NCAR
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NCAR Earth System Laboratory
Climate & Global Dynamics

ORCAS modeling frameworks

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ORCAS STM

Objectives

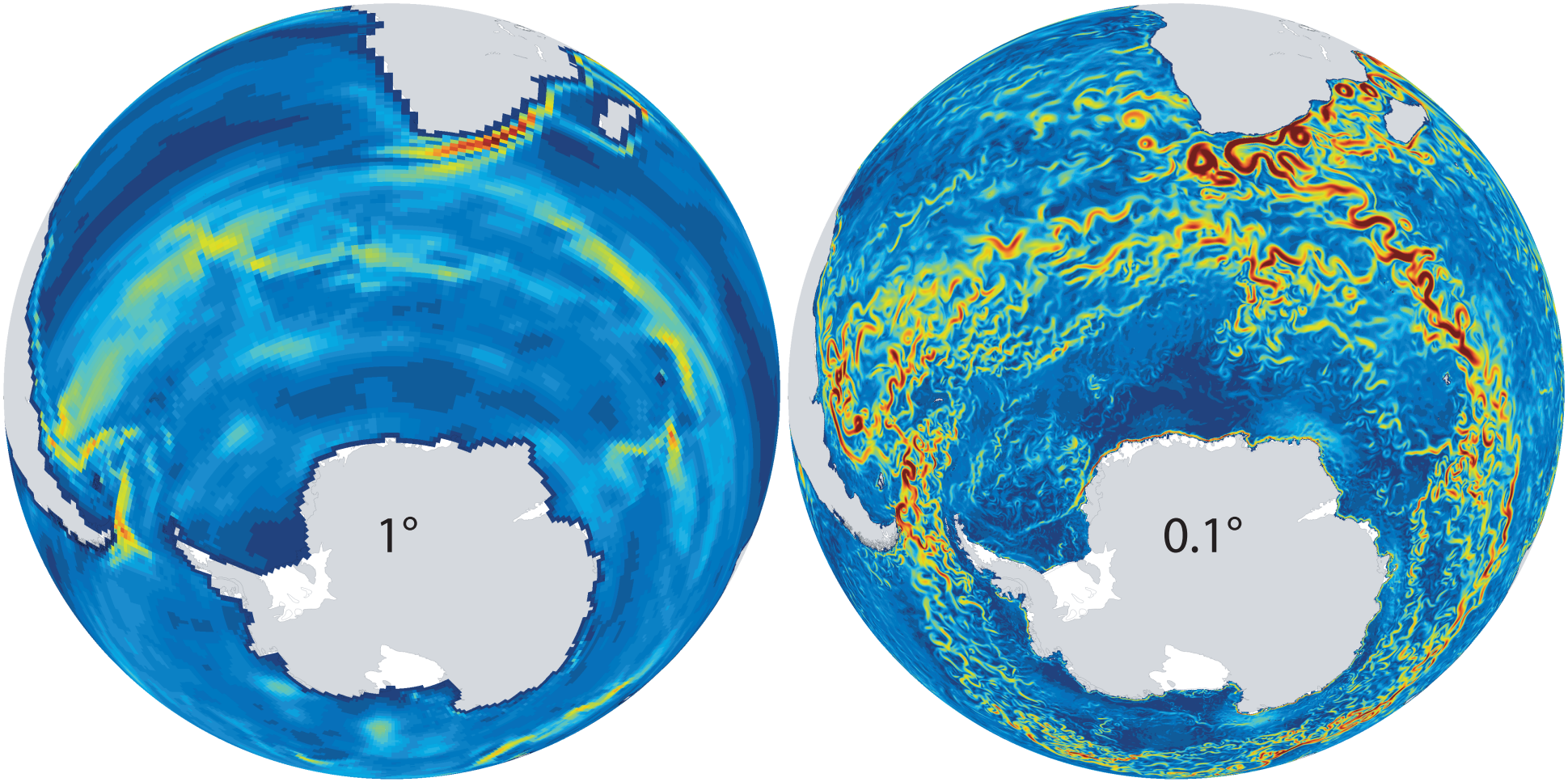
- → Contextualize the field campaign: understand time evolution, process contributions.
- → Evaluate relationship between seasonal net outgassing and column integrals (O_2,CO_2).
- → Develop process-understanding of the mechanisms driving fluxes and variations in the O_2:CO_2 ratio.
- → Identify model deficiencies; suggest improvements.

Model configurations

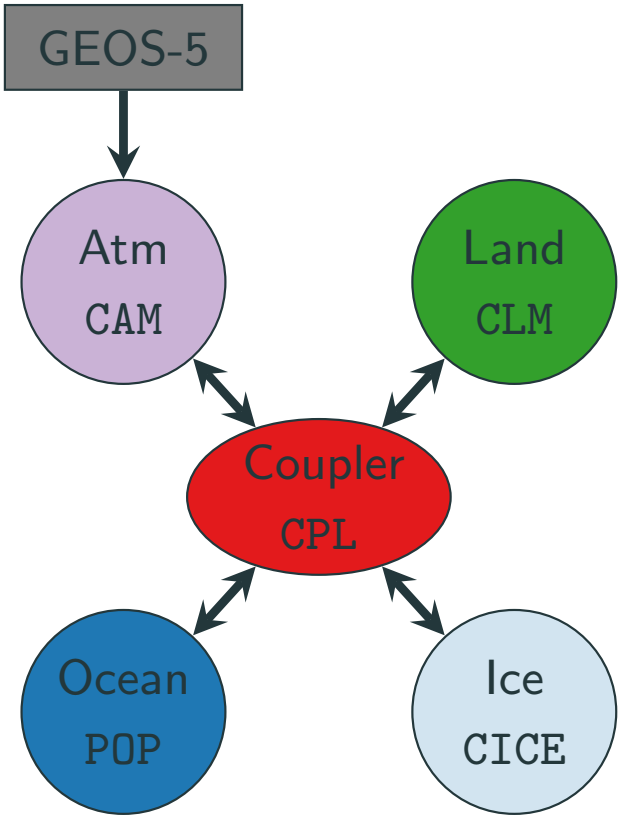
Compset	Description	Resolutions	Notes
B	Fully coupled	1°	• long control runs ($\mathcal{O}(10^3)$ yr) • internal variability, not in phase with nature • experimental application: nudge atm. state to forecast product (GEOS5, MERRA); prognostic column physics
F	Atmosphere-land	2° 1° 0.25°	• forced by observed SST • specified dynamics: nudge state to re-analysis or forecast products (MERRA, GEOS5)
G	Ocean-ice	1° 0.1°	• forced by re-analysis products • climatological or inter-annually varying forcing

Sluggish versus energetic oceans

Kinetic energy



CAM-SD coupled configuration



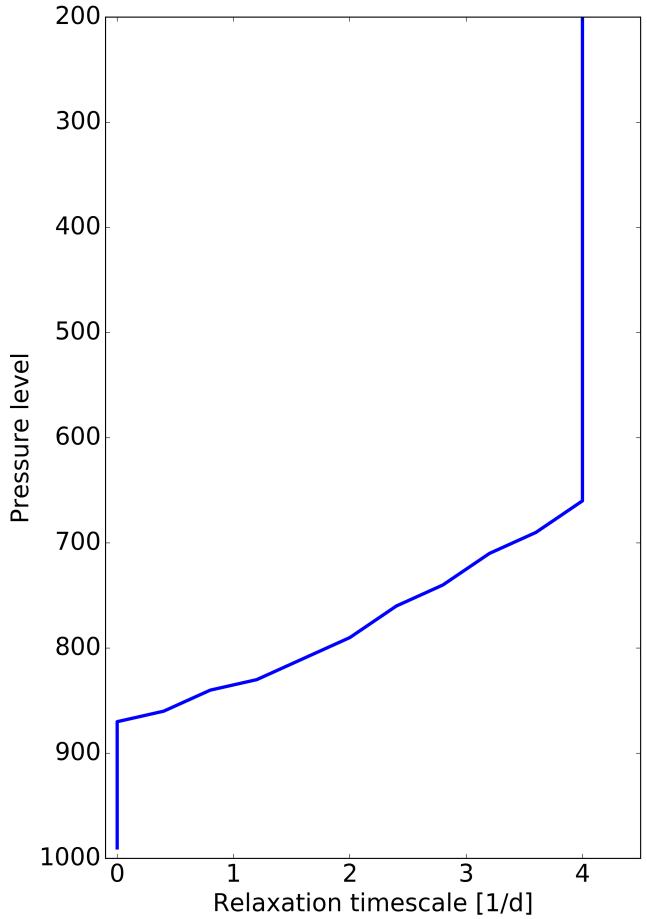
Initialized 3-day forecasts every day:

nudge CAM to GEOS-5 forecast model;

fully coupled, prognostic air-sea fluxes.

- O_2 and CO_2 distributions;
- Idealized tracers for source regions.

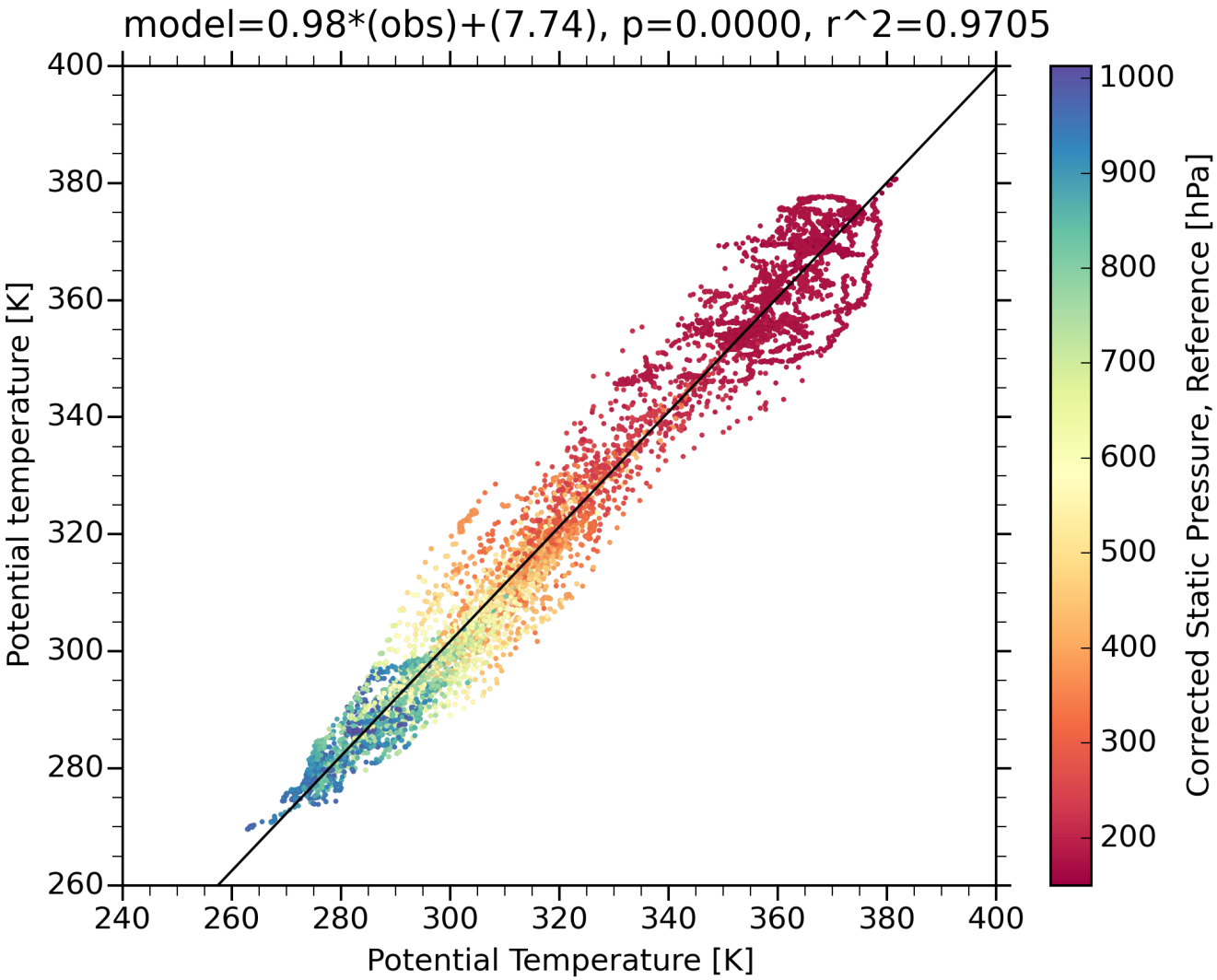
Nudging timescale



Special thanks to Francis Vitt, Jean-Francois Lamarque Andrew Gettlman and Simone Tilmes

