

Dear Editor,

please, find our replies to Referee#1 at pages 2 and 3 of this document.

We implemented the two minor corrections required by the referee at pag. 2 and pag. 14 of the manuscript (visible in the latexdiff document).

We also added a new affiliation for the second author.

Finally, we would like to inform you that we changed the colors in the figure of the manuscript using color schemes accessible to persons with color vision deficiencies, as required by the journal.

Thank you very much!

Yours faithfully,

Sara Bacer

# Authors' replies to Referee #1

We thank the referee for the interesting and helpful comments. Below, we provide our replies.

## Minor comments

*1. Value of  $k$  in WTD. I like your critical reading of DS2020---to the extent that I can accept that there are multiple alternative values of  $k$  proposed recently and consensus are yet to be reached. I do have reservations to your other interpretations of DS2020 (e.g., their Fig.2b). But because I am not further questioning your choice of  $k$ , further discussion of DS2020 might not help much in assessing your manuscript. And thanks to editor for bringing up Falkena et al. (2020), which definitely help the discussion of the value of  $k$ , etc.*

We thank the referee for the comment and for having stimulated this interesting discussion.

*2. Results using reference centroids. In your response, you said if reference centroids (obtained from reanalysis) are applied to the GCMs, “the blocking pattern obtained with some GCMs did not resemble the reference blocking pattern”. I am surprised by this. Are you sure?*

We did not apply this method (i.e. using the reference centroids to define the GCM centroids) to all GCMs used in our study, but we applied it to two GCMs. Figure 1 (below) displays the difference between the centroids obtained with this method and the ones obtained by applying the WTD on the GCM Z500 anomaly field (i.e. the methodology applied in our manuscript). In this example, the MRI-ESM2 model is considered: only Atlantic Ridge is well captured using the reference principal components (PCs) and the reference centroids.

**The four centroids obtained for the historical period (1980-2010)...**

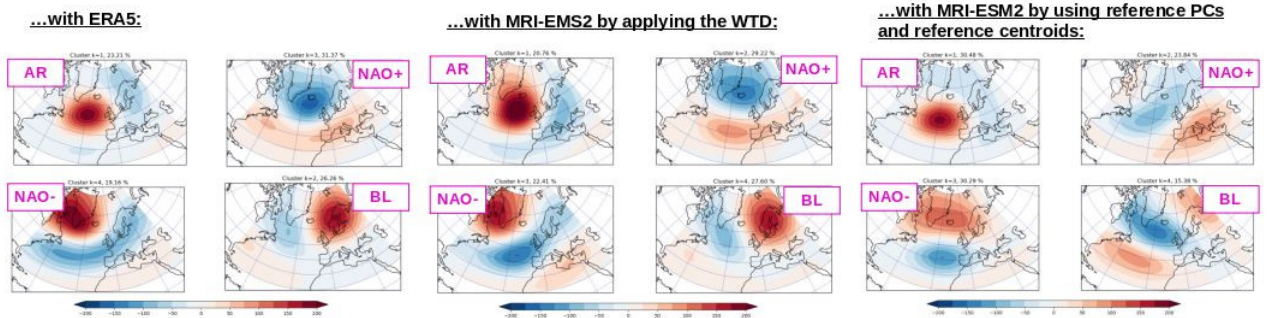


Figure 1: Centroids obtained with the reanalysis (left) and with the MRI-ESM2 model in two different ways (center and right).

*3. Some GCMs less accurate in capturing blocking? In your response, you said “using the PCA +  $k$ -means approach for each GCM, we have always obtained blocking regimes close to the reference blocking pattern.” But in your manuscript, line 182, you said “MIROC, CanESM, and IPSL are less accurate in capturing the blocking pattern”. This is contradicting.*

The two sentences look contradicting but they refer to two different methodologies. We said that “by using the PCA +  $k$ -means approach for each GCM, we have always obtained blocking regimes close to the reference blocking pattern” in comparison to the method commented in the previous reply (i.e. using the reference centroids to define the GCM centroids). On the

other hand, we wrote in the manuscript that “*MIROC, CanESM, and IPSL are less accurate in capturing the blocking pattern*” with respect to the other GCMs when the WTD is applied to all GCMs. Graphically, we mean that the blocking composites for MIROC, CanESM, and IPSL in Fig.2 in the manuscript are less accurate than the other GCMs in Fig.2, but they are anyway closer to the typical blocking pattern than the blocking centroid obtained in Figure 1 (right) of the present reply.

Overall, what is written in the manuscript is consistent, and the sentences cited by the referee look contradicting because they refer to two different situations.

4. *“Some GCM less accurate in capturing blocking” is perhaps the only significant result in the paper. But I raised questions on this in my previous review. Not sure if you responded, so I rephrase it here again:*

*In assessing the robustness (or “stationarity”) of clustering methods: DS2020 found largely different cluster centroid in different 30-year windows; Falkena et al. (2020) said “The differences between the results for odd and even years are found to be large”. Both were considered not a real signal, but a behaviour of lack of robustness.*

*When you find “cluster centroid” to be different in some models, could this be an outcome of lack of robustness of the clustering methods?*

We believe that our method is robust as claimed in our previous report, in the reply to comment-1, where we wrote that “*our methodology relies on a well established and largely used approach to define weather types: PCA+clustering. Moreover, we find similar results for the size of the blocking area by applying the WTD method and the DG method (which uses the DG index on the raw data), see Figure S6. This suggests that the noise associated with the non clear-cut clustering does not dominate the results.*” Hence, the differences among models is not due to a lack of robustness of the methodology but to the inter-model uncertainty (see also Huguenin et al. 2020).

The sentence “the differences between the results for odd and even years are found to be large” of Falkena et al. 2020 refers to the test done using half of the data set (i.e. 39/2 years), and they suggest that such a data set could be not “of sufficient length to draw reliable conclusions about the clustering results”.

Finally, regarding the DS2020’s work, as we already commented in our previous report, in the reply to comment-1, we do not know how large the difference between the results obtained for two 30-year windows shifted by only 10 years is. Indeed, DS2020 shows the differences among the clusters along the 21st century, but this is not directly comparable to our study.

5. *Line 57: “further investigations are necessary to define the Arctic amplification response to blocking”. Do you mean “further investigations are necessary to understand the Arctic amplification effect on blocking”?*

Yes, we changed the sentence.

6. *Line 302: Consider change “last generation” to “latest generation”.*

Yes, thanks.