We thank the reviewer very much for reviewing our manuscript, for providing constructive criticism and useful suggestions. We respond to all comments below.

Interactive comment on "Mechanisms of variability of decadal sea-level trends in the Baltic Sea over the 20th century" by Sitar Karabil et al.

Anonymous Referee #1

Received and published: 13 April 2017

Recommendation

Major revisions.

Synopsis

The paper analyses the sea level (SL) variability in the Baltic Sea and its drivers. Sea level observations from 29 tide gauges, some of them going back to the eighteenth century, from around the Baltic Sea are used together with a satellite-based reconstruction of sea level for the whole Baltic that goes back to 1950. Observation-based data sets of SLP, precip, and temperature are used to investigate their relation to SL variations. The paper focuses on longer time scales by considering the relation between decadal-scale trends of the variables, rather than the variables themselves.

SL variations on longer time scales are found to be highly connected to NAO (North Atlantic Oscillation) variations, with larger correlations in the northern than in the southern Baltic. Precipitation in the Baltic catchment also plays an important role for SL variability.

Discussion
The paper seems to be technically sound, but I miss an explanation of the relevance of the results. What are possible implications? Furthermore, the presentation is often unclear. The list below gives some hints as to where the presentation of the work can be improved. Together, I think that a major re-writing of the paper is necessary before it can be accepted.

Previous studies have shown that the sea-level records display relatively large variations of decadal trends in the Baltic Sea. This indicates that natural factors can cause substantial deviations from the expected spatially homogeneous centennial sea-level trend due to large-scale factors like rising ocean temperatures in the North Atlantic, melting of polar ice caps. These regional natural factors should be understood and taken into account, especially for shorter term (multidecadal) future sea-level projections. Whereas the mechanisms responsible for interanual variability have been more profusely studied, it is still not known whether the mechanisms that have been claimed to account for the interannual variations of sea-level are also responsible for the variability of decadal sea-level trends in the Baltic Sea.

In this study, we analyse long-term sea-level and climate records with the aim of explaining the observed variability of the decadal and multidecadal sea-level trends in the Baltic Sea. We mainly investigate whether the same mechanisms that have been found to explain the interannual variations

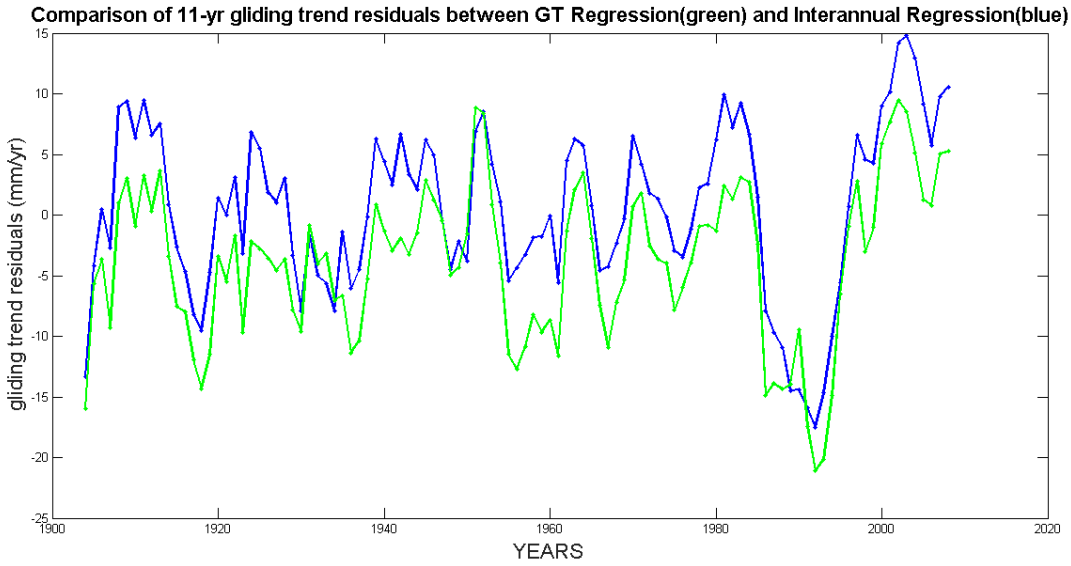
of Baltic sea-level are also responsible for the variability of the decadal sea-level trends.

We will clarify the novelty of the study in the manuscript.

Major remarks

p 7, eq. (2) Regarding the robustness of your method: you calculate the residual of the SLP trend. What happens if you exchange the order of operations, i.e., calculate the trend of SLP residuals (remove the first five SLP PCs from the SL fields and than look at the trends)?

We made a multivariate regression analysis between first 5 principal vectors of SLP fields and sea-level for the period 1900-2013 on the interannual time scale. The analysis suggested by the reviewer is compared in the following figure.



In the Figure, the 11-year gliding trend residuals of multivariate regressions between Stockholm sea-level and first 5 PCs of SLP field on the interannual sea-level variability(blue) and between Stockholm sea-level and first 5 PCs of SLP field based on 11-year gliding trend time series(green) are shown for wintertime. The correlation between residuals is 0.92. This confirms the robustness of our results.

p 8, 1st para so only 10-20% of the decadal SL trends are not directly related to SLP. How much is that in cm - I mean, what are we talking about?

