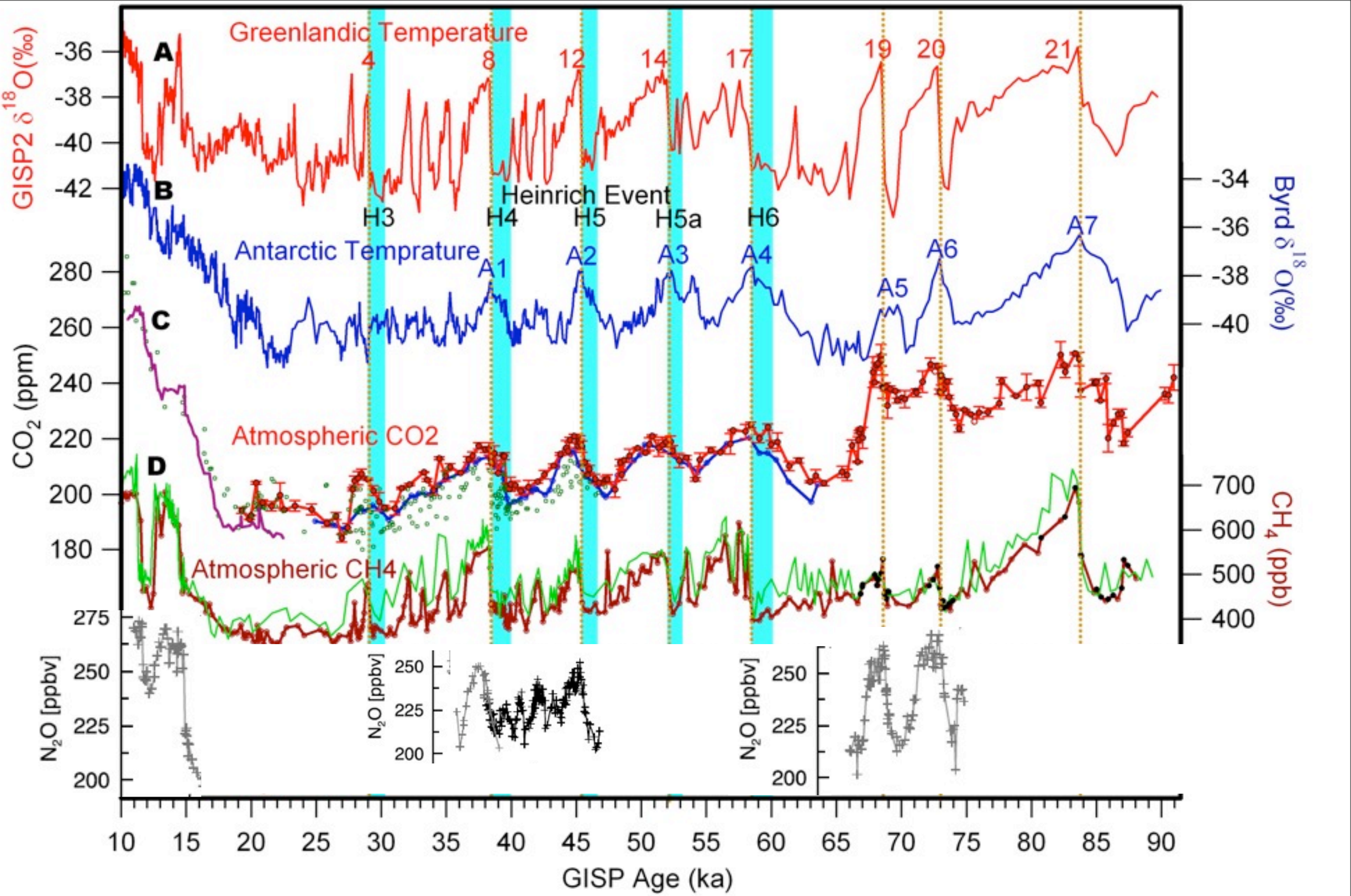
Impacts of Atlantic Meridional Overturning Circulation changes on ocean biogeochemistry and atmospheric greenhouse gases inferred from paleoclimate data and modeling

Andreas Schmittner
College of Earth, Ocean, and Atmospheric Sciences
Oregon State University

Funded by NSF's Paleoclimate and MG&G Programs



Ice Core Record of Climate, CO_2, CH_4, N_2O

Ahn & Brook (2008) Science, Flückiger et al. (2004) BGC

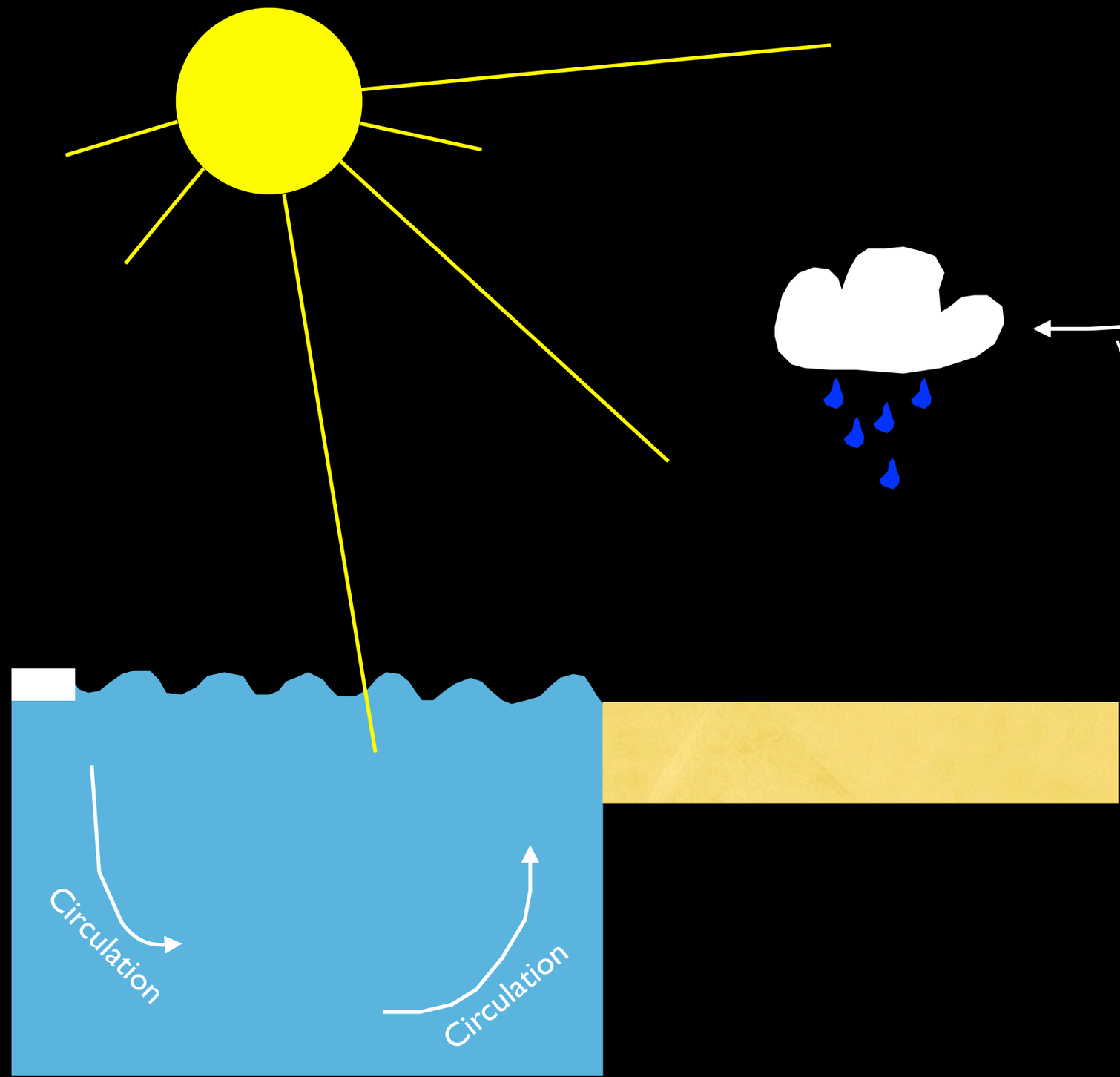
UVic Model

(Weaver et al. 2001)

2D Energy-Moisture Balance Atmosphere (fixed winds)

Dyn. Thermod. Sea Ice

3D Ocean



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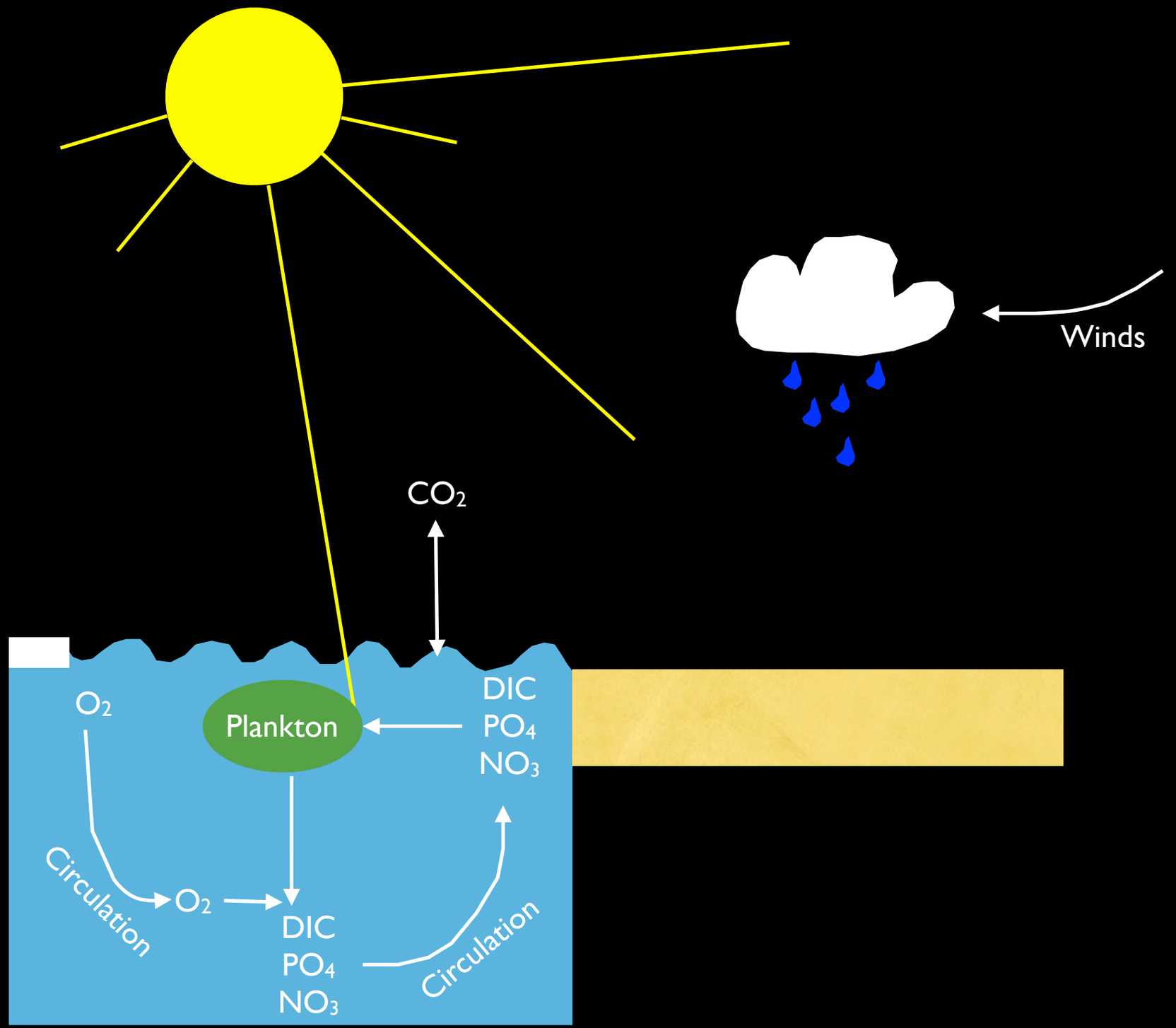

