Southern Ocean Carbon Fluxes and Air-sea Gas-exchange from Past and Future Atmospheric O_2 Measurements

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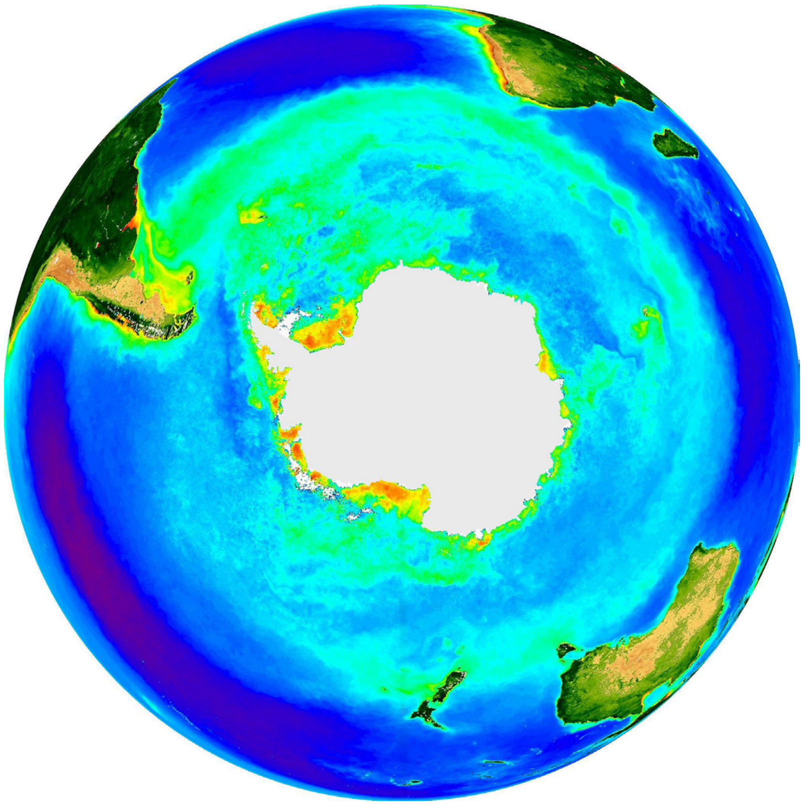

Collaborators:
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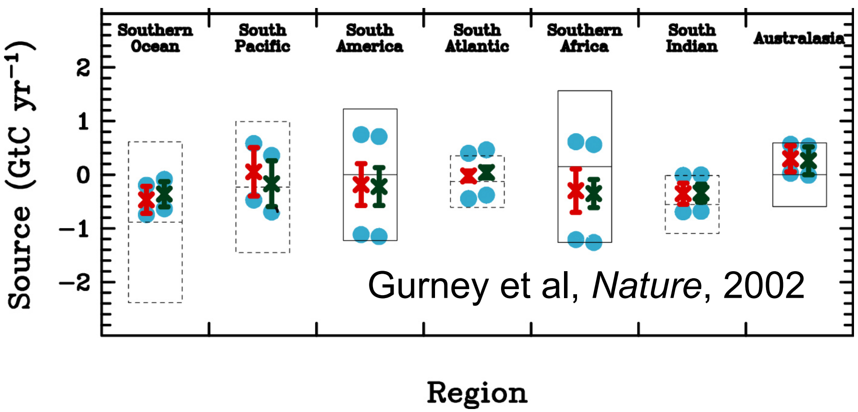
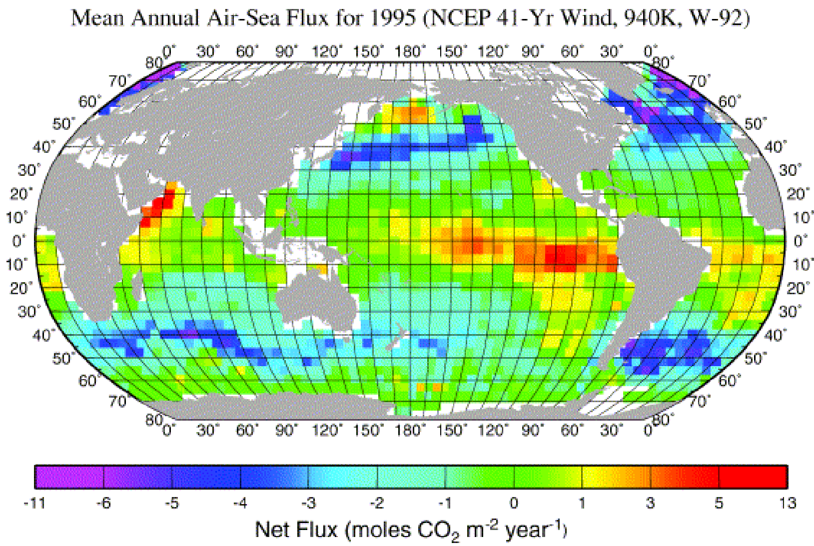
Atmospheric O_2 Applications

- Global terrestrial/oceanic carbon budget partitioning
- Seasonal hemispheric ocean productivity
- Seasonal hemispheric gas-exchange rates
- North-south ocean and atmosphere transport
- Terrestrial ecosystem dynamics
- Fossil-fuel CO_2 source characterization
- Continental air origins and boundary-layer venting
- Thermal vs. biological ocean carbon flux partitioning
- Direct eddy-covariance O_2 fluxes

