Biogeochemical Elemental Cycling (BEC) Model Improvements for CCSM4

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Improved sedimentary iron source and scavenging parameterizations

- Reduces mismatch with observations
- Improves HNLC region distributions (Moore and Braucher, 2008)

Improved phytoplankton dynamic Si/C and Fe/C ratios

- Improves surface silicate and dissolved iron distributions

Modifications to phytoplankton loss terms

- Allows for more phytoplankton blooms
- Better seasonal nutrient drawdown at high latitudes

Incorporation of atmospheric N, P, and Si (in addition to Fe)

- N has modest impacts, and deposition is changing rapidly since preindustrial
- P and Si from the atmosphere have very small impact on C cycle

Diazotroph utilization of fixed N sources (nitrate, ammonium) (Moore, submitted)

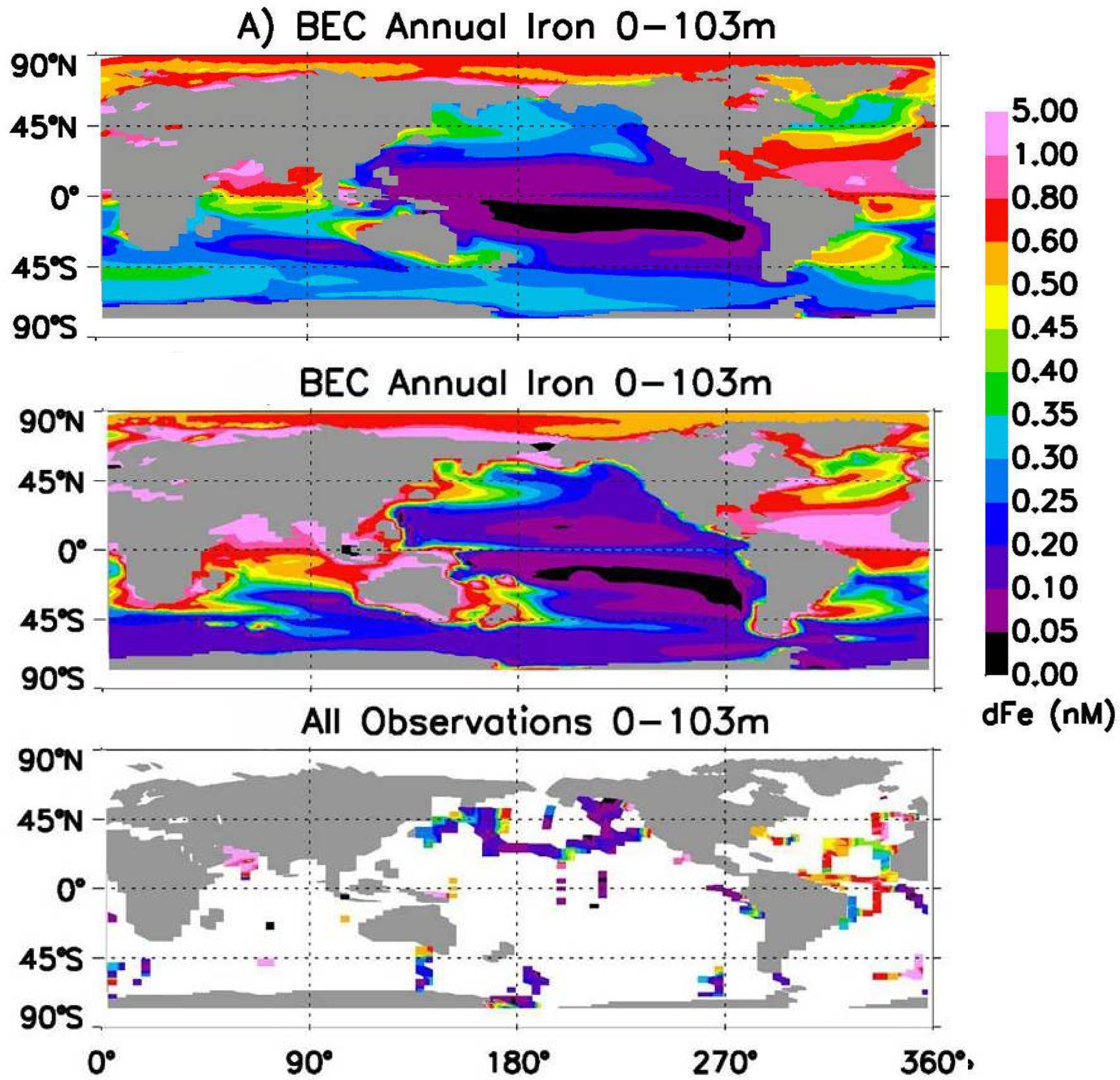
- Diazotrophs can fix N_2, but now also take up fixed N when available

