Solving the equation for the Iberian upwelling biogeochemistry : an optimization experience

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1. Motivation

The objective of this study is to simulate the seasonal cycle of chlorophyll and nutrients in the region off West Iberia (NE Atlantic) (Fig. 1).
To this end, we designed a data-assimilation framework which uses high quality observations of two observation sites to find the optimal parameters of a biogeochemichal model embedded within the physical ocean model ROMS.

2. ROMS Biogeochemical model

The biogeochemical model embedded in ROMS included 7 state variables (Fig.2). Arrows represent the processes that link one state variable to another, which are calculated in the model using the model parameters (Table 1).

This model was coupled to a one-dimensional (1D) configuration of ROMS at two sites (Fig. 1).

The parameters of this 1D model configuration were optimized using three different optimization set ups. The parameters were applied to a 3D high resolution (~3 km) configuration of ROMS for the Iberian upwelling region.

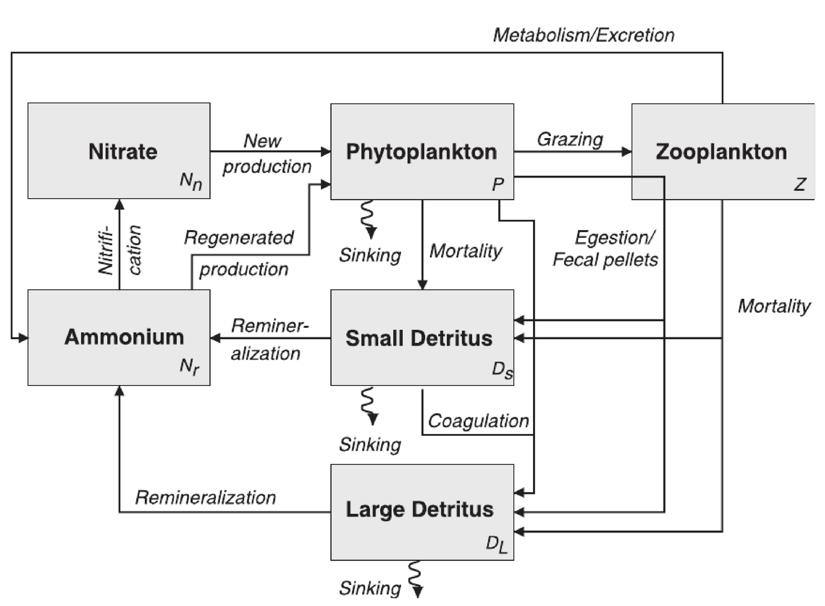

Figure 2. Diagram of the biogeochemical model (from Gruber *et al.* 2006)

Parameter	a priori	optim coast	optim ocean	optim 2 sites	Unit
Light attenuation in seawater	0.04	0.04	0.07	0.05	m^{-1}
Light attenuation by chlorophyll	0.024	0.003	0.006	0.029	$(m^2 mg Chla)^{-1}$
Initial slope of the P-I curve	1	0.17	1.39	1.89	$mg C (mg ChlaW m^{-2} d)^{-1}$
C:N ratio for phytoplankton	6.625	9.24	1.826	3.79	$mol C(mol N)^{-1}$
Cellular chlorophyll:C ratio (maximum)	0.03	0.05	0.045	0.047	$mg Chla(mg C)^{-1}$
Half-saturation for phytoplankton NO_3 uptake	0.9	0.72	0.48	0.47	$mmol N m^{-3}$
Half-saturation for phytoplankton NH_4 uptake	0.5	0.27	0.69	0.77	$mmol N m^{-3}$
Zooplankton half-saturation constant for ingestion	1	0.8	1.8	1.6	$mmol N m^{-3}$
Maximum zooplankton growth rate	0.6	0.7	0.27	0.57	d^{-1}
Zooplankton assimilation coefficient	0.75	1.24	1.48	1.26	n.d.
Phytoplankton mortality rate to small detritus	0.072	0.035	0.015	0.013	d^{-1}
Zooplankton linear mortality rate to small detritus	0.025	0.007	0.018	0.014	d^{-1}
Zooplankton specific excretion rate	0.1	0.18	0.11	0.17	d^{-1}
Detrital mineralization to NH_4 rate (samall detritus)	0.03	0.04	0.05	0.022	d^{-1}
Detrital mineralization to NH_4 rate (large detritus)	0.01	0.01	0.019	0.018	d^{-1}
Nitrification rate	0.05	0.037	0.041	0.014	d^{-1}
Specific aggregation rate(phyt+small detritus)	0.005	0.009	0.009	0.009	$1 (mmol N d)^{-1}$
Sinking velocity for phytoplankton	0.5	0.15	0.43	0.08	$m d^{-1}$
Sinking velocity for large detritus	10	4	15	9.8	$m d^{-1}$
Sinking velocity for small detritus	1	1.6	0.96	0.31	$m d^{-1}$

