Impact of global change on ocean biogeochemical cycles (N, P, C and trace elements)
Palma de Mallorca, 17 – 21 Oct 2011

IV. Ocean biogeochemical cycles

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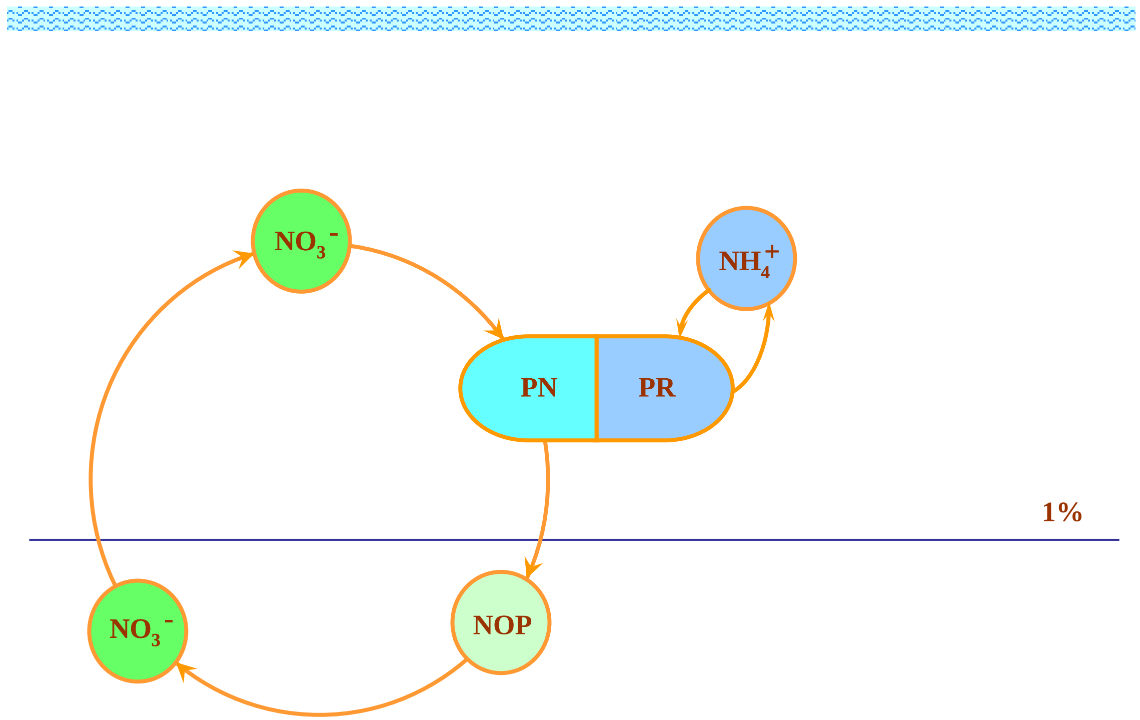
outline of this presentation

ocean biogeochemical cycles

- **the biological pump: before (1980's) and after (1990's)**
- **cycling of biogenic organic matter: nitrogen and phosphorus in the oceans**
- **cycling of biogenic inorganic matter: silicon and calcium carbonate**

the biological pump in the oceans

the biological pump in the 1980's

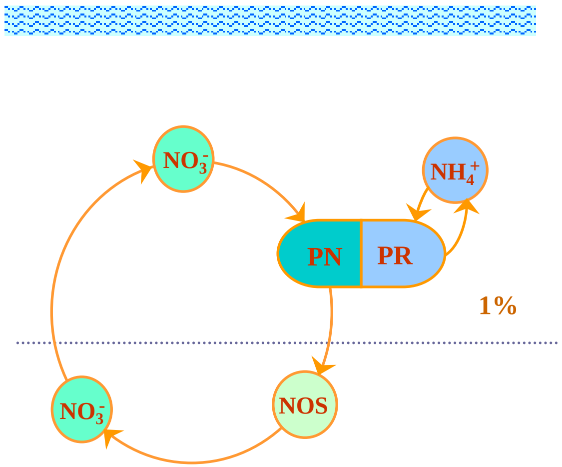


Eppley & Petersen (1979) model

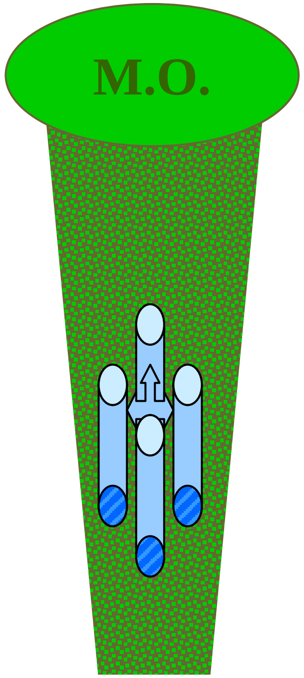
the biological pump in the oceans

the biological pump in the 1980's

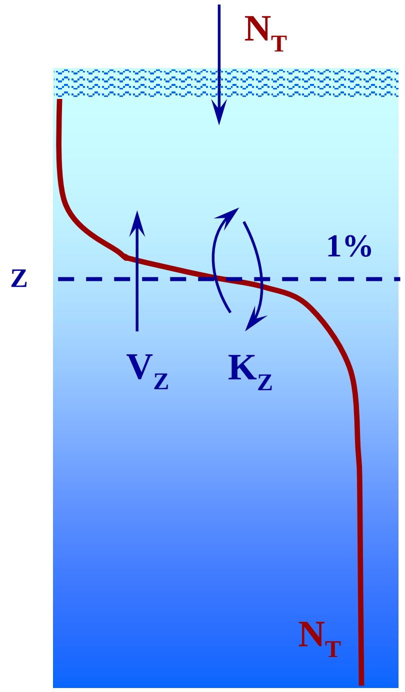
$^{15}NO_3^-$, $^{15}NH_4^+$



sediment traps



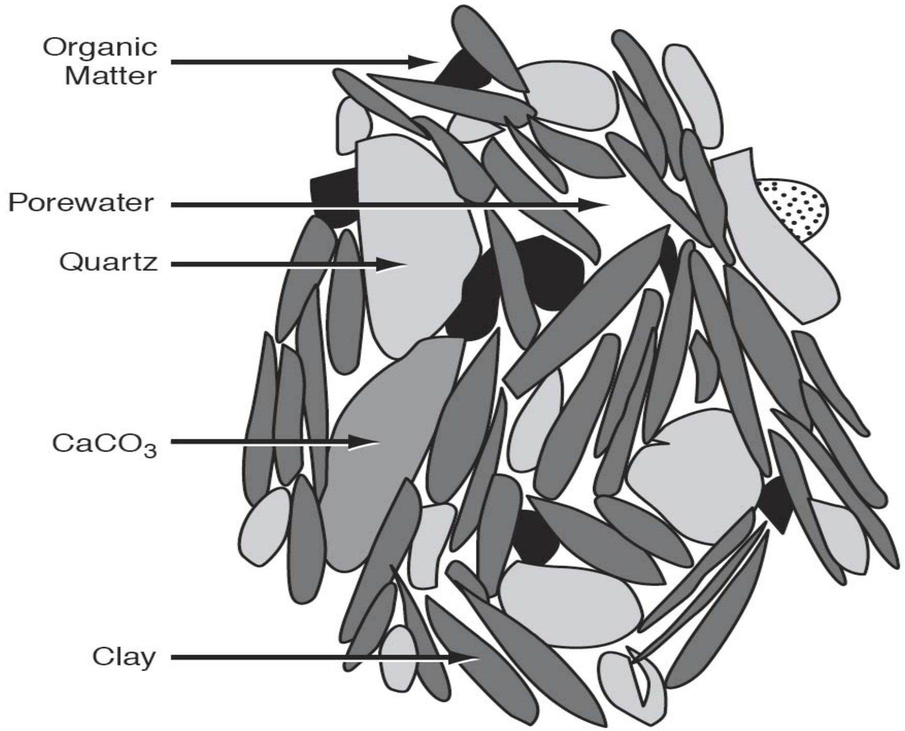
geochemical budgets



new or exportable production estimates

the biological pump in the oceans

the biological pump in the 1980’s



new or exportable production estimates

Sarmiento & Gruber, 2006 (http://www.up.ethz.ch/people/ngruber/publications/textbook)

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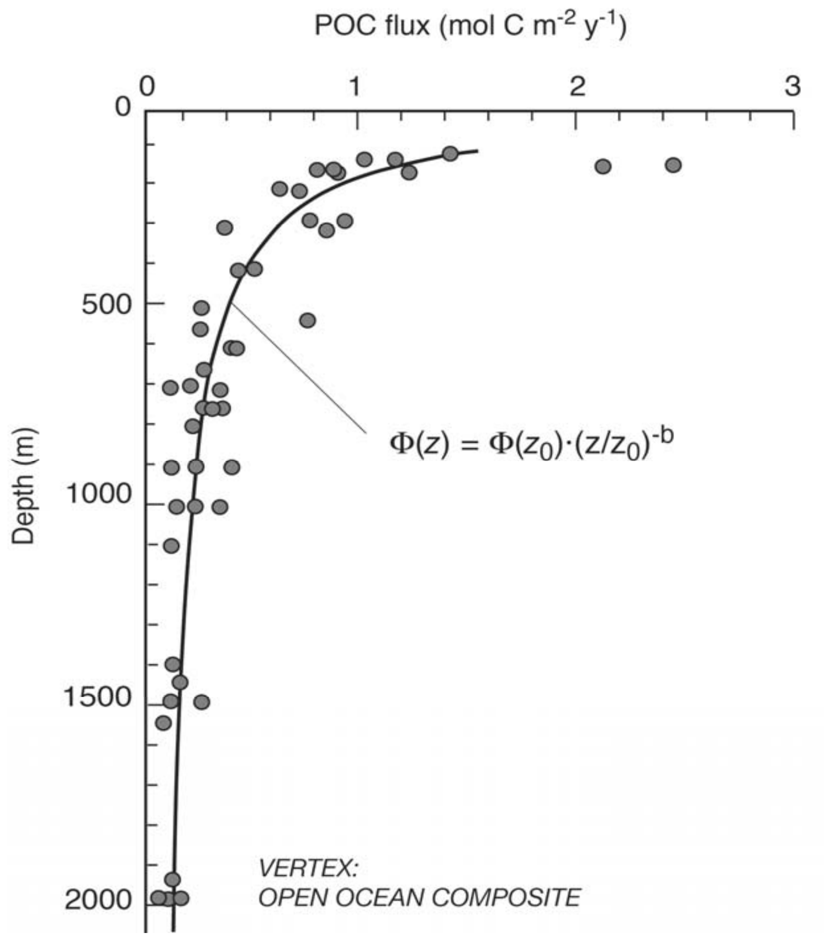

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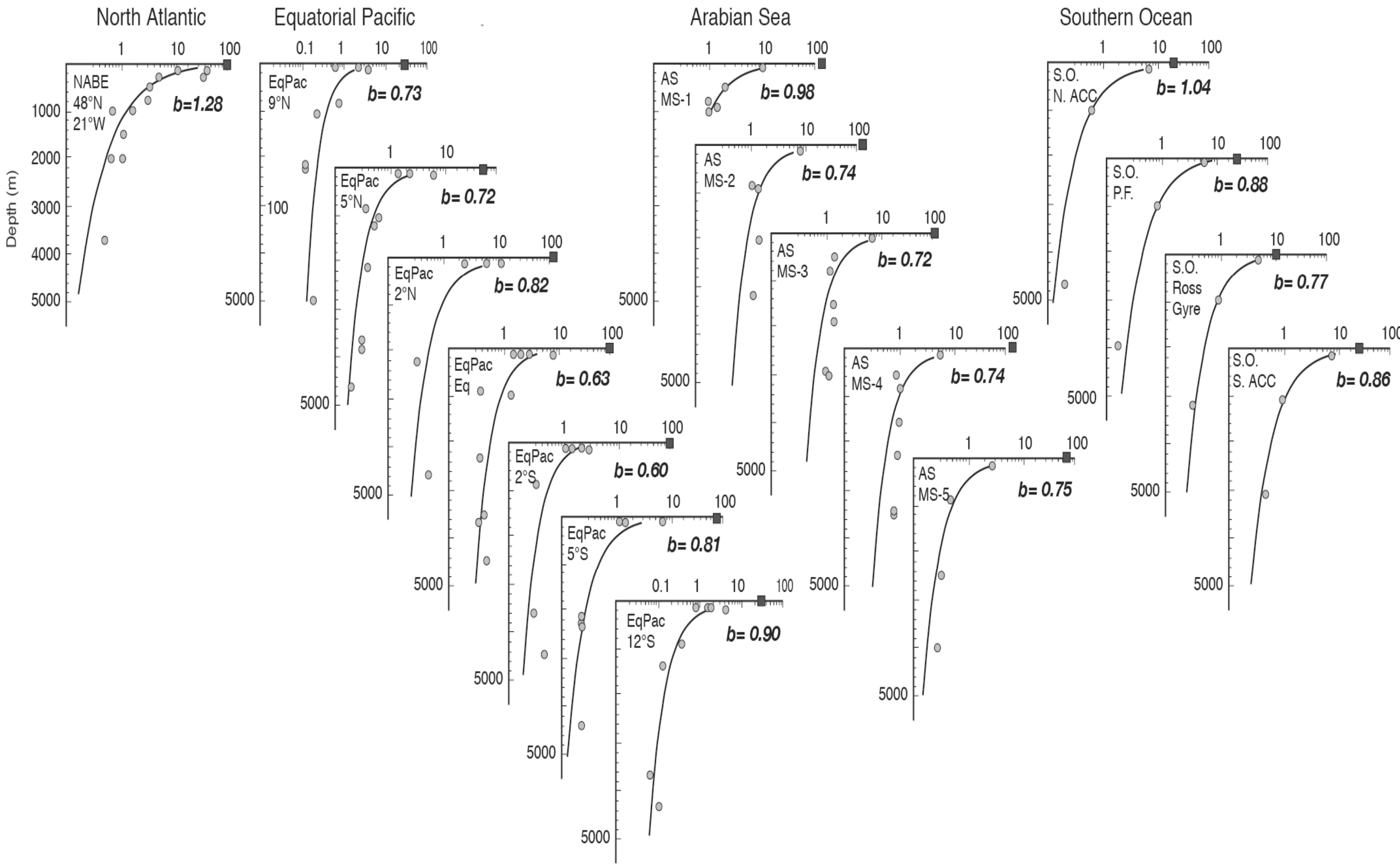

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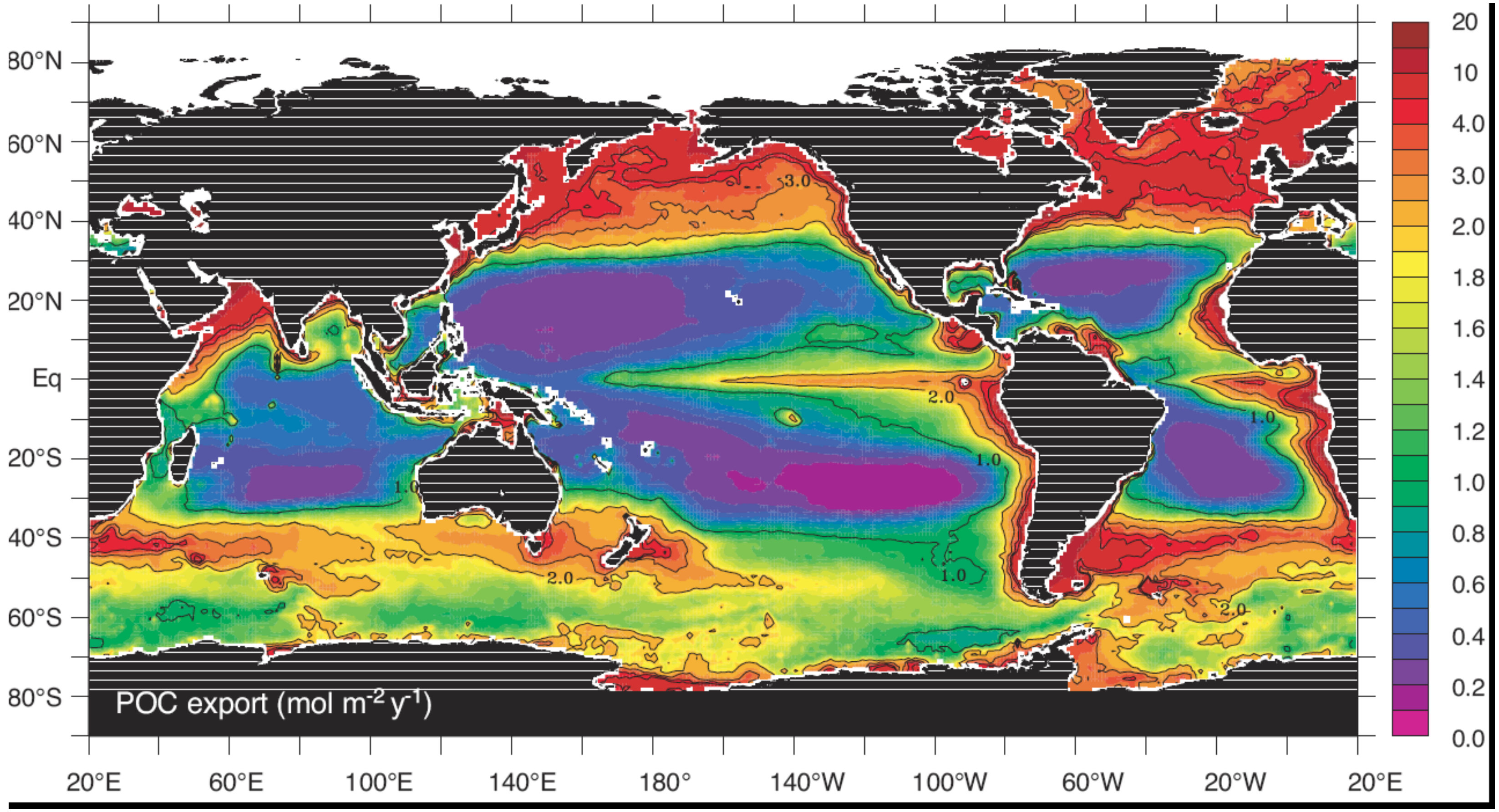

sediment traps: fluxes at the epi-mesopelagic interface (150 m)

Sarmiento & Gruber, 2006 (http://www.up.ethz.ch/people/ngruber/publications/textbook)

