Marine Ecosystem and Biogeochemistry in the Community Earth System Model

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CESM Ocean Ecosystem Component

The Biogeochemical Elemental Cycling (BEC) model has not changed much for the implementation in the CESM from CCSM 3.

It is an ecosystem and biogeochemical module that runs within the
CCSM POP2 ocean circulation model.

Key Model Components:

- Four phytoplankton functional groups,
- One adaptive zooplankton class,
- Key limiting nutrients (N, P, Fe, Si), plus C, O, and alkalinity
- Dissolved Organic Matter
- Sinking Particulates (Organic, bSi, $CaCO_3$, Dust)

Includes atmospheric deposition of nitrogen and iron.

Biogeochemical Elemental Cycling (BEC) Model

Small Phytoplankton
C, Chl, Fe, CaCO3

Diatoms
C, Chl, Fe, Si

Diazotrophs
C, Chl, Fe

Zooplankton
C

Sinking Particulates
C, Fe, Si, $CaCO_3$, Dust

Dissolved Organic Matter
C, N, P, Fe

Nitrate

Ammonium

Phosphate

Iron

Silicate

Oxygen

DIC

Alkalinity

CCSM4 POP2 ocean circulation model, ~1 degree resolution with 60 vertical levels.

CESM Ocean Ecosystem Component

Many aspects of the CESM BEC have been documented previously.

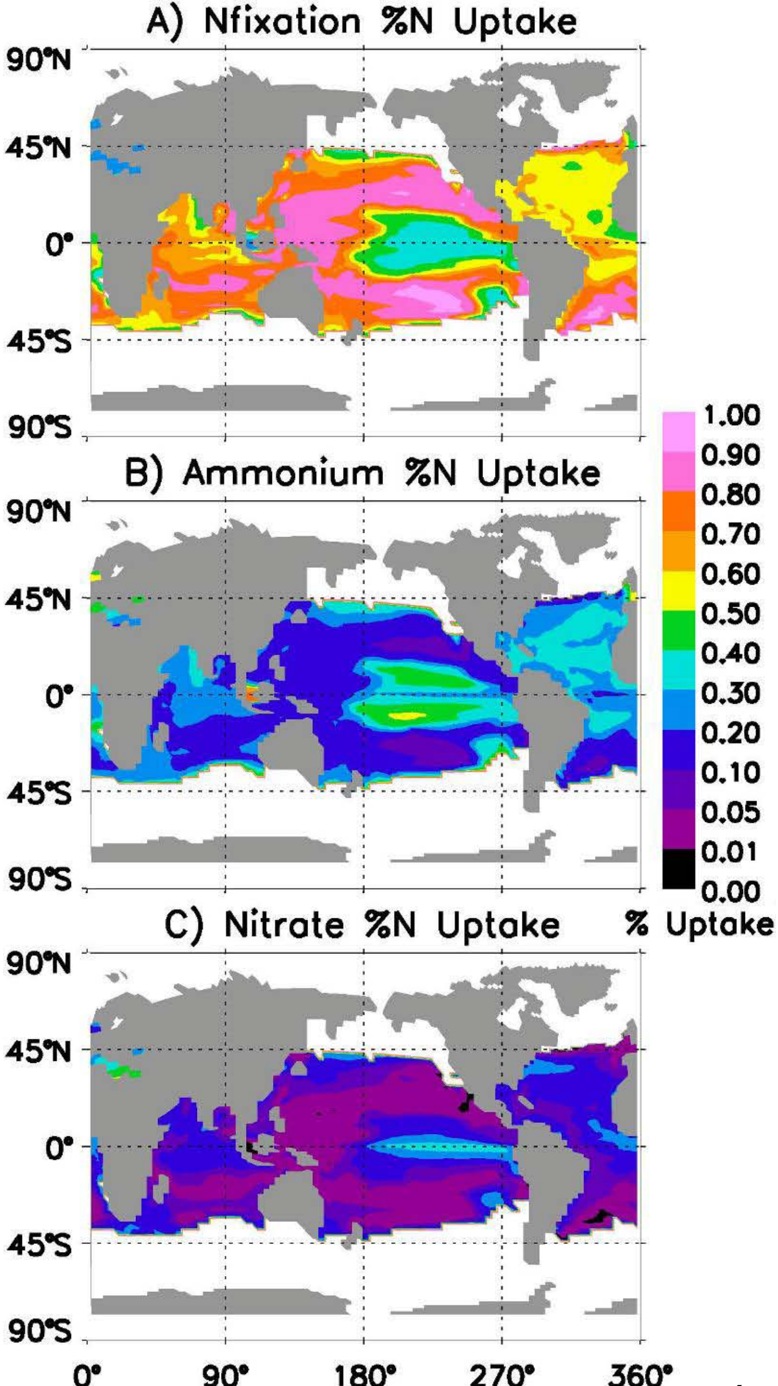
Basic Ecosystem and Biogeochemistry
(Doney et al., 1996; 2001; Moore et al., 2002; 2004)

Water Column Denitrification (Moore and Doney, 2007)

