RESPONSE TO REVIEWERS

September 15, 2025

Dear Editor,
we thank you for the time dedicated to provid another full editorial review of our manuscript. We have taken great care of answering your comments.
We provide our full answer letter below.

Sincerely,
Lia Rapella,
on behalf of the authors

General comments

0.1

After the major concern of R3, I miss an appropriate discussion already in the introduction of other factors influencing variability in impacts, such as internal climate variability, in particular interannual and decadal variability (which also affect large-scale patterns, that affect ETC occurrence, e.g. Dorrington and Strommen 2020). In that sense the major concern of R3 is not sufficiently adressed, yet. I ask to discuss the relevant literature in the introduction already to provide a more balanced introduction, given the relatively short comparison periods for factual and counterfactual periods, and caveats in ERA5 stability across these periods.
We added a discussion in the introduction to other factors influencing variability of impacts, including the suggested references.

0.2

Also the potential role of an evolving observational network should be discussed at some places (Data / Methods, Discussion). The study should build trust in the long term stability and robustness of trends in variables considered here, as well as the potential effect of an evolving observational network on the results of the attribution framework.
We included a discussion on the suitability of the ERA5 product for long-term trends and attribution studies, as well as, also more details on possible effects related to the consistency of the reanalysis products before the satellite era.

0.3

As described at the moment, the study is not easily reproducible! What is missing is more background on which times / regions contribute to the analogues. I.e. is the geographical extent fixed, or in a moving frame? (if moving land-sea mask, orography would affect the composite), what are the timesteps? How many individual cases contribute to the analogue? Some of the information might be found in the methodological references. But the paper must be self-standing, and the results reproducible. A list of the time steps in the analogue composites is the least what should be provided along with some more technical information on the geographic extent of analogues.
We added two tables in the appendix with the analogues time-steps, for each event and for both factual and counterfactual period. Following also the suggestions the Editor provided in the *specific comments* section (see comment 0.9), we added more information in section 2.2.

Minor comments

0.4

l19. The reference from 1993 seems quite old regarding the fact that technology to detect and avoid convection has improved. Consider referring to a newer study.
We added two more recent and general references.

0.5

l28-31. Here you are citing studies which investigate specific years or episodes which were characterised by an increase of a specific weather phenomon which had impact on air traffic. In the light of R3's major comment you should mention the fact that interannual variability can explain differences in the number of incidents in these specific years. Perhaps this is a good place to introduce interannual variability.
We added a discussion in the introduction to other factors influencing variability of impacts, including the suggested references.

0.6

l72. For Table 1 the abbreviations of major airports need to be introduced by first naming the cities or naming the cities in the table (caption) (as in Figure 1). In Figure 1 the introduction of abbreviations comes too late.
We have made explicit the airports abbreviations with the names of the cities in the caption of Table 1 and we reorganized the caption of Figure 1.

0.7

l110. As WCD is a journal with focus more on fundamental research rather than applied research I want to ask to actually show the formulae for TI1 and TI2, explaining with variables also which shear and deformation definition you mean and to explain how you compute it from ERA5 output. Also rather show formula as numbered equations than inline (also pertains to EDR l 119).
We made explicit the formulas for TI1 and T12, showing them with numbered equations, as well as for EDR.

0.8

As you are using ERA5 for trend assessment of ERA5-derived impact variables, you have to discuss the long-term stability and how suitable ERA5 is for trend estimates in the variables used. Please discuss the relevant findings and supporting evidence from Bell et al. 2021, Soci et al. 2024 and, for the large-scale circulation, Simmons (2022). In particular the role of an evolving (surface) observational network for the detected trends in surface weather impacts must be discussed.
Did you use the latest release of the ERA5 back extension (Soci et al. 2024), which has improved track forecast for TCs in 1950s-1970s?
We added a new paragraph at the end of section 2.1:
"ERA5 provides a suitable basis for assessing trends in our impact variables, particularly when analyses are anchored in the well-observed satellite era and supported by basic robustness checks. Large-scale circulation trends since 1979 are physically consistent, dynamically plausible, and cross-supported by other reanalyses. As an example, Simmons *et al.* [4] showed strengthened and meridionally expanded tropical easterlies, shifts in the North Atlantic jet, and increases in extreme jet-stream winds, with patterns coherent across vertical levels and datasets. The recent back-extensions of ERA5 substantially increase temporal coverage, but their stability is lower because they rely on much sparser and evolving observations, especially before the satellite era ([1]; [5]). Surface-impact variables are of course particularly sensitive to the evolving surface observing network, such as changes in station density over land or the transition from ship to buoy observations over ocean, which feed the assimilation system. These factors underscore the need for sensitivity tests and cross-dataset comparisons when interpreting ERA5-based trends, especially outside the satellite era and in regions with limited observational coverage. However, at the present time ERA5 represents the best-suited product to investigate long-term variability and to perform attribution studies [2]. Of course, the temporal stability of reanalysis products such as ERA5 is not guaranteed, as discontinuities related to evolving assimilation systems and observational inputs can affect long-term consistency, which need further assessment for

future releases.”
Yes, we used the latest release of ERA5 and we corrected the reference in the bibliography which was referring to the older version of the dataset.

