General comment: In terms of a general comment, the authors must be careful that permafrost degradation is not limited to changes in ground temperature, but also changes in unfrozen water content, which isn't mentioned once as a process. Latent heat, which is only mentioned once, plays a key role and the changes in resistivity must be evaluated in the context of phase change and not just temperature change. In addition, it would be helpful if the authors provided more information regarding the limitation, accuracy and errors of the various measurements. In other words, when can once trust that a change is a real change and not related to the limitation of the measurements.

We agree and discuss the issue in a new section of chapter 5.4 (compare comment to Line 510 and 525). We add in Line 54: *"However, the thawing and freezing processes around the freezing point can be delayed due to latent heat fluxes associated with phase change (ice–water), rather than warming or cooling of the subsurface (Mollaret et al., 2019)."* and in Line 194 *"latent heat fluxes"*. In addition, we focused our interpretation of resistivity values on changes greater than 10 kΩm to avoid an interpretation that includes smaller resistivity changes as an effect of (seasonal) cooling/thawing. This automatically implies an exclusion of the interpretation of the change in thickness of the active layer as an indication of permafrost degradation. To clarify this, we add in Line 206: *"However, we limit our interpretation to resistivity values and resistivity changes exceeding 10 kΩm as fast changing small-scale and seasonal effects (e.g. unfrozen water content, compare Fortier et al., 1994) induce resistivity changes that cannot be distinguished from resistivity changes associated with perennial external temperature changes. This also excludes a detailed interpretation of an active layer-thickness increase as an indication of permafrost-body thaw."*

Information regarding the limitation, accuracy and errors is given in a new chapter called *"5.2 Tomogram comparability and accuracy assessment"*

Line 16: Delete "mountain" as the statement is true for all of the permafrost around the world

We have deleted "mountain".

Line 20: "Alpine". Please try to be consistent throughout the manuscript. Alpine, with a capital A, reference to the Alps, whereas alpine with a small a references mountain environments with alpine climate, but are geographically not restricted to the Alps. Finally, and the most general term is "mountain". In the context of the paper I suggest to use mountain permafrost consistency.

We agree and revised/rephrased the manuscript (Line 20, 40, 41, 42, 50, 62, 78, 427, and 450) regarding the use of "mountain" instead of "alpine".

Line 24: Delete "periods of", redundant wording.

We agree and have deleted "periods of".

Line 28: Creep instead of Creeping (check also other places in the manuscript!)

We agree and revised/rephrased the manuscript (Line 28, 101, 118, 456, 457, 476, 492, and 542) regarding the use of "creep" instead of "creeping".

Line 35: "mountain" instead of "mountainous"

We changed "mountainous" to "mountain".

Line 37: Add Arenson et al. (2022) as reference:

Arenson, L. U., Harrington, J. S., Koenig, C. E. M., & Wainstein, P. A. (2022). Mountain Permafrost Hydrology—A Practical Review Following Studies from the Andes. *Geosciences*, *12*(2), 48. https://doi.org/10.3390/geosciences12020048

We added the reference.

Line 44: "used to distinguish ice-poor from ice-rich" replace with "used to differentiate between ice-poor and ice-rich"

It is replaced.

Line 48: delete "of"

"of" is deleted

Line 48: what about RST?

Line 49 is changed accordingly**:** ***"****As the installation of boreholes is cost and time intensive, indirect methods such as electrical resistivity tomography (ERT), seismic refraction tomography (SRT), ground penetrating radar (GPR) are often applied for subsurface ice detection and permafrost characterisation (Halla et al., 2021; Maurer and Hauck, 2007; Vonder Mühll et al., 2002)"*

Line 69: mountain permafrost, not mountainous permafrost

We agree and revised the manuscript accordingly.

Line 112: Following the latest guidelines from the IPA Rock glacier inventories and kinematics working group, I suggest to call this a talus derived rock glacier and not a protalus rock glacier.

We agree and changed Line 99, 112, 118, 123, 263, 304, 317, 550.

Line 125: When using a name, rock glacier, is typically capitalize (this applies at various locations in the manuscript), i.e. Gianda Grischa Rock Glacier

We changed Line 100, 107, 111, 113, 128, 129, 142, 225, 269, 326, 334, 343, 360, 376, 389, 433, 460, 469, 515, 523, 534, 535, and 542.

Line 135: Delete "in this study"

It is deleted.

Line 153: Delete "by -1.3 °C"

It is deleted.

Line 156: "Otto et al. (2012)"

We added the full stop.

Line 200ff: but also, as permafrost degrades and the amount of unfrozen water increases. Even small amounts of unfrozen water can have significant effects on the electrical resistivity.

Please refer to the main comment and the resulting changes.

Line 204: delete "perennial"

Is deleted

Line 224: "large" instead of "huge"

Is replaced

Line 255: "delete "ice" before maximized.

We rephrased the sentence as follows: *"…onto the ground maximizing the contact area."*

Line 300: " had any lab testing being performed with these electrodes, to evaluate the effect under controlled conditions? I find it very difficult to evaluate the effect if the conditions are not properly controlled. I.e. only a very general and qualitative conclusion is possible at this point.