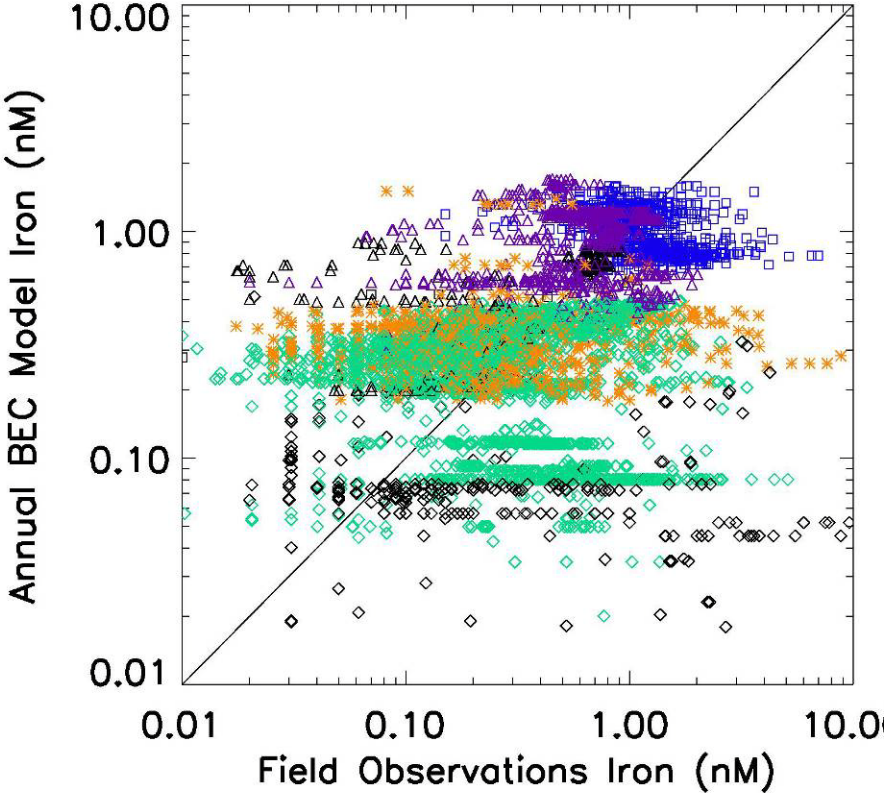
Modified O_2/Denitrification effect on remineralization lengths

- Length scales grow longer at low O_2
- Physics/mixing improvements in CCSM4 could help with low O_2 problem

Original BEC

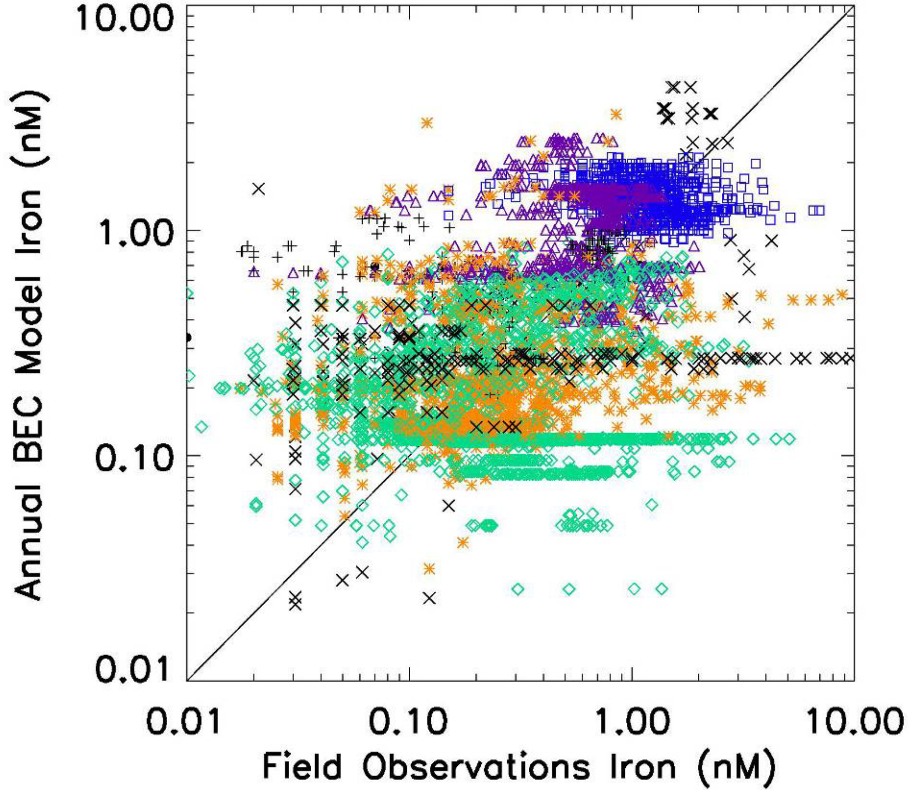
Improved BEC
sediment Fe source
Fe scavenging





N = 5609 points
r = 0.274
Mean bias = −0.10
rms = 0.753
High rms = 0.721
Low rms = 0.190
Stdev. Mod = 0.388
Stdev. Obs = 0.752
Ratio StdDev Mod/Obs = 0.515

