CBGC.v1 Marine Biogeochemstry

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Evaluation of ocean and sea ice biogeochemistry

Paper Outline:

- Analysis of the 1850 CONTROL and the BDRD historical MPAS-O/SI BGC
- Special emphasis on the polar regions, validating new sea ice bgc model and interactions with the ocean system, identifying interesting model behavior
- Contrast Arctic vs. Southern Ocean
- Key processes in the marine carbon cycle:

  -Primary Production (inorganic C -> organic C)

  limitation factors, nutrient sources (rivers)

  -Sequestration (POC flux to the deep ocean)

  -Remineralization (O_2 minimum zones)

How do we validate submodule behavior in a component in a fully coupled modeling context?

Right behavior for the right reasons

How do we validate submodule behavior in a component in a fully coupled modeling context?

Right behavior for the right reasons

Wrong behavior for the right reasons

Metrics to assess the quality of the polar climate state for sea ice biogeochemistry

Sea ice (concentration, thickness, snow), ocean (nutrients), atmospheric (shortwave) properties

Define a "bound of maximal ice algal growth rate":

Combines mean annual incident shortwave with upper ocean nitrate and silicate concentrations to estimate the maximum mean ice algal growth rate in ice covered regions.

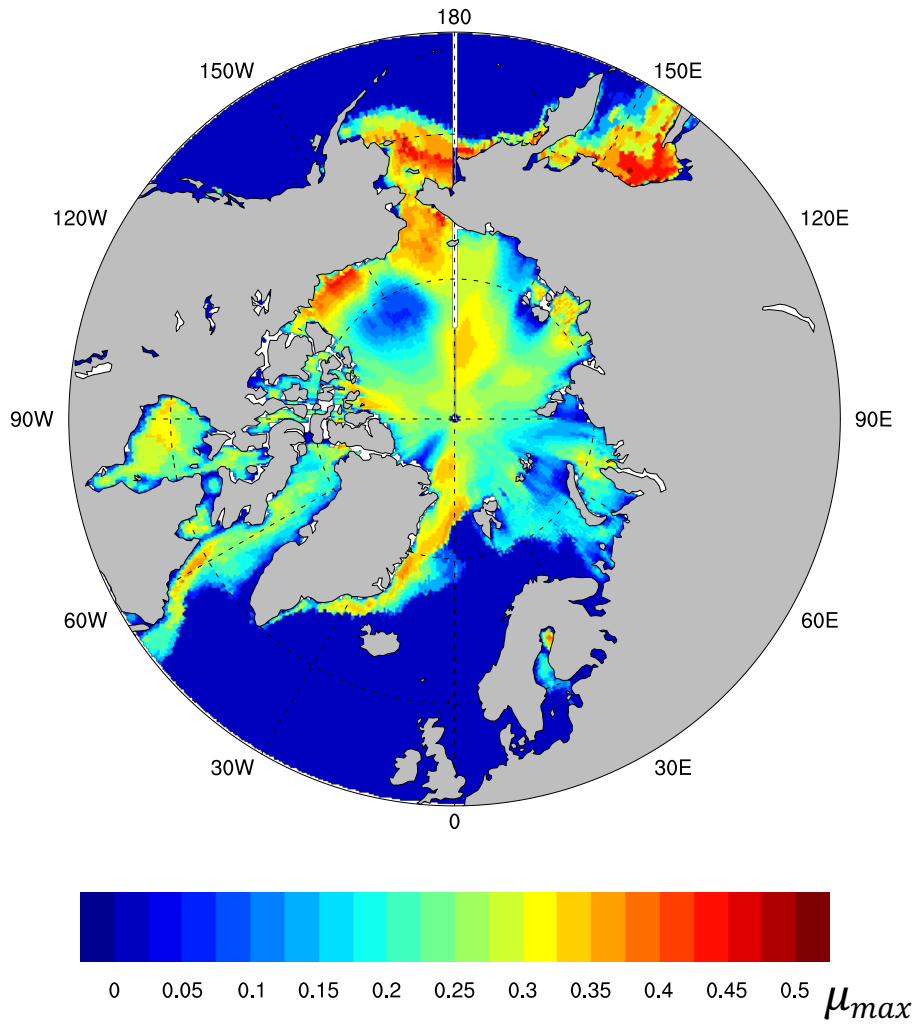
- contrast observations based/model based
- No information on sea ice thickness, meltponds, snow cover, ice bgc

No information on sea ice properties (except conc > 15%) or ice biogeochemistry

Based on Observation (Present Day)

Model Based (1850 CBGC Control)

Maximal Algal Growth Bound (obs. based)



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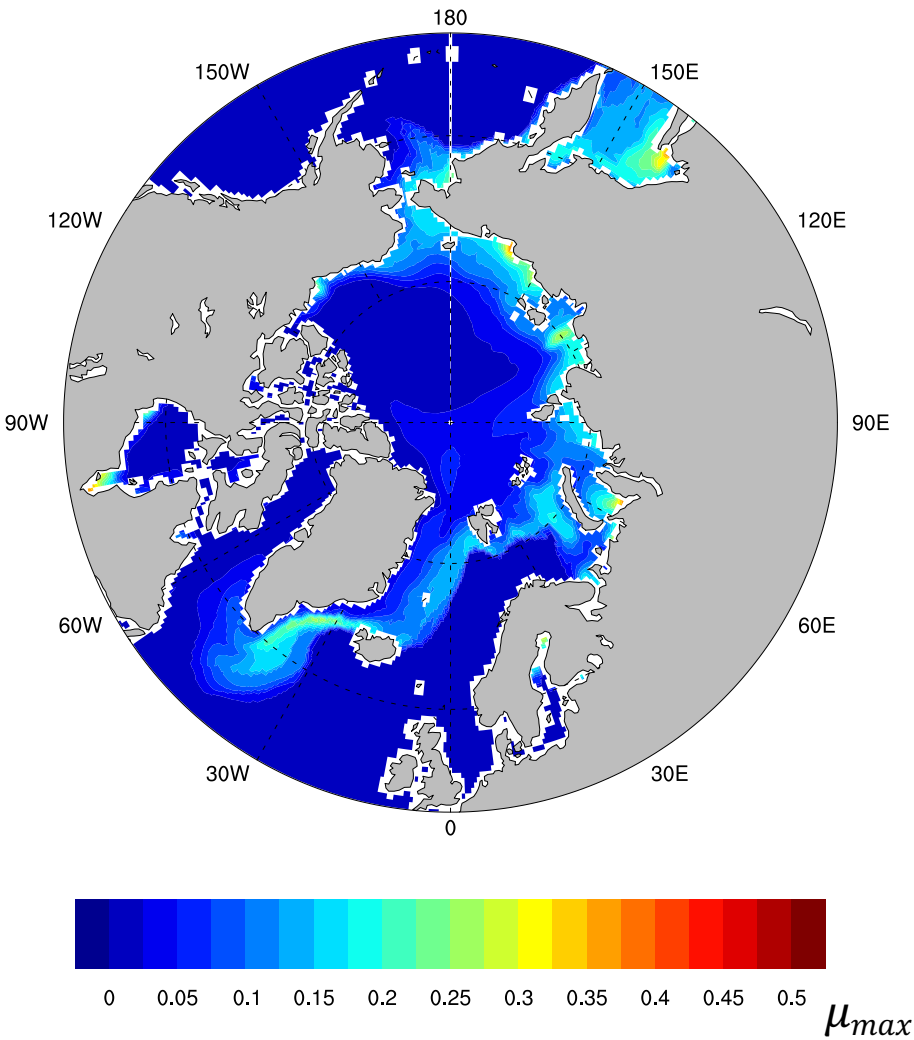
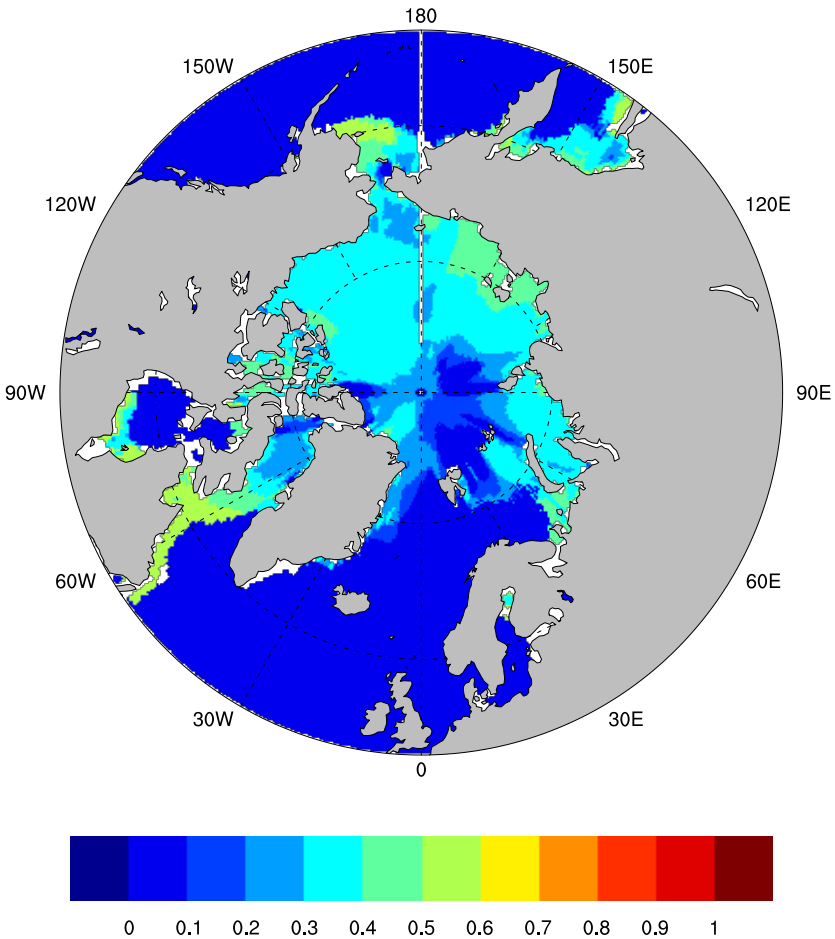
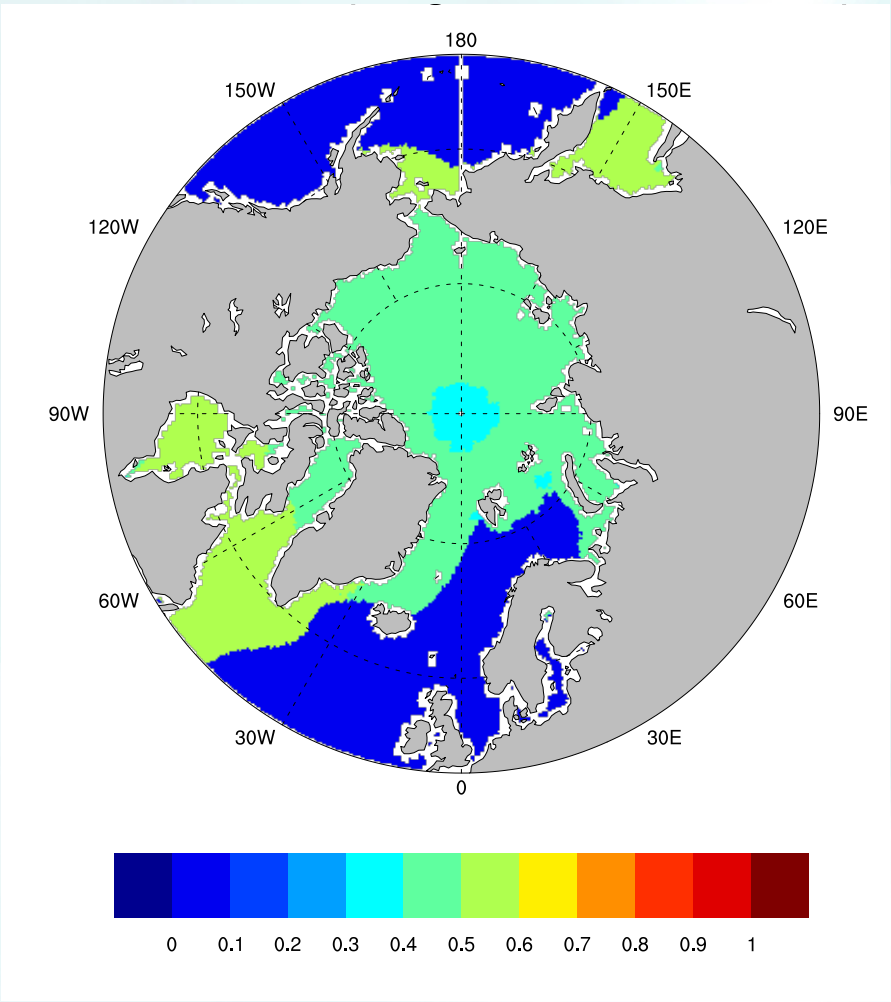


