EGUSPHERE-2025-4630: Answers to Reviewer Comments

Glacial decline next to stable permafrost in the Dry Andes? Vertical glacier surface changes and rock glacier kinematics based on Pléiades imagery (Rodeo basin, 2019–2025)

Comments by Anonymous Referee #1

General comment

The paper presents a detailed investigation of glacial and, in particular, periglacial landforms in the Rodeo Basin of the Dry Andes. Using Pléiades stereo and tri-stereo imagery, the authors derive both vertical and horizontal surface displacements through DEM generation, DEM differencing, and feature-tracking techniques. They also provide an in-depth assessment of their methodology, including a rigorous quantification of landform velocities and the associated Levels of Detection (LoD).

The results indicate that the monitored rock glaciers show no consistent trend toward acceleration or deceleration. This suggests that permafrost-related landforms in the region currently exhibit a relatively stable deformation regime, highlighting their greater resilience to climate warming when compared with the faster melt rates observed for glaciers and debris-covered glaciers.

The paper is well structured, but some improvements and minor reorganizations could help make the text more fluent and clearer. Additionally, a broader discussion addressing some of the open issues (outlined in the following section) would strengthen the manuscript and contribute to a more comprehensive and robust overall presentation.

I suggest refining the writing in sections 4.5 and 5.3 to enhance fluency. Section 4.5 is presented largely as a sequence of results, and section 5.3 combines multiple themes, which affects the coherence of the argument.

Dear reviewer, thank you for your thorough analysis of our manuscript and for the time you invested. We will pay specific attention to sections 4.5 and 5.3 when revising our manuscript.

Detailed comment

Abstract: The abstract is clear and presents the analyses conducted with a good level of detail. However, reading it, it sounds like a list of activities done, with maybe too many “we” in a row. E.g. “We investigate”, “we calculate”, “we follow”, “we conduct”, “we detect”, “we find” in only few lines. I would suggest revising it making the text more homogeneous and fluent. *We have adapted the abstract accordingly.*

Line 28: please insert the extended name of LoD acronym. *We have inserted the extended name ‘Level of Detection’ for LoD.*

Line 130: Do the mapped rock glaciers already have an activity attribute (active/ inactive)? How is this attributed to them? *Yes, the rock glaciers as mapped by Argentine Institute for*

Snow, Ice and Environmental Sciences (IANIGLA-CONICET) in collaboration with the Argentine Ministry of the Environment and Sustainable Development (Zalazar et al. 2017) are attributed with a status of activity. The differentiation is based on visual inspection of remotely sensed imagery (Zalazar et al. 2017, 2020). We do not use this state of activity as we can rely on our Pléiades-based monitoring of rock glacier surface changes indicative of a rock glacier's activity attribute. We have added the reference below to our manuscript to provide additional details to Zalazar et al. 2017. The revised version reads "For our analysis, we treat rock glaciers indifferent of their mapped state of activity allowing us to rely on measured activity rather than the visual interpretation of surface features as conducted during the establishment of the inventory (Zalazar et al. 2017, 2020)."

Zalazar L. et al. (2020): Spatial distribution and characteristics of Andean ice masses in Argentina: results from the first National Glacier Inventory. Journal of Glaciology. vol. 66, no. 260, pp. 938–949. DOI:10.1017/jog.2020.55

Line 170 and caption of Tab. 2: Stammler et a., YEAR (?) *The data used in this manuscript is in review with PANGAEA (https://doi.pangaea.de/10.1594/PANGAEA.988303). We adapted the manuscript and include Stammler et al. (2026) in both instances, as well as the full reference in the reference list. The revised version reads "We publish the additional DGNSS measurements used in this study in the paper-accompanying dataset (Stammler et al. 2026)." It further reads "All other DGNSS data are published in Stammler et al. (2026)."*

Lines 177-178: It is not clear how the bounding box are created. First a buffer of 500m is extracted around glacier and rock glaciers polygons and then a bounding box is created around the so extracted features, right? Please try to clarify this better. *Yes, we buffer the inventoried landforms first and generate rectangular bounding boxes after, resulting in bounding boxes with minimum 500 m distance to each of the landform polygons to clip our Pléiades-based DEMs. The entire processing is conducted in ArcMap 10.7.1. We make this point clear in the revised version of our manuscript. The revised version reads "We buffer the inventoried landforms and generate rectangular bounding boxes, resulting in bounding boxes with minimum 500 m distance to each of the (debris-covered) glacier and rock glacier polygons to clip our Pléiades-based DEMs."*

Lines 186-189: I find it quite difficult to understand the meaning of the cumulative median and how it is computed. Also, I don't get if the vertical change is computed only as cumulative median over time or as vertical surface change normalized to full years. Could you please better formulate this sentence? *We adapt this sentence to "Depending on the figure, vertical surface change across the cryospheric landforms in the Rodeo basin is compared as total change (sum of annual median change, Fig. 2A) or as vertical surface change normalized to full years, both calculated as median for the landforms' surfaces, Fig. 2B-D and Fig. 5A." We no longer use 'cumulative vertical surface change' but refer to 'Total vertical surface change'. The revised caption for fig. 2A now reads "Total vertical surface change for glaciers, debris-covered glaciers and rock glaciers for 2019-2025. Calculated as the sum of the median annual vertical surface change per landform polygon and within the landform surfaces (e.g., no rock glacier* *fronts) based on DEM differencing between clipped, co-registered Pléiades DEMs." In agreement, we adapt the y-axis label in fig. 2A to "Total vertical surface change".*

Vertical surface change calculated as annual vertical surface change normalized to full years is used in fig. 2 B-D and 5D. This corresponds to the change between two acquisitions normalized to 365 days instead of keeping the true time interval between the two acquisitions for better comparability between the changes.

