Earth Syst. Sci. Data Discuss.,
https://doi.org/10.5194/essd-2018-86-AC2, 2018

Interactive comment on "Reconciling North Atlantic climate modes: Revised monthly indices for the East Atlantic and the Scandinavian patterns beyond the 20th century" *by* Laia Comas-Bru and Armand Hernández

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Received and published: 4 December 2018

"Reconciling North Atlantic climate modes: Revised monthly indices for the East Atlantic and the Scandinavian patterns beyond the 20th century" by Laia Comas-Bru and Armand Hernández

We thank the reviewer for their comments.

Respose to general comments

1. Since the controlling mechanisms of the EA and the SCA are mentioned in the abstract, I would like to see a more careful description of the influence of these two patterns on climate variables and their physical meaning. Moreover, given the discrepancies across datasets and the lower percentage of variance explained by the patterns outside of the winter months, discussing their relevance would be appropriate.

We do not want to go into much detail on the influence of these two patterns on climate variables (this would be worth another manuscript!). However, we acknowledge that some indication on what these influences are would strengthen the manuscript. Therefore, to follow the referee's suggestion and to indicate the observed impacts on the main climate variables, we have now included a new section (section 3.4 Climate impact of the composite EA and SCA series) along with a new Figure 8. These show the correlations between the new monthly EA and SCA indices with precipitation amount and surface air temperature in Europe (where the correlations are expected to be more robust).

The new section reads as follows:

"Figure 8 illustrates the monthly correlation distribution maps between our composite-series (EAcomp and SCAcomp) versus surface air temperature and precipitation amount for the four seasons (DJF, MAM, JJA and SON) between 1901 and 2016 using the CRU-TS.4.01 dataset (Harris et al. 2014). The strongest correlations are found in winter, when these patterns are more prominent, and are consistent with previous studies (Moore et al, 2011; Comas-Bru and McDermott, 2014; Lim, 2015).

The only European regions for which the EA impacts on precipitation are strong and robust (i.e. on the same direction) throughout the year are the UK and Ireland. The predominantly weak correlations observed in other regions, far from the main centres of action, could arise from the low percentages of variability explained by each EOF pattern (<20% for EA; Table S22). Nevertheless, consistent patterns are observed in terms of precipitation amount across all seasons except in EAcomp/JJA, which also shows an anomalous relationship with temperature. We interpret this to be caused by the northerly shift of the EA centre of action in JJA (i.e. between Scotland and Iceland instead of off-shore Ireland; see Table 3 and Figures S3 and S4), that hampers its influence on the western Mediterranean region, which in turn becomes wetter with positive EA modes. Regarding the impact of the SCA on precipitation, a similar pattern with negative correlations in northern Europe and predominantly positive correlations in the circum-Mediterranean region, is observed across seasons, albeit with different strengths.

We observe a strong seasonality on the impact of both climate modes on surface air temperature. Weak correlations are found for the all seasons except JJA for the EA with non-significant correlations across all Europe in SON. The opposite is observed for SCA, where the strongest impact on air temperature is shown in DJF (predominantly negative) and SON (predominantly positive). Due to the low variance explained by both climate modes, they are not expected to imprint a very strong signal on the climate and thus the extent to which these correlations would be reflected in the absolute precipitation and temperature values will primarily depend on the concomitant state of the NAO, the main driver of climate variability in the region (Hurrell and van Loon, 1997; Hurrell and Deser, 2010). In addition, the impact of these atmospheric modes on the climate is not robust throughout the year. For example, none of the datasets used in this study showed a SCA pattern within the three leading EOFs in spring.

Individual EOFs such as the EA and the SCA are statistical constructs that do not necessarily represent a physically independent phenomenon linked (i.e. correlated) to climate variables in a robust manner. Full characterisation of the regional atmospheric dynamics therefore requires multiple EOFs to be taken into account (Roundy, 2015). To thoroughly characterise the climate in the region, the impacts of the EA/SCA should be investigated in conjunction with the NAO (Moore et al., 2011; Comas-Bru and McDermott, 2014; Hall and Hanna, 2018) but this is outside the scope of this study. As far as we are aware, such investigation does not exist outside the winter months."

2. The main contribution of this paper is, in my opinion, the introduction of the new, instrumental indices that date back longer than previously available ones and that have been proven consistent across different datasets. The correlation of the winter SCA with the Bergen station data is remarkably good. For this reason, I think it would be interesting to know more about the instrumental data, and mention which other stations were considered and why they were discarded.

We agree with the reviewer's comments. A new paragraph introducing the selection criteria and the stations that we were considering has been added in section 2.1. In addition, we have listed the details of all these meteorological stations in a new supplementary table (S1).

