Optimizing CESM-BEC Marine Biogeochemistry

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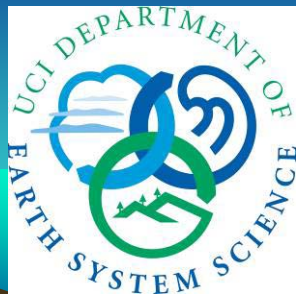


Biogeochemical Elemental Cycling (BEC) Model

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

C/N/P ratios are fixed, diazotroph N/P higher.
Coarse resolution NCAR CESM POP2 ocean model
~1 degree resolution with 60 vertical levels

Nitrate

Ammonium

Phosphate

Iron

Silicate

Oxygen

DIC

Alkalinity

Improving Ocean Biogeochemistry in the CESM

Biogeochemistry/Ecosystem

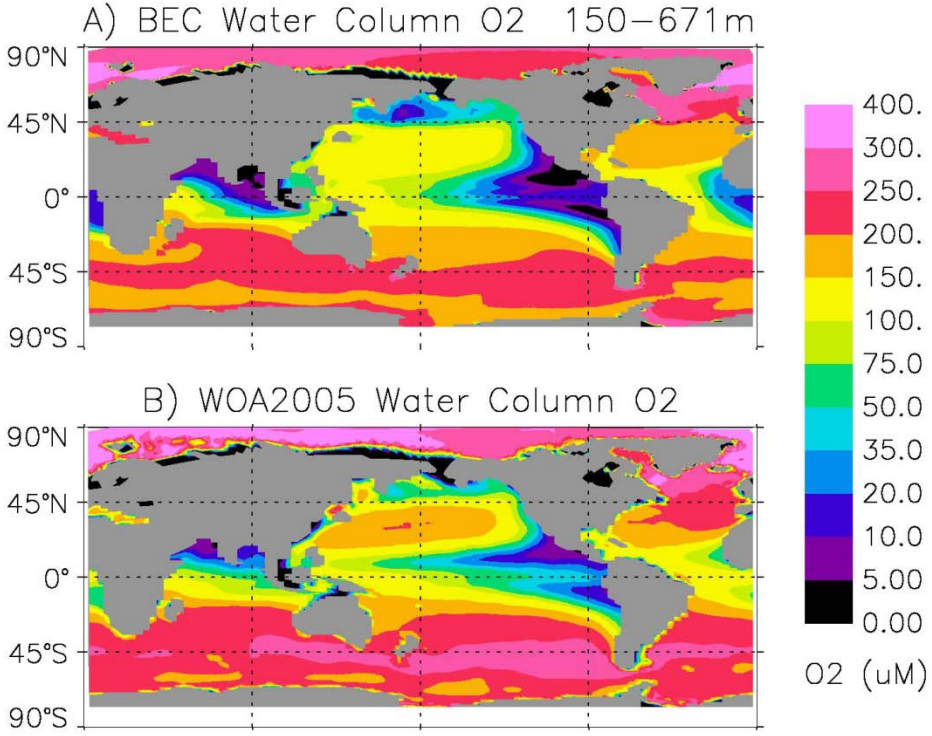
1) Optimize prescribed remineralization with depth curve
2) Increase phytoplankton maximum iron quotas
3) Optimize grazing parameters and bloom dynamics
4) Improve cycling of dissolved organic matter

Ocean Physics

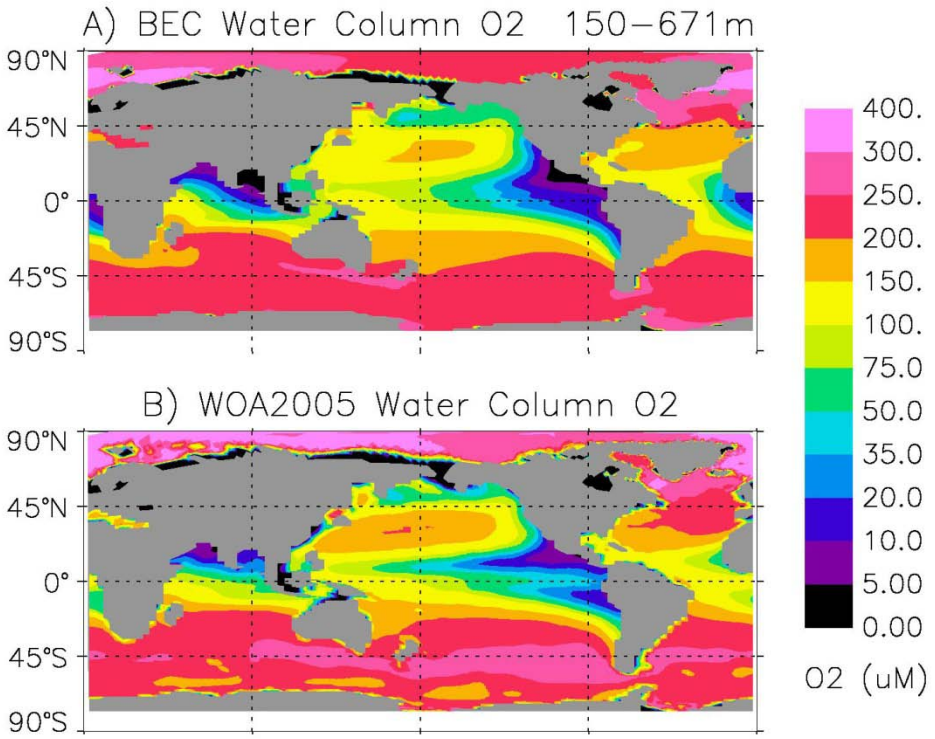
1) Increase vertical mixing in some high latitude regions
2) Increase minimum isopycnal mixing rate

Results from 3 degree gx3v7, currently porting to 1 deg gx1v6.

