Ocean Sci. Discuss., 7, C119–C124, 2010
www.ocean-sci-discuss.net/7/C119/2010/

Ocean Science
Discussions

Interactive comment on "The role of continental shelves in nitrogen and carbon cycling" *by* K. Fennel

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Received and published: 6 April 2010

I wish to thank reviewer 2 (KK Liu) for his encouraging, thorough and constructive review. I have addressed the points raised by him as detailed below.

KK Liu: Abstract: "The following statement is questionable: "Uncertainties in observation-based estimates of nitrogen and carbon fluxes mostly result from uncertainties in the shelf-open ocean exchange of organic and inorganic matter, : : :" (p. 178, Lines 6-7)

It is certain that there exist considerable uncertainties in observation-based estimates of nitrogen and carbon fluxes, but they are caused by many factors. "Uncertainties in the shelf-open ocean exchange of organic and inorganic matter" are one of the impor-

tant factors. A more generalized reason is provided by the author, when she addresses the issue of global CO2 sink. She asserts, "regional quantification and global extrapolation of coastal fluxes is highly uncertain due to large spatial and temporal variability and a general undersampling", which is a fair statement concerning the nitrogen and carbon fluxes in continental shelves as a whole. However, "uncertainties in the shelf-open ocean exchange" indeed cause serious difficulties in the closure of nitrogen and carbon budgets in continental shelves. Re-phrasing of the statements is recommended."

Response: I agree and have rephrased the statement as follows:

"Uncertainties in the magnitude of organic and inorganic matter exchange between shelves and the open ocean is a major source of uncertainty in observation-based estimates of nitrogen and carbon fluxes. The shelf-open ocean exchange is hard to quantify based on observations alone, but can be inferred from biogeochemical models. "

It should be noted that this paper is submitted to a special issue on shelf-open ocean exchange; hence the emphasis on this aspect in the abstract.

KK Liu: Introduction "The following statement is incomplete and could be misleading: "The high productivity of shelf systems is in part fueled by the input of nutrients from land, and in part by the tight benthic-pelagic coupling that allows nutrients remineralized in shelf sediments to be returned to the euphotic zone on timescales on the order of a year." (p. 179, Lines 4-7)

It has been argued in regional and global studies (e.g., Wollast, 1993; Chen and Wang, 1999; Liu et al., 2000b, 2008) that the high productivity of shelf systems is supported by nutrient input from riverine as well as marine sources, while benthic remineralization does not contribute to nutrient input but to recycling of nutrients. As illustrated in these studies, nutrient fluxes from marine origin contribute more to the nutrient supply needed for the high primary productivity than the riverine fluxes. In fact, the author's own quote also stresses the significance of the marine sourced nutrient, "continental

shelf nitrogen sink must be balanced by significant onwelling of nitrate from the deep ocean" (Seitzinger and Giblin, 1998). It should be mentioned that nutrient pumping processes at shelf edge are often more efficient than those in the open ocean and could account for the exceptionally high productivity. Regarding nutrient recycling, it has been demonstrated recently (Liu et al., 2010b) that dissolved inorganic nitrogen discharged from Changjiang (aka Yangtze River) may be recycled about 3 times on average before exiting the shelf system in the East China Sea or being removed by denitrification."

Response: Yes, thank you! In fact the model shows exactly the same. I have rephrased as follows: "The high productivity of shelf systems is in part fueled by the input of nutrients from land, in part by the tight benthic-pelagic coupling that allows nutrients remineralized in shelf sediments to be returned to the euphotic zone on timescales on the order of a year, and in large part by up- and onwelling of nutrients from the open ocean."

KK Liu: Nitrogen cycling: "The fate of anthropogenic nitrogen in continental shelves: Considerable information concerning fluxes of anthropogenic nitrogen is provided by the author (p. 180), but little is said about the fate of these fluxes aside from the riverine fluxes are deducted from the horizontal divergence of nitrogen species. It would be instructive to list the riverine input of nitrogen along with the model-based nitrogen budget. This may give us some idea about how continental shelves alter the nutrient fluxes and modify the environmental impacts from anthropogenic fluxes."

Response: The riverine input of nitrogen is now included in table 1 in the footnote.