Original BEC

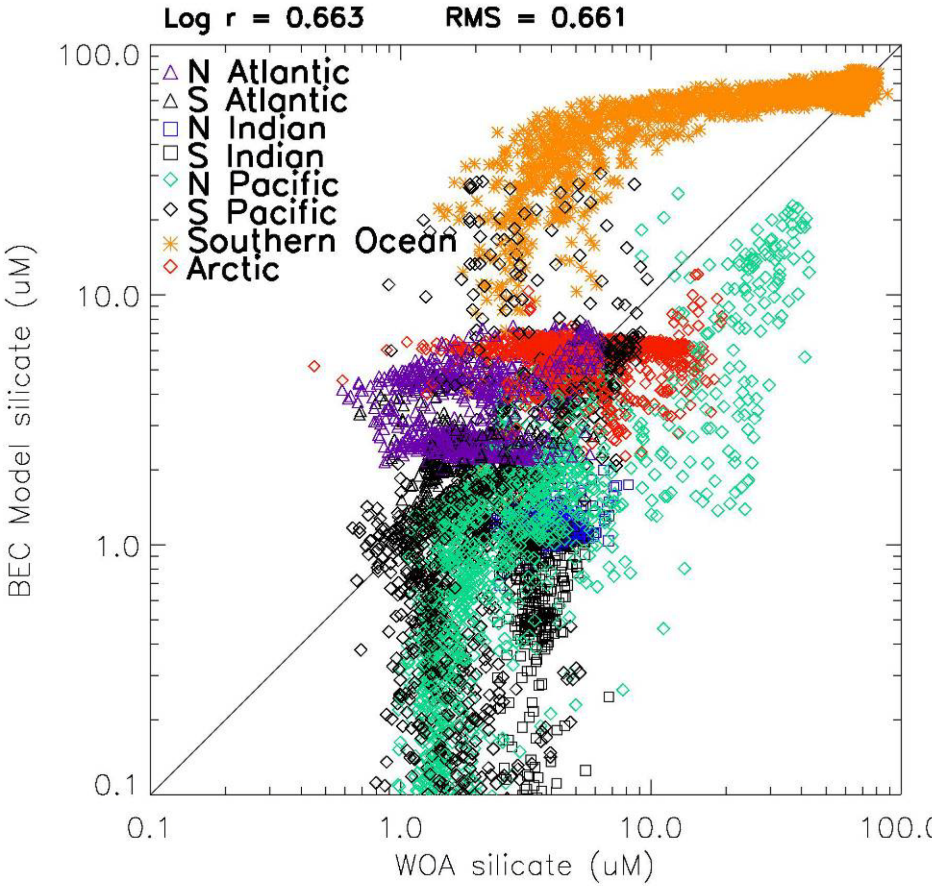


N = 5609 points
r = 0.365
Mean bias = 0.01315
rms = 0.768
High rms = 0.725
Low rms = 0.183
Stdev. Mod = 0.590
Stdev. Obs = 0.752
Ratio StdDev Mod/Obs = 0.784
Low Mean bias = 0.00106
Num Low points = 2831.

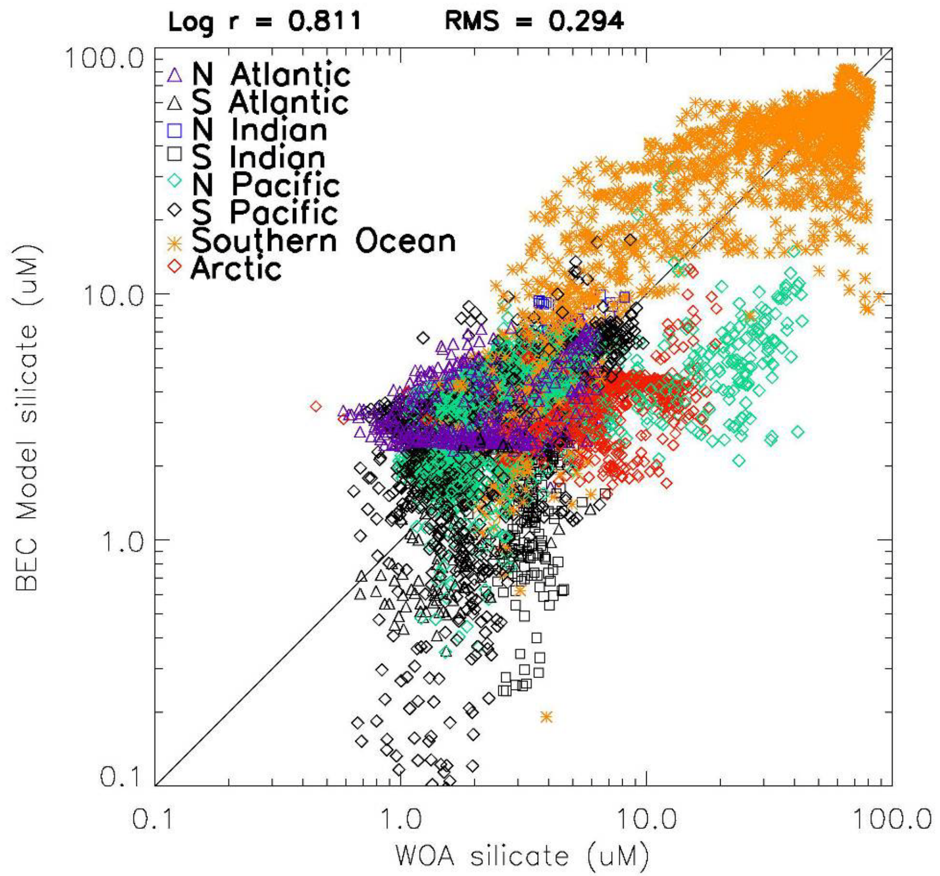
Improved BEC

sedimentary source

Fe scavenging

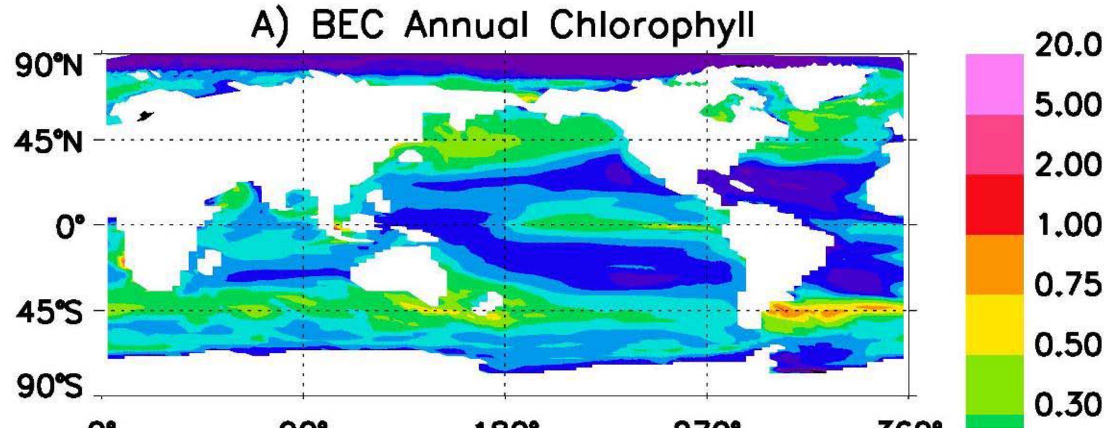


Original BEC - Si vs. Obs.

