Sensitivity of (global) biogeochemical models to particle export and recycling

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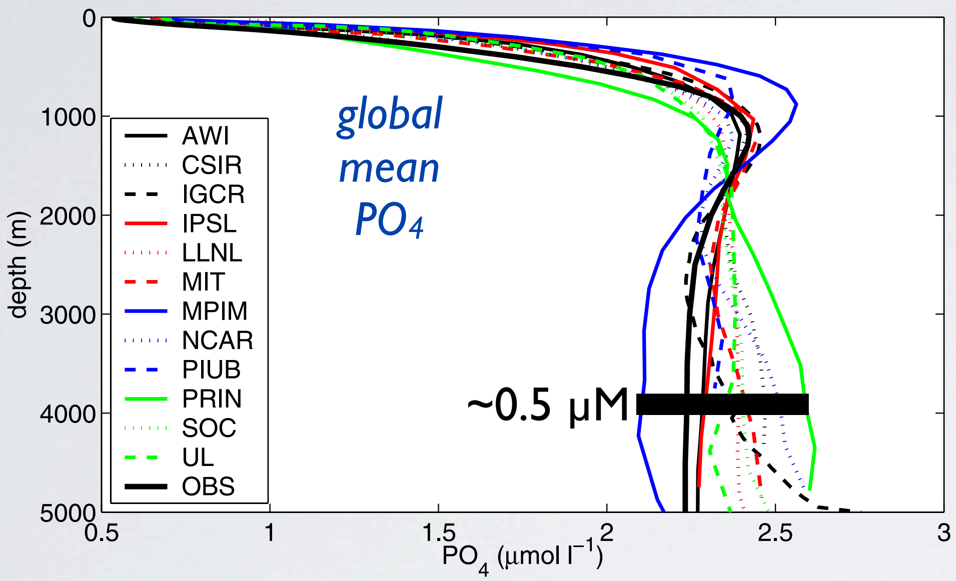
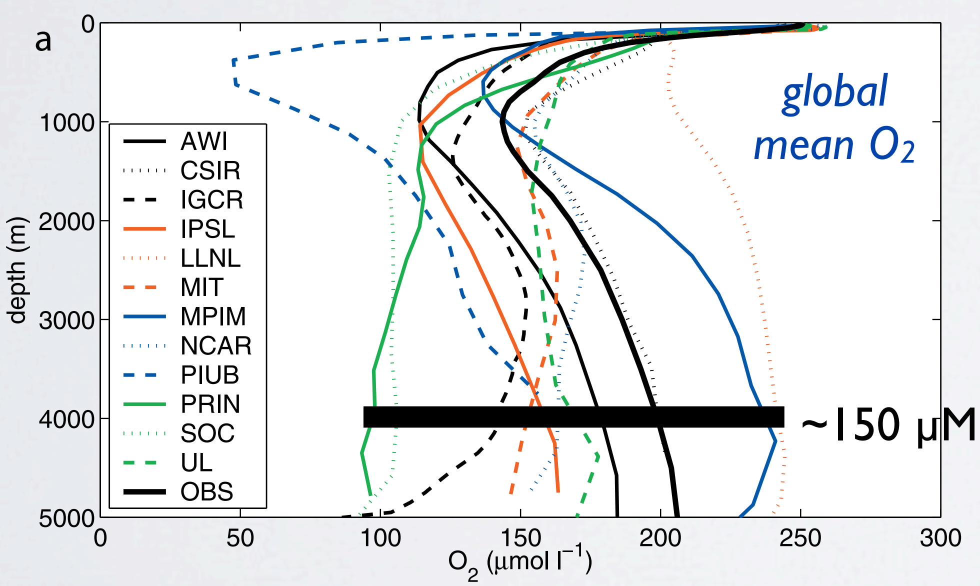
PHYSICAL VS. BIOGEOCHEMICAL MODEL SENSITIVITY

Effect of different circulations

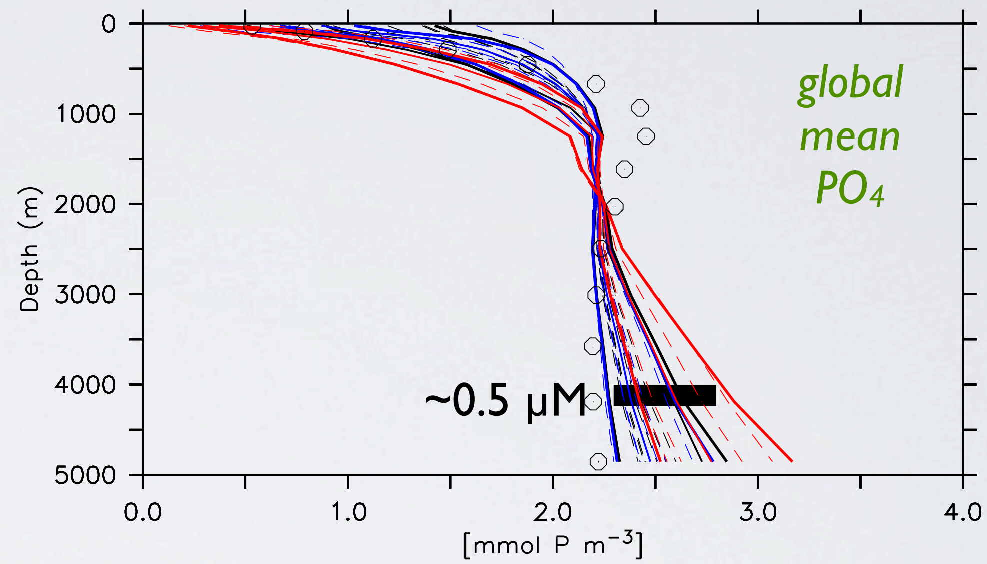
(Najjar et al., 2007; "OCMIP")

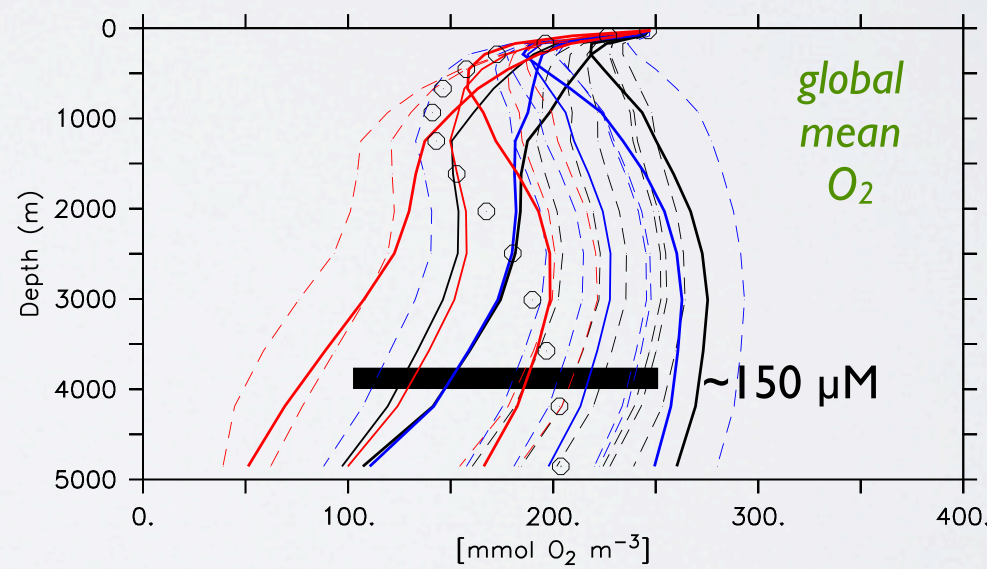




Effect of different BGC models

(Kriest et al., unpubl.)





OUTLINE

Parameterizations of particle flux in marine biogeochemical models

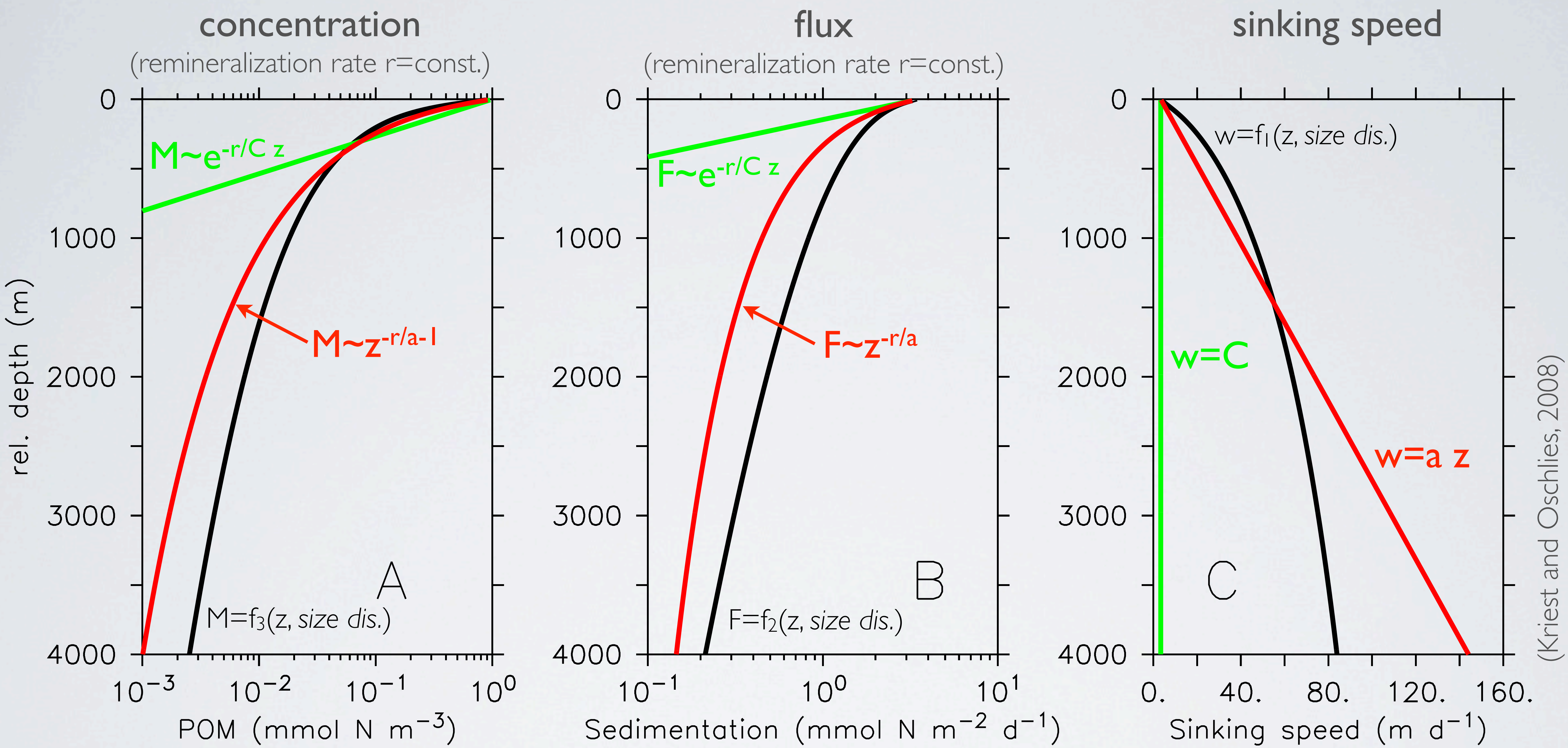
Sensitivity of simulated PO_4 and O_2 on particle flux (remineralization) vs.

