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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Identification of storm surge events over the German Bight from atmospheric reanalysis and climate model data" *by* D. J. Befort et al.

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Anonymous Referee 2

Major Comments:

1) Why is only wind speed used? How about the effects of atmospheric pressure? The combined water level will be a combination of the tide, pressure, wind and wave effects.

As it is mentioned in our introduction, our aim is to estimate changes of storm surge

risks solely due to changes in frequency and strength of storms under future climate scenario conditions. Therefore, we only used atmospheric data and did not calculate water levels.

The influence of air pressure was ignored within this investigation due to the empirical formula set out by Müller-Navarra and Giese (Improvements of an empirical model to forecast wind surge in the German Bight. Ocean Dynamics 51, 385-405,1999), stating the following about the influence of air pressure: “The well-known rule from literature according to which a pressure increase of 1 hPa produces a water level decrease of 1 cm applies only when the sea has sufficient time for adjustment to air pressure conditions (DIETRICH [1953]). In cases of fast travelling highs and lows this effect levels out.”

Therefore, their empirical formula for the surge, contains a smaller, additional part for the static influence of atmospheric pressure: g10 = (P -1015 hPa) $\times$ -0.439 cm/hPa (see their table 3).

If we assume a very low pressure of 950 hPa, we thus gain a value of g10 = 28.5 cm. The maximum surge for onshore winds however is given in table 2 as 268 cm and is hence much higher than this value. Furthermore, following the BSH definition, severe storm surges may occasionally even reach values above 300 cm. Therefore, we can assume that for stronger winds, inducing high storm surges, the value of g10 is much smaller, than the values found for the other parts of the empirical formula, which describe and take into account the influence of the wind speed on said surge height. Thus this value is negligible and therefore the influence of the air pressure was not included in our analysis.

2) Section 4.1. "neglecting the influences of the water depths" This is crucial to storms surges, as they are generated in regions of shallow water, where they become the most dangerous!

NHESSD

2, C2283–C2291, 2014

We see the point that this sentence is misleading. We reworded this sentence as we only neglected the astronomical tide. Additionally, we did not take into account that the effect of wind speed on the water level is different during high and low tide. We also shifted this sentence to the methodology section:

'As no information about the astronomical tide is included in the ECHAM5/MPI-OM simulations, our analysis is based on wind speed and wind direction only. Thus, we use the wind surge data from the storm surge catalog at the station in Cuxhaven only, neglecting any information about the astronomical tide.'

3) In some places the English is unclear and needs re-wording.

Unfortunately, the reviewer did not give any information on which parts are unclear. We hope that these parts were addressed in the revised paper.

4) The low frequency (6 hourly) of the atmospheric data is worrying and you are likely to miss fast moving storms On page 9 line 29 - page 10 line 2 you suggest increasing this window to be even longer. I don't see how this will help capture extreme events without leading to false positives?

Unfortunately, 6 hourly atmospheric data is the highest temporal resolution provided for these model simulations and also for the new IPCC-AR5 simulations. Of course a higher resolution would help to identify the effective wind component at the wind surge maximum, but this is not possible. The idea of increasing the window to search for effective wind components is motivated by the fact that in some cases the effective wind component at the wind surge maximum is not equal to the maximum during the whole track (Figure 2a). Figure 2b shows that for these events a higher effective

NHESSD
2, C2283–C2291, 2014

wind component is reached during the event, but it is still the same wind storm event. Thus, Figure 2b just points out that all events with effective wind components above about 18.5m/s are related to an observed storm surge at Cuxhaven. Please keep in mind that the threshold for the identification of potential storm surge events is taken from Figure 2a, only considering the effective wind components before and after the maximum wind surge observed in Cuxhaven.

5) As you say in your conclusions, it would be difficult to detect small, fast moving storms with this method - but these mid-latitude cyclones are exactly the type of event which is prevalent in the North Sea.

We reworded the sentence in the conclusion as it is misleading. The reasons that we can't assign these two storm surge events are due to the simple nearest neighbor approach of the wind storm tracking algorithm. As pointed out in Section 4.1, one of the wind storm events is too short and the other one is connected to a second wind field over Scandinavia rather than over the German Bight regions. This leads to the fact that the one over the German Bight region is neglected.
We updated this sentence:

'The reason that one event could not be assigned to any wind storm event is due to difficulties arising from the simple nearest neighbor approach used for the identification of large-scale wind fields. Another event does not fulfill the minimum duration criterion of 18 hours.'

6) You mention several times that the tides are not included, perhaps you could linearly combine and astronomical tide to evaluate the importance of the tide-surge interactions?

