AMOC Effects on the Carbon Cycle and Atmospheric CO_2

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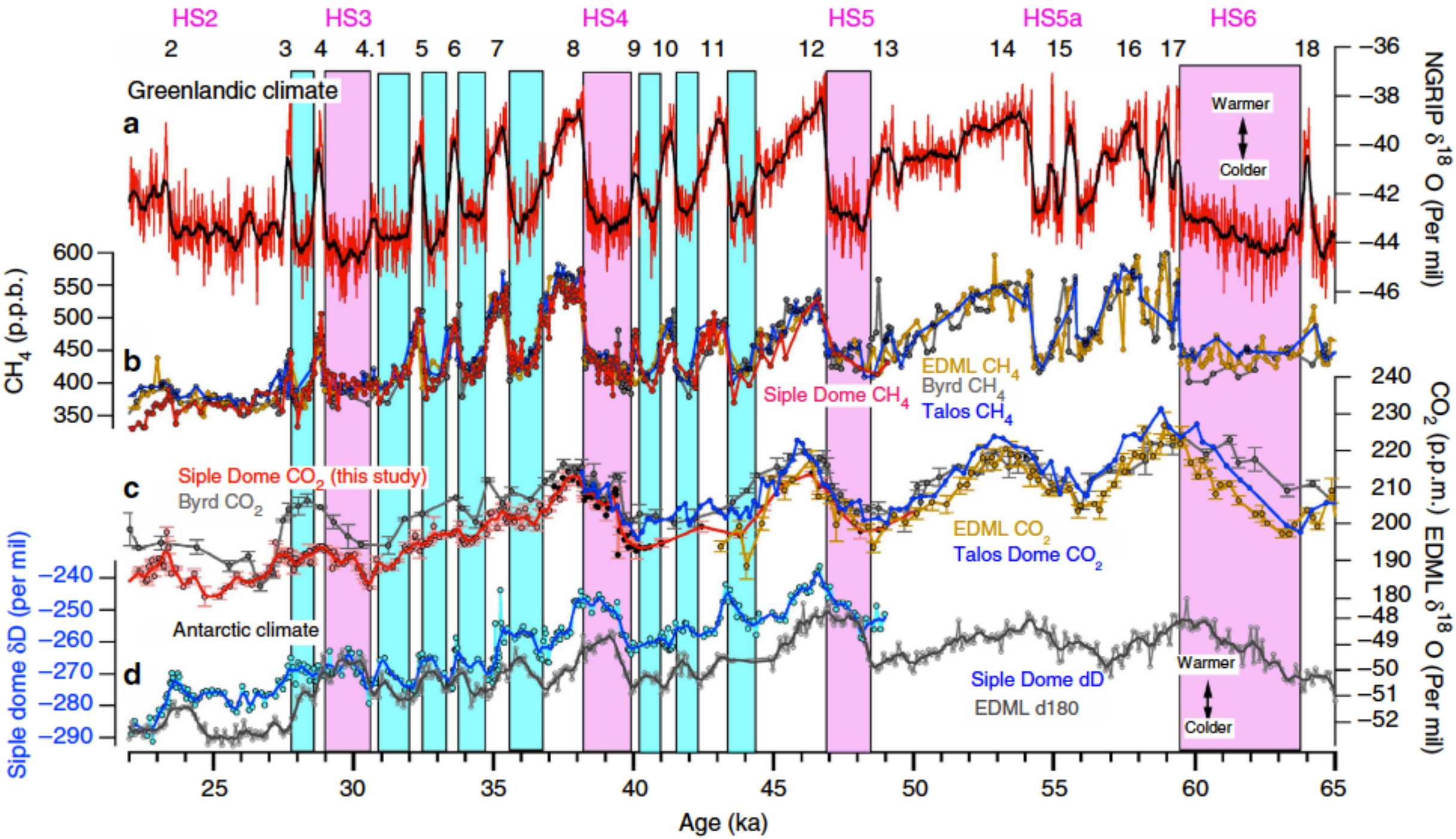
The Ice Core Record

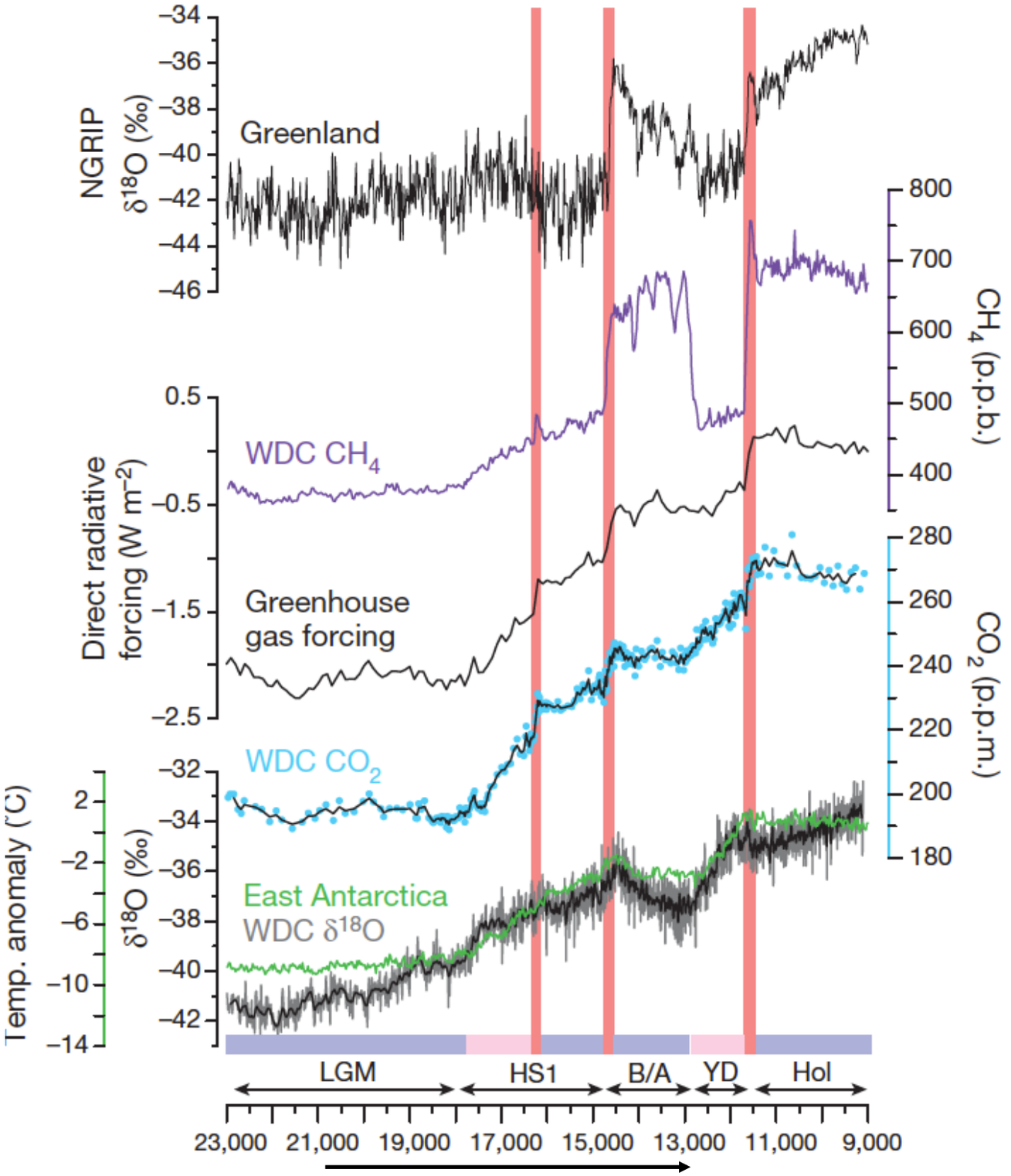
Multi-Millennial Scale Changes



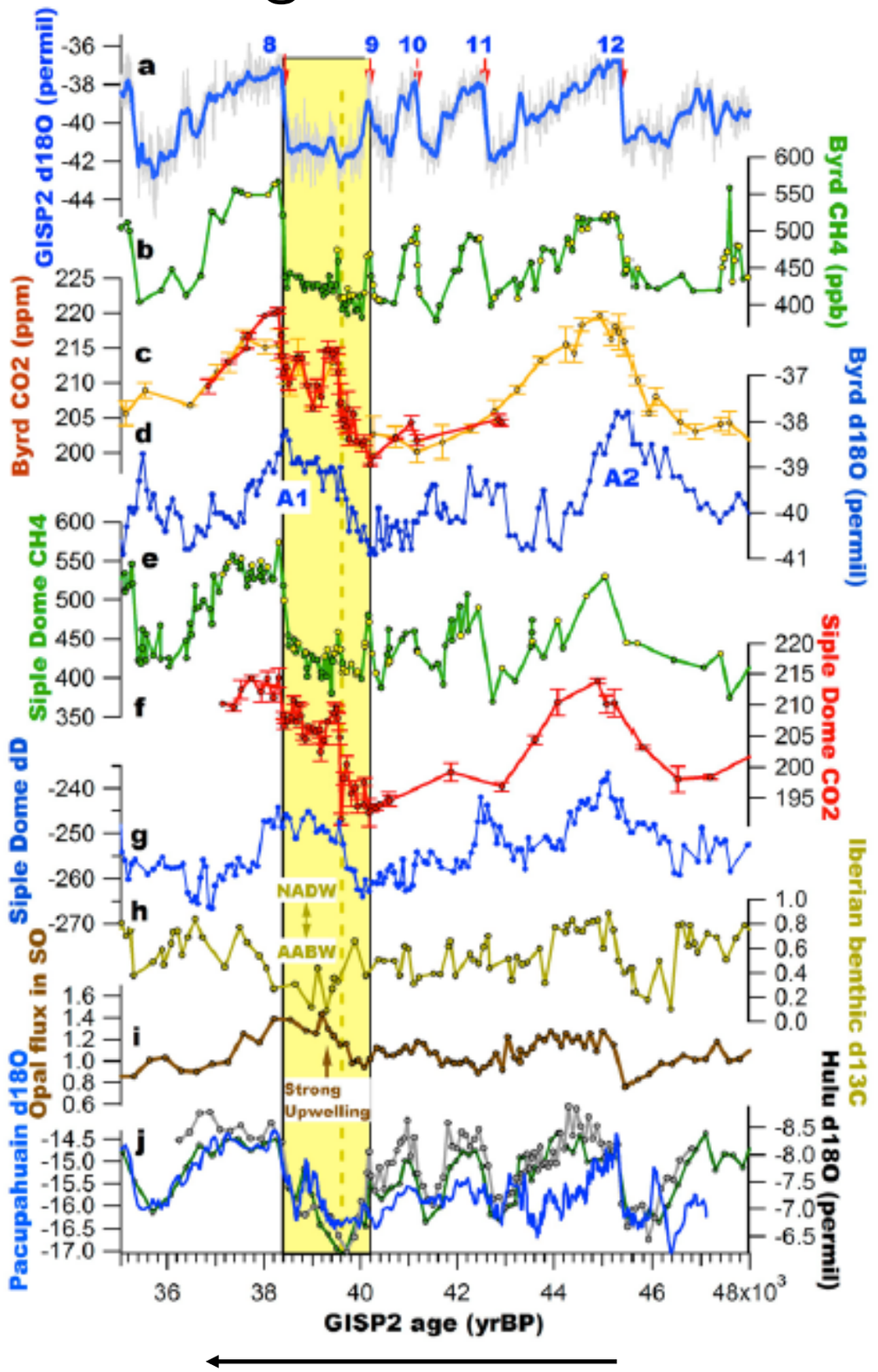
Ahn and Brook (2014) Nature Communications