This point was also raised by Reviewer 1. 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 at 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: We added in Ln 271: *"Our design results in an approximately circular contact area with a diameter of roughly 15 cm. Contact 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 surface where the steel electrodes could not be used, the average contact resistance of the textile electrodes was below 6 kΩ, which is far below the threshold above which the equipment cannot reliably measure any more (> 1 MΩ for the Geotom)."*

Line 310: Delete "nevertheless"

Is deleted.

ERT tomograms. Please add the following parameters from the overview tables (e.g. Table 1) to all the tomograms: Electrode Spacing, No. of Iterations and RMS error [%].

The parameters were added.

Line 316: But also increase in unfrozen water content. Decreasing resistivity is a combination of two processes.

We added in Line 317 *"…and probably an increase in moisture."*

Line 317: this could be a result of seasonal conditions and not necessarily the result of long term change, i.e. wetter summer

The sentence was deleted according to the main comment.

Figure 6 (and other figures): Make sure that the y-Axis are all the same

We changed the y-Axes to be all the same

Figure 6 (and other figures): Make sure that EVERY number has a unit, or that the units are clearly indicated. Distances are often not labeled with the appropriate unit.

We added in Fig.6-Fig.11 by *"Elevation [m.]*" and "*Distance [m.]*"

Line 367 (and other places); Permafrost doesn't melt, because permafrost is a thermal state. Use degrade in the context of permafrost. If you specifically refer o the ground ice, then you can use melt, but ice must be indicated.

We replaced melt by *"degrade"* in Line 367 and 546.

Line 370: 16-year period

We changed the phrase.

Line 374 (and other places): Make sure to not use massive ice and ice-rich permafrost as synonyms. I suggest to use ice-rich permafrost in this paper, unless you have physical evidence, e.g. from drilling, that there is massive ice. (e.g. also Line 399).

We agree and changed Line 204, 353, 374, 383, 399, 461.

Line 395 ff: You have to be careful that increase in resistivity is not automatically attributed to poor data while decrease in resistivity to permafrost degradation. The interpretation of your data cannot be biased towards the second.

We agree that this bias should be avoided. Since this section is not essential for the main message, we deleted Line 395, 396, 397.

Line 414 (but also other instances): Be careful with preposition "of" and "in". In this case "in" would be better. When using "reduction of" the focus on is the reduction itself, but when using "in" the focus is on what is reduced. In this case, the focus is the resistivity, because that is what you are measuring and comparing. On line 417 you have a similar situation with "similarity" or in line 472 with "increase".

We replaced "of" by "in" in Line 414, 417 and 472.

Line 427: This isn't just rue for alpine settings

Yes, therefore we deleted "in alpine settings"

Line 444: delete "of"

Is deleted

Line 456: creep instead of creeping

The entire manuscript was checked and creeping was replaced by *"creep"*.

Figure 12b: arrow lengths should be scaled according to velocity

The arrow length was adapted.

Line 510: "stronger" is relative. You are just limiting the response to temperature. Changes in unfrozen water content w/o major change in temperature may also be labeled as a strong response.

Line 525: "increase in MAGT": Don't just focus on temperatures. The manuscript provides the impression as if permafrost degradation is equal to warming. This is incorrect as changing state, i.e. the thawing of ground ice, is very critical. Changes in resistivity are perfect to record such changes. This must be discussed in more detail and the discussion should not be limited to changes in MAGT.

We agree with both comments (L510 and L525). We have to state out, that effect of unfrozen water content influence significantly the change in resistivity values. We changed the title of the chapter in *"Permafrost degradation in terms of resistivity change and temperature increase"* and introduced the chapter as follows:

"Resistivity values reflect different subsurface conditions (c.f. chapter 3.1), and are especially sensitive to the occurrence of ground ice. However, unfrozen water content, infiltration of precipitation as well as snow and ice melt lower resistivity values, even if the subsurface temperature is below the freezing point (Hilbich et al., 2011; Kneisel et al., 2008; Mollaret et al., 2019). Unfrozen water content is available between 0°C and -5°C depending on the material characteristics and lowers resistivity up to 600 Ωm for sandy soil in a laboratory experiment (Tang et al., 2020). The effect of unfrozen water content in the investigated study sites should occur at higher resistivity values due to the larger grain sizes and the resistive lithology. Fortier et al. (1994) examined the effect of unfrozen water content on apparent resistivity during active layer thickening (April – June). The unfrozen water content significantly affects the apparent resistivity up to a value of about 10 kΩm, while the ice content increases above this value: In the frozen layer characterized by high content of ice (mass proportion of ice > 30%) below the active layer, the unfrozen water content decreases significantly and the apparent resistivity exceed the value of around 10 kΩm. Therefore, we assess the effect of unfrozen water content on the interpretation of permafrost degradation in this study as minor due to used threshold (10 kΩm). Additionally, values around 10 kΩm indicate the presence of ice also in other studies (c.f. Hauck and Kneisel, 2008; Otto et al., 2012) based on different subsurface materials than in the study of Fortier et al. (1994). A delay in resistivity change can be observed during thawing/freezing due to the effect of latent heat around 0°C, the so called zero curtain effect (Farzamian et al., 2020; Mollaret et al., 2019). In general, resistivity-temperature relationships show exponential behaviour below the freezing point (Hauck, 2002). Furthermore, ice-poor permafrost is more sensitive to temperature warming than ice-rich permafrost (Haberkorn et al., 2021), as more latent heat is required to thaw permafrost with high ice content than with low ice content (Harris et al., 2009)."

