Climate Change Impacts on Primary Production and Biocalcification

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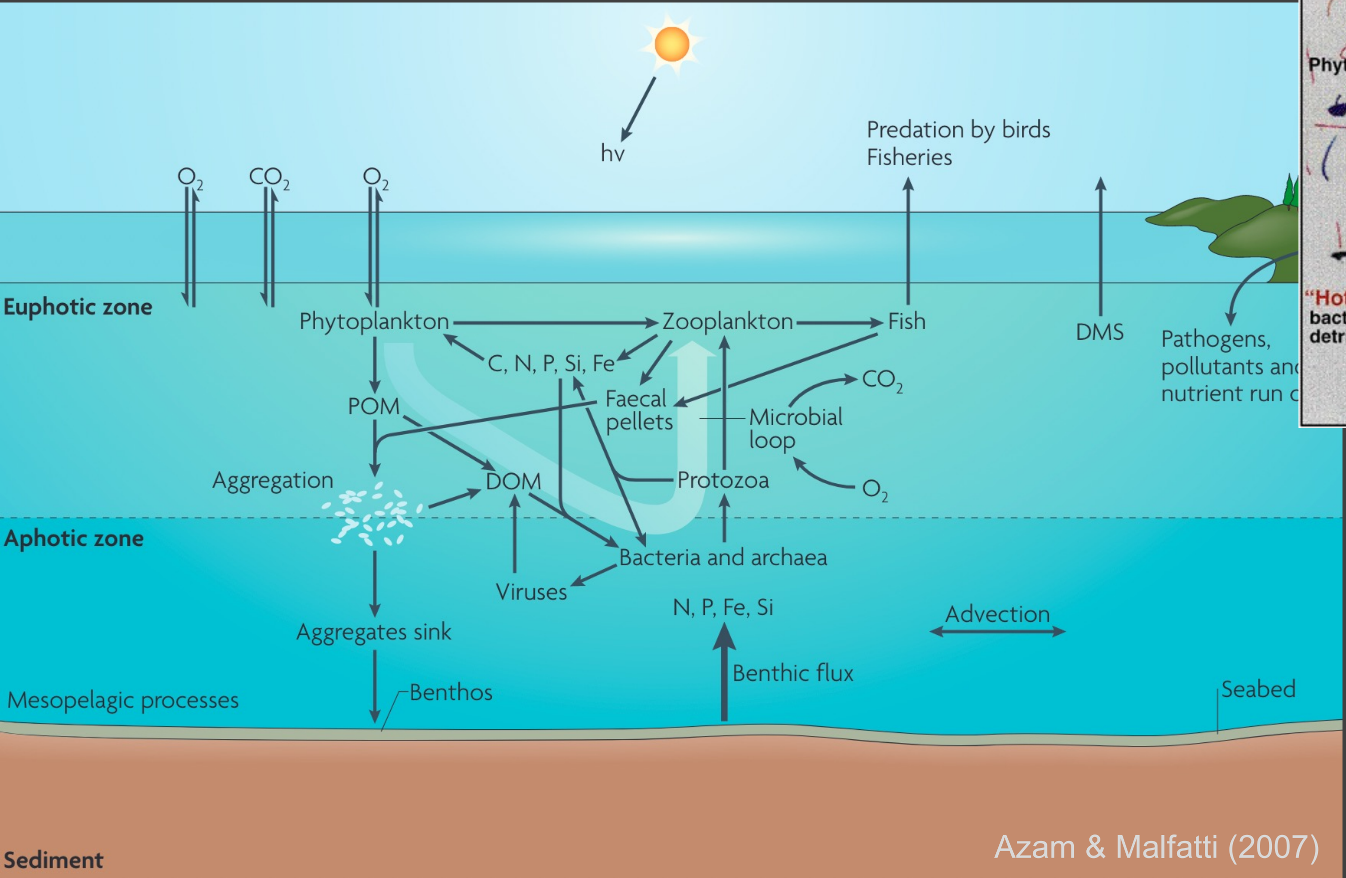
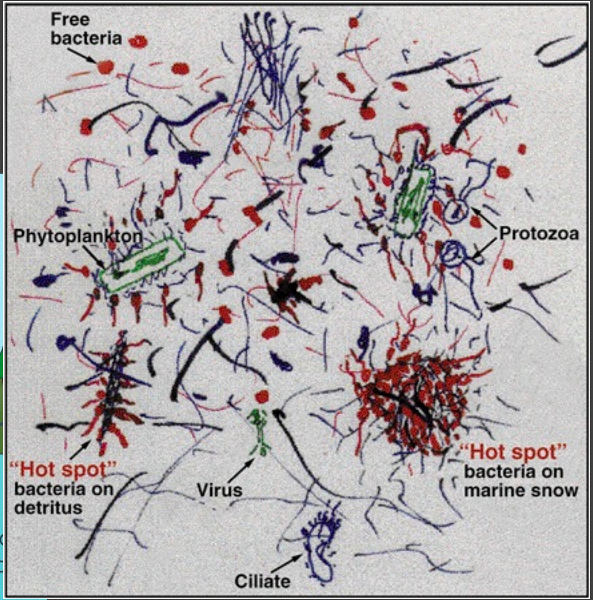
A microbiologist’s view of the ocean ecosystem

