Marine Biogeochemistry in the New CESM Simulations

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Output From New Coupled Simulations

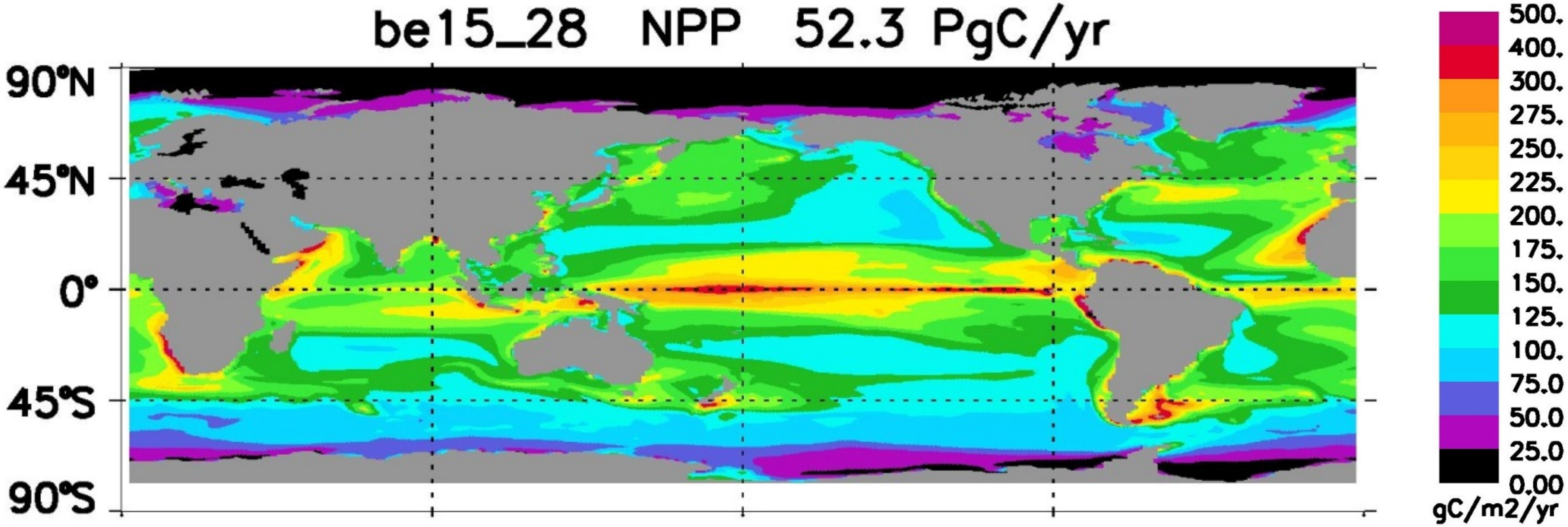
BGC Fields and Fluxes from b.e15.BHIST….28

Ocean physics in this run similar to CESM 1.2.

BGC parameters are first guess values, no parameter tuning.

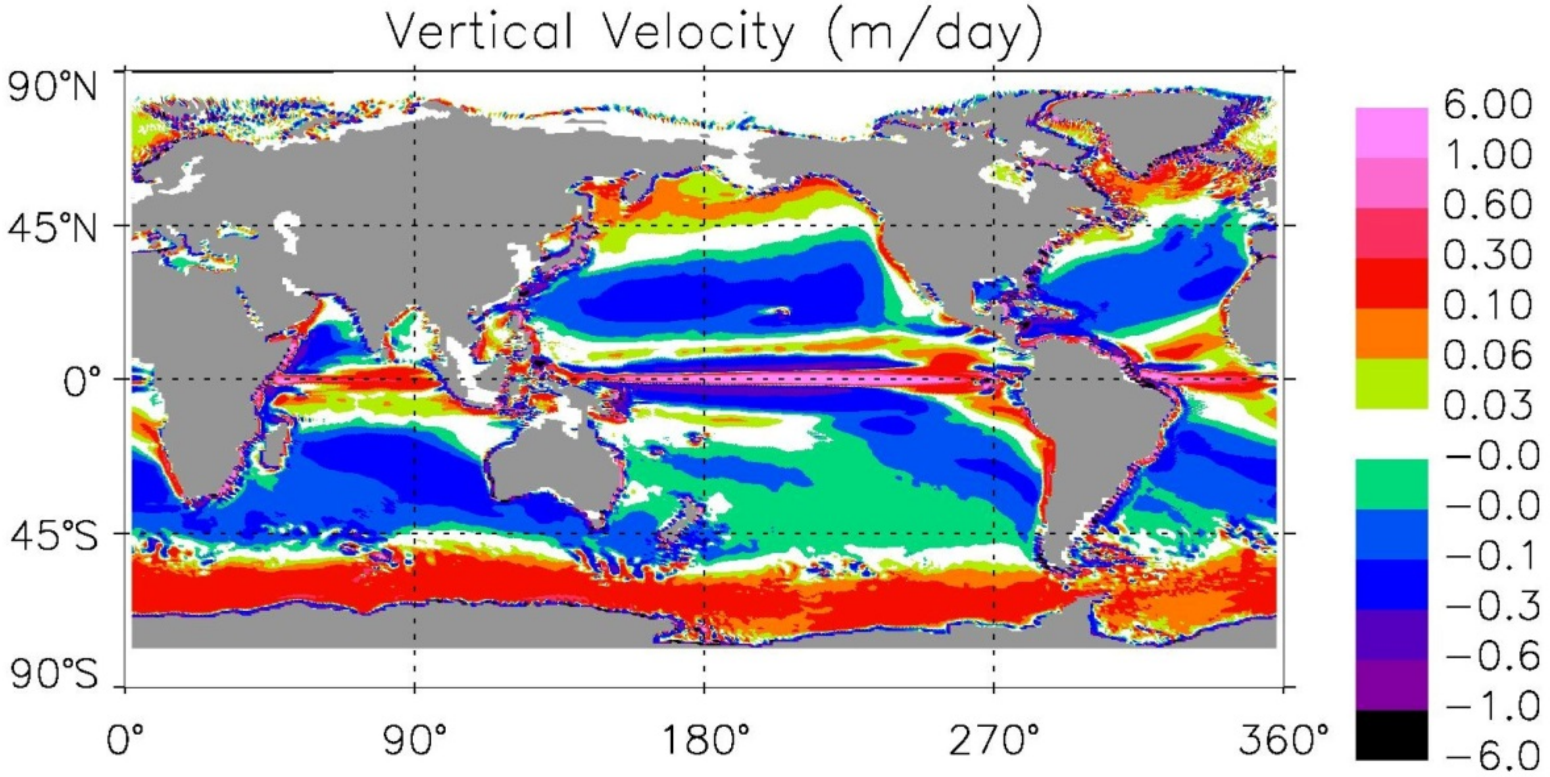
Means from last 16 years of historical simulation (1990-2005).

Offline POP Tracer Transport Matrix as a CESM Tool



Total Net Primary Production (NPP) and the spatial patterns look reasonable in general. One exception is the high NPP associated with equatorial upwelling extend too far west in the Pacific.

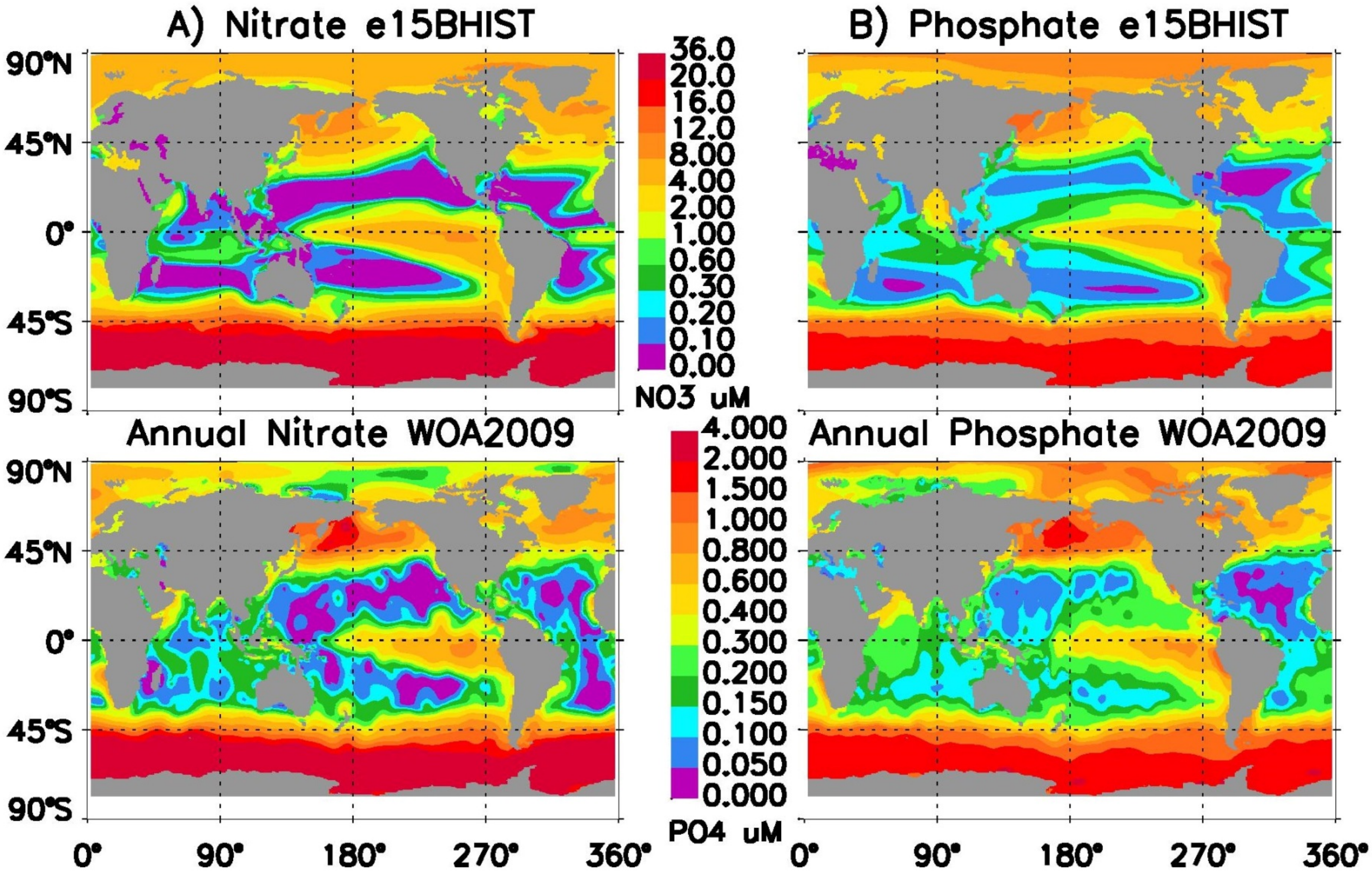
Vertical Velocity at 100m Depth



Equatorial upwelling extends too far to the west in the Pacific.

