Response to Reviewer #3 of “Characteristics of joint heavy precipitation and high sea level events on the Finnish coast in 1961–2020”

Mika Rantanen, Kirsti Jylhä, Jani Särkkä, Mikko Laapas and Ulpu Leijala

We thank the reviewer for constructive comments of our submitted manuscript. The point-by-point reply to the comments of the reviewer are below. Your comments are marked in black and our responses in blue.

General comments:

The manuscript deals with the concurrent occurrence of heavy rainfall and high water events along the Finish coast. The paper is well written, and what is presented is sound. The only thing I do not understand is, what is the point the authors want to make.

If they wanted to point out that these compound events create more severe flooding then in the case of non-compound events, well, in this case the authors failed miserably. There is no indication, and no statistics shown that can convince me that it is important to look at compound events in order to understand the severity of these events.

Actually, I am not sure why the authors have written this paper. The atmospheric circulation might be interesting, but me as an oceanographer am always looking at implications that some variables have for storm surge. I do not think that you need to analyze rain data in order to find out about flooding events.

Maybe I am missing something, maybe I was expecting too much. But as it stands now, this article is not very interesting. On these points I do reject the manuscript, but the editor might see it differently.

Specific comments:

Abstract: the authors want to correlate the rainfall and water level to compute compound flooding. Already in the abstract, they state that these events mostly are due to sea level variability (nothing surprising). I am not sure how the rainfall fits into this picture…

Thank you for this comment. We would like to emphasize that in many previous papers the potential for coastal compound flooding has been quantified using precipitation and sea level data (e.g. Bevacqua et al. 2020a, 2019). Furthermore, as

stated in Bevacqua et al. (2020b), for small- or medium-sized rivers precipitation can be used as a proxy for river (fluvial) flood and thereby also for coastal compound flooding in those rivers. Thus, we think that using precipitation is a scientifically reasonable choice.

The correlation between precipitation and sea level was found to be rather modest in the Finnish coast. Even so, we believe the modest correlation is a result which is worth documenting. Our findings are thus in line with Bevacqua et al. (2019, their Fig. 2) who documented that the probability of compound flooding is relatively small in Finland compared to elsewhere in Europe.

Bevacqua et al. (2020a): https://doi.org/10.1038/s43247-020-00044-z

Bevacqua et al. (2020b): https://nhess.copernicus.org/articles/20/1765/2020/nhess-20-1765-2020.html

Bevacqua et al. (2019): https://www.science.org/doi/10.1126/sciadv.aaw5531

36-42: for this please see also Ferrarin et al, 2021 (Progress in Oceanography)

Thank you for pointing out this interesting and also very comprehensive study. We added a citation to this study at line XXX.

30: are you sure it is the precipitation, and not some other correlated variable like wind or atmospheric pressure that makes these events compound events?

The underlying reason for the weak correlation is the passing extratropical cyclones, so it is very likely that atmospheric pressure (negatively) correlates with the sea level height as well.

98: how strong is this trend (numbers)?

The magnitude of the negative trends that were removed range from -6.4 cm per decade in Pietarsaari to -1.0 cm per decade in Hamina. This information has been added to the revised manuscript at lines 131-132.

105: please make clear if these data are observations or come from a meteorological model.

Thank you. We added a sentence “We emphasize that FMIClimGrid is an observational dataset only and does not utilize a numerical weather prediction model, similarly as done in reanalysis datasets.” to lines 142-143.

Table 1: have all points a MSL of 0?

MSL is not zero, MSL is given by annual mean sea level in N2000 reference height subtracted by the linear trend of the annual means.For some years and for some tide gauges MSL is close to zero but not exactly.

123: I guess there is also rain data in ERA5. Did you use it and compare it to the observation data? If not, why not? If yes, how did the two data sets compare?

Thank you for this comment. There is indeed total precipitation data available in ERA5, but we decided to not use it in our study. There are two main reasons for this choice:

1) We wanted to rely purely on observational data. This is one aspect of how our study differs from previous studies on compound flooding which have used global reanalysis datasets (for example Bevacqua et al. 2019). Thus, the use of observational datasets only can be considered as one novelty of our paper.
2) Furthermore, no direct observations of precipitation are assimilated to ERA5 over the pre-1979 period. Furthermore, Bell et al. (2021) state that the precipitation in ERA5 performs more poorly in Europe than in US, and given the coarser horizontal resolution in ERA5 (31 km) than in FMI ClimGrid (10 km), we do not specifically expect that ERA5 would perform better than FMI ClimGrid.

Bevacqua et al. (2019): https://www.science.org/doi/10.1126/sciadv.aaw5531

Bell et al. (2021): https://rmets.onlinelibrary.wiley.com/doi/full/10.1002/qj.4174

307-9: this is what I was fearing… that there is little correlation between rain and sea level. And for the whole article you are basically repeating it…

The correlation between precipitation and sea level is indeed rather modest, but in line with the previous studies. For example, Hendry et al. (2019) reported Kendall rank correlations between 0 and 0.3 for the precipitation and river discharge in the UK.

We added Kendall rank correlations to Figure 1 to emphasize more clearly the correlations between precipitation and sea level at the tide gauges.

375-6: Well, I was eager to see the prove of this statement, but I guess the authors do not convince me

We agree that this statement in question was perhaps a bit too exaggerated. We have rephrased the sentence to “Nevertheless, high sea level together with high precipitation might cause notable impacts even if the variables are not particularly extreme in isolation.”

406-9: This is all hypothetical. Where can I verify this hypothesis?

Thank you for this comment. The storm water management plans of Turku and Helsinki both mention that high sea level simultaneously with intense rainfall may hamper drainage operations. For example, in Helsinki, the ends of sewers will have to be closed if the sea level is too high. If it rains heavily in these situations, the sewer system will easily start flooding the streets and basements of the buildings. This was the case for example in October 2021 (news article in Finnish): https://www.hs.fi/kaupunki/art-2000008349729.html.

However, the importance of these situations is poorly studied in Finland.

431-2: It is maybe a proxy for compound flooding, but I am not sure if this is important, because you did not show the importance of compound flooding.

We would like to emphasize that the main scope of our study was more to characterize the synoptic and climatological situations when these compound flooding events take place. This study acts as a first step in paving the way for further analysis on compound flooding and their direct importance for society.

However, as other referees also asked to present the likelihood of the events, we added a section which presents the probability of single events compared with compound events. This can be found from Section 4.3 from the revised manuscript.

The 443-450: Well, you should have really shown that sea level is higher statistically during compound flooding then without compound flooding. I didn't see this analysis, hopefully I didn't miss it.

We are not sure if we understood this comment correctly. We agree that the sentence "the potential for coastal flooding arising from joint occurrence..." is misleading because the coastal flooding is indeed caused by high sea level and not from precipitation.

We changed the wording to "the potential for flooding arising from joint occurrence...".

451-5: are these levels statistically different from non-compound events?

In the revised manuscript, we present more explicitly the return levels of the single events compared with the return levels of compound events. Thus, this part of conclusions was changed.