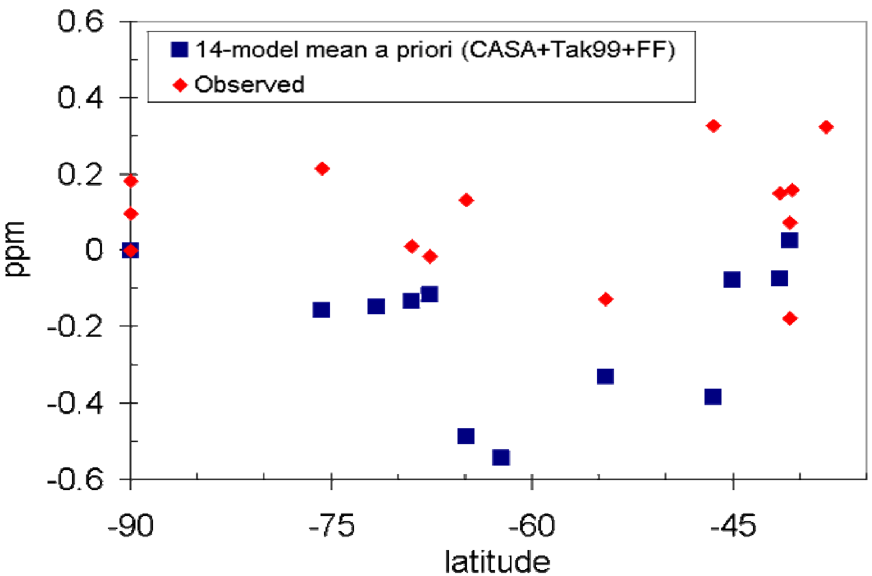
Annual mean TransCom3 results



Takahashi 2002 x Wanninkhof 1992



TransCom3 Southern Ocean *a priori* values and data



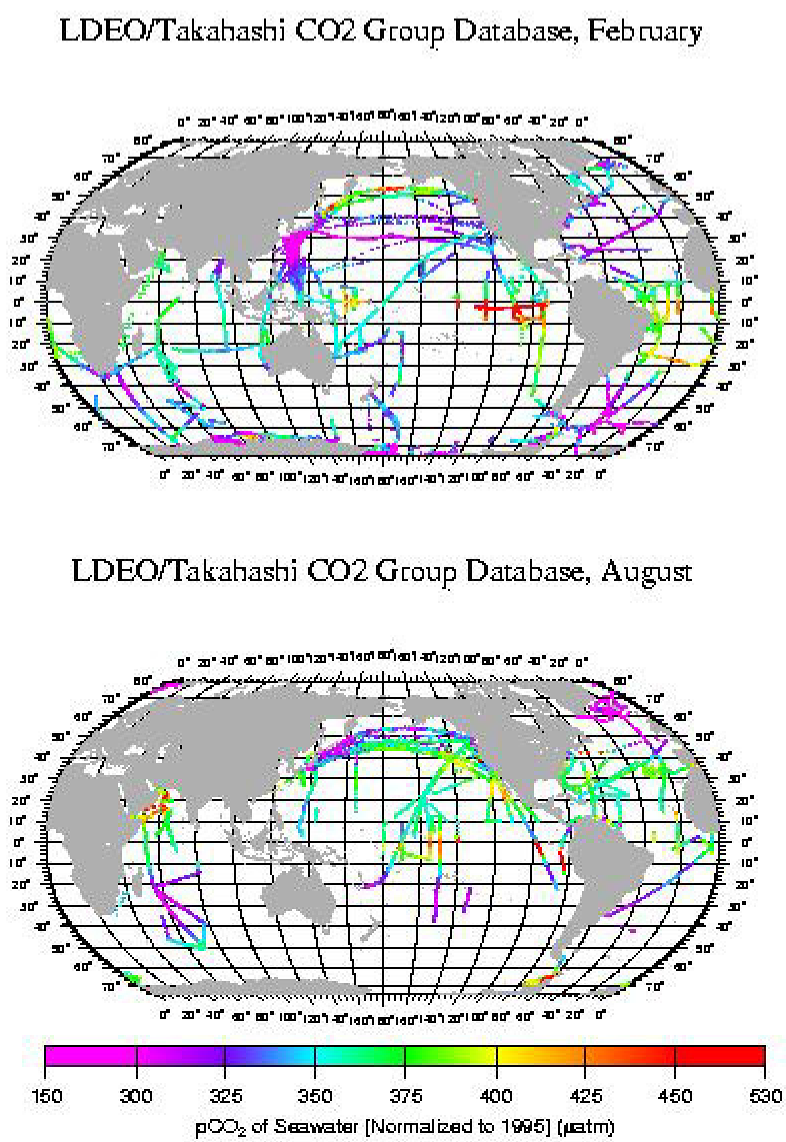
Gurney *et al.*, 2002 (-0.58)

Takahashi *et al.*, 2002 (-0.58)

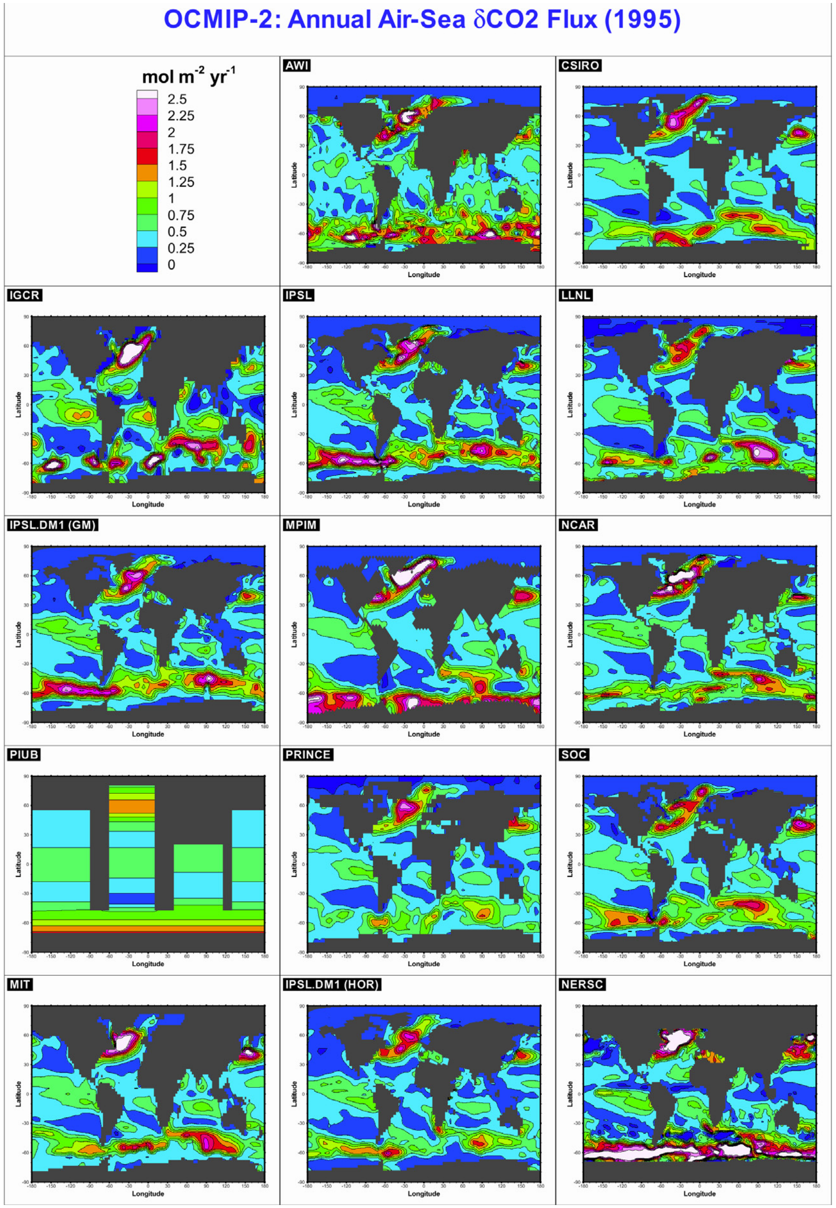
Rödenbeck *et al.*, 2003 (+0.25)

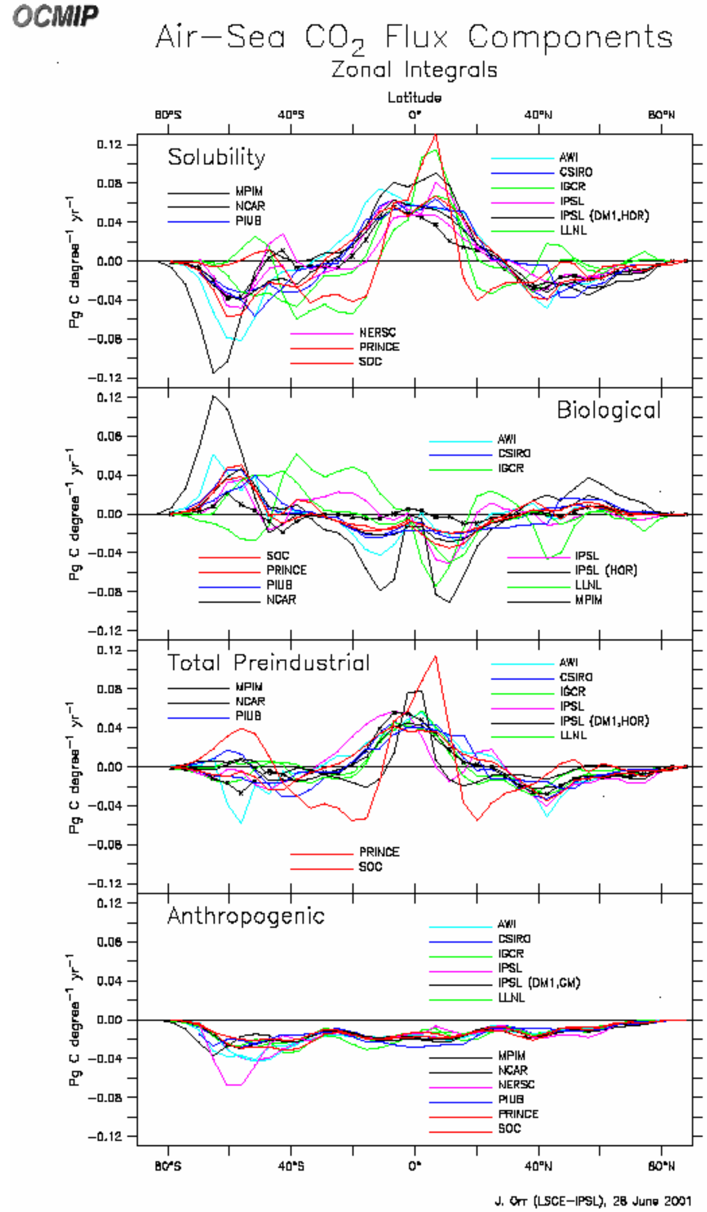
Roy et al., 2003 (-0.3)

Jacobson *et al.*, 2005 (-0.15)



[Figure courtesy of S. Sutherland]





