

### Response to Reviewer #3

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

We thank Reviewer #3 for the positive evaluation and constructive suggestions. We have addressed all points and provide a detailed response below.

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**Comment 1:** "The statements about antecedent conditions in section 4.3 are mostly semi-quantitative, and it is not clear how these statements have been derived and if they are comparable between the different events. The paper would benefit from a more systematic assessment of antecedent catchment conditions."

**Response:** We thank the reviewer for this helpful suggestion. To assess antecedent catchment conditions, we systematically evaluated all available sources, including historical flood reports, hydrological assessments, expert judgements, and pre-event precipitation data (from the hours to several weeks before peak runoff). While the density and type of available information differ between recent and older events, we aimed to reconstruct antecedent conditions as plausibly and consistently as possible across cases. We acknowledge that a fully uniform approach was not feasible, but we believe that the resulting estimates are robust and representative for the purpose of this comparative analysis.

**Manuscript change:** Section 4.3 was revised to clarify the sources and approach used to characterise antecedent conditions, and to note the differences in data availability between events.

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**Comment 2:** "Section 5.1 provides an interesting spatial analysis of peak discharge frequency and runoff coefficients. However, this assessment is only shown for Austria and should be extended to the whole region of interest (Danube basin upstream of gauge Wildungsmauer). This analysis should also be applied to the historic events. Additional details about how runoff coefficients have been derived should be provided."

**Response:** We fully agree that an extension of the spatial analysis to the entire Upper Danube basin and a comparison with past events would be highly valuable. However, for the current analysis, we were limited by data availability. High-resolution precipitation and discharge data necessary for spatially consistent runoff coefficient estimation were only accessible for Austrian catchments. Unfortunately, comparable datasets for the non-Austrian parts of the basin—especially with sufficient temporal resolution and catchment delineation—were not available at the required detail.

Similarly, applying the runoff coefficient and return period analyses to historical events (1899, 2002, 2013) would indeed provide insightful comparisons. Yet, the heterogeneity and scarcity of discharge and precipitation data across different time periods and regions presented a major constraint. Given these limitations, we focused the spatial analysis in Section 5.1 exclusively on the September 2024 flood and on Austrian sub-catchments, where reliable, high-resolution data were available.

As for the derivation of runoff coefficients, we now clarify that these were calculated based on the cumulative precipitation sums from the INCA gridded precipitation product (Haiden et al., 2011) and the corresponding event runoff volumes derived from discharge hydrographs. To isolate the event-related runoff, we applied a standard baseflow separation approach to the observed hydrographs and integrated the quickflow volumes over the relevant event window. This yielded robust, first-order estimates of runoff coefficients for a large number of Austrian catchments during the 2024 event.

**Manuscript change:** We have added this explanation of the runoff coefficient derivation method to Section 5.1 and clarified the scope limitations in the figure caption and discussion text.

### Minor Comments:

- **I.55:**  
*“Is the 2002 flood from the past century?”*  
**Response:** We corrected the wording.  
**Change:** Now reads “...one of the most extreme events in recent decades...”
- **I.117:**  
*“How is the ‘estimated peak of the events’ defined?”*  
**Response:** Thank you for this useful comment. We clarified in Section 3 and in the figure caption that the “estimated peak” refers to the time of maximum discharge at key Danube gauges—primarily based on hydrograph records for recent events and on hydrodynamic reconstructions for historical floods. For reconstructed events like 1899, the timing at the Vienna section is considered most reliable.  
**Change:** A sentence was added in Section 3:  
  - “The estimated peak times shown in Figure 2 correspond to the timing of maximum discharge at representative Danube gauges—based on hydrograph data for recent floods and reconstructed from hydraulic modelling and archival reports for historical events. For 1899, the peak at the Vienna gauge was used as a reference point.”
- **I.179:**  
*“Repeated full stop.”*  
**Response:** Corrected.  
**Change:** Removed extra punctuation.
- **I.180:**  
*“How have the time periods for accumulated precipitation been determined for the different events?”*  
**Response:** We clarified that the periods reflect the core rainfall phase leading to peak discharge.  
**Change:** Added a sentence in Section 4.1.

