Considering a coastal ocean model for global simulations

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Seawifs Data (fig 1.a)

Chlorophyll concentration (mg chl /m³)

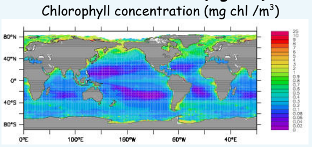


Figure 1.a. Surface chlorophyll-a (chl-a) concentrations observed by Seawifs satellite show the importance of the coastal zone for primary production.

Reference Simulation (fig 1.b)

Chlorophyll concentration (mg chl /m³)

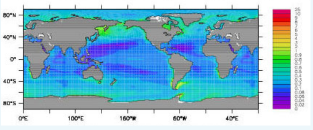


Figure 1.b shows the results of a simulation using the physical model OPA coupled with the biological model PISCES (Aumont et al., 2002). This model is used for the simulations presented hereafter.

Difference (Simulation – Data) (fig. 1.c)

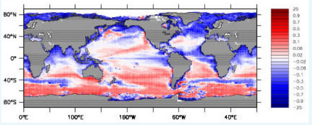
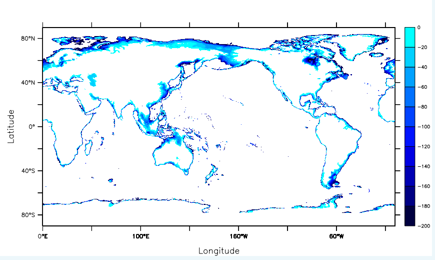


Figure 1.c highlights the discrepancies between data and model output. In general, surface chl-a concentrations of the model are under-estimated in the coastal areas, in the equatorial and coastal upwelling systems, in the south polar front and in the North Atlantic, and are over-estimated in Antarctic Ocean and in the sub-tropical gyres.

Rationale:

The coastal ocean covers about 10% of the total area of the world ocean. Yet in these regions take place one quarter of the oceanic primary production, half of the carbonate burial and most of the burial of organic carbon. Moreover, constant input by human activities occurs in these fragile areas. State-of-the-art Global Ocean Biogeochemical Models (OBM) have so far neglected the specific processes that take place in the coastal ocean.

Here we present the first step of a simplified approach to represent the vertical processes occurring in the coastal ocean in the global biogeochemical models. We investigate the impact of additional mixing processes (tides) and additional nutrient sources (sediment resuspension) on the global chl-a concentrations using sensitivity studies.



The coastal ocean (fig. 2)

Extension of the coastal ocean (depth between 0 and 200m).

This coastal domain is used to create a coastal grid and corresponds to the nutrient source distribution in sensitivity test below (fig. 5).

Sensitivity tests. Enhanced nutrient sources :

Enhanced mixing

We multiplied the vertical diffusivity in the coastal area of the OBM by x100.

➢ This higher mixing rate increases the surface chl-a mass budget in the coastal ocean (+14%) but has little impacts on the the gyres.

Homogenous nutrient source

We restored nutrients in the coastal zone of the OBM (to a minimum of 4.5 µmol NO_3/l, 3.2 nmol Fe/l and 7 µmol Si/l). By doing this, we change the nutrient limitation, and nutrients are exported to the open ocean.

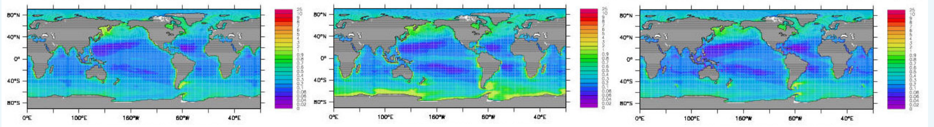
➢ It strongly influences the gyres and the equatorial upwellings, getting closer to observations in most places except in the Southern Ocean.

Heterogenous nutrient source

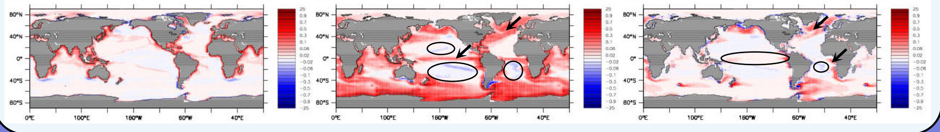
Same as the previous sensitivity test but releasing nutrients from a realistic coastal grid (shallow zones, fig. 2).

➢ The impact on the open ocean is weaker than previously (because of less sources) but still improves the global pattern.