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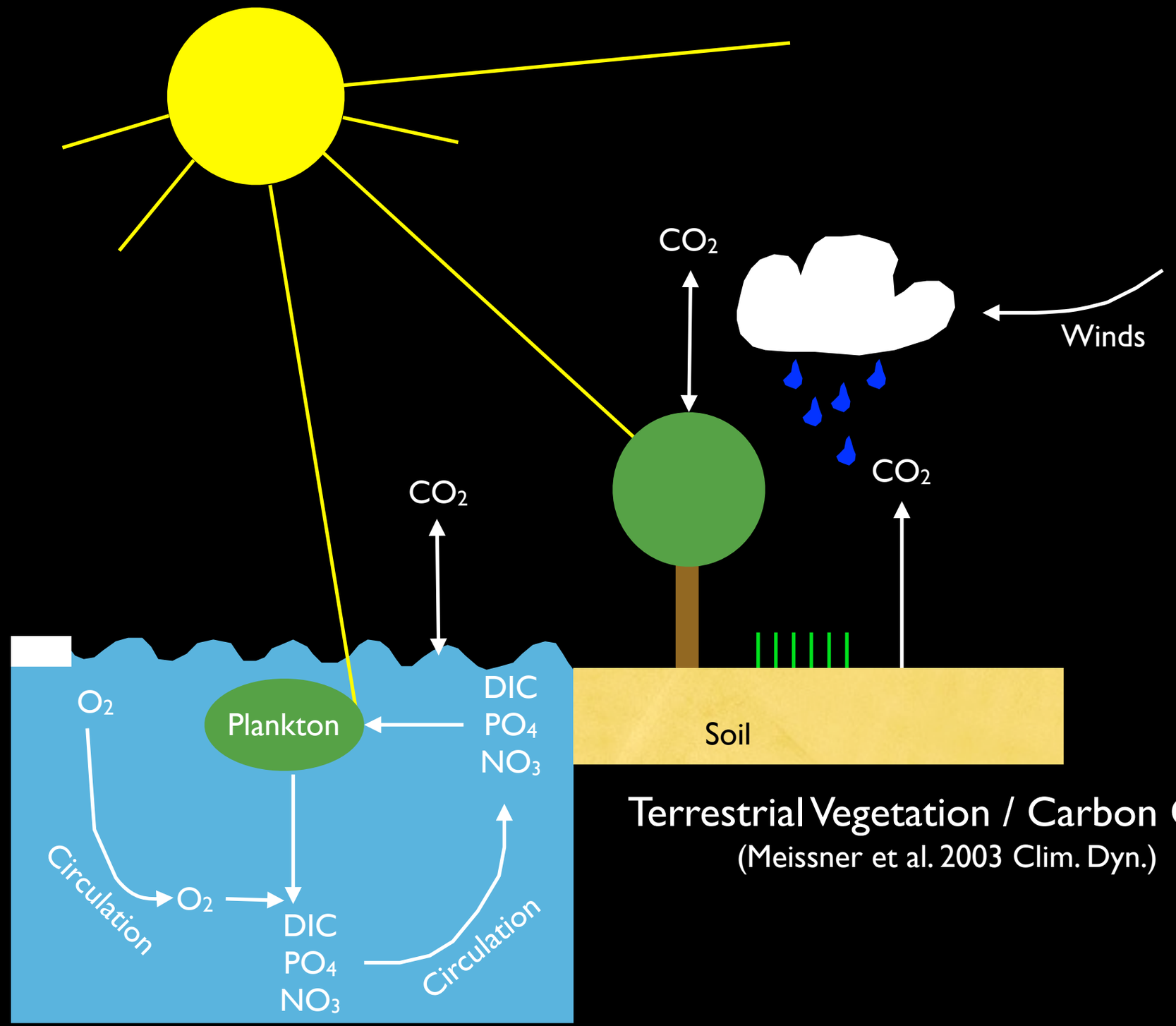

Terrestrial Vegetation / Carbon Cycle

(Meissner et al. 2003 Clim. Dyn.)

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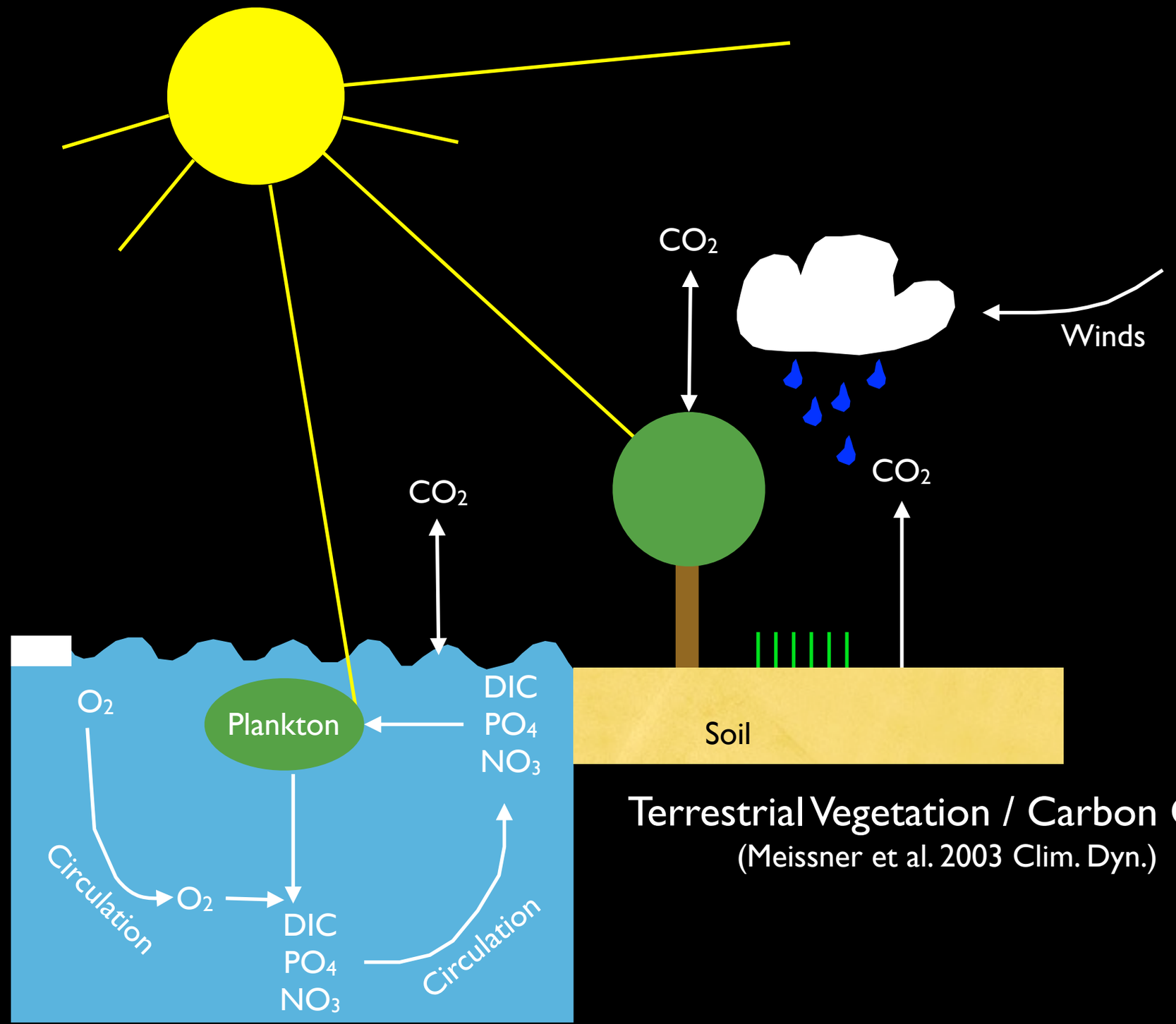

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Nevison et al. 2003 GBC

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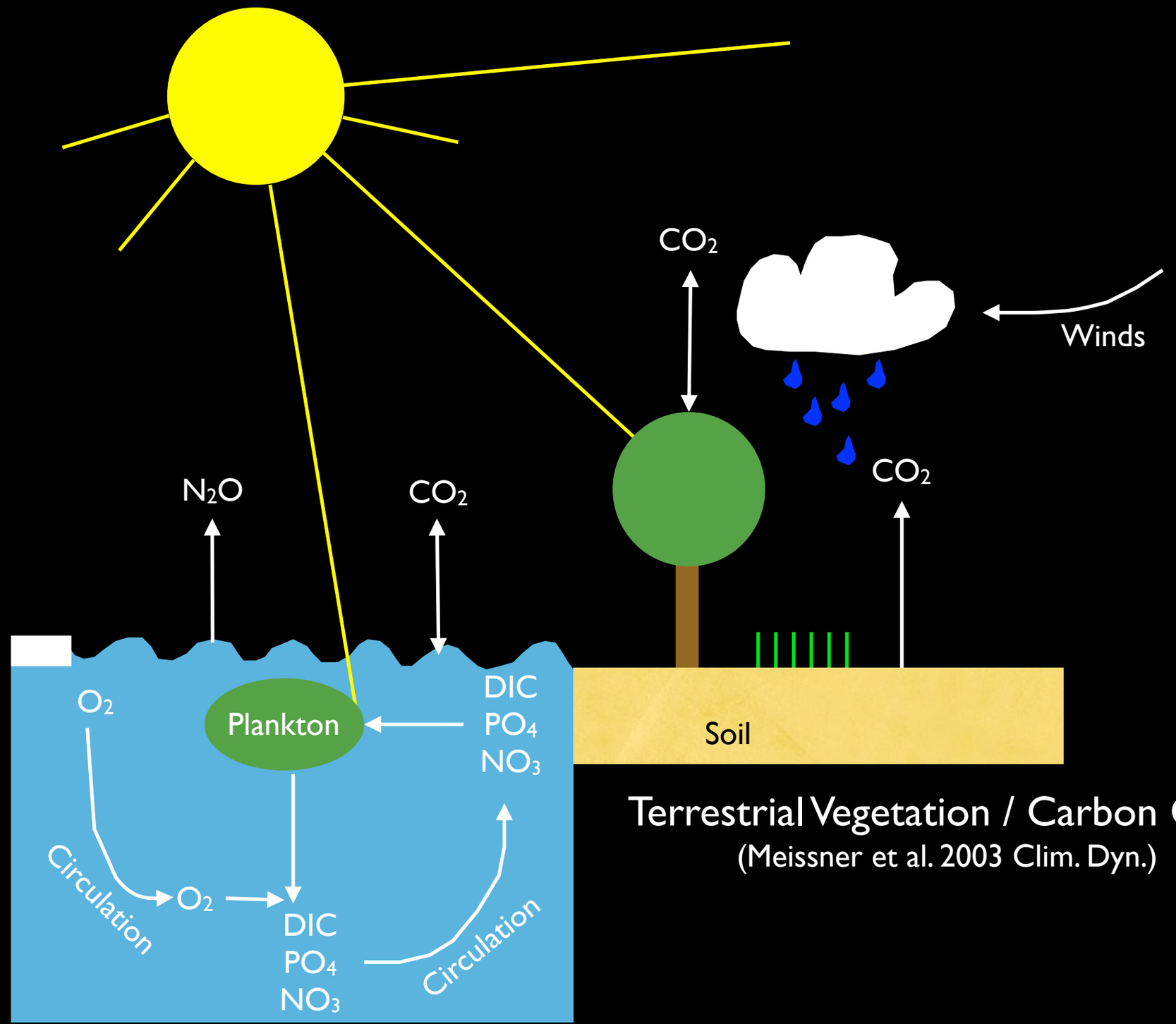

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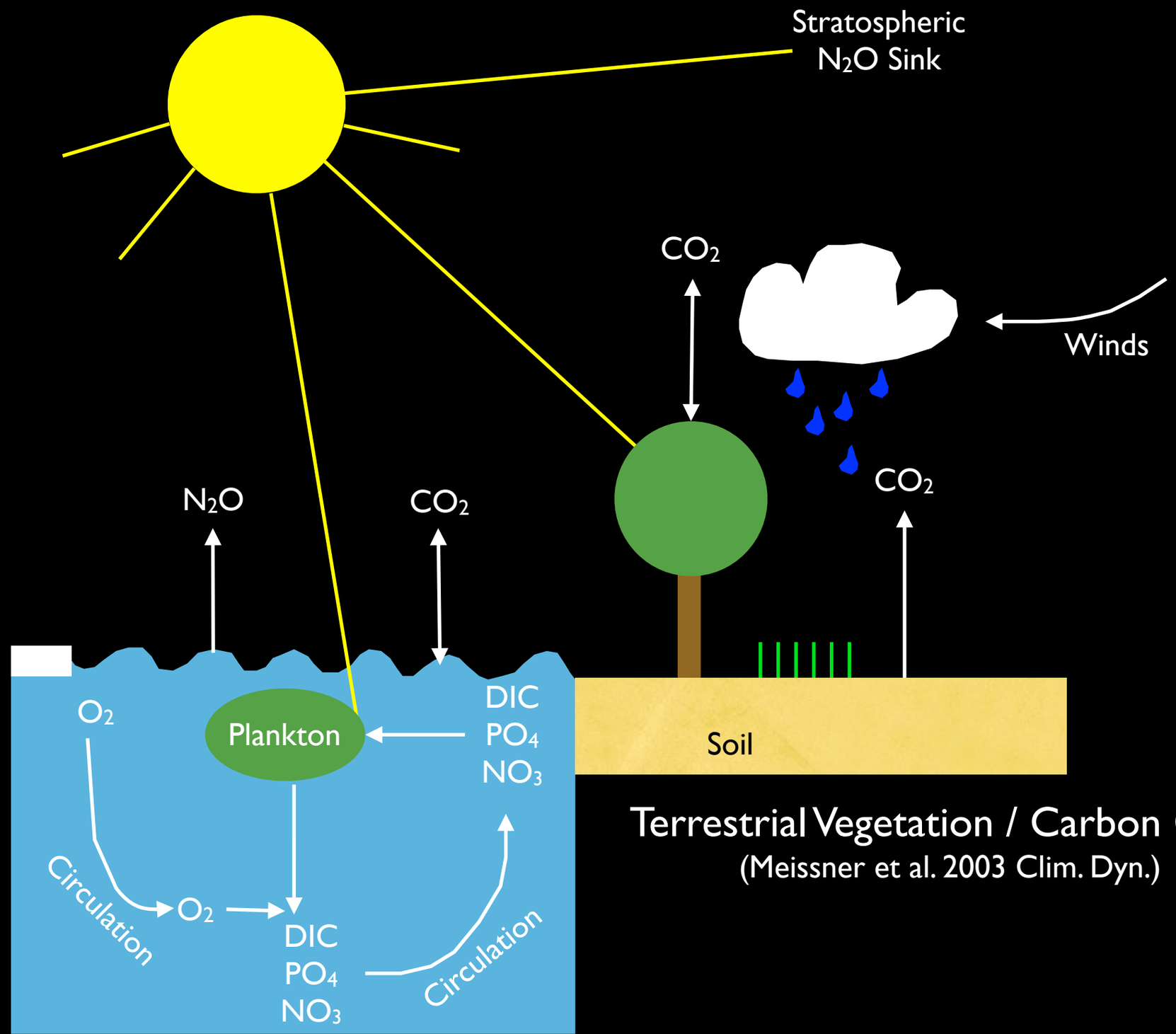

