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Ocean Science Discussions

Interactive comment on "Modelling approach to the assessment of biogenic fluxes at a selected Ross Sea site, Antarctica" *by* M. Vichi et al.

Anonymous Referee #1

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Modelling approach to the assessment of biogenic fluxes at a selected Ross Sea site, Antarctica
by M. Vichi, A. Coluccelli, M. Ravaioli, F. Giglio, L. Langone, M. Azzaro, F. Azzaro, R. La Ferla, G. Catalano, and S. Cozzi

The manuscript of M. Vichi and co-authors addresses the causal link between primary production and export flux of organic matter in the Ross Sea at a specific site (station B, located at 175^{o}E, 74^{o}S). The authors compare results of a one-dimensional biogeochemical model with observed nutrient concentrations and data from sediment traps. The physical setup is based upon the Princeton Ocean Model, whereas biogeochemical variables are simulated according to a refined and extended version of the Euro-

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pean Regional Seas Ecosystem Model (ERSEM). The biogeochemical model used for this study is explained to be a generic in terms of resolving the biogenic flux of carbon, nitrogen, phosphorous, and silica. Model simulations were forced with ERA 40 re-analysis data of the European Centre for Medium-Range Weather Forecast (ECMWF) and restored against daily sea surface temperature values from a data of the Reynolds Reconstructed Historical SST Analysis, covering the period 1990 through 2001. The authors stress that their model simulations reveal the coupling between near surface primary production, respiration within the water column, and organic matter flux at 550 m depth. Furthermore, the authors emphasize that their model simulations allow the separation of locally induced variations of biogenic flux from the variability due to horizontal advection.

1 General comment

The study of M. Vichi and his co-authors addresses an important aspect in view of the fact that a biogeochemical model is applied to better understand the complex interplay of individual processes and to provide high-resolution flux estimates in space and time. The authors stress their aim in using the biogeochemical model as a generic tool to explain data from the Italian Programme for Antarctic Research (PNRA). The authors do well in expressing their objectives and the manuscript is presented clearly. Attracted by the objectives presented in the introduction section, severe criticism emerges with respect to the implementation of the numerical study. First of all, the objectives outlined in the introductory have not been achieved. Second, the biological model applied resolves many processes that are not relevant for addressing the major questions of the study, whereas it is actually limited in resolving important processes (particle aggregation, differential settlement). Third, no conclusions can be drawn from the modelling results. Finally, relevant information, like integrated or averaged mass exchange rates between all model compartments, are not depicted and therefore a reader will not be

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able to comprehend the predominant model dynamics.

2 Specific comments

2.1 Model assessment

The interpretation of the valuable PNRA data set is of vital importance and must therefore be done with great care and accuracy. It is appreciated that the author's analyse primary production, respiration in the mesopelagial and export flux. Nevertheless, the data-model comparison is vague and does not constrain the model's dominant pathways of matter flux. For example, growth rates according to the formula given in Smith et al. (2000) were originally determined from POC measurements. Smith et al. (2000) discuss that their rate approximations may seriously underestimate actual growth rates. In effect, it would be possible to infer growth rate estimates based upon POC (not only from diatom carbon biomass) with the model proposed here and compare these results with estimates of Smith et al. (2000). The paragraph on respiration is unclear and from Figure 8 one cannot distinguish between observed rates and model results. For a model assessment, the authors need to provide information (or become explicit in their assumptions) about the range of uncertainties of the export flux data (e.g. when separating organic carbon from other material collected in the trap). Langone et al. (2000) report deviations between ^{210}Pb flux estimates and the trap samples. In their study they discussed that only if 50% of ^{210}Pb was scavenged then ^{210}Pb flux estimates would match flux into the traps. Other studies suggest that the efficiency in collecting particulate matter in cone-shaped sedimentation traps can be problematic. This issue remains unresolved in the manuscript.

A serious model assessment at this particular site in the Ross Sea must not only consider local data. Other data should be regarded; from nearby sites that show similar

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characteristics in terms of plankton composition and productivity (those areas in the Ross Sea where diatoms dominate together with heterotrophic dinoflagellates). More data are available for assessing the model performance, mainly from those studies that were extensively cited in the manuscript. Thus, cross-validation would become feasible, for instance, if the model were applied to a location further south (or within other similar diatom/heterotrophic dinoflagellates domains in the Ross Sea). For example, a more critical model comparison with data from Region III of Sweeney et al. (2000) would be substantial.