- biogeochemical model complexity
- other biogeochemical parameters
- physics (resolution/circulation)
- numerics (advection scheme for particle sinking)

Observations of particle flux as constraints for models

Summary

PARTICULATE ORGANIC MATTER (POM), ITS FLUX AND SINKING SPEED

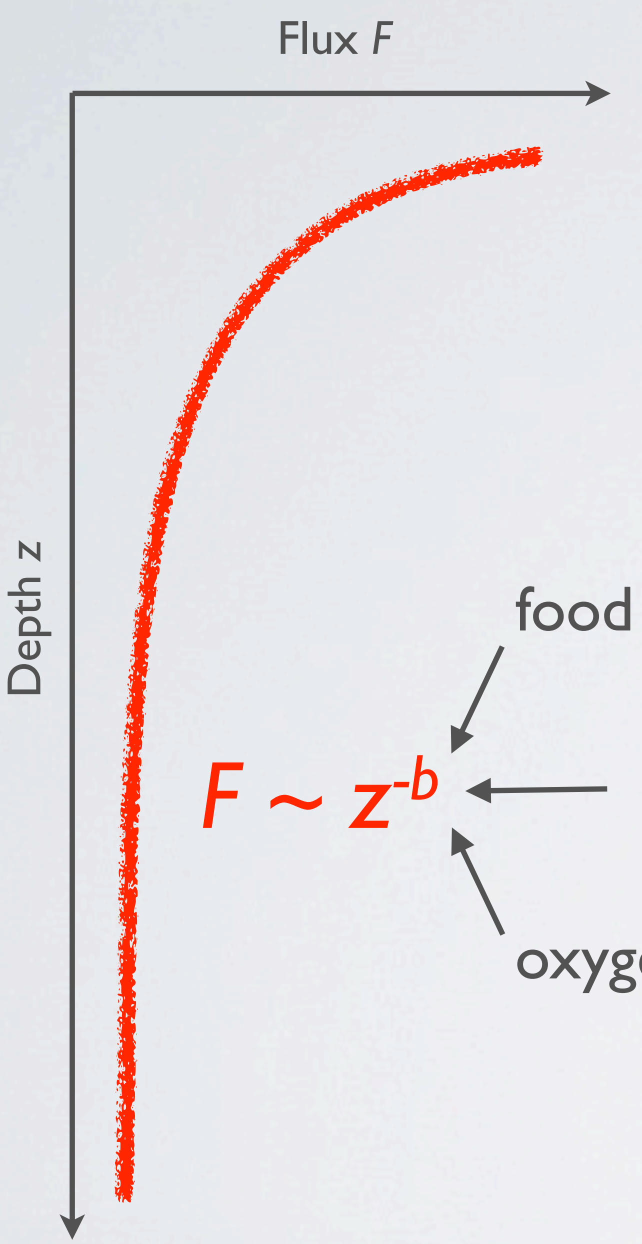


- constant sinking speed: simplest assumption
- size distribution: mechanistic; technically difficult in 3D; how to constrain by 3D data sets?
- vertically increasing sinking speed: no "real" mechanistic foundation; empirical; **commonly used**

REMINERALIZATION AND PARTICLE FLUX

Under certain assumptions $F \sim z^{-b}$ corresponds to sinking speed ~ z and remineralization rate = const.

(alternatively sinking speed = const. and remineralization rate ~ 1/z)

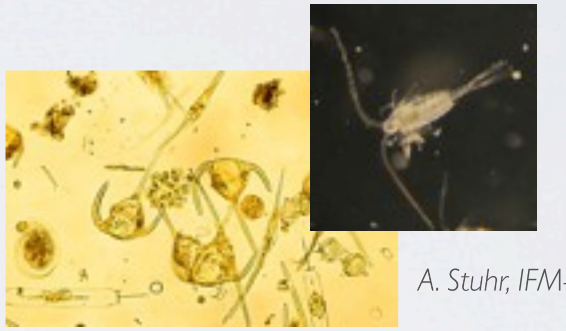


$F \sim z^{-b}$

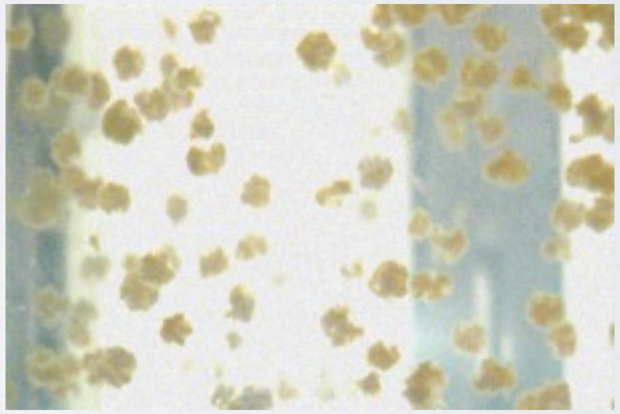
food web dynamics (particle size)

aggregation/disaggregation (particle size)

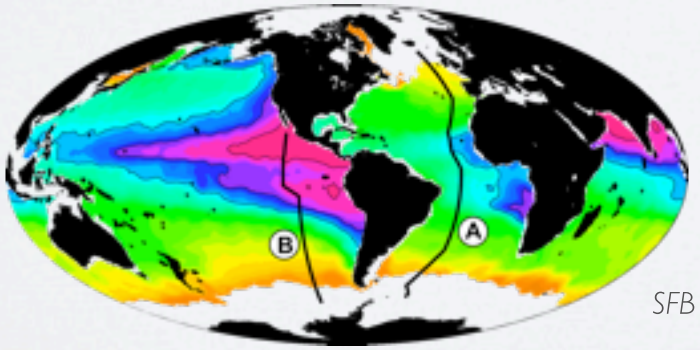
oxygen availability (remineralization rate)



A. Stuhr, IFM-GEOMAR



B. Moriceau, Inst. Univ. Europ. Mer



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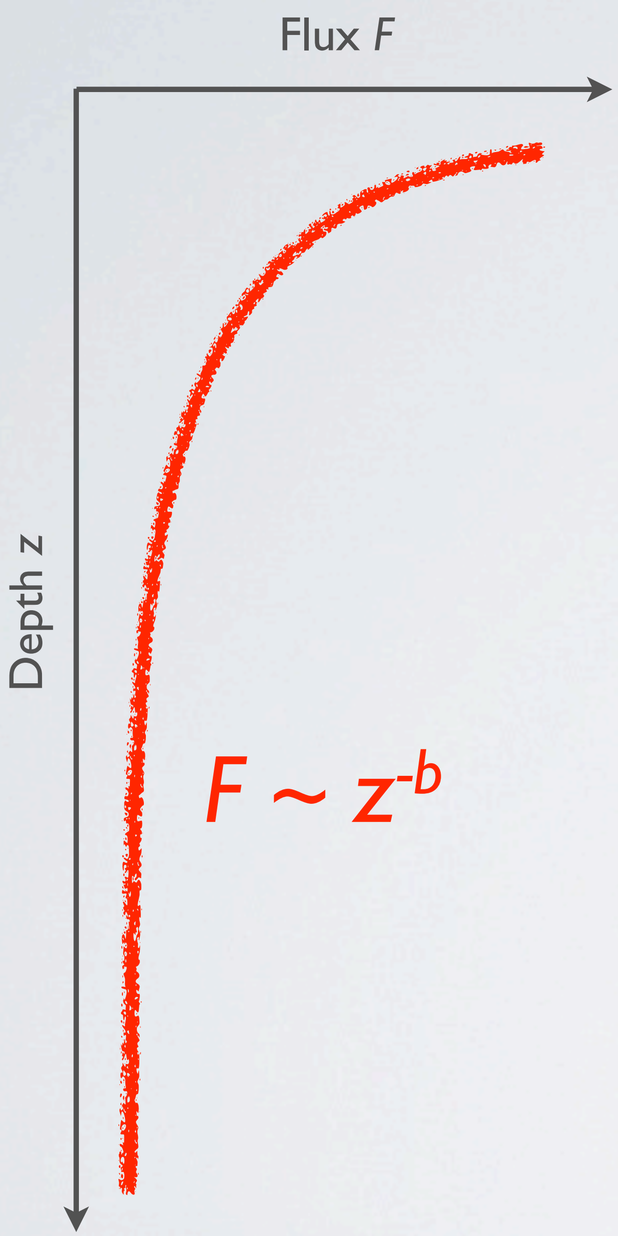
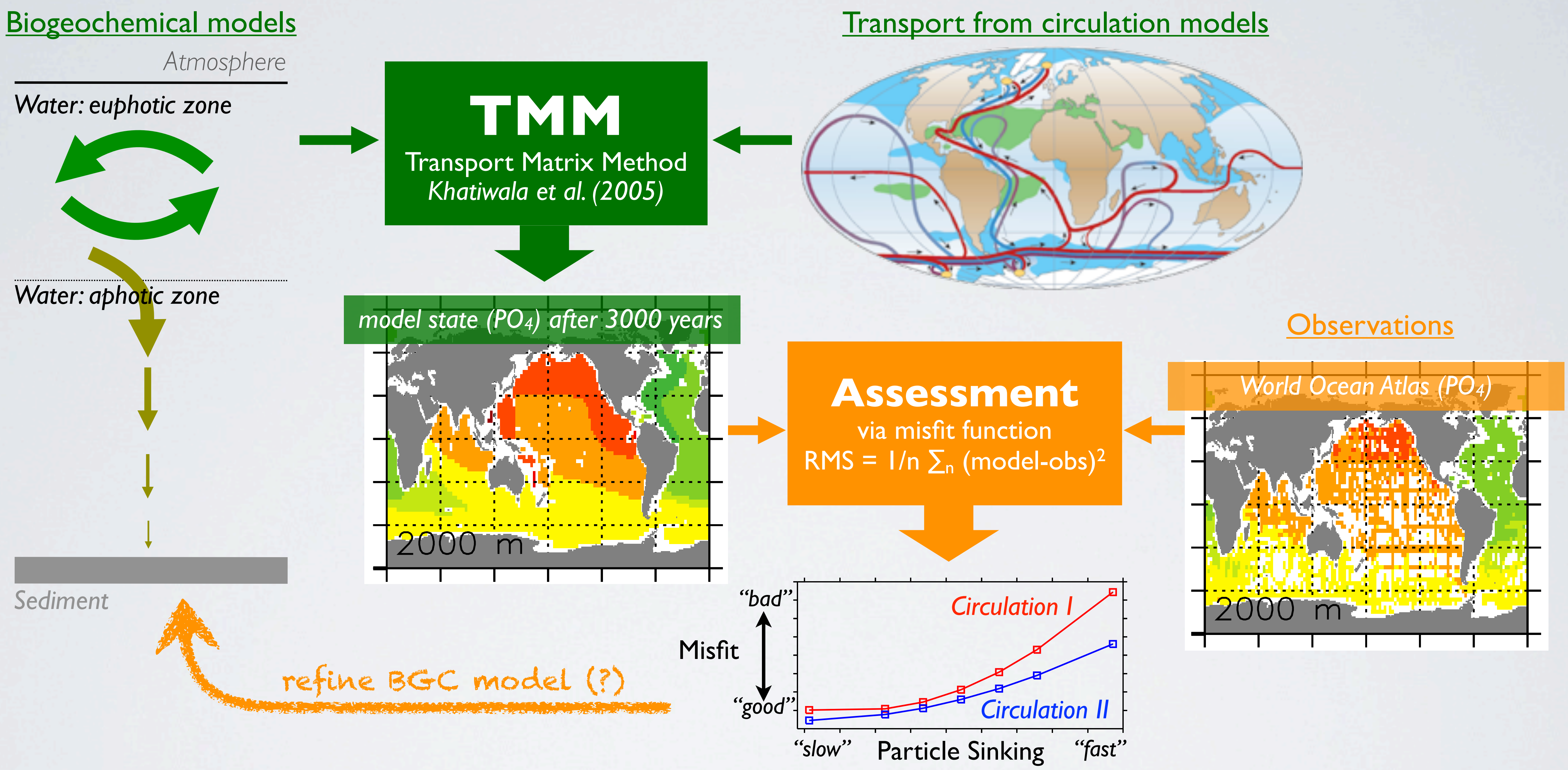
REMINERALIZATION AND PARTICLE FLUX