Based on Observation (Present Day)

Model Based (1850 CBGC Control)

Fraction of year max ice algal growth bound is nitrate limited

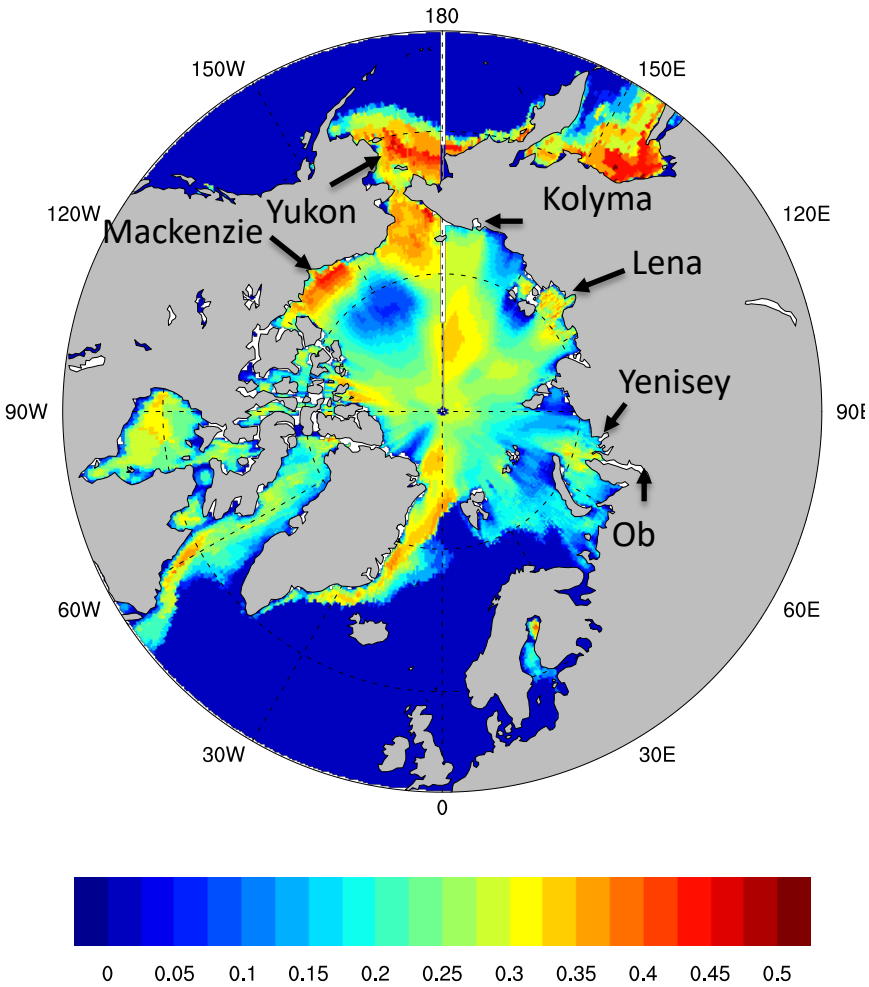




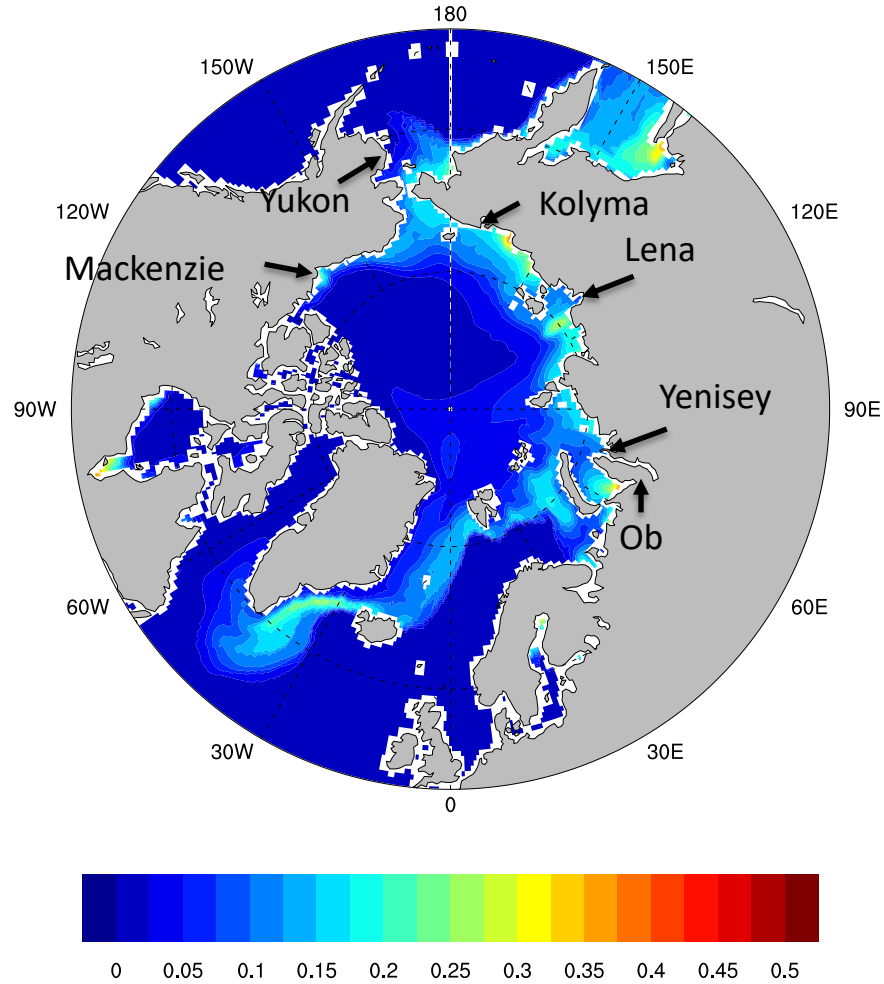
In reality and in the model, snow and ice thickness will contribute to light limitation.
Sea ice growth and melt rates contribute to nutrient limitation

Inconsistencies in riverine fluxes of fresh water and nutrients. Path/strength of Pacific water?