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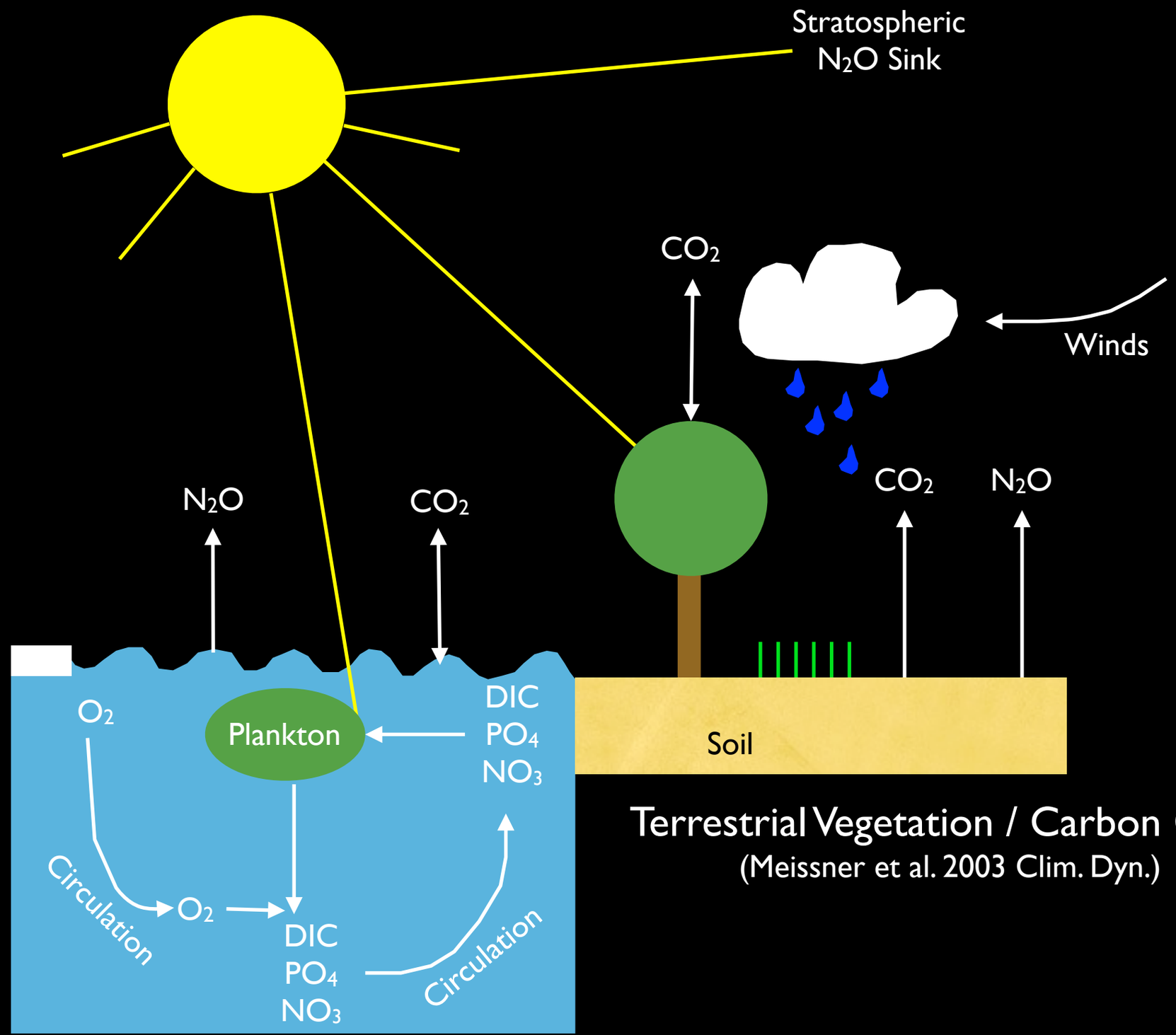

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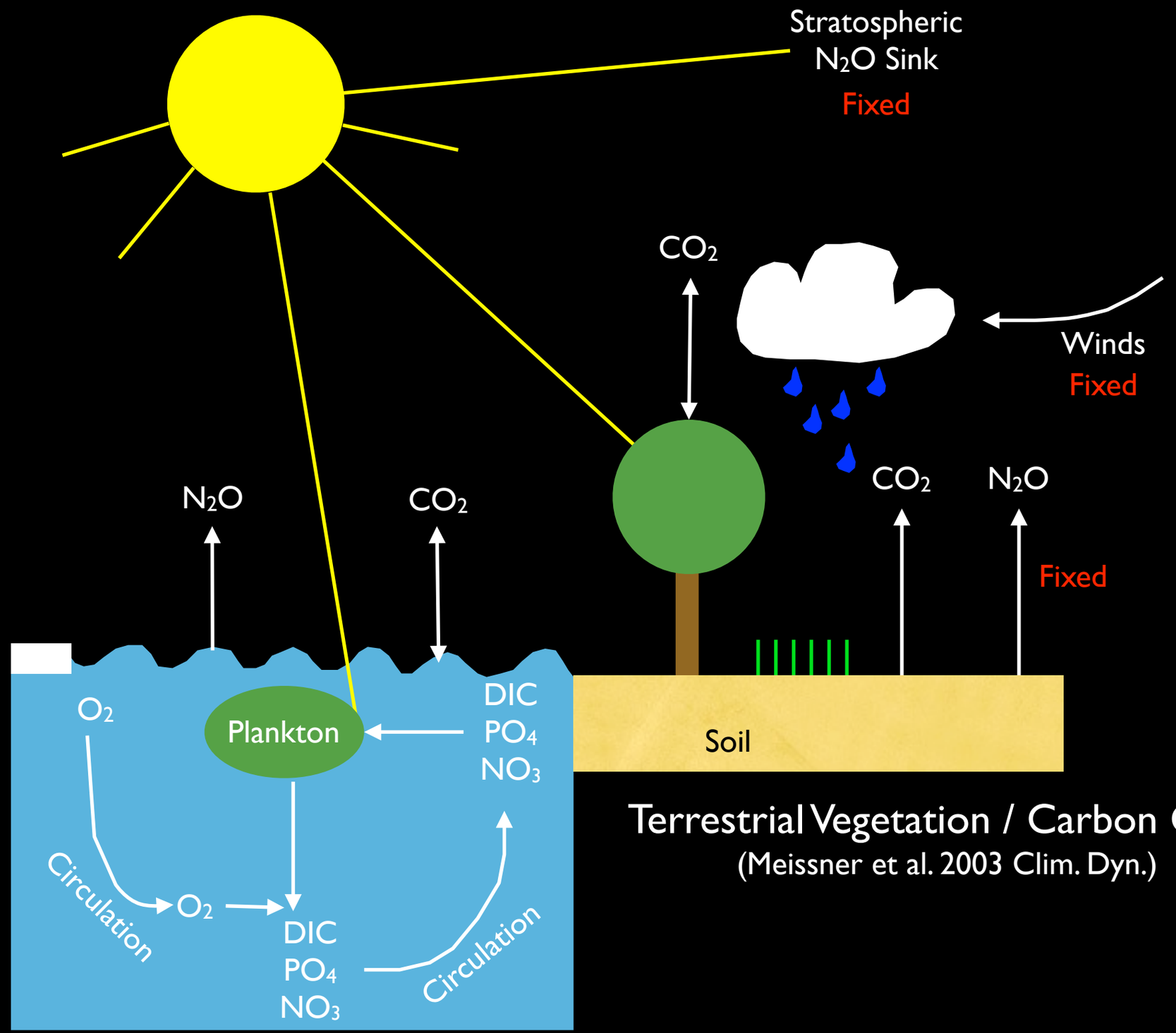

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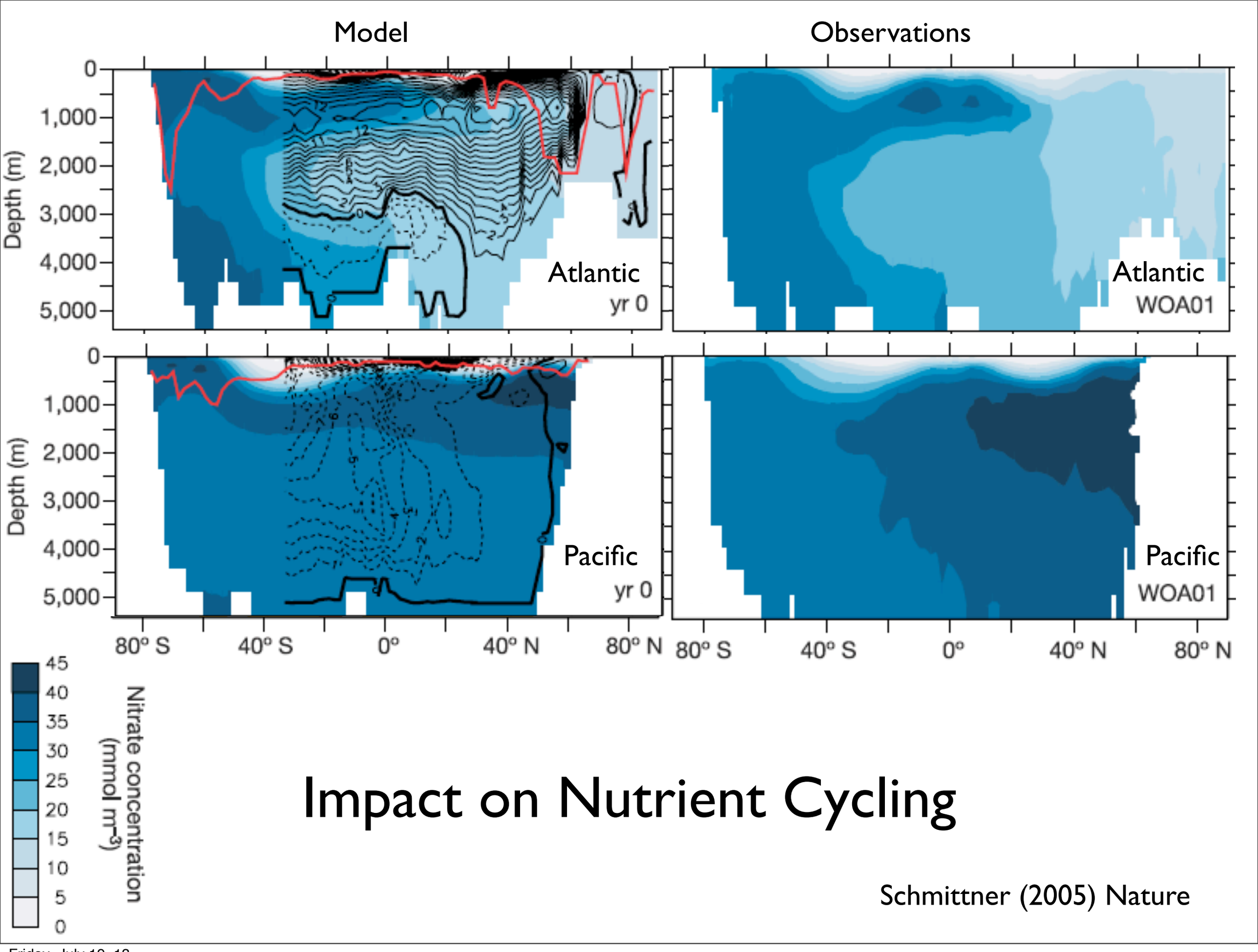
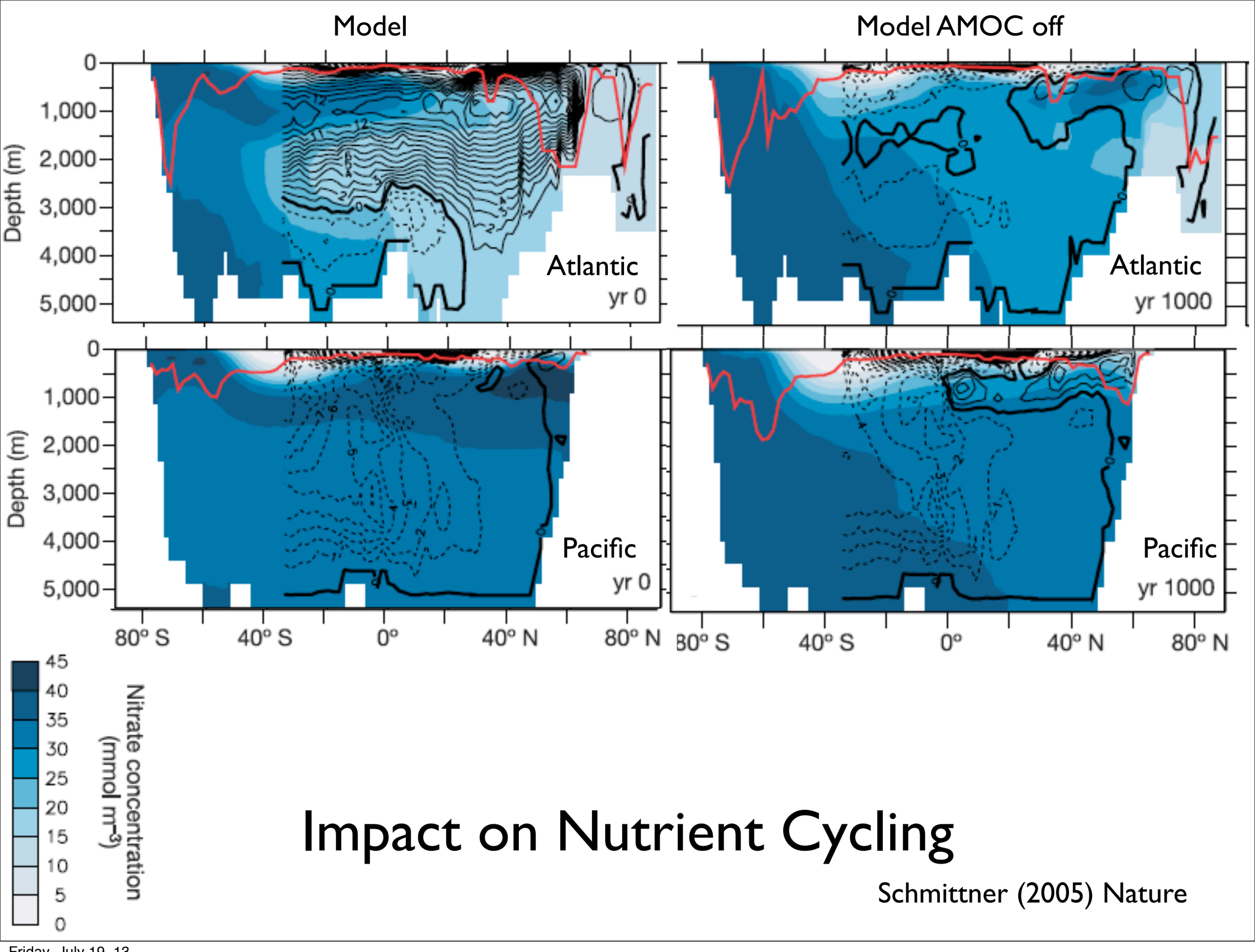