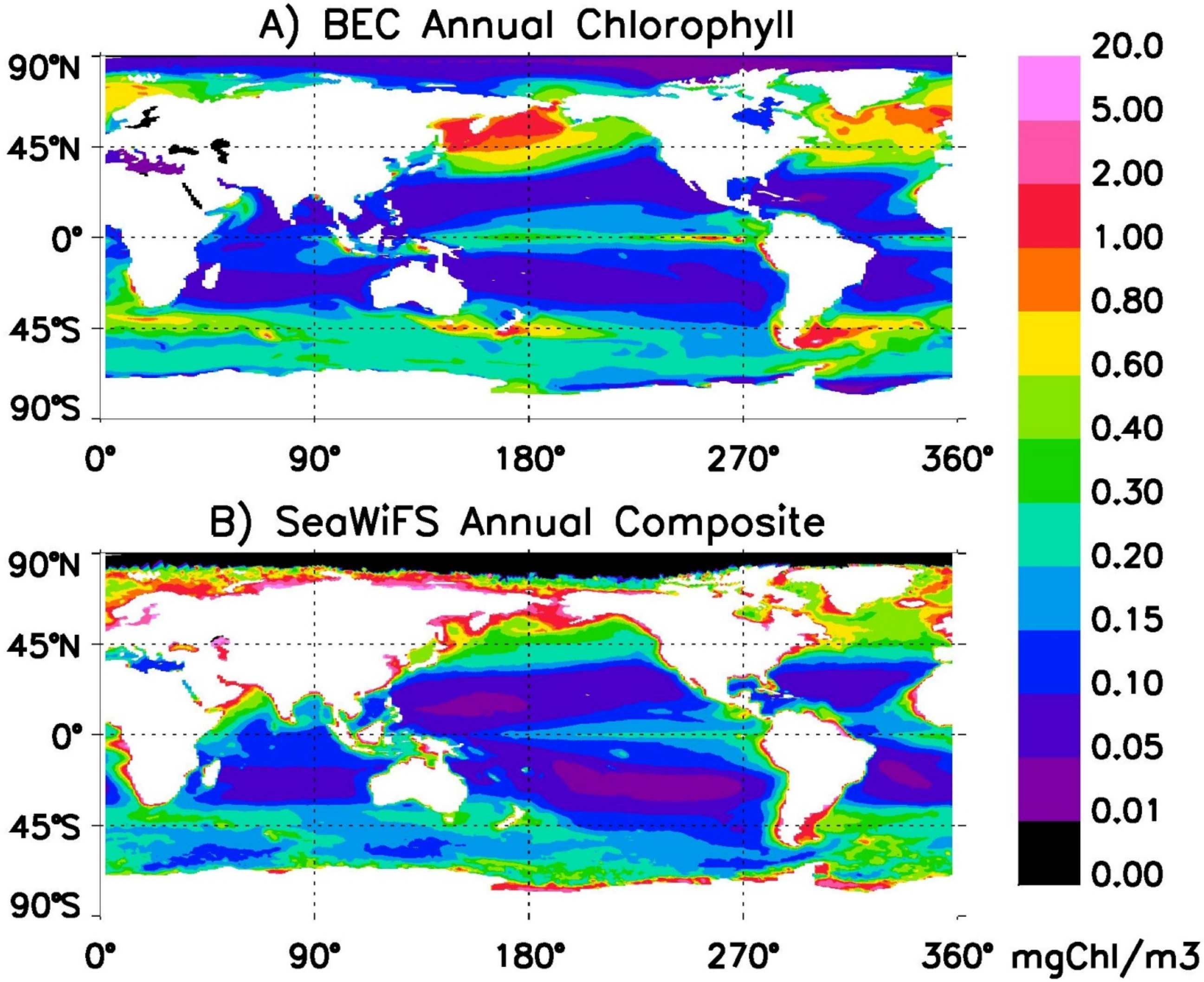
Eastern Boundary Current and Arabian Sea coastal upwelling zones look better than in CESM1.

Surface Nitrate and Phosphate Concentrations

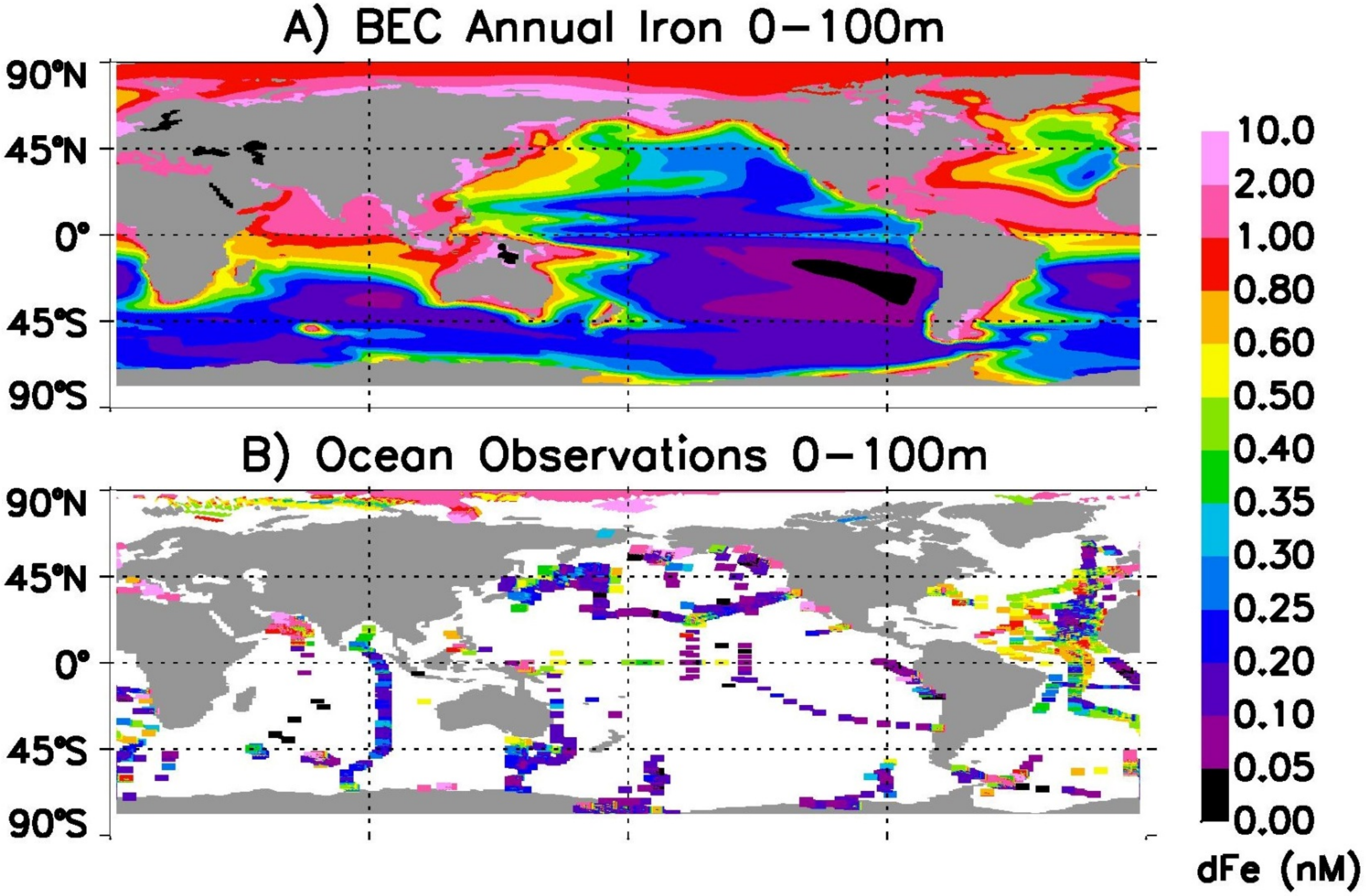


Surface nutrients look as good or better than CESM1. But note eastward extension of the high-nutrient equatorial tongue in Pacific.

