Evaluating CMIP5 model ocean biogeochemistry and Southern Ocean carbon uptake using APO:

Present day performance and future prediction

Cindy Nevison

University of Colorado / INSTAAR

R. Keeling, J. Bent, M. Manizza, M. Kahru, B. G. Mitchell

Scripps Institution of Oceanography

Britt Stephens

National Center for Atmospheric Research

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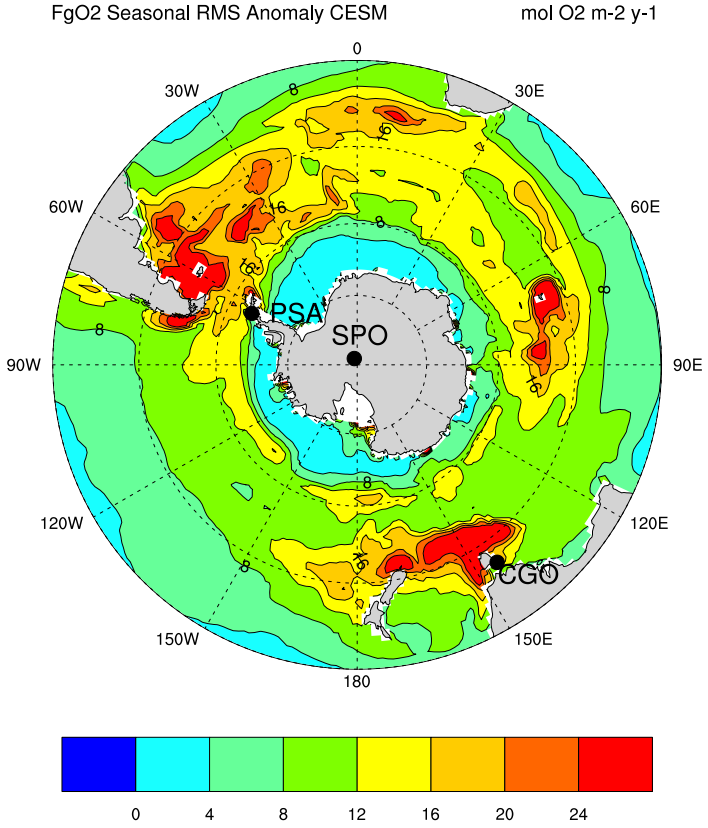
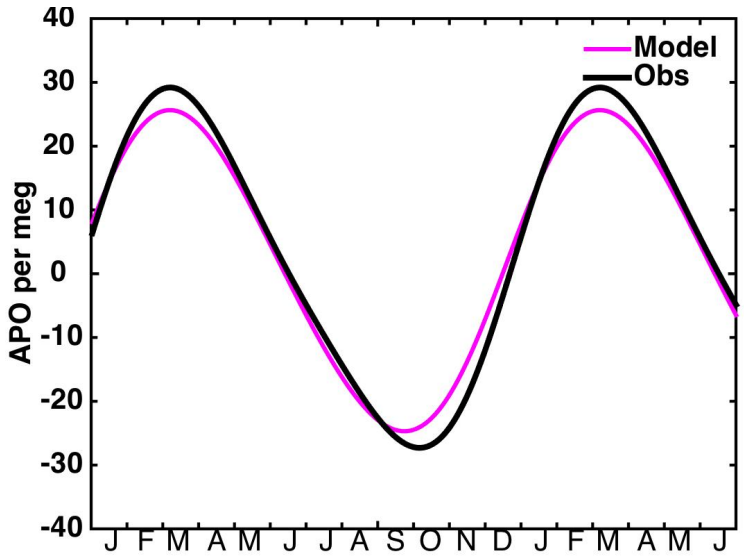
METHODS: Air-Sea O_2, CO_2, N_2 Fluxes from 8 CMIP5 Models
➔ Atmospheric Potential Oxygen (APO)



Atmospheric Transport Model

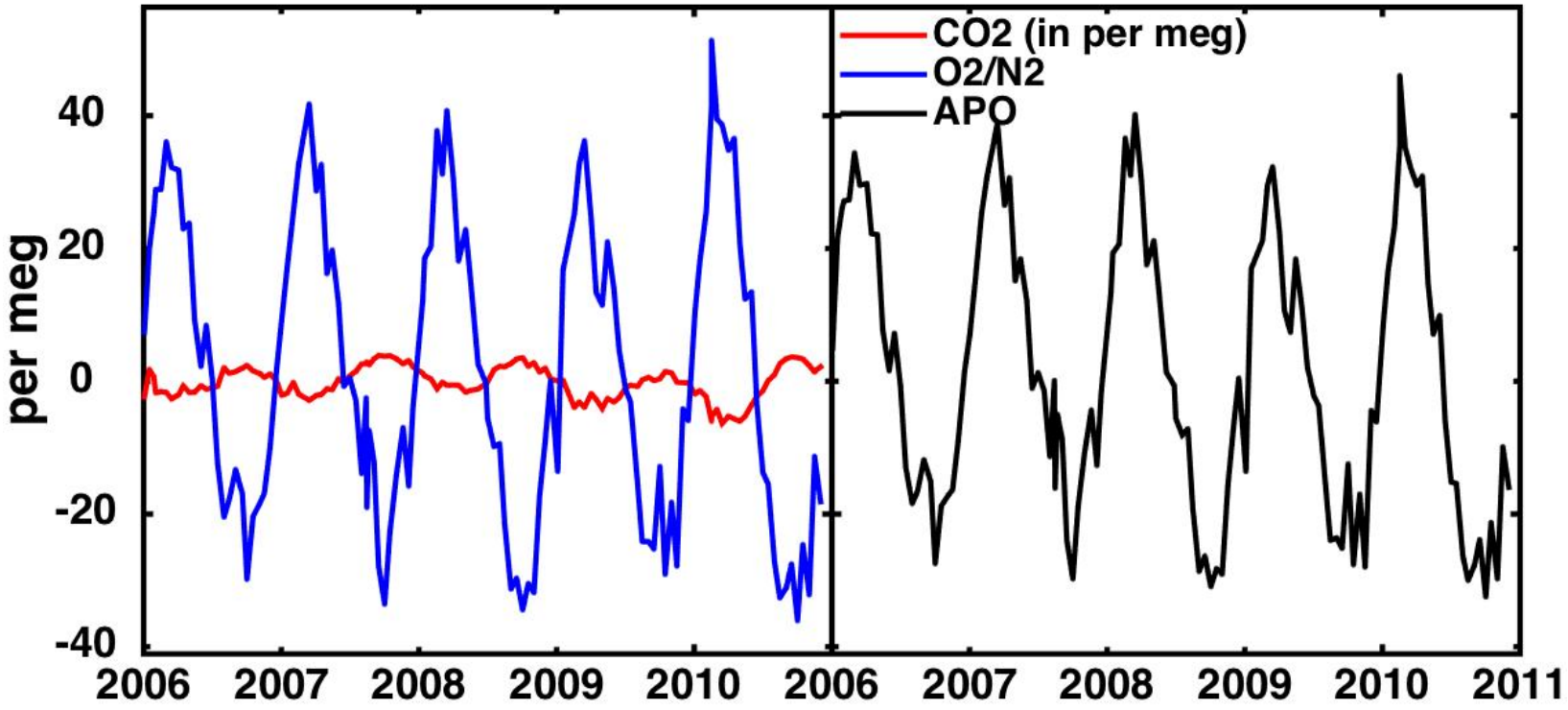
APO Seasonal Cycle
South Pole



Observed APO

South Pole

APO ≈ O_2/N_2 + 1.1 CO_2 (land + ocean)