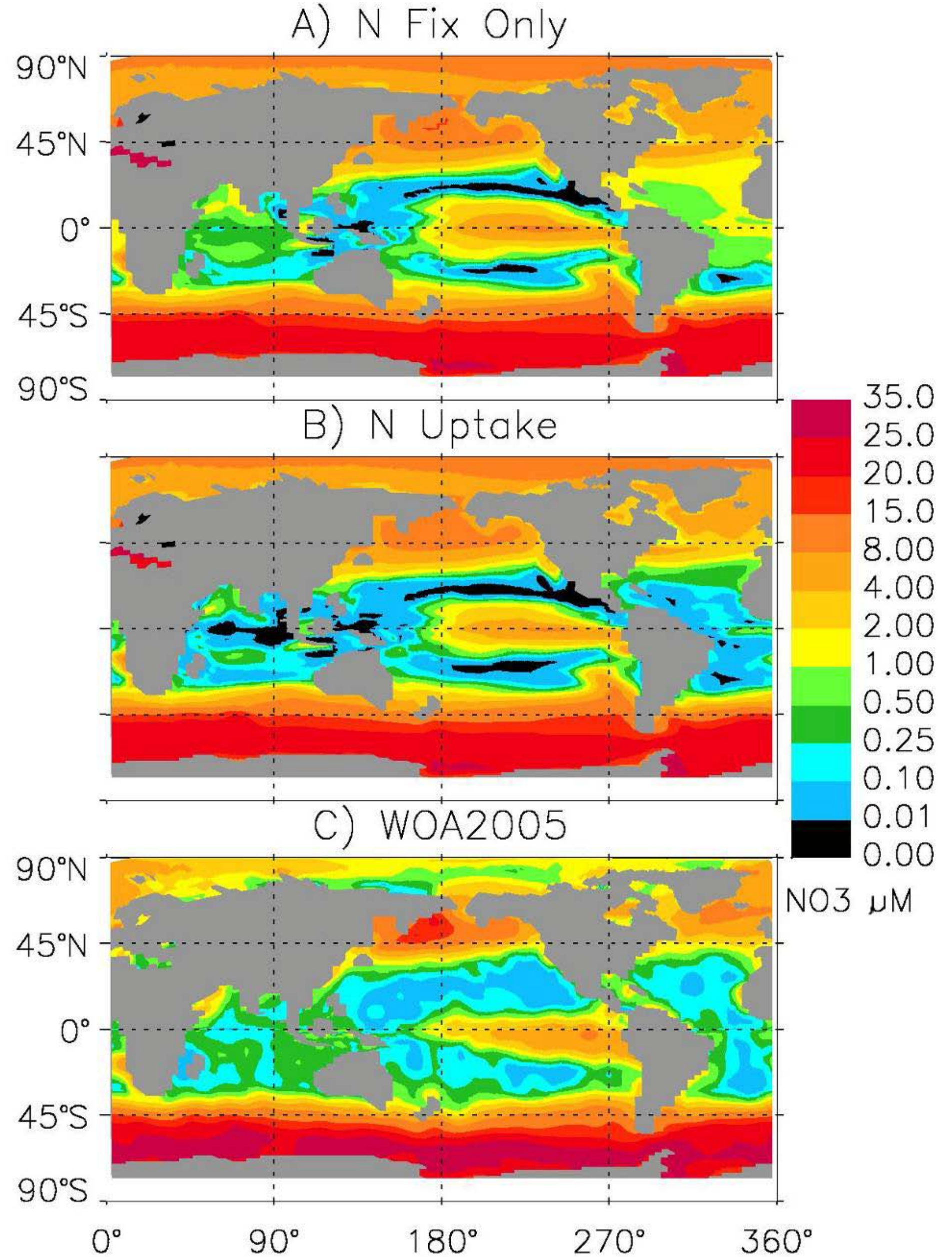
Sedimentary Iron Source (Moore and Braucher, 2008)

Atmospheric Nutrient Deposition
(Krishnamurthy et al., 2007; 2009; 2010; Doney et al., 2007)

Diazotroph ability to take up inorganic nitrogen
(previously all N from nitrogen fixation)