Impact on Nutrient Cycling

Schmittner (2005) Nature

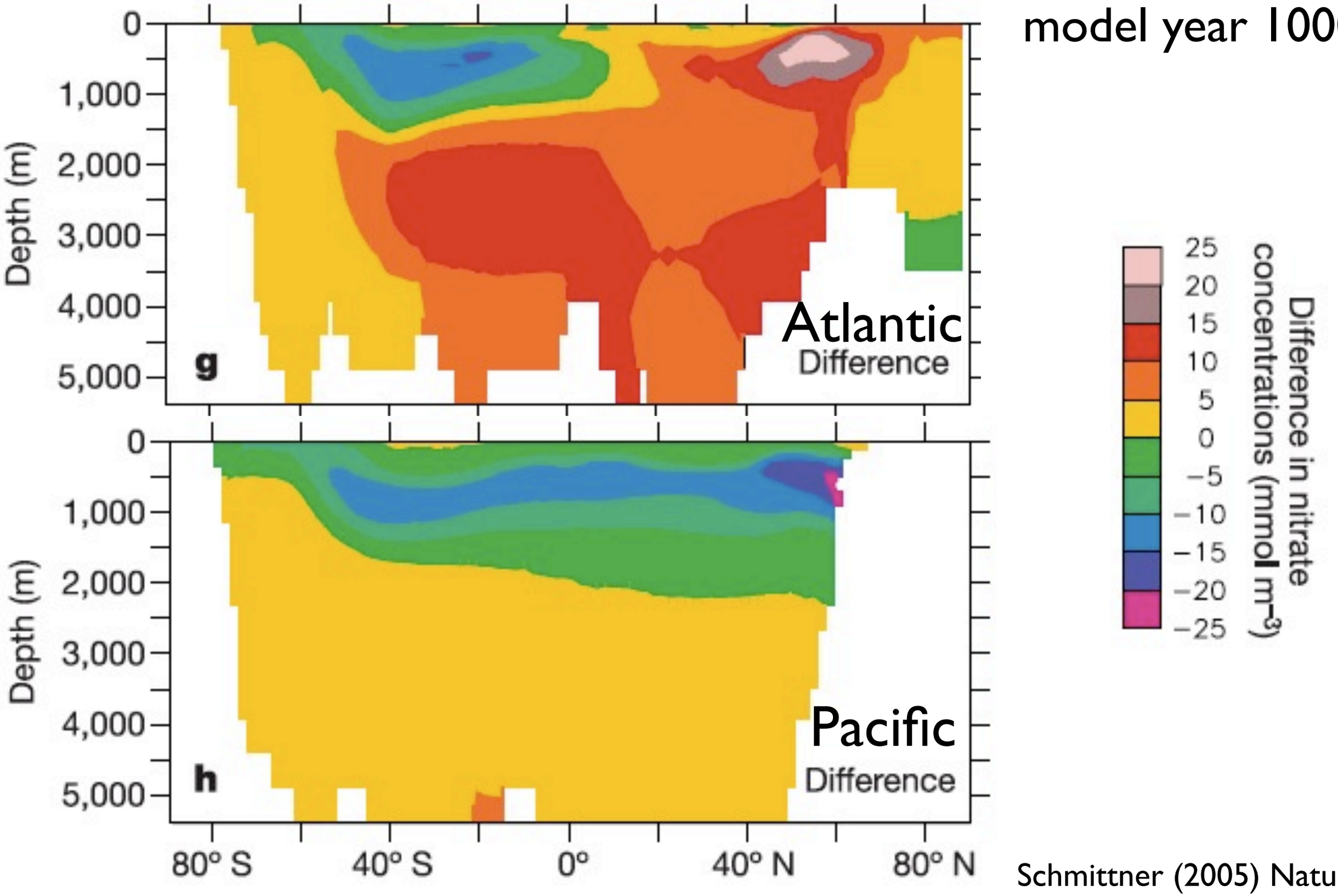


Impact on Nutrient Cycling

Schmittner (2005) Nature

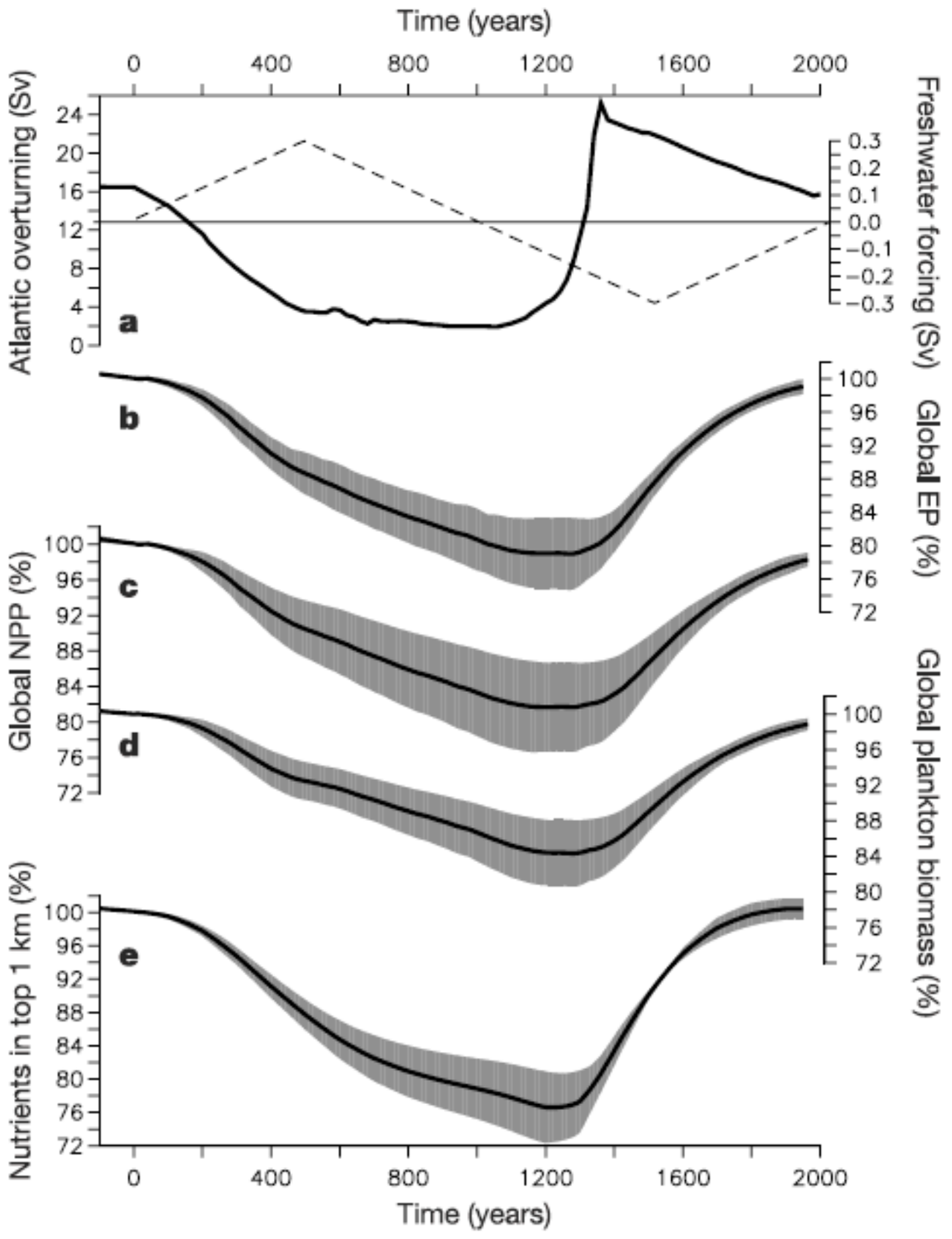
Impact on Nutrient Cycling

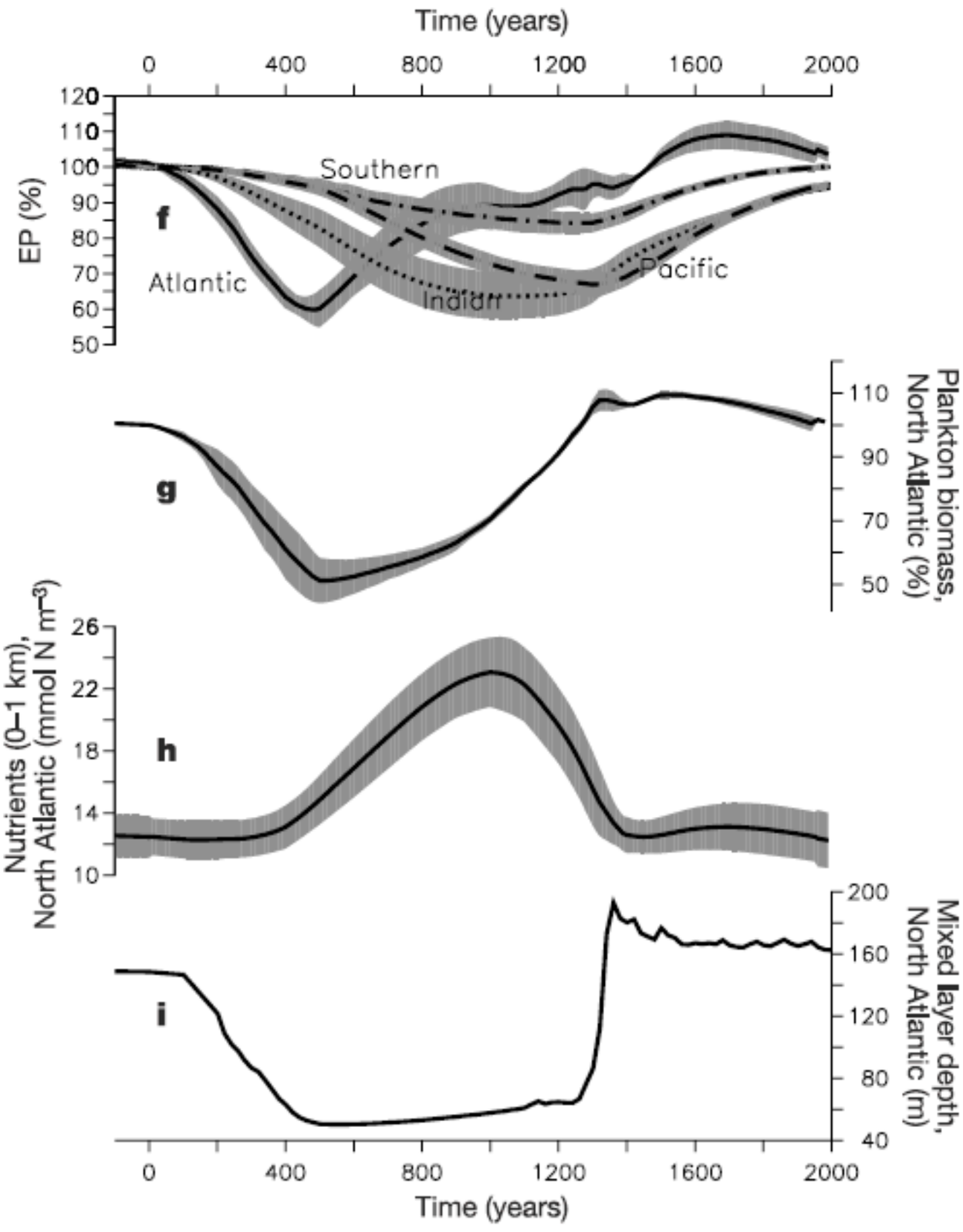
model year 1000



Schmittner (2005) Nature

