Marine Biogeochemical Modeling

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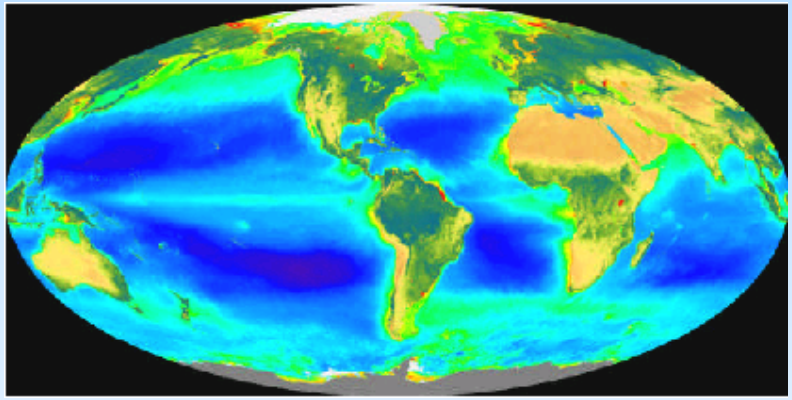
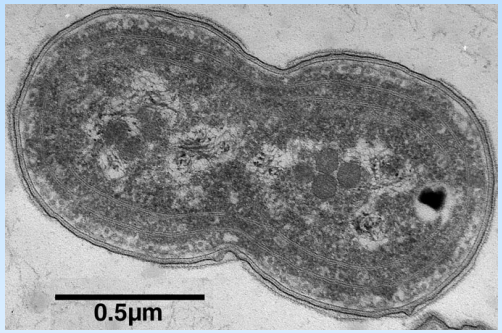
Woods Hole Oceanographic Institution

NCAR ASP Colloquium 2013

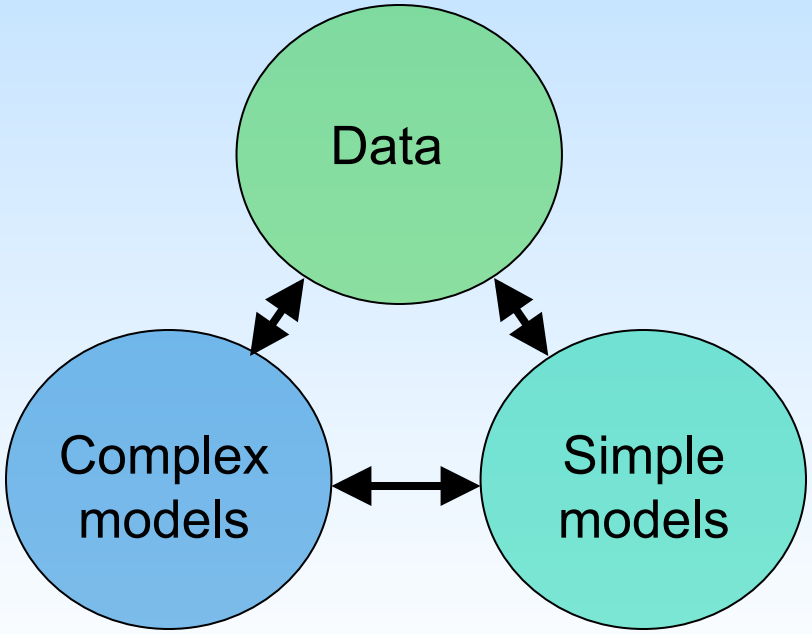




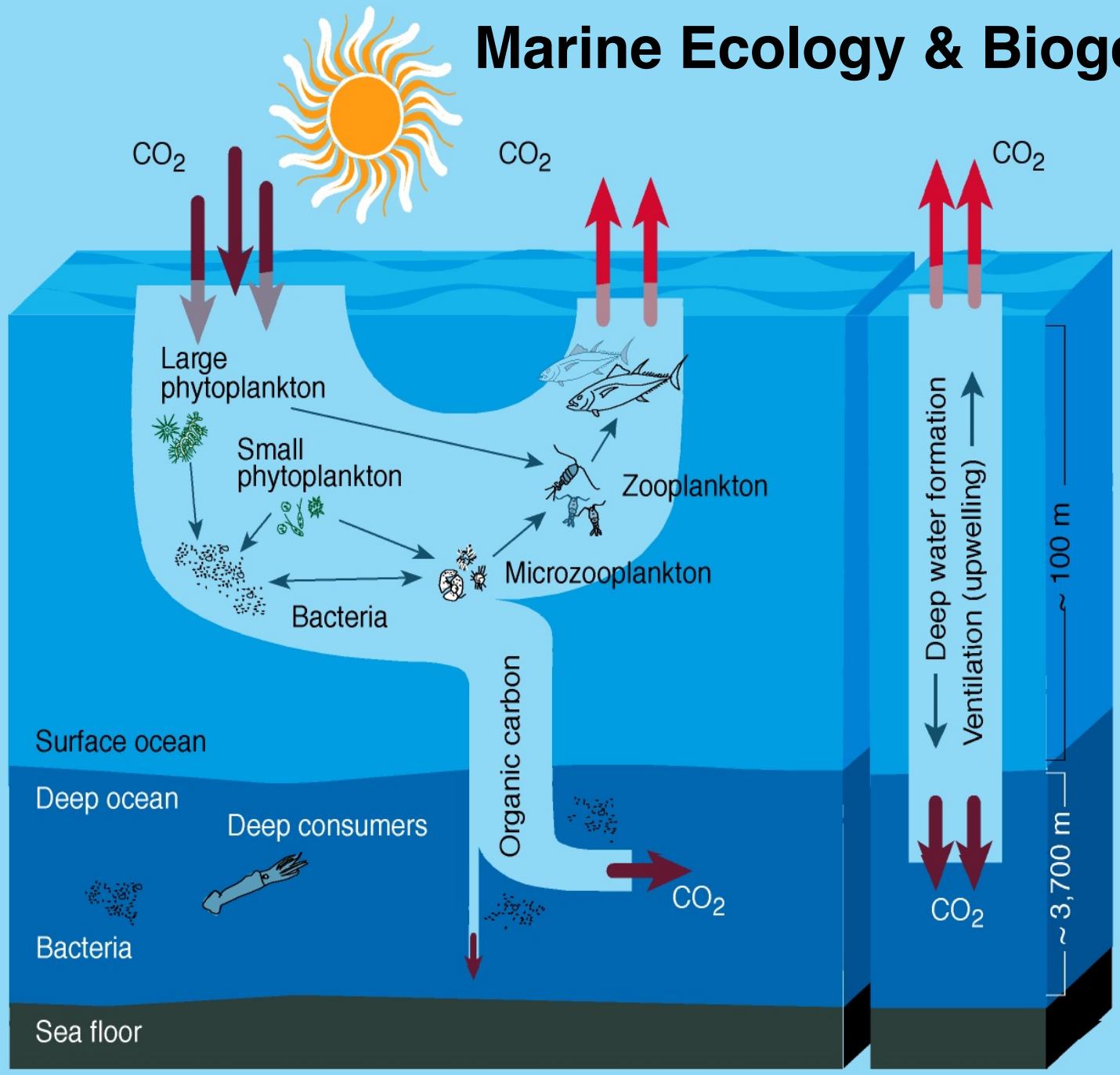
Supported by:

"I am never content until I have constructed a mechanical model of the subject I am studying. If I succeed in making one, I understand; otherwise I do not.“
- Lord Kelvin

"People don't understand the earth, but they want to, so they build a model, and then they have two things they don't understand,”
-Gerard Roe in “The Whale and the Supercomputer” by C. Wohlforth



Marine Ecology & Biogeochemistry

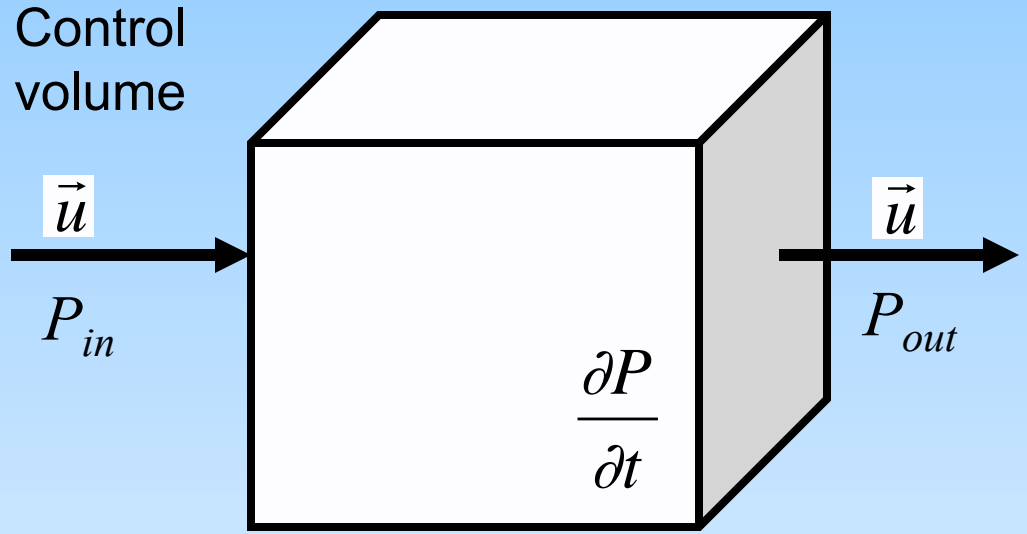


Model Elements Depend on Science Questions

Carbon Cycle & Biogeochemistry

- Inorganic CO_2 system, O_2, nutrients, iron(?), dissolved organic matter
- Net formation & remineralization of organic matter, $CaCO_3$, opal
- Particle sinking & DOM transport

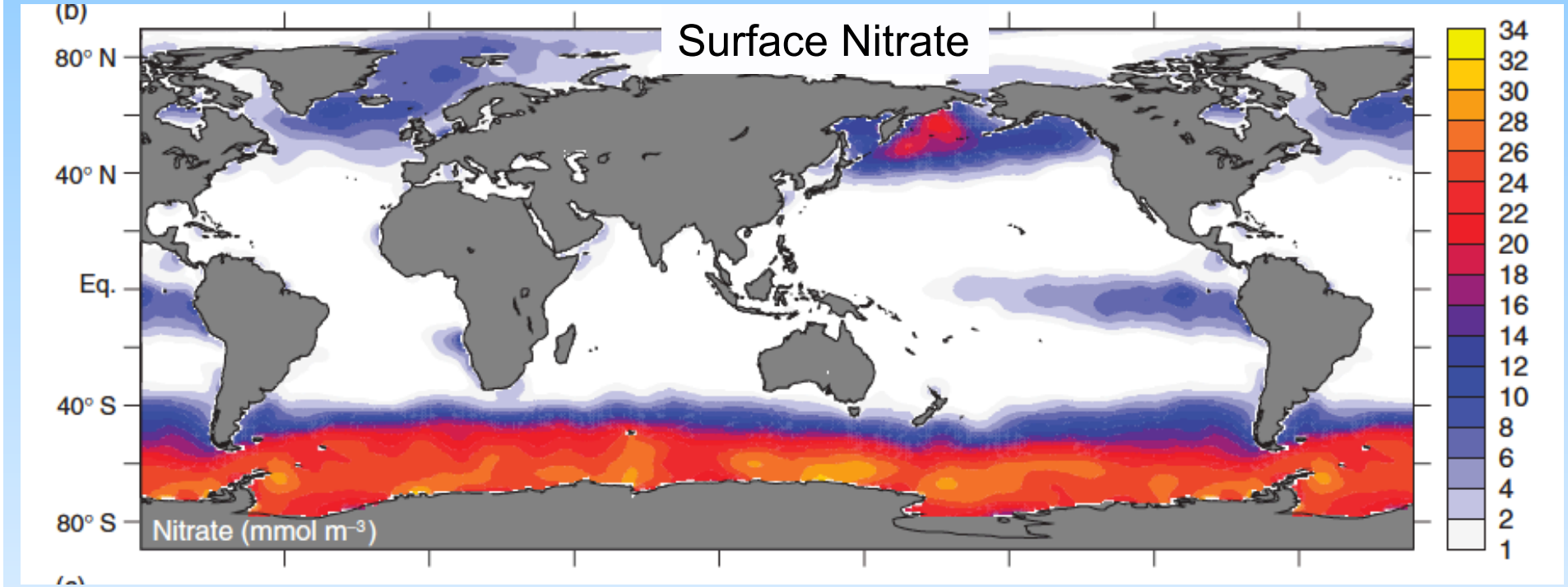
Ocean Circulation & Biology



$$\frac{\partial P}{\partial t} + \vec{u} \cdot \nabla P - \kappa \nabla^2 P = RHS$$