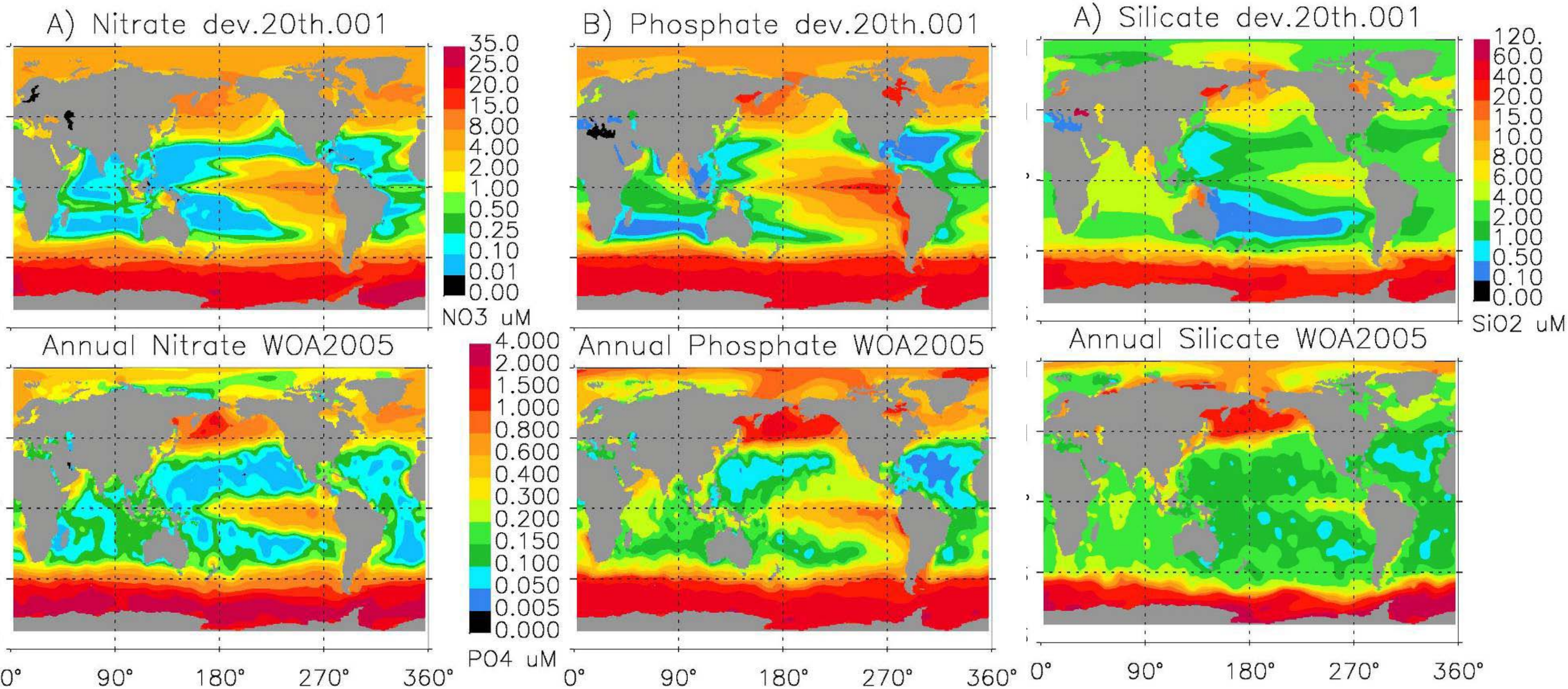


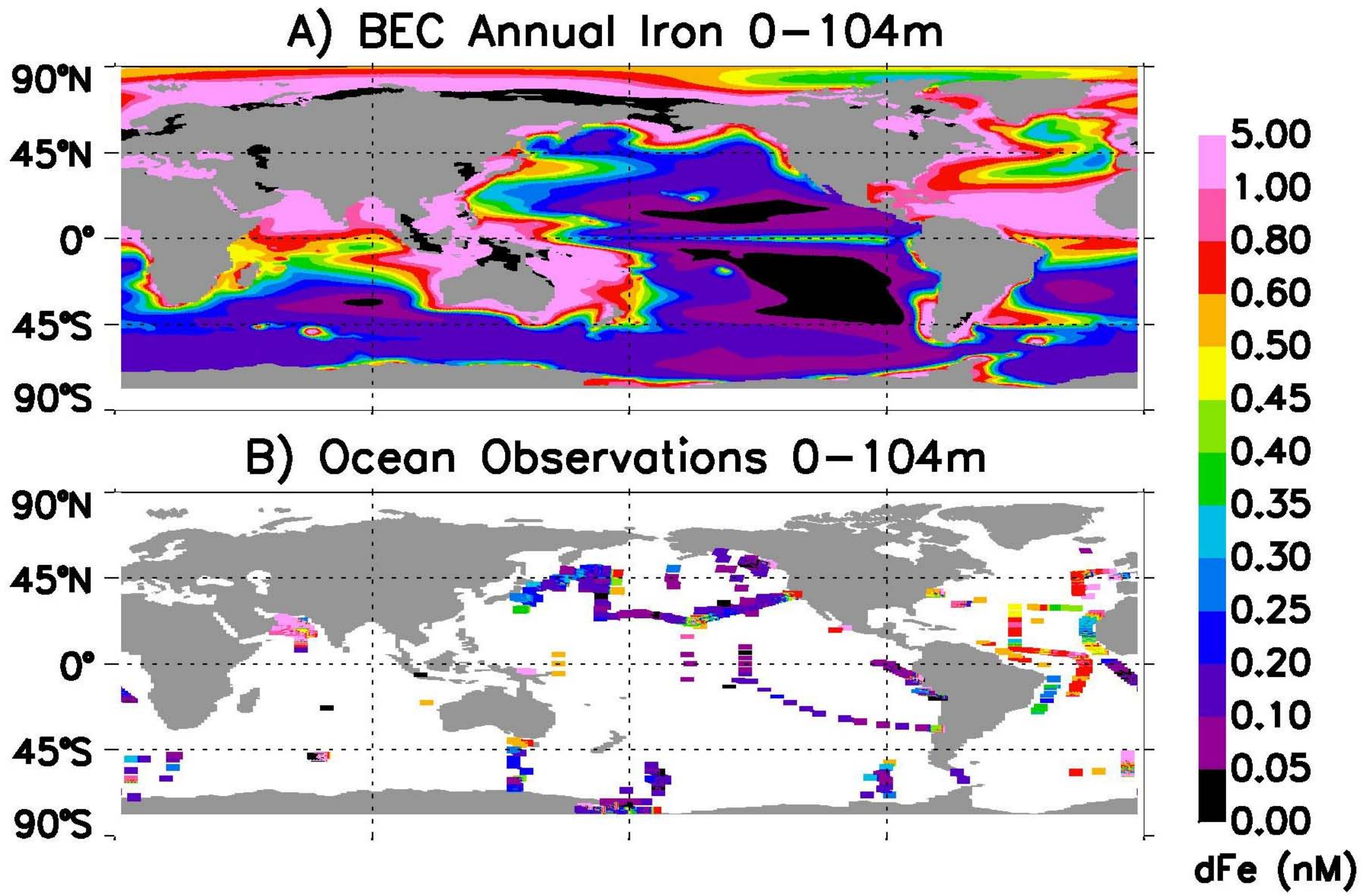