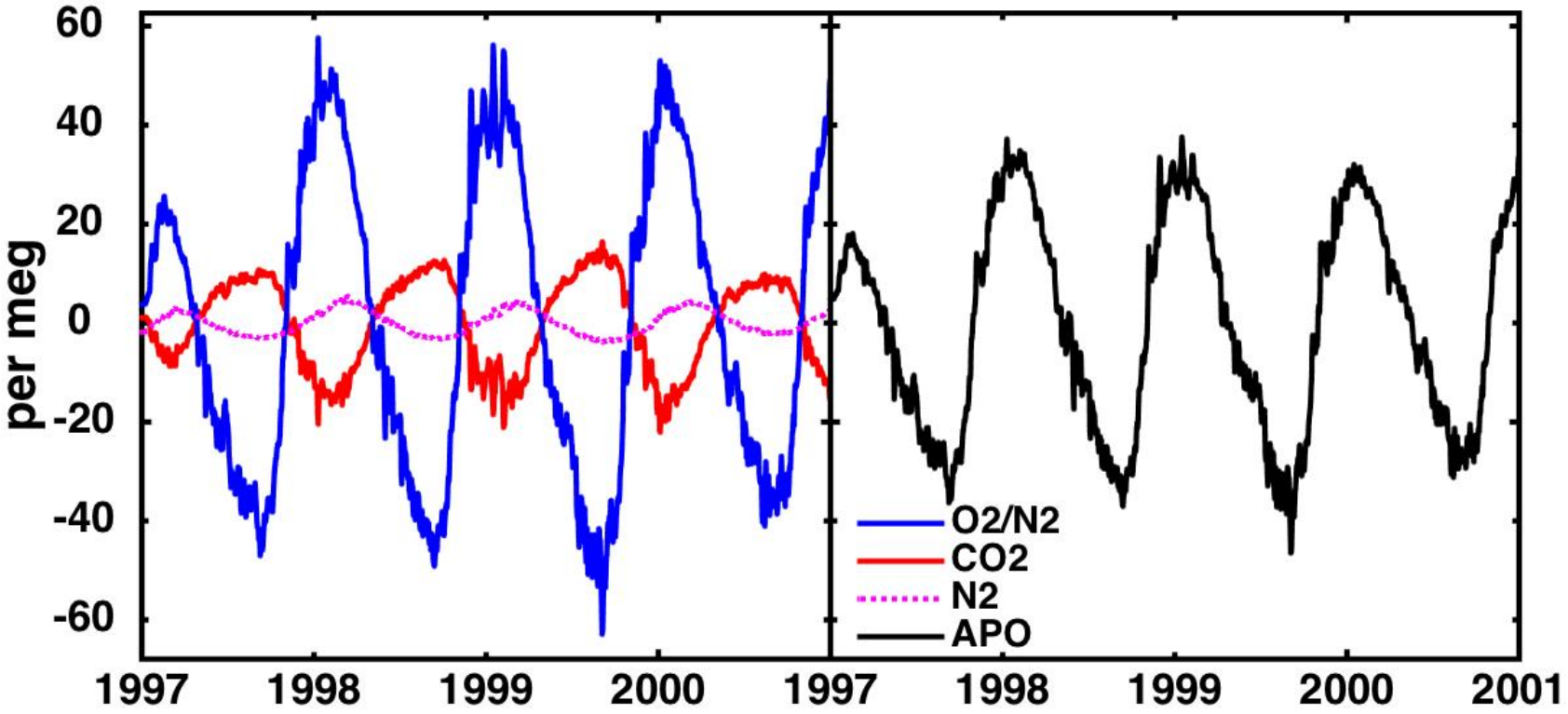


Detrended SIO Data from Keeling et al.

Modeled APO

South Pole

Model APO = $O_2/x_{O2} - N_2/x_{N2} + 1.1\ CO_{2(ocean)}/x_{O2}$

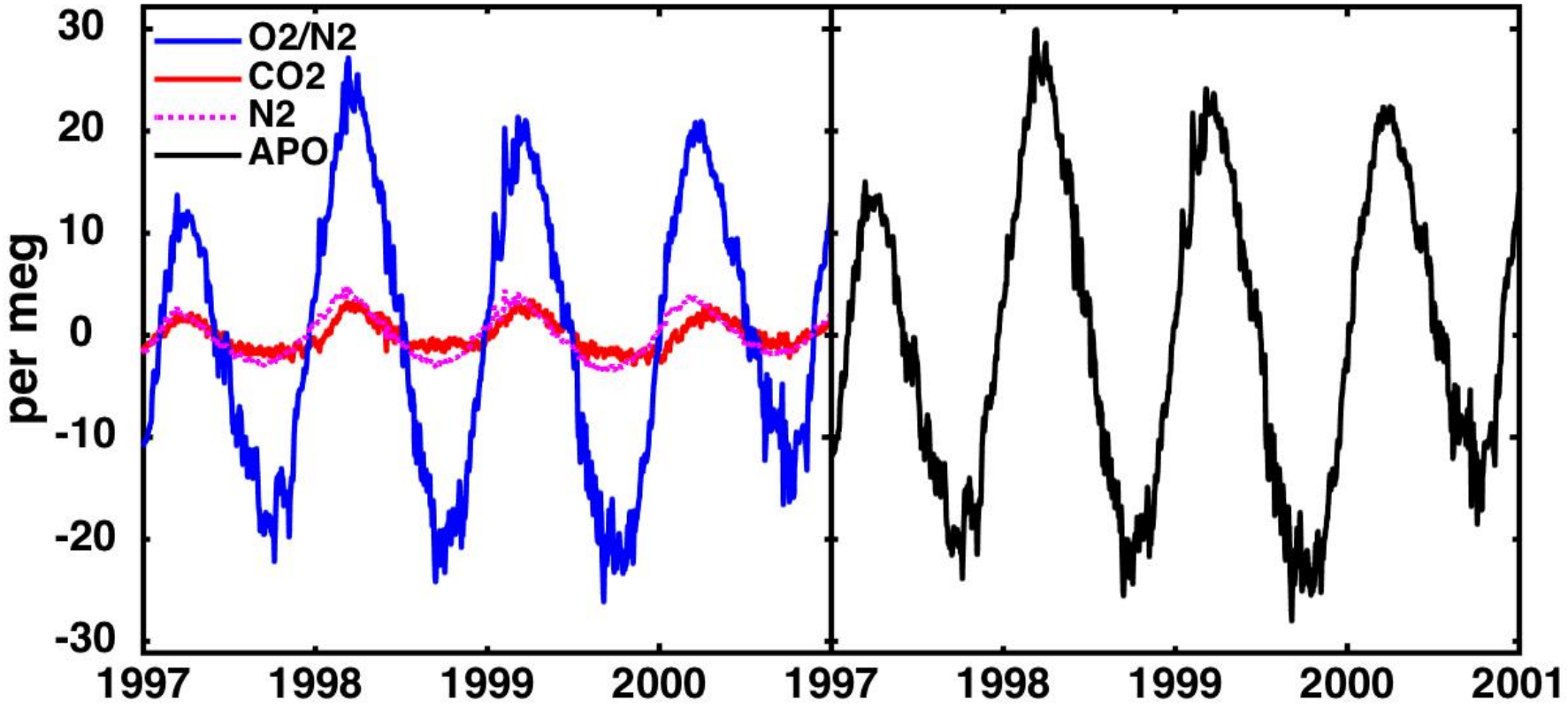


Air-sea fluxes from MPIM

Modeled APO

South Pole

Model APO = $O_2/x_{O2} - N_2/x_{N2} + 1.1\ CO_{2(ocean)}/x_{O2}$



Air-sea fluxes from IPSL

Methodology – more details

1. Assemble monthly air-sea fluxes of O_2, CO_2 and N_2* from 8 CMIP5 ocean biogeochemistry models:

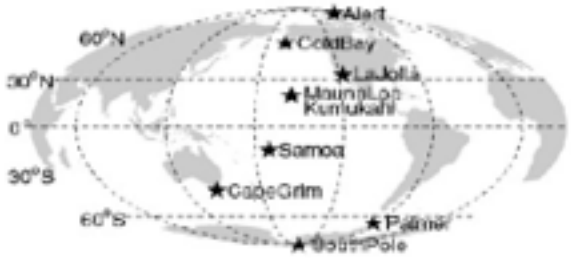
Historical (1997-2000)

