Review of "Characteristics of joint heavy precipitation and high sea level events on the Finnish coast in 1961-2020"

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The co-occurrence of extreme precipitation and extreme sea levels aggravate the flooding impacts on coastal areas, thus compound flooding should be taken into account for a complete risk coastal assessment. In this study, a co-occurrence counting is used to quantify the compound effect of extreme precipitation and sea levels along the coast of Finland using observations.

The co-occurrence of heavily precipitation and extreme sea levels have been previously analyzed in Europe, including the coasts of Finland (Bevacqua et al., 2019), finding similar results as those showed in the present manuscript. However, Bevacqua et al (2019) included the wave contribution when defining extreme sea levels, which is a plus. They also used reanalysis and modelled data to represent both sea level and precipitation. Other than that paper, the compound effect of extreme sea level and precipitation along the Finnish coast has not been assessed. The novelty of the present manuscript is the use of observations for precipitation and sea level data. The authors have found low co-occurrence of extreme precipitation and sea level along the Finnish coast, which is itself a result. Findings show decadal variability in the compound effect as well as trends in some tide gauges.

However, although the results are promising, higher effort can be done to enrich the paper; the analysis is quite simple, and more information can be obtained from the data the authors show. For instance, the authors can show the return level of those individual extreme events (precipitation only and sea level only) in comparison with the return level when considering compound effect. This can be also performed with return periods (more details below). Regarding methodology, information is missing, and overall, the methodology needs further explanation and can be greatly improved (more details below). Also, I'm not sure if the correlation between compounding effect in precipitation and sea level can be associated with climate patterns; can be an arbitrary association resulting from the low number of compound events found (something to discuss with the authors). Another aspect is the organization of the paper; the introduction and conclusions are mixed up. Finally, I have found that the grammar and

language must be revised and notably improved before publishing. Therefore, I think the manuscript is not ready for publication; major revision.

Suggested additions:

- The co-occurrence of extreme events as counting of simultaneous threshold exceedance is one way of measuring compound effect. Other way that has been extensively used in the literature is the use of compound probability. Although this method is slightly more complicated to implement, it allows to answer some questions such as "what is the return level (or period) of an individual extreme event and how does it change when accounting for compound effect?" In addition, the results can be more easily comparable with previous works that have analyzed the joint return period of precipitation and extreme sea levels in the area (despite differences in the data used). A similar procedure can be found in Bevacqua et al (2019). Another way of enriching the paper would be performing a correlation analysis and significance testing, so the results are more robust. A similar method is used in Hendry et al (2019).

  I truly believe that by implementing this type of analyzes, the authors can greatly improve the paper by enriching it with important information not only for the scientific community but also for stakeholders.

Methods

- When the authors define extreme sea levels and precipitation events (events above .95 or .98 thresholds), do they account for independency between them? If not, an overestimation of the co-occurrence of events could happen; two consecutive extreme sea levels and two consecutive extreme precipitation events driven by the same weather system should be counted as only one compound event.

- In the manuscript, the authors define co-occurrence as the threshold exceedances occurring simultaneously. They don't define what "simultaneously" mean (is it in the same day? In a 3-day time window?) Since the data is daily resolution, I'm assuming they calculate co-occurrence as the sea level and precipitation exceedances happening

in the same day. The authors may consider expanding this overlapping period to, for instance, ±1 or ±3 days (3 days was used in Bevaqcua et al., 2019). This will allow the authors to account for a weather system that caused precipitation one day and extreme sea levels the day after, for example. Also, it will allow to increase the sample size of extreme events co-occurrences, probably.

- Since the compound effect of precipitation and sea level has been assessed through a counting method, the authors couldn't assess the significance of the co-occurrence. I suggest to calculate the Kendall's rank correlation, which captures non-linear relationships, as performed in previous works (Hendy et al., 2019).

- Did the authors tested other time periods for the accumulated precipitation?

Minor comments:

- Line 4: in line 4 the authors define "compound events" but they already used this concept word in the line before. I would define it before using it.
- Lines 3 to 5 sound redundant.
- Line 23: It doesn't have to be anomalous to be a compound event.
- Lines 59 to 60: Why are the probabilities of coastal floods increasing? Is that the result of surges, waves, mean sea level rise, or a combination of all of them?
- Line 87: What kind of data is included in the reanalysis data?
- Line 91: "*In total there are 14 tide gauges on the Finnish coast, but only nine of them were used in this study*", why is that?
- Line 95*:* I would recall here that this is the highest value over 12 hours.
- Line 98: previous works have recommended not to use a linear trend to detrend sea level time series (Arns et al., 2013).
- Line 110: Why do you use another precipitation dataset near the borders? Also, I would indicate that FMIClimGrid are observations at the beginning of the paragraph.
- Line 111: *"but the number of stations has decreased towards the 21th century due to the automation of the measurement protocol"*, this needs more explanation.

- Line 159: Do you consider a time window between threshold exceedances to assure independency?
- Line 167: How many of those compound events have happen in the same year? That could be relevant when calculating the correlation with climate indices.
- Line 166: *"When calculating the numerical values corresponding to the percentiles of precipitation, also days with no precipitation were taken into account"*, Why?
- Line 167: if HL represents events over a higher threshold, all the events included in HL should be also included in EL. Then, how is it that there are more events in HL than in EL?
- Line 170: The authors may want to allow a time window between extreme precipitation and extreme sea level to consider co-occurrence, taking into account the lag in the storm. This is, the same storm can cause an extreme precipitation one day, and extreme water level the day after. This probably will increase the number of co-occurrences.
- Line 185: have the authors calculated the trends on the extreme events alone or over the co-occurrences?
- Line 221: highest sea level variability doesn't imply higher sea level values.
- Line 275: Have the authors tested if the composite maps for compound events are statistically different from the composite maps of non-compound events? The composite maps of total column of water and 10-metre wind speed for sea level only and for compound look very similar. The fact that the number of observations is notably smaller in the compound composite map (N= 27) in comparison with sea level only (N= 221), could lead into differences between the composite maps. Thus, the differences showed in Figure 6 and Figure 7 between the compound and sea level only maps can be derived from the number of observations rather than from physical process.
- Line 320: One can argue that, with only 44 to 66 compound events (EL), and knowing a weak dependence between precipitation and extreme sea level in the region, the correlation between compound events and circulation patterns is arbitrary. Also, despite being statistically significant the correlation coefficients are generally small (Figure 8).

- Line 376: can you illustrate this idea with an example in Finland?
- Line 403: *"The high sea level causes coastal flooding which is directly connected to the sea"*, I believe this sentence is redundant.
- Line 404: Section 5.3n looks more Introduction to me.
- Line 424: "rarely" means "some", can you cite them? Have they found similar results?
- Lines 451 -455: these are results, are they mentioned in the Results section?

References

Bevacqua, E., Maraun, D., Vousdoukas, M. I., Voukouvalas, E., Vrac, M., Mentaschi, L., & Widmann, M. (2019). Higher probability of compound flooding from precipitation and storm surge in Europe under anthropogenic climate change. *Science advances*, *5*(9), eaaw5531.

Hendry, A., Haigh, I. D., Nicholls, R. J., Winter, H., Neal, R., Wahl, T., ... & Darby, S. E. (2019). Assessing the characteristics and drivers of compound flooding events around the UK coast. *Hydrology and Earth System Sciences*, *23*(7), 3117-3139.