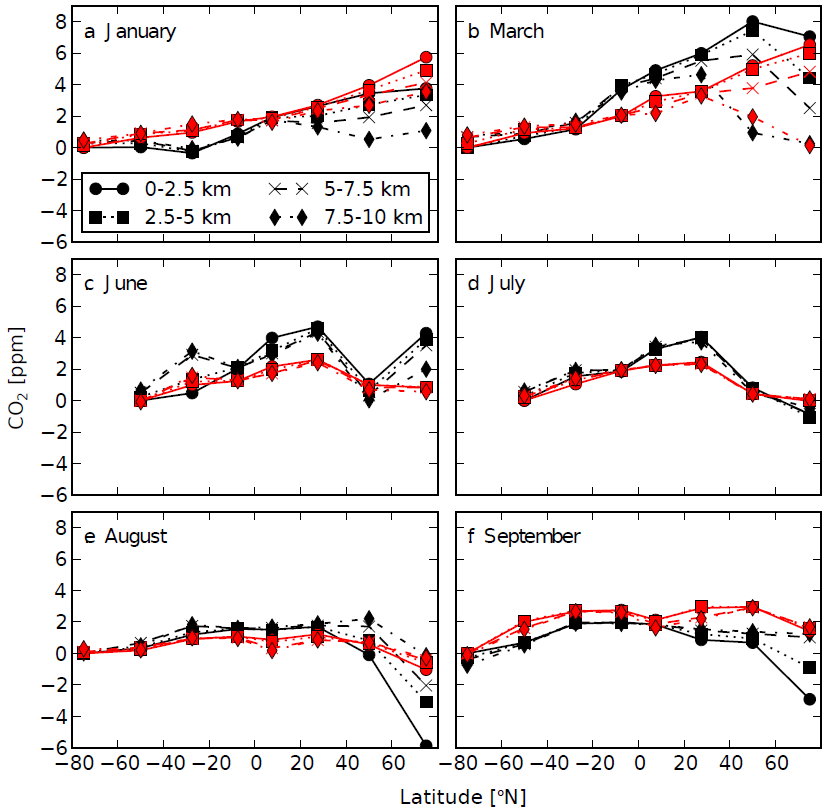
Rigid constraints on seasonal hemispheric CO_2 exchange

Britton Stephens, Colm Sweeney, Jonathan Bent, Bruce Daube, Rodrigo Jimenez-Pizarro, Ralph Keeling, Eric Kort, Sunyoung Park, Jasna Pittman, Greg Santoni, Steve Wofsy

