

We thank the two reviewers for their detailed comments and suggestions to our manuscript *Causes, consequences and implications of the 2023 landslide-induced Lake Rasac GLOF, Cordillera Huayhuash, Peru*. We have considered them in revised version of the manuscript. Below we provide our point-by-point replies (in blue).

On behalf of the collective of authors

Adam Emmer

RC1: '[Comment on egusphere-2024-2316](#)', Fabrizio Troilo, 24 Sep 2024

General Comment:

The paper by Adam Emmer et Al. presents the description and the analysis of a major mass movement event involving cascading processes that happened in February 2023 in the Peruvian Andes.

The paper is well written and well structured; the text is supported by high quality figures and the references cited highlight a good literature review.

The topic of GLOFs, cascading processes triggering GLOFs, and the evolution of such events in the present climate change scenarios are relevant.

I believe that the prompt data and informations gathering after such large events is crucial for the better understanding of these processes which are still difficult to model and to predict. The rapid publishing of such observations and studies is essential for the scientific community that studies such processes.

The hydrodynamical analysis performed in the study is interesting and can serve as a basis for future, more in-depth modeling work on this event. Another relevant point is the understanding of features or conditions that can reduce the propagation of gravitational phenomena (section 5.1) which is crucial to be correctly interpreted and integrated in dynamic gravitational modeling and eventually in risk assessment studies.

The discussion of the attribution of the event to climate change and the analysis of the variation in the likelihood of the occurrence of extreme temperature anomalies is particularly interesting, and could be the subject of future work on this and other case studies.

I believe this is an interesting paper and I hereby introduce some specific comments which i consider all as minor revisions and suggestions that could nonetheless further improve an already very good work.

- thank you for overall positive evaluation of the work done and its relevance for developing GLOF research field

Specific comments:

L20 it might be better to express the value with the estimated uncertainty. 1.3 ± 0.2 or so. Also Check and homogenize with L383 and L387 notation.

- the volume estimate 1.1 to $1.5 \cdot 10^6 \text{ m}^3$ refers to estimated thickness of displaced block 30 to 40 m; we find this expression appropriate as 1.3 ± 0.2 would suggest this estimate came from frequency distribution (which does not); we homogenized the way how this is written throughout the manuscript

L31 to make it more clear and fluent i would slightly rephrase: (ii) frequency-magnitude relationships of extreme geomorphic processes that undergo alteration because of rapidly changing ...

- revised accordingly

L33 the wording of the phrase is a bit complicate...because glacial debuitressing is implicitly an ice related effect, why dont contract into : GLOFs originating in recent decades from glacial de-buttrressing and warming permafrost (areas?)

- revised accordingly (“... originating from warming cryosphere ...”)

L62 just remove "then", "if so, how this event can be attributed" is clear enough

- revised accordingly

Fig1 the Cordillera Huayhuash outline can hardly be seen. Why don't indicate it in black in the legend and just stick to the rectangular bounding box? Then you can give the more accurate perimeter in (b). It could be a good idea to change outline color in (b) to make it more visible. I would also write the full C. HUAYHUASH in legend (b) C.H. could be not really intuitive.

- This figure will be revised also in line with comments of Referee #2

L103 Can you give a value of uncertainty for the volume estimation?

- The lake volume estimate method developed by Muñoz et al. does not quantify the uncertainty range, however, it is the most suitable method considering it is based on a large dataset of bathymetries of Peruvian glacial lakes

Table1 Could you add a column that refers to the native satellite or sensor type? For example on the first row it could be: mosaicking of worldview and Pléiades imagery...For the 2nd row PlanetScope satellite imagery etc... In the reference column you could add a detail if freely available or of restrained/commercial access. For the Sentinel images it could be good to add a reference on how to access original imagery from The copernicus data space. A column with the number of images actually used in the study could make it more complete

- thanks for the suggestion, but we have decided to keep Table 1 as it is. It presents the fundamental information needed and is consistent with reporting in other papers. These are fairly standard datasets and most readers will likely know where to access imagery from in all cases, and their cost vs. open access availability

L146 I would put two commas: "the event, as defined above, has changed ... "

- revised accordingly

L202 It would be good to introduce the Ravanel 2023 reference here as well, just after mentioning the ice aprons, as many geoscientists might not be aware of the definition of ice aprons.

- revised accordingly

L223 Here you name it Rasac Ridge. Elsewhere in the paper you also refer to the Rasac Arete Ridge. It should be named in the same way in the whole text. Wouldn't it be more straightforward to name it Rasac Ridge everywhere in the text? (But I might be missing something about local topography naming)

- the ridge doesn't have any official name, we name it according to the highest peak; the word "arête" is used to underscore its morphology; we homogenized the naming throughout the text

Figure 3 It would be really interesting for the reader to see the slope on the other side of the ridge as well if an image is available. From this side of the slope it is hard to tell that the morphology of the ridge is the one highlighted in the topographic profile in Figure 5.

- this is exactly the reason why we used the term "arête" which describes this ridge morphology

L243 Just a typo, the reference appears in red.

- revised

Figure 4 The north arrow is quite small, as long as you are showing images with the north pointing to the left (which is good for the composition of the panels of the image sequence), I would highlight it more clearly for the reader; I would add a bigger north arrow on the august 2017 panel for example, or make it bigger and/or colored to differentiate it from the main legend elements in the actual location.

