#egusphere-2024-1931

Documentation of changes and reply to the review comments

*[The original review comments are in **bold and italic**]*

REVIEWER COMMENTS:

Referee 2

General comments to the submitted manuscript: 'Paleogeographic numerical modelling of marginal seas for the Holocene – an exemplary study of the Baltic Sea' by Miluch et al.

The paper describes the paleogeographic distribution of the Baltic Sea during the Holocene. They base their observations on different data sets gathered from different countries along the Baltic Sea. For the reconstruction, they mainly use three parameters: vertical changes of the water level, vertical changes of the landmasses (tectonics and isostasy), and the thickness of the sediment deposits.

The novelty is that they include the latter one. The paper is well structured, and the Figures are certainly relevant for the message.

After reading the manuscript I have some general discussion points left:

1. ***The spatial resolution of the grid size in the Baltic is not always clear. I have no idea how accurate and variable for instance the input data of the isostacy is, nor of those of the sediment thickness data. In qualitative sense, they indicate for instance at the data in the northern Baltic Sea is sparse, but I have no idea how sparse (in a quantitative sense, how many data points per km^2).***

Author response #1:

The grid size is uniform at 0.01° x 0.01°. All point data are interpolated to this grid. The initial digital elevation model derived from the latest product of GEBCO has the resolution of 15 arc seconds (0.004167° x 0.004167°). The GIA dataset was initially at a global-scale with 0.5° x 0.5° grid size. It was then extracted for northern Europe and re-gridded to the 0.01° x 0.01° grid.

Sediment thickness data were interpolated based on several original datasests from difference sources and with different spatial resolution, including gridded data for local parts, seismic profiles and point measurements. These source data were used for trainning and validation for the machine learning approach (U-net) which was used to fill the data gaps (extrapolation) in other parts of the study area. In addition, co-krigging method was also applied for interpolation at some local parts where existing measurements show high correlation between sediment type/water depth and sediment thickness.

We will add information about the resolution of each sub-dataset as a new table in the revised version for clarification.

2. ***The spatial interpolation and extrapolation techniques are not always explicitly mentioned. A Table for all parameters including it's resolution and spatial interpolation technique would be nice.***

Author response #2:

We agree. A table for information about the resolution of each sub-dataset as well as the interpolation and extrapolocation techniques will be provided in the revised version for clarification.

3. ***The discussion about the different phases is much based on the glacial history of the area. While reading the paper, I wondered how large the influx from major rivers in central Europe was, and how this differed during the Holocene. These rivers will certainly transport sediments towards the southern shores of the Baltic.***

Author response #3:
In the paleogeographic reconstruction, we did not distinguish the contribution between riverine discharge and coastal erosion (mainly glacial till cliffs) in the total sediment deposition thickness. We did discuss the impact of rivers, though they were not the focus of this paper. As discussed in chapter 5.2 the riverine sediment supply rate is one order of magnitude smaller than the supply from soft cliff erosion in the southern Baltic. The assessment is based on present day's sediment discharge rate from major rivers including the Vistula River and Oder River. To make the discussion more comprehensible, we will add more descriptions on a comparison between riverine sediment inputs and coastal erosion.

4. **The interpretation around the Danish straits is based on very few data and probably also modeled in a very course sense. The authors discuss their results with those over earlier studies and conclude that not all studies for instance have two straits. How comparable are these studies if both studies are based on not a lot of observations, nor have a detailed modeling grid.**

Author response #4:

The timing of events such as opening of straits varies between reconstructions. Some local-scale variabilities of narrow structures such as straits may not be well visible on the regional maps due to coarse map resolution, difference in the data coverage and/or reconstruction methods. Therefore we agree that it is not comparable between regional studies on local-scale features which do not have sufficient data coverage. We will modify the discussion on this aspect.