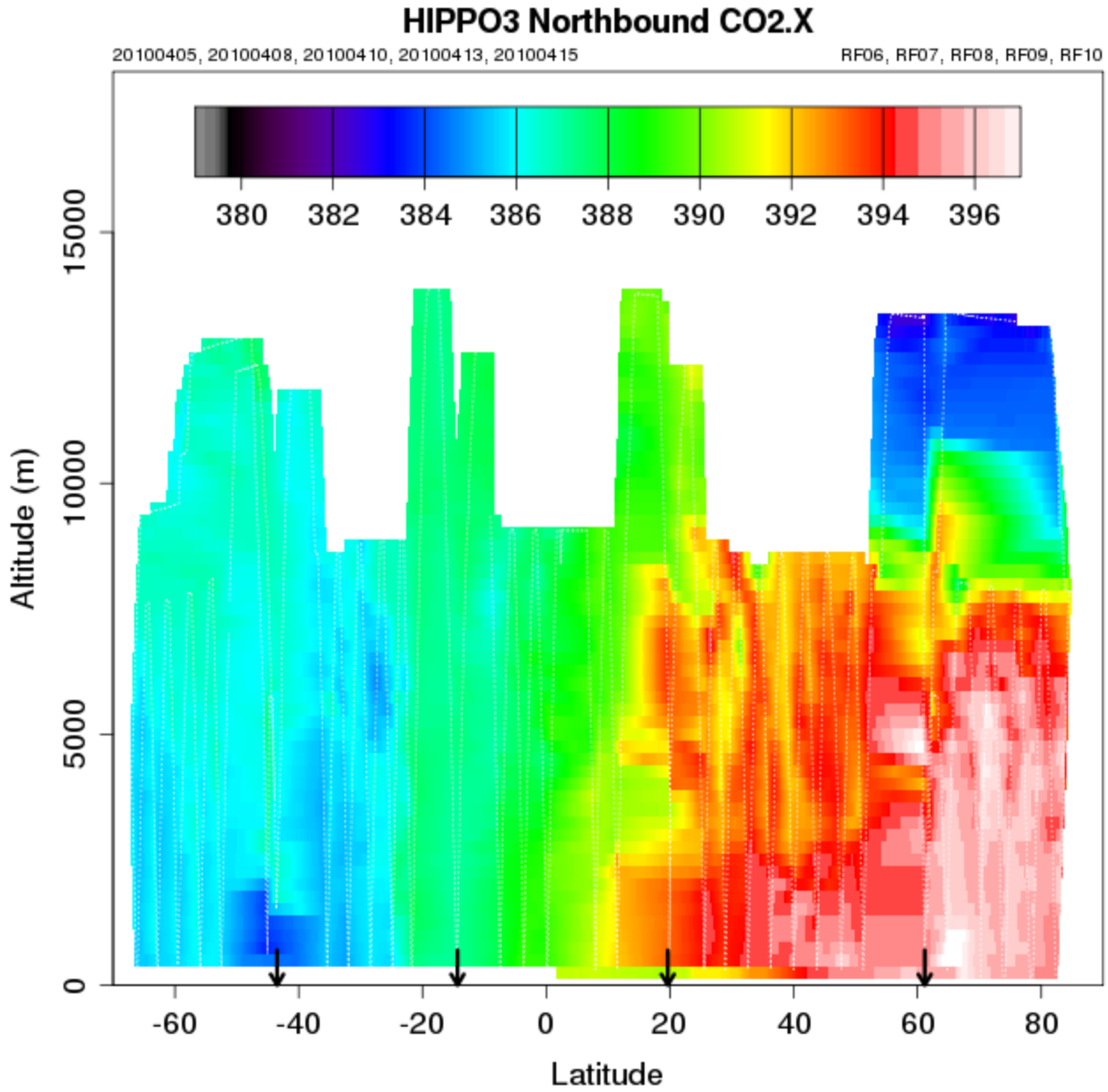
Selection of HIPPO CO_2 investigations

- Wunsch, Keppel-Aleks TCCON papers
- Keppel-Aleks: comparisons to CESM/ CAM
- Graven: IGY comparisons
- Jacobson/Wofsy: CarbonTracker comparisons
- Patra: ACTM comparisons
- Sweeney: Arctic seasonality
- AIRS comparisons
- Others?
- Stephens: counting moles

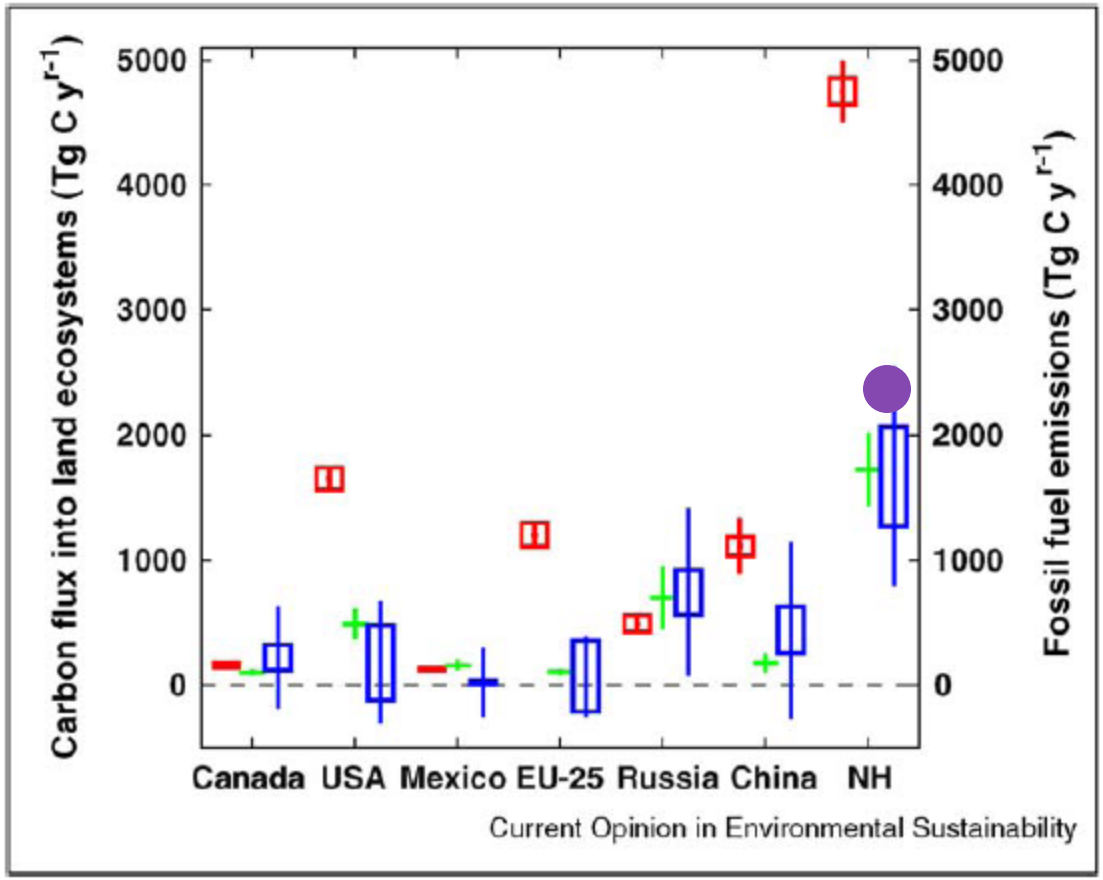
HIPPO
CESM/CAM



Keppel-Aleks, in prep, 2012


HIPPO3 Northbound CO2.X
20100405, 20100408, 20100410, 20100413, 20100415
RF06, RF07, RF08, RF09, RF10
380
382
384
386
388
390
392
394
396
Altitude (m)
0
5000
10000
15000
-60
-40
-20
0
20
40
60
80
Latitude

