The Dynamic Green Ocean Model: 6 Plankton functional groups in an Ocean Global Circulation Model.

Erik T. Buitenhuis[1,3], Corinne Le Quéré[1] and Olivier Aumont[2]
[1] Max Planck Institute for Biogeochemistry, PO box 100164, D 07745 Jena, Germany, fax +49-3641-686710
[2] Laboratoire d'Océanographie Dynamique et de Climatologie, T26-E4 4 Place Jussieu,75252 Paris cedex 05, France
[3] tel. +49-3641-686735, email martinburo@gmail.com

ABSTRACT : Our goal is to improve the representation of biogeochemical fluxes in an Ocean General Circulation Model. The components of the project are impoving model parameterisation, including a coastal model, improving the representation of the marine food web and extending model validation datasets. Here, we focus on the inclusion of six major phytoplankton groups in the model food web. This project is analogous to the inclusion of plant functional types in models of land biology. The basis for this project is the PISCES ocean biogeochemistry model (Aumont et al. in preparation), which includes the potentially limiting nutrients NO_3^-, Fe^{3+} and SiO_3^- in colimitation with light. The PISCES model already includes diatoms, nanophytoplankton, micro- and mesozooplankton. The Green Ocean Model will further represent coccolithophorids, N_2 fixers, phaeocystis and picophytoplankton. We show preliminary model results with three PFTs, and compare our results to observations. We discuss the selected plankton functional types and their parameterisation.

MODEL DESCRIPTION.

OCEAN BIOGEOCHEMISTRY. Highlights:

- 3 Nutrients (NO_3^-, SiO_3^-, Fe^{3+}), 3 Phytoplankton (nanophytoplankton, diatoms, coccolithophorids), 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.

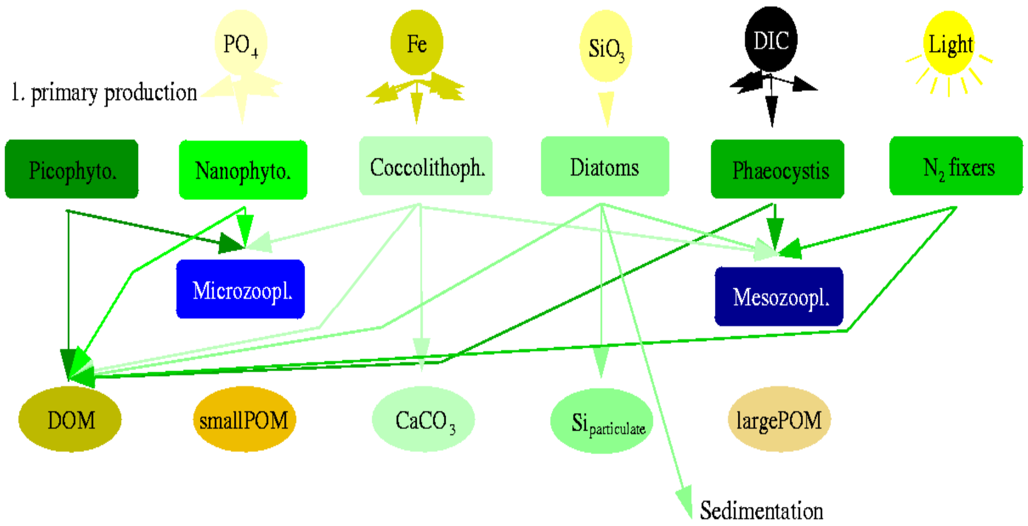


Figure 1: The Dynamic Green Ocean Model is based on the biogeochemical model PISCES (Aumont et al. in preparation), and will include 6 phytoplankton functional groups.

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) 1996 – 1998.

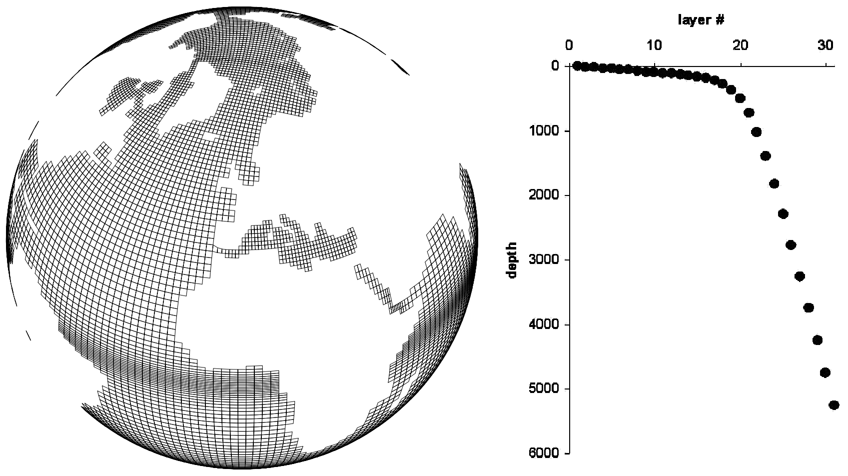


Figure 2 : The physical ocean model is from OPA (Madec & Imbard 1996) developed at the Institut Pierre Simon Laplace. Left) Surface grid of model (ORCA grid). Right) vertical resolution.