Line 528: "faster reaction" ignores the effect of latent heat, which is very energy intensive. But is also a fast reaction, it just doesn't manifest itself so quickly; and is much more difficult to measure and observe in the field.

The sentence was deleted.

Line 545: degrade not melt

Melt is replaced by degrade.

Section 5, Discussion: I would have liked a discussion on the errors / accuracy of the measurements and inversion techniques used. How much of the changes noted may be

attributed to errors and other uncertainties in the measurements? What is the level of change at which one can confidentially say that the properties of the ground have really changed?

We absolutely agree and add a corresponding chapter called *"5.2 Tomogram comparability and accuracy assessment"*. By introducing the study of (Fortier et al., 1994) we discuss in chapter 5.4 the value of 10 kΩm as a reasonable threshold for a confidentially interpretation of permafrost degradation by resistivity changes. ERT as an indirect method does not achieve absolute reliability.

"5.2 Tomogram comparability and accuracy assessment

The exact re-location of the historical profiles, different measurement equipment, electrode array, spacing as well as profile length make a comparison of historical and repeated tomograms challenging, resulting in a different data resolution and in a different depth of investigation indicated by the varying black tomogram outlines (c.f. Figures 6 - 11). Therefore, some constraints must be taken into account when comparing the tomograms. For instance, we are limited to a visual comparison based on significant anomalies greater than 10 kΩm in both historical and repeated tomograms. By using this threshold, we suppose that most of the uncertainties (proper location, unfrozen water content, water chemistry and saturation, pore connectivity, mineralogy and grain size characteristics) can be excluded (compare Fortier et al., 1994 and Mollaret et al., 2019). A direct, algorithm-based comparison seems to be an important and challenging task for the future. Temperature related changes in active layer thickness, which is strongly sensitive to climate warming (Scherler et al., 2013) cannot be inferred reliably due to the limitation of an visual comparison.

Regarding the tomogram comparability, we used the smoothness-constrained least-squares inversion (L2-Norm) instead of the often applied robust inversion scheme (L1-norm) (Emmert and Kneisel, 2017; Halla et al., 2021; Supper et al., 2014, etc.). This way, we avoid the tomograms to be dominated by sharp boundaries, the comparison of which would be misleading due to the location errors discussed above. The resulting RMS errors vary in a range from 3.2 % to 16.3 %, whereby the RMS errors are slightly higher in the tomograms from the Gianda Grischa rock glacier. Yet these values are well within the range of other ERT applications on rock glaciers (Hauck and Kneisel, 2008; Hauck and Vonder Mühll, 2003; Villarroel et al., 2021). The number of iterations needed to fit the measured apparent resistivity to the calculated resistivity model counts 4 +/-1, which is in a similar range of values of the mentioned, comparable studies. Another aspect of data quality concerns the number of filtered values compared to all collected data points. The raw data of the Gianda Grischa rock glacier were filtered by 0-20% of all data points, whereby only 0-6.1% from the raw data were filtered at the Corvatsch catchment, and 0-8.7% at the Glatzbach catchment. A similar filter approach as we used (compare section 3.1) is presented by Rosset et al. (2013) called technical and magnitude filter. The authors filtered an average of 8,79% of all data points in six tomograms of four comparable study sites. The similar filtering approach used for the 16 tomograms of this study results in an average of 6.8% filtered values."

Line 559: amount "of" ice

"of" is added

Line 560: “increased” instead of “fastened”. Note: a rate cannot get faster. Only a velocity can

“increased” is replaced

Line 562: “…, by different data acquisition(measurement equipment, electrode array, spacing, profile length) and by geomorphological circumstances that need to be considered for the comparative interpretation of the resistivity data.” This statement only appears in the conclusions, but this should be discussed further in the previous sections. It is very important and essential for the completion of similar studies in the future.

We agree and can now refer on the new chapter 5.2, where we included the sentence *“A direct, algorithm-based comparison seems to be a very important but challenging task for the future.”* Additionaly, we changed the title of the chapter 5.3: *“Geomorphological interpretation of resistivity change”*. In our opinion, this statement is now substantiated in the chapters 5.2 and 5.3.

Additionally, we added in Line 564: *“A useful future task will be to develop an algorithm-based approach that goes beyond a visual comparison of the historical and the repeated ERT tomograms.”*

Line 568: Delete “obviously”

Is deleted

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