Surface Chlorophyll Concentrations

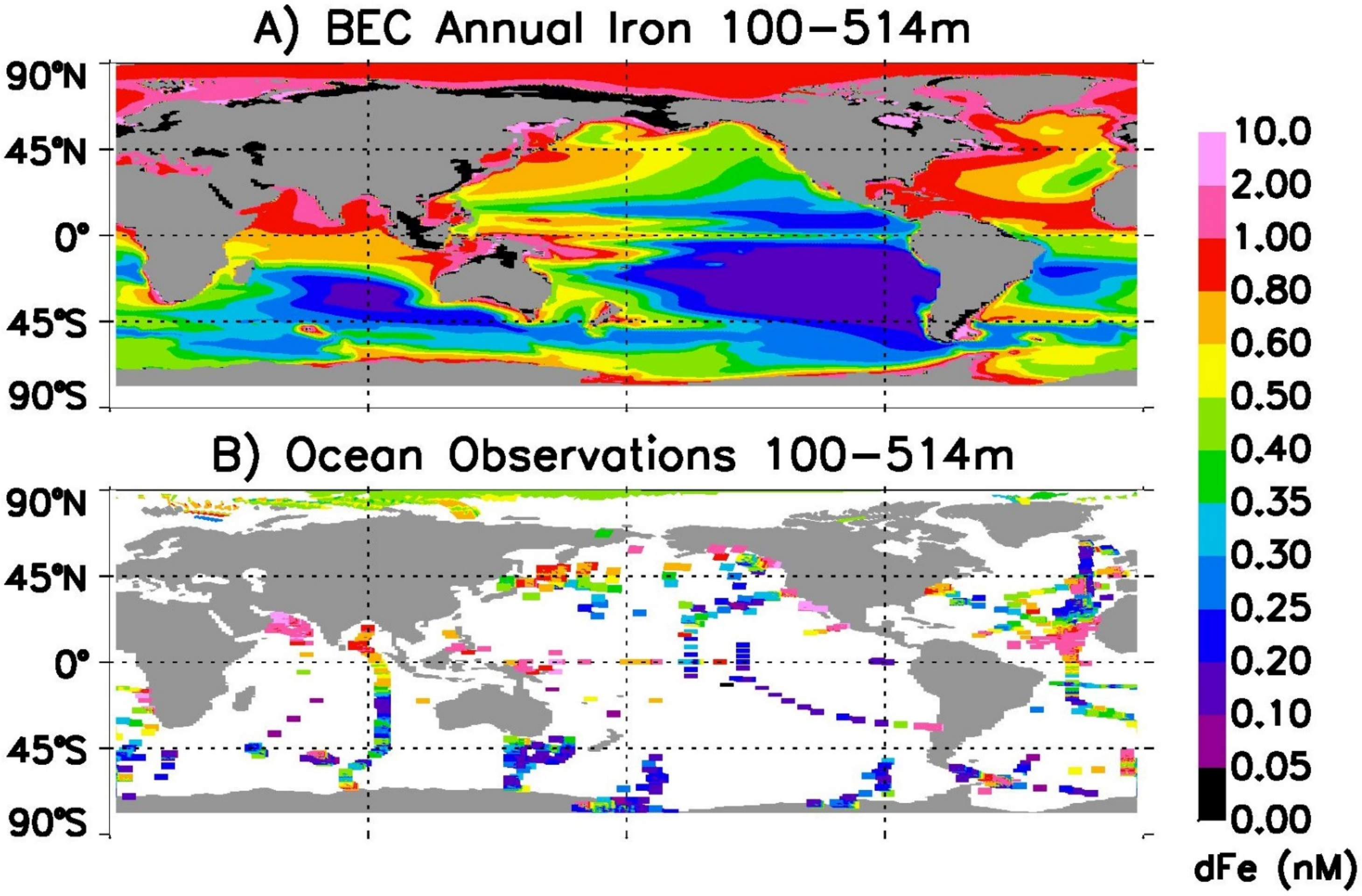


Simulated Dissolved Iron Concentrations



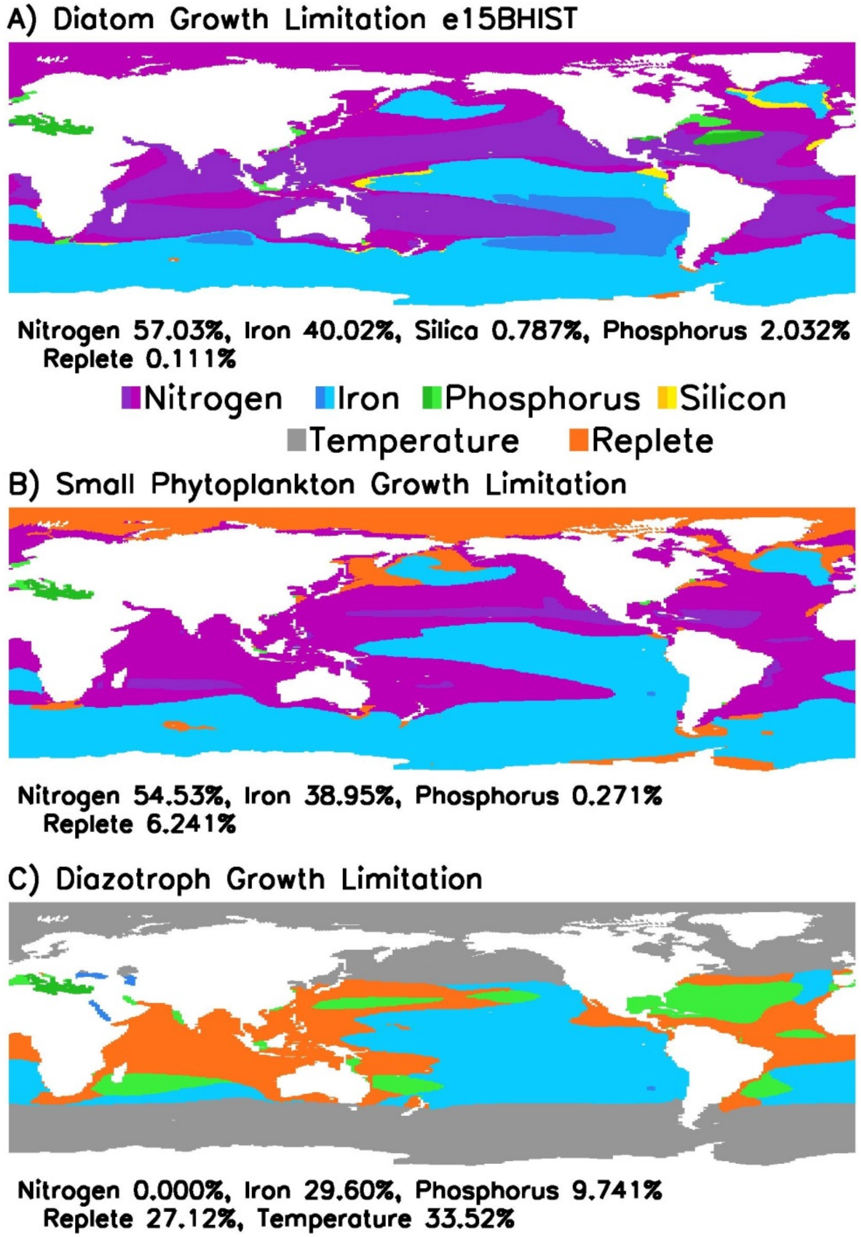
Surface iron distributions are reasonable, atmospheric inputs seem to be too high to the western North Pacific. We are working with Natalie Mahowald to tune dust and the soluble iron deposition for CESM2. Unlike in CESM1, these atmospheric inputs will be dynamically tied to the climate simulations.

Simulated Dissolved Iron Concentrations



Subsurface iron distributions are reasonable, note strong zonal gradients in the equatorial Pacific.

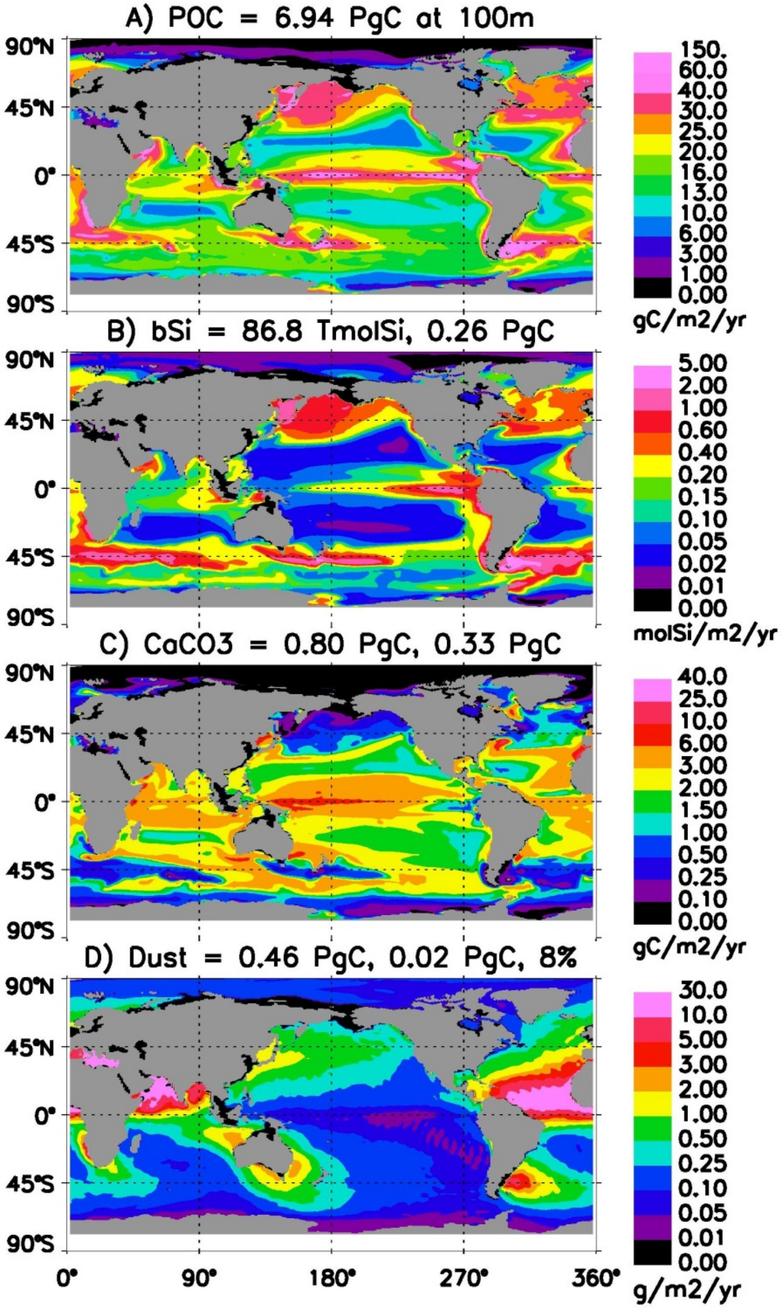
Nutrient Limitation of Phytoplankton Growth

