

Response to Reviewer #1

Manuscript: *The September 2024 Austrian flood in a historical and climatic context*
EGUsphere discussion paper: **egusphere-2025-5435**

We thank Reviewer #1 for the careful reading of the manuscript, the positive overall assessment, and the detailed and constructive comments. We particularly appreciate the recognition of the clarity of exposition, the quality of the figures, and the comprehensive hydrometeorological characterisation. Below we respond point by point to all comments.

General assessment

“The paper is structured as Blöschl et al. (2013)... The climate change issue is tackled better in this last work... The amount of information analysed here, the clarity of exposition, and the quality of the figures make the paper exemplary...”

Response:

We thank the reviewer for this encouraging and positive assessment. The manuscript was intentionally structured following Blöschl et al. (2013) to ensure comparability with previous landmark flood analyses. At the same time, the September 2024 event provides an opportunity to place such an analysis in a contemporary climatic context, drawing on more recent work on flood-rich periods and thermodynamic drivers. We are grateful that the reviewer finds this balance appropriate.

Detailed comments

Comment 1 (former line 41; Introduction)

“In Blöschl et al. (2020), the recent period is unprecedented in terms of being a flood-rich period in a warmer-than-usual climate. Blöschl et al. (2020) actually shows that other periods in the past were even more flood-rich than the recent one in Europe.”

Response:

The reviewer is correct. Blöschl et al. (2020) show that recent decades represent a flood-rich period occurring under warmer-than-usual climatic conditions, but not the most flood-rich period in absolute terms when considering the last several centuries. Our original wording was too strong and could be interpreted as implying absolute unprecedentedness.

Manuscript change:

We revised the sentence in the Introduction to clarify that the recent period is *among* the flood-rich periods, distinguished by its occurrence in a warmer climate, rather than the most flood-rich period overall.

Revised to:

“The current period is exceptional as a flood-rich period in a warmer-than-usual climate, although other, colder periods in the past have seen even more frequent floods (Blöschl et al., 2020).”

Comment 2 (former line 66; Introduction)

“What does ‘assess the plausibility’ mean in this context?”

Response:

We agree that the phrase was ambiguous. Our intention was not to imply a formal statistical plausibility test, but rather a process-based evaluation of whether the observed characteristics of the 2024 event are physically consistent with known flood-generating mechanisms and historical events.

Manuscript change:

We replaced the phrase with a more explicit formulation referring to a *process-based and physically consistent comparison* with historical floods.

Comment 3 (former lines 135 ff.; transition to event description)

“The description of the 2024 event here looks like a repetition of what was already said at lines 125 and following.”

Response:

We agree that some redundancy was present. While the intention was to move from a general introduction of the event toward the analytical sections, this transition was not sufficiently clear.

Manuscript change:

We shortened the later passage and removed repetitive elements, retaining only information that directly motivates the subsequent synoptic and hydrological analyses.

Comment 4 (former line 143)

“...during the peak of four historic flood events...”

Response:

Thank you for pointing this out. The phrasing was imprecise.

Manuscript change:

We corrected the wording to explicitly refer to *the four flood events considered (1899, 2002, 2013, and 2024)*.

Comment 5 (former line 145; synoptic description)

“For non-meteorologists, maybe comment on how low the pressures are and how high is precipitable water compared to the usual.”

Response:

We agree that additional quantitative context improves accessibility for readers without a meteorological background.

Manuscript change:

We added a brief explanation indicating how the sea-level pressure anomalies and precipitable water values during the event compare to typical climatological values for Central Europe. The following sentence was added: *“The emerging low pressure systems were rather strong synoptic systems, showing core pressure anomalies of roughly two standard deviations from the mean values for the time of the year.”*

Additionally the caption of figure 2 was updated accordingly.

Comment 6 (former line 163; Figure 3)

“Looking at Figure 3, Austria seems to be mostly covered by blue colour (negative anomaly). I do not see an abnormally warm air mass over Austria in the figure.”

Response:

This is a valid observation. Figure 3 shows temperature anomalies at an upper-tropospheric level, where the cold-core structure of the low-pressure system dominates. Near-surface and lower-tropospheric conditions, which are more relevant for moisture availability and precipitation processes, were nevertheless relatively warm. This distinction was not sufficiently explained in the original text.