Maximal Algal Growth Bound (obs. based)

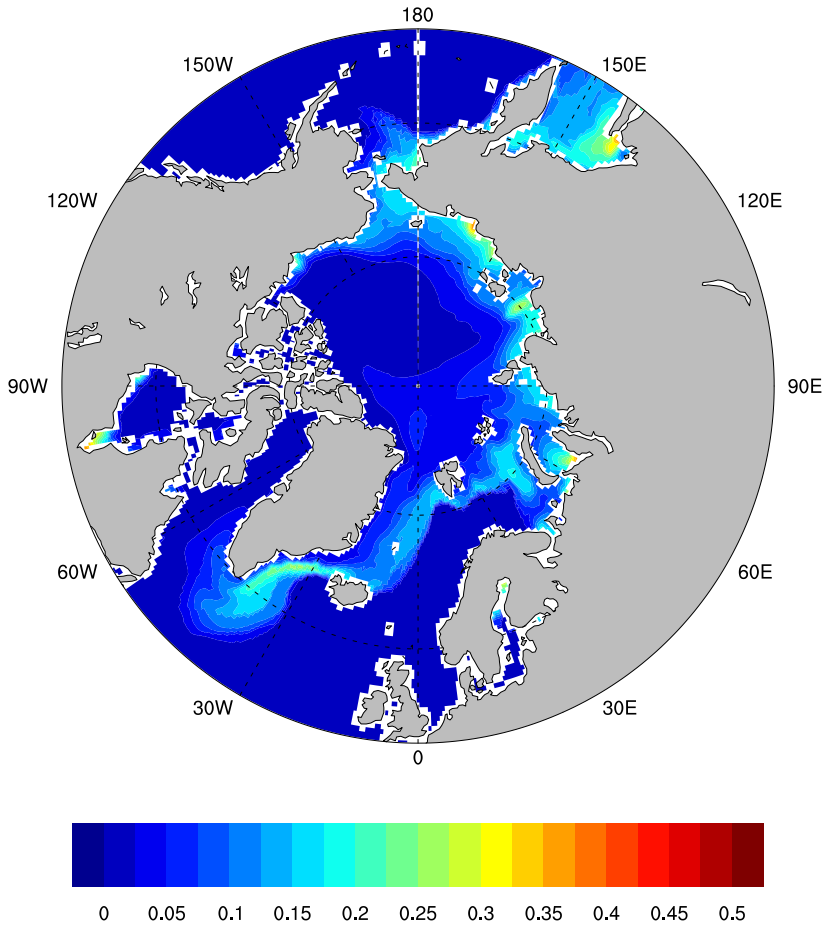


Maximal Algal Growth Bound (model based)

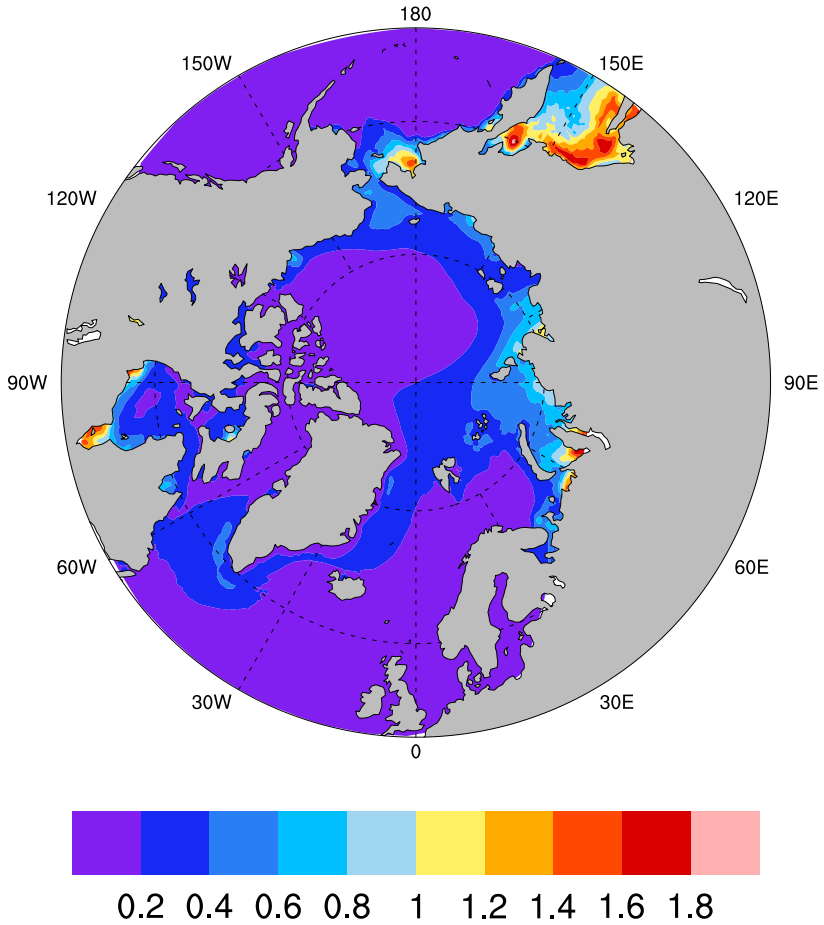


All is not lost…. Model PP and Max Growth are highly correlated (r = 0.74)

Maximal Algal Growth Bound (model based)

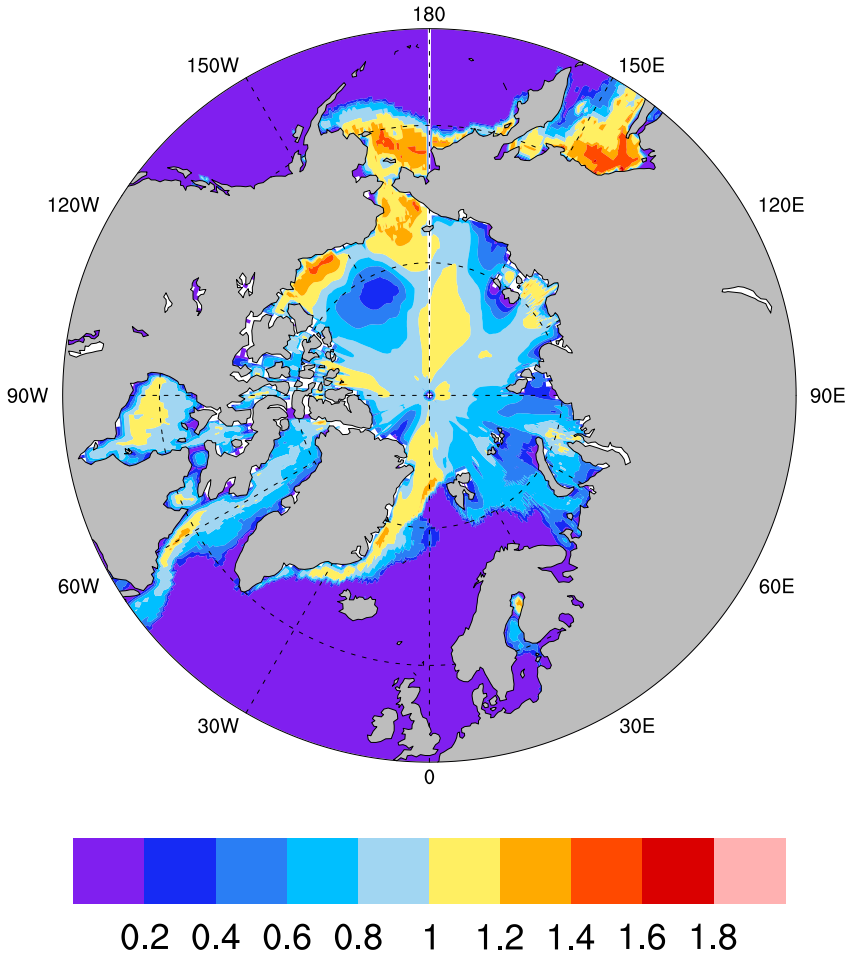


Mean Annual Ice Primary Productions (gC/m^2)



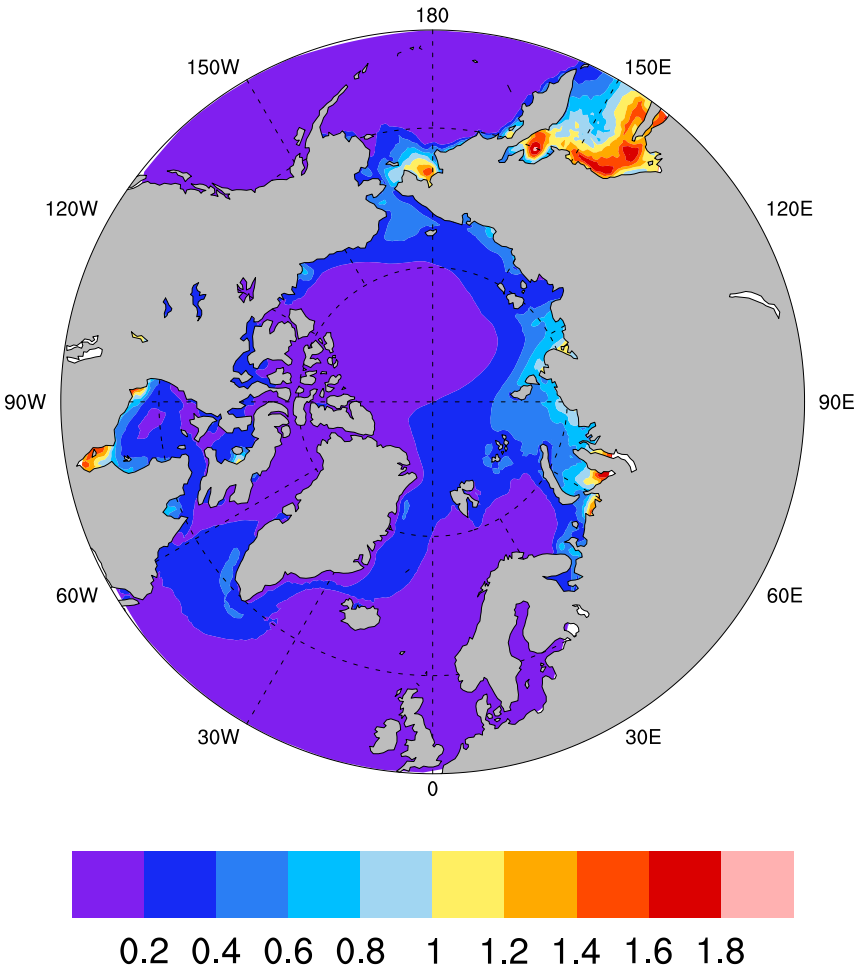
Regression Estimate (R.E.)