ACKNOWLEDGMENTS :

We thank K. Lee for providing the data of global $CaCO_3$ export. We thank C. Prentice, S. Harrison and all the participants of the Dynamic Green Ocean Model (DGOM) project for their helpful discussions. For more information on the DGOM project; the group of scientists involved, and ways to contribute please see our web page http://www.bgc-jena.mpg.de/bgc_prentice/projects/green_ocean/start.html

Literature :
- Aumont O. and co-authors, PISCES in the OPA model (in preparation)
- Aumont O., E. Maier-Reimer, S. Blain, P. Monfray, An ecosystemmodel of the global ocean including Fe, Si, P co-limitations, submitted to *GBC*.
- Aumont O., J. C. Orr, P. Monfray, W. Ludwig, P. Amiotte-Suchet, J.-L. Probst (2001) Riverine-driven interhemispheric transport of carbon. *GBC* **15** (2) 393-405
- Fichefet T., M. A. Morales Maqueda (1999) Modelling the influence of snow accumulation and snow-ice formation on the seasonal cycle of the Antarctic sea-ice cover. *Clim. Dyn.* **15** 251-268.
- Gaspar P.,Y. Gregoris, J.M. Lefèvre (1990) A simple eddy kinetic energy model for simulations of the oceanic vertical mixing : Tests at station Papa and Long-Term Upper Ocean Study site. *J. Geophys. Res.* **95** (16) 179-193
- Lee K. (2001) Global net community production estimated from the annual cycle of surface qater total dissolved inorganic carbon. *Limn. Oceanogr.* **46** (6) 1287-1297
- Le Quéré C., J.C. Orr, P. Monfray, O. Aumont, G. Madec (2000) Interannual variability of the oceanic sink of CO_2 from 1979 through 1997. *GBC* **14** (4) 1247-1265
- Madec G., M Imbard (1996) A global ocean mesh to overcome the North Pole singularity. *Clim. Dyn.* **12** 381-388
- Nanninga H. J., T. Tyrrell (1996) Importance of light for the formation of algal blooms by Emiliania huxleyi. *Mar. Ecol. Progr. Ser.* **136** 195-203
- Riegman R., W. Stolte, A. A. M. Noordeloos, D. Slezak (2000) Nutrient uptake and alkaline phosphatase (EC 3:1:3:1) activity of *Emiliania huxleyi* (Prymnesiophyceae) during growth under N and P limitation in continuous cultures. *J. Phycol.* **36** 87-96
-Tyrrell T., A. Taylor (1996) A modelling study of Emiliania huxleyi in the NE Atlantic. *J. Mar. Syst.* **9** (1/2) 83-112

RESULTS :

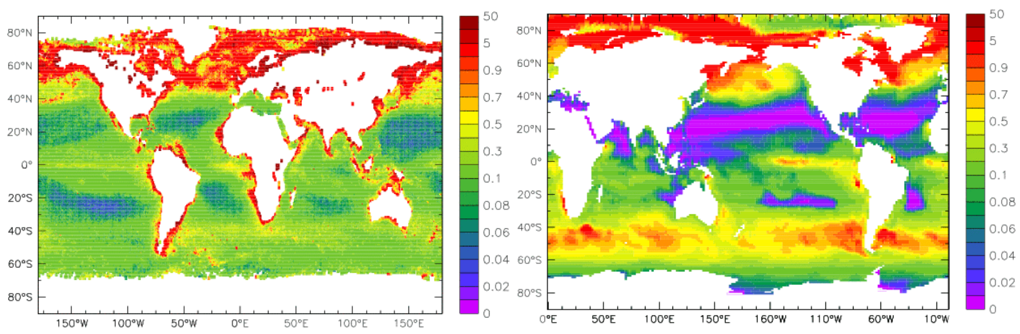
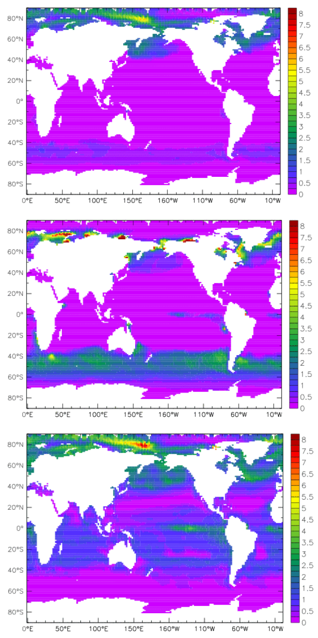


Figure 3 : Chlorophyll *a* concentration [μg/L]. Left panel: SeaWiFS data averaged over June 1997 - 2001. Right panel: model results for 19 June 1993.

