Global scale airborne and ship based observations of atmospheric potential oxygen

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Observations: Jonathan Bent, Ralph Keeling (Scripps), Andrew Watt, Steve Shertz (NCAR), Colm Sweeney (CIRES), HIPPO Science Team, NCAR RAF Staff, ARSV LMG Staff

Models: Sara Mikaloff-Fletcher (NIWA), Prabir Patra (JAMSTEC), Matt Long (NCAR), Ivan Lima, Scott Doney (WHOI), John Dunne, Anand Gnanadesikan (GFDL)

GLOBAL BIOGEOCHEMICAL CYCLES, VOL. 12, NO. 2, PAGES 213–230, JUNE 1998

Testing global ocean carbon cycle models using measurements of atmospheric O_2 and CO_2 concentration

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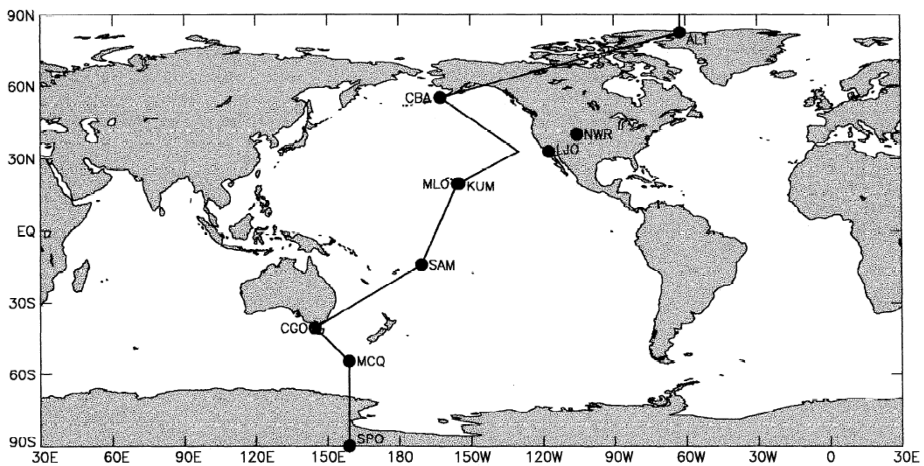
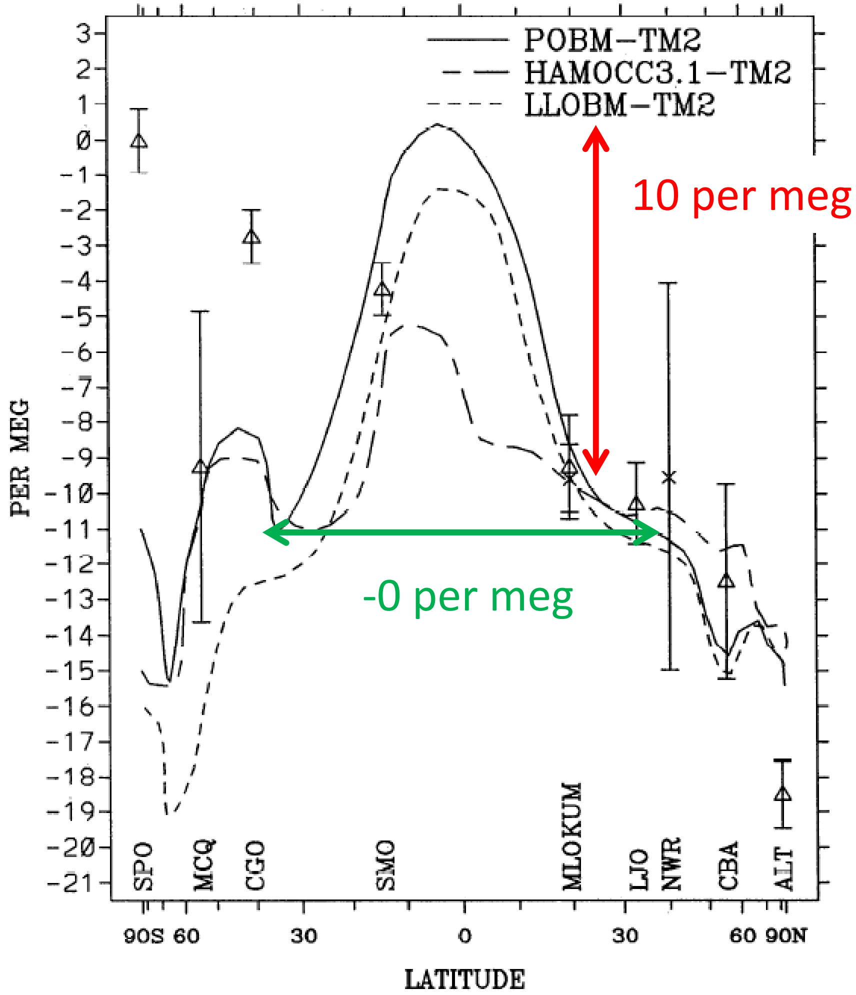
Meridional APO Distribution

Scripps O_2 Program

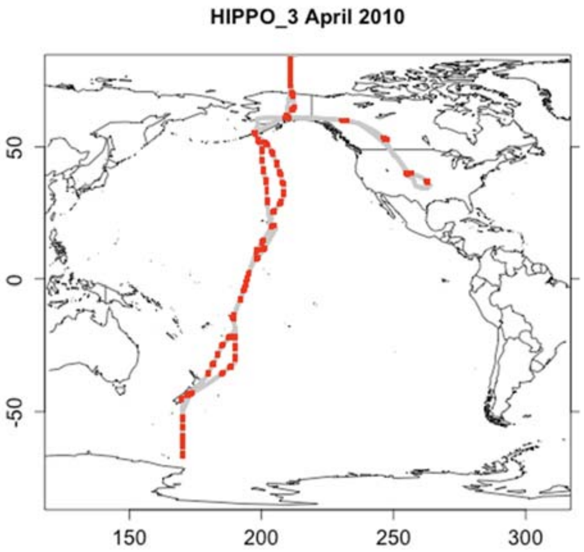


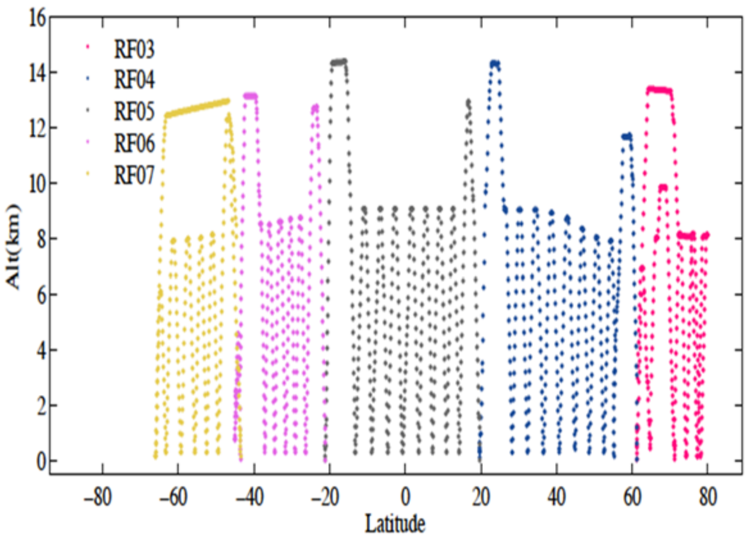


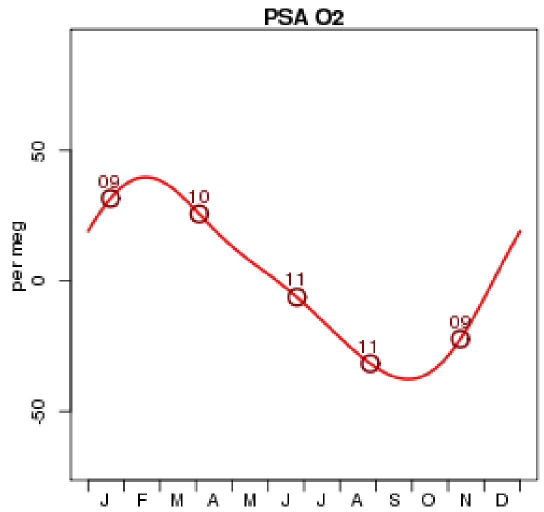
Speculated that global ocean biogeochemistry models underestimated the southward transport of O_2 and CO_2 (too much equatorial outgassing and not enough S. Ocean outgassing), and that this was caused by excessive penetration of heat at low latitudes.