Manuscript change:

We clarified the description of Figure 3 by explicitly distinguishing between upper-level temperature anomalies and lower-tropospheric thermodynamic conditions. We corrected the sentence to: *“The anomalies, computed relative to the 1991–2020 climatology, highlight an abnormally warm air mass over North-eastern Europe (5–10 °C above average) that persisted throughout the event, while a cold-core low remained nearly stationary over vast expanses of Central Europe.”*

Comment 7 (former line 217)

“The four maps show...”

Response:

We agree that the sentence was incomplete.

Manuscript change:

We revised the sentence to clearly state what the four maps show and how they support the comparison of the four events.

Comment 8 (Figure 5)

“Niederschlag to be translated.”

Response:

Thank you for noting this oversight.

Manuscript change:

All remaining German labels in Figure 5 have been translated into English.

Comment 9 (former line 239)

“The cold-air outbreak seems consistent with Figure 3 colours (being that a high elevation temperature).”

Response:

We agree with this interpretation.

Manuscript change:

We added a short clarifying sentence explicitly linking the cold-air outbreak to the upper-level temperature anomalies shown in Figure 3.

Comment 10 (Figure 7)

“The two panels seem to be one the negative of the other. Wouldn't it be prettier to have both rain and snow on the same map but with different colours?”

Response:

We appreciate the suggestion. We chose separate panels to clearly distinguish liquid and solid precipitation contributions, which we consider important for interpreting runoff generation. A combined map could reduce clarity in complex Alpine terrain.

Manuscript change:

No change to the figure layout. We added a brief justification in the figure caption.

Comment 11 (Figure 8)

“why not showing more than one hydrograph here? Are the “local” hydrographs (those not affected by major confluences) similar, i.e., increasing slowly (because of the dry initial conditions) and decreasing quickly??”

Response:

Thank you for this helpful suggestion. Initially, we had chosen a single hydrograph to maintain visual clarity, but we agree that including a second site adds valuable perspective. We revised Figure 8 to now display hydrographs from two representative catchments: Böheimkirchen (55 km²) and Lilienfeld (345 km²). Böheimkirchen exhibited a fast and sharp response, driven by embedded high rainfall intensities on already saturated soils. In contrast, Lilienfeld, representing a larger catchment in the Traisen Valley, responded more gradually, producing a broader hydrograph. We believe this combination illustrates the variability in hydrological responses while preserving the figure’s readability.

Manuscript change:

Figure 8 was revised to include both hydrographs, and Section 4.5 was updated to reflect and discuss the contrasting runoff behaviors.

Comment 12 (Figure 9)

“maybe one could add an indication on how extreme the peak was for the individual sites (e.g. through the colours of the flood waves) to better show the relative importance of the eastern tributaries of the Danube to the event.

Response:

We appreciate this suggestion and agree that it would be valuable to emphasize the relative extremeness of the tributary peaks. However, to preserve the clarity of Figure 9, we opted not to add another visual dimension (such as color) to the hydrographs. Instead, we clarified in the main text and figure caption which tributaries exhibited extreme behavior. We also added a reference to Figure 13, which explicitly compares return periods across sites and thus provides a quantitative measure of severity. Furthermore, names of the relevant locations are consistently shown in Figure 1, and further labels in Figure 9 would risk visual overload.

Manuscript change:

Text in Section 5.2 and the caption of Figure 9 were updated to (i) note that the most extreme peaks were observed in the Pielach, Traisen, and Perschling catchments, and (ii) refer readers to Figure 13 for detailed return period estimates.

Comment 13 (Figure 10)

“I would mention the distance between the sites (or show them in Figure 9).”

Response:

We agree with this helpful suggestion. To aid interpretation of the hydrograph propagation, we now refer to the approximate river distances between Achleiten, Kienstock, and Korneuburg. These distances help contextualize the travel time and

the shape evolution of the Danube hydrograph between these sites. For orientation, the river distance from Achleiten to Kienstock is approximately 208 km, and from Kienstock to Korneuburg about 74 km. These distances can be inferred from Figure 11, which displays river stations by river kilometers, and are also mentioned in the updated caption.