Do we know the particle flux (remineralization) length scale?

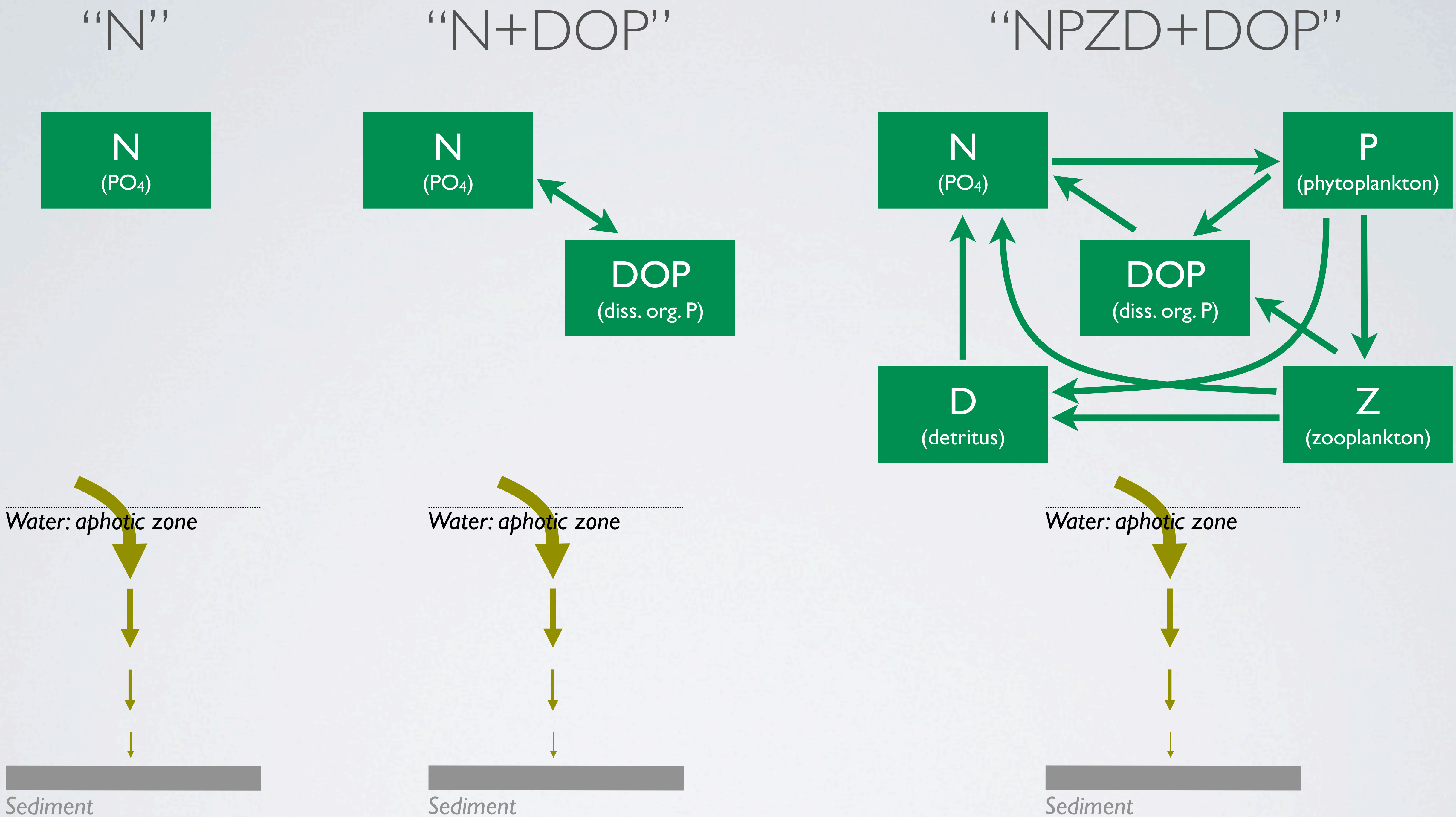


	lower b		upper b	
Observed:				
Martin et al. (1987)	**0.32**	*off Peru*	0.97	*off California*
Berelson (2001)	0.59	*eq. Pacific*	1.28	*n. N. Atlantic*
VanMooy et al. (2002)	0.40	*ETNP (low O2)*	-	
Buesseler et al. (2007)	0.51	*n. N. Pacific*	**1.33**	*ALOHA*
Models:				
Kriest & Oschlies (2008)	0.36	*"large particles"*	1.60	*"small particles"*
Kwon et al. (2006, 2009)	0.40		1.40	
Kriest et al. (subm.)	0.43		1.29	
Bacastow & Maier-Reimer (1991)	exponential flux length scale			