Lines 192-195: I suggest moving the section explaining how the LoD is derived right after the description of the image coregistration process (around line 186). This will make it immediately clear how the LoD is determined before you introduce the vertical surface-change quantification. *We agree. The paragraph now starts out with the preprocessing and co-registration, continues with the LoD calculation and finishes with the DoD generation.*

Lines 212: In the LoD estimation, the terrain outside the landform polygons is assumed stable (line 194). Yet, the text notes that the LoD for horizontal displacements accounts for potential true surface change (e.g., fluvial processes) occurring outside these polygons. Could you clarify this apparent inconsistency? If fluvial dynamics may be active, how is the 'stable terrain' assumption justified for LoD estimation? *We acknowledge that this could be interpreted as an inconsistency and added "to be predominantly stable" to the L190. In our feature tracking approach as well as for the calculation of vertical changes, we need to set a reference frame that is stable in horizontal or vertical direction. The choice of a median instead of mean can be seen as a precaution for cases where singular points of the 1000 automatically selected and used for the LoD's calculation are coincidentally placed on a moving object. The assumption that terrain outside the glacier and rock glacier polygons is stable can be confirmed with our analysis. Moreover, note that a shifting river channel or a rock fall will likely not be matched by our approach, as the geometry and surface texture change will not make it recognizable as the same feature anymore. To increase clarity, we revise the sentence and write "We accept the median of the feature tracking results at these 1000 random points as LoD. Selecting the median serves as a precautionary measure against singular points coincidentally placed on moving objects."*

Line 271: "an LoD" *We adapted the manuscript to 'a LoD'.*

Line 322- 327: The manuscript states that large and fast rock glaciers occur at higher elevations, on gentler slopes, and exhibit lower median vertical surface change. Could you elaborate on the physical mechanisms that might explain this pattern? If vertical deformation is limited, motion must be predominantly horizontal. What factors, beyond surface slope, could control this horizontal displacement? *Based on the investigation of vertical surface change and horizontal velocity on selected rock glaciers that fall into this category (Dos Lenguas and El Paso rock glaciers in fig. 3C-D; fig. 6 A-B), permafrost creep is determined as dominant physical mechanism. While higher elevation likely contributes to suitable ice content, the reduced slope is mainly driven by the volume of the large rock glacier itself which fills, e.g., valley structures. As on Dos Lenguas rock glacier, reduced velocity approaching the rock glacier front indicates a* *compressional flow regime that leads to a typical ridge-and-furrow pattern with alternating positive and negative vertical surface changes of considerable magnitude, cf. fig. 3D. And it is this compressional flow regime that also leads to the growth of a steep front with a gentle surface above.*

In addition, the relationships between elevation, slope, and the different rock-glacier classes are not immediately clear from the current figure. I suggest expanding this section and perhaps exploring a combined plot of elevation versus slope, with median velocity represented through a color gradient. Such a visualization could help clarify the spatial distribution and dynamics of the landforms. *We derive correlation matrixes to quantitatively describe the correlation between the results, tab. 1. The coefficients support that rock glaciers located at higher location are faster, that smaller rock glaciers are characterized by higher slope than larger rock glaciers, and that larger rock glaciers are faster than smaller. Comparatively low correlation coefficients support the categorization in the original fig. 5 while indicating a complex interaction of processes. We add the table to the supplementary material.*

Tab. 1 Correlation matrixes between elevation, slope, median velocity and polygon size.

	Elevation	Slope	Median Velocity	Polygon Size
Elevation	*1.000000000*	*0.019828470*	*0.197756716*	*-0.004271207*
Slope	*0.019828470*	*1.000000000*	*-0.003521543*	***-0.474669752***
Median Velocity	***0.197756716***	*-0.003521543*	*1.000000000*	***0.211467562***
Polygon Size	*-0.004271207*	***-0.474669752***	***0.211467562***	*1.000000000*

To showcase the relations between elevation and slope, but also median velocity and polygon size, we include the suggested figure, here fig. 1, as well as an adaption where polygon size is used to colour the datapoints, fig. 2. To take care of the effect of different time periods, e.g., the effect of snow cover in 2022-2023 cf. section 5.3 and fig. S1, we differentiate these in subplots. The new figures support the original fig. 5, provide more detail but do not add new insight. Therefore, we decide to keep the original fig. 5 in the manuscript as it highlights the main findings of the analysis and add the now produced figures, fig. 1 and 2, in the appendix to showcase the nuances of the analysis.

Large rock glaciers (fig. 1, row 2) clearly differ from the other two categories in slope, see original fig. 5C. In general, faster than the small and fast rock glaciers (row 3), annual difference challenge a very clear boundary between the two categories, see original fig. 5D. Small and fast (row 3) and small and slow (row 4) rock glaciers are characterized by similar slope and elevation but can be clearly separated by median velocity, see original fig. 5D. Large and fast rock glaciers (fig. 2, row 2) can be distinctively separated from the other two categories by polygon size while small and fast rock glaciers (row 2) and small and slow rock glaciers (row 3) are characterized by similar surface area, see original fig. 5A.