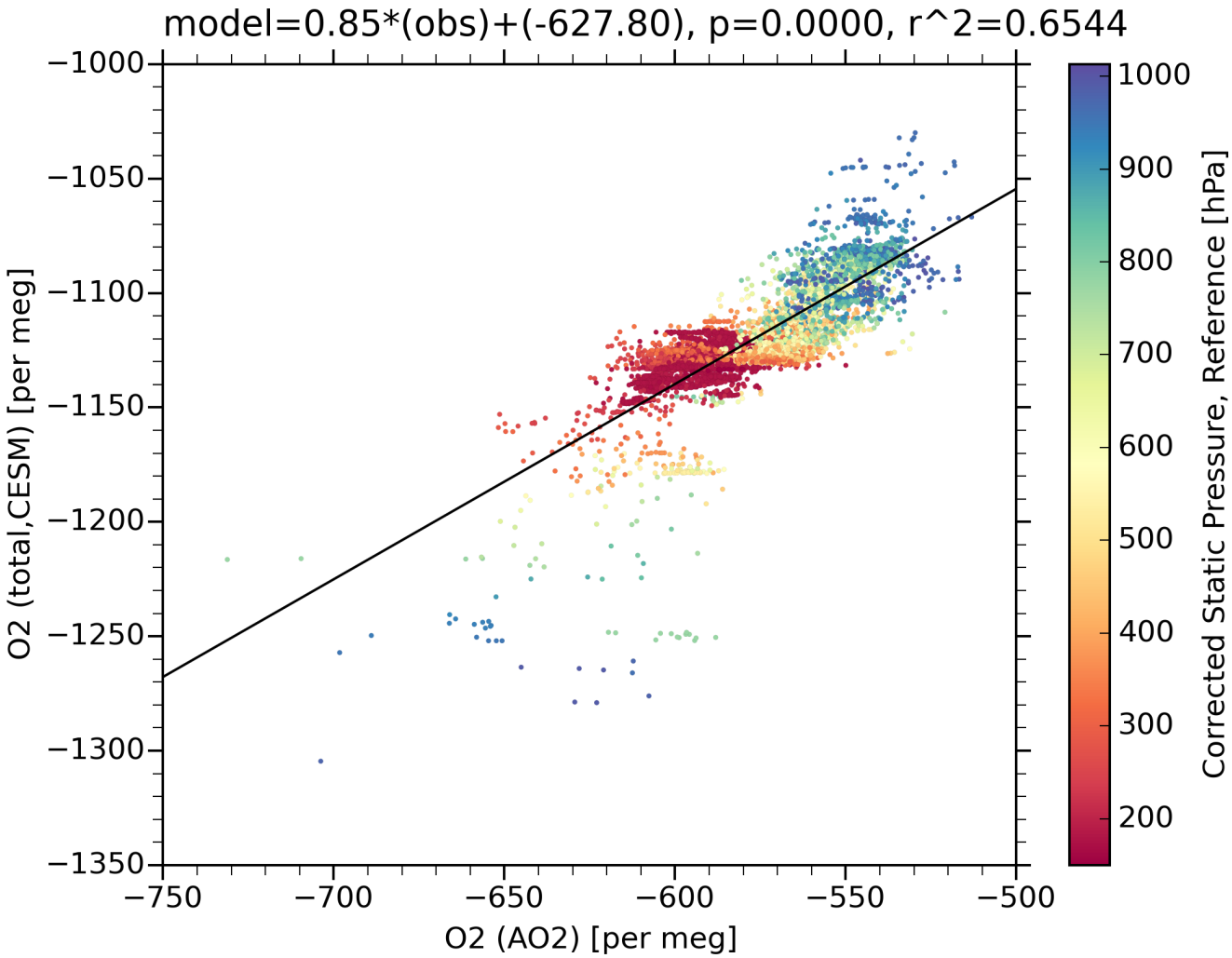
Atmospheric state validation: model versus GV

Potential temperature simulation



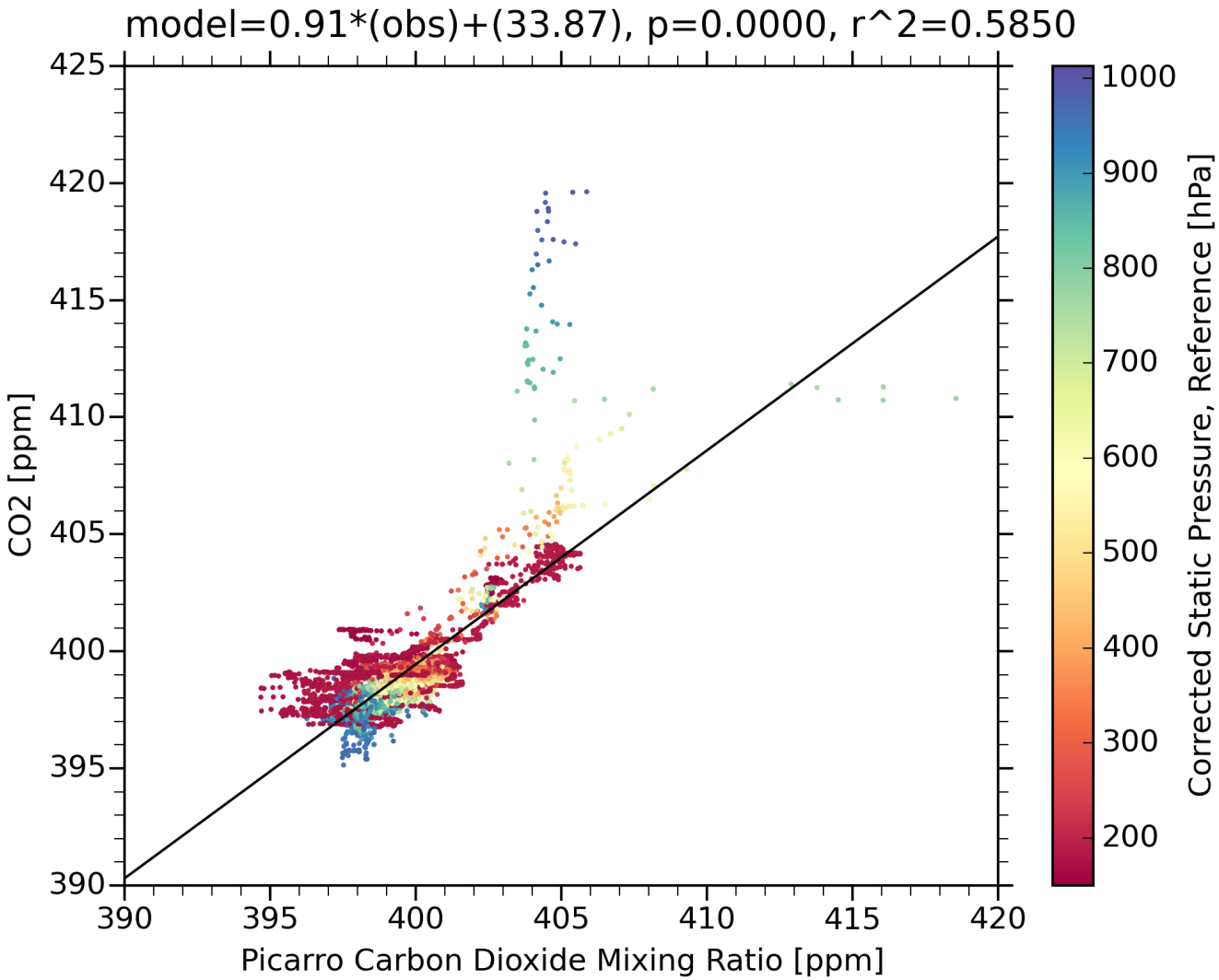
Concentration predictions: model versus GV

O_2 simulation



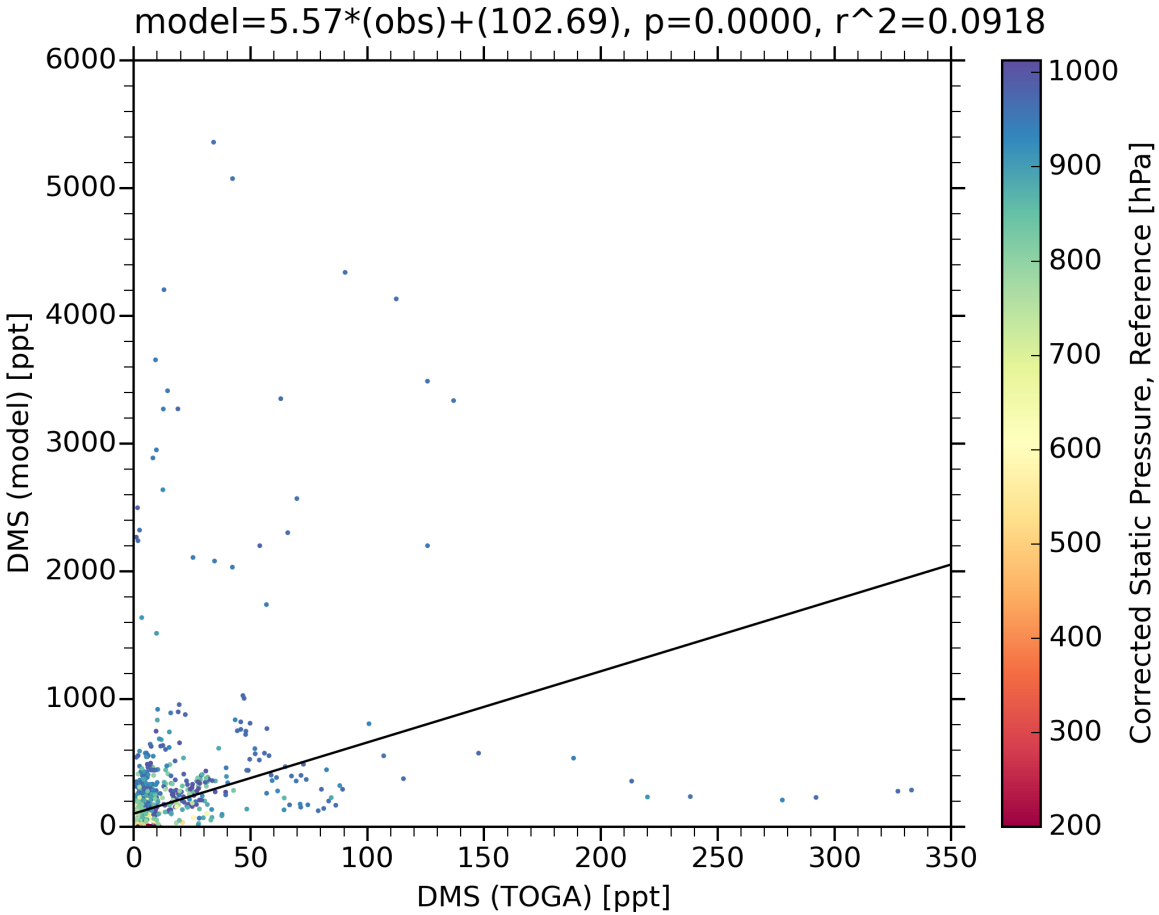
Concentration predictions: model versus GV

