Reply to Referee #2

General comment

Despite I operate outside this study area, it seems like many efforts have already been done in the literature to explain changes in mean sea level, extreme sea levels, and distribution parameters in the Baltic Sea and the Gulf of Riga. For instance, changes in extreme events as well as changes in extreme value distributions have been studied at Pärnu (Suursaar 2007, Eelsalu 2014, Ekman 1996, among others). Also, spatial variations in extreme sea level distributions have been studied along the eastern coast of the Baltic Sea (Soomere 2018, Ekman 1996). I, therefore, believe that the paper would require more work to create additional value to the existing literature, for example, by extending the study to the possible causes of the temporal changes in the tail distribution of the extreme water levels. For instance, previous works have found significant correlations between winter months sea level changes and changes in wind and pressure changes as well as with the North Atlantic Oscillation index in the Baltic Sea and at Pärnu (Anderson 2002, Suursaar 2007, among others). Although in a different study area, Tsimplis et al. (2005) found that NAO contributes both to changes in the mean and extreme water levels in the North Sea. Correlation between climate indexes and GEV distribution parameters were previously assessed in other areas (for instance, Méndez et al 2006).

Reply: We thank the referee for careful reading the manuscript, critical assessment of the analysis and useful and professional comments which helped to improve the paper. We fully agree with this observation and recommendations. There are many studies into water level extremes in the Baltic Sea in general. Also, many issues of the water level regime have been addressed in the context of Estonian, Russian (Gulf of Finland) and Finnish waters. Strangely, such studies are missing for the Latvian waters (except for a recent one by ourselves [Männikus et al., 2019]). For this reason, it seemed to us that the almost unexplored Latvian water level data deserve focused attention.

Most of the existing studies into extreme water levels in the Baltic Sea basin have been performed under the assumption of stationarity of the underlying extreme value distributions. Only Suursaar and Sooäär (2007) ask the question of possible changes in the parameters of the GEV distribution. However, they choose basically the same data set (1923-2005) and exclude the maximum in 2005 and then also the maximum in 1967. Eelsalu et al. (2014) address the possibilities of ensemble approach for the construction of a better projection of extreme water levels and their return periods, and for the identification of locations with a substantial magnitude of local effects. Ekman (1996) provides an analysis of the extremes of the water volume of the Baltic Sea. Soomere et al. (2018) study spatial variations in the parameters of extreme value distributions. All this research is, to some extent, relevant in the context of our study and has been mentioned in the original submission. We have extended the Introduction towards more precise coverage of the listed items and added (Ekman, 1996) into the list of references.

We also agree that much more research is necessary to attribute the changes and patters we highlight with the possible forcing factors. Thank you for reminding this issue and providing the relevant references. The link between the NAO and the Baltic Sea level is spatially very heterogeneous (even in wintertime) and has also displayed substantial decadal variations in the last two centuries (e.g. Andersson, 2002; Jevrejeva et al., 2005; Hünicke et al., 2015, Karabil et al., 2017). We would like to mention also that although the relation between the NAO and the mean water level was addressed in a multitude of papers, the relation to the sea level extremes is not studied in detail.

Following the suggestion, we added a section to the paper describing the connection between the extreme water levels in the Latvian waters with the main driving climatic indices in the region. Overall, the relation between the sea level extremes in the Gulf of Riga and the climatic indices is highly unstable and significantly variable in time. The figure below shows the running correlation results (only the correlations with more than 95% confidence) of Daugavgriva water level extremes with NAO, SCAND, and PNA, which showed the strongest relation. The Arctic Oscillation showed the same results as the NAO and is not shown here. The other locations in the Gulf of Riga showed the same results. Using the running correlation analysis, we found that the relation with NAO was the weakest during the 1984-1988 period.

Moreover, during that period, a shift in the months most affected by NAO is observed. Before 1984, the NAO index showed the highest correlation in January. However, after 1988, there is an abrupt shift, and after that, the largest correlation coefficients were observed in March.

Multiple teleconnections were studied using the correlation analysis, such as SCAND, AO, AAO, EA, EATL-WRUS, Poleur, EP-NP, PNA, PT, THN, WP and tested which one had shown the highest correlation during the 1985-1990 period. The highest (negative) correlation during that period is observed with the SCAND index. In the Baltic Sea region, the positive phase of NAO is associated with the westerly winds and negative phase with more frequent winds from the east and north-east (e.g., Trigo, Osborn and Corte-Real 2002). The SCAND mode, on the other hand, is responsible for the south-easterly winds in the positive phase and north-westerly winds in the negative phase (Bueh and Nakamura 2007; Gao, Yu and Paek 2017). This indicates that the change in the running correlation coefficients from positive correlation with NAO to negative correlation with SCAND is most likely caused by the short-term change in the prevailing wind direction.

