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).

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.

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.

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.

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

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.

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.

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.

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.

References

Arns, A., Wahl, T., Haigh, I., Jensen, J., Pattiaratchi, C., 2013. Estimating extreme water level probabilities: A comparison of the direct methods and recommendations for best practise. Coastal Engineering 81, 51–66.

Barbariol, F., Benetazzo, A., Carniel, S., Sclavo, M., 2015. Space-time wave extremes: The role of metocean forcings. J. Phys. Oceanogr. 45, 1897–1916.

Barbariol, F., Bidlot, J.R., Cavaleri, L., Sclavo, M., Thomson, J., Benetazzo, A., 2019. Maximum wave heights from global model reanalysis. Progress in oceanography 175, 139–160.

Benetazzo, A., Barbariol, F., Bergamasco, F., Torsello, A., Carniel, S., Sclavo, M., 2015. Observation of extreme sea waves in a space-time ensemble. J. Phys. Oceanogr. 45, 2261–2275.

Bolles, C., Speer, K., Moore, M., 2019. Anomalous wave statistics induced by abrupt depth change. Physical Review Fluids 4.

Bowen, A., Inman, D., Simmons, V., 1968. Wave 'set-down'and set-up. Journal of Geophysical Research 73, 2569–2577.

Brevik, I., 1978. Remarks on set-down for wave groups and wave-current systems. Coastal Engineering 2, 313–326.

Butler, A., Heffernan, J.E., Tawn, J.A., Flather, R.A., Horsburgh, K.J., 2007. Extreme value analysis of decadal variations in storm surge elevations. Journal of Marine Systems 67, 189–200.

Gumbel, E. J., 1958. Statistics of Extremes. New York.

Massel, S.R., Gourlay, M.R., 2000. On the modelling of wave breaking and set-up on coral reefs. Coastal engineering 39, 1–27.

Mendes, S., Scotti, A., 2020. Rogue wave statistics in (2+1) gaussian seas i: Narrow-banded distribution. Appl. Ocean Res. 99, 102043.

Mendes, S., Scotti, A., Stansell, P., 2021. On the physical constraints for the exceeding probability of deep water rogue waves. Appl. Ocean Res. 108, 102402.

O'Grady, J., Stephenson, A., McInnes, K., 2022. Gauging mixed climate extreme value distributions in tropical cyclone regions. Scientific Reports 12, 4626.

Trulsen, K., Raustøl, A., Jorde, S., Rye, L., 2020. Extreme wave statistics of long-crested irregular waves over a shoal. J. Fluid Mech. 882.