Revisions and responds to reviewer 3's comments

The study presents a hydrogeophysical investigation of permafrost and talik distribution around thermokarst lakes in the Qinghai Tibet Plateau. The topic is of interest to me due to the still limited understanding of how permafrost and thermokarst lakes interact, as well as the limited number of studies conducted in the region where this study was performed. The manuscript reads easily and is relatively well organized. I also appreciate seeing the use of TEM for deeper investigation than the ERT, as well as seeing the differences between both methods. However, I have several major concerns, outlined below. I recommend major revisions before publication.

Response: We thank Reviewer 3 for his/her comments, which helped us to improve this article considerably. Following are point by point responses to his/her comments. Reviewer 3's comments are written in normal fonts and our responses are presented in italics and blue.

Major Comments:

1. The aim of the paper is not clearly stated in the introduction. I suggest that the authors clarify this by introducing a specific research question they are trying to answer or a hypothesis they are aiming to test. Based on the title, I assume the study is focused on the impact of thermokarst lakes on permafrost distribution. Although the discussion returns to this topic, it reads more like a general summary of current literature than a clear comparison of this study's results with previous findings, or a demonstration of how the study confirms or reveals new insights. Additionally, based on the manuscript content, it appears the main focus might be the estimation of permafrost structure around thermokarst lakes, and the comparison between ERT and TEM methods. I suggest the authors refine the key research questions or focus of the study in the introduction, and revise the discussion section accordingly.

Response: We thank the Reviewer 3 for the excellent suggestion. Reviewer 1 mentioned this, too. As the reviewers mentioned, we focus on the permafrost structure and the impact of thermokarst lakes on it in this article. Following Reviewer 3's suggestion, we have refined the key research questions at the beginning of the fourth paragraph of the introduction. The corresponding text was rephrased as "Given the widely distributed thermokarst lakes and the paucity of information about permafrost degradation under their influence, we aim to answer *the following questions: (1) What is the characteristic of permafrost structure (spatial distribution and thickness)? (2) How do thermokarst lakes affect the permafrost distribution? To answer these questions, we combined ERT, TEM, and GTM methods to obtain the characteristics of sublake taliks and permafrost structures in the Qinghai - Tibet engineering corridor. ERT and TEM measurements were used to map the permafrost distribution, whereas GTM helped record the thermal state of the sublake taliks and was used to verify the ERT and TEM results".*

2. It is very difficult to evaluate the ERT and TEM results as presented. The various transects are shown with different resistivity color scales. In Figure 4, ER1 and ER3 intersect, and ER4 and ER5 are subsets of ER1, yet each has a different color/value range. I suggest using a consistent color scale throughout the manuscript, or at least adding all the figure with a consistent color scale in the supplementary material, to allow for meaningful comparison.

Response: Yes, the Reviewer is right! Reviewer 1 mentioned this, too. Following the Reviewer's comment, we have redrawn the figures and attached them below. First of all, we used the same color scale and the same threshold for all transects. However, for the ER1 transect, the maximum depth of permafrost is less than 40 m (Figure A), which is quite different from the results of borehole temperature, TEM, and other sections. There are significant differences in the range and spatial distribution of their resistivity due to the different environments (water bodies and permafrost distribution) in each transect. We comprehensively considered resistivity and its variations to infer the permafrost boundaries. Therefore, we also consider using same color scales but with different thresholds for ER1 and other sections (Figure B) to determine the permafrost structure of each transect. We think the second plan is more reasonable.

To fully address the Reviewer's concern, we present both options for consideration. While both approaches have merits, we believe that Figure B provides a more accurate representation of the permafrost structure. However, we would greatly appreciate the Reviewer's opinion on this matter and are happy to revise accordingly.