RCP8.5 (2097-2100)

2. Atmospheric transport model simulations with GEOS-Chem (2 x 2.5°)

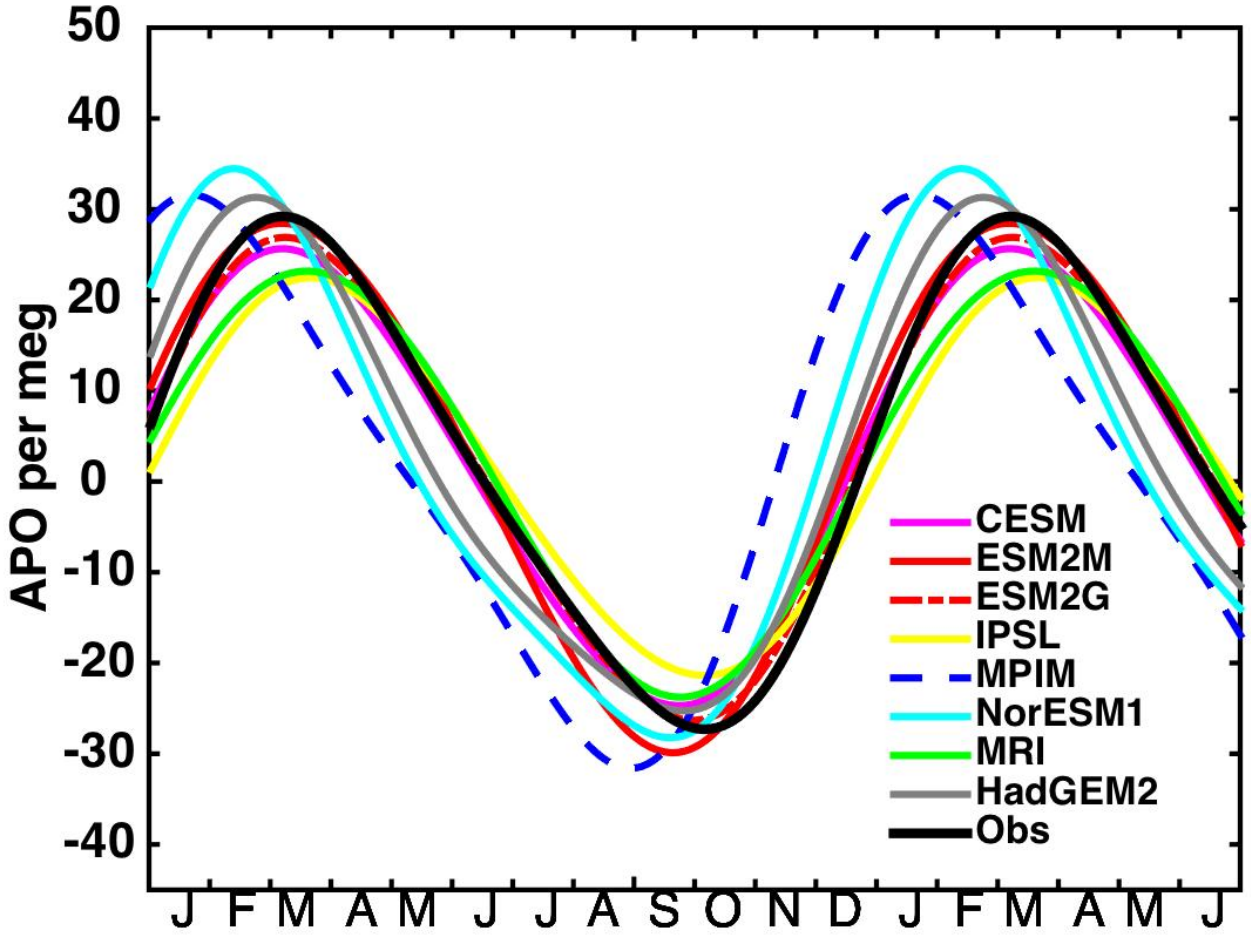
Model APO = $O_2/x_{O2} - N_2/x_{N2} + 1.1\ CO_2/x_{O2}$

3. Compare Model and Observed APO mean seasonal cycles



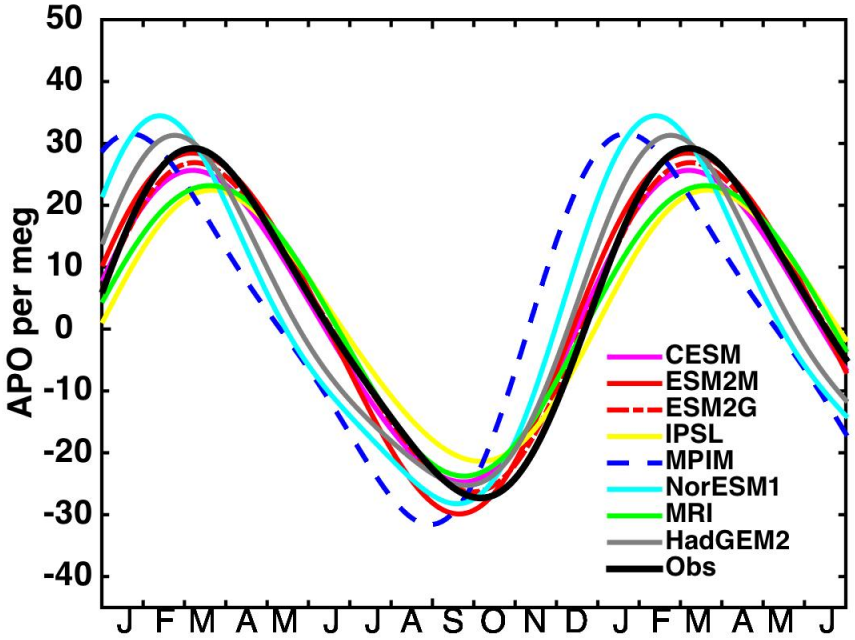
*N_2 fluxes estimated from model net surface heat flux: $fgN_2 = QS_T/C_p$ (with Jin mods)