The Ice Core Record

Multi-Millennial Scale Changes



Marcott et al. (2014) Nature



Ahn et al. (2012) GRL

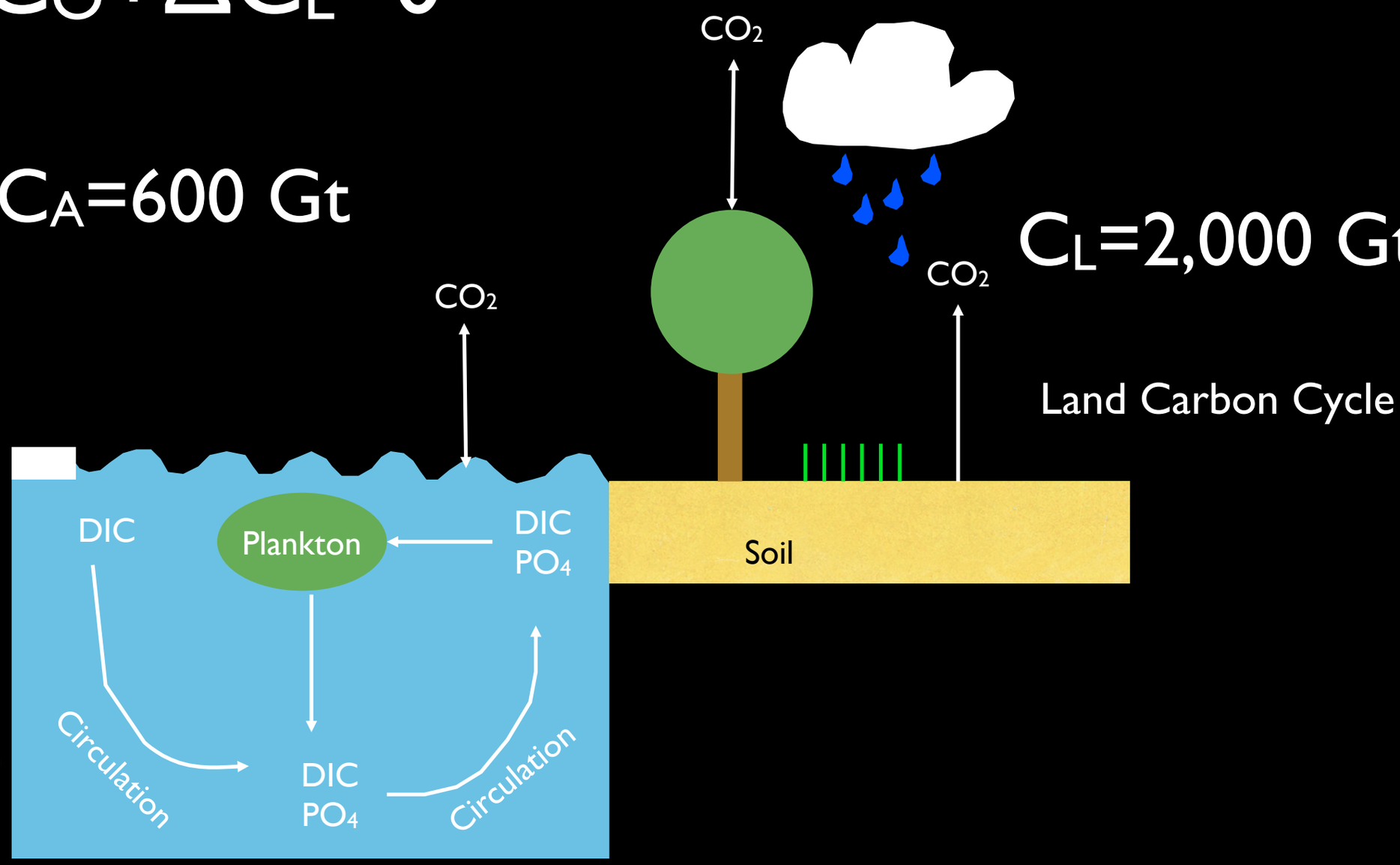
The Carbon Cycle

$$\Delta C_A + \Delta C_O + \Delta C_L = 0$$

C_A=600 Gt

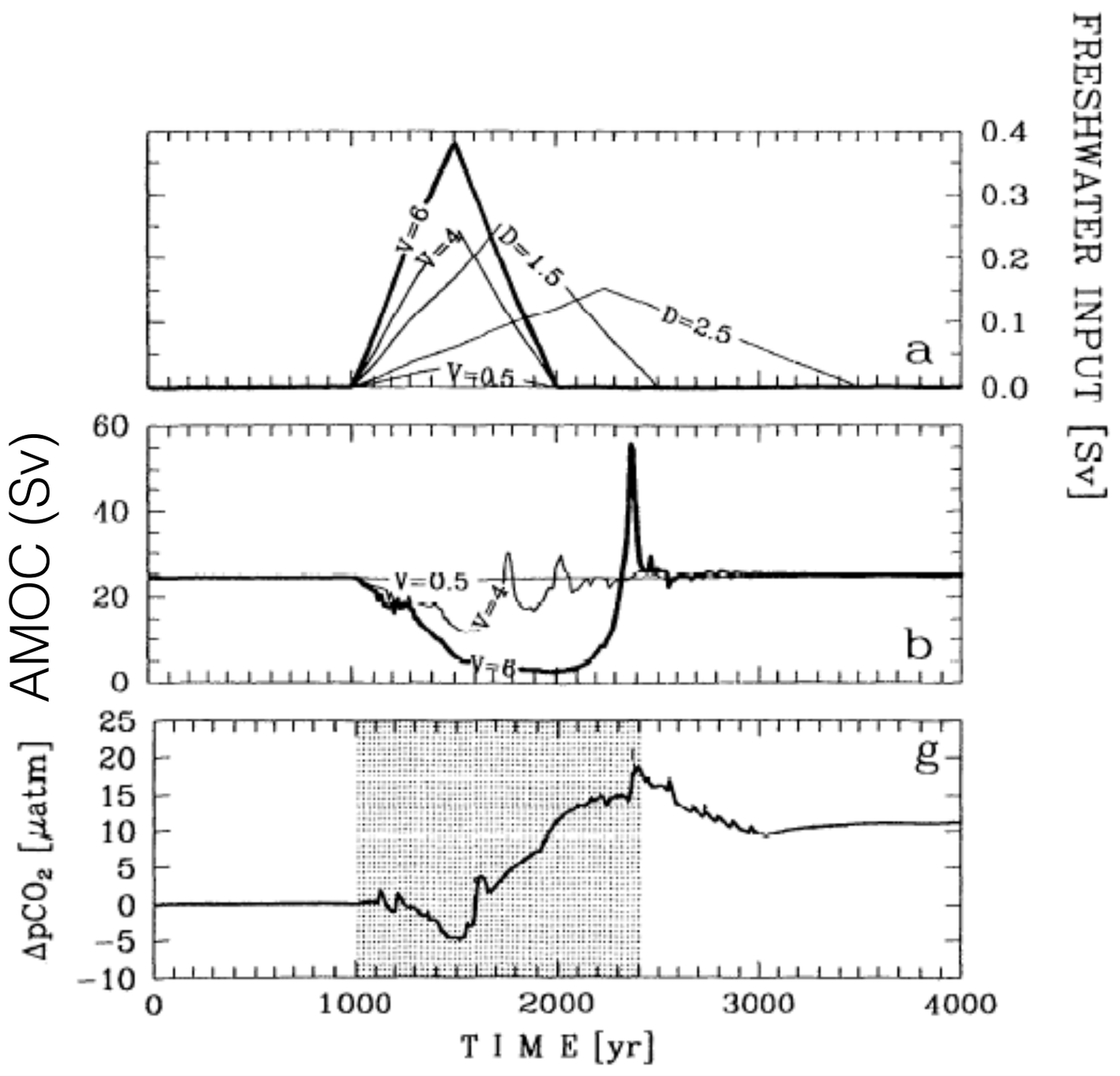
Ocean Carbon Cycle

C_O=40,000 Gt

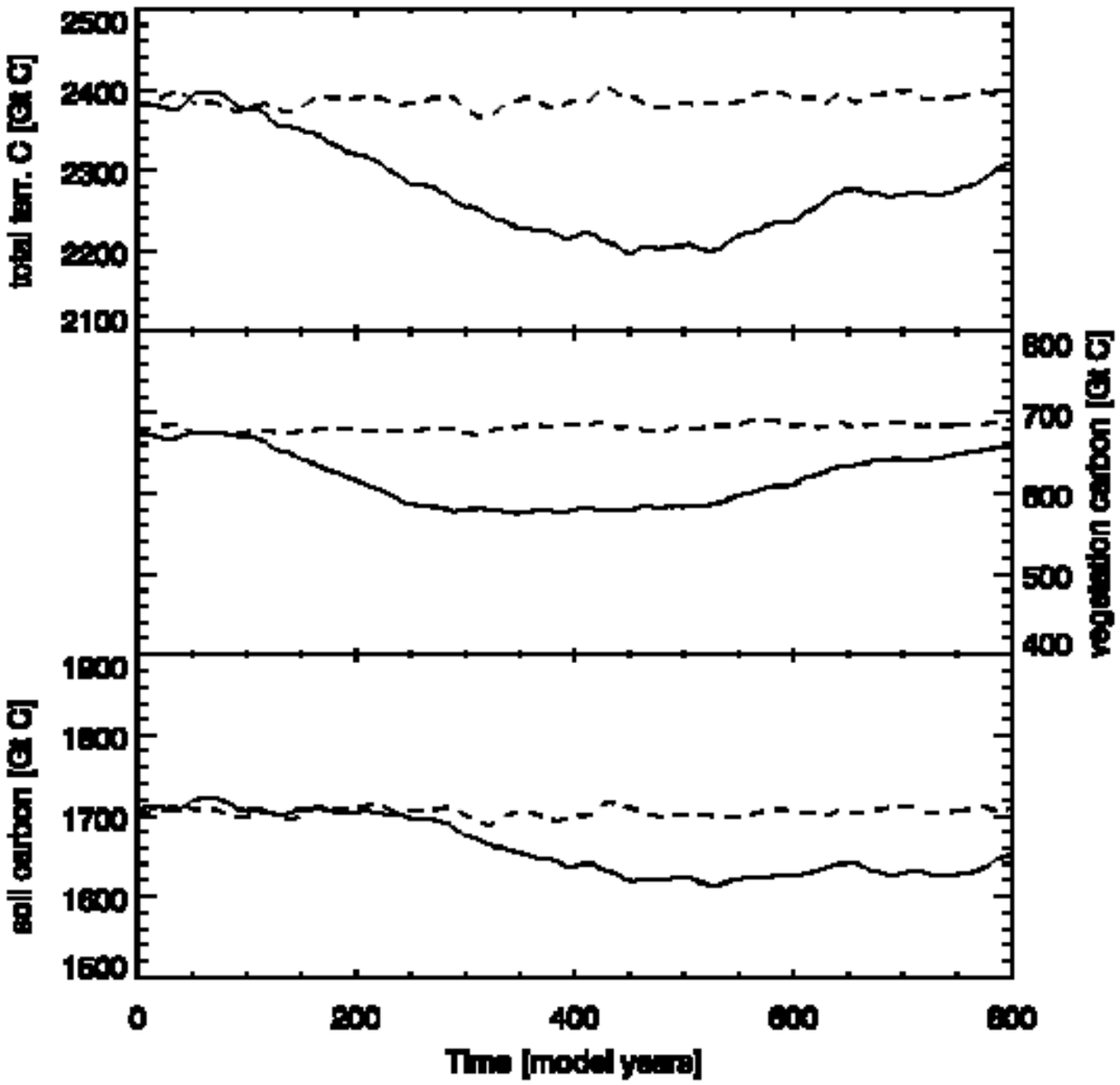


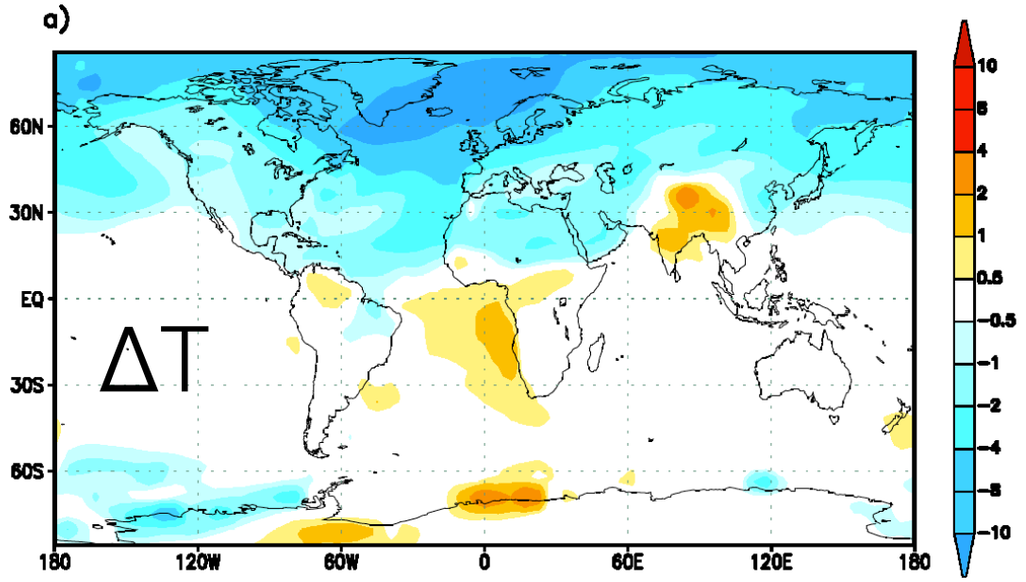
C_L=2,000 Gt

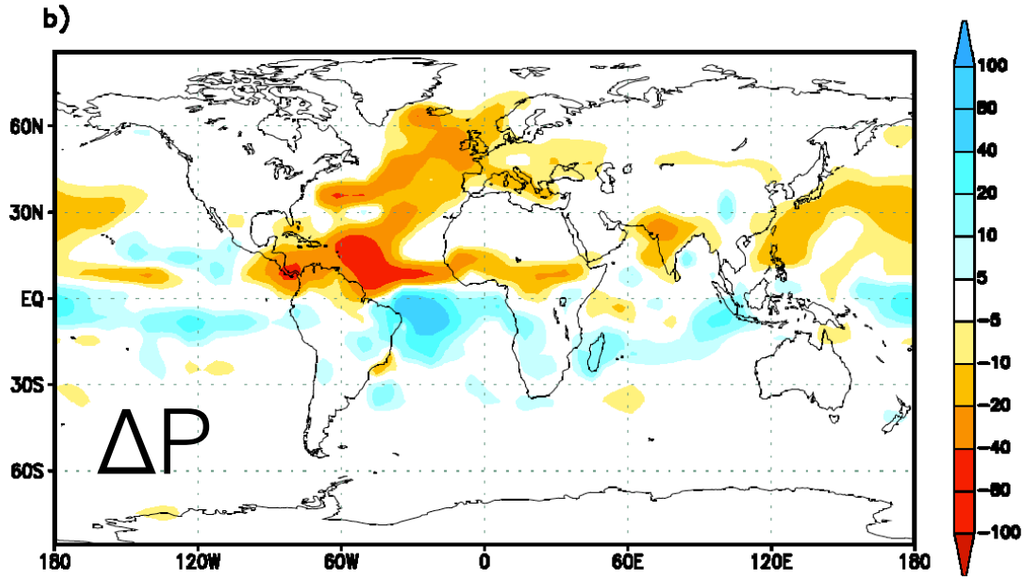