STD CESM



MOD CESM

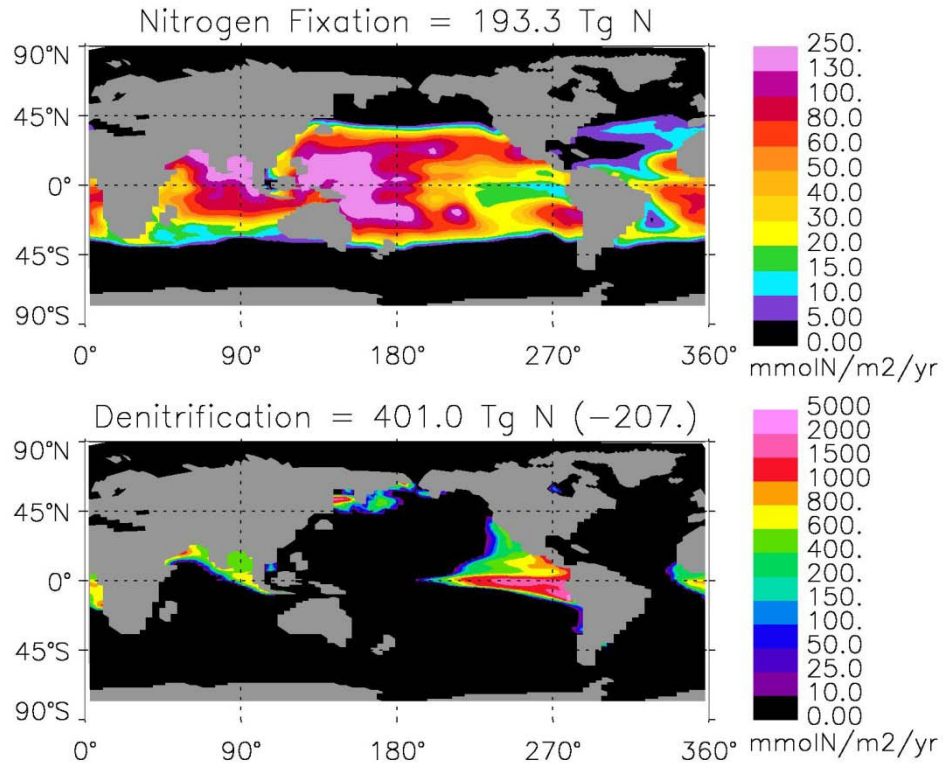


Mean Oxygen Concentration from 150-671m Depth

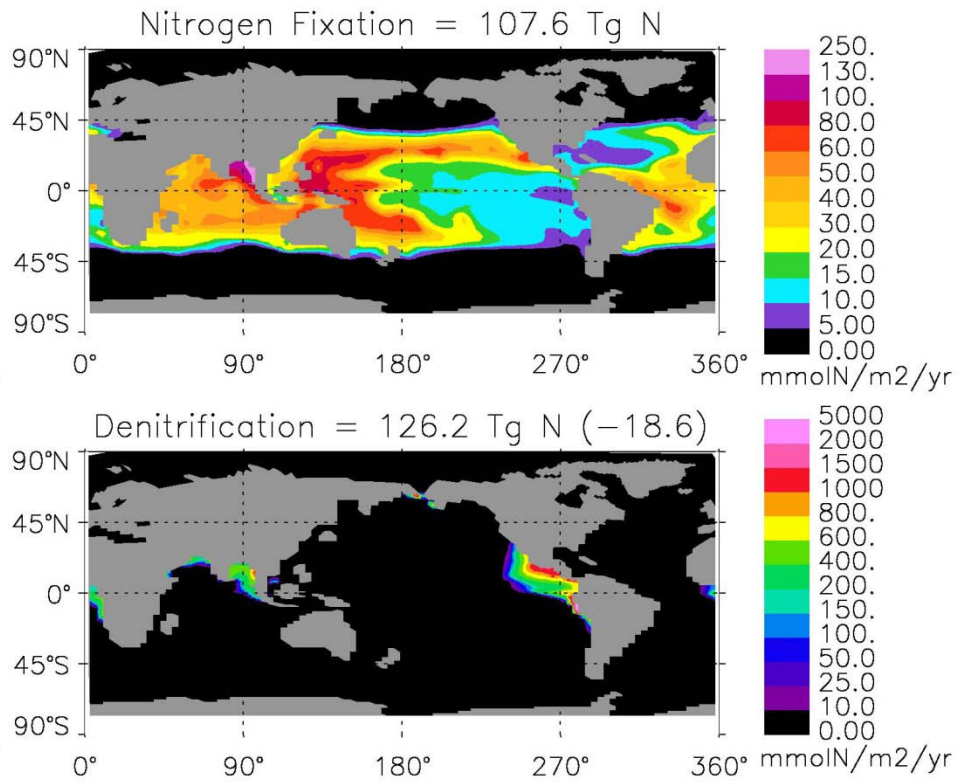
Low oxygen regions (O2 < 20 µM), Oxygen Minimum Zones (OMZ) much larger than observed.

Leads to excessive water column denitrification.