2.2 Model configuration

The one-dimensional model setup does not include sea ice but regards restoring terms in order to simulate the transition between periods with ice cover and ice-free conditions. This novel approach seems appropriate if one has to rely on a one-dimensional modelling setup. The authors stress that they added a fast sinking detritus compartment that is solely sustained by fecal pellets production of mesozooplankton. A slowly sinking detritus compartment is primarily fuelled from organic matter through means of cell lysis and sloppy feeding of microzooplankton. Basic model assumption is that fast sinking detritus is ultimately linked to the abundance of diatoms and to mesozooplankton grazing. Yet, such dominant pathway, where fast sinking fecal pellets from mesozooplankton are exclusively responsible for the export flux, has not been documented for the diatom/heterotrophic dinoflagellate dominated areas in the Ross Sea. Rather, it is suggested that particle aggregation is the mechanism responsible for the rapid export flux of organic matter in the respective diatom domains (Asper and Smith, 2003), which is consistent with the interpretation of microzooplankton (ciliates and heterotrophic dinoflagellates) being the major consumers of the diatoms (for example Caron et al., 2000). Biomass of microzooplankton could be related to diatom biomass and POC in the model and could be, for example, compared with measurements of Dennett et al. (2001).

2.3 Sensitivity analysis

The study includes a model sensitivity analysis where sinking speed of detritus and remineralisation rates are varied. Choosing these two parameters is critical, as they are not truly independent. Increasing the sinking speed while enhancing remineralisation can yield very similar model flux from organic matter back to inorganic components. The non-linear response seen in the model results must be attributed to the onset of a detectable sinking flux which in turn affects the quality of the detritus exported. The timing of biomass accumulation (which specifies the flux of phytoplankton biomass to detritus) within the upper layers depends on how light-limited growth relates to iron availability. Light-iron co-limitation is parameterised in the model. Assumptions made for the parameterisation will largely determine the timing and extent of the diatom bloom. In the proposed model this co-limitation is expressed by two non-dimensional regulation functions that are multiplied. Given this multiplicative regulation of phytoplankton growth, small deviations between light-limited growth and iron limitation are likely to have a strong impact on model results. This parameterisation introduces a critical model sensitivity. It is thus meaningful to do variations of those parameters that determine the model's co-limitation of primary production while varying sinking speed of detritus. Also, the authors have to provide a quantitative measure of data-model deviations for the sensitivity analysis, going beyond a simple visual inspection of modelled export flux and the sediment trap data.

3 Manuscript assessment according to OS guideline

1) The paper addresses relevant scientific questions within the scope of OS.

2) The paper presents some novel ideas for setting up a one-dimensional, vertically

resolved model at a local site in the Ross Sea.

3) No substantial conclusions are reached.

4) The scientific methods and assumptions are not fully outlined. The authors refer to a more detailed model description published in Journal of Marine Systems. The model is treated as if it was generic and therefore applicable to the Ross Sea. Making such strong assumption is disputable. The authors have not demonstrated the uniqueness of their biogeochemical model in a preceding study.

5) Are the results sufficient to support the interpretations and conclusions? No.

6) Is the description of experiments and calculations sufficiently complete and precise to allow their reproduction by fellow scientists (traceability of results)? Since the biogeochemical model is extremely complex, modeling results may only be reproducable with the original model code and setup (which includes details in restoring).

7) Do the authors give proper credit to related work and clearly indicate their own new/original contribution? Yes, the authors give sufficient credit to other contributions.

8) Does the title clearly reflect the contents of the paper? The title is compelling. The content of the manuscript does not match a reader's expectations.

9) Does the abstract provide a concise and complete summary? Vaguely yes.

10) The manuscript is well structured and clear.

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11) The language is fluent.

12) Important mathematical formulae of the model are given in preceding paper of the first author.

13) Should any parts of the paper (text, formulae, figures, tables) be clarified, reduced, combined, or eliminated? The authors need to depict the integrated mass exchange between model compartments, for carbon, nitrogen and phosphorous respectively.

14) The number and quality of references are appropriate. However, at least four other relevant publications should be read by the authors and included:

Arrigo, K. R., Worthen, D. L., Robinson, D. H., (2003). A coupled ocean ecosystem model of the Ross Sea: 2. Iron regulation of phytoplankton taxonomic variability and primary production. Journal of Geophysical Researc, 108(C7), 3231, doi:10.1029/2001JC000856.

Caron, D. A. , Dennett, M. R., Lonsdale, D. J., Moran, D. M., Shalapyonok, L., (2000). Microzooplankton herbivory in the Ross Sea, Antarctica. Deep Sea Research II, 47, 3249-3272.

Dennett, M. R., Mathot, S., Caron, D. A., Smith Jr., W. O., Lonsdale, D. J., (2001). Abundance and distribution ofphototrophic and heterotrophic nano- and microplankton in the southern Ross Sea. Deep-Sea Research II 48, 4019-4037.

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Sweeney, C., Hansell, D. A., Carlson, C. A., Codispoti, L. A., Gordon, L. I., Marra, J., Millero, F. J., Smith, W. O.,Takahashi, T., 2000. Biogeochemical regimes, net community production and carbon export in the Ross Sea, Antarctica. Deep-Sea Research II 47, 3395-3421.

15) No supplement material was provided.

Interactive comment on Ocean Sci. Discuss., 6, 1477, 2009.