Marchal et al. (1998) Paleoceanography

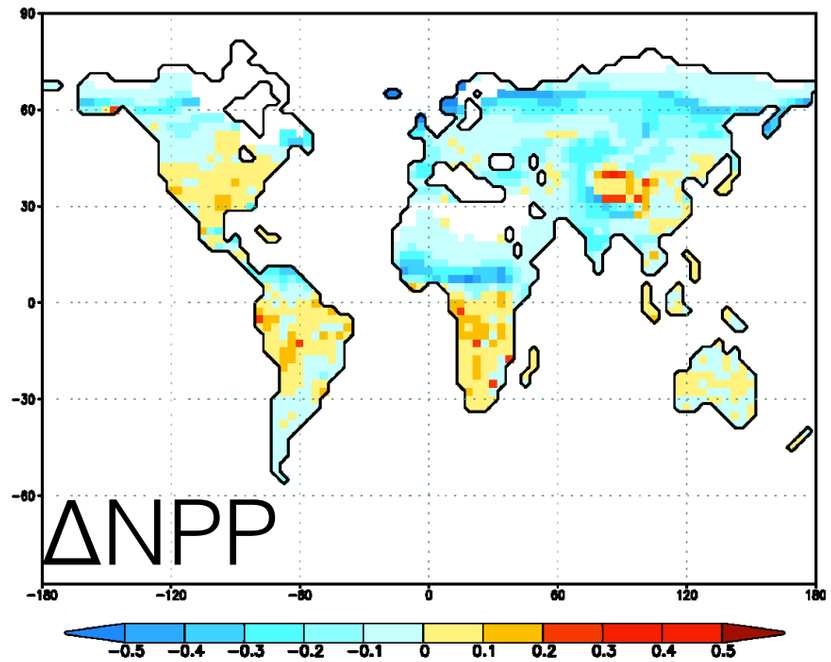


Scholze et al. (2003) Holocene









Summary

Ice core data suggest CO_2 increases if AMOC is shutdown.

Early modeling studies showed that changes in AMOC affect

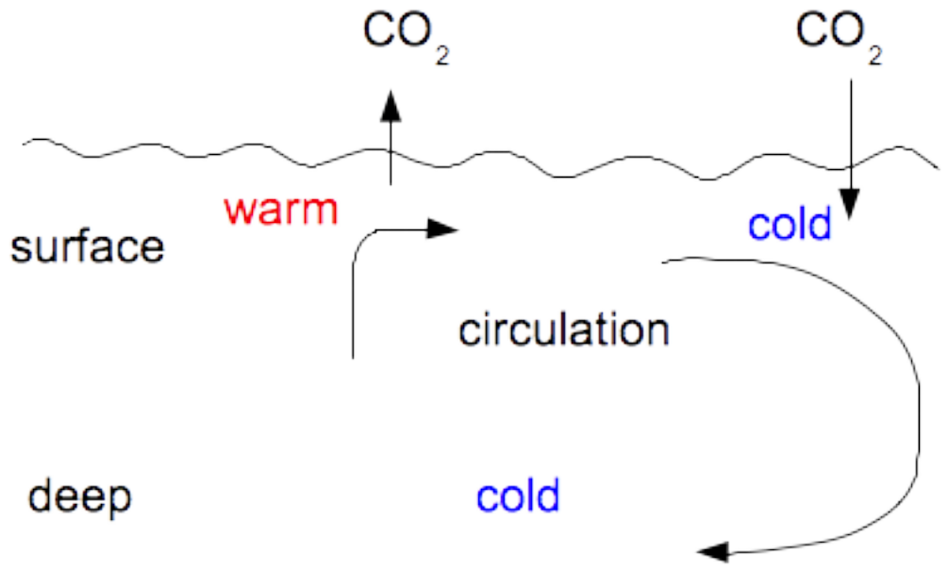
- Ocean Carbon Storage
- Land Carbon Storage
- Atmospheric CO_2

Ocean Carbon Cycle

- Solubility Pump
- Biological Pump
  - Soft Tissue (organic carbon)
  - Hard Tissue ($CaCO_3$)

