Revisions and responds to editor and reviewers' comments

First of all, we would like to thank the Editor and two reviewers for their comments and suggestions, which greatly improved the presentations and interpretations in our revised manuscript. In the revised article, we have addressed all comments and suggestions from the Editor and two reviewers. All changes made in the manuscript are in red. Our point by point response to the Editor and two reviewers' comments is outlined below. The original comments are shown in normal fonts and responses are given in italics and blue. We hope the revised manuscript will meet the journal's standards.

Editor:

Thank you for submitting your revised manuscript. As stated by the two reviewers, the paper has considerably improved. Nevertheless, I share the concerns of one of the reviewers concerning the TEM data. I also agree that the signals are actually not that weak, and you actually show a good agreement between ERT and TEM data. On the other hand, I agree that permafrost systems are very complex, and that a simple 1D model may not explain the variability you have in the subsurface. However, it would be good to either extend the discussion on that, or as the reviewer suggests that if the added value of the TEM measurements is low, to just remove them and focus on the ERT data.

Response: We are grateful to the Editor for taking the time to handle our manuscript and giving us valuable comments. As you and the reviewer were concerned, the TEM has some limitations in equipment, signal acquisition, and data interpretation. However, at present, we have no better solution to overcome these problems, either in data processing or in modeling. Following your and the reviewers' suggestions, we have removed all the information related to the TEM and focused instead on the results of the ERT. We have made every effort to address all comments and suggestions from the Editor and two reviewers, and sincerely hope that the revised article can meet the journal's standards.

Reviewer #1

The substantial revisions completed by the manuscript authors are recognized. Many of the revisions have provided meaningful improvements (e.g., addition of a research question) while others fell short of expectations (e.g., declined to apply temperature correction to ERT images).

Response: We thank the Reviewer's positive comments and encouragement which help us to improve this article considerably. The comments regarding the application of temperature to correct ERT images are highly valuable and insightful. However, inconsistencies between the temperature monitoring locations and periods and the ERT measurements present challenges for implementing such corrections. We greatly value this constructive suggestion. While we have not yet found a suitable solution to overcome this limitation in the current work, the comment provides valuable guidance for future research.

Line 31: "Permafrost is a special type of sediment…" permafrost may be any material – sediment or otherwise- that remains below 0C for 2 or more consecutive years.

Shur, Y., Jorgenson, M. T., & Kanevskiy, M. Z. (2011). Permafrost. In Encyclopedia of snow, ice and glaciers (pp. 841-848). Springer, Dordrecht.

Response: We thank the Reviewer to point out this imperfect statement. Following the Reviewer's comment, we have rephrased text as "Permafrost is ground (soil or rock and included ice and organic material) that remains at or below 0°C for at least 2 consecutive years (Gao and Coon, 2022; Shur et al., 2011)…" (line 31-32)

Line 255-285: The use of the TEM data remains concerning – after the detailed comments related to the TEM data by multiple reviewers/comments, the authors did not attempt to improve the fit or otherwise explore the inversion of the dataset, and rather provided only two possible explanations: 1) the permafrost is heterogeneous, and 2) the EM responses of resistive permafrost are weak. For 1, this may be the case (as evidenced in part by the ERT data), but if it is in fact not possible to resolve the complex structure with the TEM data, why use this dataset at all, knowing (based on ERT) that the image is fundamentally incorrect? For 2, this is physically true, however the inverted results of both EM and ERT indicate a strong conductor at 80-120m that would be expected to produce strong signals. Therefore, such an argument about low signal strength does not seem to be valid. Furthermore, the comparison between the

TEM and ERT, as described in the first paragraph of the Discussion section, is inconsistent. I suggest the TEM dataset be removed from the manuscript and focus instead on the ERT data.

Response: Thanks for your comments. We understand the Reviewer's concerns. The TEM has some limitations in equipment, signal acquisition, and data interpretation that we have no better solution to overcome presently. Following the reviewers' suggestions, we have removed all the information related to the TEM and focused instead on the results of the ERT.

Line 334: It would be helpful to have a Discussion sub-section dedicated to answering the newly posed research questions, in particular question #2 related to how permafrost structure determines distributions of thermokarst lakes, which has not been answered in the current version of the discussion.

Response: Yes, the Reviewer is right! Following the Reviewer's comment, we have added a Discussion sub-section to answer question #2 related to how thermokarst lakes affect the permafrost distribution. The added texts are as follows:

4.3 The effect of the thermokarst lake on permafrost structure

In regions without thermokarst lakes, permafrost dynamics are mainly controlled by air temperature, precipitation, and groundwater flow, which primarily influence the active layer; thus, the permafrost structure remains relatively stable (Fig. 4h) (Wu et al., 2022). However, the temperatures of thermokarst lakes are generally higher than those of the surrounding permafrost, thereby accelerating permafrost degradation (in 't Zandt et al., 2020). In the initial stage of thermokarst lake development, permafrost impedes groundwater flow, and heat transfer is dominated by thermal conduction (McKenzie et al., 2007). Under these conditions, thawing mainly occurs vertically, concentrated beneath the lake bottom and within limited areas around the lake (Fig. 4b) (Niu et al., 2018). As thawing progresses and permafrost below the lake bottom disappears, a through-talik forms, which restores groundwater flow pathways. Groundwater carrying heat preferentially migrates through highly permeable zones, resulting in progressive thawing at the base of the permafrost (Figs. 4b and f) (Li et al., 2021a). Our investigation revealed substantial thawing at the permafrost base near the lake, indicating that groundwater plays a critical role in the thawing process, which highlights the significance of

thermal convection in permafrost degradation and confirms previous numerical simulation results (Rowland et al., 2011; Zipper et al., 2018). In particular, the permafrost in the lakeshore was disturbed by the groundwater and thermokarst lakes, causing the lakeshore to collapse (Niu et al., 2018), thus accelerating lake expansion. Furthermore, in regions with a thermokarst lake group, permafrost between adjacent lakes exhibited pronounced degradation, with a remarkable thinning of its thickness after through-talik formation (Figs. 4b, c, and d) (Ke et al., 2023a). In summary, thermokarst lakes disturb permafrost structure through two primary mechanisms: (1) direct thermal erosion caused by relatively warm lake water, and (2) alterations in groundwater circulation that enhance subsurface thaw (the main mechanism). These processes emphasize the combined influence of thermokarst lakes and groundwater on permafrost dynamics in permafrost regions. These findings enhance our understanding of the interaction mechanisms between thermokarst lakes and permafrost, and contribute to research on the evolution of thermokarst lakes and their associated ecological and environmental impacts in cold regions. (lines 309-330)

Reviewer #2

Response: We sincerely thank Reviewer #2 for taking the time and effort to review our manuscript. It is our great honor to receive your recommendation.