

Reply on Reviewer #1

We appreciate the constructive comments of the reviewer. They helped us to clarify and improve our manuscript. In the following, the reviewer's remarks are listed and followed by our point-by-point response in [blue](#).

General comment

The present work addresses the impact of mean sea level rise on storm surges and tide-surge interaction in the German Bight. It relies on the use of a numerical hydrodynamic model to perform various experiments. German Bight has already been studied in terms of effect SLR on extreme water level. The main originality of the present manuscript is to investigate the sea-level rise (SLR) effect on surges and tide-surge interaction (TSI). The manuscript is well written, with clear figures, and clearly describes the experiments and results. However, before to be published, the manuscript required some complementary analysis to fully characterise the SLR effect on surge and TSI and the processes behind.

Major points to improve

- Wave setup contribution is not taken into account in the present study. The paper should at least clarify that he neglects this term, and, if existing in the literature, provide some magnitude order of this contribution.

[Response: We thank the reviewer for pointing out this omission. Wave setup is not represented in the present barotropic model configuration and is therefore not included in our decomposition of extreme water levels. We will state this explicitly in the revised manuscript and clarify that our results concern the nonlinear interactions among mean sea level, tides, and meteorologically driven storm surges only. We will also add a brief discussion of the potential relevance of wave setup based on the available literature.](#)

- As the authors intend to study effect of TSI on EWL, then I think they should investigate skew surges (in addition to hourly surge or surge at high tide), as this is the skew surge that matters for EWL (rather than the surge at high tide).

[Response: We thank the reviewer for this important suggestion. We agree that skew surge is a useful metric for extreme water level \(EWL\) analysis because it quantifies the difference between the maximum observed or simulated water level and the corresponding astronomical high tide, without requiring the surge maximum and high tide to occur simultaneously.](#)

The primary aim of the present study, however, is to identify the individual dynamical contributions of the meteorologically driven surge and tide-surge interaction using the controlled SURGE, TIDE, and FULL experiments. Skew surge combines changes in magnitude and timing and therefore does not provide the same direct process separation as our model-based decomposition. For this reason, we will retain SURGE and TSI as the principal diagnostic quantities. We will revise the manuscript to explain this distinction and to acknowledge skew surge as a complementary EWL metric.

- Line 337-338, the authors suggest that stronger surges generate stronger currents and thus stronger nonlinear interactions. Perhaps, but this is not proved here. How looks like the tidal currents (of TIDE_0 runs) depending on the tidal phase? How looks like the current of the SURGE_0 runs? These elements are missing. Completing the present study with such complementary analysis would really reinforce the novelty of this work, as very few papers (even if based on shallow water modelling) show the patterns of the currents and discuss in a quantitative way the effect of the meteorological induced-current (and tidal current) on TSI.

Response: We thank the reviewer for this valuable suggestion. We agree that our previous interpretation linking stronger surges to stronger currents and enhanced nonlinear interaction was not demonstrated directly by the analyses presented in the manuscript. We will therefore analyze current velocities from the FULL_0, TIDE_0, and SURGE_0 experiments for the selected surge events and examine their dependence on tidal phase and surge magnitude. Based on the results, we will either provide quantitative support for the proposed mechanism or revise the corresponding interpretation.

- Regarding the part on the effect of SLR on TSI (Line 365-370), I recommend extending it by analysing the various parts of the TSI changes (i.e. ITSI). Indeed, as it is written it suggest that these are just tide surge interaction changes, but this TSI changes result in fact from different processes (SLR effect on tide, SLR effect on surge, ...). If I am not wrong we may write for instance $ITSI = TSI_1 - TSI_0 = (WL_1 - TIDE_1 - SURGE_1) - (WL_0 - TIDE_0 - SURGE_0) = (TIDE_1 - TIDE_0) + (SURGE_1 - SURGE_0) + (WL_1 - WL_0) = (TIDE_1 - TIDE_0) + (SURGE_1 - SURGE_0) + (SLR_1 + RI)$, with RI the remaining interactions. Based on this equation the authors may investigate what drives the most TSI changes. This will probably change and deepen the process analysis on the TSI changes, compared to the present version of the manuscript. Such analysis would also make sense regarding the fact that the manuscript already investigate SLR effect on surges and tides.

Response: We agree with the reviewer that understanding the driver of the TSI changes would deepen the process analysis. In fact, the components of the proposed decomposition

are already separately addressed in the manuscript: TIDE_1 – TIDE_0 – 1 (IST), SURGE_1 – SURGE_0 – 1 (ISS), WL_1 – WL_0 – 1 (will be added as Section 3.5) and ISTSI. We will reorganize the results so that IST, ISS, ISTSI, and the total water-level change beyond the imposed SLR are evaluated within a common attribution framework.

“On-line” Remarks

Line 47: “SLR scales linearly with EWL” or “EWL scales linearly with SLR”?

Response: Will be revised to “EWL scales linearly with SLR”.

Line 117: why using FES2004 (22 years old) rather than the more recent products FES2014 or FES2022 than account for more tidal components and exhibit better skills (see e.g. Lyard et al., 2021)?

Response: We thank the reviewer for raising this point. FES2004 is used only to prescribe tidal forcing at the open boundaries in the northeastern Atlantic, outside the North Sea shelf. Tidal propagation and transformation within the North Sea and German Bight are then simulated dynamically by TRIM-NP. We therefore expect the influence of the coastal improvements in the newer FES products on our results to be limited. Also, according to Lyard (2021) the main improvements in tidal representation by FES2014 were achieved in shelf and coastal areas. However, because we have not performed a sensitivity experiment using FES2014 or FES2022, we cannot quantify this influence directly.

Line 118: remind the spatial resolution of the meteorological forcing dataset, and, if needed, discuss its suitability for the present study.

Response: Will be added accordingly.

Line 136: specify if nodal correction has been activated or not (as it seem that U-tide is applied to 10 year time series)

Response: Tidal constituents were estimated separately for each year, with nodal corrections enabled. We will add this information to the revised Methods section.

Line 229: clarify if the 200 events are common to the three sites (i.e. same events).

Response: The 200 largest SURGE_0 events were selected separately for each location. They are therefore not necessarily the same events at all three sites. We will clarify this in the revised manuscript.

Line 485-488: the authors may perform a tidal component analysis on there results to extract the effect of SLR on M2 amplitude and thus reinforce the discussion on the effect of SLR on tide and M2.

Response: We will add the analysis of M2 amplitude.

Line 541-550: not fully clear to me, with long sentences -> clarify / improve the readiness.

Response: Will be clarified in the revised manuscript.

Line 557 to 561: this is a bit too general. The authors may provide examples of types of application for which linear addition may be sufficient, and for which it may not be sufficient.

Response: We will expand the discussion as suggested.

Line 595-597: Clarify that the conclusion of the present paper on TSI is site specific, i.e. is valid for the German Bight study site.

Response: We will clarify this point accordingly.

References

- Lyard et al., 2021 : <https://doi.org/10.5194/os-17-615-2021>