APO: GEOS-Chem v. Observed at SPO

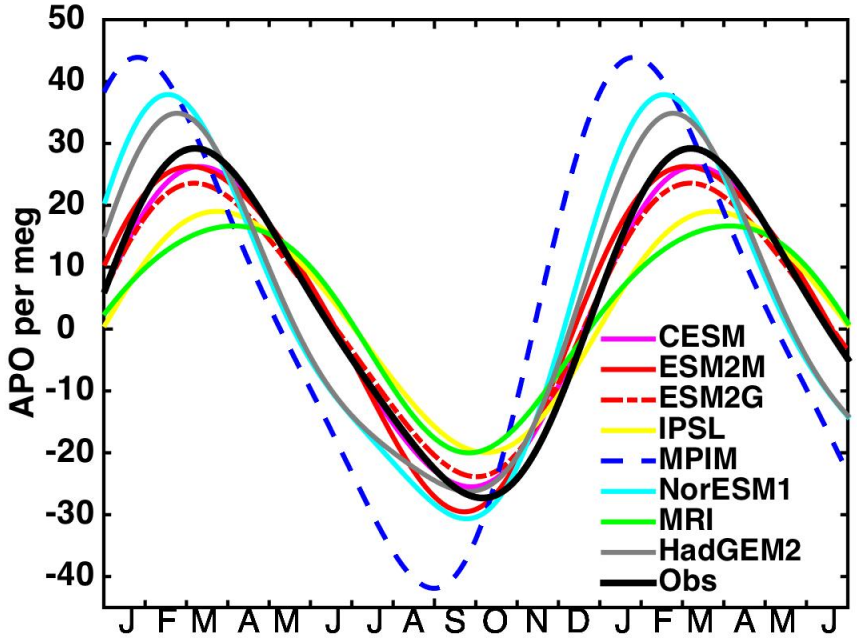


APO: GEOS-Chem v. Observed at SPO

Using Ocean Model CO_2

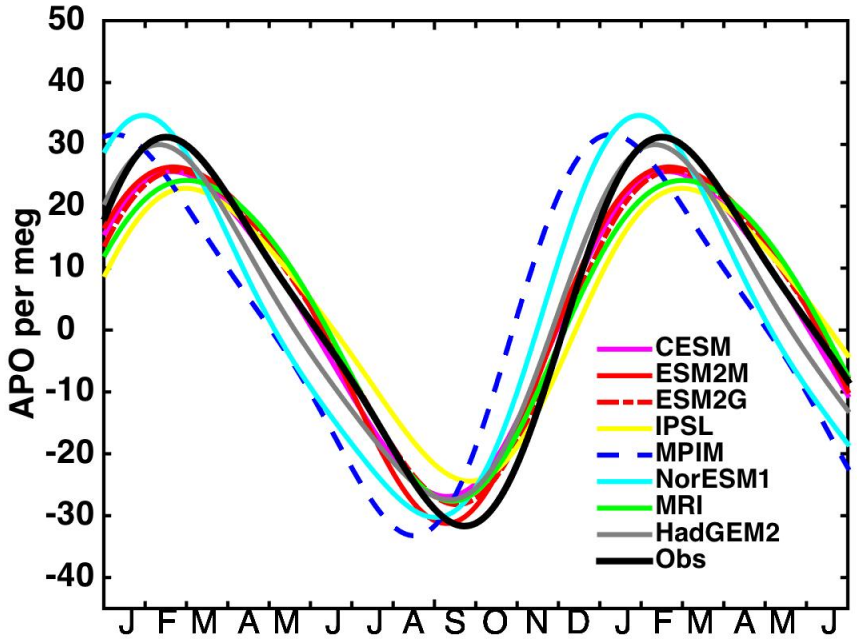


Using Takahashi CO_2

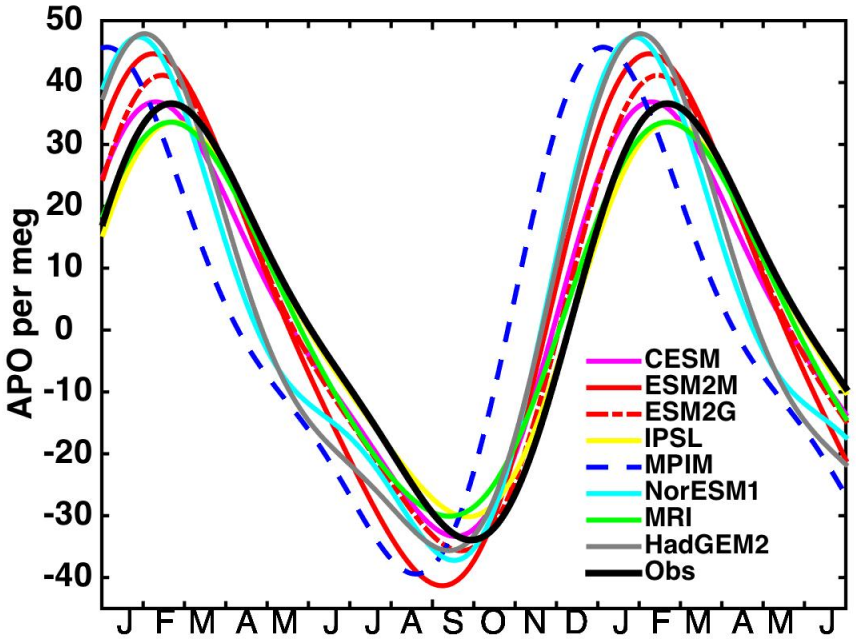


APO: GEOS-Chem v. Observed

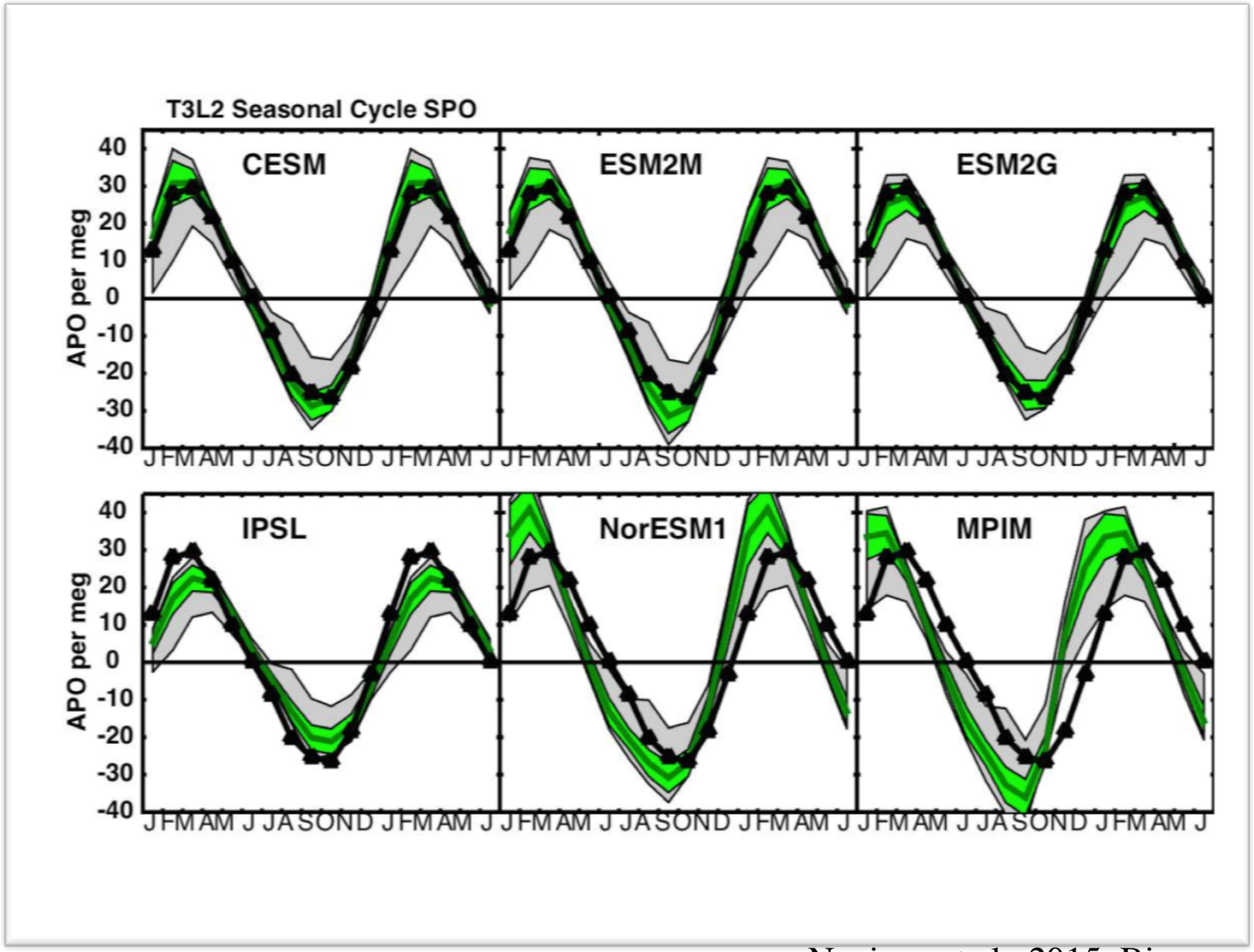
Cape Grim



Palmer Station