“State of the art” models



NH Land
mean of 4 models = 1.7 PgC/yr
range (box) = 0.8 PgC/yr

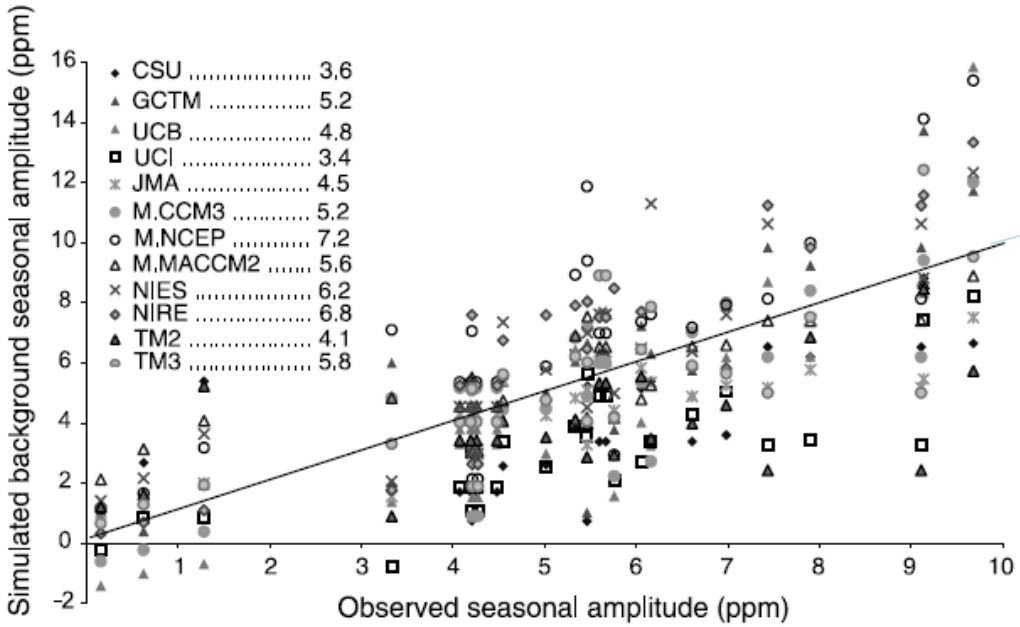
CT NL = 2.3 ± 1.6

[Ciais et al., 2010]

- Basic problem:
  - We can measure atmospheric variations in CO_2 very well, but relating them *quantitatively* to underlying terrestrial processes continues to be limited by errors in atmospheric transport models
- Two front HIPPO approach:
  - Challenge and improve atmospheric transport models so that they can be used to improve understanding of fluxes
  - Find ways to use atmospheric data to constrain fluxes that are independent of atmospheric transport models

Without improving transport models, or waiting for them to be improved, there are already metrics that can be applied independent of transport errors, including:

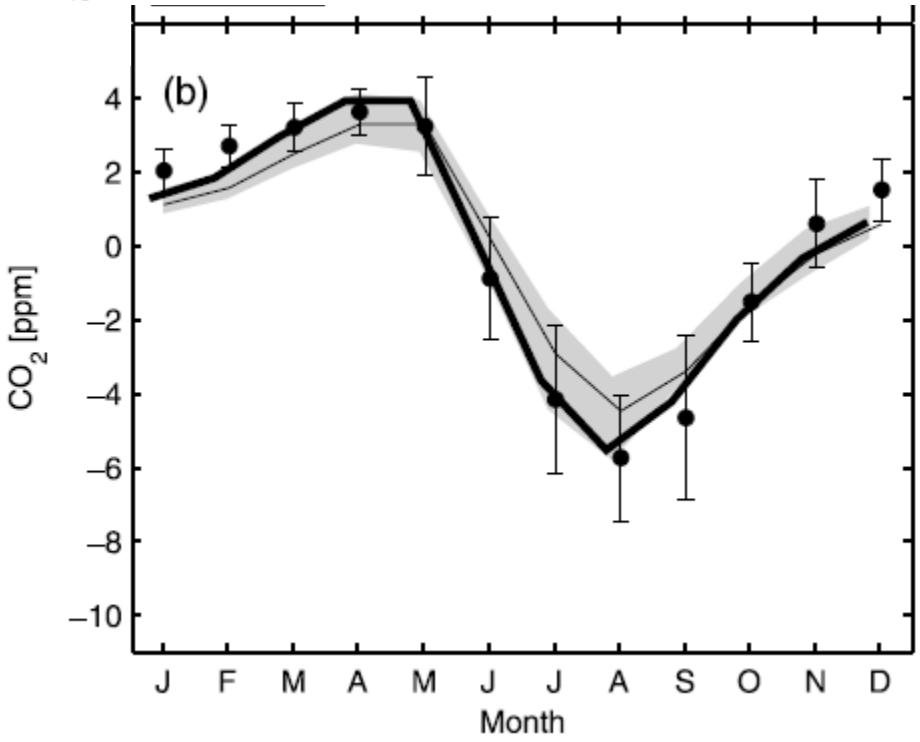
- Terrestrial CO_2: Growing season net flux (GSNF) and dormant season net flux (DSNF)
- Oceanic O_2: Seasonal net outgassing (SNO), seasonal net ingassing (SNI)



