Review of "How ice apron loss and permafrost degradation promote the Platteikogel rock slide: A thermo-mechanical reconstruction"

Response to RC1, Reginald Hermanns.

Dear Reviewer,

We sincerely thank you for your dedicated time and effort in reviewing the manuscripts.

Major remarks

We addressed the major concerns about unknowns of failure kinematics (did the event fail as one major event as proposed by us, or did it occur as multiple subsequent events, i.e., „rock collapse " as considered by you).

Therefore, the following paragraph was integrated into the discussion section:

The mechanical model indicates that the failure is strongly controlled by the stability of the toe of the slope. Simulated rockfalls (scenario S3) yield in attidional displacement of the failed rock mass above. These findings suggest that the Platteikogel rock slope failure could have occurred as a rock collapse (sequential smaller detachments). However, morphological observations suggest that detachment happened as one major, single push event. The form of deposits (bifurcation - see Fig. 2a,e), the reach angle of 24.6°, and H/L ratio of 0.45 suggest that the failure can kinematically be classified as a rock avalanche, likely resulting from a single push event (cf. kinematic model in Figure SM6) The runout length can be explained by the low contact friction and lubrication effect (basal water film) resulting from the basal contact to the glacier surface and present snow cover. The failed volume of 50,000 m^3 is at the lower end of cubatures reported for rock avalanches (cf. rock collapse vs. rock avalanche acc. to Hermanns et al., 2022). To conclude, the Platteikogel rock slope failure likely occurred as one major failure event, which was preceded by rockfalls observed in the decade before (Fig. 3) and by detachments shortly after. Post-failure activity was indicated by proximal deposits that are generally larger than distal deposits (Detailed map in Fig. SM7), suggesting secondary failure events.

To emphasize clarity, we produced new figures. A kinematic model and a detailed post-failure orthophoto (showing block sizes of deposits) were added to the supplement (Figure SM6, SM7 related to the above-mentioned discussion).

Moreover, Figure 2 was extended with a slope map to visualize the steep topography, as addressed by your comments. The profile was added (Fig. 2d). Slope maps of pre- (d) and post-failure state (e) are shown.

Newly added figures are shown at the end of the response.

We adapted the landslide terminology. Now, the more general term of rock slope failure is used throughout the publication, leaving aside process kinematics. "Rock slide" was substituted with "rock slope failure" throughout the manuscript.

Moreover, we adapted the title by switching to the new terminology, and from the present to the past form of the verb "promote": *How ice apron loss and permafrost degradation promoted the Platteikogel rock slope failure: A thermo-mechanical reconstruction*

We modified the following figures to increase readability by enlarging sizes/text/colorscales or rearranging material: Fig. 2,5,6b,9, A3. Figure 11 and A5 were split from one figure with 10 subfigures into two figures with 5 subfigures, respectively.

Minor remarks

Our answers and comments to your „minor“ observations are found below your comments in the following section.

Line 66 and 67: why is schistose and muscovite written in capital letters?
Corrected.

Line 68: numbering of supplementary material different to numbering of supplementary material in line 101.
There is an appendix (Figure A#) and supplementary material (Figure SM#). It is clearly stated in the manuscript.

Line 70: I actually see gullies on the image with two orientations.
The label refers to Fig. 2a rather than 2b; it has been corrected now.

Line 86,87: I cannot see this on the figures.
Gullies are hardly visible; true. We corrected the wording and highlighted the debris in the figure now.

Figure 2: Include orientation of figure.
Corrected.

Line 102: I think the profile line should be included in the main body of the paper as many figures reference to that.
Corrected.

Line 213: This was nicely documented by: Kuhn, D., Hermanns, R. L., Fuchs, M., Schüßler, N., Torizin, J., Aga, J., et al. (2025). Warming-induced destabilization of polar coastal rock cliffs and the role of thermokarst: A case study of Forkastningsfjellet on Svalbard. *Science of The Total Environment*, 968, 178807.
We added this citation to the existing ones. It’s a great backup of the proposed theoretical framework by field-based evidence!

Figure 5: This figure strongly suggests that several subsequent failures are feasible.
Indeed. As we described in the study site, rockfalls (small failures) precede the major failure event. If the major event happened as a single push rock avalanche or as a rock collapse (multiple sequential failure events), is now discussed in the added paragraph.