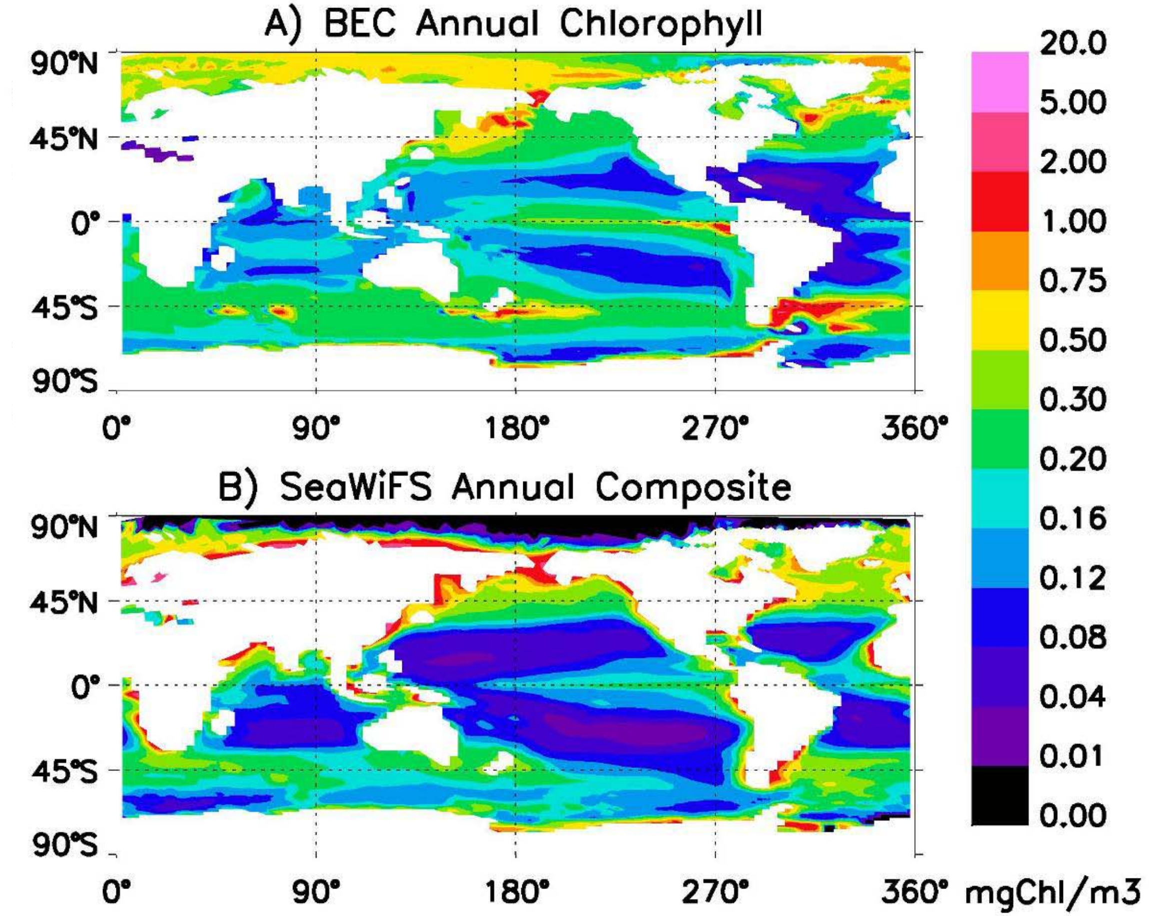


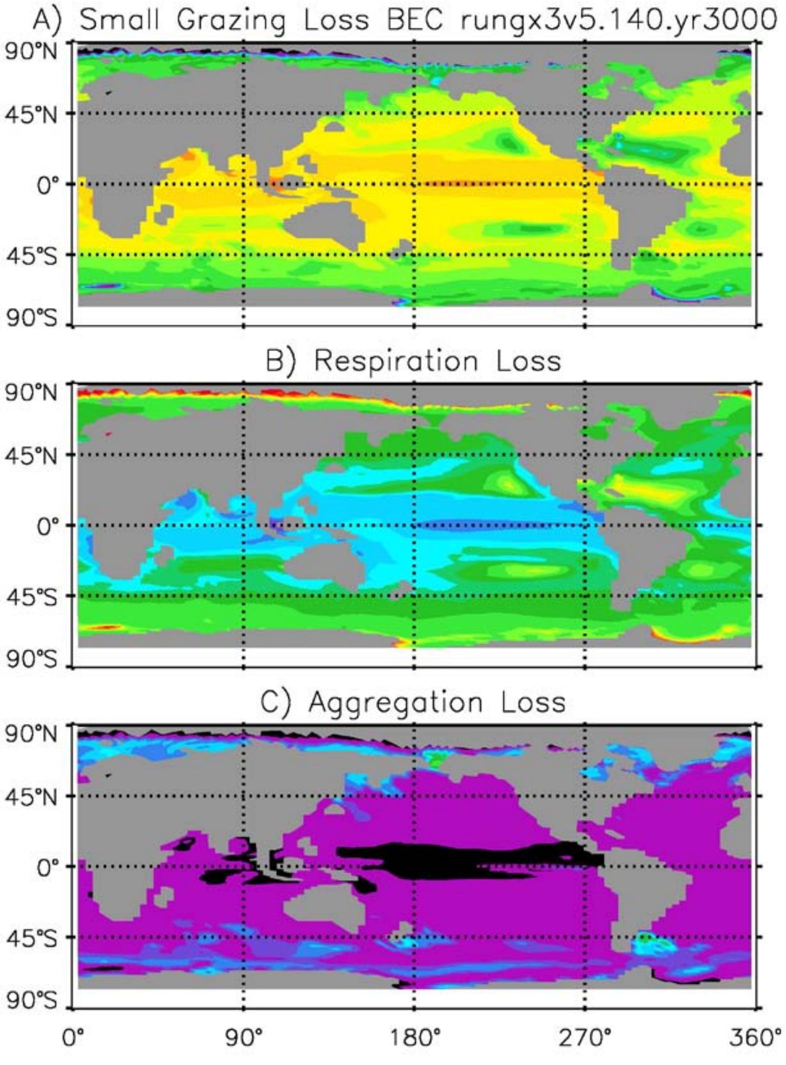
Improved BEC - Si vs. Obs.