- Figure 4:**  
*“Upper Danube catchment is not completely covered, include Lower Austria outline (yellow in Fig. 1).”*  
**Response:** Thank you for the suggestion. We added the Lower Austria outline to all panels for orientation. However, consistent with the approach taken in previous event studies (e.g. Blöschl et al., 2013), we limited the spatial extent to areas where precipitation data of sufficient quality were available for all four events. Unfortunately, full coverage of the Upper Danube basin was not possible for the historical events due to data constraints.  
**Change:** Lower Austria outline added to all panels in Figure 4. Explanatory note on spatial coverage added in Section 4.1.
- I.204:**  
*“Rain persisted for five consecutive days – why are only four days shown in Fig. 5?”*  
**Response:** We agree that the event lasted for five days. However, we limited Figure 5 to the four core days leading up to the Danube peak to focus on the most relevant precipitation period. While additional rainfall occurred after the peak, the selected panels capture the critical hydrological input. Using four panels also preserves visual clarity without loss of essential information.  
**Change:** Caption of Figure 5 revised to clarify that the four days correspond to the core rainfall phase prior to peak discharge.
- I.217:**  
*“how → show how”*  
**Response:** Corrected.  
**Change:** “The four maps show how...”
- Figure 5:**  
*“Indicate location of St. Pölten, Lilienfeld; include Lower Austria outline; legend ‘Niederschlag’ → ‘Precipitation’”*  
**Response:** Done.  
**Change:** Figure updated accordingly.
- I.240:**  
*“daily mean → daily mean temperatures”*  
**Response:** Corrected.
- I.256:**  
*“Where are Admont and Mittersill located?”*  
**Response:** Locations added.  
**Change:** Indicated in Figure 7.
- Figure 7:**  
*“Add Lower Austria outline; include contour lines for snow line.”*  
**Response:** Lower Austria outline added.  
**Change:** We added Lower Austria outline.
- Figure 9:**  
*“Add gauge station names to hydrographs; include Lower Austria outline.”*  
**Response:** Thank you for the suggestion. To avoid visual overload in Figure

9, we decided not to label the gauging stations directly on the hydrographs. Instead, all station names are clearly indicated in Figure 1 for reference. To improve orientation, we have added the borders of Austria and Lower Austria to Figure 9.

- **I.341:**  
*“Not clear: Why is the 2024 flood steeper at Achleiten?”*  
**Response:** We clarified the explanation regarding double peaks and lower magnitude.  
**Change:** Text revised in Section 5.2.
- **I.347:**  
*“Rephrase ‘closely approached...’ – the 2024 flood peak is lower and shows a double peak.”*  
**Response:** We rephrased and included mention of the double peak.  
**Change:** Adjusted sentence in Section 5.2.
- **I.356:**  
*“main-stem → main-stream”*  
**Response:** We retained “main-stem” as hydrologically correct but ensured consistent usage.
- **II.370–371:**  
*“Repetition from II.348–349.”*  
**Response:** We agree that the original sentence repeated a point already made in the previous paragraph.  
**Change:** The sentence was rephrased for conciseness and to avoid redundancy. It now reads:
- “This longitudinal increase illustrates how flood amplification in 2024 was driven by coordinated tributary inflows, shifting the system dynamics from upstream wave translation toward a response dominated by mid-basin contributions.”
- **I.387:**  
*“stem → stream”*  
**Response:** Changed to “main channel” for clarity.
- **Figure 12:**  
*“Include historical event labels for Böheimkirchen and Sieghartskirchen.”*  
**Response:** Done.
- **I.401:**  
*“‘basin-wide indicators’ → Fig. 13 only covers Austria. Should be expanded to Danube basin...”*  
**Response:** We agree that extending the analysis beyond Austria would be valuable. However, for the 2024 event, we only had access to the high-resolution precipitation and discharge data required to compute consistent runoff coefficients within Austrian sub-catchments. This limitation restricted the spatial extent of the assessment. While we recognise the importance of analysing the full Danube basin upstream of Wildungsmauer, reliable and

homogeneous data for the entire region—especially for computing peak discharge ratios and event runoff coefficients—were not available at the time of writing.

**Change:** We clarified in Section 5.1 and the caption of Figure 13 that the analysis is limited to Austrian territory due to data availability.

- **I.410 and 413:**

*“Please provide ranges of typical runoff coefficients.”*

**Response:** Thank you for this helpful suggestion. We added reference ranges for typical event runoff coefficients to clarify what constitutes an exceptional value. Based on the analysis by Merz and Blöschl (2009), typical coefficients in Lower Austria and Burgenland lie between 0.05 and 0.25, reflecting the relatively flat topography, deeper soils, and higher infiltration capacity. In contrast, the northern Alpine rim and western Austria often show values between 0.3 and 0.6 due to steeper terrain, shallower soils, and more frequent saturation.

**Change:** Ranges were added to Section 5.1, second paragraph, to contextualise the 2024 runoff coefficients.

- **I.418:**

*“Flood peaks only exceed HQ100 in tributaries, not in the Danube.”*

**Response:** Clarified.

**Change:** Sentence now specifies tributaries explicitly.

**Closing:** We thank Reviewer #3 for the thorough and constructive review, which led to many improvements in clarity and precision.