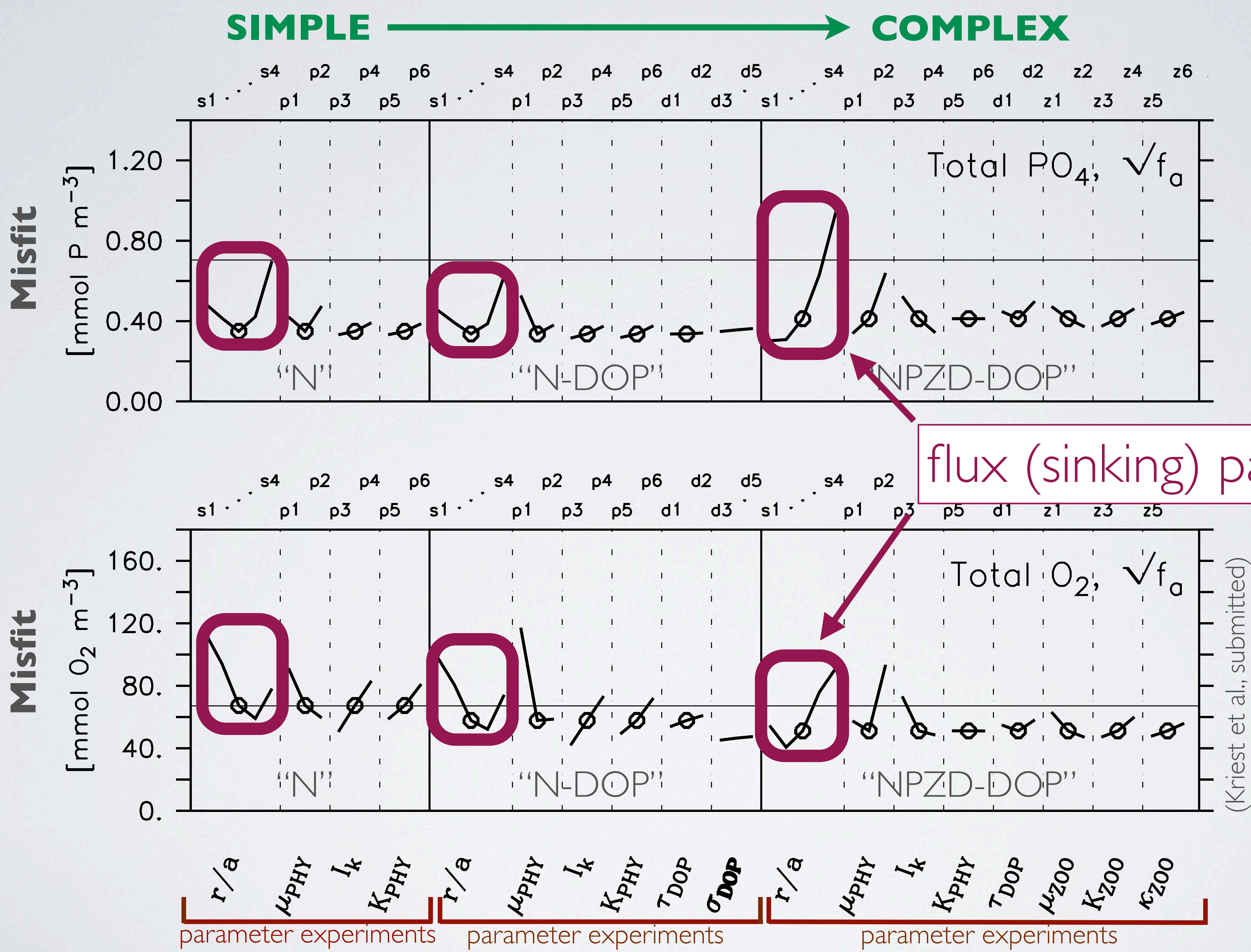
FRAMEWORK FOR GLOBAL BGC MODEL ASSESSMENT



BIOGEOCHEMICAL MODELS OF DIFFERENT COMPLEXITY



BGC MODEL COMPLEXITY AND PARAMETERS: GLOBAL MISFIT



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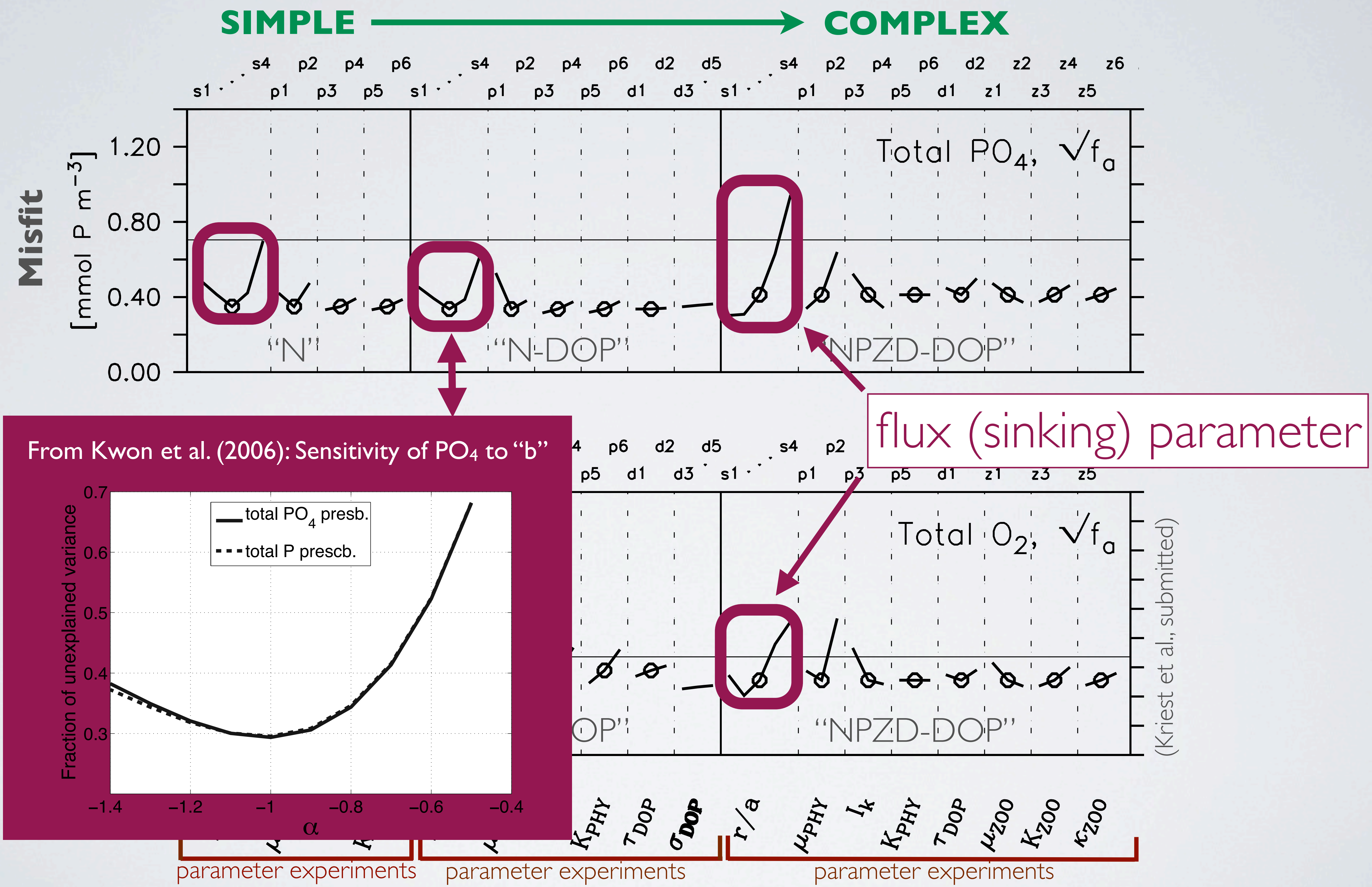
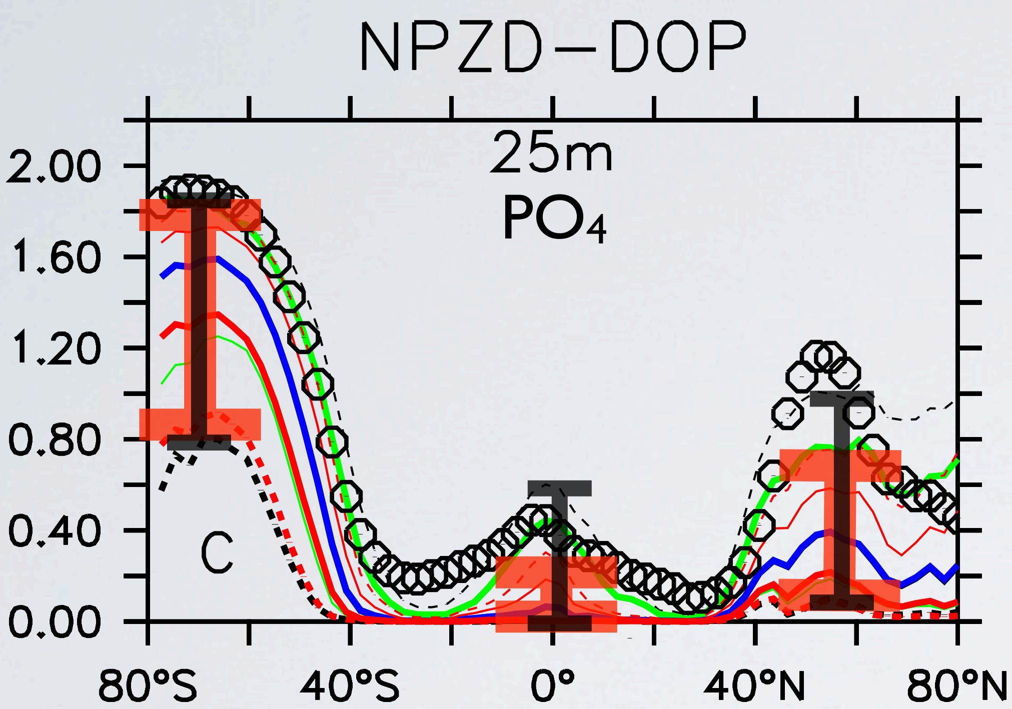


BGC PARAMETERS: DIFFERENT VERTICAL DOMAINS



Zonal average of surface (25 m) PO_4:

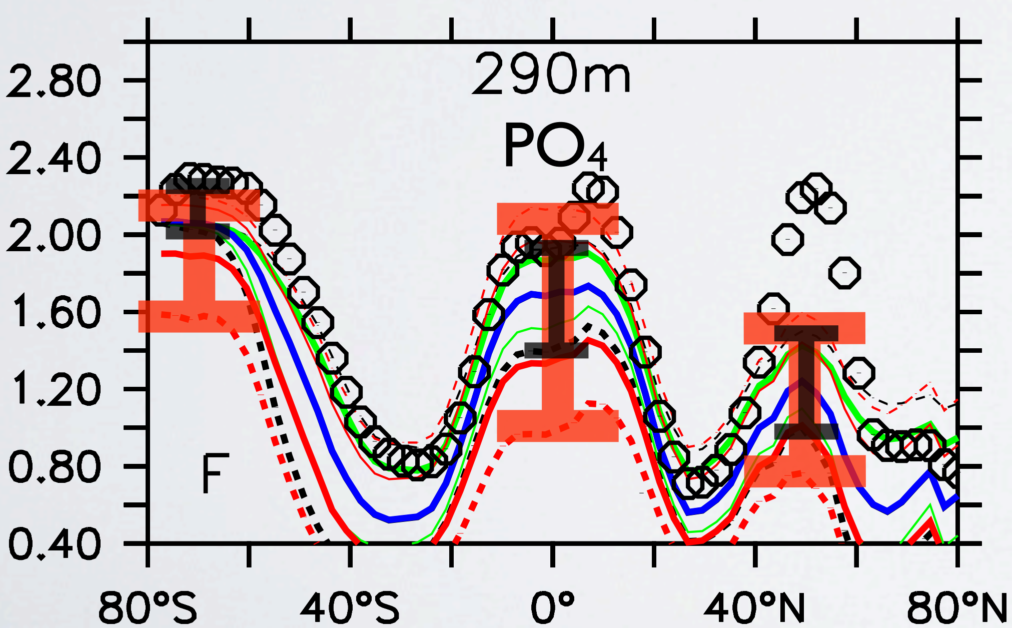
- **flux length scale** *and* **growth rate** important