advection diffusion biological source/sink terms

Biological Pump Efficiency & HNLC Regions



Nutrient Restoring

$$J_{prod} = \frac{1}{\tau}\left(N_{Model} - N_{Obs}\right)$$

$$N_{Model} > N_{Obs}$$

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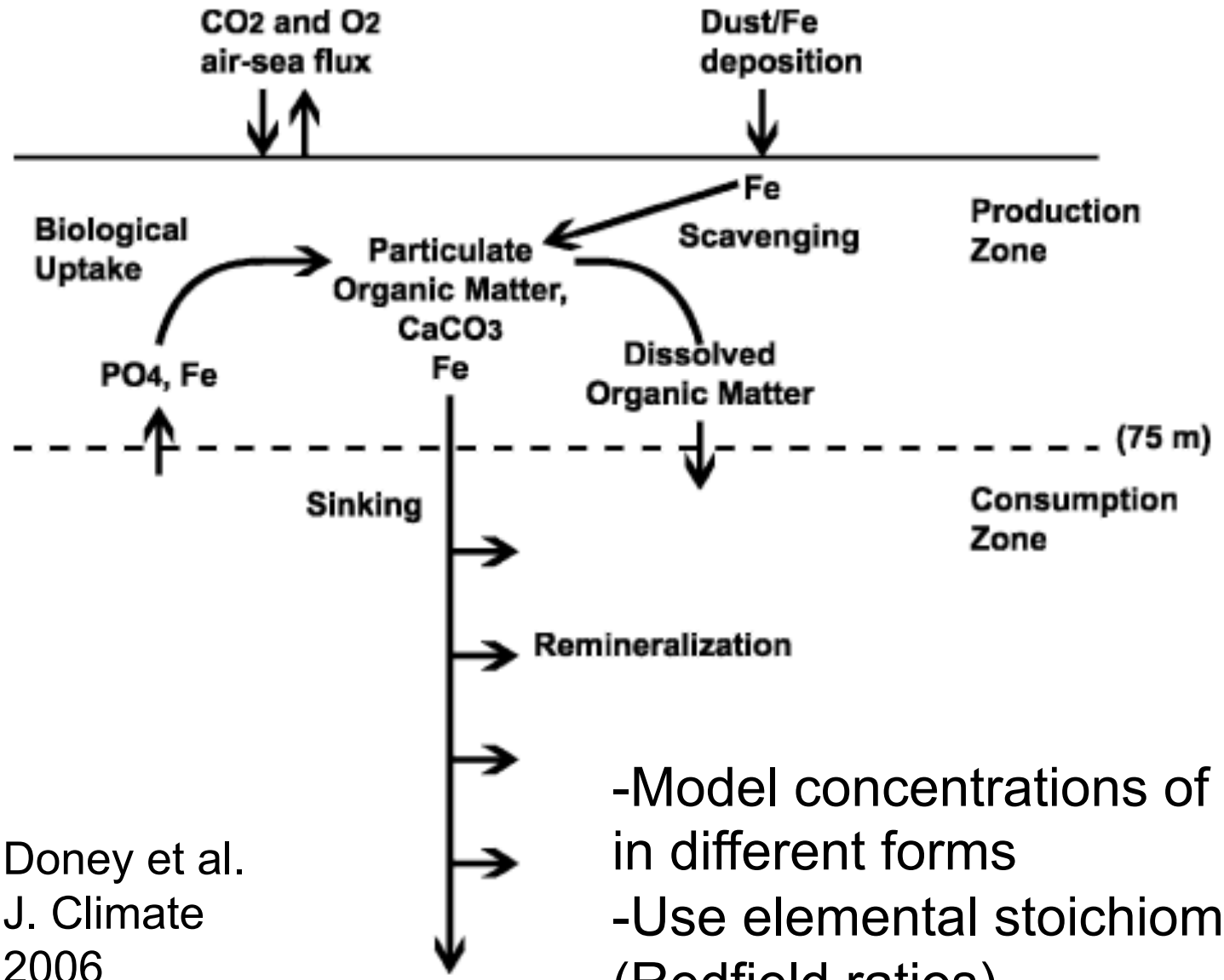
Simple Prognostic Biogeochemistry Model



Doney et al.
J. Climate
2006

-Model concentrations of elements in different forms
-Use elemental stoichiometry (Redfield ratios)

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Export Flux Parameterization

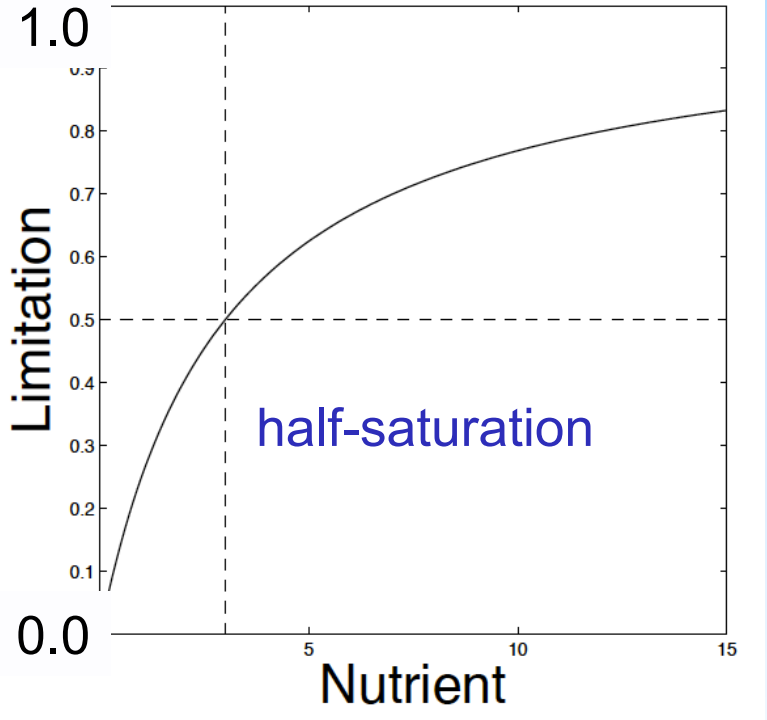
Production $J_{\text{prod}} = F_T \cdot F_N \cdot F_I \cdot B \cdot \max(1, z_{ml}/z_c)/\tau.$

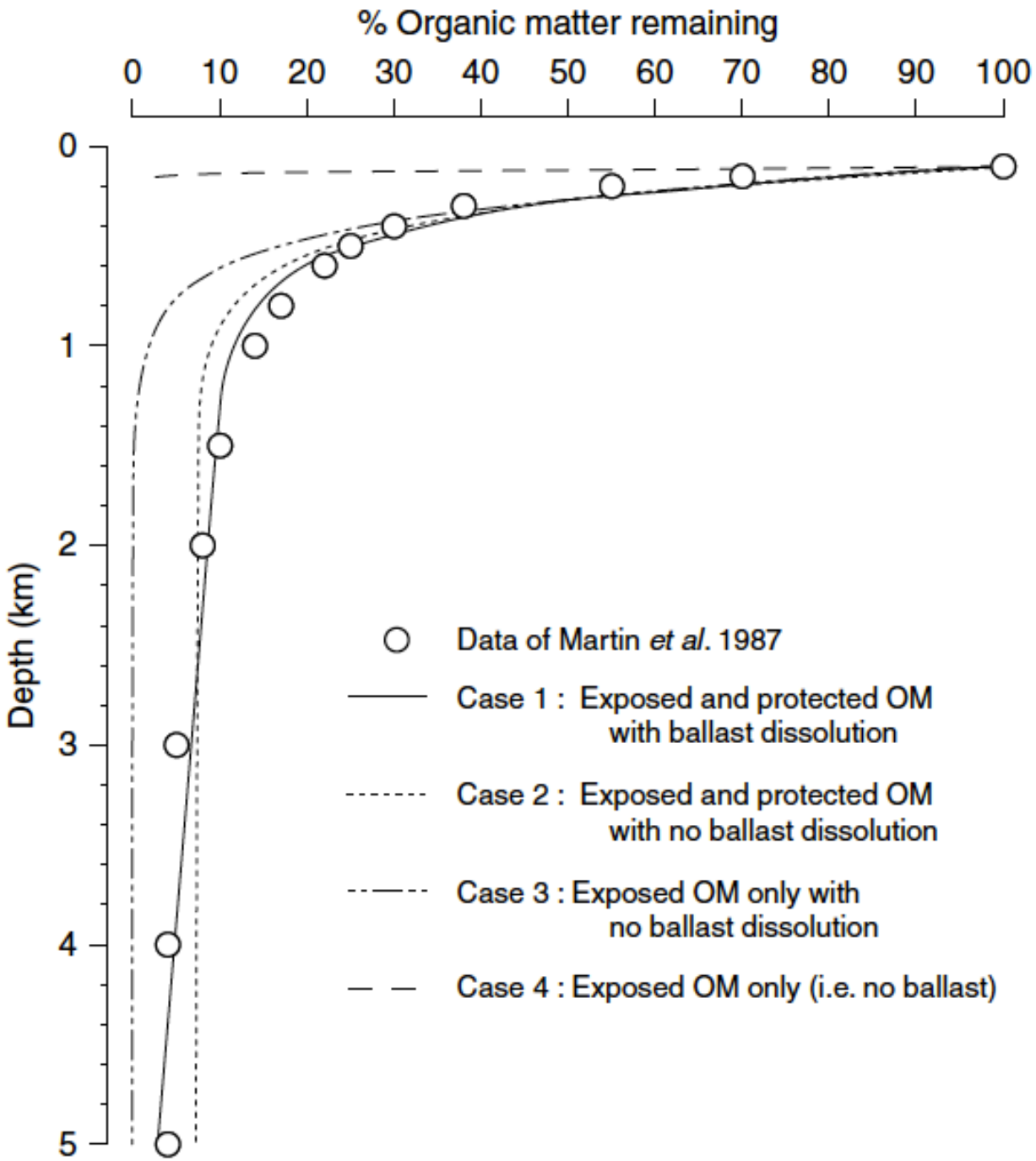
f(Temperature, nutrients, light, biomass, time-scale)

$$F_N = \min\left(\frac{\text{PO}_4}{\text{PO}_4 + \kappa_{\text{PO4}}}, \frac{\text{Fe}}{\text{Fe} + \kappa_{\text{Fe}}}\right)$$

$$F_I = \frac{I}{I + \kappa_I}$$

$$B = \min\left(\text{PO}_4, \frac{\text{Fe}}{r_{\text{Fe:}P}}\right)$$





Sinking Particle Flux & Remineralization

-Empirical power law curves (Martin Curve)

