Brief Communication: From modelling to reality: Flood modelling gaps highlighted by a recent severe storm surge event along the German Baltic Sea coast

Authors response to the reviewers

In order to enhance readability, our responses are written in green and in-text citations are displayed in italics.

Reviewer 1:

The brief communication by Kiesel et al. provides evidence that the numerical models must be improved to simulate extreme wave inundations. This is true because the numerical models still do not accurately accommodate the temporal and spatial variation in macro-roughness during flow-structure interaction.

We thank Reviewer 1 for the positive and constructive feedback, which has helped us to improve the manuscript. In response to R1's comments, we have now clarified the role of storm characteristics for creating differences in coastal hydrographs as depicted in Figure 2 and provide explanations regarding the consideration of tides in the model and the sensitivity of the water levels with respect to return period. Please find our detailed responses below.

The communication only discusses the water levels (depths). However, water velocity is an important factor for high-energy wave impact. The mismatch between the predicted and real hydrographs would be due to the flow velocity effect but not completely attributed to the assumptions. The authors need to include a section on the significance of the flow velocity of this event and how it could affect the shape of hydrographs.

We would like to thank R1 for the interesting remark. However, we argue that differences in flow velocity are not the origin of the disagreement between the water level time series of the modelled 200-year design events and the western Baltic storm surge from October 2023 (Figure 2 in the original manuscript). This disagreement is originally caused by varying storm characteristics. The hydrographs represent coastal water level time series and the shape of the hydrograph (i.e. steep or gentle slope at the onset of the event) is a function of the storm characteristics (magnitude, duration, and storm track) and potential additional basin reactions such as seiching. In general, wind pushes water against the shore where it piles up in bays, fjords, lagoons or along beaches.

The model used to simulate the design hydrographs (Kiesel et al., 2023) uses wind and atmospheric pressure as forcing conditions, causing wind shear stress on the water surface and subsequent water acceleration and thus increased water velocity. This interaction, along with coastal geometry, determines the hydrograph's shape. While flow velocity is a factor, the primary driver of different hydrograph shapes at the same location is the storm's characteristics.

To address Reviewer 1's concern, we have added a paragraph to section 2.1, where we now explicitly explain how the design hydrographs were created and that differences in storm characteristics are drivers of coastal hydrograph variability (i.e. differences in storm surge durations):

"Excluding the influences of short surface waves, storm tide hydrographs are a function of the mean sea level, astronomical tide and storm surge (Lewis et al., 2011; Pugh, 1996). *Tides can be excluded as a cause for the observed differences in hydrographs, as the Baltic Sea is microtidal. In addition, short surface waves were not considered in* Kiesel et al. (2023). *Differences in mean sea level might have affected the hydrographs only in terms of peak water levels, considering that the simulated 200-year design surges were de-trended for sea level rise. Consequently, the differences in the shapes of the hydrographs can only originate from differences in storm characteristics. The constructed design hydrographs were derived from a coastal ocean model, which covers the western Baltic Sea, using hindcast model runs (1961-2018) for each location depicted in Figure 1. Only those surges were taken into account, where the peak water level was higher than 1 m above mean sea level. Ultimately, the remaining surges were averaged in their temporal evolution* (Kiesel et al., 2023)*."*

The authors selected a 200-year return period for simulating water levels. Was the tidal effect included in the simulation?

The tidal effect was not included in the model that simulated the hydrographs shown in Figure 2. The reason for the exclusion is that the tidal range in the Baltic Sea is very small, less than 10 cm in its southwestern parts (e.g. Gräwe & Burchard (2012)). The more important periodic oscillations that are included in our simulations are seiches (inertial oscillations caused by perturbations in wind and air pressure fields, i.e. storms, e.g. Wübber & Krauss (1979)). To clarify this in the manuscript, we have now added the following sentence to the introduction and main body of the text.

Introduction:

"The Baltic Sea is a semi-enclosed, microtidal marginal sea in the eastern North Atlantic, which is under pressure from a multitude of anthropogenic disturbances and natural hazards (Reusch et al., 2018; Rutgersson et al., 2022).

Many Body:

" Tides can be excluded as a cause for the observed differences in hydrographs, as the Baltic Sea is microtidal."

What is the sensitivity of the water level to the return period?

The sensitivity of the water level with respect to return period is shown for one example GEV distribution for the station Kiel, Germany (Figure 1, taken from Kiesel et al. (2023)). The difference in peak water level for a 30- and 200-year event amounts to approximately 30 cm (see also Table 4 in Kiesel et al. (2023)).

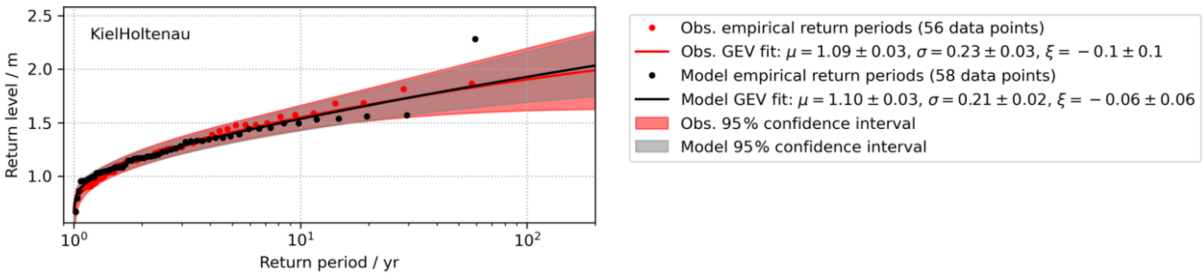

Figure 1: Peak water level and associated return period for the station Kiel-Holtenau, Germany (Kiesel et al., 2023).

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