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Biogeosciences Discussions

Interactive comment on "Impact of changes in river nutrient fluxes on the global marine silicon cycle: a model comparison" by C. Y. Bernard et al.

Answer to anonymous Referee #2

GENARAL COMMENTS:

The manuscript addresses an important component of the ocean biogeochemistry:
Rivers can have a significant impact on the hydrography and biogeochemistry of ocean areas. This manuscript is well written and easy to read. However there are some issues that need to be addressed before the paper is suitable for publication.

In the text, the authors say the results are "surprisingly similar" when comparing the models in long-term simulations. So the reader might conclude the models are so different (indeed they are) that a comparison study wouldn't even be feasible.

The authors also don't discuss/compare their results to other modeling efforts (with both box and biogeochemistry models coupled to general circulation models) made to address how riverine nutrients may influence the ocean biogeochemistry. Most of them are not focused on the silicon cycle alone, but it is worth to have them in mind. I think this would add more value to this manuscript.

Here are some citations, as suggestion to the authors:
1)Mackenzie, F. T., et al. (1998), Role of the continental margin in the global carbon balance during the past three centuries, Geology, 26,5, 423-426. 2)Ver, L. M. B., et al. (1999), Carbon cycle in the coastal zone: effects of global perturbations and change in the past three centuries, Chemical Geology, 159,1-4, 283-304. 3)Rabouille, C., et al. (2001), Influence of the human perturbation on carbon, nitrogen, and oxygen biogeochemical cycles in the global coastal ocean., Geochimica and Cosmochimica Acta, 65,21, 3615-3641. 4)Cotrim da Cunha, L., et al. (2007), Potential impact of changes in river nutrient supply on global ocean biogeochemistry, Global Biogeochemical Cycles, 21,GB4007, doi:10.1029/2006GB002718. 5)Giraud, X., et al. (2008), Importance of coastal nutrient supply for global ocean biogeochemistry, Global Biogeochemical Cycles 22, GB2025, doi:10.1029/2006GB002717. Slomp, C. P., and P. Van Cappellen (2004), Nutrient inputs tp the coastal ocean through submarine groundwater discharge: controls and potential impact., Journal of Hydrology, 295, 64-86.

Using shorter time-scale simulations, (L. Cotrim da Cunha, E. T. Buitenhuis, C. Le Quéré, X. Giraud, W. Ludwig, Global Biogeochemical Cycles 21, doi:10.1029/2006GB002718 (2007).), but a similar biogeochemistry model (PISCEST) to HAMMOC5, found that riverine Si (as well as N, P) inputs didn't have a large impact in coastal or oceanic export and primary production. These authors results suggest that most of the export production in the coastal ocean may be sustained by nutrient transport from the open ocean, by local nutrient recycling, and by sediment resuspension, with the exception of riverine Fe. Do you think that the difference in the impact in Si production found in this manuscript is due to the longer simulation time?

The manuscript conclusions are mainly focused in the results of the comparison of the 3 models, citing the advantages and disadvantages of each one. Maybe the conclusion could be divided into 2 sections, one about the limitations of each model, another one assessing the impacts of changes in riverine nutrient inputs to the ocean.

Our study mainly focuses on the silica cycle and we have now changed the title so that it reflects the content of the paper better. The new title is: “Impact of changes in river fluxes of silica on the global marine silicon cycle: a model comparison”. We have now also changed the formulation in the abstract from “surprisingly similar” to “comparable” to avoid the possible conclusion that the models cannot be compared.

Most of the references suggested by the reviewer have been introduced into the text in a new section 3.3. where we place our results into a more general perspective.

We show that the magnitude of the changes in the marine silica cycle indeed depend on the length of the simulations and what part of the ocean system is being considered: thus the near shore waters are more easily affected by changes in river input than the open ocean. This is in line with the conclusion of the studies mentioned by the reviewer as well as our earlier work on the topic (Laruelle et al., 2009; Bernard et al., 2009).

Finally, we modified our conclusions to comply with the reviewer’s recommendations and added a section discussing the overall impact of changes in riverine nutrient inputs to the ocean.

SPECIFIC COMMENTS:

1) Page 4473 - "...The box model, also includes other sources of Si: bSiO2 (Conley, 1997), ground water inputs (Slomp and Van Cappellen, 2004) and aeolian dust deposition on the open ocean (Treguer et al., 1995)." It would be interesting for the reader to have these numbers listed in a table – one could better compare the box- and gcm models, and how to compare the magnitude of riverine, ground waer and atmospheric input of silica.

This was actually a mistake in the text, since we used only the results for the boxes for the continental margins and open ocean from the box model of Laruelle et al. (2009) in this paper and excluded the estuarine filter. Thus, groundwater discharge and input of bSiO2 is not relevant. We have now removed this section from the text. Aeolian dust deposition to the open ocean is still included, however, and we have modified figure 1 to make it easier to identify this flux and we also added the value in the text.

2) Page 4475 - "Export production of opal and burial of Si in the sediment were used as indicators of pelagic and benthic Si processing in the box model and HAMOCC2 as done by Heinze (2006)." Which depth do you consider for "export production" in each one of the models? It appears only in the figures, you could cite it in the text too.

