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Biogeosciences Discussions

Interactive comment on "Modeling the nitrogen fluxes in the Black Sea using a 3D coupled hydrodynamical-biogeochemical model: transport versus biogeochemical processes, exchanges across the shelf break and comparison of the shelf and deep sea ecodynamics" *by* M. Grégoire and J. M. Beckers

M. Grégoire and J. M. Beckers

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Answers to reviewer 3 Dear Reviewer, Here are my answers to your remarks. In bold, I have repeated your remarks. We agree that the high frequency forcing is crucial for the generation of the mixing layer which is a key factor in the development of the biological productivity. At the time of our simulations, the climatological monthly mean forcing was the only one available at basin scale with a acceptable horizontal resolution (1 degree * 1 degree). High frequency forcing had a horizontal resolution of 2.5 degrees. So what you earn in time you lose it in space. Since, the horizontal variability of atmospheric forcing functions could lead to important dynamical effect, we prefer to use the 1*1

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forcing. It will be improved in the future.

Thank you very much for your opinion on our paper.

Specific comments:

The model presented in this paper is used with the aim of understanding the macroscale (i.e. time scales of a few weeks to months) Black Sea's ecohydrodynamics and more specifically : (1) to estimate the transport at the Ĕ.For the transport variability an important contribution at these time scales have the mesoscale variability. How the authors distinguish between the meso- and macro- scales?

The model has a horizontal resolution of 15 km and it already marginally resolves the first internal radius of deformation which is 20 km in the Black Sea (Ozsoy and Unluata, 1997). The model simulates the macroscale and synoptic currents (times scales of a few weeks to months) while, mesoscale processes (i.e. time scales from a few hours to days) are filtered out and represented by a horizontal diffusion (The horizontal subgrid scale viscosity for momentum is 500 m2/s and the horizontal subgrid scale diffusion for tracers is 50 m2/s) .The comparison of the circulation pattern simulated by this model (called hereafter the coarse resolution model) with the one simulated by a high resolution hydrodynamical model (horizontal mesh 5km), shows that the coarse resolution model is able to simulate the main characteristics of the shelf circulation and in particular the reversal of the shelf circulation at the end of spring until the end of fall. However, it has been found that the frontal instabilities and the resulting ejection of filaments is not well simulated and this, of course, could lead to an underestimation of the exchanges between the shelf and the deep sea. In Beckers et al, 2002 Special issue of EROS 21, we compare the water fluxes from the coast to the deep sea computed by the GHER hydrodynamical model with a horizontal mesh of 15km (as in the present study) and 5km. It has been shown that the variability of the export is higher with the high resolution model and the net export was also higher. However, the coupling of a high resolution model with a biogeochemical model for several years needs very long

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time of simulations. In addition, you need high frequency atmospheric forcings for the whole basin with a high spatial resolution. This type of forcing is unavailable at this time. The horizontal resolution of ECMWF data is 2.5 degrees.

2) The GHER primitive equations model is derived from the general “marine weather” model by averaging over a time scale of several weeks ..The GHER model is an explicit free surface model, i.e. it resolves time scales of the fast surface gravity waves, which for the deep part of the sea with resolution of 15km should be about 2 minutes. How the model equations are then averaged over a time scale of several weeks?

The mode splitting technique is used to solve the equations of the rapidly evolving surface gravity waves [Madala and Piacsek, 1977].This methods is based on the fact that gravity waves are described by a system of 2D equations (one equation for the sea surface elevation + 2 equations for the transport obtained by integrating over the vertical the horizontal momentum equations) that can be separately solved from the complete 3D equations system. This technique is advantageous because the computation loads necessary to solve a 2D system is much lower than the one associated to a 3D system. Also, the 2D equations are solved during several 2Dtimestep to obtain the sea surface elevation and the associated barotropic pressure gradient. These variables are then injected in the system of 3D equations which is resolved over a 3Dtimestep, which is much larger than the 2Dtimestep, in order to compute the internal mode of the solution (i.e. the baroclinic mode). The determination of this term allows to compute the baroclinic terms appearing in the 2D transport equations, and this 2D system can then be integrated once again Ĕ After each 3Dtimestep, the 3D velocity is readjusted in order that the associated transport corresponds to the transport created by the 2D mode.

3) Using the results of the tenth year of integration of the physical model, it is not clear from the text with what frequency were stored the hydrodynamics data used as input for the ecosystem model (hourly, daily, weekly,Ĕ)

The ecosystem model is online coupled with the hydrodynamical model. It means that,

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at each time step, the results of the hydrodynamical model (i.e. the temperature, the velocity and the diffusivity) are injected in the ecosystem model. It is mentioned in the paragraph 2, see the first two lines.

4) Even though not mentioned explicitly from the text, it comes out that the coupling between the hydrodynamic and ecosystem model is one way.

That is true. I have added a sentence to specify this feature. See paragraph 2, the third line.

4) continued .. Some observations suggest that the feedback between the phytoplankton concentration and vertical mixing and the mixed layer depth may play an important role especially in the area of the NW shelf. The observations show in particular that the high productivity in this area results in decreasing of the attenuation length for the solar radiation and thus strongly influences the stability of the water column.

In the evolution equation for the temperature, we have no source term. I totally agree with you but since in the mode influence of the solar radiation on the temperature profile is not taken onto account. This could be justified by the fact that the size of the vertical boxes is large (about 5m in the first 30 m and 10 m to 100 m), this will not allow a fine resolution of the temperature profile. In a 1D model, with smaller boxes, this effect will have its significance because the vertical structure is accurately represented.

5) The application of vertical k-l mixing schemes in a model forced by annual mean surface momentum fluxes and relaxation of surface temperature and salinity to the climatology may not give reasonable results for the surface mixed layer depth. It is not mentioned in the text however whether a daily variability of the short wave solar radiation is also included in the forcing. If not that may be additional source of errors in the model mixed layer depth.

Please, see my answer to remark 4. The solar radiation does not influence the physics. It is only used for the biology. The light varies daily. It is computed from astronomical

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Interactive Comment

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formulation (Brock, 1981) and the parameters appearing in this formulation are calibrated using monthly mean values available for the Black Sea.

Technical corrections: 1)\It has been changed 2) I could not find this wrong bracket

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