Referee 5

1. The Referee wrote "*I have evaluated the revised manuscript together with the authors' response letter and the previous review round. The revised version shows some improvement: the writing is clearer, data availability is more transparently documented, the laboratory calibration is described in more detail, and several figures have been moved to the appendices. The authors have therefore made an effort to address the reviewers' concerns. However, there is still a noticeable mismatch between the scope of the stated objectives, particularly regarding hydrogeological characterization and temperature quantification, and what the available data can actually support. A tighter alignment between aims, results, discussion, and conclusions is still required to strengthen the manuscript. In addition, further restructuring of the paper is needed to improve readability, scientific clarity, and to better articulate the novelty of the study, which remains limited in the current version. For these reasons, I recommend major revision and provide the following comments*."

Response: we thank the Referee for his constructive comments that help to improve this manuscript. We have done our best to accommodate the referee comments in the previous round and we continue to do so in this round. Regarding the structure of the manuscript, we pass our revised manuscript to 4 of our colleagues specialized in the field and their unanimous feedbacks was that the current structure was very clear.

2. The Referee wrote "*1. Paper structure: one of my main concerns remains the structure of the manuscript, which is still difficult to follow even after revision. The paper reads more like a technical report than a scientific article. The separation between Materials and Methods, Results, and Discussion is unclear, and these sections are strongly mixed. Many results are already presented and interpreted within the Materials and Methods section, while some methodological aspects are introduced later in the Results. For example, the time-lapse inversion approach is described in Section 5.3 rather than in the data processing section. In addition, several figures are not sufficiently described, and in multiple cases it is unclear why specific dates or results were selected and how they are representative of subsurface dynamics at the site. A clearer and more rigorous restructuring of the manuscript would significantly improve readability and scientific clarity*."

Response: We thank the Referee for this detailed comment regarding the structure of the manuscript. We acknowledge that the initial organization may have made it difficult to clearly distinguish between the Materials and Methods, Results, and Discussion sections. In response to this comment, we have revised the manuscript to improve its clarity and readability. In particular, we have clarified the description of the data processing and inversion workflow and consolidated all methodological aspects related to processing and inversion (including the time-lapse inversion approach) into the appropriate section. We have also strengthened the interpretation of the results and added new figures showing 2D sections of temperature estimated from the geophysical measurements, which illustrate realistic temperature gradients and distributions consistent with typical permafrost conditions. Finally, the hydrogeological section has been revised and expanded with additional information about the site in order to better support the interpretation of subsurface dynamics.

3. The Referee wrote "*2. Hydrological interpretation based solely on ERT data. The revised manuscript still lists hydrogeological characterization (e.g., water infiltration and drainage in fractures) as one of its main objectives, but the discussion and interpretation remain weak. The hydrological interpretation is based solely on resistivity changes, without independent hydrological constraints or a clear presentation of the existing conceptual understanding of the site. Without complementary information, resistivity variations remain non-unique and cannot be interpreted unambiguously. This limitation is further amplified by the absence of an uncertainty analysis for the resistivity models and the observed changes. As a result, the hydrological conclusions remain speculative and should be more clearly framed as hypotheses rather than objective of paper*." **Response:** Hydrogeological processes is a key challenge to address to better assess non-linear permafrost degradation processes and rock slope destabilisations (e.g. Krautblatter et al., 2012 ; 2013 ; Magnin and Josnin, 2021 ; Cathala et al., 2024; Walter et al., 2020; Fischer et al., 2010). Ponctual and repeated ERT measurements have been the only used approach to assess potential hydrogeological processes in-situ in steep alpine frozen bedrock (Keuschnig et al., 2017; Krautblatter and Hauck, 2007), because of the field constrain in such a harsh environment. Only very recently other approaches have been deployed to apprehend water flow in steep alpine frozen bedrock, such as coupled thermal and hydrogeological models (Magnin and Josnin, 2021; Ben-Asher et al., 2023), or direct observations (Ben-Asher et al., 2025; Scandroglio et al., 2025). All the methods have been developed independently and their coupling remains highly challenged by the harshness of the field work: some methods can be deployed at some areas but not in others because of access or security issues. As an example, at the Aiguille du Midi, we developped several approaches (numerical modeling, direct observation and A-ERT ➔ in this paper) but at different locations or based on different hypotheses (due to the youngness of the research fields), such as their explicit comparison or coupling is yet impossible. The only study that couples direct observation (with piezometer) and A-ERT is the one from Offer et al., 2025, that is really recent. Therefore, based on the past studies that have built up existing knowledge and conceptual models based on ERT only, and the uniqueness of our site, whose settings are different from other settings in steep bedrock slopes (single rock faces embedded in glaciers and resulting proximity of the possible piezometric level) we claim that our observations are as valuable as any other observations reported and interpreted before, despite uncertainty analyses are inherently not feasible, and that they have the main asset to bring a different perspective than the one discussed so far. Furthermore, in our revised version, we rather insisted on the novelty **related to quantitative temperature interpretation**, that is for the **very first time evaluated against in-situ temperature measurements.** The hydrogeological investigation remains a side-quest that has demonstrated some contrasting patterns compared to previous studies that deserve to be shared and discuss in light of existing data and knowledge.