Surface Nitrate



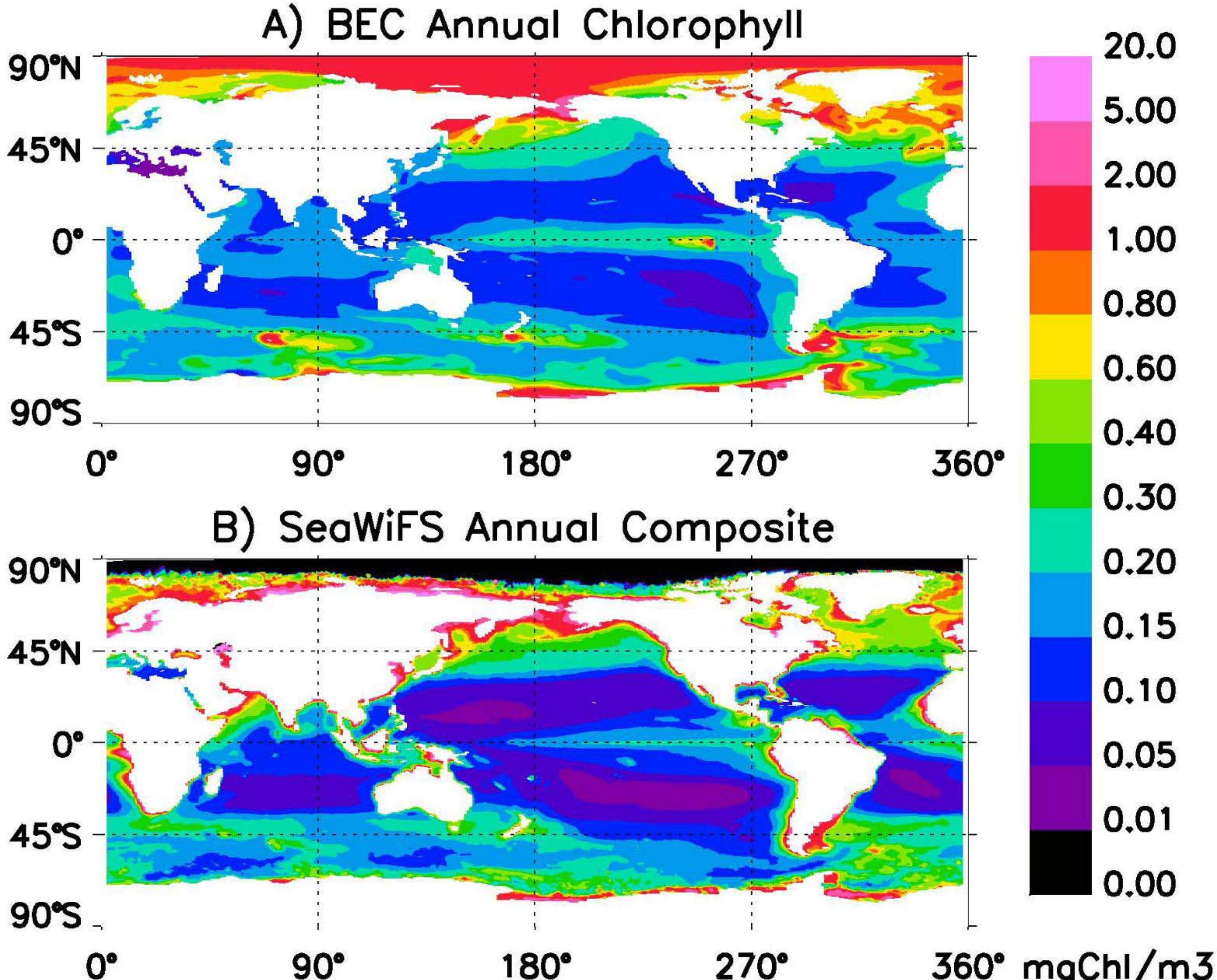
(CCSM3)

