A Dynamic Green Ocean for Earth System Models

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Rationale

The links between climate and marine ecosystems are poorly known. Recent studies have highlighted large changes in plankton and fish composition, but current ocean biogeochemistry models can hardly reproduce observed variations in surface chla. **We present plans to build and validate an ocean biogeochemistry model more closely based on ecological principles**, to address questions regarding the impacts and feedbacks between marine ecosystems and climate.

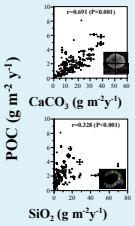
Model development strategy

Ideal set of plankton functional types to be included in the model:

	PFT	size (um)	biomass (PgC)	characteristics
	Silicifiers	20-200	0.09[a]	Large. Produce dense ballast. Form blooms.
	Calcifiers	5-10	0.13[a]	Produce dense ballasts. Affect carbonate chemistry. Form blooms.
	N_2-fixers	2000-5000 (single cell 10)	0.13[a]	Fix nitrogen from the atmosphere.
	Muco-colonies	100-500 (single cell 5)	0.13[a]	Produce DMSp precursors. Abundant at the coast. Form blooms.
	Pico-phyto.	0.5-2	0.13[a]	Grow fast.
	Generic phyto.	2-5	0	Include all other types of phytoplankton.
	Bacteria	0.5-2	0.39[b]	Remineralize organic matter
	Micro-zoo.	20	0.16[b]	Feed on prey in specific size ranges.
	Meso-zoo.	200	0.1[c]	Feed on prey in specific size ranges.
	Macro-zoo.	2000	?	Graze across a wide spectrum of size. Form blooms.

[a] Derived from a combination of the statistical analysis of a HPLC pigment database and SeaWIFS Chla composite maps (Uitz et al., 2003), assuming that the micro size class is mostly silicifiers, the nano size class is equally distributed between calcifiers and muco-colonies, and the pico size class between the N_2-fixers and picoplankton. We use a C/Chla ration of 50 gC/gChl for silicifiers and 125 for other PFTs.

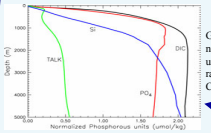
[b] Gasol et al., 1997. [c] Estimated using data from the World Ocean Atlas 2001 and from Hirst and Bunker [2003] and Beaugrand et al., [2002].



Fate of organic matter: Once nutrients and carbon have been sequestered in organic tissue, **the reverse transfer of organic to inorganic material and the depth at which this occurs depends on the formation of the particles, the sinking speed, the remineralization and the final sedimentation at the ocean bottom. In theory, these processes result from the composition of the ecosystem**, including the grazing behavior and environmental factors such as temperature. In practice, however, not enough is known about particle dynamics, grazing and remineralization to develop a fully prognostic model, and more data analysis and experimental studies are needed to parameterize and validate this part of the model. For example, an analysis of sediment trap data revealed that the carrying capacity of $CaCO_3$ for organic carbon was larger than that of SiO_2 (left: Figure from Klaas and Archer [2002]), a characteristic that yet has to be included in models.

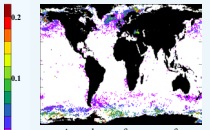
Model evaluation strategy

We use data from several published sources in an effort to systematically evaluate important processes included in the model. Although a lot of data has already been compiled, some key processes such as the sinking speed of particles are still poorly constrained.



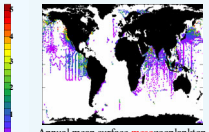
Global mean concentration of tracers normalized to surface values and to P units using a C/P ratio of 122 and a Si/P ratio of 55 (mol/L; from WOA and CDIAC)

nutrients

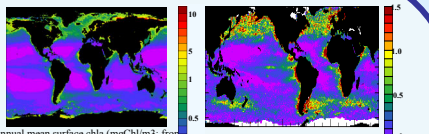


Annual mean frequency of coccolithophorid blooms (data from C. Brown based on analysis of SeaWIFS; Brown and Yoder, 1994)