NHESSD
2, C2283–C2291, 2014

We added some new analyses on the probability of potential storm surge events with specific effective wind components leading to observed storm surges (Sect. 4.2). As found in Sect. 4.1 the probability of potential storm surge events (identified by our method) is increasing with higher effective wind components (see Fig. 2a and Fig 2b). We calculate these probabilities for four different categories of potential wind storm events according to their effective wind component (weak, moderate, strong, very strong). We find increases in three out of four of these categories under future climate conditions compared to 20C. However, only the increased number of moderate potential events is statistically significant. As given in the revised text, this class has a probability of about 13% to lead to a storm surge event in reality.

This attempt is meant to enhance the interpretation of the results discussed in this manuscript. (Please see also answer to Major Comment 1, Referee 1)

Minor comments:

1) page 2, line 5: 'high wind speed' please quantify

We would like to keep this sentence as the interpretation of the threshold for the effective wind component used to identify potential storm surge relevant events requires a general understanding of the methodology presented in the paper.

2) page 2, line 20: replace metropolitan with urban
Done

NHESSD
2, C2283–C2291, 2014

3) page 3, line 5: 'heavy storm' surge → 'heavy storm surge'
Done

4) page 3, line 25: 'The optional..' do you mean 'The optimal'?
Thank you very much. In fact, we meant 'optimal' and changed it in the revised manuscript.

5) page 3, line 25: 'The raise to the water level . . .' replace with rise
Done

6) page 5, line 10: again you say 'the astronomical tide and the wind surge'. Really you're considering the total atmospheric surge generated by winds and low pressures. See major comments.

Please see our answer to Major Comment 1 (of Referee 2) about the relevance of pressure compared to wind speed and direction. As pointed out in the following sentence, we are aware of the fact that 'wind surge' (derived by substracting the astronomical tide and the total water level) is not only influenced by wind speed and direction.

7) page 5, line 10: replace 'gain' with 'advantage'
We replaced 'gain' with 'advantage' on page 6, line 10. We hope this is the page the comment refers to.

8) page 7, line 9: replace ' Eventually' with 'Finally'
Done

NHESSD
2, C2283–C2291, 2014

9) page 7, line 11: replace 'whereof 82 occur. . .' with '82 of which'
Done

10) page 7 lines 17-19 needs rewording

We reformulated the sentence:

'The same percentile value is used to detect wind storm events in the 20C period (1900-2000) and in the A1B scenario period (2001-2100).'

11) page 8, line 4: 'As a first step'
Done

12) page 8, line 6: reword: solely over the German Bight
Done

13) page 8, line 15 'are applied'
Done

14) page 8, line 24: 'deviated' do you mean 'derived'?
We changed 'deviated' to 'derived' in the revised manuscript.

15) page 9, line 1: replace Afterwards with Next
Done

NHESSD
2, C2283–C2291, 2014

16) page 9, lines 6-7: 'we take for the height..' I don't understand this sentence – please rephrase

We reformulated this sentence in the revised manuscript:

'In general no wind data from reanalysis (six hourly) is available at the exact date of wind surge maximum (every five minutes). Thus, we take effective wind component data for the time step before and after wind surge maximum into account.'

17) page 9, lines 7-11. What is this ratio that you calculate? Are you saying it's stormy for? 3.7% of the time? 13.5 days per year?

We reworded this part:

'To estimate the usability of this method we calculate the total number of the 6 hourly time steps in ERA-40 data, for which this threshold of the effective wind component is exceeded. Afterwards, we calculate the ratio between all observed storm surge events at Cuxhaven and the total number of time steps exceeding this threshold. We calculate a value of about 3.7 %, indicating that only 3.7 % of all time steps in ERA-40 reanalysis data, which exceed the minimal value of the effective wind component (observed for the storm surges at Cuxhaven), lead to a storm surge.'

*18) page 10, line 25: The storm surge is *always* independent of the astronomical tide.*

We changed this sentence in the revised manuscript to:

NHESSD

2, C2283–C2291, 2014

"In contrast to this, events with effective wind components between 16.5 m/s and 17.5m/s lead in about 50%, and events with effective wind components exceeding about 18.5m/s always lead to an observed storm surge at Cuxhaven"

19) e.g. similar study done for the British Isles = UKCP09. They're findings are also inconclusive - it is not clear whether the frequency of storm events is likely to increase under future climate.
Lowe, J. A., Howard, T., Pardaens, A., Tinker, J., Holt, J., Wakelin, S., Milne, G., Leake, J., Wolf, J., Horsburgh, K., Reeder, T., Jenkins, G., Ridley, J., Dye, S., Bradley, S. (2009), UK Climate Projections science report: Marine and coastal projections. Met Office Hadley Centre, Exeter, UK.

We added this technical report to the introduction of the revised manuscript

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Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., 2, 3935, 2014.

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