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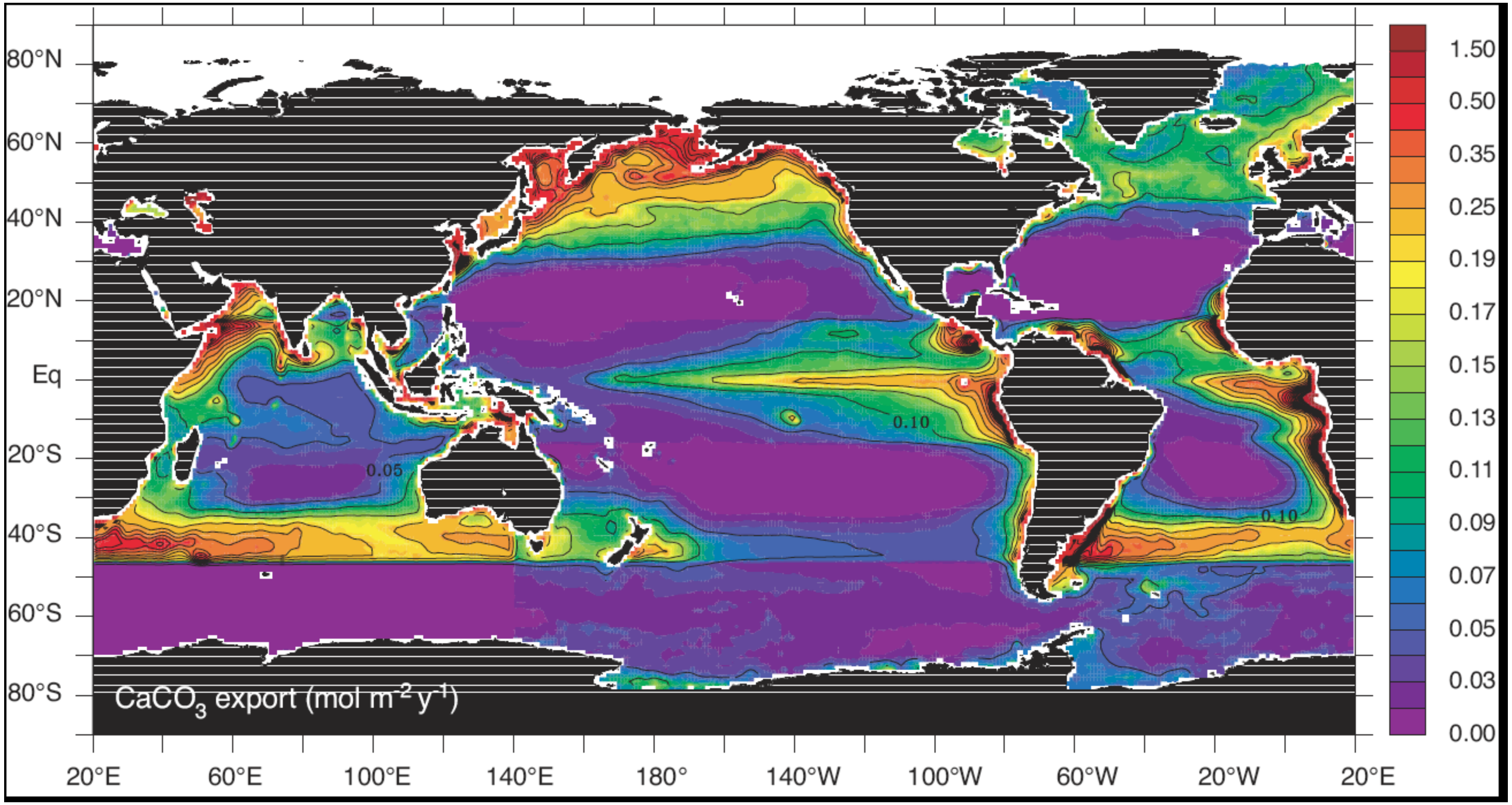

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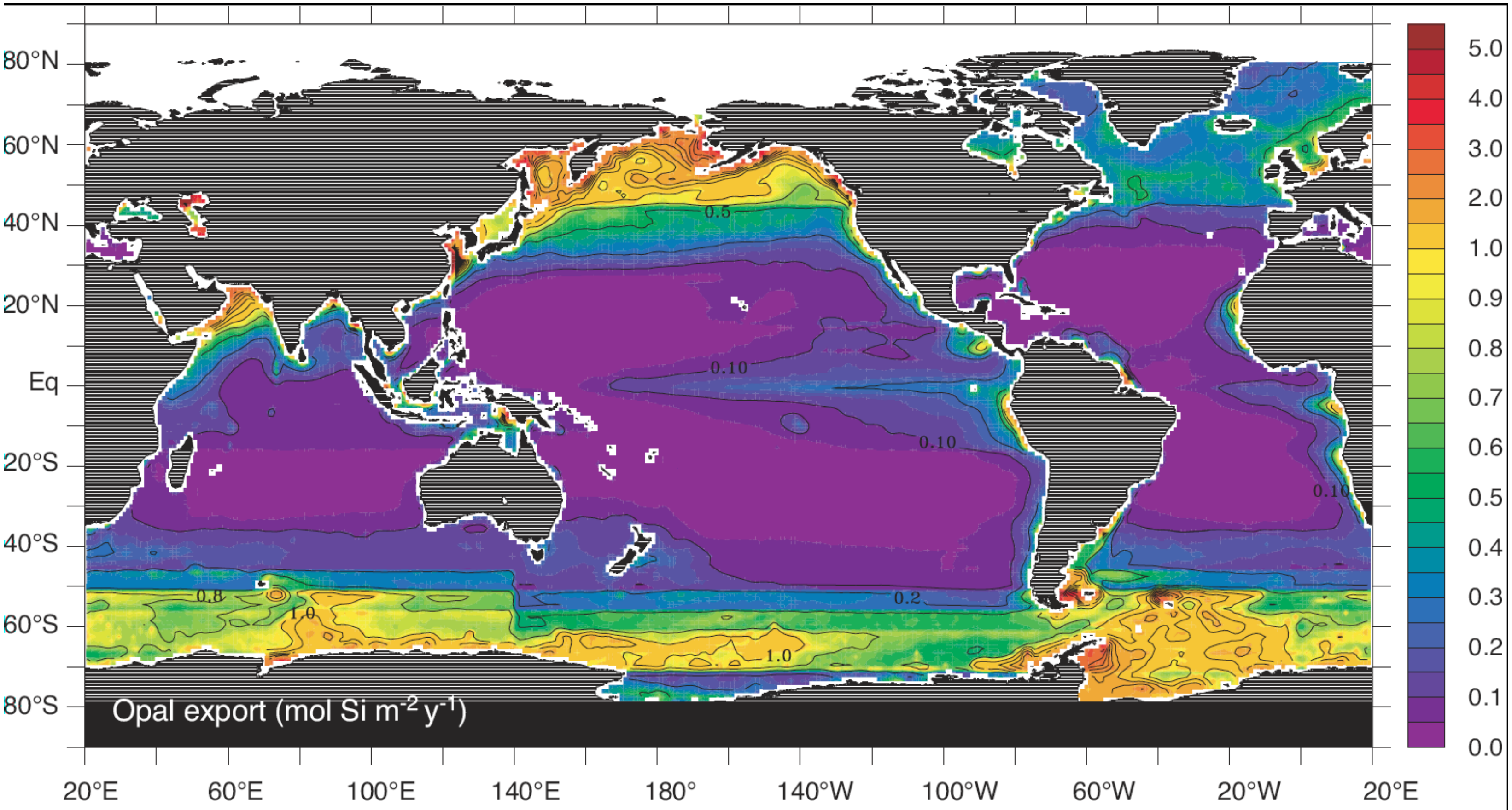

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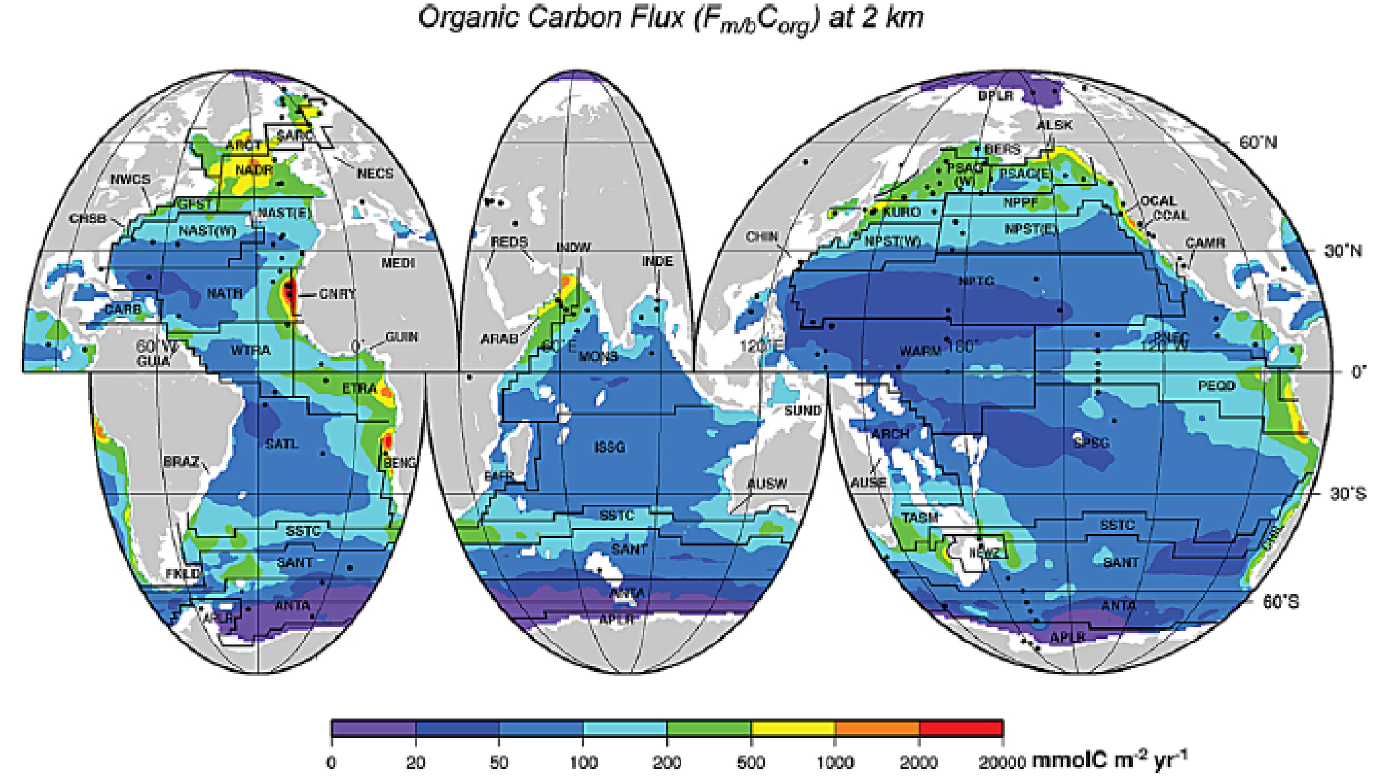

Fig. 9. Global parameterization of $F_{2\ km}C_{org}$ in mmolC m^{-2} yr^{-1} based on individual TS-trap data sets from four model domains—the Trade Wind Domain (as in Longhurst et al., 1995), the Arabian Sea Region, the Antarctic Zone, and data from default stations—projected on the geography of biogeochemical provinces and stations that were used for analyzing the data presented in this paper.

sediment traps: fluxes at the meso-batipelagic interface (2 Km)

Honjo et al.., Prog. Oceanogr., 2008

the biological pump in the oceans

the biological pump in the 1980's

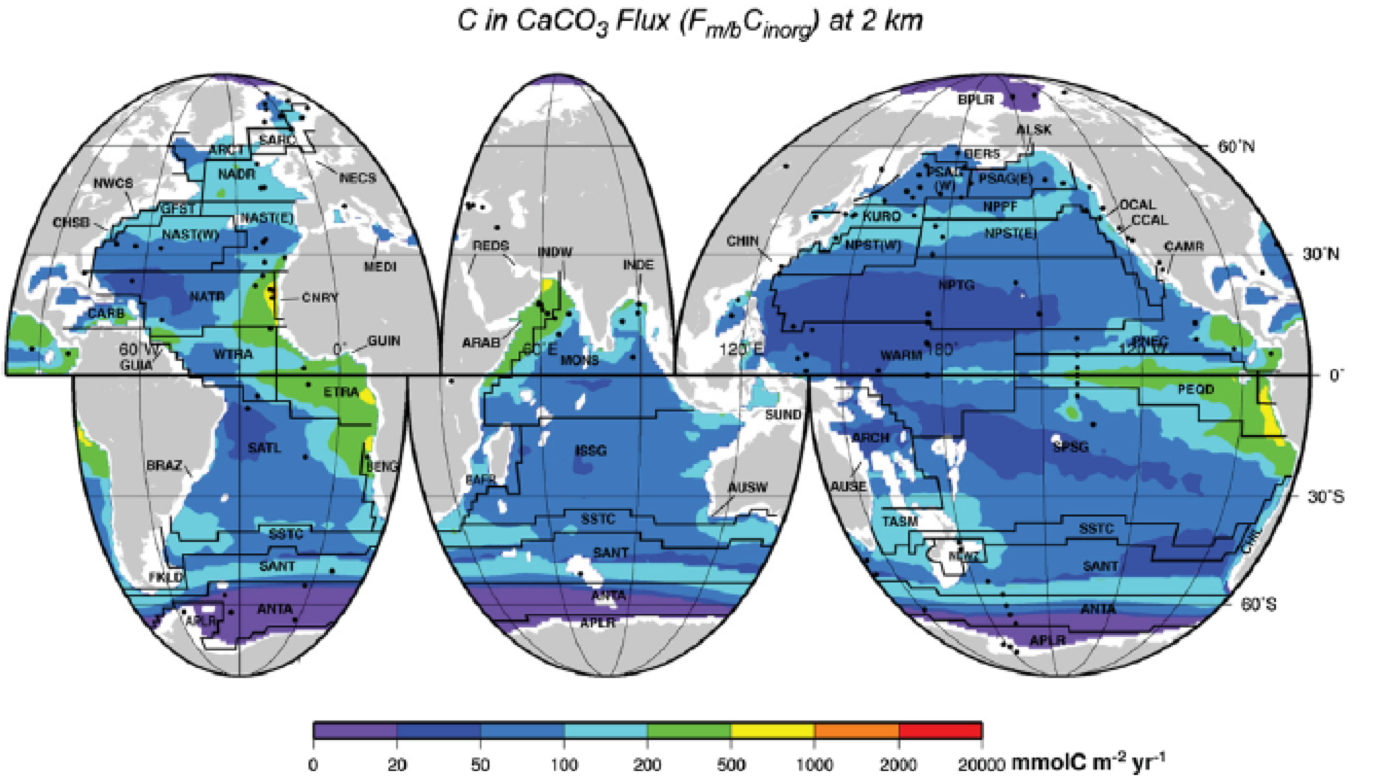

Fig. 10. Global parameterization of $F_{m/b}C_{inorg}$ in mmolC m^{-2} yr^{-1} based on individual TS-trap data sets from four model domains as in Fig. 9.

sediment traps: fluxes at the meso-batipelagic interface (2 Km)

the biological pump in the oceans

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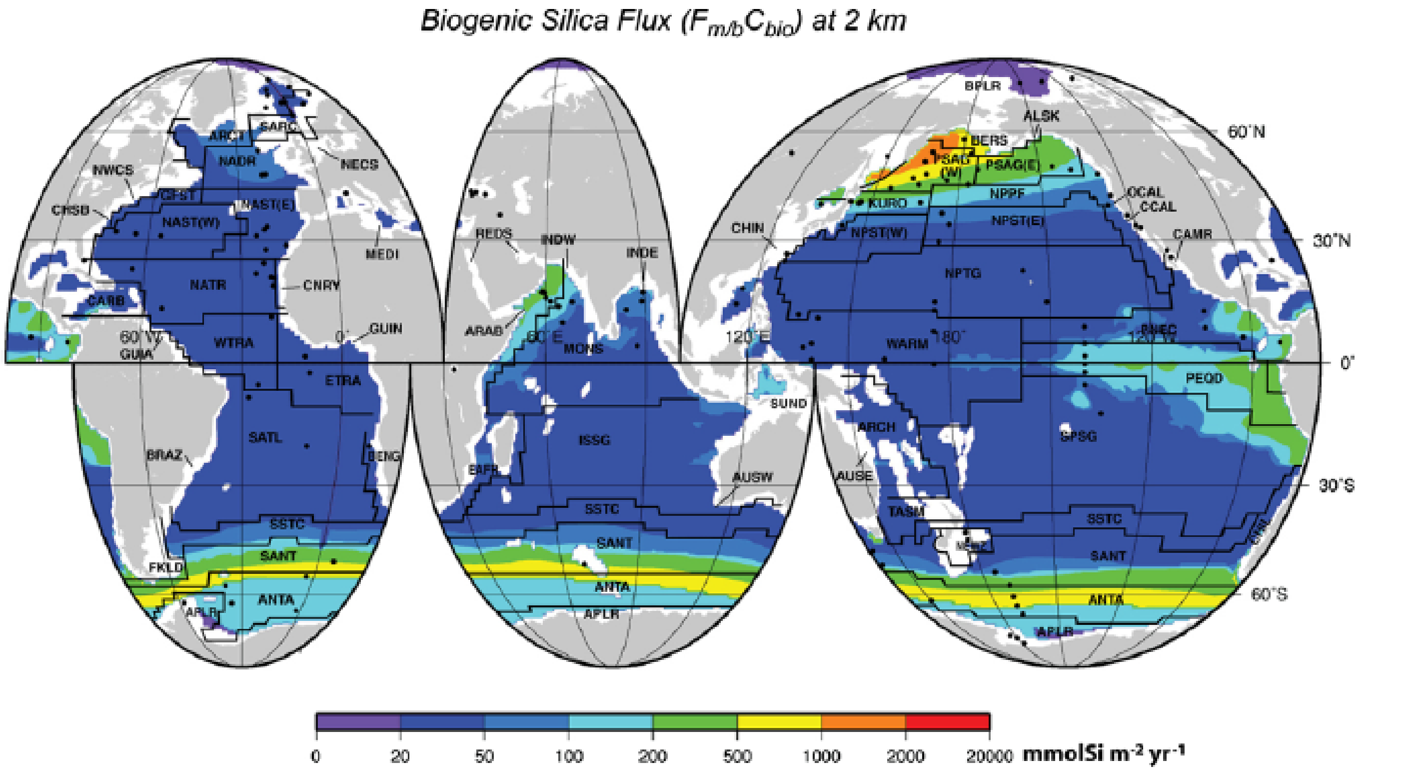
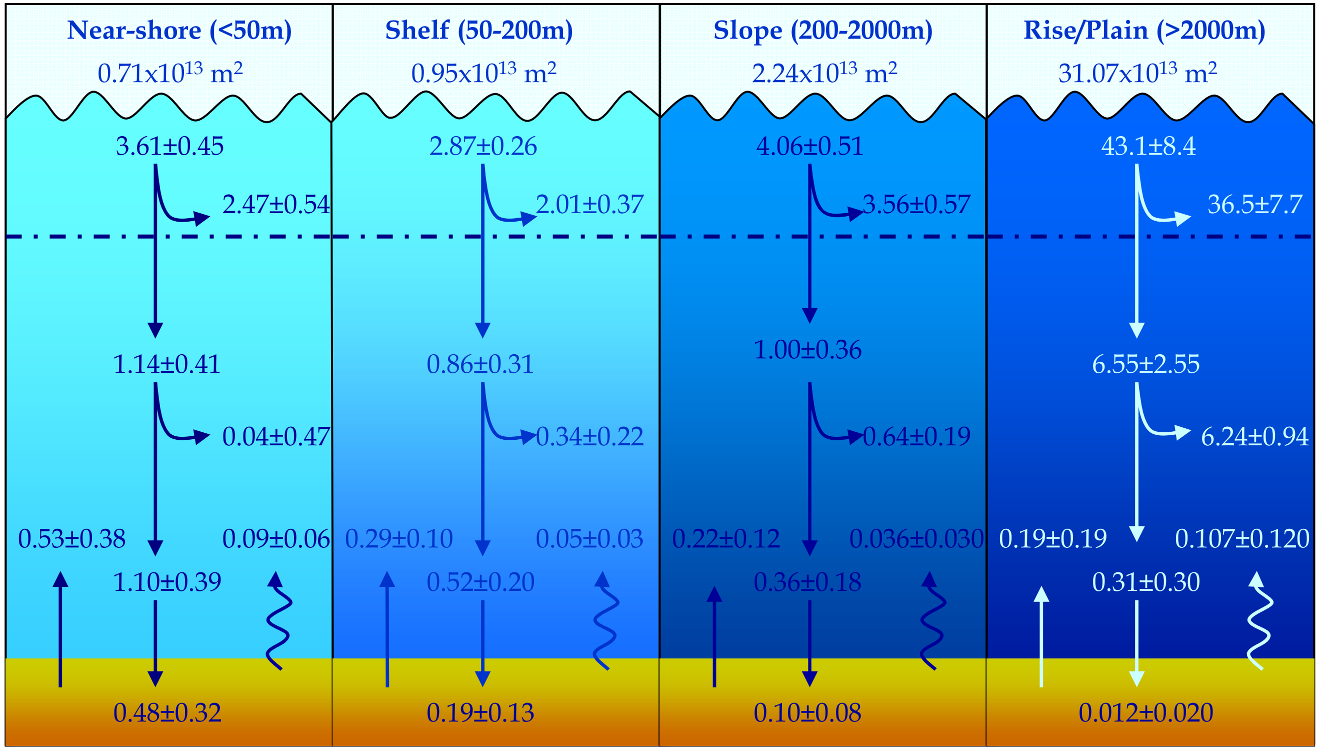