Line 399, 400: This concept was discussed much earlier using different terminology: static boundary conditions (conditions that do not change in time), dynamic boundary conditions (conditions that change in time), triggering factors. (Hermanns, R., Niedermann, S., Villanueva Garcia, A., & Schellenberger, A. (2006). Rock avalanching in the NW Argentine Andes as a result of complex interactions of lithologic, structural and topographic boundary conditions, climate change and active tectonics. *Landslides from massive rock slope failure, NATO Science Series IV*, 49, 539-569.). However, ice aprons and permafrost were not included in the list by Hermanns et al., 2006.

In our view, the same concept holds true, yet it was phrased in different wordings. Static boundary conditions: The rock slope's predisposition to failure (geology, tectonic structures). With promoting factors and triggers, we refine the suggested concept of triggers by distinguishing promoting drivers (long-term impact, events/actions yielding progressive rock mass damage, and preparing for future failure), and triggers (the detachment itself can be linked to a specific event which directly triggered the failure). The concepts are backed up with recent literature.

Discussion: I think a short paragraph could be included discussing if the event was indeed a one event failure in seconds or if it could have occurred in more length in time or in several events. Does the geomechanically model suggest something?

Added. See first response at the top of this letter.

New Figures:

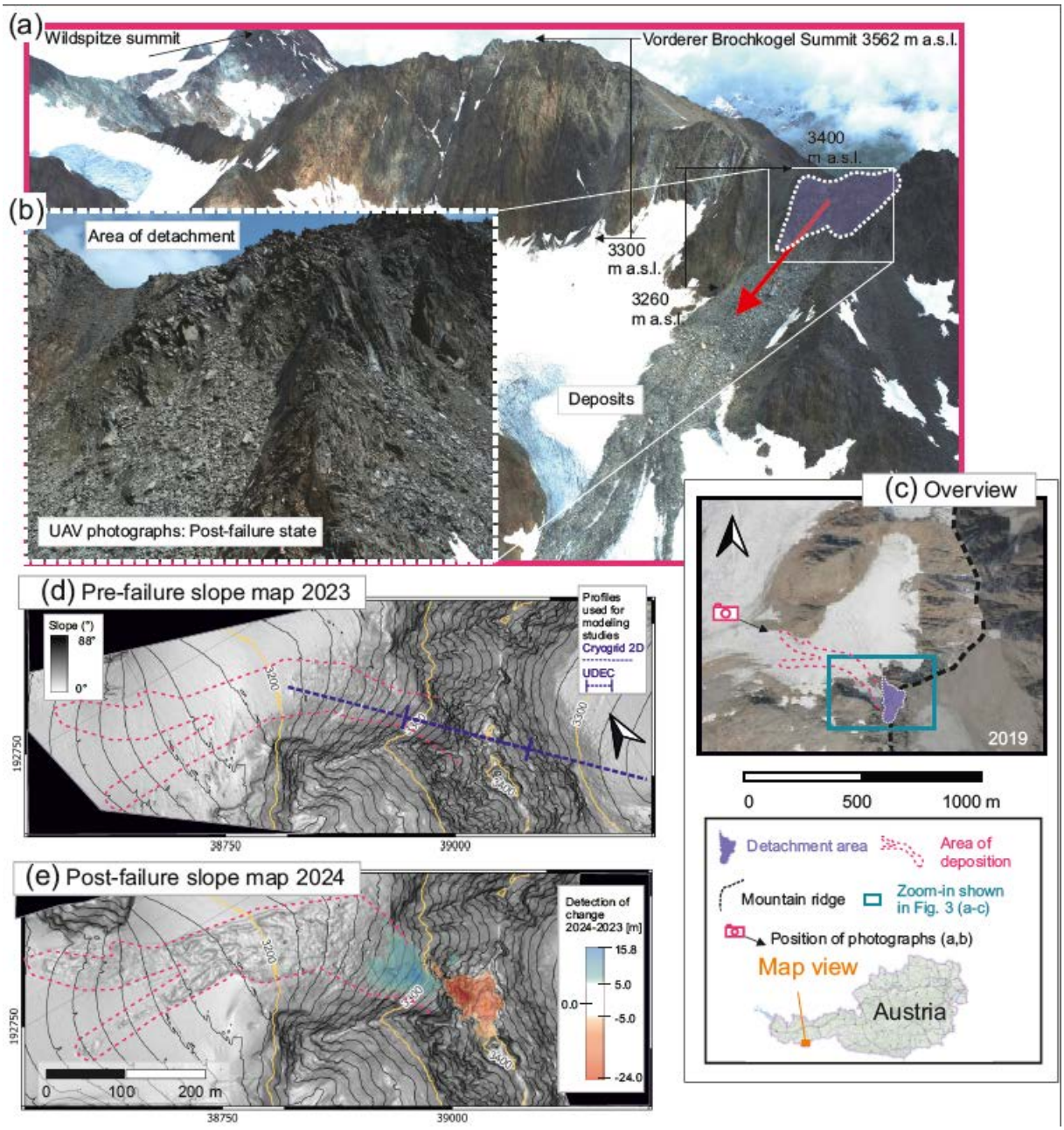

Figure 2. (a) Aerial view from NW showing the full dimensions of the affected area at post-failure state, and (b) zoom-in to the detachment area. Both photographs (a and b) were captured by a UAV on 8 August 2024. (a) From the macro perspective, the steep and vertical gullies incised in the headwall of the Vorderer Brochkogel summit clearly demonstrate the tectonic structure of the foliated metamorphic rock mass. (b) The shape of the individual boulders and blocks of the disintegrated rock mass is slab-like according to the foliation structure. Distinct zones with a high concentration of fine grains are visible in the detachment zone. (c) Overview of the location and extent of the Platteikogel rock slope failure situated in the cirque of the Kleiner Vernagtferner. (d) Slope map at pre-failure state, including the profiles used for modeling studies. (e) Slope map at post-failure state showing the morphology of deposition, and the change detection (threshold of detection: 5 m). Data source: (c) Orthophotography acquired by Land Tirol - https://www.tirol.gv.at/data/ (last access: 7 January 2025)

