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Interactive comment on "Active and inactive Andean rock glacier geophysical signatures by comparing 2D joint inversion routines of electrical resistivity and refraction seismic tomography" *by* Giulia de Pasquale et al.

Giulia de Pasquale et al.

giulia.depasquale@ceaza.cl

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Dear editor, With respect to the comments from Referee #3, we have addressed the major concerns indicated by the reviewer in this document and minor changes suggested in tc-2020-306-RC3-supplement.pdf file (attached). The figures modified accordingly to the comments of Referee#3 are included in the answer to Referee #1. The paper lacks a clear focus as the authors are trying to cram too many ideas and thoughts, some supported by good evidence and others purely speculative.

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Discussion paper

With the aim of strengthening the focus of the paper we decided to follow the suggestion of Reviewer 2 and change the title and focus of the manuscript to the geophysical signature difference between active and stagnant rock glaciers. The new proposed title is now “Geophysical signature of two contrasting Andean rock glaciers”. In the new manuscript, we focus on the individual inversion results and present the petrophysical joint inversion to aid the interpretation of the differences in the geophysical signature of the two rock glaciers and completely delete the structural joint inversion approach.

I understand that the novel joint inversion is the key of the research and as such, the authors should focus on those measurements and results.

The joint inversion analysis as presented in this paper is not novel. A comparable structural joint inversion analysis was presented in the paper by Jordi et al., 2019; and the petrophysical joint inversion was first presented in Wagner et al., 2019 and then tested for different parameters and sites in the study by Mollaret et al., 2020. As stated before, and following the suggestion of reviewer 2, we decided to focus on the geophysical signature rather than on the joint inversion methods completely deleting the structural joint inversion from the manuscript and leaving the petrophysical joint inversion as an interpretative aid to the individual inversion results.

The discussion on the hydrological significance is not essential for this publication and in fact distracting. In addition, there seems to be several misconceptions regarding the hydrogeology. For example, the authors imply that water in the watershed must originate from a cryoform. That is incorrect and I think the measurements seem to indicate that there are relatively shallow groundwater aquifers likely below the base of the rock glacier. The measurements also do not support a discussion on the periglacial hydrology as presented, and it would really be better to completely delete these sections.

Thank you for this critical review of the paper with regards to the hydrology. We agree that water may originate from groundwater sources as well as from the rock glacier. We have modified the sentence starting on line 310 to clarify our uncertainty in the inter-

pretation and remove the part of the statement implying that the water originates from the rock glacier. We agree that the discussion on periglacial hydrology is tangential to the main results and conclusions of the paper. We have therefore significantly reduced section 5.5, maintaining those portions of the text that are most directly supported by the geophysical data. We do think it is valuable to maintain this section as it synthesizes some of the main geophysical results from El Jote and El Ternero and provides context for the importance of the findings with respect to their hydrological role.

âĂć After reading the manuscript I'm still confused about the El Jote Rock Glacier. Is it now an inactive rock glacier, or is it a relict rock glacier? Based on the inversion results it seems that the average (!) volumetric (I assume it is volumetric) ground ice content is 1 – 2%. (IS 1%) Unfortunately, the authors did not provide any error ranges for their outputs (something that mustbe added in the revised version), but even if the error is +/- 5%, which would be very good, this landform is more likely to not contain any ground ice anymore. This means,the probability for the El Jote Rock Glacier being a relict rock glacier, i.e. there is no permafrost left, is significantly higher than it being an intact rock glacier (active or inactive).

After careful review of the geophysical results we agree that El Jote should be classified as a relict rock glacier. We have modified the text to refer to this glacier as "stagnant" before the results are presented, and "relict" in the discussion section once the rock glacier has been interpreted as relict. Also, we quantified the maximum average volume content for different scenarios varying the initial porosity and porosity ranges within the petrophysical inversion results. These sensitivity results have been added to the paper and can be used to quantify the model error.

The new inversion presented seems reasonable; however, there is very little evidence for it to be accurate because there are no in-situ data available, as the authors indicate. I'd like to remind the authors that geophysical investigations have been completed by others for which data from boreholes are available. The authors are therefore encouraged to first test their new approach for a well-known site and once confirmed that

the methodology is accurately working, applying it to a site for which no information is available can be done.

As specified above, the petrophysical joint inversion presented in this paper is not novel and has been presented in Wagner et al.(2019) and thoroughly tested by Mollaret et al.(2020). It is true that the paper could be significantly improved with in-situ sampling data to validate the choice of the petrophysical parameters, but it was impossible to collect core data for this field study given the remote location and equipment available. For this reason, in the new manuscript the inversion approach has been moved to the appendix and used solely to aid in the interpretation of the individual inversion results.

I was also surprised why the authors did not collect any soil samples from the front of the rock glaciers to at least get an idea of the potential gradation of the soil material and some of its characteristics, but instead they rely on references from the Alps. It also would have been helpful if the authors had extended their lines past the edge of the cryoforms and carried out additional lines perpendicular to the only one they completed, which would have allowed them to measure the ERT and RST characteristics of the natural terrain without a rock glacier as well as providing a cross calibration point.

Thank you for this comment, we will consider collecting such soil samples in a future field campaign. During the field work for this study there logistical constraints impeded the complete geotechnical characterization of the material at the rock glacier front. Regarding the geophysical line we add the following lines to the manuscript:

“While the geophysical line extended slightly past the edge of the El Jote rock glacier, it was impossible to do so for El Ternero due to the high, steep, unstable and therefore dangerous slopes of the rock glacier front and lateral margins.”

Finally, I’m very surprised by the depth of the surveys. The authors managed to go much deeper than most ERT and RST surveys using similar configurations and I could not find an explanation for that. It is important that the authors better acknowledge the very limited data they have. It is understood that the measurements are challenging

to complete, but this major limitation must be reflected in the interpretation of the results,the discussion and ultimately in the conclusions drawn from the two, very different surveys.

In the new version of the manuscript we added a new section in the discussion where we address the data quality:

5.1 Data quality and comparison of inversion routines

For both field sites the acquisition of data and their quality were limited by the environment: the presence of large boulders with air-filled voids between them at the surface of both glaciers attenuated both mechanical and electrical energy propagation.The quality of the data was especially affected in the case of El Ternero rock glacier, clearly demonstrated in Figures 4(a)-(b) and 6(a)-(b). It must be stressed that the parameter domains shown in the individual P-wave velocity inversion results and in the petrophysical joint inversion results (Figs. 4c, 6c, 5 and 7) are geometrically delimited by the lowermost ray path but the ray-coverage within the displayed area is limited. . ..

Finally, there are several conceptual problems in the manuscript, such as when it comes to the origin of the water, or calling the form El Ternero glacier, instead of El Ternero rock glacier, saying that the rock glacier surface is below a layer of rocks, setting the permafrost table equal with the top of an ice-rich layer, or implying that an inactive rock glacier must be in a degrading state, etc..

We are really thankful to the reviewer for their comments and have tried to correct and address them within the new manuscript.

Please also note the supplement to this comment:
https://tc.copernicus.org/preprints/tc-2020-306/tc-2020-306-AC3-supplement.pdf

Interactive comment on The Cryosphere Discuss., https://doi.org/10.5194/tc-2020-306, 2020.