HIAPER Pole-to-Pole Observations

- PIs: Harvard, NCAR, Scripps, NOAA
- Global and seasonal survey of CO_2, O_2, CH_4, CO, N_2O, H_2, SF_6, COS, CFCs, HCFCs, O_3, H_2O, CO_2 isotopes, Ar, black carbon, and hydrocarbons (over 90 species).
- NSF / NCAR Gulfstream V
- Five 3-week campaigns over 3 years, across Pacific between 87 N and 67 S
- Continuous profiling between surface and 10-14 km
- 64 flights, 787 profiles, 434 hours in situ data + 4235 flasks
- hippo.ucar.edu, www.eol.ucar.edu/hippo, hippo.ornl.gov



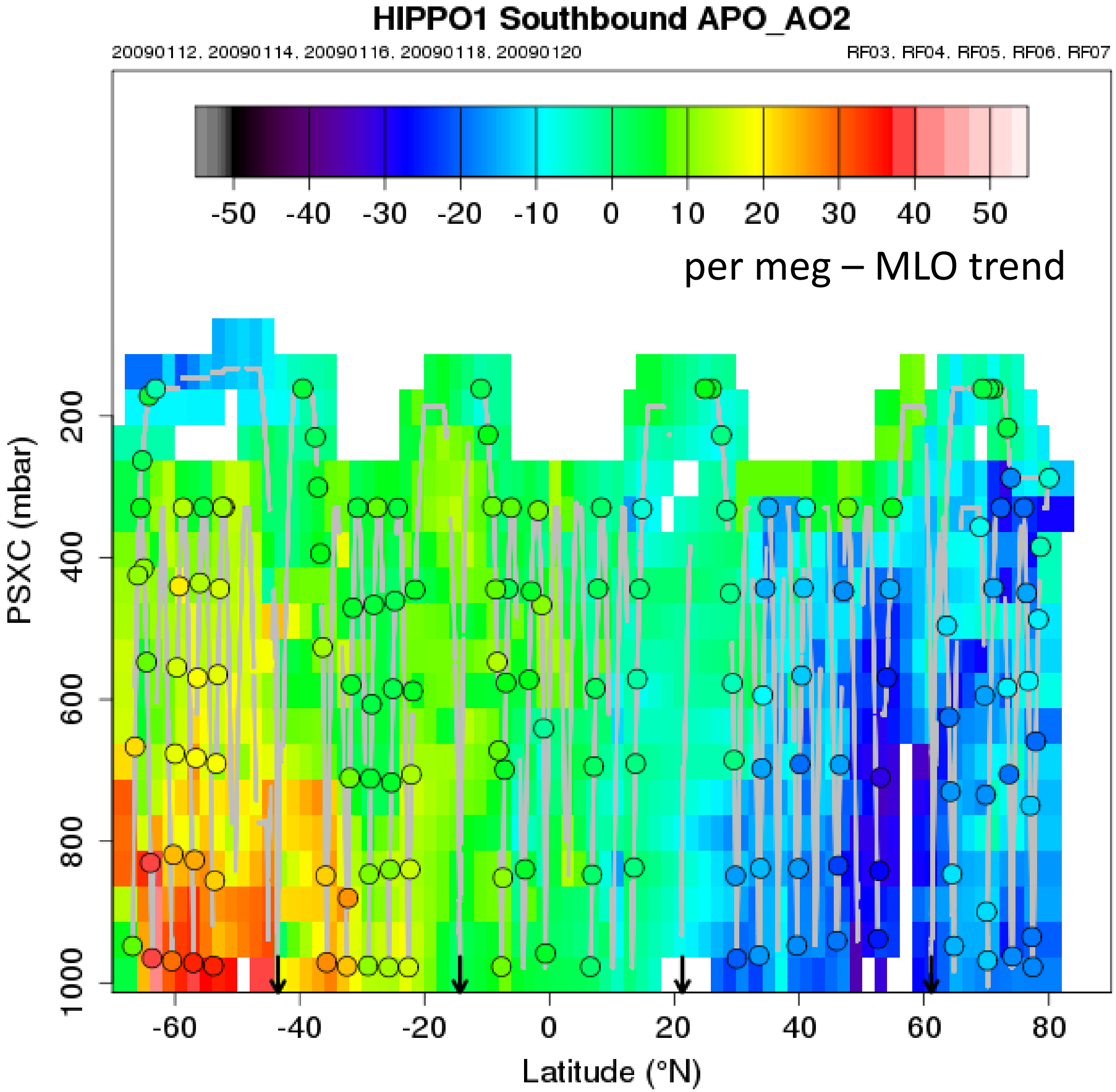




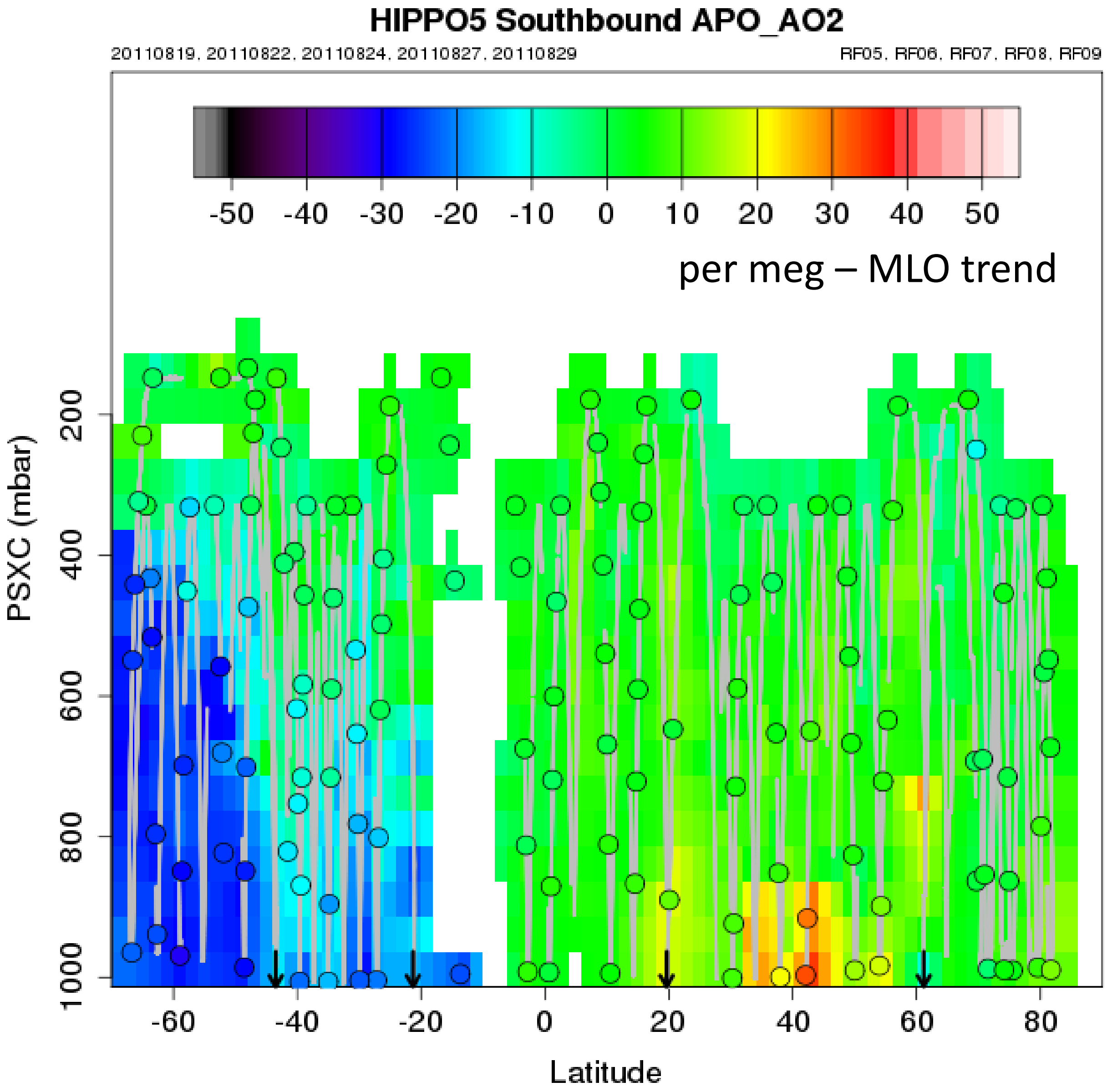
NCAR Airborne Oxygen Instrument (AO2)