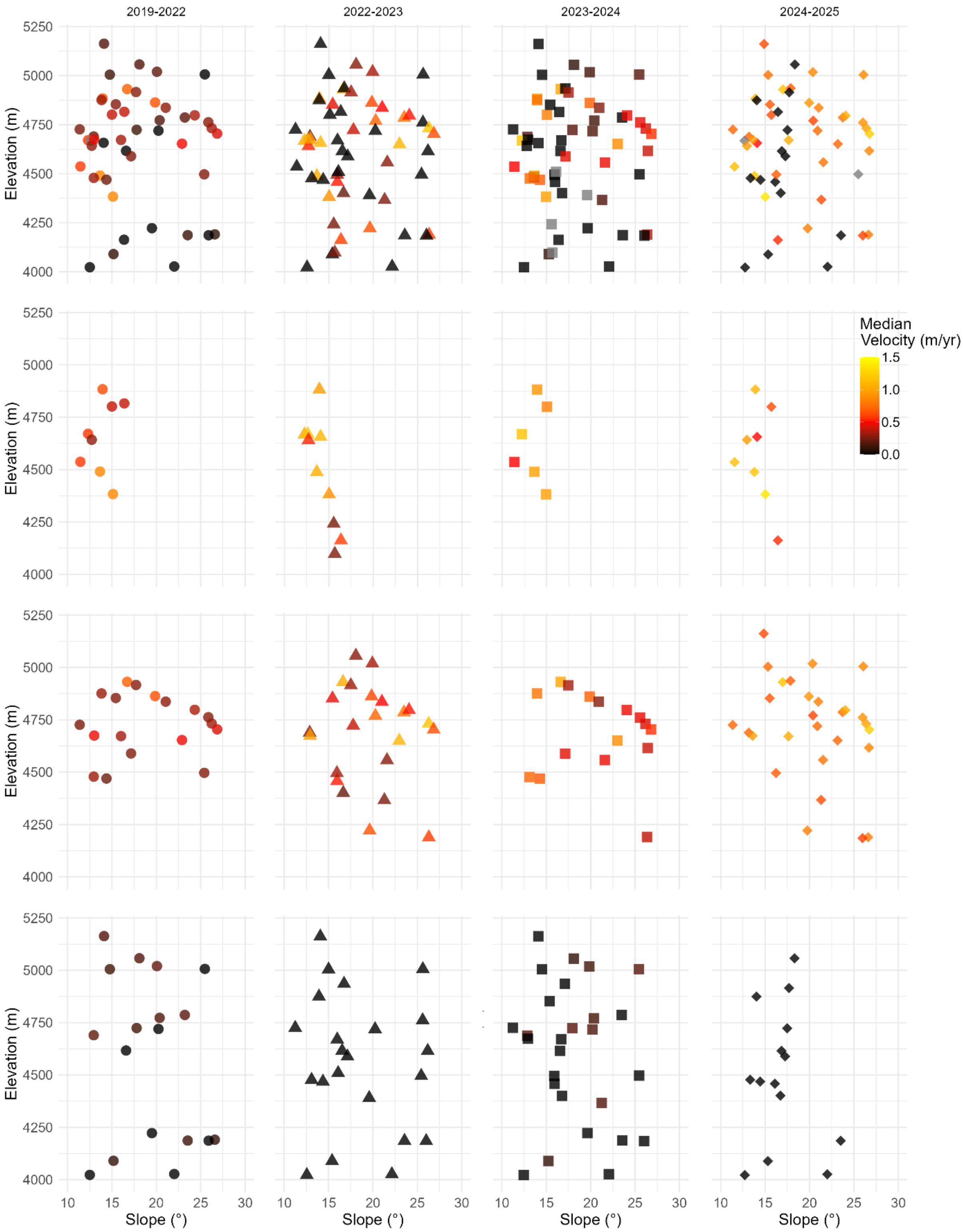

Fig. 1 Elevation vs slope for all rock glacier velocities (row 1), blue category of rock glaciers (row 2), pink category of rock glaciers (row 3), green category of rock glaciers (row 4), coloured by median velocity (m/yr). The categories refer to the original fig. 5. The columns and symbols correspond to the different time episodes: circles (2019-2022), squares (2022-2023), triangles (2023-2024), and diamonds (2024-2025).

