

***Interactive comment on* “Looking beyond stratification: a model-based analysis of the biological drivers of oxygen depletion in the North Sea” by F. Große et al.**

F. Große et al.

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Dear referee,

first of all, we would like to thank you for the positive reception of our manuscript and the constructive criticism mentioning certain issues to address during the revision process.

As the second review is not yet available, we cannot provide an updated manuscript at the current stage, but would like to take the opportunity to clarify the issues you raised. For this purpose, the points we identified in your comment are listed below (in a

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wrapped up way), including some feedback on these. Your feedback is highly welcome.

List of issues:

- **general point:** The manuscript is too long and technical, and the storyline is occasionally missing or hard to follow.

- **reply:** We agree that the manuscript turned out to be rather lengthy and a shortening is required to improve the readability. With respect to the “too technical” issue it would also help to clearly separate the Methodology from the Results/Discussion as you already pointed out in the specific comments.

- **specific points:**

1. The O₂-related issues and gaps indicated in the introduction do not lead to a clear research question. The paper should be focused on only one research question which is either technically (“can models fill the gap between data requirements and availability?”) or content based (“how important is eutrophication with respect to O₂ minima?”). The second type of question is basically included in the current manuscript.

-**reply:** We are grateful to get this clear feedback. Of course, we aim to provide the reader with a clearly formulated research question which defines a distinct frame for the manuscript. Apparently, the question we want to address got bioblurred during the course of this study. The scope of our study is to show that biogeochemical models are capable of providing a temporally and spatially consistent picture on O₂ conditions with respect to their occurrence and extent. In addition, they provide detailed information about the processes leading to low O₂ conditions and by this improve our understanding of the system, in our case the North Sea. The present study does not allow for an analysis of the importance of eutrophication on the North Sea O₂ dynamics as the North Sea has to be considered as eutrophicated during the analysed period (2000-2010), i.e. a non-eutrophicated reference period is not considered. Furthermore, we do not distinguish between anthropogenic and natural factors, which would also be required when focusing on eutrophication.

2. Move parts of the manuscript (e.g., extended validation) into an appendix.

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-reply: Here, first our question is, what you consider as the “extended validation”? Does it mean the Taylor diagram or does it mean the more qualitative parts of the validation? The second would imply to only keep the Taylor diagram in the main article as it kind of summarises (most aspects of) the qualitative part of the validation, and provides additional quantitative measures. However, the qualitative validation also provides insight in the North Sea system with respect to its O₂ dynamics and spatial distribution which is important for readers who are not familiar with the North Sea. Therefore, we consider this as an essential part of the manuscript.

In general, we agree that moving parts of the manuscript into an appendix would help to shorten the main article. We will make this decision depending on the already achieved shortening of the manuscript due to the previously mentioned comments.

3. Clearly separate Results and Discussion from each other.

-reply: This is indeed an arguable issue which we already discussed internally before the initial submission of the manuscript. In the end, we decided to write a combined Results/Discussion section (and only provide a Conclusion wrapping up the main findings) as we considered it easier for the reader to have the discussion of a certain aspect of the study directly aside the related results. Especially, since we address various aspects during the course of this study (e.g. validation, driving processes in the O₂ minimum zone, spatial variability, temporal variability). Because of this we prefer to keep this combined Results/Discussion section as is, but it may help to separate Results and Discussion within each of the different subsections.

4. Methodology should be clearly separated from Results/Discussion (e.g. equations in Sect. 3.2.3 and description of subdomains).

-reply: We agree with this and will change this in the revised manuscript.

5. The reasons for the selection and the representativeness of the subdomains are not clearly discussed. Why not analysing the whole domain (e.g., on grid cell basis) to identify regions of distinct characteristics and representative subregions?

-reply: Regarding the selection of the four 4x4-subdomains, you are right, that the

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definition of these areas (at page 12569, lines 6-12) is only linked to stratification characteristics. This may not be sufficient information to justify the selection of these regions, if you want to take into account all (or at least more) potential factors for the development of low O₂ conditions. We may not have pointed out sufficiently, but our current set-up and selection is based on findings by previous studies which discussed which regions of the North Sea are susceptible to low O₂ conditions (e.g., Queste et al. (2012)) and which factors are of importance for the O₂ development (e.g., Druon et al. (2004)). With this foreknowledge we stepped into our analysis and also included subdomains which are unlikely to experience low O₂ conditions to demonstrate the validity of these previous studies. As the title “Looking beyond stratification ...” says, we first approach the topic of North Sea O₂ dynamics towards different stratification regimes. For this purpose, we defined these subdomains based only on different stratification characteristics. The subsequent analysis of additional O₂-related parameters (primary production, advection of organic matter, sub-mixed-laxer volume etc.) discussed, e.g., by Druon et al. (2004) is then used to identify and reduce the set of key parameters defining the regional susceptibility to low O₂ conditions.

The alternative (reversed) approach you suggested is indeed a very interesting way to create a regional characteristic of low-O₂ susceptibility independent of previous studies. In addition, it would automatically answer the question on the representativeness of the selected subdomains, as the selection would base on the findings of the multivariate analysis. However, this probably would go beyond the purpose and frame of the present study.

In order to stick to our current approach, but to show the representativeness of our subdomains, it may be helpful to conduct a grid-cell based analysis using the key parameters for low O₂ conditions identified by our current analysis – similar to the approach by Druon et al. (2004), but based only on stratification period, water depth/sub-MLD volume and primary production. We are considering to provide such analysis.

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With this we would like to conclude and thank you again for your helpful comments.

Kind regards

Fabian Große

on behalf of all authors

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