NCAR/Scripps Medusa Flask Sampler

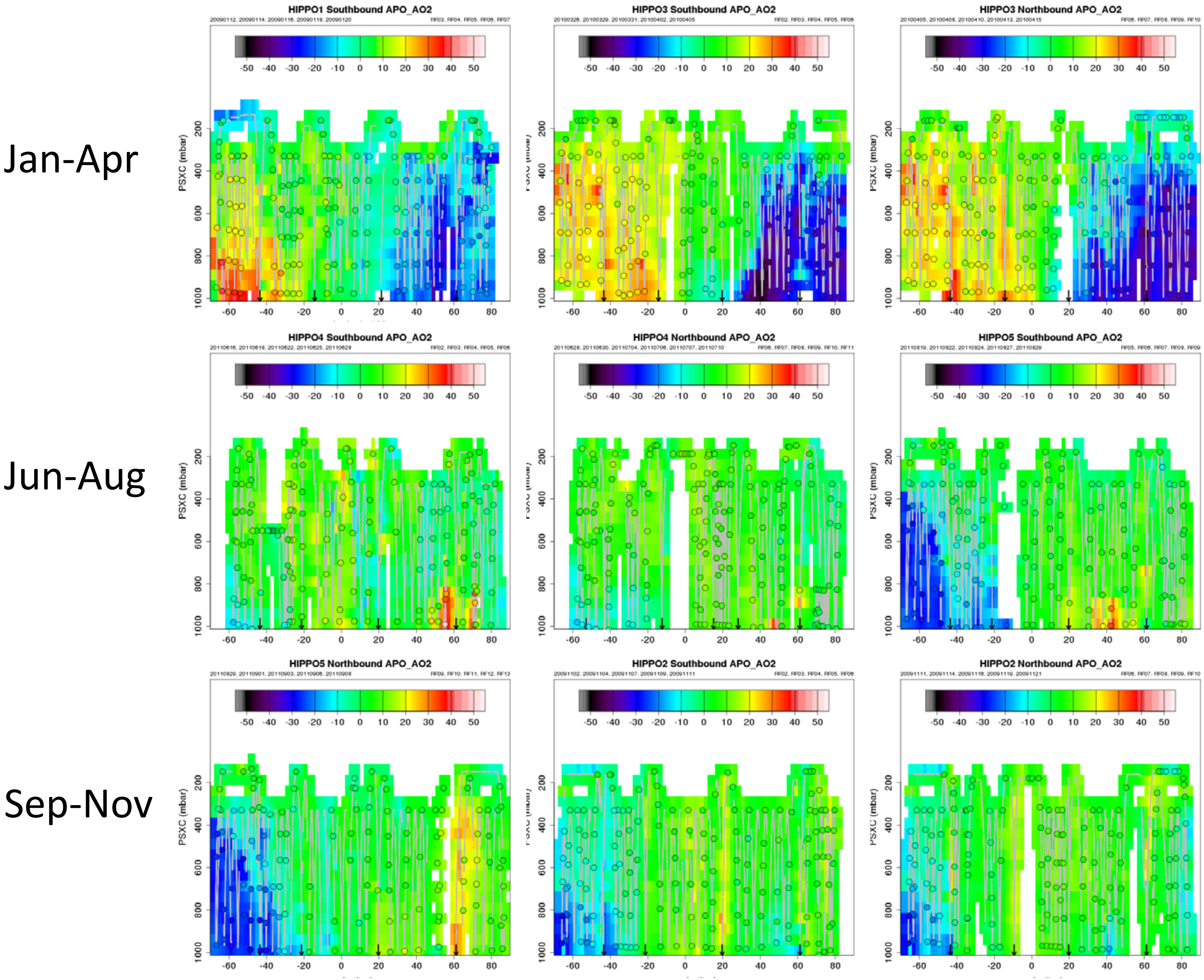
January, 2009



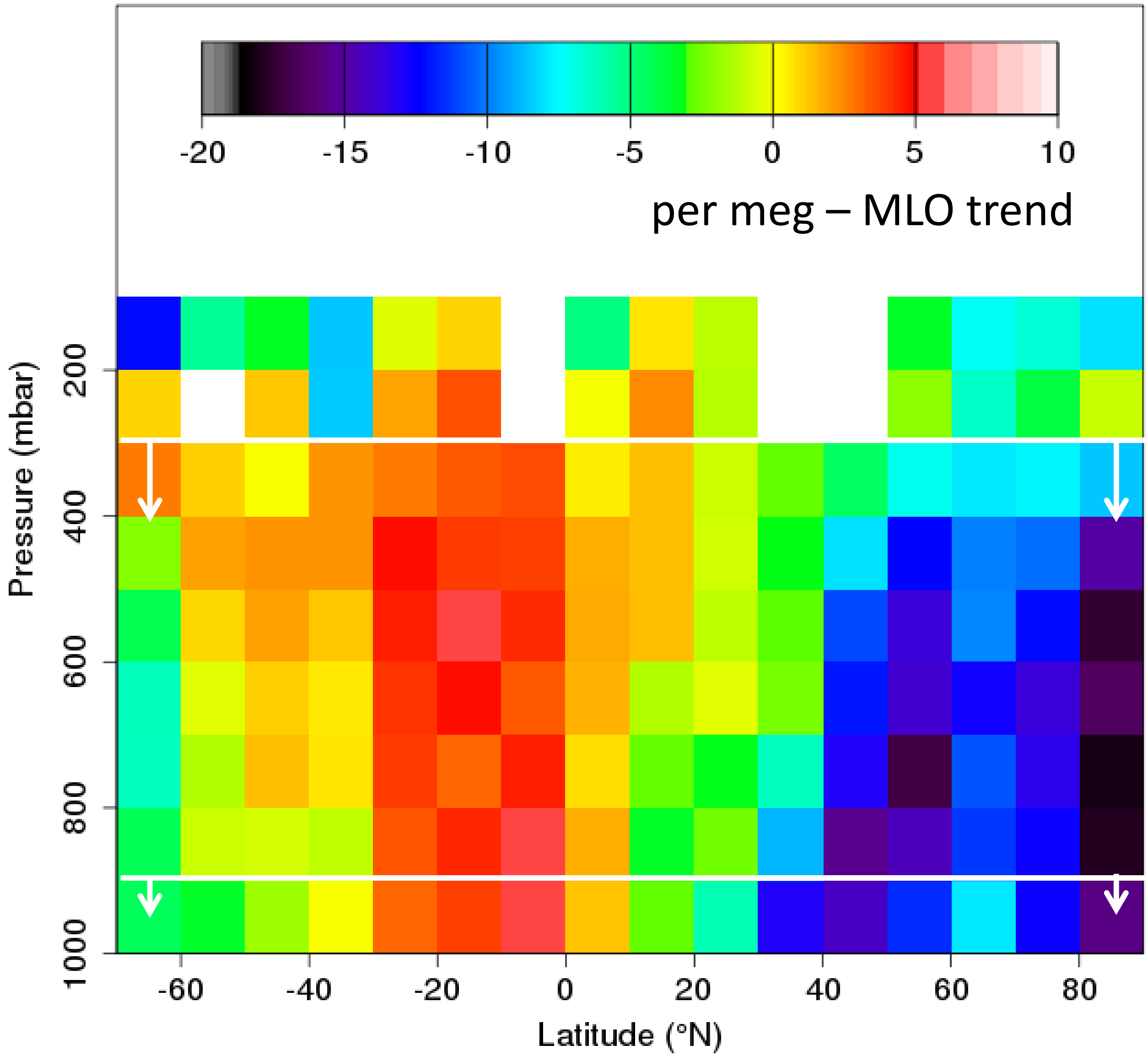
August, 2011



HIPPO5 Southbound APO_AO2
20110819, 20110822, 20110824, 20110827, 20110829
RF05, RF06, RF07, RF08, RF09
-50 -40 -30 -20 -10 0 10 20 30 40 50
per meg – MLO trend
PSXC (mbar)
200
400
600
800
1000
-60 -40 -20 0 20 40 60 80
Latitude


Jan-Apr
Jun-Aug
Sep-Nov
HIPPO1 Southbound APO_AO2
HIPPO3 Southbound APO_AO2
HIPPO3 Northbound APO_AO2
HIPPO4 Southbound APO_AO2
HIPPO4 Northbound APO_AO2
HIPPO5 Southbound APO_AO2
HIPPO5 Northbound APO_AO2
HIPPO2 Southbound APO_AO2
HIPPO2 Northbound APO_AO2
PSXC (mbar)
-50 -40 -30 -20 -10 0 10 20 30 40 50
-60 -40 -20 0 20 40 60 80