Table 1. Parameter values of the N2PZD2 model

3. Variational Optimization

Assessment of the optimal parameters Xopt:

- Minimization of the cost function: $J(X)=1/2[(Y-M(X))^T R^{-1}(Y-M(X)]$
  Optimal parameters sets minimize model-data misfit
  M(X): Model Outputs Y: Observations
  X: Parameters R: Error matrix of Obs.

- Multiobjective Genetic Algorithm (Deb et al., 2002)

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4. Optimizations set ups and observations

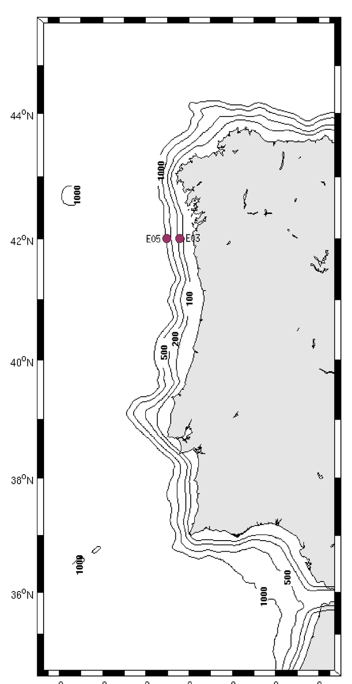

Figure 1. Stations location

Three types of optimizations were carried out using different observations:

A. A **coastal station** (~150 m) (**E03**)
B. An **oceanic station** (~1500 m) (**E05**)
C. **Both stations** at the same time.

Assimilated observations consisted of fortnightly profiles of chlorophyll and nitrate obtained during the DYBAGA project (May 2001-April2002) (IIM-CSIC) (Fig.1).

Results were compared to the prior results (using "first guess" parameters) (Fig.3)