Fig. 11. Global parameterization of $F_{m/b}Si_{bio}$ in mmolSi m^{-2} yr^{-1} based on individual TS-trap data sets from four model domains as in Fig. 9.

sediment traps: fluxes at the meso-batipelagic interface (2 Km)

the biological pump in the oceans

the biological pump in the 1980's

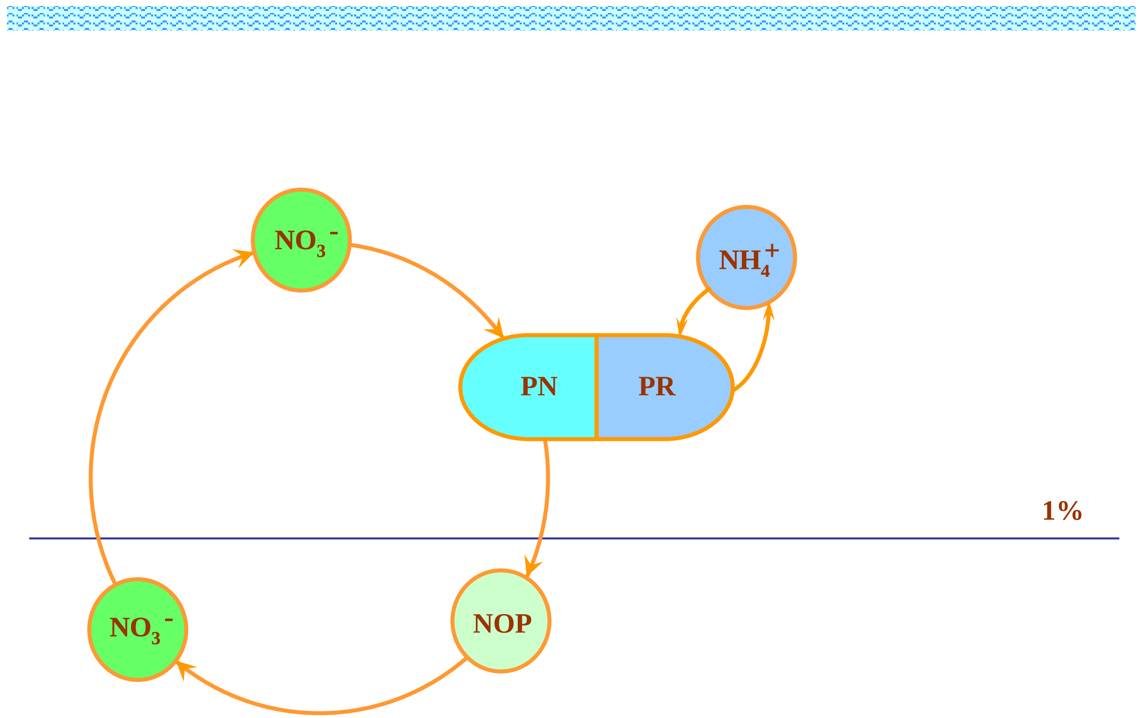


sediment traps: summary of organic carbon fluxes (Pg C/a)

Dunne et al.., Global Biogeochem. Cy., 2007

the biological pump in the oceans

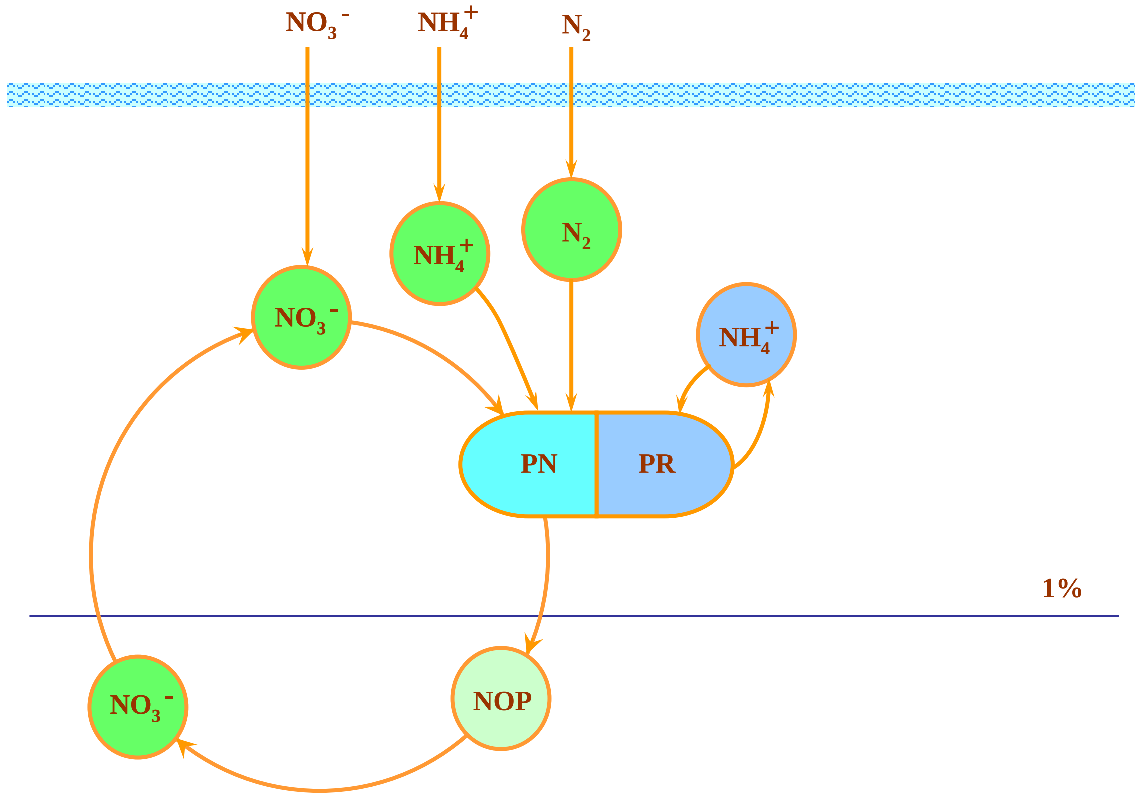
the biological pump in the 1980's



atmospheric inputs

the biological pump in the oceans

the biological pump in the 1980's



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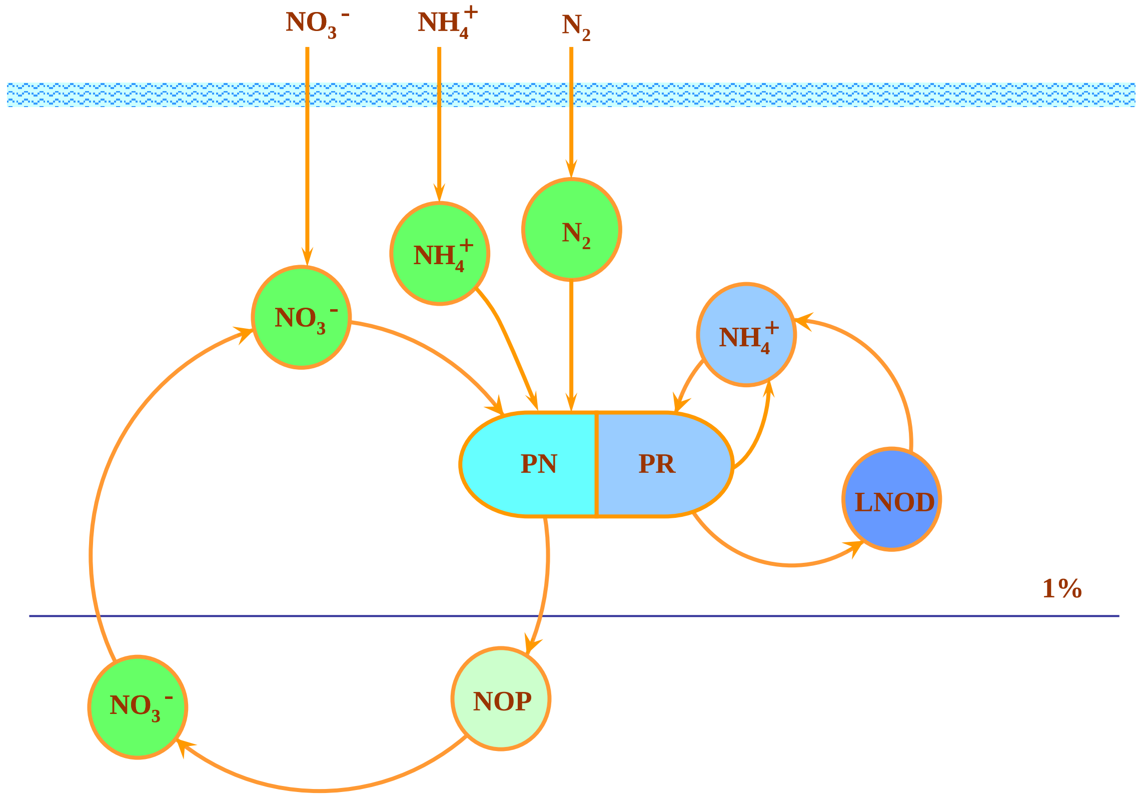
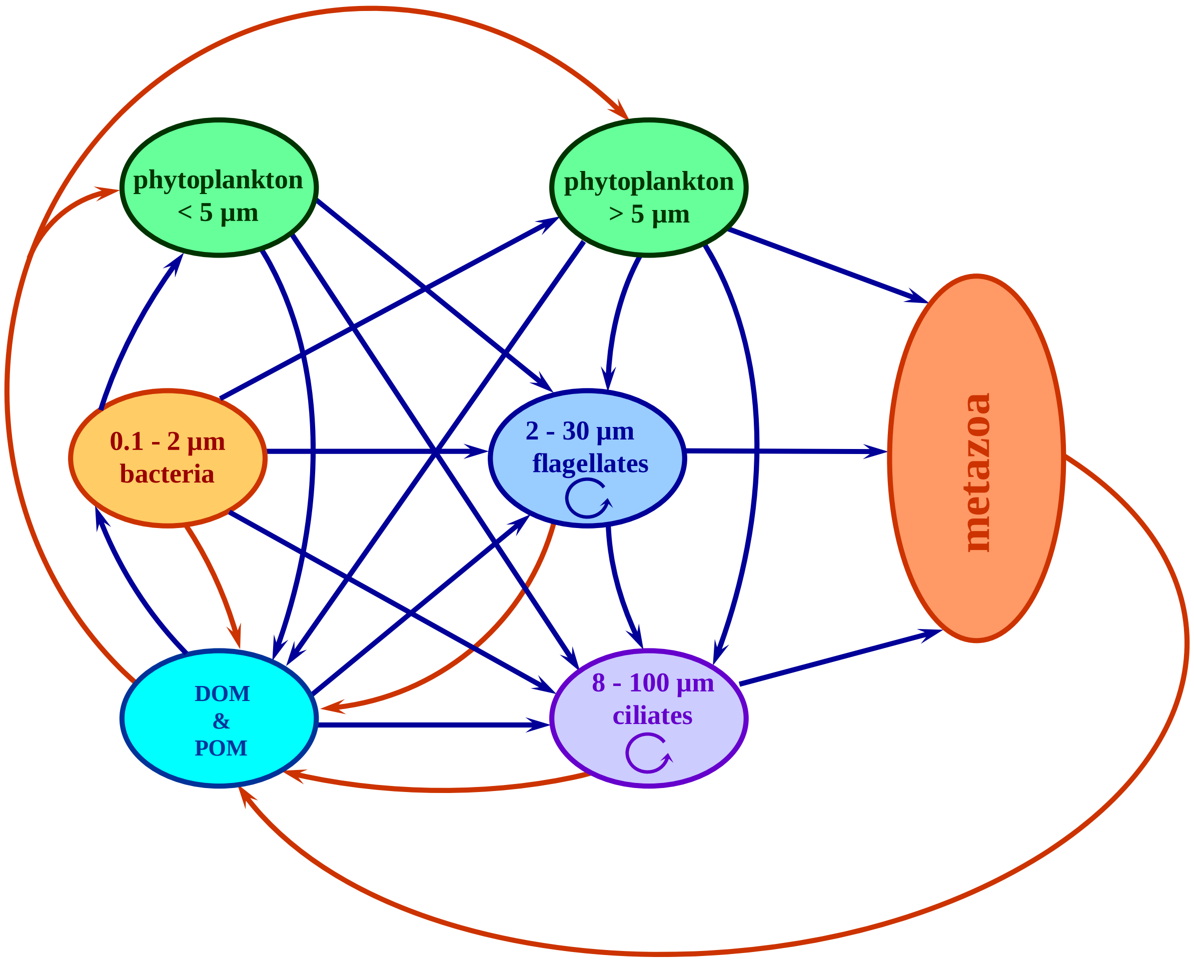


l-DOM: recycled in hours-days

the biological pump in the oceans

the biological pump in the 1990's



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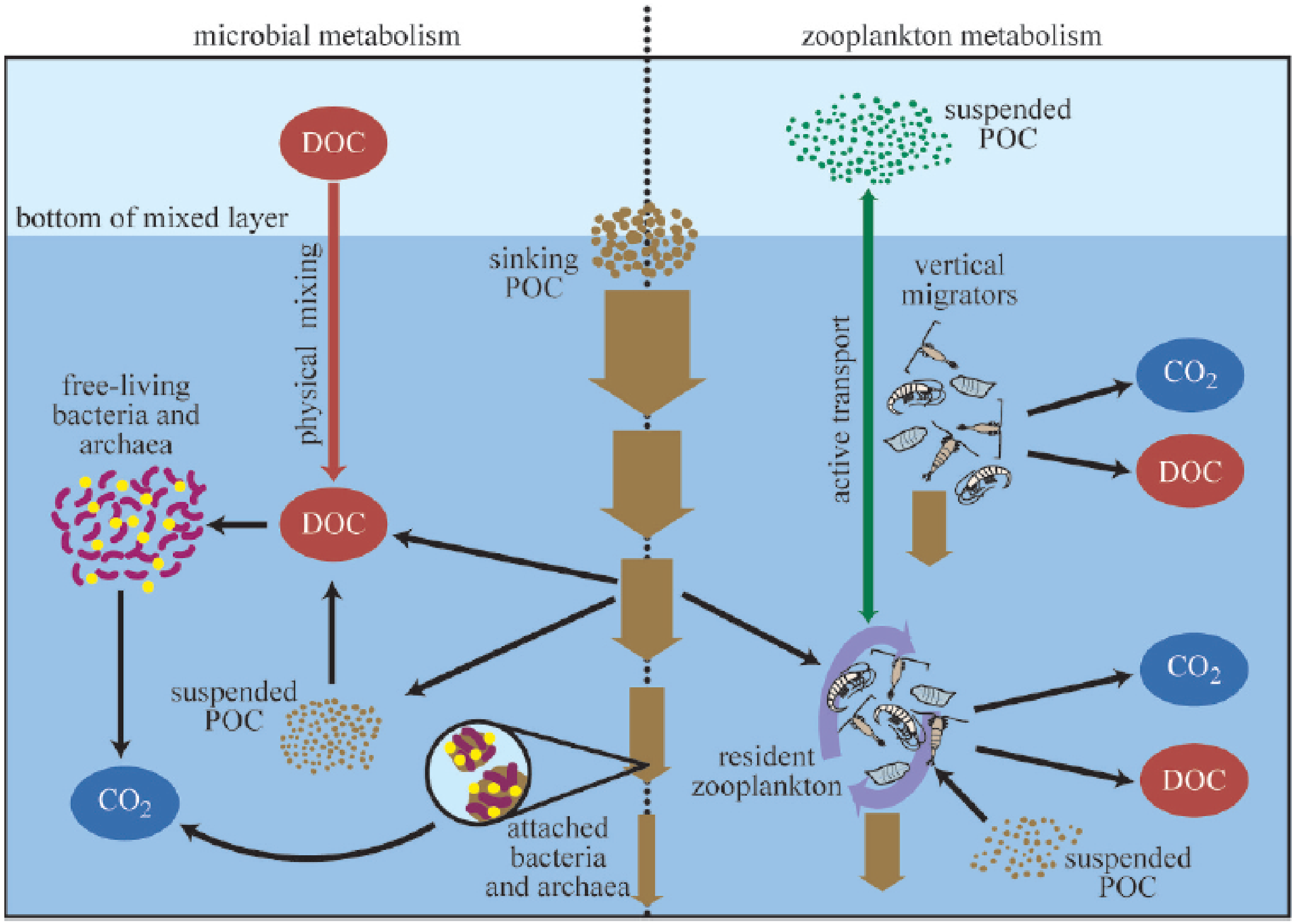

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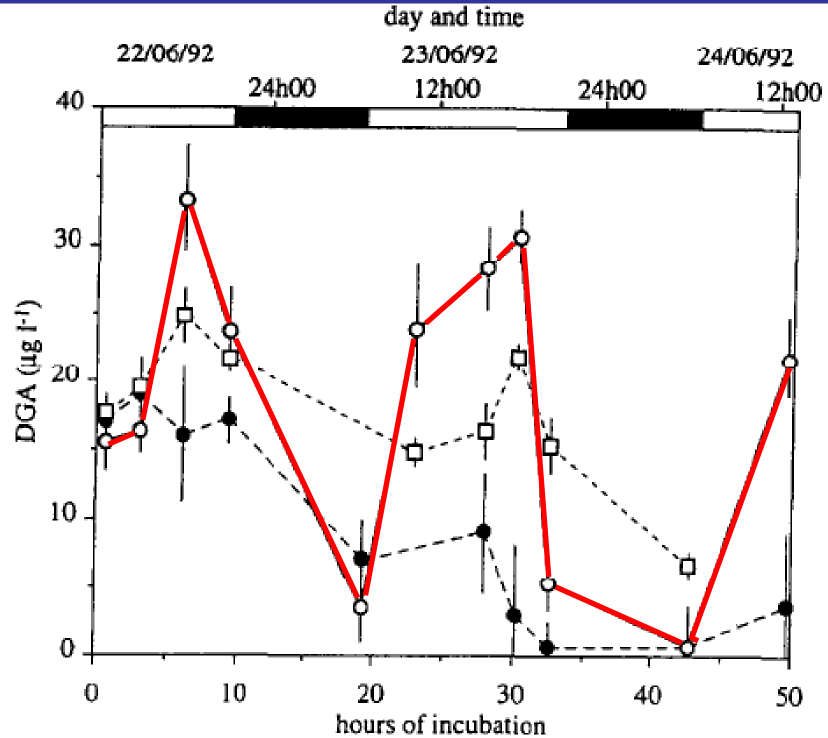