[Gurney et al., GBC 2004]

LEF

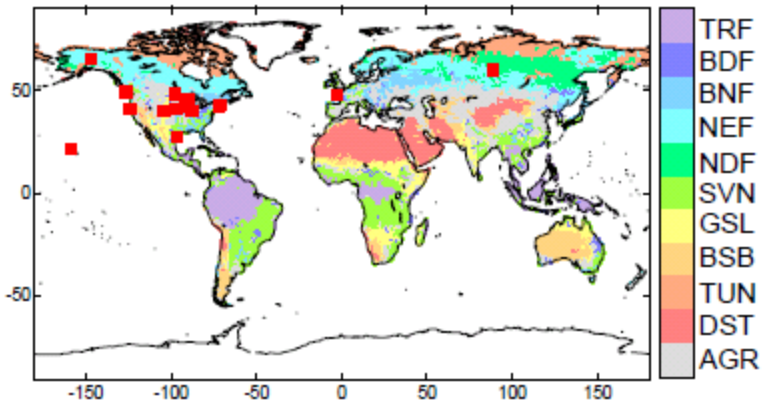
LEF Column Average



[Yang et al., GRL 2007]

"vertically-integrated observations . . . provide a measure of CO_2 variations that is not highly sensitive to error in the transport fields. As a group, the seasonal cycle in column CO_2 is most sensitive to the seasonal fluxes themselves."

"(unoptimized) CASA underestimates GSNF by ~ 25%"

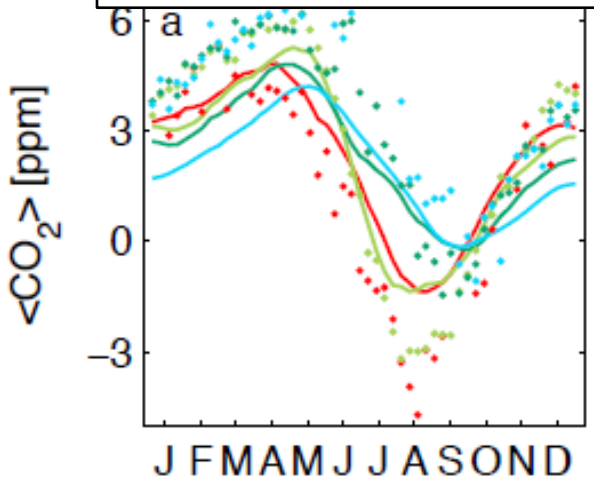


[Nakatsuka and Maksyutov, BGS 2009]

Using light-aircraft profile data:

"Surface-optimized CASA underestimates GSNF by 15%"

Have successfully said what the world is *not* (CASA), now let's say what it *is* – define hemispheric DSNF-GSNF quantitatively from data



"Our simulations suggest that boreal growing season NEE (between 45-65°*N) is underestimated by ~40% in CASA."*

[Keppel-Aleks, et al., Biogeosci., 2012]

Hypothesis: like column averages, integrated HIPPO slices are also much less sensitive to atmospheric transport errors.

Plan:

- Average detrended HIPPO CO_2 over Northern Hemisphere for 9 slices (Northern Hemisphere Meridian Integral):

