

***Interactive comment on* “The carbon budget of the North Sea” by H. Thomas et al.**

H. Thomas et al.

Received and published: 11 November 2004

We very much appreciated the constructive discussion on our paper “The carbon budget of the North Sea”. The comments have contributed to a significant improvement of the initial manuscript and we have chosen to acknowledge this in the revised version of our manuscript.

Anonymous Referee 1:

We appreciate the comment on the discussion of the water budget, which is indeed crucial to the North Sea’s and any other marginal sea’s budget. We have performed an in-depth literature review in order to reliably address this issue and we came to the conclusions reported in the ms. In brief, only the water budget by Eisma and Kalf reports the water inputs from notably the Baltic Sea and from the rivers reliably. All other studies report a by far too high input from the Baltic Sea. Since the Baltic Sea is one of the main players in the net-budget, it appears to be essential to reliable information here. We agree that we have presented only the conclusions of this analysis and we are aware that this might appear as too concise. We will pay special attention to this issue and will give more details of this discussion in the revised version.

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We appreciate the comment on the consideration of the direct assessment of the CO₂ air-sea fluxes. At the preparation stage of our manuscript we decided to present the C-budget including the closing term and use the CO₂ air-sea fluxes as independent validation, since these have become available only shortly before submission of the present work. In the revised version we will consider the CO₂ air-sea fluxes as component of the overall, and then comprehensive, budget.

We have realized that atmospheric deposition of carbon compounds might play a role in the carbon budgets of coastal seas, however unfortunately to the best of our knowledge there is no specific information available for the North Sea. Moreover, because of the low uncertainty in the comprehensive budget or the good agreement of the closing term and direct assessments of the CO₂ air-sea fluxes presented in the current version, respectively, we think that we have captured the major players in the carbon budget of the North Sea.

Obviously we will consider all technical comments in order to improve our manuscript.

Anonymous Referee 2:

We very much appreciate the constructive comments by referee 2 and agree that a careful assessment of the errors involved in our budget is lacking. We will provide a careful discussion in the revised version. We are fully aware of the problem when budgeting any compound in marine environments, that often large background fluxes dominate the budgets, whereas the main focus is on the minor (net) fluxes, which determine the net-budget. Very similar is the situation found when budgeting the ocean's uptake of anthropogenic CO₂, while the natural exchange fluxes are significantly larger. Since we used for all flux assessments a larger number of observations on both a temporal and spatial scale, systematic errors in the data might be considered as minor. A part of the entire program is outlined by Bozec et al., Marine Chemistry, doi:10.1016/j.marchem.2004.07.006). Moreover, we did not consider POC as a relevant player in the budget, since the POC contributions to the fluxes are orders of

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magnitude lower than those of the dissolved components. The concentrations of DOC are assumed to represent the organic contribution to the carbon fluxes. Nevertheless, we are fully aware of the relevance of POC in the carbon metabolism.

In a separate study the CO₂ air-sea fluxes were assessed from pCO₂ observations. The CO₂ air-sea exchange was calculated using five different formulations of the CO₂ air-sea exchange coefficient and therefore allowed us to calculate an error estimate with respect to the different air-sea exchange coefficients. These appear to us as the major source of uncertainty. Since both approaches are fully independent and thus complementary, one might argue that they support each other.

As indicated in the manuscript and in the above comment to referee 1, still we think that the water budget is the key control (and source of uncertainty) of the carbon budget, and we can have more confidence on the carbon data. We will include a more detailed discussion on this issue in the revised version.

The present study aims for an annual budget and thus annual water budgets and annual means of the concentrations have been used to establish the budget. Any seasonal resolution of the budget would obviously require different techniques and would more or less directly rely on any kind of modeling approach. Despite the fact that we are working on this task, we think that modeling approaches do have strong points, but also are subject to errors. Therefore, we consider it as relevant to complementarily apply different approaches and exploit their strong points individually. As mentioned above the aim of the present study is an annual carbon budget as a first ever step in this direction, based on observations. This also related to the comment by Andersson et al. with respect to any temporal variability of the carbon pools.

Obviously we are grateful to referee 2 for suggestions improving of the presentation of our manuscript.

We are grateful for the comments by Andersson et al. and J.-P. Gattuso, which helped clarify the discussion about the relationship between the trophic status of marine

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ecosystems and the direction of the CO₂ air-sea fluxes.

Interactive comment on Biogeosciences Discussions, 1, 367, 2004.

BGD

1, S354–S357, 2004

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