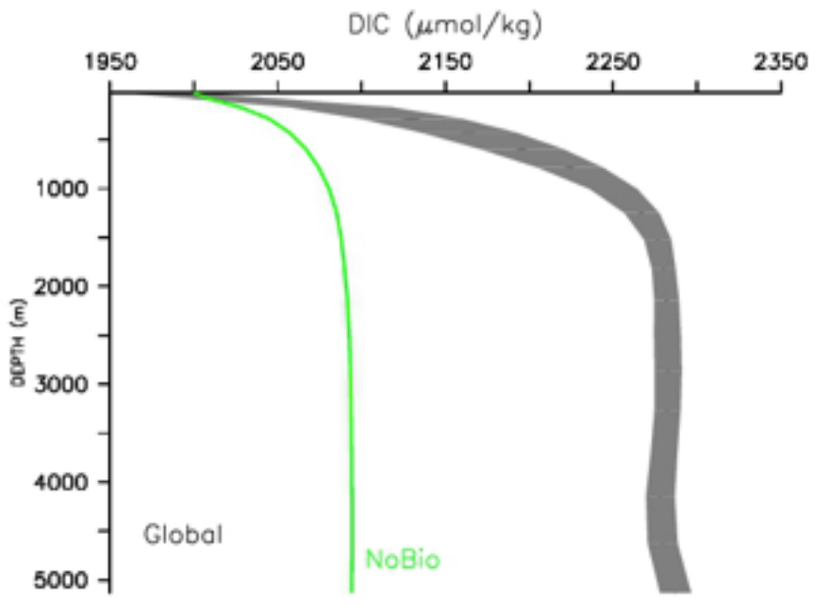
The Ocean's Carbon Pumps

1. The Solubility Pump



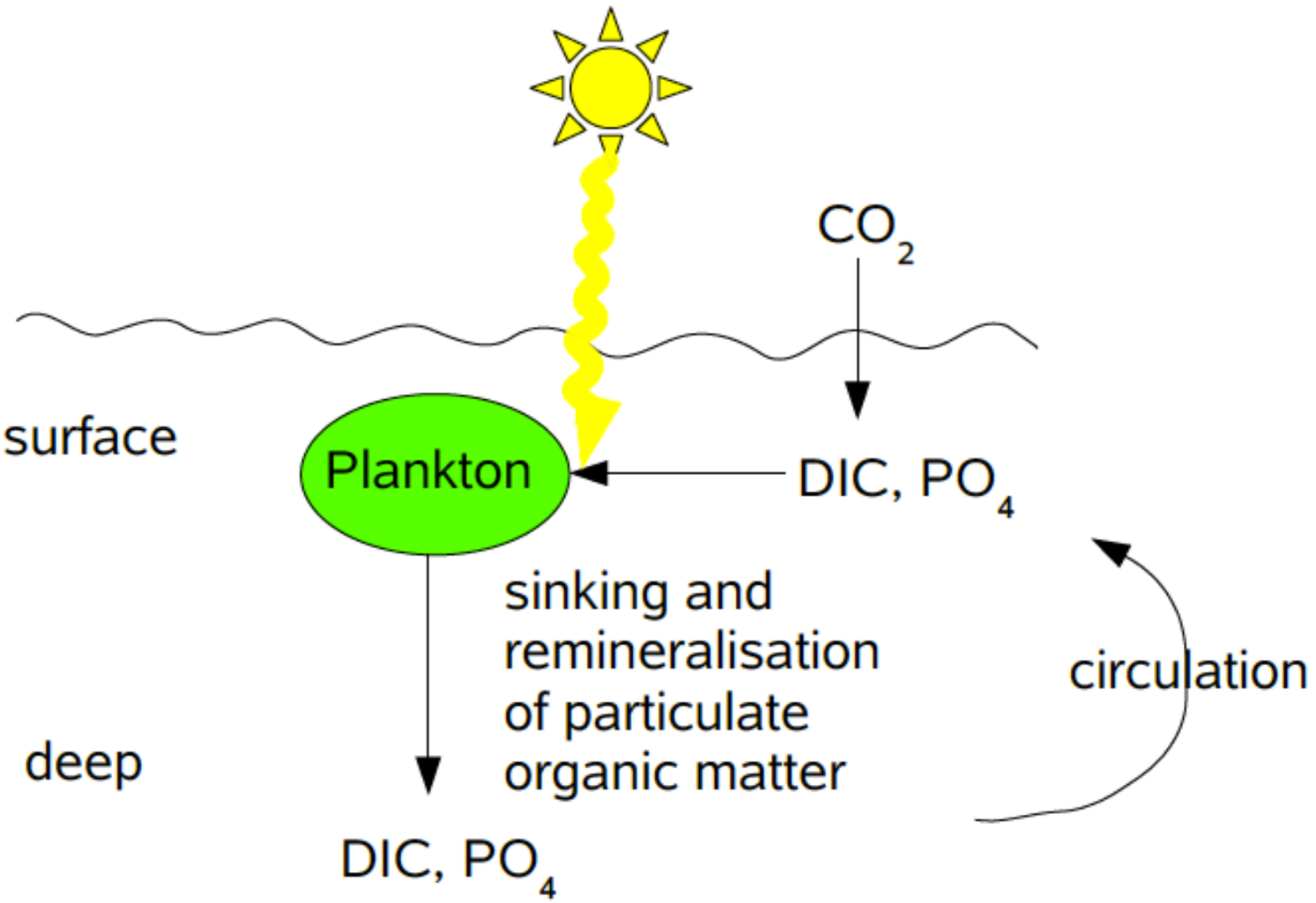
Solubility pump leads to higher carbon concentrations in the deep ocean because CO2 is more soluble in cold water than in warm water