Fig. 1. Evolution of dissolved glycolate concentrations in closed bottles of unenriched natural sea water. Water was taken at 139 m depth at the oligotrophic site, eastern Atlantic Ocean, and filtered on 200 µm mesh to remove large particles and grazers. Open circles and bold lines are for the natural surface light incubations; open squares and dashed lines are for 1% light irradiance bottles; and closed circles and dashed lines are for the dark incubation. Beginning of the experiment was at 10h00, June 23, 1992, and night periods are marked by black bands. Errors bars = SE (3σ).

l-DOM: recycled in hours-days

the biological pump in the oceans

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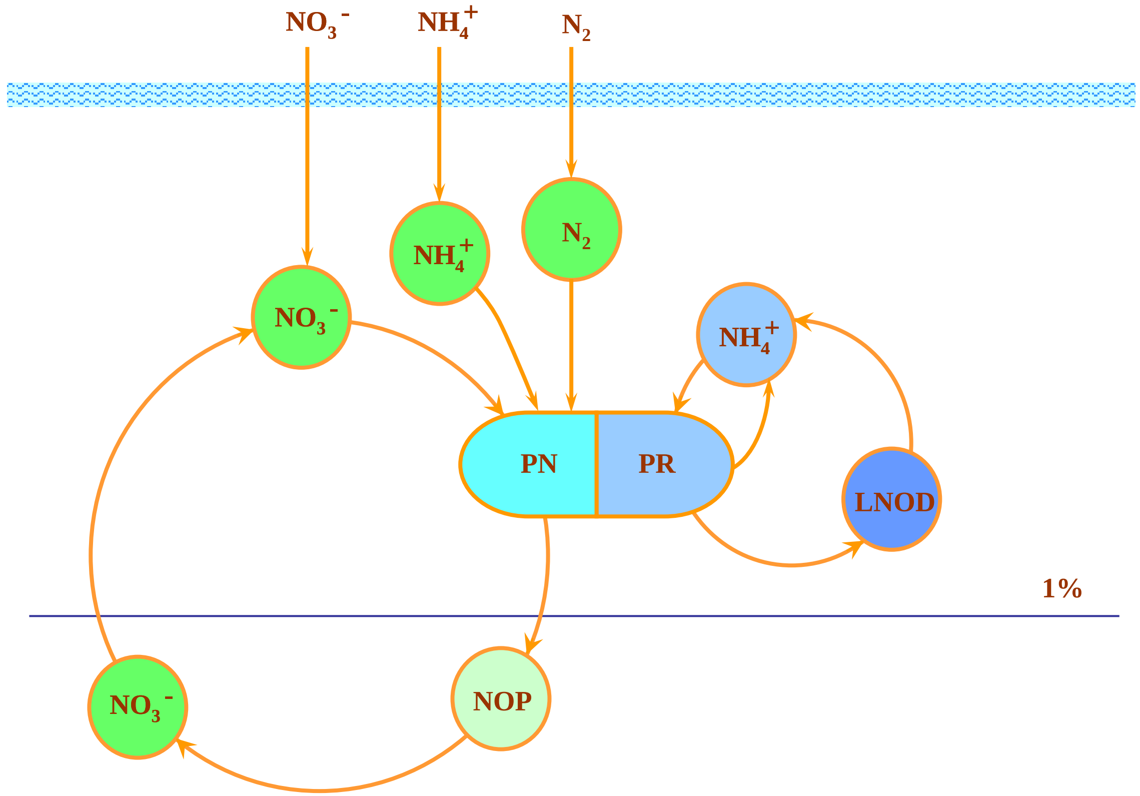

s-DOM: recycling in weeks-months

the biological pump in the oceans

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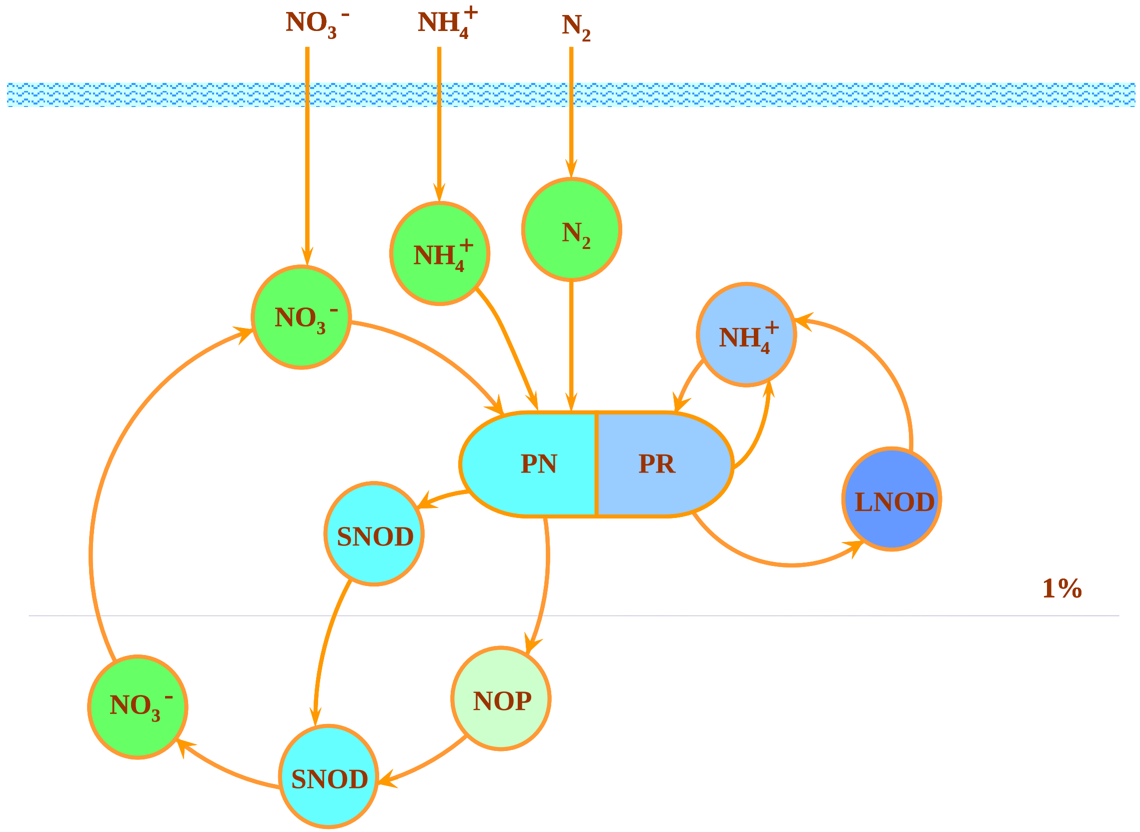

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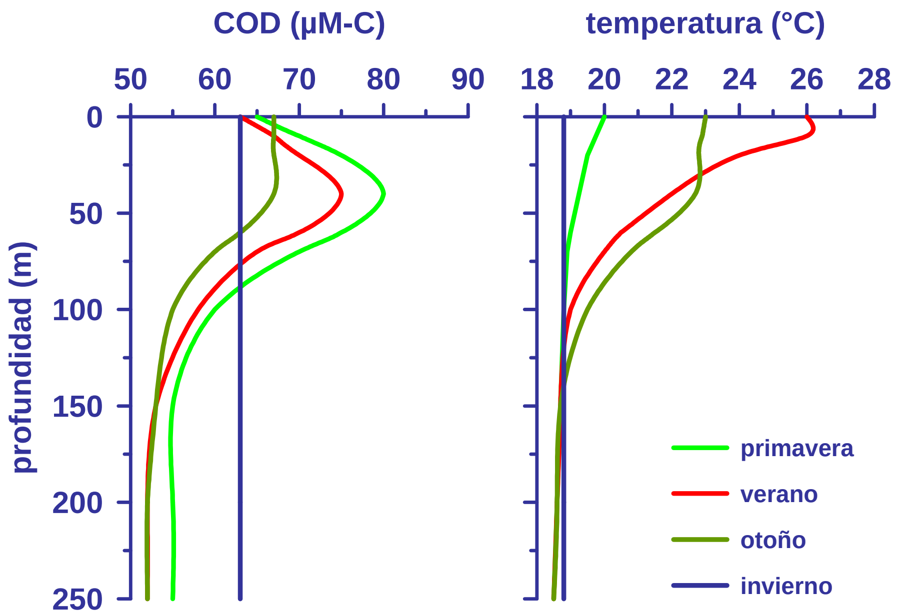

s-DOM: recycling in weeks-months

Carlson et al., Nature, 1994

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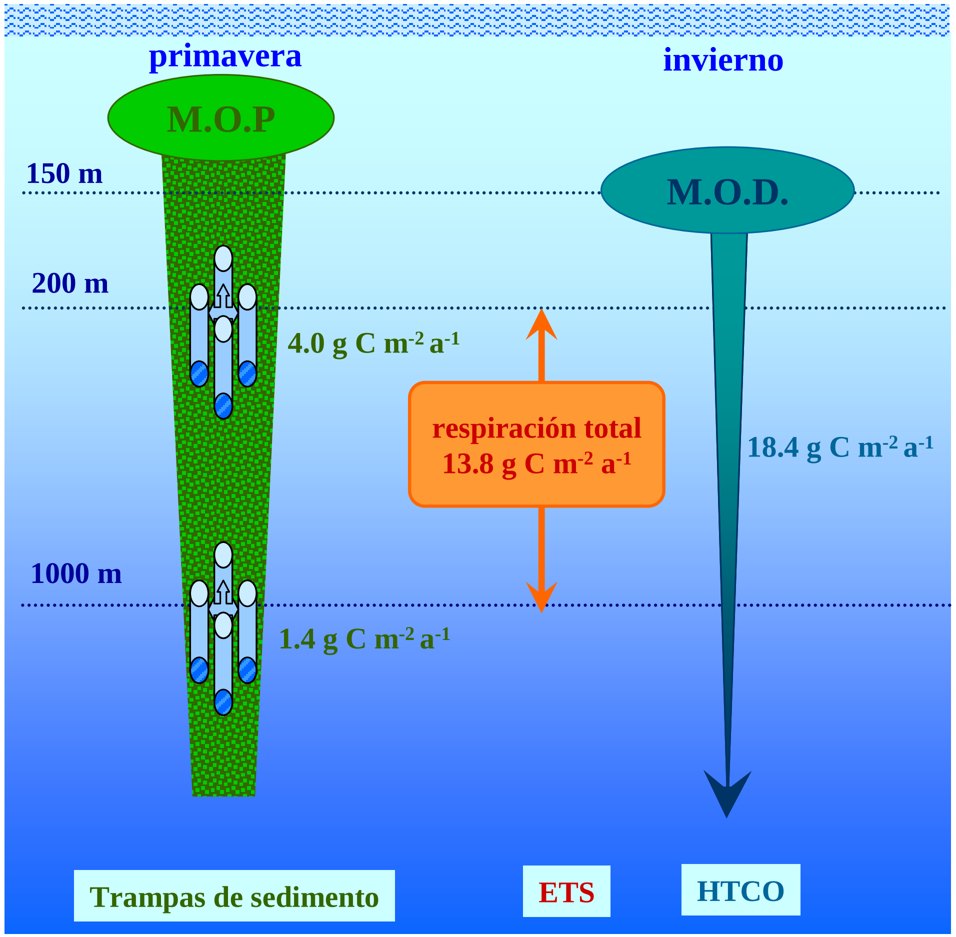

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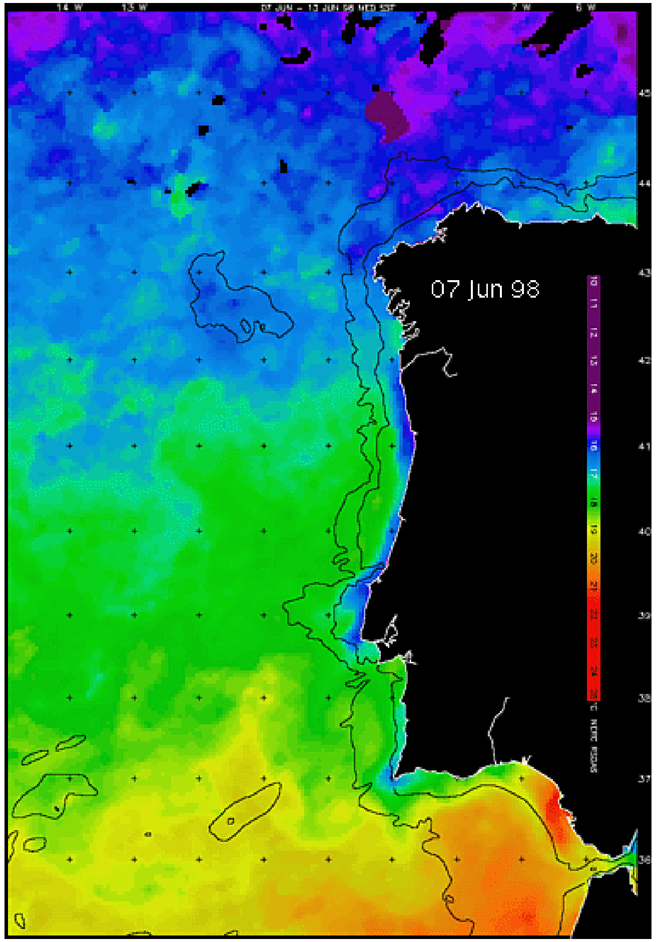

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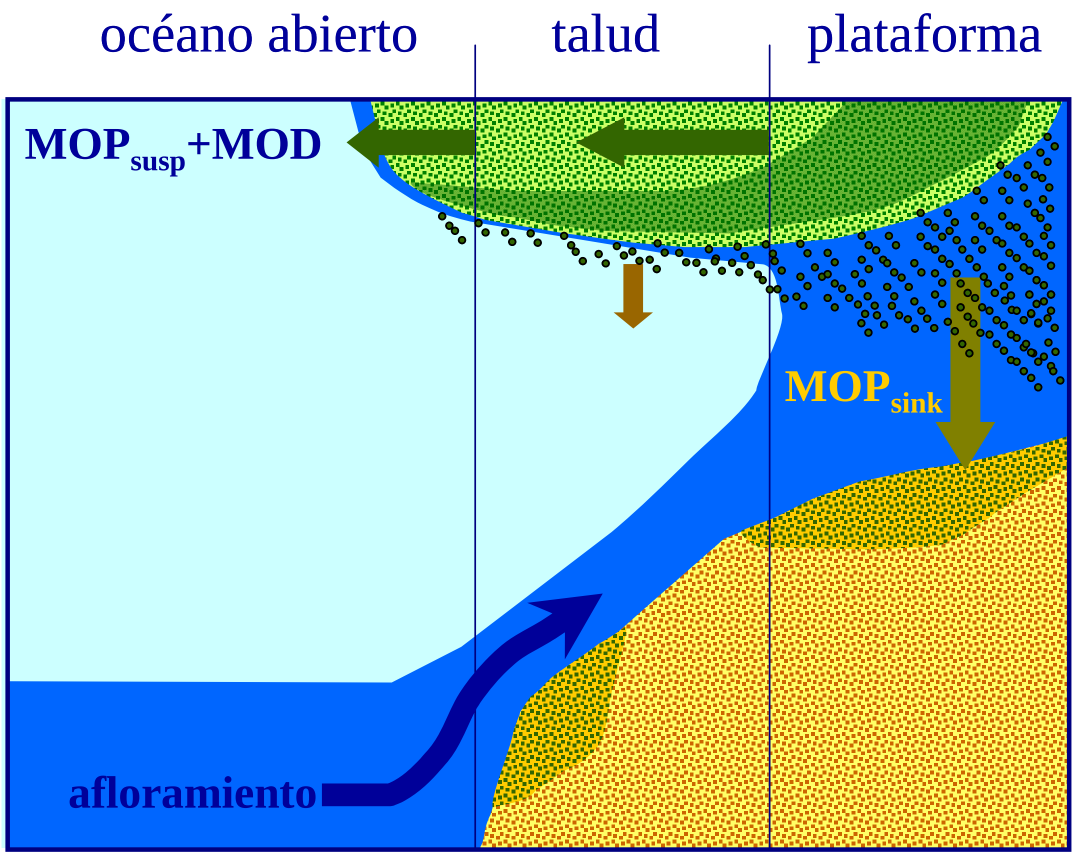

s-DOM: recycling in weeks-months

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Table 1. Compilation from published dissolved and suspended particulate organic carbon (DOC, POC) and total inorganic nitrogen (N_T) concentrations in upwelled (up; average of 100–200 m depth range) and surface outwelled (out; upper 50 m off Iberia and upper 100 m off NW Africa) waters of the study filaments at the shelf break; DOC and POC excesses (ΔDOC, ΔPOC) and inorganic carbon deficit (ΔC_T) in shelf-break surface waters; percentage of the exported organic material in the dissolved form (ΔDOC/[ΔDOC + ΔPOC]) and percentage of the new production that is exported off shelf ($-[\Delta DOC + \Delta POC]/\Delta C_T$); volume transport (VT) of shelf surface water and organic carbon flux (C flux) exported by the filaments (annual basis); area (A) of the shelf that is exported by each upwelling filament; primary production in that area (PP), and the percentage of PP exported by the filaments (−[ΔDOC + ΔPOC]/PP); filament : Ekman transport ratio (dimensionless).

