

# ***Interactive comment on “Contribution of atmospheric circulation to recent off-shore sea-level variations in the Baltic Sea and the North Sea” by Sitar Karabil et al.***

## **Anonymous Referee #2**

Received and published: 28 April 2017

### General Comments

The paper at hand offers an original approach on how seasonal mean sea level in the Baltic Sea are related to large scale atmospheric patterns. The analysis is based on correlations between sea level pressure differences and tide gauge and altimeter derived sea level anomalies. An effort is made to come up with explanations on how different atmospheric processes might contribute to the sea level variability.

A new index is introduced that overcomes the poor correlation between the NAO-index and sea levels in Baltic Sea during summer. Also, the varying degree of long term correlations between NAO-index and winter mean sea levels in the Baltic Sea has been addressed. The most important contribution of the paper is probably to renew

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the discussion on how seasonal mean sea levels in the Baltic Sea are related to the regional climate.

I definitely recommend the paper for publication. Some parts are weaker than others and those should be reformulated before final publication. The paper also might be improved by addressing the specific questions and comments below.

### Specific Comments

A major part of the paper is the presentation and discussion of how much better the BANOS-index correlates to sea level changes in the Baltic Sea than the NAO-index. It would be helpful to the reader to discuss the BANOS-index with respect to other slp indices that have been used for the Baltic Sea. For example the BAC index in Andersson, 2002 or the BSI in Lehmann et al, 2002. How much different are those indices from the BANOS-index? Would the slp gradient over the transition zone between North Sea and Baltic Sea be different between BANOS and BAC or BANOS and BSI?

Is the BANOS-index usable without a gridded slp field? Can it be inferred from station data (e.g. Stockholm - Odessa), like the NAO-index and would it show good correlation the the one derived from gridded data?

How sensitive are the results and the conclusions for summer when the summer was defined as the months JAS? Baltic Sea sea level in summer show little variation during these three months (e.g. Hünicke and Zorita, 2008, Meier et al., 2004). The month of June usually lies between the spring minimum and the summer values. What is the reason to choose June, July and August as the summer season?

The title of the paper suggests the investigation of North Sea and Baltic Sea sea levels. In the derivation and evaluation of the BANOS-index only Baltic Sea sea levels are taken into account. From Figures 4 and 13 one would expect that the correlation of winter mean sea levels in the North Sea improve over the NAO correlations. For summer at least in the eastern part of the North Sea. Please consider to show one or

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two tide gauges from the North Sea in Figure 12, or add a figure like Figure 12 for two North Sea tide gauges.

In the abstract it is said that the wind associated with the slp pattern of the BANOS-index does not lead to transport of water into the Baltic Sea. The analysis in Section 4.8.4 is a good idea, but since the return flows along the coasts and at depth are not taken into account, the statement might not hold up to a more thorough investigation.

I would like to see the correlation coefficients for all of the nine stations in Table 1. Future studies might benefit from that information and for the present study the information might help with the interpretation of Figures 2 and 3.

Good correlations between altimetry and tide gauge data is said to indicate progress in satellite altimetry. Could the source of the improvement over earlier comparisons be specified? It is probably not the altimeter instruments themselves that have progressed so much. Information on the geoid? New algorithms? Amount of data?

In Section 4.8.1 yet another index is introduced as the slp differences between two geographical locations that differ from the ones introduced in Section 4.4. Would you please explain why there is a need to introduce different locations where to measure slp to get at the IBE contribution? Why Denmark Strait and not Labrador Sea for the summer for example? But more importantly why not stick to the definition (5W, 45N) - (20E, 70N) for winter and (30E, 45N) - (20E, 60N) for summer?

In Section 4.8.2 please indicate in the text whether the whole water column was heated or just the mixed layer (down to what depth?) to absorb the energy.

Section 4.8.4 discusses an interesting point but the argumentation stops halfway through. How is the Ekman transport different in the transition zone between North Sea and Baltic Sea for NAO- or BANOS-index related patterns? And what are the consequences for the sea-level in the Baltic Sea?

In Section 4.8.4 it is argued that during summer BANOS and NAO related wind forcing

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(slp gradients) could be similar. I thought the main reason to introduce the BANOS index was the liberty to define an index separately for winter and summer, so that missing correlation for summer sea-level variability in the Baltic Sea could be explained. This section would benefit from a rewrite, I suppose.

The Conclusions (page 18, line 28-29) mention that there is no contribution of NEF in summer. Section 4.8.2 states that summer has not been included in the analysis, because of negative correlations. Please reformulate the sentence in the conclusions, page 18, line 28-29.

For the last part of the Conclusions (page 19, line 2-4) the evidence is missing. See also the comments above on Section 4.8.4 and the Abstract.

The conclusion might benefit from a restructuring. The itemized list could be shortened to contain the keywords only as a summary of a continuous text around it.