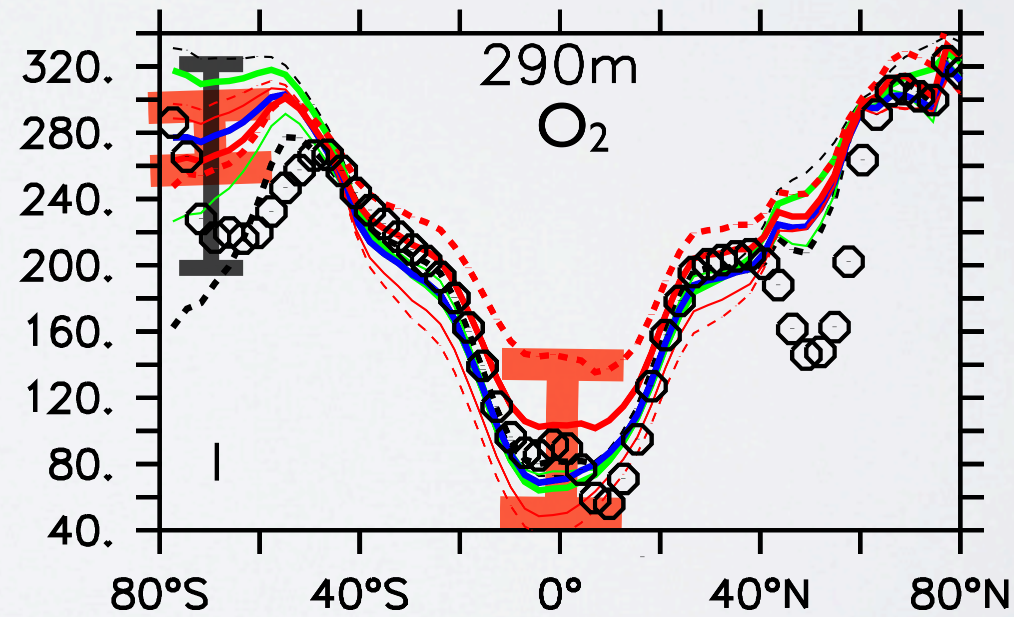
Zonal average of mesopelagic (290 m) PO_4:

- **flux length scale** important

Zonal average of mesopelagic (290 m) O_2:

- **growth rate** important in Southern Ocean
- **flux length scale** important in equatorial regions



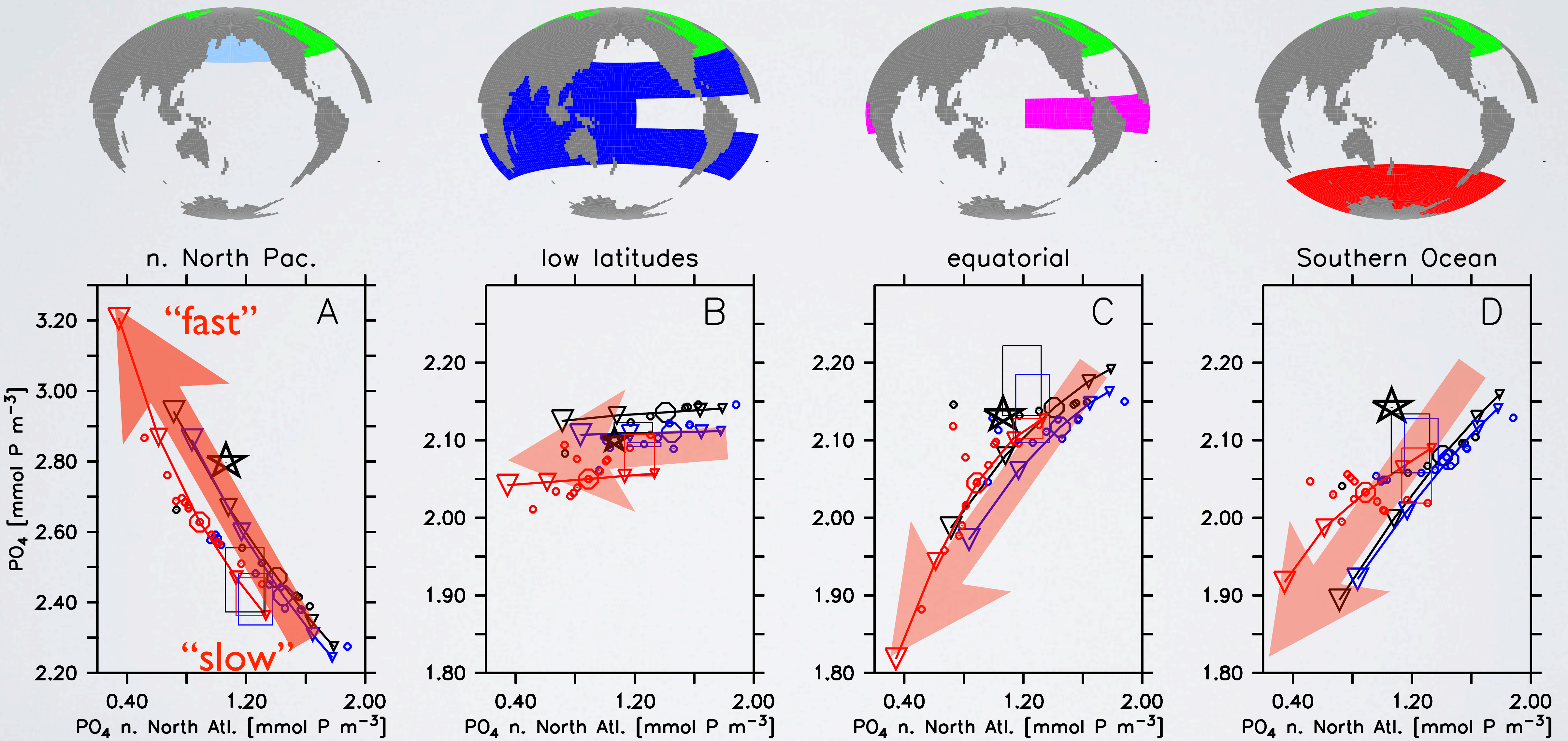


(Kriest et al., submitted)

BGC PARAMETERS: DIFFERENT REGIONAL DOMAINS

Regional averages of PO_4 in northern N. Pacific, low latitudes, equatorial region, Southern Ocean vs. regional average in northern N. Atlantic:

- Flux length scale acts as a kind of balance, tilted either in favour of northern N. Atlantic ("slow"), or in favour of northern N. Pacific ("fast").



(Kriest et al., submitted)

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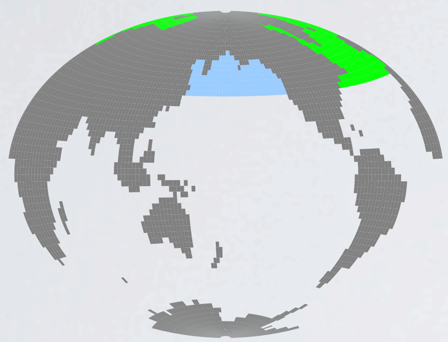
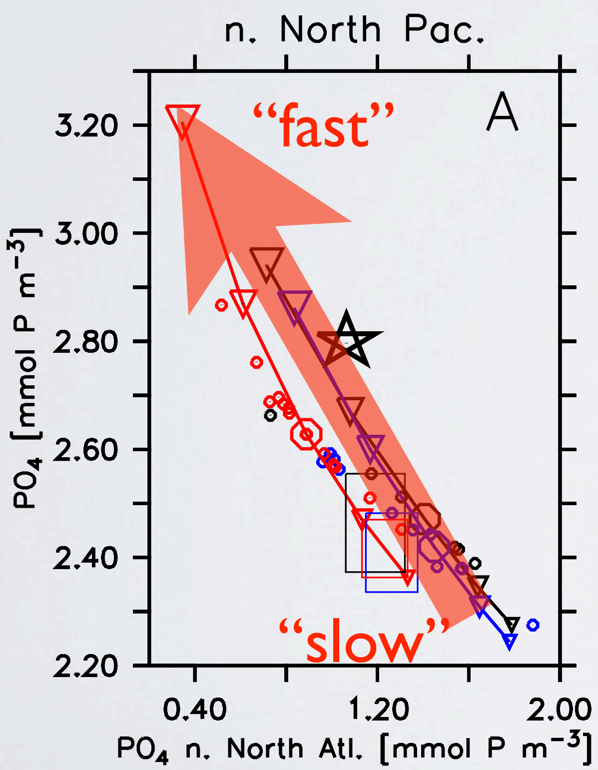
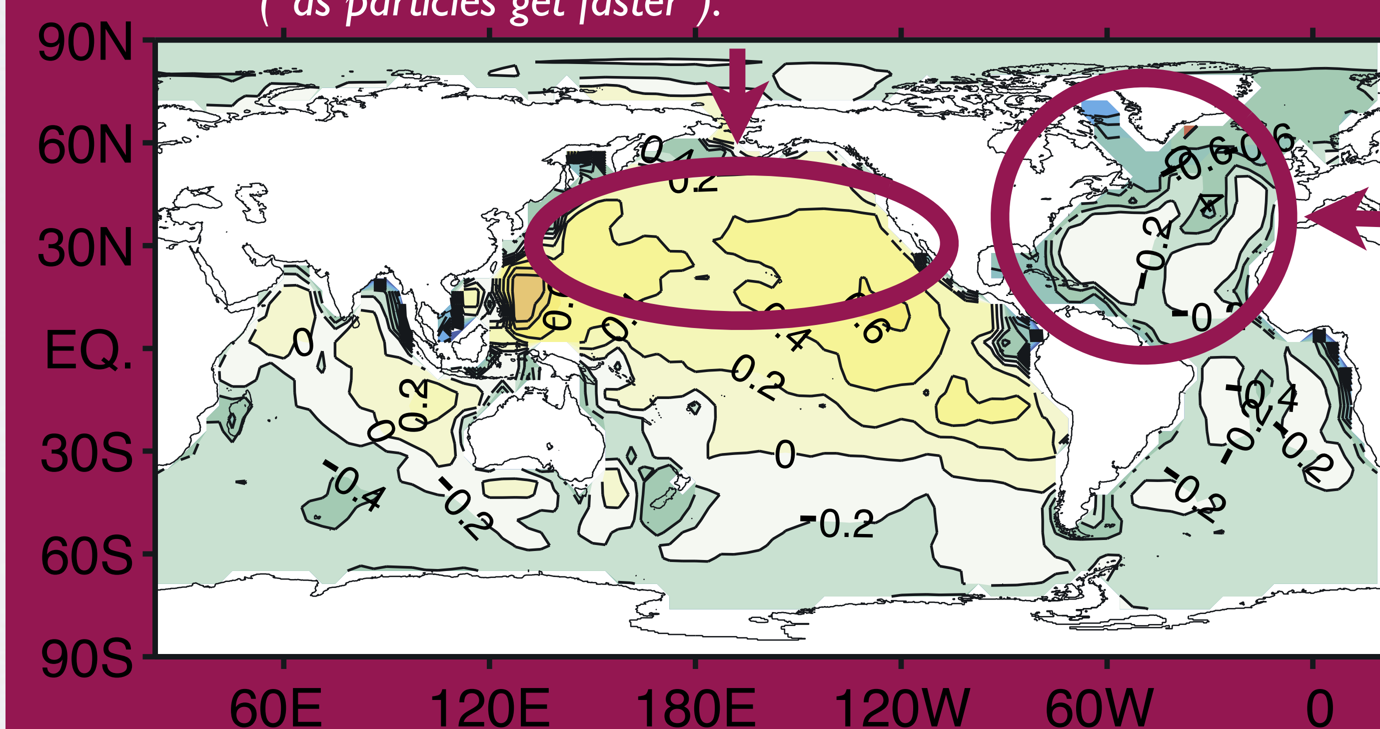