We have now added the depth used for the calculation of opal export production in the different models in the text: “The limit of 100m is used to compute export production”

3) Page 4475 - "Results show that a 25% reduction in Si inputs induces comparable decreases in both models for export production and sediment burial (Fig. 2a, b)." To avoid *confusion, it would be better to refer to the simulation as either "Simulation 1" or use "a reduction of 75% in Si inputs" and so on, or create subsection for each one of the simulations. One other suggestion is to say that model results "suggest" instead of "show" - after all model results are different from sample results.*

We now use the names "Simulations 1-4" in the text and we edited the caption of the figure 2 accordingly for consistency. We prefer to keep the formulation "show" since, where we use it, it is always clear from the text that we are speaking about changes in the models and not in the real ocean.

4) Page 4476 - "Overall, while HAMOCC2 appears to reach a new steady state after only 20–30 kyrs, despite a residence time for 5 Si of 23 kyrs. While it takes about 100 kyrs for the box model, with the shorter residence time of 17 kyrs, to reach a new equilibrium." I think these sentences need rewriting - they are fragments of 2 sentences. Are you comparing the time needed for the 2 models to reach the steady state after the perturbation in the Si inputs?

We reformulated this sentence:
"While HAMOCC2 appears to reach a new steady state after only 20–30 kyrs (despite a residence time for 5 Si of 23 kyrs), it takes about 100 kyrs for the box model (with the shorter residence time of 17 kyrs) to reach a new equilibrium."

5) Page 4477 - "The step function, imposing a very strong increase of riverine Si input (10-fold) followed by a shutdown results, in a strong increase in export production and opal burial followed by a significant drop 50 kyrs after the beginning of the simulation in both models." Here again I think the sentence needs re-writing; seems to be missing a verb after 'shutdown results'.

The coma was altering the sense of the sentence which now reads:
"*"The step function, imposing a very strong increase of riverine Si input (10-fold) followed by a shutdown results in a strong increase in export production and opal burial followed by a significant drop 50 kyrs after the beginning of the simulation in both models."*"

6) Page 4478 - Comparison between HAMMOC5 and the box model: To maintain the manuscript text style, could you describe the simulations as in section 3.1? Use something as scenario/simulation 1/2/3 etc, as previously used. You could also include all simulations, with a brief explanation for each one in a table.

To avoid confusion with the long term simulations, these scenarios are named simulations A-C and their meaning is explained in a newly added Table 2.

7) Page 4479 - "The opal production is limited by other nutrients such as N, P or Fe. As a consequence, switching off the riverine input of N and P (Fig. 3d) causes a stronger decrease of the opal export production (-22%) than switching off the riverine silica input alone (-16.6%)." Here I repeat the comment of page 4478: a table and a brief explanation in the text of all scenarios would make the text easier to read and understand. It is not clear from a first reading that riverine N and P input were also changed in the comparison between HAMMOC5 and the box model.

See answer to previous comment.

8) Pages 4480-4481 - About the fate of the Amazon Plume: The Amazon River plume delivers not only Si but also other nutrients towards the Caribbean Sea. How was the behavior of the plume in the simulation without river nutrients? In this area, a large fraction of the delivered nutrients could be already taken up by phytoplankton as soon as the light limitation is alleviated. Would the Amazon River Si inputs alone be able to support the N Atlantic Si uptake?

Combined with the Orinoco, the Amazon load is the strongest input of silica to the open ocean and can be traced all along its plume drifting North West sustaining a 10 µmol l^{-1} excess concentration into the Caribbean (Bernard et al., 2009). These two rivers alone contribute to maintain an annual opal export of up to a 0.8 mol Si m^{-2} along the north coast of South America. However, at the time scale of the simulation used in this study, no effects are observed at the scale of the North Atlantic Ocean.
Regional effects of riverine inputs of dSi were already described in Bernard et al (2009). On the request of reviewers, the section about the effect of the Amazon River plume will be further developed in the revised version soon to be resubmitted. The authors think that this discussion point better fits in Bernard et al (2009), and choose not to develop this point here to avoid repetition.

9) Page 4489 - Figure 1 - Are the units in Tmol Si yr-1? Are there opal primary production numbers for HAMMOC2 and HAMMOC5?

All units in Figure 1 are Tmol Si yr^{-1}. This is now clearly stated in the figure caption.
HAMOCC2 and HAMOCC5 only compute opal export production from the POC (Particulate Organic Carbon), and not the opal primary production. Hence, these values are not available.

10) Page 4491 - Figure 3 - Please explain each one of the panels, as in figure 2 and figure 4

The figure has been improved according to the recommendations of the reviewer.

References

Bernard, C. Y., Dürr, H. H., Heinze, C., Segschneider, J., and Maier-Reimer, E.: Contribution of riverine nutrients to the silicon biogeochemistry of the global ocean - a model study, *Biogeosciences Discuss.*, 6, 1091-1119, 2009, 1810-6277.
Conley, D. J.: Riverine contribution of biogenic silica to the oceanic silica budget, *Limnology and Oceanography*, 42, 774-777, 1997, 0024-3590.
Laruelle, G. G., Roubeix, V., Sferratore, A., Brodherr, B., Ciuffa, D., Conley, D. J., Dürr, H. H., Garnier, J., Lancelot, C., Le Thi Phuong, Q., Meunier, J.-D., Meybeck, M., Michalopoulos, P., Moriceau, B., Ní Longphuirt, S., Loucaides, S., Papush, L., Presti, M., Ragueneau, O., Regnier, P. A. G., Saccone, L., Slomp, C. P., Spiteri, C., and Van Cappellen, P.: Anthropogenic perturbations of the silicon cycle at the global scale: Key role of the land-ocean transition, *Global Biogeochem. Cycles*, 2009, doi:10.1029/2008GB003267, in press.