We thank the reviewer for constructive comments of our submitted manuscript. The point-by-point replies to the comments of the reviewer are below. Your comments are marked in black and our responses in red.

Review

On the manuscript "Simulating sea level extremes from synthetic low-pressure systems" by

Jani Särkkä, Jani Räihä, Mika Rantanen, and Matti Kämäräinen.

Overview: Conditional Acceptance Upon Minor Revision

The paper presents simulated conditions of both Baltic sea level hydrodynamics and cyclone pressure conditions in an attempt to better understand extreme sea level variations caused by the latter. The employed method is sound and leads to interesting results. However, the manuscript lacks a proper review of the literature on the methods of extreme value theory on sea level or storm surge extremes as well as in the quantification of these extremes based on the aforementioned theory. Specific comments include:

1. The authors must remind the reader that there already exists a theoretical framework to estimate how much the extremes will deviate from the maximum of a typical Gaussian population. Following the seminal work of Gumbel (1958), the extreme value theory has found important applications on both global and local sea extremes. In global terms, I refer to studies such as of Butler et al. (2007), Arns et al. (2013) and O'Grady et al. (2022).

We recognize the importance of extreme values in the assessment of sea level hazards. The aim of our study was to describe the physical mechanisms leading to extreme sea levels, not to investigate sea levels using extreme value theory. We feel that adding extreme value theory here is beyond the scope of this study but is an important topic in future work. We added discussion explaining the aims and methods of this study at the end of the Introduction.

2A. While the authors correctly point out to the relevance of metocean parameters for the local effect of sea level change, such as wind and currents. To clarify the local effects of wind/waves/currents, the authors should mention that as waves become more nonlinear towards the shore they can decrease the sea level in about 5% of the significant wave height and through wave dissipation increase the sea level in up to 20% of the significant wave height (Bowen et al., 1968; Massel and Gourlay, 2000). For the effect of currents on the mean sea level, the authors could cite at least the theoretical work of Brevik (1978). Additionally, attention has to be made to the fact that extreme waves can further increase this oscillation in mean water level, and estimates from extreme value theory indicate that extreme heights can be increased by 10-30% depending on the sea conditions such as shoaling effects (Benetazzo et al., 2015; Barbariol et al., 2015, 2019; Bolles et al., 2019; Mendes and Scotti, 2020; Trulsen et al., 2020; Mendes et al., 2021), which can further amplify oscillations in the mean water level.

2B. In particular, given a distribution of a time series (let it be the mean sea level for example), one can compute the expected maximum extreme value following section 4b of Benetazzo et al. (2015) or section 3 of Mendes and Scotti (2020). I encourage the authors to attempt to compute this expected maximum of a Gaussian sea for the sea level and compare with their simulations. The authors should discuss the magnitude of the local wind-wave effects with that of the purely atmospheric pressure. At the very least, I expect the authors to discuss this alternative method.

Thank you for the comments 2A and 2B. The aim of our study was to find lower limits for sea level maxima that go beyond the observed extremes in the Baltic Sea. Therefore, we have not included waves in this study. For more accurate studies for individual locations (as in Apukhtin et al. 2017 and Gordeeva and Klevannyy 2020), wave simulations must be performed separately using the wind fields and simulated sea levels as input data. These studies are left for a future study. We added text explaining why wave studies were not included in this study in the Conclusions.

3. There should be a review of mathematical modelling on cyclone pressure fields, and a discussion of why the particular choice (eq. 1) has been chosen.

The Gaussian shape in eq. 1 was originally chosen for two main reasons:

1. the Gaussian shape requires only a few parameters to describe it, and

2. the Gaussian shape characterizes the shape of the low-pressure system with sufficient accuracy.

In the revised manuscript, we highlight the rationale more clearly and also provide a discussion of other choices made for synthetic cyclones in the literature.

4. The authors provide an ERA5 analysis of cyclone speeds that pass through the Baltic sea, but this information is not sufficient. They also need to display the average spatial (and vector) shape of these cyclones, not to mention the duration of their path in the Baltic Sea. Furthermore, a brief discussion (or figure display) of the intensity of the cyclone as they enter the Baltic Sea.

Thank you for this comment. In the revised manuscript, we have expanded Figure 4 (Fig. 3 in revised version) to include three panels showing the propagation speed, intensity, and duration of cyclones over the Baltic Sea.

The average shape of cyclones in the Baltic Sea would also be an interesting research topic but obtaining the structure of cyclones from e.g. the ERA5 reanalysis would clearly require more methodological resources. In addition, such a study has recently been carried out (Laurila et al., 2021). Therefore, we decided not to calculate cyclone composites for this study.

Laurila, T. K., Gregow, H., Cornér, J., & Sinclair, V. A. (2021). Characteristics of extratropical cyclones and precursors to windstorms in northern Europe. Weather and Climate Dynamics, 2(4), 1111-1130.

5. In section 2.3 the governing equations should be written down, and assumptions and limitations discussed thereof.

The governing equations are the well-known shallow water equations, suitable for the shallow Baltic Sea. We have added explanation for the equations used in the simulations.

6A. The main results are presented in figures 5-6. The text should be clear on whether this analysis can be made only at a few locations, or if these locations were picked for a particular physical reason.

Otherwise, I encourage the authors to provide a Baltic Sea analysis (as claimed in the text) instead of a few locations.

The analyses presented for three sites could be done for any other coastal site, but we chose those sites to represent different bay areas of the Baltic Sea. We modified the text in the beginning of Section 2.5 to clarify this.

6B. While figure 6 is clear on the extremes, it should be normalized by the expected significant wave height as the cyclone passes. This comparison provides a better scale of the cyclone effects as compared to local wind/wave effects on sea level change.

6C. I encourage the authors to provide several contour plot panels showing the scale of normalized sea level change (by the significant wave height) across the entire Baltic sea coast. Each panel would show the sea level change at a particular time since the appearance of the cyclone.

Thank you for comments 6B and 6C. As explained in the earlier comment, the waves are not considered in this study as their effect varies greatly with location and our aim was to find lower limits for the maxima of sea level. For more refined estimates the effects of waves need to be included, this will be a subject of a future study.

6D. Pages 135-145 describe the path of the cyclone affecting the three cities of figure 5. Why not plot

the path on a figure? It would better suit the manuscript and help the reader.

We are confused by this comment. The simulated cyclones have a constant propagation speed, with the origin moving along the straight path indicated by the arrows. So the paths of the three cyclones are described by the three arrows.

Conclusion

The reviewer thanks for the opportunity to read this important work. Overall, I support the publication of this preprint once all these minor issues have been clarified/amended.

Thank you for this positive feedback.