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Discussions

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

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General comments

It is timely that the author addresses how continental shelves may affect the cycling of nitrogen and carbon in the ocean, as the biogeochemistry of continental margins is drawing increasing attention. She reviews the physical transport and biogeochemical transformation processes affecting the fluxes into and out of continental shelf systems and discuss their role in the global cycling of both elements. The author notes that the high spatial and temporal variability of the coastal ocean results in significant uncertainties in the flux estimation. She also stresses the difficulty in quantifying the lateral transports across the shelf break based on observations. Therefore, she takes a modeling approach to the issue, which has long been recommended (Liu et al., 2000a)

but only gaining momentum in recent years (Moisan, 2010). Hence, it is laudable that the author presents the model-based nitrogen and carbon budgets for the Northwestern North Atlantic continental shelf as the major evidence along with a few important observational features to support her argument. She concludes that shelves are an important sink for fixed nitrogen and a source of alkalinity, but are not much more efficient in exporting organic carbon to the deep ocean than the adjacent open ocean for the shelf region considered. Since most of the model results are published previously, the author does not address the issue of model validation. However, this does not mean that the model is perfect, but rather has its own limitations and uncertainties. Nevertheless, models are powerful tools in evaluating the validity of hypotheses proposed to account for certain features related to the theme. While the author rightfully recognizes the usefulness of models, it is only fair that the limitations of the modeling approach should also be addressed. More importantly, the author, basing on her review of the current understanding of the topic, should come up with recommendations for future research on the unresolved issues.

Specific comments

1. 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 important 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 car-

bon 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.

2. 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.

3. 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.

4. 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 observations 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.

5. 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.

6. 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.

Technical comments

1. "observational-based nitrogen budget" (p. 181, Line 12): should be "observation-based nitrogen budget".

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