

The Cryosphere Discuss., referee comment RC1
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Comment on tc-2021-77

Anonymous Referee #1

Referee comment on "Multi-decadal (1953–2017) rock glacier kinematics analysed by high-resolution topographic data in the upper Kaunertal, Austria" by Fabian Fleischer et al., The Cryosphere Discuss., <https://doi.org/10.5194/tc-2021-77-RC1>, 2021

General comments

This is a very interesting study investigating the long-term evolution of a relatively large sample of individual rock glaciers. Despite the increasing number of studies on rock glacier dynamics and evolution, there is still a lack of knowledge on the past velocities of rock glacier. This study aims at filling this gap and gives very interesting results. The analyses are thorough, very detailed and original. The errors are systematically considered and their analyses are carried out in depth.

I have however a major concern regarding the length and the structure of the manuscript. First, the text is very long and it should be reduced by about 20%. Second, and most important, the manuscript is not well structured. The results and discussion are merged into a single very long chapter, which does not allow the reader to have a clear view on the most important results of the study. The results must definitely be separated from the discussion, which is the classical way for a research paper. The references to the literature must be systematically moved to the Discussion chapter, allowing the keep the Result section more strictly factual (typical examples P16L424-428). There is also a countless number of subtitles. As a consequence of all of this, we get progressively lost. In the end we lose the main information, which is a pity because the quality of the analyses is very good and the results very interesting. Therefore, a strong effort must be made to improve the structure of the manuscript and to make it clearer.

Examples of modifications to the structure to be made :

- Move chapter 4.1 after 4.2
- Chap 4.4 (and 4.3.3., which should be merged with 4.4) should be moved in the Discussion and condensed.

The difficulty for such a study relies on its intrinsic interest : whereas similar studies generally consider one or two landforms, here a large amount of data is available for 9 rock glaciers. Thus, the authors must find a way between presenting sufficient data without losing the reader in too many details. A way to do it would be to focus more on the general trends and to reduce a bit the analyses of the exceptions and of the special cases.

The introduction is a bit lengthy and not well structured. Up to line 55 it's a long summary on the general characteristics of a rock glacier. Not everything is useful, thus I suggest to shorten this part and to keep only what is necessary. Another issue is that we must wait the end of the introduction to know the goal of the study. Ok, the precise objective must be presented after the state of the art, but the general objective, or at least the topic of the paper must be stated much earlier. Thus, I recommend to reorganize the introduction and to better structure it (see specific comments).

The state of the art is generally good, but additional references on the current state/velocities of rock glaciers, including destabilizing ones, could be added. For example Kummert et al. 2018, Vivero & Lambiel 2019, Marcer et al. 2021,...

In such a study it would really help to have a Google Earth link to visualize the rock glaciers, or/and pictures of each rock glacier.

The results of the rock glacier inventory are presented in the Study area section, whereas the method for achieving it is presented after, in the Material and Methods section. This is not coherent. Since this rock glacier inventory is part of this study, the results must be moved in the corresponding section and removed from the Study area section.

The calculated 3D displacements are changes normal to the surface. As explained by the authors, they are an alternative to the traditional DoD, and even a better quantification of the thinning/thickening processes on an ice-saturated permafrost body (see Vivero & Lambiel 2019 for a similar study). But this is not 3D displacement. The latter is rather a displacement that considers the 3 components x, y and z. As such this defines the displacement parallel to the slope angle, and thus the real displacement, contrary to the horizontal 2D displacement. The titles and text related to this must then be reformulated.

If I understand well the chart on Snow cover onset, snow arrived roughly early September around the years 2010. This means that what you consider as the snow cover onset in fact corresponds to the first snow, meaning that snow can then melt completely until new

snow falls. Hence, this parameter cannot have any influence on the rock glacier kinematics. Much more important is the date when a substantial snow cover is established (~50 cm), allowing ground insolation. In addition, I suggest to add as a parameter the date of complete snow melt in spring. This has a strong influence on the MAGST and thus on rock glacier kinematics. See PERMOS 2019. Permafrost in Switzerland 2014/2015 to 2017/2018. Noetzli, J., Pellet, C. and Staub, B. (eds.), Glaciological Report Permafrost No. 16–19 of the Cryospheric Commission of the Swiss Academy of Sciences, 104 pp.

The interpretations of the velocities and surface changes regarding the external parameters are sometimes rather hypothetical and should more systematically rely on existing literature. This would be much easily achieved by moving these interpretations in the Discussion chapter.

Specific comments

P1L12. Two times “change” in the same sentence.

P1L20. In the rest of the manuscript you don’t talk about vertical 3D, but only 3D. Be consistent. But take also in consideration my comment above about 3D.

P2L31. **are** responsible

P2L32. **generally** coarse debris layer (the coarseness depends on the lithology).

P2L33. landforms

P2L38. Remove “also”. If the origin is periglacial, then the ice forms by freezing of water.