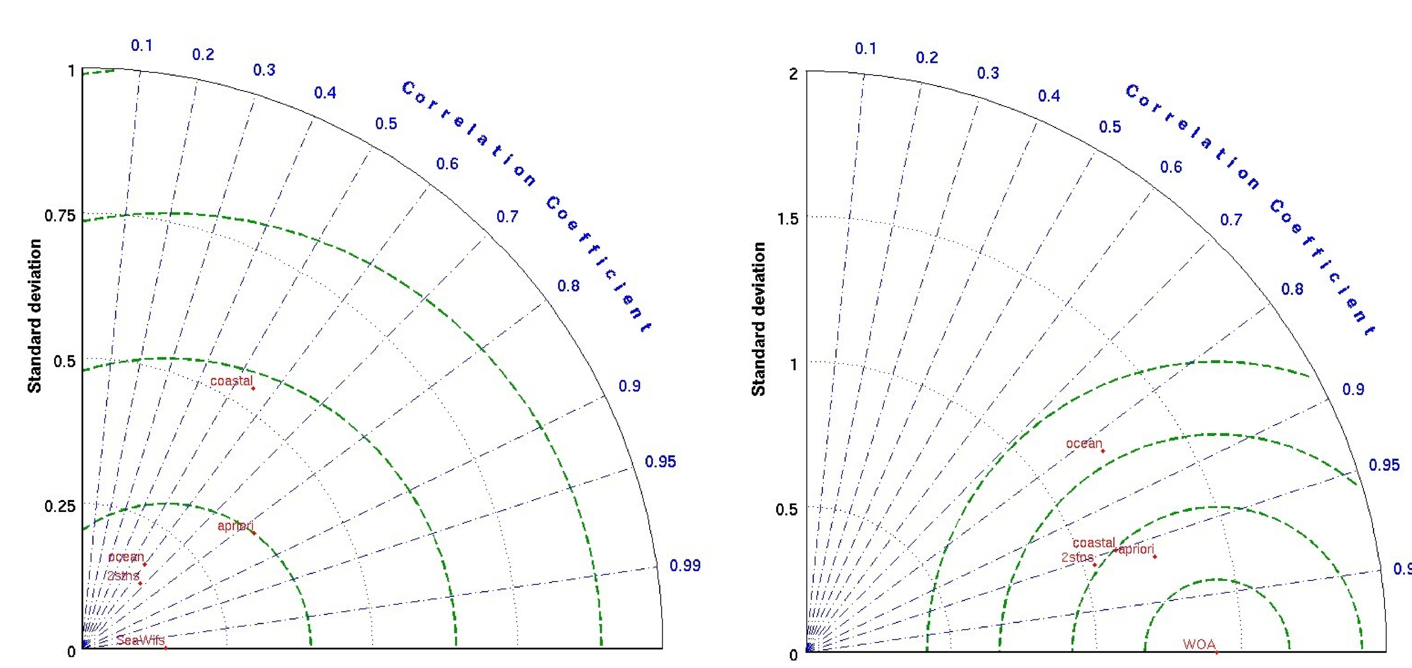

Figure 5. Taylor diagrams comparing chlorophyll model results with SeaWifs climatology (left) and nitrate model results with World Ocean Atlas climatolgy (right) for the different optimization tests. Data compared correspond to monthly surface means within the model domain.

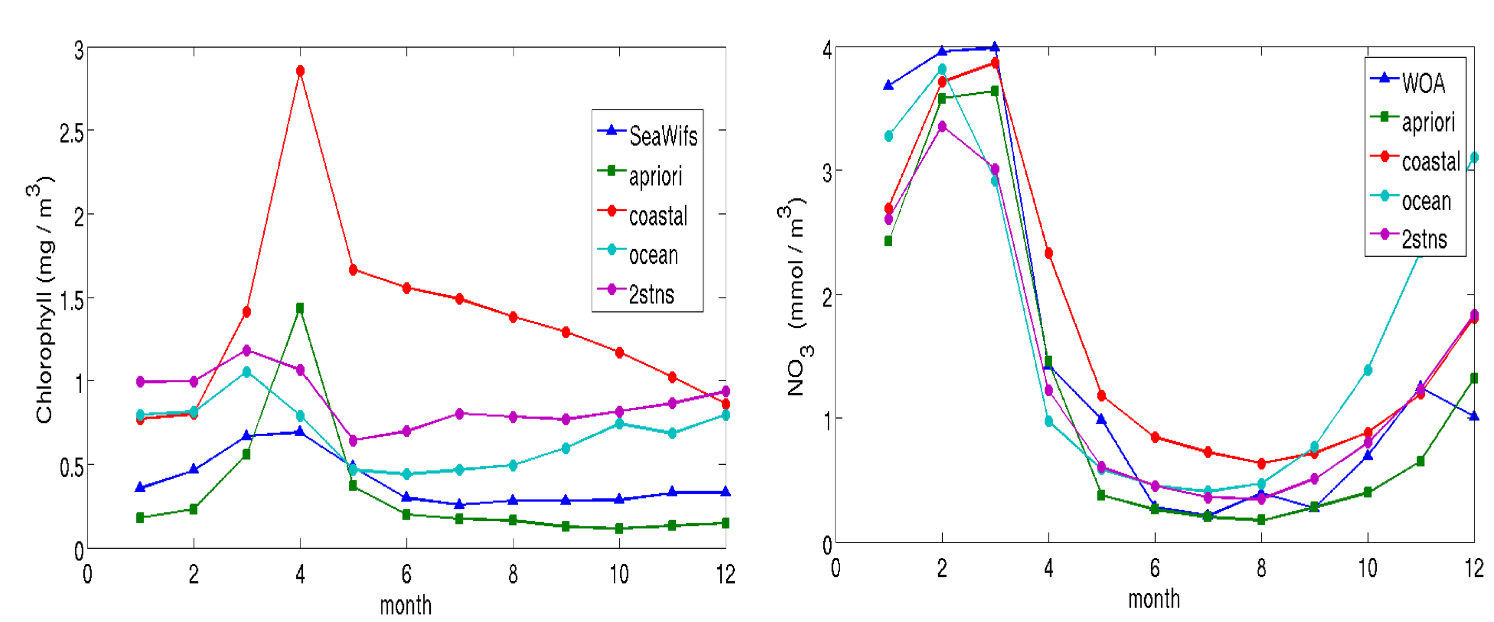

Figure 6. Time series of surface chlorophyll (left) and nitrate (right) for the optimization tests, showing the chlorophyll bloom in spring and nutrients depletion in summer.