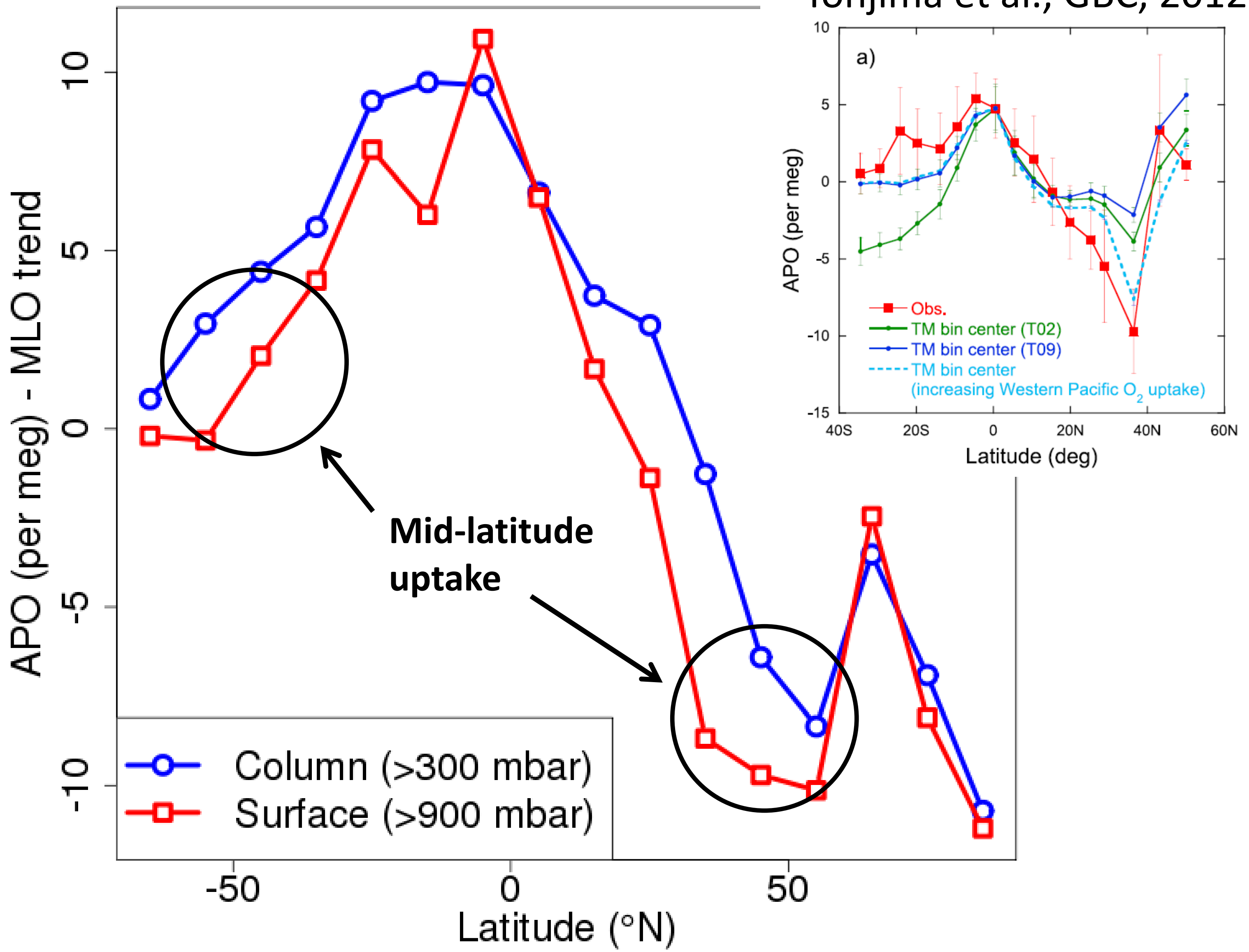
HIPPO Annual APO Means

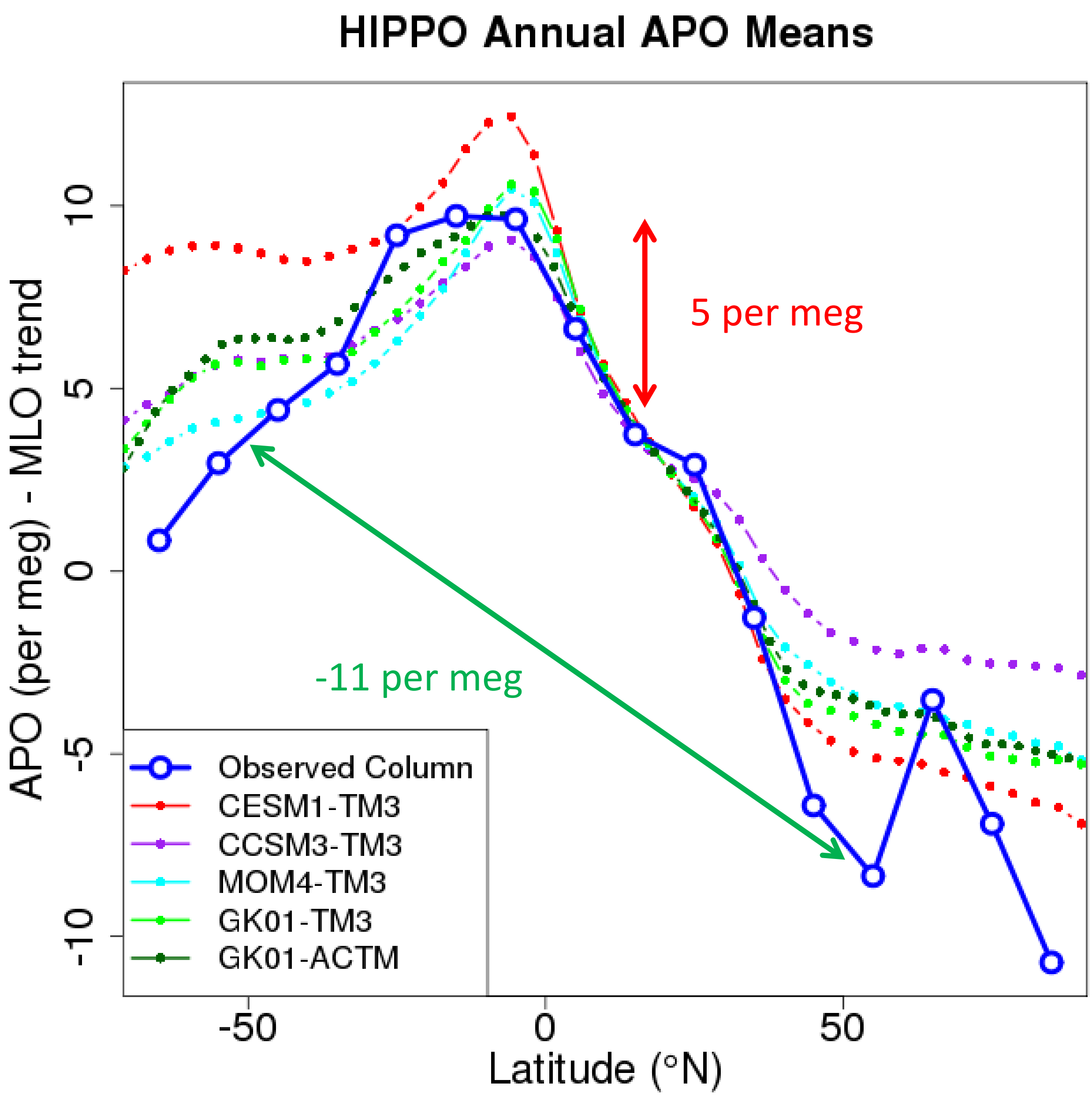


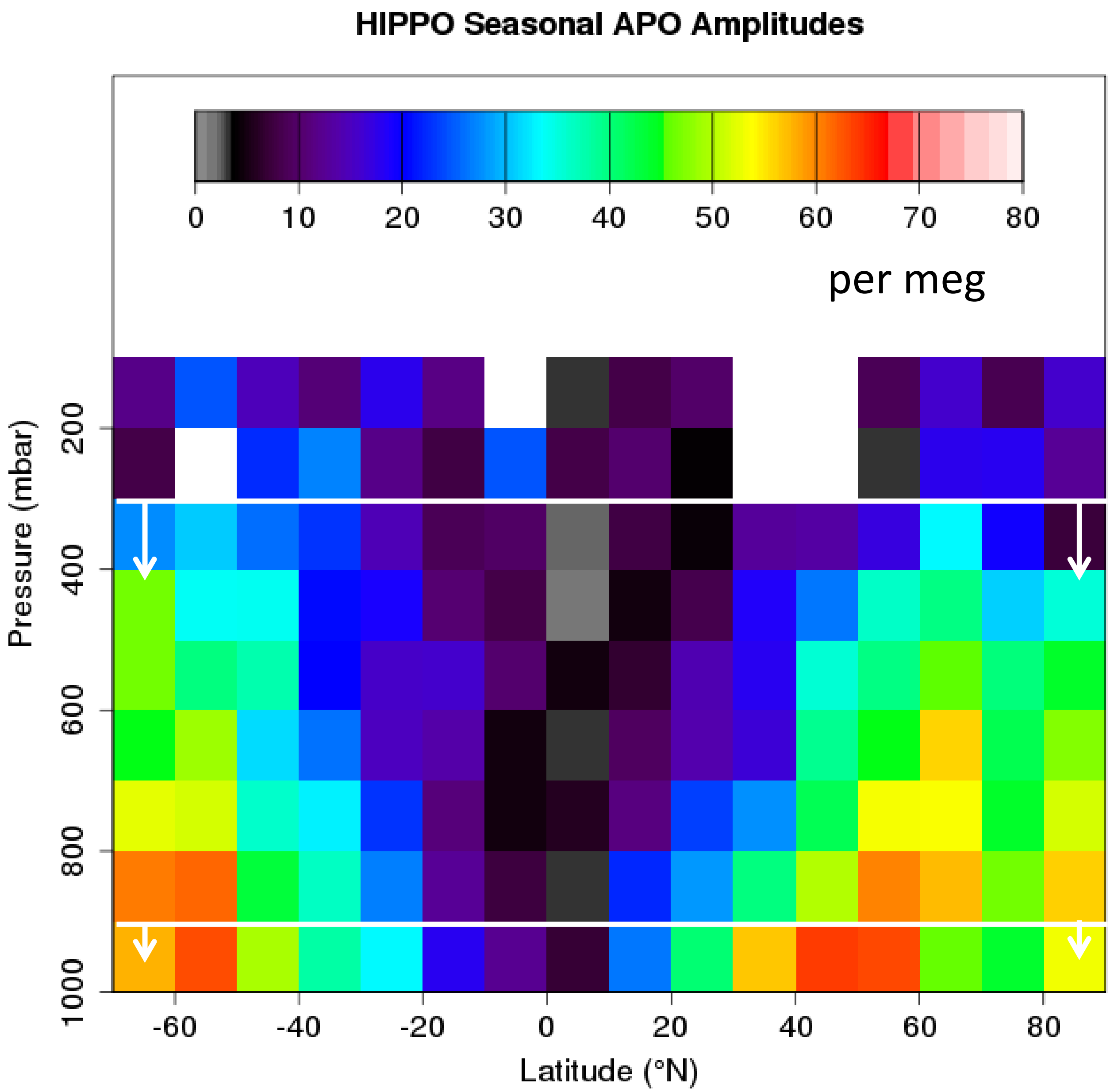
from single harmonic fits to binned and detrended observations