		NW Iberia	NW Africa	
		42°–43°N	30°–31°N	26°–28°N
Period		Apr–Sep 1995	Sep–Oct 1997	Aug 1999
DOC (μmol L^{-1})	Up	63.0*	51.0†	60.0‡
	Out	78.6*	75.6†	90.0‡
POC (μmol L^{-1})	Up	1.4*	0.8†	1.7‡
	Out	10.1*	2.1†	6.0‡
N_T (μmol L^{-1})	Up	9.5*	10.0†	8.0‡
	Out	0.1*	0.1†	0.1‡
ΔDOC (μmol L^{-1})		15.6	24.6	30
ΔPOC (μmol L^{-1})		8.7	1.3	4.3
ΔC_T (μmol L^{-1})		−70	−74	−59
(ΔDOC)/(ΔDOC+ΔPOC)		64%	95%	87%
$-(\Delta DOC+\Delta POC)/\Delta C_T$		35%	35%	58%
VT (m^3 yr^{-1})		1.4×10^{12}§	9.9×10^{12}†	7.5×10^{12}‡
A (km^2)		3,400	6,660	13,400
C flux	(kg C yr^{-1})	4.1×10^{8}	3.1×10^{9}	3.1×10^{9}
	(g C m^{-2} yr^{-1})	120	460	230
PP (g C m^{-2} y^{-1})		630‖	750¶	750¶
(ΔDOC+ΔPOC)/PP		20%	60%	30%
Filament : Ekman transport ratio		2.5	4.4	2.4

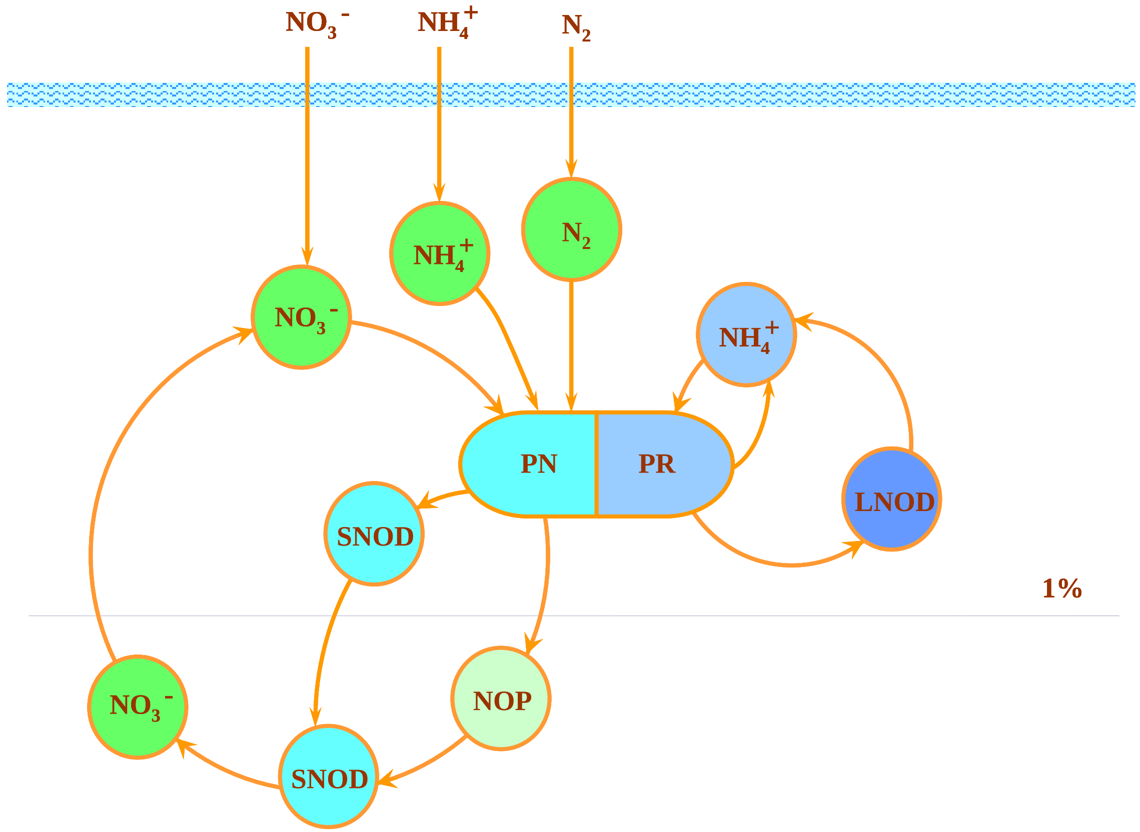
* Álvarez-Salgado et al. (1999).
† García-Muñoz et al. (2005).
‡ García-Muñoz et al. (2004).
§ Álvarez-Salgado et al. (2001).
‖ Arístegui et al. (2006).
¶ Longhurst et al. (1995).

s-DOM: recycling in weeks-months

Álvarez-Salgado et al., Limnol. Oceanogr., 2007

the biological pump in the oceans

the biological pump in the 1990's



r-DOM: recycling in years-millennia

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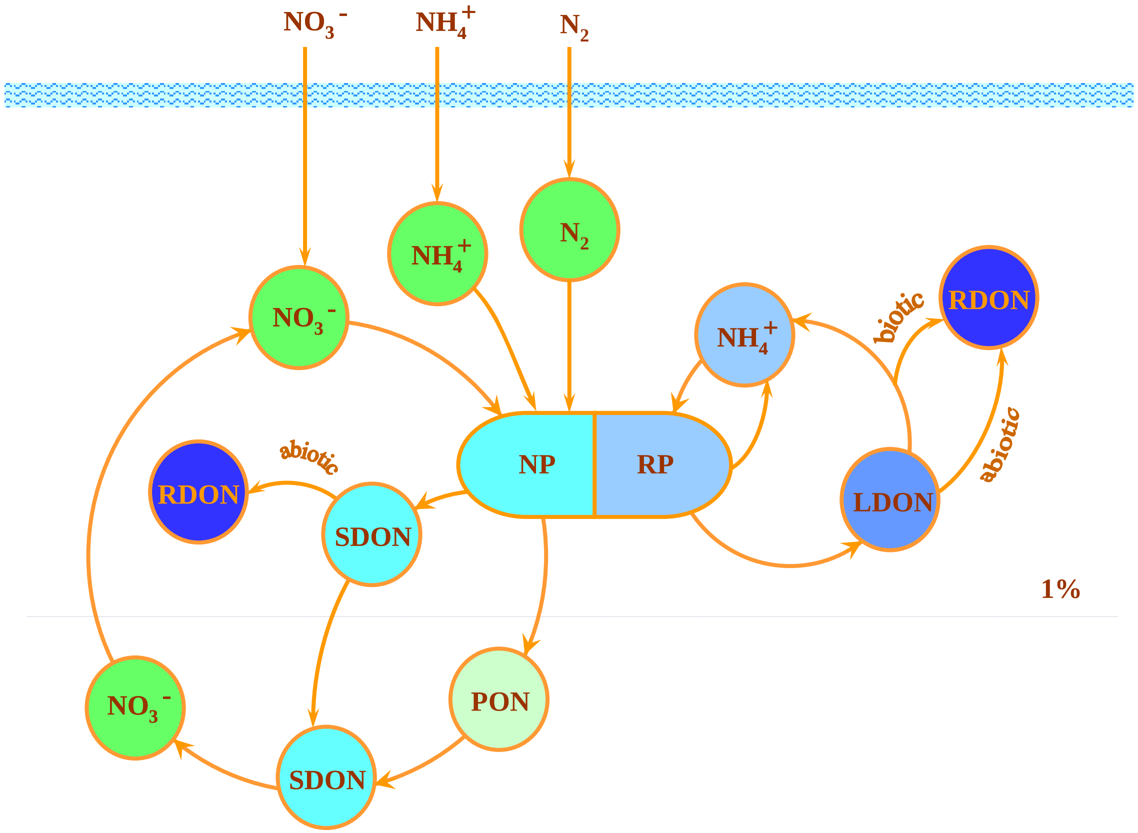
the biological pump in the 1990's



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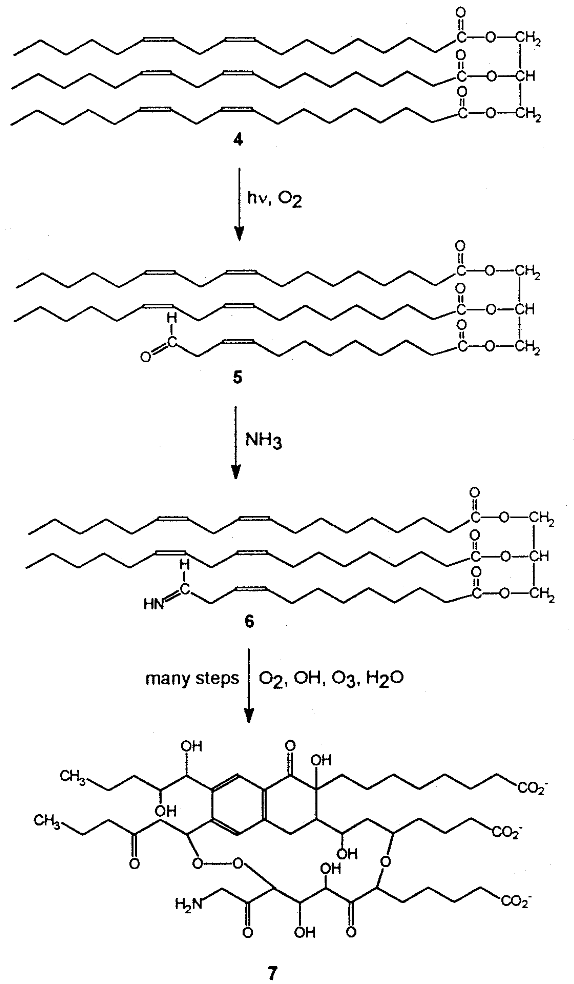

r-DOM: recycling in years-millennia: abiotic processes

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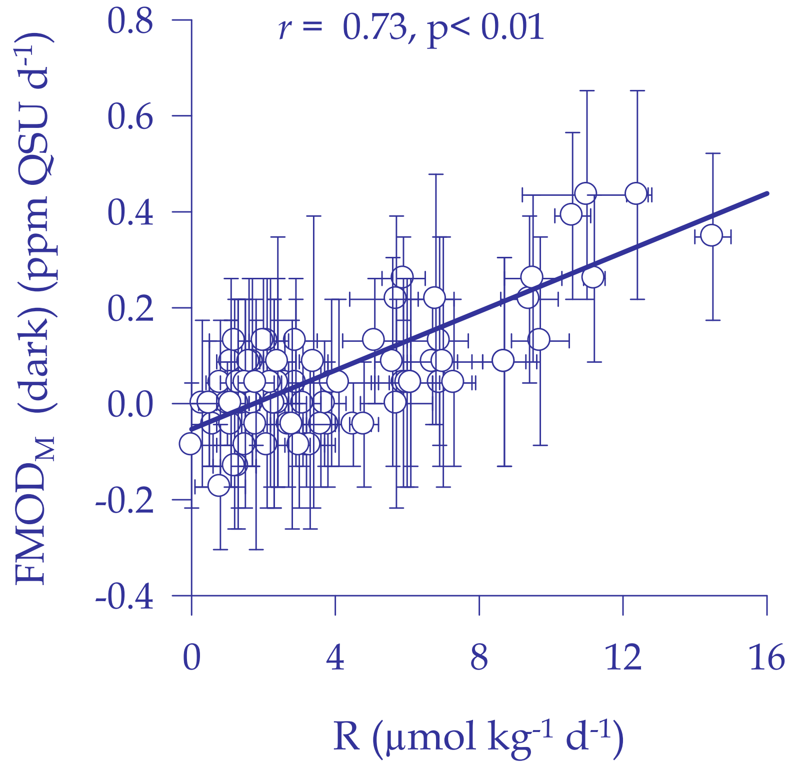
$FMOD_M = -0.05(\pm 0.01) + 0.027(\pm 0.003)\ R$



r-DOM: recycling in years-millennia: biotic processes

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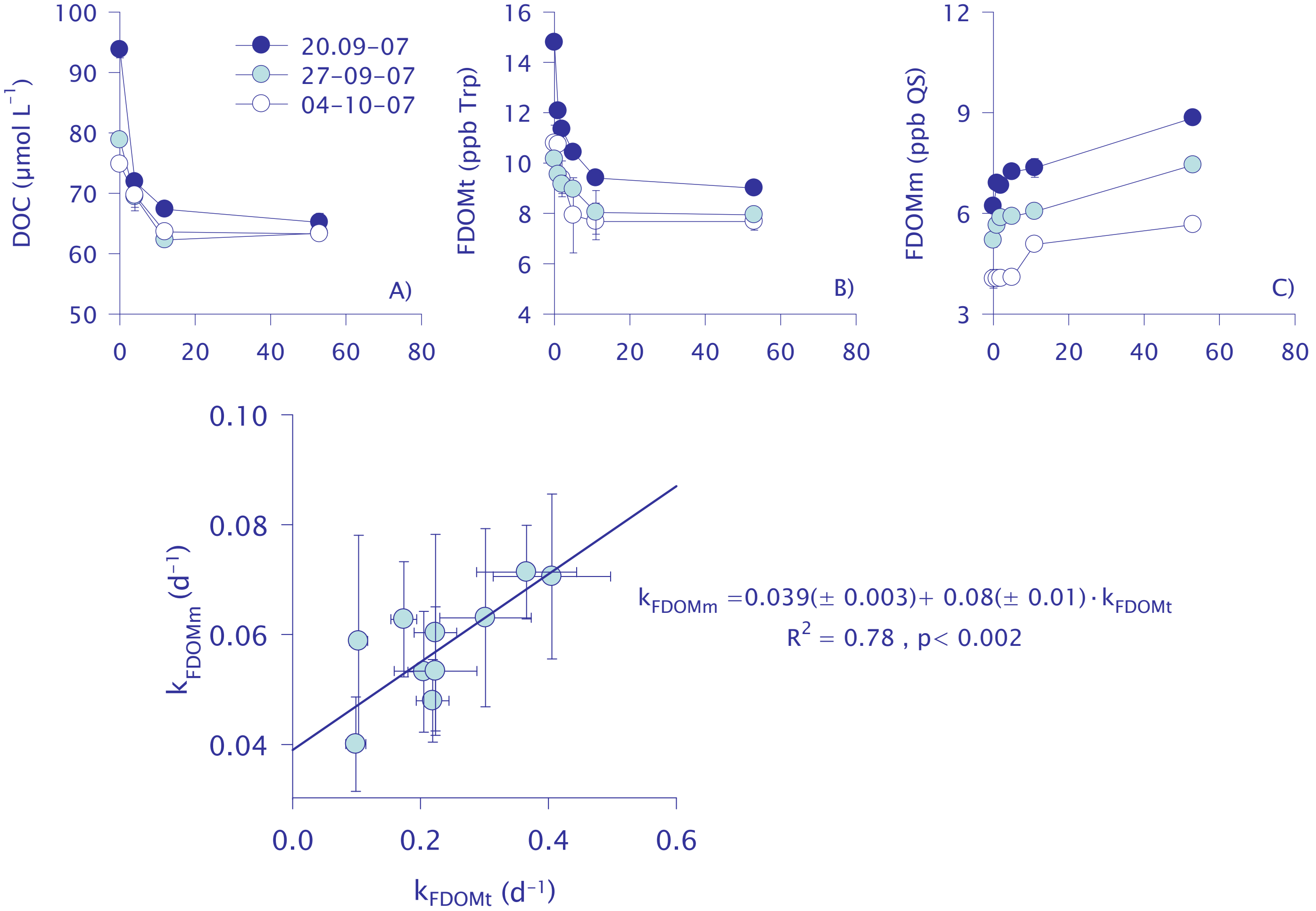

r-DOM: recycling in years-millennia: <u>biotic processes</u>

the biological pump in the oceans

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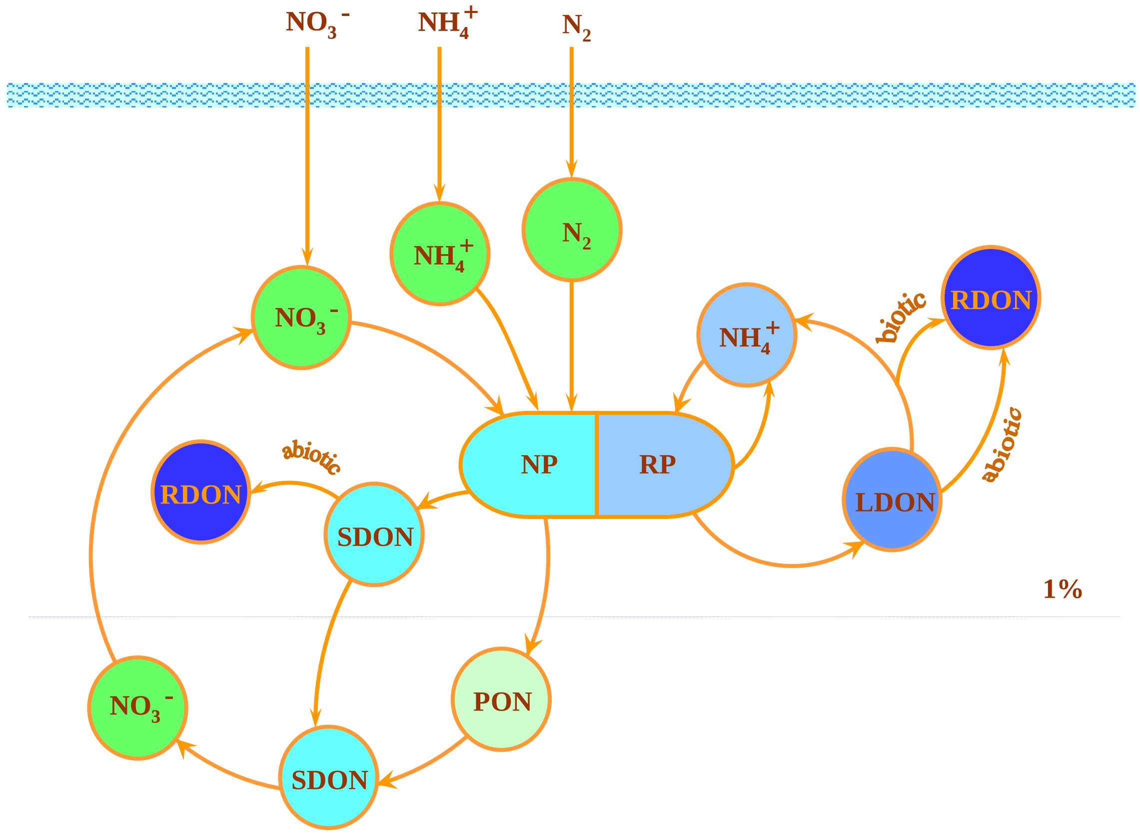

r-DOM: recycling in years-millennia

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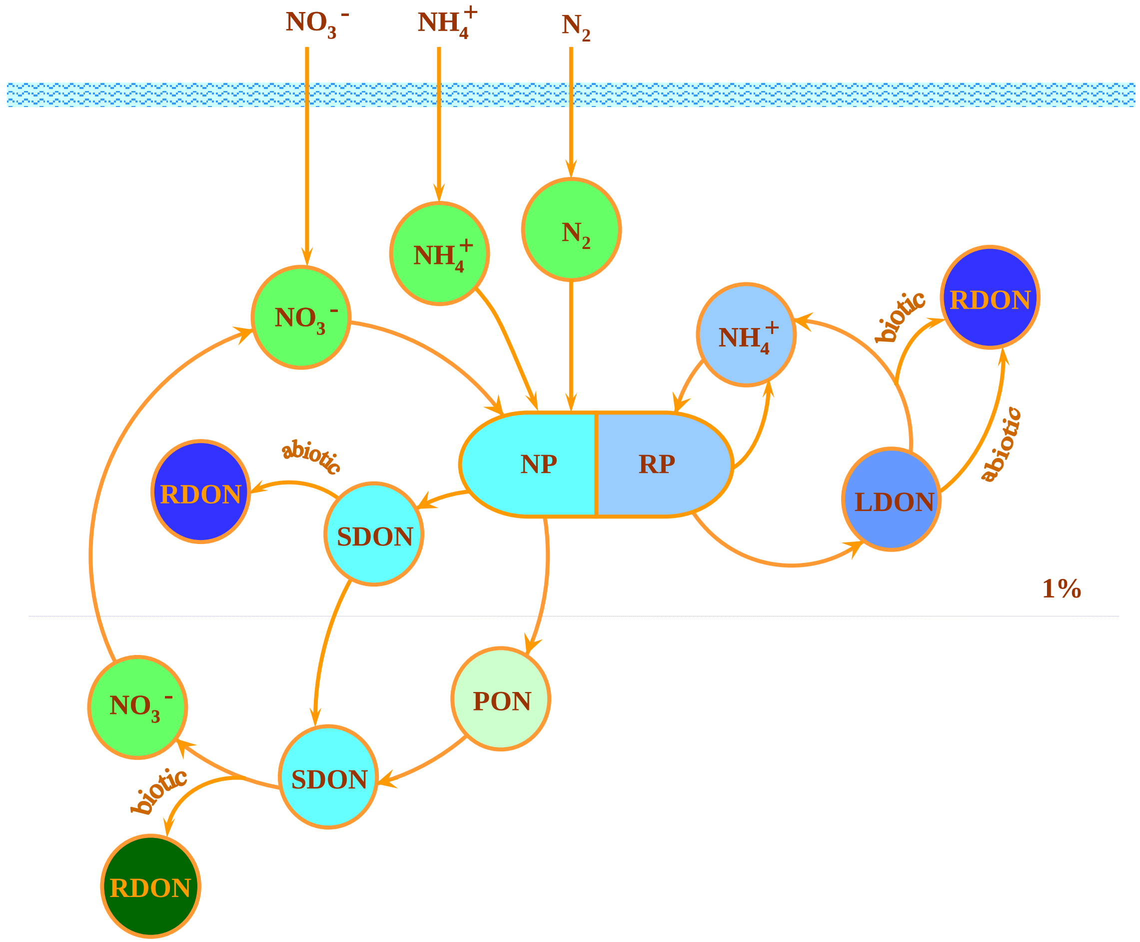