Simulations (fig. 3) (fig. 4) (fig. 5)



Comparison with the refence run (Simulation – reference run)



Discussion

• The relative ratio of NO_3, Fe, Si released in the coastal zone determines its influence on the open ocean. When the ratio is the same as in the OBM (fig. 3), there is little impact on the open ocean. On the contrary, when the ratio is different (fig. 4 & 5), the influence extends to the entire ocean.

• In all sensitivity studies, diatoms and mesozooplankton are favored (Table 1) because of the relatively high growth rate of diatoms.

• Simulations with realistic sources and sinks are on the way. This will be considered by a Coastal Model (coastal grid + specific processes) coupled to the OBM. See below.

Table 1. Global mass budget of biological species (in Gt C).

Term	Reference run (fig. 1b)	Enhanced mixing (fig. 3)	Homogenous nutrient source (fig. 4)	Heterogenous nutrient source (fig. 5)
Nano-phytoplpamkton	0.54	0.54 (+0.9%)	0.52 (-3.3%)	0.53 (-1.5%)
Diatoms	0.72	0.74 (+3.0%)	0.83 (+15.4%)	0.74 (+3.2%)
Micro-zooplamkton	0.23	0.25 (+6.5%)	0.24 (+4.8%)	0.23 (+0.0%)
Meso-zooplankton	0.08	0.11 (+27.0%)	0.13 (+49.4%)	0.09 (+5.9%)
Total	1.57	1.64 (+4.1%)	1.72 (+9.3%)	1.59 (+1.3%)

Processes to be taken into account in the coastal model (future work) :

Sediment resuspension

The sediment resuspension is a function of the bottom sediment composition and the bottom shear stress. The resuspension flux (Φ) is in the following form (Ribbe and Holloway, 2001):

$$\Phi = \beta M_t \left(\frac{\tau - \tau_{cr}}{\tau_{cr}} \right) \quad \text{if } \tau > \tau_{cr}$$

where M_t is the total mass of sediment on the seabed available for resuspension, β the entrainment rate, τ the bottom shear stress and τ_{cr} the critical bottom shear stress for resuspension. The critical bottom shear stress depends on the sediment composition and can be expressed as follows (Peterson, 1999) :

$$\tau_{cr} = 0.11803 \rho \Delta^{0.8} g^{0.8} d^{0.4} \nu^{0.4}$$

where ρ is the water density, Δ is the relative specific gravity of the particles, g is the gravity acceleration, d is the diameter of the particles and ν is the water viscosity. The total mass of sediment on the seabed will be parameterized using a "bucket" type model : a sediment box of the model cumulates the sinking sediments, which are further available for resuspension.

Vertical tidal mixing

Tides may have two different consequences:

. The sea surface elevation due to tidal propagation may contribute to a baroclinic component of the currents.

. **The dissipation of tidal energy** enhances vertical mixing and brings nutrients to the surface.

We use a simple parameterization of the vertical mixing rate (K) in relation with the dissipation of tidal energy (E_D), in the form:

$$K_{coast} = \frac{E_D}{T_i N^2} = \frac{\pi \rho g}{Q N^2} \frac{A_i^{\,2}}{T_i}$$

where N is the Brunt-Vaïsala frequency, T_i is the period of the considered tide mode, A_i is the tide amplitude, Q is the fraction of dissipated tide energy.

Conclusion

We are developing a simplified approach to represent large biogeochemical fluxes occurring in the coastal ocean in global biogeochemical models. Full results with the coastal model are not yet available.

The method and strategy are being elaborated to relate the forcing conditions (the surface wind stress and the tidal forcing) and the resulting vertical mixing rate and bottom shear stress in a fully prognostic way. It thus potentially addresses questions related to the impact of global changes on ocean biogeochemistry.

Comments on this first step are welcome. (xgiraud@bgc-jena.mpg.de).

Acknowledgments : We thank O. Aumont for making this model available to us, M. Heimann, M. Gloor, and E. Buitenhuis for comments and helpful suggestions.

References:

Aumont O., E. Maier-Reimer, S. Blain and P. Monfray, 2002, An ecosystem model of the global ocean including Fe, Si, P co-limitations, Global Biogeochem. Cycles, *in press*.
Peterson E., 1999, Benthic shear stress and sediment condition. Aquacultural Engineering, 21, 85-111.
Ribbe J. and P. Holloway, 2001, A model of suspended sediment transport by internal tides. Cont. Shelf Res., 21, 395-422.