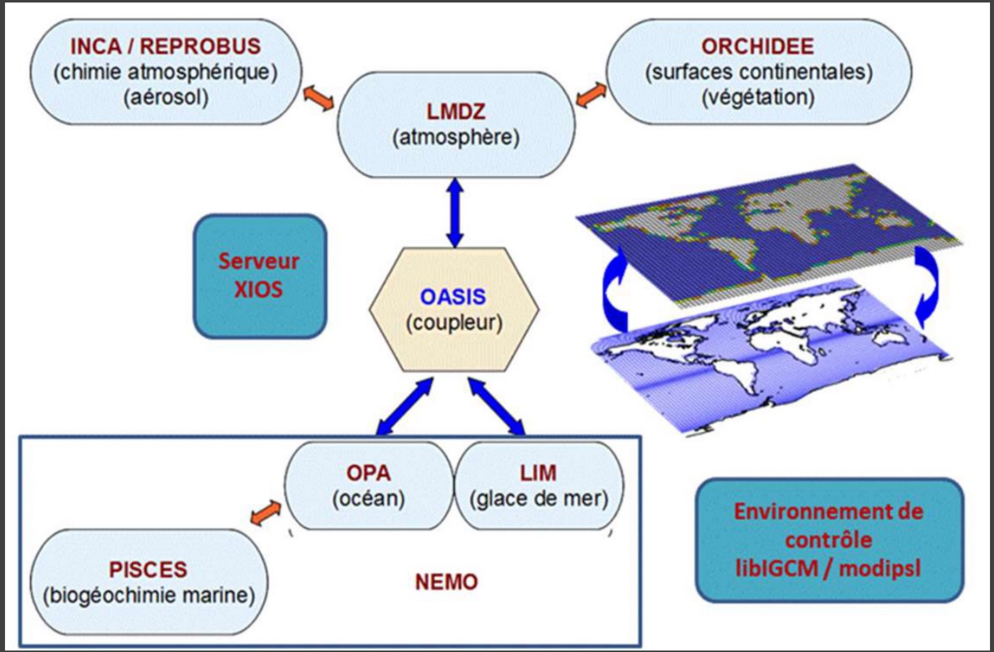


Azam & Malfatti (2007)