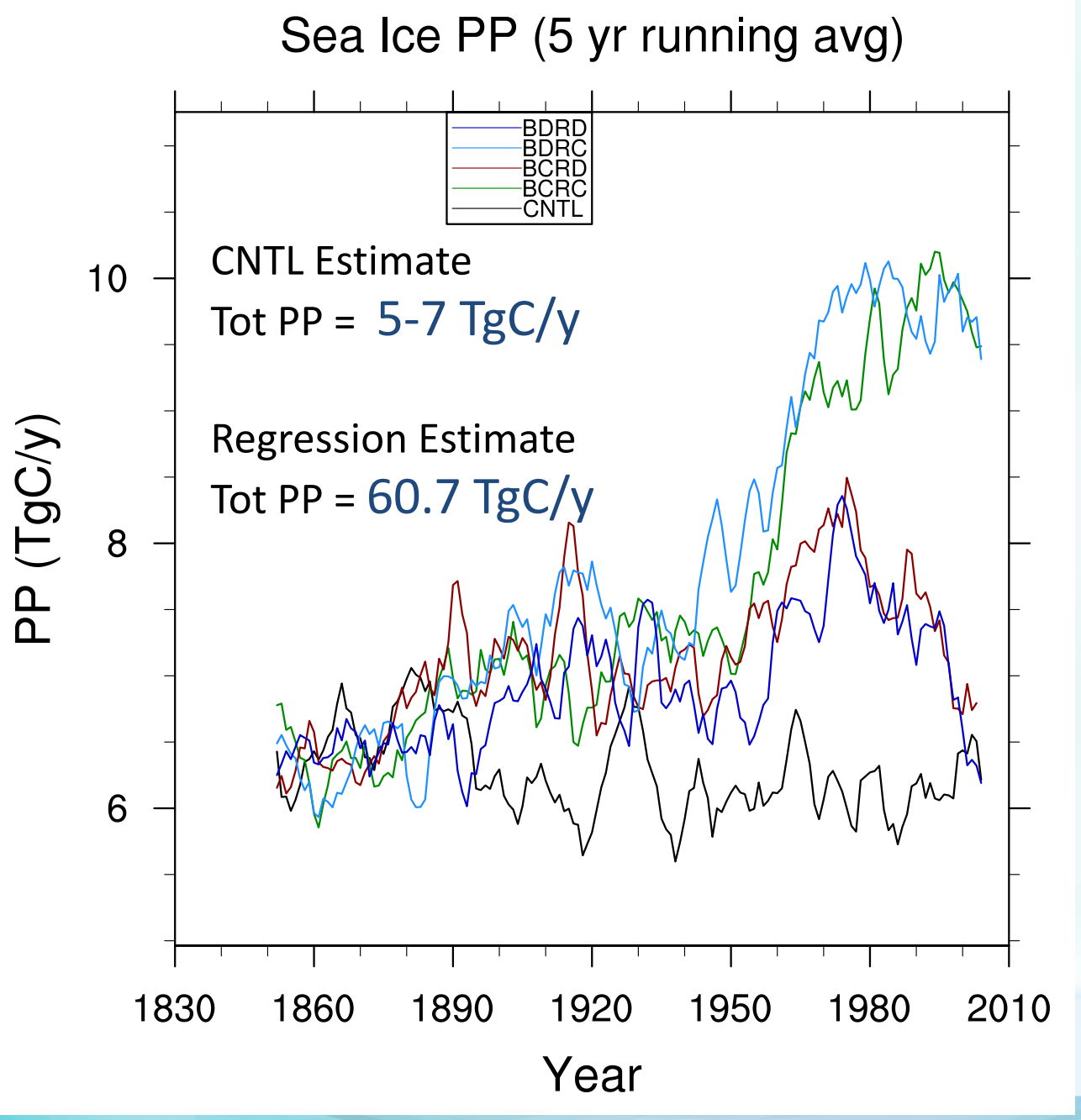
Mean Annual Ice PP: regression (gC/m^2)



CBGC-CNTL

Mean Annual Ice Primary Productions (gC/m^2)





Estimate for total Arctic ocean primary production is

~135 TgC/y

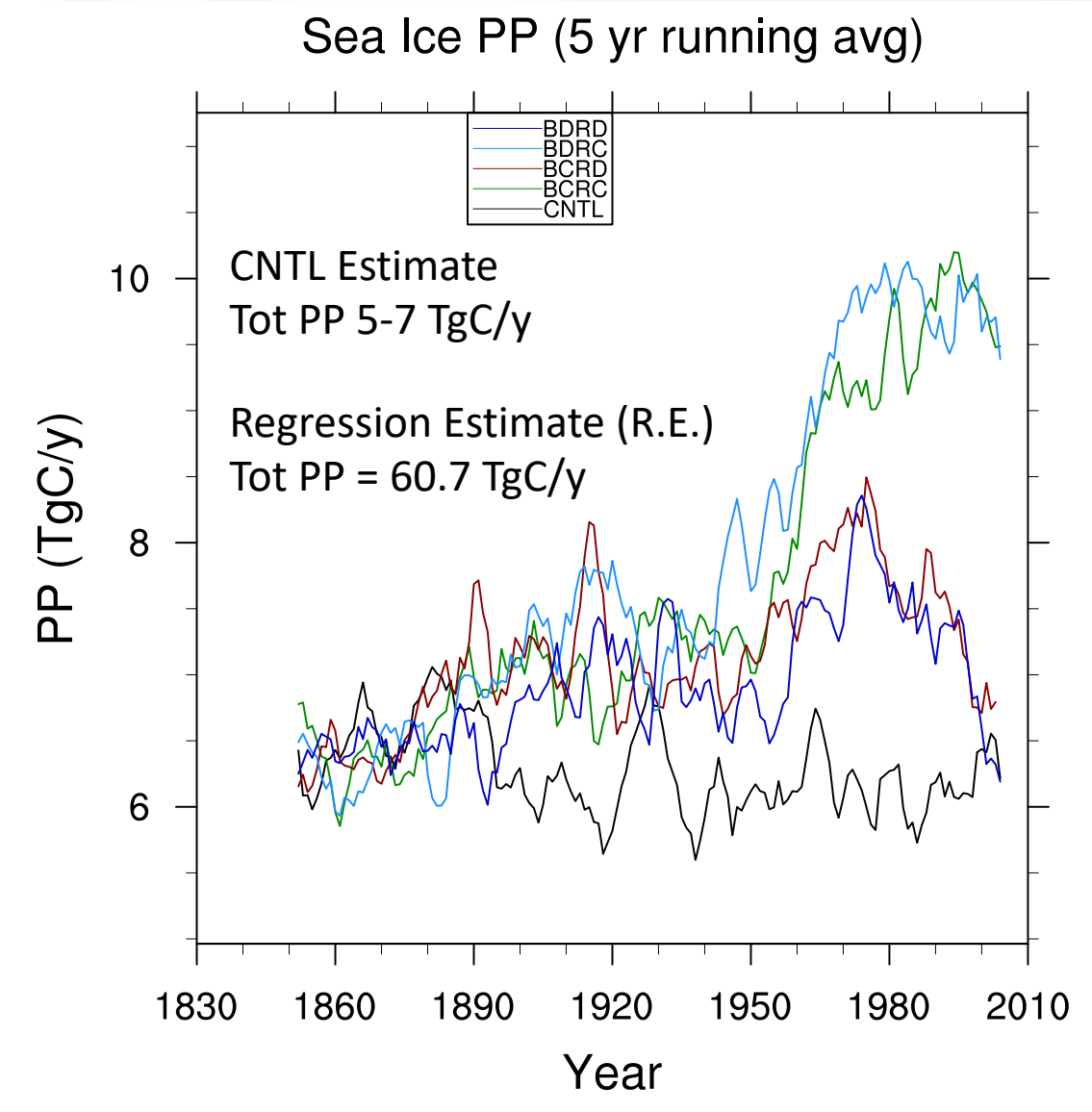
(Macdonald et al. 2010)

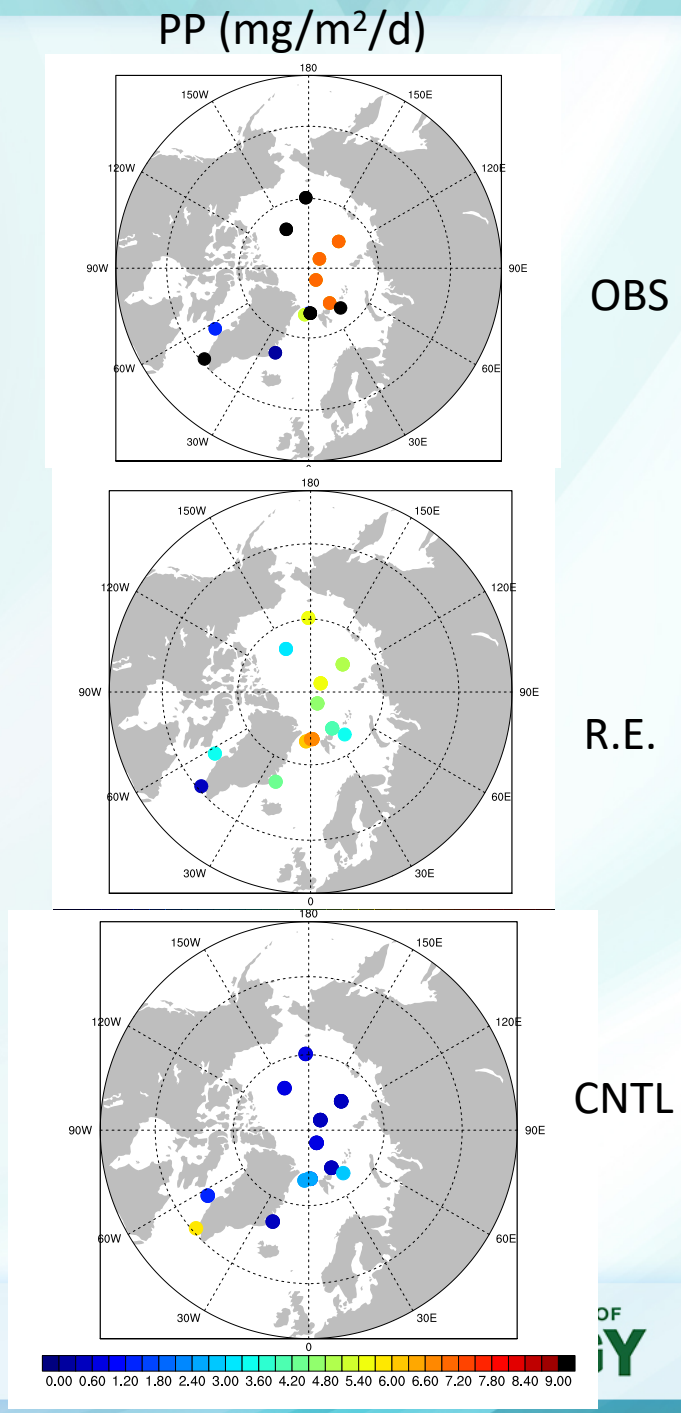
Estimates for total Arctic Ice Algal Primary production is