Impact on Nutrient Cycling and Productivity





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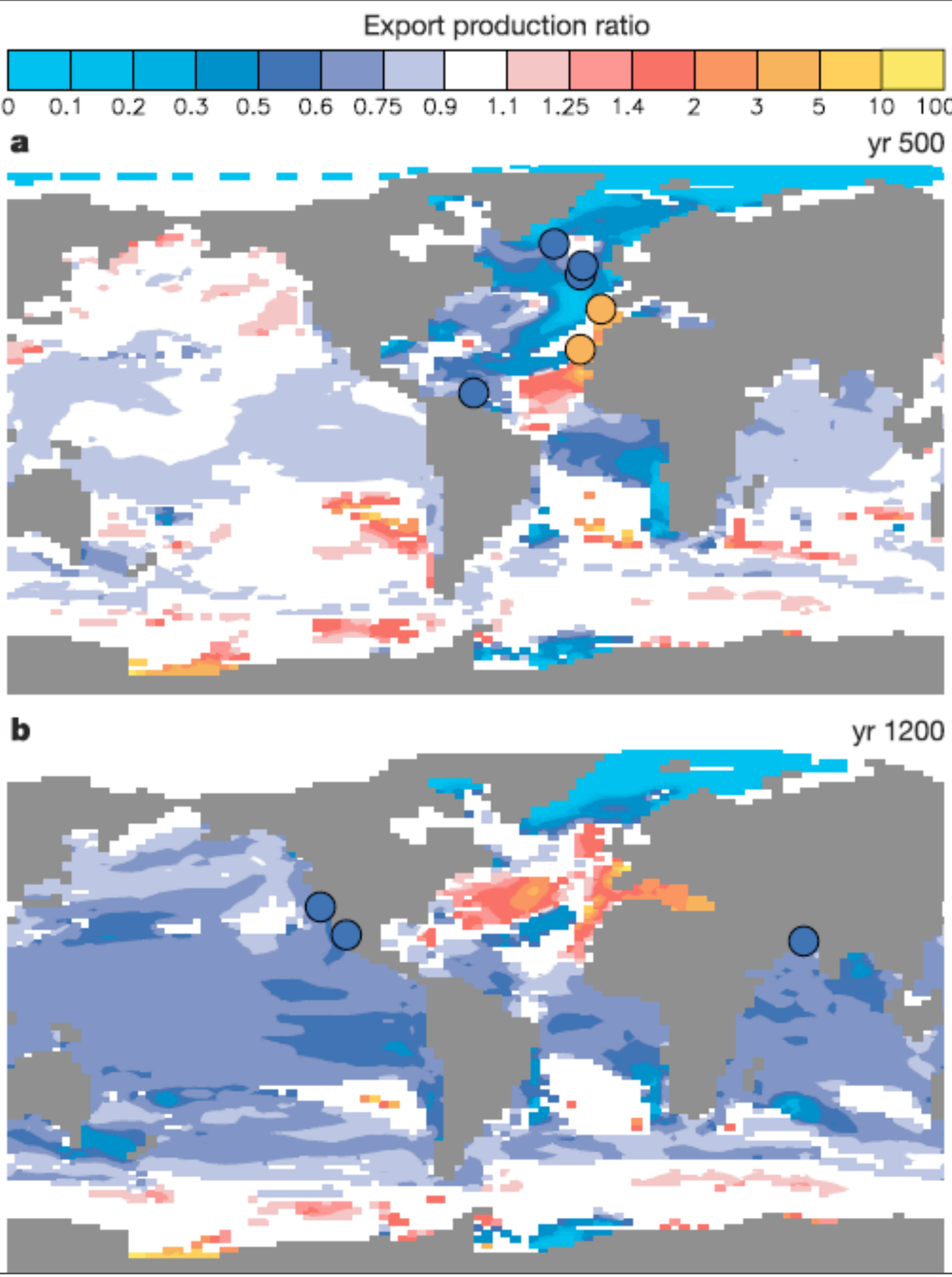

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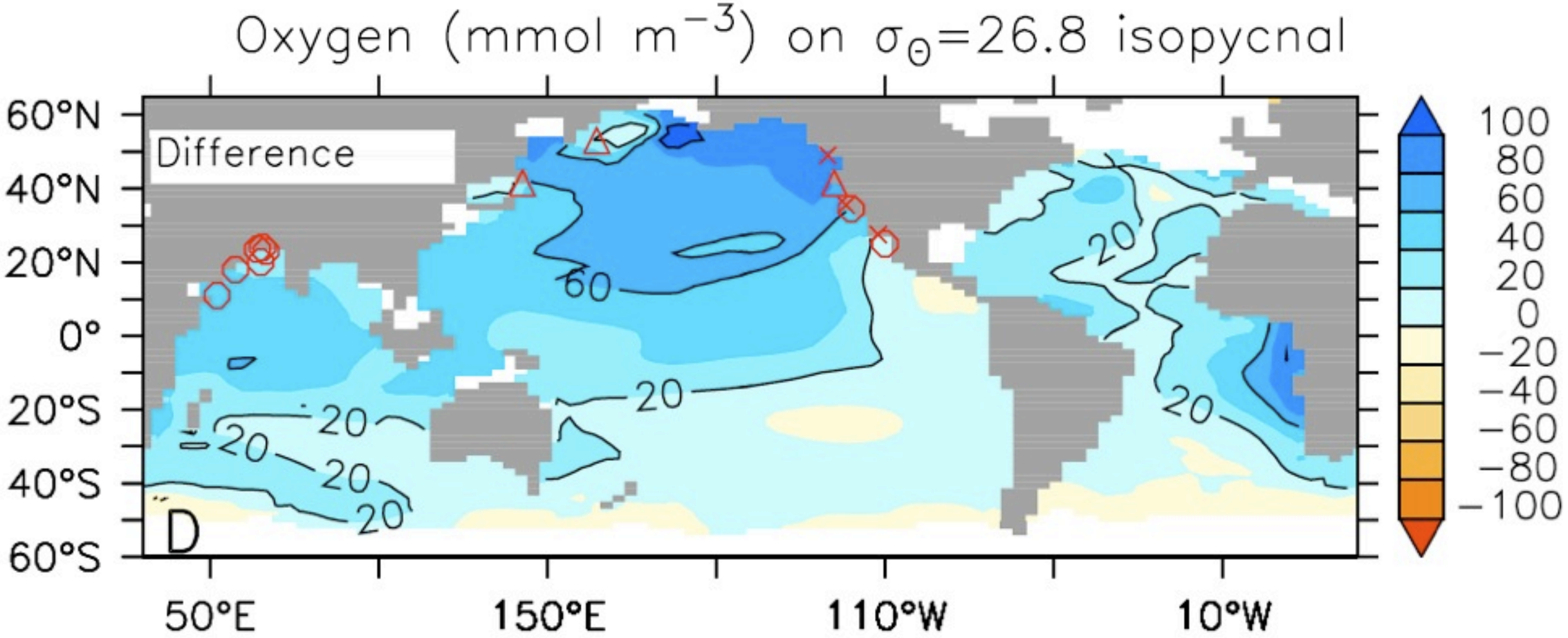
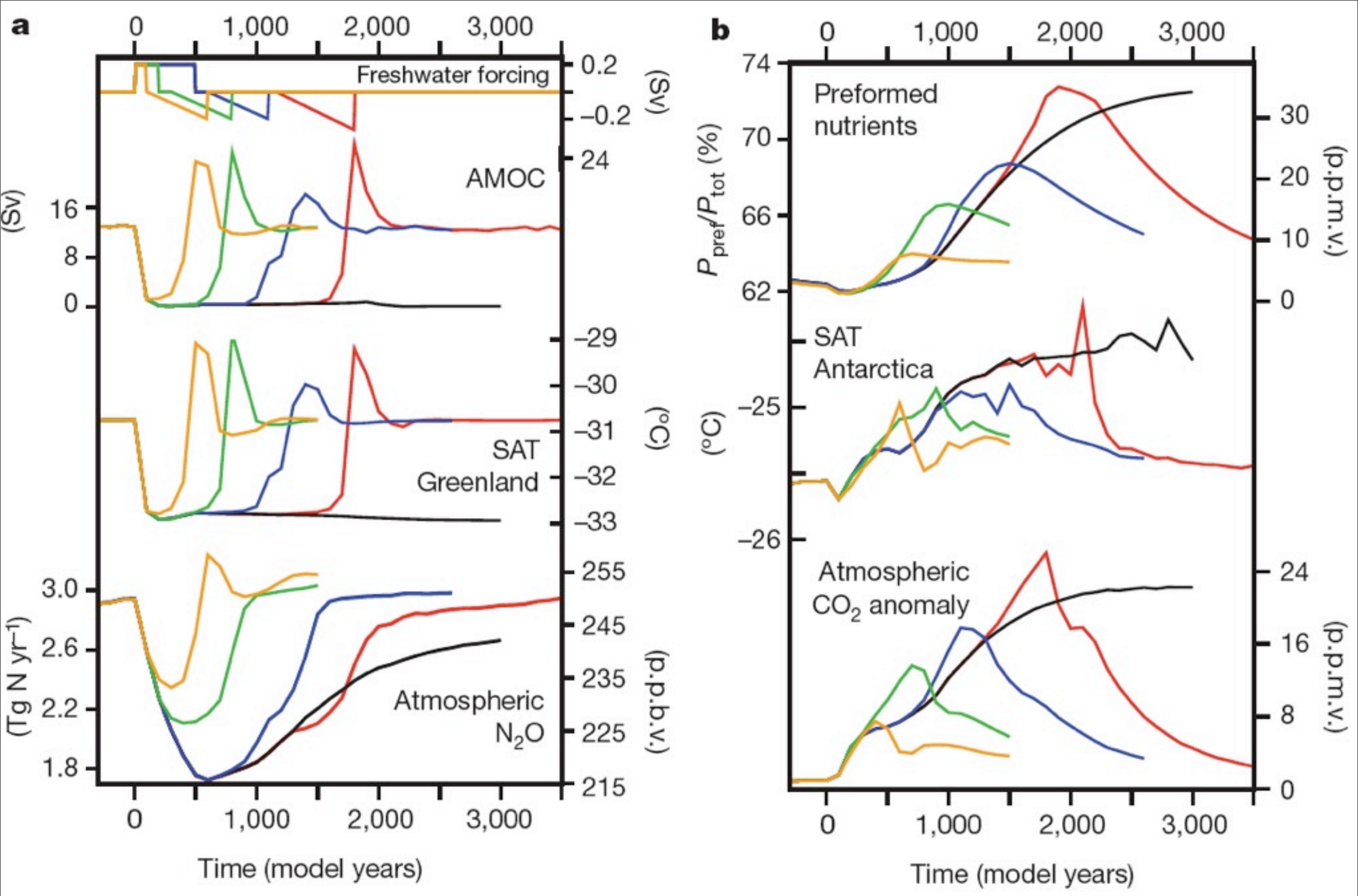