CO_2 simulation



Concentration predictions: model versus GV

DMS simulation



Fixed emission climatology

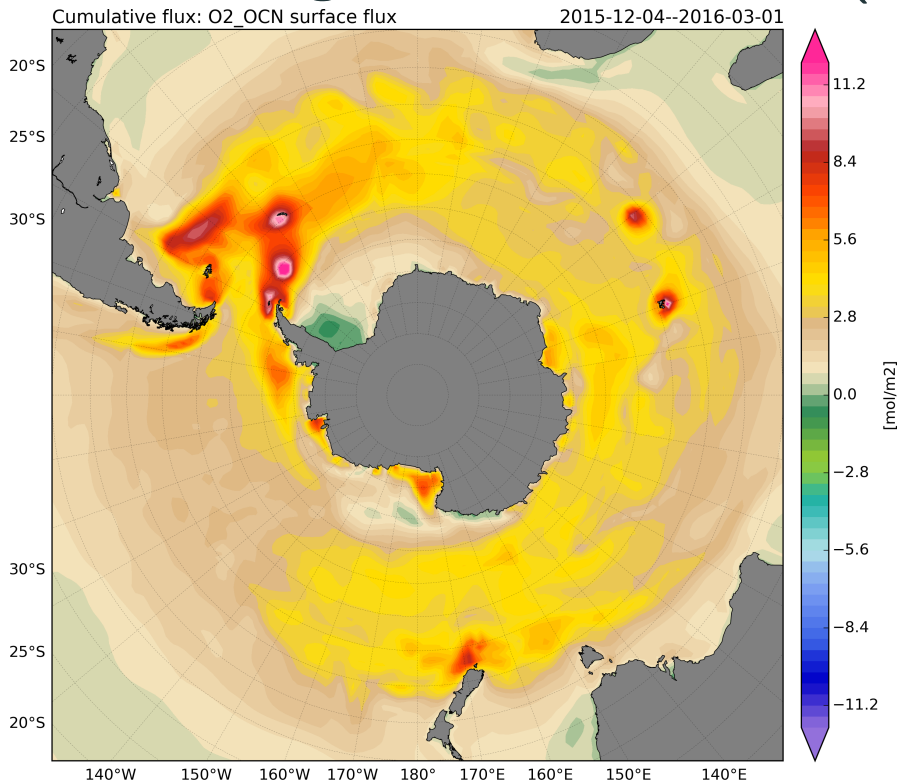
Limited prognostic chemistry

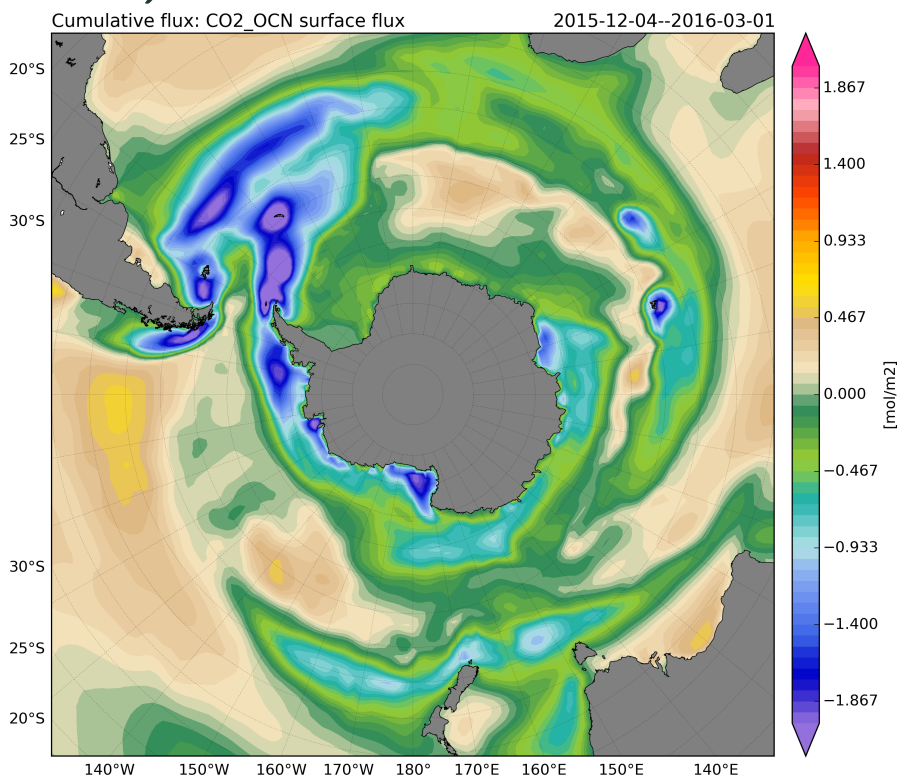
```
HO2 + HO2 -> H2O2
H2O2 + OH -> H2O + HO2
SO2 + OH -> H2SO4
DMS + OH -> SO2
DMS + OH -> .5 * SO2 + .5 * HO2
DMS + NO3 -> SO2 + HNO3
```

SOx concentrations specified.

Simulated fluxes

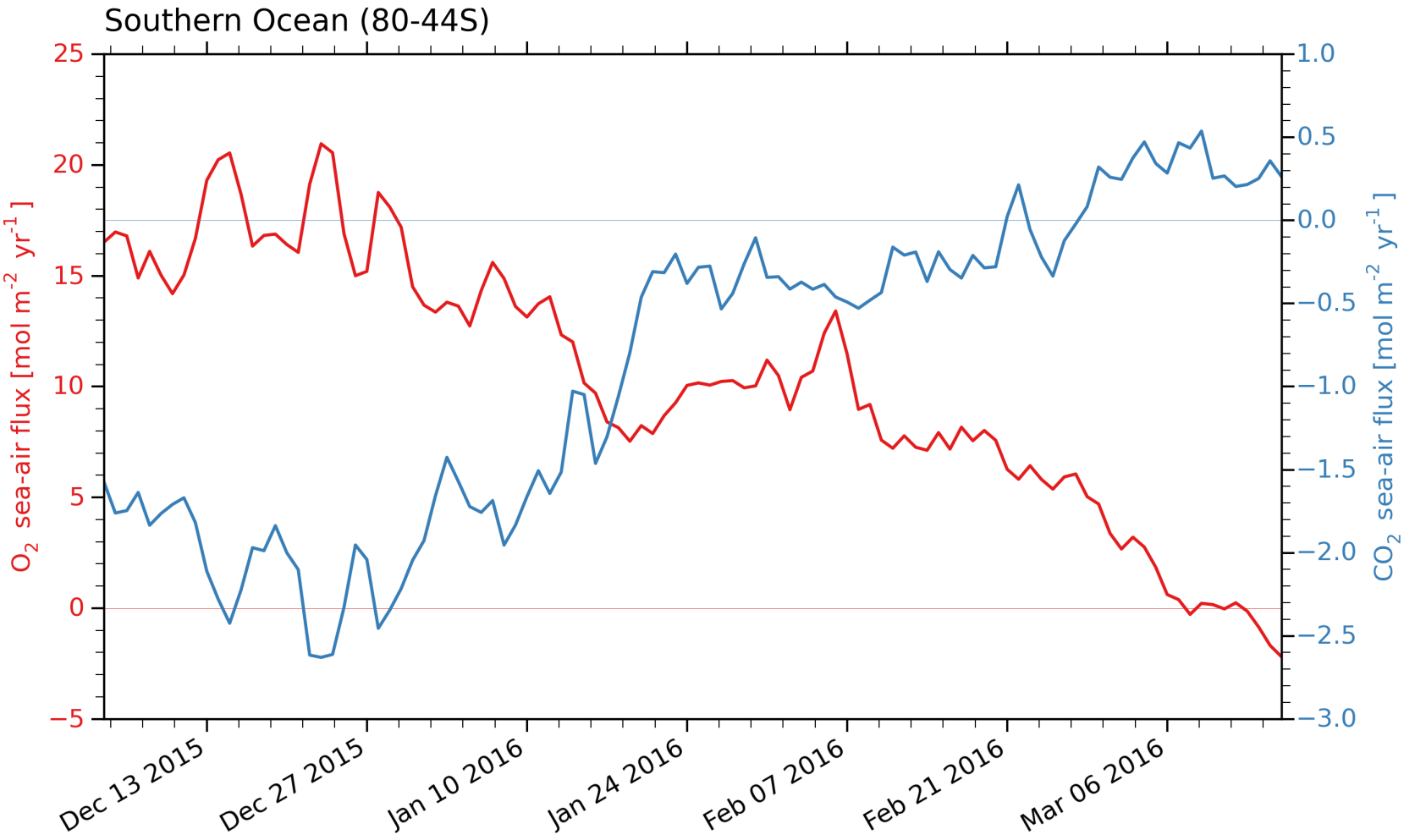
Time-integrated surface fluxes (Dec–Feb)





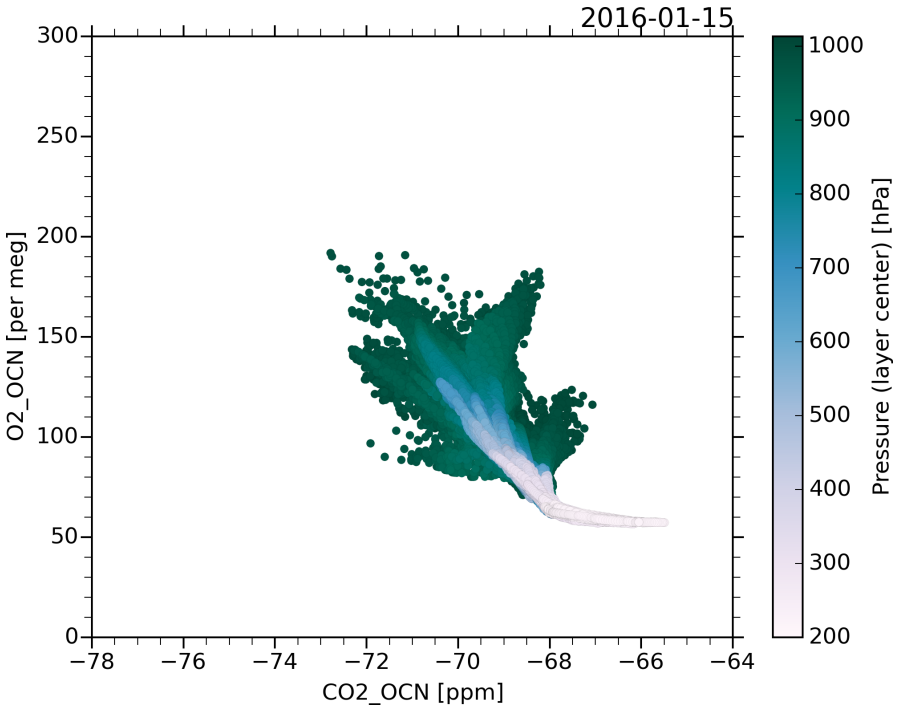
Time evolution of surface fluxes

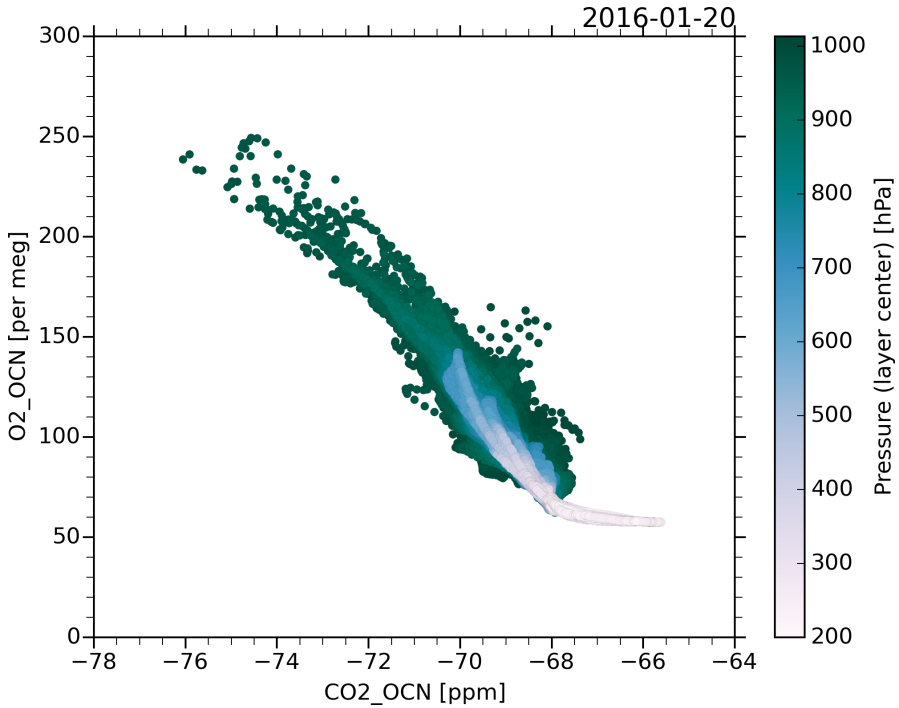
Simulated fluxes (Dec-Mar)



Simulated O_2:CO_2 ratios

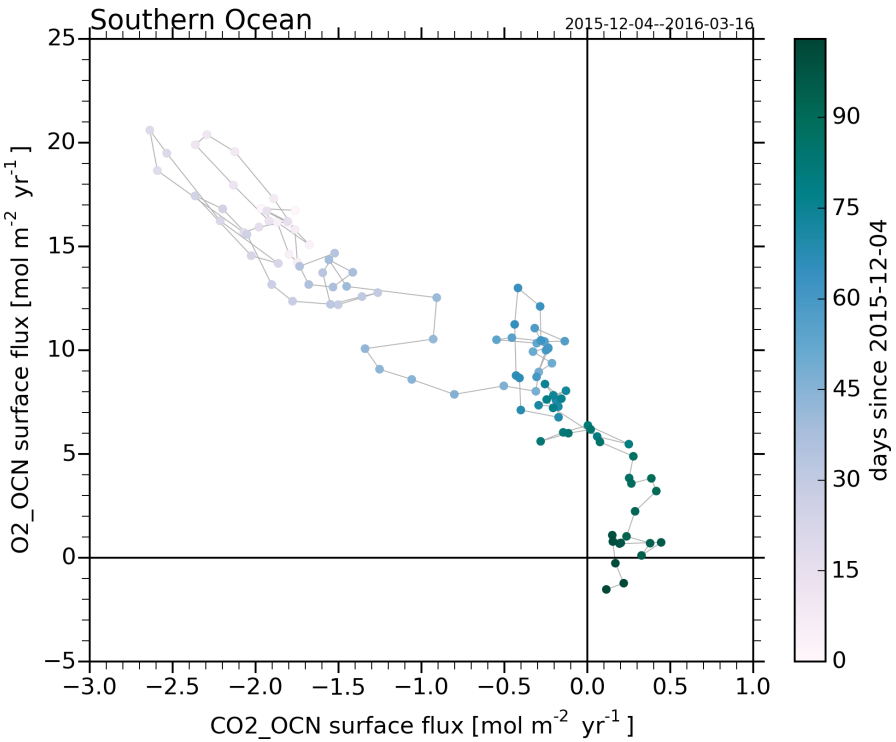
Daily mean mixing ratios (Southern Ocean)