Interestingly, the second-highest correlation (corr. coefficient ~0.55) during 1985-1990 is found between the water level extremes and PNA index (see the bottom panel of the figure below). The PNA pattern is well known as the most influential climate patterns in the Northern Hemisphere mid-latitudes beyond the tropics and is strongly influenced by the El Niño-Southern Oscillation phenomenon. However, it was never considered to be influencing the sea level variability in the Baltic Sea (except for some discussed influence on the Baltic Sea ice, Jevrejeva, Moore, and Grinsted 2003). Our analysis showed for the first time that PNA could affect the Baltic Sea extreme sea levels in intermittent periods. This can occur during the transition period of the regime shifts when the relationship with NAO is weak.

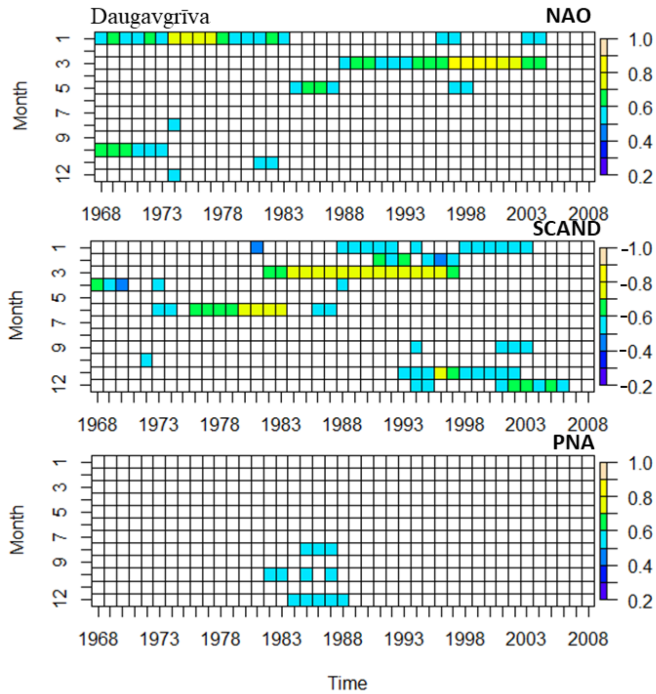

Figure 1 Sliding correlation results for Daugavgriva and NAO, SCAND, and PNA climatic indices. The correlation is calculated for the water level monthly maxima with a window of 15 years. Only the correlation coefficients with the significance of more than 95% are shown.

1. *Sometimes in the text, Fig and Figure are used indistinctly.*
    - The names of the figures were unified
2. *Line 190. Figure 4 is called before figure 3 in the main text.*
    - In the new version of the manuscript, it is corrected
3. *Line 220/225. In order to assure reproducibility, I would recommend indicating the equations, functions, or tools used in Matlab as well as a quick description of Hydrognomon, for those who are not familiar with it.*
    - Thank you, we added the description in the manuscript
4. *In the same sense, I recommend an extension of the explanation about the water level data processing before performing the distribution fitting. By doing so, the reader can reproduce and understand how the data have been processed to obtain the extreme water level from the tide gauge records.*
    - The additional description was added to the manuscript
5. *Figures. The overall quality of the figures should be improved, for instance, by matching the font size and font name with the main text.*
    - The figures were improved
6. *Line 260. I would recall here, as the authors do in section 2.3, that changes in the shape parameter have consequences in the tail of the distribution, determining the behavior of the events with very low frequency.*
    - We added the additional description of the consequences of the tail distribution
7. *Line 270, figure 5. It would be good to see results for all other locations, as in figure 7. Same for the results of scale parameters (figure 6).*

- The figures for the other locations are added

8. *Line 290. "As the 95% confidence intervals of estimates of this parameter for single years mostly overlap, it is safe to say that the location parameter of the GEV distribution of water level extremes has not experienced any substantial changes in Latvian waters since the 1960s". I'm curious about changes in the location parameter at Skulte, these changes appear significant when comparing the location parameter obtained by ~2000 vs ~1975. Also, including a grid in the figures would improve the comparison across years. I recommend also to further explain how the statistical significance has been calculated.*
    - What we meant is that although visually there is a change in the location parameter, the uncertainties in Fig.5 are rather large. Considering the uncertainties, the location parameter could have been ~98 (lower level) in 1975 and ~99 (upper level) in 2001. The uncertainties (95% conf. intervals) were obtained during the GEV fitting. We added a more detailed explanation about it.
9. *Line 415. "… observed and measured water maxima in…". Aren't they the same?*
    - The typo was corrected

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