Plankton functional type



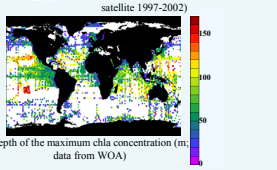
Annual mean surface mesozooplankton biomass (mol/L; data from WOA)



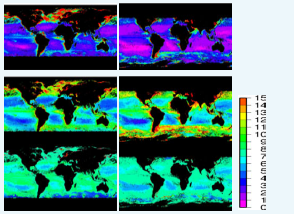
Annual mean surface chla (mgChl/m3; from SeaWiFS satellite)

rd deviation of interannual Chla (mgChl from SeaWiFS satellite 1997-2002)

biomass



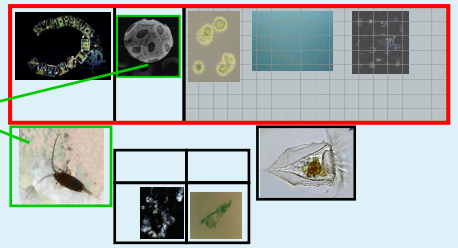
Depth of the maximum chla concentration (m; data from WOA)



Biomass of micro (top), nano (middle) and pico (bottom) phytoplankton for June 2000 (left) and December 2000 (right) derived from a combination of the statistical analysis of HPLC pigment database and SeaWIFS Chla composite maps (Uitz et al., 2003).

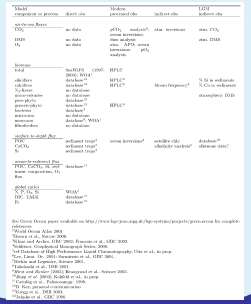
Model in its current state

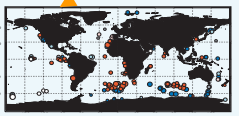
Fe | P/N | Si



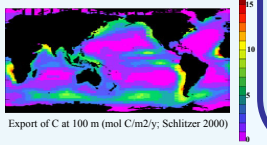
export

Available set of evaluation data





Change in export production recorded in marine sediments between the Last Glacial Maximum and today (red=higher export at the LGM; Bopp et al., 2003)



Export of C at 100 m (mol C/m2/y; Schlitzer 2000)

Discussion:

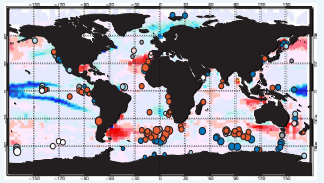
The development of a Dynamic Green Ocean model requires:

- **compilation of observations to derive traits for all PFTs**
- **compilation of validation data for modern and past ocean**
- **model developments in a community framework**

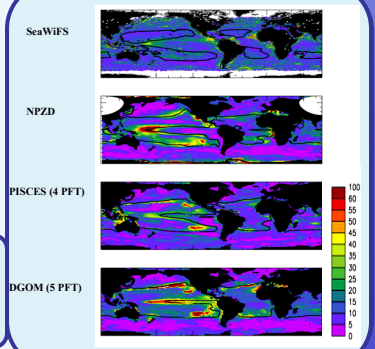
Here we present a strategy for the development of a Dynamic Green Ocean Model. The present model configuration is based on the PISCES model of Aumont et al. [2003] and includes five PFTs (silicifiers, calcifiers, generic phytoplankton, micro and meso zooplankton). Results suggest that the behavior of observed chla is better captured when the ecosystem composition is more complex compared to classical NPZD models. More information on this project can be found on **http://www.bgc-jena.mpg.de/bgc-systems/projects/green_ocean/** or requested to lequere@bgc-jena.mpg.de

Results

Last Glacial Maximum: The original PISCES model (without explicit calcifiers) was used in a simulation of the Last Glacial Maximum (Bopp et al., 2003). The model reproduces some key patterns, but highlights room for developments.



Modern (1997-2002): A suite of ecosystem models increasing by complexity were used to estimate the interannual variability in the surface chla. No models reproduce the observed patterns of variability. See presentation OS52H-10.



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