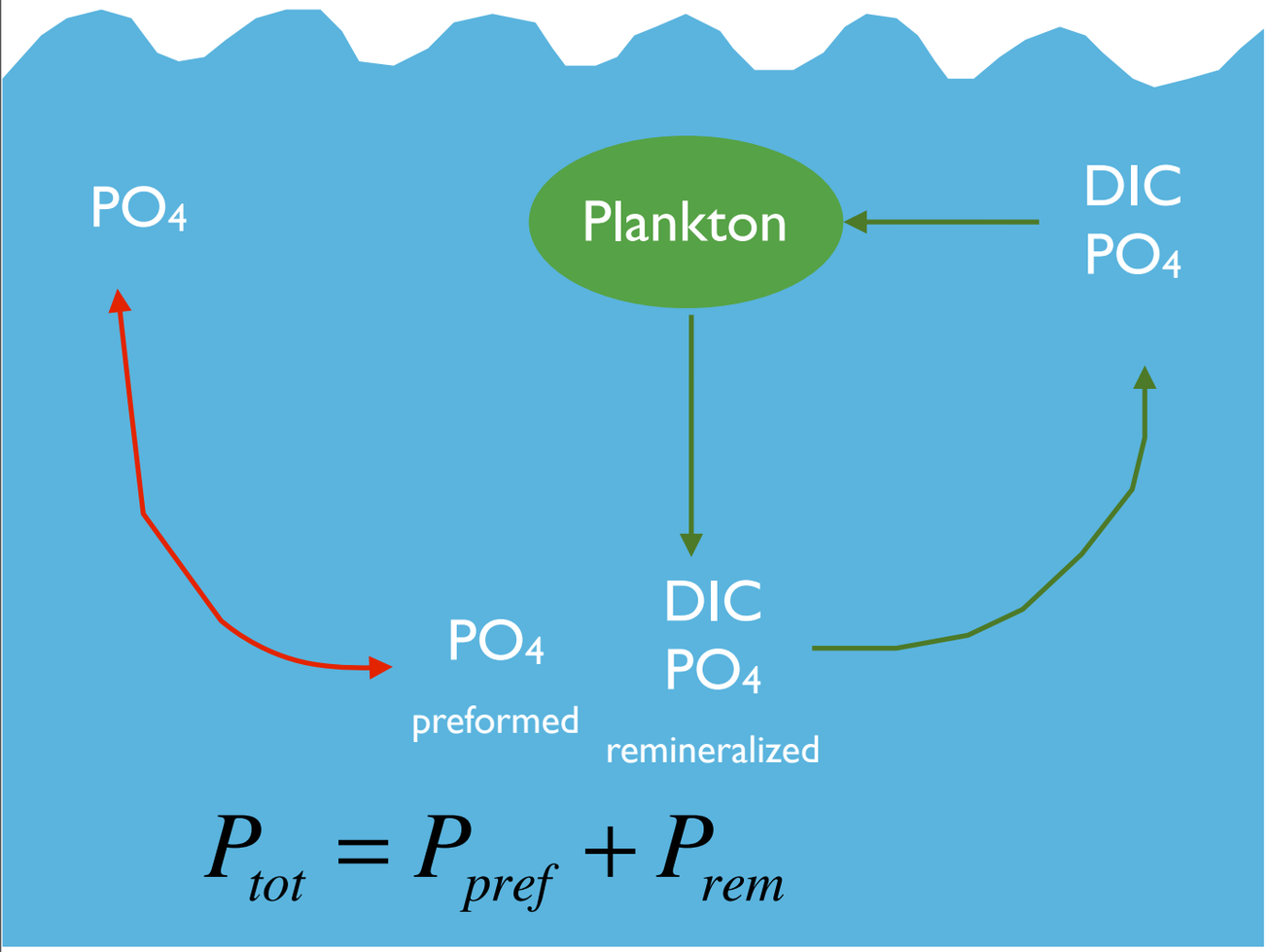
Upper Ocean Oxygen Increases

Schmittner et al. 2007 Paleoceanogr.

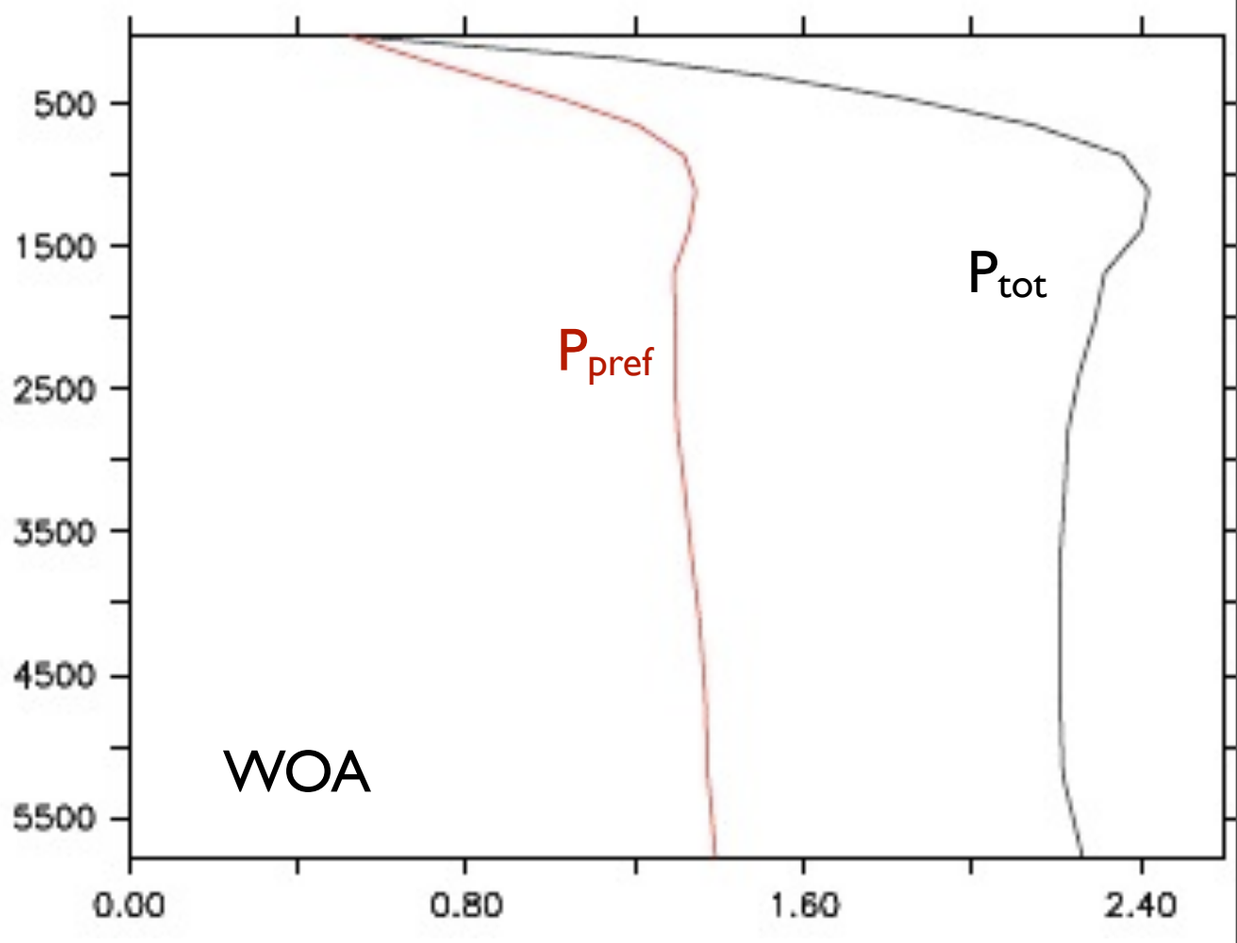


Schmittner & Galbraith 2008 Nature

Efficiency of the Biological Pump and Preformed Nutrient Inventory



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



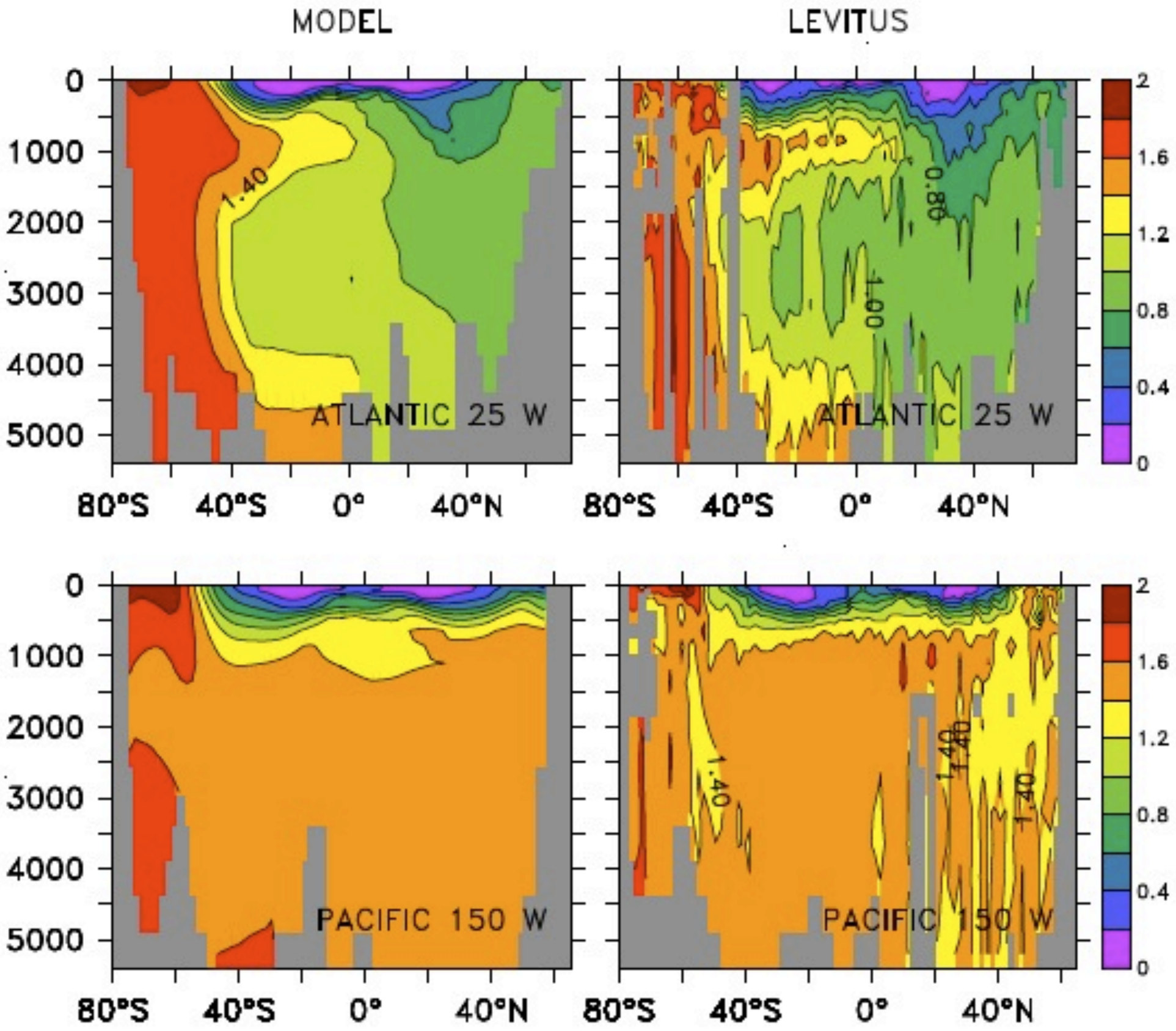
Ito & Follows 2005 J. Mar. Res

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

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

$$AOU = O_2 - O_2^{sat}(T)$$

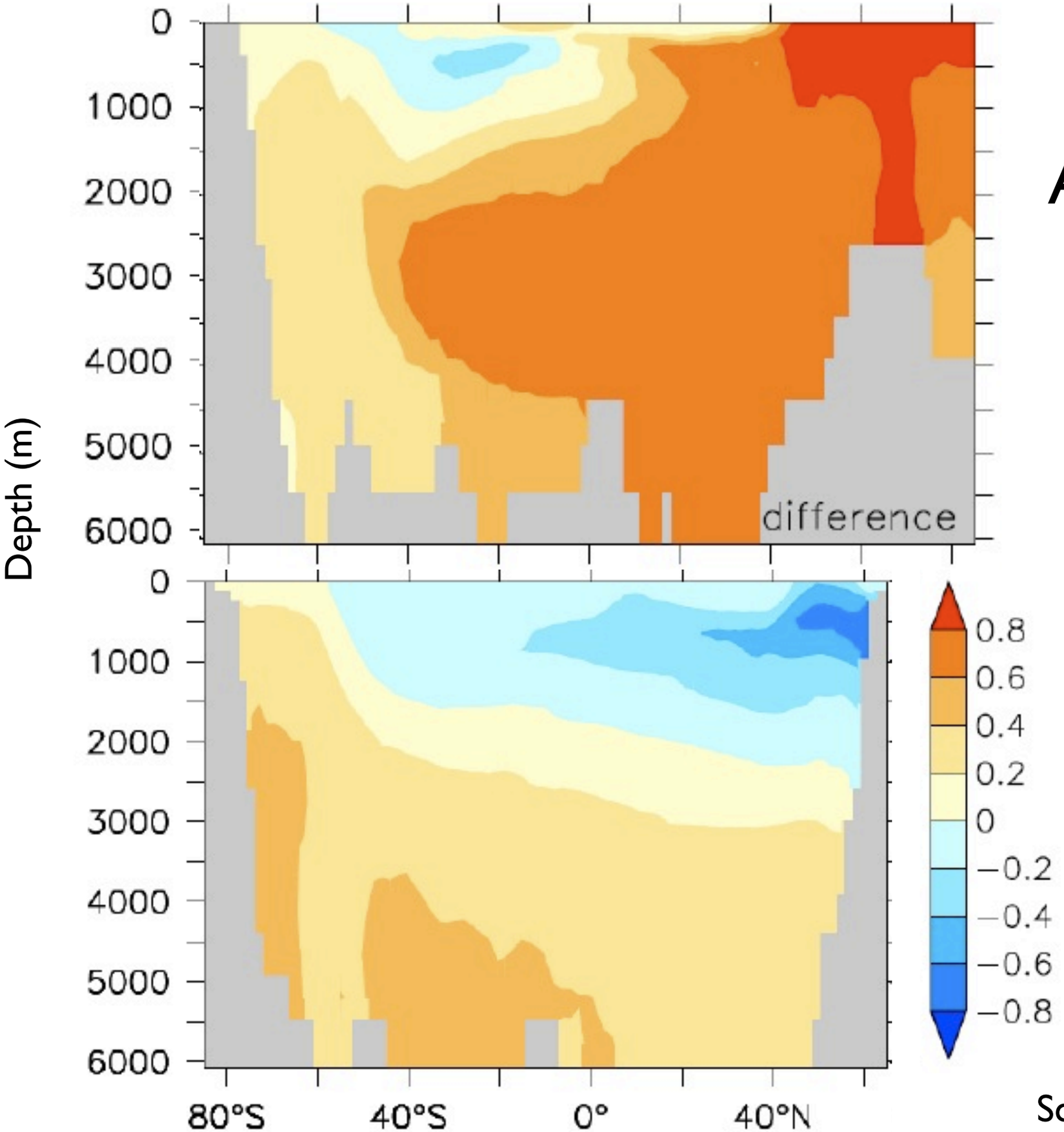
PREFORMED PHOSPHATE (mmol/m^3)



