

Authors' reply to Anonymous Referee #1 from 04 Jul 2024

General comments:

I thank the authors for addressing the comments presented in the first version.

While I believe that the manuscript has improved, I do not get the sense that the major comments I addressed have been appropriately integrated into the article. Furthermore, there are some additional comments that I wish to bring to light.

Below I present comments related to the text and revisit these topics in light of the author's response.

In addressing these, I believe the paper would be a valuable contribution to the literature.

Answer:

Thank you for your continued engagement with our manuscript and for your thoughtful comments and suggestions. We appreciate your acknowledgment of the improvements made in the revised version, and regret that some parts of the revisions did not fully address all of your major comments. We understand the importance of thoroughly integrating your feedback to enhance the manuscript's clarity and impact. We are committed to addressing these concerns more comprehensively in our updated version of the manuscript.

We also appreciate the additional comments you have provided. Below, we address your comments in detail and outline how we plan to incorporate your feedback. Thank you once again for your constructive feedback and for helping us improve our work.

General scientific comments:

1. The duration of the time series:

Would it be possible to address processes, such as sediment exhaustion, that could affect the characteristics of events over the time series see Zhang et al. 2022 and Antoniazza and Lane 2021. The authors demonstrate that their method is based upon individual events, which I think is the correct way. Rather, I wonder if the predictor variables could change over the study period given processes not associated with hydro-meteorological conditions, i.e. evolving sediment access. The authors state as much in line 518 "multiple processes... same signal." Furthermore, event type 4 seems to be access-driven, therefore could this access change through the time series? Would examining the hysteresis of events through time address this?

I do not think this can be fully addressed in the manuscript, but I would expect this to be discussed.

Answer: We have now added the following section to the "Benefits and limitations of methodology" section.

"Sediment dynamics in glaciated catchments are subject to long-term changes in driving processes and sediment availability (Zhang et al., 2022; Antoniazza and Lane, 2021). Annual sSSY and discharge in the Vent-Rofental catchment have remained largely stable during the study period (2006-2021) compared to long-term trends (Schmidt, 2023; Schmidt et al., 2024, 2023), especially

if considering the inter-annual variability. We infer that ongoing long-term changes in the catchment have had only minor effects on our results.

To confirm that the sediment-discharge event characteristics stayed constant over the study period, we checked whether annual averages of event metrics and PCs changed over time and found no significant trends (Mann-Kendall test with 5 % significance level). Likewise, the total annual sSSY and sSSY contributed by rainfall-melt extremes (type 0), freeze-thaw-modulated events (type 2) and late season glacier melt events (type 3) do not show significant trends. However, the annual sSSY contribution of high melt events (type 1) decreased significantly over the study period by $-31 \text{ t km}^{-2} \text{ a}^{-1}$ (Fig. 14c). This decrease in the annual contribution of high melt events (type 1) is less due to fewer events occurring, but rather a consequence of the average SSY magnitude of type 1 events decreasing. Does this trend influence the detection event types? If the magnitude of high melt events (type 1) had continued to decrease over time, then melt-driven events later in the study period would have differed enough from earlier ones to be separated by the cluster analysis. The advantage lies in considering events individually, which allows our methodology, at least to some extent, to deal with long-term trends.”

2. Definition of event types and the ability of the method to capture supply-limited events:

I do not believe that the author's response to this comment was fully adequate and that their justification in the review response was not presented in the manuscript. Some of the responses to my comment in paragraphs 138 to 147 could fit well in an "Experiment limitation" section. However, the response to the general comment did not adequately address the concerns that I presented.

The authors suggest that supply-limited events unrelated to water discharge increases might be rare in this catchment, and these events could be rare in general for that matter. However, this at the very least needs justification and may limit the transferability of their methodology to other catchments. For instance, they state that "our methodology is transferrable... any catchment with subdaily time series" (Ln 478). This seems misleading given the event definition. The methodology might be transferable, however, the event definition should be considered in each case, in my opinion.

Better support for this event definition and its limitations is needed.

Answer: We agree that for some catchments the transferability of the methodology is dependent on the event definition and parametrisation detection routine. We have added the following text in the “Benefits and limitations of methodology” section, which we hope makes this clearer:

“Given that fluvial sediment transport is primarily driven by hydrology, it is reasonable to delineate events by streamflow. Single SSC spikes without a corresponding increase in streamflow are expected to be rare, at least in the Vent-Rofental catchment. However, when applying our method to other catchments, other conditions may apply. Consider a mass wasting event without hydro-meteorological drivers, such as an earthquake-triggered landslide. Our event detection would lump the resulting sediment pulse together with an unconnected streamflow pulse. Thus, in catchments where such processes are thought to be relevant, our methodology may be less appropriate. Similarly, in catchment where sediment exhaustion effects are important, or where this is the focus of research, the event filtering by SSC could overlook supply-limited events. In such cases, it may be appropriate to lower $\theta_{SSC,peak}$ to include more events. However, removing the filtering completely would cease to be an event detection, instead splitting the entire time series into event-sized portions, which we advise against. Moreover, the length of the local-minima search window is a parameter to be adapted to the hydrological and sediment response time of the study catchment. In

short, the appropriate choice of parameters for event detection is crucial. The event definition should be adjusted to align with the focus of the study and the hydrological and sediment transport dynamics of a given catchment.”