CESM BEC 2005 Nutrients Compared with WOA Observations

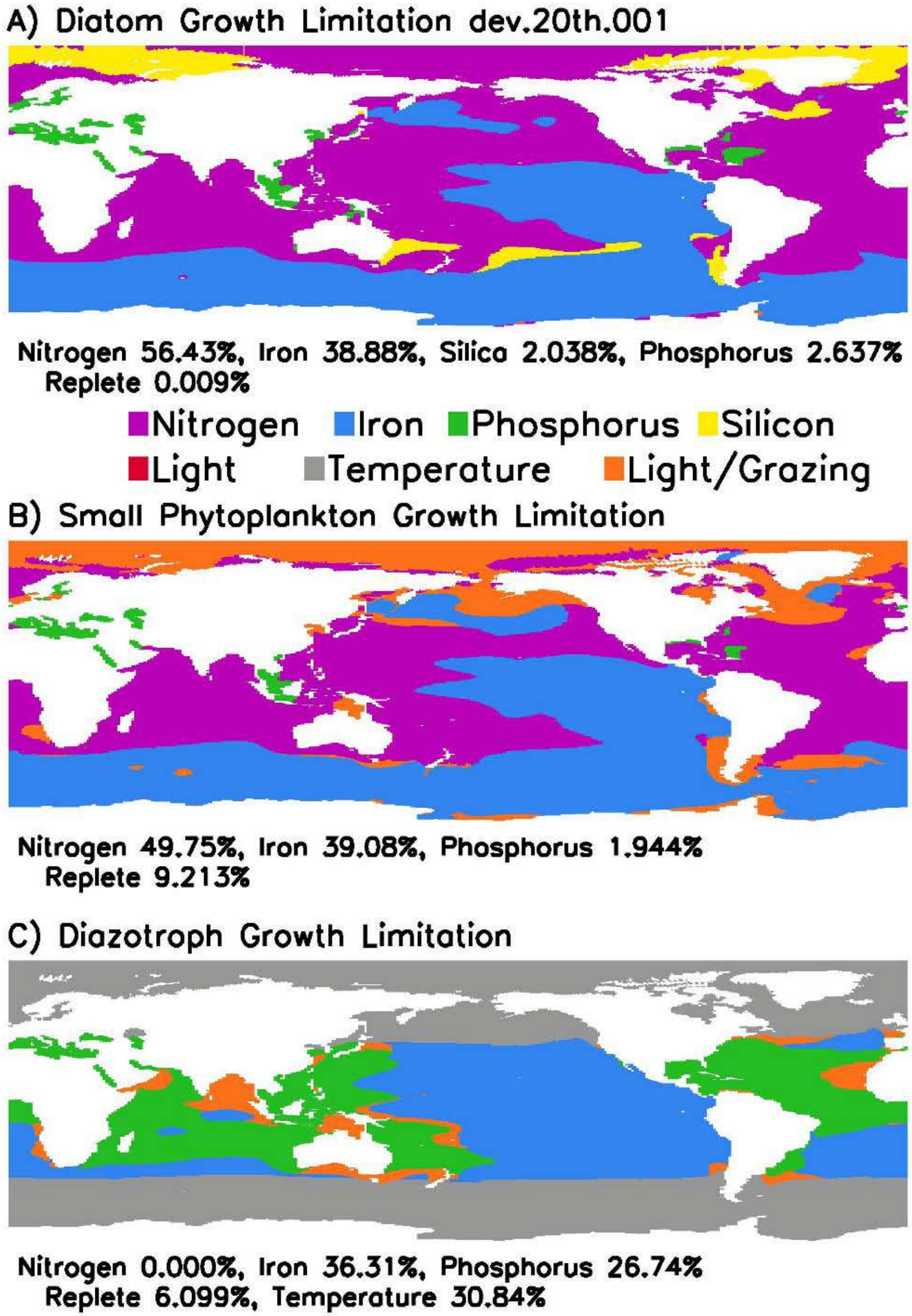


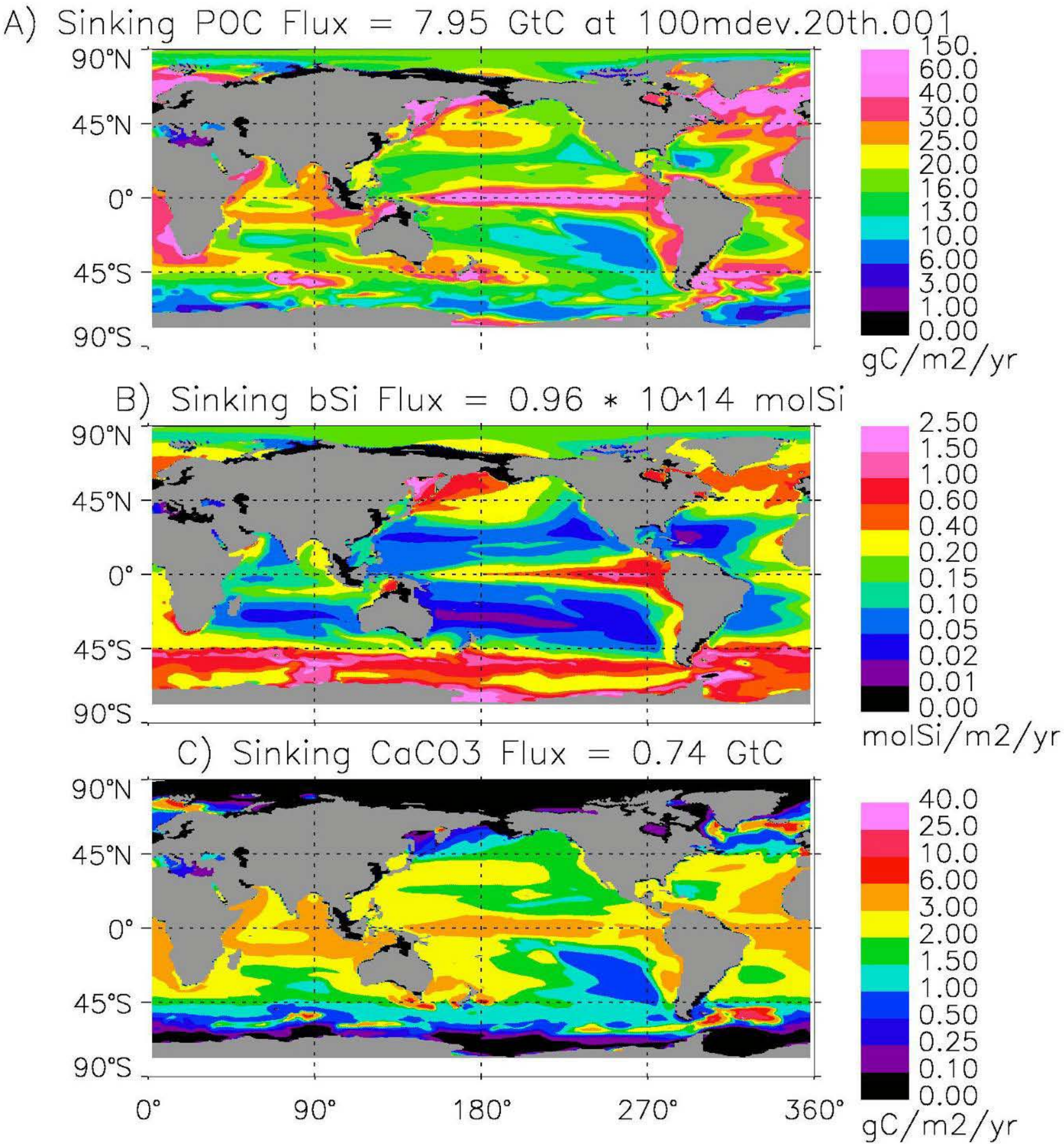


A) BEC Annual Iron 0–104m
90°N
45°N
0°
45°S
90°S
B) Ocean Observations 0–104m
90°N
45°N
0°
45°S
90°S
5.00
1.00
0.80
0.60