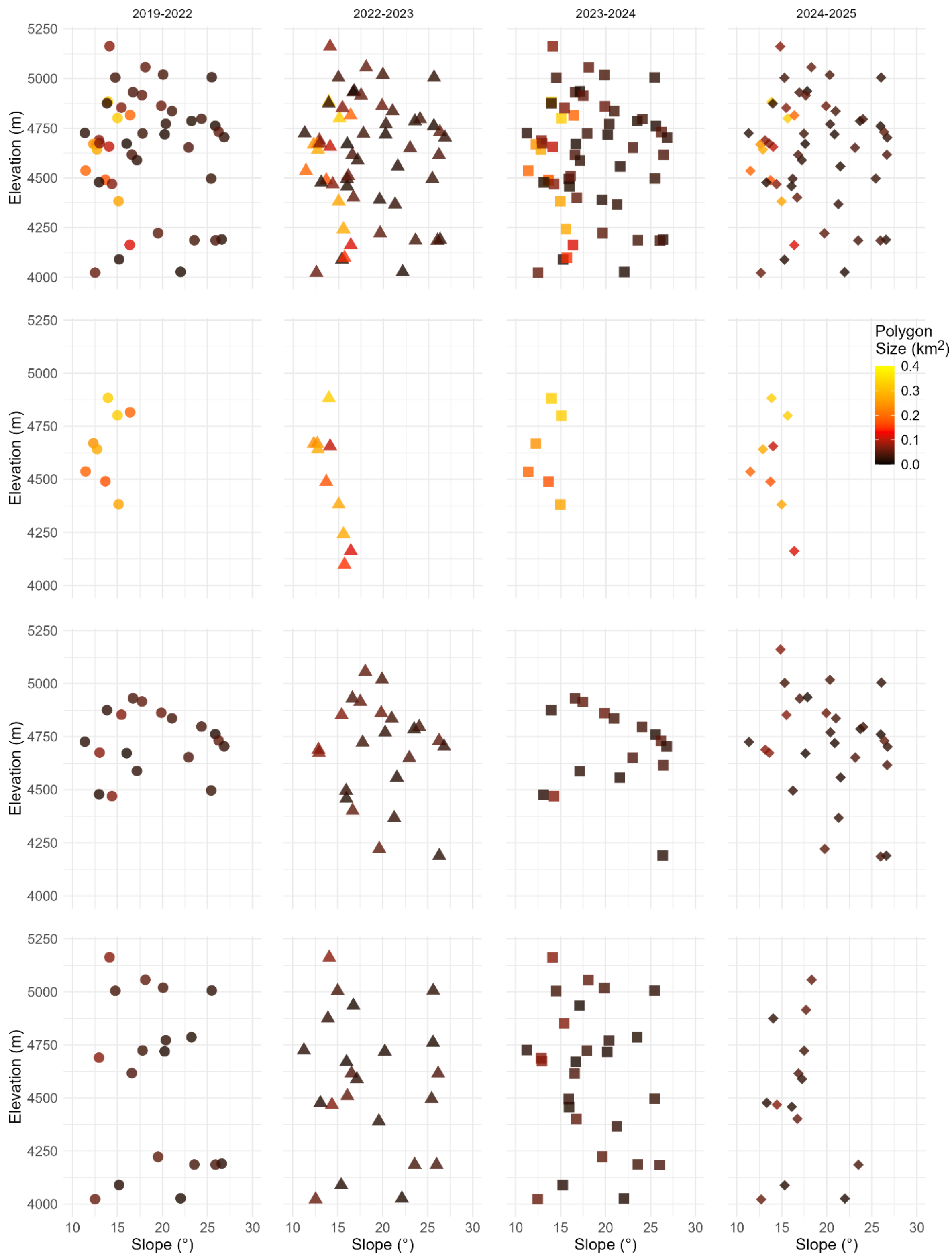

Fig. 2 Elevation vs slope for all rock glacier velocities (row 1), blue category of rock glaciers (row 2), pink category of rock glaciers (row 3), green category of rock glaciers (row 4), coloured by polygon size (km²) – equal to rock glacier surface area. The categories refer to the original fig. 5. The columns and symbols correspond to the different time episodes: circles (2019-2022), squares (2022-2023), triangles (2023-2024), and diamonds (2024-2025).

Line 340: are these vertical or surface velocities? I would suggest always clarifying this in the text. *In the submitted version, we addressed changes in the vertical component as vertical change and changes in the horizontal component as velocity. We adapted the entire manuscript and refer to the horizontal component with 'horizontal velocity'. Interchangeably, we use the term 'rock glacier velocity', as introduced in the original line 60. For example, the introducing paragraph now reads "In this paper, we investigate the current state of the cryosphere in Rodeo basin (Dry Andes of Argentina, 30ºS and 69ºW) by analysing vertical surface change on 19 glaciers, three debris-covered glaciers, and 59 rock glaciers, as well as horizontal surface velocity on, due to data coverage, 47 of the 59 rock glaciers for 2019-2025 based on (tri)stereo panchromatic Pléiades imagery."*

Lines 358-360: the sentence seems to miss a part, and it is not totally clear. *The lines now read: "No rock glacier is fastest for all time periods. The different rock glaciers fastest for a specific time period reach magnitudes of 0.86 m/yr in 2019-2022 (LoD ±0.15 m/yr, Dos Lenguas), 1.16 m/yr in 2022-2023 (LoD ±0.87 360 m/yr, ID 23), 1.18 m/yr in 2023-2024 (LoD ±0.56 m/yr, ID 9) and 1.38 m/yr in 2024-2025 (LoD ±0.64 m/yr, Dos Lenguas)."*

Lines 394-400: In these sentences, the differences between the DGNSS and Pléiades-based velocities are sometimes reported in meters (m), although velocities are expressed in m/yr. It is therefore unclear whether these values refer to differences in annualized velocities or to absolute positional offsets. Please clarify what these numbers represent and adjust the units or wording accordingly to avoid confusion. *The differences between the DGNSS and Pléiades-based velocities ought to be reported in m/yr. We have adapted the manuscript accordingly.*

Section 4.5: The section presents many numerical values (errors, medians, LoDs, differences, per year changes) for three sites and two time periods but rarely summarizes what these numbers mean. *We agree, and also in coherence with your comment at the very beginning, we reorganized the chapter transferring the results into tables and splitting the text in three paragraphs: DGNSS measurement error, DGNSS-based vertical surface change and horizontal surface velocity, and lastly to a comparison of the DGNSS- and the Pleiades-based rock glacier surface changes. Each of the paragraphs is introduced with an explicative sentence setting the intent of the analysis or comparison, e.g., "Vertical and horizontal errors of our DGNSS measurements describe their measurement quality. The magnitude of acceptable error depends on the magnitude of the surface changes investigated."*

Line 445: remove rock glaciers at the end of the sentence. *Our intention was to say that these bodies of rock and ice equal rock glaciers. To reduce potential confusion, we agree with removing 'rock glaciers'. The sentence now reads "This corresponds often with smaller landforms, as larger landforms with their elongated tongues 'flatten' the topography by building up bodies of rock and ice."*

Line 494: by is repeated 2 times *We adapted the manuscript accordingly.*

Line 517: How were the UAV-derived surface changes obtained? From differences between point clouds or offset tracking on images? *In both Halla et al. (2021) and Stammler et al. (2025a) all surface changes are derived from UAV imagery based DEMs: Vertical surface changes are derived from differencing of georeferenced DEMs and the horizontal surface changes from feature tracking on UAV-DEM derived hillshades. No surface changes are based on differences between point clouds. For details on the processing, please kindly refer to the original publications.*