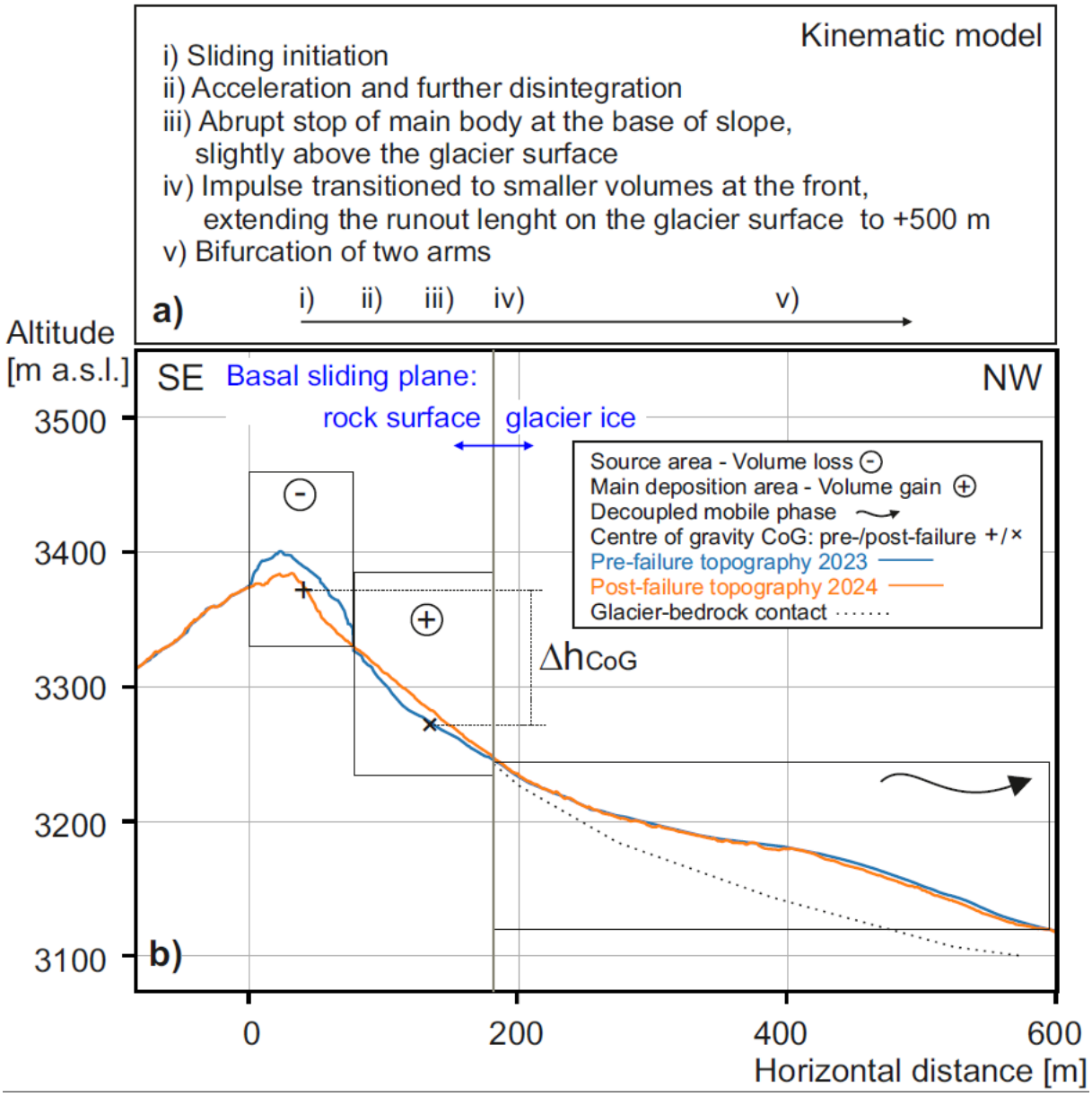

Figure SM 6. Kinematic model of the Platteikogel rock slope failure. (a) Chronological description along the travel path. (b) Cross-section covering the full extent from the detachment area to the distal deposits.