STD CESM

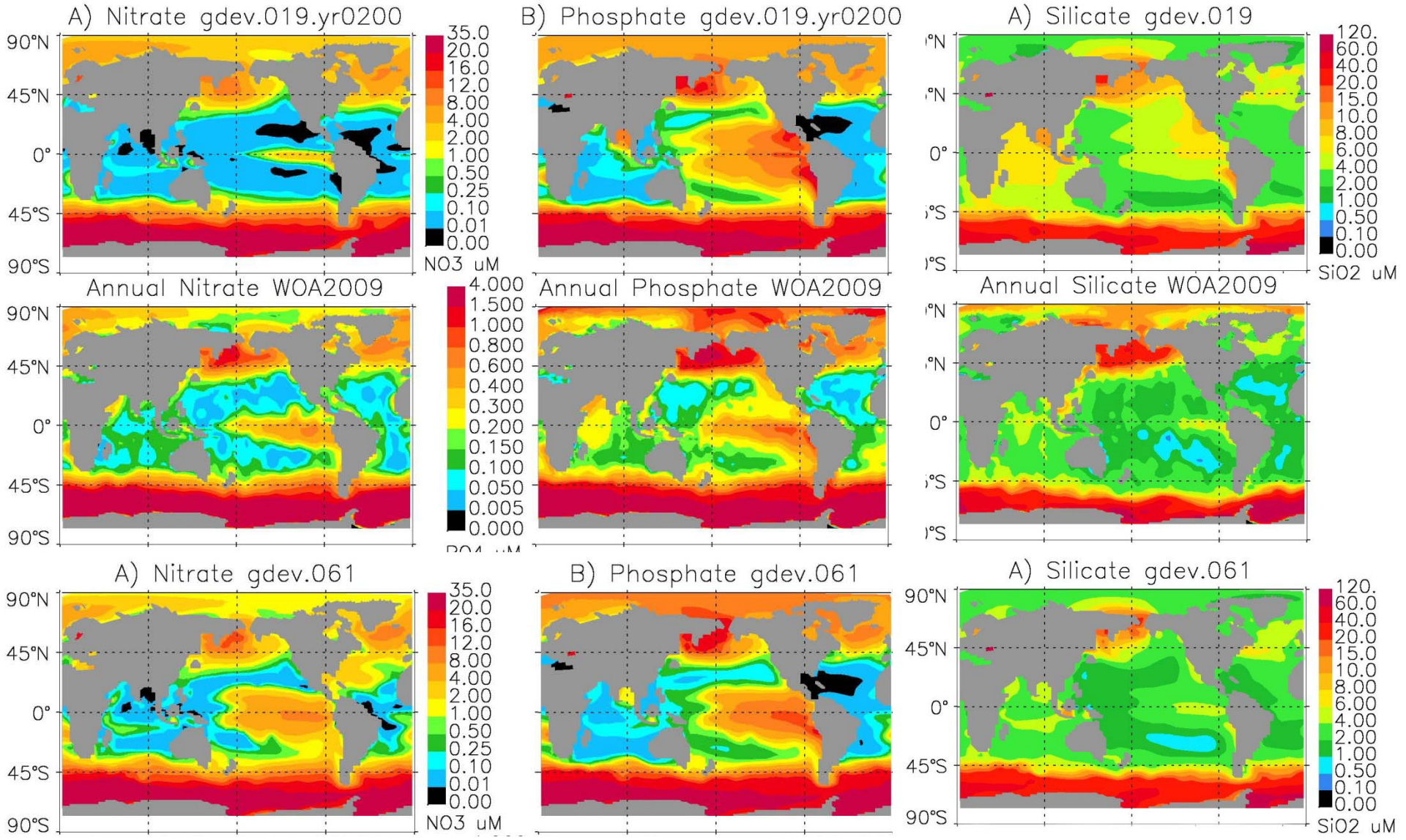


MOD CESM



Standard CESM has large imbalance in the nitrogen cycle.

Modifications allow for balanced nitrogen cycle.