KK Liu: Model description: "Although the model presented here has been published before, it is still a good practice to inform the readers of some crucial aspects about the model set-up, such as the initial and boundary conditions for the biogeochemical tracers, especially the carbonate species. The readers need to know how they should interpret the model output. Is the model output completely independent of the observa-

tions they are compared with? Or is there some adjustment done to the model set-up so that the model output matches the observations better? If the former, the model would be highly reliable in simulating the real situation. If the latter, the model is still useful in delineating the respective importance of different processes in contributing to the observed features. In this case it should be mentioned what needs to be done to improve the model to the desired level of accuracy for realistic simulation of any continental shelf pump."

Response: The following text and two new references were added to describe initialization of DIC and alkalinity: "DIC and alkalinity are initialized using the T- and S-dependent relationships derived by Lee et al. (2000) and Millero et al. (1998), respectively. Riverine alkalinity values were determined using Millero et al.'s (1998) relationship for S = 0. DIC was assumed to be in equilibrium with atmospheric values of CO_2 in the river sources. Since the model-predicted air-sea fluxes are very sensitive to the initial concentrations of DIC and alkalinity, T- and S-dependent relationships based on more recent data and based on data from the shelf systems under consideration would be more desirable, but aren't available at present."

With this information it should be obvious that the model output is independent of the pCO2 observations that model is compared with. No adjustments were made so the model matches the observations better.

KK Liu: Nitrogen fluxes and budgets: "To support the rather large modeled fluxes of DIN removed during denitrification, the author plots the N-star sections (Fig. 7) along the observational transects in the Mid Atlantic Bight, which are very illuminating. The plots show significant negative N-star values, evidence of DIN removal, in the shelf region, especially in the inner shelf near the bottom. However, this can only serve as qualitative evidence supporting the model results. It is worth mentioning that a dual nutrient biogeochemical model including the phosphorus cycle would be required to produce the modeled N-star distribution for direct comparison with the observations. Then a quantitative validation of the modeled DIN removal terms would be within reach."

Response: To address this point the following text has been included: "The N* distributions serve as qualitative confirmation of the large denitrification sink on the shelf. Since the described model does not include phosphate as separate nutrient the observed N* can not be compared with corresponding model-derived fields. "

KK Liu: Carbon fluxes and budgets: "The author reports the latitudinal dependency of the modeled air-sea CO2 fluxes, which is potentially useful for parameterized extrapolation of the CO2 uptake capacity of the continental shelf pump to the global scale. She also discusses the tidal effects on carbon transport and inter-annual variability of the air-sea CO2 fluxes. As mentioned earlier, it would be valuable, if the author would address the needs for future improvement. For instance, the author mentions DOC and its possible export from the shelf, but the model lacks DOC as a biogeochemical tracer. Whether DOC is an effective agent for carbon export probably deserves investigation. A suite of physical and biogeochemical processes have been proposed to account for the seemingly very effective continental shelf pump (Liu et al., 2010a). The author may suggest which of them are more important to her case studies and how they can be tested using modeling approaches."

Response: A brief discussion of the major uncertainties in the model are now discussed in Section 3.3: "Two significant sources of uncertainty in the model simulations described above are (1) the choice of initial and boundary conditions for DIC and alkalinity, which are based on climatological data mostly from the open ocean, and (2) the lack of dissolved organic carbon (DOC) dynamics. On the continental shelf the DOC pool is significantly larger than the pool of particulate organic carbon (by one to three orders of magnitude; Bauer et al. 2001) and strong gradients in DOC concentration exist between shelf waters and the open ocean (Hopkinson et al. 2002). Exchange of DOC across the shelf break may thus be a significant component of the shelf carbon budget. Adequate representation of DOC dynamics in biogeochemical models critically depends on a mechanistic understanding of DOC sources and transformations."

Also, the review of continental margin carbon fluxes by Liu et al. (2000) and the new

book on carbon and nutrient fluxes at continental margins that just appeared in the IGBP book series are now cited in the Introduction.

KK Liu: Technical comment: “observational-based nitrogen budget” (p. 181, Line 12): should be “observation-based nitrogen budget”.

Response: Agreed and now corrected.

Interactive comment on Ocean Sci. Discuss., 7, 177, 2010.