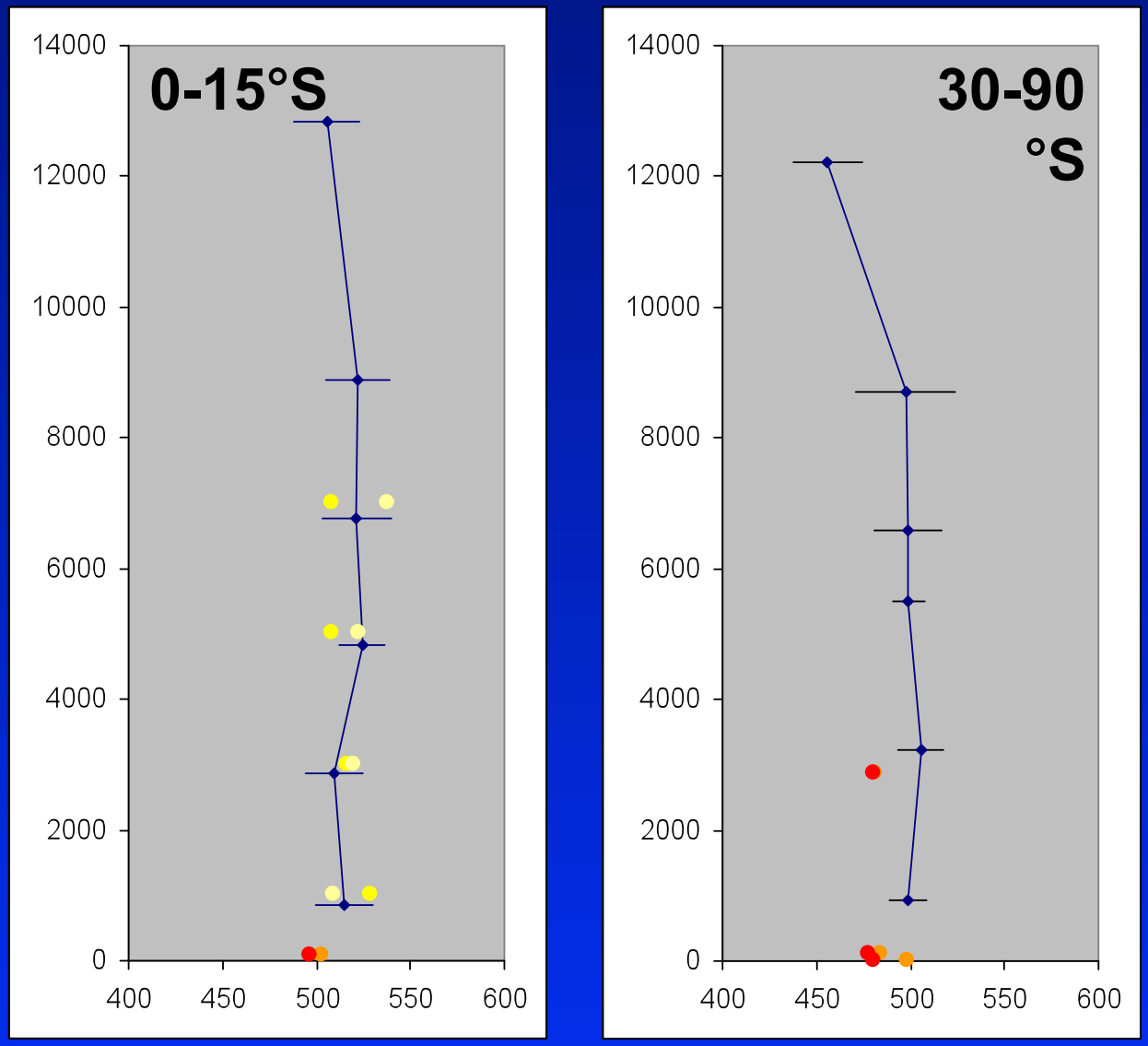
Gnd: SMO
Air: RTA

Gnd: SPO, CGO, PSA

Mar-Apr

COS (ppt)

HIPPO 2, SH


0-15°S
30-90 °S
Altitude (m)
14000
12000
10000
8000
6000
4000
2000
0
400
450
500
550
600
Gnd: SMO
Air: RTA
Gnd: SPO, CGO, PSA
Oct-Nov
COS (ppt)

Comparisons showed:

Consistent gradients most everywhere

implying source and sink regions…

Mixing ratios similar (though differences exist)

calibration or artifacts ?

temporal issues…

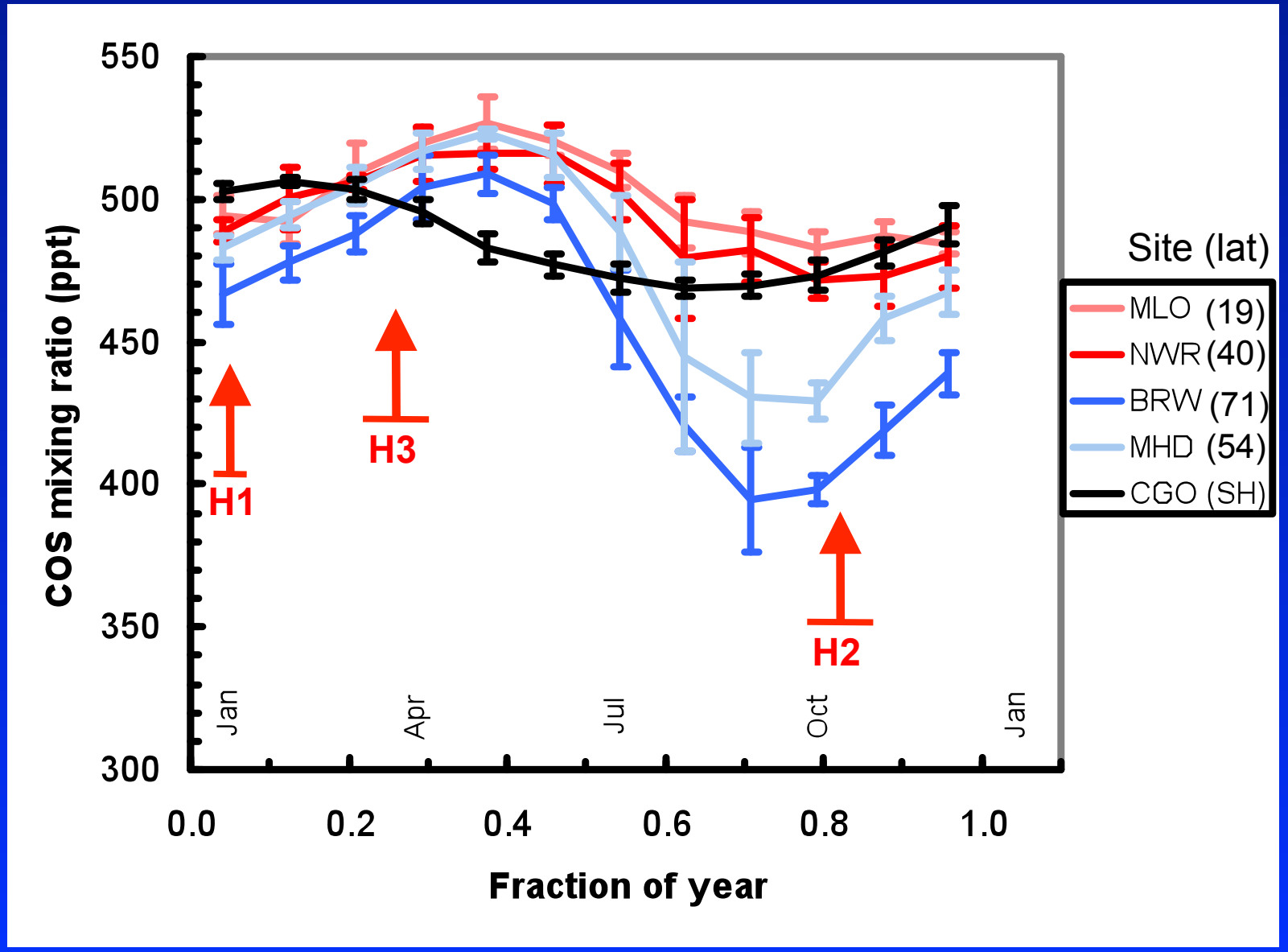
spatial variability?

Next:

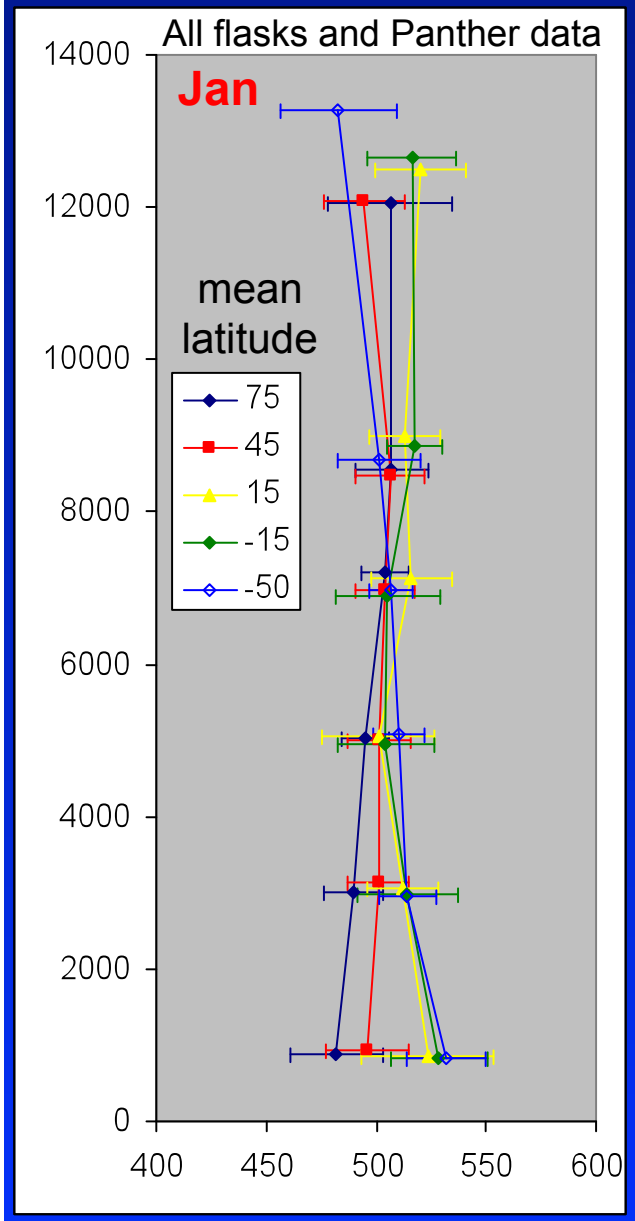
COS seasonality vs latitudes at surface sites

Seasonality in hemispheric means…

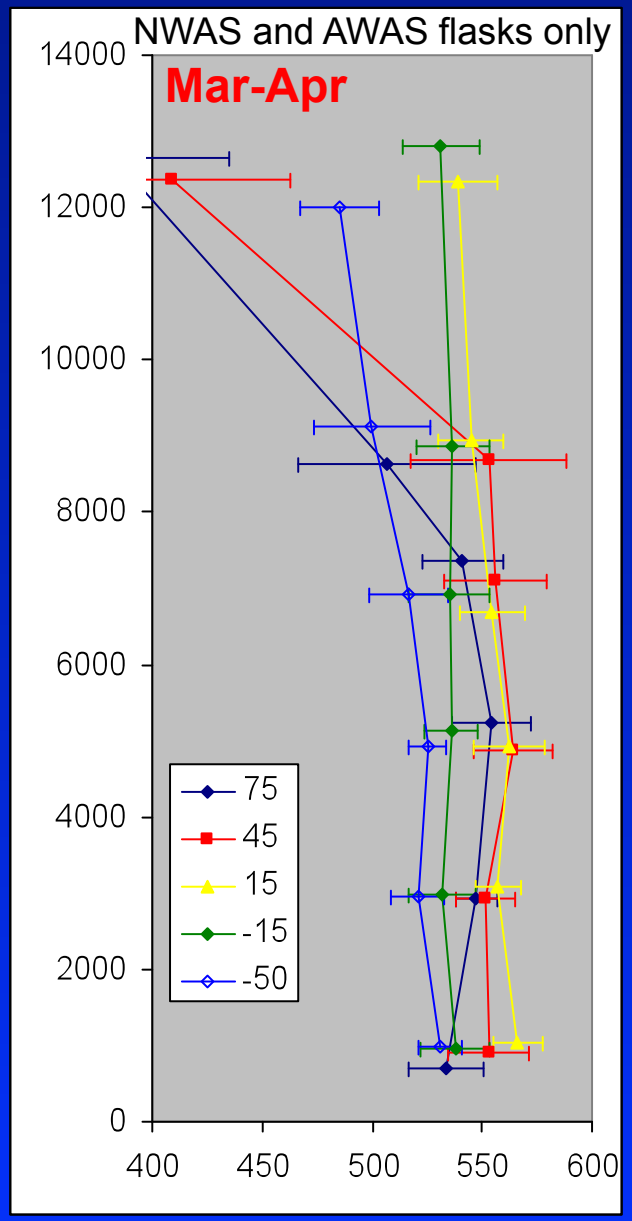
Surface stations only (marine and continental)