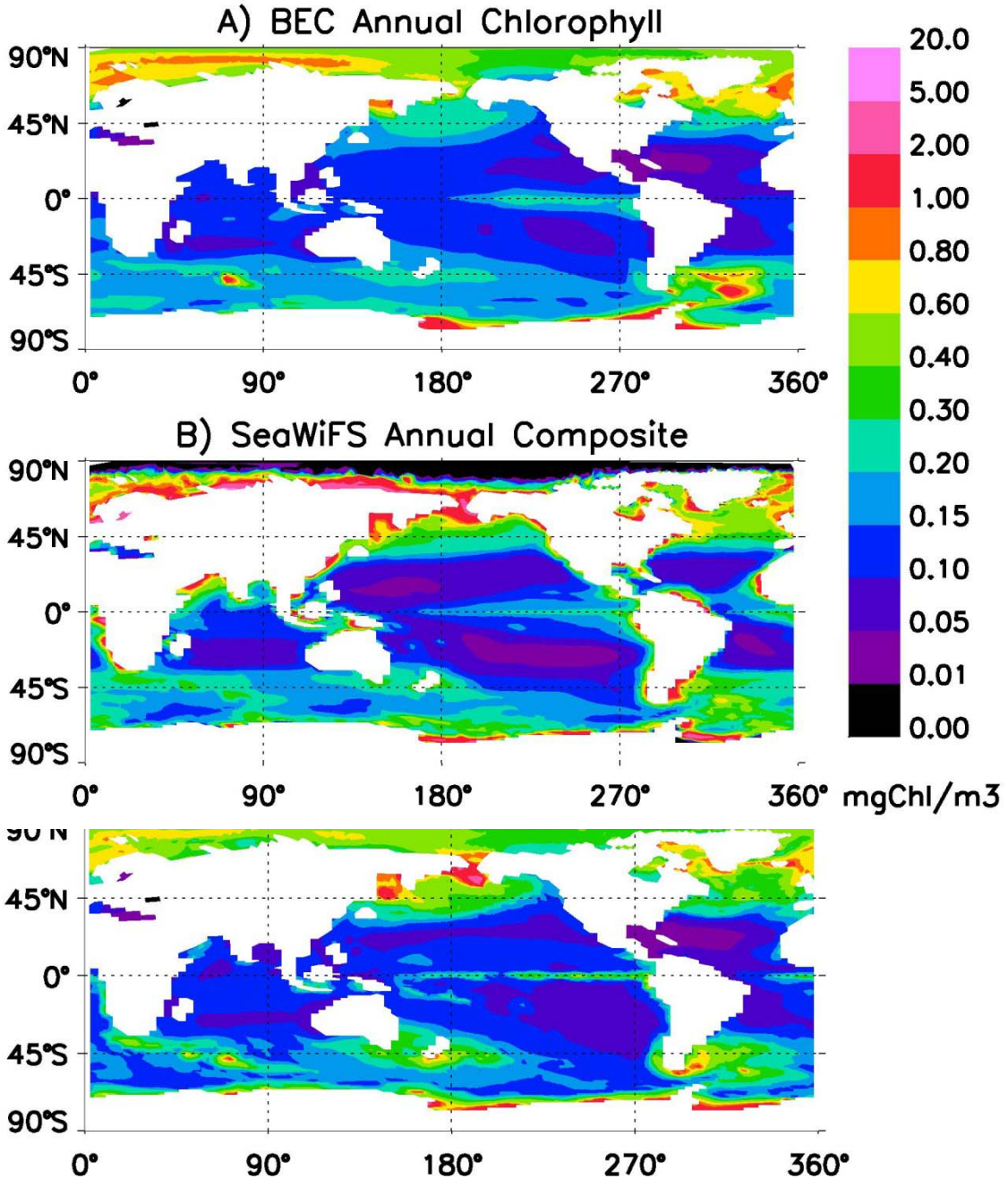
Top Row STD-CESM **Middle Observed** **Bottom MOD-CESM**

Modifications also improve surface nutrient distributions.

Standard CESM

Observed Chlorophyll

Modified CESM



STD CESM

A) Diatom Growth Limitation gdev.019

Nitrogen 70.81%, Iron 22.12%, Silica 1.150%, Phosphorus 5.899%
Light/Grazing 0.000%

Nitrogen Iron Phosphorus Silicon
Temperature Light/Grazing

B) Small Phytoplankton Growth Limitation

Nitrogen 64.56%, Iron 23.92%, Phosphorus 4.761%
Light/Grazing 6.744%

C) Diazotroph Growth Limitation

Nitrogen 0.000%, Iron 27.42%, Phosphorus 34.17%
Light/Grazing 5.379%, Temperature 33.02%

MOD CESM

A) Diatom Growth Limitation gdev.061

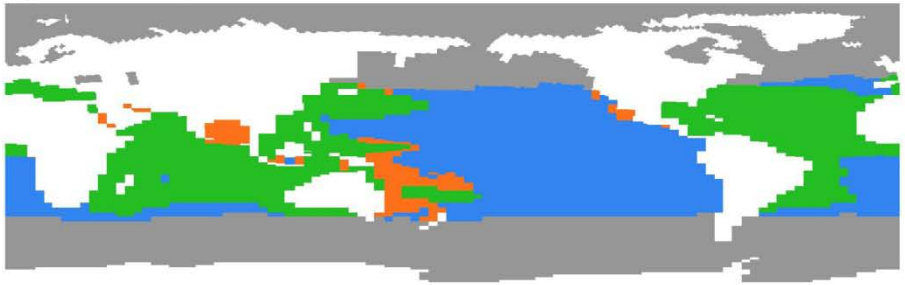
Nitrogen 37.01%, Iron 43.81%, Silica 4.449%, Phosphorus 14.71%
Light/Grazing 0.005%