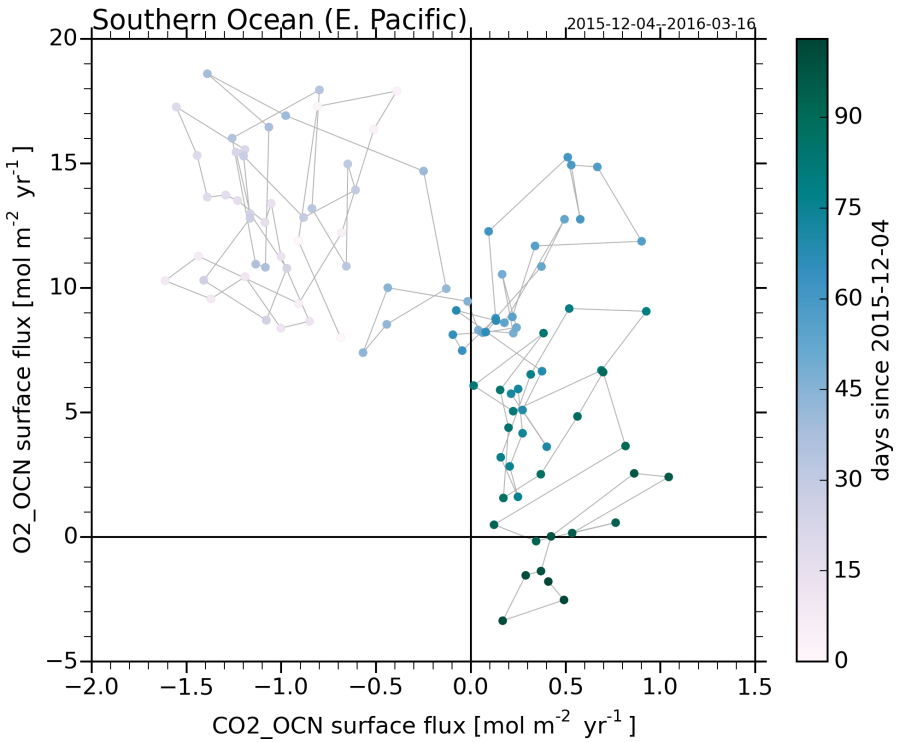




Simulated O_2:CO_2 ratios

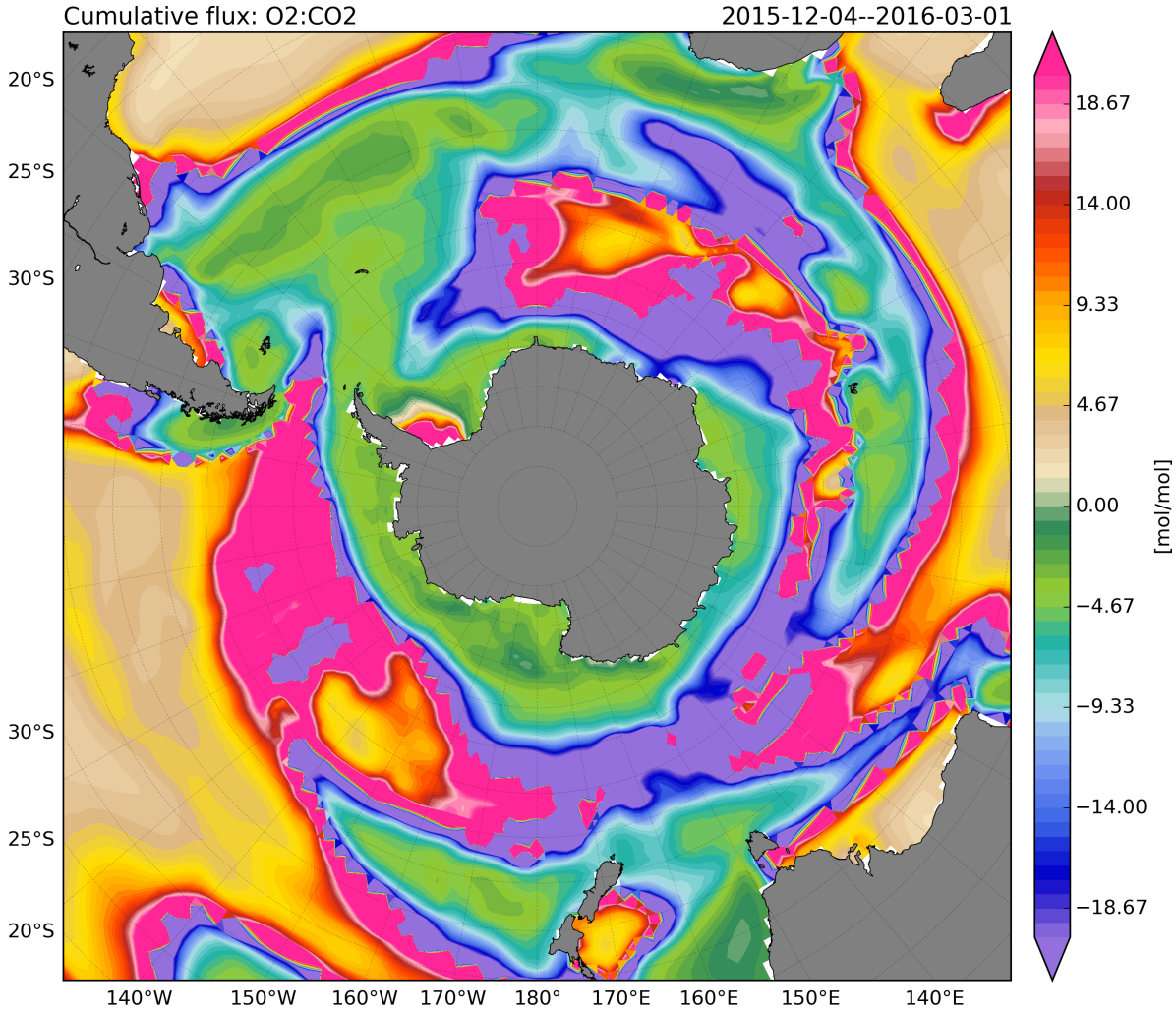
Surface fluxes in phase space (Dec–Feb)





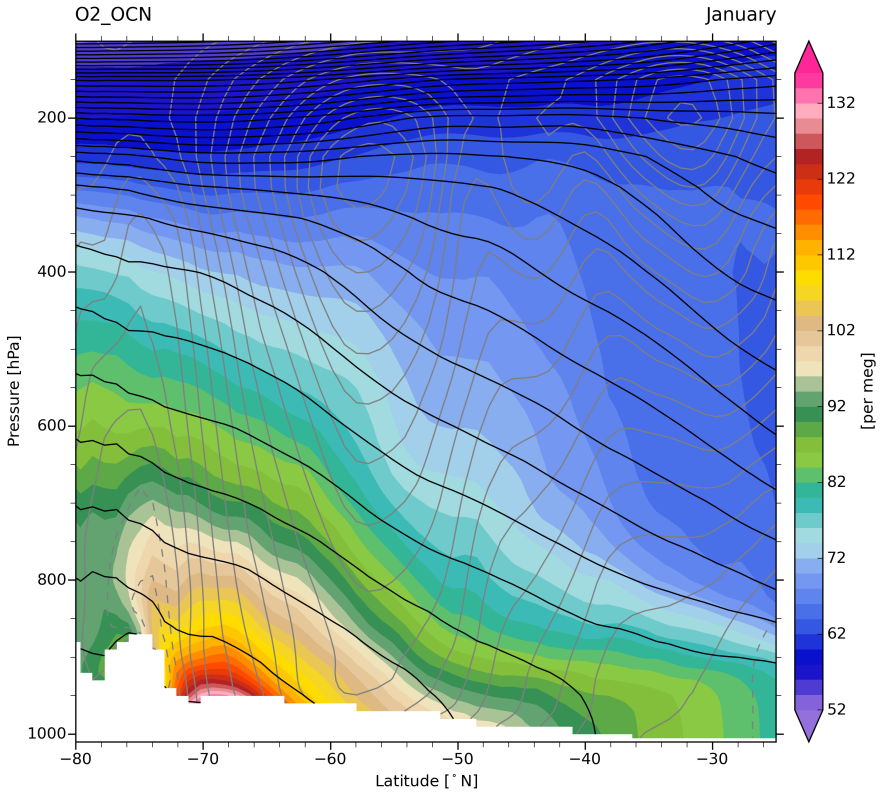
Simulated O_2:CO_2 ratios

Time-integrated surface flux O_2:CO_2 ratio (Dec–Feb)

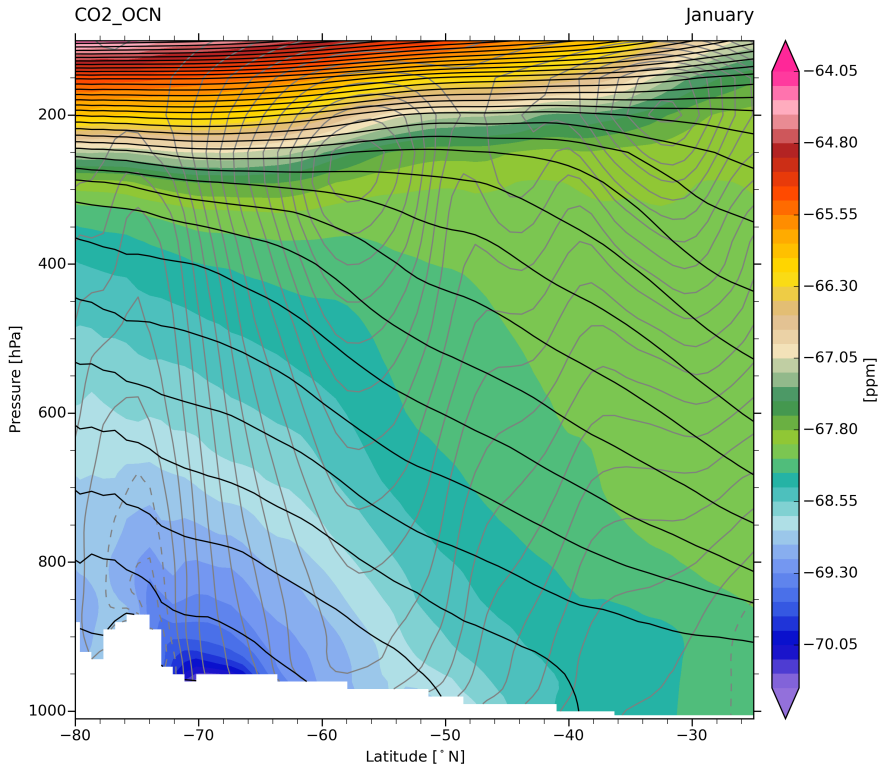


Hemispheric signals: constraints on seasonal net flux?