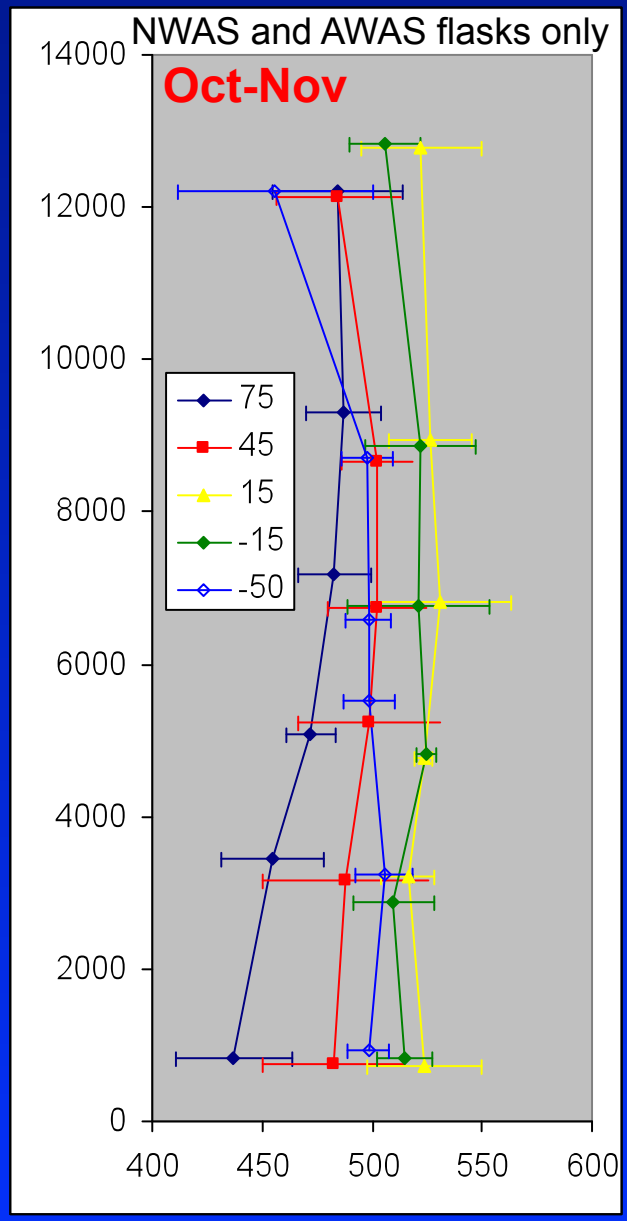
Carbonyl Sulfide during HIPPO (alt. vs mixing ratio)



HIPPO 1



HIPPO 3



HIPPO 2

Seasonality observed:

similar pattern so far

HIPPO data consistent with remote/marine/high alt seasonality

Looking forward to H4 and H5!

Next:

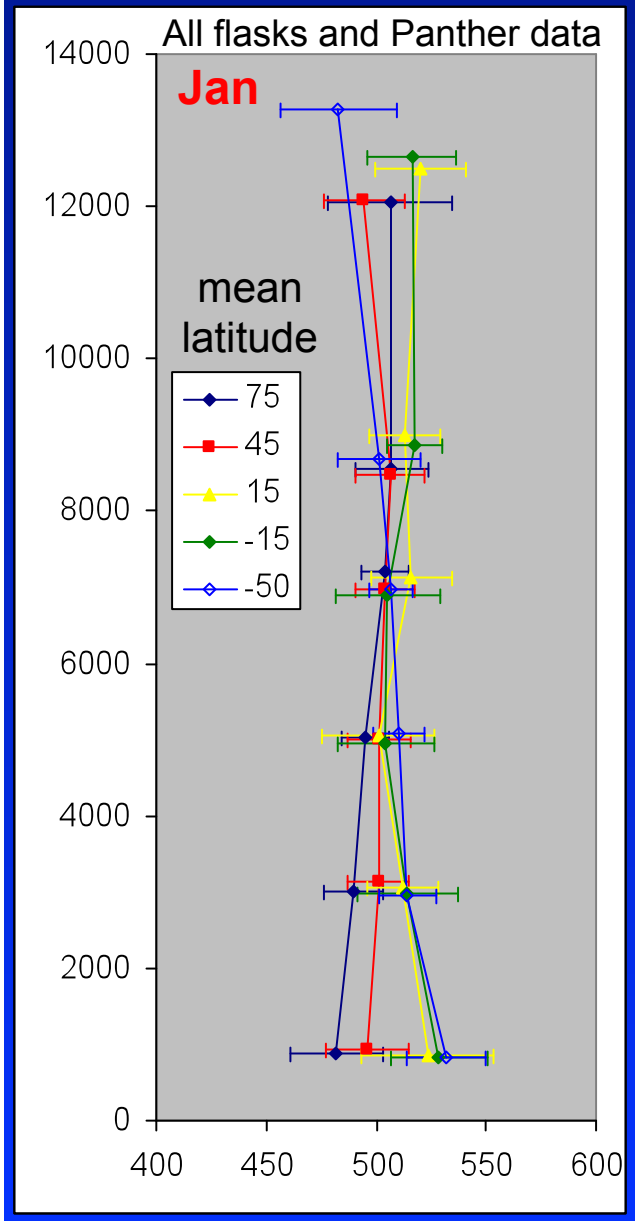
COS vs other gases…

Hydrogen

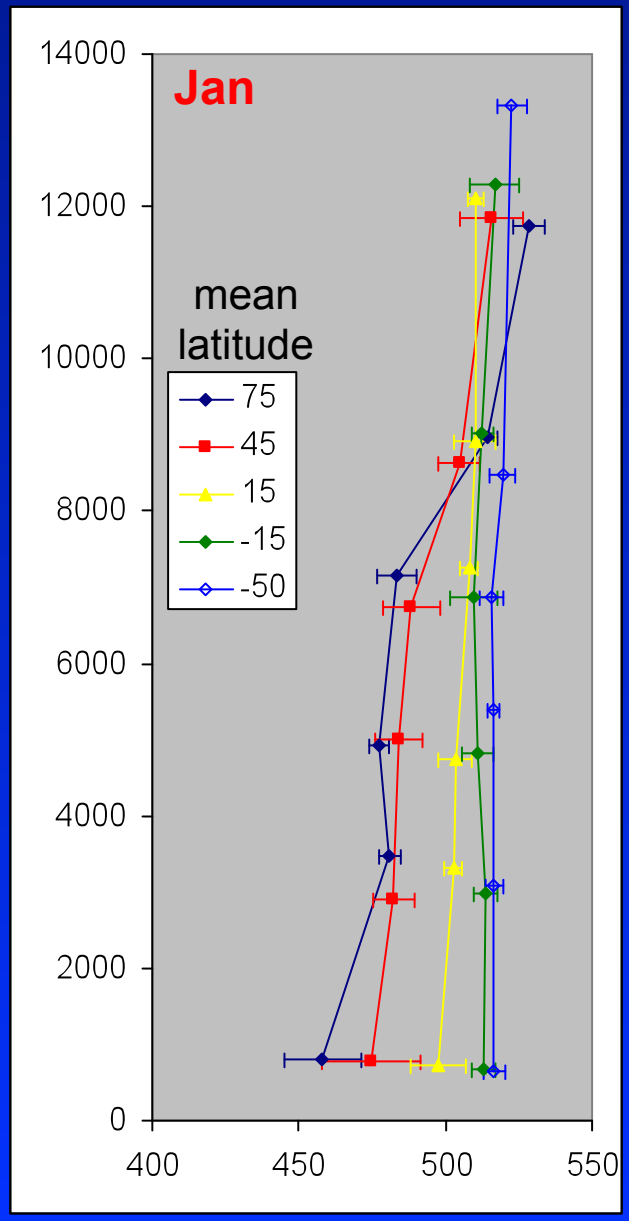
Carbon dioxide

HIPPO 1 Altitude vs. mixing ratio

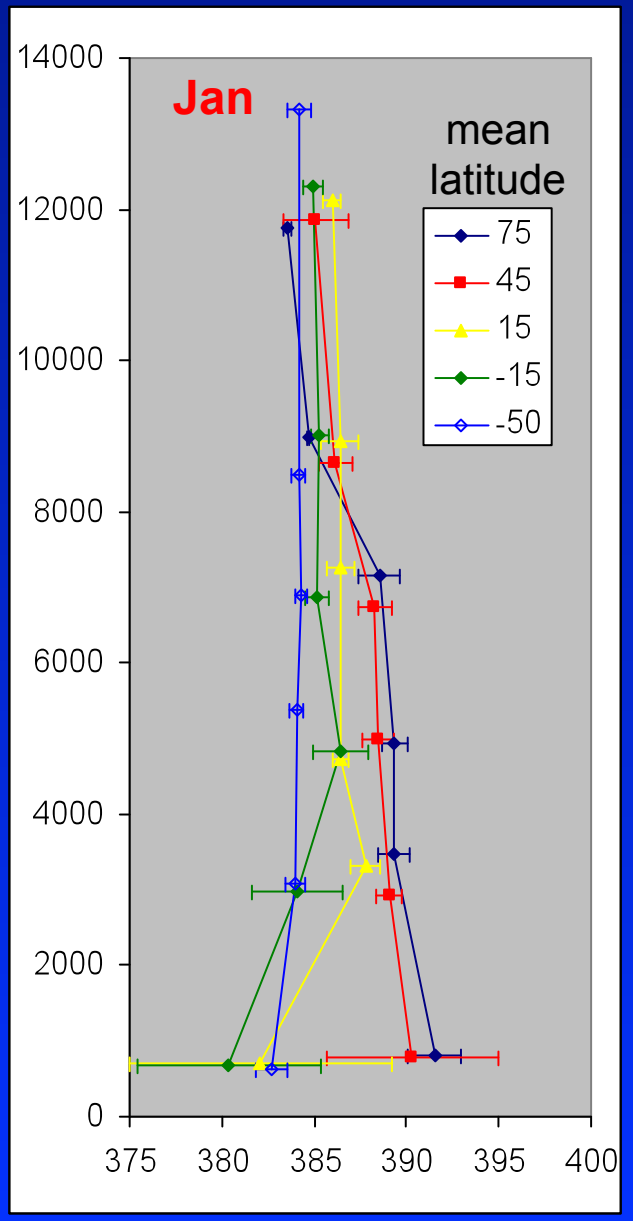
COS (ppt)



Hydrogen (ppb)