- Revised version of this figure will include larger north arrow

L256 Permafrost thawing might be more appropriate?

- Replaced by "permafrost warming" since we do not assume thawing (see Fig. 7)

L315 In this paragraph you highlight the fact that the Rasac Ridge is very sharp and horizontal heat flow component is present. Because of this setting, wouldn't it be reasonable to discuss (maybe in 5.2) the possibility that glacial debuttrressing from the elevation loss of the big glacier tongue located to the East of the Rasac ridge could have played a role in the destabilization process? Maybe the recent exposure of part of the eastern flank of the Rasac ridge have also had consequences in the variation of the thermal condition of the slope as well as water percolation od circulation? Glacial de-buttressing effects are introduced generally in the paper and it could be worth to contextualize it to the local setting. The data from the paper of (Hugonnet et al. 2021) could maybe give an idea of the elevation loss rates on this Glacier. Maybe historical data or geomorphologic evidence can at least give an idea of the LIA glacier extentions in the area?

- Thanks for opening this topic; the vertical difference between the Rasac arete ridge and the glacier in the valley on the E side of the ridge is > 500 m; this suggests that it has been remodelled by repeated glaciations and it is very unlikely that the LIA ice thickness would come even close to upper parts of the ridge where the 2023 mass movement was initiated; and it is even more (>1000 m) on the W-facing side of the ridge; considering the location of the release zone very high up above the valley floor and glaciers, the substantial role of debuttrressing in what has happened is considered unlikely in this setting

- Glacier debuttressing in the paper is mentioned in discussion and conclusion sections where we put the Rasac event in the context of other events from the Peruvian Andes in some of which it was an important process

L324 "interested by the detachment" instead of "with the detachment" probably sounds better to the reader.

- The sentence was revised

L325 Temperature rise "is" from both sides of the ridge. It might sound better: temperature rise "have origin" or "comes" .

- Revised accordingly

L330 In 4.2.3, the content of figure 8 is very clear, but the text is very short. You could perhaps describe this data a little more, for example: skin temperature reached the highest anomaly peaking at +1.4°C etc... the temperature anomaly started from mid-january and returned to less extreme values by end of February etc etc ...

- Thanks for the suggestion, we have revised the text to provide a more detailed description of the updated figure 8, for which we have extended the data back to 1940 (as the data had become available recently) to provide a longer view of the climate conditions & trends.

A more general consideration on the analysis of meteorological conditions is the following:

You show that a strong positive temperature anomaly was present at the time of failure of the rock avalanche of 12th of February, which is really interesting, but wouldn't it be interesting to show a bit more data from the previous months? Or maybe from the previous 2 or 3 years? It seems that the reader would need a bit larger temporal outlook on these data. Maybe another 2 panels in figure 8 could highlight a little larger time window? In this direction you could also highlight in colored lines years 2021 and 2022 for example in the panels A, C and E of figure 6.

- Thanks for the suggestions. We have added 2 panels in figure 8, to show the meteorological conditions 2 years prior, showing the anomaly with respect to a 30-year climatology (1981-2010, same as what's been show in figure 8); we have also highlighted years 2021 and 2022 in the updated figure 6.

Figure 9 i would reproduce the (c) outline in (A) also, to better compare A and B panels

In (B) the label "GLOF impact area" covers the area itself, if you shift it to the north, the reader can better appreciate the change in the impact area occurred in between (A) and (B) panels

It could be good to have another panel highlighting the (D) area showing the same detail of this area prior to the GLOF. Remember to add a North arrow

- This figure will be revised accordingly

L364 "apparently"

- Revised accordingly

L366 isn't it referring to fig 9?

- Revised accordingly

L385 add a reference to fig 9. maybe it is also worth better highlighting the fact that there are 2 different overtopping locations on fig 9 with 2 additional circles or better separate the 2 arrows

- [Revised accordingly](#)

L387 don't express "millions" but $0.8 \times 10^6 \text{ m}^3$

- [Revised accordingly](#)

L389 it is not clear .. lake rasac persisted in a more limited extent .. compared to pre-glof extent?or refers to temporal extent?

- [Clarified in the text](#)

L393 just say unusual if it is so, dont say quite. You should also explain why it is unusual.

- [Revised accordingly](#)

L397 why is it rather unlikely?

- [This is considered unlikely because deposition have not occurred in the rear part of the lake where it could possible interrupt water inflow into the lake, but a frontal part](#)

L403 it would be more fluent by merging the two sentences: a partial role, in the sense ... This way you eliminate the repetition of the word partial.

- [Revised accordingly](#)

L418 "prior to" sounds better than "leading up" if I interpreted correctly the meaning.

- [Revised accordingly](#)

Figure 11 Orange and purple coloring might be hard to differentiate.

(a) and (c) panels have the x axis label truncated on the 10000 label

- [Revised accordingly](#)

L456 Typo: event , not evet

- [Revised accordingly](#)

L465 Building on the regional

- [Revised accordingly](#)

L474 Maybe a little table with some BASIC data on the events you mention could make the paper more complete at this point.

- [New Table 2 with basic description of the mentioned events has been added](#)

Hoping that my comments will be useful for the publication of your manuscript,

Best regards,

Fabrizio

[Thank you again for your review!](#)