-Ballast hypothesis models as a function of dust, $CaCO_3$, opal

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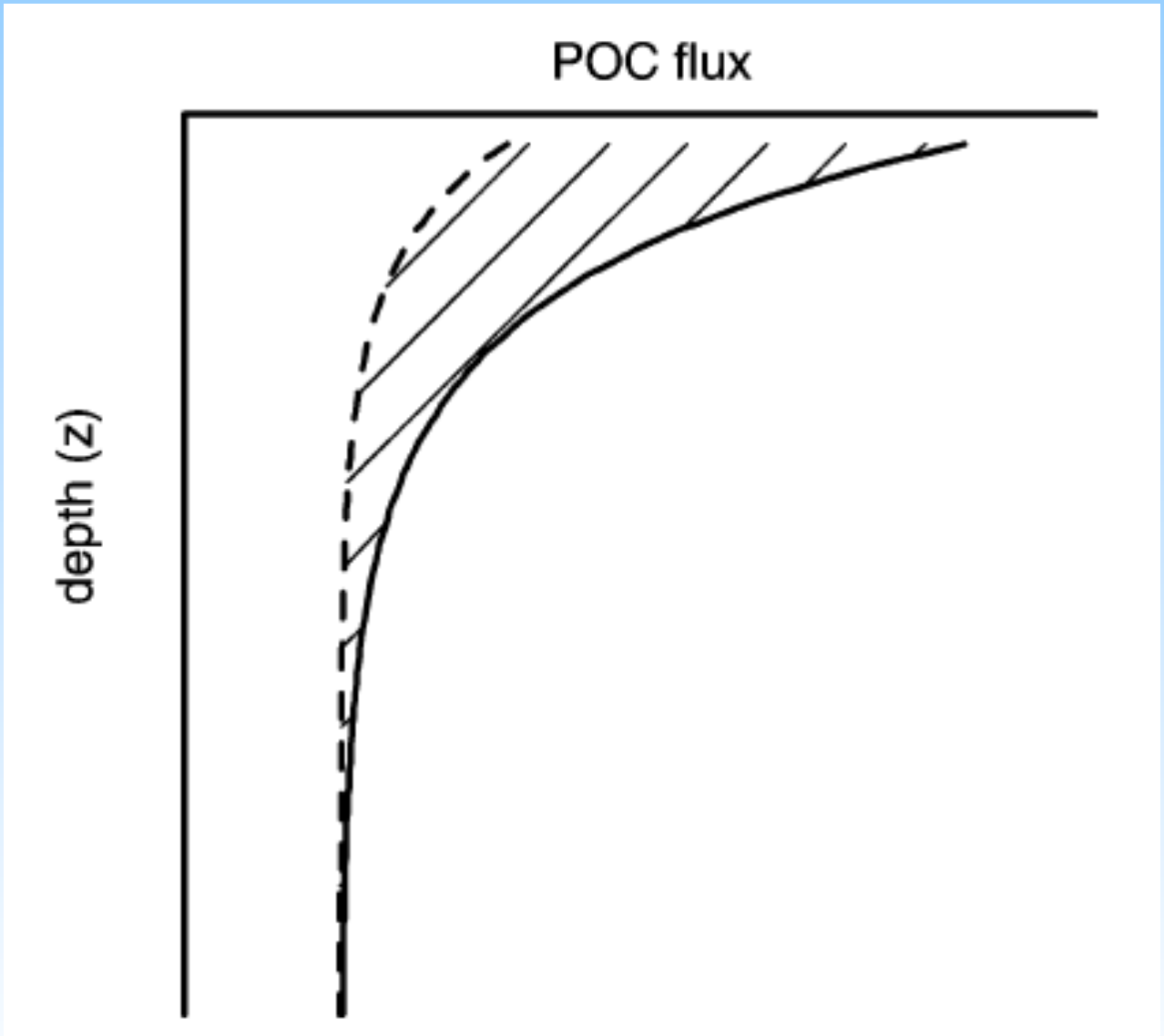
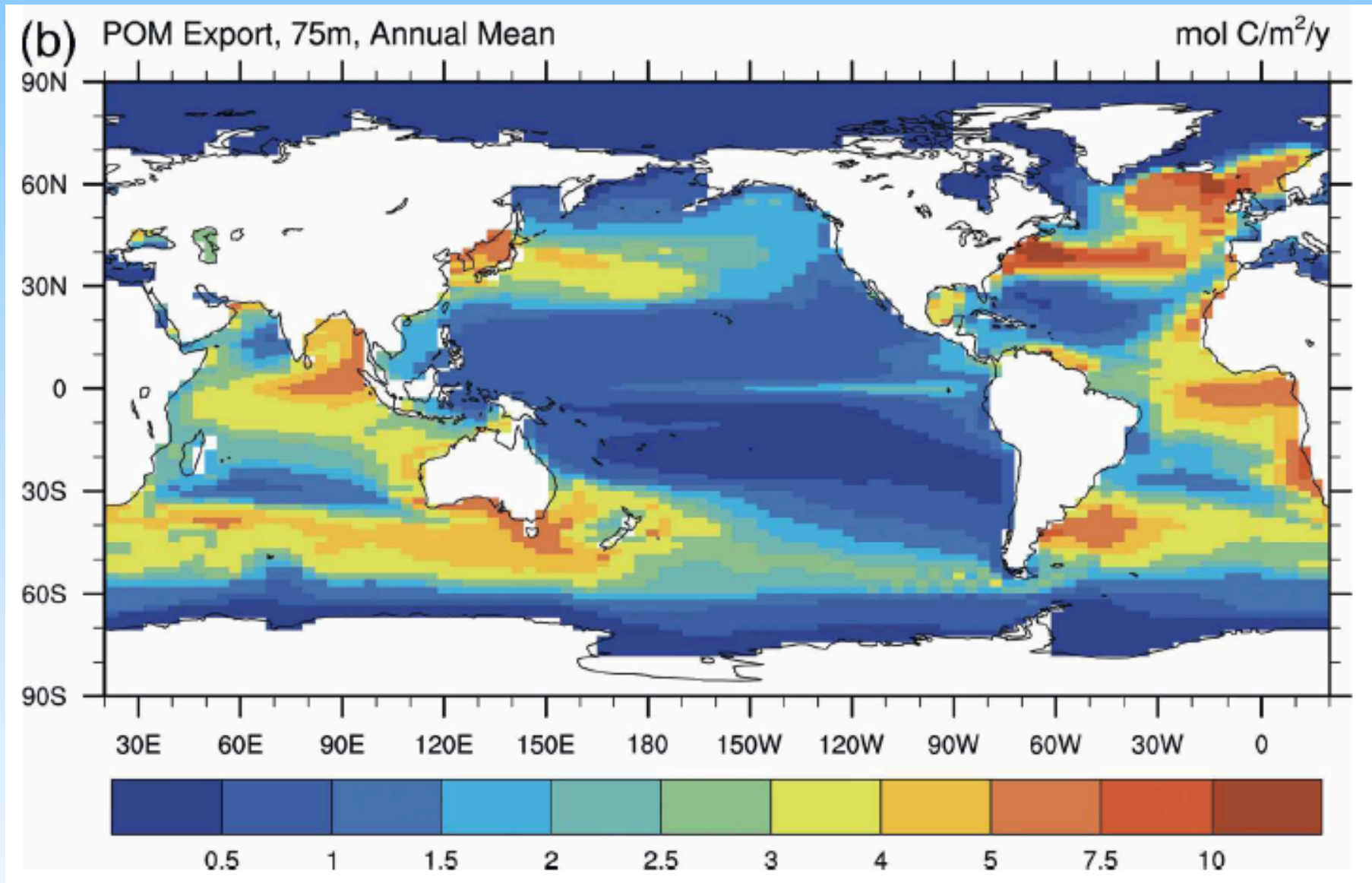
Ballast Model



Armstrong et al.
Deep-Sea Res. II
2006



Doney et al.
J. Climate 2006

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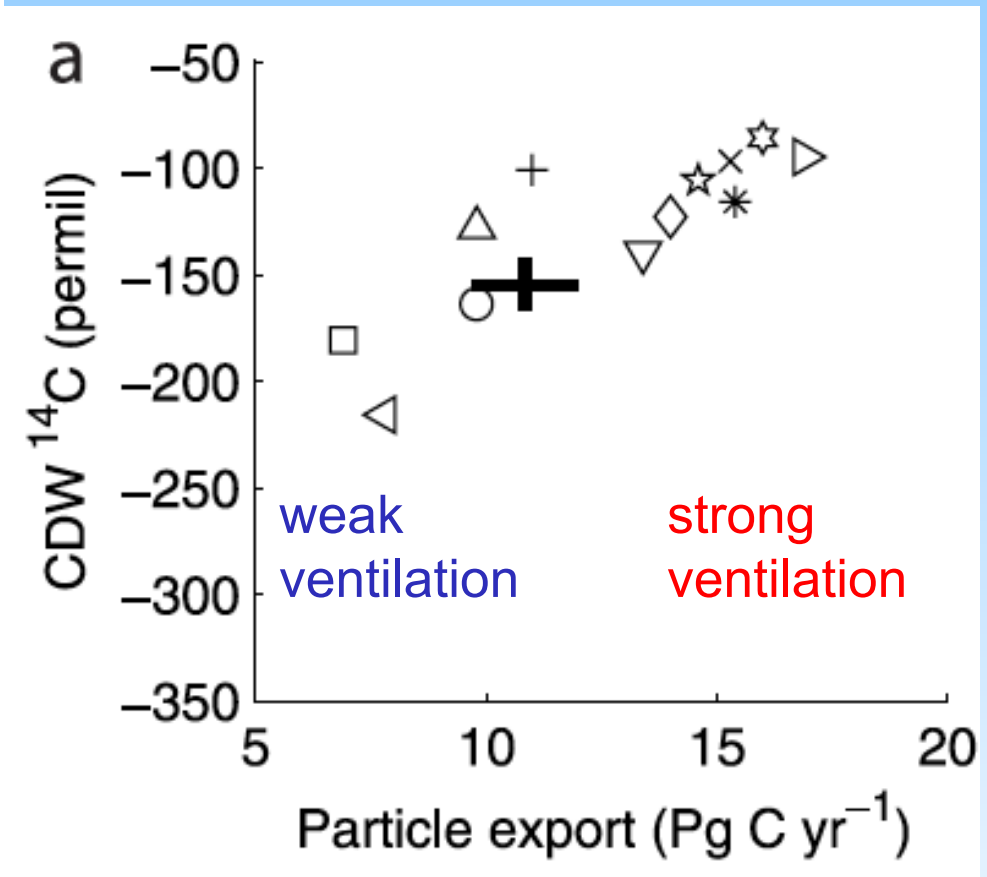
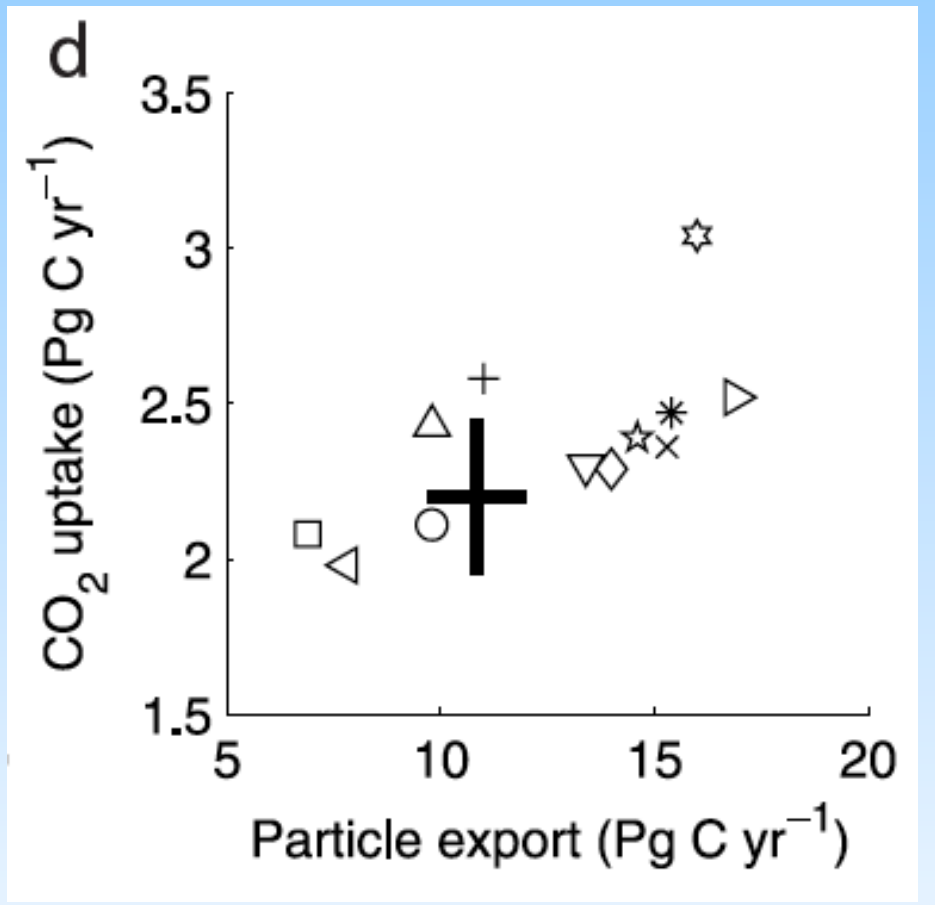
Role of Large-scale Circulation on Productivity