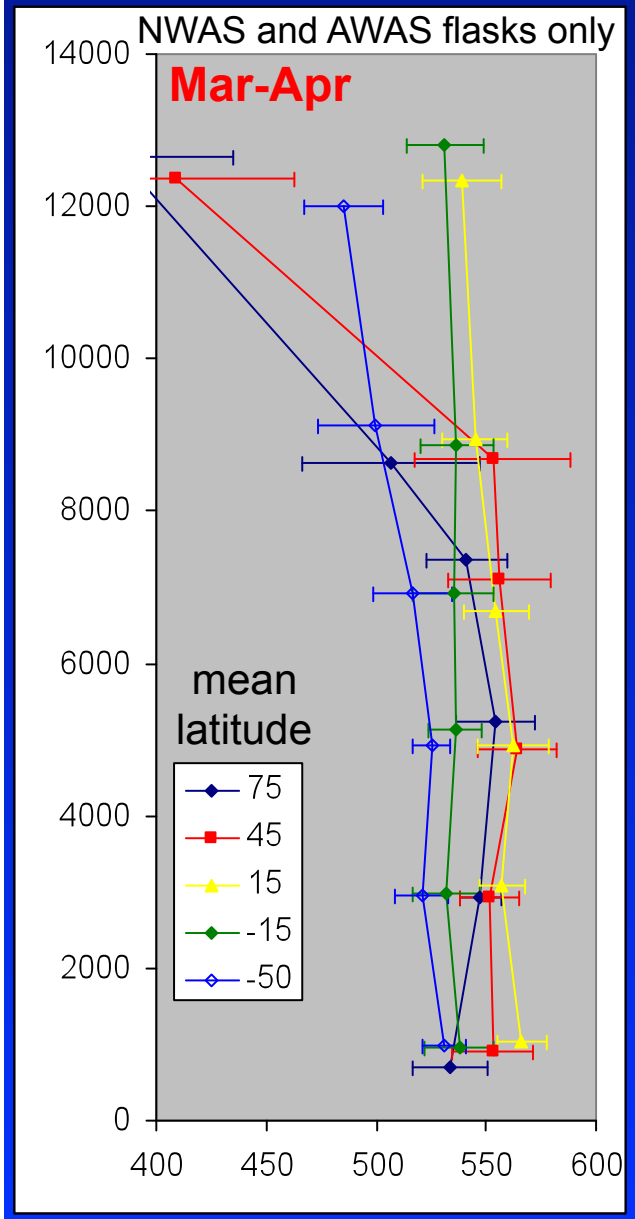


CO_2 (ppm)

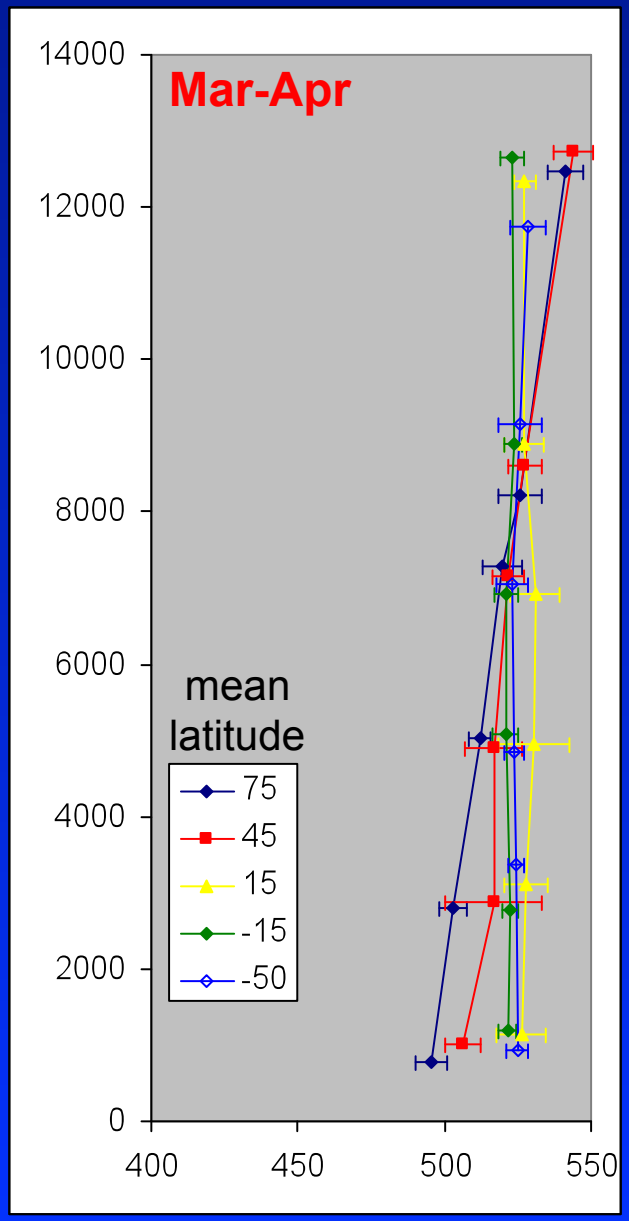


HIPPO 3 Altitude vs. mixing ratio

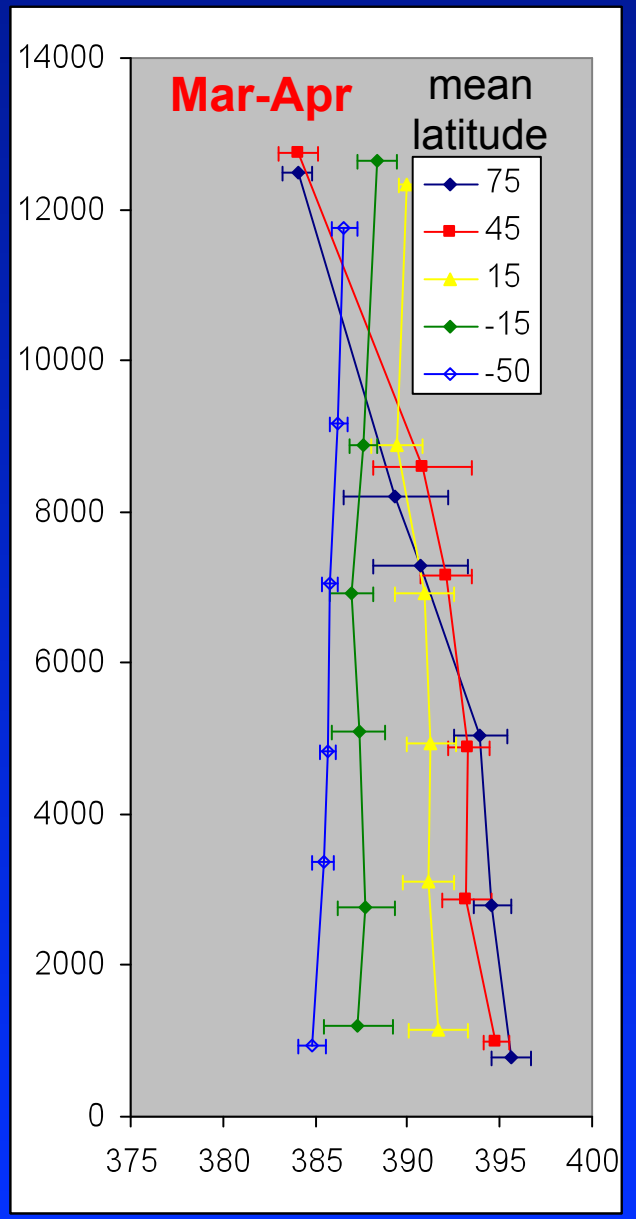
COS (ppt)



Hydrogen (ppb)

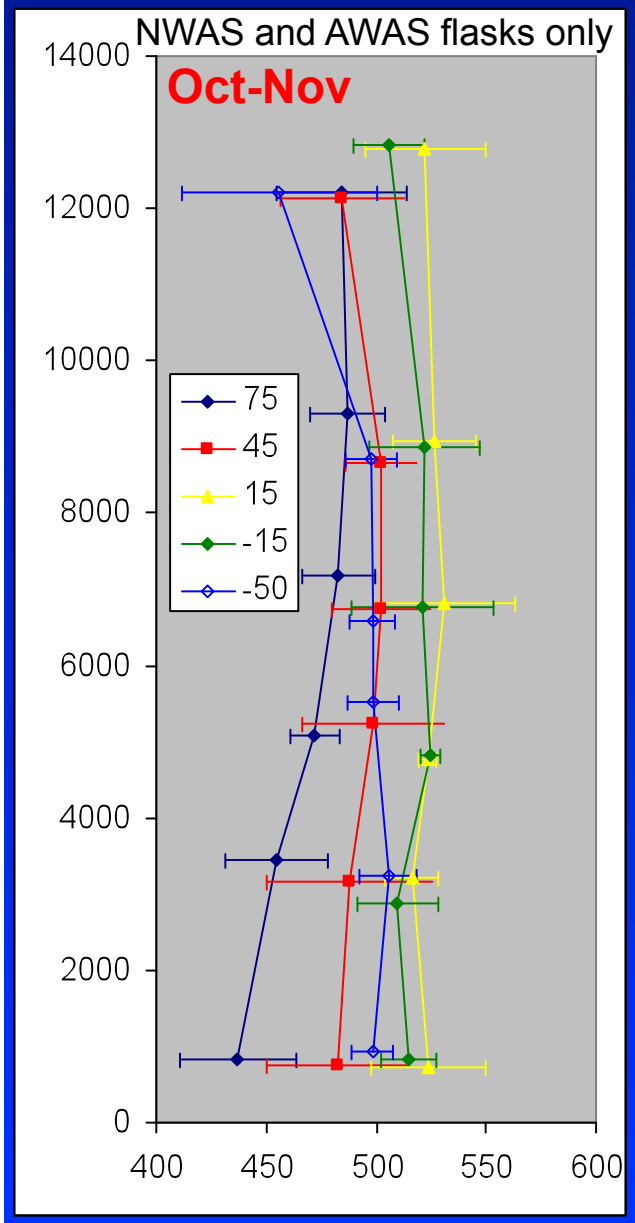


CO_2 (ppm)

