Interactive Discussion: Author Response to Referee #2

Brief Communication: Stay local or go global? On the construction of plausible counterfactual scenarios to assess flash flood hazards

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RC: ***Reviewer Comment***, AR: *Author Response*, ☐ Manuscript text

Dear Referee,

thank you for taking the time to review our manuscript and for the nice feedback. We are glad to answer to your comments and to improve the manuscript accordingly. Please see below the detailed answers to your comments.

Kind regards,
Paul Voit and Maik Heistermann

RC: ***L.23: Please define the abbreviation HPE, preferably at the first occurrence of the full name.***

AR: Thank you for spotting this. We added the abbreviation now at the first occurrence in line 23:

> In the context of flood hazard assessment, one option for counterfactual scenario design is to spatially shift the location of a heavy precipitation event (HPE) in order to assess the impact that it could have effectuated elsewhere.

RC: ***L.52: Formatting error in „HQextrem"***

AR: Fixed. It is now: $HQ_{extreme}$.

RC: ***L.75: The SCS-CN method is often criticized for its simplicity and its empirical character. Could you justify why this method is appropriate for calculating infiltration and surface runoff in your study?***

AR: We chose the SCS-CN method because it is widely known and accepted and requires only a few parameters. All flash flood models that we are aware of use the same method for the calculation of the effective precipitation. E.g. the models used by in Borga et al. (2007), Marchi et al. (2010), Ruiz-Villanueva et al. (2012), Tarolli et al. (2013), Gaume et al. (2004), Versini et al. (2010) and Emmanuel et al. (2017).

Due to the restriction of the number of references, we do not cite all of these references in the brief communication. Further justification of the model approach can, however, be found in Voit and Heistermann (2024).

Apart from that, the application of more advanced models for runoff generation is typically limited by the robust parameterisation, specifically in small basins.

Altogether, we suggest to enhance section 2.3 after l. 82 of the preprint:

> First, the effective rainfall is estimated using the SCS- CN method (U.S. Department of Agriculture-Soil Conservation Service, 1972). The SCS- CN method is widely used in flash flood modelling while more advanced modelling approaches are typically difficult to parameterize specifically in small catchments.

RC: ***L.79: More information about the hydrologic model is needed. Which hydrological model is used? If an own model is used, please mention this.***

AR: You are right, this is unclear. We developed our own implementation of the model for the study in Voit and Heistermann (2024) which is, however, very similar to the modelling approaches used on other flash flood studies. We will change the first sentence of section 2.4 for clarification:

> We specifically tailored the hydrological model to represent flash flood events in small- to medium-sized basins. A comprehensive model description can be found in Voit and Heistermann (2024).

RC: ***L.91: "We model the quick runoff" is a too short for the methods. Could you elaborate more how you have modelled quick runoff?***

AR: Quick runoff here corresponds to the effective rainfall as obtained from the SCS-CN method. This should become clear from section 2.4. In order to clarify this, we supplement the sentence in ll. 82-82 as follows:

> Secondly, the geomorphological instantaneous unit hydrograph (GIUH), as derived from the DEM, is used to represent the concentration of quick runoff (i.e. of the effective rainfall).

RC: ***L.93: In FFA studies, at least 30 years are usually used to calculate the annual maxima series and to generate the distribution function. Please explain in more detail why 23 years are sufficient in your analysis.***

AR: This is a major limitation of using RADKLIM data for extreme value statistics, and we acknowledge it transparently in line 94. However, the answer on whether a time series is long enough depends on the return period you want to address by FFA. To our knowledge, an extrapolation up to 3 times the length of the time series is often considered as justified. For this reason we wrote:

> Given the length of our yearly maxima series (2001-2022), we consider the estimation of the 50-year return level as reasonably robust, while the 200-year return level will obviously be highly uncertain.

RC: ***Fig. 2: Description of X-axis and Y-axis is missing &***

Fig. 2: What is the meaning of "0 50" and so on? Even if it is explained in the caption, the subplot titles should be more specific. &

Fig. 2: And add an explanation for two lines (green, blue) to the legend. At the moment, only one line (red) is explained.

AR: Unfortunately, the figure is incomplete. We submitted it in PDF-format and it must have been compiled faulty. We already contacted the editorial office regarding this but have not yet received feedback. You can find the correct figure (Fig. 1) at the end of this document.