Nitrogen Iron Phosphorus Silicon
Temperature Light/Grazing

B) Small Phytoplankton Growth Limitation

Nitrogen 34.55%, Iron 53.19%, Phosphorus 10.18%
Light/Grazing 2.065%

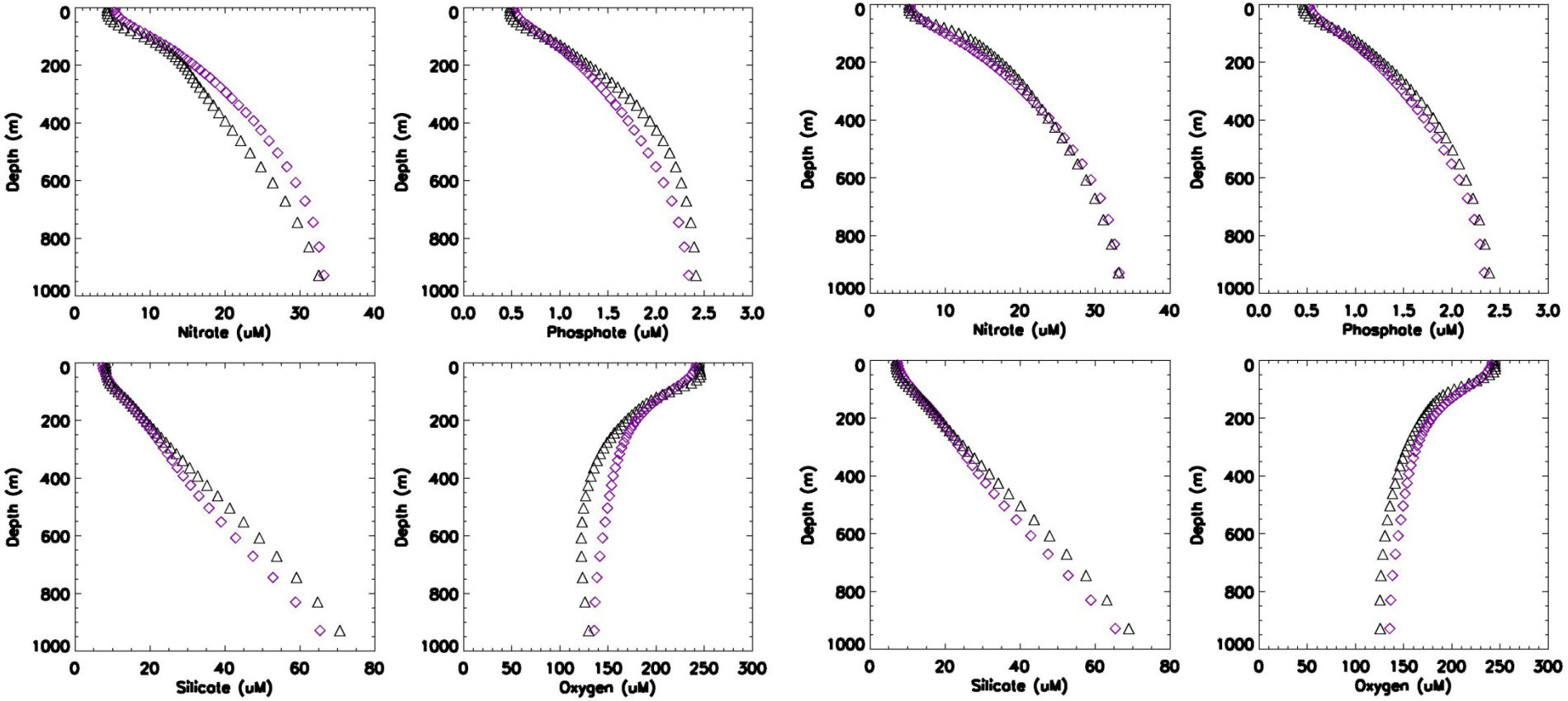
C) Diazotroph Growth Limitation



Nitrogen 0.000%, Iron 33.99%, Phosphorus 28.76%
Light/Grazing 4.113%, Temperature 33.12%

