Dear Prof. Dr. Jacopo Boaga!

I hope you started well into the new year. Thank you very much for your review and your encouraging as well as important comments. This letter contains point by point responses on your comments. New/rephrased sentences are indicated by italic letters.

Ln 55-60 This paragraph seems to introduce ERT use in permafrost studies, but most of the references here cited are not relative to ERT application case studies. It sounds strange.

We carefully scrutinized citations to permafrost studies regarding typical periglacial landforms (protalus ramparts, talus slopes and rock glaciers). All the mentioned studies detected and characterized subsurface ice by using ERT except one: The citation "Kenner, R., Phillips, M., Beutel, J., Hiller, M., Limpach, P., Pointner, E. and Volken, M.: Factors controlling velocity variations at short-term, seasonal and multiyear time scales, Ritigraben rock glacier, Western Swiss Alps, Permafr. Periglac. Process., 28(4), 675–684, doi:10.1002/ppp.1953, 2017." was replaced by the correct citation *"Kenner, R., Phillips, M., Hauck, C., Hilbich, C., Mulsow, C., Bühler, Y., Stoffel, A. and Buchroithner, M.: New insights on permafrost genesis and conservation in talus slopes based on observations at Flüelapass, Eastern Switzerland, Geomorphology, 290(April), 101–113, doi:10.1016/j.geomorph.2017.04.011, 2017."*

The sentence was re-phrased to: *"ERT measurements have also been successfully applied to detect and characterize permafrost on periglacial landforms as…"*

Ln 66-70 I'm not sure statistical approach can solve the problems of contact resistance, maybe this sentence should be re-phrased.

We re-phrased the sentence as follows: *Emerging challenges such as changing contact resistances, different instruments or inversion artefacts can be addressed, for example, by statistical analysis (Supper et al., 2014) or adapted data processing schemes (Oldenborger and LeBlanc, 2018).*

Ln 85 Here or in line 440, for specific galvanic contact in debris problem consider also https://doi.org/10.1002/nsg.12192

We agree and have now included the mentioned publication in Ln 85 and in the citation list.

Ln 179-186 No clear the relative standard deviation 0.3%. Is this the stack error? Authors for sure appreciated how pre-processing is essential in ERT inversion. The filtering of the dataset should be then better described, if it is done with some pre-processing code or in the RES2DINV suite. 'Visually identifiable' is a weak approach for repeatable measurements.

This unclear paragraph was re-written as follows:

"An initial quality assessment of the field data was achieved during the data acquisition 2021 by using the GeoTom software (V. 7.19, Geolog 2000). In a first step, the data quality of each quadrupole measurement is checked visually by comparing its value with neighbouring points in the pseudo section. Large deviations or outliers (e.g. given by a defect in one cable which produced random values for measurements with one specific electrode) indicate poor data quality. In a second step, (a) all data points with a relative standard deviation of all stacks (stack error) above 0.3 %, and (b) all data points collected with the maximum value of the input voltage, which indicates that no sufficient signal strength can be achieved, were identified. Visually identified outliers as well as the values identified by (a) and (b) were re-measured after checking the placement of the electrodes and improving the contact between the electrode and the surface by adding salted water. Remeasured data points still meeting one of the criteria (a) or (b) or being obvious outliers were deleted and reconstructed by interpolating the neighbouring values before the inversion. Because information on stack error and input voltage was unavailable, this process could not be performed on the historical data. Instead, the historical data were filtered manually using the "Exterminate bad datum points"-function in the RES2DINV software. Bad data points are values with apparent resistivity that are apparently too large or too small compared to the neighbouring values. The overall number of filtered data points is given in tables 2 to 4 for the three surveyed catchments."

Which error was used during the inversion process?

The inversion in Res2DInv was carried out without taking information on the data error into account.

Ln 252-260 The very important point highlighted by Uhlemann and Kuras should be inserted here, since breaking the point assumption is the first doubt arising from this (very interesting) textile approach.

In the corresponding paragraph in the Methods and Data section, we added information (Ln 258) on the actual electrode size ("*Our design results in an approximately circular contact area with a diameter of roughly 15 cm.*") and make reference to the discussion in 5.1 ("*Possible effects of the large electrode size and the violation of the point-source assumption during the inversion of the ERT data will be addressed in the discussion section.*").

The discussion of possible effects of the electrode size in section 5.1 is further extended as follows:

"For capacitively coupled electrodes, Uhlemann and Kuras (2014) argue that the point-pole approximation is valid, if the electrode spacing is at least 4 times the diameter of the contact area. Since the diameter of the contact area of our new textile electrode is <15 cm and our minimum electrode spacing is 4 m, we are well within these limits. To assess the effect of the size of square surface electrodes on ERT measurements, Cardarelli and De Donno (2019) carry out finite-element modelling studies. They find that for electrode separations five times the electrode size or larger, the relative error compared to a point source falls well below 1 %. This is in good agreement with the findings by Uhlemann and Kuras (2014) and further supports the feasibility of our relatively small textile electrodes."