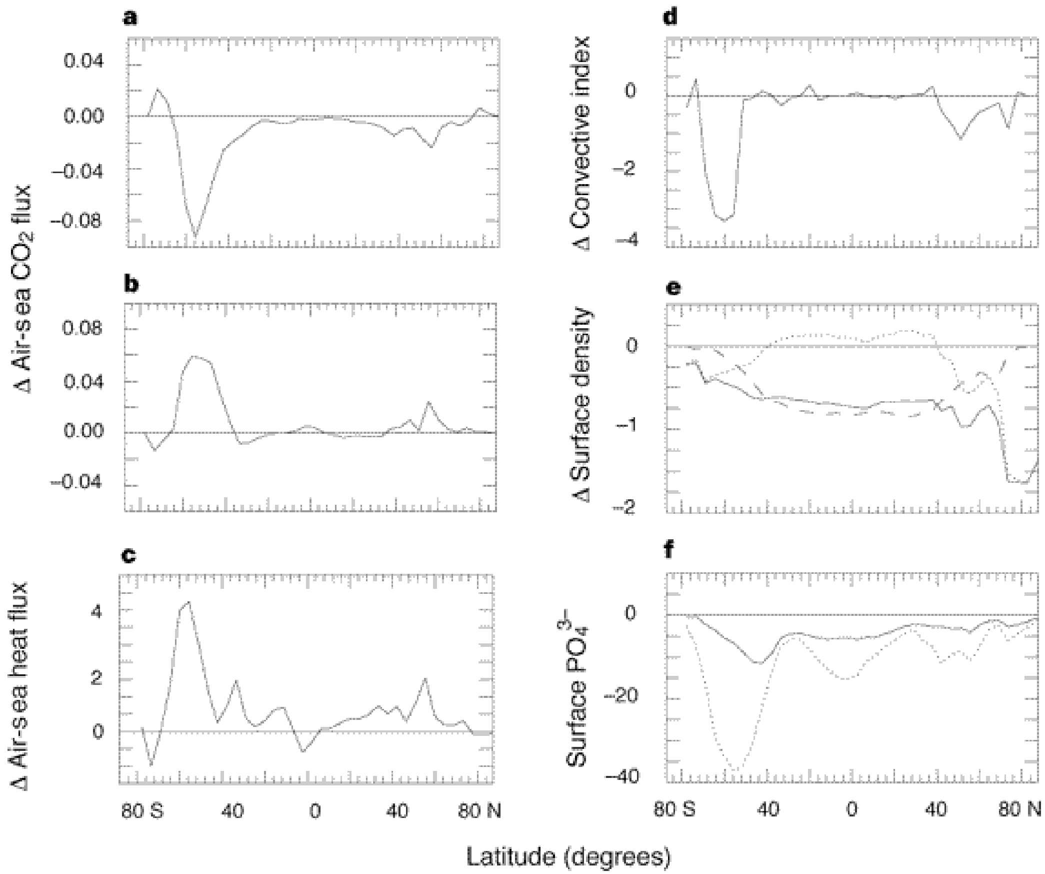
Orr *et al.*, 2002

The Southern Ocean will play a key role in future anthropogenic CO_2 uptake, mediated by strong opposing solubility and biological influences

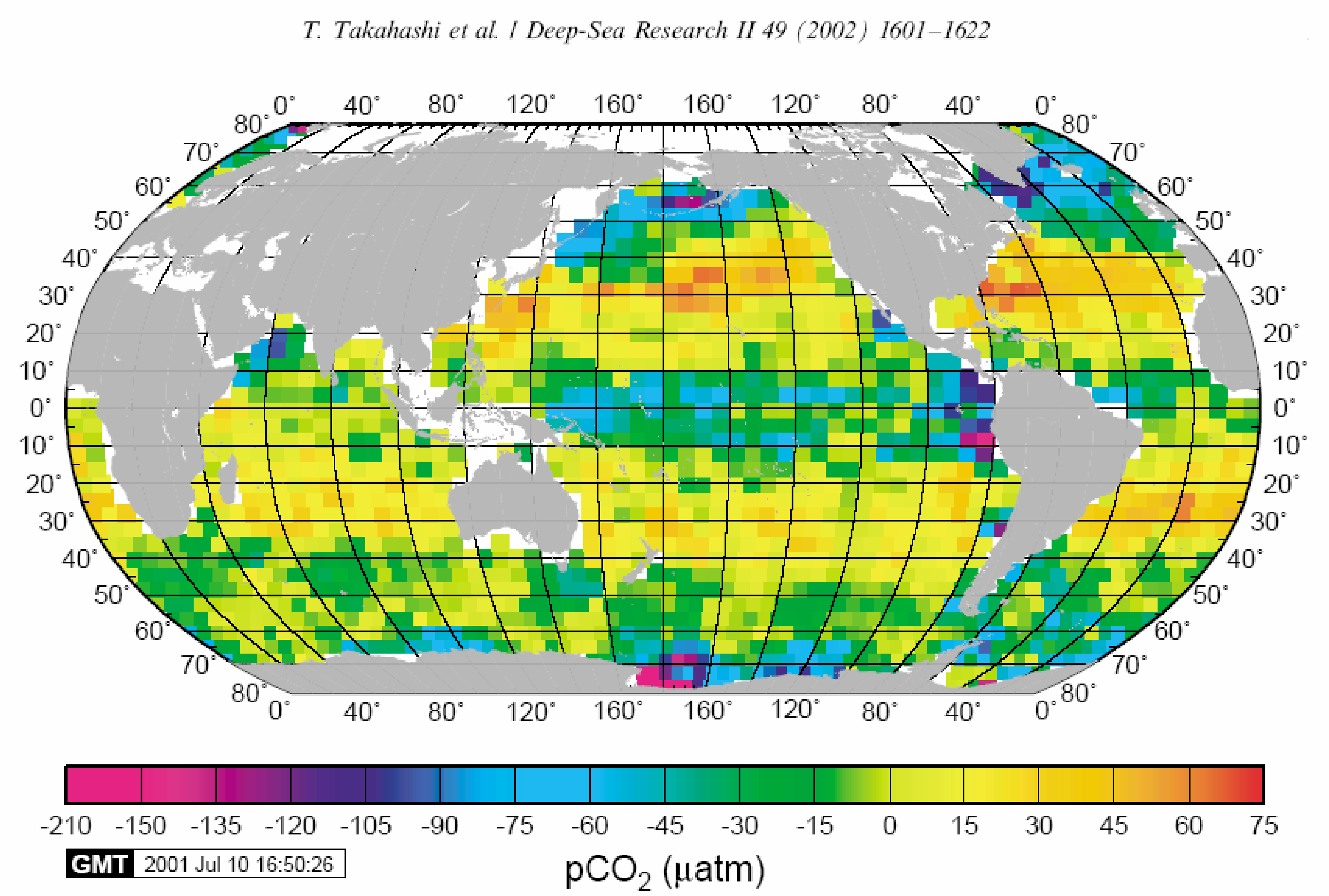
2056-65 Global Warming Simulation [Sarmiento *et al.*, Nature 1998]