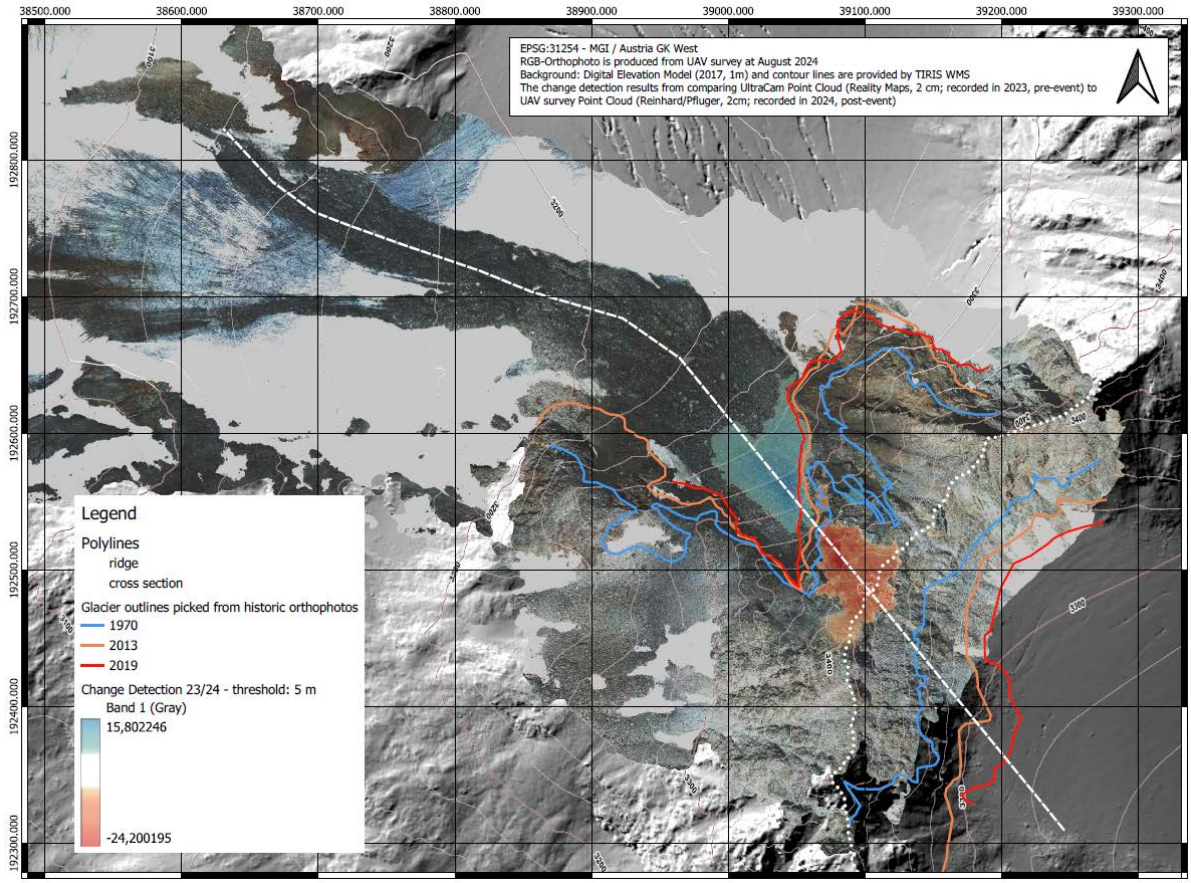

Figure SM7. Overview map of the post-failure state. (Note that the Figure is provided in the final publication in a higher resolution to enable zoom-in to the deposits.)