It contributes ~1/3 to the total global surface-to-deep DIC gradient

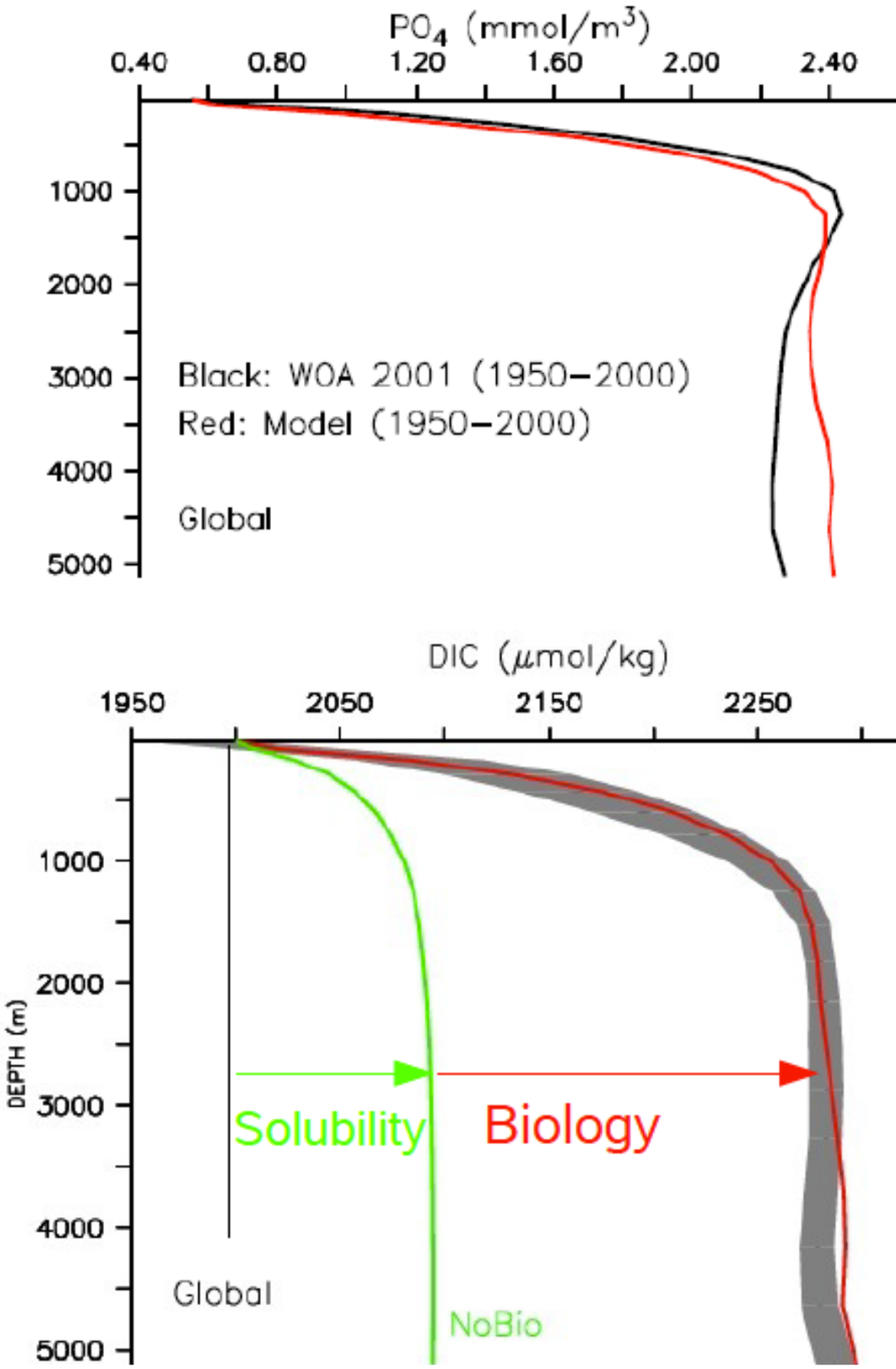


The Ocean's Carbon Pumps

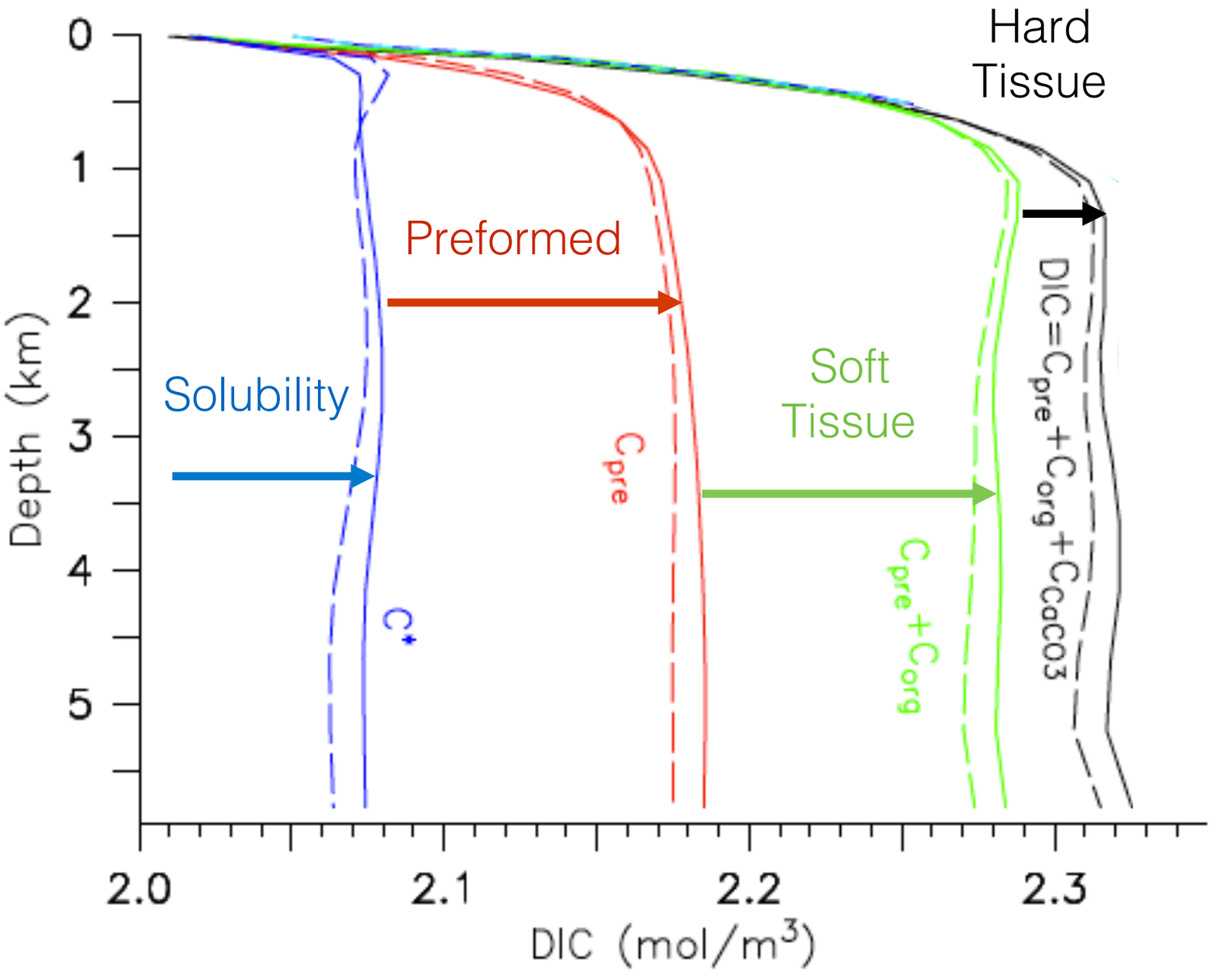
2. The Biological Pump

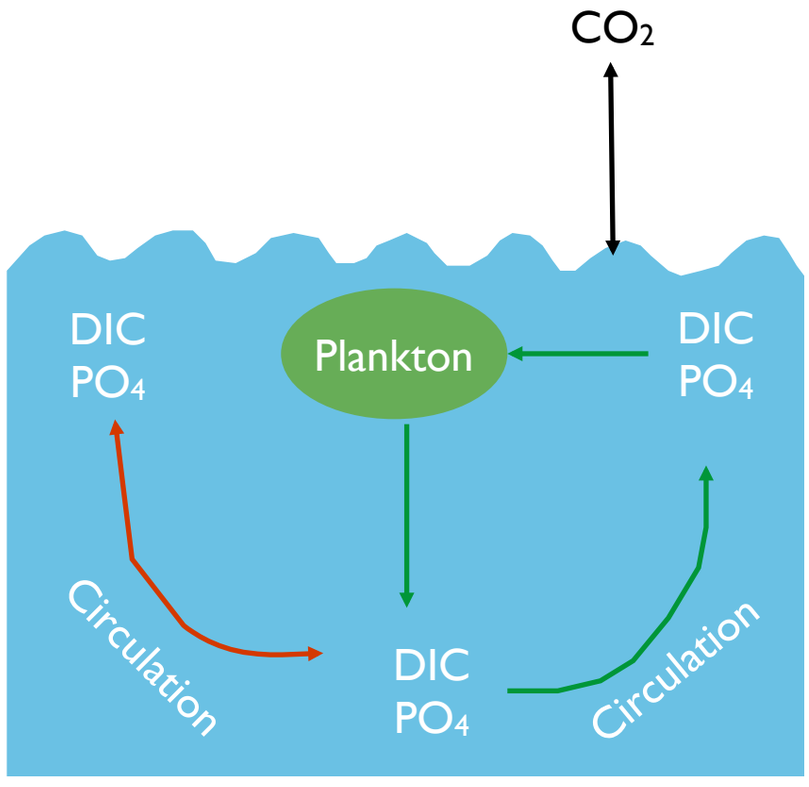


It contributes ~2/3 to the total global surface-to-deep DIC gradient



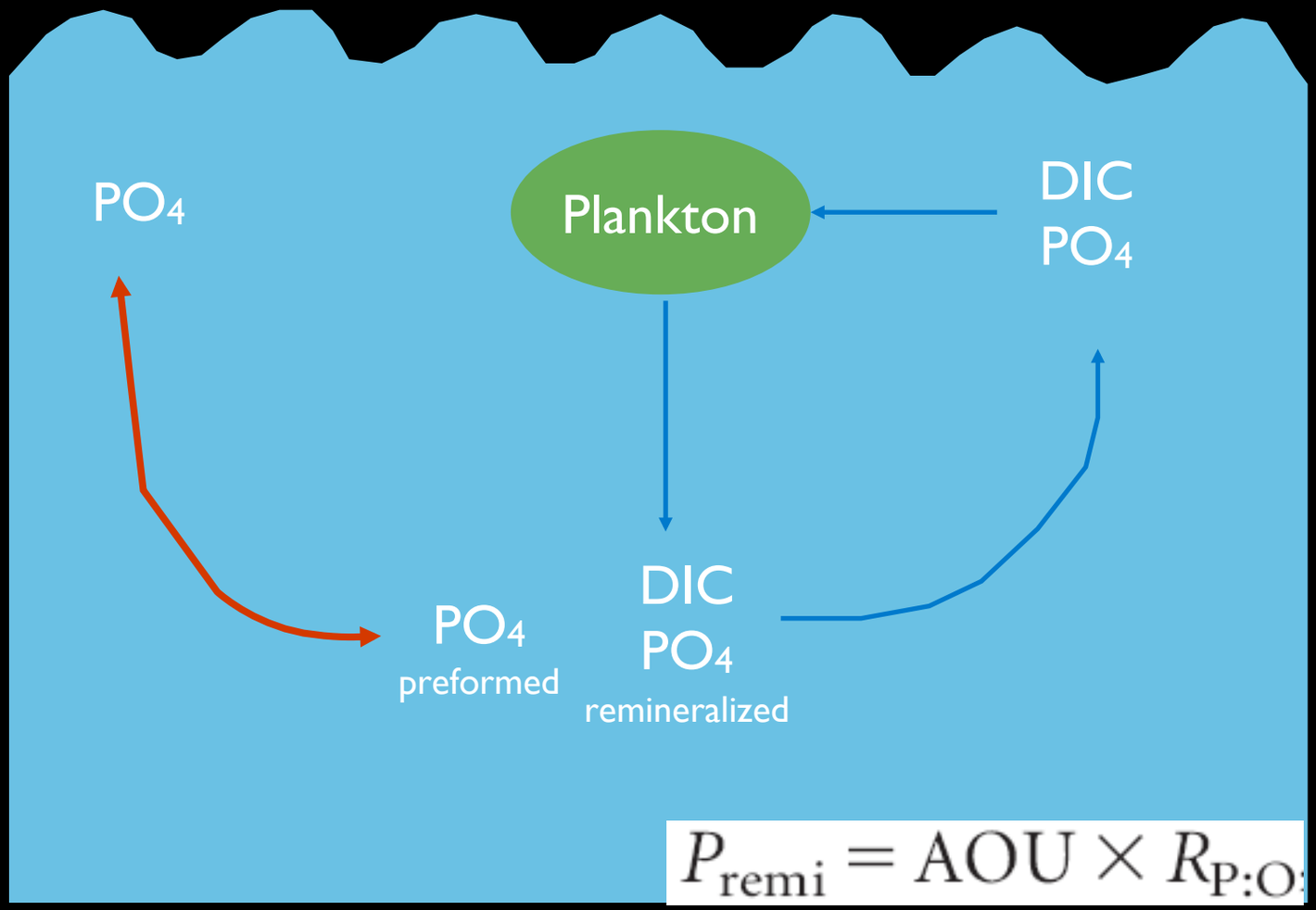
The Ocean's Carbon Pumps



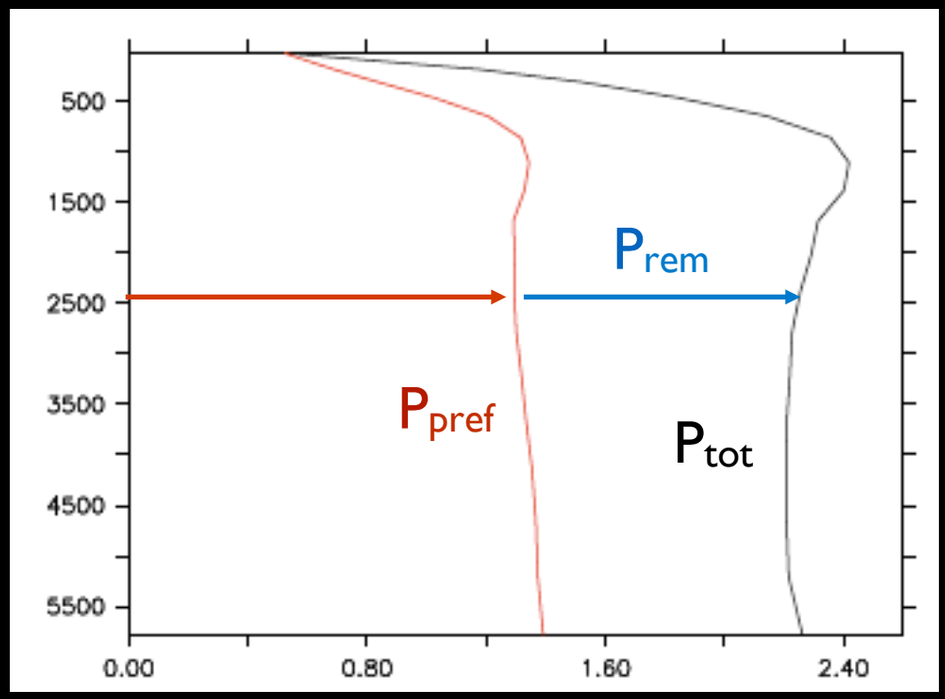


Schmittner et al. (2013) Biogeosc.