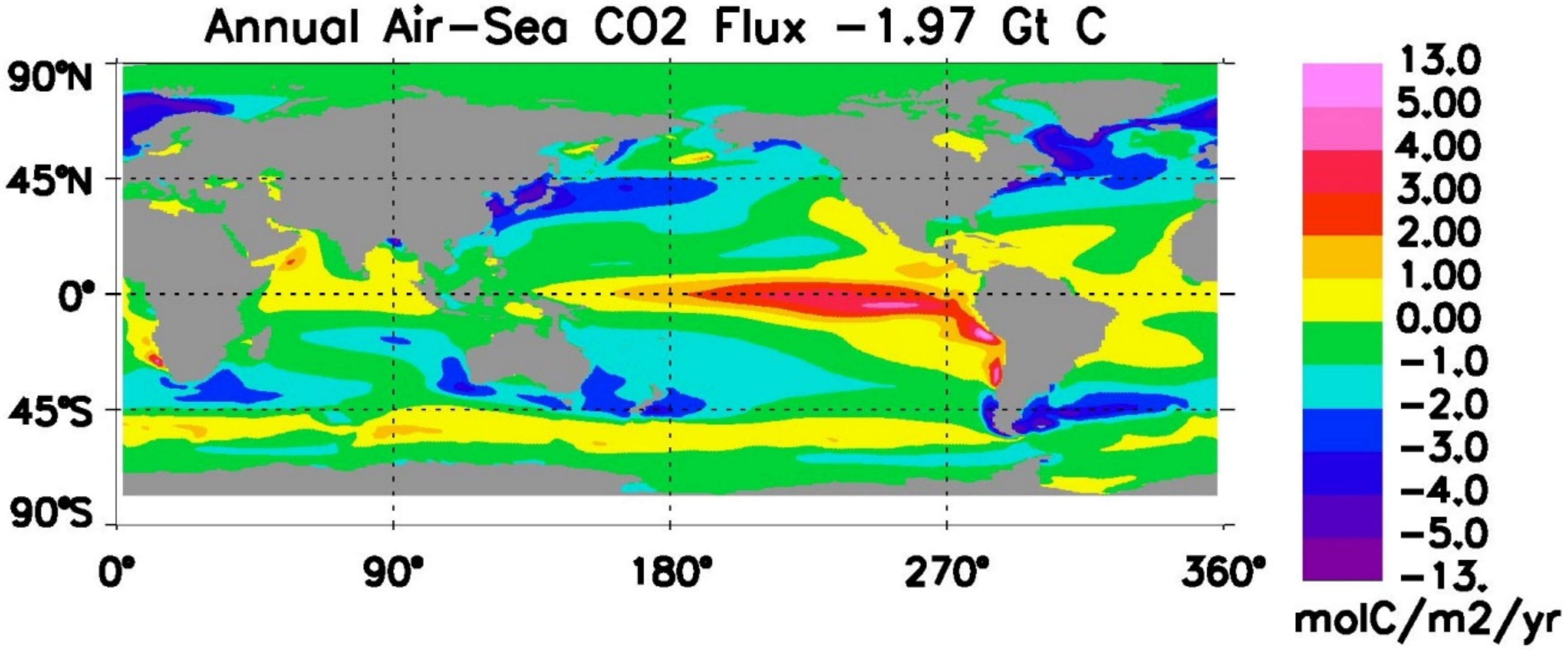


Iron limitation is underestimated in the subarctic N. Pacific.

Iron limitation extends too far west in equatorial Pacific.

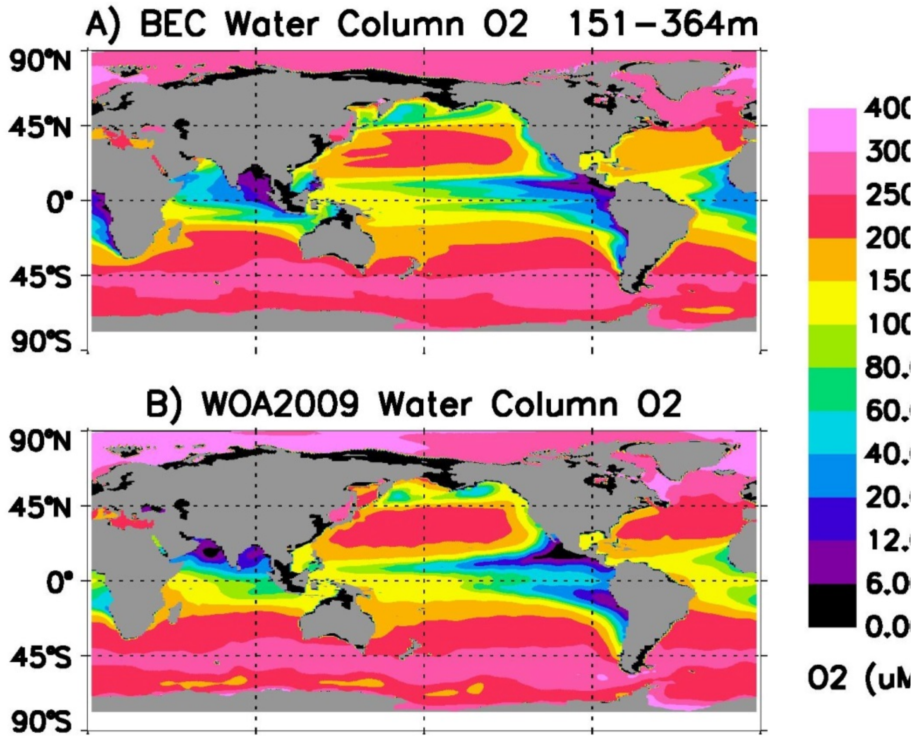
Sinking Particulate Fluxes at 100m Depth

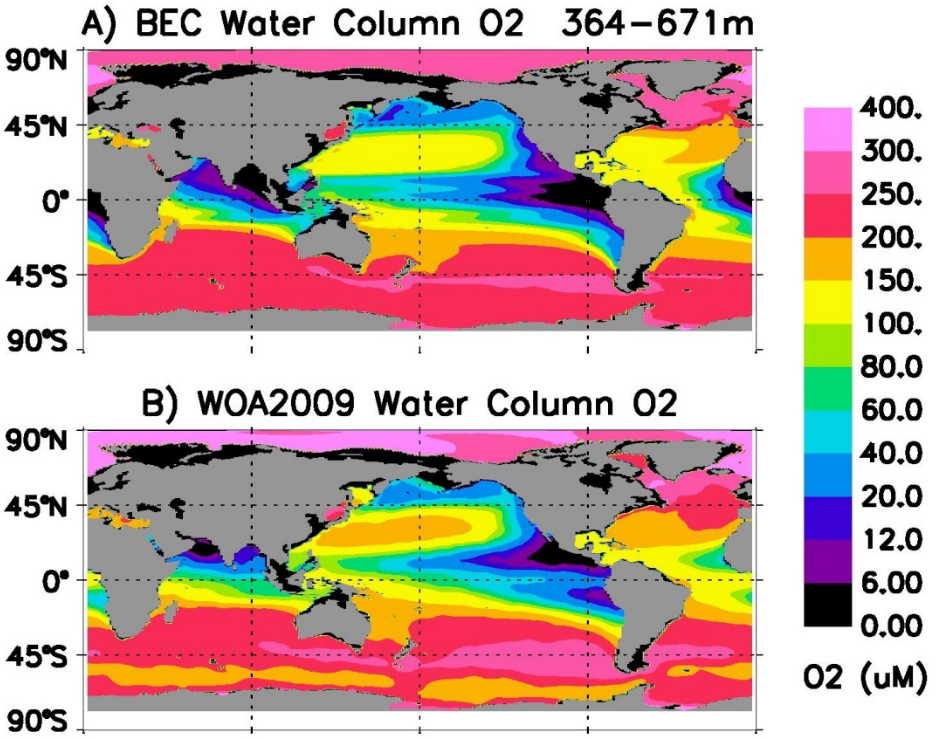




Patterns of air-sea CO2 flux look reasonable, net uptake is low for this period. But ocean carbon was not fully spun up for this run. Net uptake may also be reduced by excessive equatorial outgassing.

Oxygen Concentrations at Depth

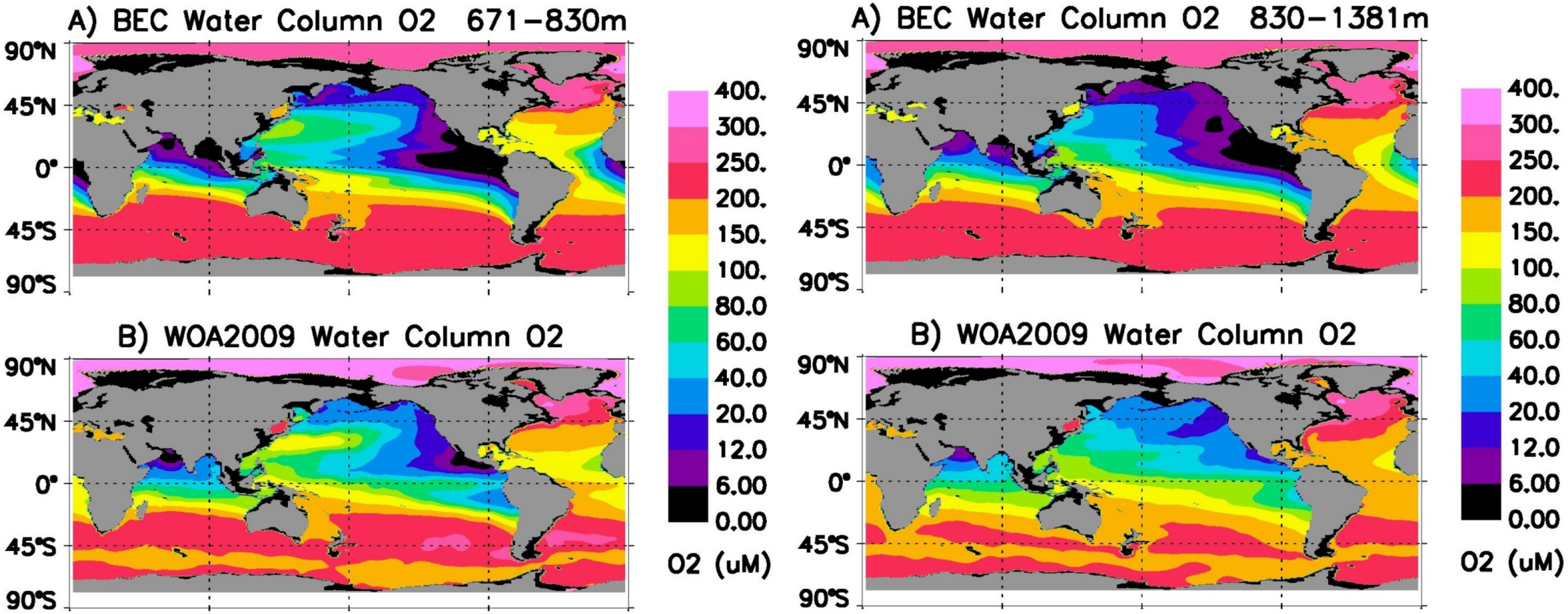




In the upper ocean (left column < 364m) O2 better than CESM1.

But oxygen steadily gets worse moving deeper in the water column.