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.10
0.05
0.00
dFe (nM)

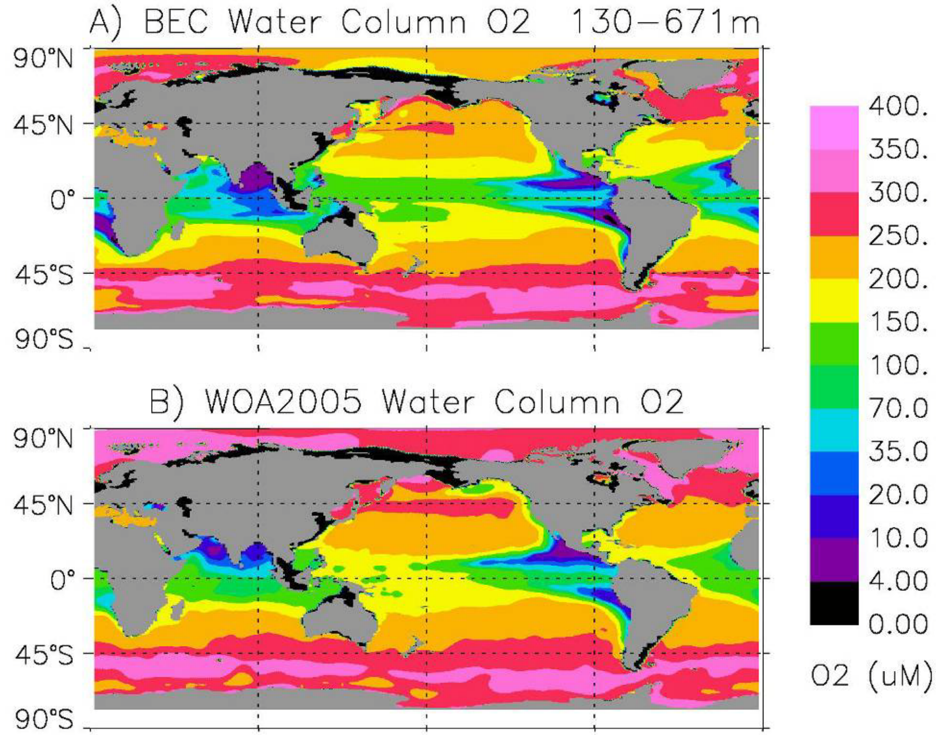


A) BEC Annual Chlorophyll
B) SeaWiFS Annual Composite
90°N
45°N
0°
45°S
90°S
0°
90°
180°
270°
360°
20.0
5.00
2.00
1.00
0.80
0.60
0.40
0.30
0.20
0.15
0.10
0.05
0.01
0.00
mgChl/m3