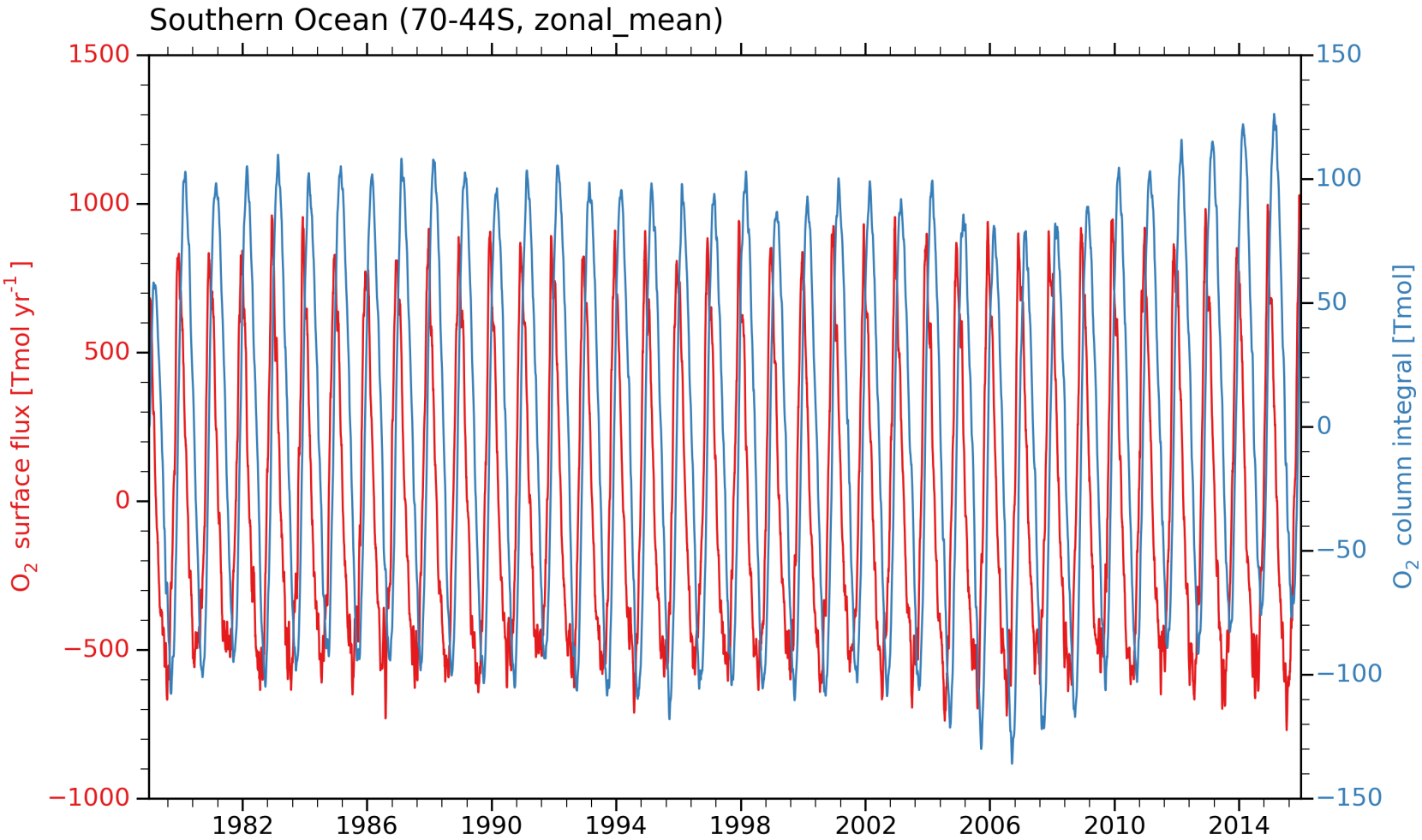
Oxygen



Carbon dioxide

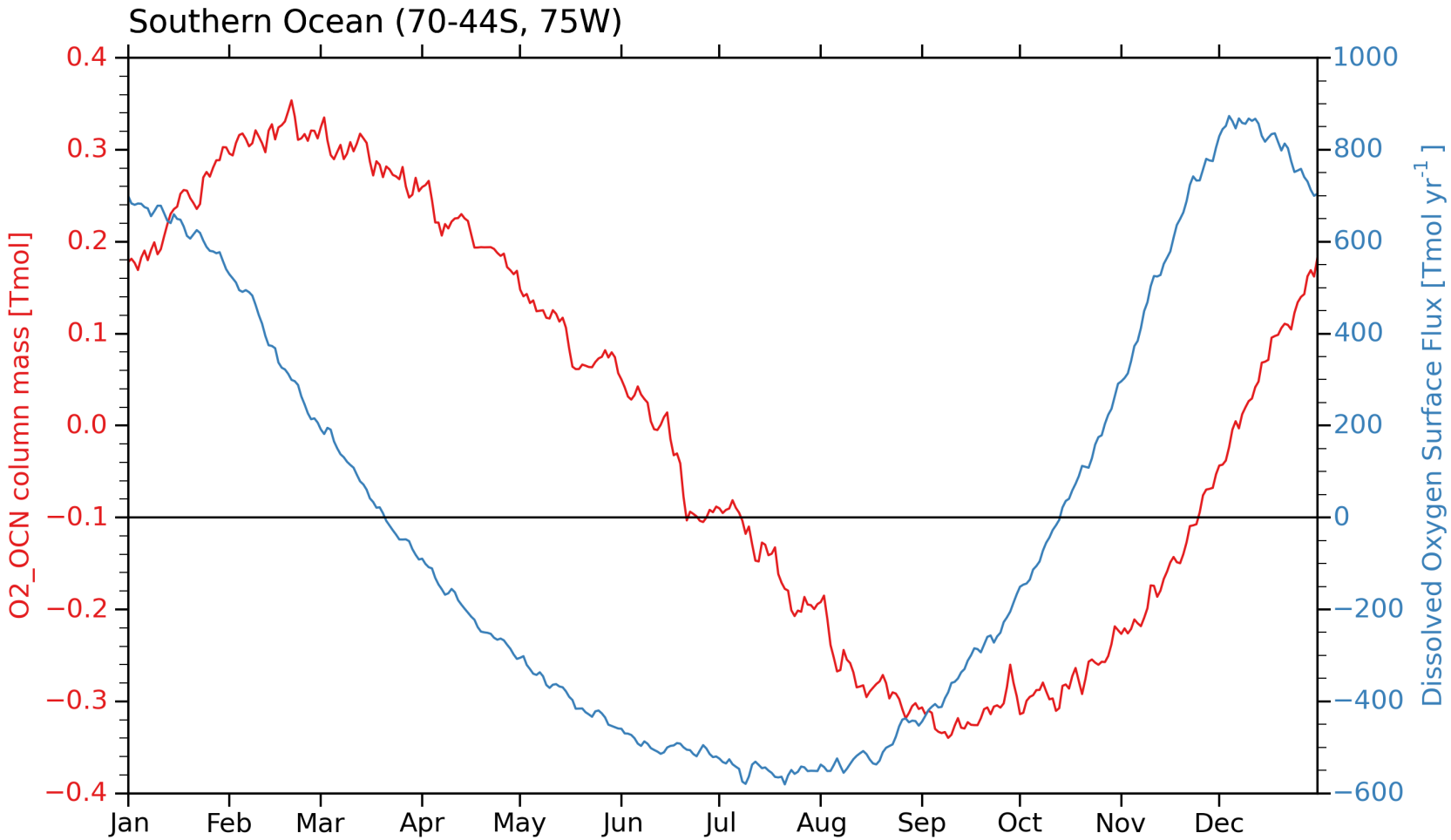


Seasonal net outgassing and column integral



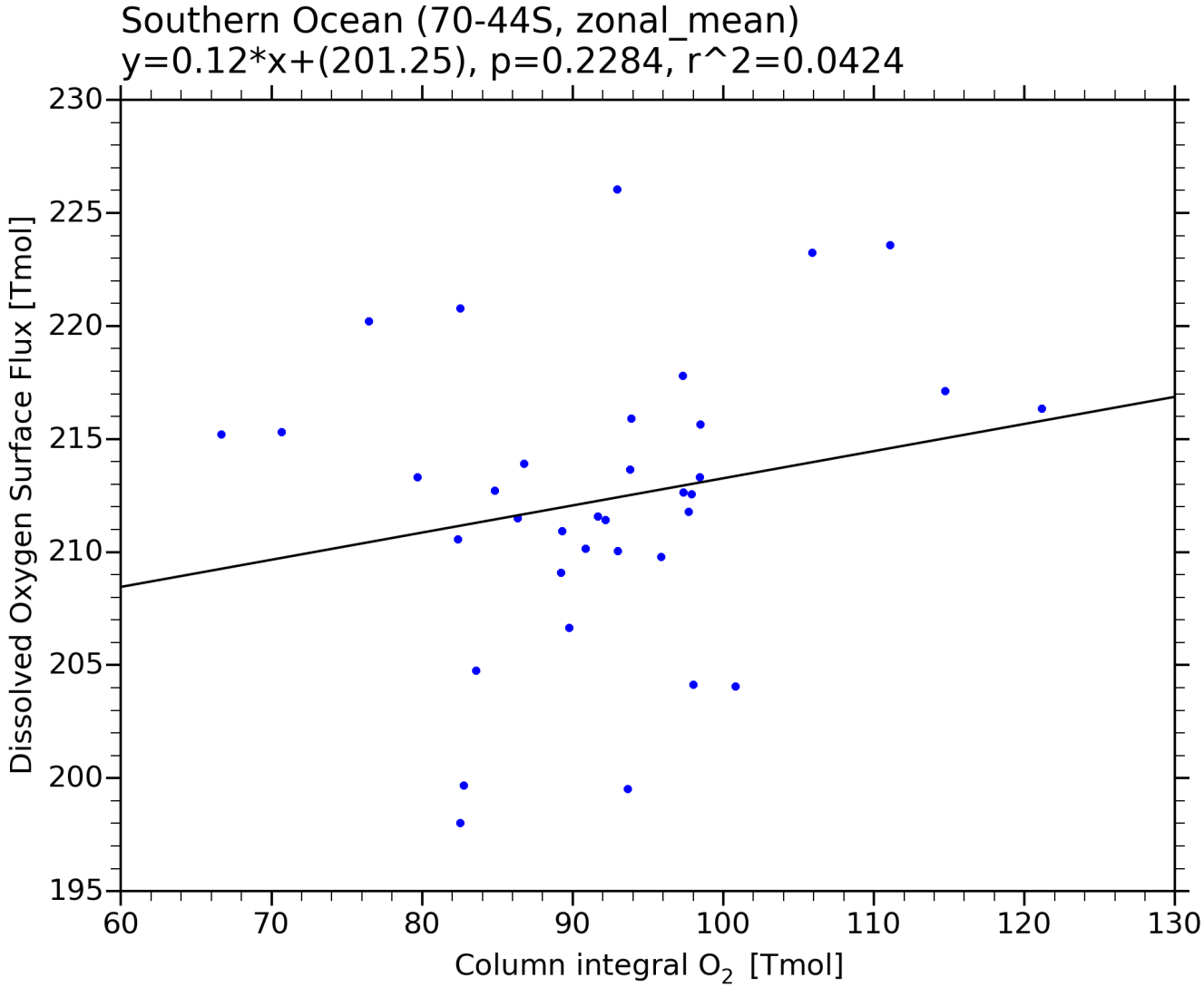
Seasonal net outgassing and column integral

Climatology (1979-2015)



Seasonal net outgassing and column integral

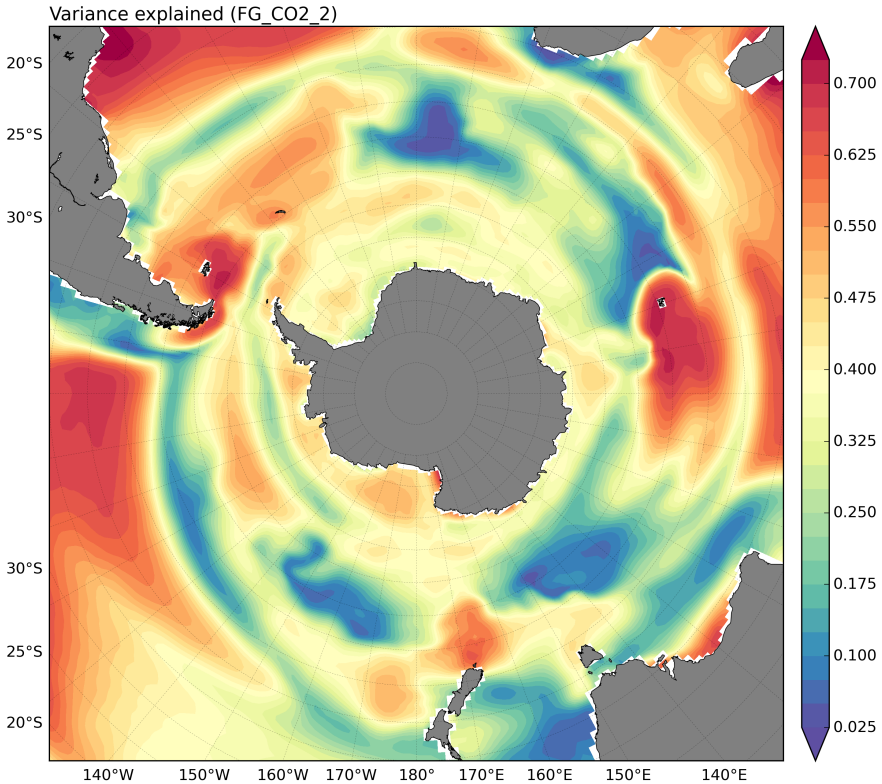
Flux versus column integral (1979-2015)



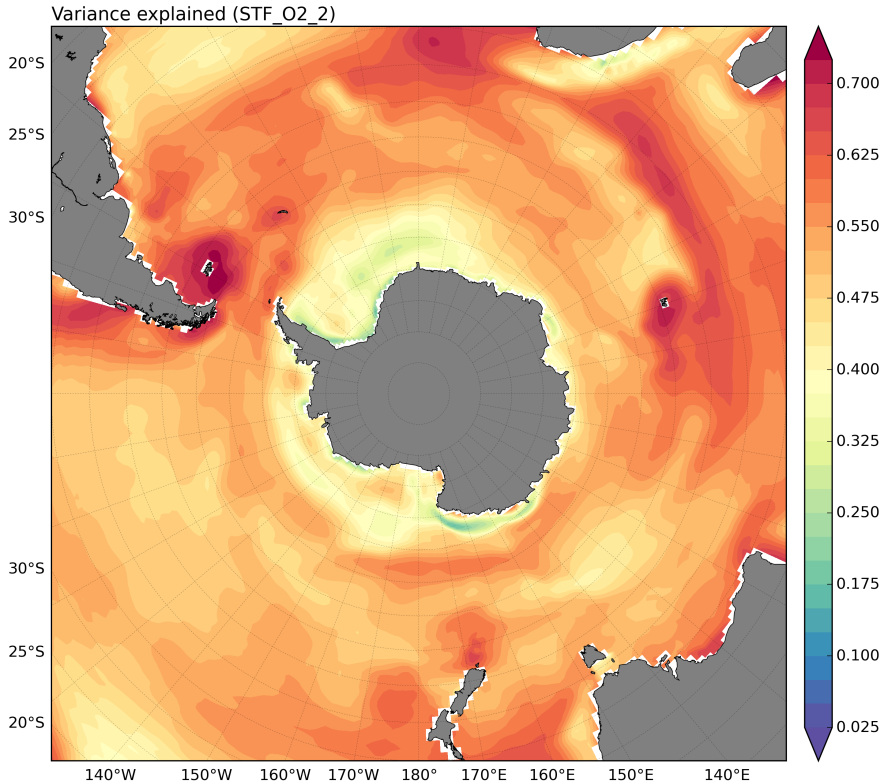
Synoptic variability drives CO_2 flux

Variance explained by climatology (detrended)

CO_2



O_2



1948–2015 CESM hindcast (g.e11_LENS.GECOIAF.T62_g16.009; modified CORE-forcing)