This agrees with model sensitivity calculated by Kwon et al. (2006)

positive sensitivity: increase in PO_4 with increase in flux exponent ("as particles get faster").



negative sensitivity: decrease in PO_4 with increase in flux exponent. (" as particles get faster")

(Kriest et al., submitted)

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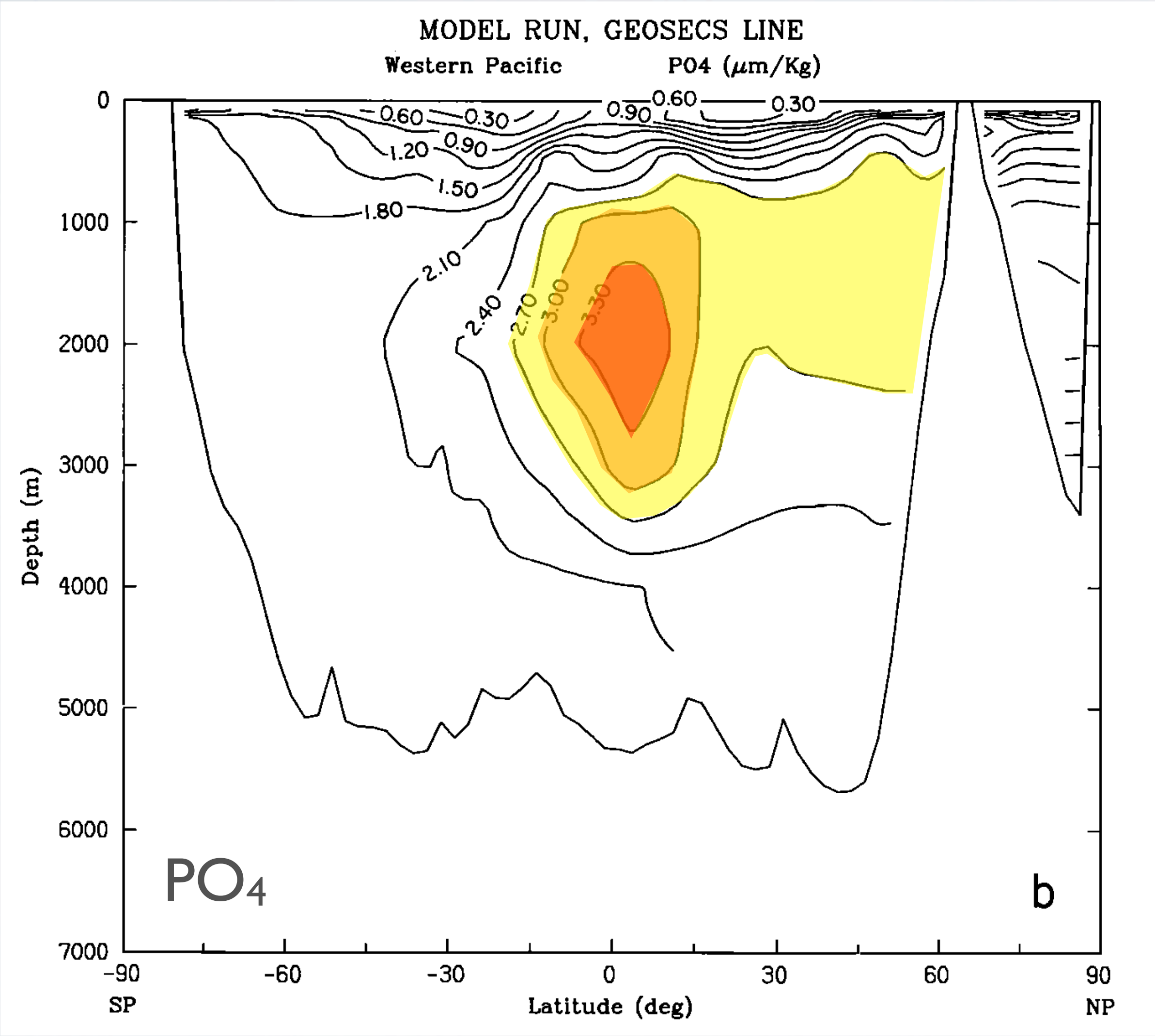
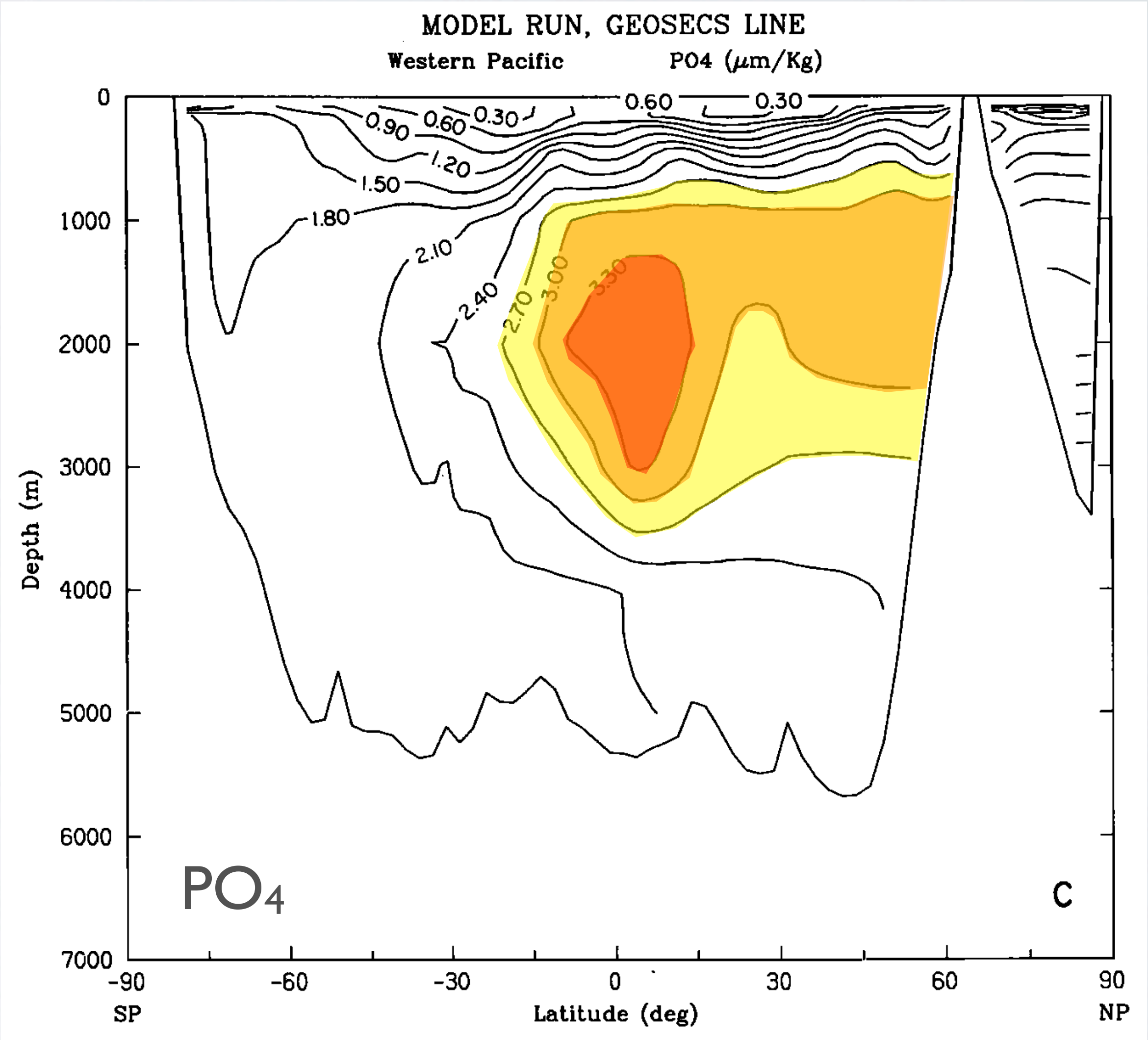
BGC PARAMETERS: NUTRIENTS IN THE WESTERN PACIFIC

A similar effect (increase of nutrients in the northern N. Pacific with increasing sinking speed) has been found by Bacastow & Maier-Reimer (1991; with e-folding flux length scale).