5. **The novelty is concentrated on the inclusion of sediment thickness data for the Baltic Sea. In the manuscript, the authors talk about 'sediment dynamics', 'sediment budget', 'sediment mass', and 'sediment thickness'. The paper becomes much more precise when a clear terminology is chosen. Really like your terms 'thickness' or 'mass'. Perhaps even better 'thickness' and 'vertical changes in thickness'. 'Budget' is perhaps more than you present (with a budget, you normally also mention lateral fluxes in the system). 'Dynamics' is closely related to sediment transport resulting in areas with erosion or deposition and you are not showing that.**

Author response #5:

We refer to different meanings when using different terminologies. 'Sediment dynamics' corresponds to dynamic processes including sediment transport, deposition and erosion. We used this term to highlight the novelty of our method by including the impact of sediment deposition on the paleo-morphology and explain why integrating sediment dynamics is important for paleogeographic research. 'Sediment mass' is an overall mass of sediments calculated from a grid, whereas 'sediment thickness' refers to the vertical thickness of sediment deposition for the period of interest. 'Sediment budget' refers to detailed analysis regarding sediment sources, sinks and transport pathways. Clarification of each term will be added in the revised manuscript. We agree that lateral fluxes such as riverine input, coastal erosion and sediment exchange between the North Sea and the Baltic Sea should be included in the sediment budget analysis, and we will add estimates of these fluxes in the revised version.

6. **More specific comments are included in the pdf-file of the manuscript.**

Author response #6:

Thank you for the attached comments. We have implementated modifications to text based on the comments. Here a couple of answers to your important questions or comments:

Line 42. We decided to leave 'post glacial period' here. We believe it's clear enough and it's not strictly limited to very beginning of Holocene.

Line 56. Above we discuss factors in general. Here we discuss details of model components.

Lines 146 and 147. These sentence discusses in general tools of the software, which comprises of various interpolation methods and allows to generate grids with pre-defined resolution.

Line 172. It is not specified however we know that this region, due to being situated on the hinge-line is the least-GIA-influenced area of the Baltic.

Line 278. It's purely random. This method is characterized by little randomness.

Line 299. Sediment budget analysis, discussing the sediment sources is conducted in chapter 4.2.

Line 305. We are aware of the fact that the sediment accumulation rates varied throughout the Holocene. Even though these rates could be estimated based on analysis of sediment cores (being point data), expanding it to other sections of Baltic Sea basin would be hard to justify as sedimentary environments of the Baltic varied not only in time but also in space. Moreover at the Baltic Sea regional scale, ΔSED remains as a minor component of the equation in comparison to ΔEC and ΔGIA. Also, the highest sedimentation rates are situated in the deeper basins. Therefore assuming different sedimentation rates would have very minor influcence on the paleo-bathymetry.

Our attempt is one of the first applications of this method. As pointed out in discussion chapter, applying it to more sedimentation-dominated environments, such as the SE Asian shelf, would require a slightly different approach by distinguishing the impact of sediment erosion and accumulation rate in different periods. However, on the other hand, incorporating complicated paleo-morphodynamic models of sediment accumulation, erosion, redeposition or compaction as well as sediment fluxes will bear high uncertainty due to insufficient data for model forcing, boundary configuration , calibration and validation. This needs to be addressed in future studies.

Line 369. These locations are the connections between the Baltic and the North Sea. We refer to them in the text, therefore we decided to place them on the map.

Line 436. Indeed. Paleo-cliffs may be found inland of Wolin Island (Poland) nearby Szczecin Lagoon shoreline (it was a marine bay during Littorina trangression). Also terraces of paleo-coastlines are well-seen on the Gotland Island, however, in this case it is mainly related to isostatic uplift.

Line 457. In this paragaph we simply compare present sediment accumulation rates from Porz et al. (2021) with our modelled thickness and refer to the proportion of sediment sources input to the basin.

Line 463. We would rather leave the word „dynamics" here. Even though for the Baltic Sea study we simply subtract the thickness grid, the following chapter acts as an outlook for future studies. We discuss application of this method to more sedimentation-dominated environments in which

sediment dynamic processes (erosion, accumulation, redeposition, sediment fluxes) need to be taken into account, or application of it in a local scale.

Line 467. There are spits like this in the Baltic coast: Hel Peninsula (Poland), Vistula Spit (Poland/Russia) or Curonian Spit (Russia/Lithuania). We would rather keep the sentence and add examples into the text.

Line 509. In this sentence we summarize what is a new achievement of our study and discuss application of consistent methodology of paleogeographic modeling into different climatic zones. There are no new material here.