Solubility Pump →

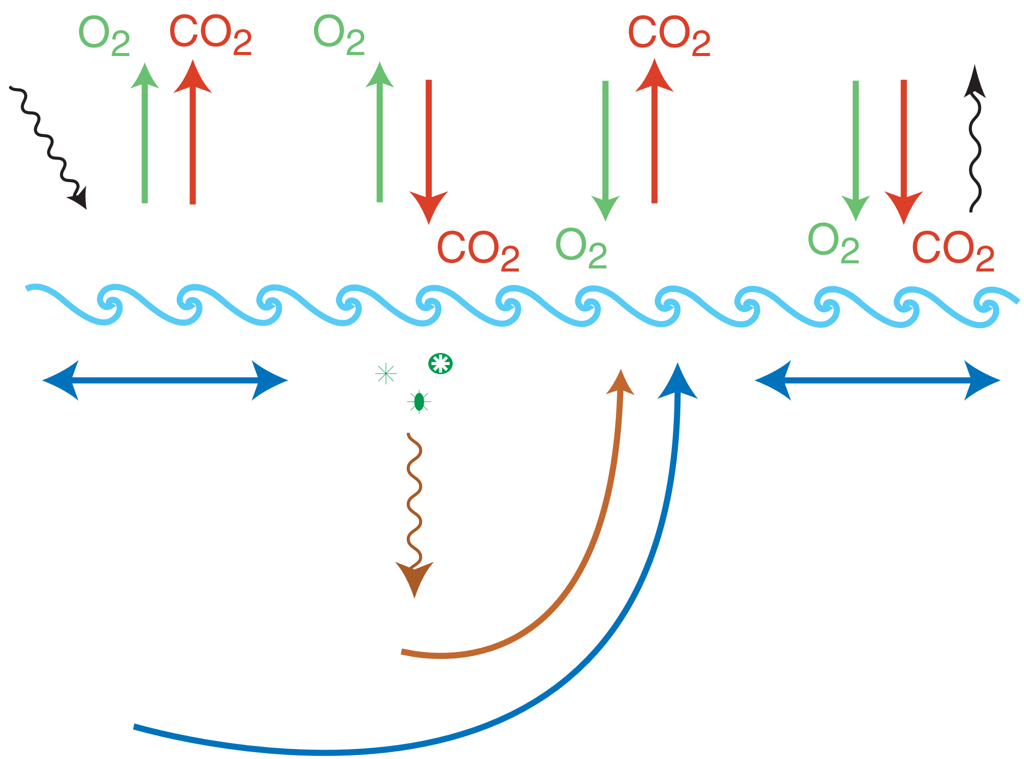
Biological Pump →



(Thermal – Biological) component of seasonal pCO_2 cycle

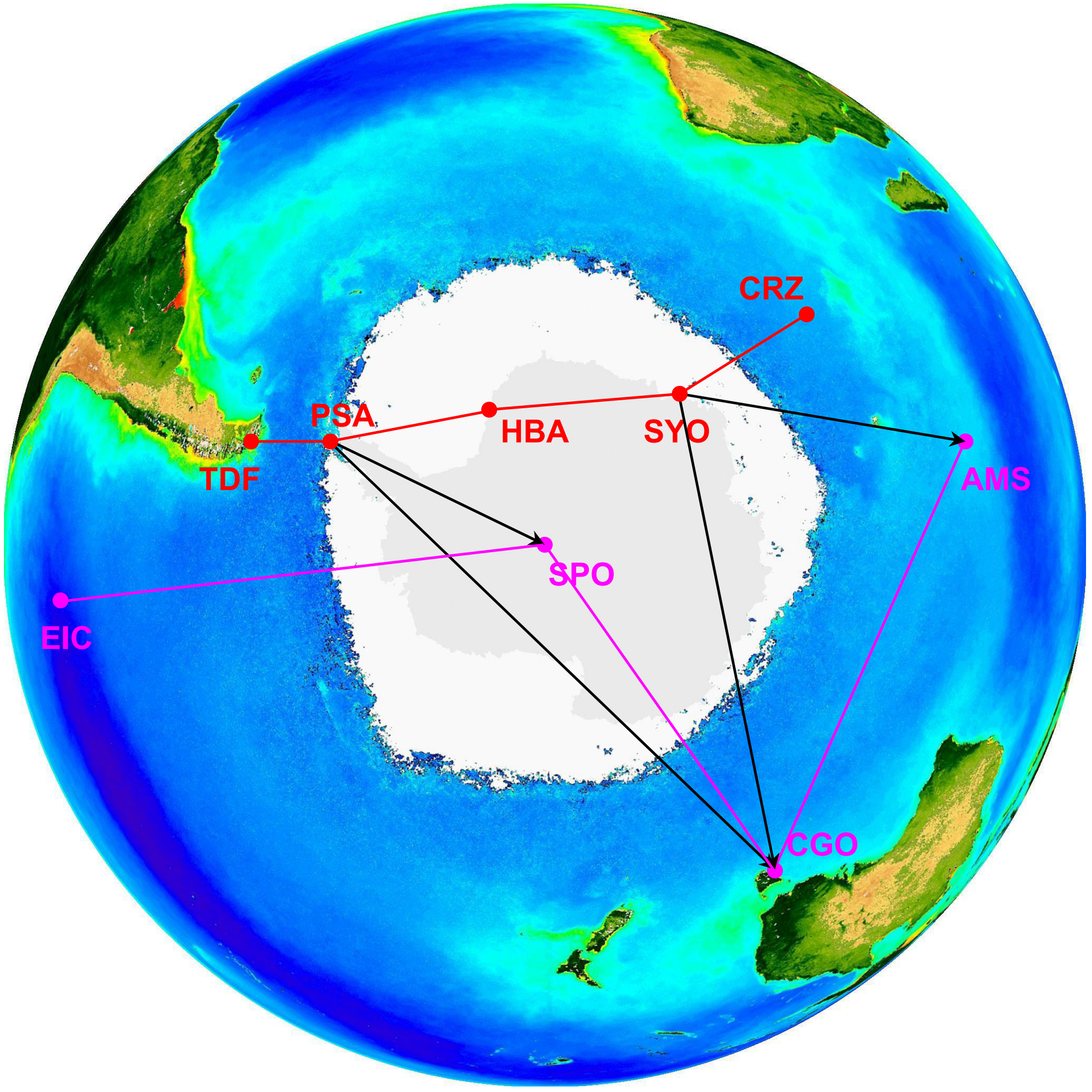


Air-sea CO_2 and O_2 Exchange

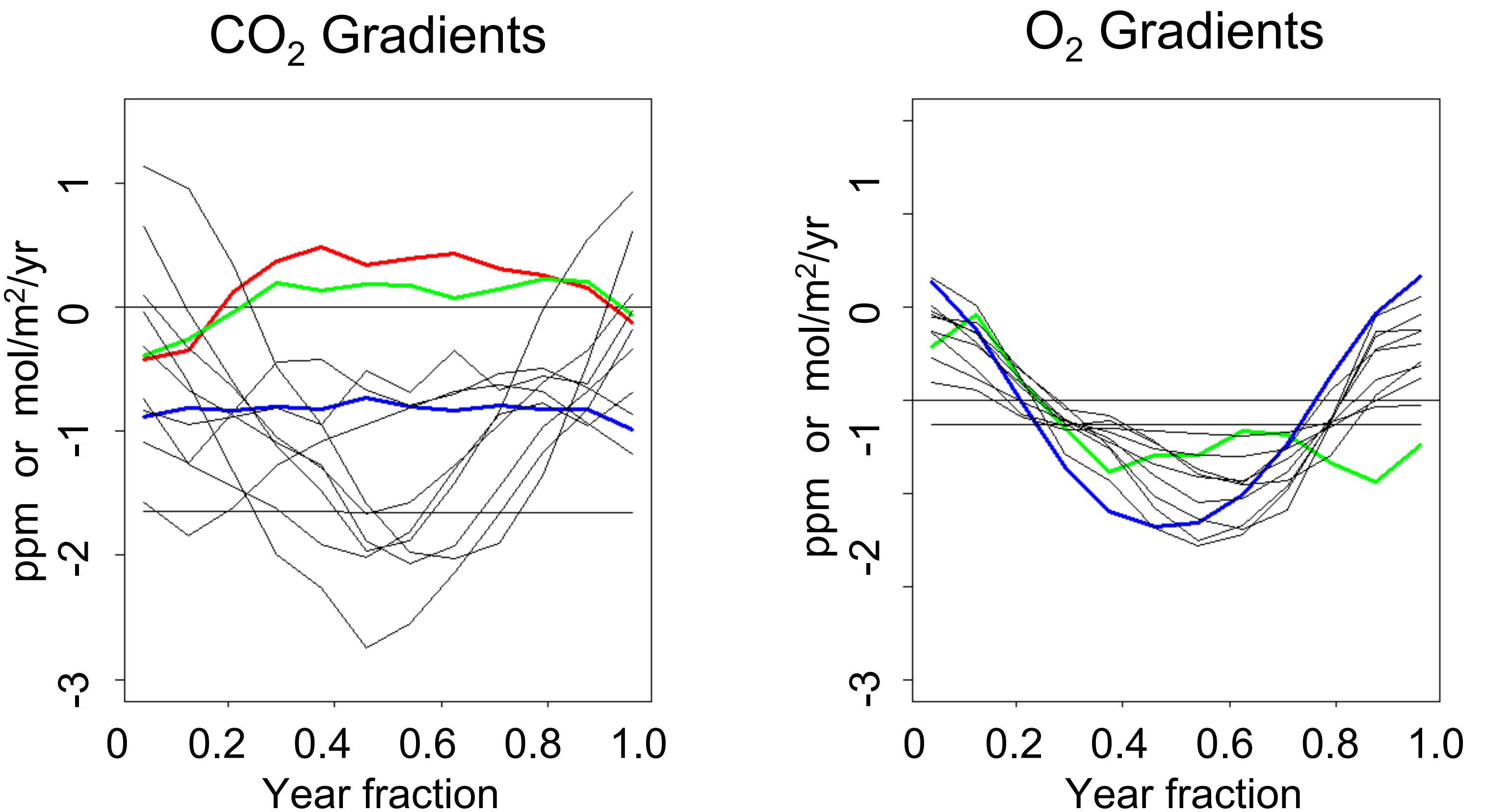


Solubility (thermal) and biological processes have discernable effects on atmospheric O_2 and CO_2