Najjar et al.
Global Biogeochem.
Cycles 2007

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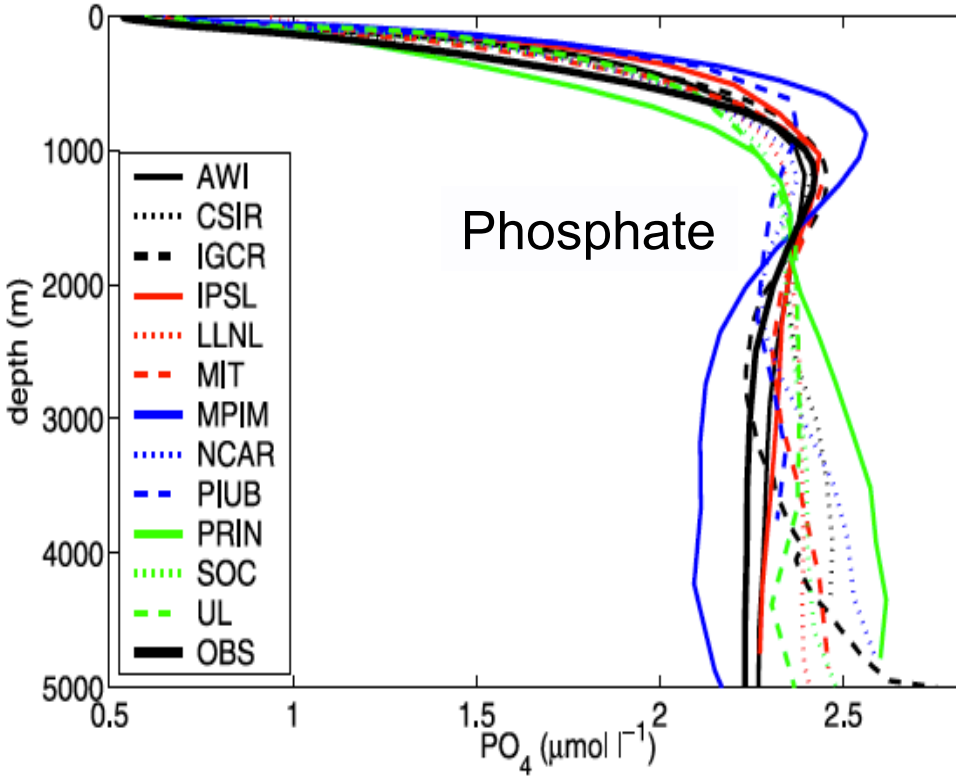
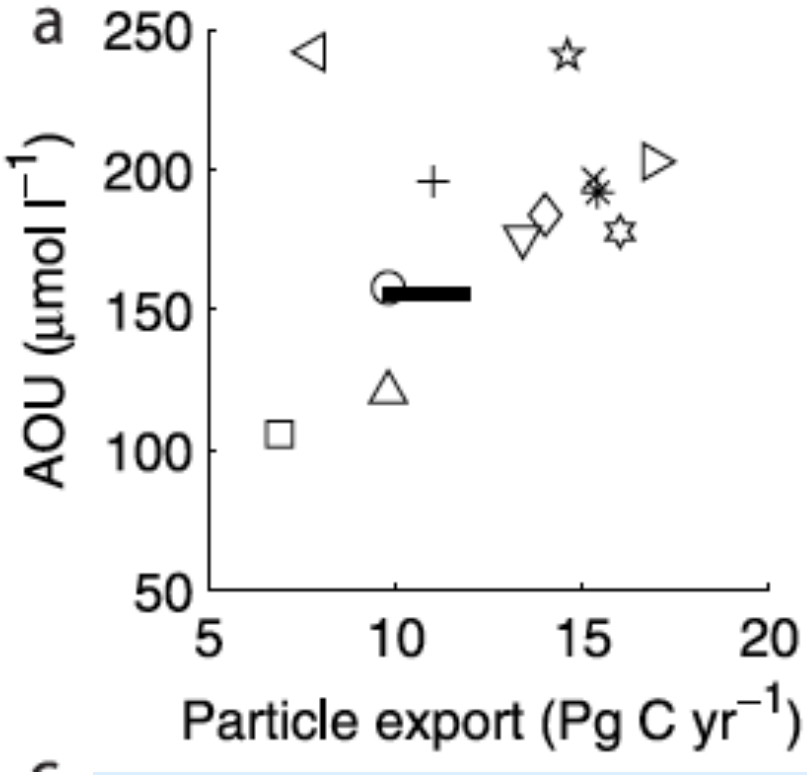
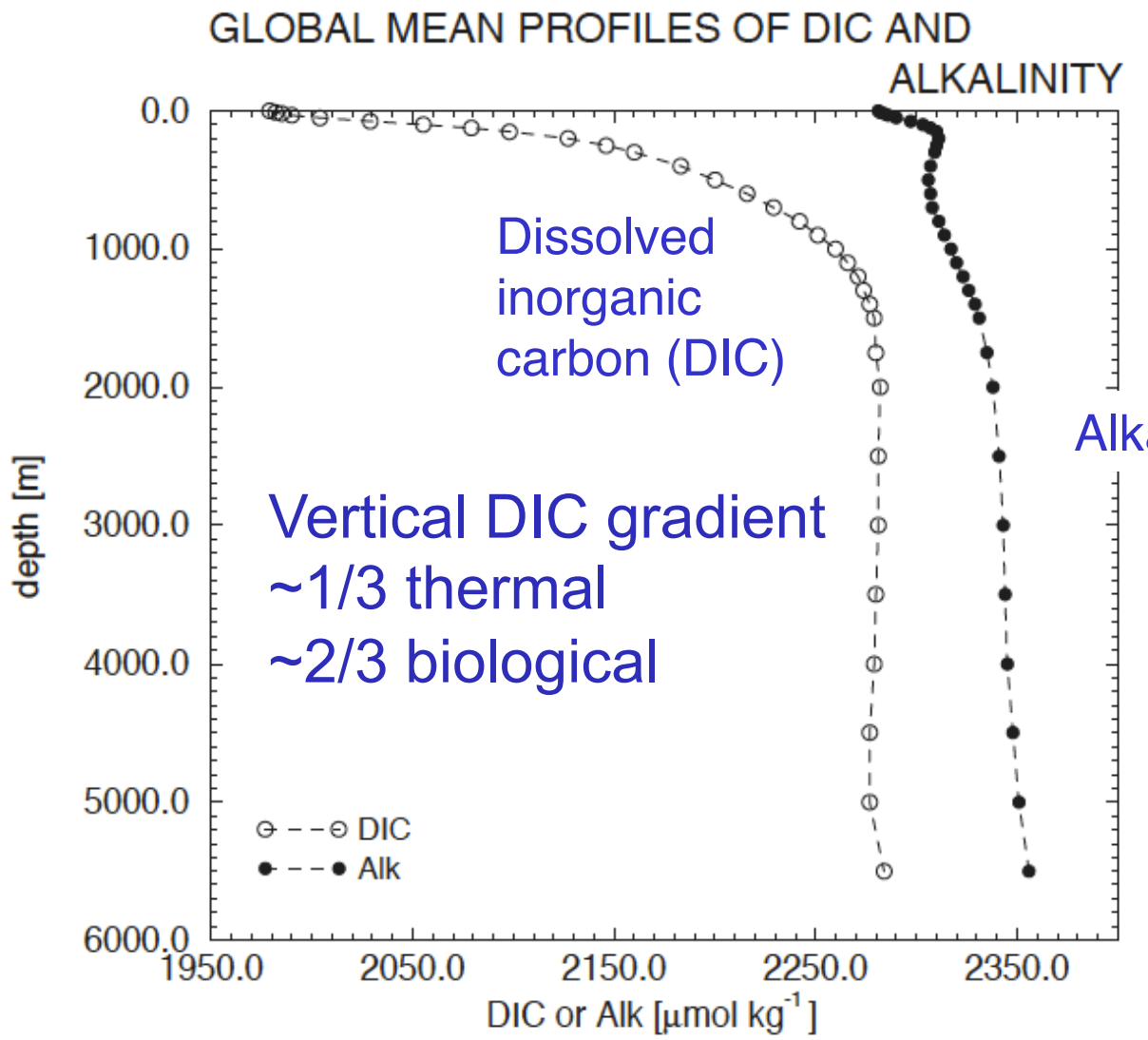
Large-scale Nutrient Constraints





Ocean Inorganic Carbon Distribution



DIC = Total of all dissolved inorganic carbon species
Alkalinity = Measure of acid buffering capacity