STD CESM

MOD CESM

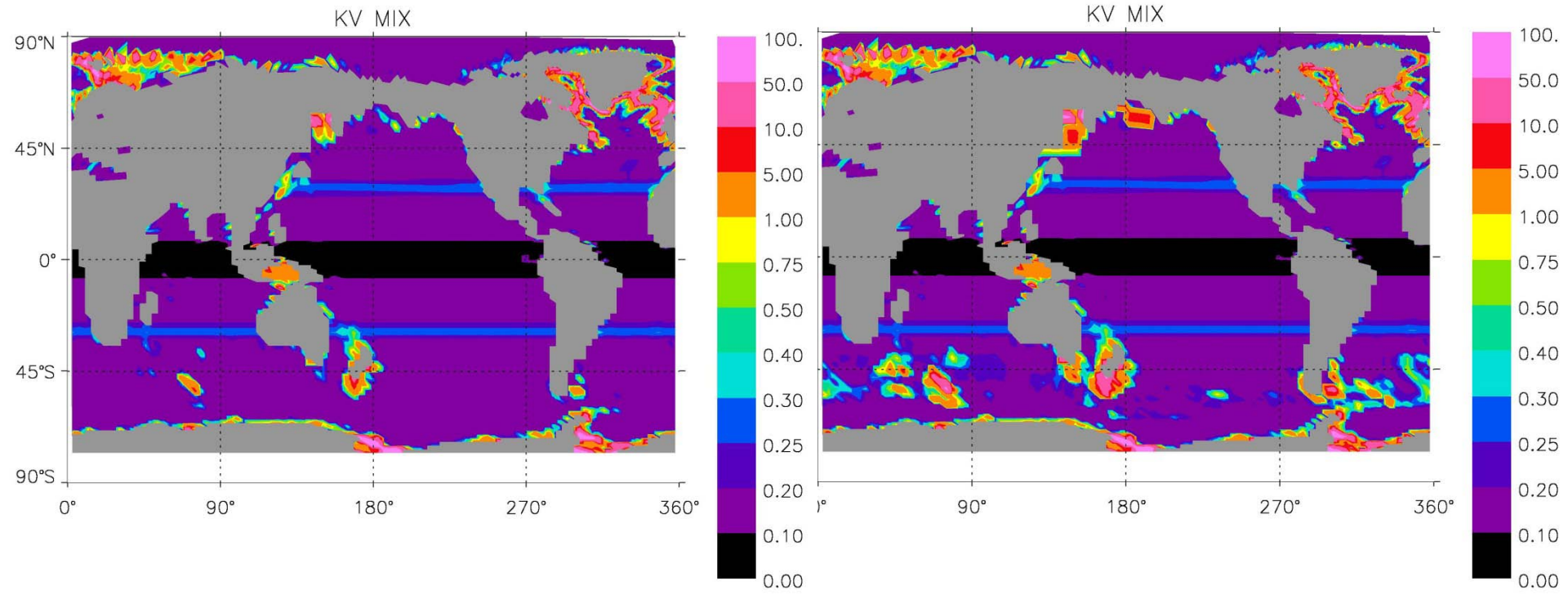


Black Triangles – CESM Global Mean Nutrient Profiles

Purple Diamond – Observed WOA2009 Mean Profiles

STD CESM

MOD CESM

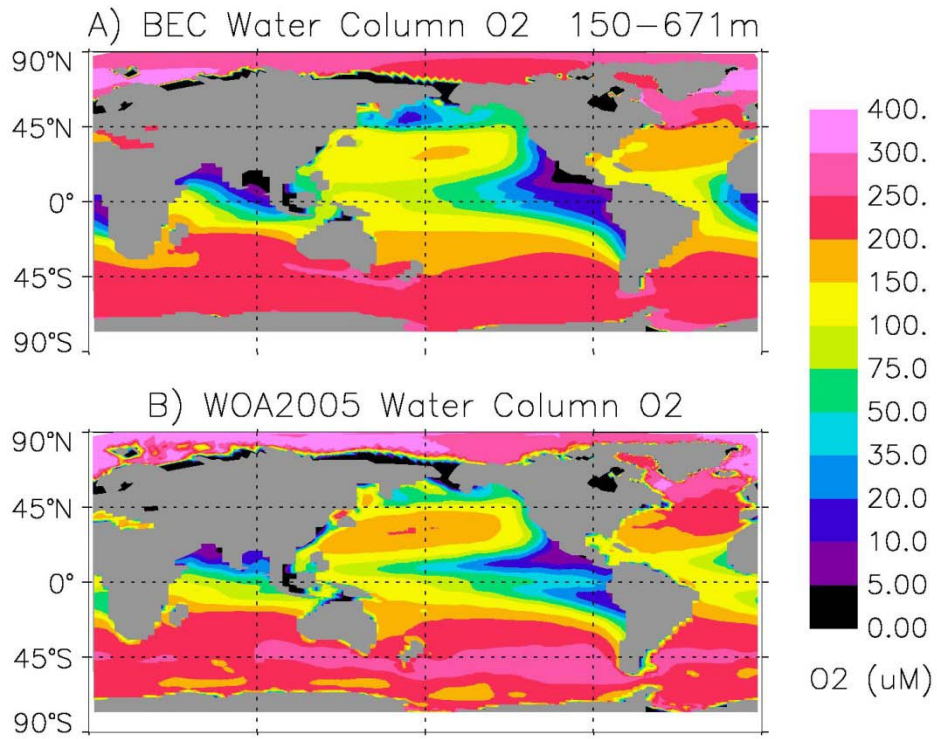


Vertical mixing rates 50-500m

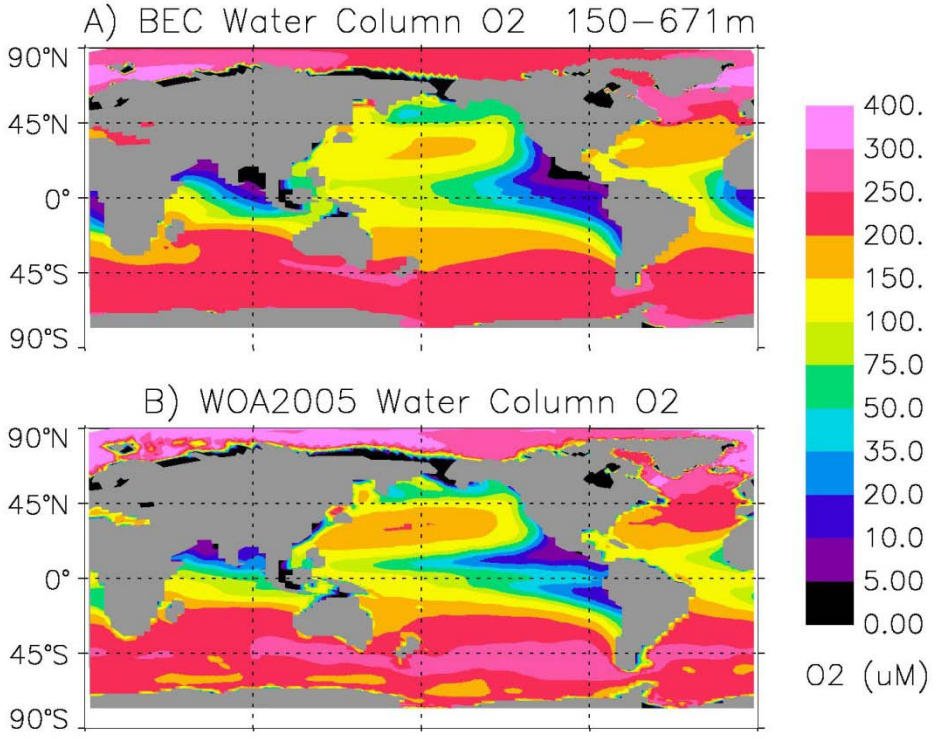
Increased mixing in NW Pacific (Kuril Islands, Bering Shelf)

Increased mixing in Southern Ocean (over rough bathymetry)