These explained variances only show how much variance of the SLP field trends can be explained by first five principal components of the SLP trends, and not the amount of SL variance that is explained by the SLP field. We will rewrite that part to clarify that those explained variances driven from SLP PCA and not related to the SL gliding trends.

p 8, l 21/22 It is not clear from the caption (nor from the text!) what you are doing. As far as I understand the top row is correlation between full decadal SLP trend and full SL trend. In the bottom row the SLP signal is removed from the tide gauges, but what about SLP? Do you correlate the decadal SLP trend with the tide gauge residuals, or do you also subtract the first five PCs from the SLP trends? – Note that this remark not only applies to this figure, but to the whole paper.

The figures display the correlation of the SL residuals with the complete SLP field. They are intended to show that the residuals do not really contain any simultaneous SLP signal.

We will rewrite and clarify that caption.

p 9, Tab. 1 What do you mean by "previous season"? You show four correlations. Take for instance "winter". You correlate it with winter - which winter? The same, or the following? You also correlate it with summer, but winter is not previous to summer. I guess that what you are doing is a lag-correlation with lag of 0, 1, 2, and 3 seasons, but I am not sure. Please clarify.

The reviewer is right. We will clarify the table and use lag0, lag1, lag2, lag3 notation.

p 8, l 27/28 Why would you expect a relation between air temp and SL in winter? I could imagine a relation between summer T and autumn (or winter) SL because of evaporation, but why winter? Which brings me to another question: Why do you consider precip in the following, but not evaporation?

We explore here the indirect correlation between SL and temperature in wintertime, mediated by the atmospheric circulation. The NAO is correlated with both SL and air temperature. We were not referring to a causal relationship between winter temperature and SL. This paragraph will be reformulated.

We will also do calculation with considering the evaporation (P-E).

p 9, Fig. 8/9 precip is probably not independent of SLP. So if you remove the effect of SLP from your analysis, you probably also remove a lot of the precip effect. I guess that the purpose of these two figures is to somehow disentangle the two effects, but I do not understand what the result is. Does precip have an effect beyond SLP?

The reviewer is right. We cannot disentangle the effect of precipitation in one season from the effect of SLP in the same season, and some of the effects of precipitation will also be filtered out when considering the SL residuals. However, the effect - in any - of precipitation in the previous season (lag -1) should still be contained in the SL residuals. This is the effect we are looking for.

p 10, l 3-11 Are you saying that for some (but not all) seasons precip affects SL in the following season, and that it depends on data set (reanalysis vs. CRU) for which seasons you find an effect? OK, so what, what are the implications?

CRU data is available only over land, whereas reanalysis data, though imperfect, also over the whole basin. We think that it may be the main reason for the different results.

Detailed comments

p 1, l 23/24 Sounds odd - "decadal trend" depending on previous season precip. What you mean is that previous season precip also has a decadal trend.

We will clarify the text.

p 3, l 8/9 To my knowledge the physical connection between the North Sea and the Baltic is through the Danish Straits, which are more or less exactly north-south (i.e., meridionally) oriented.

Old version: "*its narrow physical connection to the North Sea and North Atlantic is also zonally oriented*"

New version: "*has also a narrow physical connection to the North Sea*"

p 3, l 13 Of course is the impact of NAO higher in winter than in summer. NAO is mainly a winter phenomenon. The explained variance of a NAO-like pattern is highest in winter, and small in summer.

We agree with the reviewer's comment, but we are unsure as to how it prompts us to change the text.

p 4, l 6 remove GIA effect ! remove the GIA effect

We changed this accordingly.

p 4, l 6 I would start a new paragraph after "time series"

We changed this accordingly.

p 4, l13-15 too long a sentence and not to follow.

We will clarify the text.

p 4, l 18 of Atlantic Multidecadal Oscillation ! of the Atlantic Multidecadal Oscillation

We changed this accordingly.

p 6, l 3 continues ! continuing

We changed this accordingly.

p 7, l 1 the _ coefficients in this equations are different from those in eq. (1). Please use different symbols to prevent confusion.

We changed this accordingly.

p 7, l 2 SLP principal component - I think yo mean the PC of SLP-trend, don't you?

We changed this accordingly.

p 7, l 19 NAO is major factor ! NAO is the major factor

We changed this accordingly.

p 7, l 21 as it stands, this sentence implies that Stockholm is representative for the southern Baltic and Warnemünde for the Baltic proper.

We changed this accordingly.

p 8, l 21/22 & l 29/30 The lower row is not explained.

We will add the explanation.

p 9, l 11 tide gauge residuals ! tide gauge trend residuals ????

We changed this accordingly.

p 9, l 28 delete second appearance of between

We changed this accordingly.

Figures

(i) *Please add an indication of significance to all correlation maps.*

We will add the significance information for all correlation maps.

(ii) *Consider removing panels from the figures. Having correlations for different seasons or for the two stations does not add significant information.*

We will remove unneeded panels from the figures.