Oxygen Concentrations at Depth



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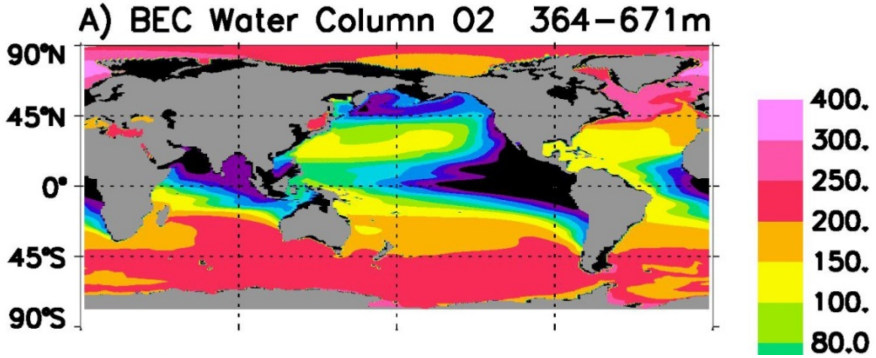
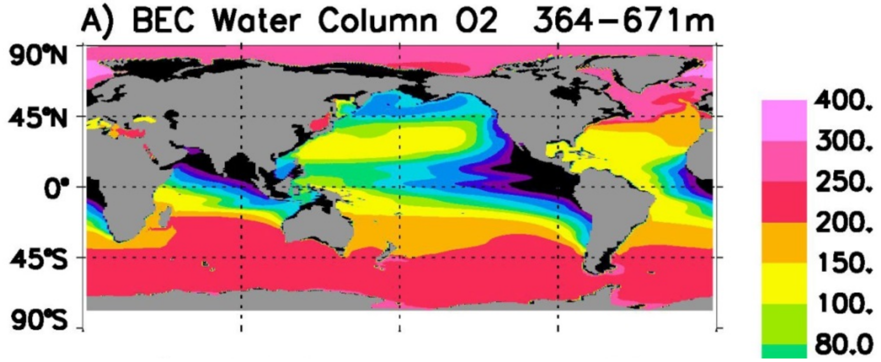


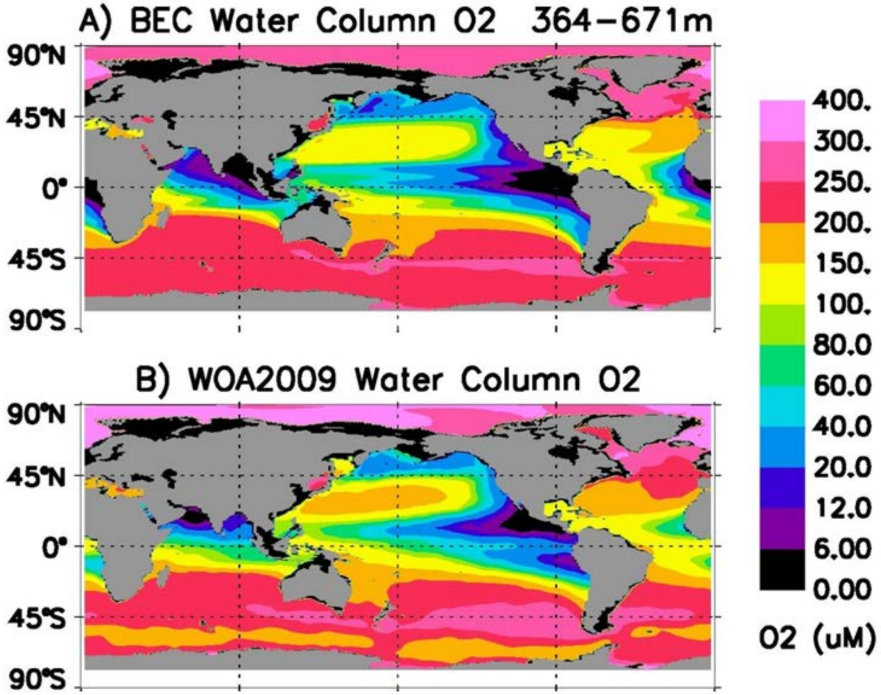
CESM 1.0

OMZ volume 281% observed



CESM 1.2.1

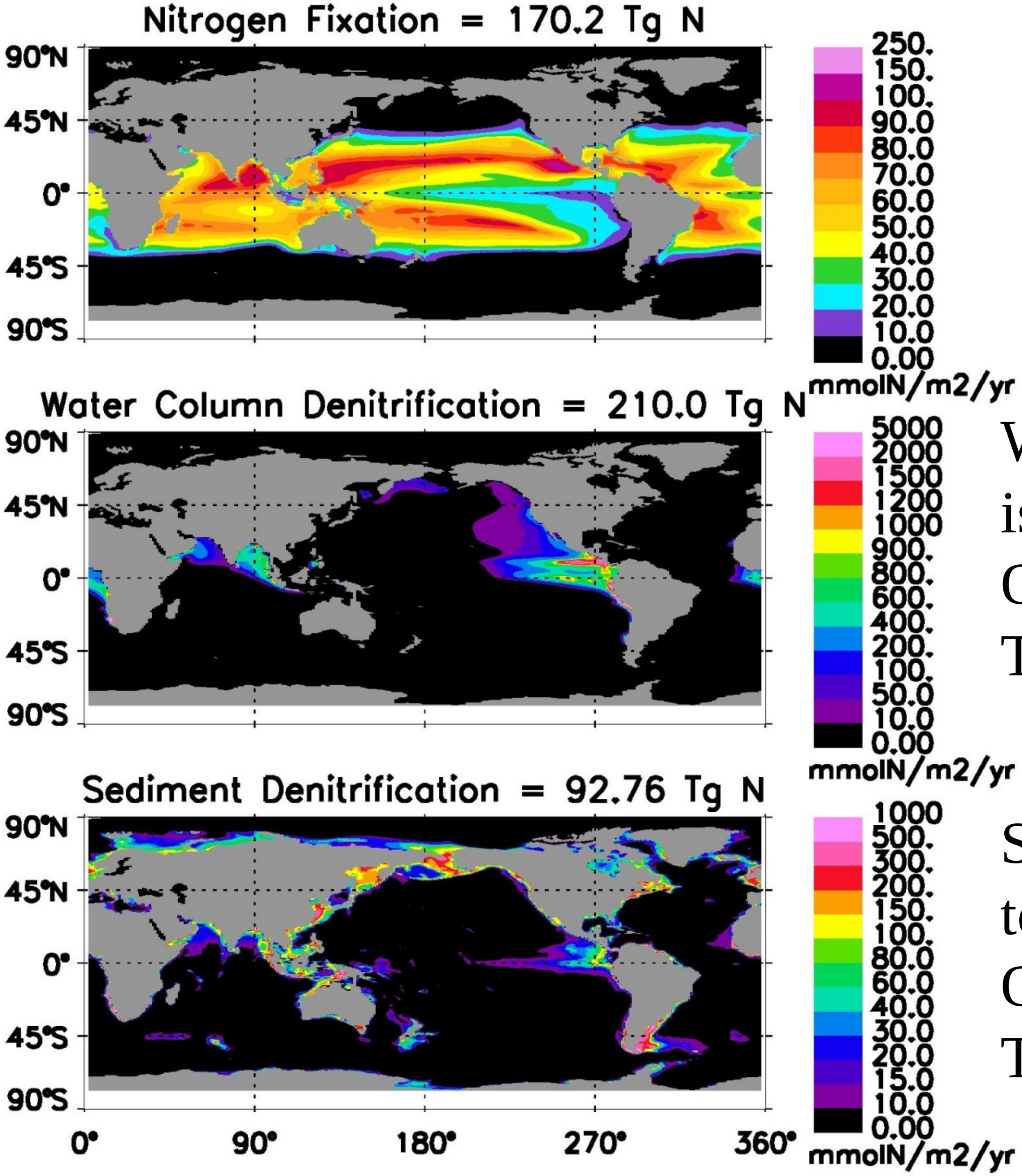
OMZ volume 180% observed



CESM b.e15.BHIST

OMZ volume 185% observed

Key Fluxes in the Marine Nitrogen Cycle



Nitrogen Fixation = 170.2 Tg N

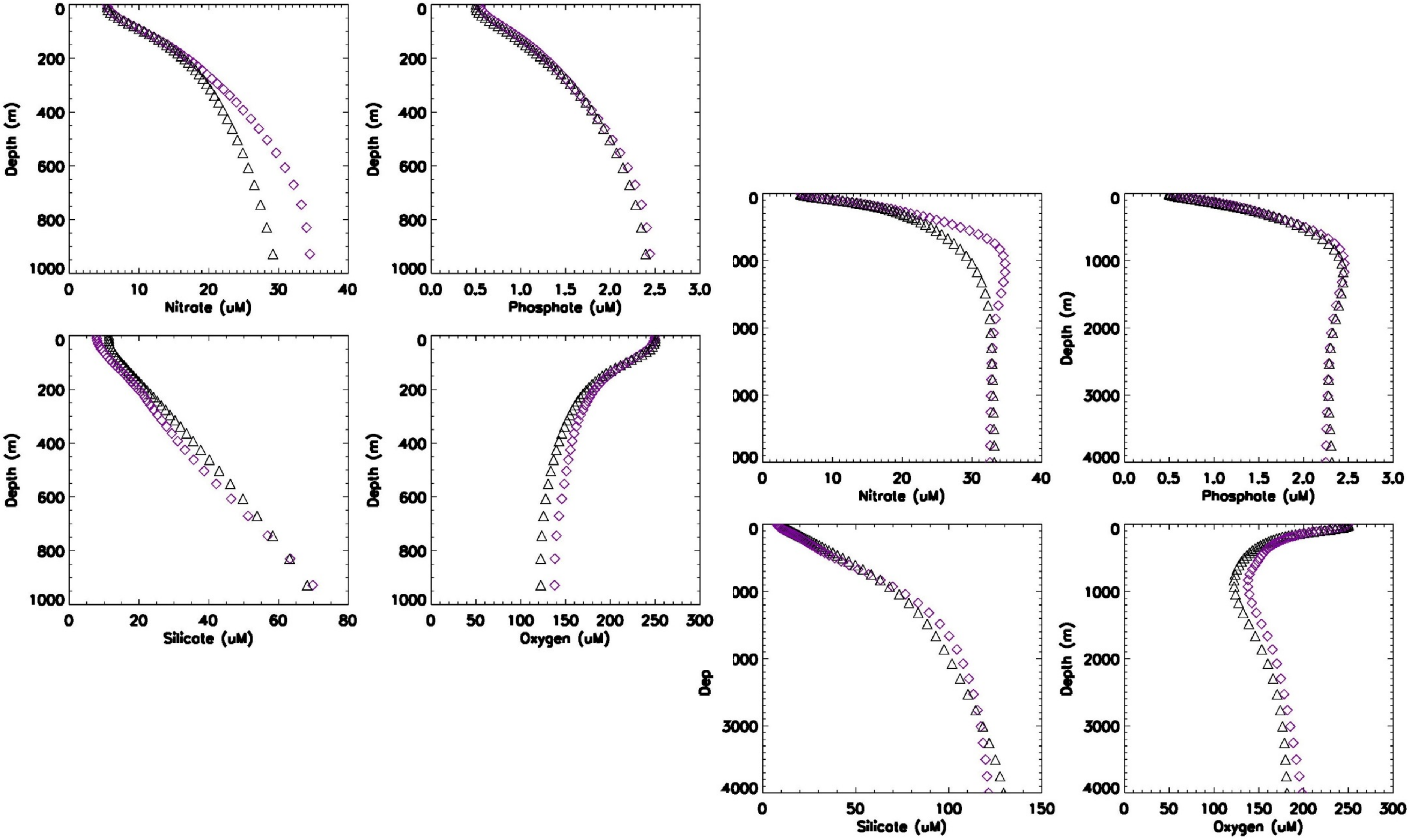
Water Column Denitrification = 210.0 Tg N