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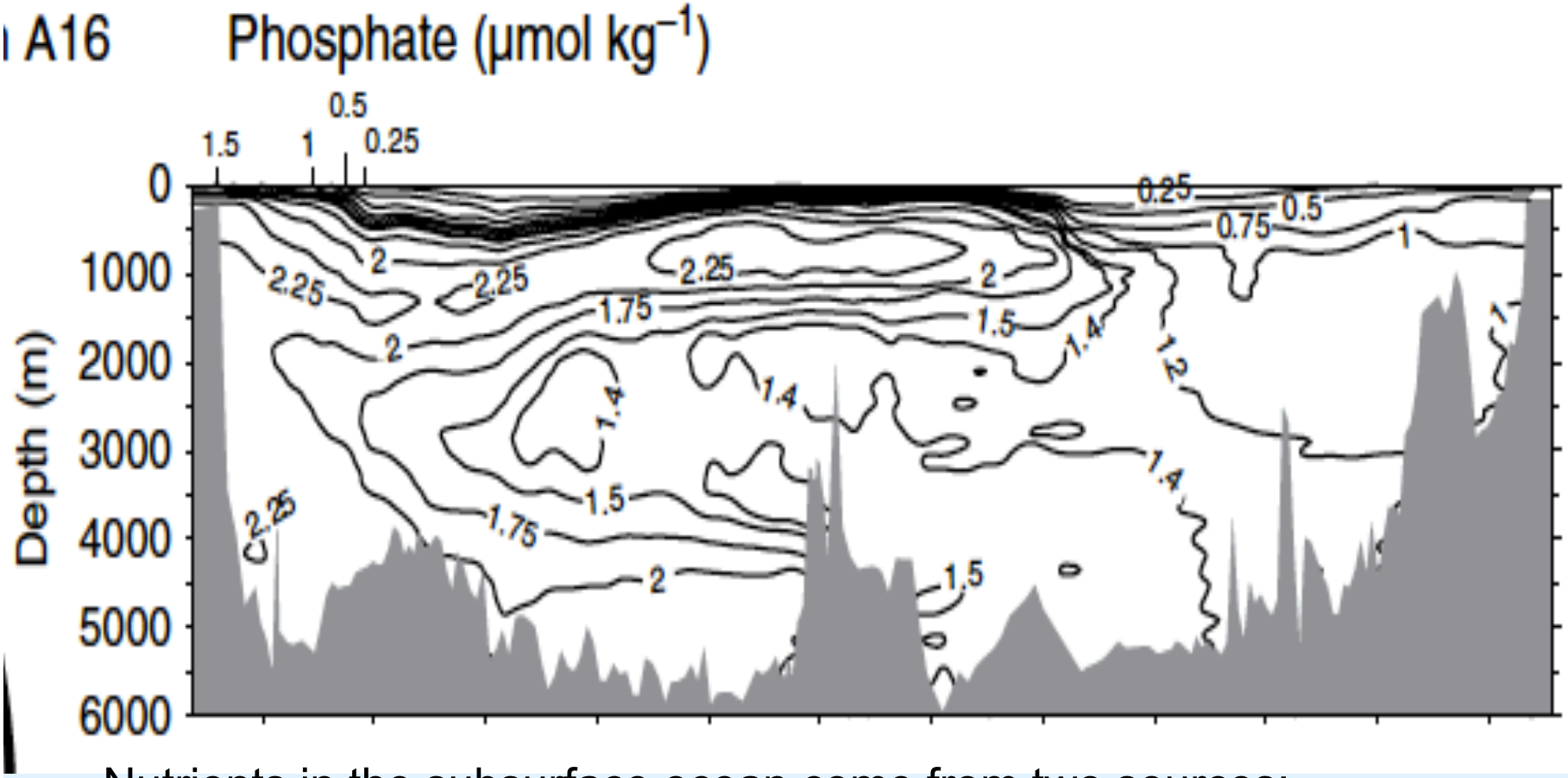
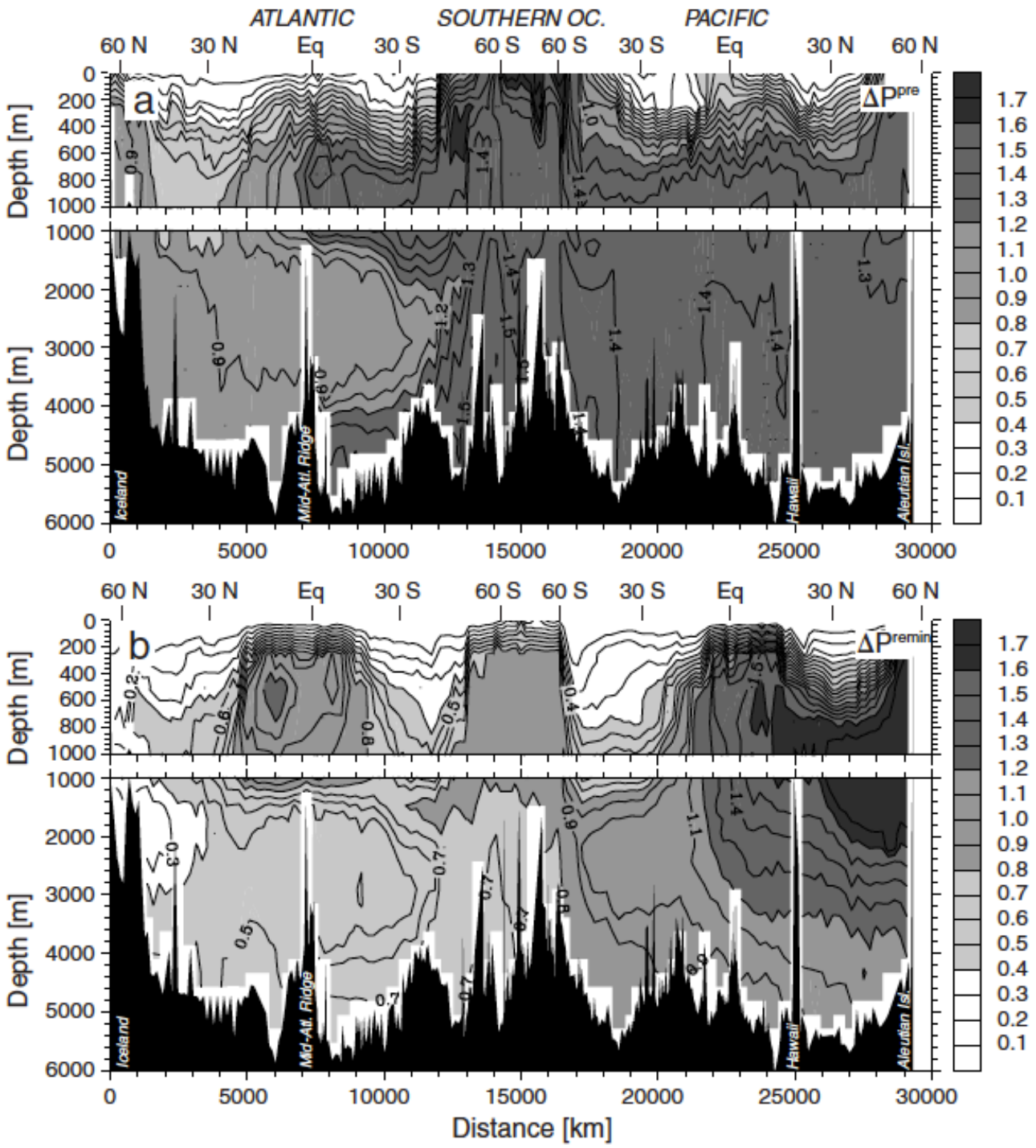
Ocean Nutrient Distribution



Nutrients in the subsurface ocean come from two sources:

- Remineralized (nutrients and CO_2 released from organic matter)
- Preformed (transported from surface water sources; leads to decoupling of nutrients and CO_2)



Preformed vs. Remineralized Nutrients

Gruber and Sarmiento
The Sea
2002

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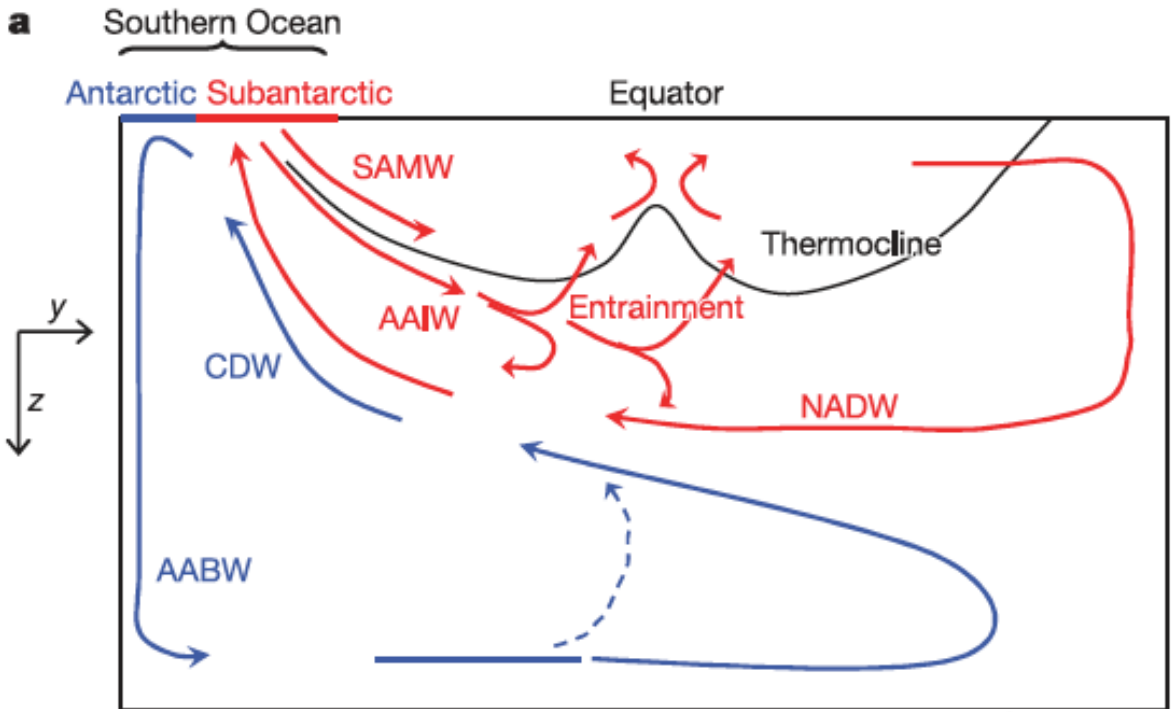
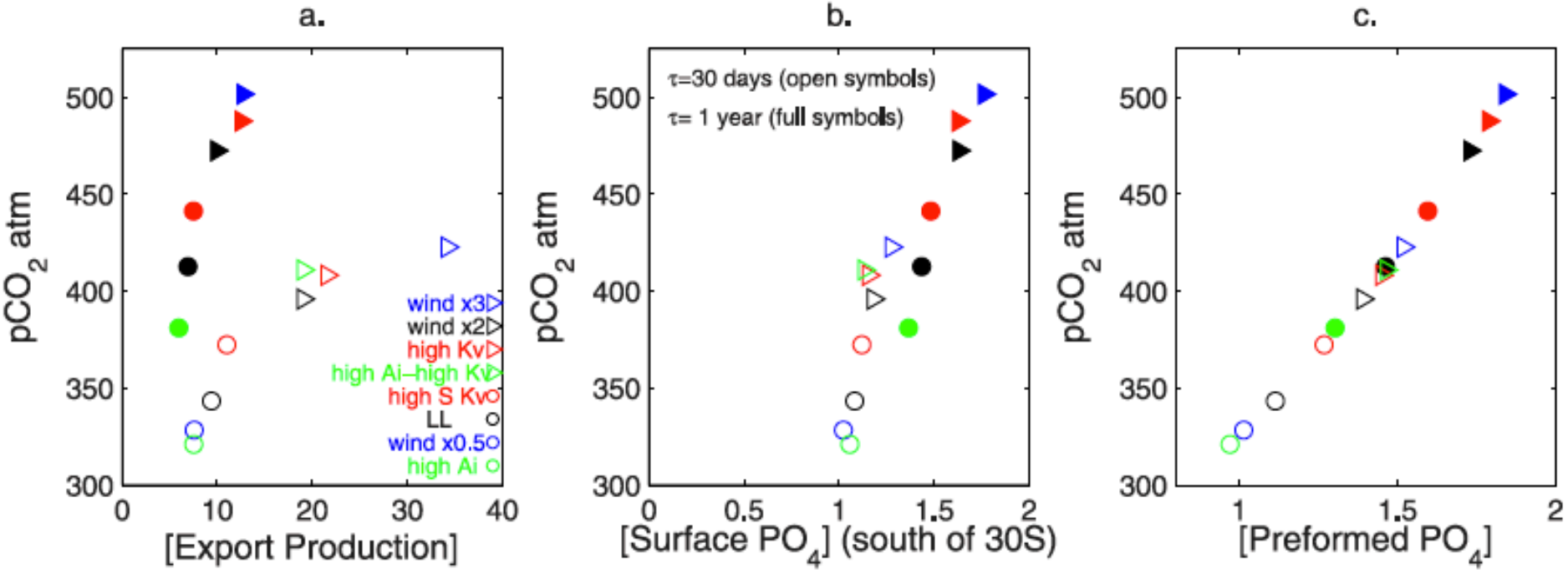
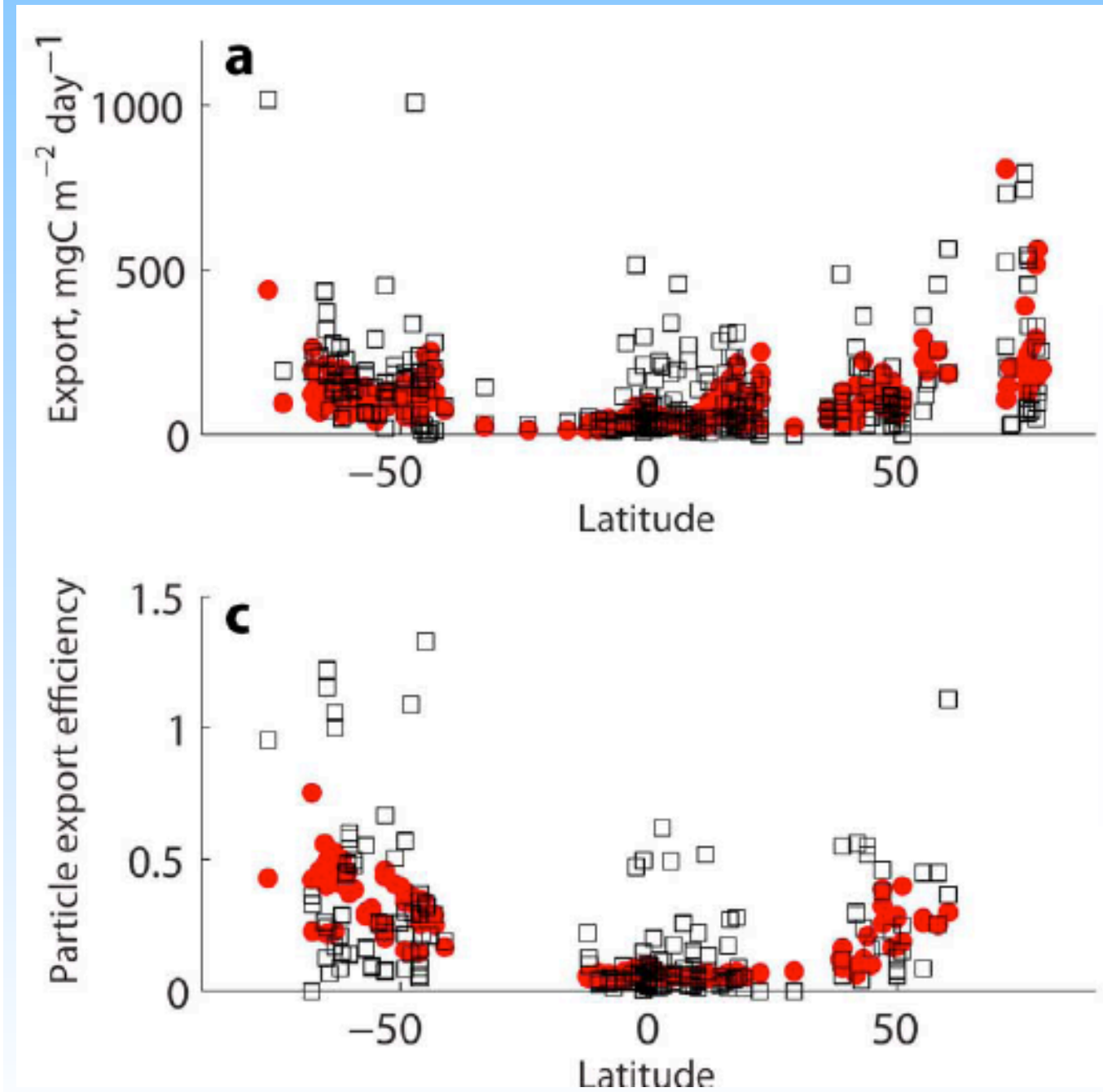
Preformed Nutrients & Ocean Carbon Storage

