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Biogeosciences
Discussions

Interactive comment on "Simulating the effects of phosphorus limitation in the Mississippi and Atchafalaya River plumes" *by* A. Laurent et al.

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Below the reviewer's comments were inserted. Responses are interspersed in italic font. Changes in the revised manuscript text responding to these comments are highlighted in blue.

Comment:

1. In order to justify the choice of the boxes for averaging model results, I recommend that the authors provide some figures showing the spatial variability of model results (for instance chla) that will help to justify the selection of regions.

Response:

Please see response to comment 1 by Referee 1. We added the standard deviations to the simulated surface chlorophyll time series in Figure 4 to show the variability in each region. We also added a new figure that shows the location of the boxes over the SeaWiFS climatology and simulated surface chlorophyll in May, July and September (Fig. 5).

Comment:

2. These maps can be compared with satellite images allowing to assess (using some error statistics) the ability of the model to represent the spatial variability of chla (this is important since the model is 3D and in the manuscript no spatial maps are shown).

Response:

Following this recommendation we included a comparison of simulated surface chlorophyll with satellite observations in the new Fig. 5 including 2-dimensional histograms and correlation coefficients. Also included now is a table (new Table 2) of root-mean-square-errors between simulated and observed surface chlorophyll. We would like to note that the N-only version of the model has been assessed extensively in Fennel et al. (2011) including chlorophyll comparison maps. The new Fig. 5 shows May, July and September only which are characteristic months for P limitation (May, July) and N limitation (September). The whole period from April to September is presented in Fig.1 (control run with phosphate) and Fig. 2 (N-only run) below, but only a selected number of panels is given in the new Fig 5 in order to save space and avoid duplication.

Comment:

3. Moreover, some more justifications need to be given for keeping only the observations of Sylvan et al. compared to other studies that used them successfully.

Response:

Please see the response to comment 4 by Referee 1.

Comment:

4. The manuscript presents an extended version of the model published in Fennel et al 2011. Therefore, we can expect that the authors show that adding a phosphorus limitation improves the performances of the model. A suggestion would be to compare the simulated chla and nutrients obtained with and without the phosphorus limitation with available data (e.g. spatial maps of chla computed with and without PO4 limitation, nutrients). This will help convincing the readers that phosphorus limitation is necessary in order to adequately represent the dynamics of the system. This is important, since the authors mention in the abstract and discussion that due to phosphorus limitation the distribution of benthic fluxes changes and hence the distribution of hypoxia. Therefore, we need to be convinced that the modifications of benthic fluxes obtained by adding PO4 limitation is more realistic (this is indeed not accepted that because the model is more complex it will be more reliable).

Response:

We agree that adding complexity for complexity sake is not desirable and that more complexity does indeed not imply a more reliable model. Following the recommendation we included several comparisons between the baseline (with P) and the N-only models in the revised manuscript. Specifically, we added the N-only chlorophyll results to the chlorophyll time series comparisons in Fig. 4, included chlorophyll correlations between baseline model and satellite observations and between N-only simulation and observations (in the new Fig. 5) and root-mean-square-errors or RMSEs (in the new Table 2). The model with phosphorus does improve the correlation between observed and simulated surface chlorophyll (see Fig. 5; see also correlation values in the response to comment 2 above), mainly in the spring (no improvement is expected in September because P is not limiting then). Table 2 shows that the RMSEs are significantly smaller (improved) in the Mississippi Delta and Intermediate regions.

We would like to note that our main motivation for adding phosphate to the model was

not to improve the model skill (although that is certainly a positive effect), but rather to test the hypothesis that P-limitation effectively extends the effects of river nitrogen over a larger area. More complexity (i.e. adding phosphate) was required to test this hypothesis.

Comment:

5. We can note that benthic outfluxes simulated without a phosphorus limitation are still in the range of observed values. Moreover, do you think that the variations on the export flux obtained by adding a phosphorus limitation are significant in comparison notably to the error you have in the model? This is not obvious to compare fluxes at the base of the euphotic layer with benthic outfluxes, please comment on this.

Response:

We compared the simulated depositional fluxes with export fluxes at the base of the euphotic layer from Redalje et al. (1994) because those are the only flux observations available for comparison. Model fluxes are in the lower end of the observed range of export fluxes at the base of the euphotic layer, but the observed values are expected to decrease with depth and therefore better match our simulated values of depositional flux.

The variations in export flux and benthic outfluxes in the control and N-only simulations are both within the observed values, which are unfortunately rather limited. We do not claim to improve the match between simulated and observed benthic fluxes by adding P-limitation. Rather, using the two simulations and a realistic set up, we try to demonstrate the link between phosphorus limitation and the spatial and temporal variability in primary production as well as depositional fluxes. Despite the simplifications of the model and the associated errors, we are able to demonstrate this link. We now show that depositional fluxes, benthic fluxes and denitrification rates are simulated reasonably well by our model.

While the change in simulated export flux and benthic outfluxes simulated with and without P remains within the observed range, the important result of our study is that these changes are distributed in space and time. The largest change is a decrease in depositional fluxes in the Mississippi delta region. This change can have important implications for hypoxia development.

Comment:

6. Paragraph 4: Please specify how varies spatially the denitrification rate in the model and how it has been estimated. This is indeed an important parameter that can change the N:P ratio and hence the limiting element and the conclusions.