MOD CESM except NW Pac mixing



MOD CESM

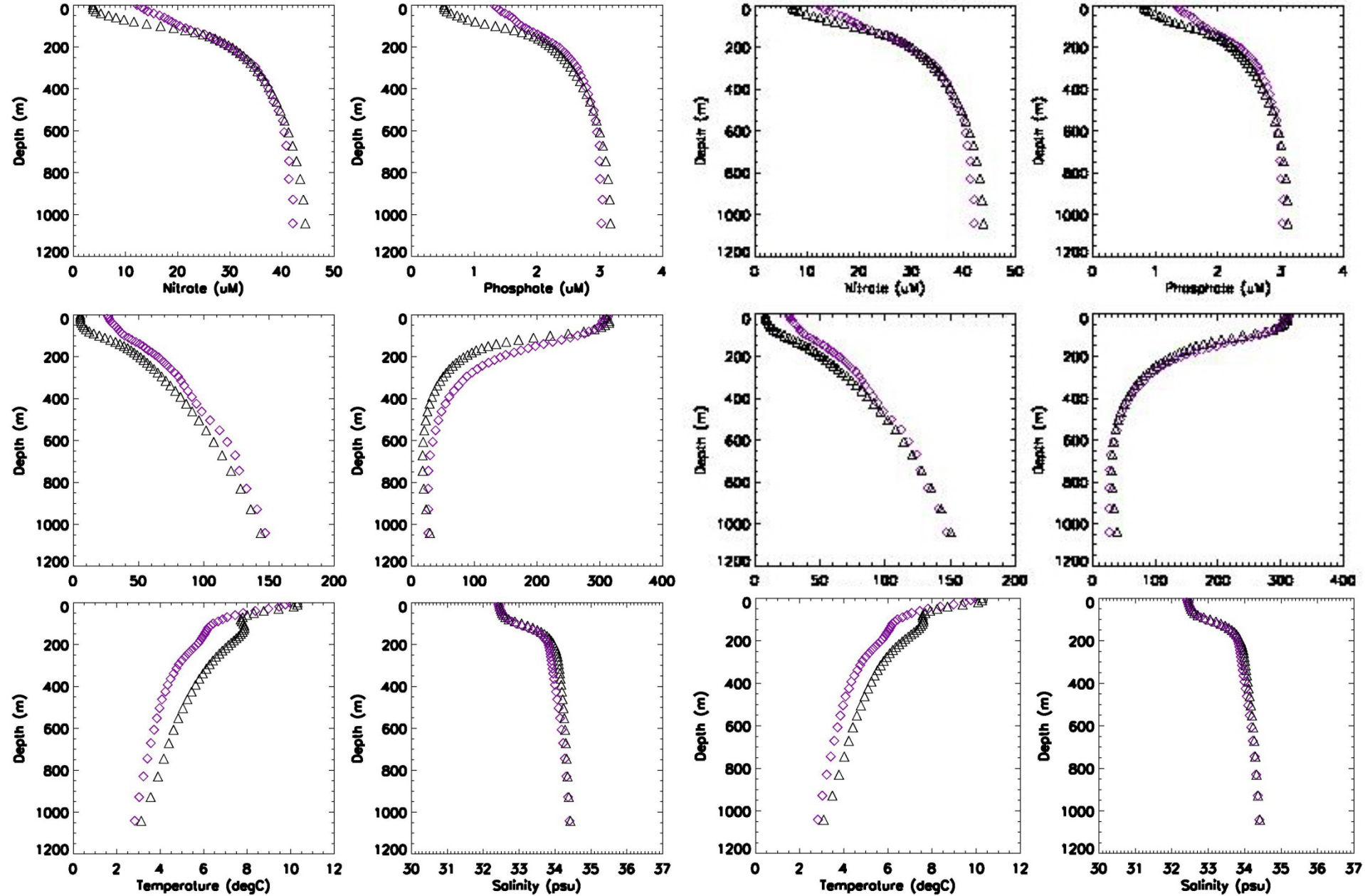


Mean Oxygen Concentration from 150-671m Depth

Kuril Island and Bering Sea shelf regions critical for ventilating the subarctic North Pacific.

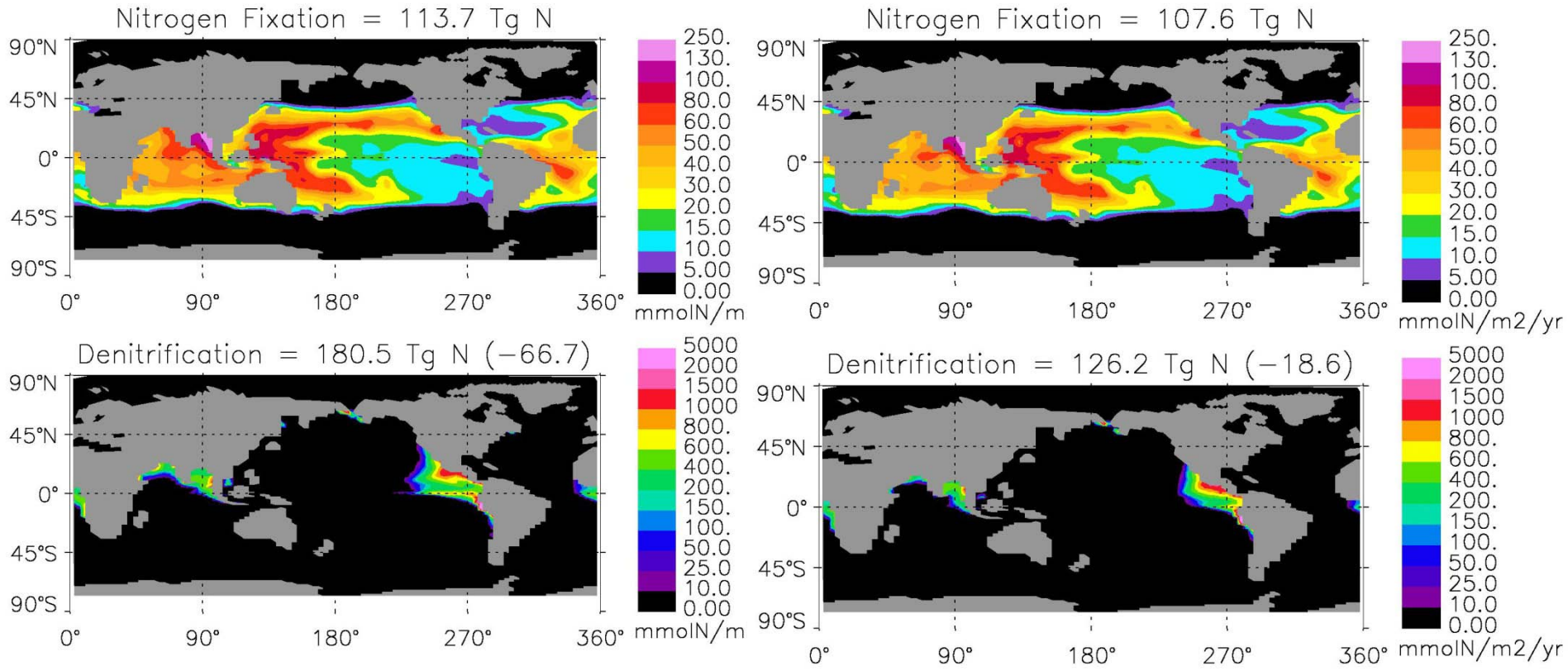
MOD CESM (except NW Pac mixing)