sinking rate = 300 m/d



sinking rate = 500 m/d

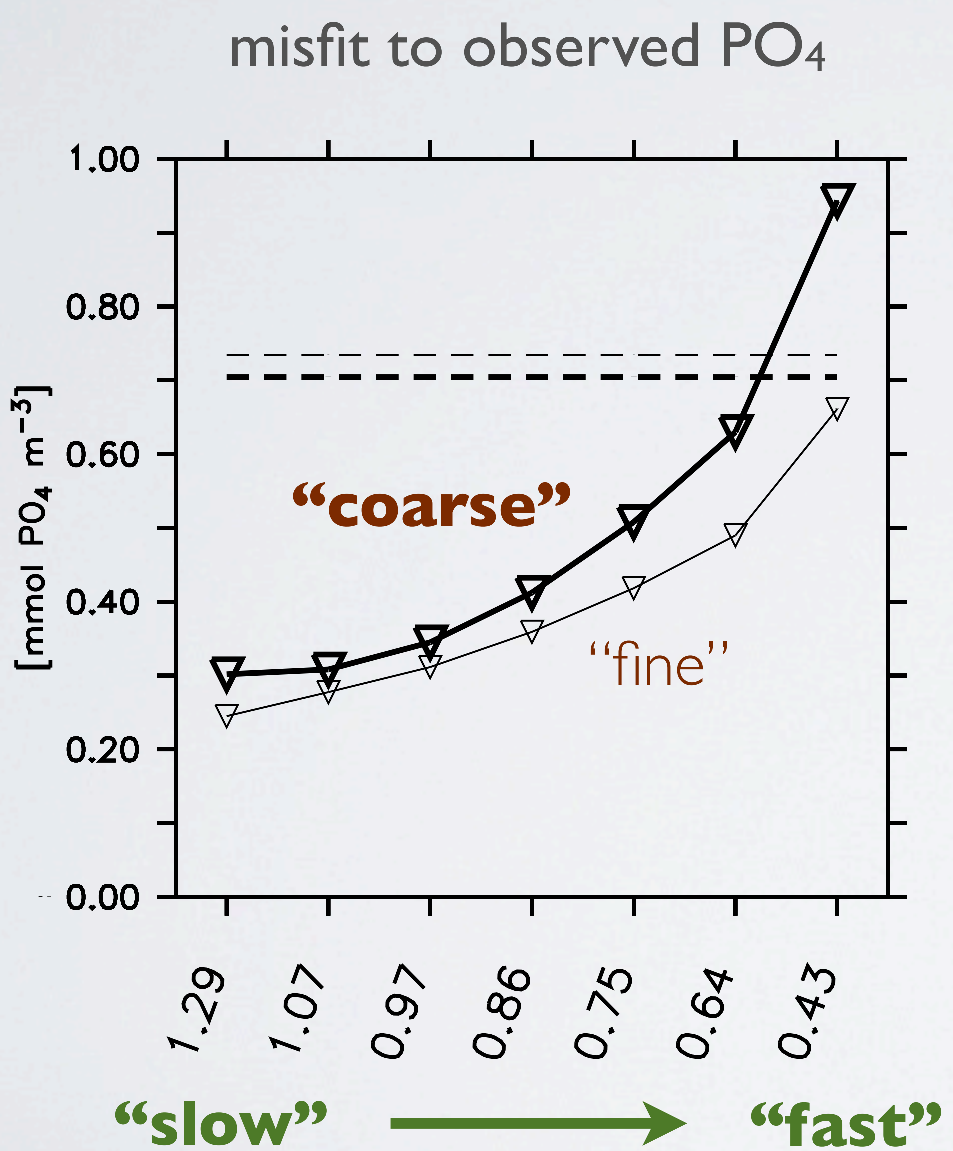


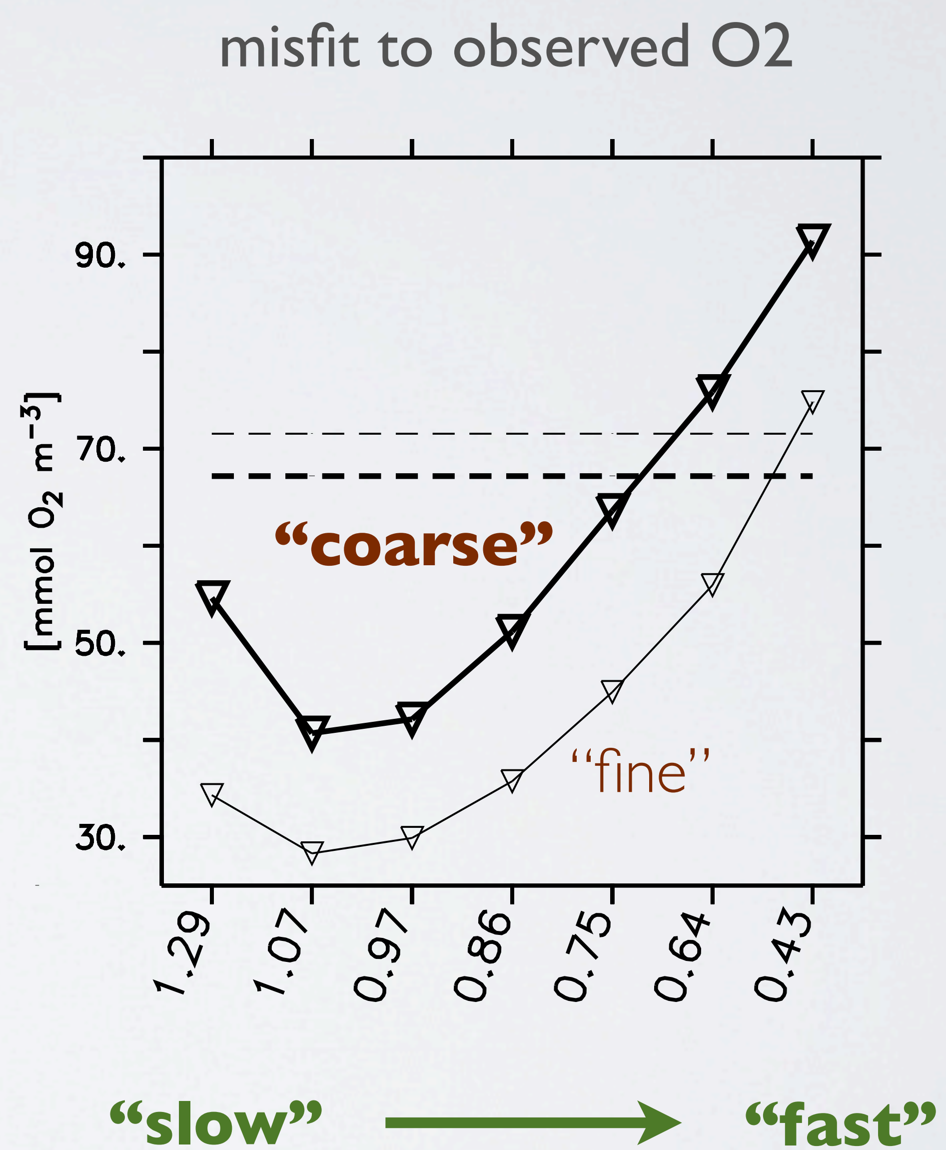
(modfiied from Bacastow & Maier-Reimer, 1991)

EFFECT OF RESOLUTION / PHYSICS

Using improved spatial resolution and different physics (1x1°, 23 vertical levels, "ECCO" circulation):

- improved fit to observations
- same sensitivity to remineralization length scale