#### Technical Corrections

page 1, line 7: interannual time scales.

page 2, line 24: NAO-index describes weaker

page 3, line 19: Andersson (2002) who focused on

page 3, line 20: Dangendorf et al. (2014) who investigated the

page 3, line 20-21: investigated the North Sea, reported that atmospheric variability that differs from the NAO may still explain part of the sea-level variability.

page 3, line 32: different sorts of data sets

page 4, line 32: This study focuses on the winter

page 5, line 1: this study and the following section

page 5, line 5-7: Although the threshold of any computation involving tide gauge records was set at 75% availability of data for the considered period, seasonal means

are calculated in case of availability of tide gauge records for two months. [I am not sure whether I understand it the way the authors mean it. Could this information be written a little more clearly?]

page 5, line 23: the northeastern boundary of [If Smögen is meant by the northeastern boundary of the North Sea I recommend to call it Skagerrak.]

page 6, line 14: and produces a complete gridded data set

page 6, line 16: resolution of a T62 Gaussian grid [Or mention the resolution in deg or km]

page 7, line 9: examine the correlation of the satellite [see below]

page 7, line 11-13: The seasonal means ... linear regression. [This has been said in the methods section. It could be scratched.]

page 8, line 30, 32 in the southern Baltic Sea

page 9, line 5: Figure 4-lower [see also comment below]

page 9, line 28: does seem to be strongly connected to the NAO-index from 1998 in wintertime. OR does not seem to be strongly connected to the NAO-index until 1998 in wintertime.

page 9, line 30: could indicate the existence of

page 10, line 30: from what the NAO implies.

page 11, line 33: most of the time the gliding

page 13, line 31: region on the interannual time scale. OR region on interannual time scales.

page 14, line 27:  $(3.44 \cdot 18.09)$  OR  $(3.44 \cdot 18.09)$  AND  $(1.39 \cdot 7.02)$

page 15, line 3: radiation reaching the earth surface and longwave (LW) emitted

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page 15, line 9: [SH and LH do not correspond to the naming in the equation.]

page 15, line 18: estimated as  $3.28 \text{ (W m}^{-2} \text{ u}^{-1}\text{)}$

page 15, line 24: of 25,505,280  $\text{(W m}^{-2}\text{)}$  per one unit [How much change is that? It might be easier to grasp by using something like  $2.5 \cdot 10^7 \text{ (W m}^{-2}\text{)}$ ]

page 15, line 24: of 25,505,280  $\text{(W m}^{-2}\text{)}$  per one unit [Should the units be  $\text{(J/winter m}^{-2}\text{)}$  instead of  $\text{(J/s m}^{-2}\text{)}$ ?]

page 16, line 9:  $\text{(2257 kJ kg}^{-1}\text{)}$

page 16, line 16-17: [During summer the western North Sea is not similar in precipitation and freshwater flux.]

page 16, line 29: [It would be more concise to use the regions defined in Figure 1 when describing the correlation pattern.]

page 17, line 2: of sea-level would reach  $\sim 10 \text{ mm}$  per one unit

page 17, line 3: [Either remove the last sentence or explain why the high correlation in the north eastern part of the North Sea drainage basin (incl. Norway) does not contribute to North Sea sea level variability.]

page 17, line 14: be similar to the case of the NAO.

page 17, line 15: assuming that the Ekman layer

page 17, line 16: interrupted by bathymetry.

page 17, line 21: if bathymetry would not interrupt

page 17, line 22: is generated by the BANOS-related north-easterly winds

page 18. line 1: [The Norwegian coastline is in the north-eastward direction. That contradicts the previous argumentation.]

page 18, line 4: on interannual time scales. OR on the interannual time scale.

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page 18, line 15: is more important for the

page 18, line 32: [The last sentence seems to contradict what has been said in the first sentence (line 30-32). Would you please specify which contributions of the freshwater flux are negligible.

page 19, line 4: to that related to the NAO in

caption Figure 14: Note the different intervals on the color scales.

Readability: The readability of Section 2 could be improved by omitting the sub-sub-sections.

Figure captions: I'd recommend to change the naming of the positions in the plots from down to lower/bottom and from up to upper/top.

Coherency or correlation (page 7, line 9ff): Did you really look at correlations on different time scales or is "coherence" used here as a synonym for correlation? The expression coherence or coherency appears more often later on. It would be helpful to specify what is meant by coherency or perhaps just use correlation.

Station Smögen (page 5, line 24ff): It appears in some places in the text, it should be Smögen.

Caption Figure 5: for the winter (solid line) and summer (dotted line) seasons.

Figure 8-9: These two figures could be combined in the same way Figure 10 was done.

Figure 10: Why is the northern half of the figure blank? If possible, the figure should be redone. It avoids unnecessary doubts.

Figures 8-10: The reader might appreciate the eye be guided with a mark on the plots, where the BANOS-index is defined.

Figure 11: It is hard to see similarities and even more so difference between the two indices. An additional running mean could improve the figures. Red-blue bar plots like

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they are used for the display of the NAO-index might be an option.

Caption Figure 18: It is not clear which index or which season is displayed in the upper and lower panel of Figure 18. Also, for the sake of completeness it would be good to indicate the units and a reference vector.

Sub-sub-section 4.8.2: It would be clearer to use one name only for the net energy flux. Either Q<sub>nef</sub> or NEF. Also, in the text the "net"- and "nef"-part of names like SW<sub>net</sub> should be a subscript. Or maybe drop the "net" altogether in the whole section.

Sub-section 4.8: In my opinion it would suffice to indicate the sensitivities with one digit after the floating point.

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Interactive comment on Earth Syst. Dynam. Discuss., doi:10.5194/esd-2017-23, 2017.