Preformed Nutrients Change

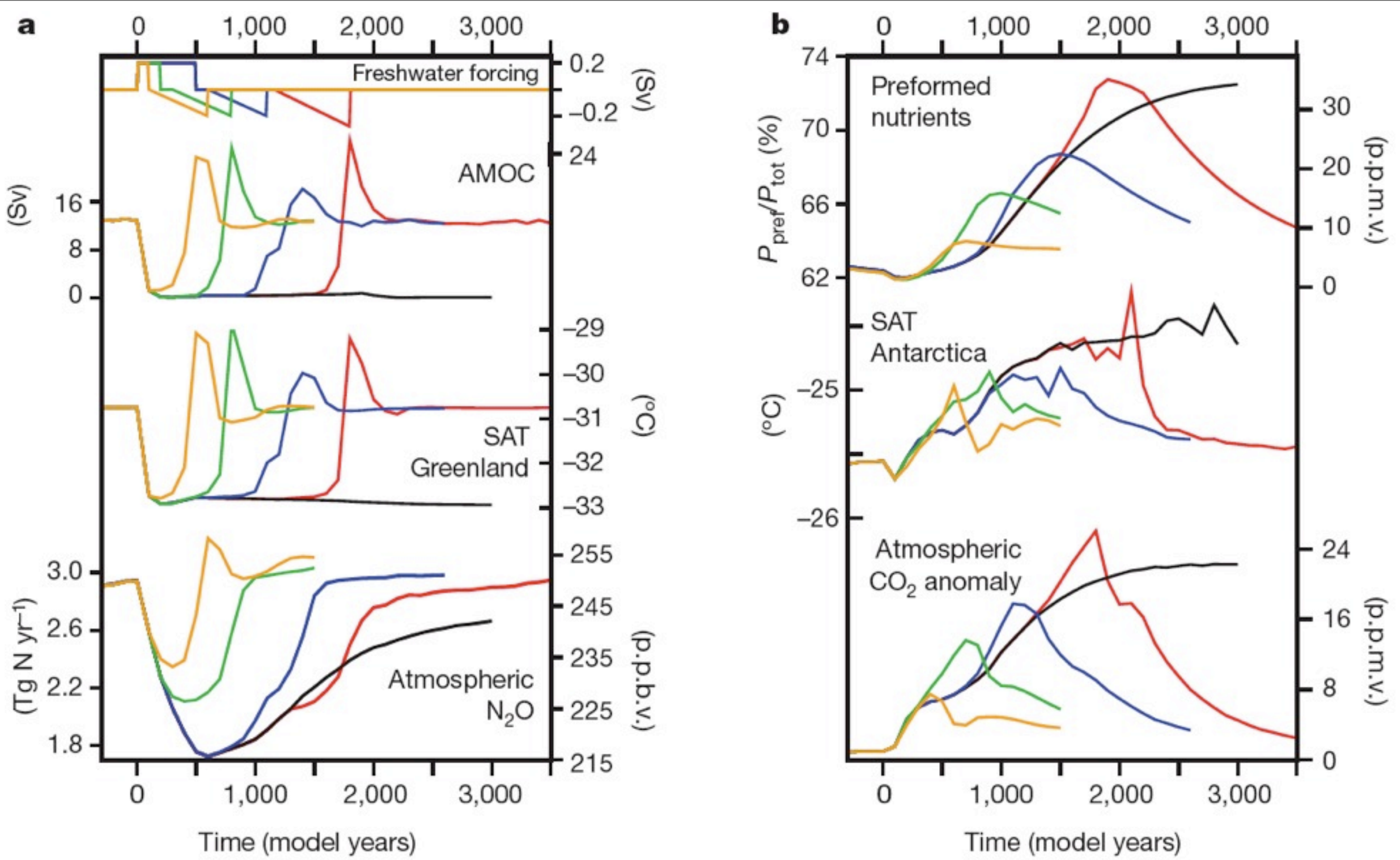
model year 2500

Atlantic



Pacific

Schmittner & Galbraith 2008 Nature

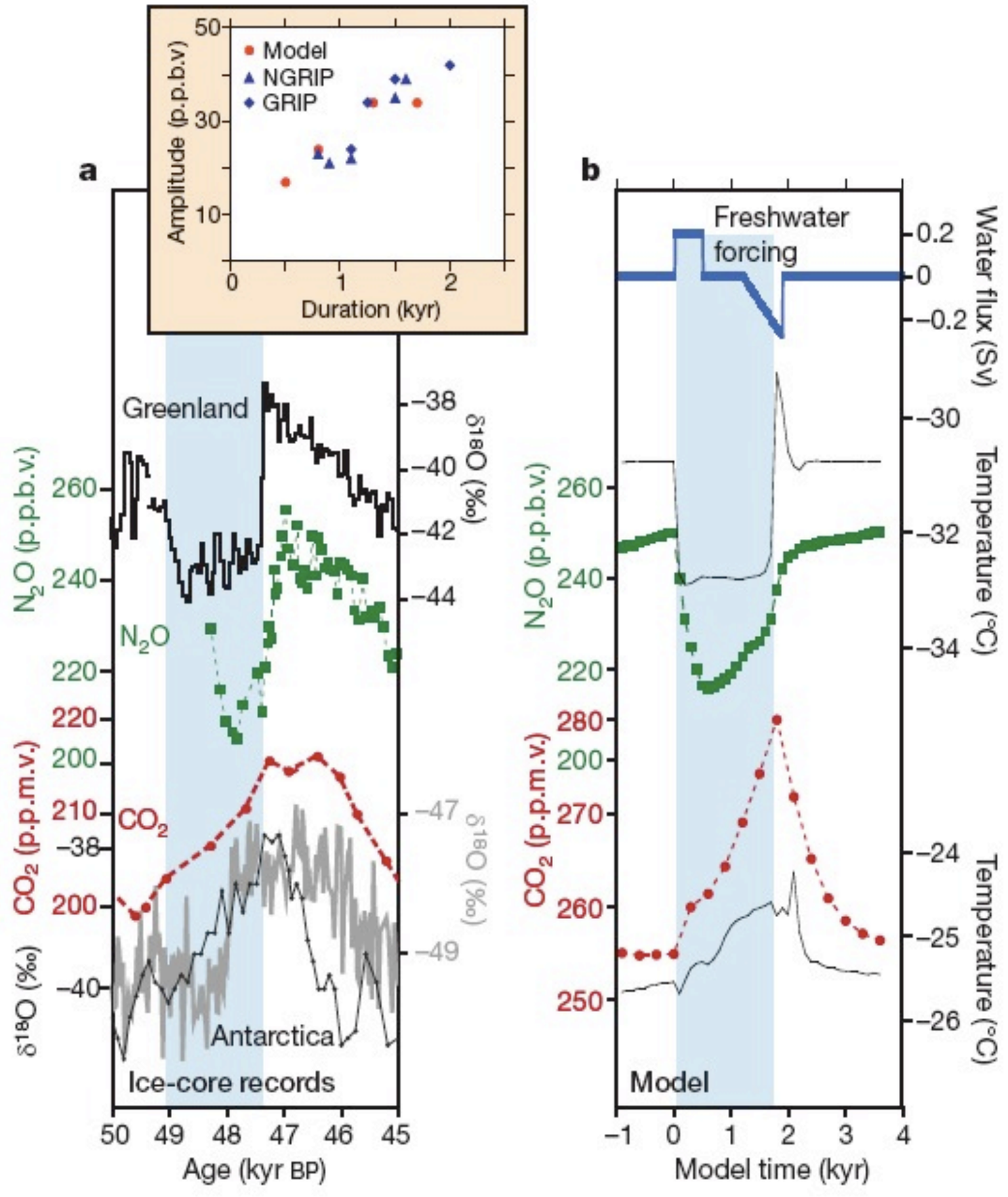


Impact on Greenhouse Gases

Schmittner & Galbraith 2008 Nature

Comparison with Ice Core Record

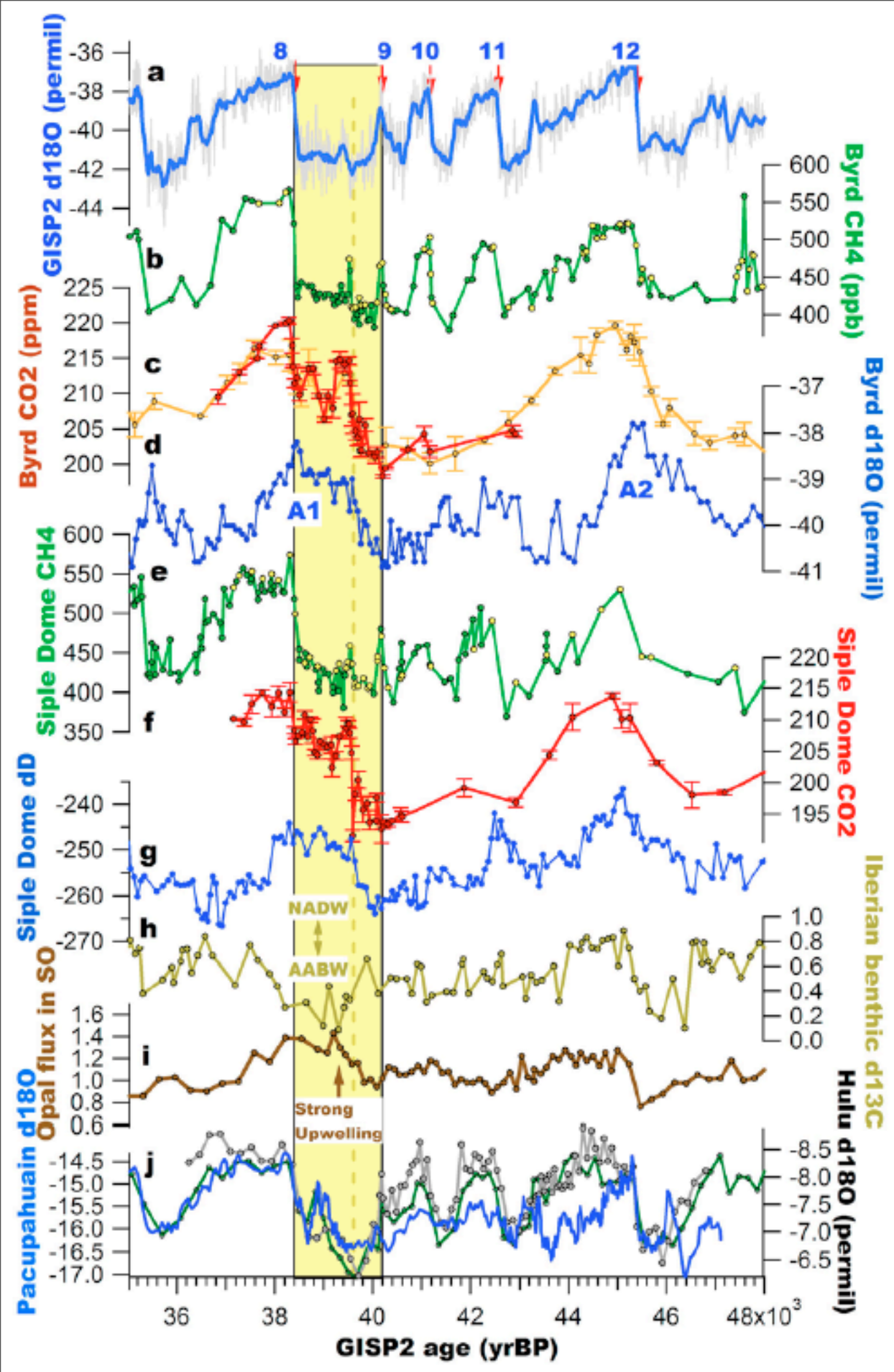
- Model reproduces N_2O amplitude and timescale
- Model reproduces CO_2 amplitude and timescale
- CO_2 decreases too rapidly after Greenland warming



