Explicit representation of calcifying phytoplankton in a global biogeochemical model: export and rain ratio.

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Abstract: Thanks to the addition of Fe and Si as limiting nutrients global biogeochemical models now give reasonable distributions of chlorophyll in the surface ocean (Moore et al. 2002, Aumont et al. 2003). We have added calcifying phytoplankton to improve the representation of the alkalinity cycle and the export and settling of particulate matter. We compare our results to recent compilations of observations.

Background:

Our goal is to improve the representation of biogeochemical fluxes in an Ocean General Circulation Model by explicitly describing the biomass and activity of individual plankton functional types. The parent model (PISCES) already includes nanophytoplankton, phytoplankton silicifiers, micro- and mesozooplankton. At present, the Green Ocean Model has been extended with phytoplankton calcifiers. We present model results of export of organic carbon, CaCO3 and particulate Si, both at 100 meter depth and at 2768 m., and compare these results to observations.

MODEL DESCRIPTION:

OCEAN BIOGEOCHEMISTRY. Highlights:

- 3 Nutrients (N, Si, Fe), 3 Phytoplankton (nanophytoplankton, silicifiers, calcifiers), 2 Zooplankton (meso-, microzooplankton), 3 Detritus (small POC, large POC, DOC)
- Additional passive tracers are DIC, alkalinity, O_2, $CaCO_3$, particulate Fe pools, particulate Chl*a* pools, particulate Si
- The model has a fixed C:N ratio, and variable C:Si, C:Fe and C:Chl*a* ratios.

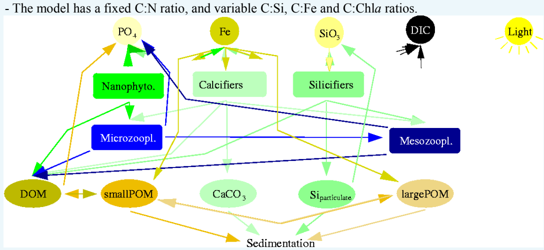

Figure 1: The Dynamic Green Ocean Model is based on the biogeochemical model PISCES (Aumont et al. 2003), and further includes calcifying phytoplankton.

Table 1: Differences in physiological parameter values of growth and loss rates among the phytoplankton functional types.

	nanophytoplankton	calcifiers	silicifiers
$K_{m,N}$ [µM}	0.26	0.05	1.0
$K_{m,Si}$ [µM]			2
$K_{m,Fe}$ [pM]	20	20	120
α_{light}	4	4	3
light stress factor	0.5	1	0
microzoopl. preference	1	1	0.3
mesozoopl. preference	0.2	0.2	1

OCEAN DYNAMICS. Highlights :

- Ocean dynamics from OPA ocean circulation model (Madec & Imbard 1996)
- 2° by (on average) 1.5° resolution, 31 vertical levels (Figure 2)
- LLN ice model (Fichefet & Morales Maqueda 1999)
- Vertical eddy diffusivity and viscosity coefficients computed from a 1.5 order turbulent closure scheme (Gaspar et al. 1990)
- Forced by weather data and satellite observations (Le Quéré et al. 2000) 1990 – 1995. Results are averages over 1995.
- Initialised with observations.

Results 100m:

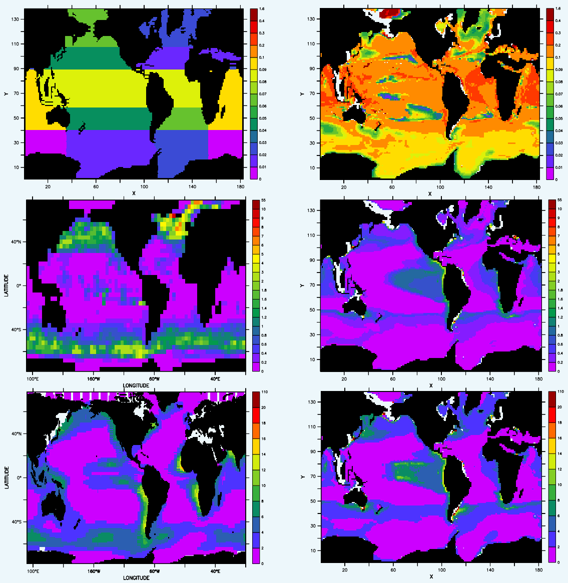

Figure 2: Comparisons between observations at 100 m (left panels) and model results (right panels), for $CaCO_3$/POC sinking ratio from the vertical gradient of potential alkalinity and nitrate (top; Sarmiento et al. 2002), export of $CaCO_3$ from the seasonal depletion of alkalinity in the surface mixed layer (middle; Lee 2001), and POC export from inverse modelling of nutrient observations (bottom; Schlitzer 2002).

Results 2768 m:

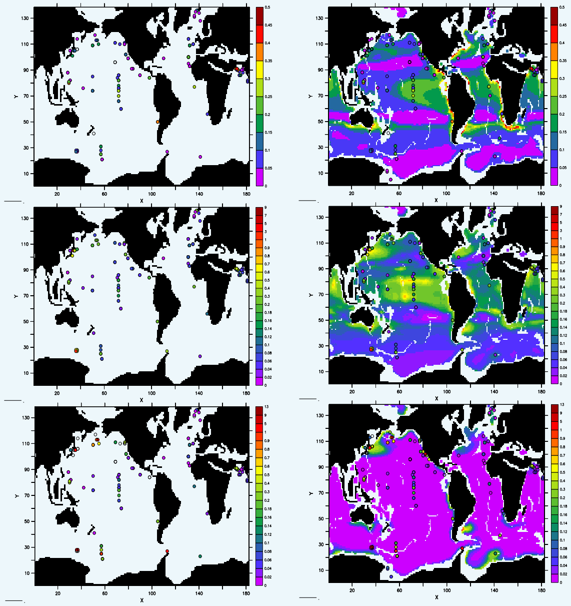

Figure 3: Comparison between sediment trap observations (left panels, extrapolated to 2768 m depth, Klaas & Archer 2002) and model results (right panels) (mol/m2/year), for $CaCO_3$ (top), organic carbon (middle), and particulate Si (bottom).

Results:

•The global average $CaCO_3$/POC ratio (0.13) is higher than the value of 0.06 ± 0.03 estimated from observations by Sarmiento et al. (2002), but shows the same pattern: higher in the tropics than in the subpolar regions, and lower in the North Atlantic than in the North Pacific.

• In contrast to the $CaCO_3$/POC ratio, the observations of $CaCO_3$ export (Lee 2001) are higher in the subpolar regions than in the tropics. Although the contrast is partly due to the low POC export in the subtropical gyres, the three observational data sets are not fully consistent. This may be partly because the CaCO3 export data were derived from the seasonal decline in alkalinity, which may not give very reliable results in the tropics.

•The model compares reasonably well with the export of organic carbon at 100 m, compared to the inverse model (Schlitzer).

•At present we have no observational data set for Si export at 100 m.

•The model gives a reasonable distribution of settling organic carbon and $CaCO_3$ in the deep sea compared to the sediment trap data (Klaas & Archer 2002)

•The settling of particulate Si needs attention.

Discussion:

•Simulated export patterns of $CaCO_3$ and POC are consistent with observations. This suggests that laboratory studies and field measurements give a proper representation of the processes associated with the different plant functional types.

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