Soft-Tissue Pump and Preformed (Unused) Nutrient Inventory

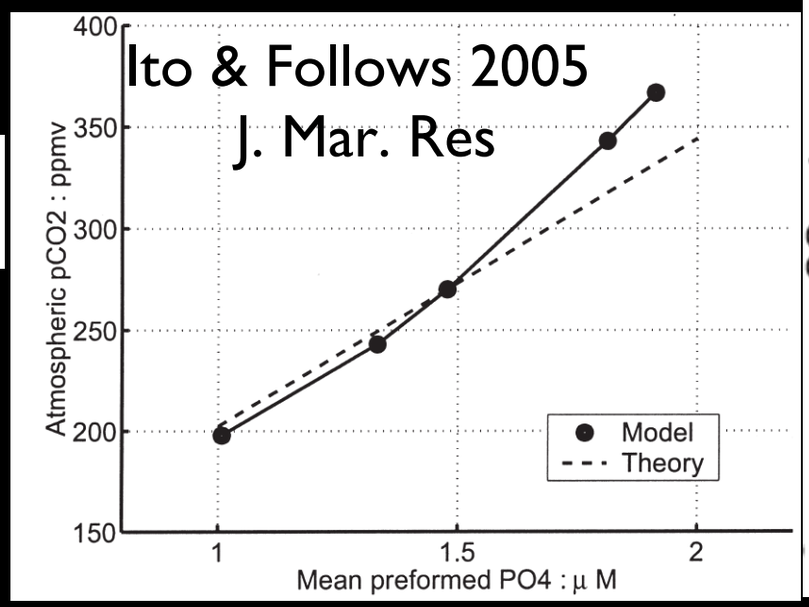


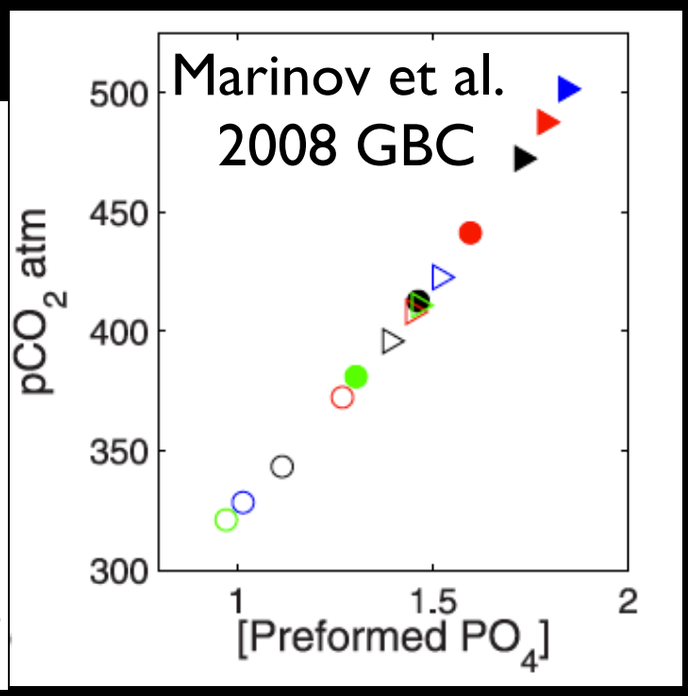
$$P_{remi} = AOU \times R_{P:O}$$

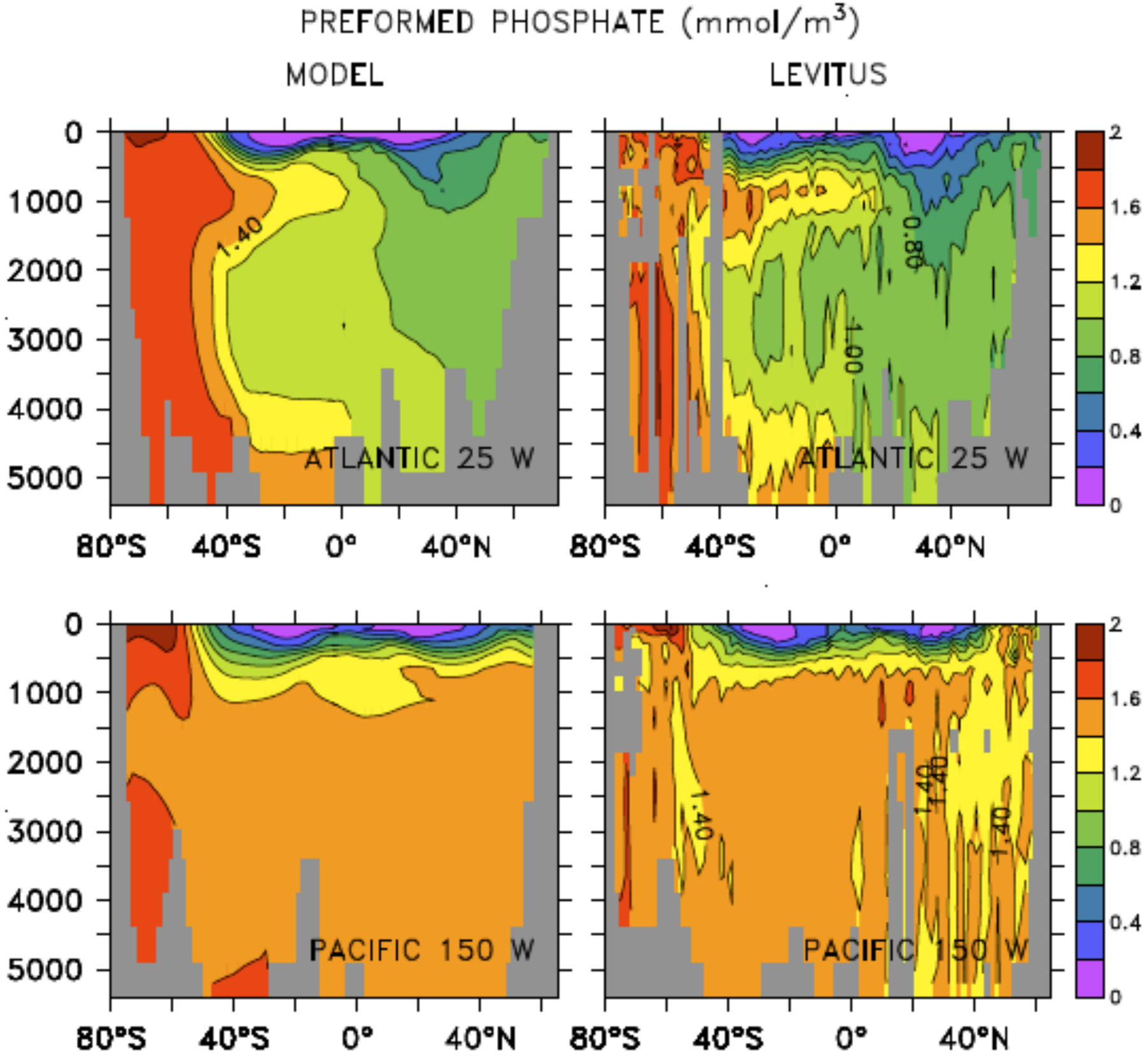


$$P_{tot} = P_{pre} + P_{rem}$$

$$\Delta p_{CO_2} = 312 \times \Delta P_{pref} / P_{tot}$$







NADW injects relatively low preformed nutrients into deep ocean.

This makes biological pump efficient.

AABW & AAIW inject high preformed nutrients into deep ocean.

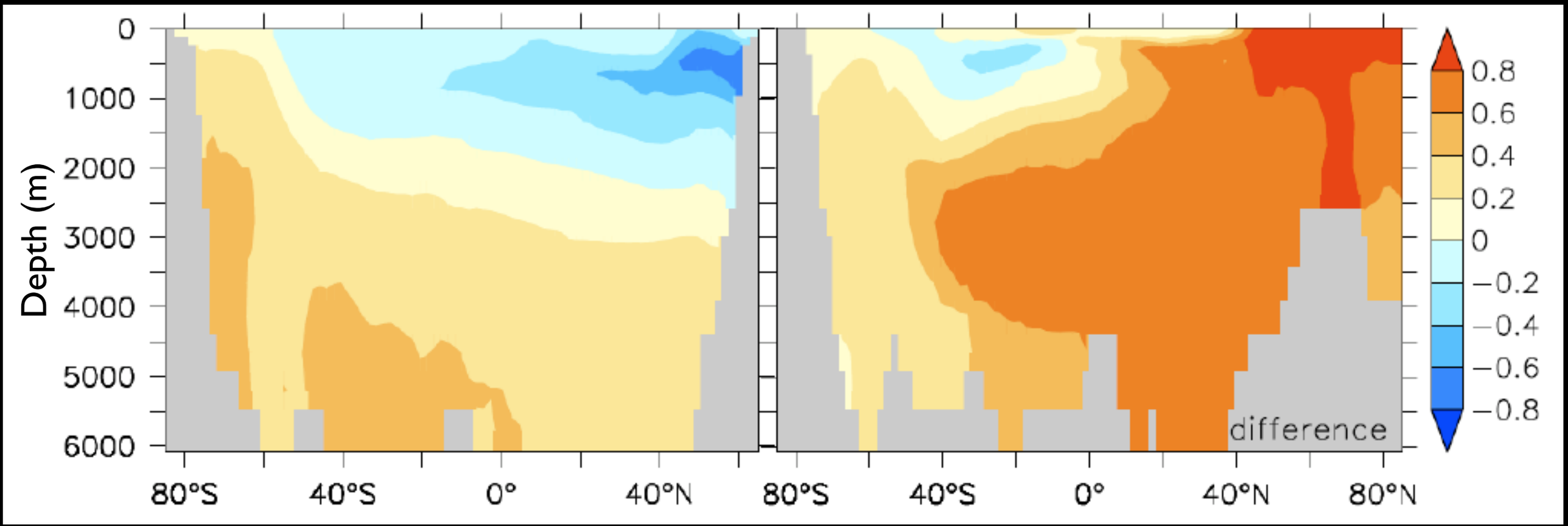
This makes biological pump inefficient.