Conclusions

Large reduction in model AMOC leads to

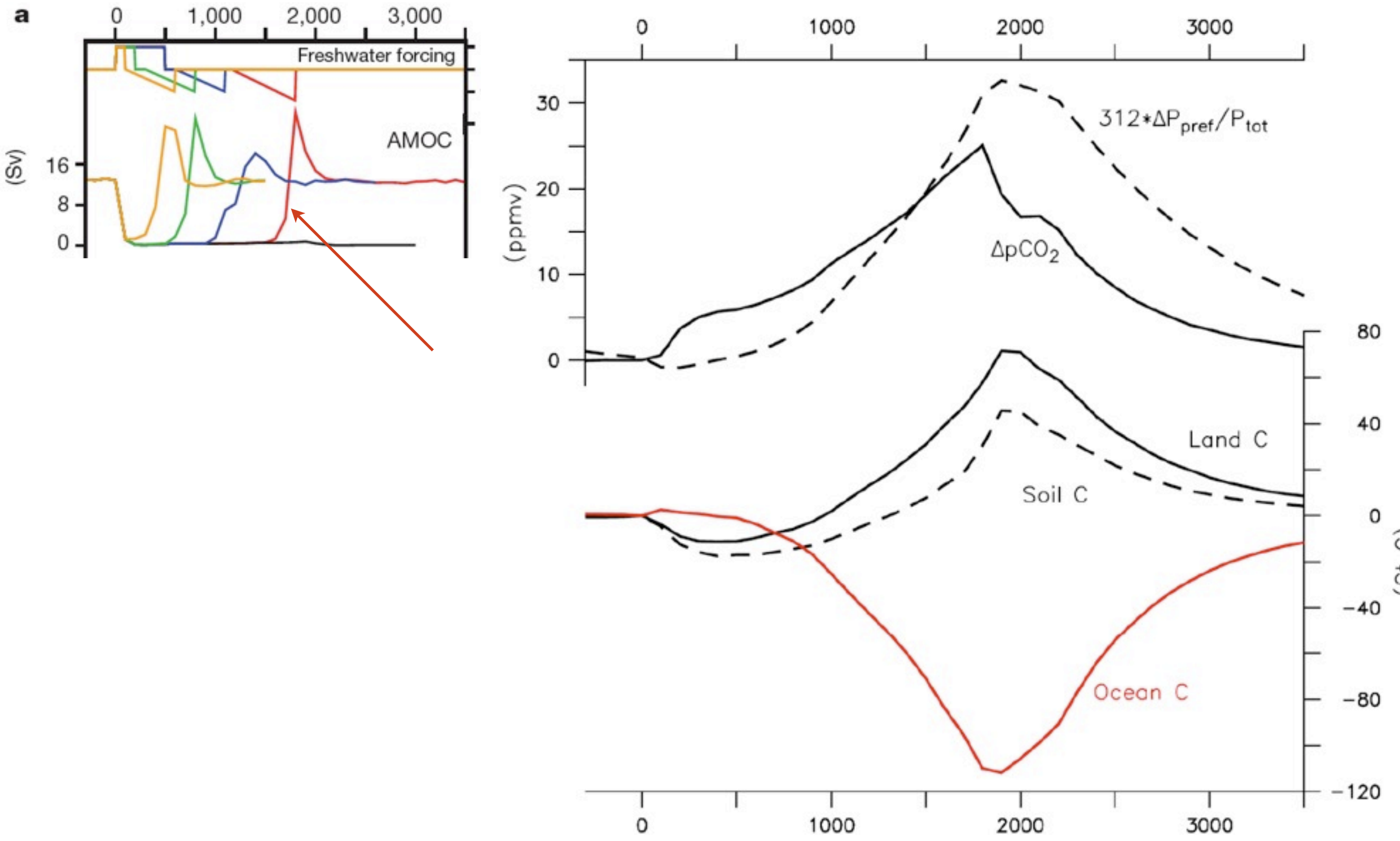
- decreased upwelling of nutrients
- reduced productivity globally
- increased subsurface oxygen in Pacific and Indian ocean
- reduced N_2O production, lower atmospheric N_2O (centennial)
- reduced efficiency of the biological pump: increased atmospheric CO_2 (millennial)
- consistent with paleo record
- BUT ...



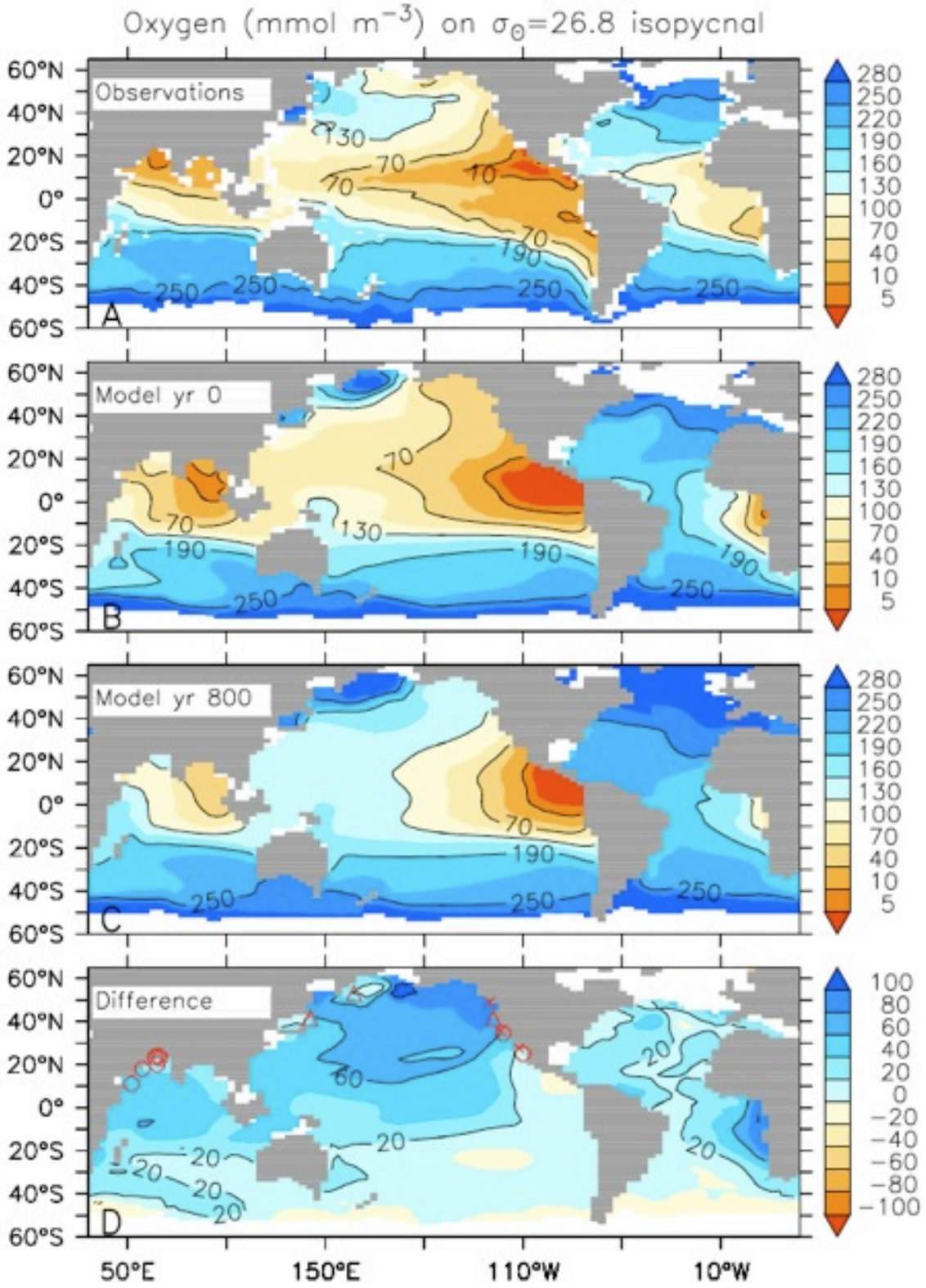
BUT: what causes the rapid CO_2 variations recently discovered in high resolution measurements ?

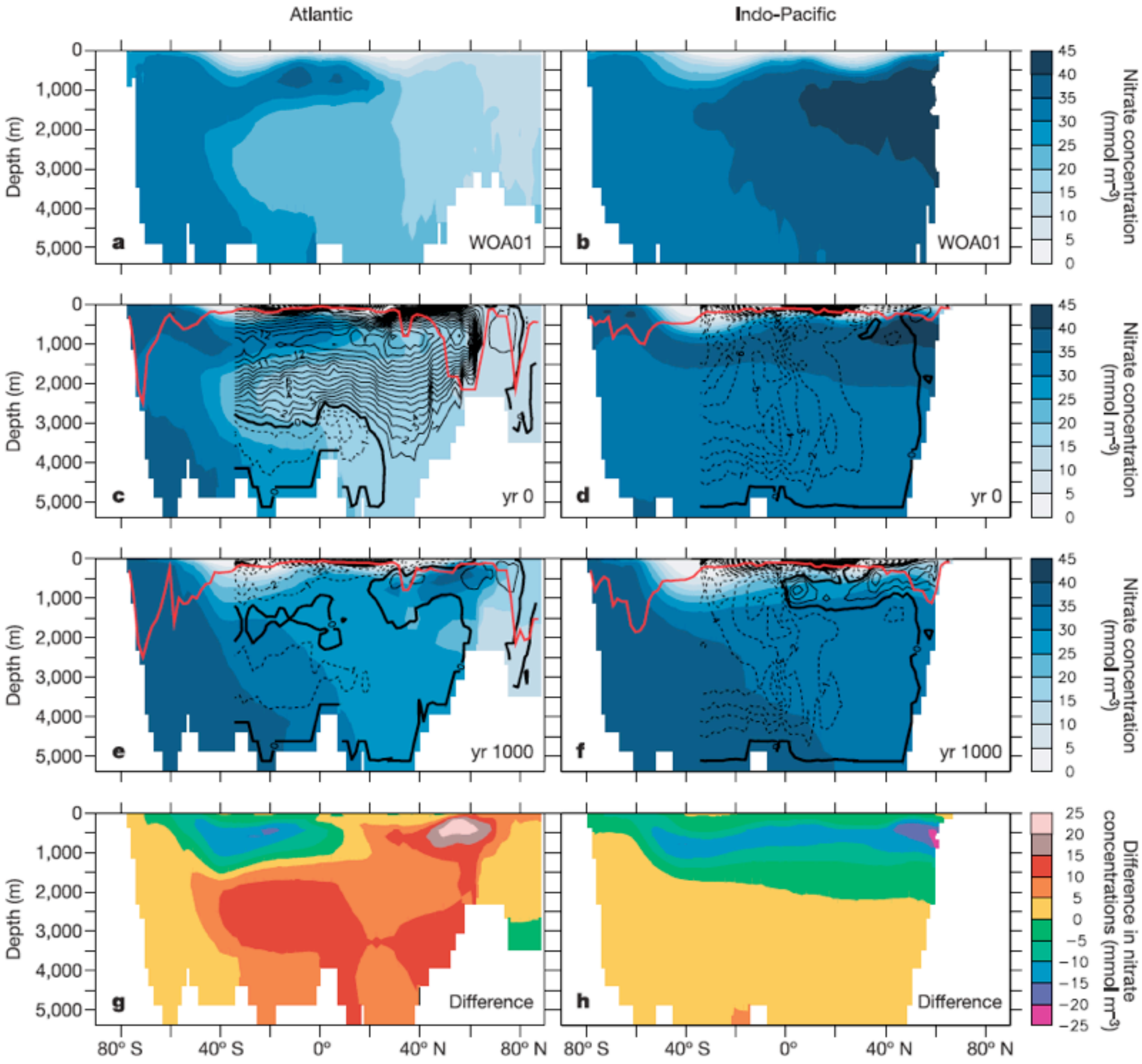
Ahn et al. (2012) GRL

THANKS



Schmittner & Galbraith 2008 Nature


Oxygen (mmol m^{-3}) on σ_0=26.8 isopycnal
Observations
Model yr 0
Model yr 800
Difference
A
B
C
D
60°N
40°N
20°N
0°
20°S
40°S
60°S
50°E
150°E
110°W
10°W
280
250
220
190
160
130
100
70
40
10
5
100
80
60
40
20
0
−20
−40
−60
−80
−100


Atlantic
Indo-Pacific
Depth (m)
0
1,000
2,000
3,000
4,000
5,000
a
WOA01
b
WOA01
c
yr 0
d
yr 0
e
yr 1000
f
yr 1000
g
Difference
h
Difference
80° S
40° S
0°
40° N
80° N
Nitrate concentration (mmol m-3)
45
40
35
30
25
20
15
10
5
0
Difference in nitrate concentrations (mmol m-3)
25
20
15
10
5
0
−5
−10
−15
−20
−25