MOD CESM Mean North Pacific Profiles(>45N)



MOD CESM except for increased isopycnal mixing

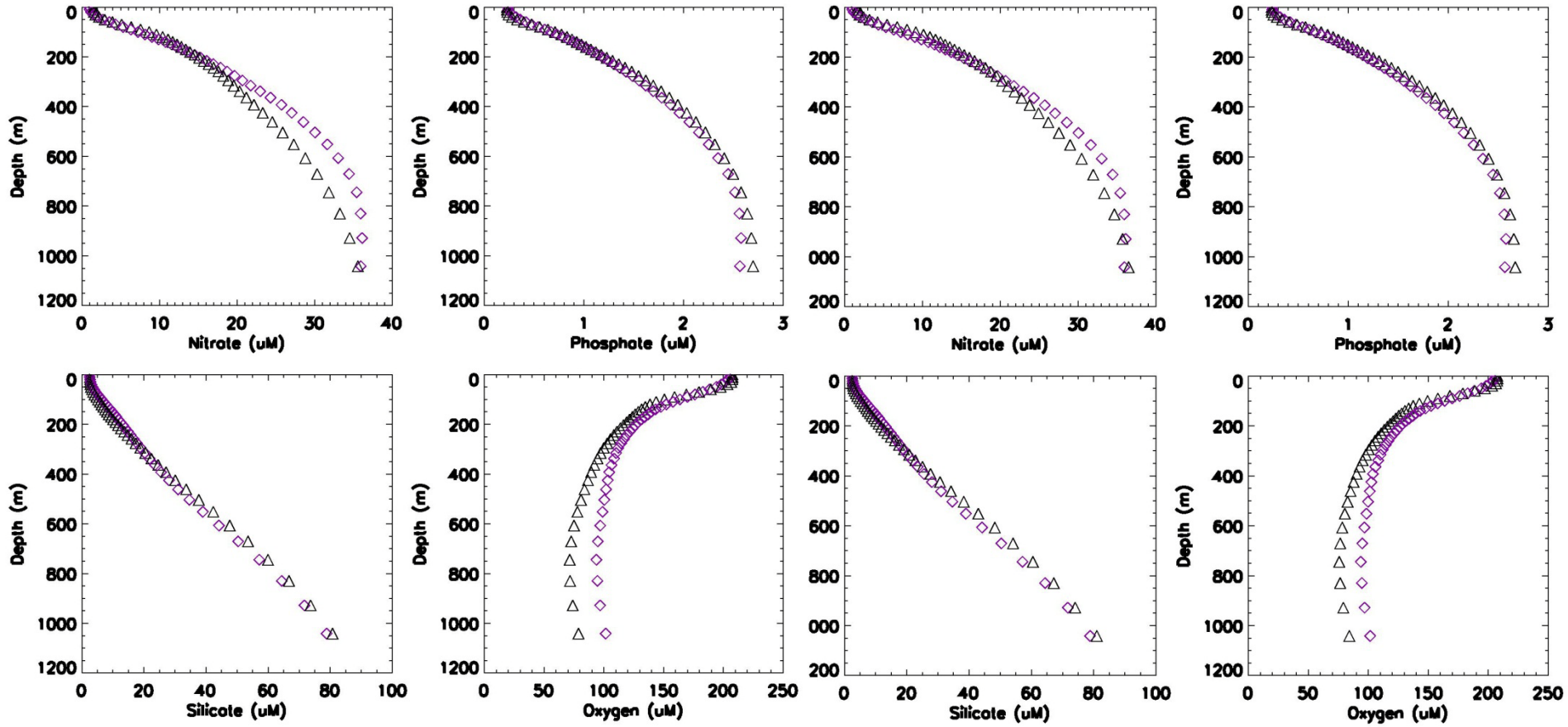
MOD CESM



Isopycnal mixing has a strong influence on ventilating the low latitude regions. Without the increased isopycnal mixing denitrification increases by almost 50%.

MOD CESM except for increased isopycnal mixing

MOD CESM



Low Latitude Mean Vertical Nutrient Profiles (25S – 25N)

Conclusions

1) Modifications to the biogeochemistry reduce but cannot eliminate the mid-depth oxygen bias at low latitudes.
2) Increased high latitude vertical (diapycnal) mixing and increased minimum rate of isopycnal mixing improve BGC simulation.
3) The physics of the 3 degree and 1 degree CESM ocean models are similar enough that BGC modifications port smoothly. Three degree model is a good development platform.