Sediment Denitrification = 92.76 Tg N

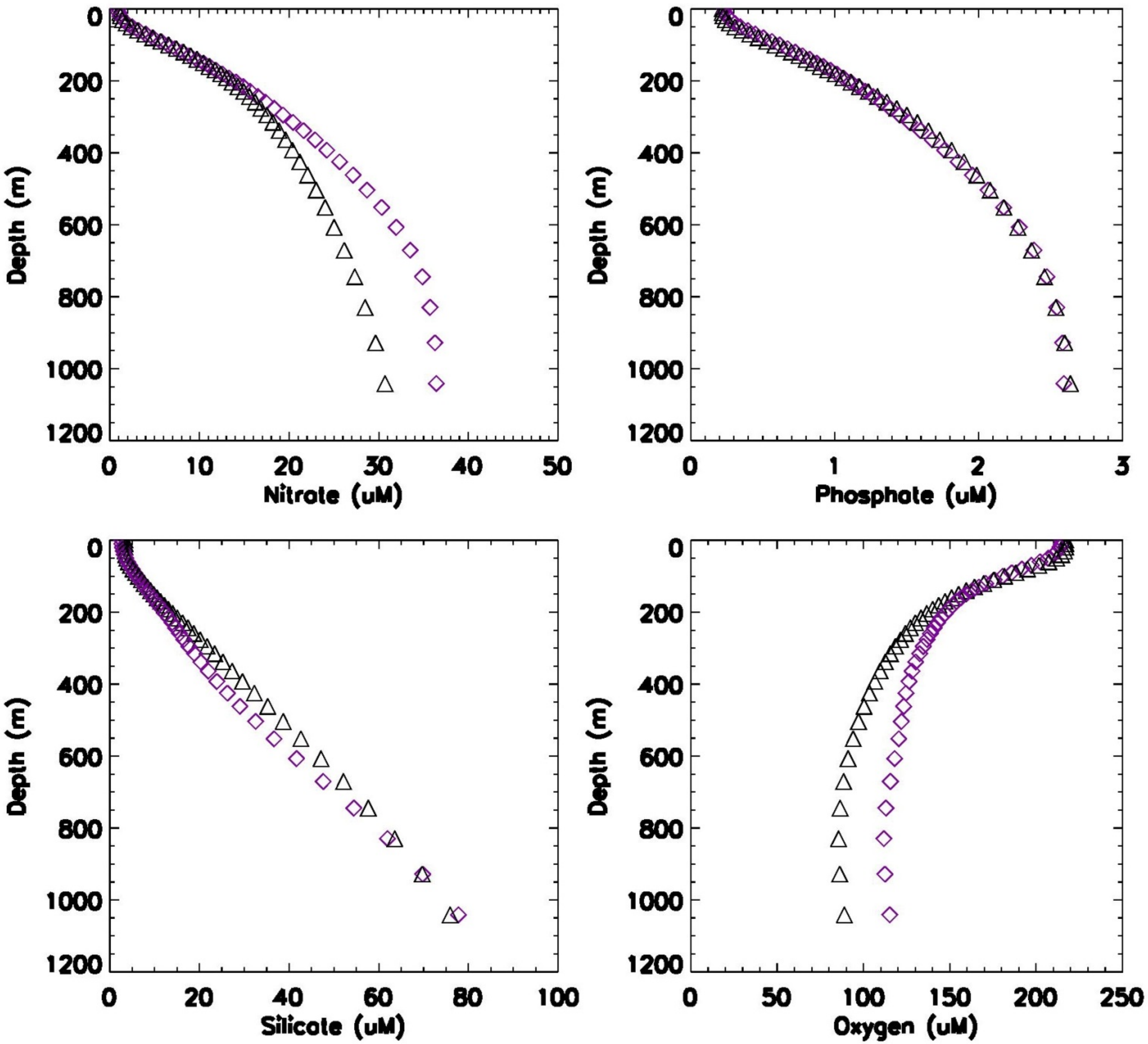
Water column denitrification is too high due to low O_2 bias. Observational estimates ~75 TgN/yr.

Sedimentary denitrification is too low.
Observational estimates > 150 TgN/yr.

Global Mean Nutrient and Oxygen Profiles



Mean Nutrient and Oxygen Profiles 25S-25N



Equatorial Intermediate and Deep Jets

Zonal jets apparent in ARGO float velocities at depth.

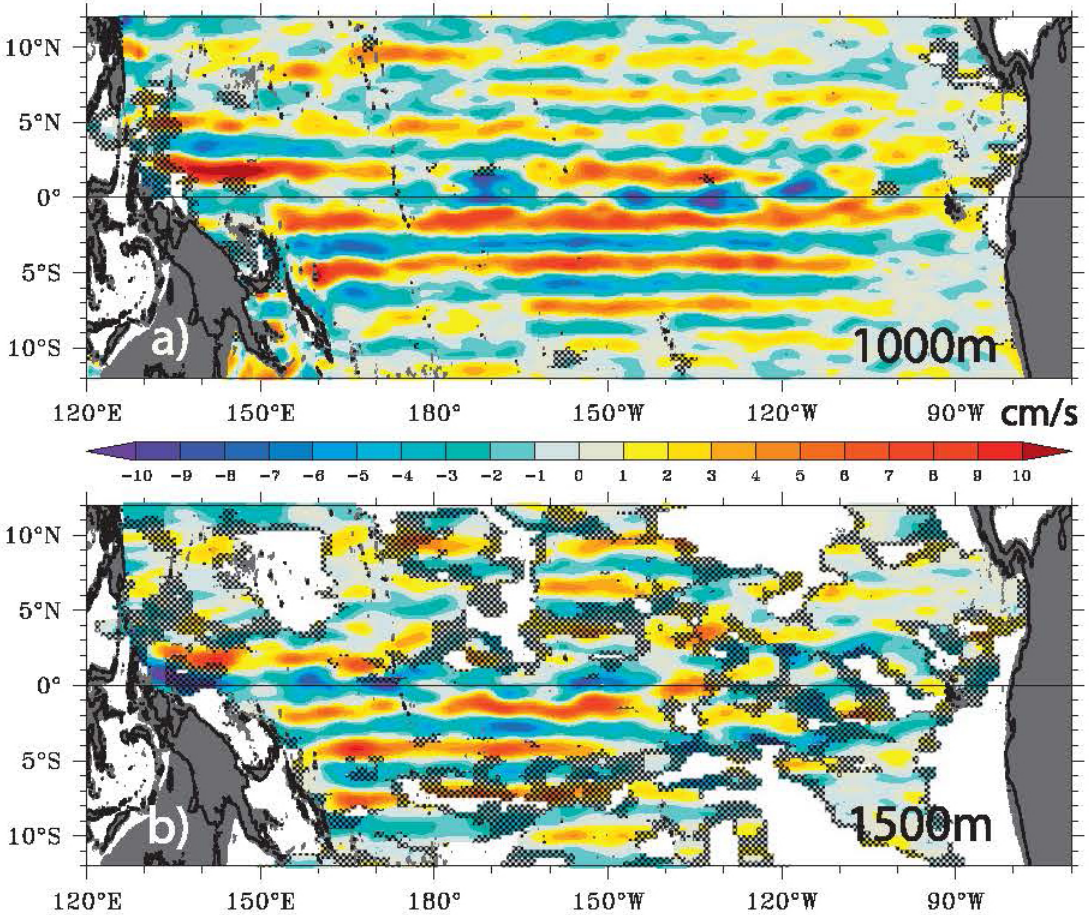


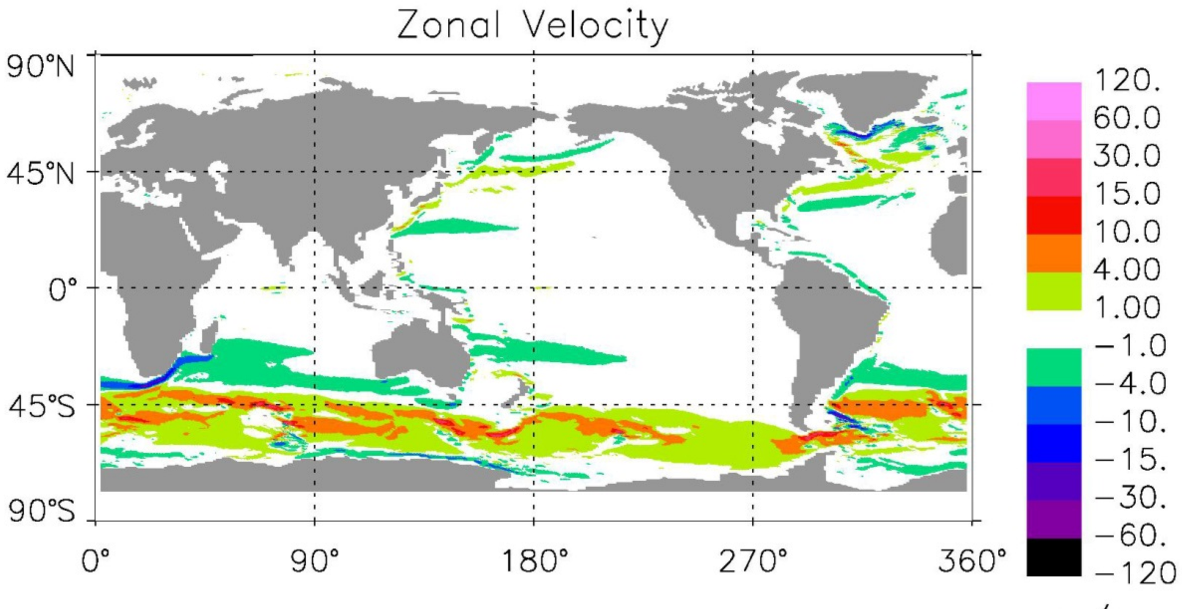
FIG. 2. Mean zonal currents (cm s^{-1}) at (a) 1000 and (b) 1500 m, from optimal interpolation. Topography shallower than 1000-m depth is shaded in dark gray. Boxes with less than five values are blanked. Regions where zonal velocity estimates could be biased seasonally are hatched in black (see text in section 2).