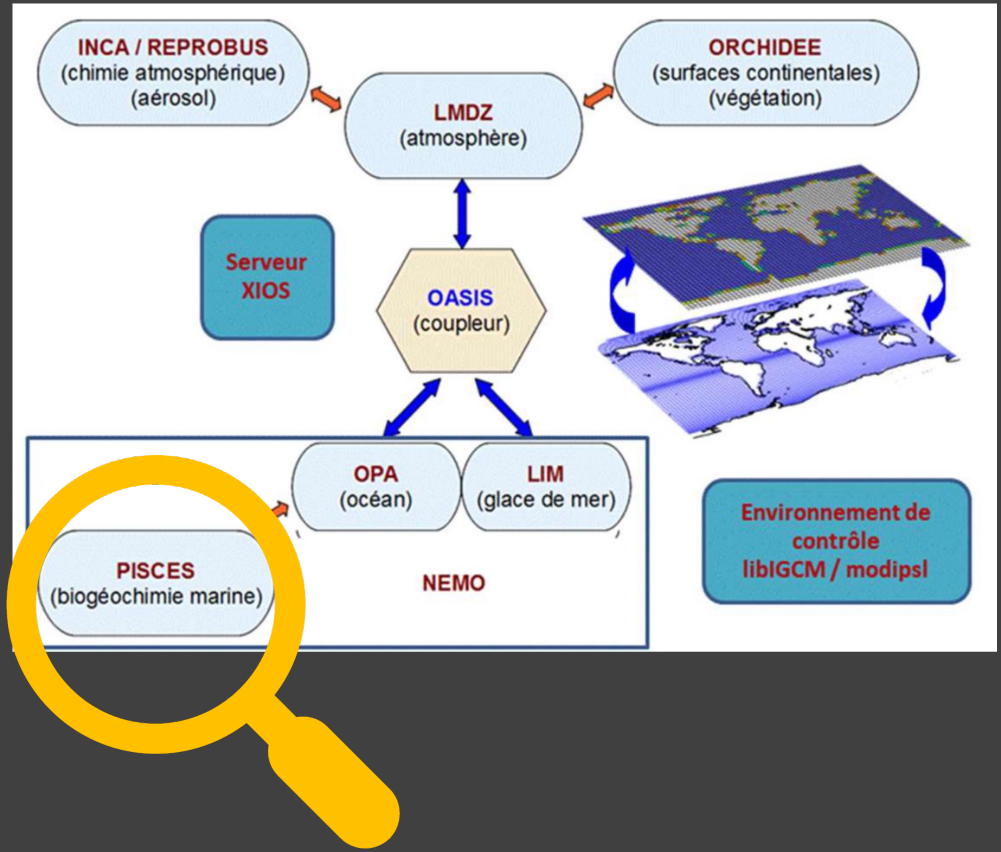


Azam (1998)

IPSL CM6


INCA / REPROBUS
(chimie atmosphérique)
(aérosol)
LMDZ
(atmosphère)
ORCHIDEE
(surfaces continentales)
(végétation)
Serveur
XIOS
OASIS
(coupleur)
OPA
(océan)
LIM
(glace de mer)
PISCES
(biogéochimie marine)
NEMO
Environnement de
contrôle
libIGCM / modipsl

