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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Estimations of statistical dependence as joint return period modulator of compound events. Part I: storm surge and wave height" *by* Thomas I. Petroliagkis

Anonymous Referee #2

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General Comment The paper addresses compound events defined by combined high surges and high wind waves along European coastlines, especially in estuaries/river mouths. Statistical methods are used to investigate joint probabilities of compound events and the statistical dependency, since flood risk is not a function of one parameter (storm surges with peak value and duration) but usually of more (e.g. wind waves, river runoff). Large scale weather systems can cause either high storm surges or high wind waves and further more high precipitation and river runoff/discharges. Two sets of almost 35-year hindcasts of storm surges and wave heights were used to analyse the correlation and statistical dependency. As expected the frequency of the occurrence of the top compound events in different coastal areas were found to be higher during

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the winter months. In the introduction the hydrological and meteorological conditions for high wind waves and extreme tidal surge events which can occur simultaneously with extreme precipitation events and high river flows (compound events) leading to increased flood risk is highlighted clearly. But the paper and the used methodology focused only on very few parameters. What is the background of the generalization? The subject of the paper is interesting yet a little confusing especially in the context of coastal engineering therefor the manuscript should be major improved. The paper and its structure is not easy to understand and the description of different data sets (and different time spans) of observed and modelled hindcast data is confusing (e.g. a lot of unusual abbreviations). The number of tables and especially the huge amount of data should be reduced as they are displayed in figures. The selected 32 stations at the end of the rivers or estuaries cover a wide variety of geographical areas and meteorological, oceanographical and hydrological (currents and tides) systems in coastal zones along European coasts. E.g. the tidal range varies from nearly zero to some meters and within the deterministic part of compound events in comparison to the stochastic part (surges, wind waves and river flow) of these compound events. Further discussion of the deterministic and the stochastic part of the compound events and the effects in the statistical analyses (dependency of different parameters) is recommended (page 41, line 26-30). In general I agree completely with reviewer # 1!

Comment 1 The description whether storm surge and/or wind waves are capable of reproducing extreme values is incomplete (e.g. river runoff?). It has to be explained, why river runoff is not taken into account!

Comment 2 In the context of the paper a very interesting problem is discussed where copula functions should be taken into account, so far only a simple approach for copula functions has been taken into consideration, the discussion of different copula functions within the scope of the addressed topic is to be considered, more references to copula functions could be helpful (e.g. Wahl, T., Jain, S., Bender, J., Meyers, S. D., & Luther, M. E. (2015). Increasing risk of compound flooding from storm surge and rainfall for

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major US cities. Nature Climate Change, 5(12), 1093-1097).

Comment 3 A point of criticism is that the meteorological conditions and oceanographic system were not sufficiently described and the temporal developments of surges and wind waves are also not clearly described. E.g. in fig 10 and 12 it is shown that for the Weser (RIEN 29) the dependence for the prevailing (highest frequency) and dominant (highest intensity) wind during the top 80 extreme compound events are caused by wind direction from WSW. This is completely in contrast to my experience and has to be explained (same for e.g. RIEN 3, 12,... 23, 24, ... and 32)! From my point of view, it would be advisable to consider a subarea, e.g. only the North Sea, and after a successful investigation of the statistical dependence then implicate other areas.

Comment 4 (Length of observations/hindcasts) As I understood the water level data/storm surge/wind waves: The 32 RIEN (Table 1, page 10) were selected mainly because of their proximity to tidal gauges, although many of them cannot be evaluated due to lack of long-term measurements. For most RIENs, there are no data from nearby open wave buoys. Only for the Rhine (RIEN 28) are the tide and sea data (without data gaps) available from a nearby wave buoy for a period of 3 years. The validation of the combined hindcasts (tide and wind waves) was done on the basis of measured data at the Rhine (NL) was done on the tidal data at Hoek von Holland (HvH), wave buoy: Lichteiland (LiG) over a period of $\sim$ 3 years on measurement data without gaps and comparison of daily and half-day maxima. The generation of the hindcast of storm surge data was done with Delft3D-Flow (according to Vousdoukas et al. (2016) and the generation of the hindcast of the wind waves data was done with ECWAM wave model (according to Bidlot et al. (2006), Bidlot (2012), ECMWF (2015), Philips (2017)), e.g. $\sim$36 years, wind- and pressure fields from ERA-Interim (ERAI) (time resolution: 1 h, spatial resolution: 28x28 km, fixed water level, signif. wave height, max. wave height, mean wave period, mean wave direction and validation based on available records from 101 wave buoys throughout Europe + North Atlantic (1996-2015) (Fig. 2)) The overlapping period of the two hindcasts ($\sim$ 35 years) was used in statistical analysis.

The methodology of the research (using the hindcast data sets and observed data) has to be explained more detailed and especially what that means for the interpretation of the results (for all 32 RIEN). A time series of observed water level and wave buoy of only 3 years and only for one station in the area at Hoek van Holland seems to me as being not sufficient and much too short for comparison/evaluation with the modelled (hind cast) data and the conclusions. There should much more field data (water level, surges, wind waves, river runoff) available around the 32 RIEN! Approx. 2.3 "extreme events" (at least 3 days between peaks) per year (total 80 top events) were chosen. It has to be explained more detailed why 2.3 “extreme events” where chosen and what that means for the interpretation of the results.

Improvements: The number of tables and graphs should be reduced and more summarized. The paper is not easy to understand for a wide diversified audience, the length of the paper is too long and has partly too much redundancy (e.g. table 1 and fig. 1) The pure agreement between hindcast and observation of daily maximum of storm surges in Fig. 4 has to be explained. Why are small storm surges, e.g. below 0.5 m are taken in to account? What is the definition of a storm surge? What is the reason to use the storm between 25th December 2012 and 24th January 2013? The pure agreement between hindcast and observation of daily maximum of the significant wave height in Fig. 6 has to be explained. Fig. 8: The fairly pure agreement (chi) of the statistical dependence (chi) of storms surge and significant wave height between observation and hindcasts has to be explained. Fig. 9: For the lower and higher quantiles the chi plots have to be explained and discussed. Fig. 10: I do not find the category dependence “negative” and “zero”? Symbol and wind N to NNW is not necessary. The description of tables and figures should be improved.

English writing: Overall the writing style is good.

Some more suggestions:

- I do not find a clear definition of highest intensity, → page 34, row 2 and page 41,

row 9, does it mean only the dominant wind? Direction and/or speed? - I do not find a clear definition of negative bias: Systematically underestimated parameter? Minor improvements page 2 row 18 “This is”, page 5/6 row 19/1 “Matlab” page 7 row 22 “also uses”, page 8 row3 “. . ..Good (1994)”page 14 row 14 “to the”, page 16 rows 10-14 “Storm Emil” as well as page 18 rows 1 and 30. p.42, row 10: providing “us”?

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