HIPPO Annual APO Means

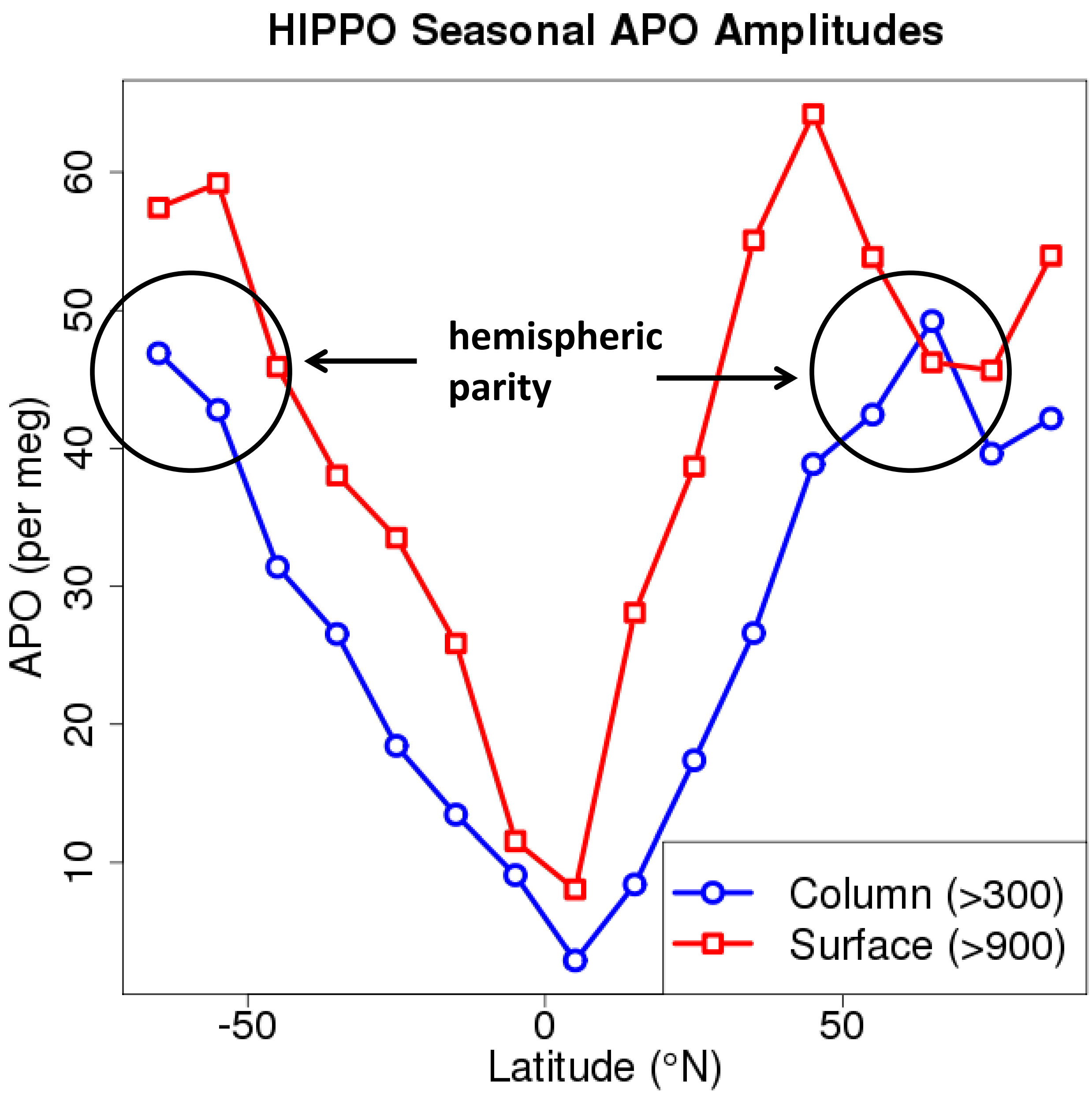
Tohjima et al., GBC, 2012



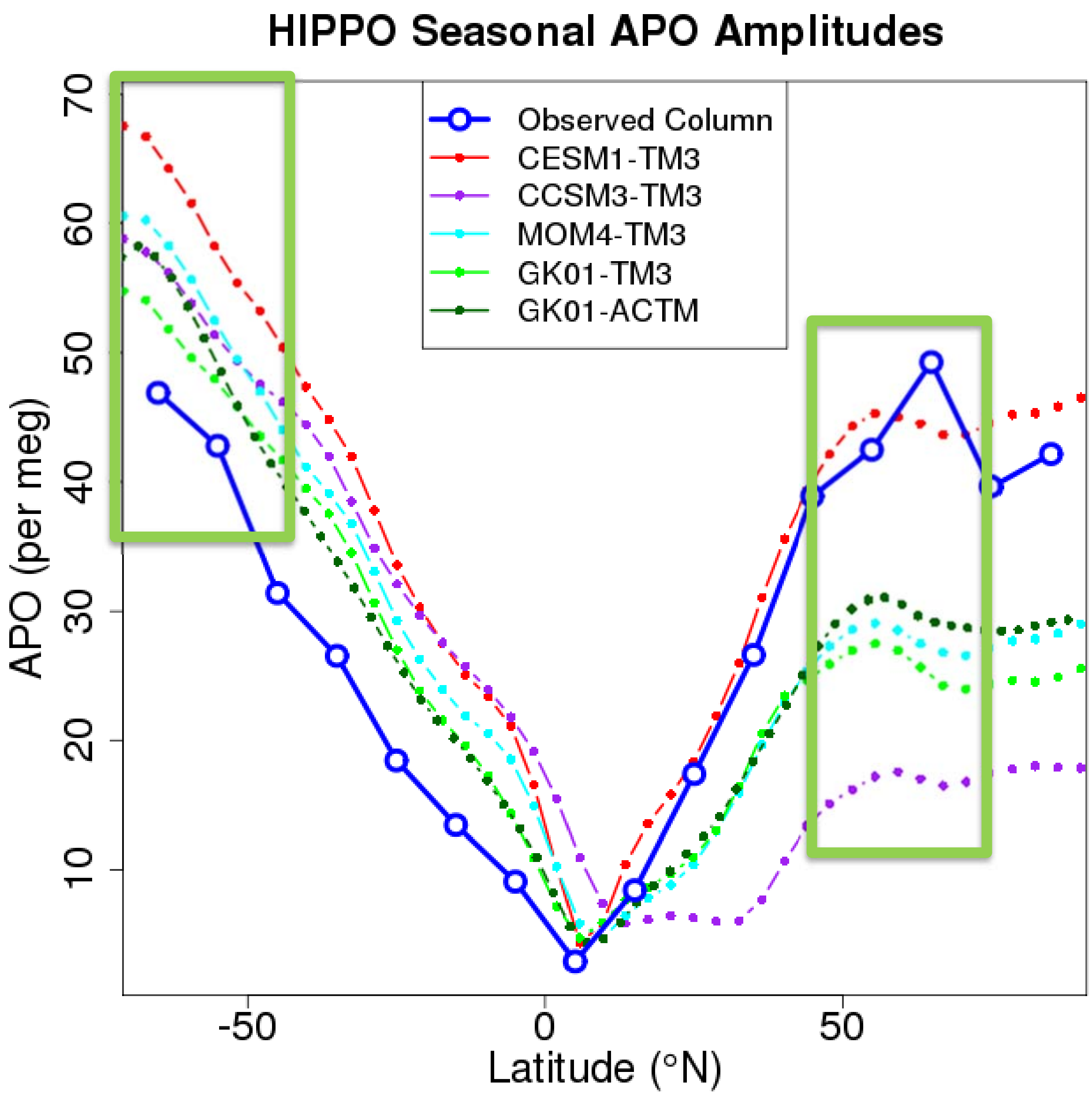

HIPPO Annual APO Means
5 per meg
-11 per meg
Observed Column
CESM1-TM3
CCSM3-TM3
MOM4-TM3
GK01-TM3
GK01-ACTM
APO (per meg) - MLO trend
Latitude (°N)
10
5
0
-5
-10
-50
0
50



from single harmonic fits to binned and detrended observations

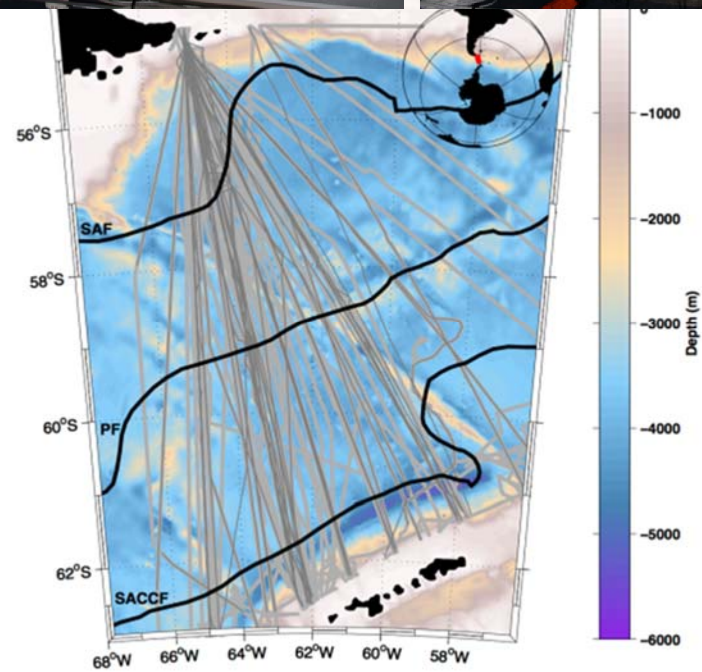


HIPPO Seasonal APO Amplitudes
hemispheric
parity
APO (per meg)
60
50
40
30
20
10
-50
0
50
Latitude (°N)
Column (>300)
Surface (>900)