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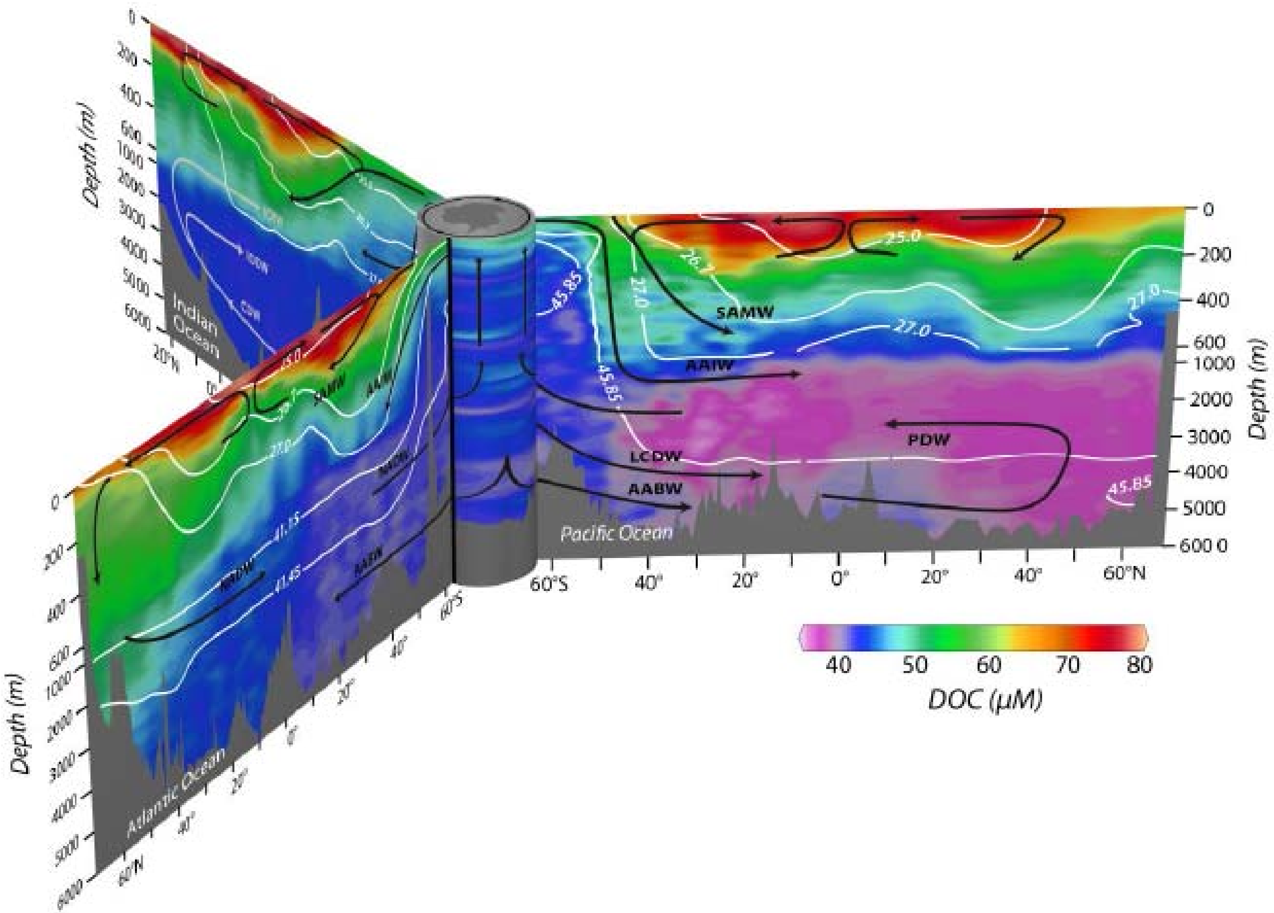

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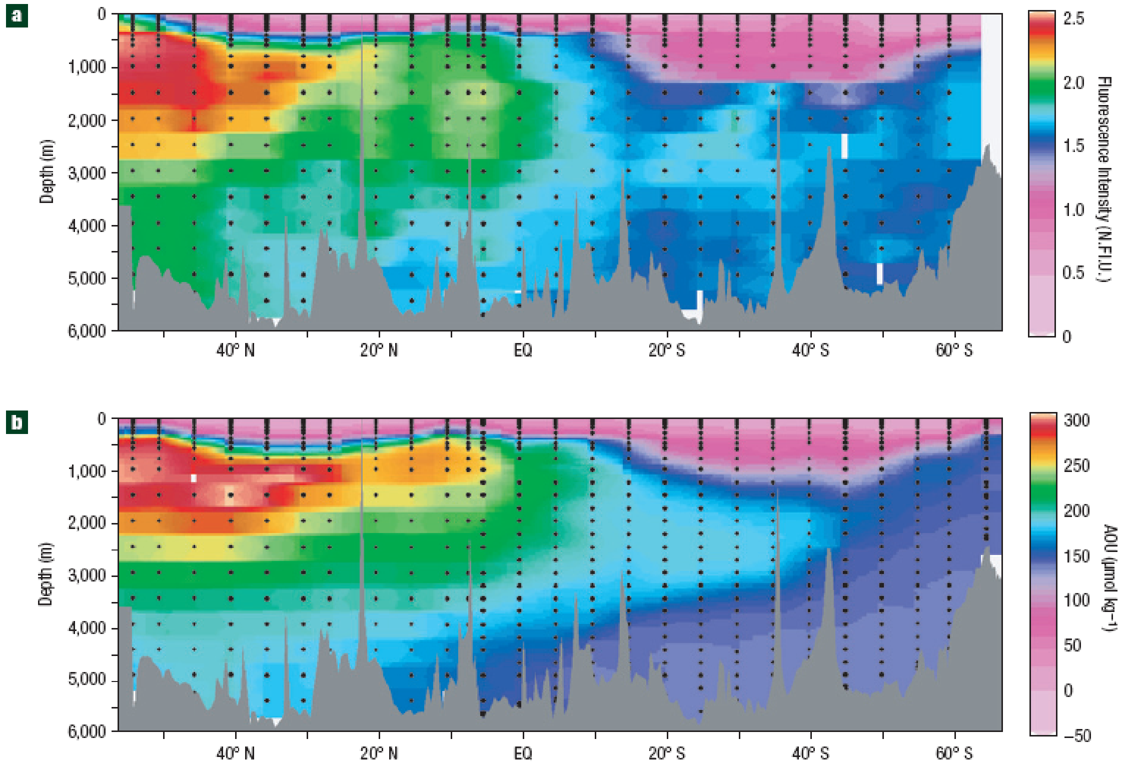

Figure 2 Contour maps of fluorescence intensity and AOU along the transects at 160° W and 170° W. a,b, Levels of fluorescence intensity (**a**) and AOU (**b**). Contour maps were illustrated using Ocean Data View[26].

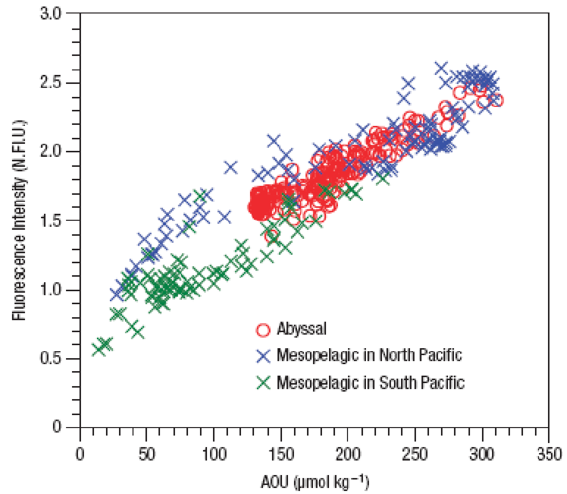

Figure 3 Fluorescence intensity versus AOU in the mesopelagic (200 m–1,000 m) and abyssal layers (>1,000 m). The relationship determined by regression analysis is [FI] = 0.0043 × [AOU] + 1.10, $R^2 = 0.86$, $n = 99$, $p < 0.001$ in the mesopelagic layer in the Northern Hemisphere of the Pacific (blue crosses), [FI] = 0.0049 × [AOU] + 0.70, $R^2 = 0.79$, $n = 79$, $p < 0.001$ in the mesopelagic layer in the Southern Hemisphere of the Pacific (green crosses) and [FI] = 0.0047 × [AOU] + 0.96, $R^2 = 0.85$, $n = 210$, $p < 0.001$ in the abyssal layer throughout the Pacific (open circles).

r-DOM: recycling in years-millennia

Yamashita and Tanoue, Nature, 2008

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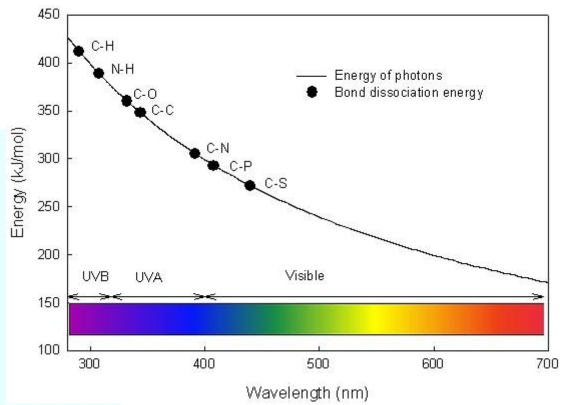

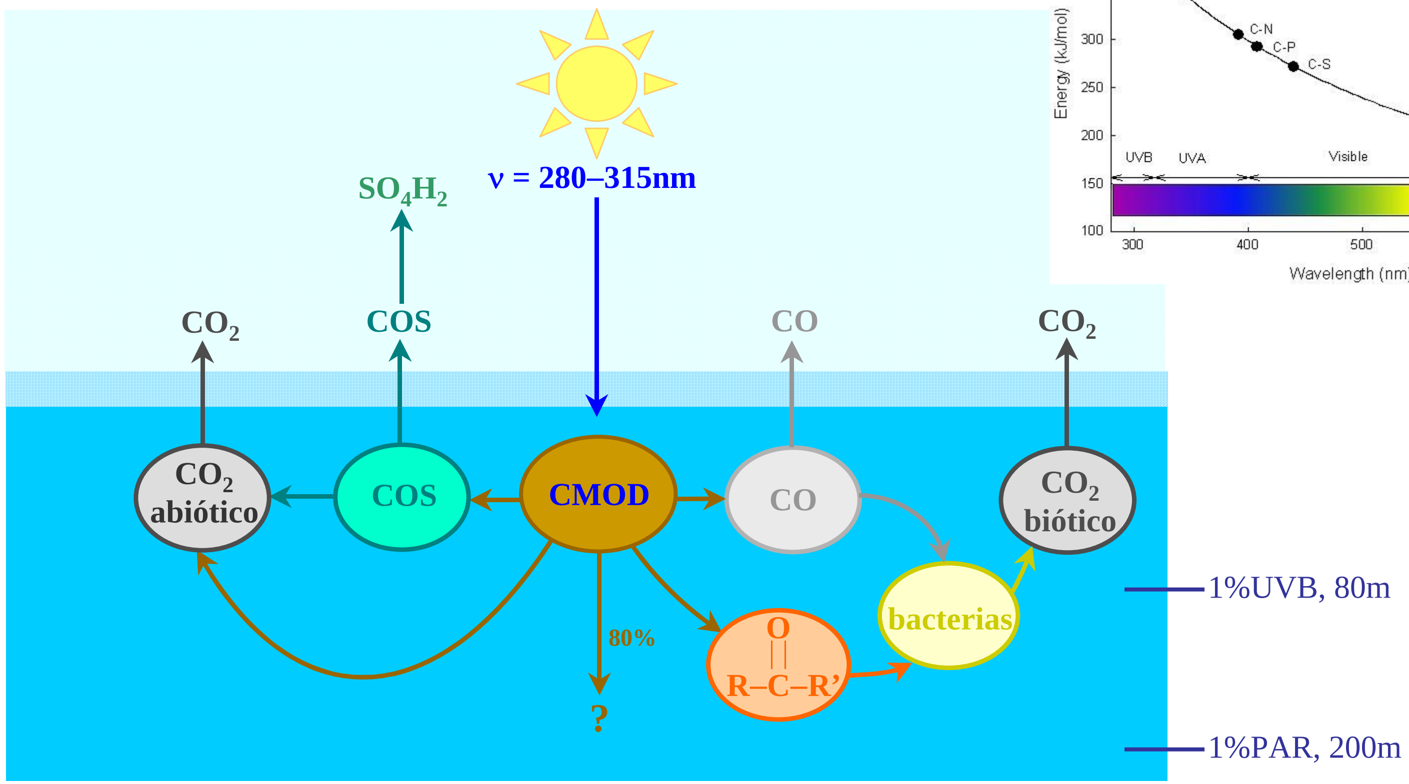

r-DOM: photochemical decomposition in surface waters

the biological pump in the oceans

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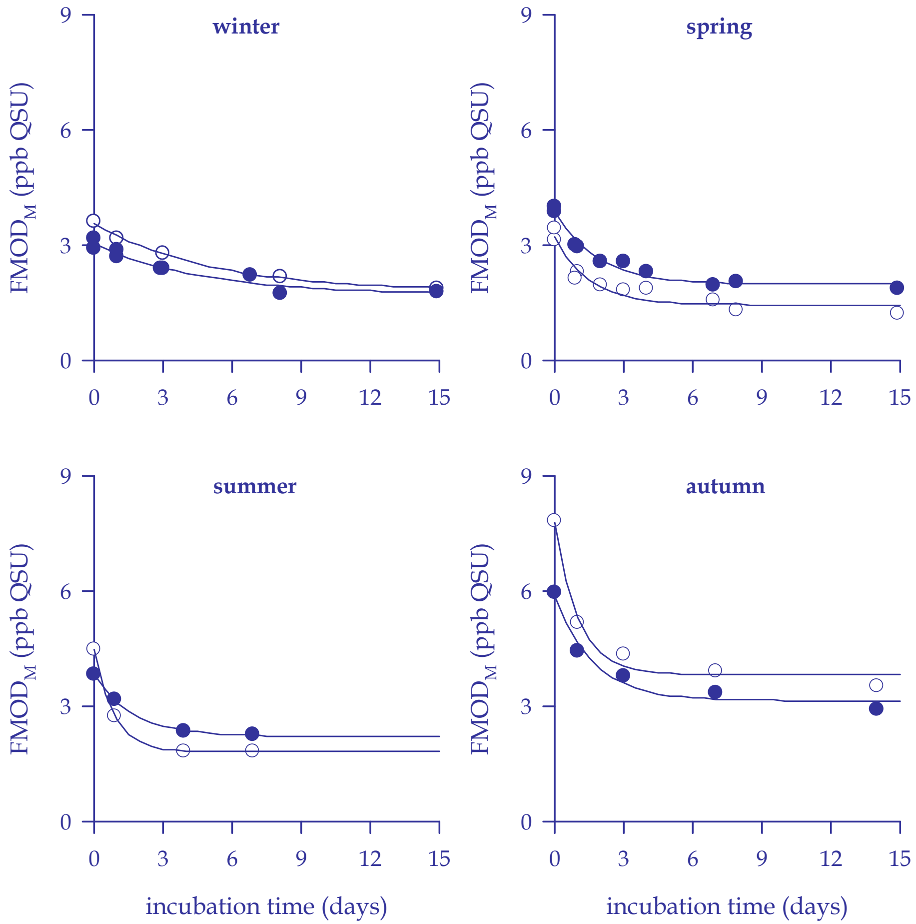

r-DOM: photochemical decomposition in surface waters

Nieto-Cid et al., Limnol. Oceanogr., 2005

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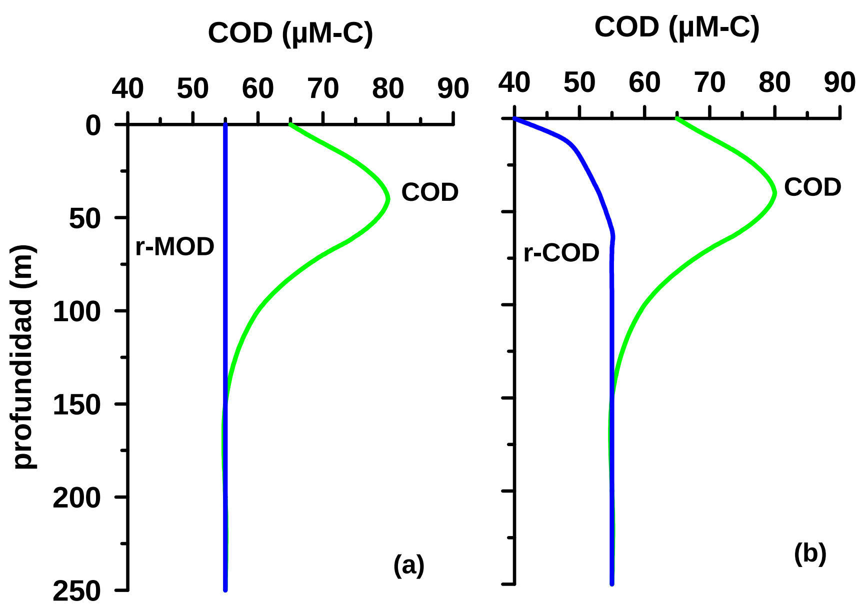