IPSL CM6



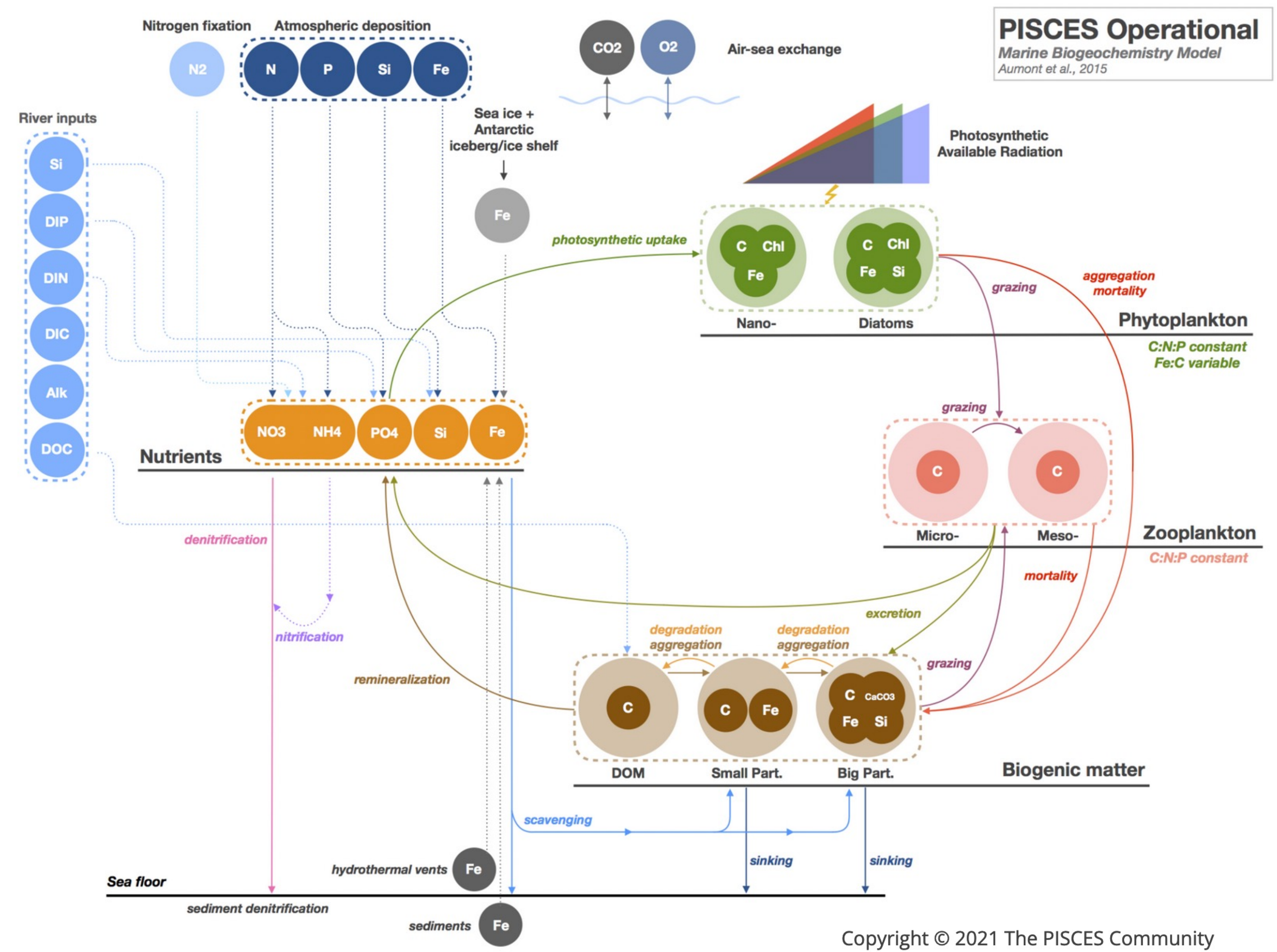
A Biogeochemist's view of the ocean ecosystem