4. The Referee wrote "*3. Temperature - resistivity relationship: Another major objective of the paper "assessing the accuracy of temperature estimates derived from resistivity data" is still not convincingly addressed. In agreement with the other reviewers, I do not consider a single rock sample, and a limited laboratory experiment sufficient to infer a representative petrophysical model for the site. Furthermore, the statement that "temperature estimation based on ERT data leads to good agreement with observed temperatures, with differences of less than ±1 °C at depths of 4 to 10 m" is based on a single borehole comparison and appears*

limited to specific periods, likely when the active layer is unfrozen. In contrast, Figure 11 shows discrepancies of up to approximately 5 °C between laboratory-based and field-derived temperature estimates, which should be considered in the final discussion. I wonder also why not the authors applied the methodology to another borehole available, in proximity of ERT profile. As with hydrological interpretation, no uncertainty analysis is presented. A significant part of the observed discrepancy seen in figure 11 may originate from data quality issues and inversion artefacts. Given that a key motivation for using A-ERT is its potential as a proxy for temperature over larger spatial and temporal scales, a more explicit discussion of its ability to capture spatiotemporal temperature variability would be very useful."

Response: Below, we address each point individually: First, the study site consists of granite and fractured granite. Laboratory measurements performed on one or several samples are expected to yield very similar results, as the samples originate from the same lithology. However, at the field scale, the presence of fractures— which cannot be adequately represented in laboratory samples— strongly influences the measurements and the resulting interpretations. Furthermore, we have already discussed the points raised concerning the temperature–resistivity relationship and the estimation of temperature from resistivity data. We also introduced the assumptions required to apply this model, the results obtained under these assumptions, and the limitations encountered in this study. We developed the section about Temperature - resistivity relationship with 2D section of temperatures evaluated from geophysical measurements at different times which provides reasonable temperature distribution and gradient with depth. The discrepancy observed in Figure 11 may result from field-scale heterogeneity as well as from the influence of metallic structures and the tunnel, which can affect the distribution of the electrical field in uncontrolled manner. We used data from the borehole located along the geophysical profile. The other borehole (BH-S) is located far from the geophysical profile and was therefore not considered in our interpretation. However, the geophysical measurements along the North-East profile (coincident with borehole BH-E) encountered some cable issues, as was mentioned in the manuscript. Therefore, in the aim to avoid any speculative conclusions, we refrained from using data from these boreholes whose data cannot be compared to ERT data.

5. The Referee wrote "*4. Novelty beyond the use of A-ERT in extreme environments. In line with the two other reviewers, I still find the novelty of the work insufficient or at least insufficiently articulated. The authors describe the main novelty as a "multi-year high-resolution A-ERT dataset obtained at the Aiguille du Midi site providing new insights into temporal permafrost dynamics," but this contribution is not clearly demonstrated in the manuscript. While I acknowledge the uniqueness of the multi-profile setup in such a challenging environment, it remains unclear, even in the revised version, what specific new understanding is gained from the A-ERT data. In particular, the added value of continuous A-ERT monitoring compared to repeated ERT surveys is not clearly demonstrated, especially given the data gaps, missing periods, and substantial maintenance challenges. A more explicit discussion of what these challenges reveal, what can and cannot be improved, and how this experience advances current practice would significantly increase the relevance of the study for the permafrost and geophysical monitoring communities. In addition, further discussion of*

data processing choices (e.g., how filtering criteria and thresholds were defined) and the inclusion of uncertainty/sensitivity/resolution analyses would substantially strengthen the paper and improve the interpretation of both hydrological and temperature-related results."

Response: First, the temperature field is modeled modelling based on the joint petrophysical models and A-ERT surveys validated and the result is validated against borehole temperature measurements. This work provides insights for future studies about the uncertainty associated with using the petrophysical model to estimate temperature from geoelectrical measurements. This is particularly valuable because it allows the construction of 2D or 3D model about the thermal state of a permafrost site, rather than relying on local borehole measurements, which are not always feasible due to the high cost and logistical constraints of accessing such sites. (i) Novelty: This study advances permafrost monitoring from a purely point-based quantitative approach toward a quantitative and spatially distributed monitoring framework, allowing improved imaging of the subsurface and better identification of permafrost zones and fracture networks. (ii) New insights into the capability and limitations of A-ERT monitoring for detecting water flow pathways and identifying potential infiltration zones that warrant further investigation in future studies. (iii) Key research directions for monitoring at such high altitude that still deserves lot of work.

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