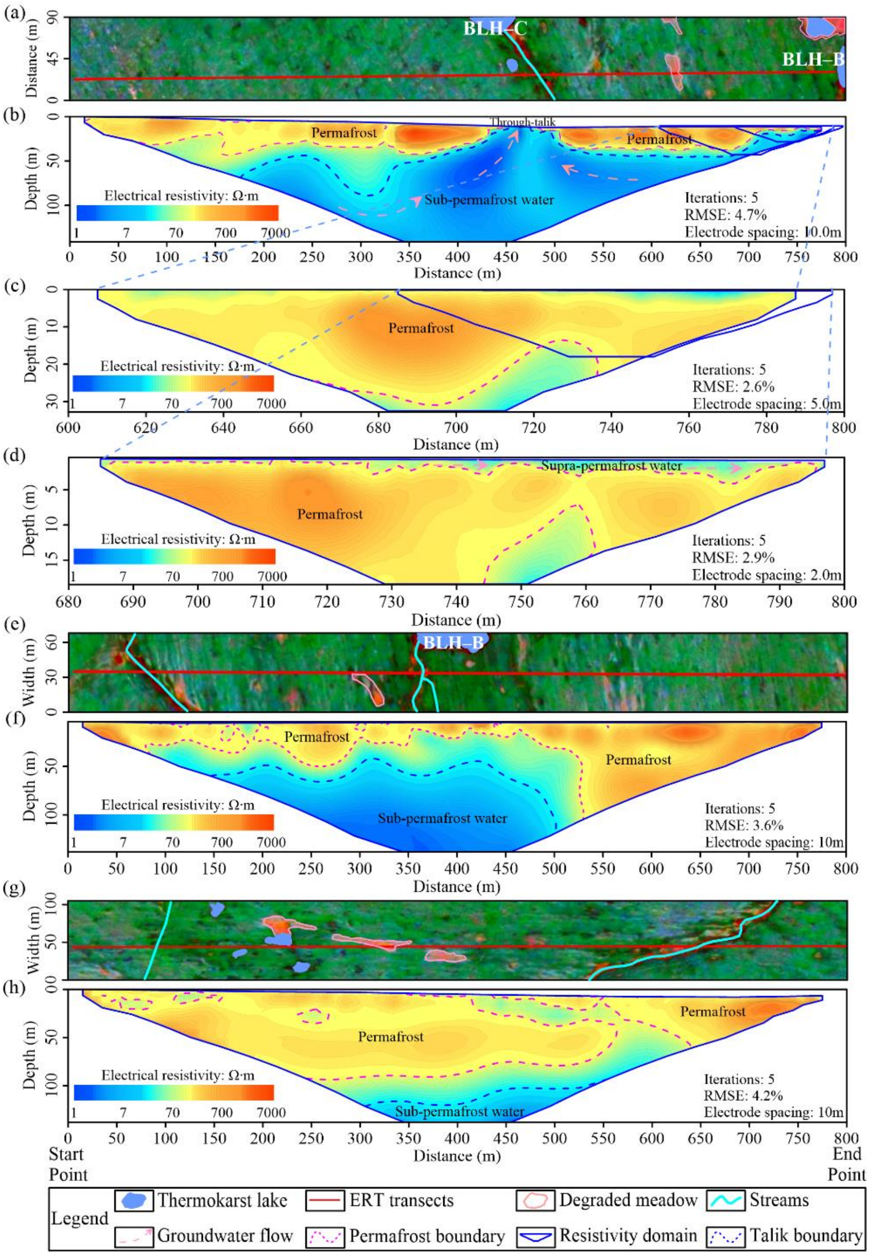


Figure A: Inversion results of ER1 (b), ER4 (c), ER5 (d), ER2 (f), and ER3 (h) that used the same threshold.