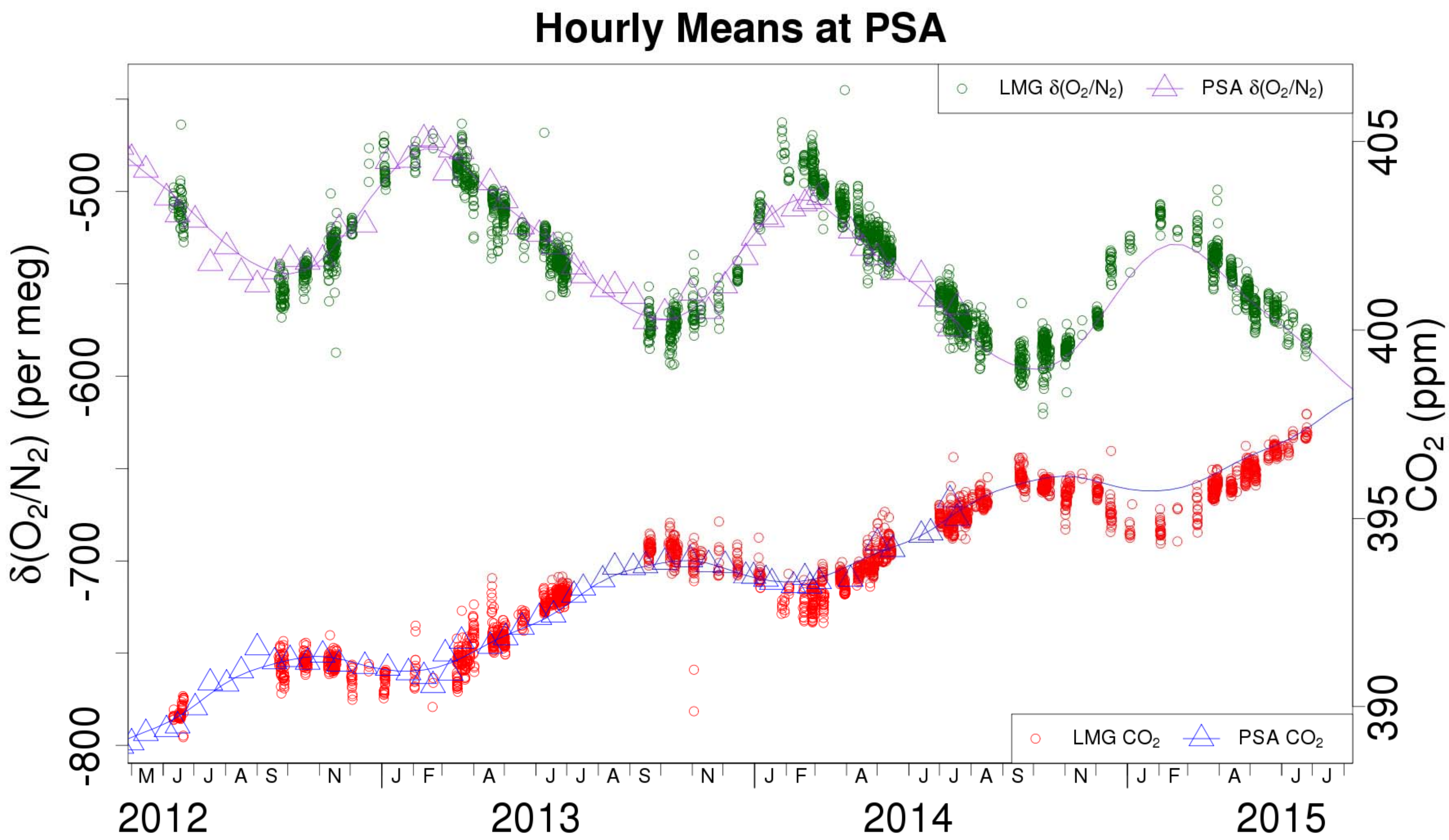


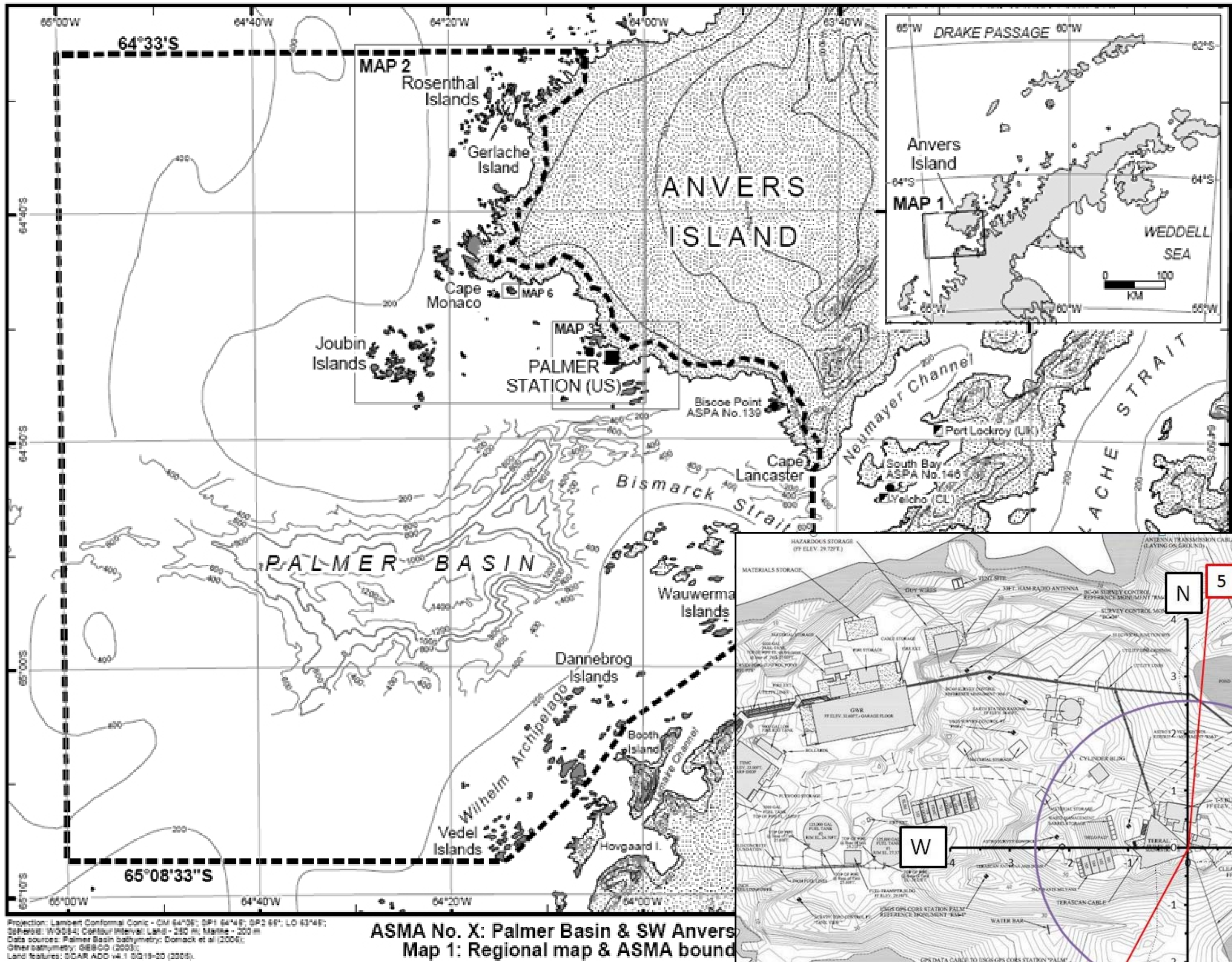
HIPPO Seasonal APO Amplitudes
Observed Column
CESM1-TM3
CCSM3-TM3
MOM4-TM3
GK01-TM3
GK01-ACTM
APO (per meg)
10
20
30
40
50
60
70
-50
0
50
Latitude (°N)

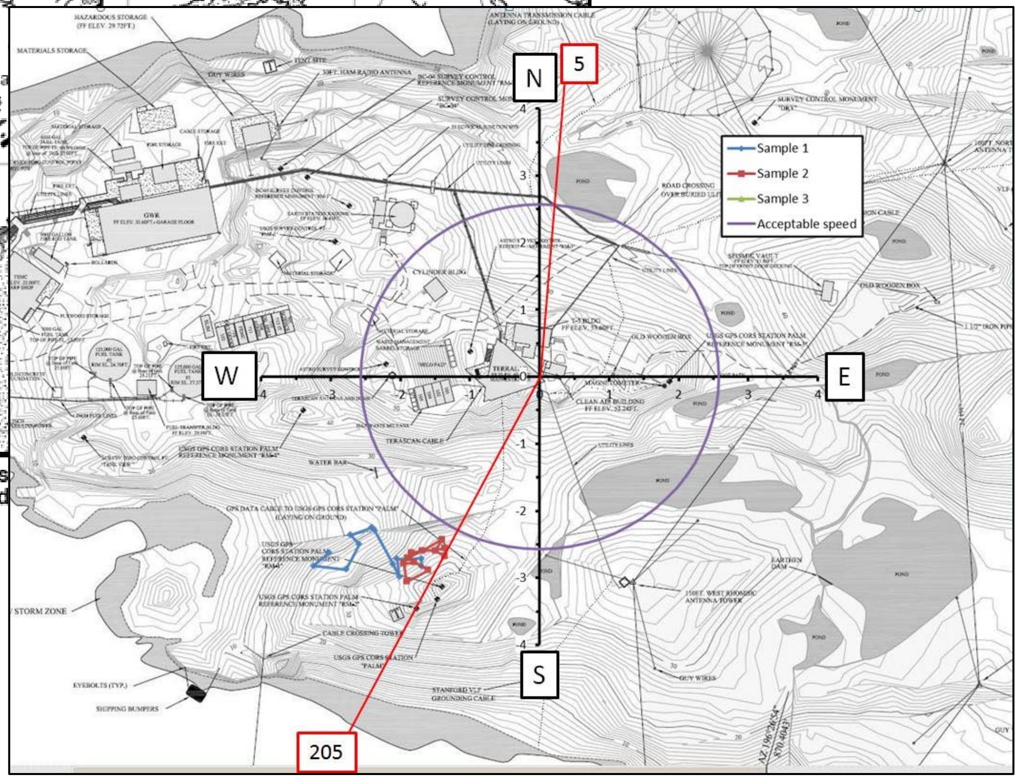
NSF ARSV L.M. Gould Atmospheric O_2 / CO_2 installed in June of 2012