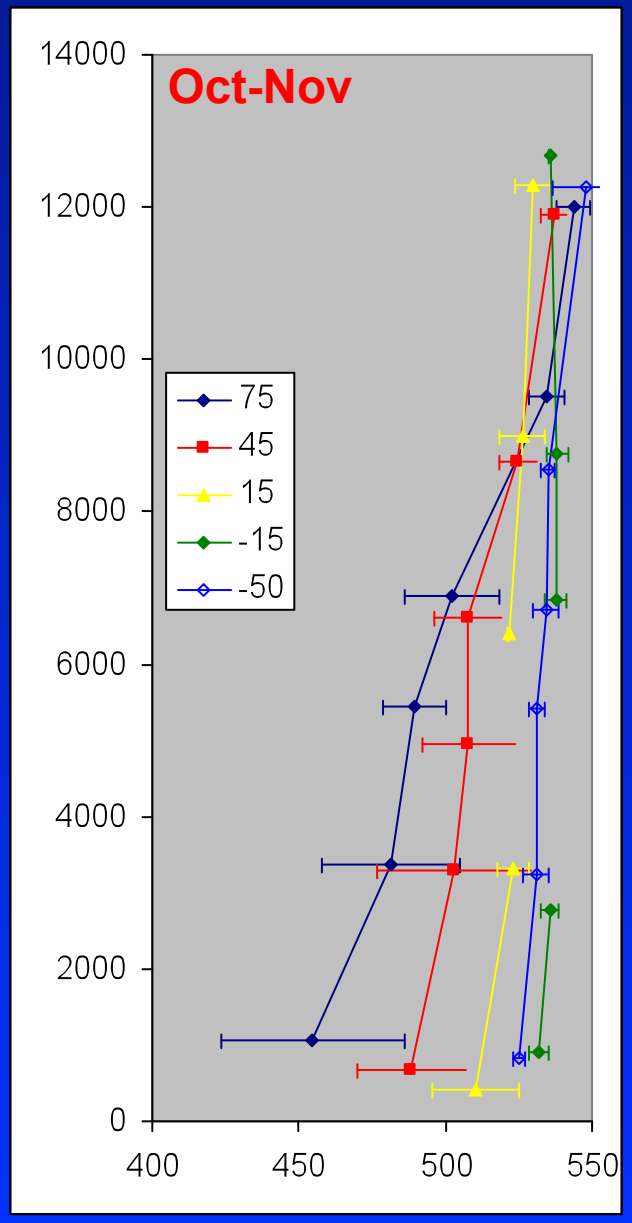


HIPPO 2 Altitude vs. mixing ratio

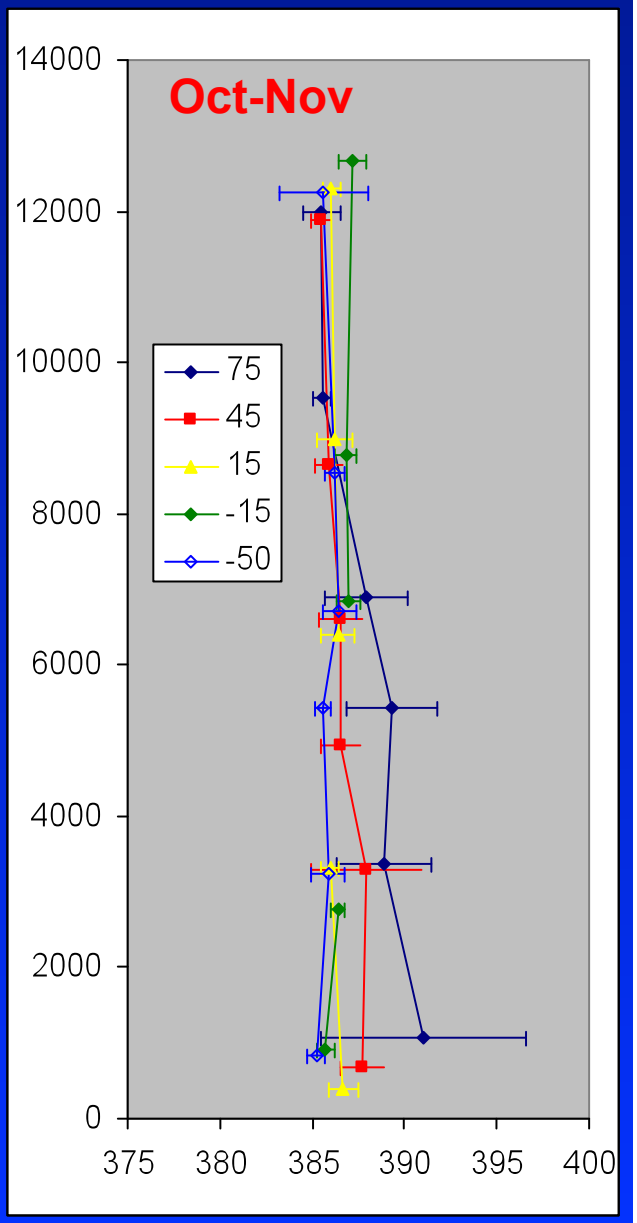
COS (ppt)



Hydrogen (ppb)



CO_2 (ppm)



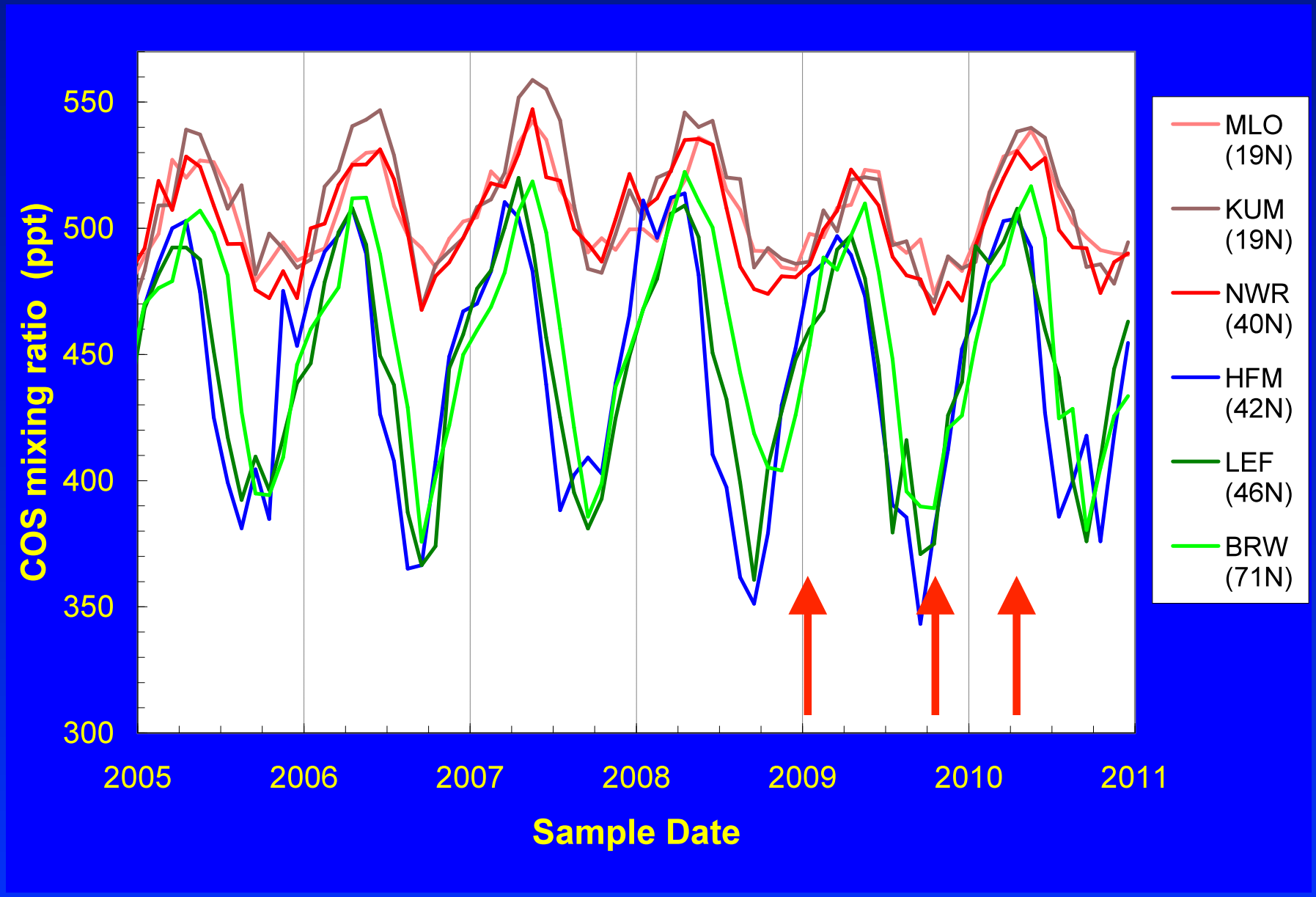
So where is the large terrestrial loss of COS??

COS vs month

Substantially lower COS mixing ratios at mid-continental surface sites in summer

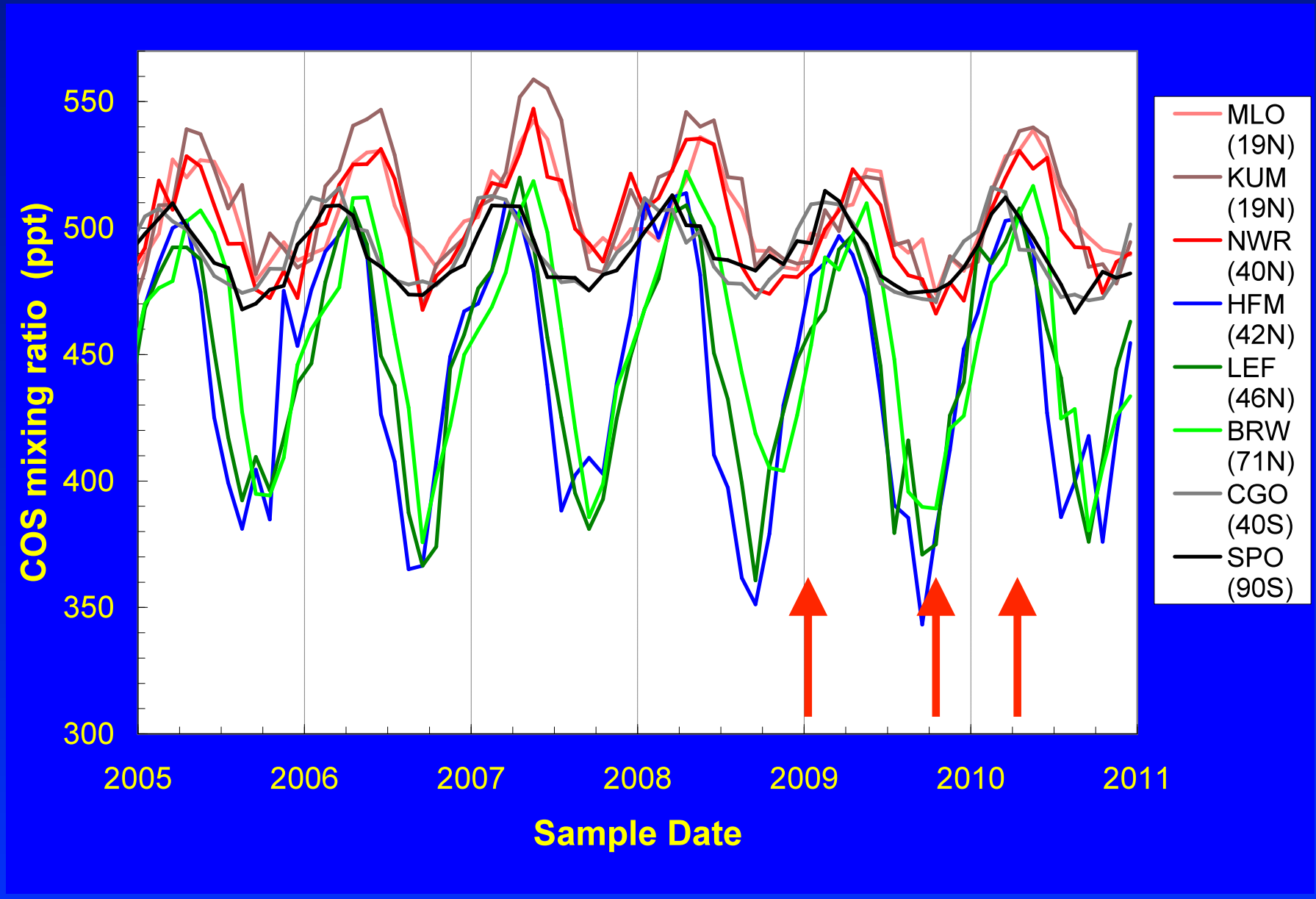
…why?