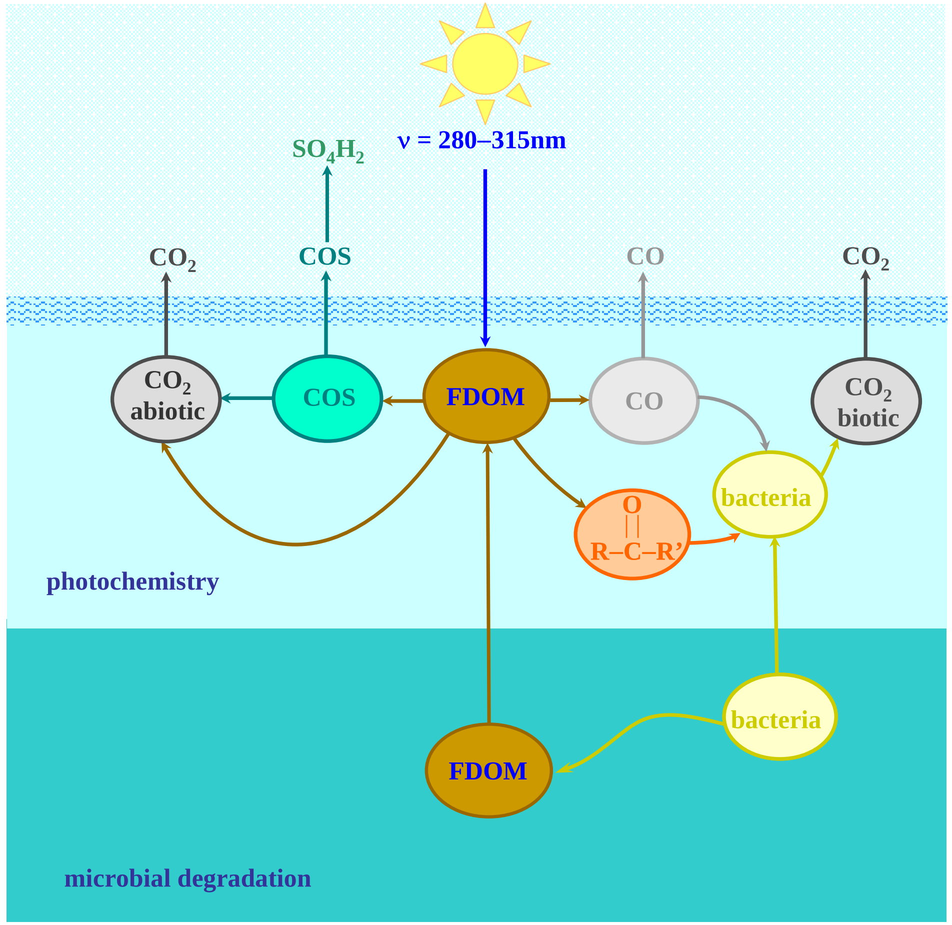

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Nieto-Cid et al., Limnol. Oceanogr., 2006

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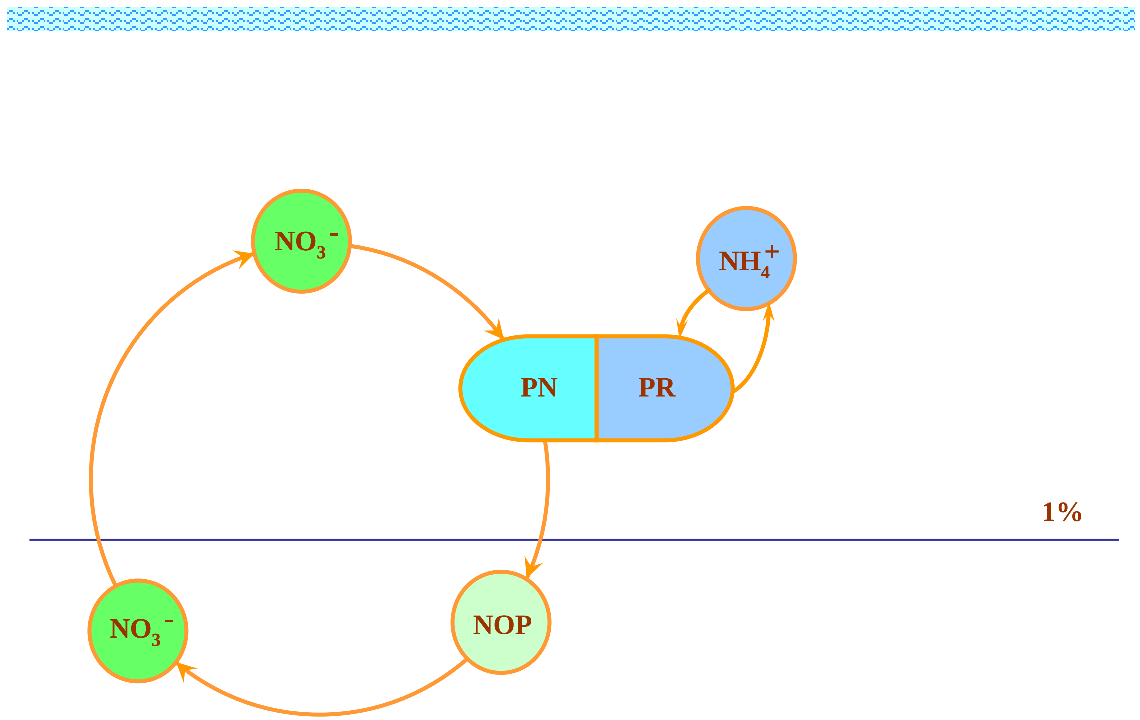
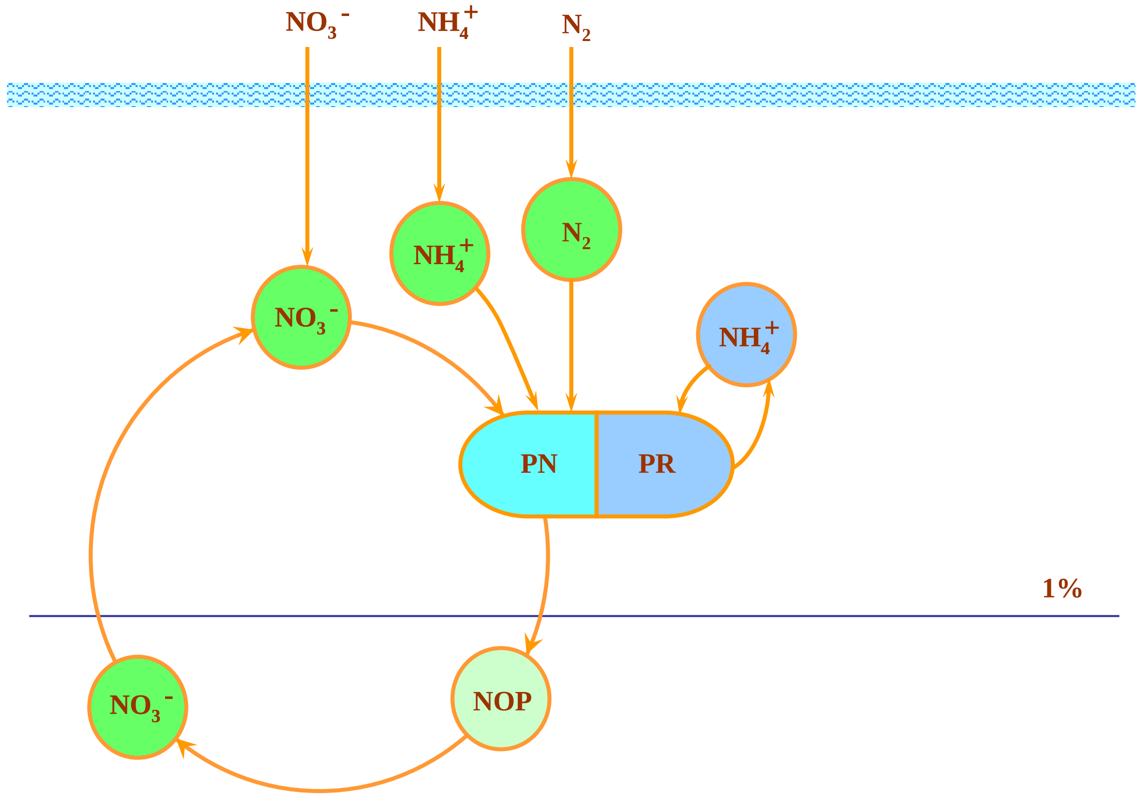


DOM: summarizing

the biological pump in the oceans

the biological pump in the 1990's



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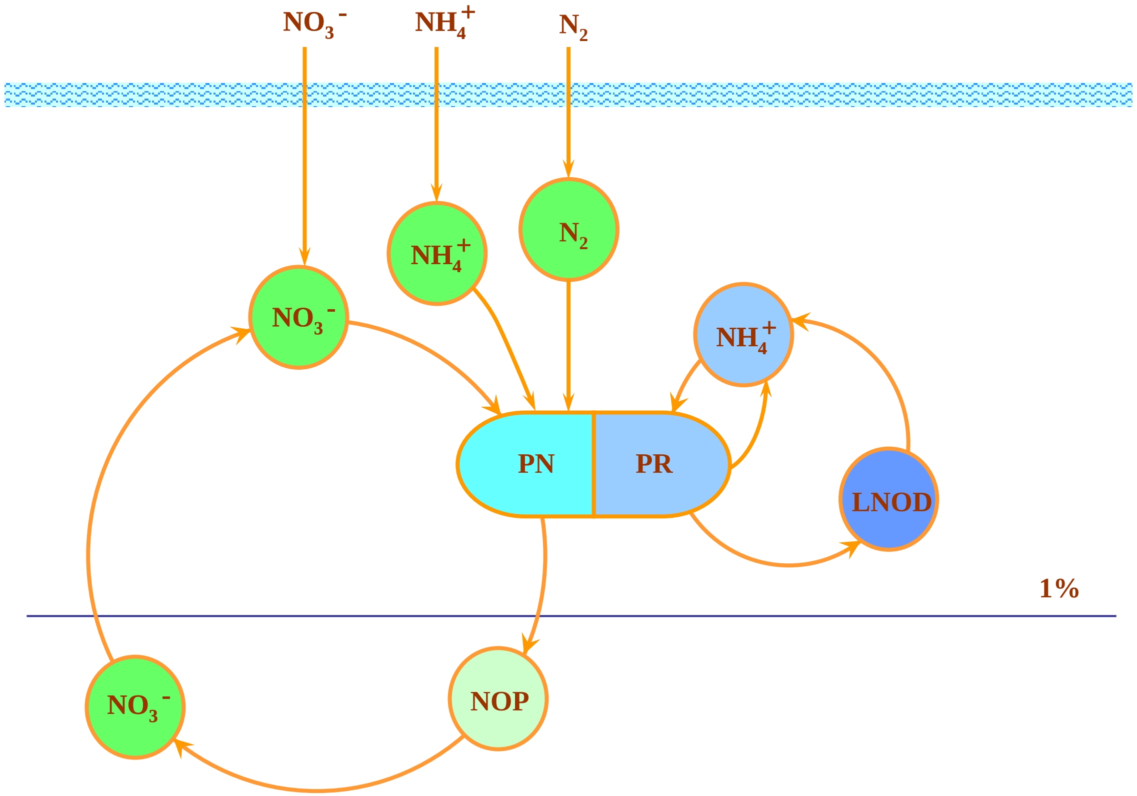

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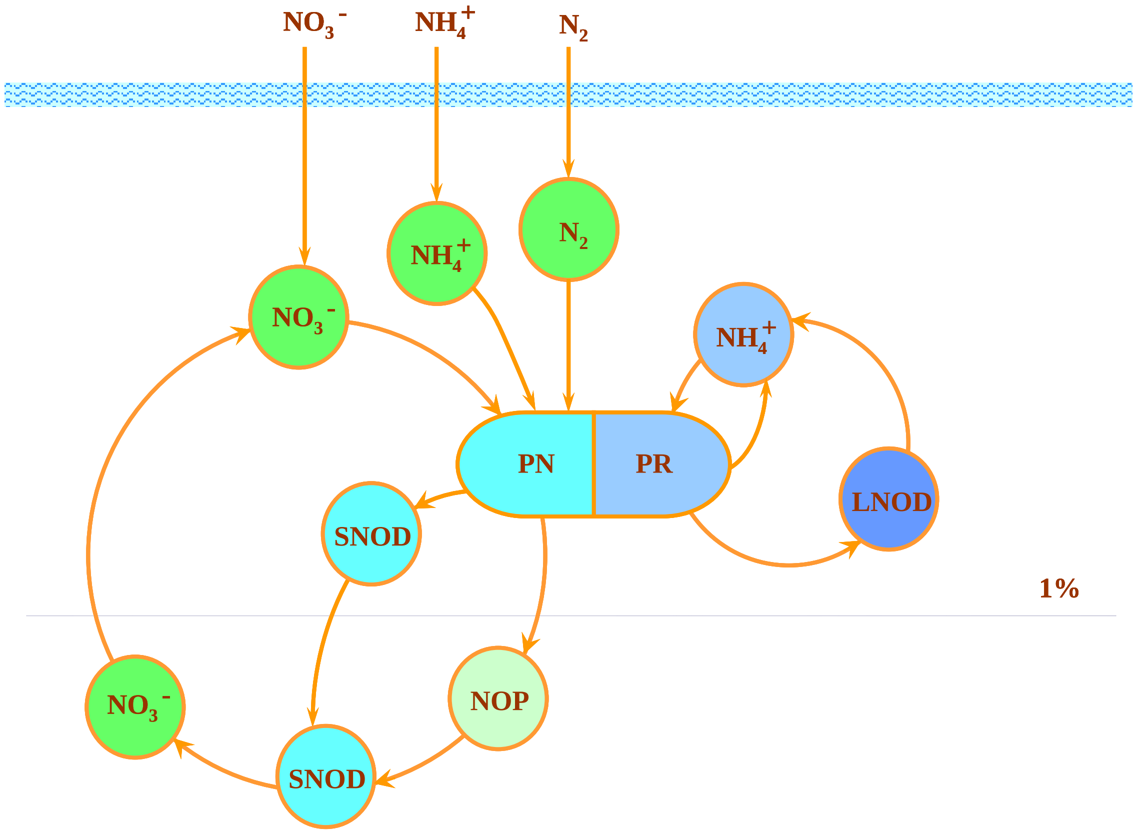

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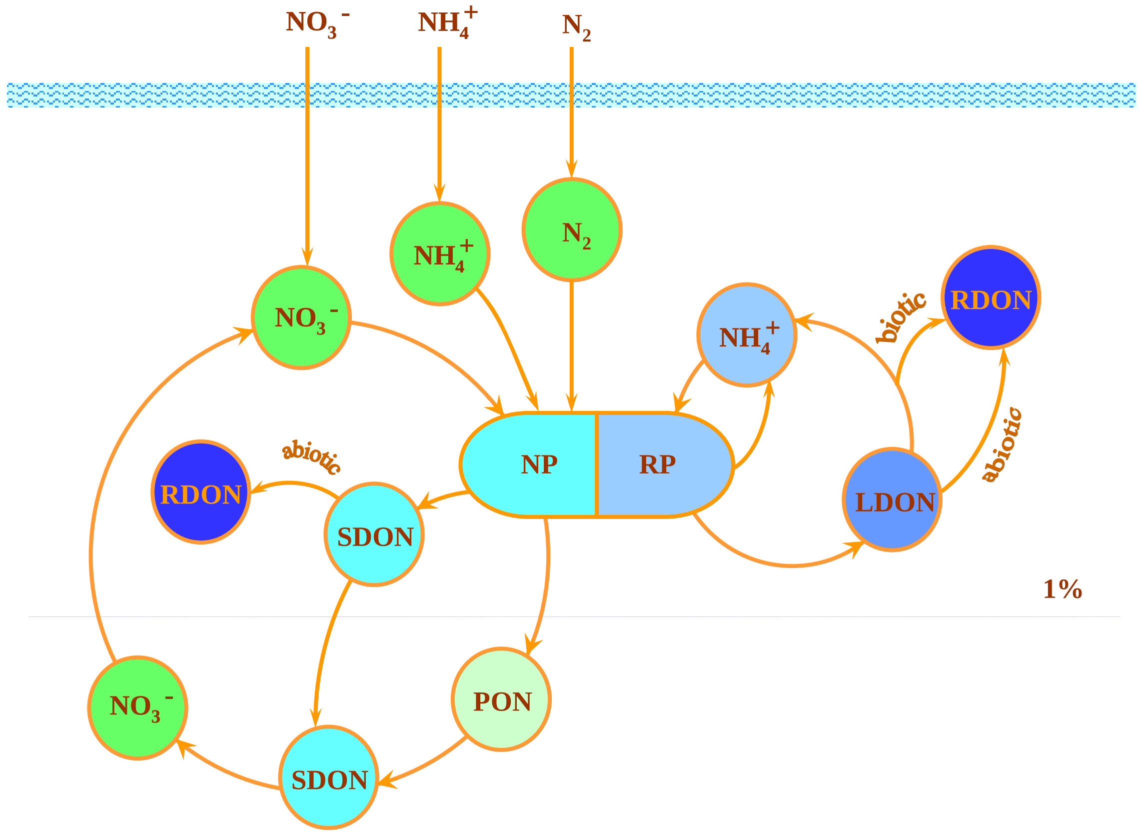

