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Earth System Dynamics
Discussions

Interactive comment on "Uncertainties in projections of the Baltic Sea ecosystem driven by an ensemble of global climate models" *by* Sofia Saraiva et al.

Sofia Saraiva et al.

sofia.maretec@tecnico.ulisboa.pt

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Answers to the comments submitted by anonymous Referee #2 concerning the manuscript entitled "Uncertainties in projections of the Baltic Sea ecosystem driven by an ensemble of global climate models" by Sofia Saraiva et al.

Anonymous Referee #2 Received and published: 5 June 2018

We acknowledge the comments of the reviewer. We rephrased large parts of the text and added a figure with a conceptual diagram of the modelling approach, as

the reviewer suggested. We hope that the manuscript is now better readable for the reviewer and the readership of ESD. The answer to specific comments are addressed below.

This manuscript investigated the uncertainties/changes in future projections of ecosystem processes, such as primary production, nitrogen fixation and hypoxic areas, over the Baltic Sea. The authors employed a regional ocean model with capabilities of simulating coastal and ocean biogeochemical processes, driven by output from regional coupled atmosphere-ocean climate and hydrological models. The regional models, in turn, were forced by boundary conditions from global GCMs (IPCC models). The authors argued that uncertainties in ecosystem processes originate mainly from various scenarios of nutrient load, rather than model deficiencies or future greenhouse gas emissions. This study could be of interest to ESD readers and contribute to understandings of the uncertainties in future projections of Baltic Sea ecosystem. However, I feel that the authors' manuscript needs to be improved substantially, both in terms of their analysis and general writing on their results, before it can be published in ESD. Please see my detailed comments bellow. Major comments:

1. *So far, description of experimental configuration (section Methods in the authors manuscript) is not very clear to me. It would be better, if the authors could make a schematic diagram to illustrate how their experiments are setup. For example, they can show how the "Baltic Sea model" is forced by variables from reginal hydrological and climate models, and how the regional models are forced by global GCMs. A good schematic diagram could help readers tremendously.*
Answer: A new figure was added to the manuscript, illustrating the hierarchy of models used in this study.
1. *I suggest the authors also validate their regional ocean experiments individu-*

ally against historical observations of ocean temperature, salinity, sea-ice cover, etc. Currently, it is done as ensemble mean and standard deviation compared with observations (e.g., Figures in Appendix). It is beneficial to show, out of the four GCMs, which provides a better forcing fields for the regional model during historical period? How do the biases in GCMs propagate to the regional ocean model used by the authors?

Answer: The authors agree with the reviewer on the importance of comparing individual performances obtained by the use of the different CGMs downscales. However, the topic would, per se, deserve a separate manuscript. After a selection of available models that could reasonably reproduce the historical period, the main goal of the present study was to compare the uncertainty induced by different nutrient scenarios with the inherent uncertainty induced by the use of different GCMs. For that reason and to enhance the comparison between scenarios in the future simulation rather than the validation of the different models, the paper gives more focus on the ensemble than on the individual performances. However, although not explored thoroughly, the individual results are shown for salinity and runoff (Fig. 9), hypoxic area (Fig.10) and also the GCMs individual performances in terms of average profiles of the main properties through comparison with average observations, in the supplementary material (Fig. S1). In addition, in some parts of the manuscript the reader is invited to search for model information through the reference to other studies. The main goal of these figures and the manuscript is to present the range of possible solutions, rather than the selection of the best model. In fact, as far as we can say from our results during the historical period, either the comparison of atmosphere conditions imposed in the coupled physical-biogeochemical model or its water conditions impacts, there is no unique best model to use. Each model has its own strengths and weaknesses (being better or worse to simulate particular properties or

features) and for that reason, we suggest that the best methodology, in this type of studies, is exactly to not select, and to use several models that could represent a range of possibilities.

2. *Sea-ice processes were not mentioned at all in the current manuscript. In fact, sea ice plays an important role in the budget of heat, freshwater, carbon and nutrients over the Baltic Sea (Granskog et al., 2006; Vihma and Haapala, 2009). I think the authors should discuss how sea ice is treated in their experimental setup, how well sea-ice processes are simulated in their model, and how response in sea ice influences their results.*

Answer: We agree with the reviewer on the fact that sea ice plays an important role in the budget of heat. However, in our manuscript we focus on biogeochemical cycles and eutrophication which is an important pressure in the Baltic proper where in historical climate on average the extent of sea ice cover is small. Changes were made in the text and the manuscript points now to the study from Eilola et al. (2013) where the impact of future sea ice retreat on the Baltic Sea biogeochemistry at the end of the 21st century is more thoroughly studied. Eilola et al. (2013) found an earlier onset of the spring bloom, increased wind and wave-induced resuspension and increased winter mixing in areas having reduced ice cover. Our results corroborate those findings.

3. *The authors keep using the word "model deficiencies" when discussing results from experiments forced by four GCMs but fail to describe what exactly these model deficiencies are, and how these deficiencies influence regional simulation of the physical climate and biogeochemistry over the Baltic Sea. Also, spread between multiple models is not always the same as deficiencies in models. Internal variability could also contribute to some of the multiple-model spread. Model deficiency are usually discussed with some exact physical/biogeochemical processes.*

Answer: We agree with the reviewer that the concept of model deficien-

cies is not defined properly in the submitted version of the manuscript. Changes were made in the introduction of the manuscript to clarify that concept: GCM deficiencies are considered in this study as the uncertainties inherited to the Regional Climate Model, and consequently to the coupled physical-biogeochemical model, from the GCMs projections, that are used as boundary forcing. We added: These deficiencies are defined as model shortcomings that affect in the dynamical downscaling approach the performance of the RCMs and consequently of the coupled physical-biogeochemical ocean model. However, GCMs are biased not only due to model deficiencies but additionally such models cannot be considered to be in phase with the real climate due to decadal climate variations (Deser etal. 2014). Together with this natural variability uncertainties in GCM initialization will shift the period of the GCM climate to a different state. Moreover, even though there are internationally coordinated protocols (e.g. CMIP) for how to equilibrate GCMs, the tuning strategy of a GCM varies widely as well as the used observational reference data sets do (Hourdin etal. 2017, Schmidt etal. 2017). Likewise, large scale patterns reflecting key climate characteristics are the tuning target rather than the fit with the region of interest of the RCM (Mauritsen etal. 2012). The above mentioned deficiencies sum up and translate into RCM deficiencies via the boundary forcing. We investigate in our study only the combined impacts on scenario simulations of Baltic Sea biogeochemical cycles.

4. *The authors simply described results from their experiments and did not provide in-depth analysis/assessment on physical and biogeochemical processes producing these results. Some degree of mechanistic interpretation of their results could be interesting.*

Answer: Since the Baltic Sea has been intensively studied in the last years, literature is vast on the description of the main processes influencing the dynamics of the ecosystem and the authors consider that there is no need

to describe those in detail. However, we agree with the reviewer that the manuscript did not explain in detail the mechanistic reasons behind the results. Changes were done in the text to improve the understanding of the underlying processes behind the results, particularly on the subsection on the biogeochemical variables under the Results section.

5. *The writing of the current manuscript needs improvement. I do have some editing suggestions, but I feel there is no point in addressing them in this early stage.*

Answer: We rephrased large parts of the text and we hope that the manuscript is now better structured and easier to read following the suggestions of both reviewers.