"A set of meteorological stations were selected according to their proximity to the EA and SCA centres of action shown in our EOF analyses: Ireland for the EA and Norway for the SCA. Only one meteorological station with SLP measurements in Ireland could be used in this study: Valentia Observatory. On the other hand, five Norwegian stations with SLP data were located in the region of interest. The most suitable Norwegian station was further selected according to three criteria: i) length of the record, ii) continuity (i.e. the least missing data, the better) and iii) correlation with the EOF-based SCA time-series. Bergen Florida (Norway) was the station which better fulfilled these criteria. Details of all meteorological stations are available in Table S1."

Response to specific comments

Page 1, Line 25: "The spatial structure of climate changes..." I would suggest talking about regional climate variability rather than 'climate changes', given the data span no longer than two hundred years.

Done: "The spatial structure of regional climate variability follows recurrent patterns often referred to as modes of climate variability or teleconnections, which provide a simplified description of the climate system (Trenberth and Jones, 2007)."

Page 2, Line 21: A strong centre of positive SLP anomalies is said here to be associated with above-average temperature and wetter conditions in Northern Europe. Please review this. Is it possible that those effects correspond to the positive phase of the reverse EA index, as used in other publications? (i.e., Moore et al., 2011)

Indeed! We have rephrased the sentence to match the direction of our EA index.

“Here we use the positive phase of the EA as a strong centre of positive SLP anomalies offshore Ireland. This is associated with below-average surface temperatures in Southern Europe, drier conditions over Western Europe and wetter conditions across much of Eastern Europe and the Norwegian coast (Moore et al., 2011; Rodríguez-Puebla and Nieto, 2010).”

Page 3, Line 18: The orthogonality imposed by the EOF technique should be one of the constraints listed

Agreed. We have now added this as one of the constrains:

“. . . while EOF-based indices better capture the inter-annual variability in an area larger than the exact location of the centres of action (Folland et al., 2009), they are constrained by (i) the accuracy of the reanalysis products from which they are derived; (ii) the non-stationarity of the EOF pattern;(iii) the orthogonality imposed by the EOF technique; (iv) the fact that the constructed EOFs are influenced by the region selected; and (iv) having to repeat the analysis every time an update is required, which may change previously obtained time-series (Wang et al., 2014; Cropper et al., 2015). It is also worth noting that the EOFs are statistical constructs and are not always associated with climate physics (Dommenget and Latif, 2002)”

Page 5, Line 6: Looking at Table 3, no discrepancies are observed across datasets for EOF 3 during MAM months

The referee is right. We have removed this from the text.

“For example, while the geographical patterns are very stable across datasets during winter (Table 3), some discrepancies are observed during summer (JJA; see EOF2 or EOF3)."

Page 5, Line 21: "Because of this spatial pattern, ..." I suggest rephrasing the sentence since the meaning is not entirely clear to me.

We have rephrased the sentence and hope it is now clearer:

"Due to the spatial extent of the winter's EOF3 positive centre of anomalies covering from Scandinavia to SW Ireland, ValSLP (purple dot in Figure 1 and S1-S4) is unsurprisingly correlated with all winter EOF3s (0.5<<0.6; Table 4)."

Page 6, Line 27: I think it is erroneous to assume that the datasets have to capture the climate modes, since the variability is in the SLP data themselves. Comparing different reanalysis datasets is out of the scope of this paper, but an indication of known quality issues that might account for the differences would be suitable

Following reviewer's 1 comment, we have now added some information on the anomalous SLP observed in the 20CRv2c dataset for the period 1951-1965. This has also been highlighted in all figures with a grey box.

In order to address the reviewer's concern, we now direct the reader to Fujiwara et al., 2017, which provides an extensive review of the quality of all the reanalyses products used in this study. We've also added a short paragraph highlighting the main differences of each of the reanalyses datasets used in this study.

"Five reanalyses datasets have been used in this study (Table 2). ERA-40 (Uppala et al., 2005) is a conventional-input reanalysis used in many studies that require long-term atmospheric data. ERA-Interim (Dee et al., 2011) improves ERA-40 in that it assimilates a more complete set of observations and therefore it achieves more realistic representations of the hydrologic cycle and the stratospheric circulation relative to ERA-40, as well as it improves the consistency of the reanalysis products over time. ERA-20C (Poli et al., 2016) directly assimilates surface pressure and surface wind observations, enabling it to extend back in time to cover the entire 20th century. 20CRv2c (Compo et al., 2011) is also a surface-input reanalysis with a different assimilation procedure than that of ERA-20C. The main limitation of 20CRv2c is that it does not correct for biases in surface pressure observations from ships and buoys, which results in the anomalous SLP observed for the period 1850-1865. Finally, the NCEP/NCAR (Kalnay et al., 1996) was the first modern reanalysis of extended temporal coverage (1948 to present) and it is still widely used. For an extensive review on the quality of these datasets, the reader is referred to Fujiwara et al., 2017."

Figure 2: many data are shown on the same plot, so that it is a bit difficult to visually recognise the agreement between the series. Also, could the x axis show dates rather than number of months?

Done.

Figure 6: I suggest including DJF, MAM, JJA and SON instead of a, b, c and d on the top left corner of each panel, both for clarity and for consistency with Figures 3 and 4

Done.

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