Original BEC

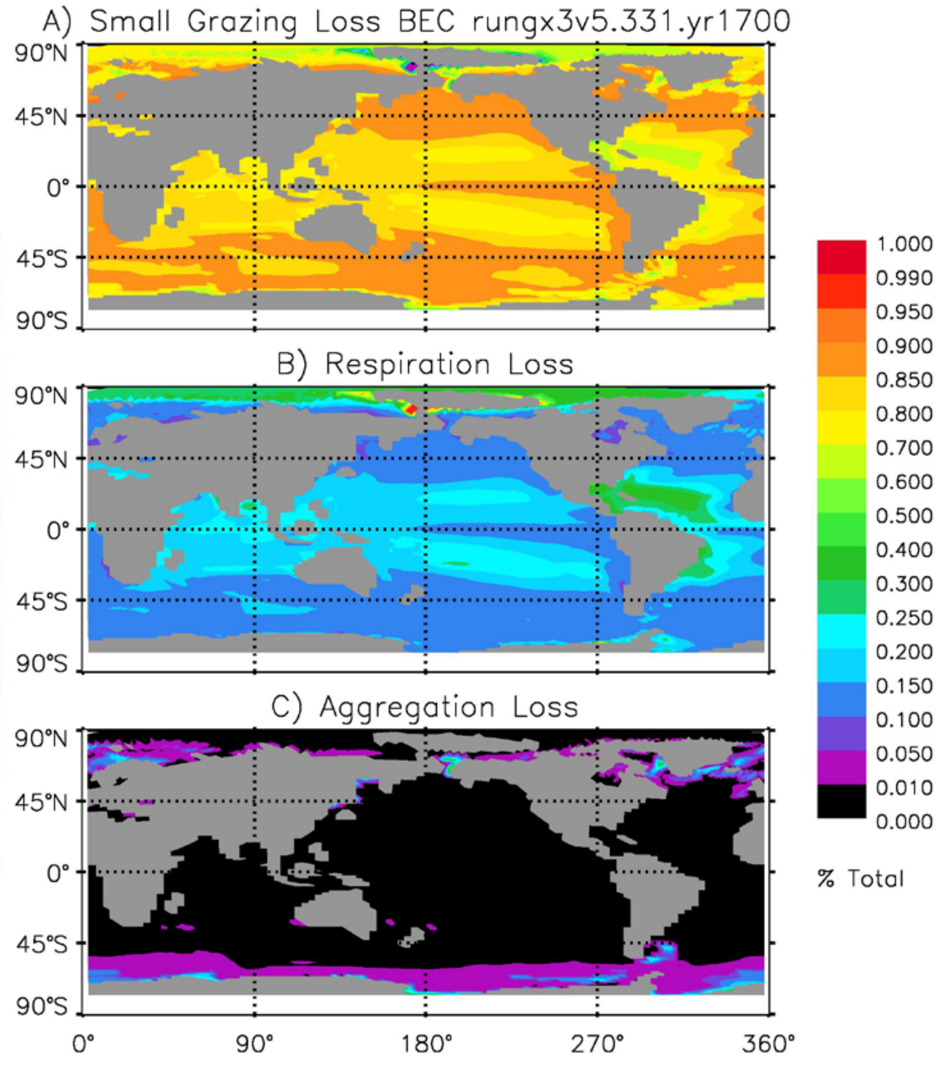


Improved BEC



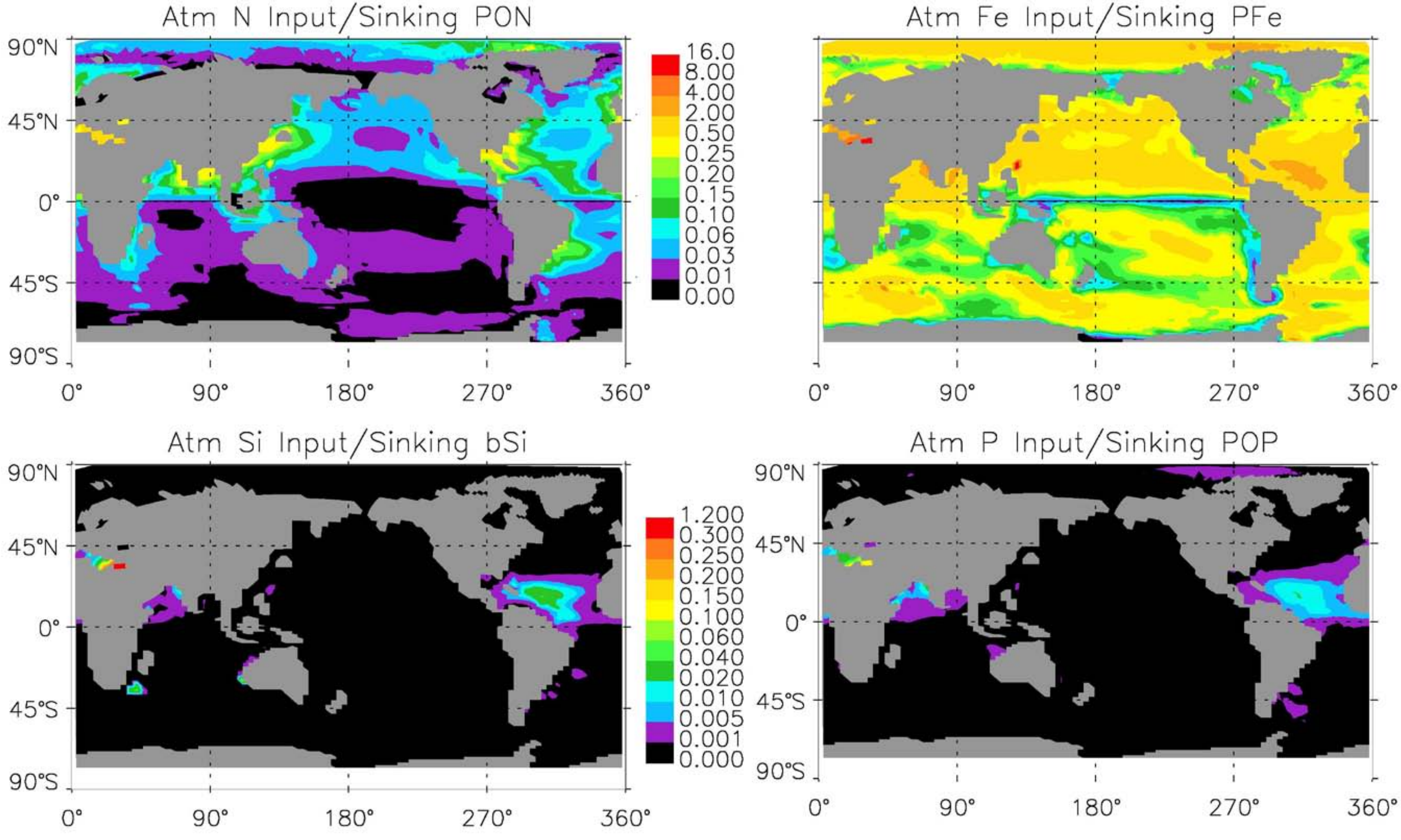


Original BEC



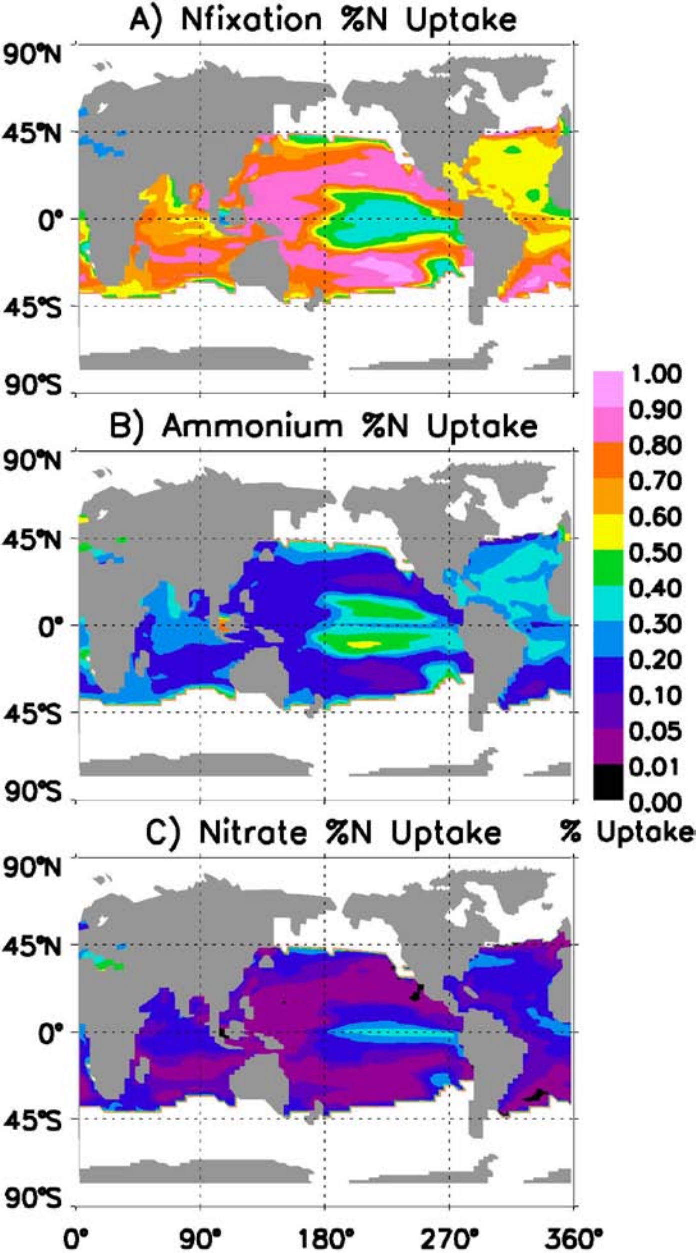
Improved BEC

- temperature effect on respiration
- reduced aggregation loss
- increased grazing loss



Plots show the fraction of export production potentially supported by nutrient inputs from the atmosphere, using variable aerosol Fe solubility plus the combustion Fe source from Luo et al. (2008).