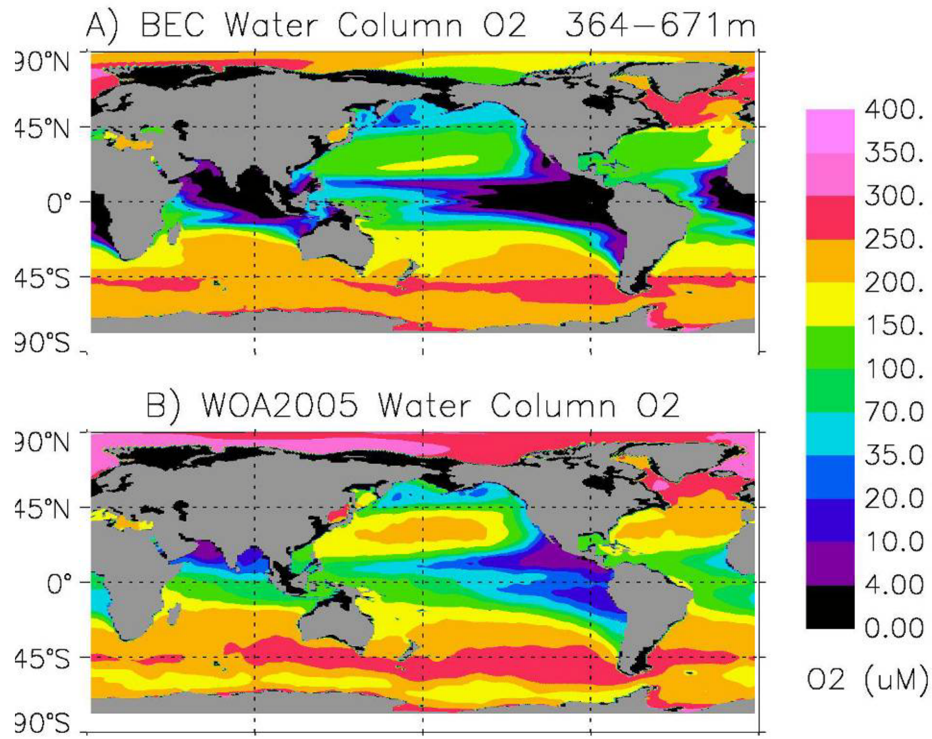

A) Diatom Growth Limitation dev.20th.001
Nitrogen 56.43%, Iron 38.88%, Silica 2.038%, Phosphorus 2.637%
Replete 0.009%
Nitrogen
Iron
Phosphorus
Silicon
Light
Temperature
Light/Grazing
B) Small Phytoplankton Growth Limitation
Nitrogen 49.75%, Iron 39.08%, Phosphorus 1.944%
Replete 9.213%
C) Diazotroph Growth Limitation
Nitrogen 0.000%, Iron 36.31%, Phosphorus 26.74%
Replete 6.099%, Temperature 30.84%