COS at background NH surface sites

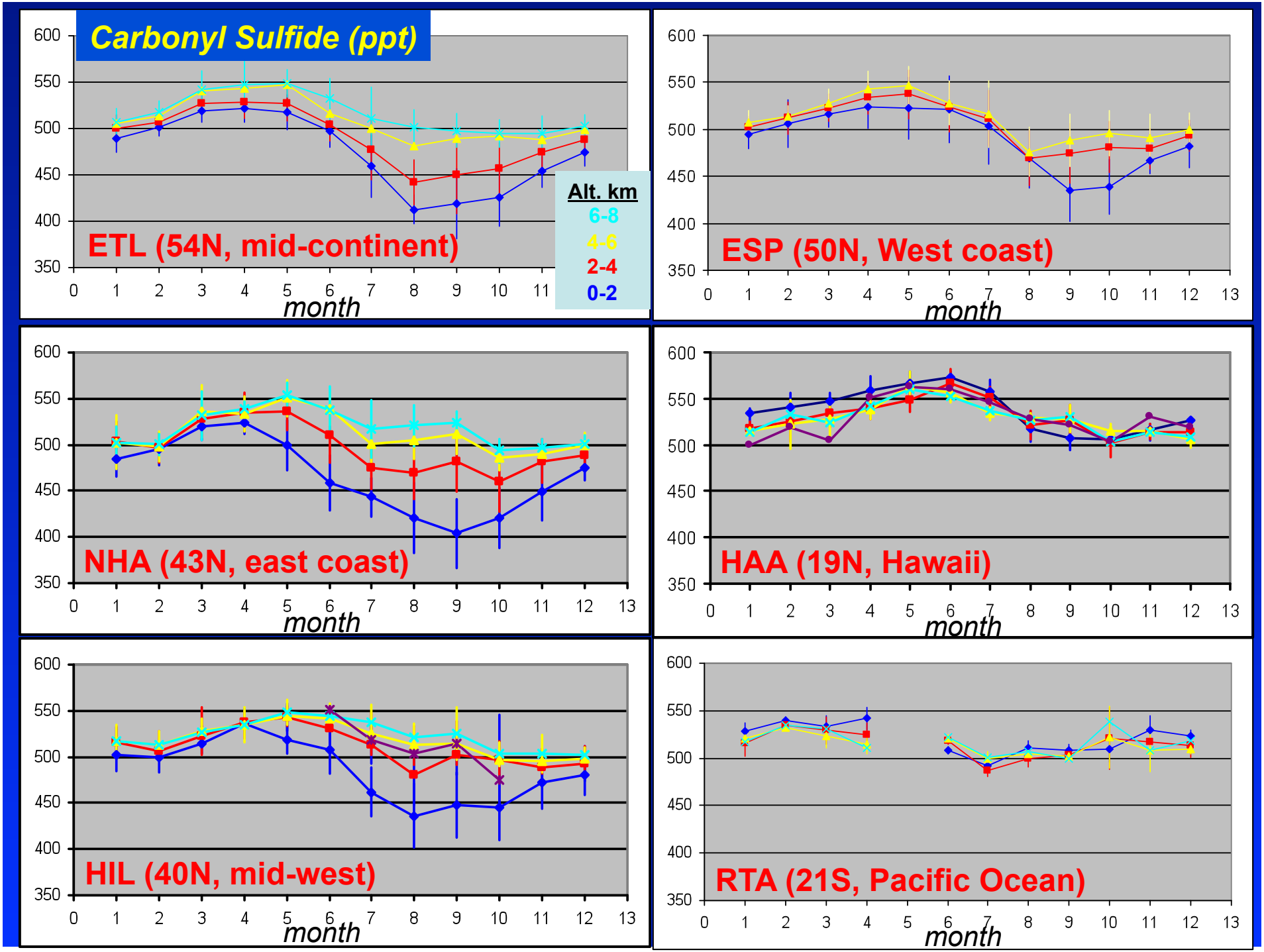


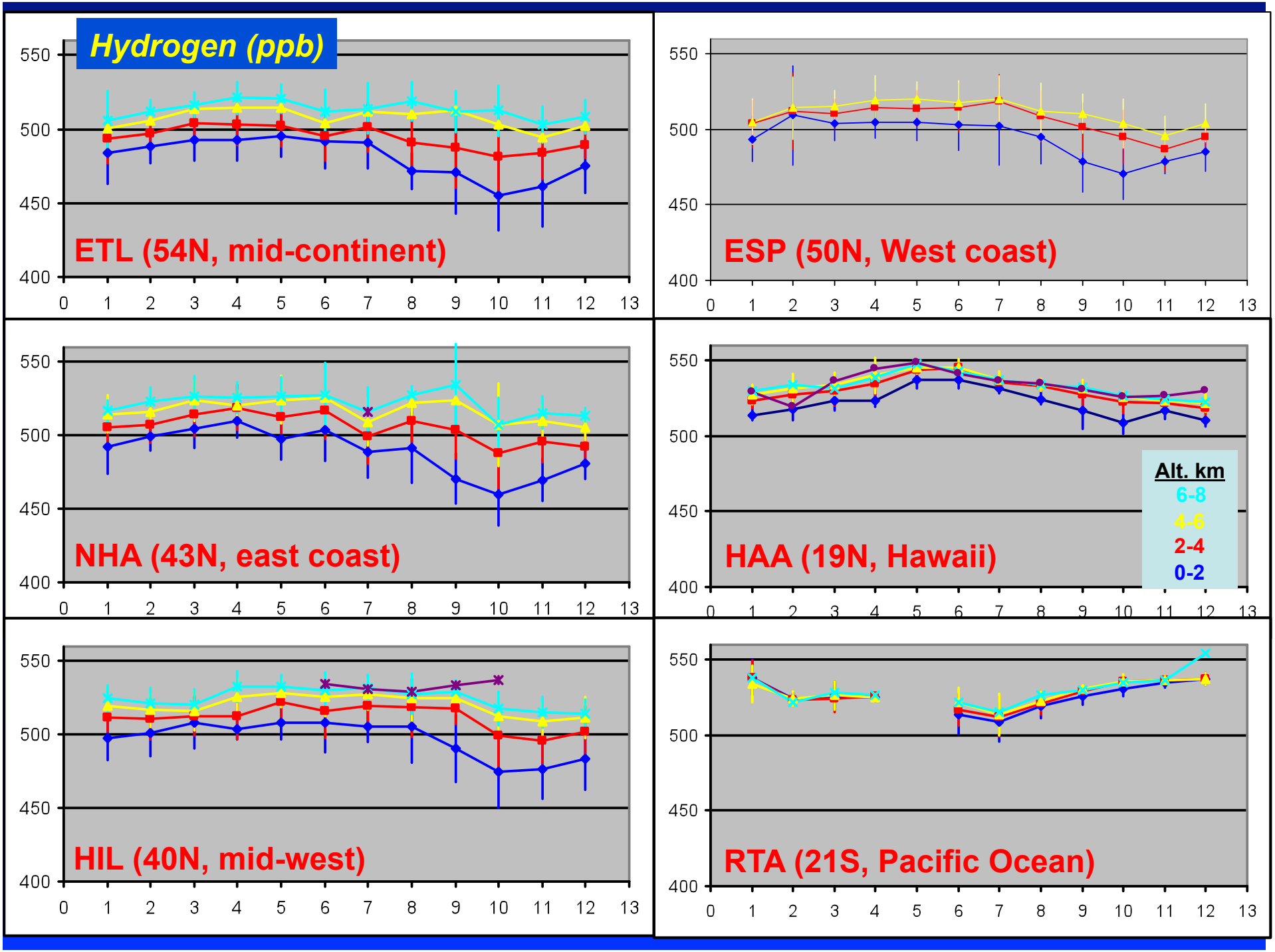
MLO at 3.4 km, NWR at 3.5 km, others are low altitude sites

COS at background NH&SH surface sites

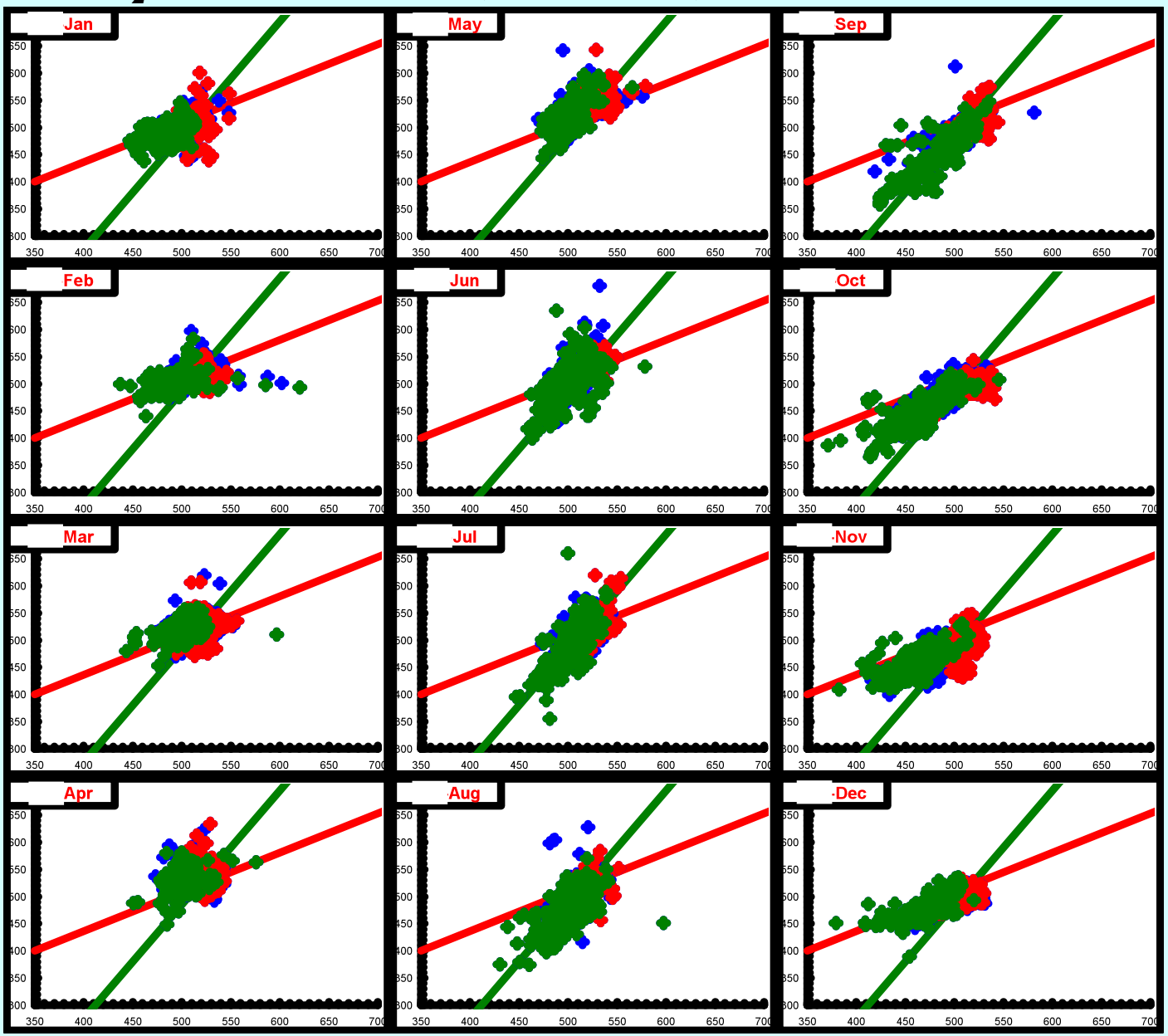


MLO at 3.4 km, NWR at 3.5 km, others are low altitude sites


Carbonyl Sulfide (ppt)
ETL (54N, mid-continent)
ESP (50N, West coast)
NHA (43N, east coast)
HAA (19N, Hawaii)
HIL (40N, mid-west)
RTA (21S, Pacific Ocean)
Alt. km
6-8
4-6
2-4
0-2
month
600
550
500
450
400
350


Hydrogen (ppb)
ETL (54N, mid-continent)
ESP (50N, West coast)
NHA (43N, east coast)
HAA (19N, Hawaii)
HIL (40N, mid-west)
RTA (21S, Pacific Ocean)
Alt. km
6-8
4-6
2-4
0-2
550
500
450
400
0 1 2 3 4 5 6 7 8 9 10 11 12 13

COS *vs.* H_2 *vs.* altitude <2000, 2000-5000, 5000-8000 masl



Carbonyl Sulfide (ppt)

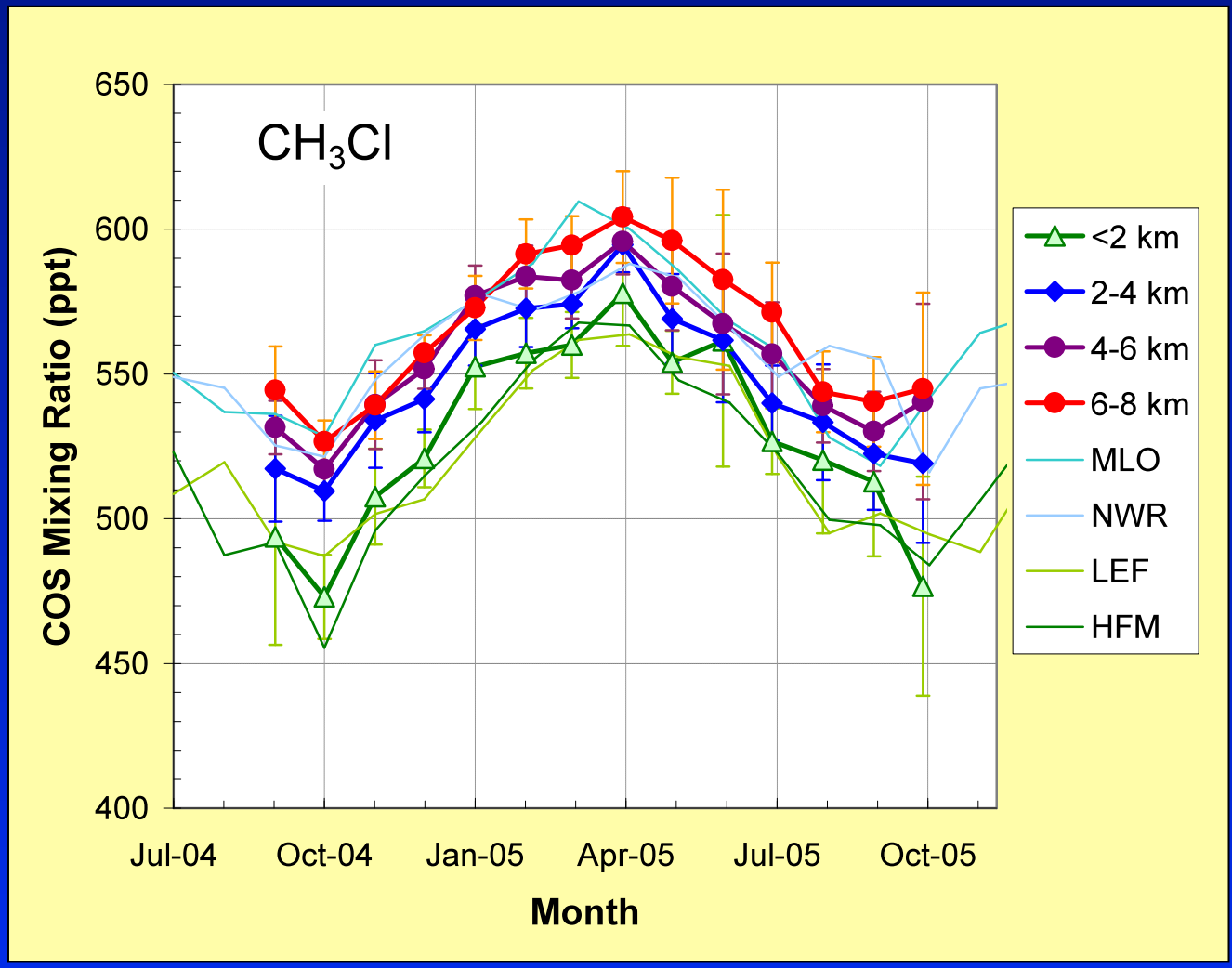
Hydrogen (ppb) Data from fall 2004-fall-2007