Marinov et al.
Global Biogeochem.
Cycles 2008







Net Community & Export Production

Data
-O_2/Ar
-Th-234
-nutrients
-DIC & $\delta^{13}C$
-sediment traps
-satellite & prognostic models

Henson et al. Global Biogeochem. Cycles 2010

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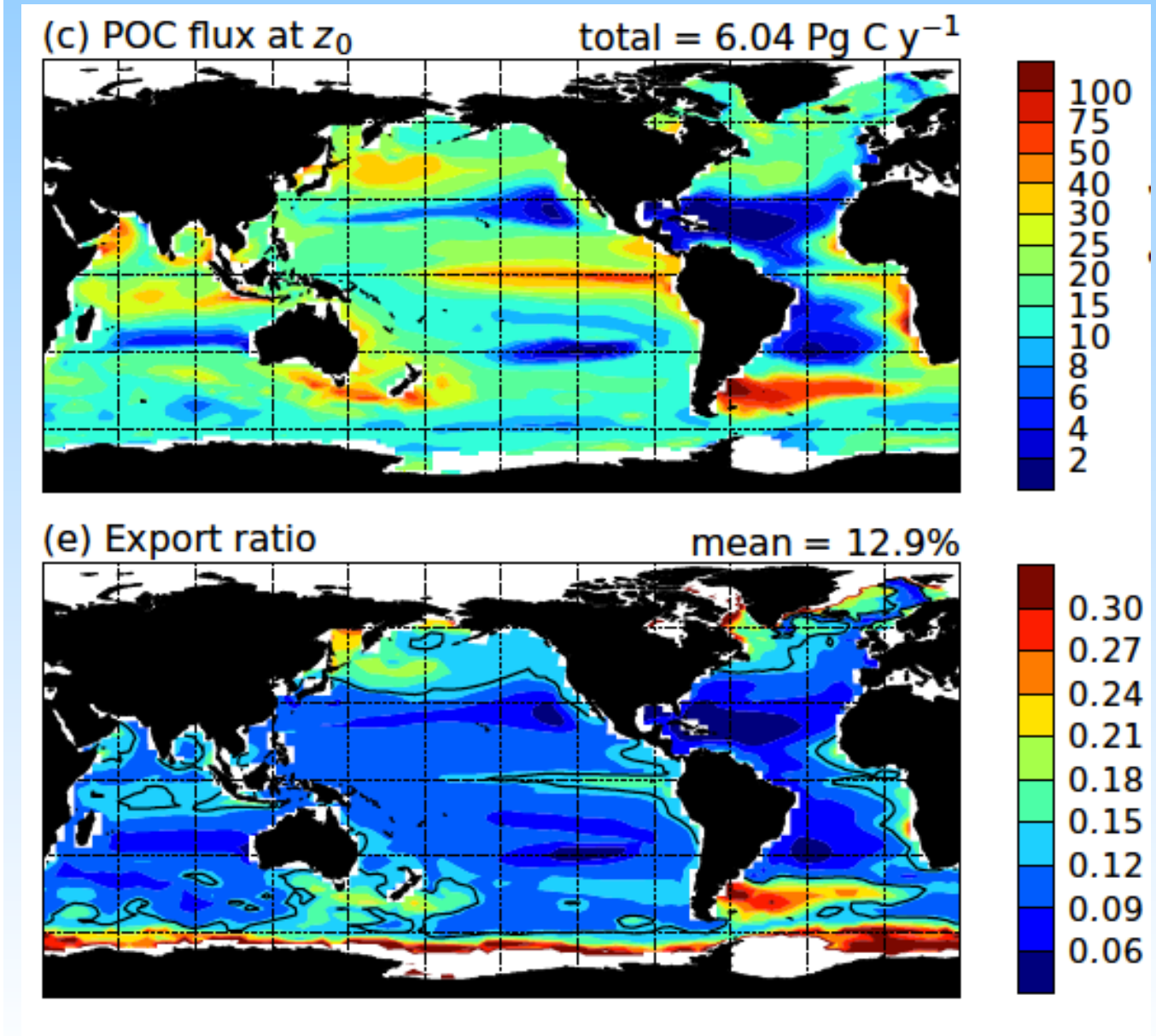
Export Flux & Export Ratio



Lima, Lam & Doney
Global Biogeochem.
Cycles submitted

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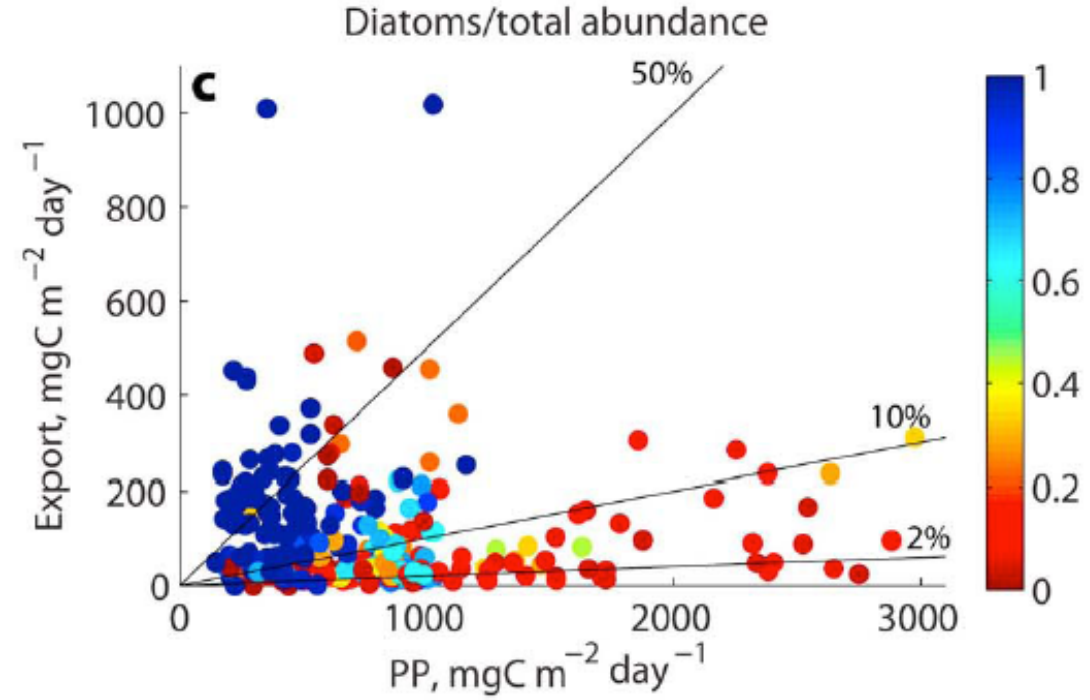
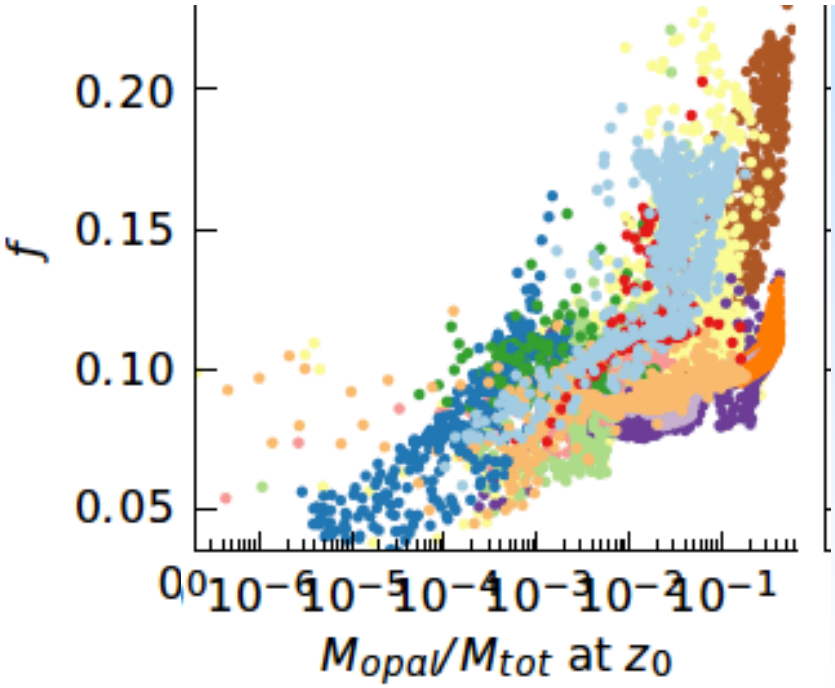
Export Ratio & Diatoms