“CMDL Gradient” = (TDF+PSA+HBA+SYO+CRZ)/5 - (EIC+SPO+CGO)/3



SeaWiFS Winter Chlorophyll a



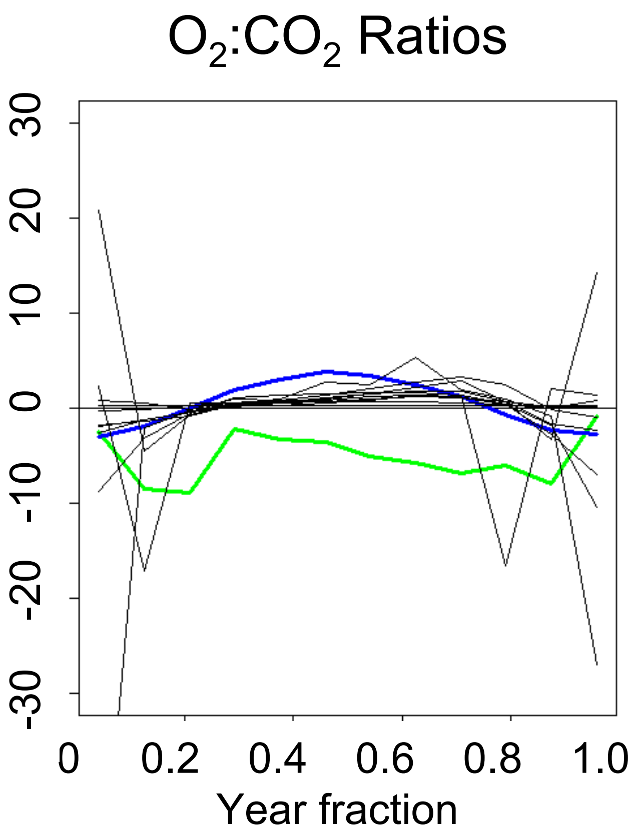
Red = CMDL: (TDF+PSA+HBA+SYO+CRZ)/5 - (EIC+SPO+CGO)/3

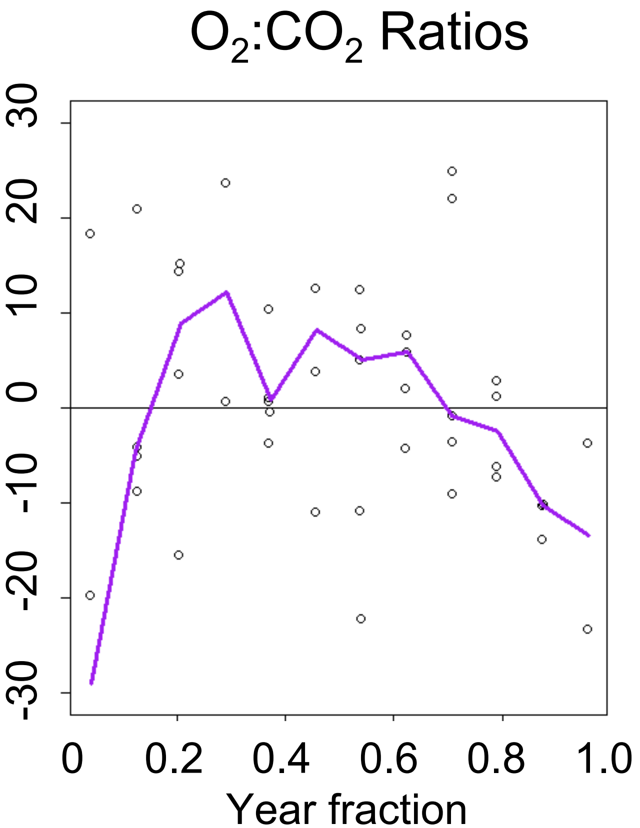
Green = SIO: PSA - (CGO+SPO)/2

Blue = Climatology S of 40 S (Takahashi 2002 or Keeling and Garcia 2001 + Gruber 2001)

