

**Precipitation extremes in Ukraine from 1979 to 2019: Climatology, large-scale flow conditions, and moisture sources**

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***Final author comments***

We thank all three reviewers for their thoughtful and constructive comments that help us to improve the manuscript. Based on the reviewers' suggestions, we implement several changes in the manuscript. The main changes are that:

- We add a new figure to show more insight into the EPEs in summer (in response to suggestion by reviewer #3).
- We further clarify the data availability (in response to comment by reviewer #3).
- We add more discussion about the moisture source composites in comparison to those for upper-level PV (in response to comment by reviewer #2).
- We better motivate the choice of the 100 mm per day threshold to identify EPEs (in response to comment by reviewers #1 and 2).

Below we provide a one-to-one response to all points raised by the reviewers. The reviewers' comments are in **red** and our replies in black.

**Reviewer #1**

This paper presents a analysis of EPEs and their climatological drivers in Ukraine using a combination of advanced techniques and models. It identified the common trend of anomalies associated with EPEs in different seasons, and moisture sources of the EPEs. The findings like the important role of land evapotranspiration and the formation of an upper-level trough in all seasons except winter are quite interesting and informational on the relationships between cyclones and flood related hazards. Overall I find the work to be interesting and sound, and the paper well presented. However, I believe the paper can be better if there are more physical background discussed either in section 3 or section 4. The findings are interesting and I believe that they are important, thus it's very natural for the audience to wonder what could be the physical explanations of the findings (such as geospatial patterns, relationships between the trough and precipitations, the difference between winter and other seasons). I would recommend the authors to have more of these discussed, better with references to former studies, together with the description of their findings.

Overall, I would recommend that this manuscript is suitable for publication in this journal ensuing to the authors addressing the major concern above, and my minor comments below.

We are very grateful to Reviewer #1 for her/his thorough analysis of our work, and for all the comments and suggestions regarding our paper. Incorporating solutions to these particular questions into the revised version of our manuscript will enhance its overall quality.

1. Line 45 – 48: Cite the data source in the corresponding format (newspaper, research paper, book, conference meeting, website, etc.)

Yes, we added a reference (Ukrainian State Agency of Water Resources; Mykhailiuk, 2022).

2. Line 54-55: It would be better if the authors can briefly talk about how the cyclones and blocking systems are relevant to EPEs.

We added a brief description of the mechanism of interaction between blocking systems and cyclones.

“This pattern effectively hinders the usual westerly large-scale atmospheric flow, resulting in flow anomalies around the blocking system and persistent conditions in its immediate region. The mechanism for the formation of any type of blocking circulation involves the nonlinear amplification of atmospheric Rossby waves, ultimately leading to their breaking. Blocks are long-lasting, quasi-stationary systems that frequently occur over specific regions (Moore et al., 2019). Their presence and characteristics significantly impact the occurrence of surface weather extremes (Rex, 1950a; Lenggenhager et al., 2019; Kautz et al., 2022), including EPEs. Furthermore, the most extreme weather is often associated with atmospheric blocking and coexisting upper-tropospheric cutoffs (Portmann et al., 2021).”

3. Line 68: ERA5 is an important data source in this paper, but it was not introduced properly. I would recommend the authors to introduce it before its first appearance in the paper.

Yes, we added: “For this, we use the dataset ERA5, which is the fifth-generation reanalysis from the European Centre for Medium-range Weather Forecasts (ECMWF) that is available since 1940. ERA5 provides hourly estimates for a large number of atmospheric, ocean-wave and land-surface quantities.”

4. Line 114: I'm not quite familiar about this so I can be wrong, but I'm wondering if the threshold  $0.025 \text{ g}/(\text{kg}\cdot\text{h})$  is a common practice in this research field. If not, I would recommend the authors to briefly justify their choice or support it with former studies.

For the identification of moisture sources, we apply the methodology by Sodemann et al. (2008). This approach identifies moisture sources from positive increments of specific humidity along a trajectory. We only consider changes in specific humidity exceeding  $0.025 \text{ g}/(\text{kg}\cdot\text{h})$  (detection threshold), because this threshold suppresses spurious uptakes due to numerical noise and keeps the analysis computationally feasible. Currently, this is a frequently used method for determining moisture sources (see, e.g., the references in the paper and Papritz et al., 2021; 2022).

5. Line 238: Add a comma before “southward in summer”.

Added. Thanks!

Line 264: The period from the former text paragraph seems to be after the figures and the caption.

Yes, you are right.

7. Line 338, 348, 359, 371, 391, 400: Use the standard citation format of ESWD. The citation needs to be both in text and in the reference list.

Added. Thanks!

### References:

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6. Papritz, L., Aemisegger, F., Wernli, H.: Sources and Transport Pathways of Precipitating Waters in Cold-Season Deep North Atlantic Cyclones, *J. Atmos. Sci.*, **78**, 3349–3368, <https://doi.org/10.1175/JAS-D-21-0105.s1>, 2021.
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