23-170 TgC/y

(Arrigo 2013)

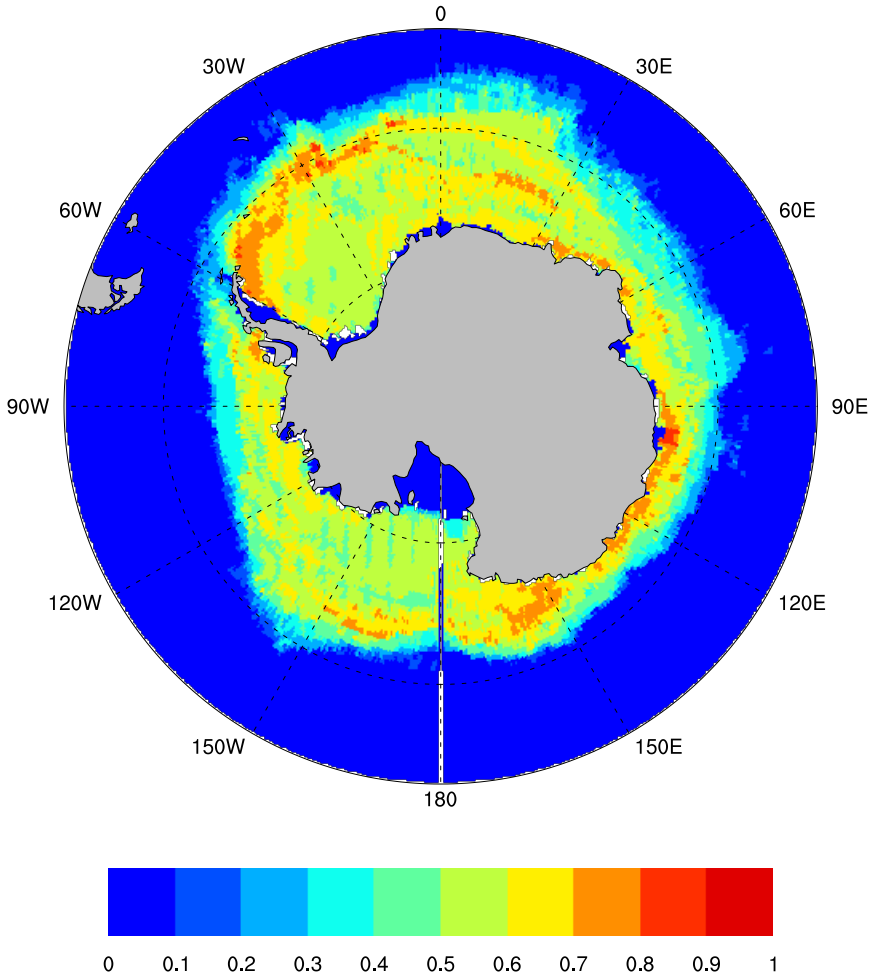
U.S. DEPARTMENT OF ENERGY


Sea Ice PP (5 yr running avg)
BDRD
BDRC
BCRD
BCRC
CNTL
CNTL Estimate
Tot PP 5-7 TgC/y
Regression Estimate (R.E.)
Tot PP = 60.7 TgC/y
PP (TgC/y)
10
8
6
1830
1860
1890
1920
1950
1980
2010
Year

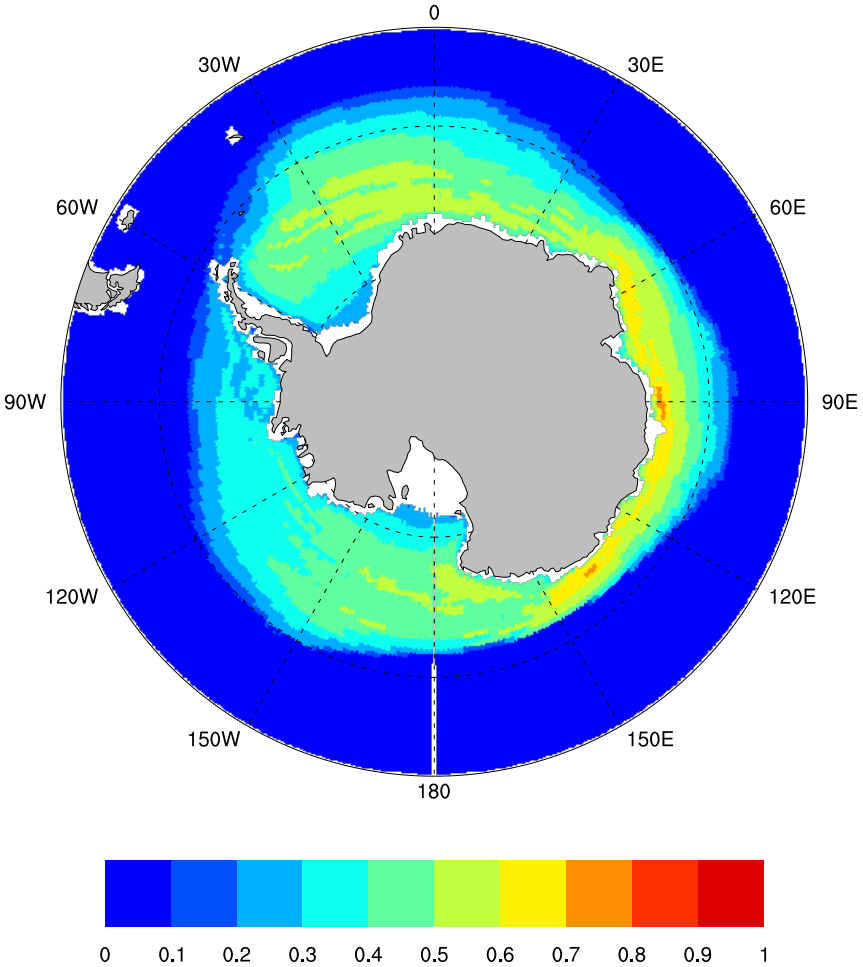

PP (mg/m²/d)
OBS
R.E.
CNTL
180
150W
150E
120W
120E
90W
90E
60W
60E
30W
30E
0
0.00 0.60 1.20 1.80 2.40 3.00 3.60 4.20 4.80 5.40 6.00 6.60 7.20 7.80 8.40 9.00

Ocean nutrients are plentiful, light is essentially the only limiting factor + ice conc.

Maximal Algal Growth Bound (obs. based)

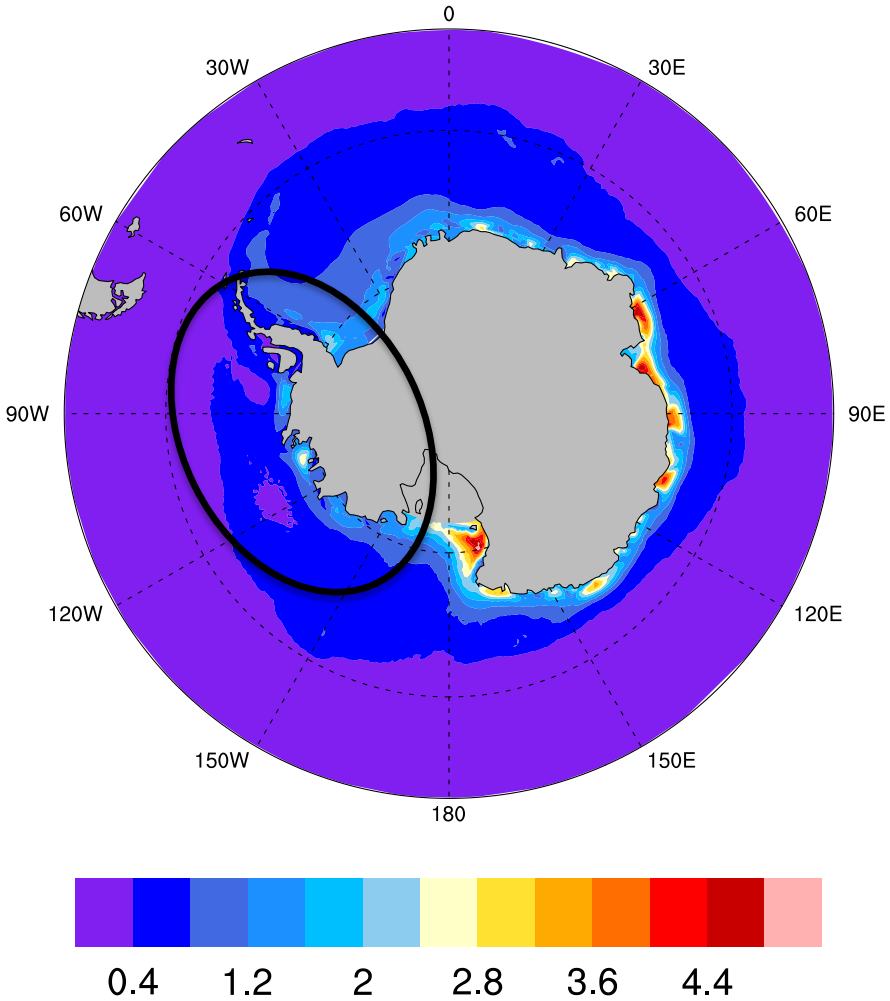


Maximal Algal Growth Bound (model based)