Ln 278 Input voltage ? Do you mean current injection ?

Changed to *"…the input voltage used for current injection."*

Ln 285-290 This is my main criticism to the work: authors do not present a quantitative comparison of the most relevant aspect of these new electrodes: contact resistance. I expect that, as first testing of these very interesting approach, authors measure and compare contact resistance in KOhm. Did you measure contact resistance before collecting measurements ? Which range was measured? Did you compare textile and electrode contact resistance during the hybrid line collected ? When different instruments were used, internal resistance problem should be addressed too in the comparison of the electrodes performance.

In fact we did not measure contact resistance at this particular site, because under these difficult logistical conditions we tried to be as time-efficient as possible. We relied on earlier investigations of the textile electrodes within a bachelor's thesis (see Westphal et al. 2022: (https://dgg2022.dgg-tagung.de/englisch/conference-booklet/)), in which the contact impedances of textile electrodes were investigated and compared with conventional steel electrodes over different surfaces. The main conclusion is that the textile electrodes perform as well as steel electrodes as long as a small amount of water is used to moisten the textile. Following these guidelines, we had no concerns about contact impedances during this survey. We added a few sentences in section 3.3 summarizing the results of previous investigations, including actual values of contact impedances.

Moreover, in order not to exceed the scope of this manuscript, a compromise had to be found to present different, very interesting aspects (permafrost degradation, geomorphological interpretation, remote sensing, ERT) in this manuscript. We focused on permafrost degradation and the geomorphological interpretation by ERT and remote sensing data. The use of the textile electrodes is (not mentioned in the title) therefore helpful, but detailed analyses can be expected in a separate manuscript in order not to go beyond the scope of the present manuscript here.

We added in Ln 271: *"Our design results in an approximately circular contact area with a diameter of roughly 15 cm. Contacted resistances were investigated prior to the campaign over* *different surfaces and compared with those of conventional steel electrodes. It was found that the textile electrodes generally perform as well as steel electrodes as long as a small amount of water (e.g. 80 ml) is being used to moisten the textile. For example, on a semi-paved surface, both electrode types provided resistances between 2 and 5 kΩ, and even on a hard gravelly path where the steel electrodes could not be used, the average resistance of the textile electrodes was 6 kΩ, which is far below the threshold above which the equipment cannot reliably measure any more (> 1 MΩ for the Geotom).*

During the survey described here, the surfaces were generally rugged, blocky and not flat, and therefore additional measures had to be taken. We placed wet sediment and sediment containing biotic material (e.g. roots, moss) between the textile electrode and the rugged surface of boulders."

Ln 395 Here contact resistance is cited but without values, as in ln 567.

See comment above. Unfortunately, no information on the actual contact resistances during the data collection in the field is available.

Ln 558-560 This speculation about increasing in resistivity is very interesting and maybe need more space in the discussion, rather than in the conclusion. Here again injected current and contact resistance may play a relevant role and should be compared in the time-repeated ERT section.

The increasing resistivity during the period of 16 years is indicated in two profiles (GG-P2 and GG-P3). We attribute this resistivity increase to a geomorphic background and not to a technical issue. If this increase should be attributed to contact resistances or the potential injected current, it would also have to be recognizable in other profiles (e.g. GG-P1 and GG-P4).

Furthermore, as long as the contact resistance of the textile electrodes is not orders of magnitudes higher than the contact resistance of traditional spike electrodes, we do not expect any significant effect of the contact resistance on the reconstructed resistivity values in the subsurface. This can be seen in Figure 6 of the manuscript, which compares resistivity models reconstructed from three different electrode-substrate coupling types (steel pikes, steel pikes with sponges, textile electrodes). As long as a reasonable contact can be established between the substrate and the electrode, the apparent resistivity measured with a four-point setup should, in principle, be independent of the contact resistance.

In all all the ERT sections I suggest to increase fonts of axes, legend scale and labels.

We agree and all fonts were increased.

Best regards, Johannes Buckel

References:

Cardarelli, E. and De Donno, G.: Chapter 2 - Advances in electric resistivity tomography: Theory and case studies, in Innovation in Near-Surface Geophysics, edited by R. Persico, S. Piro, and N. Linford, pp. 23–57, Elsevier., 2019.

Westphal K., Mudler J., Buckel J., Bücker M., Hördt A. (2022): Die Anwendung von Textilelektroden bei geoelektrischen Widerstandsmessungen. 82. Jahrestagung Deutsche Geophysikalische Gesellschaft,07.–10. März 2022, München (online) (Abstract&Poster)