Model of intermediate complexity

24 tracers

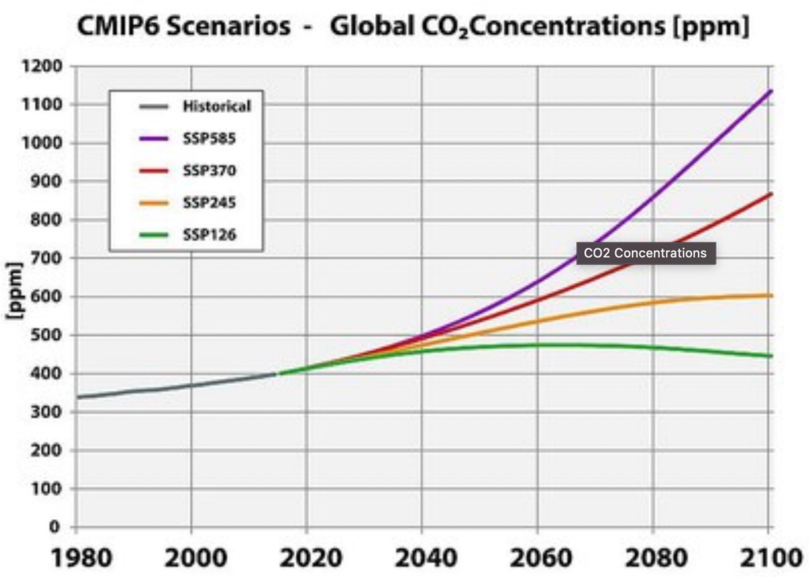
4 PFTs
2 phytoplankton
2 zooplankton

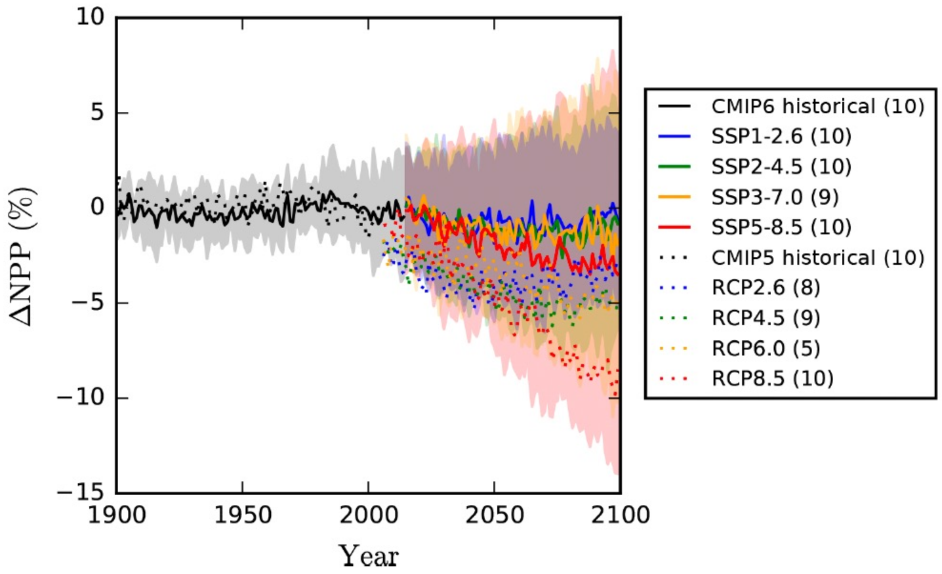
+ grazing
+ sinking
+ implizit representation of microbial loop
+ implizit representation of $CaCO_3$ production



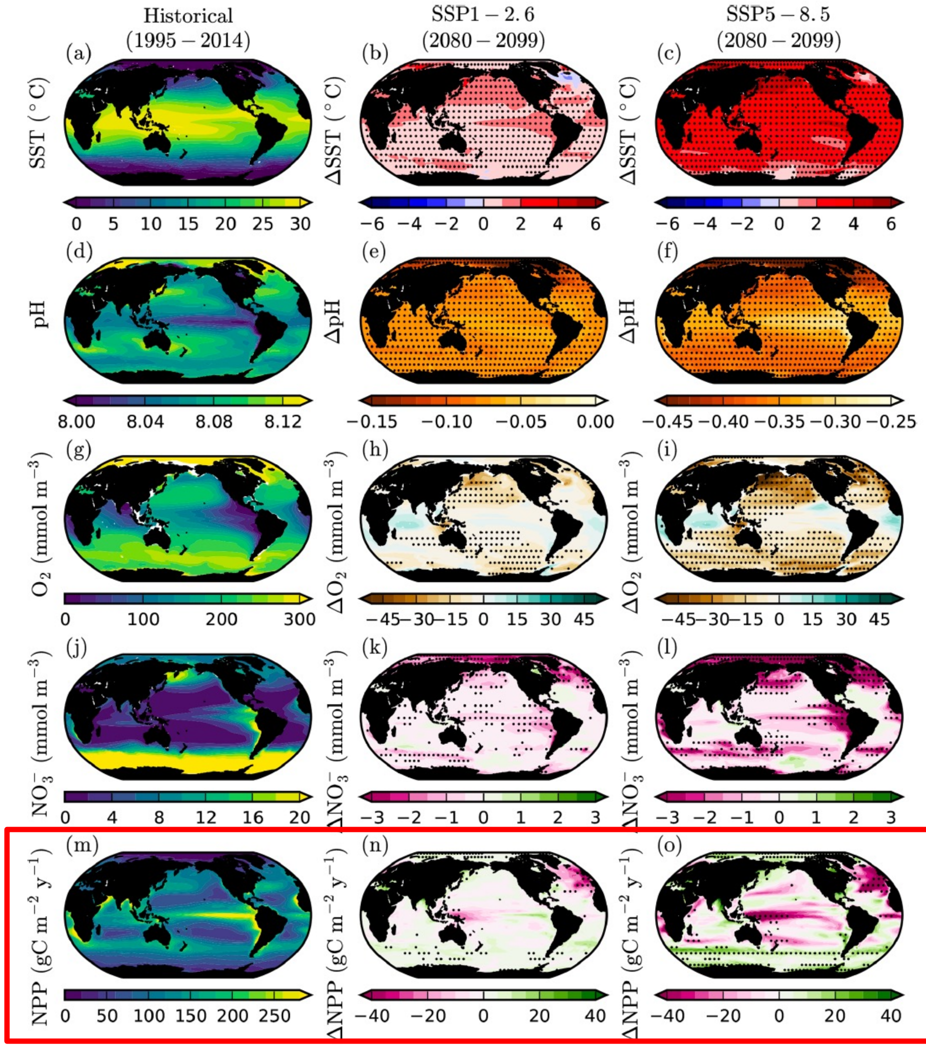
One PFT is described by a single set of parameters (growth, nutrient uptake affinity, mortality etc.), but modulated by environmental conditions