NSF ARSV L.M. Gould Atmospheric O_2 / CO_2 timeseries



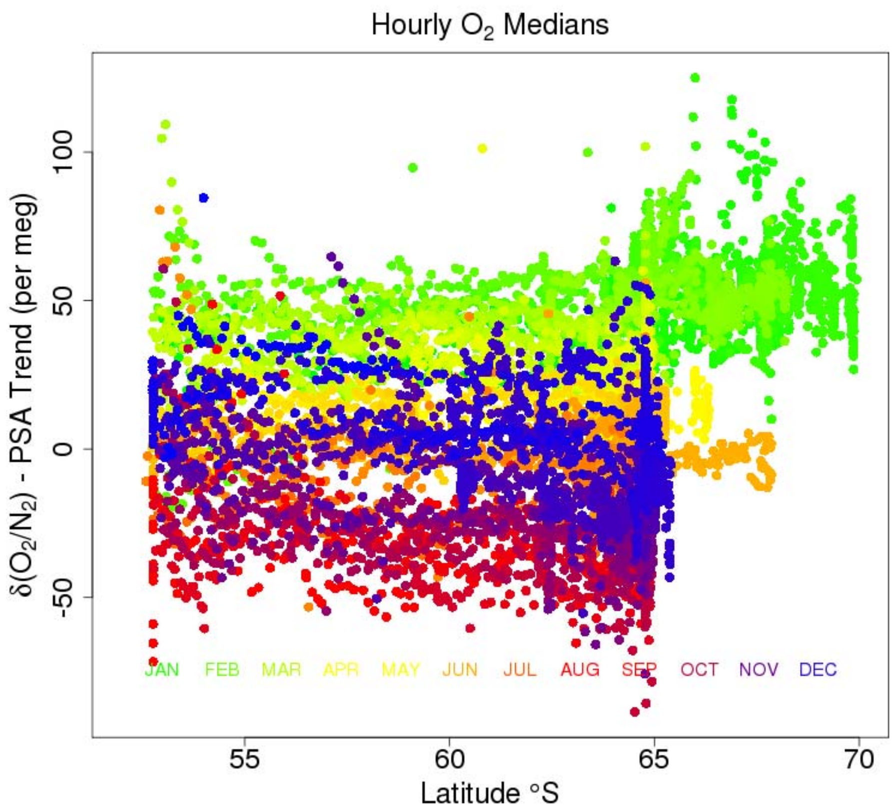


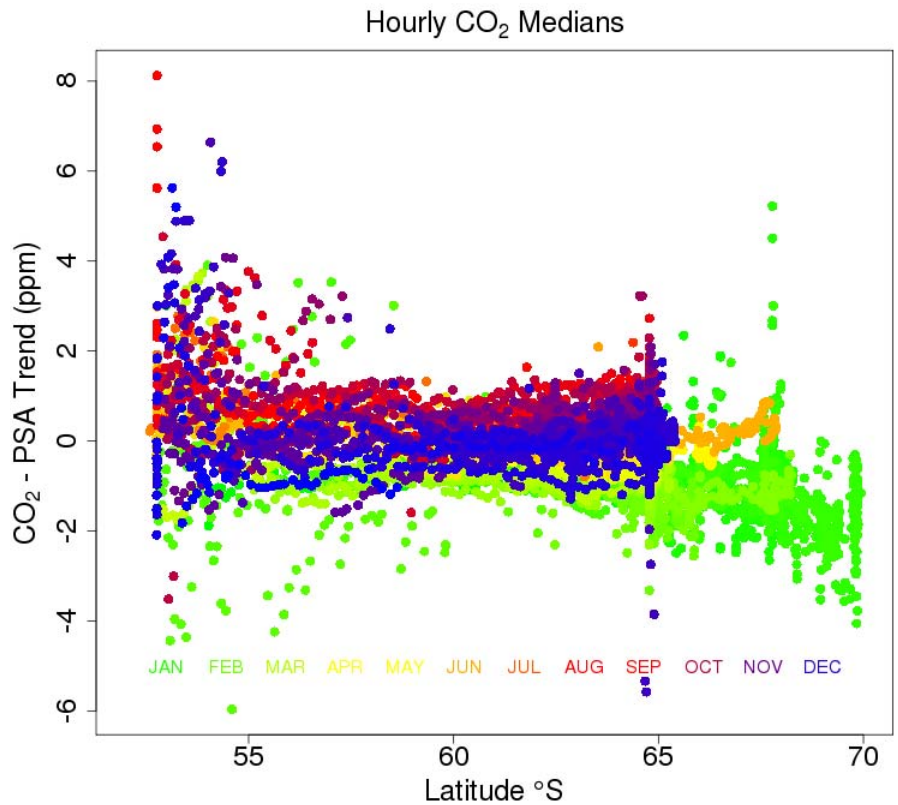


Ship clean air sector = W

SIO flask clean air sector = E

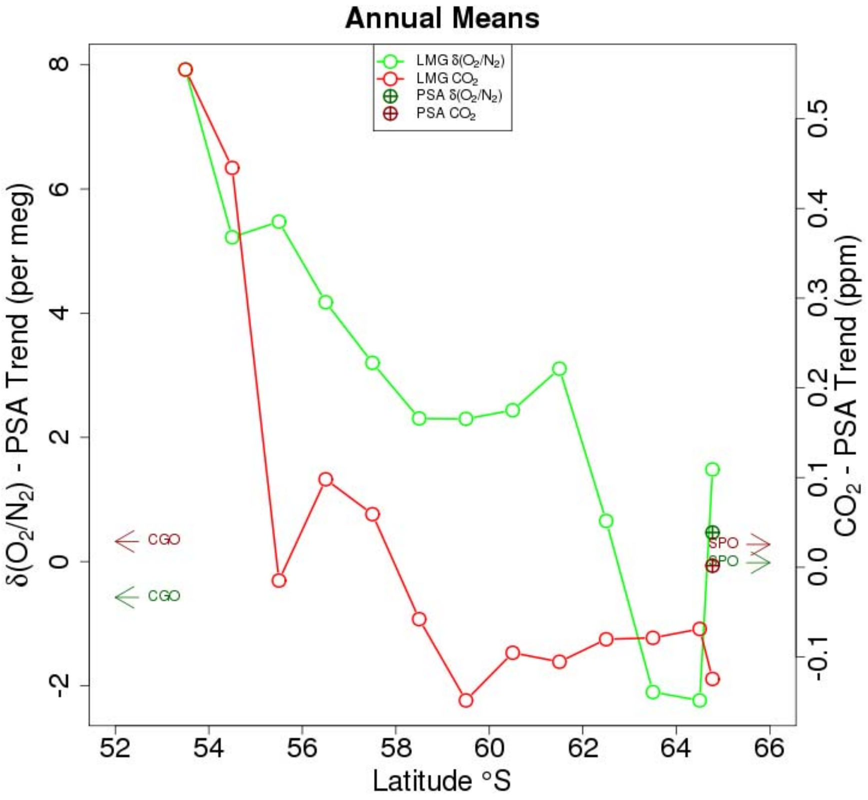
NSF ARSV L.M. Gould Atmospheric O_2 / CO_2 latitudinal gradients

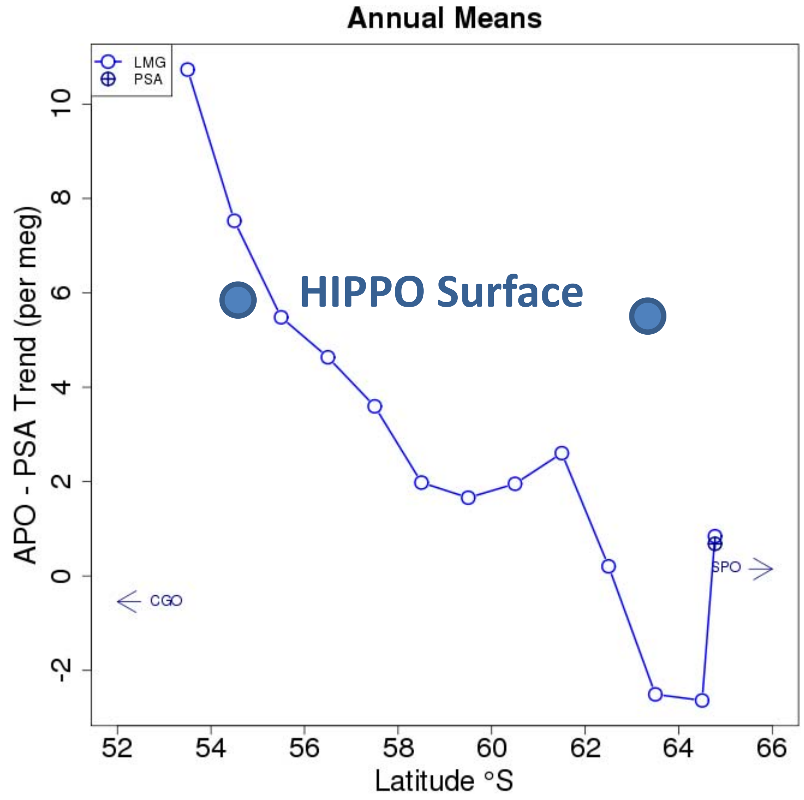




- High O_2 variability reflects atmospheric signals related to synoptic transport and local exchange
- Low instrument noise of < 5 per meg evident on high latitude June cruise

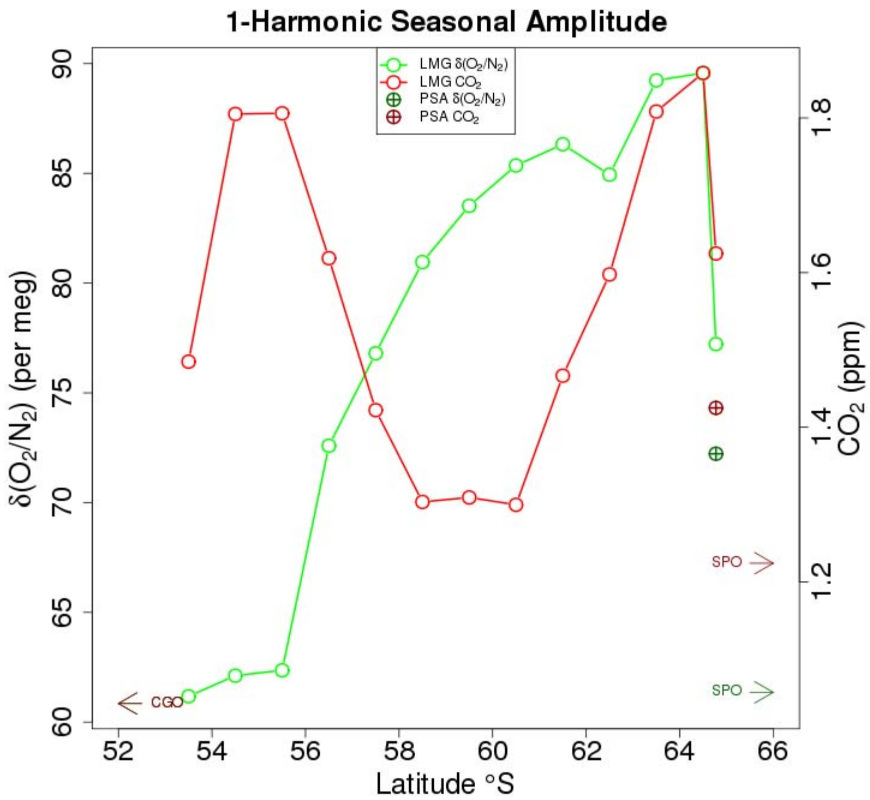
NSF ARSV L.M. Gould annual mean latitudinal gradients