Black = OCMIP2 Models S of 40 S

Purple = PU: SYO – (CGO+AMS)/2

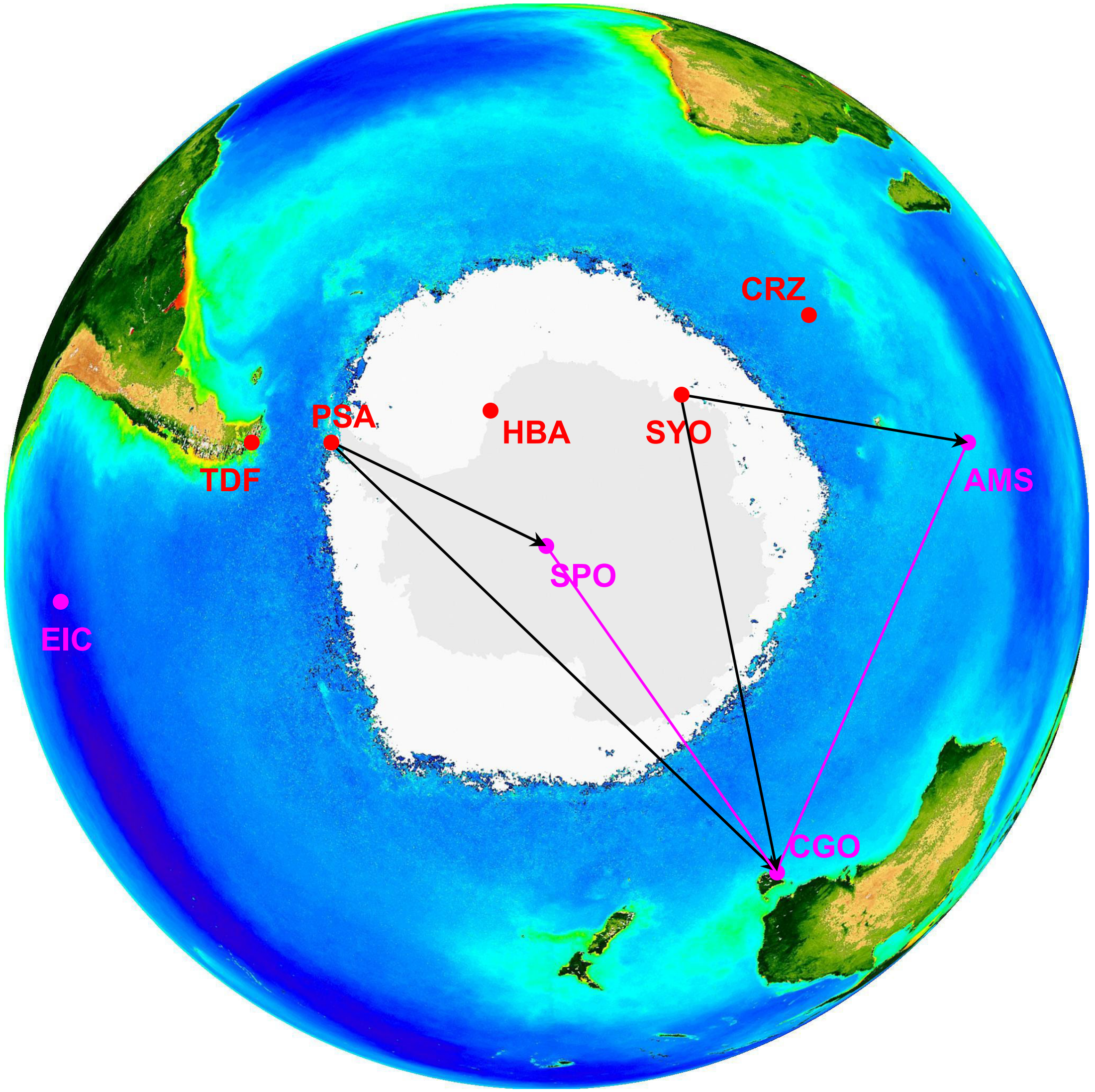




approximate annual-mean differences

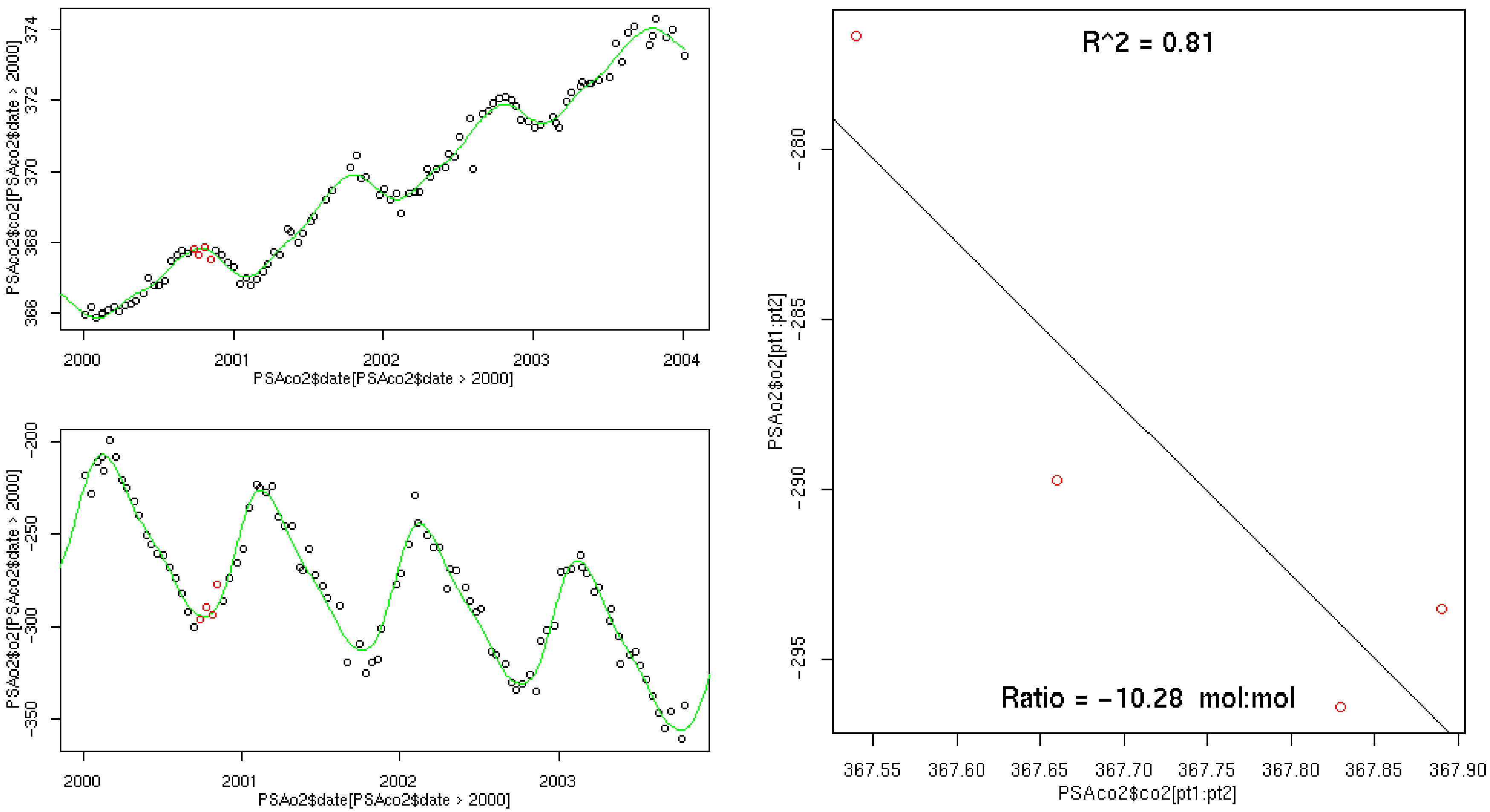
	CO_2	O_2
SIO: PSA – (CGO + SPO)/2	+0.07	-5.0
PU: SYO – (CGO + AMS)/2	+0.16	+4.7

“PU Gradient” = SYO – (CGO+AMS)/2



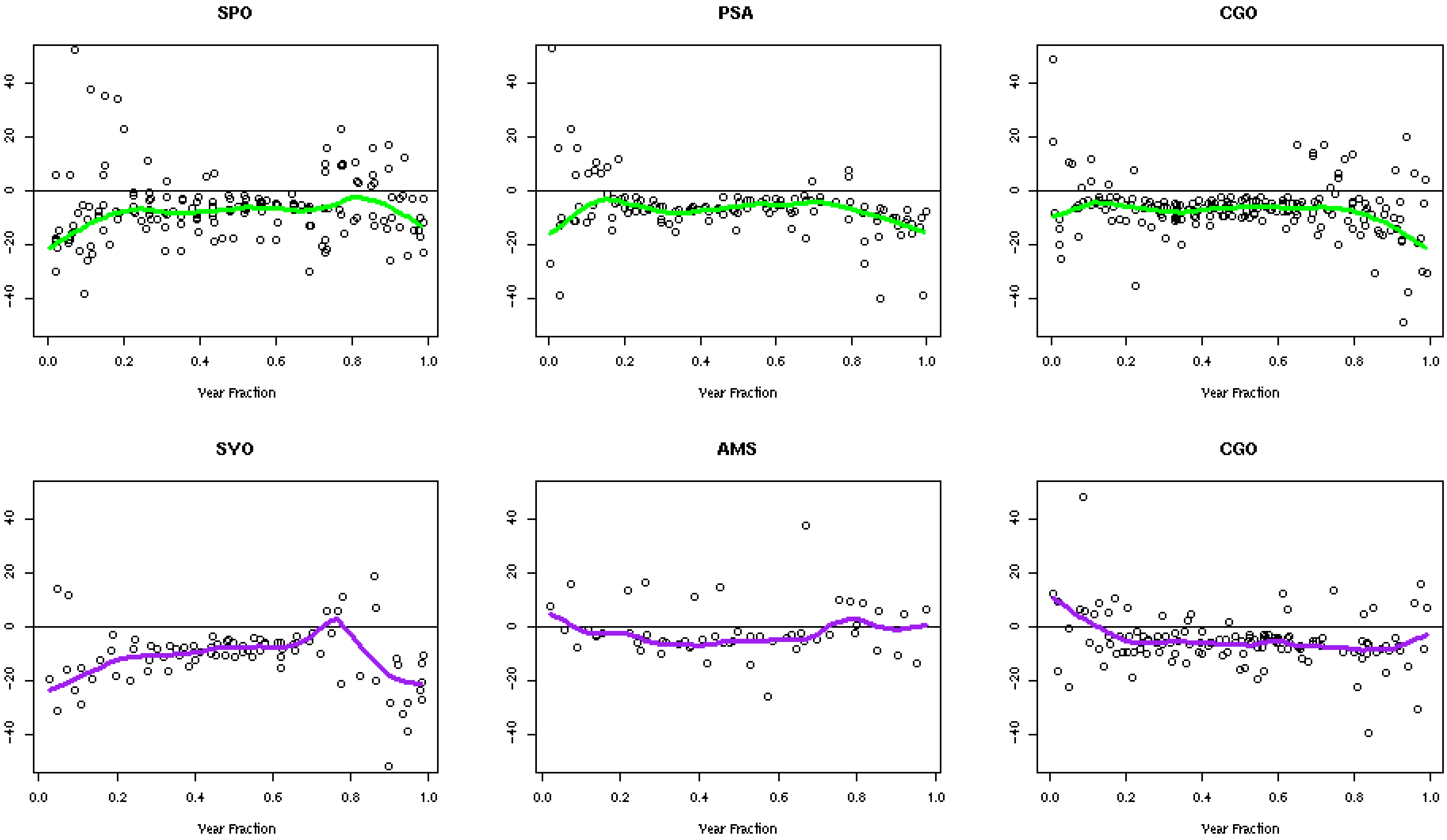
SeaWiFS Winter Chlorophyll a

O_2:CO_2 ratios from 4-sample (~ 2 month) fits



(screening for $R^2 > 0.3$)