Net Primary Production: Future Evolution in response to climate change





Kwiatkowski et al. (2020)



Drivers of upper-ocean ecosystem impacts

Anomalies are 2080–2099 mean values relative to the 1995–2014 baseline period

sea surface temperature (°C)

surface ocean pH

subsurface dissolved O_2 concentration (mean 100 – 600m)

euphotic-zone NO_3^- (mean 0 -100 m)

depth integrated NPP

Kwiatkowski et al. (2020)

One PFT is described by a single set of parameters (growth, nutrient uptake affinity, mortality etc.), but modulated by environmental conditions

- no plasticiy of response to changing climate (acclimation, adaptation)
- no representation of biodiversity (more PFTs ≠ diversity)
- no or little functional redundancy (beyond PP, grazing)

=> function might be unrealistically down(up) regulated under future climate change

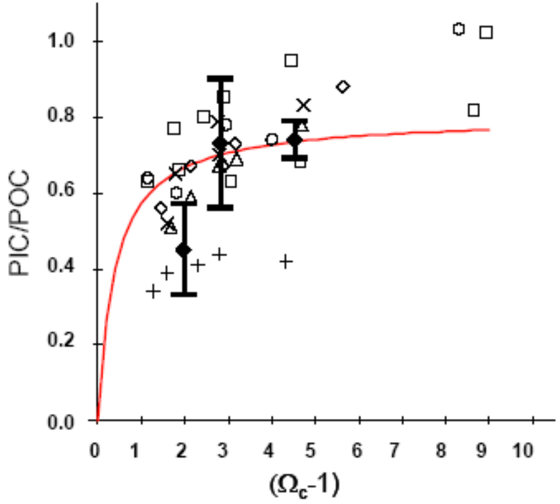
Carbonate Production : standard model, calcite

nutrient limitation   biomass criterion

$$\frac{PIC}{POC} = \frac{PIC}{POC}^{*} L_{\lim}^{P} \max\left(0.0001, \frac{temp}{2+temp}\right) \max\left(1, \frac{NANOPHYTO}{2}\right)$$

temperature effect

$$\frac{PIC}{POC}^{*} = \left(\frac{PIC}{POC}\right)_{\max} \frac{(\Omega_c - 1)}{K_{\max} + (\Omega_c - 1)}$$



where:

$$\Omega c = \frac{\left[Ca^{2+}\right]_{SW} \times \left[CO_3^{2-}\right]_{SW}}{K_{sp}^{*}}$$