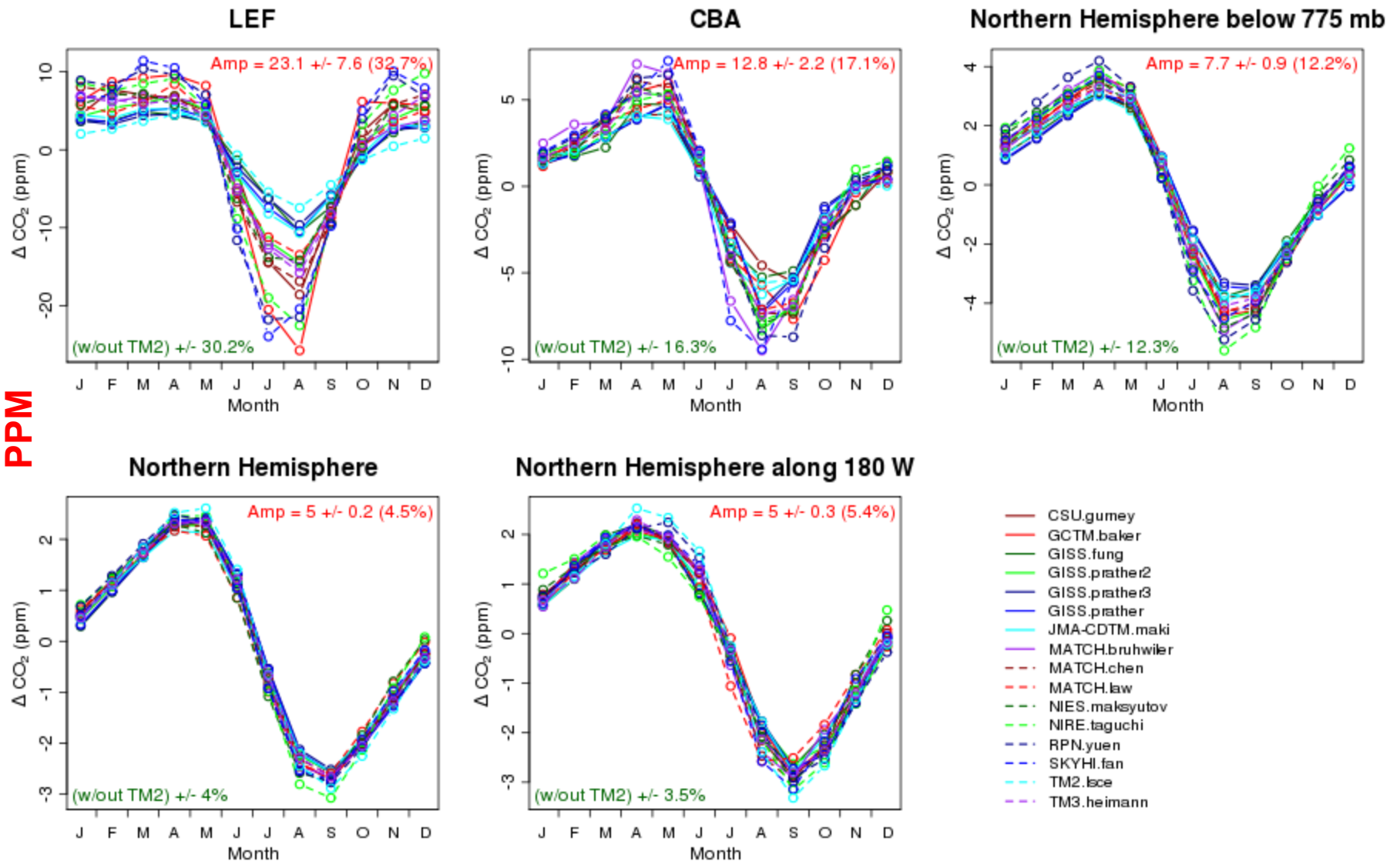
$$NHMI = \frac{\sum CO_2 \times Pwt \times LATwt}{\sum Pwt \times LATwt}$$

- Analyze model output (TransCom3, CT, ACTM) to test hypothesis
- DSNF-GSNF values as a rigid constraint on global ecosystem models and CO_2 inverse calculations

Possible add-ons:

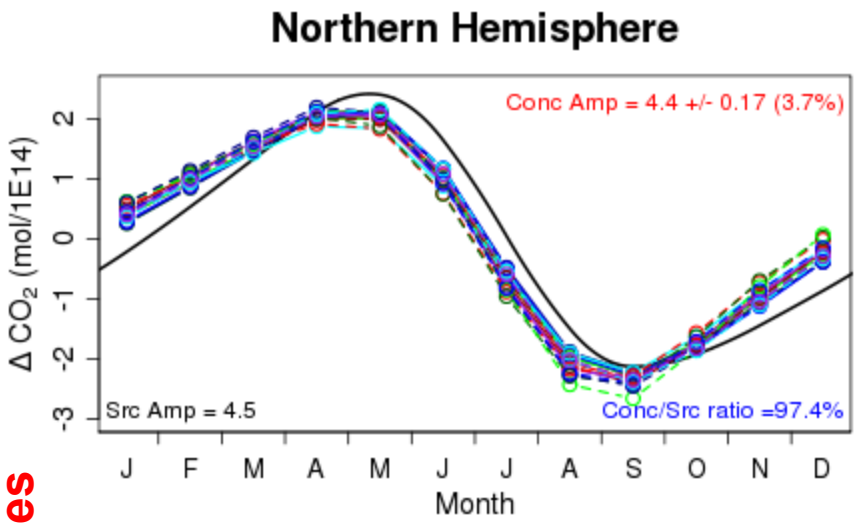
- Combined analysis with TCCON and light-aircraft profile data
- Additional gases

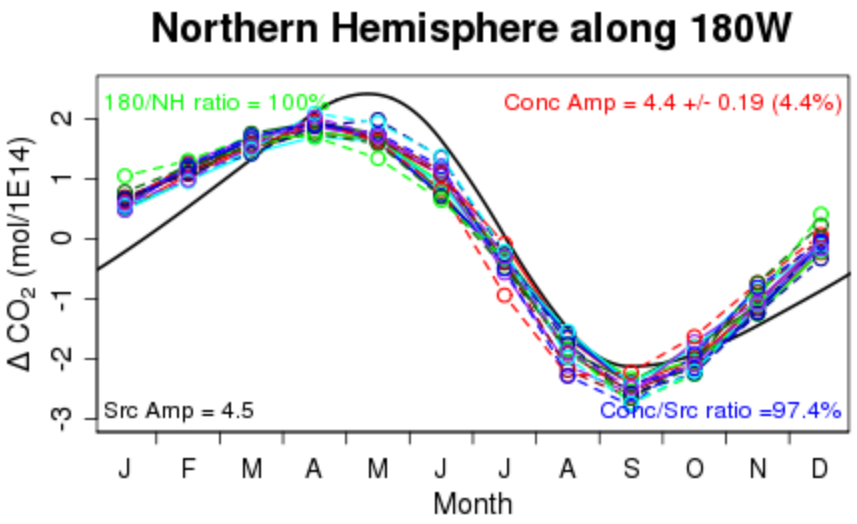
TransCom 3 *a priori* terrestrial signal estimates (CASA ca. 2000)