Flux decomposition

Reynold's decomposition

$$c = \overline{c} + c'$$

where

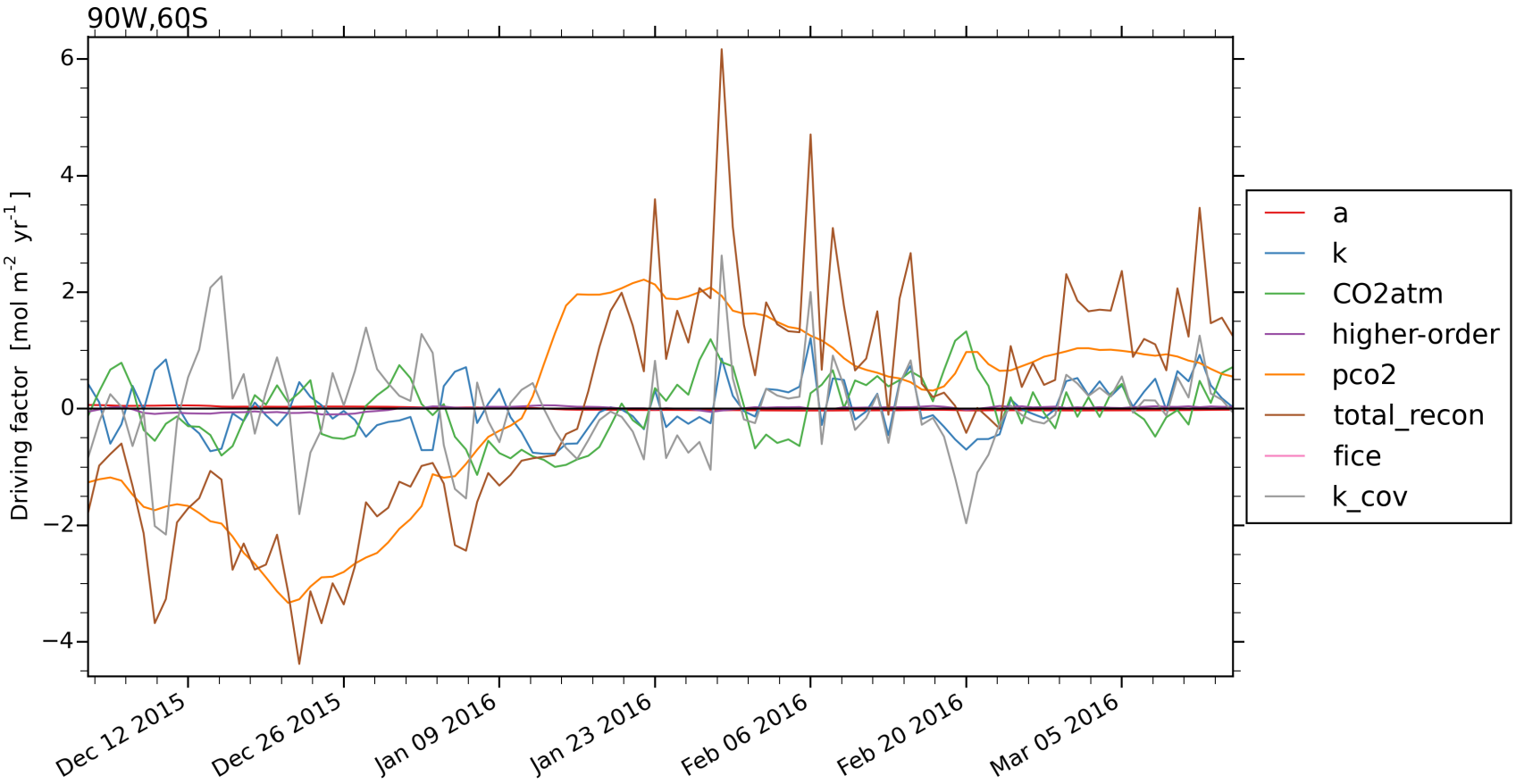
$$\overline{\overline{c}} = \overline{c} \text{ and } \overline{c'} = 0$$

Linear decomposition of anomalies for function of two variables

$$\begin{aligned} F &= AB \\ F' &= (AB)' = AB - \overline{(AB)} \\ &= A'\overline{B} + \overline{A}B' + A'B' + \overline{A'B'} \end{aligned}$$

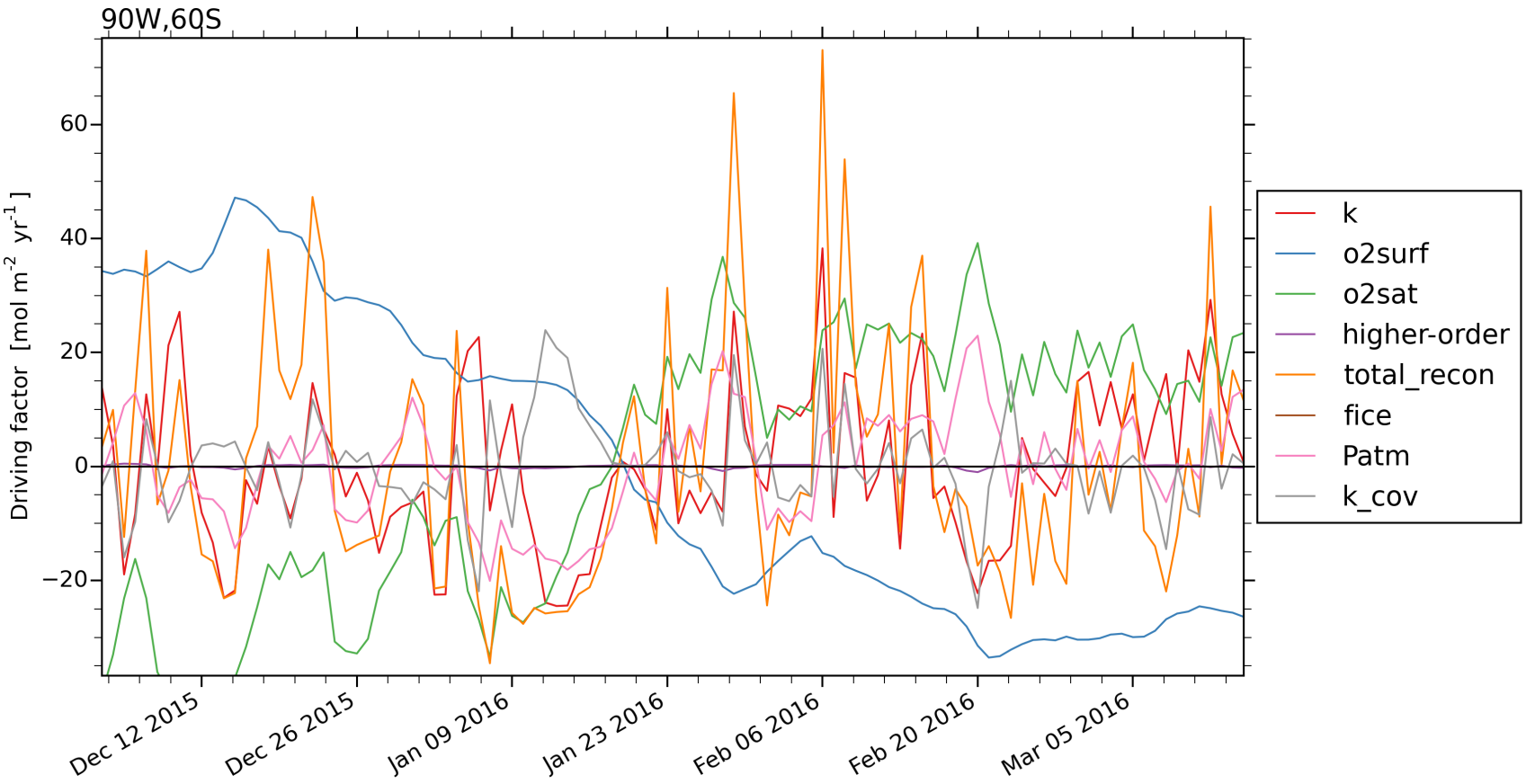
Flux decomposition

CO_2 flux components (at arbitrary point)

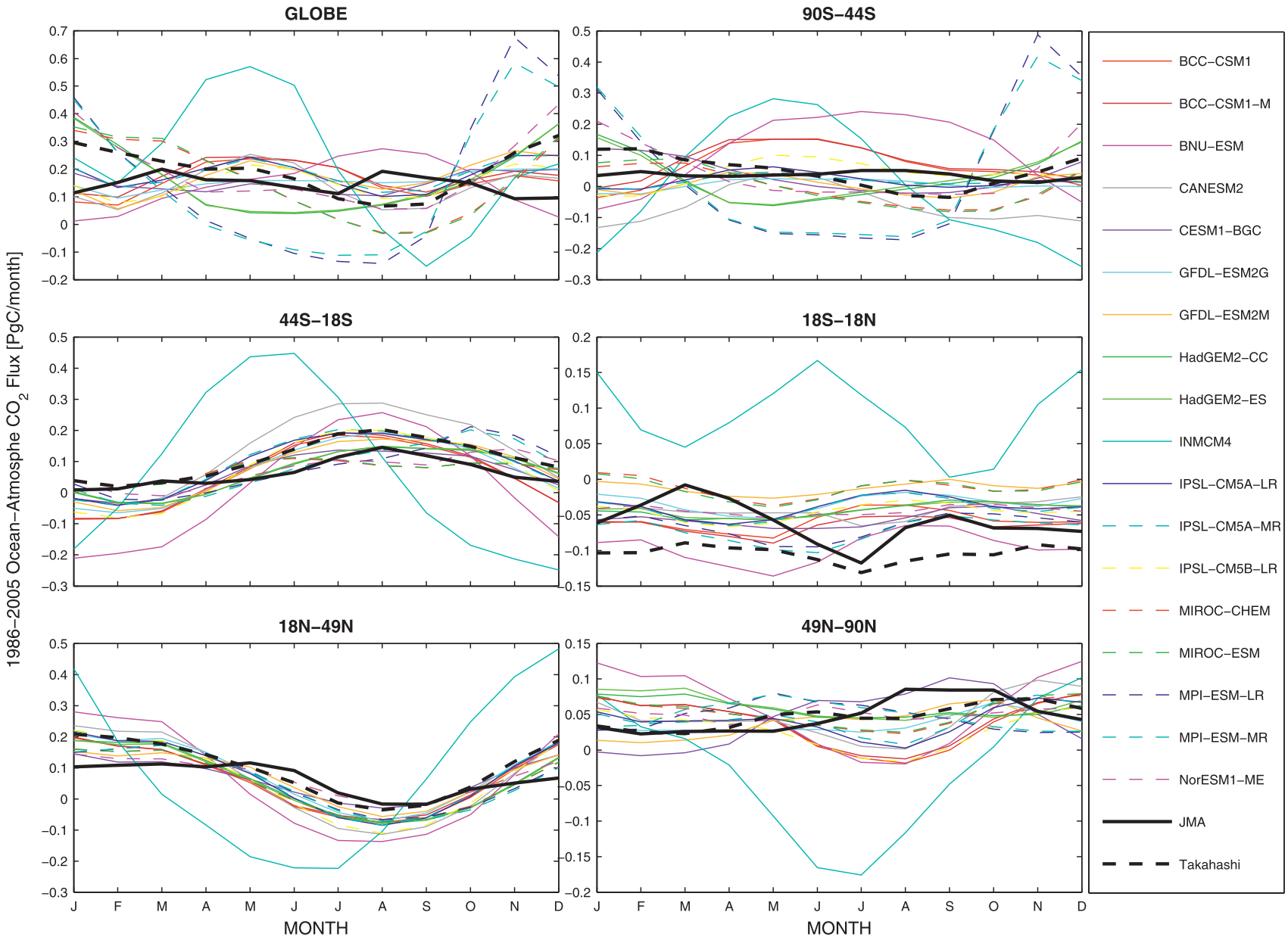


Flux decomposition

O_2 flux components (at arbitrary point)