6. Conclusions

The optimization of the 1D configuration at the observational stations could improve the seasonal variability of the surface chlorophyll simulated by the 3D configuration within the whole domain. However, this enhancement leads at the same time to an increase bias in the simulated annual means. Improvements observed in the local chlorophyll vertical profiles are promising for a local configuration of the model.

5. Optimization results

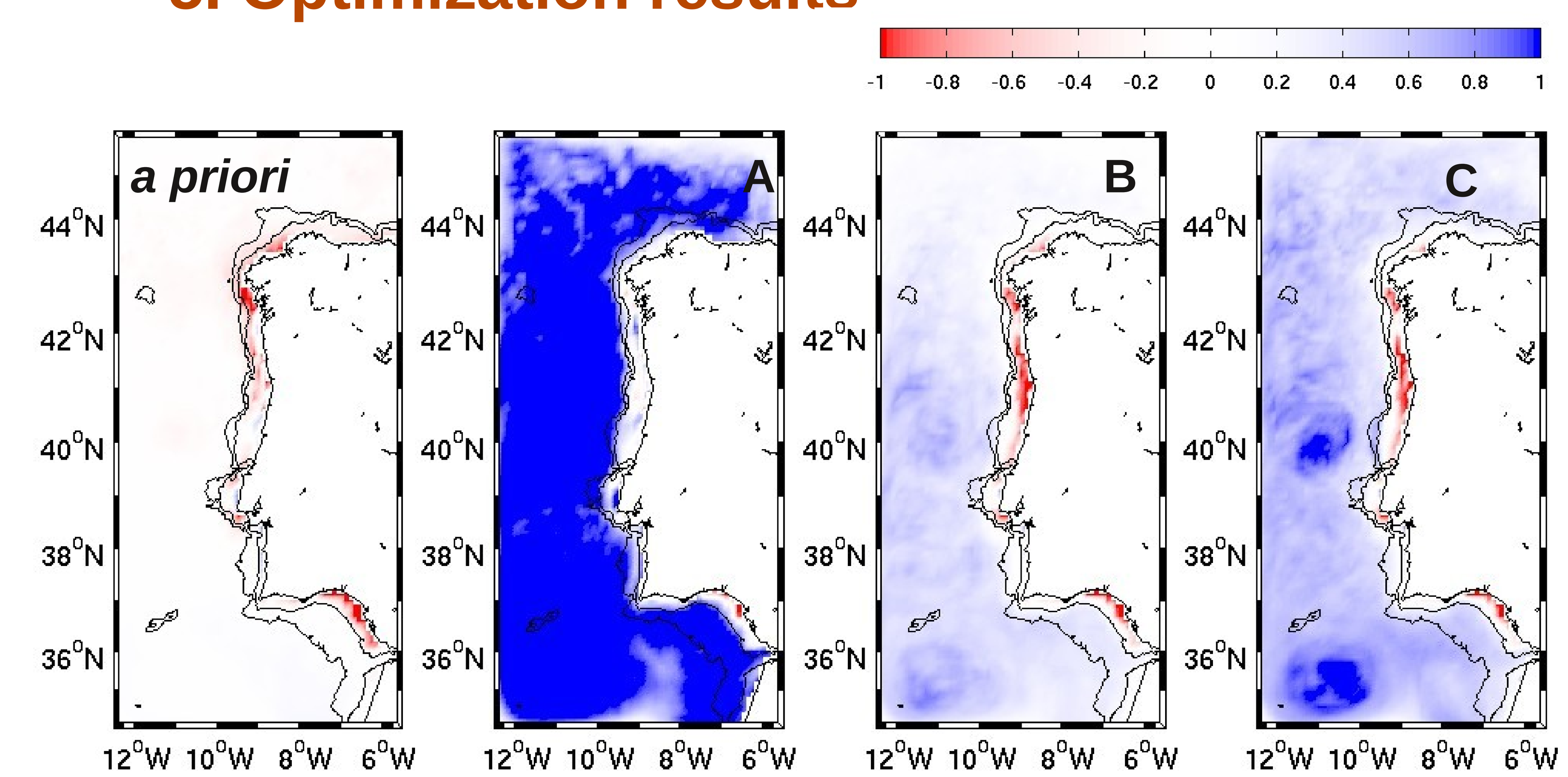

Figure 3 Chlorophyll bias of annual mean (model vs SeaWifs climatology) for the different optimization tests.