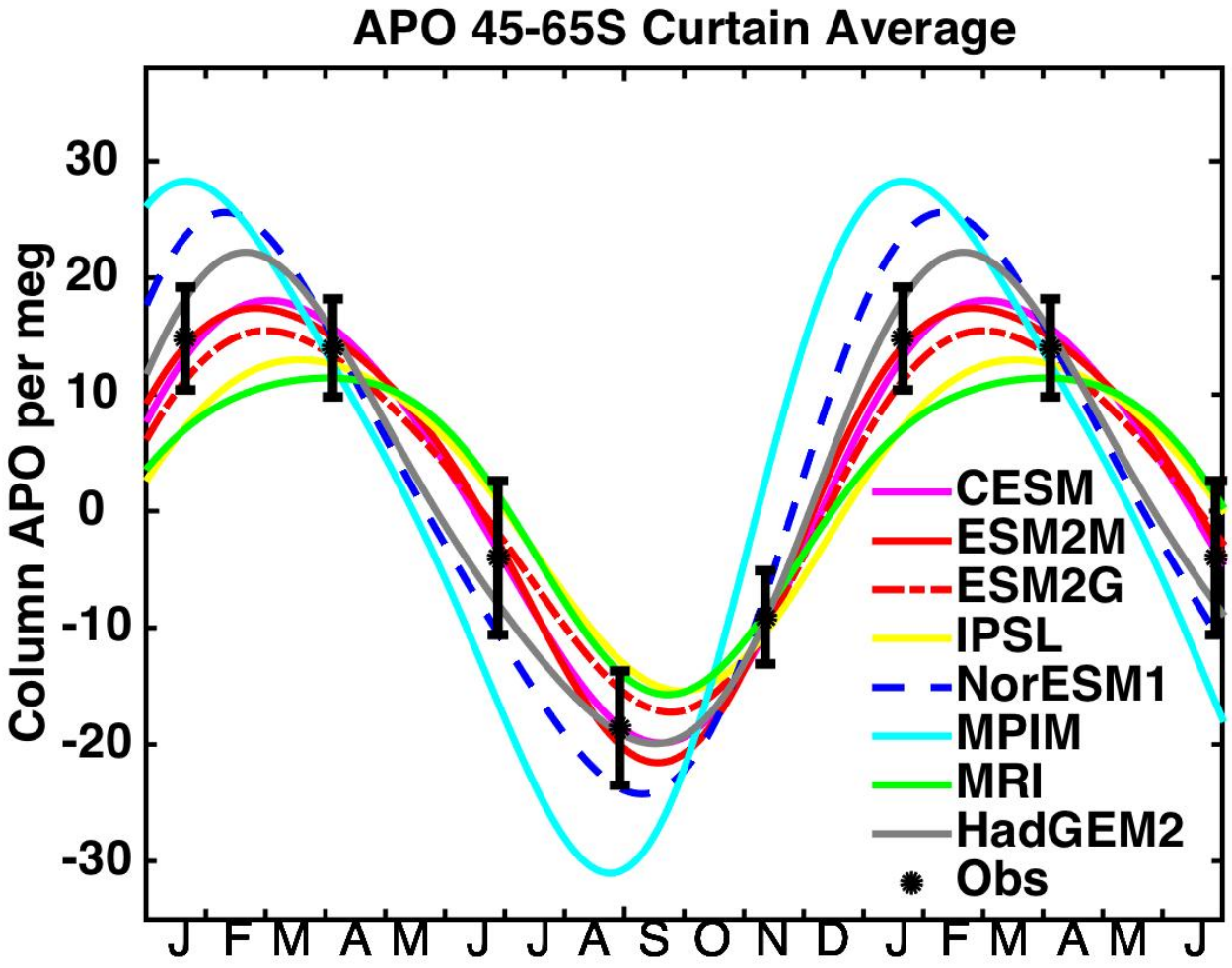


APO: Transcom Matrix Method



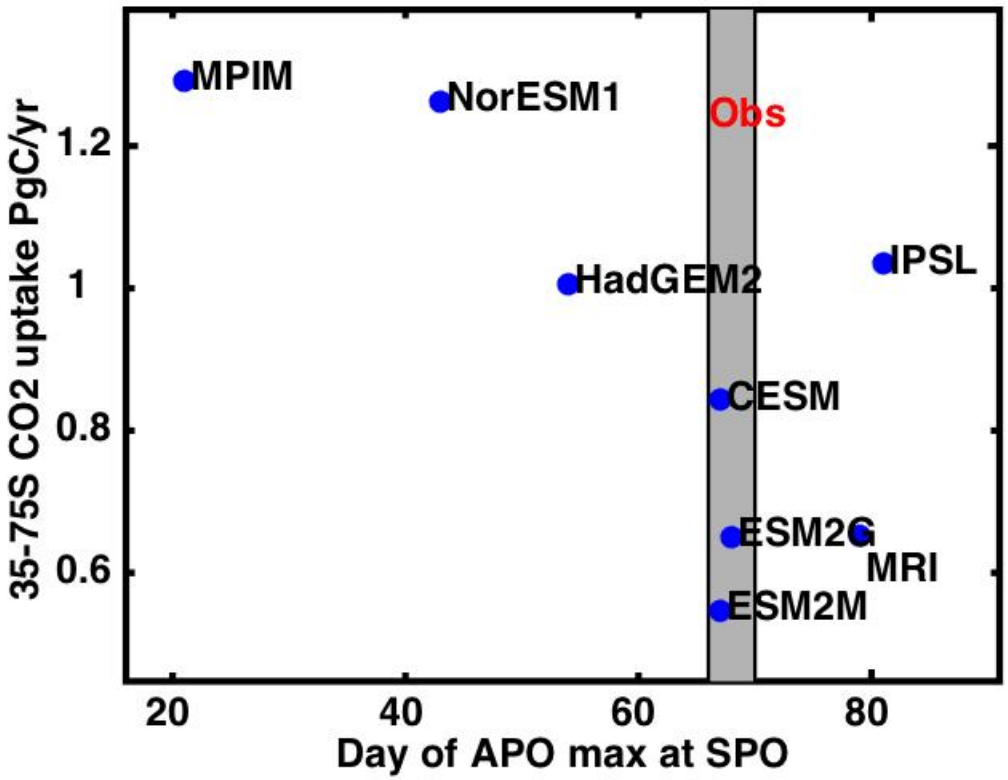
Nevison et al., 2015, Biogeosciences

Column APO: Model v. Observed



Observations from HIPPO aircraft campaign, Jonathan Bent, Ph.D. thesis

Models that best capture the observed APO seasonal cycle generally predict smaller Southern Ocean CO_2 sink