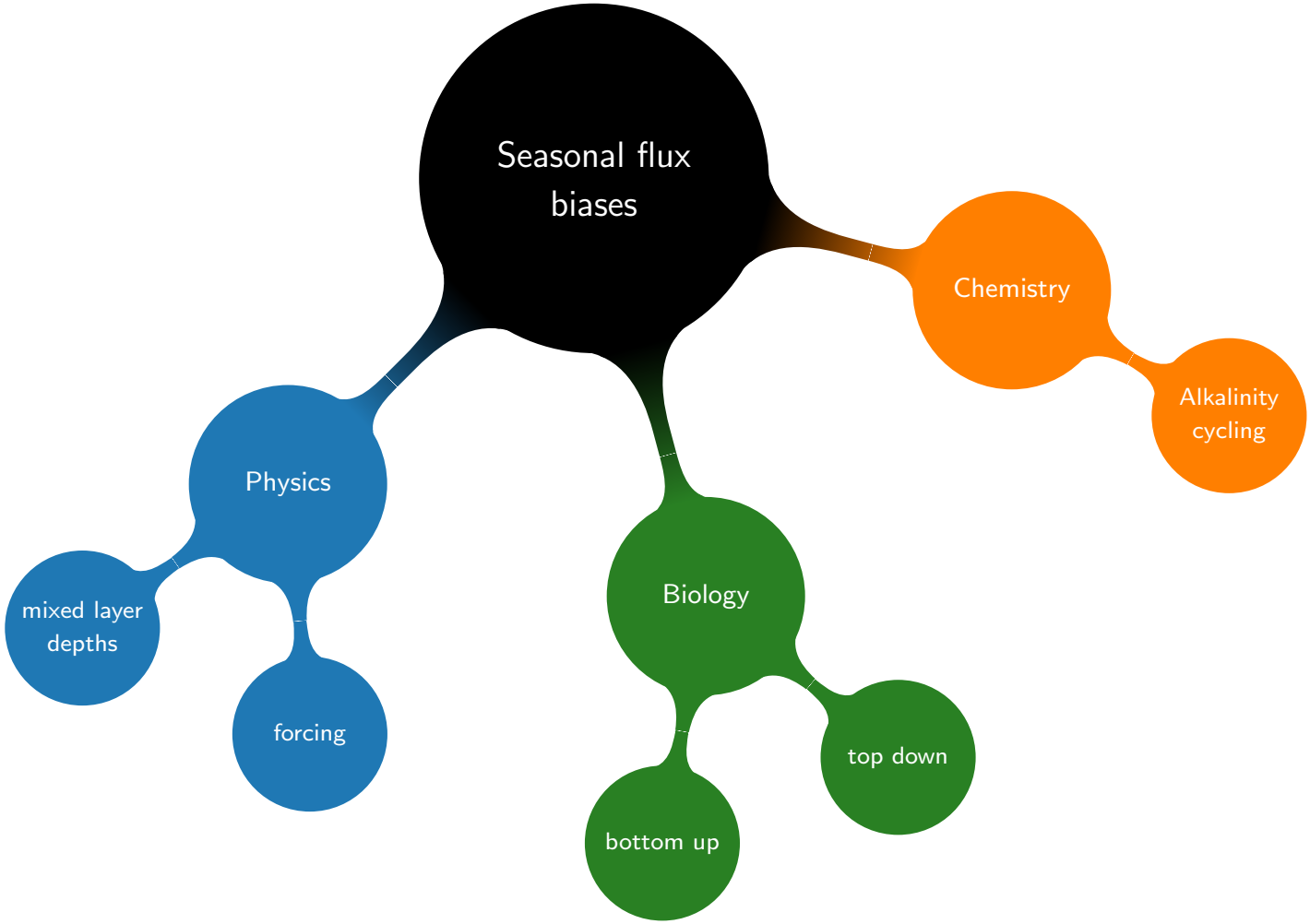


CMIP5 model skill metrics: Seasonal cycle in air-sea CO_2 flux

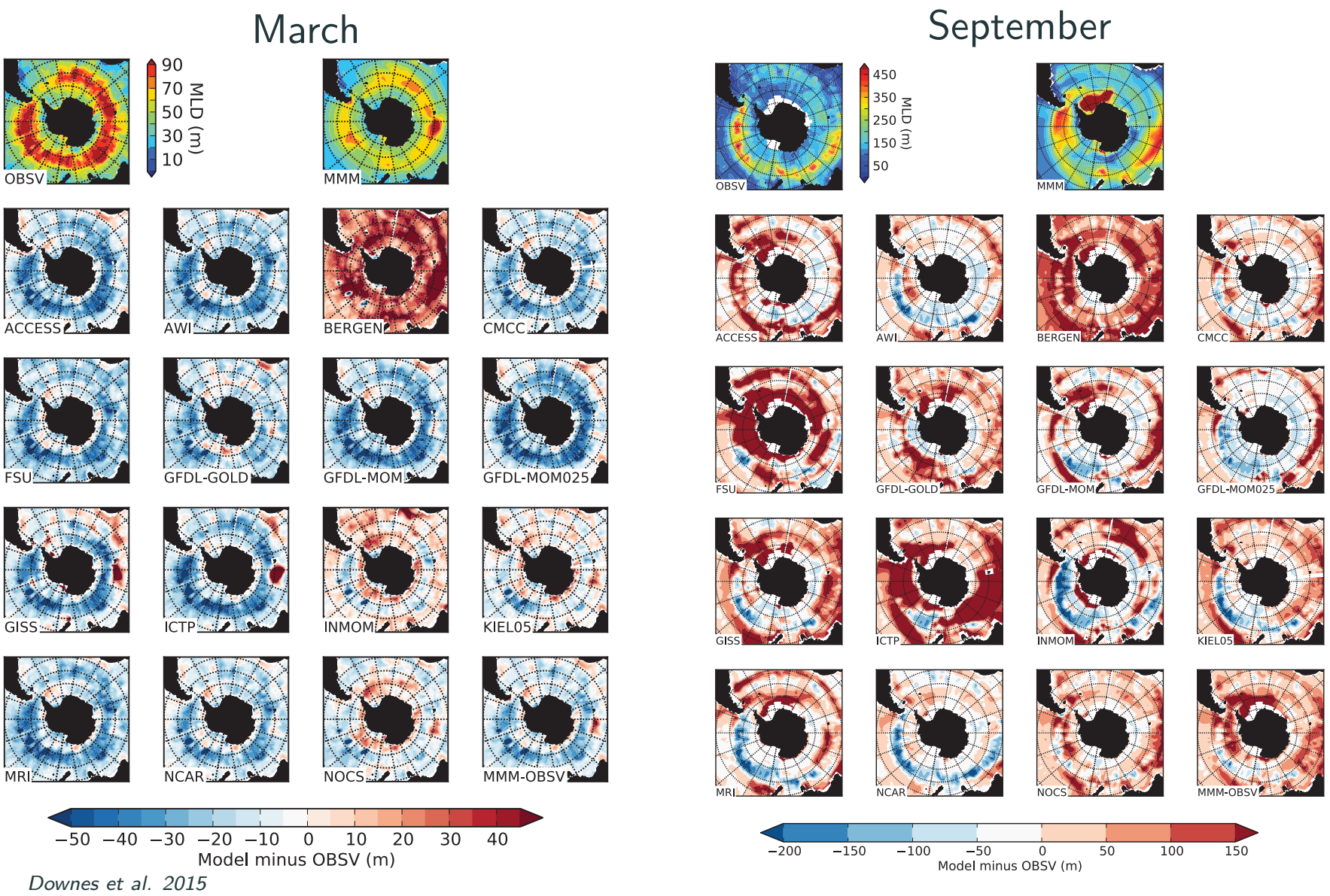


Anav et al. 2015

Attribution



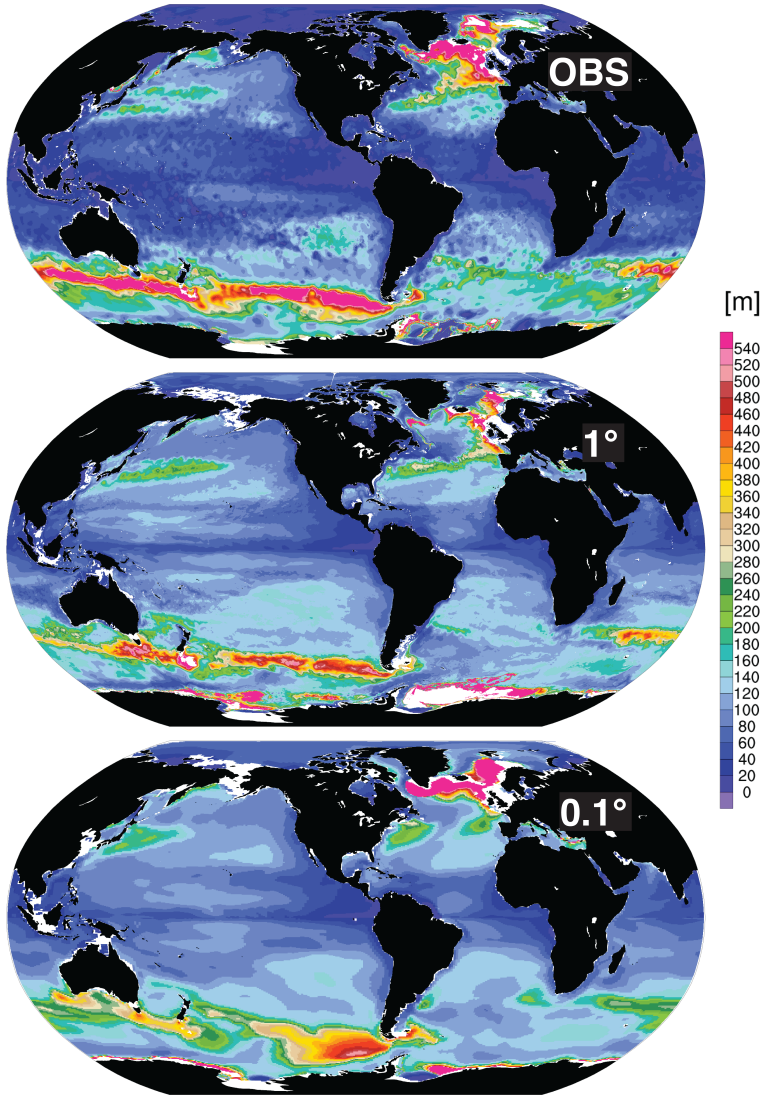
Mixed layers depth biases in hindcast runs: Missing physics?



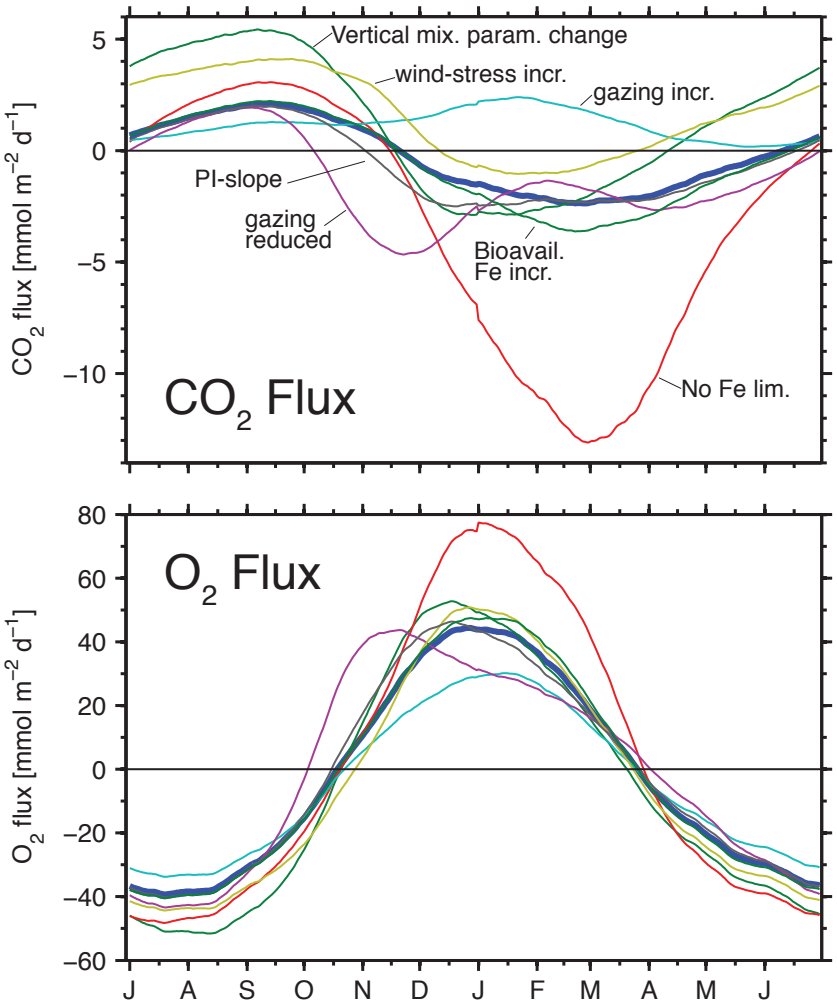
Downes et al. 2015

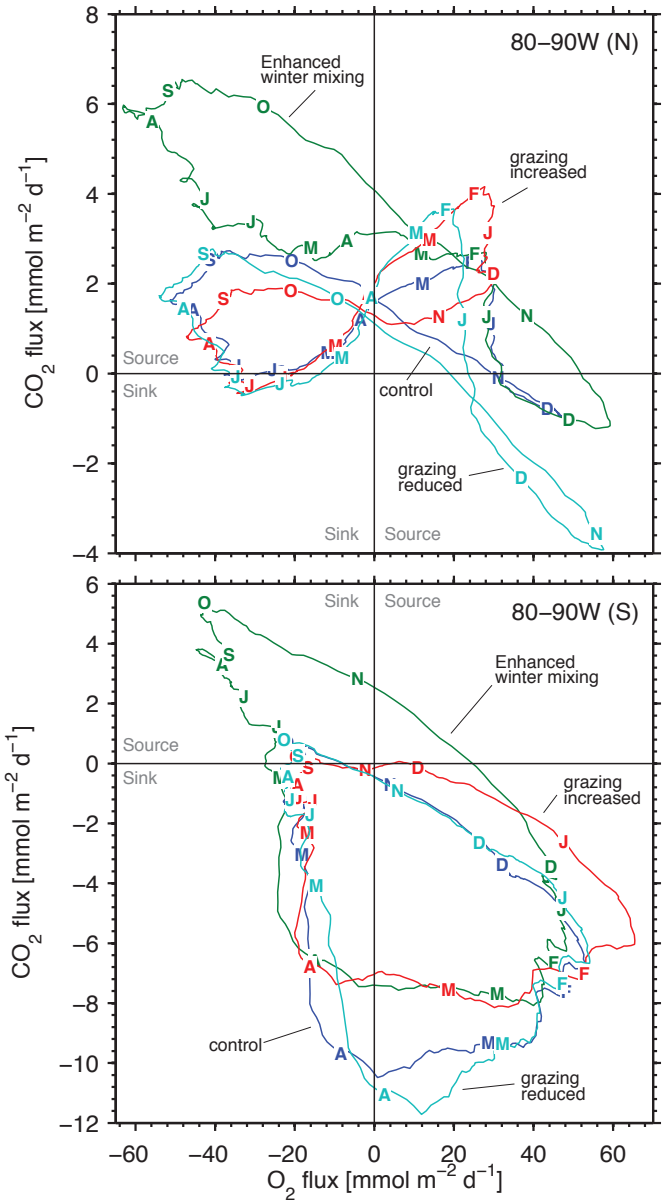
Mesoscale modulation of vertical mixing

Mixed layer depth (winter)

