Response to Reviewer's technical corrections to the manuscript esurf-2023-10:

Massive sediment pulses triggered by a multi-stage 130,000 m³ alpine cliff fall (Hochvogel, DE/AT)

By Natalie Barbosa, Johannes Leinauer, Juilson Jubanski, Michael Dietze, Ulrich Münzer, Florian Siegert, Michael Krautblatter.

Dear Dr. David Mair, Dr. Georgie Bennett, Anonymous reviewer, and Editor,

You will find below my responses to the comments made by Dr. David Mair, Dr. Georgie Bennet and Anonymos reviewer. I am very grateful for their constructive comments and suggestions that have led to improving the scientific significance, scientific quality, and presented style of this manuscript. Their comments appear in black text below while my responses are in blue.

Best regards,

Natalie Barbosa, on behalf of the co-authors of this manuscript.

Point-to-point response to Reviewer 1 Dr. David Mair

We want to thank Dr. David Mair for the time devoted to the manuscript. All the suggestions were considered and included in the revised version of the manuscript. Points that required clarification are detailed below.

Line 289: UAV… and its default onboard camera?

The AUV flight was performed using the default onboard camera from the DJI Phantom 4.

Line 290: Here it might be helpful if you could add one sentence on the approx. ground sampling distance and how the UAV images were referenced, i.e., with/without GCPs or if the UAV had an RTK positioning module and pot. RMSE thereof. This could inform readers on the expected uncertainty of the volume estimation based on the UAV SfM/MVS derrived surface data.

Despite the existence of UAV surveys for the upper part of the summit, we didn't use their photogrammetric point clouds. The UAV flight has an approximate ground sampling distance of 0.05 m and the images were referenced using at least 8 GCPs measured at the summit. We decided to refer to the UAV flight only in the caption of Figure 3 because, for this manuscript, the UAV images were used for visual comparison.

Figure 6. could really profit from having the same scale range on the y-axis (i.e., in the left columns of plots). Consider using a log scale for the SDR values.

Thank you very much for the suggestion. We have plotted the y-axis for the SDR values in a symlog scale.

Line 479 to 485: Can you give a number here to give a better idea on the order of magnitude? / Also here; could you provide a number on the magnitude of what is considered lower?

The assessment of a unique uncertainty for the whole temporal series is unlikely because of the diversity of acquisition conditions. However, we have stated a range of high and low uncertainty in the text.

Figure 8: A color legend could improve Fig. 8. Are the colors indicative of the years/time intervals? In this case, the labels could be colored (similar to Fig. 9). If the colors represent the a continous coloramp with the intention of displaying the time "distance" to the cliff fall, a small colorbar could be added (with indication of start/end time and the cliff fall).

Thanks for the suggestion. We have added a color scale to clarify the relation between the aerial imagery acquisition years and the time intervals analyzed.

Point-to-point response to Reviewer 2 Dr. Georgie Bennett

We want to thank again Dr. Georgie Bennet for the time devoted to the manuscript during the first and second rounds of reviews. All the comments were considered and included in the revised version of the manuscript. We consider her feedback key to improving the scientific significance, scientific quality, and present style of this manuscript.

Point-to-point response to Reviewer 3 Anonymous

The manuscript introduces an approach to assess the redistribution of sediment before and after a disturbance. Especially the combination of photogrammetry and seismic methods to bridge spatio-temporal gaps is very relevant. The revised manuscript is well-structured and easy to follow. There remain only a few minor questions in regard to the photogrammetric approach.

We thank the reviewer for their encouraging comments and the time devoted to the manuscript. The suggestions regarding improving the working and moving towards using the photogrammetric point clouds to decrease uncertainty are very welcome. We are looking forward to continuing our research on the usability of nadir-view aerial photogrammetry in the field of topographic change detection and natural hazards.

Why did the DSMs from aerial photogrammetry need some further co-registration? If I understood correctly the data was already provided including the georeferencing information (i.e., camera poses). Were there issues in the bundle adjustment during the photogrammetric processing? I think, this should be displayed shortly.

Despite having all the relevant information regarding the photogrammetric flight i.e., camera orientation and camera calibration, there are still slight systematic differences between years, mostly in the vertical component. These slight differences are significant in the level of detail we aim to analyze; therefore, we propose the co-registration approach in order to extract the best results from the available data.

Furthermore, the authors use a Helmerttransformation to align the areas of interest. Also, this approach might be fine in this application, I think in future studies an automatic approach considering matched stable points via ICP (iterative closest points) would be more suitable.

We agree with the reviewer that ICP normally leads to better registration results. However, the point density obtained from the photogrammetric surveys, combined with the lack of stable regions at the summit limits its application.

In addition, the usage of time-SIFT according to Feurer & Vinatier (2018) or Cook & Dietze (2019), which was specifically developed for change detection, could further solve issues with remaining alignment errors.

We appreciate the suggestion. We have already included SIFT in the registration workflow for further publications.

Another issue remains in regard of the error consideration. As the authors highlight the importance of error propagation to best assess the accuracy of the finally derived volumes, I am surprised that no approach like M3C2-PM (James et al., 2017), which allows for the consideration of spatially correlated errors in photogrammetry point clouds (instead of a global error) and is especially relevant in the complex terrain introduced in this study. When using this tool, also the approach to classify different topographic regions would not be needed (see also lines 484-486). Already, the first M3C2 version (Lague et al., 2013), originally developed for laserscanner data, aims to deal with these issues. In general, M3C2 should be preferred over cloud-to-cloud distances (chapter 3.2.1) as they also provide significance information and are less influenced by point cloud densities and data gaps (especially relevant in complex terrain).

It is a very good suggestion. We decided to work with DSM rather than point clouds because we aimed to develop a methodology that can be used for fast detection of topographic changes at a wider scale i.e., mountain ranges, as a support for an early identification of hazardous regions. Even if the processing of point clouds has peaked in recent years, a lot of pre-processing is still needed to obtain relevant M3C2 distances. Working with the photogrammetric point clouds extracted from the nadir-view aerial imagery might decrease the volumetric uncertainty of the rockfalls but increase considerably the processing time. However, we will consider exploring the usability of M3C2 on the nadir-view aerial imagery photogrammetric point clouds in further research.

The authors discuss the relevant issue of bad representation of vertical structures in 2.5D data (chapter 3.2.1). However, why was no comparison done to the mentioned UAV data, which provides a more favorable perspective at the cliff and could thus serve as a suitable reference?

Unfortunately, the UAV monitoring at the summit started in 2017 a couple of years after the cliff fall, therefore, the representation of the pre-event slope topography is only possible by using the aerial photogrammetry point clouds from 2015 or earlier. The point cloud from 2015 represents poorly the southwestern slope, therefore, we used the most complete point cloud from 2014 to calculate the total volume of the rockfall.

In addition, when volumetric measurements done, it would be more suitable to fit a plane into the cliff and use this plane for the subsequent projection for the volumetric calculations and thereby to some degree avoiding the mentioned interpolation issues. Might that be an option of further assessment?

We mentioned (line 188) that we used non-interpolated DSMs to avoid the creation of errors. On the other hand, fitting a plane to generalize the pre-rockfall surface is an option, however, we have observed that due to the fracture pattern of the summit, rockfalls tend to follow a pseudo-cubic form. Therefore, fitting a plane might underestimate the rockfall volume.

Line 253: steeps to steps?

Thanks for the observation. We have modified it.

Line 411: though time to through time?

Thanks for the observation. We have modified it.