3. Please consider making a section i.e. 5.1.5 about the "non-events." Here, more sediment seems to be exported than in Type 2 and Type 3 events (Figure 14). Knowing more details about this could be useful.

Answer: We now added this section on the non-event periods of the time series and how it relates to the proportion of annual SSY contributed by “non-events”:

“The periods of the time series without events are concentrated towards the edges of the monitored SSC period, specifically in May-June and September-October. These periods are characterized by markedly lower streamflow rates (90% below $12.3 \text{ m}^3 \text{ s}^{-1}$) and SSC (90% below 588 mg l^{-1}). Therefore, sediment fluxes too are markedly lower during the non-event periods (roughly between 0.01 and $10 \text{ t } 15\text{min}^{-1}$) compared to event periods (roughly between 1 and $100 \text{ t } 15\text{min}^{-1}$). However, as non-events occupy the largest part of the time series (Fig. 14d), a notable portion of the annual SSY is exported during these non-event periods, especially in years with fewer events, such as 2013 and 2019 (Fig. 14a).”

We discourage any more discussion of the non-event periods in the manuscript for the following reasons:

Firstly, our study focuses on the characterization and analysis of events of a certain magnitude defined by suspended sediment concentration (SSC). The primary objective is to understand the behaviour and drivers of these larger magnitude events within the context of the Vent-Rofental catchment. Adding too much information on "non-events" would diverge from our main research question and dilute the focus of an already long manuscript.

Secondly, “non-events” are per definition not clearly delineated into time chunks like the events are. Rather they are simply the parts of the time series outside marked increases in SSC (i.e. where SSC goes above the threshold of 1196.5 mg/l). Therefore, it is difficult find a meaningful way to compare events and non-events, apart from comparing the overall distributions of the time-steps during and outside of events as we did in the response to the first round of reviews (see <https://doi.org/10.5194/hess-2023-300-AC1>). This information is included in a simplified manner in the new section added to the manuscript.

We hope this explanation clarifies our rationale for not including a more information on “non-events”.

4. The writing is thorough and generally clear. However, there are places where it could be condensed. Please consider.

Specific scientific comments:

Ln 75 - reference problem in document.

Answer: The problem was due to a preprint that has since been published, we corrected it now.

Ln 167- "studies" please cite the relevant ones or omit them.

Answer: We have now included a selection of studies that use duration and magnitude related metrics.

Figure 8. Can the yellow of Cluster 2 be changed to green? this will help it appear in printed versions.

Answer: The colours have been carefully selected to be colour-blind friendly while trying to consistently use the same colours to denote the same things throughout the manuscript. Changing the colour of cluster 2 to green would be problematic for colour-blindness.

Paragraph 367- 375: Paragraph can be streamlined? Can the figure or manuscript be referenced to support the first two sentences?

Answer: We have adjusted the paragraph to bring up the main point first, and added a reference to Figure 8 to illustrate the timing of the events.

Figure 11. Where is precip? It is a bar plot on top of other figures, but zero here. Mention in the caption or remove axis?

Answer: We have added the information to the caption to make it clearer to the reader that there was no precipitation observed, not that there were no observations.

Lines 420-423. Please make the statements of these processes more specific. The connection between "complexity of event shape" and "freezethaw on driving hydrological processes" is not clear to me.

Answer: We have attempted to make our meaning more clear. The paragraph now reads:

“As with the rainfall-melt extremes (type 0), the complex event shape and high variability in sediment-discharge characteristics within this event type (Fig. 9c) primarily reflect multiple drivers of streamflow and SSC. Unlike rainfall-melt extremes, the complex event shape of type 2 events may also partly be the result of a modulating effect of freeze-thaw on the driving hydrological processes (mechanisms discussed below). The effect of freeze-thaw is thus two-fold, first by affecting the hydrological processes themselves and second by constraining the erodible landscape that contributes sediment to the channels. A similar effect of catchment freeze-thaw state regulating suspended sediment dynamics has been proposed for the Tibetan Plateau (Li et al., 2021b).”

Section 5.1.4. Consider renaming these "sediment access events" or "high elevation melt events." The processes are different from the glacier melt events of T1.

Answer: These suggestions with names for type 3 events would not reflect the processes and mechanisms we attribute to these events. "High elevation melt events" would not add more than "glacier melt events", since it is clear that glaciers are located at the higher elevations of the catchment. Also we would like to include the "glacier" here, as "melt events" could imply that there is snow melt involved. "Sediment access events" would go against our argumentation that the lower sediment yields of type 3 events are not driven by a lack of sediment supply or sediment access, but rather by transport limited conditions (i.e. lower streamflow rates).

Ln 477 - I think that the comma after types is a mistake.

Answer: Yes, it is. We've removed the comma.

Ln 478- Please see the general comment above for this comment.

Ln 509 - "Hysteresis analysis can be a useful tool" -> for what?

Answer: "For exploring the temporal dynamics of SSC and streamflow during events." We've updated the sentence accordingly.

Ln 520 - "although... each event type." This sentence can be clearer. For instance, "although the strength of these characteristics varies with each event type."

Answer: Now reads: "..., although the strength of this linkage varies with each event type."