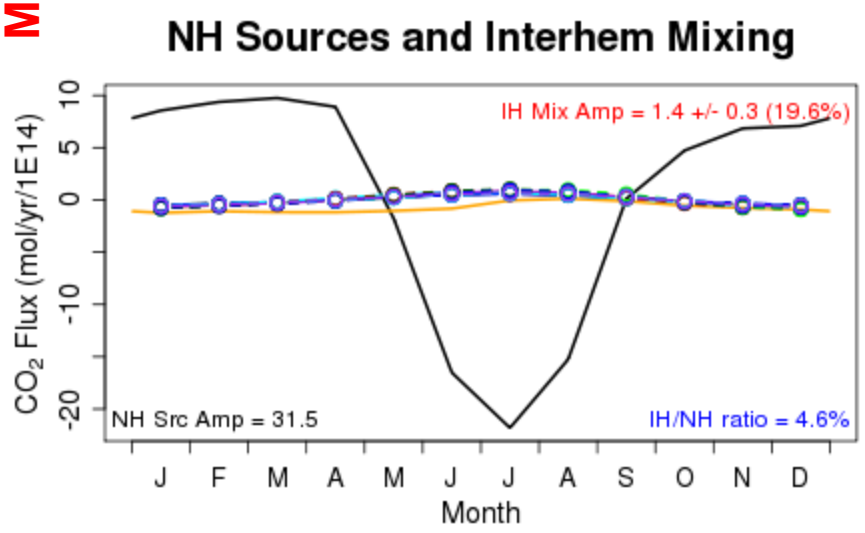


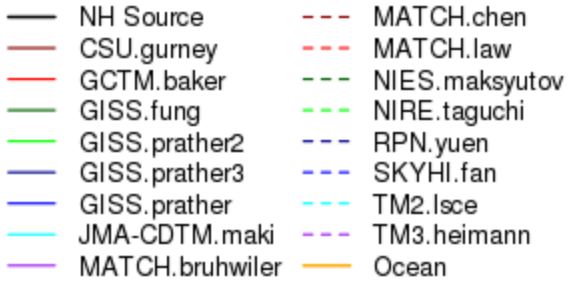
TransCom 3 *a priori* terrestrial signal estimates (CASA ca. 2000)