0.9

For reproducibility, please also state how the teleconnection indices NAO etc. are computed or where they are retrieved from. Also for reproducibility and avoiding the need to look it up in (the various) methodological paper, please state how many analogues contribute in each case study to the factual and counterfactual composites, both in terms of time steps and distinct analogue cases. Also state if the geographical area in which analogues are taken from is moving in space or geographically fixed. The paper must be self-contained in its essential parts. **With the sake of reproducibility, we added the following sentence indicating the source of the teleconnection indices, at line 192: “The monthly indices are computed from the NOAA/ERSSTv5 data and retrieved from KNMI’s climate explorer. In particular, the ENSO index is the 3.4 version as defined by Huang *et al.* [3], the AMO index is computed as described in Trenberth and Shea [6] and the NAO index is the rotated empirical orthogonal function of Z500.”. To clarify that the geographical area in which analogues are taken is fixed, we added the following sentence at line 169: “The analogues are searched in the same fixed area where we look for the SLP minimum.”. The analogues which contribute in each case study to the factual and counterfactual composites are thirty, as mentioned at line XX “For both factual and counterfactual periods, we select the thirty best analogues”. As mentioned in the answer to the general comment 0.3 we added two tables with the explicit analogues time-steps.**

0.10

Figure 1 differences in lower row: It is very difficult to discern shading vs. no-shading . It could be interpreted as the value ”0.0”. Either use a mask or a different color (white, grey) than on the color bar to discern non-significant areas. **We modified the figure as suggested, adding a white mask for the non-significant areas.**

0.11

Figure 4 caption: Make even clearer that the data are for all dates (months) in the respective periods and the dot is for the actual event date (here 18.2.2022). According changes for similar plots in discussion of other cases. **We modified the captions as suggested.**

0.12

Discussion of North American Winter storm: It would be easier to start with the discussion of Figure 6, just for avoiding keeping scrolling back and forth from text to appendix figures. Or relocate Figure A7 to the main. **We prefer to keep this sequence since we need firstly to highlight the meteorological features of all events which are unique for each event and then to show common features for turbulence-related metrics.**

0.13

lines 340-344: repeat that this statement refers only to the analogues for Storm Eunice and the picture looks different for the European summer storm, and the North American and Typhoon examples. **We modified the text as suggested.**

References

[1] Bill Bell, Hans Hersbach, Adrian Simmons, Paul Berrisford, Per Dahlgren, András Horányi, Joaquín Muñoz-Sabater, Julien Nicolas, Raluca Radu, Dinand Schepers, Cornel Soci, Sebastien Villaume, Jean-Raymond Bidlot, Leo Haimberger, Jack Woollen, Carlo Buontempo, and Jean-Noël Thépaut. The era5 global reanalysis: Preliminary extension to 1950. *Quarterly Journal of the Royal Meteorological Society*, 147(741):4186–4227, 2021.

[2] Davide Faranda, Gabriele Messori, Erika Coppola, Tommaso Alberti, Mathieu Vrac, Flavio Pons, Pascal Yiou, Marion Saint Lu, Andreia NS Hisi, Patrick Brockmann, et al. Climameter: contextualizing extreme weather in a changing climate. *Weather and Climate Dynamics*, 5(3):959–983, 2024.

[3] Boyin Huang, Peter W. Thorne, Viva F. Banzon, Tim Boyer, Gennady Chepurin, Jay H. Lawrimore, Matthew J. Menne, Thomas M. Smith, Russell S. Vose, and Huai-Min Zhang. Extended reconstructed sea surface temperature, version 5 (ersstv5): Upgrades, validations, and intercomparisons. *Journal of Climate*, 30(20):8179 – 8205, 2017.

[4] A. J. Simmons. Trends in the tropospheric general circulation from 1979 to 2022. *Weather and Climate Dynamics*, 3(3):777–809, 2022.

[5] Cornel Soci, Hans Hersbach, Adrian Simmons, Paul Poli, Bill Bell, Paul Berrisford, András Horányi, Joaquín Muñoz-Sabater, Julien Nicolas, Raluca Radu, Dinand Schepers, Sebastien Villaume, Leopold Haimberger, Jack Woollen, Carlo Buontempo, and Jean-Noël Thépaut. The era5 global reanalysis from 1940 to 2022. *Quarterly Journal of the Royal Meteorological Society*, 150(764):4014–4048, 2024.

[6] Kevin E. Trenberth and Dennis J. Shea. Atlantic hurricanes and natural variability in 2005. *Geophysical Research Letters*, 33(12), 2006.