Section 5.3: Overall, the section contains valuable comparisons and a solid contextualization of your vertical surface change results with previous studies. However, the text would benefit from clarification and improved structure to enhance readability. Several paragraphs are dense, and the narrative flow is sometimes difficult to follow. For example a reorganization of the text into smaller thematic paragraphs on snow cover impact, comparison with published mass balances and debris-covered glaciers could make the text easier to read. *We rearranged original section 5.3 and split it into three sections: 5.3 Vertical surface change of glaciers in the Rodeo Basin, 5.4 Vertical surface change of debris-covered glaciers in the Rodeo Basin and 5.5 Rock glacier kinematics in the Rodeo Basin. This allows for a landform-oriented separation which increases readability.*

Figures:

Fig.2: What are the triangles, square and circles? It is not clear in the caption. *The different symbols are used to denote the different time periods, relevant in row 2 of fig. 2. Circles are used for 2019-2022, squares for 2022-2023, triangles for 2023-2024, and diamonds for 2024-2025. We now include legend entries to be more precise.*

Fig. 3: Is the reported vertical surface change derived directly from the DoD between the 2019 and 2025 DEMs, or is it calculated as the cumulative sum of DoDs from consecutive DEMs? *The vertical surface changes are derived directly from the DoD between the 2019 and 2025 DEMs. The revised caption of the original figure 3 now reads "Vertical surface changes (m) between 2019-2025, generated by DEM differencing of the co-registered Pléiades DEMs of 2019 and 2025, for Agua Negra Glacier (…). "*

Fig.5: As for Fig.2 it is not clear what squares, triangles and circles refer to. As also stated in the detailed comment (Line 322-327) I would suggest trying to plot elevation and slope in the same graph to see if the different types of rock glaciers cluster in specific areas. *Regarding the symbols and their reference to the different time periods, please see our answer to your comment on fig. 2. Regarding the additional plotting, please see our answer to your comment on the original line 322-327.*

Fig.7: In the vertical axis I would explicitly state "median horizontal velocity" *We agree and include your suggestions to our original fig. 7 which is now fig. S3 (supplementary material), as well as to the revised fig. 7, in coherence with the suggestions of reviewer 2.*

Fig.8: I suggest putting a title to this graph with also the position of the point considered. Which velocity is the one from Sentinel-1? Is it measured along LOS or projected on slope? For a more detailed comparison between SAR and optical data, a reprojection of the optical-derived velocity values onto the SAR line of sight is recommended. Have you tried this? I suggest adding a brief explanation of the criteria used to select the Sentinel-1 baselines, as their selection currently appears rather arbitrary. *We adapt the figure caption to increase readability and to answer some of the questions raised in your comment. The revised figure caption reads "Inter-method comparison between our Pléiades-based rock glacier velocity compared to Sentinel-1 InSAR (Strozzi et al. 2020; white, grey and black dots) and UAV-based rock glacier velocity (Stammler et al. 2025a; red and dark red solid lines), all for a coordinate located in the upper part of Dos Lenguas rock glacier, see Fig. 6B. The colour of the dots corresponds to differences in time interval caused by the observation scenarios of the Sentinel-1A and 1B satellites. The InSAR-based velocity is measured along LOS and is projected along the maximum slope direction, for details please see Strozzi et al. (2020). Given this projection, we do not reproject the optically-derived velocities - here presented with solid lines (red: UAV, dark red: Pléiades). Dashed lines indicate the corresponding LoDs. Note that velocities reached in the upper part of Dos Lenguas are higher than respective median values." To not duplicate information, we kindly refrain from including a title to the figure. However, we now include (Strozzi et al. 2020) and (Stammler et al. 2025) to the legend to indicate that this is not data from the current study.*

Assuming you refer to temporal baselines in your comment, the answer is that Strozzi et al. (2020) processed all the acquisitions in series. The differences in time interval are caused by the observation scenarios of the Sentinel 1A and 1B satellites and the changes that occurred during the time period investigated.

Thanks - *Thank you!*

EGUSPHERE-2025-4630: Answers to Reviewer Comments

Glacial decline next to stable permafrost in the Dry Andes? Vertical glacier surface changes and rock glacier kinematics based on Pléiades imagery (Rodeo basin, 2019–2025)

Comments by Dominik Amschwand

First, I would like to apologize for the last-minute submission of my review. I enjoyed reading the paper and have no major issues, just a remark on the methodology, a suggestion for an additional analysis, and a few minor points.

The authors analyse vertical and horizontal surface velocities over the 6-year period 2019–2025 of 19 glaciers, 3 debris-covered glaciers, and 59 rock glaciers in the Rodeo catchment in the Dry Andes of Argentina using Pléiades imagery. The detailed kinematic analysis includes validation using in-situ DGNSS measurements at selected sites, which is in itself a logistical feat in such remote terrain. The main finding is that downwasting clean-ice and debris-covered glaciers, showing consistent and considerable surface lowering, contrast with kinematically stable rock glaciers, showing no trend (small vertical changes fluctuating about zero). The key contribution is a large kinematic data set in an otherwise data-scarce region at a crucial point of time, providing a baseline observation to assess the future permafrost evolution in the Rodeo catchment.

