

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.

Anonymous Referee #2

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Summary:

The paper presents electrical resistivity and seismic refraction measurements from two Andean rock glaciers and its objective of the paper is twofold: On the one hand, the authors present new field data acquired under challenging conditions at an active (El Jote) and an inactive rock glacier (El Ternero) and discuss their hydrogeological roles in semi-arid Chile. On the other hand, the authors present a comparison of individual common geophysical inversions of both data sets as well as recently developed structurally-coupled and petrophysically-coupled joint inversion approaches. Both ob-

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jectives are certainly of interest to the cryospheric-geophysical community. The former perfectly fits the scope of The Cryosphere (TC). (The latter as well, but I feel that it currently requires a lot of geophysical prior knowledge and that further explanations and reasoning are necessary for the audience of TC as I will outline in my general comments below.)

The paper starts with an introduction on the importance of monitoring rock glaciers in a warming climate, the benefit of surface-based geophysical measurements and means to combine geophysical data sets in joint inversion approaches. Section 2 introduces the two study sites. Section 3 briefly describes the theory of Electrical Resistivity Tomography (ERT) and Refraction Seismic Tomography (RST) and the two joint inversion approaches. This is followed by results (section 4), discussion (section 5) and conclusions and outlook (section 6). The work is illustrated with 9 figures, most of which are high-quality vector graphics. The paper is generally well written, but contains multiple linguistic oversights.

While I find the content of the paper very interesting and feel that the material compiled in this manuscript is generally well suited for publication (i.e., both the field data as well as the comparison of joint inversion approaches in a permafrost context are novel), the current manuscript requires major revisions. The authors are kindly requested to refer to my general, as well as line and figure-specific comments below during revision of their manuscript.

General comments:

Target audience I feel that the two objectives (both of which are really interesting) present a challenge, because the latter (comparison of structurally and petrophysically-coupled joint inversion approaches) requires a lot of prior knowledge on the two inversion approaches (and regularized inversion in general) considering that TC targets a broad (and not necessarily geophysical) audience. In

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contrast, a reader with an expertise in geophysical (joint) inversion would probably be interested in a more detailed comparison of the two approaches, i.e., a comparison which allows to see under which circumstances one approach outperforms the other for instance. Such a comparison should also come with a discussion on the motivation of two approaches. For example: Are structurally-coupled joint inversions (and the underlying assumption of structural similarity) appropriate in a permafrost context, where a transition from ice to air can result in an order of magnitude change in velocity, while electrolytic conduction stays negligibly low?

Scope and objectives Somewhat related to the previous point, I question if the 3 inversion approaches and their comparison are actually necessary for the conclusions drawn in this paper. In the key figure 9 for example, which the authors use for drawing several conclusions and recommend as a diagnostic tool for future studies, only 2 of the 3 inversion approaches appear and the corresponding inverted velocity and resistivity distributions and thus also the scattered points look very similar. This makes me wonder, if this case study could be presented with individual inversions only, while a follow-up study could then focus on a detailed comparison of joint inversion approaches in a permafrost context.

Brevity Some figures are discussed too briefly. The first paragraph in subsection 4.1 for example ends with the sentence "The model results for El Jote are given in Fig. 2(a) and (b)." (line 275). This should be directly followed by a discussion on what can be seen in Fig. 2. The reader is left alone here until the figure is briefly mentioned again in the next subsection (4.2, line 322). Furthermore, subsection 4.1 ends with a single sentence on which quantity is plotted in Fig. 5. A further discussion on this figure and the shown residuals is missing.

Structure: The paper formally follows a standard structure, i.e. introduction, methods, results, discussion, conclusions and outlook. However, the current version of the

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manuscript deviates from this structure several times, which is confusing for the reader. For example section 3 "Methods" contains a lot of theory and could be re-named more appropriately to "Theory and methods". Furthermore, many details with regard to the processing (e.g., used correlation lengths in the geostatistical regularization, choice of regularization strengths using L-curve analysis, choice of starting model, etc.) appear in the results section (rather than in methods). The manuscript would benefit from a clearer differentiation between theory, methods and results.

Missing information / lack of clarity I had problems following the data acquisition and processing. For example: Where were the off-line shots located? I feel that an additional figure illustrating the roll-along scheme and source/receiver positions, potentially in combination with Fig. 1, would come a long way here. With regard to the processing, not much information is given. How was the data quality? How did the authors process and filter the data sets? Please provide a plot with raw and filtered seismic and electrical data (e.g., apparent resistivities and apparent velocities) and explain the filtering steps applied.

Specific comments:

- First line of abstract: "four-times" → "four times"
- Third line of abstract: Please rephrase or explain "human pressure"
- L14: "four-times" → "four times"
- L45: "semiarid" was written with hyphen ("semi-arid") earlier in the abstract. Be consistent.
- L56: This sounds as if there were only two options, but borehole-based geophysics and a combination of approaches exist as well.

- L74: "their" is unfortunate here as it could refer to both the glaciers and the inversion methodologies.
- L105: Space missing between number and unit (3020 m)
- L130: "Geophysics measurement" → "Geophysical measurements"
- L136: "collects" sounds a bit too easy (data is easily collected, but the parameter estimation is a bit more tricky). Maybe use "tries to infer" or "aims to estimate" instead.
- L152: "Following Maurer and Hauck (2007) methodology" → "Following the methodology of Maurer and Hauck (2007)"
- L210: Does it really enforce structural similarity? I think "promote" would be more correct here.
- L223: So what's the difference to the superposition of damping and smoothing then?
- Eq. 5: Is ψ_m the same as in equation 1 here, i.e. does the petrophysical joint inversion use geostatistical regularization as well? Otherwise, I'll recommend to use a different symbol.
- L243: "constrain" → "constraints"
- L255: "no-physical" → "non-physical"
- L259: Please provide more justification here. How and for which substrate types were the literature values determined? What assumptions are implied by using them to your study sites?
- L261: Remove comma after Wagner et al. (2019).

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- L269: "we implemented". Was it really implemented from scratch or were codes available / provided to you? Please specify or reformulate to "we applied based on the implementations provided by Jordi et al. [...]".
- L271 and L319: I suggest to use ρ_a^{median} instead of ρa_{median} . Otherwise, the apparent resistivity ρ_a cannot be differentiated from the resistivity times a factor a , i.e. ρa .
- L276-279: These details would fit better in section 3.
- L293: "(Mollaret et al., 2020)" → "Mollaret et al. (2020)"
- L307: Subscripts are capitalized here (but not in equation 6).
- L309-311: This would be better suited in the section of data acquisition.
- L328: I appreciate that the authors use the same colorbar limits to allow visual comparison. I think this is valuable between the inversion approaches of a single profile, but there is no reason to keep it the same for the different sites as well. It is somewhat unfortunate that velocities of up to 7000 m/s appear for El Ternero, while the colorbar is limited to 4000 m/s. As a consequence, Fig. 6 is mainly yellow.
- L369-L370: Please elaborate: What is meant by remaining ambiguity within the interpretation of observations?
- L406: Redundant space after opening bracket
- L412: It looks like the colors in Fig. 9 have changed (red is joint inversion) and black vs. blue.
- L462: Missing space after period.

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- L467: Missing space after comma.

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