Manuscript change:

Text in Section 4.6 was updated to note the distances between the key gauges.

Caption of Figure 10 updated to: “Figure 10: Comparison of Danube hydrographs during the 2013 and 2024 floods at the gauging stations Achleiten, Kienstock, and Korneuburg. The river distance from Achleiten to Kienstock is approximately 208 km, and from Kienstock to Korneuburg 74 km. See also Figure 11 for river station locations along the profile.”

Comment 14 (former line 370; Discussion)

“Are 4 events enough to detect the transition of flood dynamics? Is this transition something to be feared?”

Response:

We agree that four events are not sufficient to *detect* a transition in a statistical sense. Our intention is exploratory: to discuss potential changes in flood-generating mechanisms rather than to claim definitive trends.

Manuscript change:

We clarified this explicitly, framing the discussion as hypothesis-generating and noting the need for larger-sample analyses.

Comment 15 (Figure 11)

“If these sites were visible in Figure 9, that would help the reader.”

Response:

Thank you. Many of the stations included in Figure 11—particularly those referring to historic events—do not have full hydrograph records, as the peak discharges were reconstructed from hydraulic analyses or archival reports. As a result, not all of these stations are included in the schematic overview in Figure 9. However, all key stations with available hydrographs from the 2024 event are represented in Figure 9. To support orientation, Figure 11 provides the full set of river stations and river-km markers, allowing readers to localize the respective sites. We have added a cross-reference in the captions.

Manuscript change:

Clarified in the captions of Figures 9 and 11.

Comment 16 (former line 408)

“The patterns in the two panels of Figure 13 do not look that similar to me.”

Response:

Thank you for this observation. We agree that the similarity is qualitative rather than exact. We revised the manuscript text to clarify that the correspondence between the Q_{peak}/HQ_{100} ratios and runoff coefficients is particularly notable in Lower Austria, where both indicators reached exceptional values in areas that typically exhibit low runoff efficiencies. In other regions, high runoff coefficients are more common due to different hydrological characteristics.

Manuscript change:

Clarified that the patterns in Figure 13 are not identical but show a strong overlap in Lower Austria. Language was softened from “looks similar” to “shows a spatial overlap,” and the interpretation was refined to distinguish between event-based extremes and climatological patterns.

Comment 17 (former line 410)

“Does this imply that the other regions with high runoff coefficients are not that unusual?”

Response:

Yes, exactly. We clarified in the text that high runoff coefficients in some western and northern Alpine basins are consistent with their typical hydrological behavior, including higher annual precipitation, shallow soils, and steeper slopes. What was unusual in 2024 was the occurrence of such high runoff coefficients in central and eastern Lower Austria, where infiltration is usually much greater.

Manuscript change:

Added a sentence to explain that high runoff coefficients in western Austria are in line with known regional behavior, while the exceptionally high values in Lower Austria were unusual and due to saturated soils and storm structure.

Comment 18 (former line 439)

“High runoff coefficients...”

Response:

Thank you for telling us.

Manuscript change:

Corrected this typo.

Comment 19 (former line 446)

“Shall we expect more synchronicity in neighbouring small-medium catchments only, or does the reasoning apply also to large catchments?”

Response:

Thank you for raising this important point. We agree that the implications of runoff synchrony extend beyond small and medium catchments. While synchronised peaks are most readily observed in smaller neighbouring basins, our results indicate that spatially coherent rainfall under persistent atmospheric conditions—such as in September 2024—can also align hydrograph peaks in larger river systems. We now clarify this in the revised text.

Manuscript change:

We added the following sentence toward the end of the paragraph on synchrony and future flood risk: “Although synchronised flood peaks are most apparent in neighbouring small to medium-sized catchments, the 2024 event suggests that under persistent atmospheric conditions, synchrony can extend across sub-regions and even affect larger river segments through spatially coherent rainfall.”

Closing

We once again thank Reviewer #1 for the constructive and thoughtful review. The comments helped us to improve the clarity and precision of the manuscript, while maintaining the core results and conclusions.