Preformed Nutrients Change

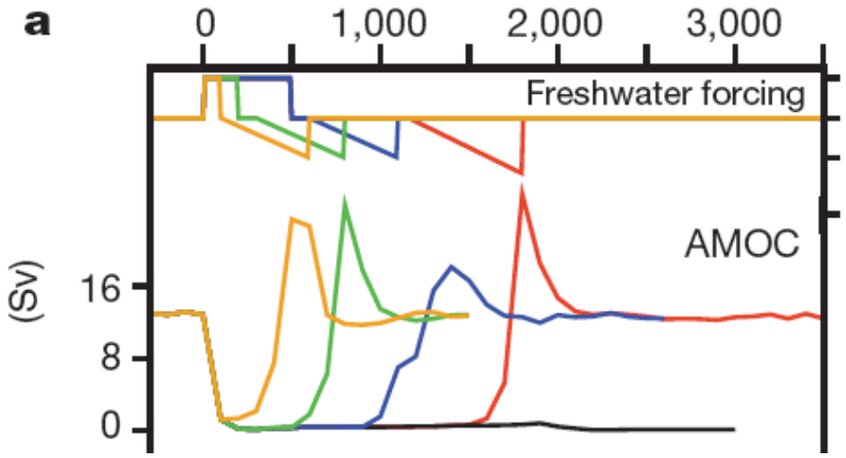
model year 2500

Pacific

Atlantic

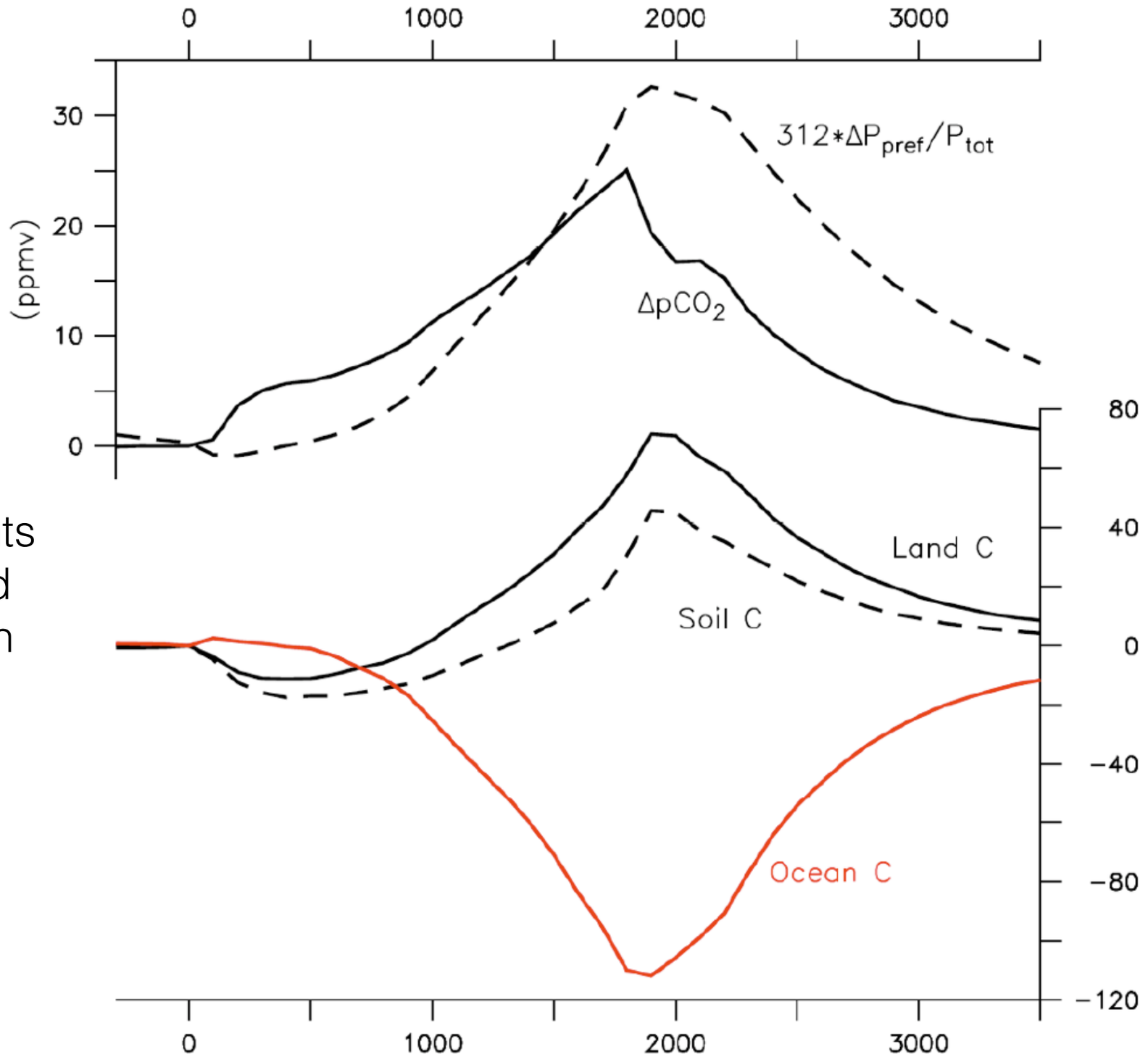


Schmittner & Galbraith 2008 Nature

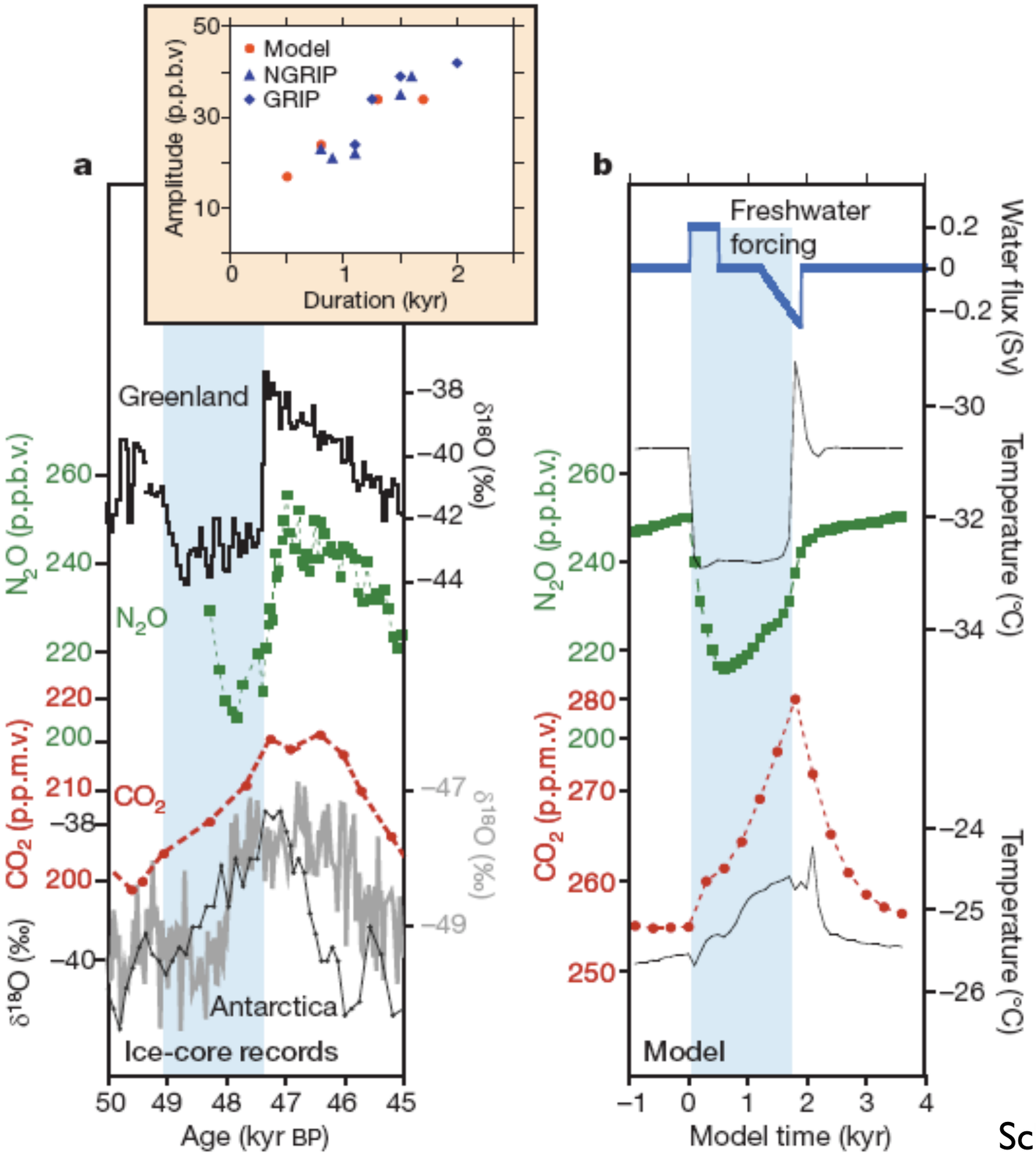


Hypothesis

AMOC shutdown decreases input of low pre-formed nutrients thus increases the pre-formed nutrient inventory of the ocean

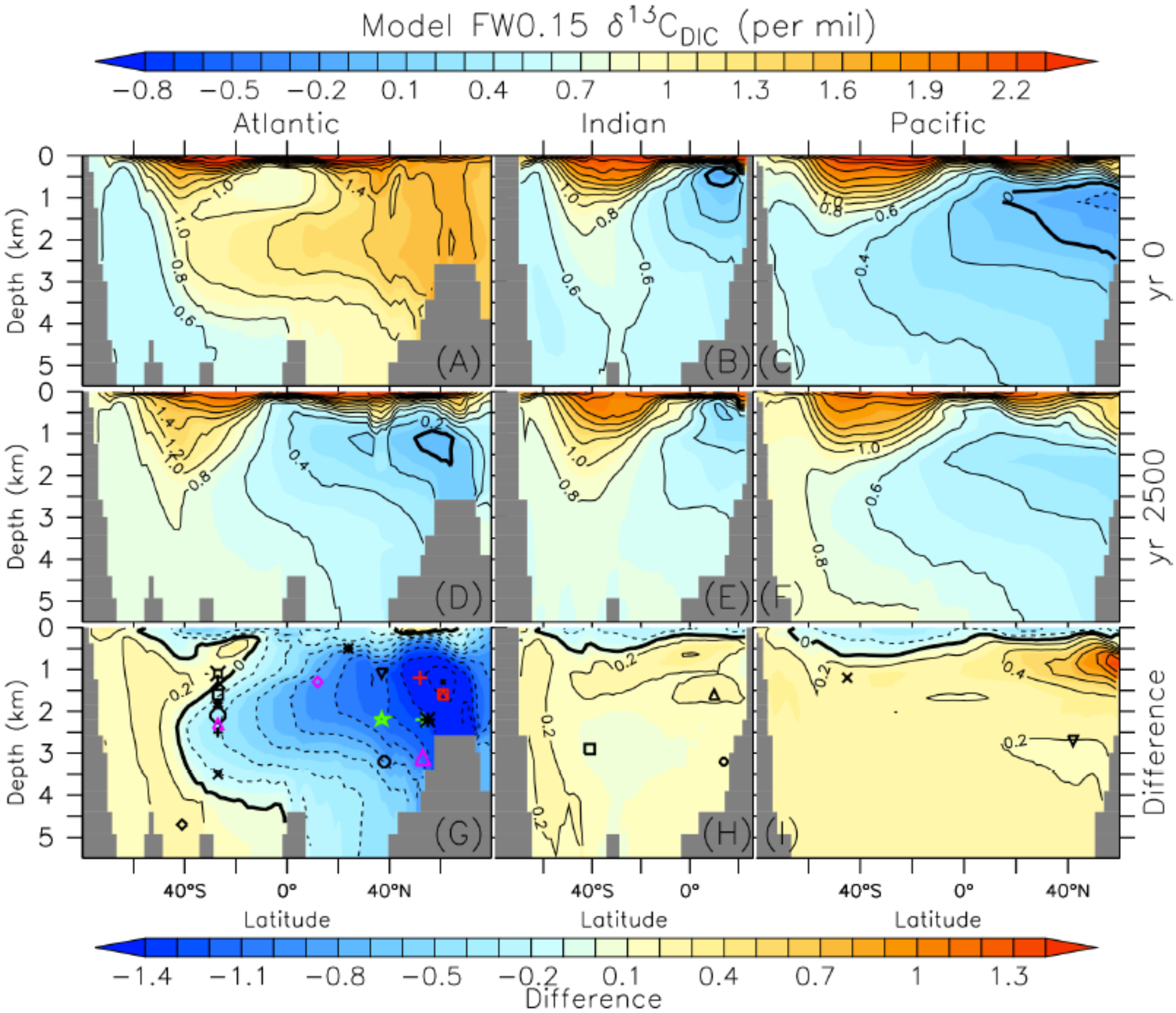


Schmittner & Galbraith 2008 Nature



Simulated changes in CO_2 are similar to observations.

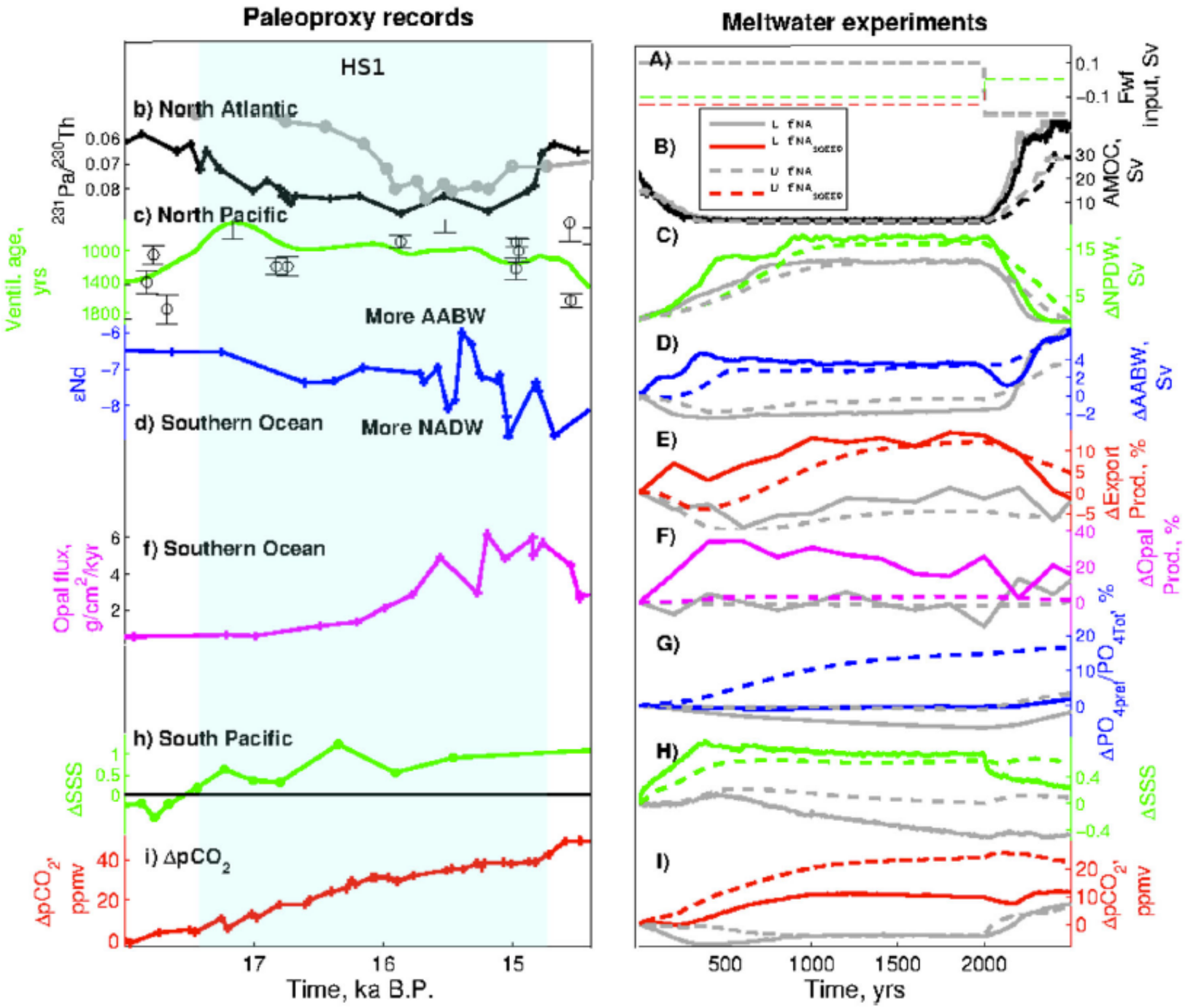
Schmittner & Galbraith 2008 Nature



Simulated changes are highly correlated with sediment reconstructions (r=0.85)

