

# Response to Reviewer 1 - "Characteristics of extratropical cyclones and precursors to windstorms in Northern Europe"

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We thank the reviewer for constructive comments on our submitted manuscript. We have addressed all specific points raised by the reviewer (copied here and shown in black text), and include our response (in blue) below.

## Reviewer 1

### General Comments

The paper uses the ERA5 reanalysis dataset to obtain 40 years worth of Lagrangian meteorological fields for extratropical cyclones crossing into Northern Europe. Since the paper uses a new reanalysis data set to examine extratropical cyclones and their precursors over Northern Europe, it is novel. I find the composite results interesting and useful not only for specialists in the field, but also for a more general audience.

In the paper, composite analysis is used to characterize and understand Northern European extratropical cyclones, while ensemble sensitivity analysis is used to find correlations between precursor fields and the selected response functions: Minimum Mean Sea-Level Pressure (MSLP) and 10m wind gusts. Four precursor fields were selected: 850 hPa potential temperature, total column water vapor, and 300 hPa wind speed and potential vorticity. Regressions were computed for 1, 2, and 3 days before extrema in MSLP and 10m wind gusts.

The results are presented in a series of 18 figures that are legible, well-labeled, and generally of a high quality. Some notable results in the context of cyclones affecting Northern Europe include; no significant trends in cyclones were found over the 1980-2019 period; summer cyclones are less intense than winter ones; 1995-2005 lull in cyclone activity, which can be attributed to anomalously lower numbers of windstorms over the period; windstorms are more common in the winter; overall, numbers of cyclones do not show an appreciable seasonal cycle over Northern Europe; windstorms have distinct genesis regions compared to non-windstorm cyclones; windstorms preferentially genesis over the sea

while non-windstorms that affect Northern Europe genesis over Northern Europe; summer tracks are further poleward than winter tracks, and summer cyclones live longer.

The paper reads well, and it also establishes the scientific relevance of the study well. The paper also embeds its results in the established literature. I can recommend this paper for publication after some major revisions are made.

#### Major Comments

While the nature and characteristics of extratropical cyclones are of interest to practitioners and specialists in the field, I found the ensemble sensitivity part of the paper quite weak. The paper makes causal inferences when the method as is does not support causal inferences. The causal inferences from the Dacre et al., 2019 study were valid because the authors isolated the precursor fields from the effects of the cyclone itself before the regression. In the present study, all that can be said is that stronger baroclinic and moisture conditions in a developing cyclone are associated with stronger maximum cyclones. When put like that, the results of the ensemble sensitivity analysis don't seem as exciting. Thus all causal inferences (like L328 or L339-L342) should be removed prior to publication. Changing "leads to" or "causes" to "is associated with" may address this problem, but a broader rethink of how the method is used could lead to a far superior manuscript.

Thank you for a good comment. We agree that since the ensemble sensitivity analysis uses correlation we may not imply the results as causalities but rather in a way that the response function and the precursor are associated with each other. Although the influence of the cyclone is removed in the study by Dacre et al. (2019), there are other papers which have used the ensemble sensitivity analysis that have not removed the cyclones, e.g. Dacre and Gray (2013) and Garcies and Homer (2009). In addition, the sensitivity results without cyclone removal are more useful for forecasters since they look at the full fields of for example total column water vapour, potential vorticity etc. and rarely just at the background state. In our study, we think that finding correlations between the response functions and precursors is a valuable contribution to the literature. Therefore, we do not apply the cyclone removal to our current paper but instead, the sentences with causation interpretations are revised as suggested: to change "leads to" or "causes" to "is associated with".

#### References:

Dacre H.F., O. Martínez-Alvarado, C.O. Mbengue, 2019: Linking atmospheric rivers and warm conveyor belt airflows. *J. Hydrometeorol.*, 20, pp. 1183-1196, <https://doi.org/10.1175/JHM-D-18-0175.1>.

Dacre H.F., and S.L. Gray, 2013: Quantifying the climatological relationship between extratropical cyclone intensity and atmospheric precursors. *Geophys. Res. Lett.*, 40, 2322–2327, doi:10.1002/grl.50105.

Garcies L. and V. Homar, 2009: Ensemble sensitivities of the real atmosphere: application to Mediterranean intense cyclones. *Tellus A*, 61: 394-406. <https://doi.org/10.1111/j.1600-0870.2009.00392.x>

## Minor Comments

Figure 2 a,c,e: Make the origin non-zero so that the bars aren't unusually long and so that the variation among bars, not length of bars, is emphasized.

Figure 2 is now modified based on the comments from both reviewers: we now include only absolute numbers (i.e. the left panel), the origin is set to non-zero to see the variation among bars better, and we added horizontal lines to show the annual means.

Figure 3: Label the y-axis in the figure.

The y-axis in Figure 3 is the number of cyclones, and the y-axis label is now added. In addition, we added the y-axis label to Figure 2 as well (shows also the number of cyclones).

L209: A citation is required for the Mann-Kendall reference.

Relevant references are now added.

L210-211: I would end the discussion at no statistically significant trend was found because this line reads as if the experimenter is beholden to a particular finding.

We decided to keep this text because the threshold for the p-value is somewhat subjective (e.g. 90th or 95th percentile) but we'd like to reassure the reviewer that we were not beholden to a finding that the trend was significant.

Is there any explanation for the drop in windstorms between the years 1995 and 2000?

This is an interesting question but really difficult/impossible to answer. As we see from Figure 2, there is a large inter-annual and decadal variability in the number of extratropical cyclones and windstorms. A similar result, a large inter-annual and decadal variability, was found for the mean wind speeds and the 98th percentile wind speeds in the North Atlantic and Europe (Laurila et al., 2021). Additionally, Laurila et al. (2021) showed that the inter-annual variations are regional and hence different parts of Europe can experience quite different wind conditions during the same year. Therefore, we would like to highlight here in this response that it is "normal" to the climate to have periods with a lower number of windstorms (and likewise periods with a higher number of windstorms).

Reference: Laurila, T.K., Sinclair, V.A., Gregow, H., 2021: Climatology, variability, and trends in near-surface wind speeds over the North Atlantic and Europe during 1979–2018 based on ERA5. *Int J Climatol.*, 41: 2253– 2278. <https://doi.org/10.1002/joc.6957>

Section 6. It may be helpful to indicate the direction of cyclone propagation on figures 7 and 8 (left to right?).

The arrow showing the propagation direction of the cyclone is now added to Figures 7 and 8.

L322: This causal statement does not follow from the results presented.

The statement is revised to say "is associated with".

L325: This causal statement does not follow from the results presented.

The statement is revised to say "is associated with".

L326: This causal statement does not follow from the results presented.

The statement is revised to say "is associated with".

L329: This causal statement does not follow from the results presented.

The statement is revised to say "is associated with".

L337: This causal statement does not follow from the results presented.

The statement is revised to say "is associated with".

L357: This causal statement (and the others that follow) does not follow from the results presented.

These statements are revised to say "is associated with".

L430: less → fewer

Corrected.

L456: Sentence unclear

The previous sentence was: "In addition, the spatial patterns of MSLP and 850-hPa potential temperature in our composites are similar that are found in the composites of the 100 strongest extratropical cyclones in the Northern Hemisphere (Catto et al., 2010)." Now this sentence is revised to say: "In addition, the spatial patterns of MSLP and 850-hPa potential temperature in our composites are similar to the spatial patterns found by Catto et al., (2010) when they created composites of the 100 strongest extratropical cyclones in the Northern Hemisphere." We hope this revised sentence is clearer.