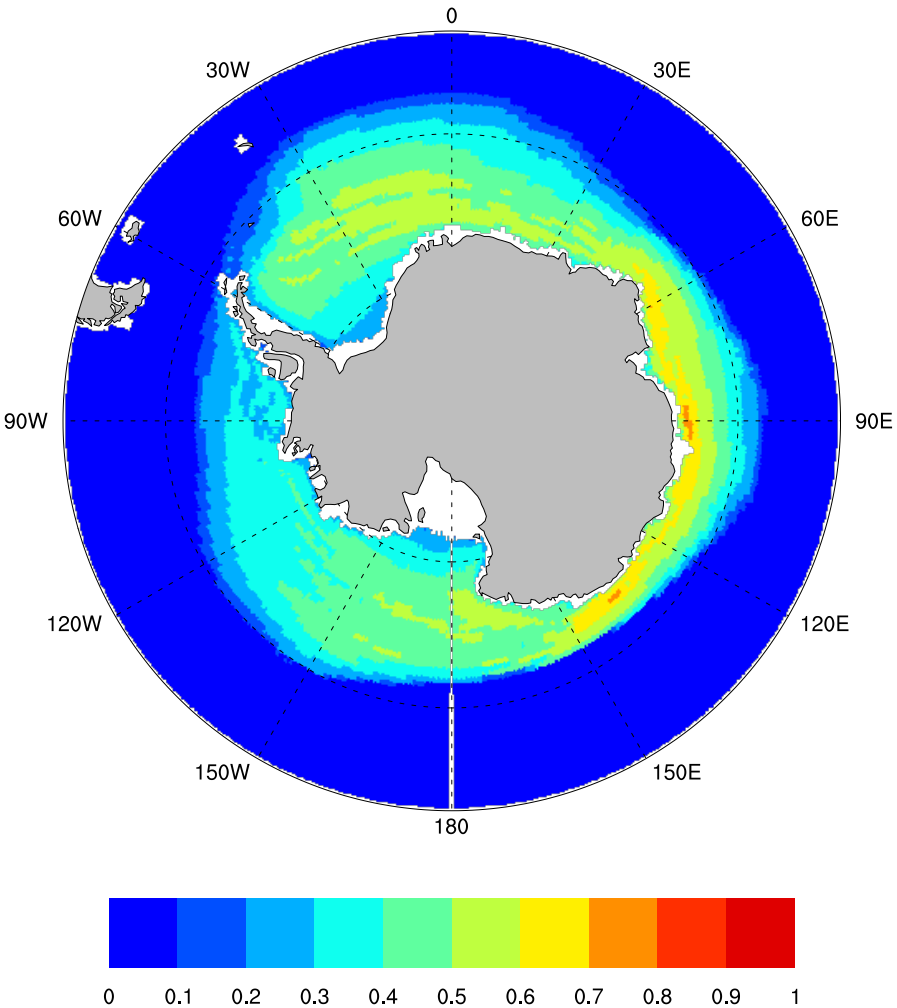


No correlation (r = 0.05)

Mean Annual Ice Primary Production (gC/m^2)



Maximal Algal Growth Bound (model based)

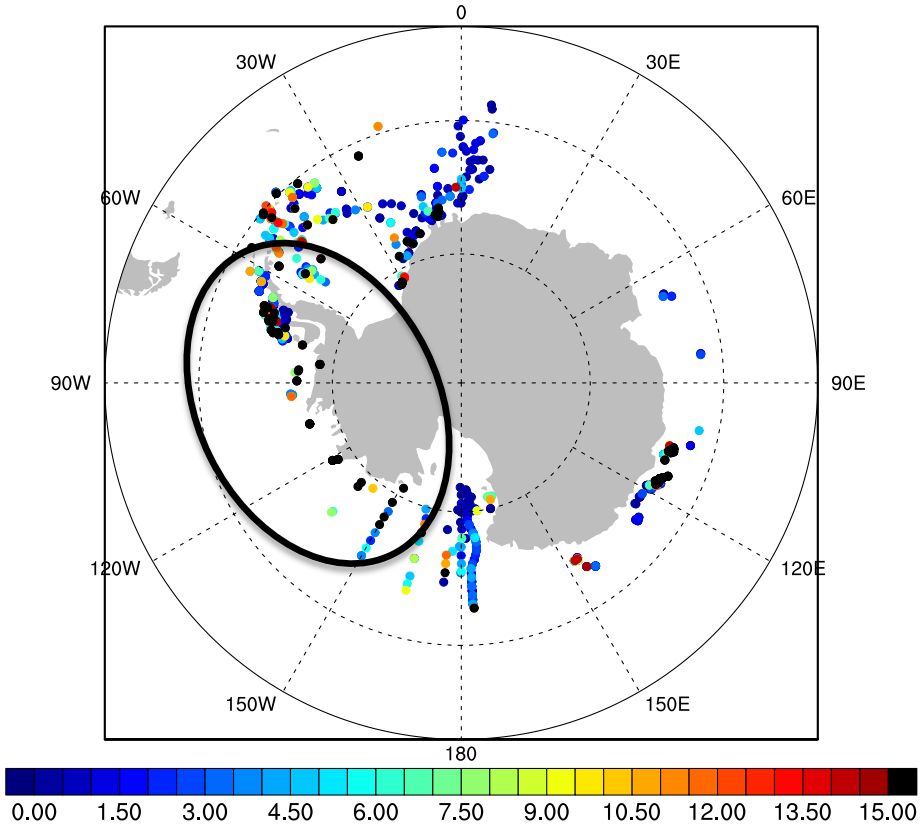


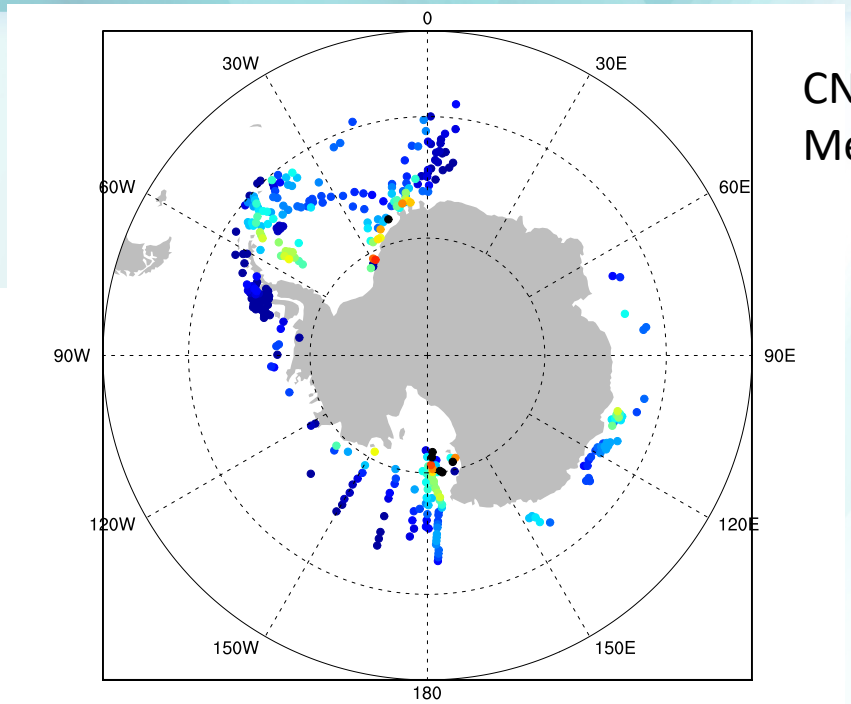
Tot PP = ~15 TgC/y

Obs estimates 3.6-456 TgC/y (Arrigo 2013)

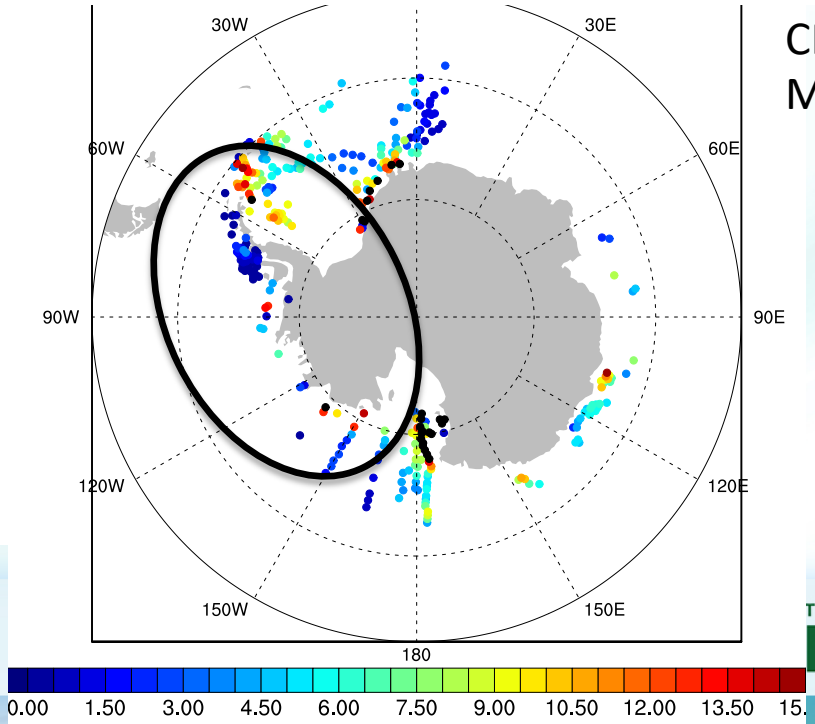
Observations

ASPeCT Ice Cores Integrated Chl-a (mg/m2)