RC: ***Fig. 3: Description of X-axis and Y-axis is missing. &***

Fig. 3: What does “0 50” and so on mean? Even if it is explained in the caption, the subplot titles should be more precise. &

Fig. 3: The legend needs to be reformatted. The lines are partly covered by the legend. The green line has no explanation. The explanation for the other two lines (red, blue) should be presented consistently, either on the left or the right-side. &

Fig. 3: The legend needs to be reformatted. The lines are partly covered by the legend. The green line has no explanation. The explanation for the other two lines (red, blue) should be presented consistently, either on the left or the right-side

AR: Also this figure was not rendered correctly when the preprint was generated by Copernicus. You can find the correct figure (Fig. 2) at the end of this document.

RC: ***Fig. 3: Why m³/s/km² 0 6 and Why 2 0 6?***

AR: Also here the unit got formatted wrongly after we had submitted the figure as PDF. The unit of the unit peak discharge (UPD) should be: $m/s/(km)^{0.6}$.

While some studies use no exponent for the catchment area, other studies suggest to limit the influence of the upstream area by using an exponent to account for the decrease of unit discharges with upstream catchment areas. Figure 3 at the end of this document illustrates this.

For instance, the upper limit for Flash floods for Europe (envelope curve) is evaluated as $Q = 100 * A^{0.6}$ in Gaume et al. (2008). For this reason we also decided to use 0.6 as exponent for the catchment area.

RC: ***Results and discussion: Could you perhaps add sub-chapters to make it easier to read?***

AR: We suggest to split this section into two subsections. The first sub-section about the comparison between local and global counterfactuals and the second one about the case study regarding the Danube flood in June 2024.

References

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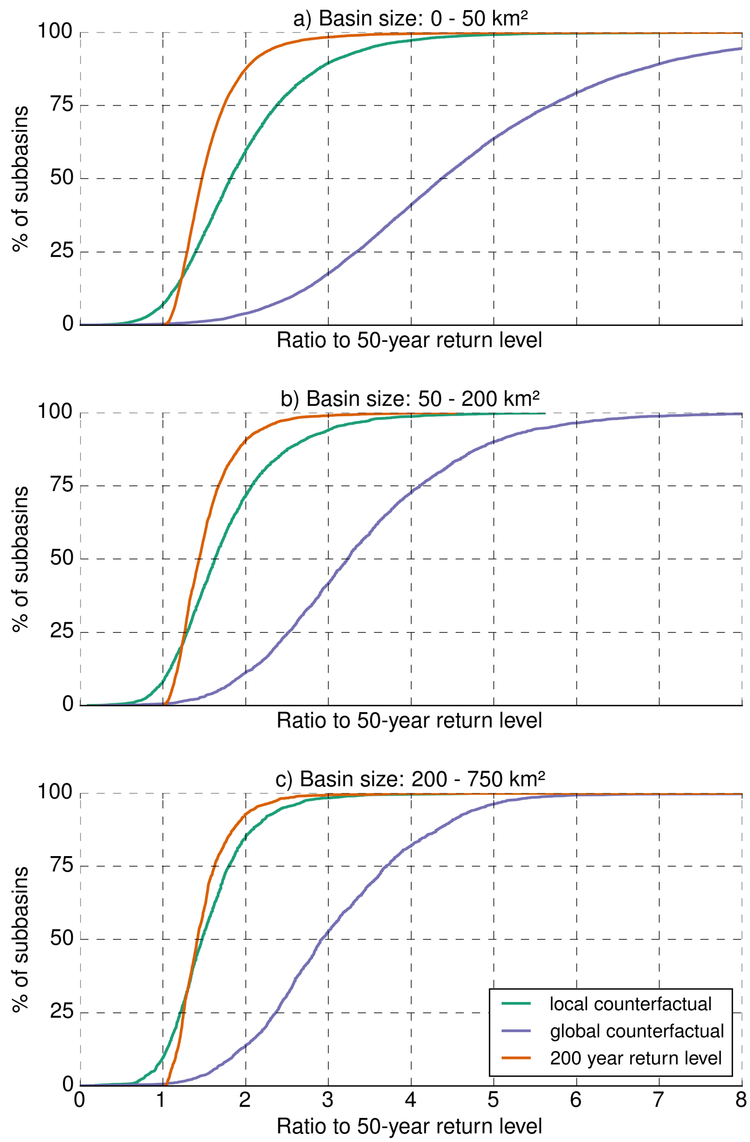

Figure 1: The cumulative density distributions show, for different subbasin sizes [a) < 50 km^2, b) 50-200 km^2, c) 200-750 km^2], the ratio between three different discharge estimates and the 50-year return level: (1) the local counterfactual peak discharge (green), (2) the global counterfactual peak discharge (purple), (3) the 200-year return level (orange).