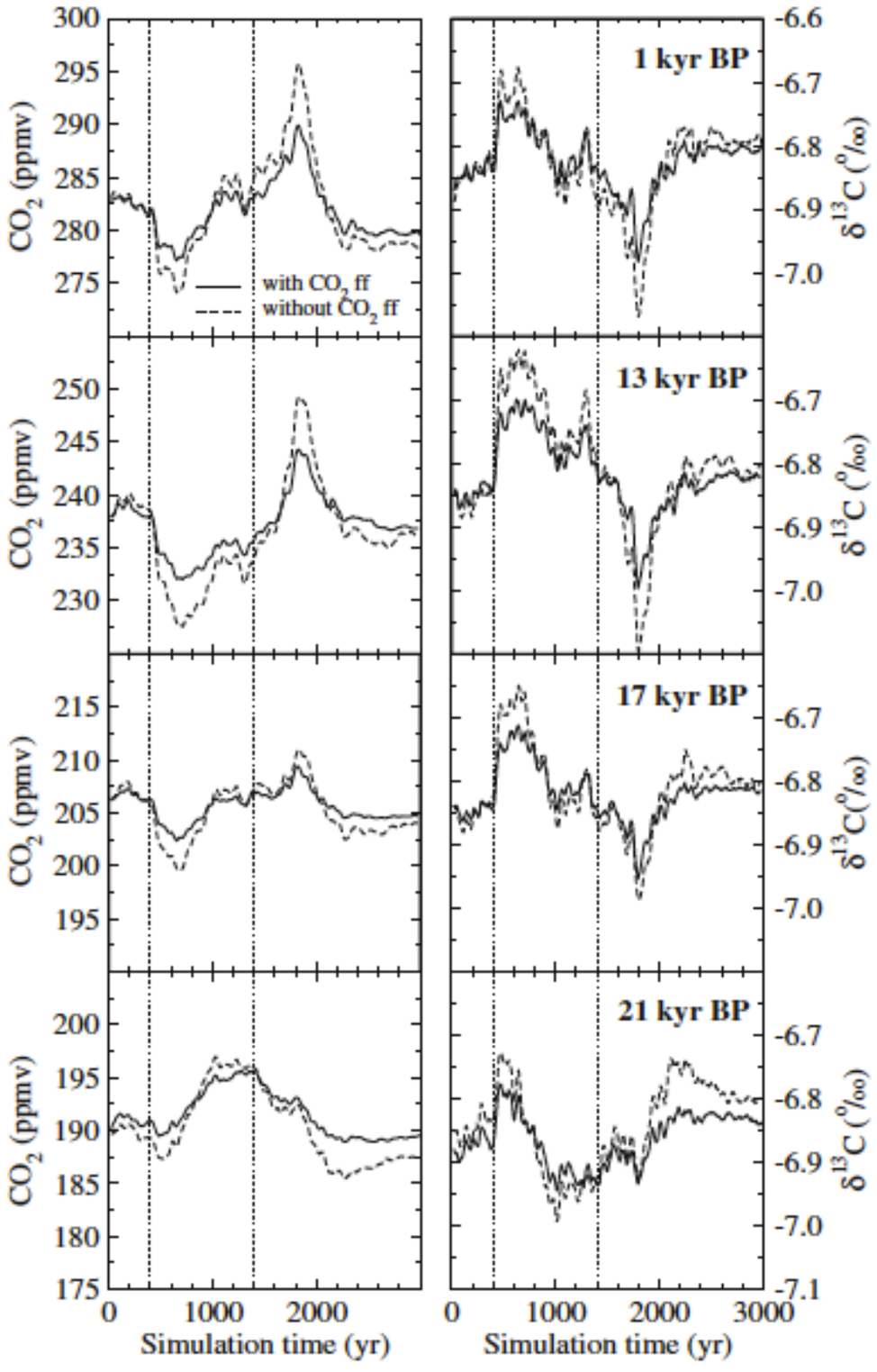
Schmittner and Lund (2015) Climate of the Past

 (2014) Paleoceanogr.

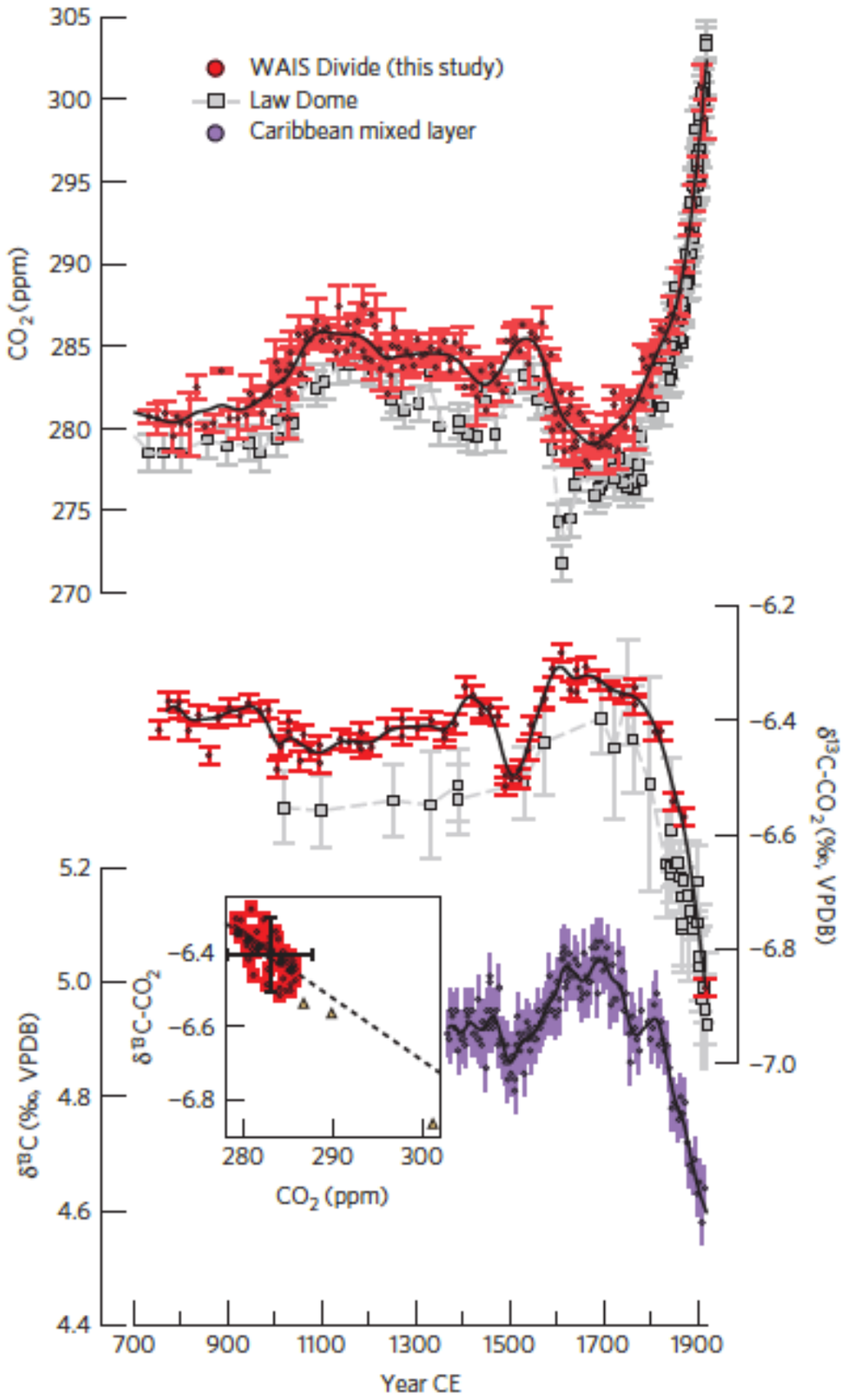


FW fluxes in SO and EEqP required to simulate observed CO_2 increase

Köhler et al. (2005)



Land carbon response is sensitive to initial conditions

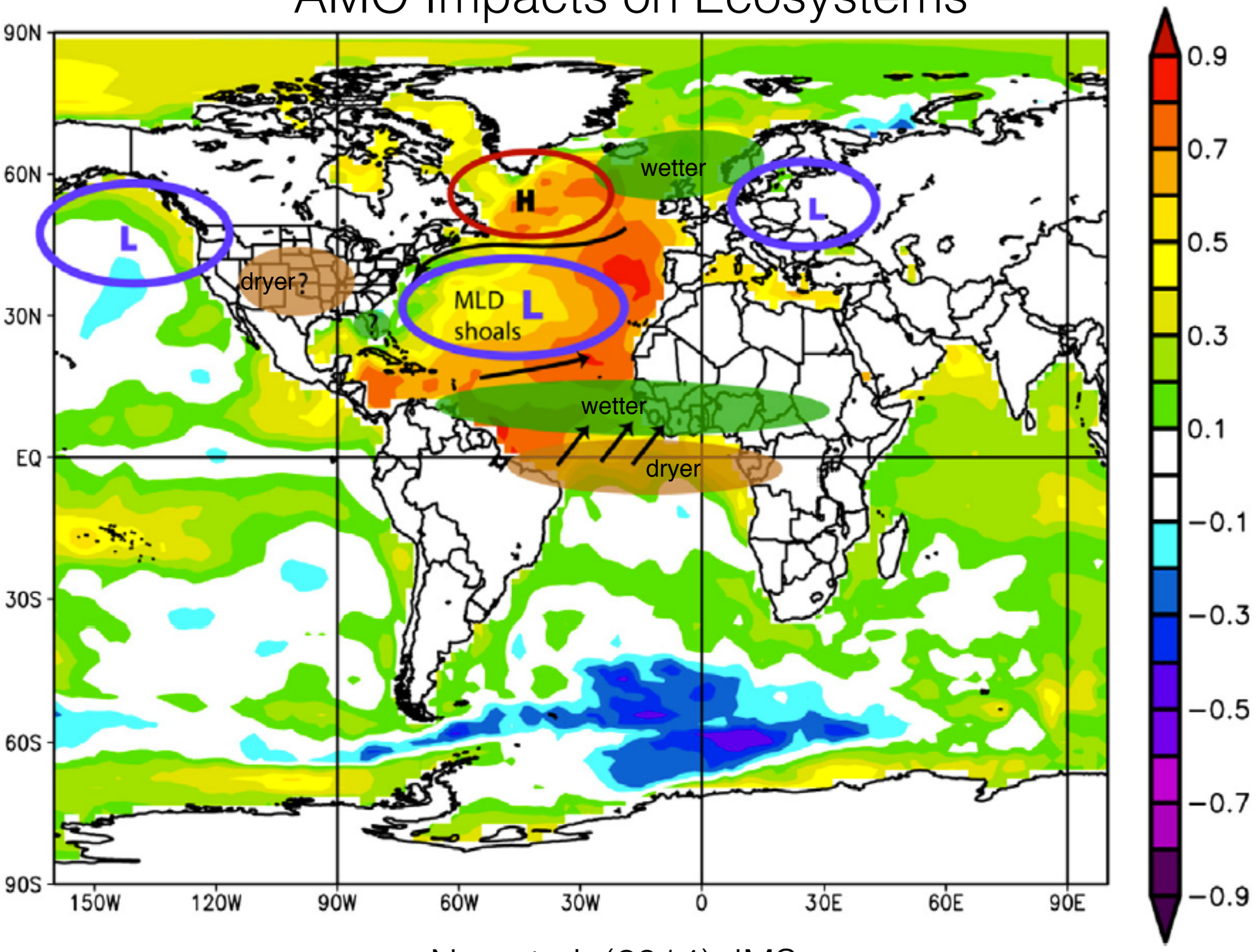


Bauska et al. (2015) Nat. Geo.

Observed centennial CO_2 variability remains unexplained.

Is there an AMOC connection?

AMO Impacts on Ecosystems



Nye et al. (2014) JMS

Conclusions

- Multi-millennial CO_2 changes due to AMOC effects on biological pump efficiency
- Rapid CO_2 changes remain unexplained (Land ?)
- Multi-centennial CO_2 changes in Holocene remain unexplained