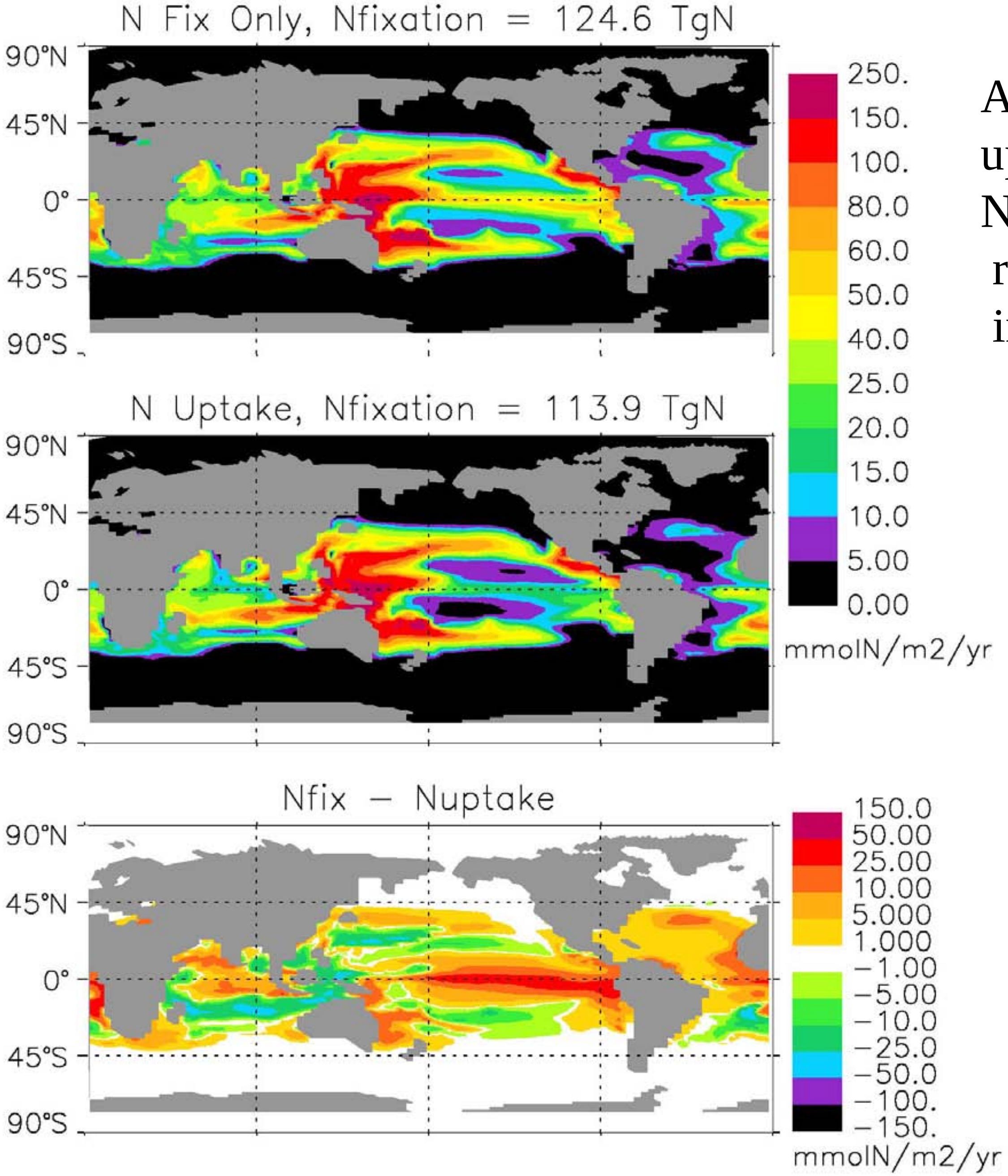
Note atmospheric P and Si inputs account for << 1% of export production.



The diazotroph phytoplankton group can now take up fixed N (nitrate, ammonium) when available, with any unmet N demand then met by N_2 fixation.

Uptake kinetics set conservatively to be the same as the diatoms, small phytoplankton are much more efficient taking up fixed N.

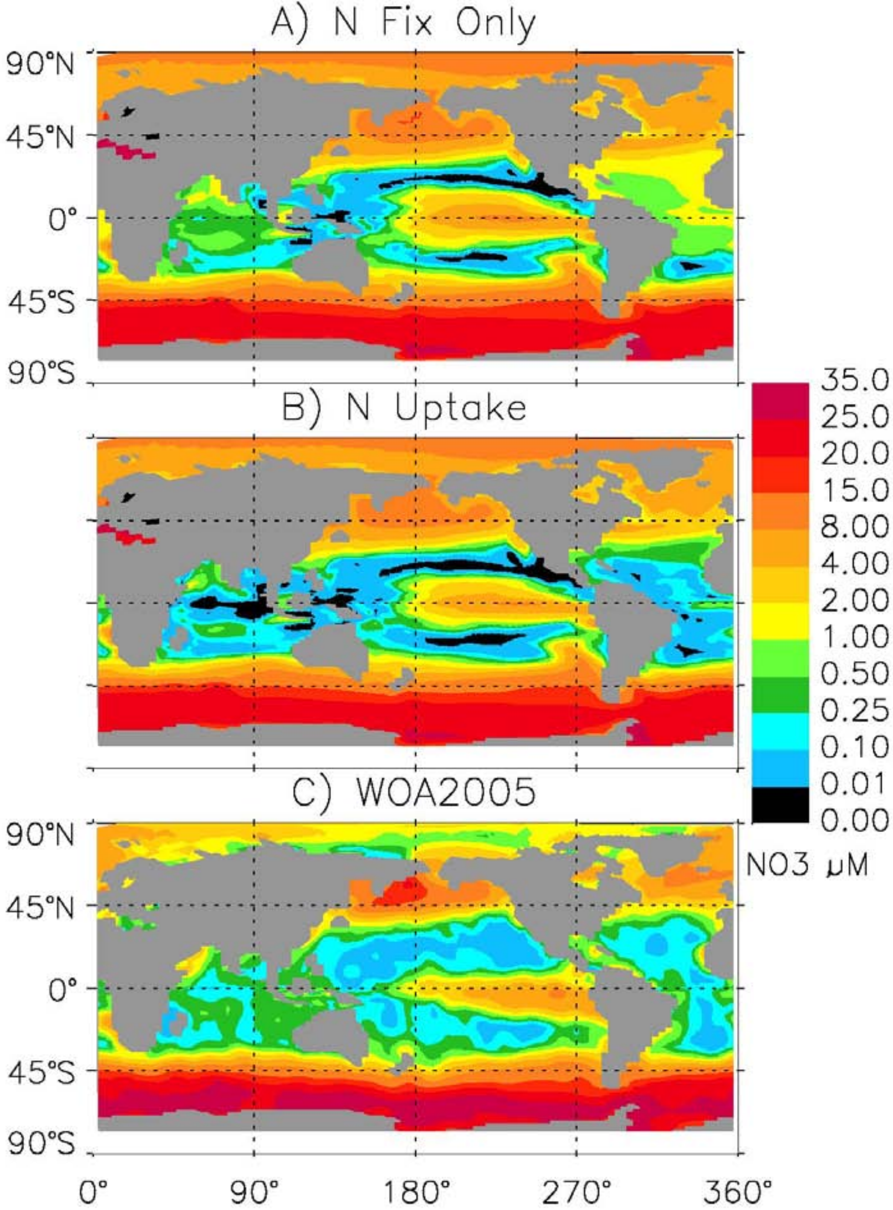
In the N-limited subtropical gyres, >80% of N uptake is still due to N-fixation. However, in the Fe-limited, equatorial Pacific most N demand met through uptake of fixed N.