(Cravatte et al., 2012)

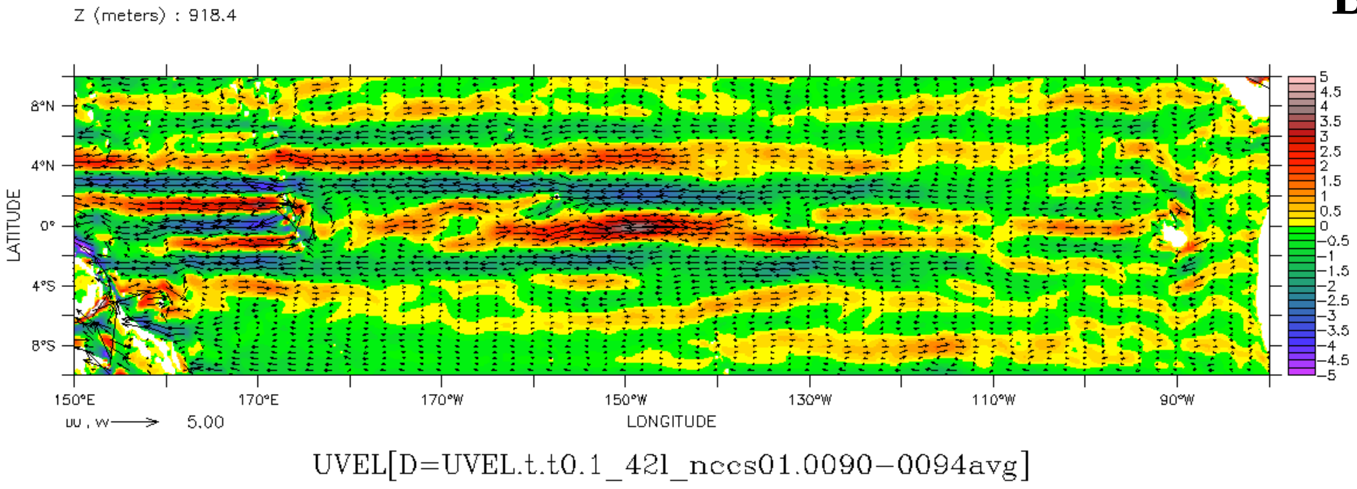
Alternating zonal jets, strongest 5S-5N

Observational (Brandt et al., 2008; 2012) and modeling studies (Dietze and Loeptien, 2013; Getzlaff and Dietze, 2013) suggest these zonal jets are important for oxygen distributions and ventilation of the eastern boundary shadow zones.

Equatorial Intermediate and Deep Jets



Mean zonal velocity CESM1 (gx1v6) at 1000m. No equatorial zonal jets.

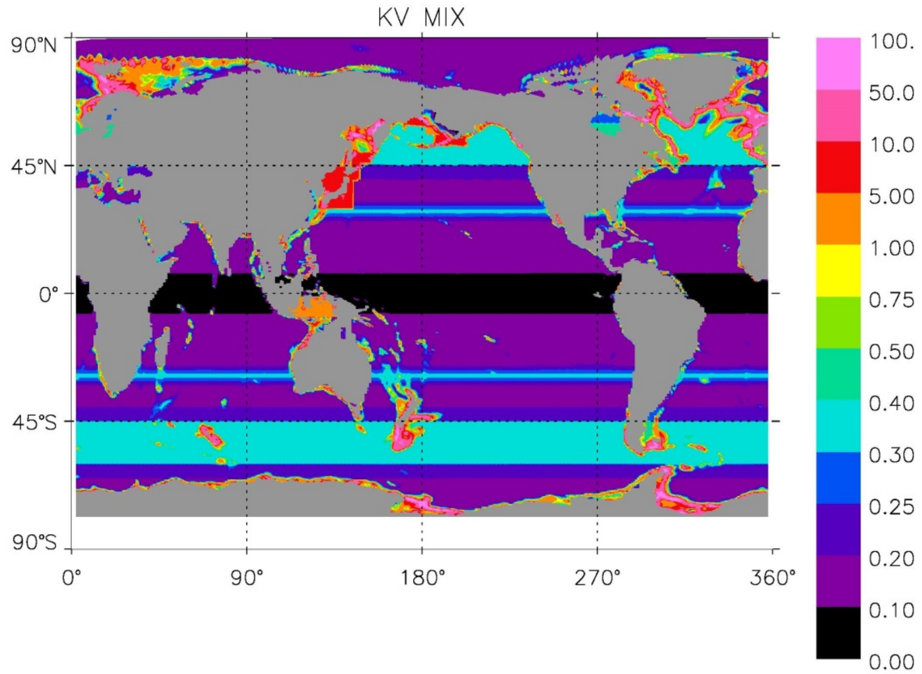


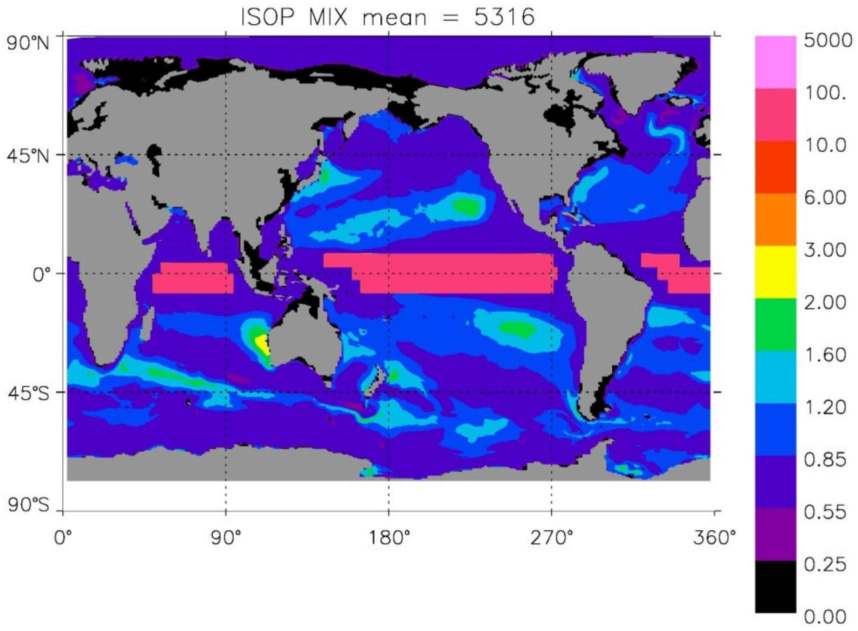
UVEL[D=UVEL.t.t0.1_421_nccs01.0090−0094avg]

But the zonal jets do showup in 0.1 degree POP2 simulations (here at 918m depth in the Pacific).

(image courtesy Mat Maltrud, 10 day mean zonal velocity).

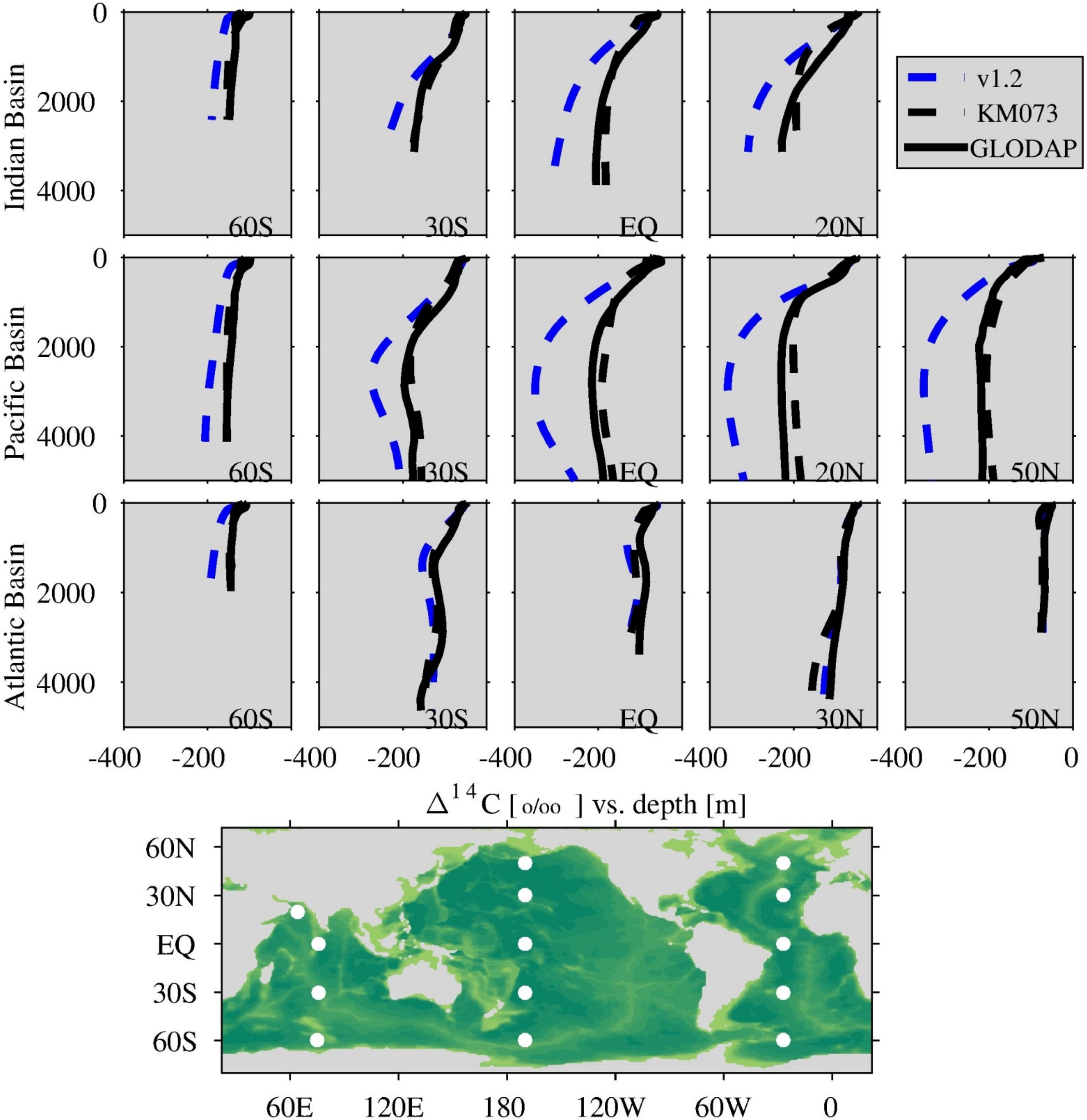
Modified CESM 1.2 Physics - Run 073





1) Increased diapycnal mixing at mid-latitudes and in the NW Pacific.
2) Increased isopycnal mixing along equator from 180-1800m.
3) Increased minimum GM parameter values from 10% to 22% surface.

