Anonymous Referee #2 from 22 Oct 2025

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General comments

This manuscript addresses the critical and timely topic of suspended sediment dynamics in a rapidly deglaciating Alpine catchment under the influence of increasing extreme rainfall events. This work is highly relevant to the scope of Hydrology and Earth System Sciences (HESS) as it provides quantitative insights into how climatic shifts are altering hydro-geomorphic processes in high-mountain environments. The study is well-conducted and presents a thorough analysis linking extreme precipitation characteristics to suspended sediment fluxes in the Tumpen-Ötztal and Vent-Rofental catchments in Austria. The methods are robust and clearly described, and the resulting data analysis is systematic. The manuscript is well-written, and the discussion is generally comprehensive. Overall, I recommend publication of the manuscript following minor revisions. Some comments are listed below.

Specific Comments

Antecedent Catchment Conditions. The discussion (lines 484–486) highlights the role of sediment availability for interpreting the year-to-year variability in SSY. In my opinion, authors should also consider the influence of antecedent catchment conditions, specifically factors like soil moisture, which might impact both overland flow generation and soil erosivity, the sequence of events, which dictates the depletion of readily available in-channel and hillslope sediment supply, and the presence/absence of snow cover, which might modulate the rainfall-SSY relationship. An event-based analysis of few targeted events could provide insights on these factors.

> ***Reply:*** *As the reviewer suggest, we will include information on (1) antecedent precipitation to give an indication of soil moisture, and (2) snow conditions in the catchment during events. Snow cover could well play a role in spring early and early summer, and we will include some discussion on this. Given the size of the catchment, and that many events are small scale only affecting some parts of the catchment assessing the depletion of sediment stores will be challenging. We will, however, have a look for cases where large scale events occur in sequence.*

Snow and Ice Melt Processes. In general, little space is given in the discussion on the impact of snow and ice melt processes on sediment transport. I suggest the authors expand this discussion to address the temporal dynamics and potential overlap with rainfall extremes. Specifically: When does the peak ice melt happen? Is it overlapping with the period characterized by the highest short-duration convective rainfall? Could this interaction explain the higher SSFmean observed for short-duration events? Furthermore, describing a typical pattern of snow cover duration in the catchment would add context. Again, by analyzing a few events with different characteristics, as they did for 2020, the authors would be able to incorporate these key cryospheric processes more fully into the discussion.

> ***Reply:*** *We will include information about the seasonality of glacier melt, snowmelt and snow cover in the description of the study area.*

As for whether the short-duration events have higher SSFmean because they occur in the months with high ice melt, we propose to include the excess SSY of each event. This substracts the "base" sediment load at the beginning of the event before calculating the SSY, and then SSF excess can be calculated.

Event classification. I have a clarifying question regarding the event classification described in Lines 224–226. Does this methodology imply that a genuine long-duration event could be identified or partially characterized as a sub-daily extreme if it contains a single, very intense sub-daily peak? I am not sure I understood this and I wonder how potential mis-classification might influence the results showed in Figure 6 as well as the discussion in 5.2.2. and 5.2.3.

Reply: *Sub-daily extremes exclusively have detected extreme peaks above the 1 to 12 h threshold. This means that if an event has event a single extreme peak above a 24-, 48- or 72-hour threshold, it is classified as a long-duration event. So there is no case where a long-duration event might be classified as a sub-daily extreme.*

However, there might be let us say an event was extreme at the 6-, 12- and 24-hour duration. That event under our classification that event would be labelled as a long-duration extreme. We would not say this is a misclassification of said event, since it was extreme at a longer duration in addition to the short ones.

We felt that keeping the purely sub-daily extremes together in one category was the cleanest way to separate the events into two categories. However, as we introduce in section 5.2.3. some events classified as long-duration ones, also have extreme peaks detected above the 1 to 12 hour thesholds.

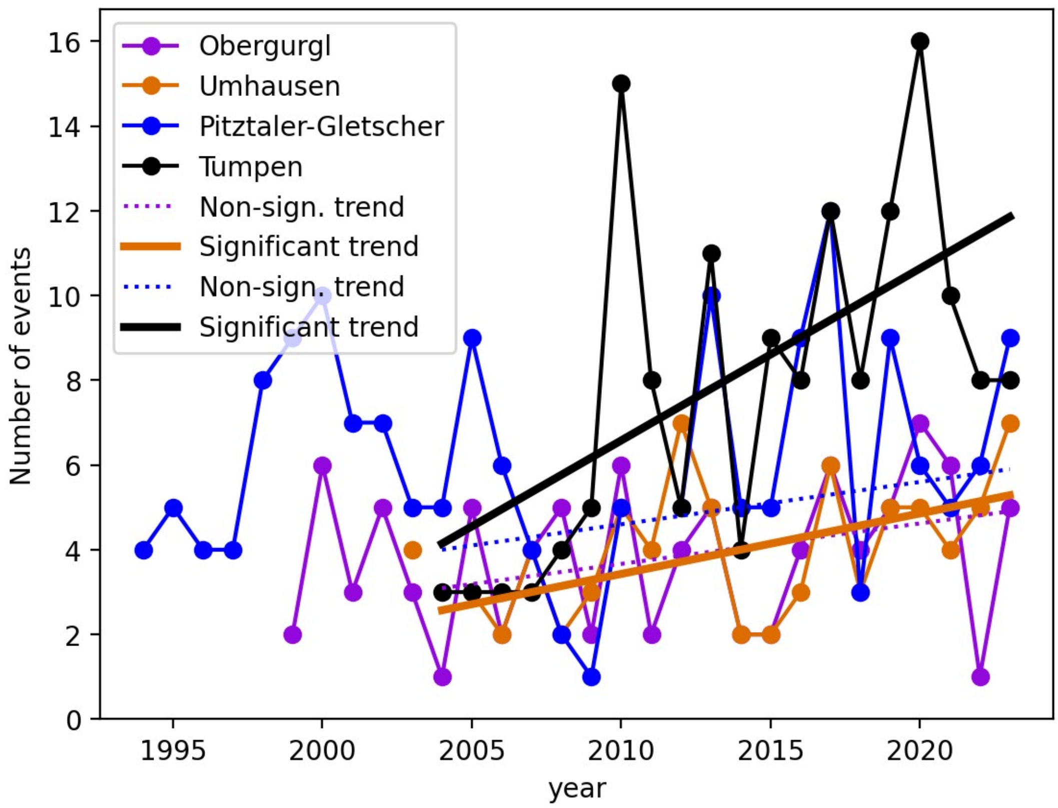
Using this three way classification, with "purely" long-duration, mixed long-duration and sub-daily extremes, may have implications for the linear relationships showed in Figure 6.