Allowing diazotroph fixed-N uptake, shifts spatial patterns of N-fixation,

reduced in HNLC regions,

increased in downstream regions.



Allowing for diazotroph fixed-N uptake also maintains more realistic surface nitrate concentrations (i.e. tropical North Atlantic. Thus, this uptake seems an important feedback helping maintain surface ocean N/P ratios at close to the Redfield value.

Original BEC

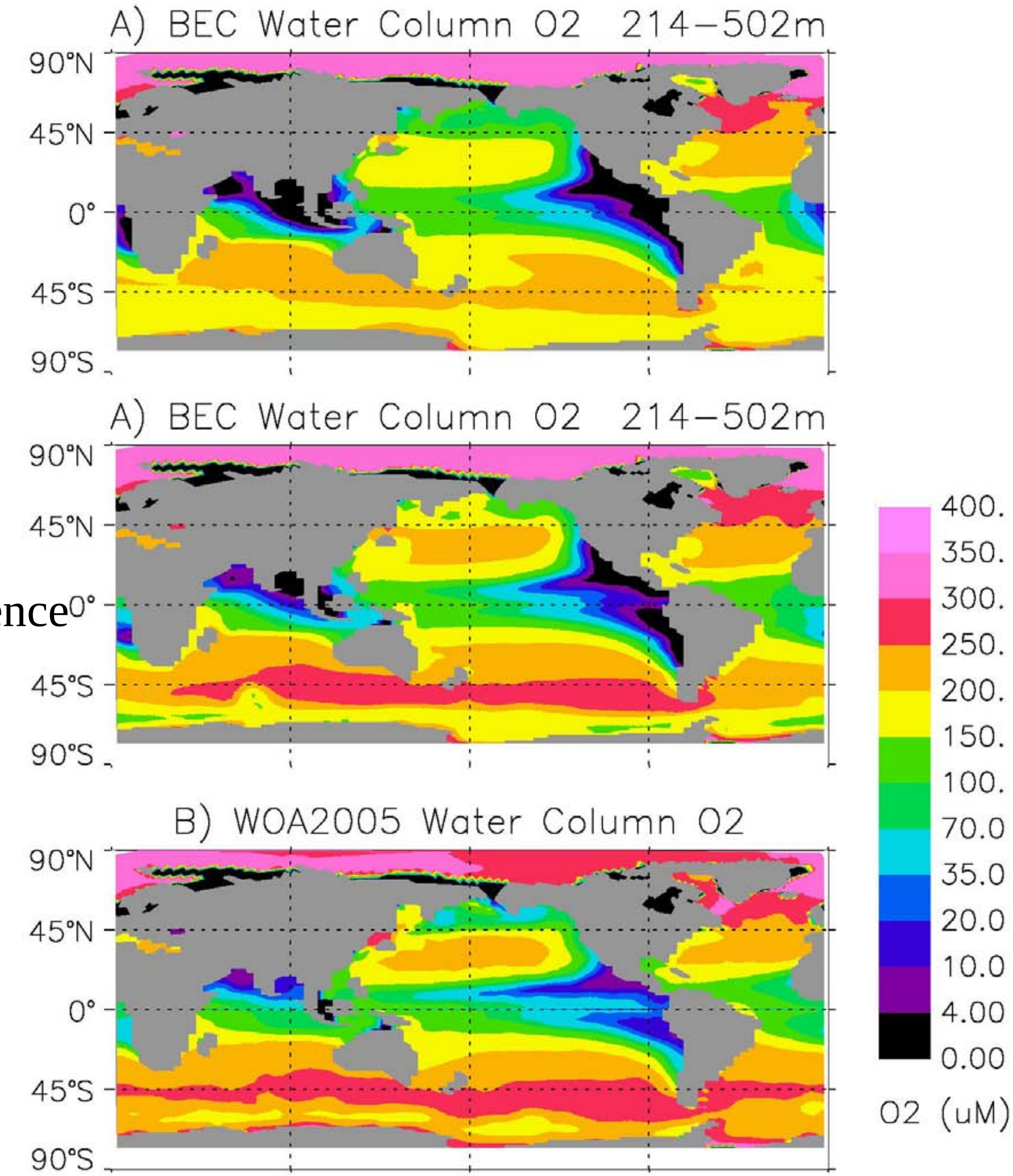
Low O_2 in Southern Ocean

Low O_2 in OMZs

Improved BEC

Increased SO mixing

Increased background turbulence



Conclusions and Future Work

1) Improved physics/mixing in CCSM4 will benefit biogeochemistry through better mixed layer depths, O_2 ventilation, and Oxygen Minimum Zone distributions.

2) Remaining improvements to be incorporated into the BEC, over next few years:

Fast Solver – will greatly decrease spin up time, allow for better tuning of parameters controlling remineralization of organic matter at depth.

River Nutrients – needs to be incorporated as nutrient sources to the oceans.

Expanded Nitrogen Cycle – sedimentary denitrification, ocean ammonia and N_2O emissions, better treatment of DON/DOP, etc...

CaCO3 Dissolution – needs to tied more directly to saturation state and water column chemistry.

Sediment Biogeochemistry Module