The sum of these changes greatly improves simulated O_2 distributions.


Indian Basin
Pacific Basin
Atlantic Basin
0
2000
4000
60S
30S
EQ
20N
30N
50N
v1.2
KM073
GLODAP
-400
-200
0
Δ^{14}C [o/oo] vs. depth [m]
60N
30N
EQ
30S
60S
60E
120E
180
120W
60W
0

Variable C:N:P stoichiometry of Dissolved Organic Matter (DOM)

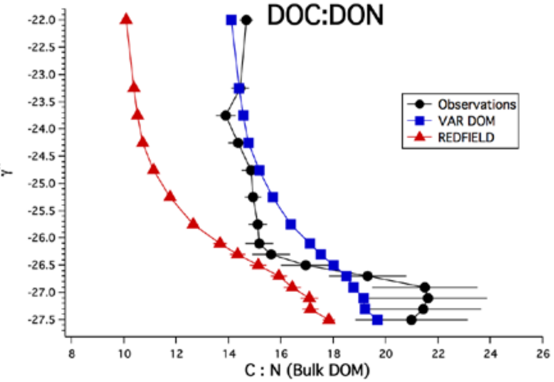
New in CESM2 is a variable stoichiometry in the DOM and representation of the both semi-labile and refractory pools for DOC, DON, and DOP.

Lifetimes for these six pools range from a few years to thousands of years.

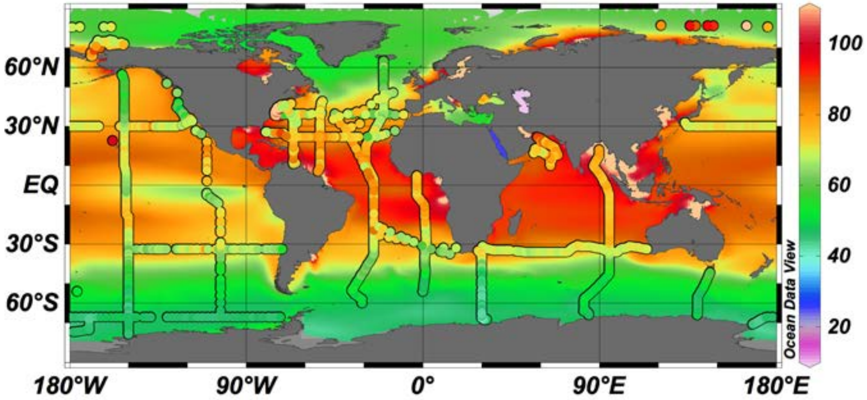
Rapid Accurate Parameter Optimization

Inverse approach with the offline POP tracer transport matrix gave optimal parameter values constrained by observed DOC, DON, and DOP distributions.

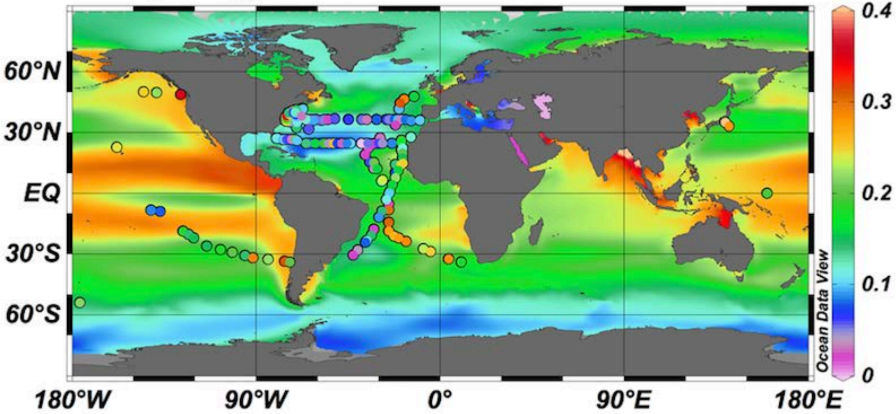
NON-REDFIELD STOICHIOMETRY



[DOC] μM at surface from Model & Obs



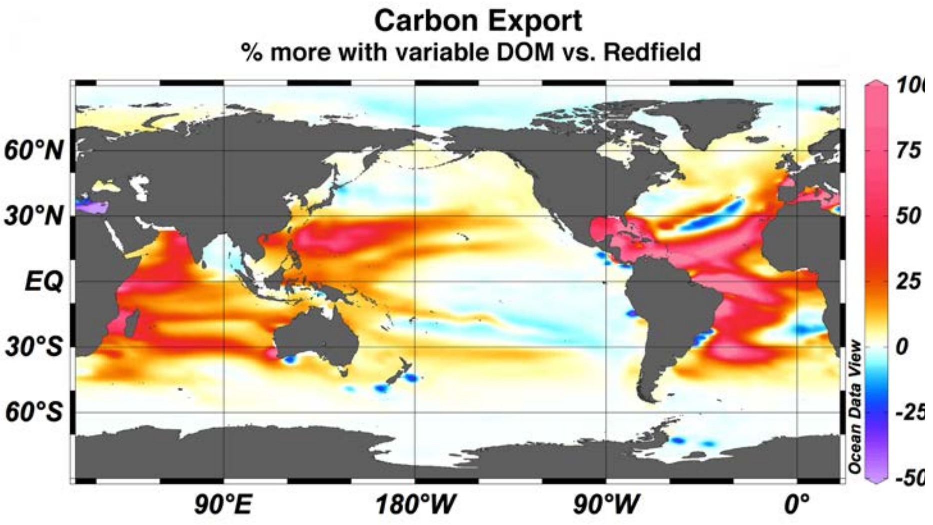
[DOP] μM at surface from Model & Obs



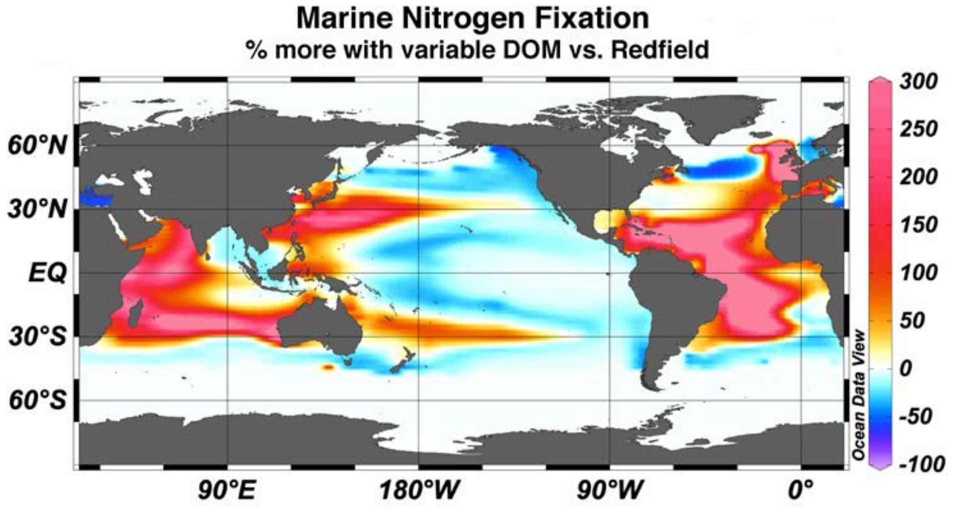
R.T. Letscher, J.K. Moore, Y.C. Teng, and F. Primeau
Biogeosciences, 12*,* 209-221, 2015. Funded by DOE.

Variable C:N:P Stoichiometry of Dissolved Organic Matter (DOM)

Improved treatment of DOM cycling had significant imacts on the spatial patterns and magnitude of Net Primary Production, Nitrogen Fixation, and Carbon Export, in part driven by faster recycling of DOP relative to DON and DOC.



Carbon Export
% more with variable DOM vs. Redfield



Marine Nitrogen Fixation
% more with variable DOM vs. Redfield

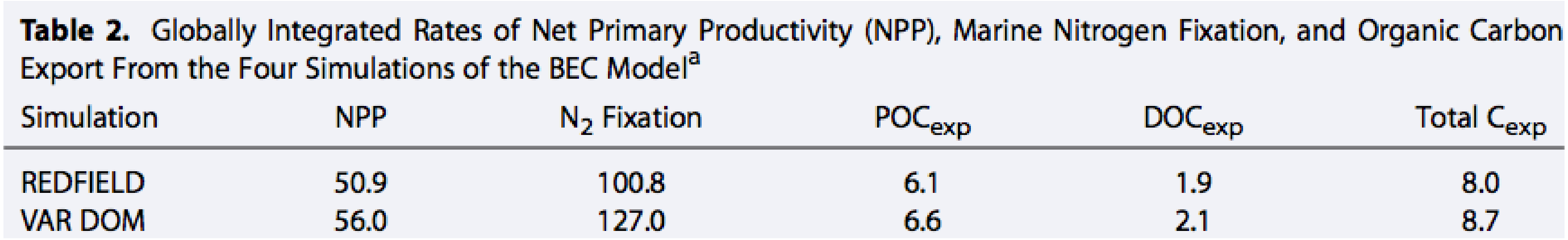


Table 2. Globally Integrated Rates of Net Primary Productivity (NPP), Marine Nitrogen Fixation, and Organic Carbon Export From the Four Simulations of the BEC Model[a]

Simulation	NPP	N_2 Fixation	POC_{exp}	DOC_{exp}	Total C_{exp}
REDFIELD	50.9	100.8	6.1	1.9	8.0
VAR DOM	56.0	127.0	6.6	2.1	8.7

R.T. Letscher and J.K. Moore, *Global Biogeochemical Cycles*, 29, GB20252, 2015. Funded by DOE.

Conclusions

1) BGC fields and fluxes look reasonable in new coupled run.

2) Pacific equatorial upwelling extends too far to the west.

3) Ventilation of mid-depth waters is weak leading to low O_2.

4) Physics modifications and developments discussed yesterday are currently being tested with BGC.

5) The offline tracer transport matrix with Newton-Krylov is a useful new tool for development of the ocean model.