The important methodological choice in this work is to approach glaciers and rock glaciers, i.e., glacial and periglacial landforms, from the surface kinematics and the mass conservation equation, essentially arguing with the geodetic mass balance (as pioneered by Cusicanqui et al. (2021) for rock glaciers). In that sense, this study adds a valuable complementary approach to that of assessing changes in the ground thermal regime (as e.g., in Koenig et al. (2025)), where rock glaciers as climate-conditioned permafrost landforms are investigated with the lens of the surface energy balance/energy conservation equation. However, while down-wasting glaciers can be quite directly linked to climatic warming/drying (with little lag), kinematically stable rock glaciers are more indirect proxies of stable ground thermal conditions and the climatic forcing (L54–56, L548–556; Yu et al., 2025). The authors raise this point in L512ff: "The question here is the comparability between the meaning of vertical surface changes on glaciers and rock glaciers, which is why we focus on rock glacier velocities as indicator of (in)stability of permafrost conditions […]". Depending on the ground temperature and the soil freezing characteristic curve (SFCC), ground warming might not lead to excess (!) ice melt and subsidence. Furthermore, interannual ice storage changes as estimated by Halla et al. (2021) for the Dos Lenguas rock glacier could in principle mask (in their short monitoring period) a slow long-term subsidence (such processes could be discussed more thoroughly). Taking horizontal creep rates into account is a smart move that makes the correspondence between stable ground thermal conditions and surface kinematics convincing enough in the scope of this analysis, albeit future in-situ investigations of the ground hydro-thermal regime would of course be helpful for a more conclusive assessment.

Dear Dominik, thank you very much for taking the time to review our manuscript, for the sharp and thoughtful overall summary and for providing the very helpful comments. To address your points raised on more explicitly elaborating on the meaning of our findings in the scope of the rock glacier analysis, we add the following paragraphs into our manuscript.

Abstract: … permafrost conditions in the Dry Andes based on borehole investigation and rock glacier kinematics for the last decade. ***This apparent stability may partly reflect the extreme aridity conditions, limit snow insulation and liquid-water input, thereby damping inter-annual variability in ground thermal conditions and associated changes in rock glacier creep.*** *We investigate vertical surface changes of 19 glaciers, …*

Discussion: Thus, we highlight the strong need for continued monitoring of rock glaciers in this basin in this potentially dynamic point in time. Slow and small rock glaciers do not show any activity above the LoD, confirming our conclusion on little activity. ***A plausible explanation for the absence of a basin-wide acceleration is that, in this semi-arid Andean setting, persistently low precipitation may limit both seasonal snow insulation and liquid-water input into the active layer, thereby damping interannual variability in ground thermal conditions and hydro-mechanical softening that can otherwise promote speed-ups in rock glacier creep (Cicoira et al., 2019). This interpretation is consistent with evidence that aridity strongly constrains permafrost thermal regimes in the Dry Andes (Koenig et al., 2025) and with recent findings that precipitation scarcity can contribute to comparatively stable rock glacier behaviour (Stammler et al., 2025a). Under this hypothesis, the slightly higher velocities in 2024–2025 would reflect short-lived departures from typical moisture limitation (e.g., an anomalously wet season) similar to the variability described in Halla et al. (2021), a possibility that requires confirmation using local precipitation/snow proxies and longer kinematic time series.*** *This lack of a regional trend in increasing velocities elucidates stable permafrost conditions in Rodeo basin during 2019 …*

Conclusions: … domains of the Rodeo basin, we conclude a delayed response of the permafrost landforms to the increasing temperatures that are declining the glaciers and debris-covered glaciers alike. ***We further hypothesize that the absence of basin-wide rock glacier acceleration is partly linked to extreme aridity, as persistently low precipitation can reduce snow insulation and liquid-water input to the active layer, damping inter-annual variability in ground thermal conditions and limiting kinematic changes.*** *Given the hydrological significance of all meltwaters, we highlight the strong need for continued monitoring of surface changes in the glacial and periglacial domains, supported by interdisciplinary studies focusing on their potential interaction.*

Minor comments and a suggestion for further analysis

Fig. 7. The large number panels are somewhat hard to synthesize for a human but would be doable for a machine. Consider, for example, a hierarchical clustering (of absolute or normalized median velocities), and report the (few) representative trend pattern(s). This would really be a useful (and not too costly) additional analysis to more quantitatively ground

your key result (L541: “We do not detect a regional trend in increasing rock glacier velocities in the Rodeo basin between 2019-2025, Fig. 7”. (It would be interesting whether these clusters coincide with the three rock glacier groups “fast-large”, “fast-small”, and “small-slow/stagnant” as mentioned in L540f). *We agree with your comment and have redesigned the original fig. 7, see fig. 1. We use the revision as fig. 7 and relocate the original fig. 7 to the appendix. To be able to synthesize the different velocity patterns while including the respective LoDs, we decide to move towards LoD exceedance: For each rock glacier category and time step, we calculate the median exceedance from the corresponding LoD, fig. 1A. We filter the rock glaciers and count them towards a category when velocities are > 0 m/yr and at all time periods coherent with the respective category. Rock glaciers that do not fulfill this filtering are attributed ‘other’ and are shown in grey. To keep the information on residue correlation coefficients and to exemplify the LoDs, we include a selection of three rock glaciers in fig. 1B-D – with the rest now remaining in the appendix. We adapt the corresponding text sections to the new figure.*