Chlorophyll profiles at the 2 stations were improved with the three optimizations (3D conf.), whereas nitrate profiles were already similar to observations prior to optimization (Fig.4). The seasonal variability of surface chlorophyll in the whole domain was improved by the optimizations using data of both stations (C) and of the single oceanic station (B) (Figs 5 & 6). Annual biases were however introduced by all optimizations with respect to the prior simulation of surface chlorophyll concentrations (Fig. 3).

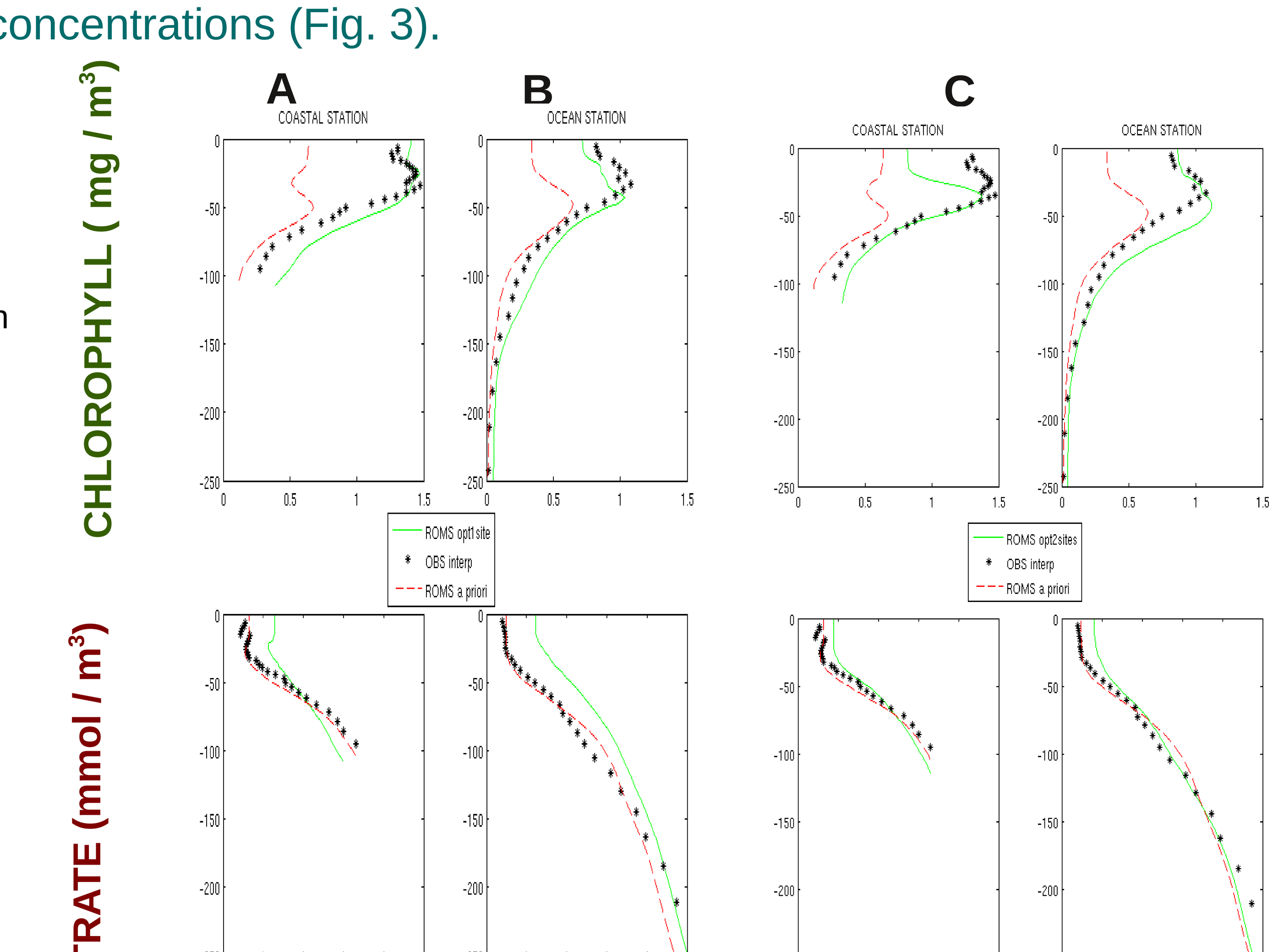

Figure 4. Vertical profiles of chlorophyll and nitrate (annual mean 4th year run) at the two stations comparing model results (3D configuration) and observations.