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Ocean Science Discussions

Interactive comment on "Extreme Sea Levels in the Baltic Sea under Climate Change Scenarios. Part 1: Model Validation and Sensitivity" *by* Christian Dieterich et al.

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Answers to referee #2

Thank you for your detailed comments and suggestions. It helped to improve different aspects of the manuscript including readability.

General comments

However, I think, there are some issues needed to be clarified in terms of content and writing style of the paper. ...

- We have reworked the manuscript to streamline it and improve the consistency and

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style. In many places the reviewer's suggestions have helped to eliminate redundant formulations or to add necessary explanations.

First of all, the novelty of paper is not well written. ...

- We have added a paragraph towards the end of the introduction that specifies more clearly what this study contributes to the ESL research in the Baltic Sea.

- The beginning of the abstract now also highlights the contribution to the uncertainty discussion.

Secondly, the paper is a little bit hard to read. ...

- This is a good point. The beginning of the article should be inviting to read on. We have simplified the first sentence and made other changes to the abstract that are meant to improve the readability.

Technical corrections

P1L3 (Page1Line23): Sentence:'. . .have been downscaled'. ...

- We have introduced 'dynamically' downscaled in the sentence.

P1L4: Sentence 'Validation of 100-year. . ..' Is also complicated to read. ...

- Agreed. We have reformulated the sentence.

P1L5: Sentence reads: 'The ensemble mean 100-year return levels turns out to be the best estimator with biases less than 10 cm.' ...

- The idea here was to mention that the ensemble mean of an ensemble of model runs shows a better agreement with observations than a single model run, even the ERA40 hindcast. We have simplified the sentence.

P1L6: Sentence starts with: 'The ensemble spread..'. This sentence is redundant. It should be removed from the abstract.

- We think this is among the important findings of our study. The 5% to 95% range of the ensemble solutions (the likely range in IPCC parlance) includes the estimates based on observations. This gives us some confidence that the solutions in the ensemble cover what has been observed. This will be important in cases where there are no observations. We have combined this finding with the summary of the GCM uncertainty at the end of the abstract.

P1L10: Please update the sentence starting in this line in this way: 'Some regions like Skagerrak, Gulf of Finland. . .'.

- We have changed the text according to the reviewer's recommendation.

P1L14: which observational records? Tide gauges?

- We have clarified in the text that we mean tide gauge records.

I did not understand the sentence in P1L23:

- Yes, the text was mentioning relative sea level rise and fall due to two different processes. We have now removed the example on sea level fall due to GIA to improve the readability. The estimates for GIA appear now after the introduction on GMSL rise.

- We prefer to leave the first paragraph at the beginning of the introduction. It explains why we want to know about SLR and ESL.

What does 100-year return level mean? ...

- Yes, it is true, we did not explain the return level concept. We have added a short paragraph to Section 3.2 (Extreme Sea Levels) where the return levels are introduced.

P2L7 Please revise 'has coordinated to an ensemble' to 'has coordinated to an ensemble mean.'

- We think that the formulation as it is describes better that the CMIP5 project (Taylor et al., 2012) has coordinated an ensemble of model runs with GCMs. From this ensemble

we have downscaled five individual ensemble members (GCMs) with a regional climate model and calculated return periods that we want to discuss.

P2L9 again add ‘mean’ to next to the word ‘ensemble’

- We would like to mention in the text, that many aspects of the ensemble of GCMs are discussed in IPCC’s AR5. This includes also the ensemble spread (the uncertainty) not only the ensemble mean.

P2L13 Sentence starts at this line does not mention about the region. ...

- The effect of GIA and GMSL on Baltic Sea level depends on the region in the Baltic Sea and on the climate change scenario. We have tried to describe this in the sentences that follow.

Can authors briefly explain the methods that they applied in this study at the end of introduction? (before P4L3).