Response:

The following text was added to explain denitrification in the manuscript (page 6, lines 116-123): "All sinking POM (phytoplankton and detritus) is instantaneously remineralized into phosphate when reaching the sediment-water interface. This is analogous to the treatment of N at the bottom, except that a fraction of PON reaching the sediment-water interface is lost through denitrification (see Eqs. A14–A15). This fraction is fixed and was determined empirically from a relationship between sediment denitrification (representing all processes of N2 gas production) and oxygen consumption in several aquatic environments (Seitzinger and Giblin, 1996; Fennel et al., 2009). The sediment-water interface parameterization assumes that denitrification occurs through coupled nitrification-denitrification only. A detailed description of the calculation is presented in Fennel et al. (2006)."

We also included denitrification rates and discuss the differences between the Atchafalaya and Mississippi Intermediate regions with the following text (page 9, lines 276-283): "In the model organic matter that is deposited to the sediment is remineralized instantaneously, as described in section 2.2. Organic phosphorus is restored to the bottom water as phosphate, while a fraction of the organic nitrogen is assumed to be denitrified (the remainder is restored to bottom waters as ammonium). The re-

sulting denitrification rates range annually from 1.6 to 5.5 mmolN m^{-2} d^{-1} in the delta regions, from 0.6 to 4.2 mmolN m^{-2} d^{-1} in the intermediate regions and from 0.5 to 1.3 mmolN m^{-2} d^{-1} in the far-field region. These rates are similar to the denitrification rates of Lehrter et al. (2012) who measured rates from 0.9 to 2.8 mmolN m^{-2} d^{-1} on the Louisiana Shelf. In the Atchafalaya intermediate region this N removal amounts to 37% of primary production in June in average, but only to 21% in the Mississippi intermediate region."

Minor comments:

Comment:

Figure 2: please specify what are the data (nutrients loads or concentrations).

Response:

The legend of Figure 2 specifies that the upper panel shows nutrient loads and the lower panel shows nutrient concentrations. Pi has been replaced by DIP in the figure. We also changed dissolved inorganic phosphorus into DIP in the rest of the manuscript.

Comment:

In the text, reference to Figure 2 comes after reference to Figure 3.

Response:

We inverted Fig. 2 and Fig. 3. We now first mention the figures in the Model Description section.

Comment:

Please use DIP for dissolved inorganic phosphorus throughout the manuscript.

Response:

We now use DIP throughout the manuscript.

Comment:

A table summarizing the values of the parameters would be helpful. Notably how is computed kPO4?

Response:

The parameters are the same as in Fennel et al (2011), which is why we didn't include a summary table in the first version of the manuscript. We now added this table in the revised manuscript (Tab. 1). We assume that nutrient uptake occurs in Redfield stoichiometry and therefore we used k_{PO4} = k_{PO3}/16. We added this relationship to the methods section (page 4, line 104).

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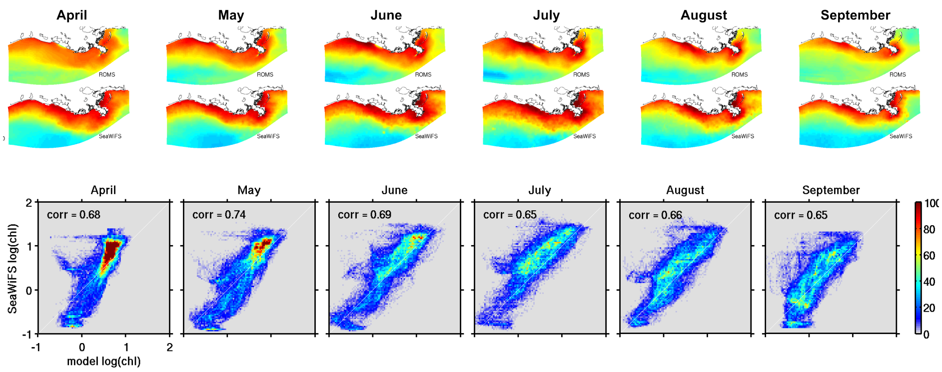

Fig. 1. Comparison of simulated surface chlorophyll (control run) with satellite observations (upper), and 2-dimensional histograms and correlation coefficients (lower panels).

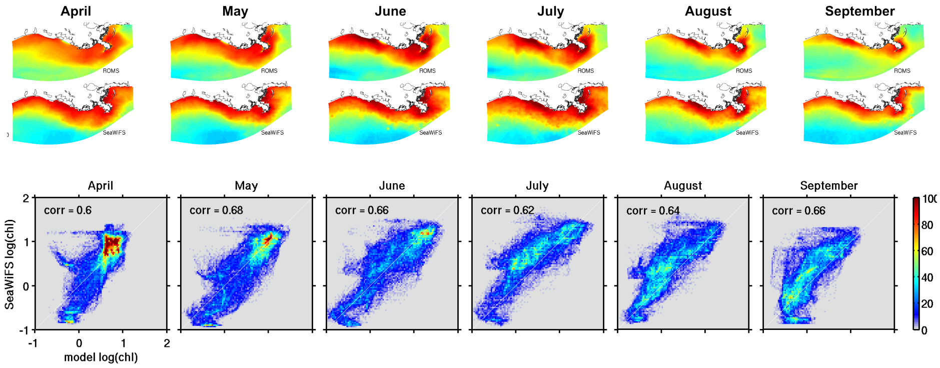

Fig. 2. Comparison of simulated surface chlorophyll (N-only run) with satellite observations (upper), and 2-dimensional histograms and correlation coefficients (lower panels).