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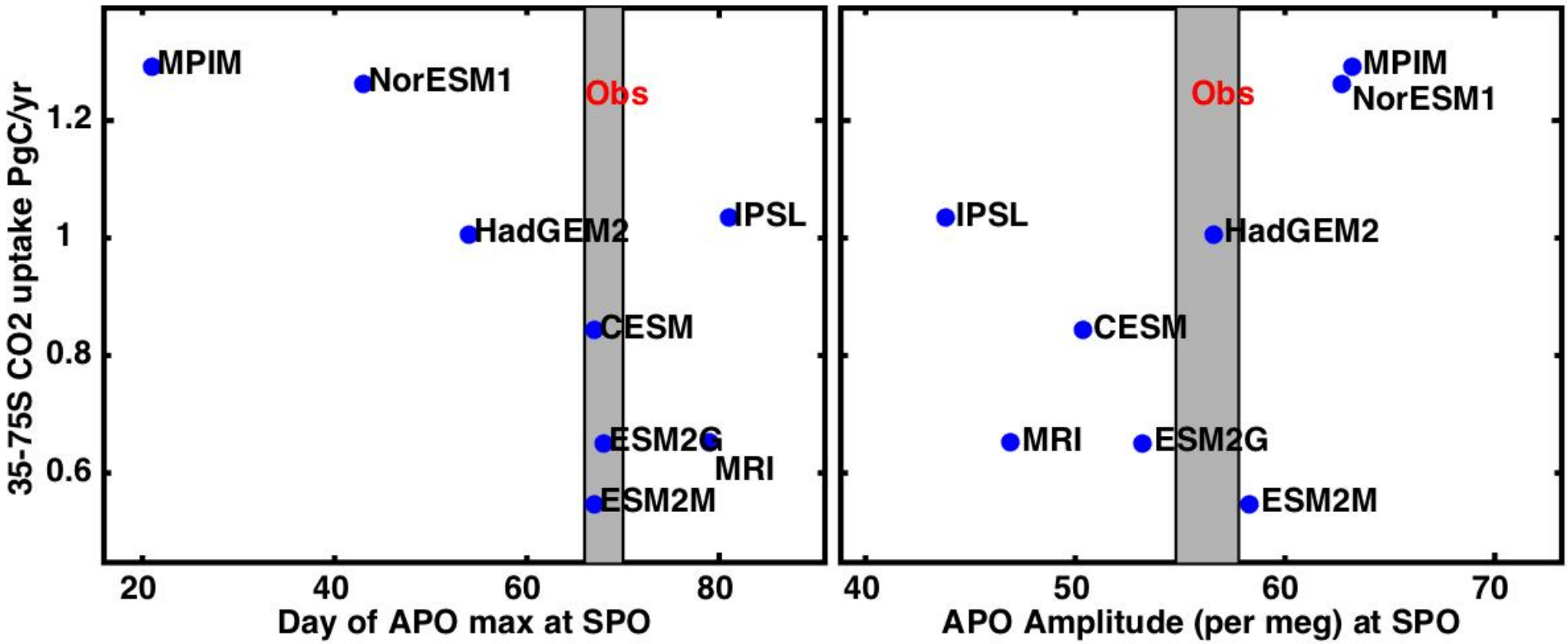
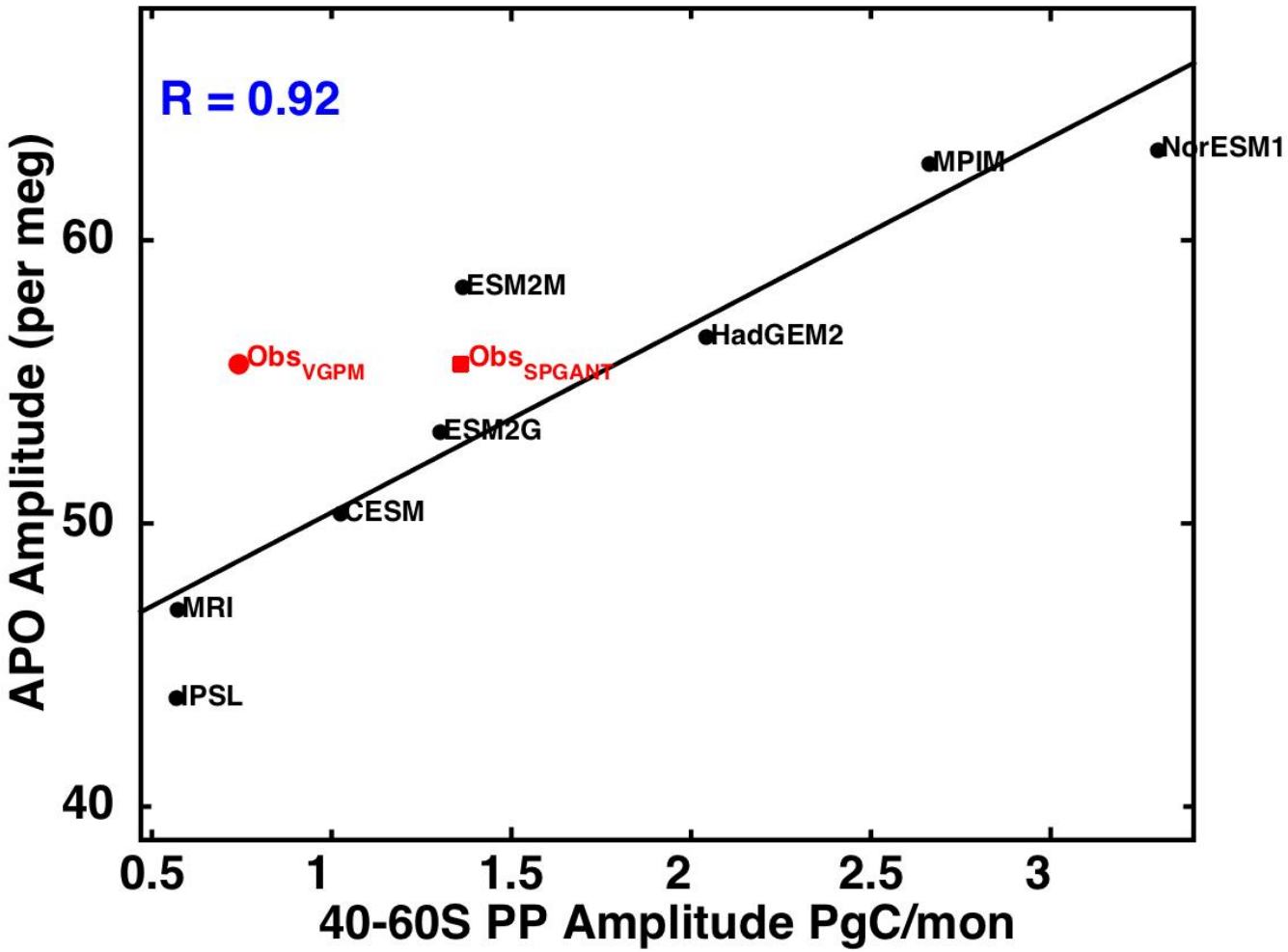


Amplitude of model APO seasonal cycle is correlated to Southern Ocean productivity



