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Biogeosciences Discussions

Interactive comment on "NW European shelf under climate warming: implications for open ocean – shelf exchange, primary production, and carbon absorption" *by* M. Gröger et al.

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Authors

We would like to thank referee 2 for his feedback and giving fruitful comments on the manuscript from which a revised version will clearly benefit.

Referee

In this discussion paper the authors examine the efficiency of the carbon shelf pump in the North Sea using a global ocean general circulation model coupled to a bio-geochemistry model with a distorted grid providing a maximal resolution for the NW

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Interactive Discussion

Discussion Paper

European shelf and the adjacent North Atlantic. A series of numerical experiments are conducted to examine the effects of global warming, increasing atmospheric CO2 concentration and discharge of anthropogenic nutrient loading. The model predicts that warming of about 2.0 K of the sea surface leads to a reduction of primary productivity by 30% and weakening of the shelf pump in the North Sea by 34%. Tracer experiments tracers indicate that no more than 20% of the carbon absorbed in the North Sea contributes to the long term carbon storage in the deep ocean

Generally speaking, this is a very interesting paper with numerical experiments revealing a few important features in the function of shelf pump. The paper demonstrates the apparent importance of biological processes in contributing to the shelf pump and the significance of riverine and marine nutrient supplies. Especially important is the investigation of the fate of carbon taken up by the shelf pump. However, this is not the first attempt to attack this critical issue. An earlier study conducted by Yool and Fasham (2001) explored the same issue from a global perspective using a model with rather coarse grid resolution. Despite the rather crude results, the earlier work is worth mentioning in the new study. Compared to the old study, this paper exemplifies the unique strength of the global ocean model employed by the authors.

Authors

We agree with referee 2 that the Yool and Fasham study was an important step forward in assessing the shelf pump on a global scale. Thus, this study and our approach differ from most regional modelling studies using open boundary conditions. We will mention this and we will elaborate the advantages and disadvantages published modelling efforts compared to our approach. This has also been requested by referee1.

Referee

This paper will be more convincing, if the authors can properly clarify or address a few key points described below. 1. Model resolution: The best model resolution is 10 km in the horizontal and 16 m in the vertical. Will this resolution good enough to catch

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small but efficient transport modes, such as dense water cascading. Such mode of material transport has been observed in the Mediterranean Sea (Canals et al., 2006). It is capable of injecting carbon directly into the deep sea from the shelf. Please clarify.

Authors

Our model does not include the process of sediment laden dense water cascading flows (DSWC) which have been shown to be locally important in the Gulf of Lion (Canals et al., 2006). We will mention this in the next version. We assume that the North Sea DSWCs will play only a minor role since the North Sea is relatively vast shelf with a long distance between the coast and the slope compared to the narrow Gulf of Lion which has also a steeper slope. Eventually such processes might play a role along the Norwegian trench.

We will clarify how this could bias our results and make this clear in a revised version. We will also clarify which processes can be addressed with the model's spatial resolution.

Referee

Fate of organic carbon: The biogeochemistry model includes detrital and dissolved organic carbon (Lines 16-18 on p. 16629), but nothing is presented in the model output. One wonders the organic components play any role at all in the carbon shelf pump. Since the anthropogenic nutrient loads apparently stimulate primary production, it is natural that organic carbon fluxes should also increase during nutrient enhanced production. Yool and Fasham (2001) demonstrate that injection of organic carbon or inorganic carbon from the shelf edge will lead to different results in terms of penetration into the deep ocean. The authors should look into this aspect and provide some insight. If the model setup is not adequate to investigate the organic carbon fluxes (e.g., POC or DOC degradation rates are not properly modeled), the authors should also make it clear.

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Authors

The Yool and Fasham approach assumes that all carbon sequestered by the pump is of biological origin forming DOC which is degraded at prescribed constant rates to DIC. It is not surprising that in this setup the results are sensitive to the degradation rates of DOC which usually degrades at lower rates compared to detritus thus providing a higher efficiency for carbon shelf pumping. Our carbon model is a bit more complex and has a prognostic calculation for the carbon pools of DIC, DOC, and detritus. DOC is formed by phytoplankton exudation and zooplankton excretion. Because of this our model is not so sensitive to the DOC pool. Compared to the DIC pool the DOC pool is by 2 -3 orders of magnitude lower in the North Sea. We will clarify this point in a revised version.

Referee

3. Deep water formation: According to the authors, their model predicts "too weak production of Antarctic Bottom" (Lines 14 on p. 16632). In fact, one is more concerned with the North Atlantic Deep Water Formation, which is probably more relevant to the fate of the carbon taken up by the shelf pump in the North Sea. If the NADW formation is also too weak, will it affect the assessment of efficiency for the long-term storage. Please clarify.

Author

The referee mentions an important issue here. We totally agree NADW formation is much more important in this concern compared to AABW as due to the convective adjustment, upper ocean layer waters can be efficiently brought to the deep ocean. Our NADW formation and the MOC are within the lower range of published model estimations and observations. However, Fig. 7b of the current MS version shows that North Sea water exported to the open ocean flows with the Norwegian Current directly to the Arctic Ocean far away from the deep convection sites in the Norwegian Greenland Sea. We will report of the models' strength of the AMOC in a revised version.

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Referee

4. Marker experiment: The description is not very clear. How is the tracer distributed in the water column? Is the initial concentration 1 uniformly throughout the water column? If so, then this experiment is not a good analog to the reality, because the absorbed carbon is not uniformly distributed in the water column. After the model is initiated, for how many model years is it run?

Authors

Good point. The tracer was uniformly distributed in the North Sea. However, given the fact that the southern North Sea is generally well mixed and the northern NS at least during winter we consider a potential bias rather low. We will mention this point in a revised version and improve the experimental description for experiment MARKER (also requested by referee 1).

Referee

There are some minor points listed below: a. Line 20 on p. 16628: "(Sweby, 1984)" should be "Sweby (1984)". b. Line 6 on p. 16630: "odel" should be "model". c. Line 14 on p. 16640: "is rises" should be "rises". d. Fig. 5 caption: "along the y-achsis" should be "along the y-axis". e. Fig. 7 caption: "in exeriment CO2-NS" should be "in experiment CO2-NS".

Authors

We will correct this in a revised version. Again, the authors thank for obtaining valuable comments and suggestions.

Interactive comment on Biogeosciences Discuss., 9, 16625, 2012.