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The Cryosphere Discussions

Interactive comment on "Ice content and interannual water storage changes of an active rock glacier in the dry Andes of Argentina" *by* Christian Halla et al.

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GENERAL COMMENTS

The manuscript presents an extensive investigation of an active rock glacier using innovative techniques in an attempt to delineate the internal structure and quantify the distribution and amount of ice and liquid water. This is an ambitious and impressive study. The high-quality data set produced in the study contributes significantly to advancing the scientific understanding of rock glaciers and their hydrological functions. The manuscript is well organized and written, and the quality of figures is superb. Photogrammetric survey data and geophysical data are analyzed with sufficient rigor, and

the results are interesting and significant. However, considering that the main objective of this work is focussed on water storage, hydrological data interpretation could be strengthened by: (1) critically examining the assumptions used in calculations, (2) scrutinizing water balance calculations, and (3) including hydrologically relevant information such as the differences in air temperature and precipitation between 2016-2017 and 2017-2018. Please see below for specific suggestions.

SPECIFIC COMMENTS

Line 22. Please spell 'groundwater' in one word, following the standard practice in the contemporary literature.

Line 51. Please spell out RCP8.5 and briefly indicate what it represents.

Line 294. Estimates of ice and liquid water fraction must be also sensitive to other poorly constrained parameters such as the p-wave velocity of rock and the three Archie parameters. Please comment on the model sensitivity and uncertainty concerning these parameters, and briefly explain how the values were 'taken from literature'.

Line 296. I feel that 70% is a large number for a talus rock glacier. How were these values selected? Based on the literature? I am not sure how much information is in the literature, but Merz et al. (2016, Geophysics, 81, WA147-WA157) used 30% as a rough estimate, and pointed out the need for 'dependable estimates of porosity across the rock glacier' as a future challenge. As estimated ice and water volumes are highly sensitive to porosity (Fig. 7), I think that the choice of these values need to be critically examined and justified in light of the existing body of literature.

Line 316. Mean fw and mean fi. Mean of what? Please explain.

Line 340. Please annotate 'central area' etc. in Fig. 4, so the reader can clearly understand which region is referred to here. Alternatively, this sentence can refer the reader to Fig. 1b.

Table 5. This table is a bit difficult to understand at a first glance. It will be helpful to

add vertical lines across the two tables, so the reader can relate the top table to the bottom table.

Line 357. How are these average values calculated? Simple average of all grid cells shown in Fig. 4? Please briefly explain it here.

Figure 5. 'Depth' is used for the vertical axis in this figure, but it is a bit odd because depth is always referenced to the ground surface of a particular location. Please use elevation instead of depth.

Figure 6. The delineation of permafrost and ice-rich permafrost in SRT images are not consistent with that in ERT images (Fig. 5). Please comment on the differences in this paragraph, and discuss it again in the last paragraph of this section.

Line 440. Figure 7 shows the mean values of ice fraction and liquid water fraction over 'model depth', but I am not sure what the model depth refers to. Please explain how the model depth is defined.

Line 445-446. High porosity values are used for the mixed porosity model. Please see my comment on Line 296.

Line 482-484. Liquid water saturation and ice saturation are used in Fig. 8, instead of water content and ice content. This way of presenting the spatial distribution of water and ice is a bit misleading, because the reader cannot actually see the amounts of water in 'aquifers'. For example, 'aquifers from adjacent talus slopes' are in the bedrock, not in talus sediments. In the bedrock, water saturation is high due to low porosity, but water content is small. For the discussion of water storage, it is more meaningful to show water and ice contents. Please revise the figures.

Line 490. The lines delineating aquifers and aquitards are similar, and not easily distinguishable. Please use more distinguishable line types. These diagrams show aquitards that look like vertical chimneys. It is hard to imagine how such vertical aquitards could form in rock glacier. A more plausible explanation for the presence of shallow perched

aquifers (e.g. x = 150 m in C1) is the horizontal aquitard (i.e. permafrost) underneath the aquifer.

Line 503. Gruben rock glacier abruptly appears here. Please provide the context. The same applies to the Galena Creek rock glacier in Line 505.

Line 547-550. Please note that high water saturation does not necessarily indicate an aquifer. To qualify as an aquifer, the material needs to have high enough porosity and permeability. Please see my comment on Line 482-484 as well.

Line 673. How is this number calculated from Table 6? Please explain the steps and assumptions. It seems that the range of uncertainty in this number is unrealistically small in light of all the uncertainties in model parameters, as well as the geophysical data inversion. Please provide an explanation as to why the number can be so well constrained.

Line 681. I cannot follow the conversion between mm d-1 and kg. Also, I cannot understand why 36:28 is not equal to 19.8:14.7. Please explain how these numbers are calculated.

Line 688-690. The difference in meteorological conditions between the two seasons is casually discussed here, referring to a supplemental figure. I feel that this topic is central to the main objective of the paper and deserves more attention. For example, what was the difference in precipitation? What was the actual difference in mean air temperature during the two thawing seasons? Please expand the discussion and demonstrate a clear link between the meteorological condition and estimated storage change (negative in 2016-2017 and positive in 2017-2018).

Line 691. Please show the location of the spring in Fig. 1b.

Line 691-695. I feel that the discussion on the water balance needs a bit more care, again because this is central to the main objective of the paper. For example, if the area of the rock glacier is 0.36 km2 (Line 127), then 104 x 10^6 kg is equivalent to 290

mm of water averaged over the rock glacier area. This is a large magnitude compared to annual precipitation of 50-150 mm (Line 106). What is the source of this water? Does the spring flows only for five months (Line 692), or does it flow all year? What was the actual precipitation amounts in 2016-2017 and 2017-2018? How are 14-30% and 70-86% calculated?

Reviewer: Masaki Hayashi

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