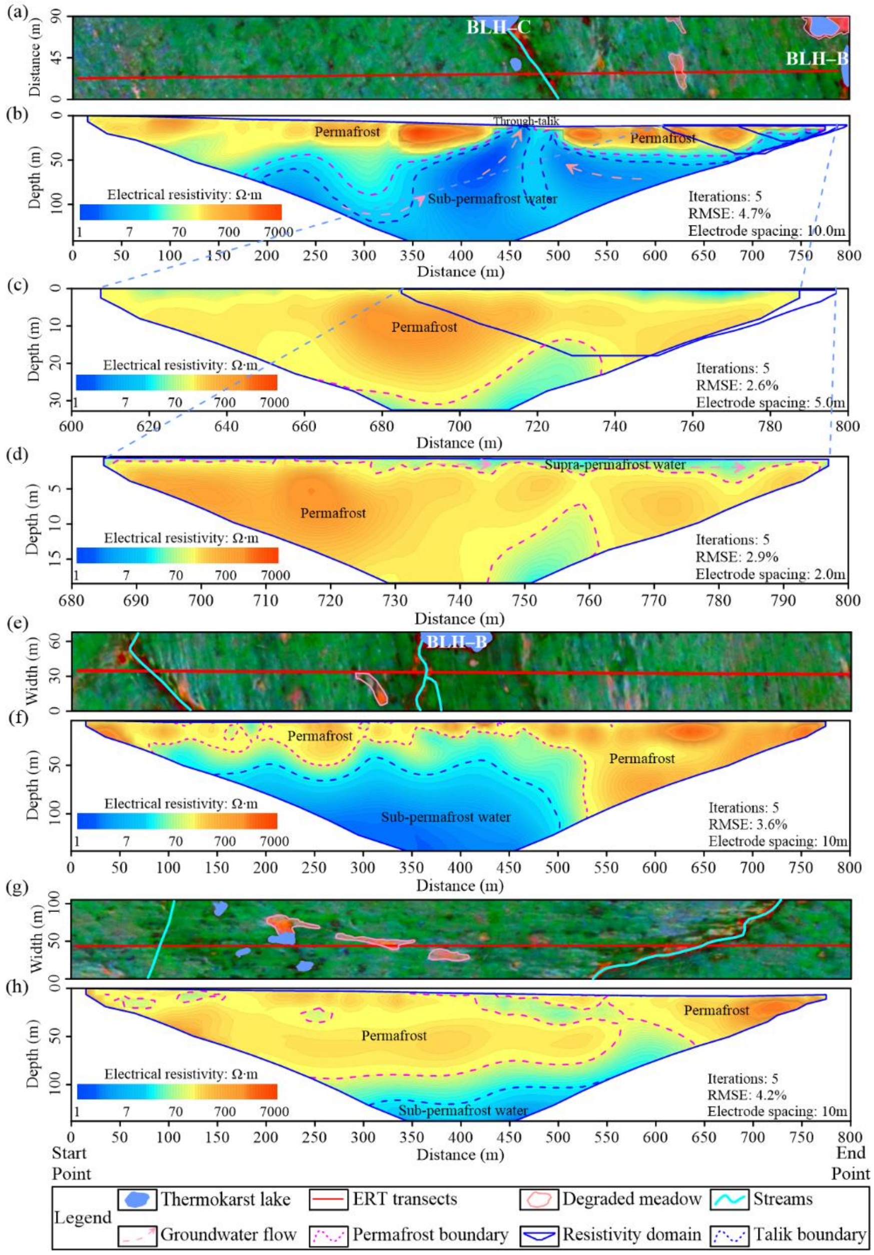
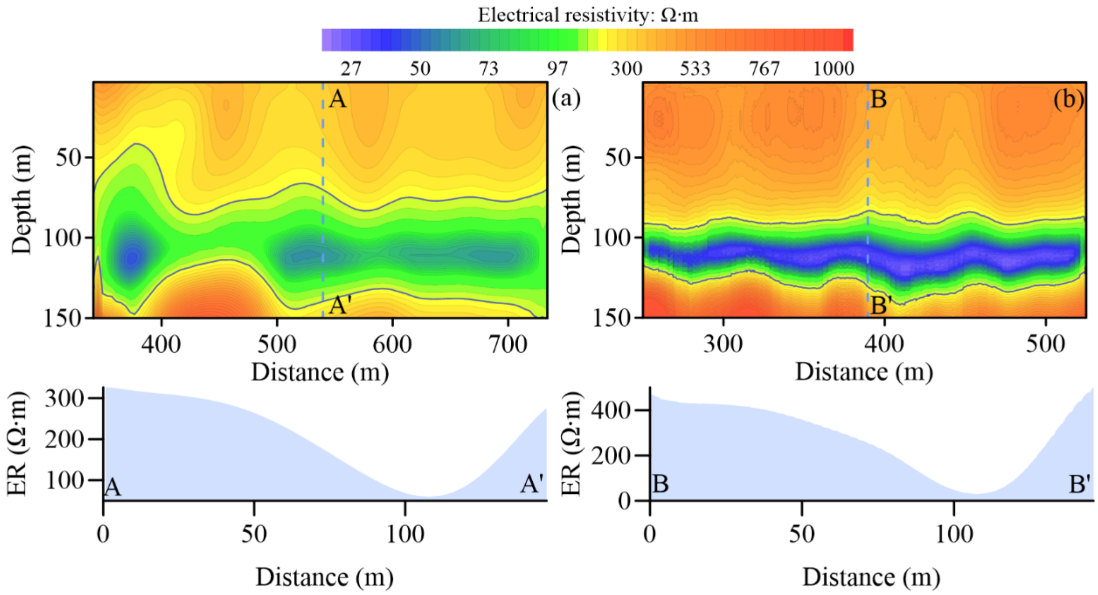


Figure B: Inversion results of ER1 (b), ER4 (c), ER5 (d), ER2 (f), and ER3 (h). The threshold of ER1 is different from that in other sections.