Increasing frequency of extreme precipitation – Stations. The finding of an increasing trend in the frequency of extremes derived from the INCA product is central to the study's context. Have the authors checked if a similar increasing trend is observable in the precipitation station data used for INCA development? Recognizing the already thorough nature of the analysis, I suggest the authors check if a similar increasing trend is observable in some targeted stations. This would enhance the robustness of the signal by ruling out the possibility of the trend being an artifact of the gridded product or its calibration process.

Reply: *This is a good suggestion. We have checked the trend in the number of events detected (with the same methodology as for the catchment time series). We selected 3 Geosphere Austria stations that are used in INCA (see Haiden et al., 2011). Two of these stations, Obergurgl and Umhausen are situated within the Tumpen-Ötztal catchment. The Pitztaler-Gletscher station is situated in a neighbouring catchment, but was included as a high elevation station, that is situated quite close to the watershed boundary.*

It is important to note that precipitation data from stations are only representative of the area immediately around the station. Thus the number of events are not directly comparable to the events detected from the catchment time series, as the station data cannot take into account the spatial scale of events, and might also miss extreme events occurring within the catchment.

Below we have compared the number of events detected at the stations each year including the trend over the same 20-year period as for the Tumpen catchment (2004-2023). The trend in the number of events (Mann-Kendall test with 5% significance level) is also shown. Umhausen station shows a significant increase in the number of events. The other two stations also show an increasing trend, but which is not significant.



Technical Corrections

Figure 2. The font size is rather small. The figure could be a bit bigger.

Reply: *We will increase the figure size.*

Line 100-101, 108-109: In the sentence "The accuracy of INCA estimates can vary, particularly in complex terrain, with an average error of 50-100% in the 15-minute precipitation grids and 1.0 to 1.5 ◦C in the temperature grids (Haiden et al., 2011).", the 15-minutes precipitation grids confuses because in line 100-101 the authors describe the INCA datasets as "… hourly 1-km grids for all of Austria.". Perhaps just add "… and sub-hourly …" to the sentence in line 100-101.

Reply: *Haiden et al. describe the INCA data with 15-min resolution in their analysis, whereas we used the hourly resolution, which the freely available resolution. Since the resolution of the data matters for the error metric we felt that it was important to make the difference in resolution clear here. We will add a clarification to the lines 100-101.*

Line 115-116: Please, provide a brief (few words) explanation of the rainfall/snowfall separation method used in openAMUNDSEN.

Reply: *We will add a brief explanation.*

Line 120-123: As I understand here, you used hourly, 1-km grids, precipitation for the period 2004-2024, and rainfall for the period 2011-2024. Correct? Please, clarify.

> ***Reply:*** *Correct. As clearly stated in lines 117-119:*
>
> *"As rainfall estimates rely on temperature grids (GeoSphere Austria, 2024a), which begin on 15 March 2011,* ***hourly rainfall grids are only available for the same time period as temperature (i.e. March 2011 to December 2024)****."*

Line 125. Figure 1 to Figure 1b.

> ***Reply:*** *Will do.*

Line 190: Please improve clarity by changing "Detection thresholds, u, for each …" to "Detection thresholds, u, for each DURATION d and spatial scale (i.e. GRID-SCALE It or CATCHMENT-AVERAGED Pt).

> ***Reply:*** *Will do.*

Line 210: I believe I understood what you did, but could you please write this iterative merging in a clearer way?

> ***Reply:*** *The merging was done in several passes. Will try to write it more clearly.*

Line 265: Since you are talking about events with SSC larger than the 90th percentile, I find P90(SSCt) a confusing definition and would change it to SSC90.

> ***Reply:*** *Will do.*

Figure 8. Font size rather too large. I suggest being more precise in the legend: from "extreme" to "extreme precipitation", from "non-extreme" to "non-extreme precipitation".

> ***Reply:*** *Will adjust the font size. As for the legend labels, we prefer to keep these consistent with Figure 7 (that needed these abreviated legend labels to not get cluttered). The classification is also described in the caption.*