Henson et al.
Global Biogeochem.
Cycles 2010



Lima, Lam, & Doney
Global Biogeochem.
Cycles 2010

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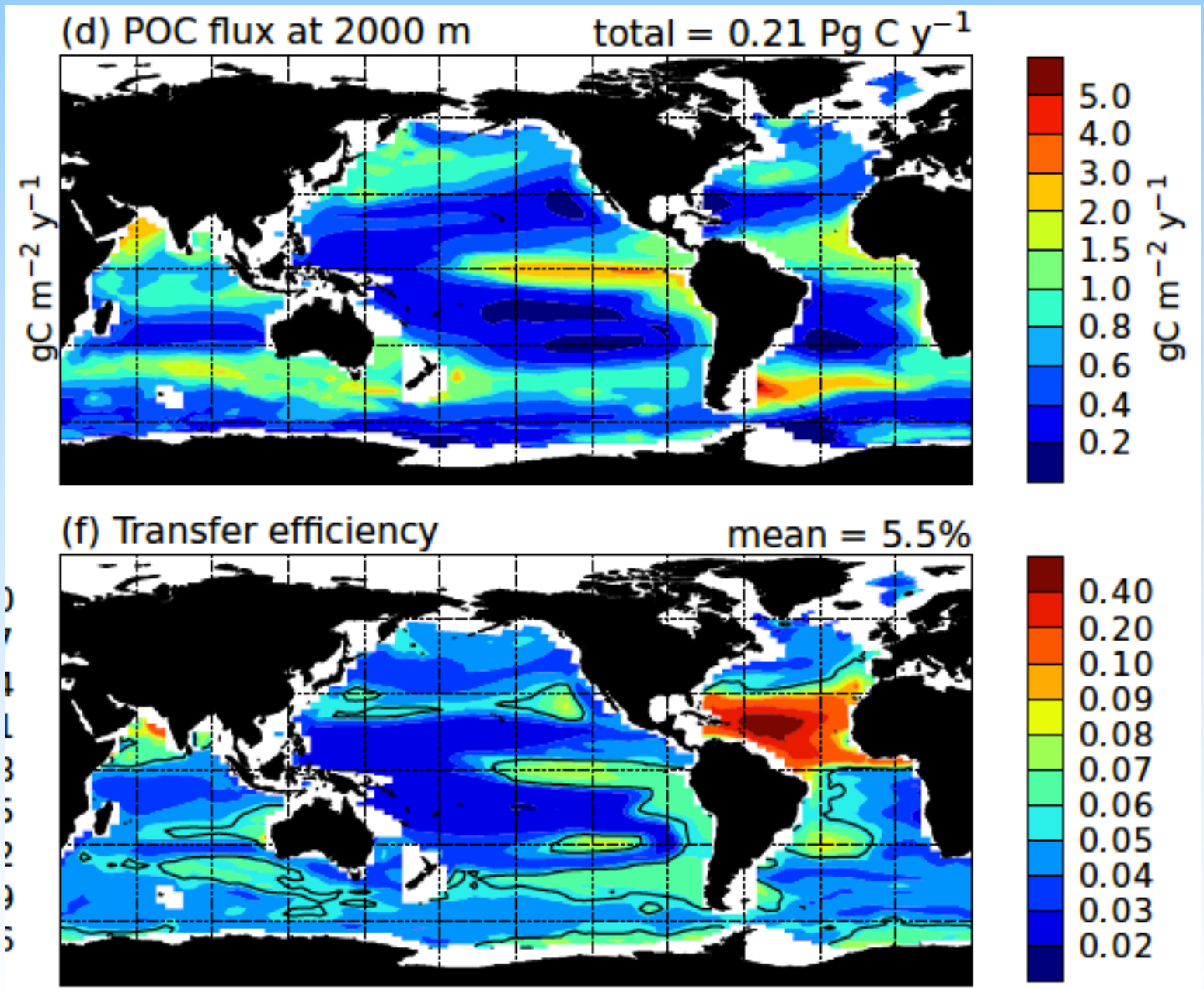
Particle Flux to Depth



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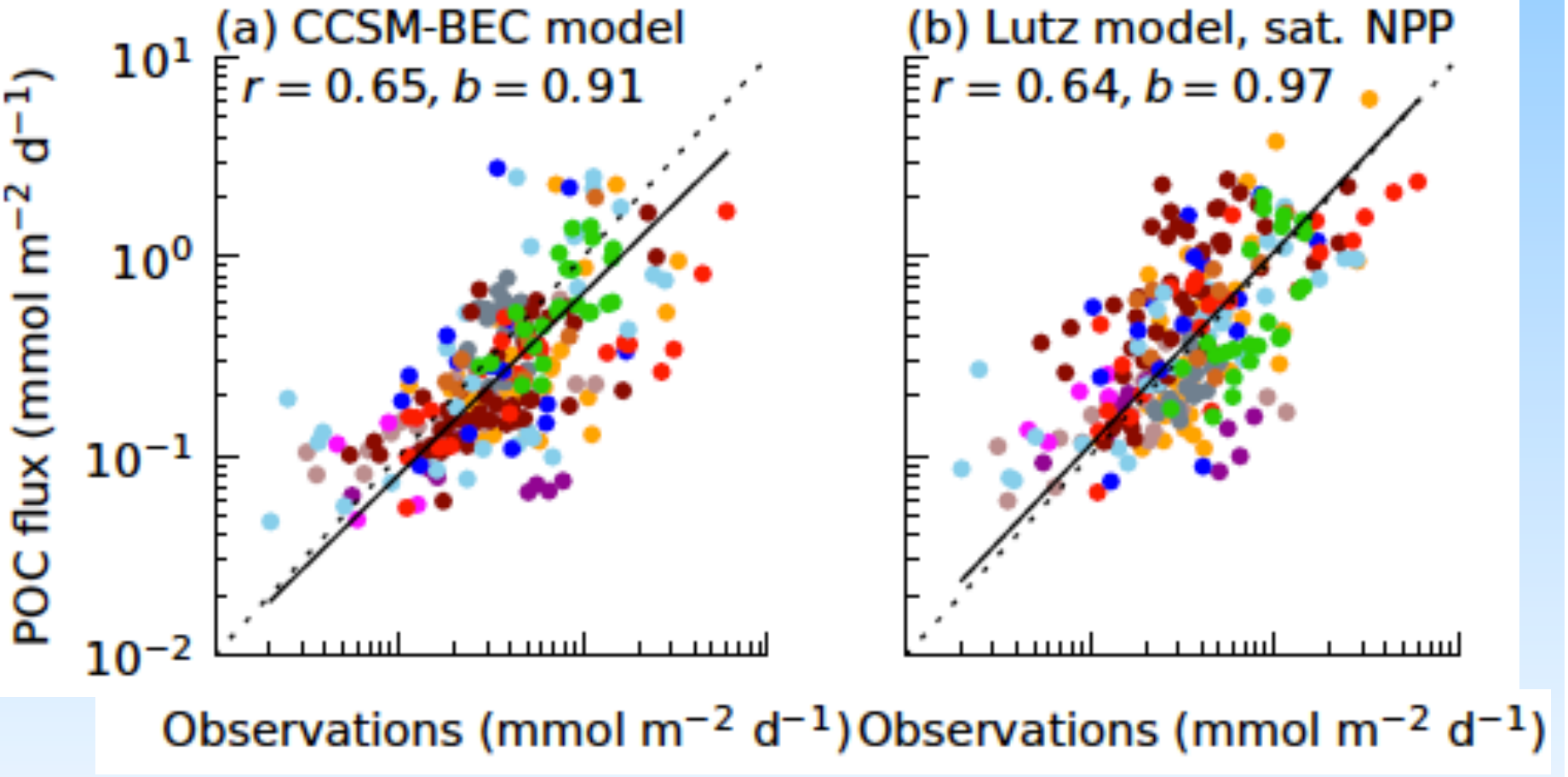
Flux Data & Models



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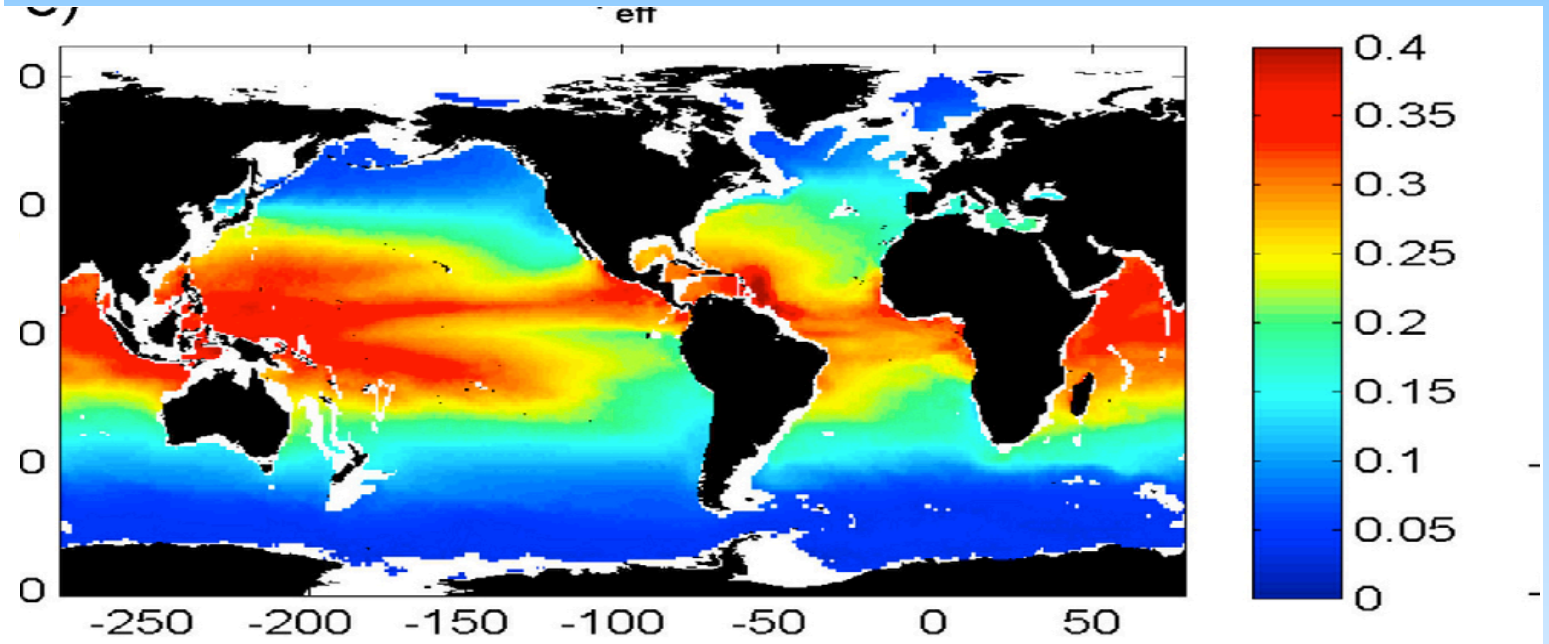
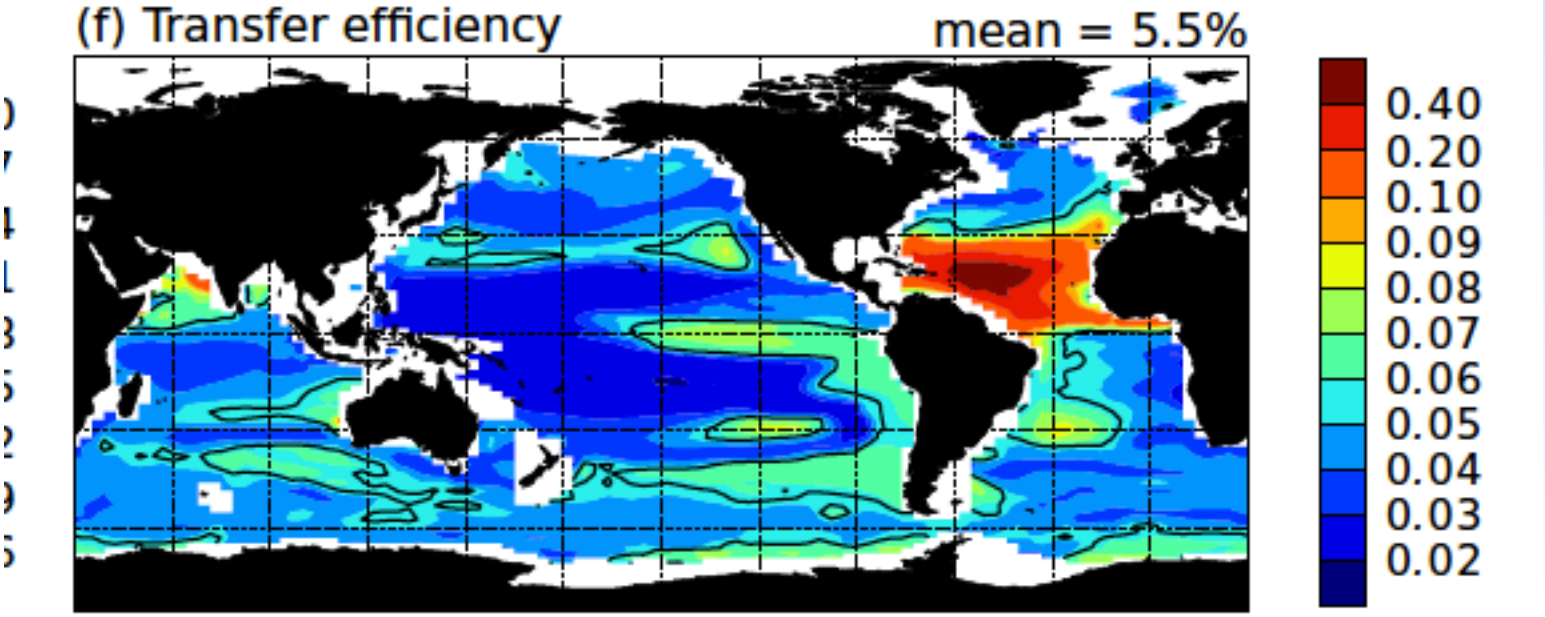
Particle Flux to Depth