3. The use of color scale is also misleading in Figure 8, I think. It gives the impression of a sharp subsurface boundary without showing the actual “smoothed” inversion result. If the authors want to show results in this manner, I believe the inversion should first be presented with a more typical color scale at least in the supplementary material for transparency. In addition, it is very likely that there are discrepancies btw the resistivities values and boundaries identified with the TEM and ERT. I do believe that improving the discussion of differences and reasons (in section 3.4 or section 5) would benefit the paper.

Response: Yes, the Reviewer is right! Subsurface boundary should be smoothed, like the profile (AA' and BB') captured in the contour map. To show the differences between frozen and unfrozen strata more clearly, we changed the color scale and transparency and added some contour lines in Figure 8.



Following the Reviewer's comment, we have added the clarification for the discrepancies between the resistivity values and boundaries identified with the TEM and ERT. The revised text is as follows:

These differences may be attributed to the transmitting frequency (25 Hz) used in the TEM survey and simplified inversion model. A high transmitting frequency can capture shallow information; however, the lower limit of the permafrost may be difficult to obtain. Therefore, a low transmitting frequency was used, in which case the shallow layer information may be ignored. Although inversion can reconstruct geological features to some extent, the simplified model cannot fully capture the complexity of geological structures. Moreover, the TEM inversion models tended to smooth abrupt resistivity changes, leading to smoothed or displaced boundaries. Additionally, the highly heterogeneous geoelectrical structure of permafrost, driven by strong freeze–thaw dynamics, may further amplify discrepancies between inversion results.

Specific Comments:

1. Line 127: Apparent resistivity (ρ_s) is not the same as resistivity. In this paragraph, the term "apparent resistivity" seems to be used incorrectly or inconsistently. Consider clarifying by discussing the measured resistance and the inferred electrical resistivity separately.

Response: Thanks to the Reviewer for indicating this incorrect and inconsistent term. We originally regarded the resistivity measured by ERT and calculated by inversion as apparent resistivity and resistivity, respectively. Following the Reviewer's comment, we have changed apparent resistivity (ρ_s) to measured resistance and unified the inversion resistivity as electrical resistivity (ER). The revised text is as follows:

The ERT method, which is based on the electrical differences between geological bodies (rock and soil), can be used to obtain the distribution of the measured resistance by artificially establishing an underground stable current field (Gao et al., 2019). In this method, current is emitted to the subsurface through electrodes, and measured resistance is calculated from the potential difference between the electrodes (Zhou and Che, 2021) (Fig. 3a). The distribution of measured resistance is obtained by multiple automatic measurements between different electrodes; it is then used to invert the distribution of the ER and infer the geological elements. For permafrost regions, the ER variations can be attributed to changes in the unfrozen water content, assuming that other conditions (lithology, pore space, and electrode coupling) are constant (Hilbich et al., 2008). Since ER of unfrozen water is significantly lower than that of frozen water (Tang et al., 2018), the ER variation in permafrost regions is indicative of the change in the water (ice) content of the formation. Thus, the permafrost distribution can be inferred from these changes.

2. Line 173: Consider moving Section 2.5 earlier in the manuscript to explain the survey strategy before providing details about each method. This will help the reader understand the overall approach more clearly.

Response: This is an excellent suggestion, and we appreciate the reviewer for making our manuscript more fluent and readable. Following the Reviewer's comment, we have moved Section 2.5 (Processes for talik and permafrost detection) after Section 2.2 (Hydrogeological characteristics) to make it the new Section 2.3.