Nanophyto plankton

Diatoms

Coccolitho phorids



$CaCO_3$ export, courtesy of K. Lee 2001

$CaCO_3$ export, preliminary results

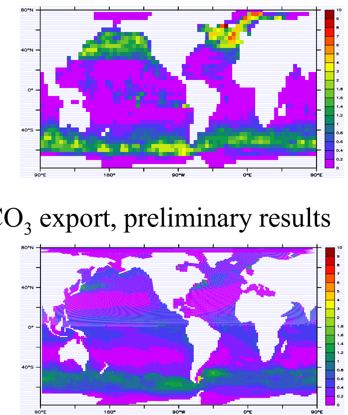


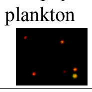
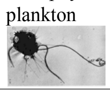
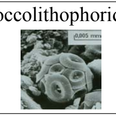
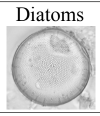
Figure 4 : Preliminary model results with parameters as in Table 1. Surface layer concentrations [μM] for 1993. Top panel) Nanophytoplankton. Middle panel) Diatoms. Lower panel) Coccolithophorids.

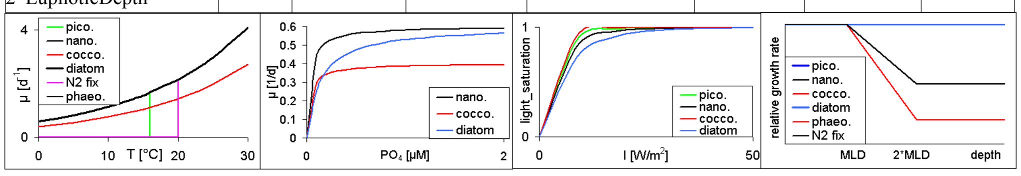
Figure 5 : $CaCO_3$ export. Top panel) CaCO3 export based on potential alkalinity decrease in the surface mixed layer (mol· m^{-2}y^{-1}, Lee 2001). Lower panel) $CaCO_3$ export (mol· m^{-2}y^{-1}), preliminary results of the previous model version.

PARAMETERS :

Parameter selection is still at an early stage. The following parameterisation of primary production is based on a qualitative analysis of the PFTs. Based on sensitivity analysis of an earlier version of the model, POP use as an alternate source of phosphorus for coccolithophorids is not included in the present model version.

Table 1 : Parameter values for primary production.

Description	Units	Picophyto-plankton 	Nanophyto-plankton 	Coccolithophorids 	Diatoms 	Phaeocystis 	N_2 fixers 
maximum specific growth rate μ at 0°C	1/d	0.6	0.6	0.6	0.6	0.6	0.4
Temperature [°C] dependence of μ	-	1.066^T	1.066^T	1.066^T	1.066^T	1.066^T	1.066^T
Minimum growth temperature	°C	16					20
half saturation constant for phosphate	nM	19	19	4	75	19	75
half saturation constant for silicate	μM				2		
half saturation constant for iron	pM	20	20	20	120	20	120
affinity for light	arbitr.	>6	6	6	4	6	4
light stress factor if MixedLayerDepth > 2*EuphoticDepth	-		0.5	1	0		



DISCUSSION :

The preliminary results after including coccolithophorids in PISCES show that the change in PO_4 requirement of coccolithophorids has the largest impact on its global inventory (Figure 4). The combined coccolithophorid specific behaviour improves the ability of the model to correctly simulate the $CaCO_3$ export (Figure 5). However, it also results in coccolithophorids becoming the dominant phytoplankton group in the tropics (Figure 4). It is known from sediment trap data that the coccolithophorids are important contributors to the phytoplankton community in the tropics, and there are methodological reasons for expecting that the $CaCO_3$ export in the tropics determined by Lee (2001) might be underestimated. Still, the extent to which coccolithophorids outcompete nanophytoplankton in the tropics in the model is not supported by current observations.

Another point that we are working on is zooplankton grazing. Grazing and other loss terms are an important factor in structuring the marine food web. We are currently working on a data compilation that would allow us to define more ecological niches for the other phytoplankton groups, that we think should be included in our biogeochemical model.