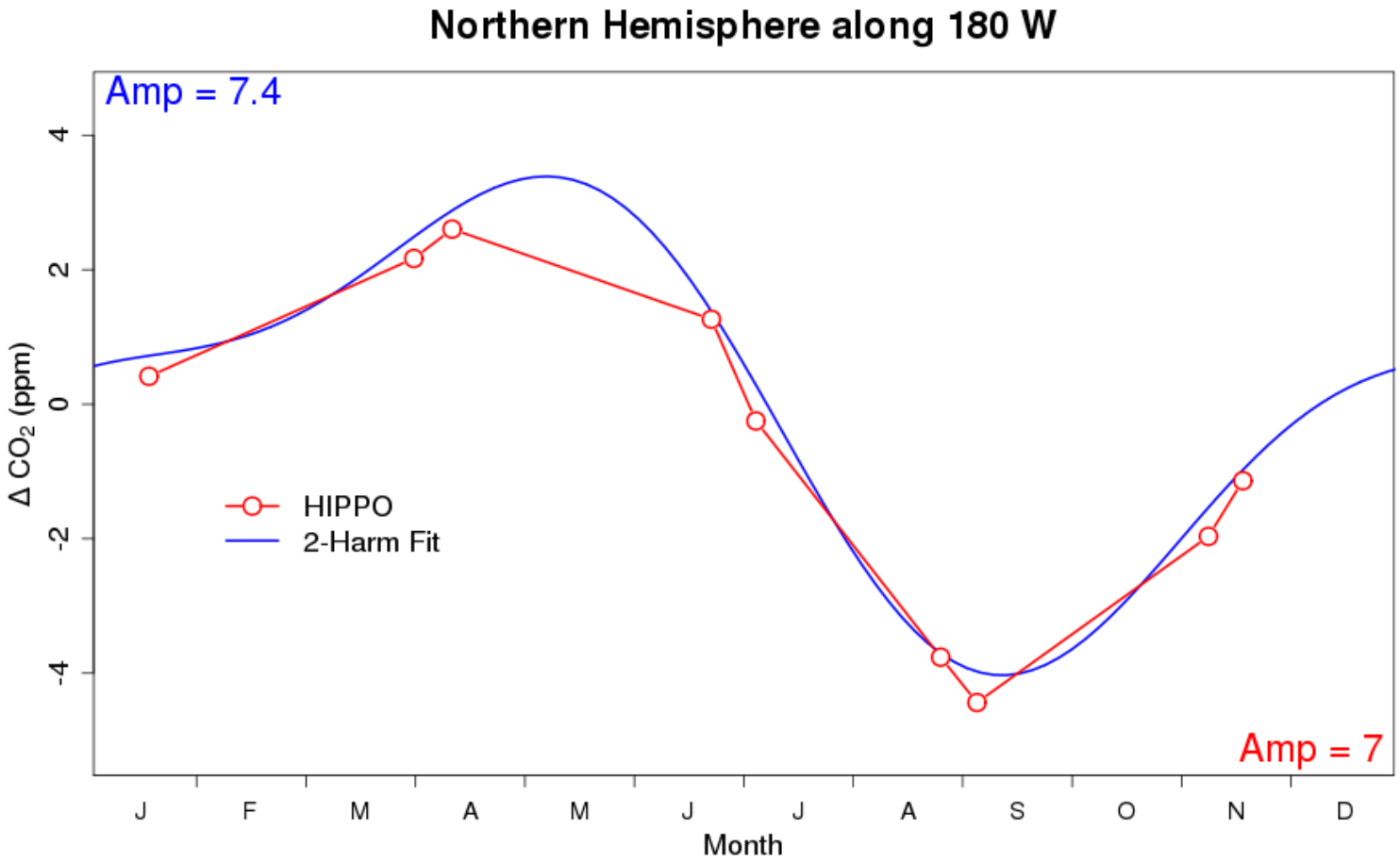
Moles







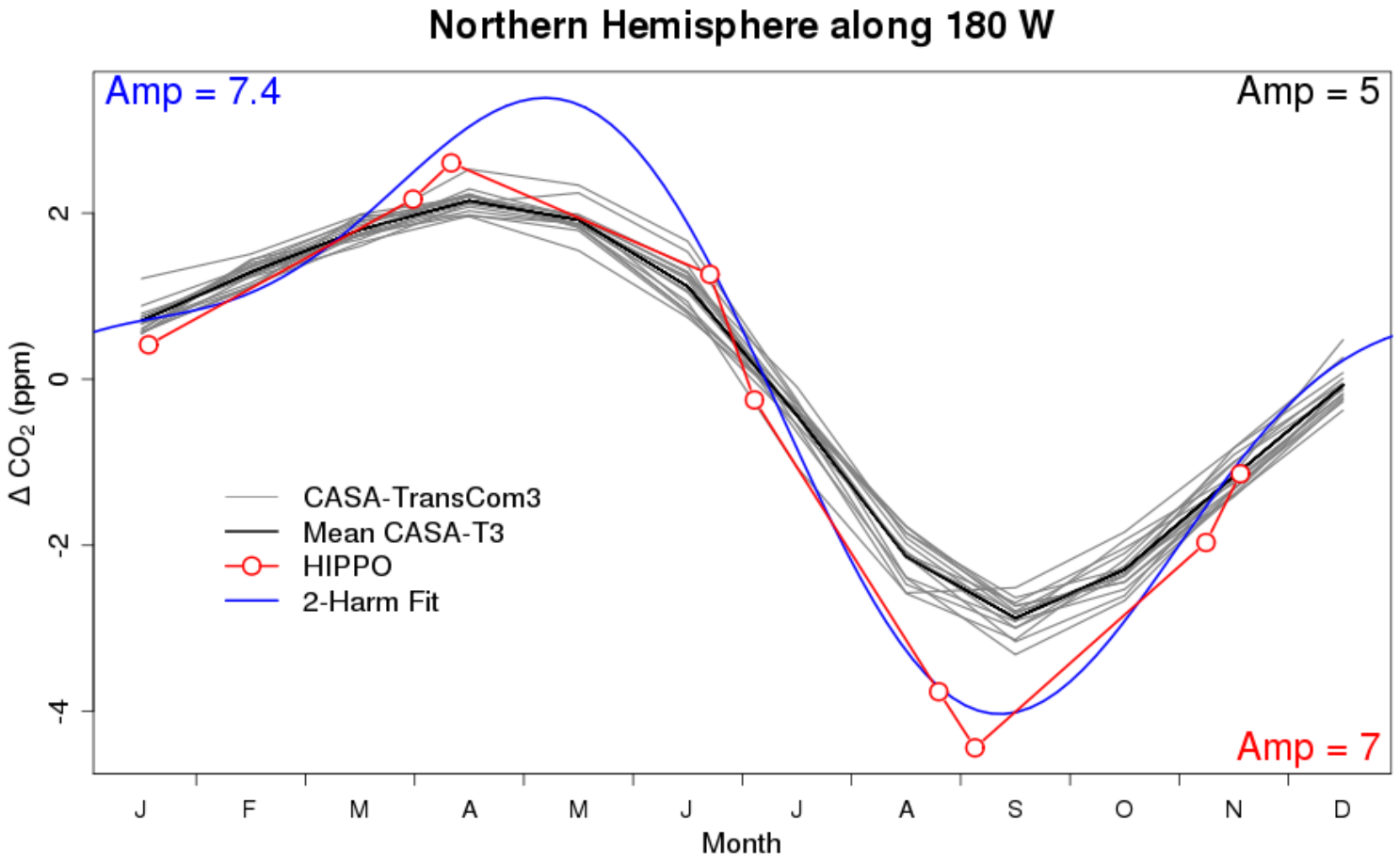




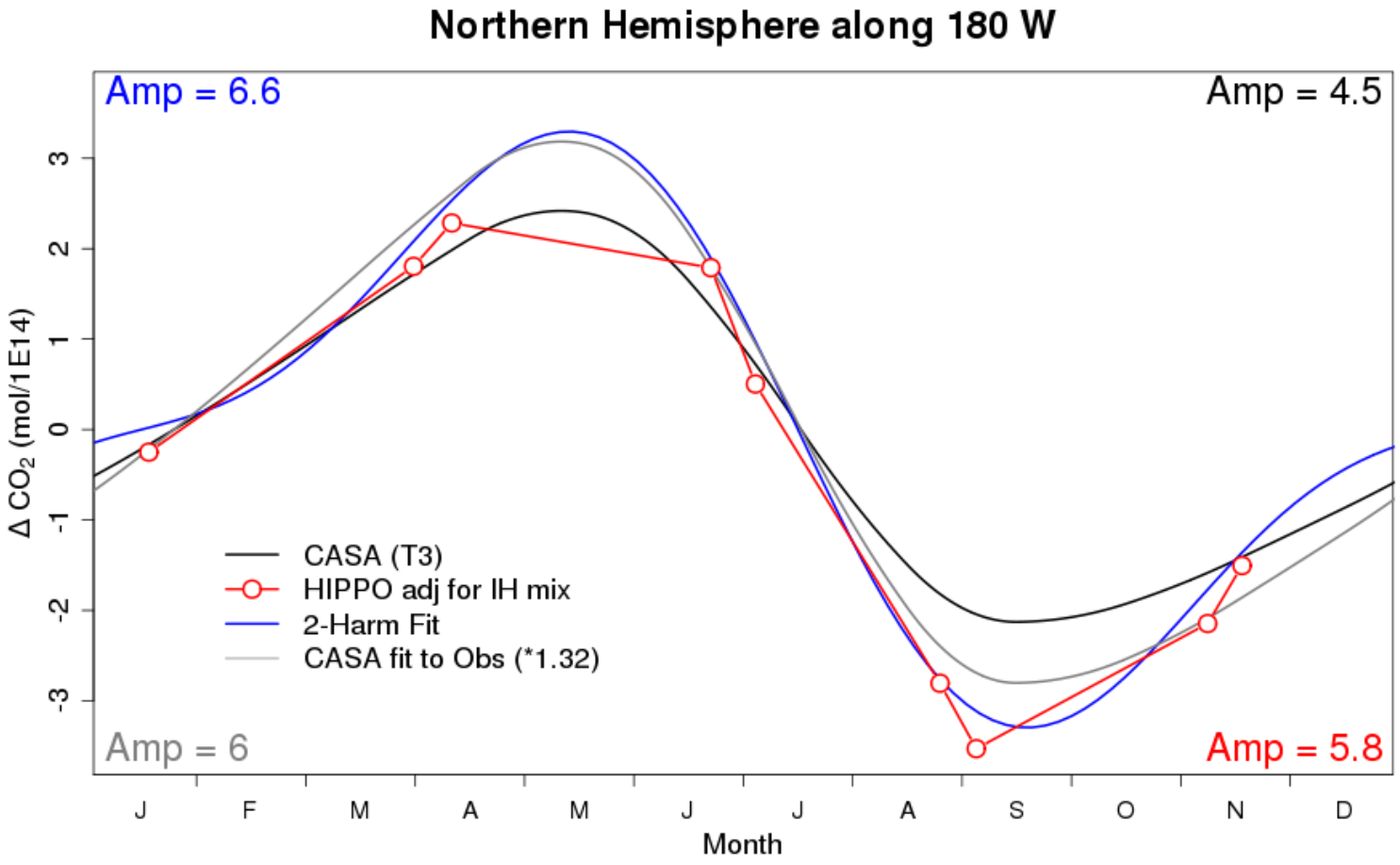
Model-data mismatch components (missing “error bars”):

1) Temporal (short-term) representativeness. Assess by sampling CT/ACTM along 180 W every day and quantifying influence of synoptic variability
2) Interannual variability. Compare to corresponding model output or assess from CT/ACTM over multiple years
3) Spatial representativeness. Address by sampling CT/ACTM along flight tracks and compare to 180 W slice

NHMI in ppm compared to CASA-TransCom3 concentrations



NHMI in moles, corrected for IH mixing and ocean component, compared to CASA ca. 2000 fluxes



Conclusions

- The total number of moles in a slice down 180 W is relatively non-sensitive to errors in model transport (± 4 %)
- A slice down 180 W is a very good estimate of hemispheric mean composition at monthly scales
- A slice down 180 W primarily reflects seasonal hemispheric exchange with the terrestrial biosphere, with small contributions from interhemispheric exchange and oceanic fluxes (fossil fuel contribution not yet analyzed)
- HIPPO results show seasonal amplitude of 7.0 ppm
- Correcting for ocean and interhemispheric mixing gives DSNF-GSNF = 5.8 X 10^{14} mol CO_2
- Preliminary results suggest Northern Hemispheric CO_2 exchange underestimated by 32% by ca. 2000 CASA
- Next steps include analysis of spatial and temporal representativeness, inclusion of “state-of-the-art” terrestrial flux estimates, and exploration of NOAA aircraft and TCCON data