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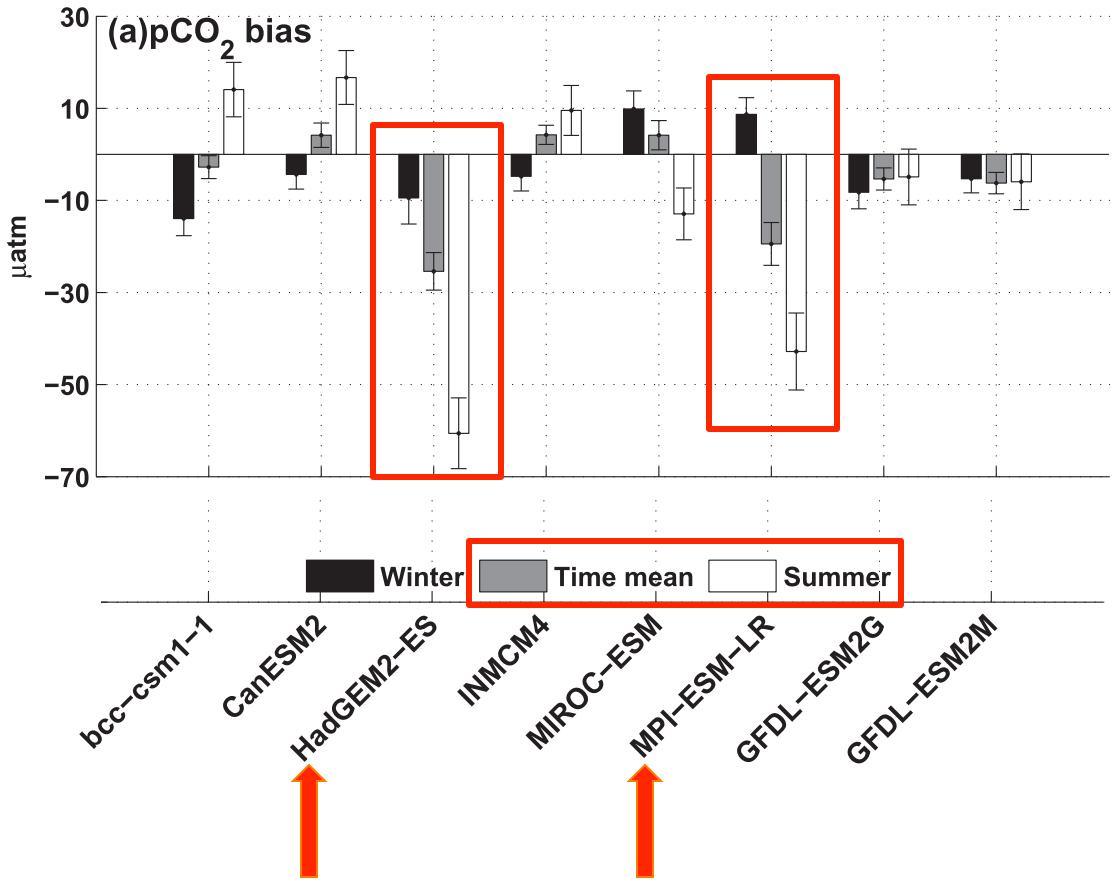
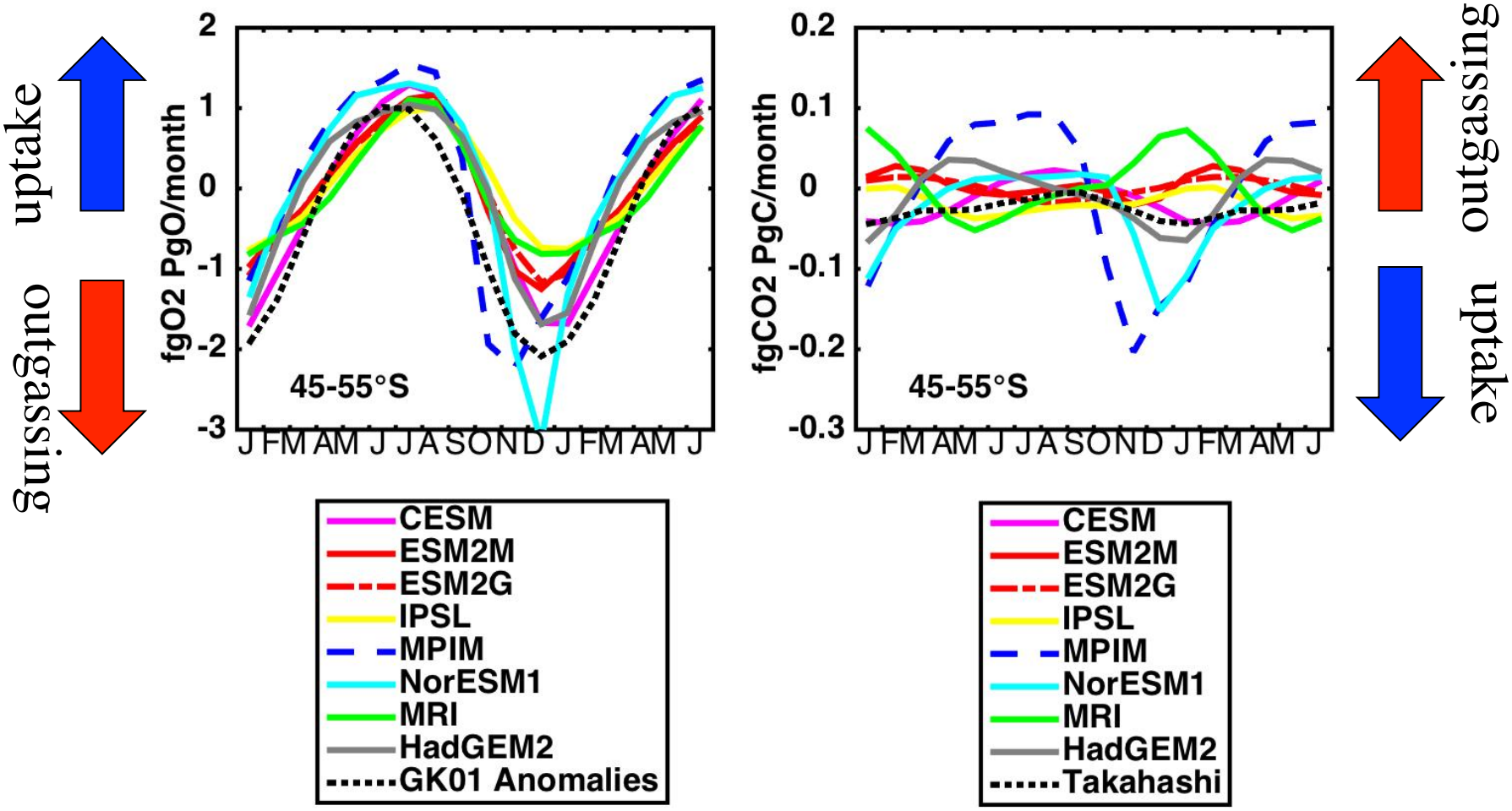
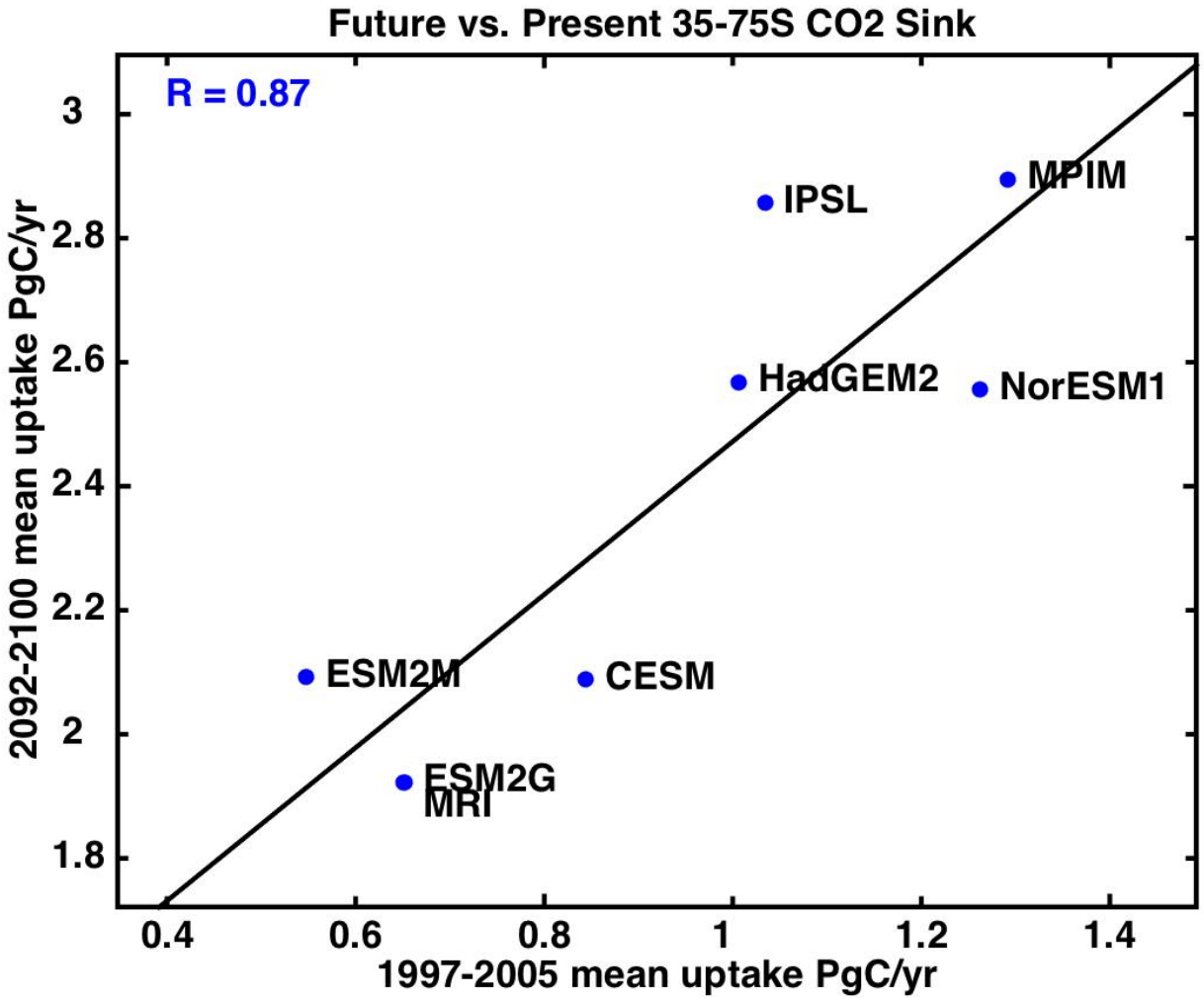