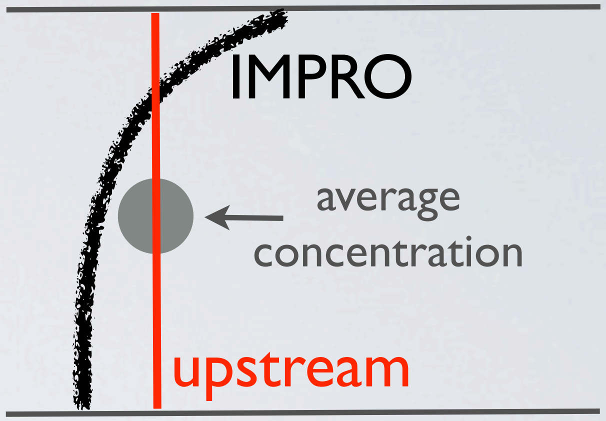




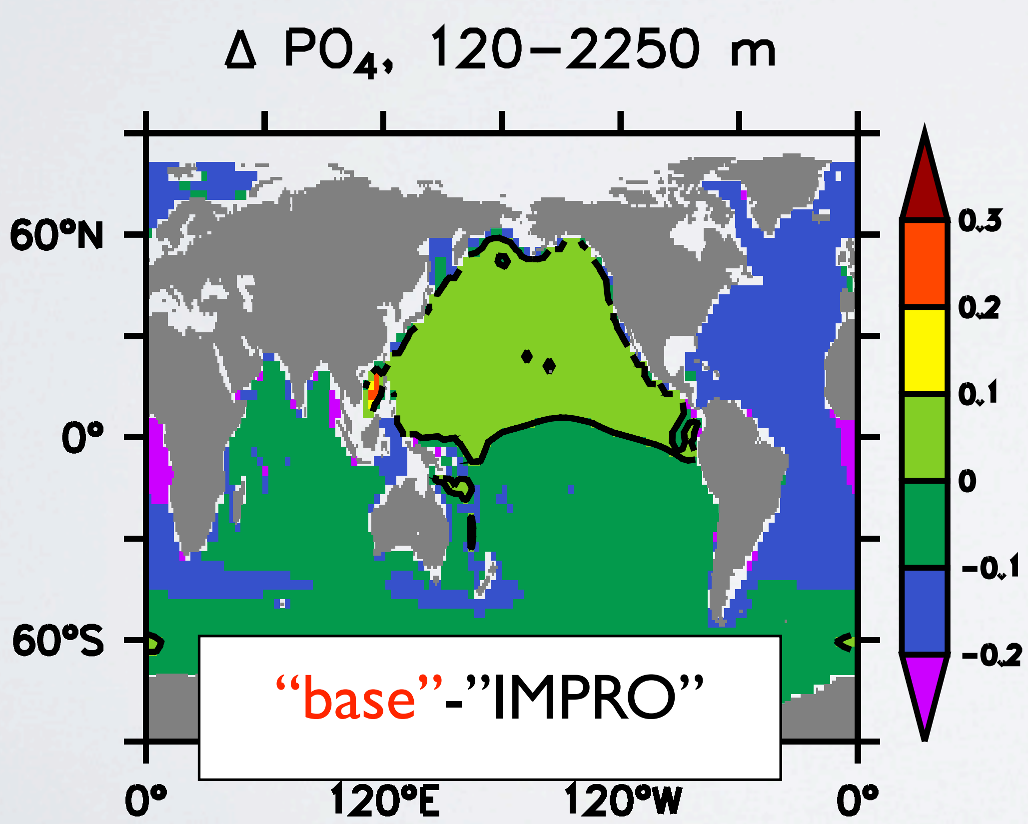
EFFECT OF ADVECTION SCHEME FOR PARTICLE SINKING

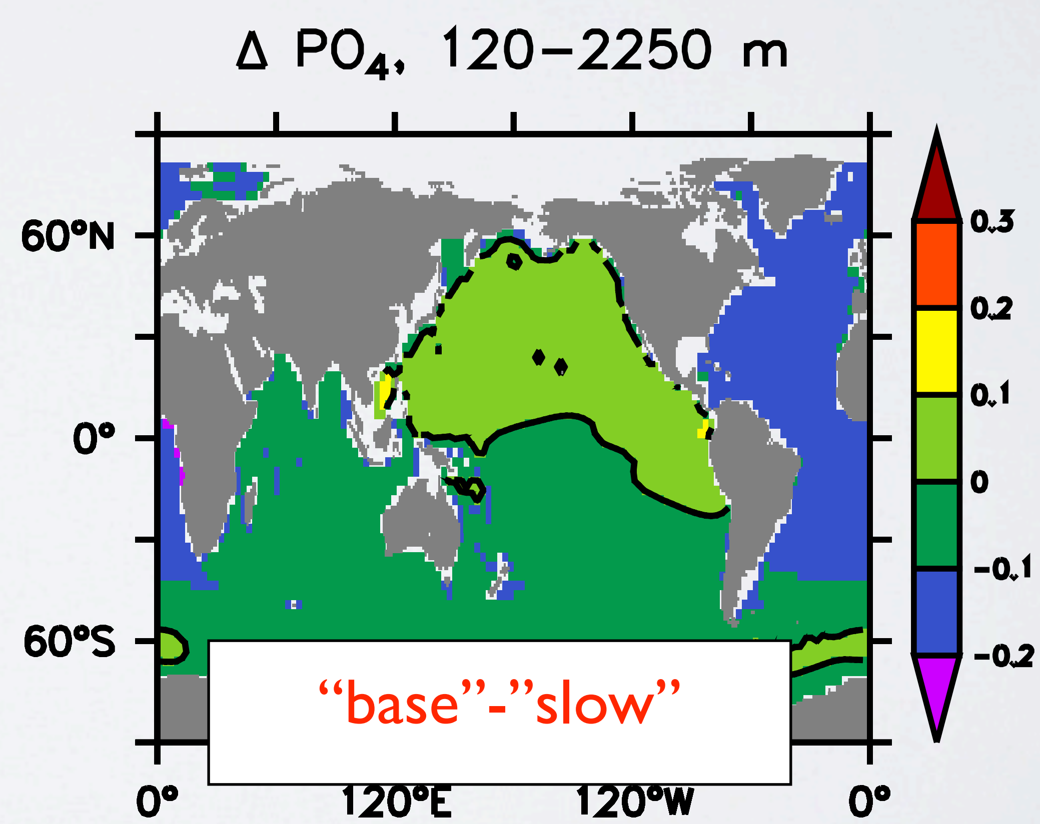
Different advection scheme for particle sinking:
("IMPRO", Kriest & Oschlies, 2011):

- accounts for implicit detritus profile within vertical boxes.
- the implicit profile is consistent with flux length scale.



The effect of advection scheme is similar to a 12.5% increase of "b".



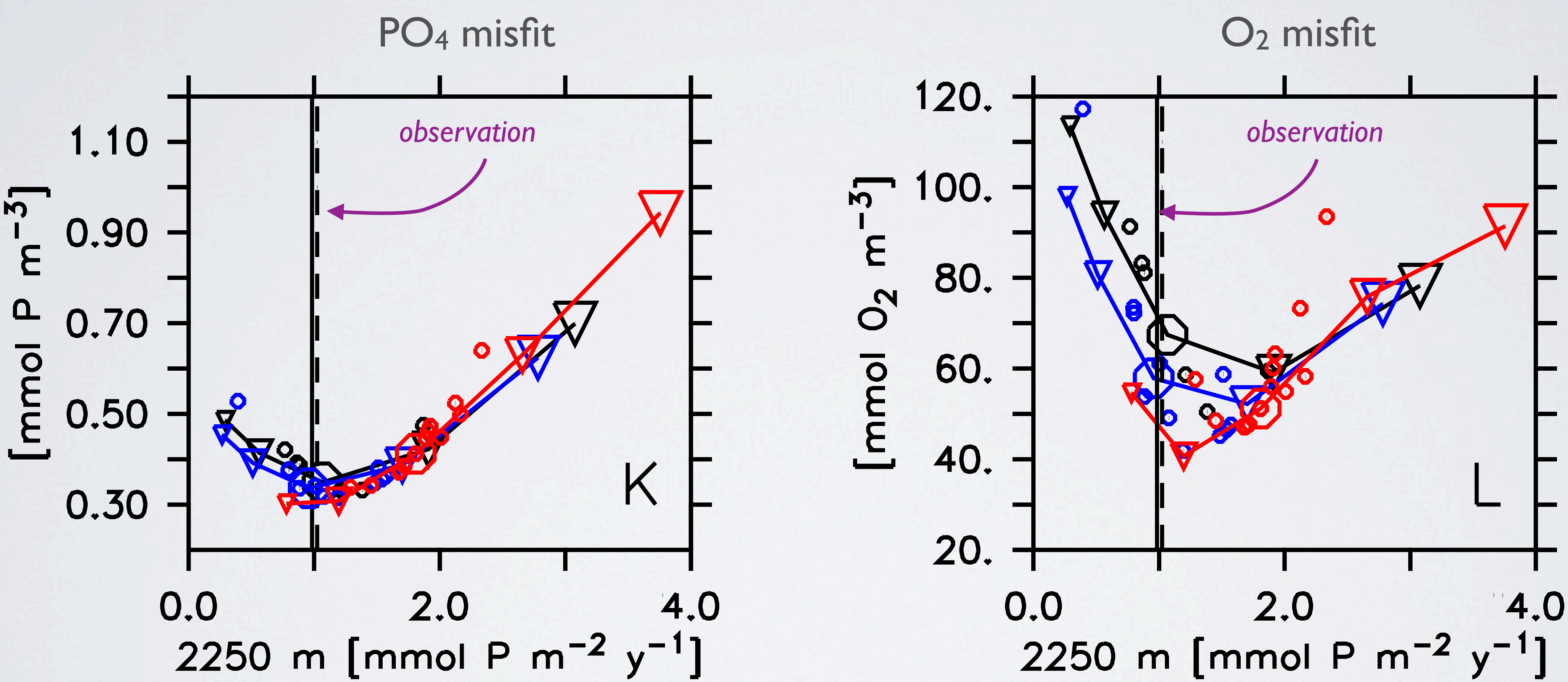


(Kriest and Oschlies, 2011)

USE OBSERVATIONS OF GLOBAL PARTICLE FLUX?

Plot model misfit vs. global deep particle flux:

- Many of the best models agree with observational estimates.



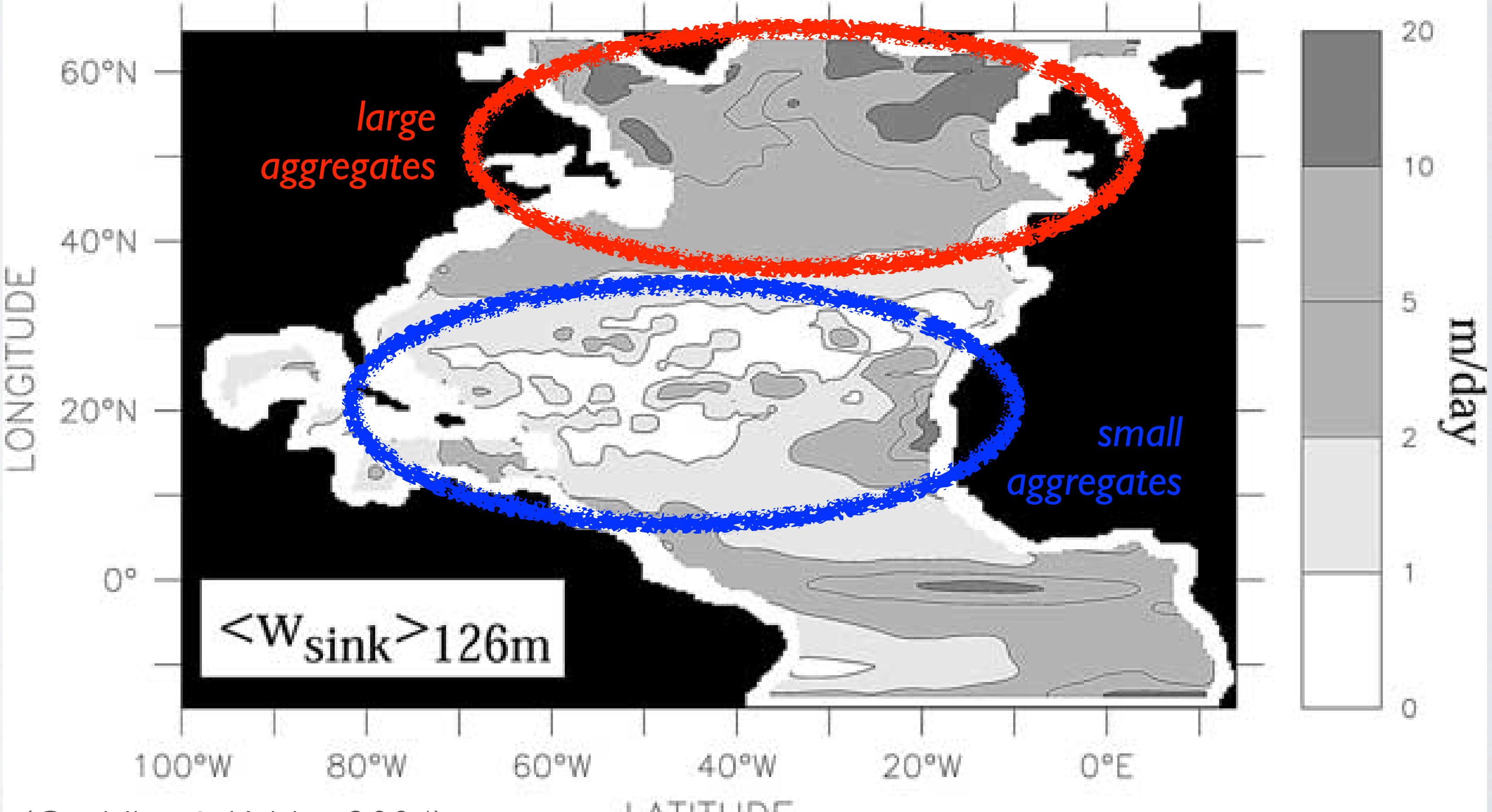
(Kriest et al., submitted; Observations: Honjo et al., 2008; Lutz et al., 2007)

SUMMARY

- Compared to particle sinking
  - so far, biogeochemical complexity of lesser importance for nutrients & oxygen.
  - other biogeochemical parameters mostly important for surface layer.
- Particle sinking important for deep nutrients & oxygen and their global distribution.
- Improved physics can improve fit to nutrients and oxygen, BUT: Sensitivity to particle sinking so far independent of physics/resolution.
- Sensitivity to numerics similar to moderate change in particle sinking.
- Deep particle flux of best models agrees with observed global estimates.

What about spatially and/or temporally variable sinking speed (particle size)?

To constrain such models well, observations of size (distributions) would be very helpful!



(Oschlies & Kähler, 2004)

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