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Interactive comment on "The long-term variability of extreme sea levels in the German Bight" *by* Andreas Lang and Uwe Mikolajewicz

Anonymous Referee #1

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The manuscript presents an interesting study on the long-term evolution of extreme sea-levels in the North Sea Sea, as simulated by a rather unique model chain including a global ocean model and regional atmospheric and ocean models. The period of analysis covers the past millennium. The study focuses on the the connections between the variations in extreme sea-level and the mean sea-level, their causes of variability (external forcing, internal climate variability), and the uncertainties in the estimation of return value statistics. The main conclusions are (1) that the variations in the statistics of extreme sea-level are mainly driven by internal climate variations; (2) that these variations are only weakly connected to the variations of background sea-level; (3) that the estimation of return values based on short observational records are hampered by larger uncertainties as assumed so far.

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Discussion paper

My impression of the manuscript is quite positive. The study is also relevant and I am happy to recommend it for publication. I have a few suggestions to some particular points in the manuscript, but in general my opinion is that the manuscript is in quite good shape. Some of my suggestions refer to the English formulation- these should be doubled checked by the authors

1. 'Extreme sea levels particularly arise when these components are in superimposition'

superposition

2. 'Yet, a comparison in terms of extreme value statistics is possible. considering storm flood statistics, we compare the simulated ESL with observations from..'

I think the authors mean 'meaningful' rather than possible. A comparison is always possible, but it may be conceptually wrong

3. The return values at Cuxhaven derived from observations seem to be biased low. The authors write '...rather underrepresented, pointing to a bias towards too zonal (westerly) winds'. I am not sure whether this points to a bias. The estimations from the simulated 100-year segments cover the observations-derived value. As we only have one observations-derived value we cannot assert , I think, that the (theoretical) distribution of observational values is biased relative to the distribution of modelled values. I would rather write that the observational value is at the lower x-quantile of the model-derived distribution.

4. Figure 4 includes a label 'observed'. However, these time series are not observed per se, they are derived from observations, and these derivations can be obtained with different estimation methods, e.g. POT or GEV. I would use 'observations-based' or 'derived from observations'.

5. 'In agreement with observational studies (Gerber et al., 2016), simulated storm floods at Cuxhaven stem from predominantly west-north-westerly directions, while their

associated daily pressure anomaly patterns are similar to observations of storm flood weather situations (Donat et al., 2010; Dangendorf et al., 2014c)'

It would be helpful for the reader to include here either a reference to Figure 8 or, if the authors do not wish to disturb the ordering of in-text figure citations, to mention that this SLP pattern will be shown later. Otherwise, the reader may get stuck here wondering if the paper will show it or not.

6. The correlation between BSL and ESL is comparably low (r = 0.35) and highly variable over time (see black curve in Fig. 6 for a 100 year running correlation), while the different magnitudes of variances lead to a low explained variance

Here, it would be interesting to show the correlation between the indices describing the intensity of the SLP patterns that are linked to BSL and ESL (shown in Figure 8), and maybe also mention the correlation of both to the NAO index. This , it would become even more clear that, as I expect, the SLP pattern behind ESL is indeed different from the NAO, which in itself would be (the confirmation of) a quite important result.

7. '....trends between ESL and BSL during the last century that have often been described (Kauker and Langenberg, 2000; Menéndez and Woodworth, 2010) might merely be an unusual state if compared to a longer time horizon as obtained from our long-term simulation.'

This is perhaps my more substantial comment. The 20th century observations, according to this paragraph, show that there is a link between background sea-level and extreme sea-level in that century. It is not clear to me whether the model run also shows this link, and it also not clear to me which mechanisms may explain this link in reality. Is it that the two patterns in Figure 8 have tended to evolve coherently in the 20th century and not in previous centuries ? is it that the strong background sea-level rise in the 20th century has affected the probability of ESL, and that in previous centuries the variations in BSL were not strong enough to supersede the influence of internal atmospheric variability? In this regard, an important question is whether or not the simulation is able to replicate the observed sea-level rise both at global and at regional scales due to thermal expansion and maybe also to forced changes in the large-scale ocean circulation (AMOC), Perhaps I missed it in the manuscript, but I think this information is not present, and I think it is relevant, since it would support the simulation of past BSL variability. At least the thermal expansion component in the model and in the observations since 1950 should roughly agree at global scales. In Figure 3 (green line) it is difficult to eyeball. It seems that the regional not-land-ice related sea-level rise in the 20th century is not remarkably different from past variability, but accurate numbers would help the reader.

8. Fig 6 . Time series have been smoothed with a 11y moving window.8.

It is not totally clear to me how this has been calculated. Were the 100-year gliding correlations later smoothed with a 11-year running mean, or where the initial series first smoothed and then the 100-year gliding correlations calculated. This is important for the set-up of the bootstrapping.

9. range of the Gumbel fit doubles though if the spread in RL100 is taken into account (grey bar). The non-parametrically obtained RL1000 lies with 3.7 within both distribution ranges, but closer to the median of the Gumbel distribution fits. Considering the

3.7 meters, I guess

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