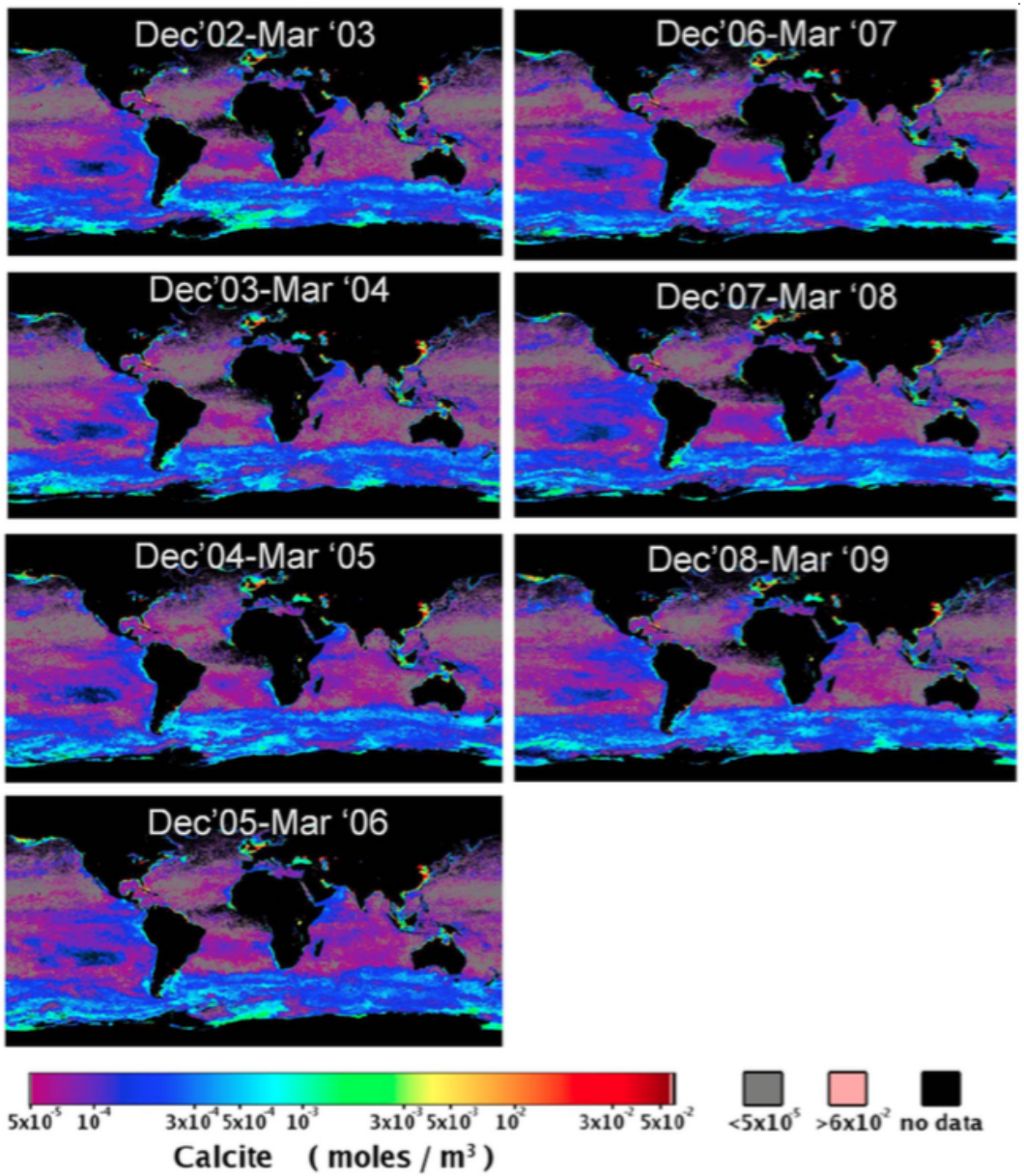


Physical and biological controls





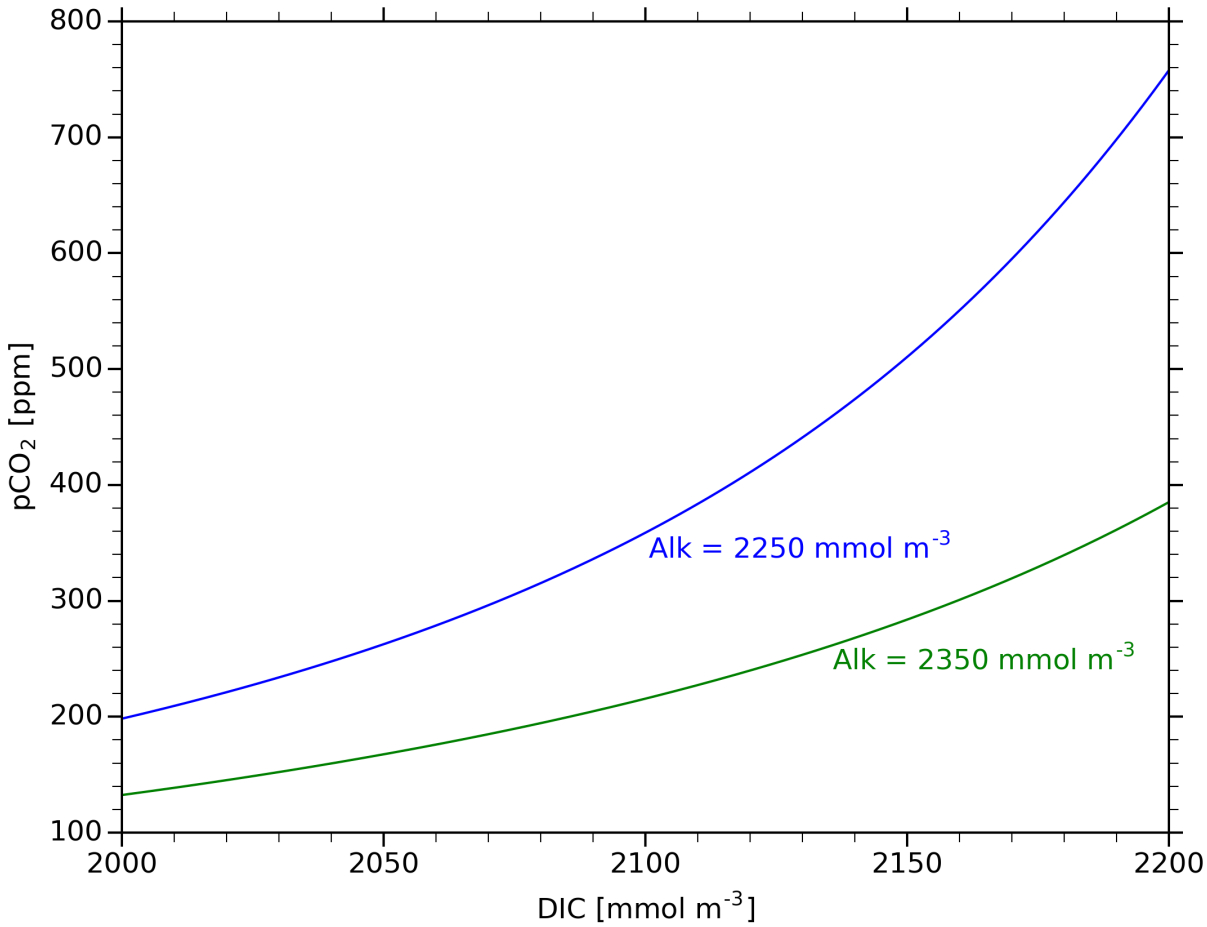
Carbonate production: active alkalinity cycling?



Balch et al. 2011

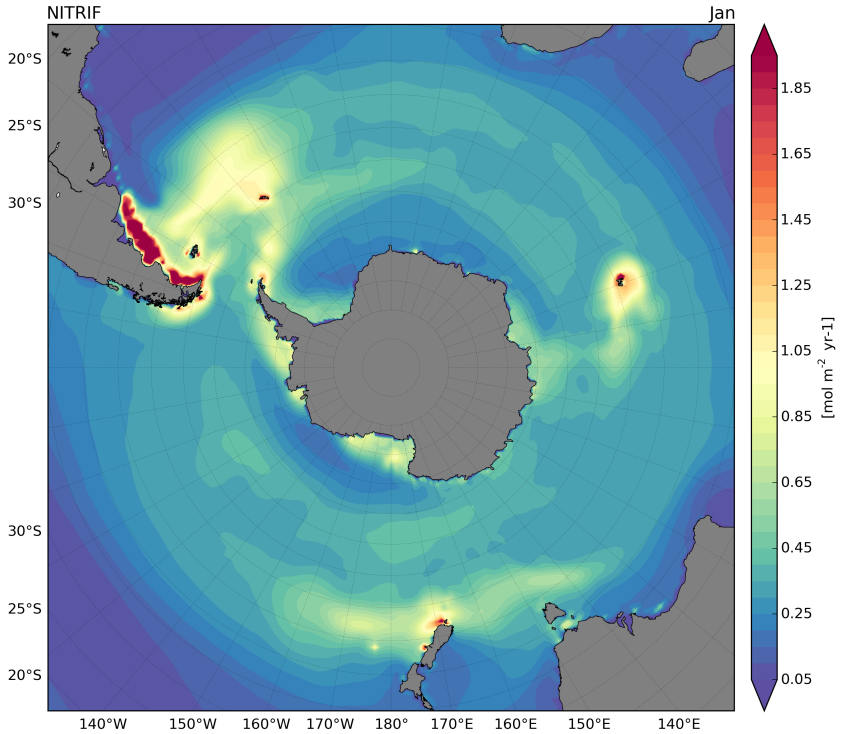
Carbonate production: active alkalinity cycling?

Closed system: pCO_2 versus DIC and Alk

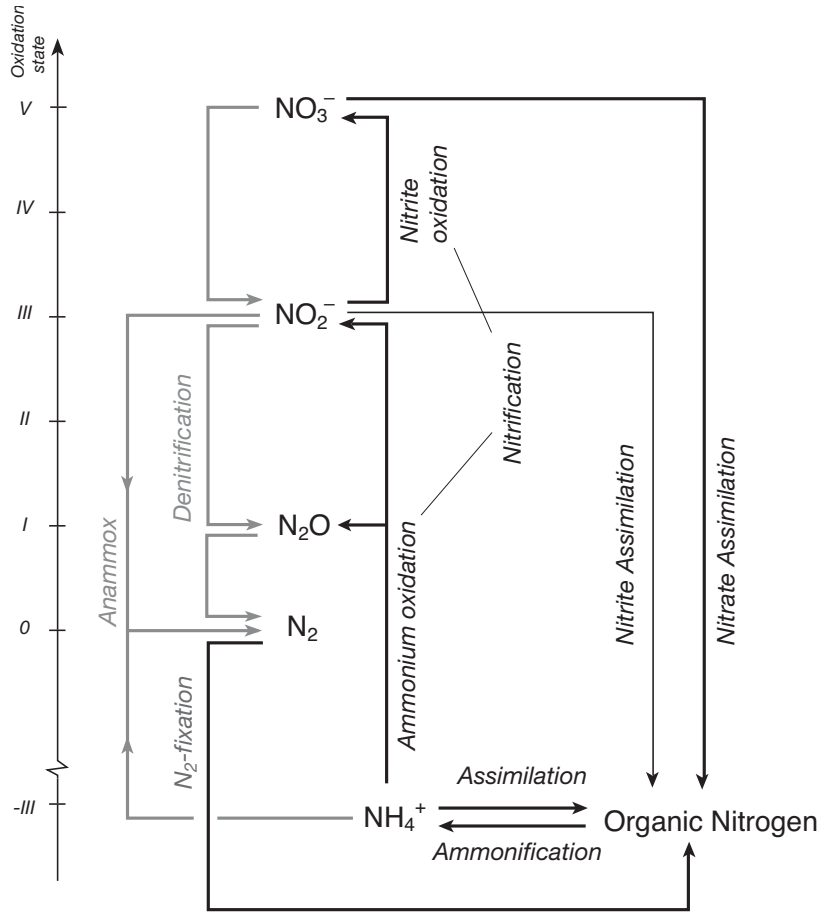


N_2O cycling?

Simulated nitrification ($z > -100$m)



Jan Climatology (g.e11_LENS.GECOIAF.T62_g16.009)



Sarmiento & Gruber 2006

Summary

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