Conclusions:

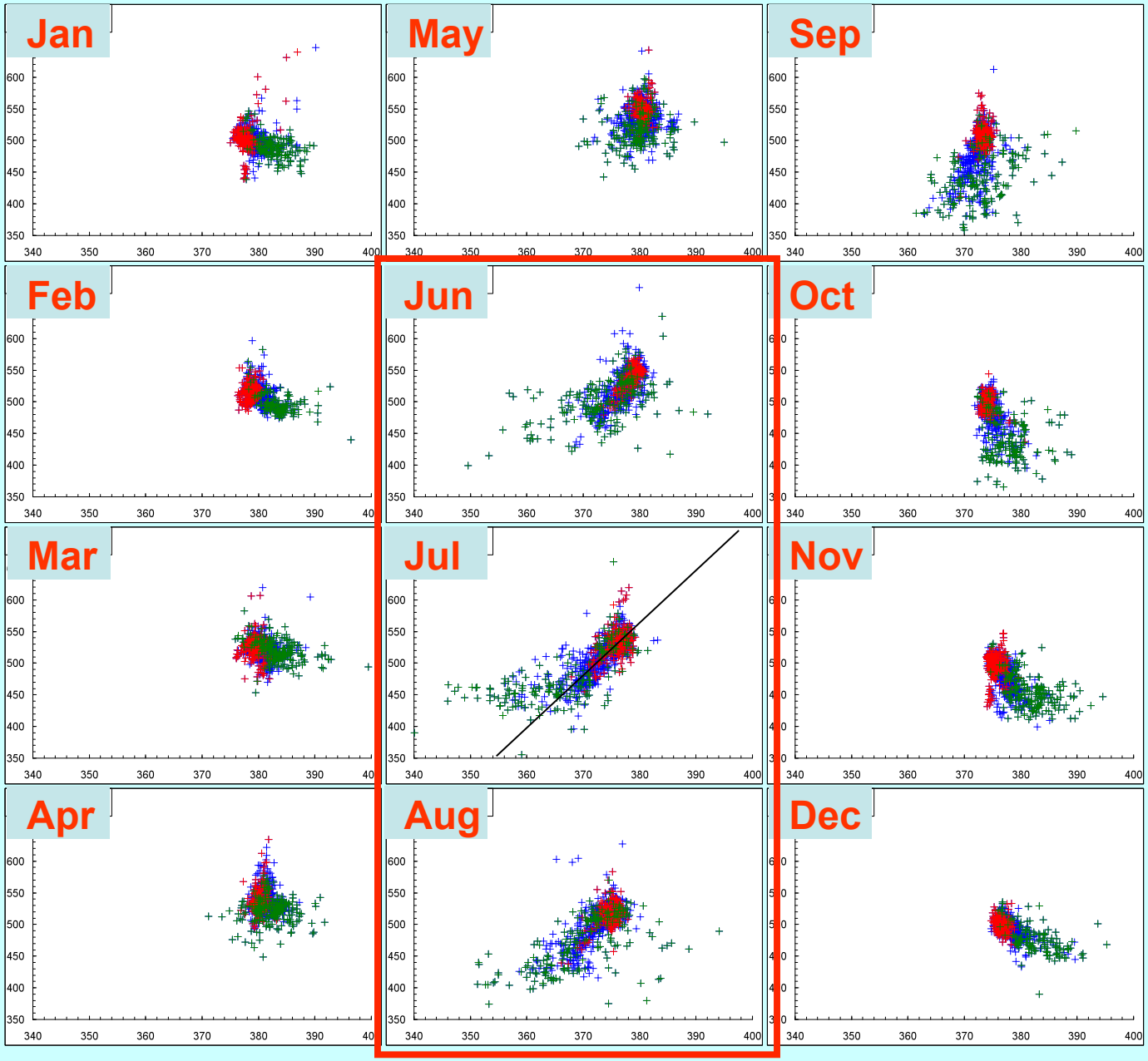
Results from HIPPO 1, 2, & 3

- Show many consistencies with other data…
  - in vertical gradients
  - in seasonal variations
- But some interesting differences too…

Anticipating an increased land uptake signal in H4 and H5!


CH3Cl
650
600
550
500
450
400
COS Mixing Ratio (ppt)
Jul-04
Oct-04
Jan-05
Apr-05
Jul-05
Oct-05
Month
<2 km
2-4 km
4-6 km
6-8 km
MLO
NWR
LEF
HFM

COS *vs.* CO_2 *vs.* altitude <2000, 2000-5000, 5000-8000 masl



Data: fall 2004-fall-2007

Aircraft Results From ALL SITES

Color scheme:

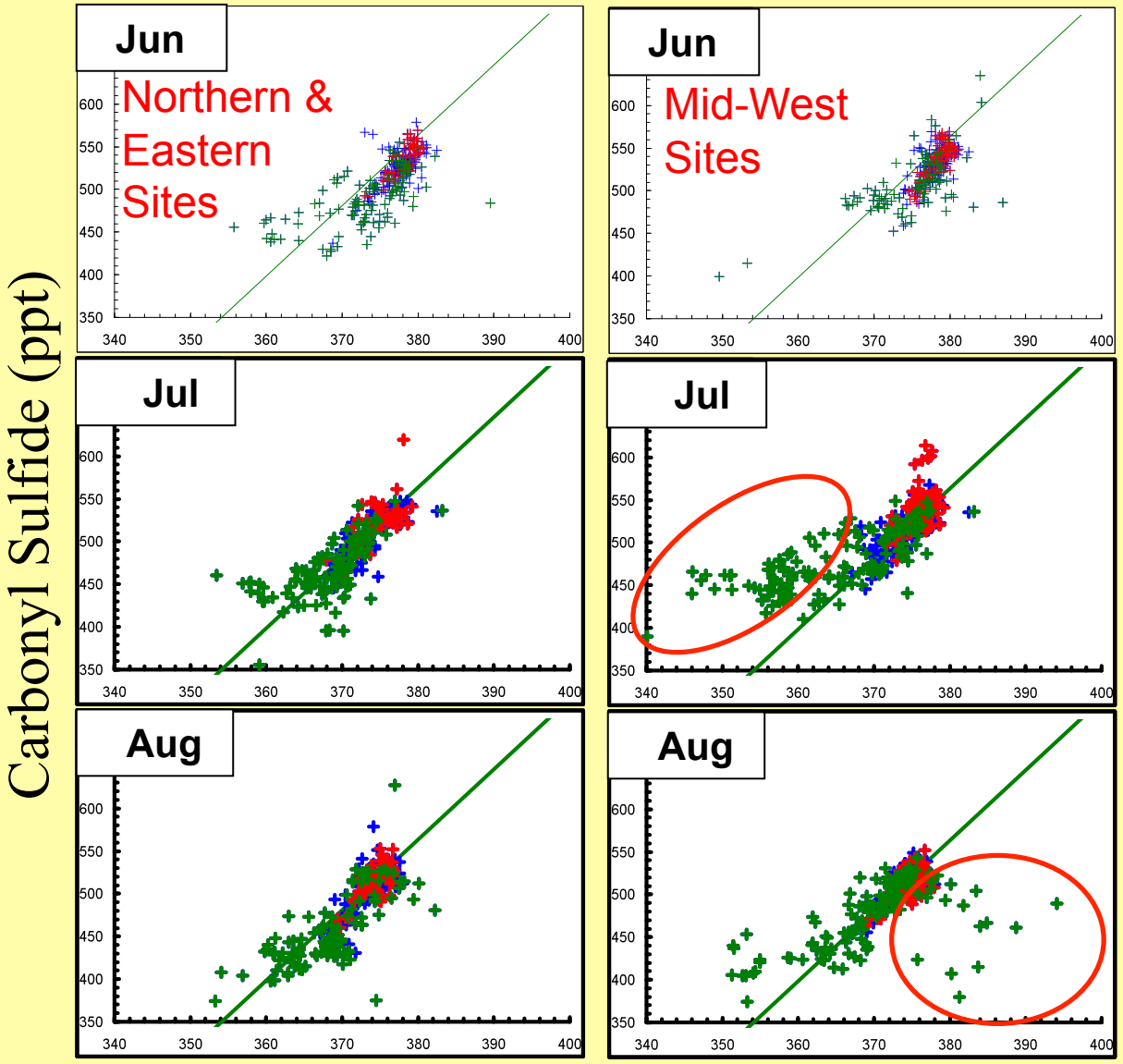
5 to 8 km asl

2 to 5 km asl

< 2 km asl

Line represents an uptake ratio of ~6

COS *vs.* CO_2 *vs.* Site



Line represents an ERU of ~6

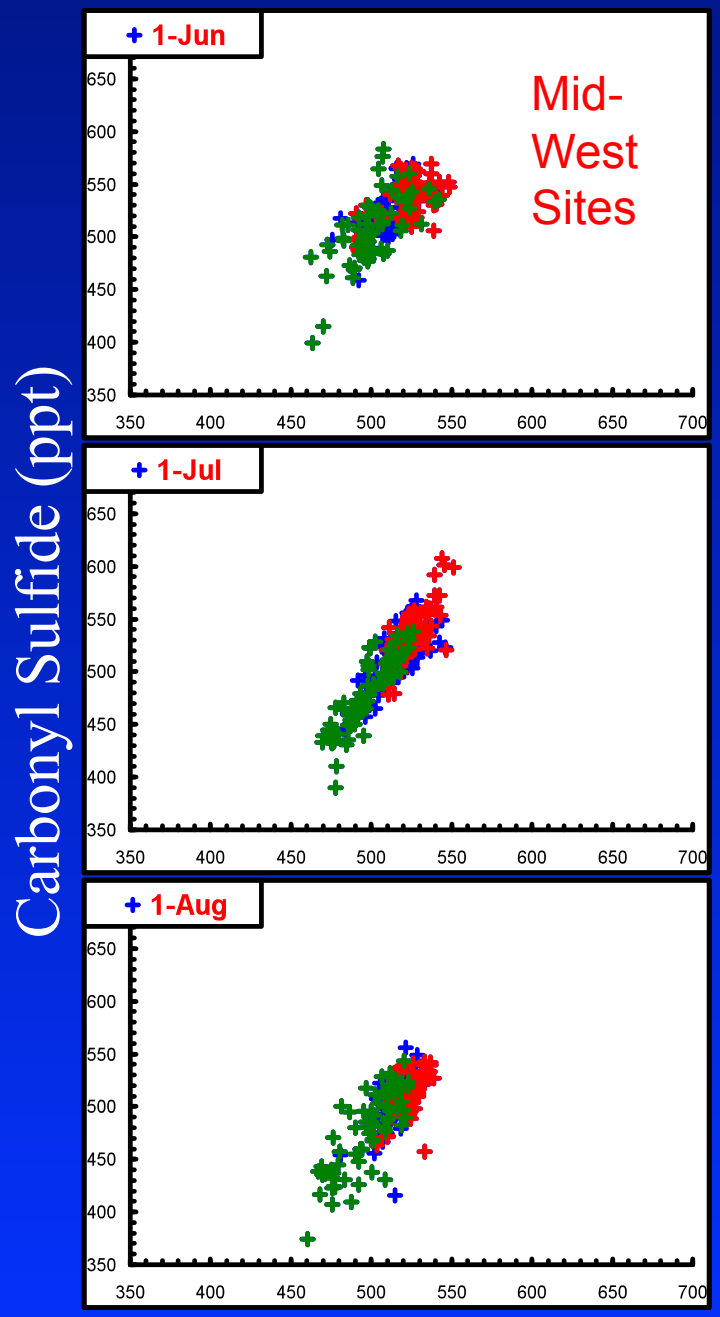
Color Scheme:

Sample altitude (masl):

Green: <2500

Blue: 2500-5000

Red: 5000-8000

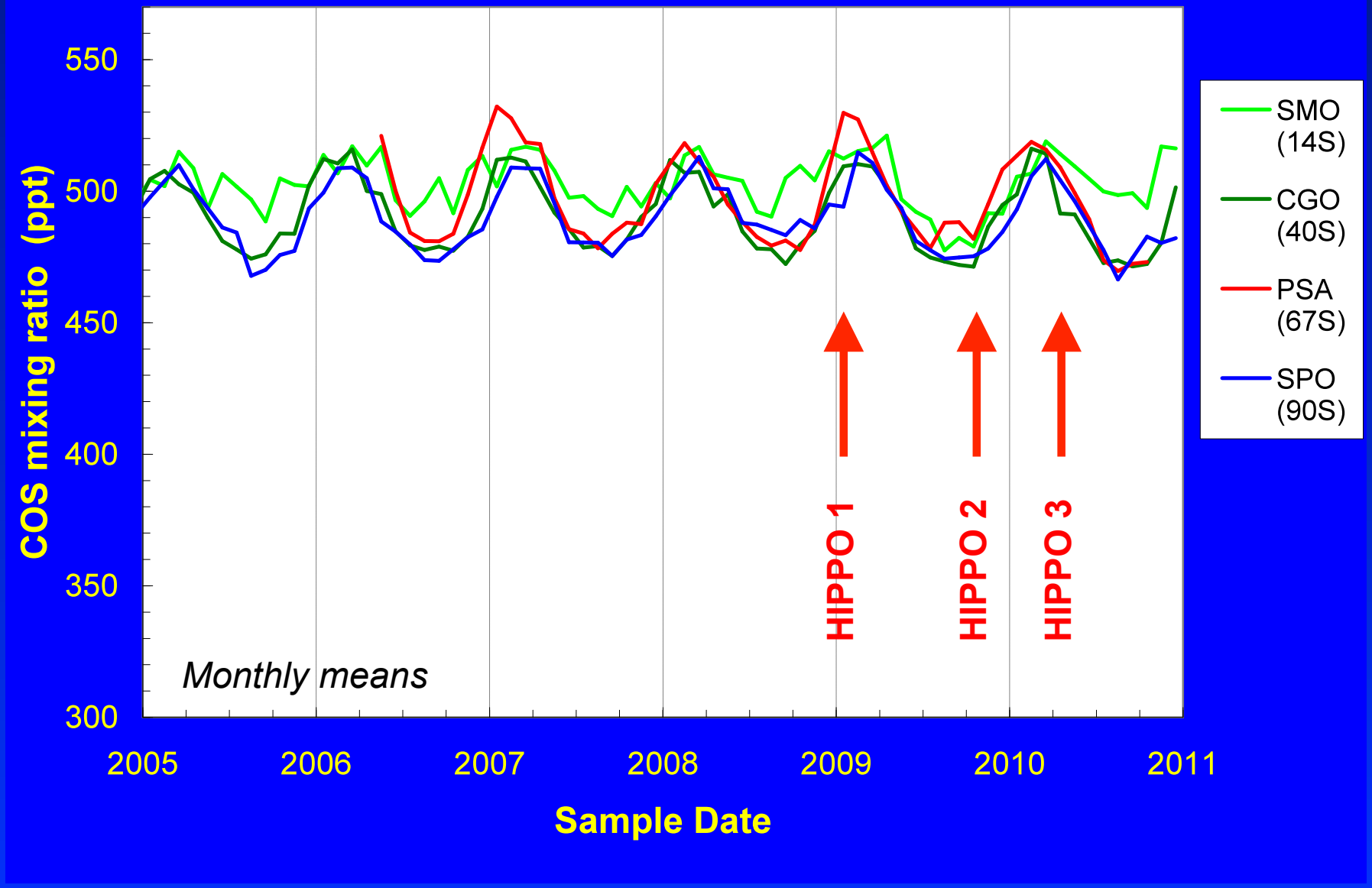


COS *vs.* Hydrogen (a gas with a strong suface sink)

Consistent correlation observed even during July…

Perhaps CO_2 in July was anomalous…?

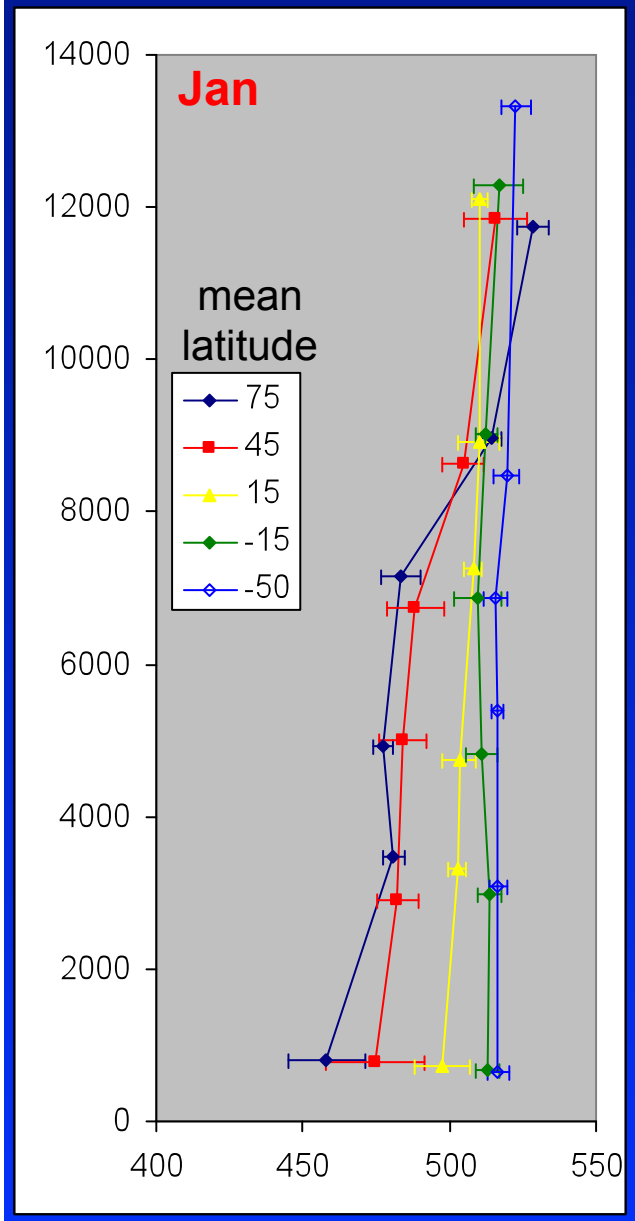
COS at background SH surface sites



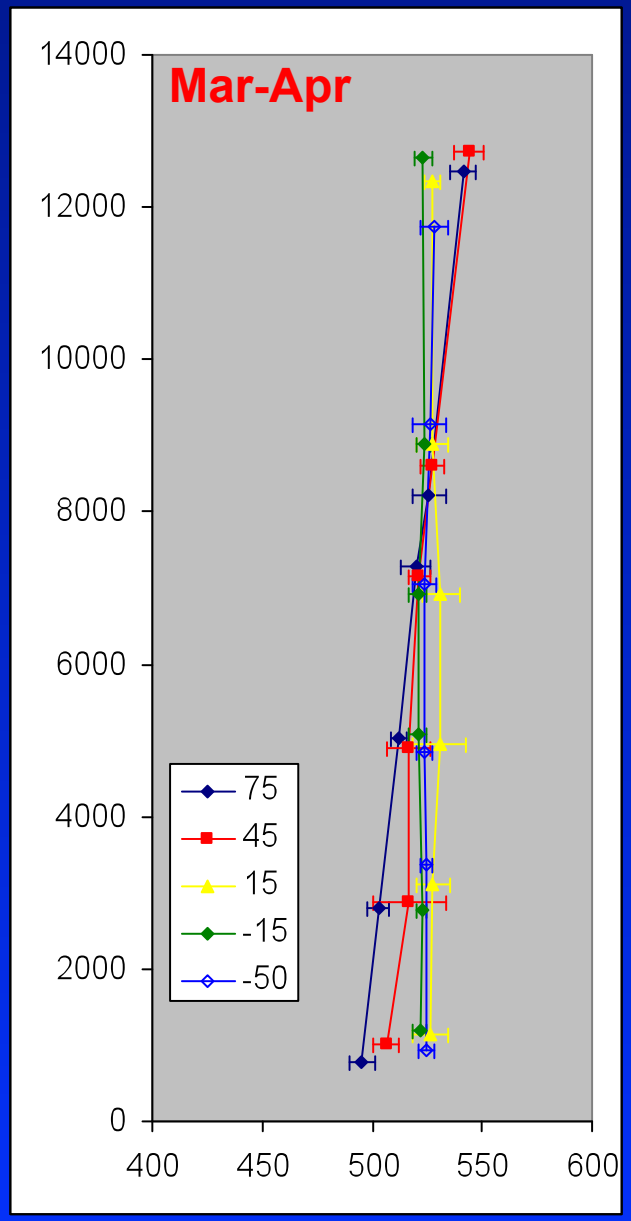
SPO at 2.9 km asl, others are low altitude sites

Measurements since 2000

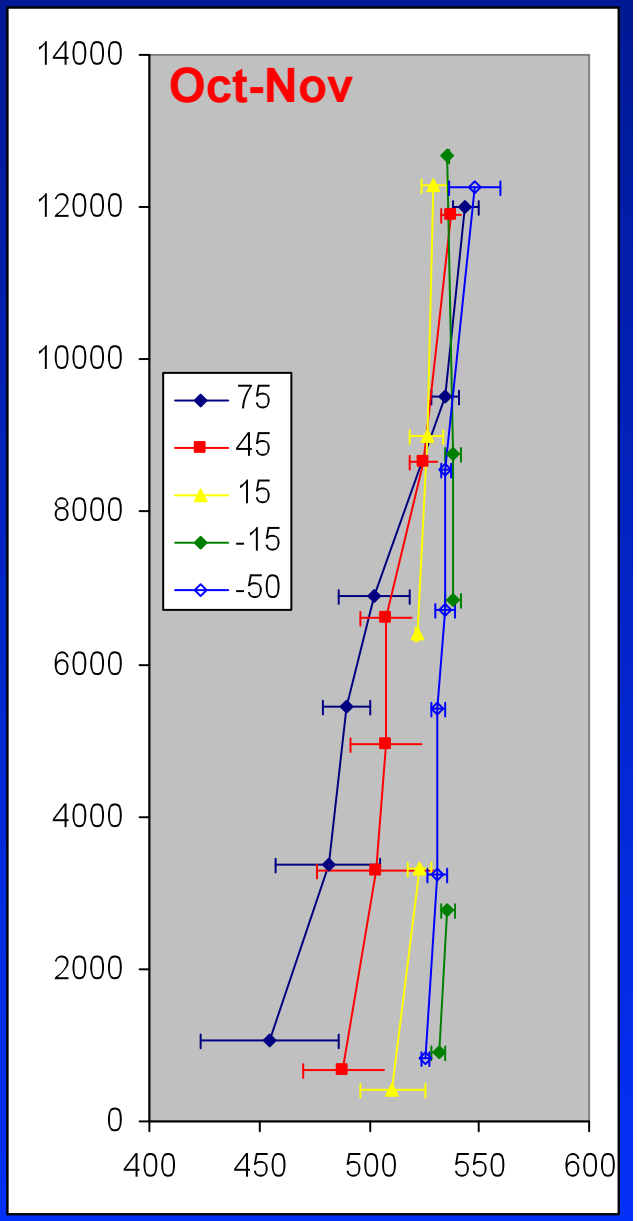
Hydrogen during HIPPO (P. Novelli, NOAA)