CNTL Mean

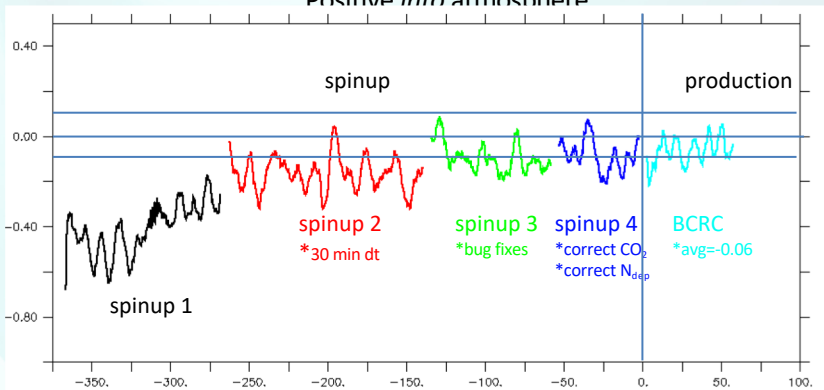


CNTL Max

Ocean BGC Global Metrics

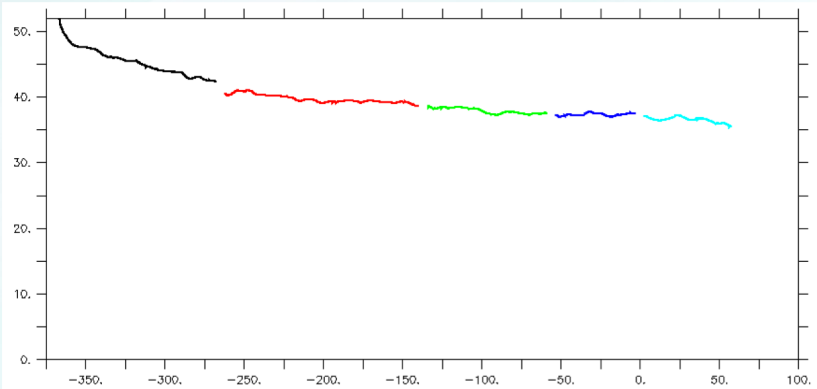
Globally integrated air-sea CO_2 exchange (Gt-C/year)

Positive *into* atmosphere



Model year (relative to start of production)

Globally integrated primary production (Gt-C/year)

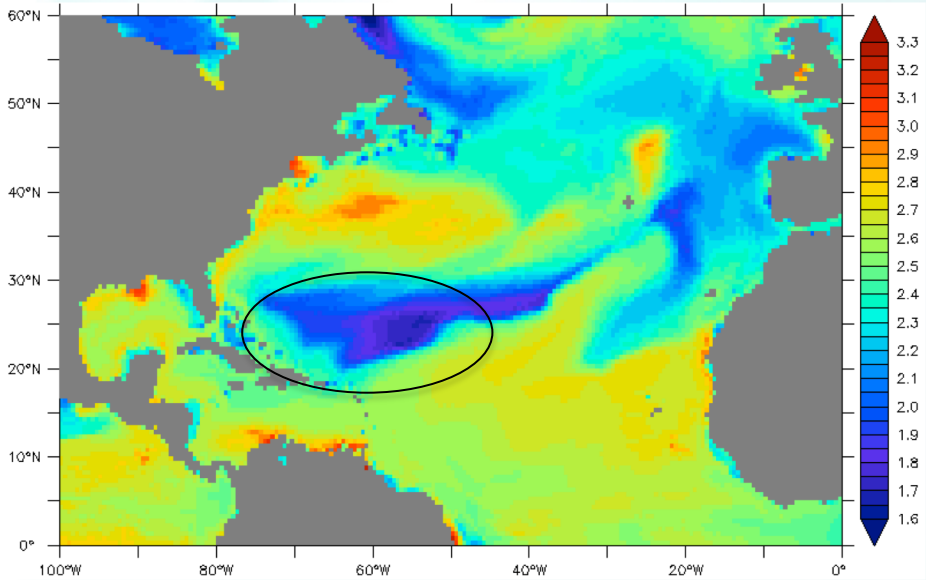


Model year (relative to start of production)

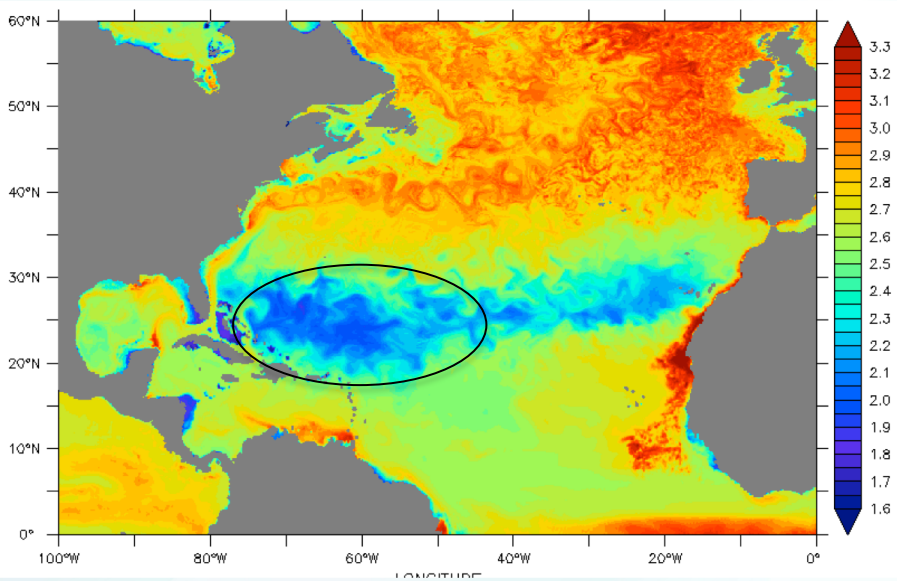
$\log_{10}$(primary production)

(mg-C/m^2/day)

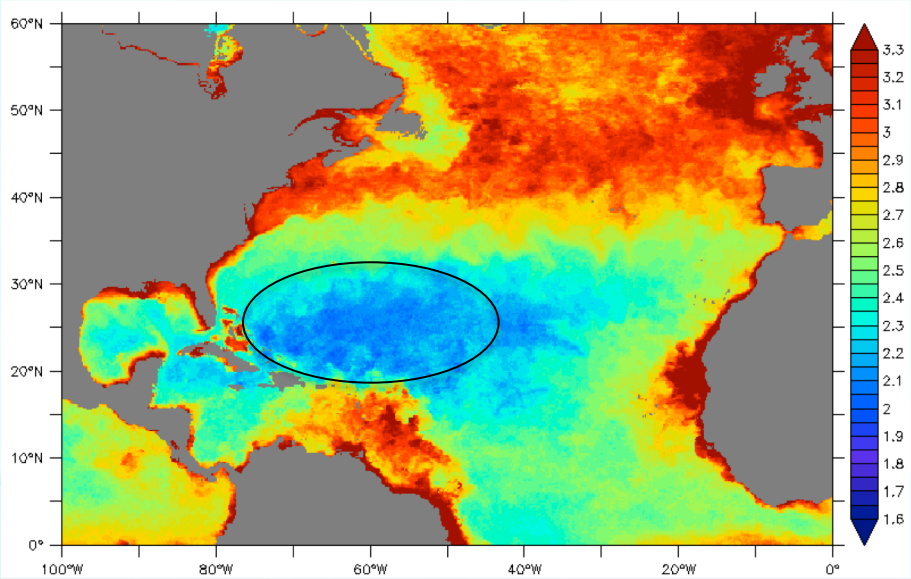
low resolution



high resolution

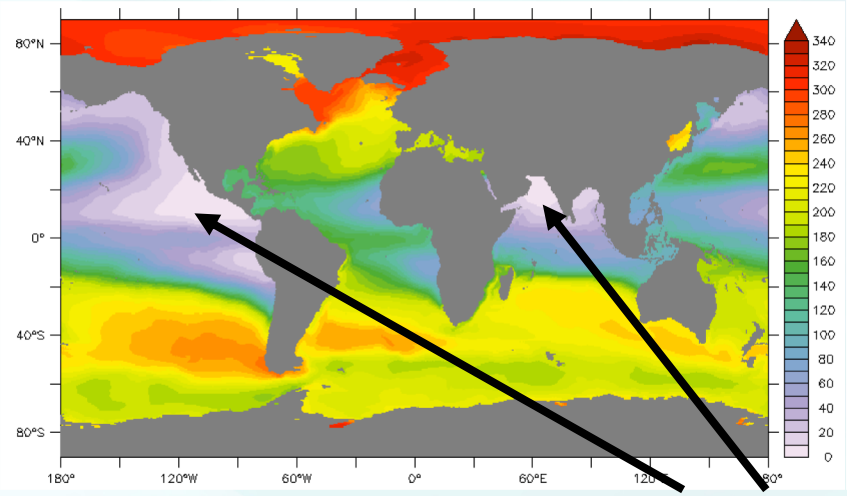


observational estimate

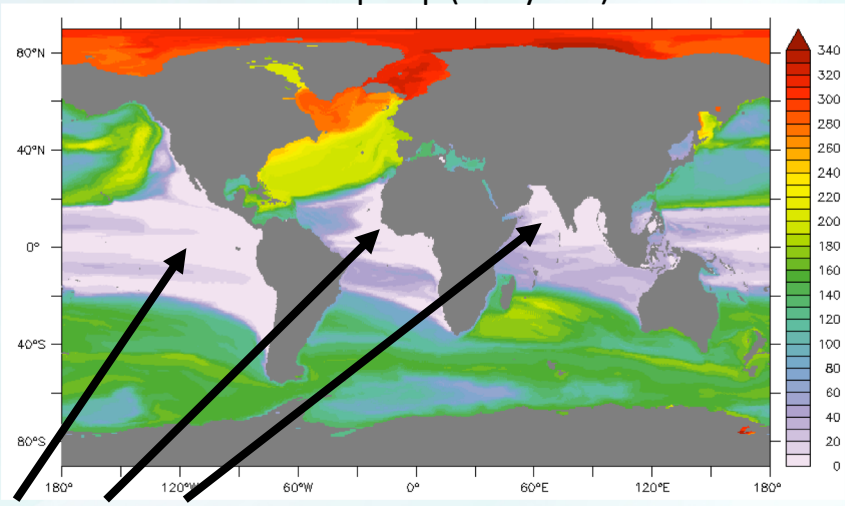


Dissolved Oxygen at 640m (mmol/m³)

Initial condition (World Ocean Atlas)



End of spinup (370 years)