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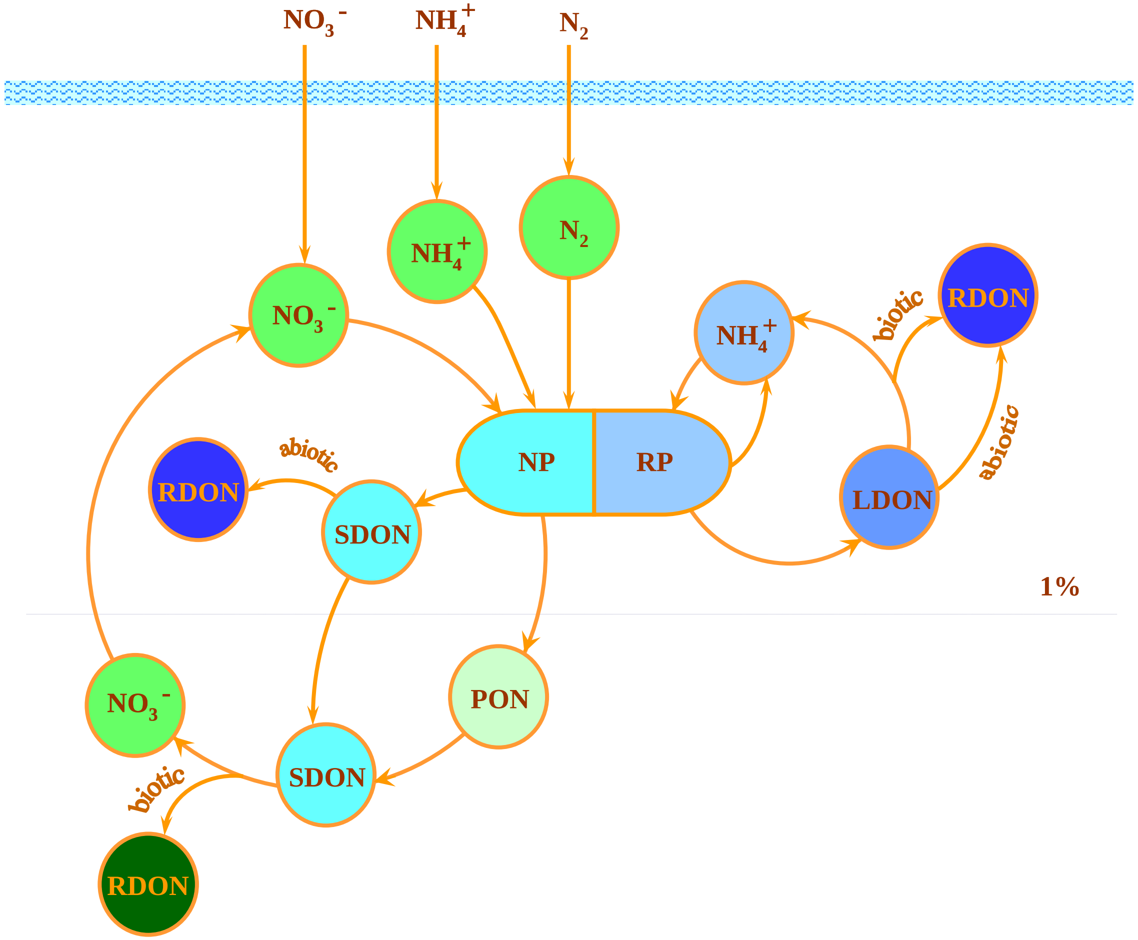
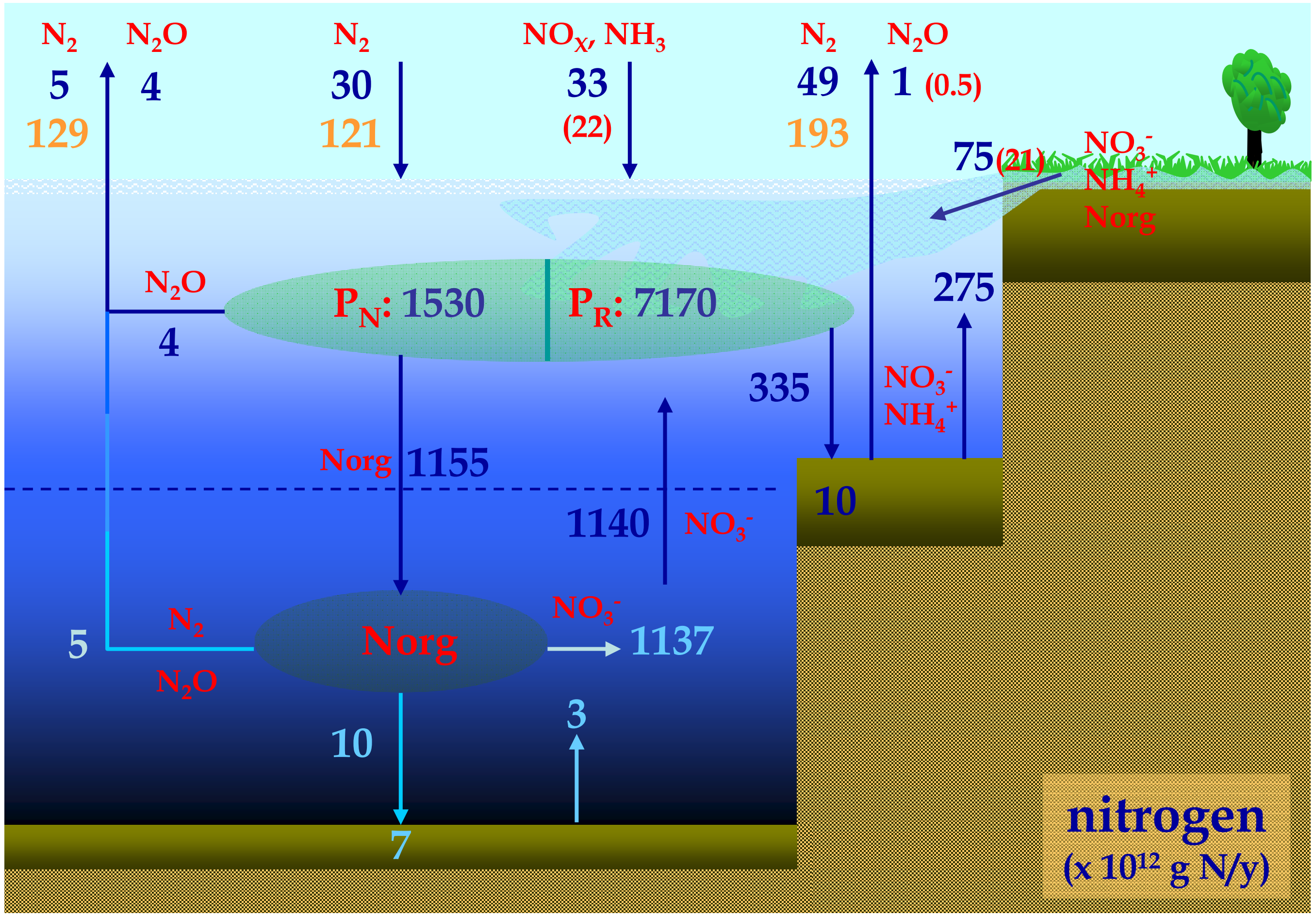


DOM: summarizing

organic matter cycling in the oceans

nitrogen

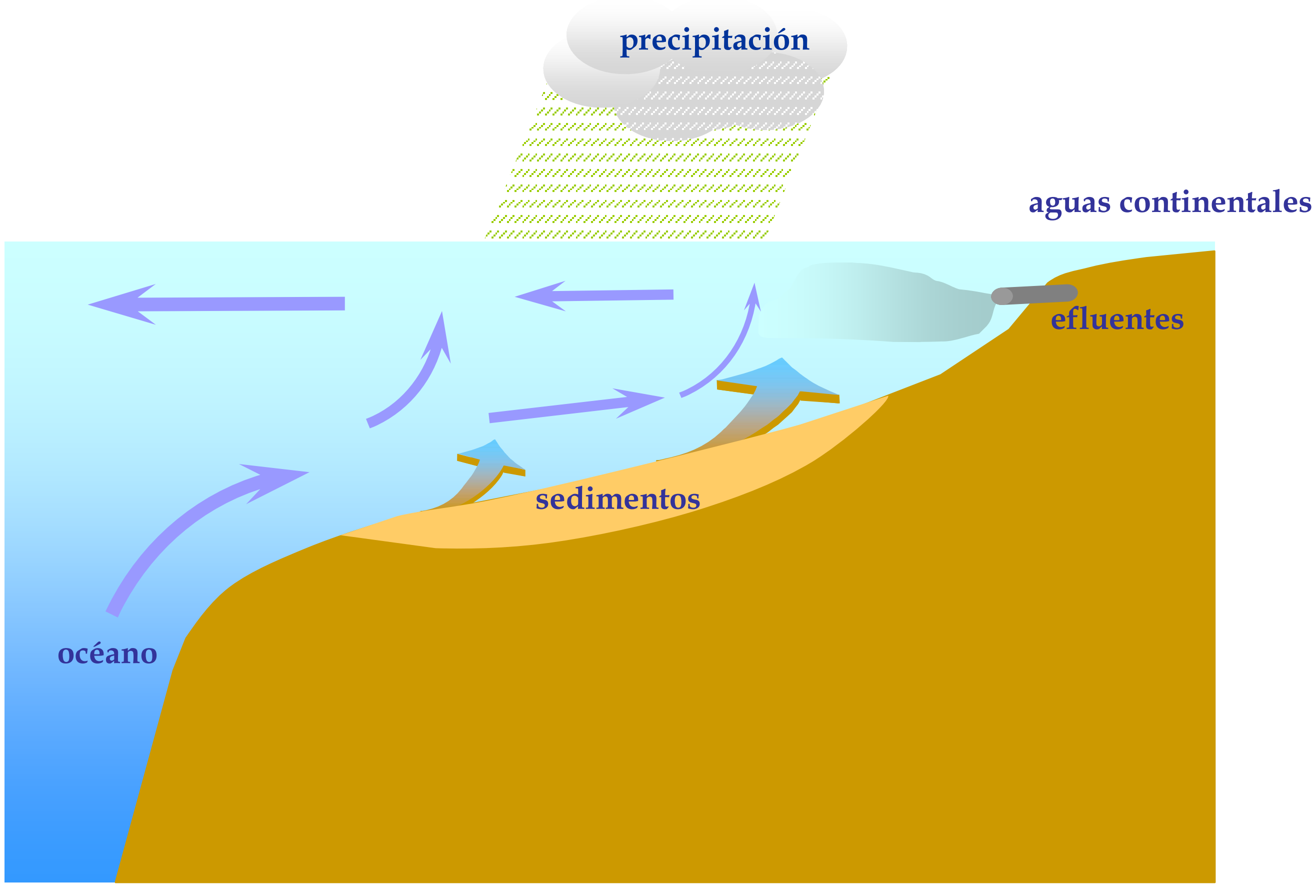


Galloway et al., Biogeochemistry, 2004

Wollast, 1993

organic matter cycling in the oceans

nitrogen



nitrogen cycle in the coastal zone

organic matter cycling in the oceans

nitrogen

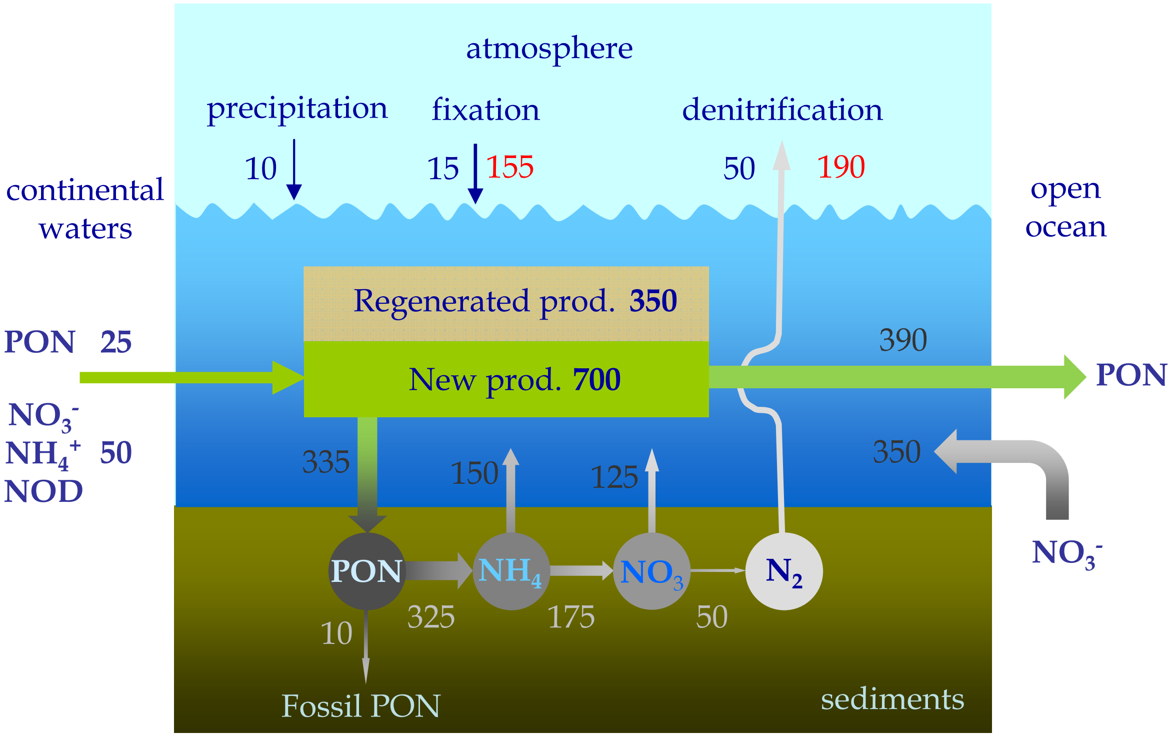
- ►represent <10% of the area and <1% of the volume of the oceans
- ►support between 25% and 50% of the global new production
- ►receive 80% of the sedimentation of the oceans
- ►about 90% of the fish resoruces are extracted from the coastal zone

nitrogen cycle in the coastal zone

Gattuso et al., 1998

organic matter cycling in the oceans

nitrogen

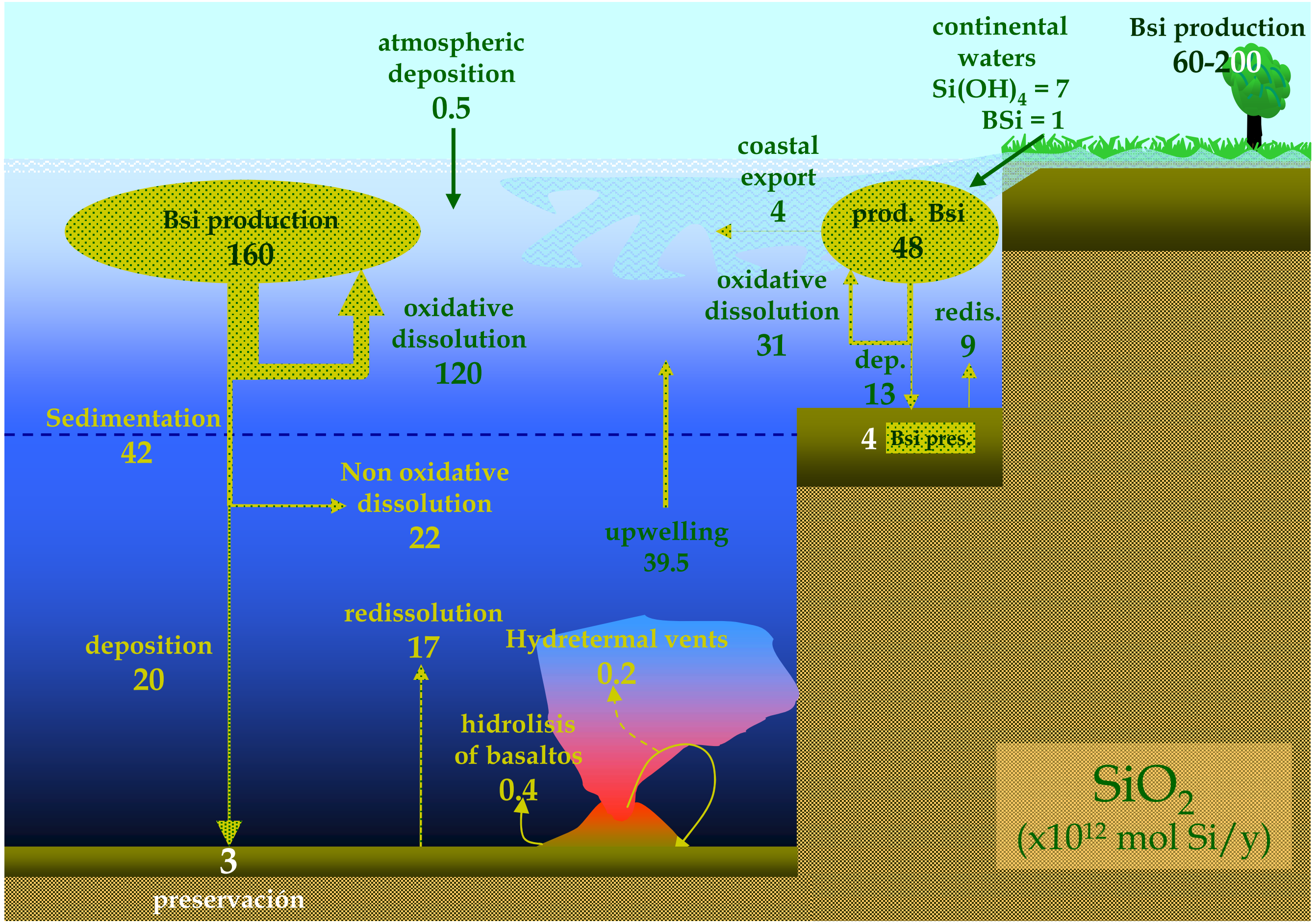


nitrogen cycle in the coastal zone (in 10^{12} gN/y)

Galloway et al., Biogechemistry, 2004 Wollast, 1993

organic matter cycling in the oceans

silicon



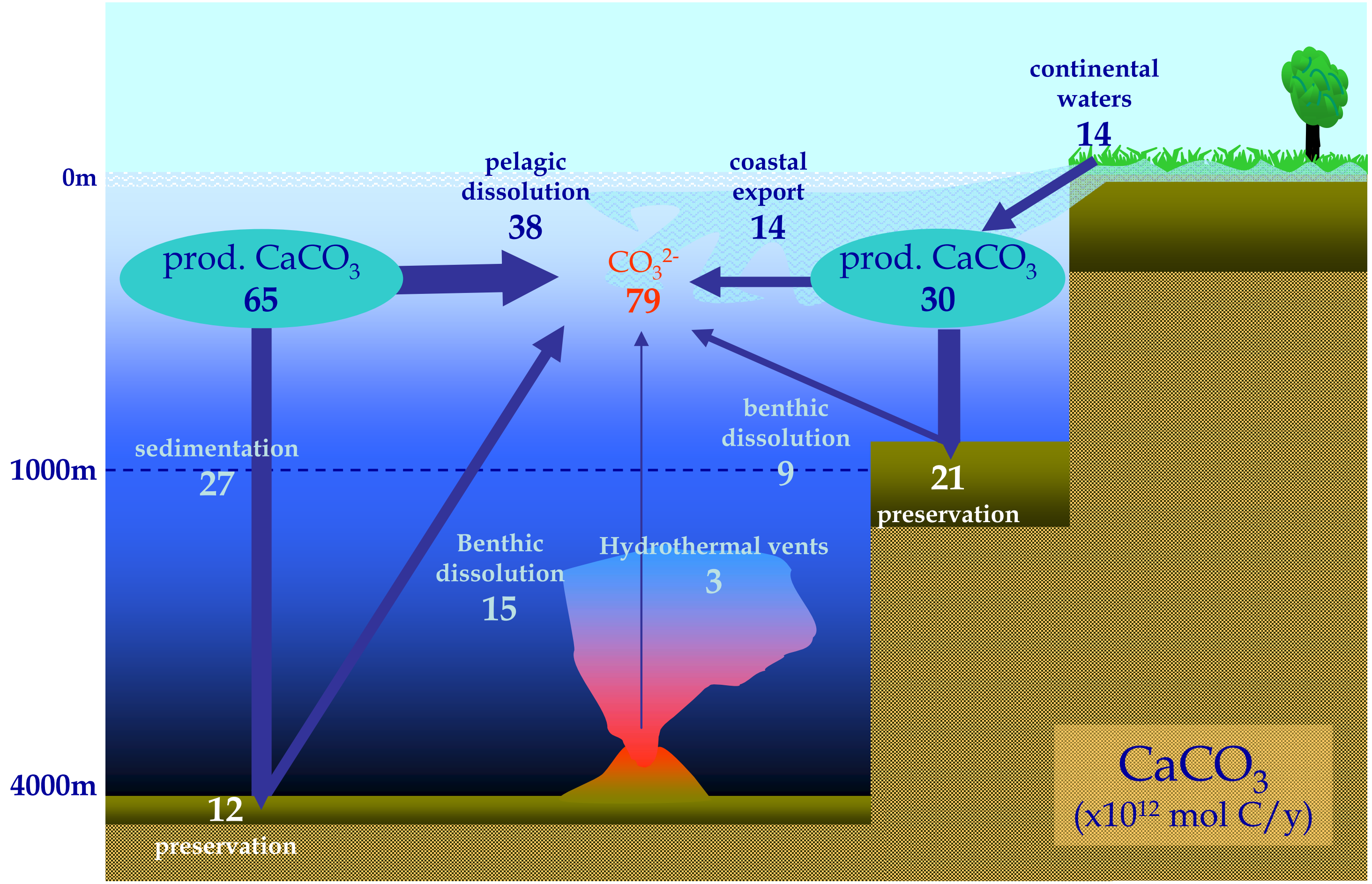
silicon cycle in the open ocean and the coastal zone

Laruelle et al., Global. Biogeochem. Cy, submitted

Nelson et al., Global. Biogeochem. Cy, 1995

organic matter cycling in the oceans

calcium carbonate



CaCO$_3$ cycle in the ocean and the coastal zone

Wollast, 1994

Milliman et al., Deep. Sea Res., 1999