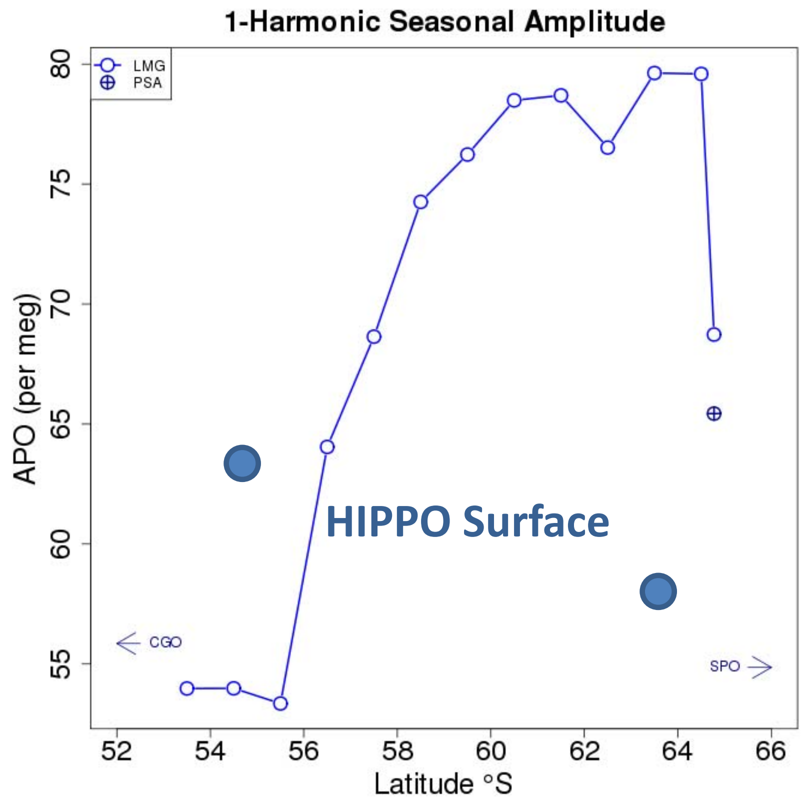




- Averaged in 1-degree latitude bins, detrended, and fit with 1 harmonic. Observations while docked at Palmer Station binned separately
- Annual mean decrease in O_2 and APO to the south follows hemispheric gradient but deeper than western Pacific
- Agreement with station flasks remarkable but partly by luck

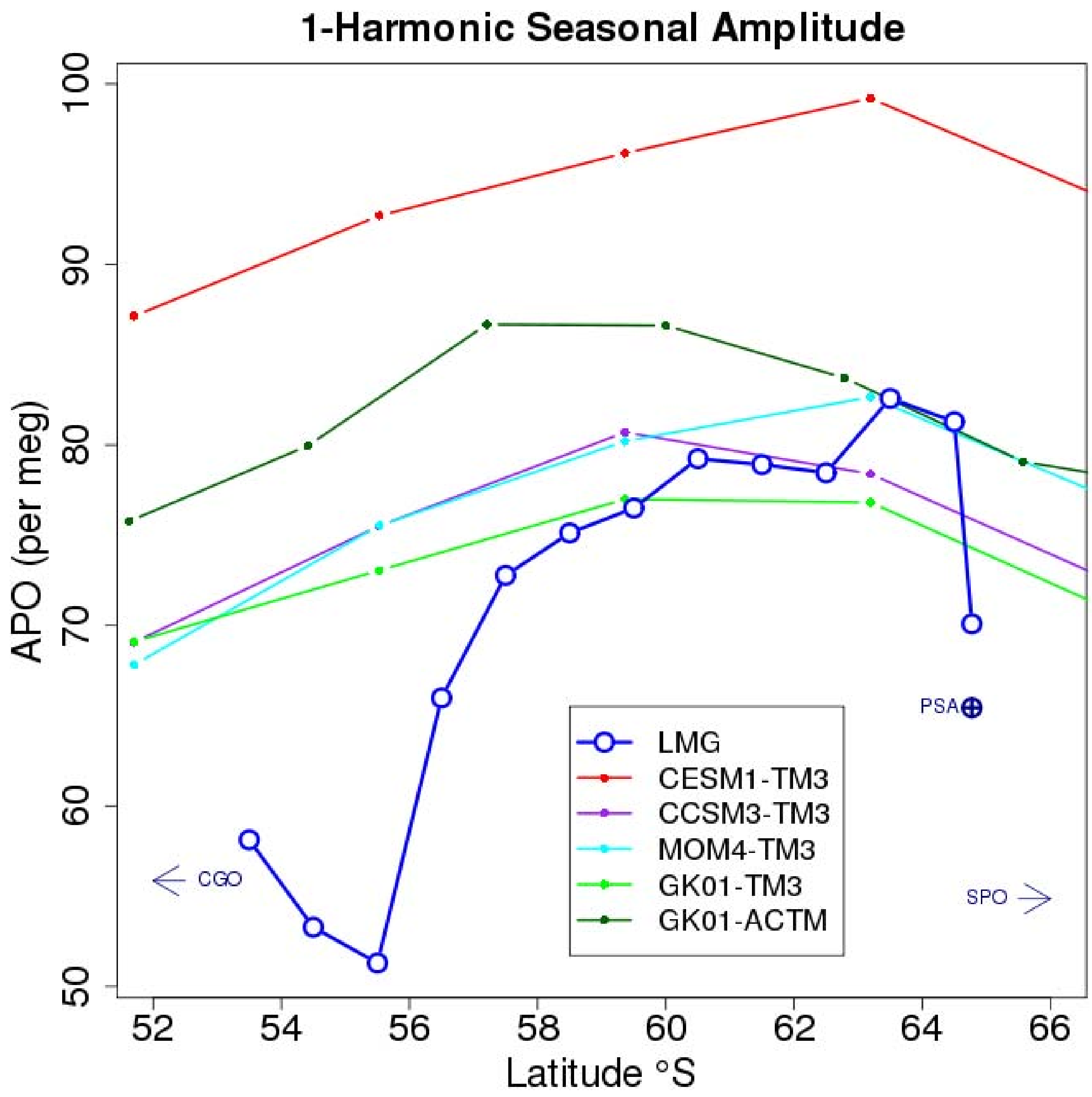
NSF ARSV L.M. Gould latitudinal gradients in seasonal amplitude





- APO amplitude peaks near 80 per meg from 60-65 S
- APO amplitude at Palmer Station much lower – local effect or continuing further south?
- Potentially large zonal differences in ampitude in Southern Ocean

NSF ARSV L.M. Gould Atmospheric APO seasonal amplitudes

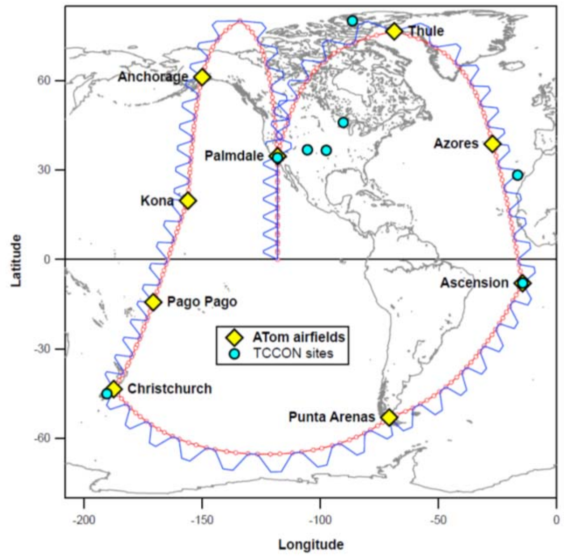


The O_2/N_2 Ratio and CO_2 Airborne Southern Ocean (ORCAS) Study

Collaborative Science Team representing:
NCAR (EOL, CGD, ACD, MMM), Scripps,
U. Michigan, U. Colorado, NOAA, JPL,
U. Connecticut, LDEO, WHOI, Duke,
Rutgers, Princeton, U. Miami, NASA GMAO

CSIRO R/V Investigator O_2 / CO_2 System to be installed in Mar. 2016

NASA Atmospheric Tomography Mission (ATom 1) (*2-4 TBD*)



Conclusions

- Column average airborne measurements are effective at eliminating atmospheric transport uncertainty in model-data comparisons
- The equatorial mid-Pacific APO bulge is vertically homogeneous, smaller than some early estimates at approximately 5 per meg, and shifted south of the Equator
- The interhemispheric APO gradient is approximately 11 per meg (lower in the north), consistent with strong northward heat transport (Resplandy presentation)
- North Pacific APO dip / bulge previously seen in W. Pacific (Tohjima presentation) is also evident in HIPPO data (Mikaloff-Fletcher presentation)
- Several models that match seasonal APO amplitudes over the Southern Ocean (Bent presentation) do poorly over the North Pacific, and vice versa
- The seasonal APO amplitude in the mid Pacific is very similar between the two hemispheres, despite the disparity in ocean area (Nevison presentation)
- The seasonal APO cycle in Drake Passage is bigger than adjacent station observations, and the latitudinal peak is sharper than represented in coarse resolution models
- At Palmer Station, annual mean agreement with station flask measurements is very good, but with opposing seasonal differences reflecting significant sector effects
- We now have extensive observations of the latitudinal and vertical distribution of atmospheric oxygen within the Pacific Basin, and we encourage others to use them