P3L77-80. Here you present the results of a specific study on velocity variations for selected rock glaciers. But it must be moved around L60, where you talk about rock

glacier velocities. In addition, it appears weird to give details for a specific region only for one study. Thus, either you stay more general, or you keep these details but, in the meantime, you must give similar details for the other referenced studies.

P3L85. **of** rock glaciers

Figure 1: add the location of the study area in Austria; add the location of the highest summit.

P4L103. Why "pseudo" ? It sounds weird.

P4L106-108. Obviously the road was built for the ski activities. You could make it clearer and say a bit more on the anthropogenic influence.

P6L127. To avoid repetition replace the second "Berger et al. (2004)" by "The latter".

P6L150-154. This refers to the state of knowledge on factors controlling rock glacier kinematics. Therefore, it should be moved into the introduction.

Table 1: Ministry

P7L170. This is an open reproach towards the company that can be critical. I suggest to moderate your sentence.

Table 2: Uniformize the font

P8L200-201. How many GCPs did you use ?

P10L240. **had**. In general, check the tenses. Sometimes the present is used, sometimes the past (L245: better were than are).

P11L274. Figure number ?

P12, chap. 3.6. See my general comment on the 3D displacements.

P12L300. **a LoD**

P13L320-322. Syntax problem with this sentence.

P15L366-367. The end of the sentence is strange.

P15L367. **Elevation.**

P15L375. You could complete with additional references.

P15L389-390. I don't understand this sentence. You mean that P increased from 931 mm/yr to 957 mm/yr at Weißsee ? Please reformulate. And in the following lines it is not clear of which station you are talking about. And why not showing the data for Weißsee station ?

P16L408. Honestly the tiny decrease in the snow duration cannot be considered as a trend. it only takes one year with a positive anomaly for the trend to reverse. And how do you calculate the snow cover onset ? From which snow depth do you consider that the snow cover is permanent ? P16L422. How much were the velocities for this period ? According to Fig. 8 they should not have been much higher than 0,5 m/yr. Such displacements should not have provoked decorrelation. P17L433. You could also reference to the PERMOS reports.

Figure 4: What do the red dots and bars indicate ?

P18L454. Space before "Roer" P18L458. Could it be differently ? At the scale of the study area the changes in external forcing are the same for all the rock glaciers. P19L482. Fig 5. To compare the size of the different rock glaciers the scale should be the same, and obviously it is not (in any case it is too small to verify it). P19L483-484. ... which is so normal ! I don't know any rock glacier showing uniform velocities on its entire surface. P19L491-492. This is highly speculative. With such a low sample it is not possible to conclude anything about the link between rock glacier acceleration and altitude. And there is no objective explanation why higher rock glaciers would react more than lower ones.

P20-21, Figure 5. Figure a bit complicated. Everything is too small and thus difficult to read. I suggest to make 2 figures with 1) the charts and 2) the maps.

P22L523. What do you mean by "system state" ?

P22L225. "summer" instead of "autumn".

P22L530. But the velocities are not only controlled by air temperature but also, and in a large portion, by the historic development of the snow cover, including the date of complete snow melt.

Figure 6: Indicate the period of comparison regarding the anomalies in T and P. I guess 1961-1990 ?

P25L570. But generally a long duration of the snow cover is related to a thick snow cover, and thus leads to increasing liquid water, considering also that the latter is available all along the snow melt period.

P25L582. Looking at Fig 7 the value for RG 05 seems to be lower than 0.031

P25L591. What is this other rock glacier pushed forward ?

P26L598-606. Please refer to the corresponding Figure. This is an example of too long paragraph regarding the data that have to be presented. The same could be said in 3 lines. Not necessary to give all these details for RG 02.

P26L615. ...different sizes. We already know this.

P27L618-621. Despite the fact that the maps are tiny (please increase the size, for instance by making 2 figures), I rather see patterns of positive or negative changes instead of scattering. Or you mean scattering at a larger scale ? But anyway the figures are too small to be analyzed by the reader.

P27L621-622. I don't understand the sentence. And avoid references in the middle of a sentence.

P29, chap. 4.6.1. I don't see any particular evolution for this rock glacier, since most of the landforms studied show an increase in velocities from 1997. This section is highly speculative and I suggest to delete it.

P29L671. RG04 is obviously a push moraine (i.e. frozen sediments – probably a rock glacier – deformed by the LIA glacier advance). This is highlighted by the back-creeping movement towards the former glacier position and the strong subsidence, indicating high ice content. This must be considered in the analysis.

P29L681-687. Ok for the possible reactivation, but it would be interesting to propose some hypothesis to explain such a reactivation process.

P30L702. Permafrost is a thermal phenomenon. It can thus not melt.

P30L708. "... in the area of shear surfaces..." : what do you mean exactly ?

P30L709. "change" without s

P31L720. "similar magnitude". Do you mean similar values ? Because it is evident that horizontal velocities are expected to be much higher than "3D" changes.