- The main method that was used to generate the model estimates for the ESLs was the dynamical downscaling of a number of GCMs. This is part of the paragraph (previously) starting at P5L9 in Section 2. We left out the details of how the dynamical downscaling and the coupling between atmosphere and ocean was done. This has been published in e.g. Wang et al., 2015, Dieterich et al., 2019.

- We first followed the suggestion and summarized our approach with the statistical methods in the paragraph on novelty in the introduction (see also next answer). That would have required to introduce the return period concept in the introduction. We have decided against it and prefer to explain the return period concept where we show the first return levels for different return periods (Tab. 7, Sect. 3.2). To avoid repetition we have now added a brief outline of our approach at the beginning of Section Extreme Sea Levels, not in the introduction.

P4L3: First two sentences of this paragraph should be placed earlier in the introduction section where the authors explain the novelty of this study.

- We have moved the two sentences further up in the introduction and combined them with the description of the novelty of this study.

P4L10: Which paper? Please put the reference. And please also write the principle conclusion of that paper, if it is needed to understand the scope of this paper.

- We have added a short explanation at the end of the introduction how this paper is related to the companion paper. We also added the reference. The second part is not needed to understand the results and discussion in this paper. The second part gives an extra motivation for this study.

P5L12 please cite the paper at the end of the sentence.

- We have added the reference for the paper, which is in preparation.

P8L11: Why Landsort is chosen, not Stockholm?

- We chose Landsort because it is usually taken as the reference station in the middle of the Baltic Sea, near the nodal line, that represents the amount of water (or the mean sea level) in the Baltic Sea, e.g. Lisitzin, 1974., Meier et al., 2004, Mohrholz et al., 2015. It is also the station with the least amount of spread in ESLs among different ensemble members, cf. Fig. 2 and 7. The tide gauge station in Stockholm is close to the city center, where it can be affected by freshwater from lake Mälaren (Samuelsson and Stigebrandt, 1996) and where the model resolution is too coarse to properly resolve the Stockholm archipelago.

P8L18: Authors mention that modeled and observed sea surface for the period 1970-1999 is compared in Fig 1. ...

- We validate the model results for MSL along the coast, where observations from tide gauge stations are available. The model results show a reasonable agreement with observations. We implicitly assume that MSLs along the coast are tightly connected to MSLs in adjacent regions in the open Baltic Sea. Those are mainly determined by the shallow water equations including the atmospheric and riverine forcing. These are

properly represented in our model, although there is room for improvement. To avoid confusion we have changed the wording in the paragraph and call the observations mean sea level, not mean sea surface. We have not used a mean sea surface based on observations.

- We have updated Figure 1b) to show the names of the different gulfs and basins in the Baltic Sea that are mentioned in the text.

P15L1: What is a,b,c in Figure 5?

- We have now included station labels in Figures 2 to 8 to make it easier to identify individual stations. This was a suggestion of reviewer #1.

P16L2: Sentence: 'In the Baltic sea the impact on ESLs is negligible'. ...

- We have eliminated this sentence.

- We have tried improve the text in many places to make it more readable.

P23L7; It is mentioned that SLR,tides. Storm surges and wind waves increase ...

- The idea was to show an example where the interaction of waves and sea level has a large effect. That's why we chose to cite Arns et al., 2017. We agree that the interaction with tides is not significant in the Baltic Sea. We have replaced the sentence with examples from the Baltic Sea, that have been described in Weisse and Weidemann, 2017, Viitak et al., 2016, Wisniewski and Wolski, 2011 and Averkiev and Klevanny, 2007.

P23L25. Again the same issue. The sentence 'Similar for the ocean-only models'. ...

- We have changed the text to make the statement clearer.

P23L35. I think sentence should start with 'Observation based' not 'Observationally based.' ...

- We have changed the wording in this sentence to 'Observation based'.

- The reason for mentioning the second part of the study was to provide a clue for the interested reader to the scenario part of the model ensemble in connection with the uncertainty discussion. We have now eliminated the sentence.

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