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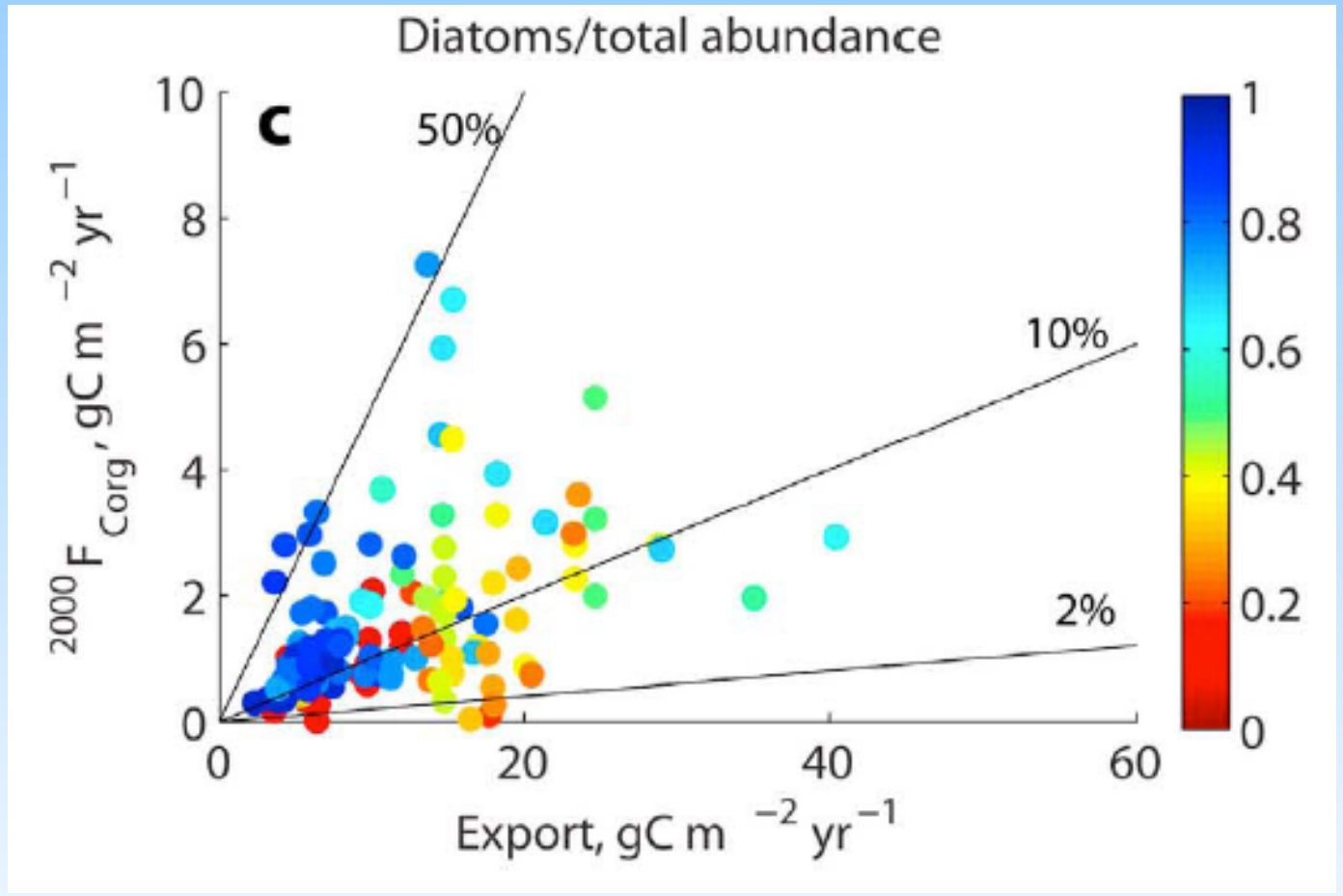
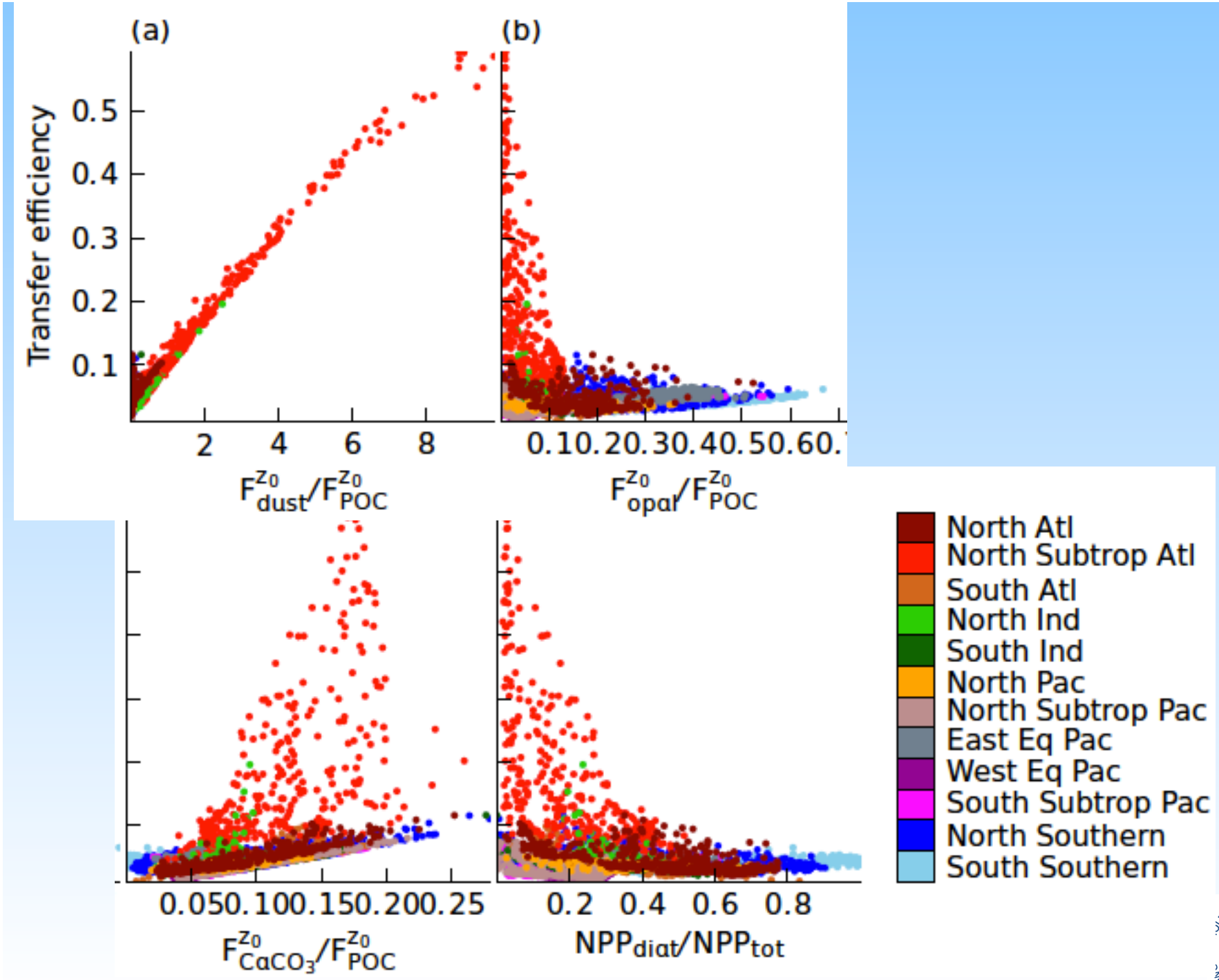

Diatoms/total abundance
c
50%
10%
2%
$^{2000}F_{Corg}$, gC m $^{-2}$ yr $^{-1}$
Export, gC m $^{-2}$ yr $^{-1}$
0
2
4
6
8
10
0
20
40
60
0
0.2
0.4
0.6
0.8
1


(a)
(b)
Transfer efficiency
0.5
0.4
0.3
0.2
0.1
2
4
6
8
0.10.20.30.40.50.60.
$F^{z_0}_{dust}/F^{z_0}_{POC}$
$F^{z_0}_{opal}/F^{z_0}_{POC}$
0.050.100.150.200.25
0.2
0.4
0.6
0.8
$F^{z_0}_{CaCO_3}/F^{z_0}_{POC}$
NPP_{diat}/NPP_{tot}
North Atl
North Subtrop Atl
South Atl
North Ind
South Ind
North Pac
North Subtrop Pac
East Eq Pac
West Eq Pac
South Subtrop Pac
North Southern
South Southern

Marine Ecology & Biogeochemistry