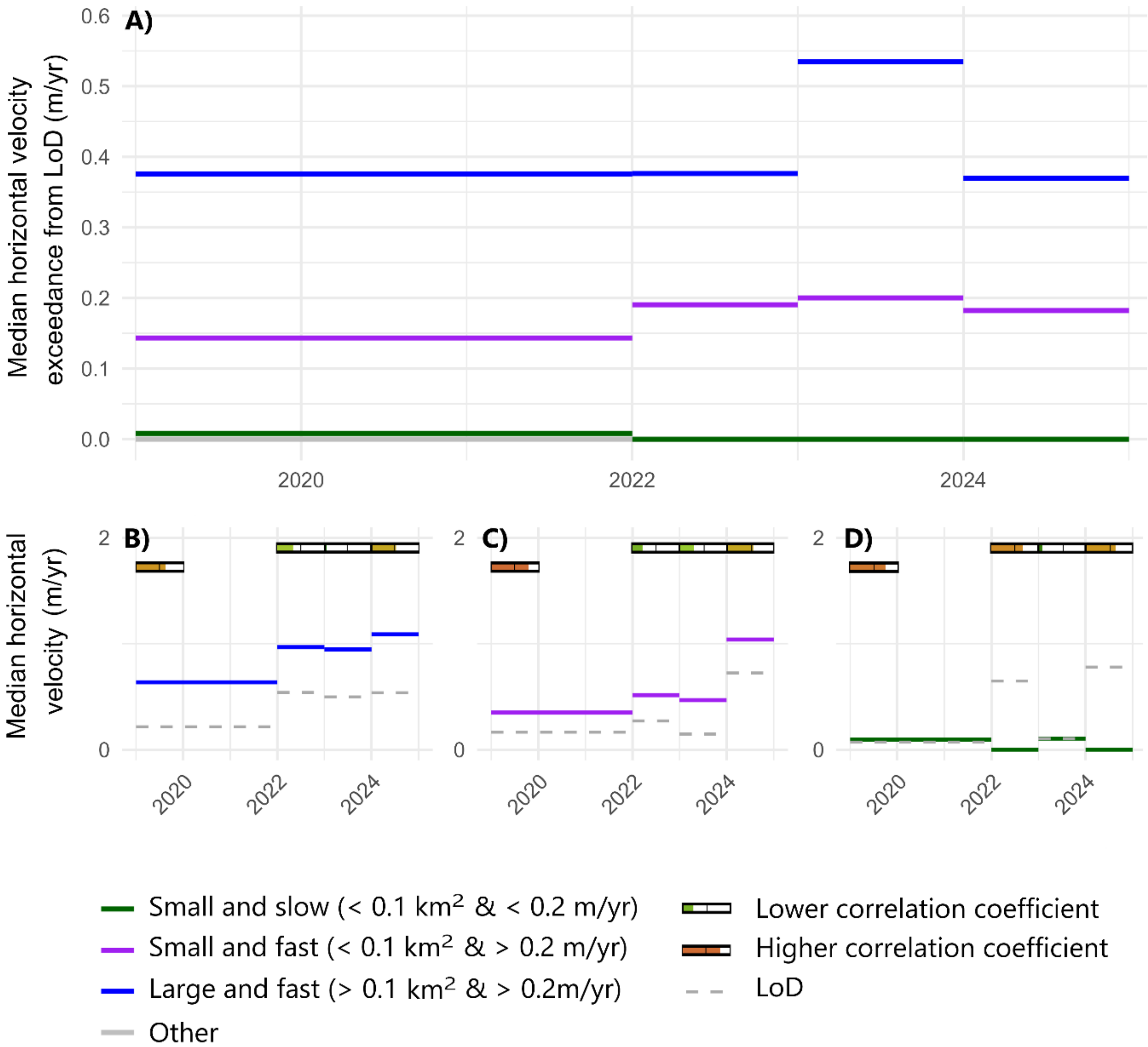

Figure 1 Temporal evolution of median rock glacier surface velocity exceedance from LoD (m/yr) between 2019-2025 based on feature tracking on panchromatic Pléiades imagery. Median horizontal rock glacier velocity is calculated for the rock glacier surface based on tracked horizontal velocity at 5 m resolution. Exceedance is calculated from the corresponding LoD. Rock glaciers are attributed to the three categories when > 0 m/yr and at all time periods coherent with the respective category (A). Selected rock glaciers and their temporal evolution of velocities over time including their LoD and the quality indication using residue correlation coefficients. The latter are included as bars – one each per time period (B-D).

The vertical changes over the landforms are aggregated in terms of the median and not the mean (or any other measure). Why was the median chosen, and wouldn't the mean value be more indicative of the whole-glacier geodetic mass balance? If the distribution of surface lowering is, say, right skewed, then the median is smaller than the mean and would underestimate the glacier-average changes. Are such considerations numerically relevant at all? *We chose the median to limit the influence of outliers on our aggregated results. After receiving your comment, we calculated mean values and plotted them against the median values, see fig. 2. While the differences between median and mean show a little higher difference for glaciers and debris-covered glaciers (polygon numbers > 60, colours purple to pink) compared to rock glaciers (polygon numbers < 60, colours orange to blue), all differences between median and mean are minor. We conclude based on the comparison of our vertical surface change results on glaciers compared to the literature that this effect is negligible.*