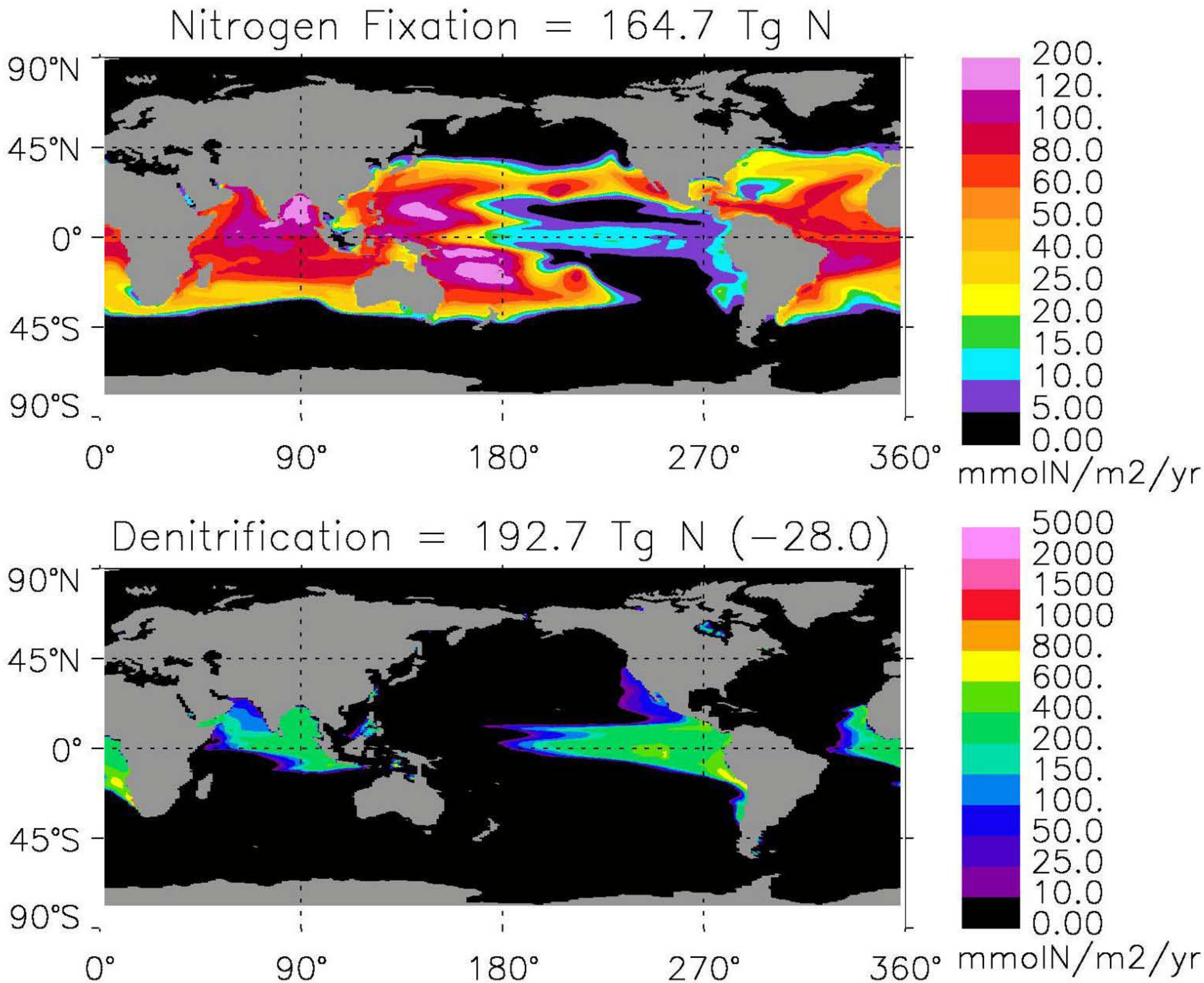
A) Sinking POC Flux = 7.95 GtC at 100mdev.20th.001
B) Sinking bSi Flux = 0.96 * 10^14 molSi
C) Sinking CaCO3 Flux = 0.74 GtC
90°N
45°N
0°
45°S
90°S
0°
90°
180°
270°
360°
150.
60.0
40.0
30.0
25.0
20.0
16.0
13.0
10.0
6.00
3.00
1.00
0.00
gC/m2/yr
2.50
1.50
1.00
0.60
0.40
0.20
0.15
0.10
0.05
0.02
0.01
0.00
molSi/m2/yr
40.0
25.0
10.0
6.00
3.00
2.00
1.50
1.00
0.50
0.25
0.10
0.00
gC/m2/yr



RMS= 44.409,Ind= 46.405,Pac= 45.326,Atl= 60.978,SO= 18.412
Bias= −13.61,Ind= −42.07,Pac= 5.7843,Atl= −52.90,SO= −2.371
VolObs(<20 uM) = 1.26411e+15m^3, ModVol=1.22567e+15m^3
Mod/Obs=0.9695, TotVol=6.58740e+15m^3,Obs/Tot=0.1918
SOlowrms = 19.686,SOlowbias = −12.53
SOaccrms = 13.743,SOaccbias = −4.762
SOhirms = 21.178,SOhibias = 1.2481



MS= 45.759,Ind= 79.806,Pac= 33.481,Atl= 88.138,SO= 29.375
ias= −26.23,Ind= −69.92,Pac= −24.20,Atl= −74.24,SO= 8.7494
olObs(<20 uM) = 3.62990e+15m^3, ModVol=6.16658e+15m^3
Mod/Obs=1.6988, TotVol=1.45681e+16m^3,Obs/Tot=0.2491
SOlowrms = 29.668,SOlowbias = −25.94
SOaccrms = 22.430,SOaccbias = −1.763
SOhirms = 32.947,SOhibias = 24.560



Nitrogen Fixation = 164.7 Tg N
90°N
45°N
0°
45°S
90°S
0°
90°
180°
270°
360°
200.
120.
100.
80.0
60.0
50.0
40.0
25.0
20.0
15.0
10.0
5.00
0.00
mmolN/m2/yr
Denitrification = 192.7 Tg N (−28.0)
90°N
45°N
0°
45°S
90°S
0°
90°
180°
270°
360°
5000
2000
1500
1000
800.
600.
400.
200.
150.
100.
50.0
25.0
10.0
0.00
mmolN/m2/yr

Conclusions

1) The CESM BEC captures observed nutrient and carbon distributions to first order, suitable for climate studies.

2) There is a positive bias in low latitude surface nutrients and phytoplankton biomass.

3) High latitude surface nutrients are often too low.

4) Oxygen minimum zones are much larger than observed.

5) OMZ expansion leads to excessive water column denitrification and imbalances in the N cycle.

6) We are actively working to address these biases.