fgO_2 v. $fgCO_2$

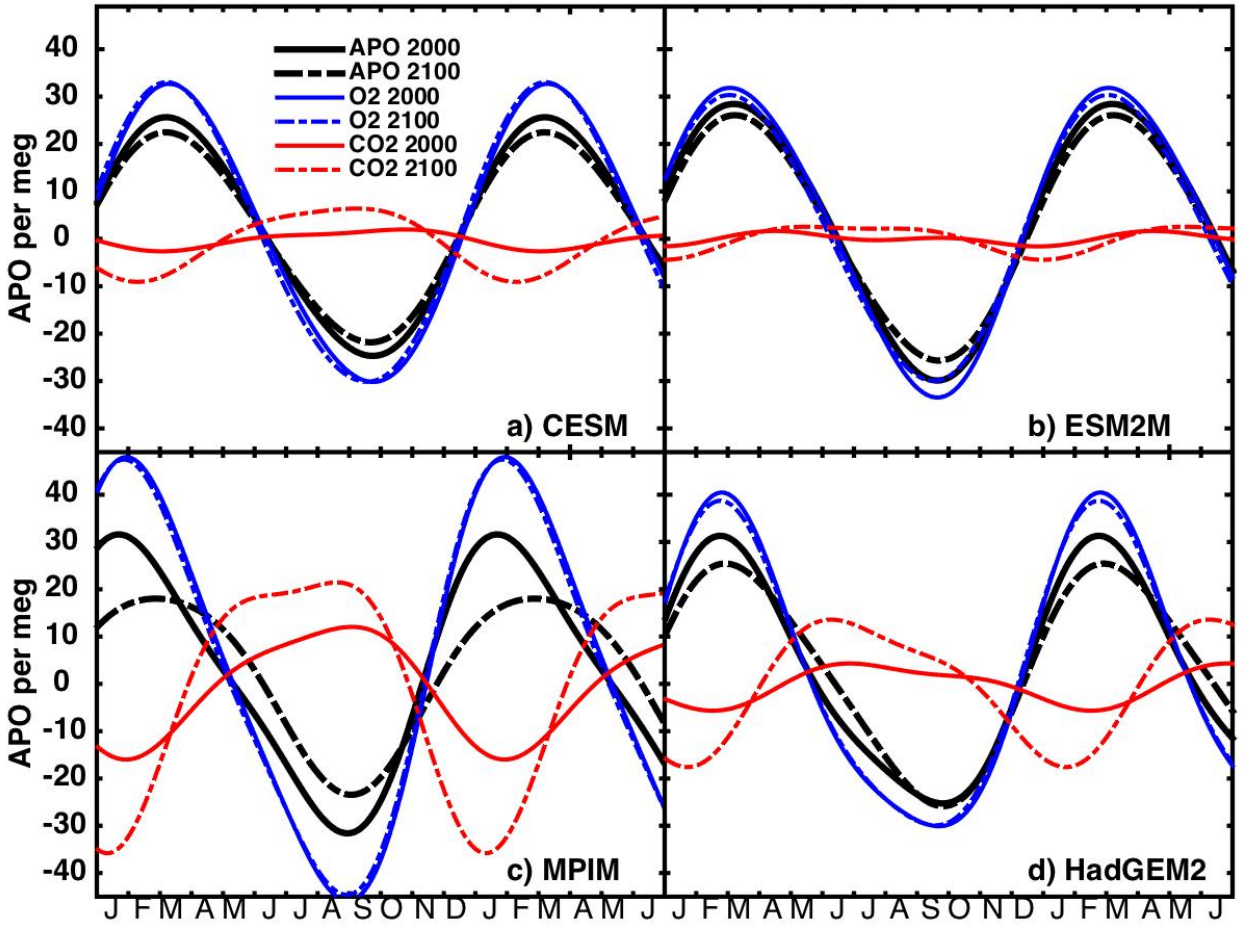

uptake
outgassing
fgO2 PgO/month
2
1
0
-1
-2
-3
45-55°S
J FM AM J J A SOND J FM AM J
CESM
ESM2M
ESM2G
IPSL
MPIM
NorESM1
MRI
HadGEM2
GK01 Anomalies
fgCO2 PgC/month
0.2
0.1
0
-0.1
-0.2
-0.3
45-55°S
J FM AM J J A SOND J FM AM J
outgassing
uptake
CESM
ESM2M
ESM2G
IPSL
MPIM
NorESM1
MRI
HadGEM2
Takahashi

Future APO under RCP8.5

Southern Ocean CO_2 sink under RCP8.5 correlated to present day sink

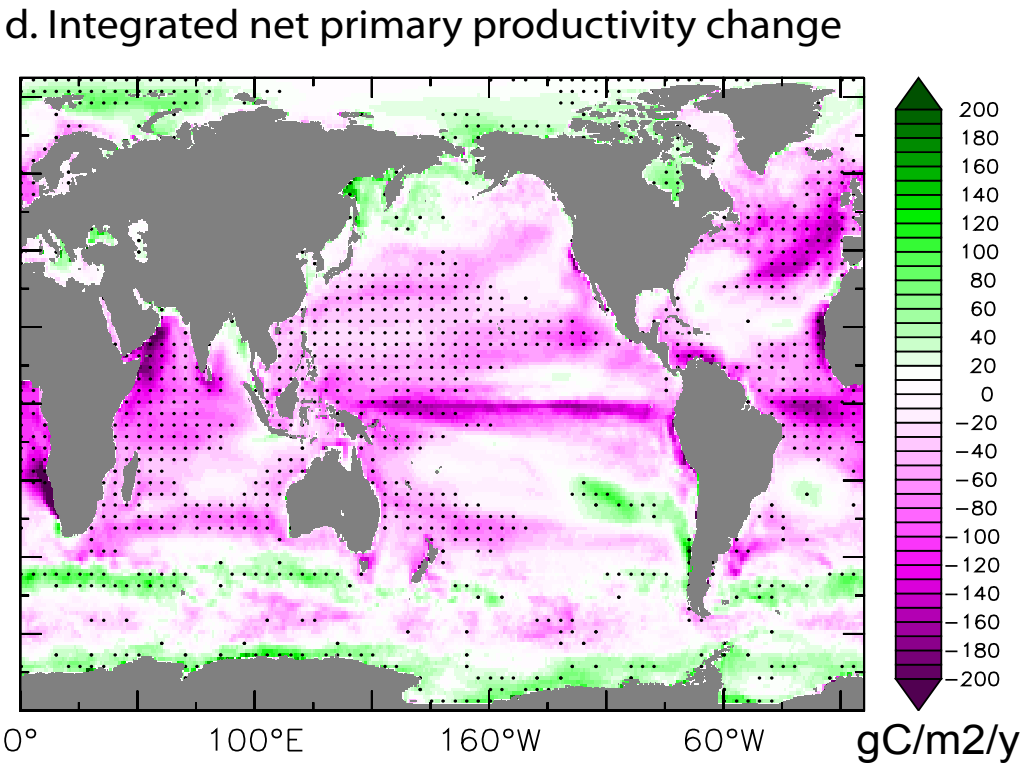


APO Historical v RCP8.5 at South Pole



Future changes in NPP under RCP8.5 in CMIP5 models (Bopp et al., 2013)

Figures show 2095-1995 difference



Summary

1. CMIP5 ocean models reproduce observed APO cycles in the Southern Ocean region with varying skill. Ranking of models consistent across matrix method, column average, and GEOS-Chem results at SPO.

2. Models that capture present-day APO cycle the best tend to predict a smaller Southern Ocean CO_2 sink, for both historical and RCP8.5 runs.

3. CMIP5 Models predict relatively small future changes in the O_2 component of APO under RCP8.5 at Southern Hemisphere stations, but some predict large changes in the oceanic CO_2 component.