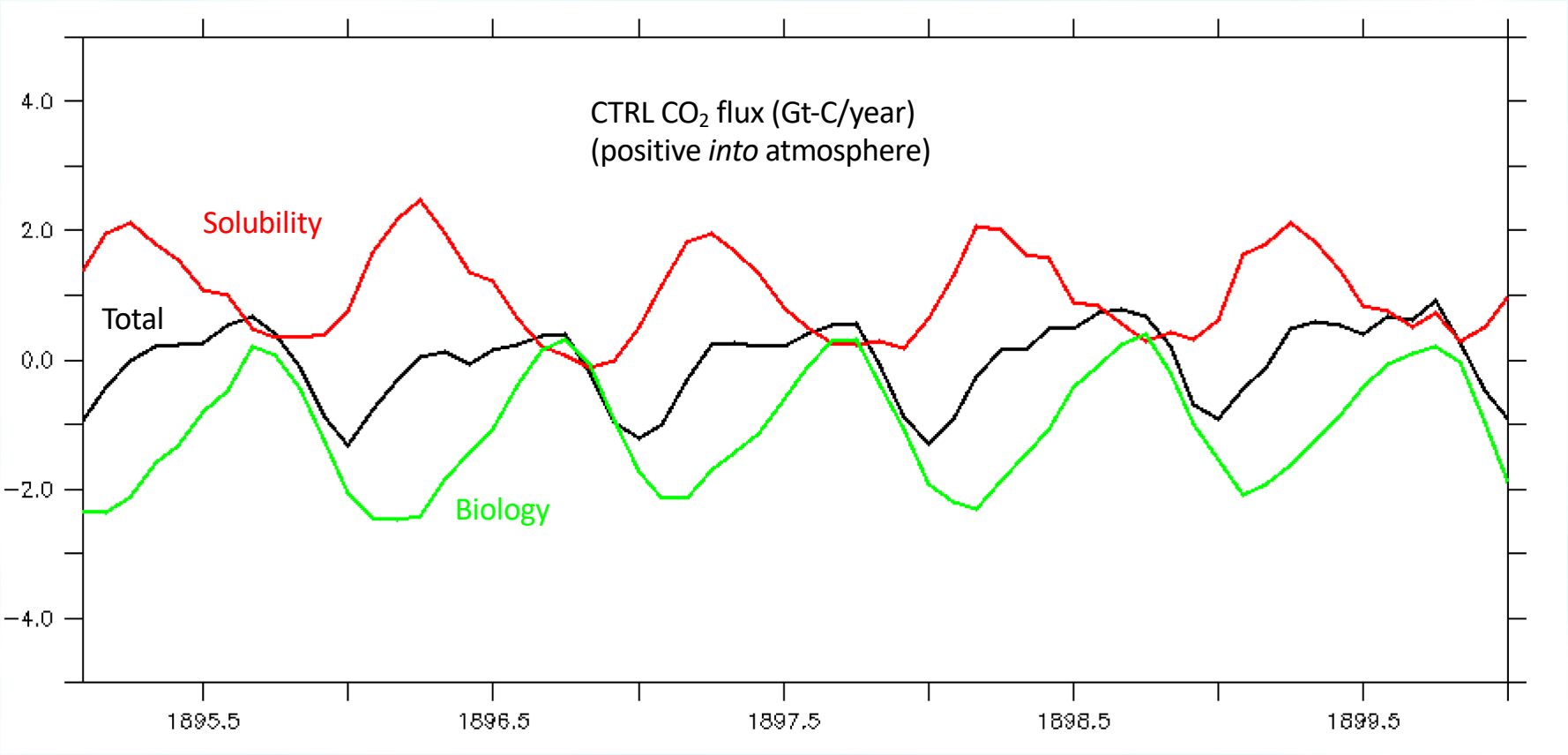


Oxygen minimum zones

- Too extensive Oxygen Minimum Zones (OMZs)
  - Atlantic should not be anoxic
  - Partly due to poor representation of Antarctic Intermediate Water (AAIW)
  - Affects denitrification and remineralization
- Southern ocean deficit due to unrealistically shallow mixed layers

Biotic vs Abiotic effects

- 2 kinds of DIC in BEC => DIC and DIC_{alt}
- For non-BPRP cases (all of ours), they are redundant
- Instead, assign 'B' CO_2 to DIC, 'R' CO_2 to DIC_{alt}
- Split ocn-atm flux into 2 parts: **B**iological and **S**olubility
  - Not exact, but a good approximation
  - $F = B(T,\cancel{CO_2},\cancel{N_{dep}}) + S(T,CO_2)$
    - No pH effects on biology
    - Climatological N_{dep}
- In addition, turn off ecodynamics for DIC_{alt} except for BCRD, BDRC


CTRL CO_2 flux (Gt-C/year)
(positive *into* atmosphere)
Solubility
Total
Biology
4.0
2.0
0.0
−2.0
−4.0
1895.5
1896.5
1897.5
1898.5
1899.5

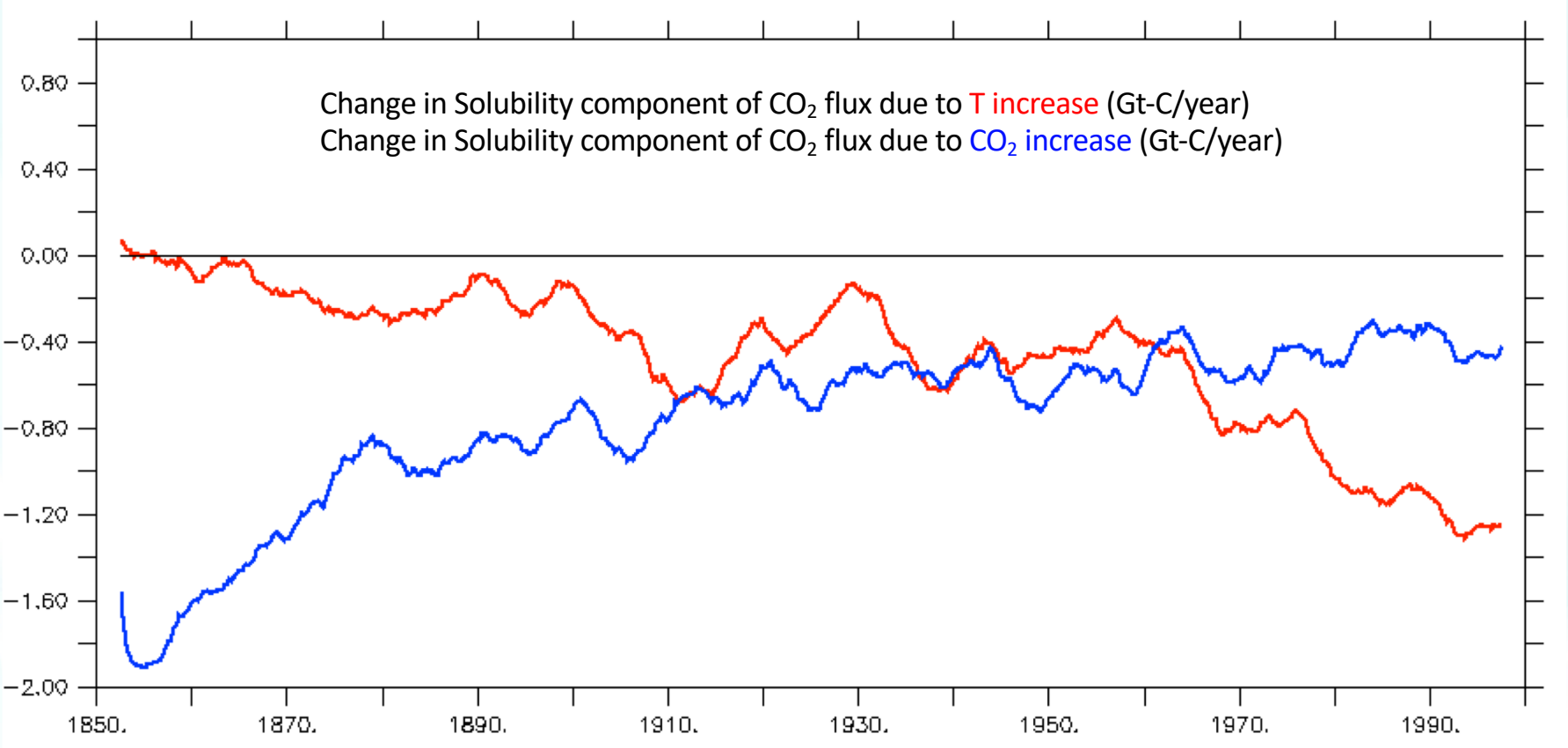
	DIC	DIC_{alt}	$DIC - DIC_{alt}$
CTRL	$B(T_{CTRL}) + S(T_{CTRL,}CO2_{CTRL})$	$S(T_{CTRL,}CO2_{CTRL})$	$B(T_{CTRL})$
BCRC	$B(T_{RC}) + S(T_{RC,}CO2_{CTRL})$	$S(T_{RC,}CO2_{CTRL})$	$B(T_{RC})$
BDRD	$B(T_{RD}) + S(T_{RD,}CO2_{RD})$	$S(T_{RD,}CO2_{RD})$	$B(T_{RD})$
BCRD	$B(T_{RD}) + S(T_{RD,}CO2_{CTRL})$	$B(T_{RD}) + S(T_{RD,}CO2_{RD})$	$-(S(T_{RD,}CO2_{RD}) - S(T_{RD,}CO2_{CTRL}))$
BDRC	$B(T_{RC}) + S(T_{RC,}CO2_{RD})$	$B(T_{RC}) + S(T_{RC,}CO2_{CTRL})$	$S(T_{RC,}CO2_{RD}) - S(T_{RC,}CO2_{CTRL})$

Isolate $S(T_{RD,}CO2_{CTRL})$:

Change in Solubility component due to T increase => $(DIC)_{BCRD} - (DIC – DIC_{alt})_{BDRD}$

No $S(T_{CTRL,}CO2_{RD})$, so compute $S(T_{RC,}CO2_{RD})$:

Change in Solubility component due to CO_2 increase => $(DIC_{alt})_{BCRC} + (DIC – DIC_{alt})_{BDRC}$


Change in Solubility component of CO_2 flux due to T increase (Gt-C/year)
Change in Solubility component of CO_2 flux due to CO_2 increase (Gt-C/year)
0.80
0.40
0.00
−0.40
−0.80
−1.20
−1.60
−2.00
1850.
1870.
1890.
1910.
1930.
1950.
1970.
1990.