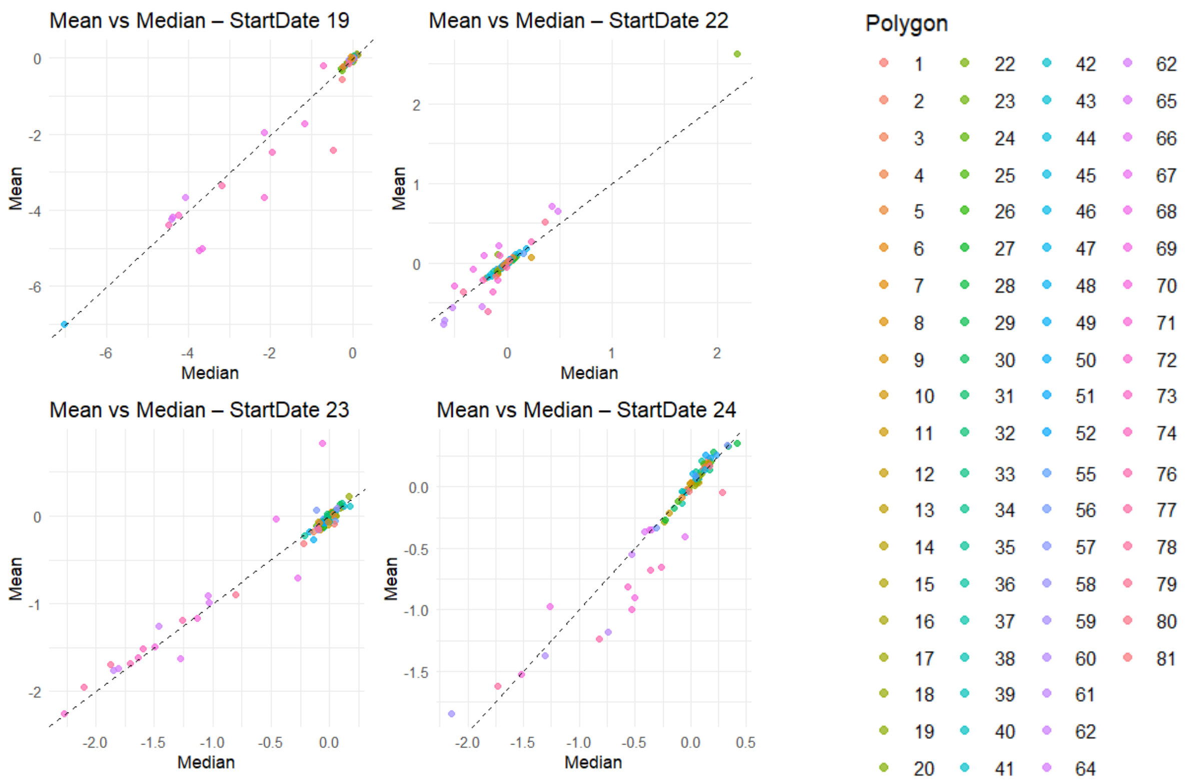

Fig. 2 Vertical surface change per polygon calculated as median or mean. Please note the differences in axis increments when comparing the four subfigures. Polygon IDs < 60 = rock glacier, > 59 and < 79 = glacier, > 78 and < 82 debris covered glacier. StartDate 19 corresponds to the vertical change 2019-2022, and so on.

L25, "dominantly negative annual surface lowering for all glaciers investigated." Consider writing "surface lowering" instead of "negative surface lowering". *We agree and have adjusted the manuscript accordingly.*

L190. LoD abbreviation not defined. *We missed the definition of the LoD and included it now at its first appearance, original line 28.*

Fig. 7: The bars show a "fill level" and a colour. What do they mean? Colour coding: There are 4 colours (black, purple, blue, green) in Fig. 7, but only 3 in Fig. 5. What do the black lines refer to? *The bars and fill levels describe the residue correlation coefficient of the residuals of the*

affine transformation during our feature tracking approach. The fill level scaled from 0 to 1 and the colours essentially show the same. Values are from 0 to 1 whereby low values (0 to 0.5, green to yellow) indicate a lower correlation coefficient meaning a high-quality feature tracking and higher values (>0.5 to 1, yellow to red) indicate a higher correlation coefficient referring to a lower quality feature tracking. This is exemplified in the lower, right corner of the original and the revised fig. 7 and explained in more detail in the original lines 216-222. Regarding the lines: blue corresponds to large and fast rock glaciers, pink to small and fast and green to small and slow. Selected rock glaciers that correspond with these categories are highlighted in these colours; the rest is shown in black. The revised fig. 7 includes a legend.

L309, L344, and others: Consider replacing "horizontal surface change" with "horizontal velocity" or "horizontal displacement (rates)" (the feature tracking gives labelled points whose position can be followed through time, not merely a change). This would make the terminology of "vertical surface change", "rock glacier velocities" (always horizontally defined, correct?), and "glacier surface lowering" more consistent. *In agreement with your comment, we now refer to 'vertical surface change' and 'horizontal velocity' in the entire manuscript. The only exception is when introducing 'rock glacier velocity' in the introduction (original line 62).*

L533ff/L571. What do you mean by "volume dominated" vs. "creep-dominated" and "gravitational force to have a strong impact"? I do not fully understand this distinction, because all active rock glaciers move by gravity-driven creep. Do you refer to the material composition (ice content)? The motivation for this analysis could be better explained and better tied to the conclusions, currently it feels like an argumentative "dead end". *We agree that this analysis was only loosely tied to the main string of arguments and therefore decide to remove it from the discussion on rock glacier kinematics in the revised section '5.5 Rock glacier kinematics in the Rodeo Basin'. This section now focuses on the benefit of using Pléiades imagery to enlarge the analysis from the previously investigated Dos Lenguas rock glacier to the catchment as well as on the absence of a regional trend of increasing horizontal velocities. We add more details on the meaningfulness of this absence as inserted at the very beginning of this document.*

L540. Sentence unfinished ("Fig. 3C-D blue area on rock glacier front"). *With the as such perceived unfinished sentence we intend to refer the reader to the blue area on the rock glacier front in fig. 3C-D as an example of how the horizontal velocity imprints on the vertical change. We have adapted the sentence which now reads "Fast rock glaciers, independent of their size, are characterised by coherent areas of positive vertical surface changes on the rock glaciers front, cf. Fig. 3C-D, caused by the rock glaciers horizontal movement."*

L554: Possible additional references are works from A. Kellerer-Pirklbauer for the Austrian Alps, from PERMOS for the Swiss Alps, and from M. Marcer for the French Alps. *Thank you for pointing out the references which we have added to our manuscript.*

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