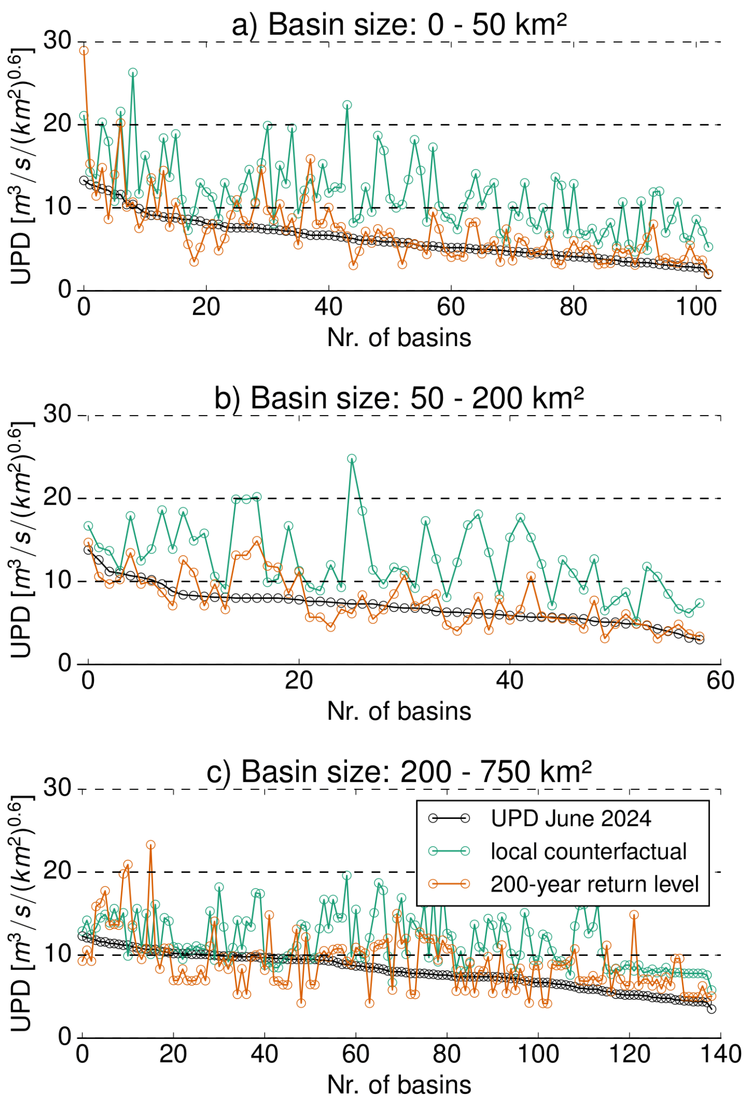

Figure 2: Case study of the recent heavy precipitation event from May 30 to June 4, 2024: the black lines show the simulated unit peak discharge (UPD) of the event for all subbasins within the Danube catchment with a return period > 20 years; for comparison, the green lines show the local counterfactual UPD and the orange lines the 200-year return level estimated from simulations between 2001 and 2022.

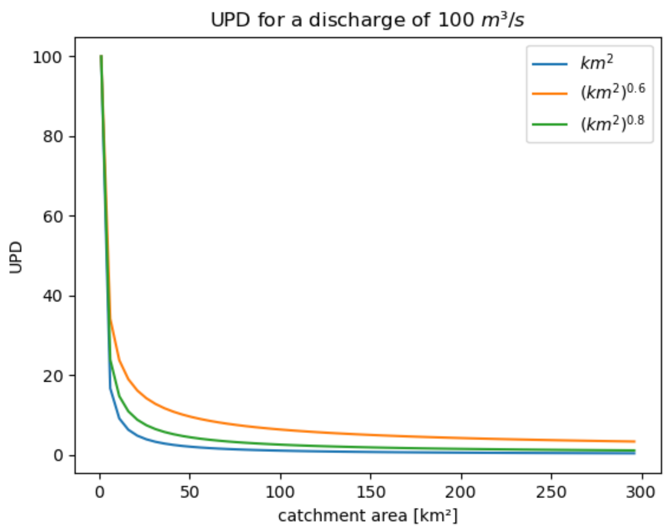

Figure 3: Unit peak discharge (UPD) for a discharge of 100 m^3/s and changing catchment sizes. Different exponents are used to limit the influence of the catchment area on the UPD: no exponent (blue), exponent=0.6 (orange), exponent=0.8 (green).