O_2:CO_2 ratios from 4-sample (~ 2 month) fits

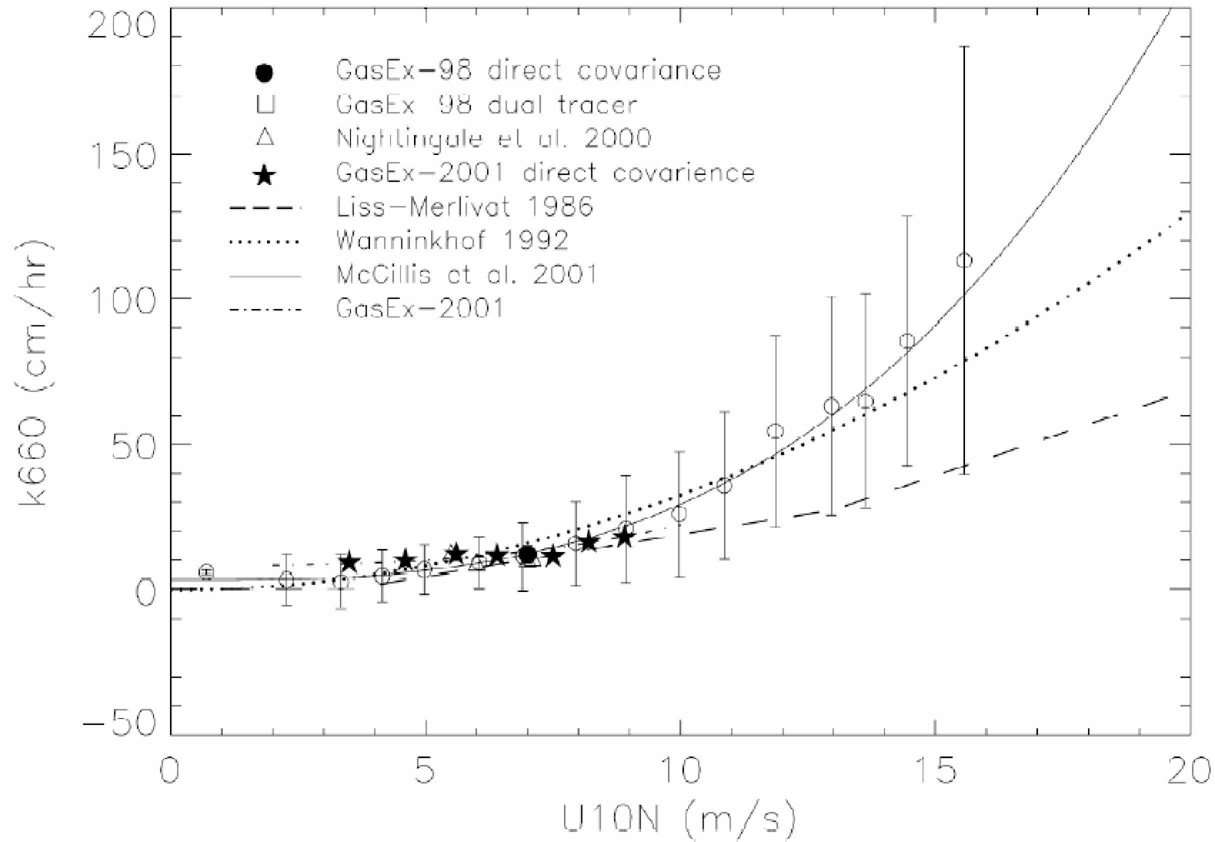


(screening for $R^2 > 0.3$)

Conclusions (part 1)

- There is a clear atmospheric signature of wintertime Southern Ocean CO_2 outgassing and approximate annual-mean CO_2 flux balance.
- Atmospheric O_2:CO_2 ratios suggest a dominant biological influence on CO_2 fluxes year-round.
- Small Southern Ocean atmospheric gradients are useful in evaluating pCO_2 climatologies and the OCMIP2 models.
  - → Incorporate existing and future winter pCO_2 measurements
  - → Continue to evaluate OCMIP2 model physics, and evaluate more sophisticated models

New constraints on air-sea gas-exchange



[Figure courtesy W. McGillis]

$$F_{CO2} = k\ S\ (pCO_{2w} - pCO_{2a})$$

VUV Absorption O_2 Instrument

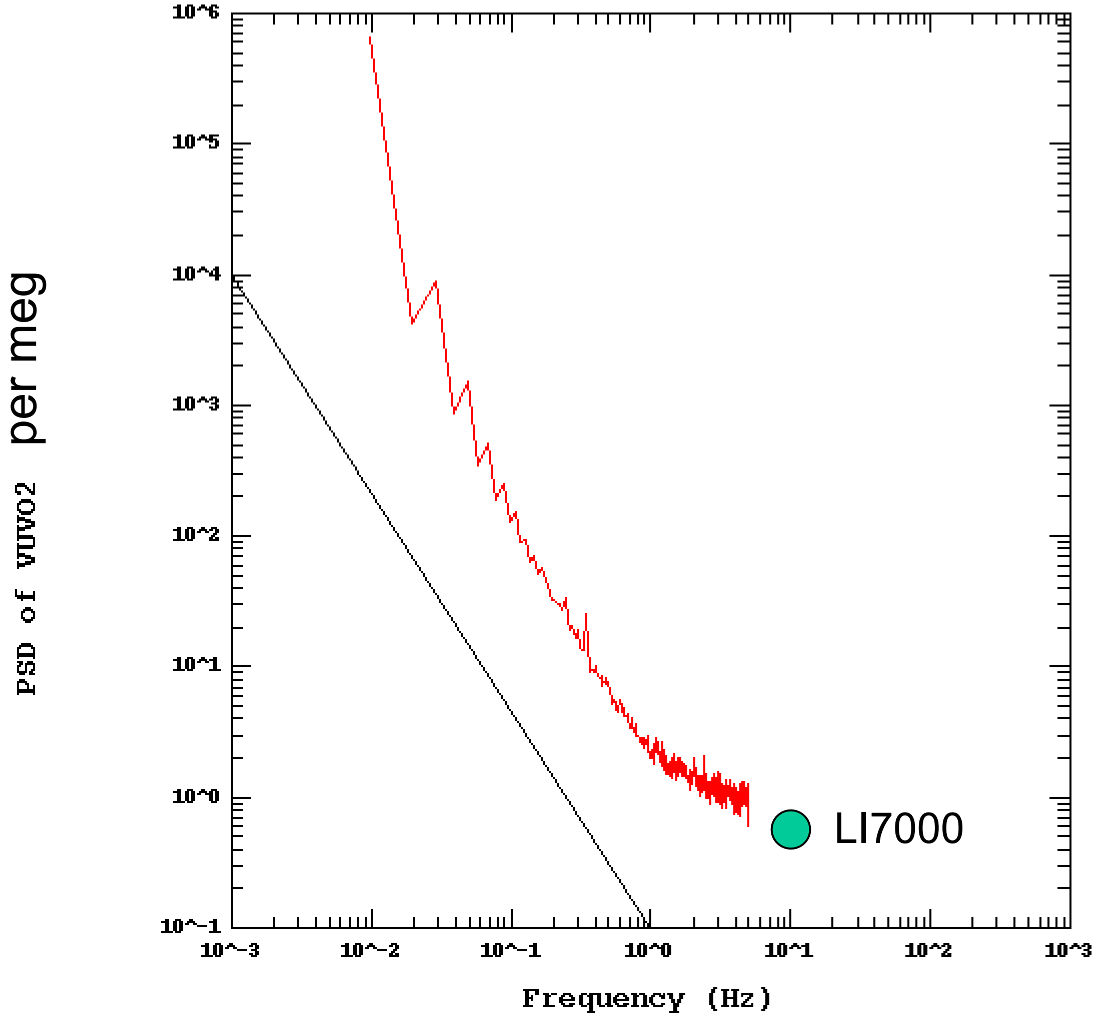
Deployed at Jefferson County Airport, Colorado