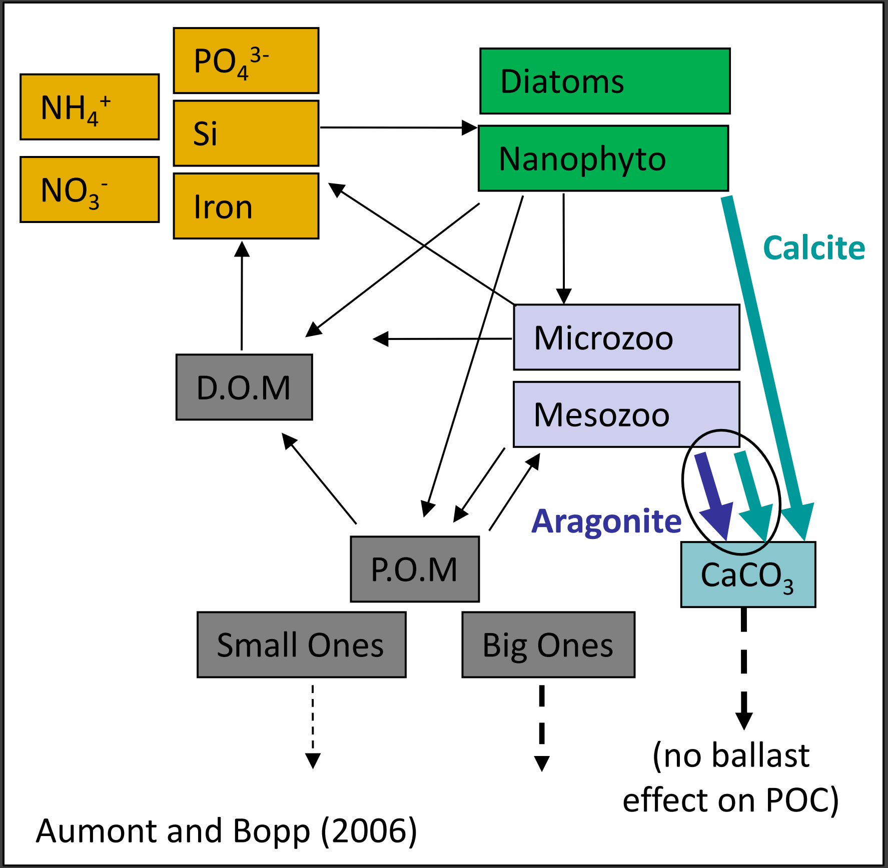
$K^{*}_{sp} = [Ca^{2+}]_{SAT} \times [CO_3^{2-}]_{SAT}$

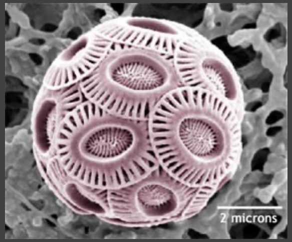
calcite stoichiometric solubility product

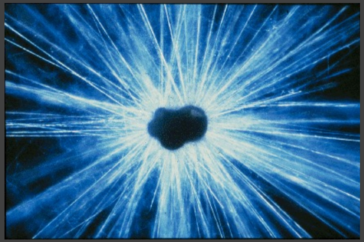
a function of pressure, salinity and temperature (Mucci, 1983)

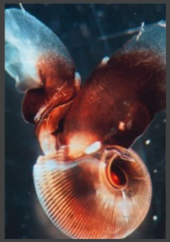
Gehlen et al. (2007)

Carbonate Production : Calcite & Aragonite









$CaCO_3$ production is attributed to:

1. **Nanophytoplankton**
   = Calcite
2. **Mesozooplankton**
   = Aragonite (new)
3. **Mesozooplankton**
   = Calcite (new)

Gangstø et al. (2008 & 2011)

Maximum feedback on atm. CO_2 from multiple model simulations

Year	Max feedback on atm. CO_2	CO_2 perturbations
1766-2100	**11.4 ppm**	~980 ppm
1766-2500	**24 ppm**	~600 ppm

⇒ Feedbacks on atmospheric CO_2 from decreasing $CaCO_3$ production are small

Gangstø et al. (2008 & 2011)

Exploration of sensitivity of marine carbonate cycle to climate change ocean acidification:

- implicite representation of multiple calcifiers
- quantification of feedbacks to atm CO_2 robust across a range of models (no shown)
- decrease of $CaCO_3$ production highest with zooplankton calcifiers

=> projections of biogeochemical function « $CaCO_3$ production » possible with current ESMs, but no ecosystem impacts

Thank you for your attention !