HIPPO 1

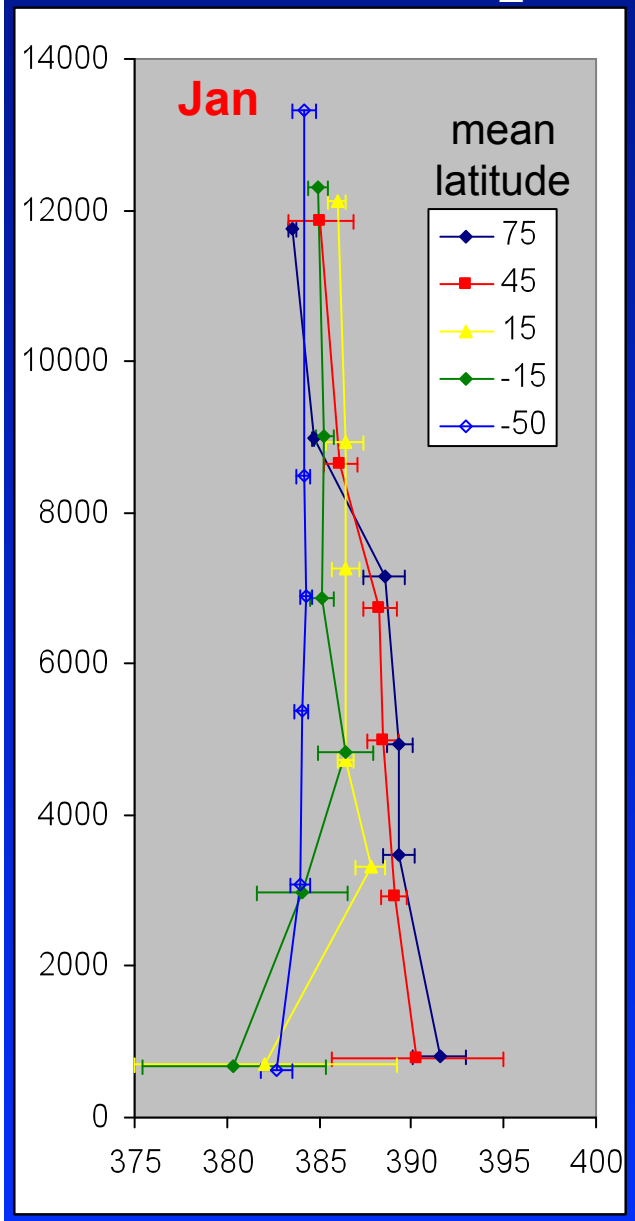


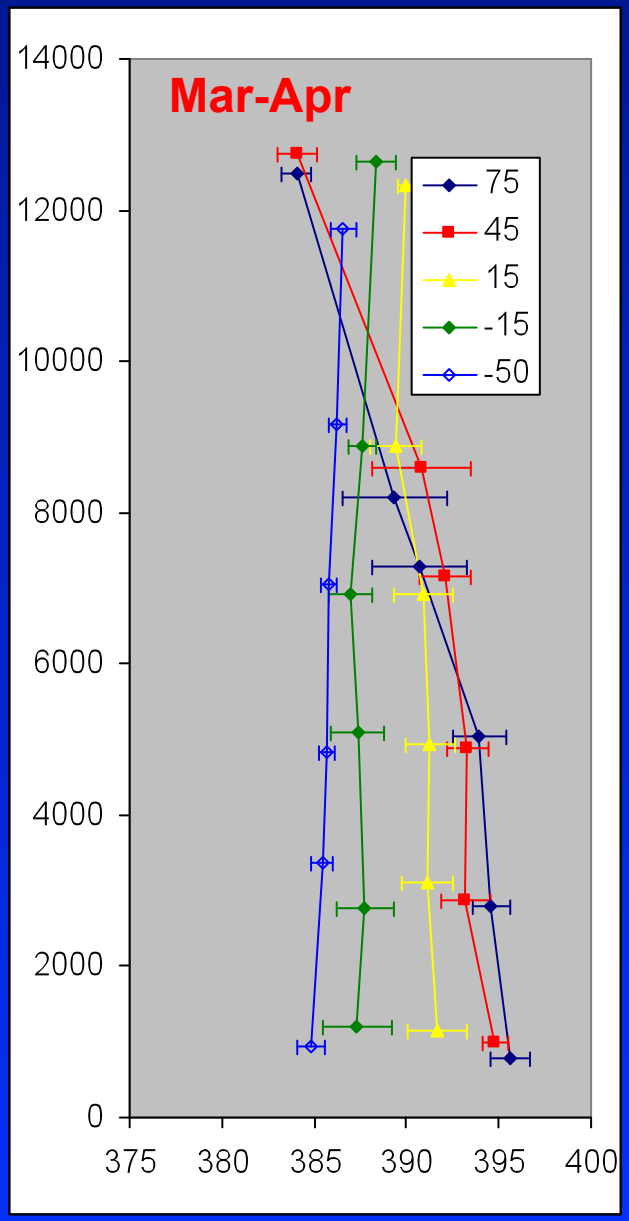
HIPPO 3

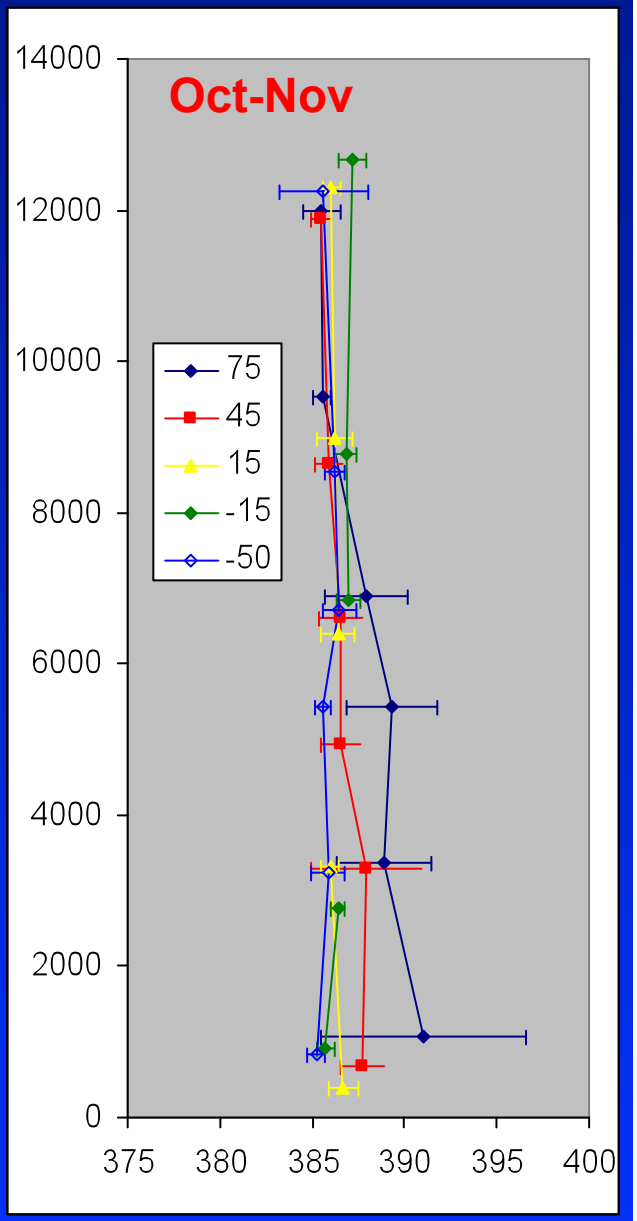


HIPPO 2

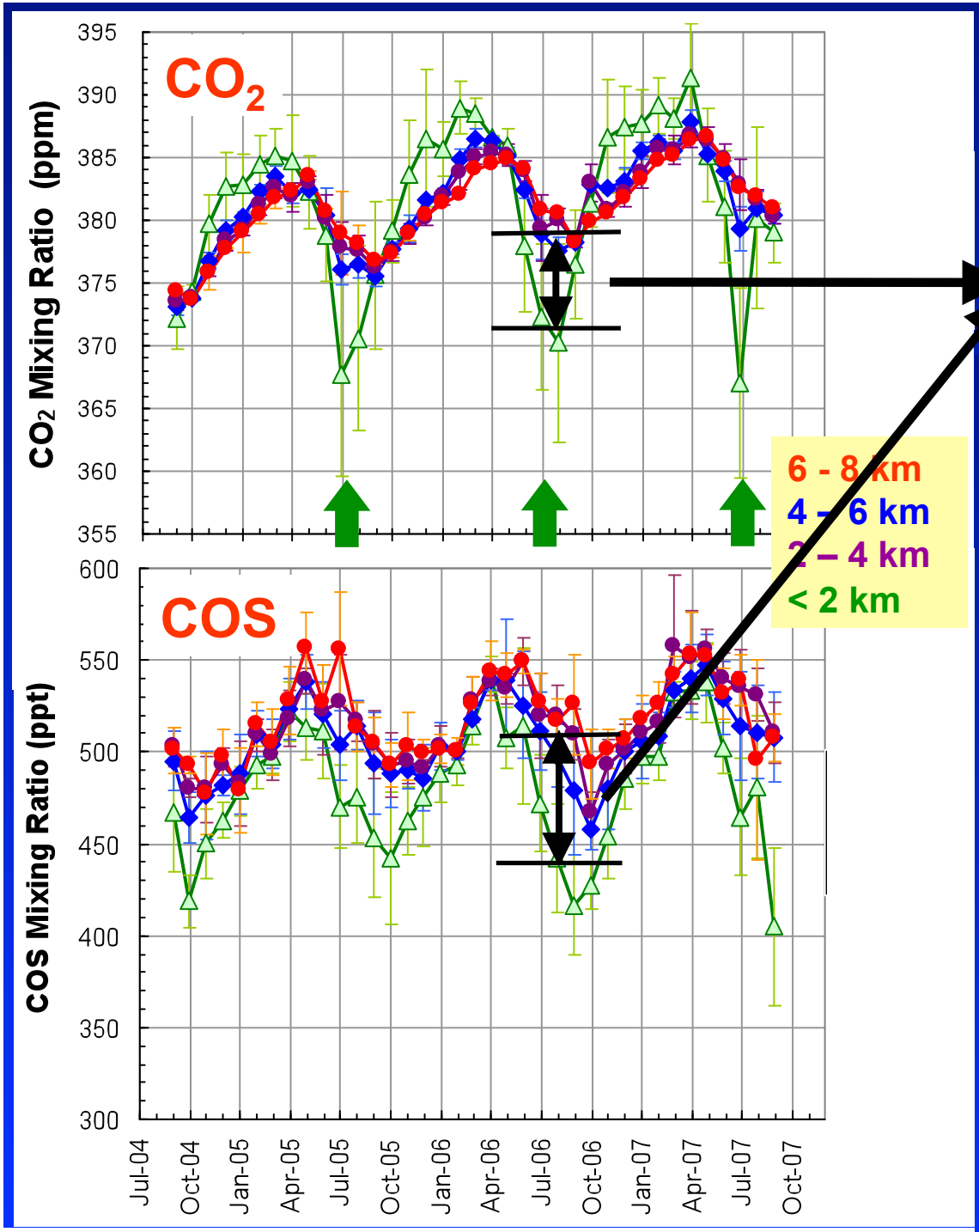
CO_2 during HIPPO (pfp flask results only)







HIPPO 1 HIPPO 3 HIPPO 2



From aircraft, Mid-west sites…

Relative Uptake of $\Delta COS / \Delta CO_2 = 4 - 8$

Regional scale gradients for COS above continents likely explain the broader scale seasonal variability (as is true for CO_2)