Differential precision: 2 per meg (0.4 ppm) rms in 4 seconds

Short term precision: 2 per meg (0.4 ppm) rms in 1 second

Fundamental response time: ~ 100 Hz

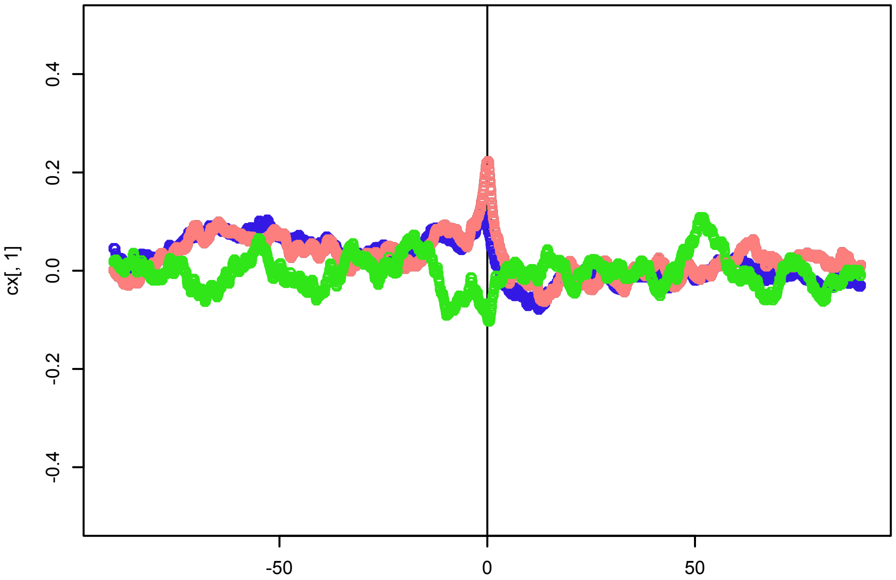
Power spectrum of VUV Signal



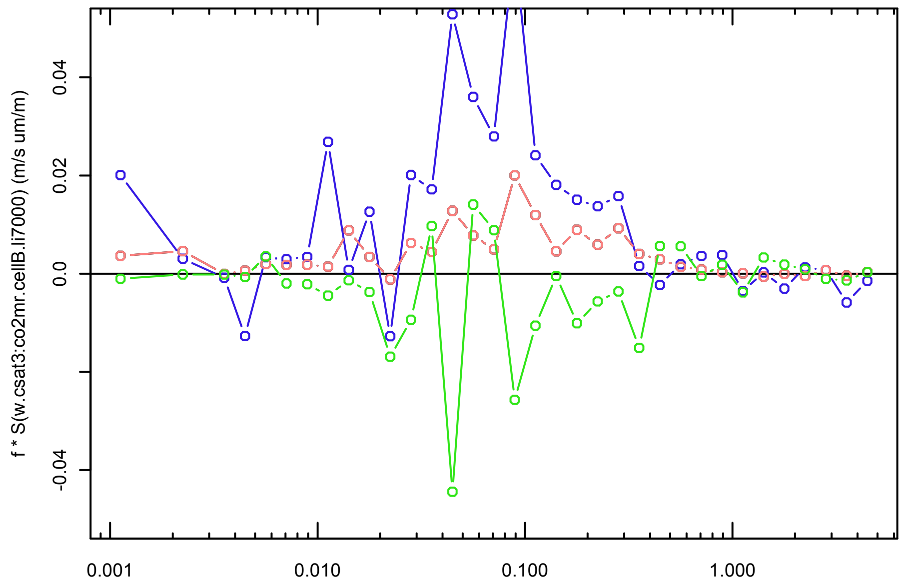
Total variance = 25415.7
Variance (w/o DC component) = 6626.26
K = 55, M = 512, nPoints = 27410

Early evening respiration signal

Cross correlation with vertical wind



Cospectra with vertical wind



Red: CO_2

Blue: H_2O

Green: O_2

O_2 fluxes are generally larger than CO_2 fluxes

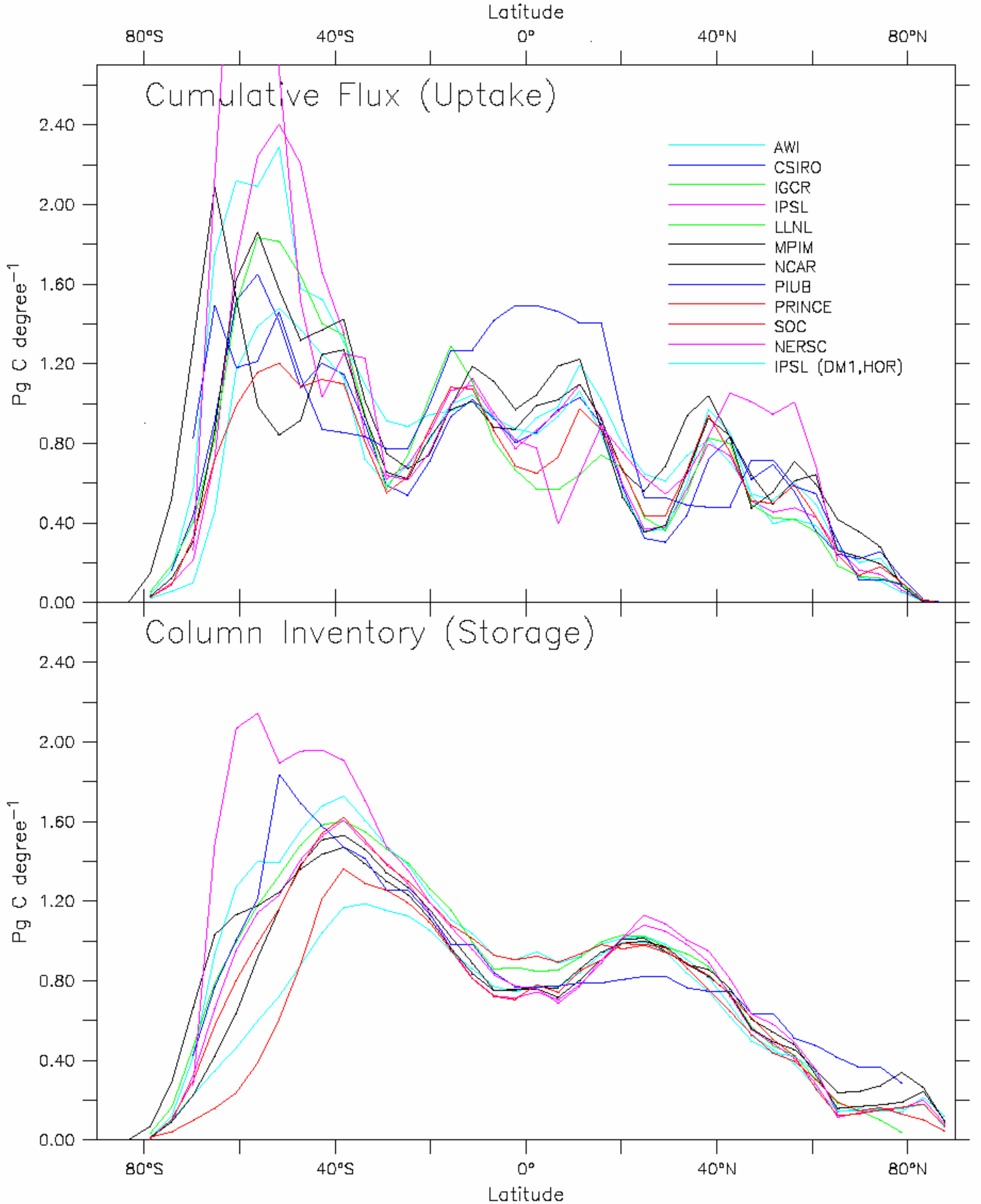
Upper range of HAMOCC3.1 fluxes (mol/m^2/year)

	CO_2 Flux	O_2 Flux
June in the North Atlantic	-5	+30
Febuary in the Equatorial Pacific	+3	-25
December in the Southern Ocean	-5	+15

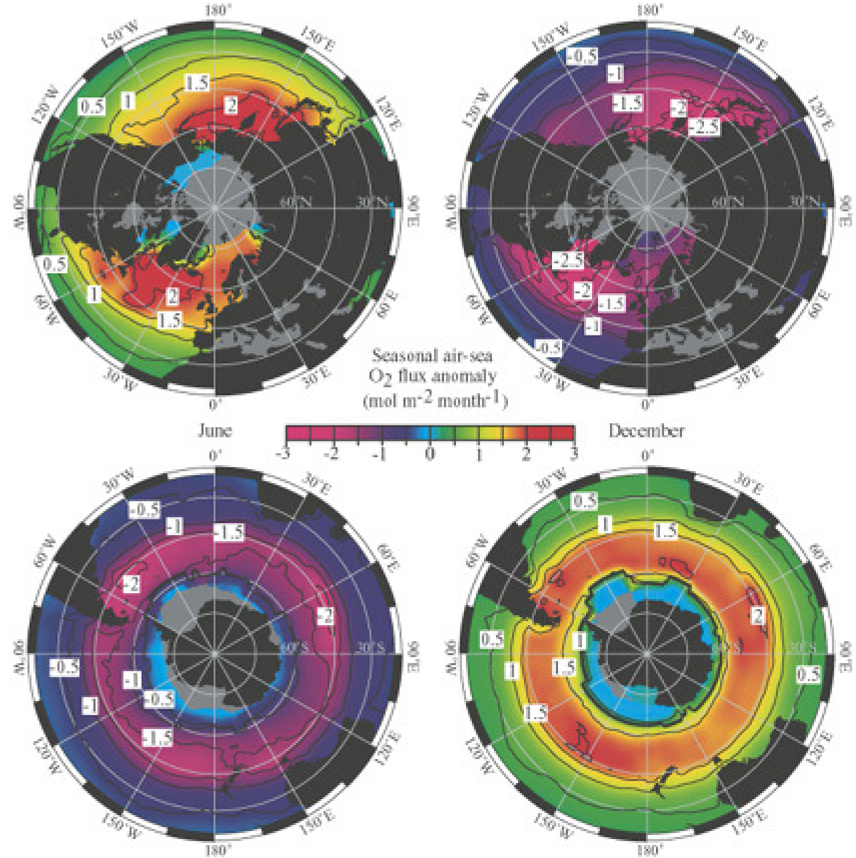
Conclusions (part 2)

- Preliminary tests suggest that the VUV instrument may be capable of measuring O_2 fluxes by eddy-correlation.
- This would enable a new constraint on air-sea gas-exchange rates and their solubility dependence.
- Drying air to a few ppm H_2O while maintaining turbulent flow through inlet tubes is the primary challenge.

Large model differences in the Southern Ocean



Simulated 1995 cumulative CO_2 fluxes and inventory



Seasonal air-sea
O2 flux anomaly
(mol m-2 month-1)
June
December
-3
-2
-1
0
1
2
3