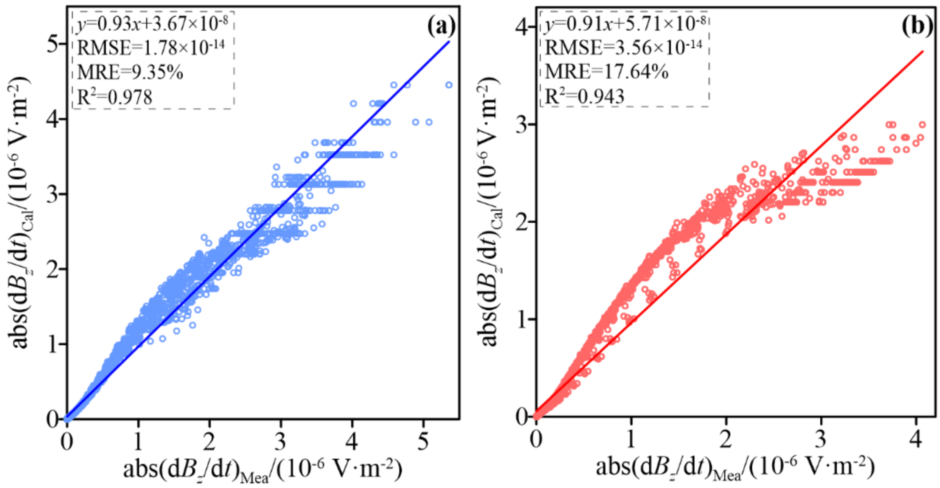
3. Line 227: The statement "The ERs for each profile are relative values rather than true values..." is confusing. Electrical resistivity is not a relative value. Please clarify what is meant here.

Response: Yes, the Reviewer is right! We thank the Reviewer to point out this confusing statement. We have deleted this sentence.

4. Figure 5: Consider explaining why the fit appears low. If the misfit were expressed as a percentage, I believe it would appear significant. Please consider providing the misfit in % and discussing the possible reasons more clearly.

Response: Yes, the Reviewer is right! The misfit in % can show the difference between the measured and simulated values. The mean relative error (MRE) of the TE1 and TE2 transects have been added in Figure 5, which were 9.35% and 17.64%, respectively. Furthermore, we also calculated the REs of the average values of the TE1 and TE2 transects, which were 0.07% and 2.63%, respectively. We have explained the possible reasons for the errors in the manuscript and the corresponding text is as follows:

The calculated and measured induced electromotive forces exhibited a similar temporal variation, with the lowest R^2 and highest RMSE being 0.923 and $6.53\times10-14\ V\cdot m^{-2}$ (Fig. 6), respectively, suggesting that calculated values were close to the measured values. Nevertheless, there were deviations between the measured and simulated values, with the mean relative errors (MREs) of TE1 and TE2 being 9.35% and 17.64%, respectively. There may be two main reasons for these errors. First, the simplified model cannot fully reflect the complex geological conditions. Permafrost has a strong spatial heterogeneity in electrical conductivity due to the uneven mixture of ice, water, and minerals. This causes local enhancement or attenuation of electromagnetic fields, which simplified models difficult to capture–particularly near electrical conductivity anomalies like permafrost-aquifer boundaries, where errors were more significant. Second, electromagnetic responses in high-resistivity permafrost were weak, further contributing to discrepancies between the model and actual observations.



5. Line 364: It is great to see a section dedicated to "Limitations." However, I am surprised there is no discussion of challenges related to data inversion in TEM, the comparison of ER values between ERT and TEM, or the difficulty in defining a boundary value to delineate permafrost.

Response: Yes, the Reviewer is right! Thanks for noticing, we only focused on the limitations of the field investigation. This is the first attempt to obtain information on deep permafrost and sublake taliks in the QTP using GPM and GTM. Therefore, there are inevitably some limitations and challenges regarding field investigation strategies, geophysical exploration applications, and methodology, which are hoped to be further overcome in future studies. Following the Reviewer's comment, we have added the shortcomings related to data inversion in TEM, the comparison of ER values between ERT and TEM, and the determination of permafrost boundaries. The revised text is as follows:

The findings of this study need to be seen in light of two major limitations. One is regarding the field investigation. Studies during the cold season and long-term investigations were not performed. Considering that the interaction between thermokarst lake and permafrost is long-term and complex, long-term monitoring will be significant to understanding the process of permafrost degradation and talik development. Moreover, only measured 5 ERT and 2 TEM transects, which may be insufficient for the complex lake–permafrost systems such as the one studied. Additionally, no new drilling work or temperature measurements were conducted because of the difficulty and high cost of deep drilling. Another limitation concerns the GPMs themselves. TEM inversion is based on a simplified model that may not adequately reflect the *complex subsurface environment in permafrost regions. Discrepancies in ER between ERT and TEM make it difficult to direct comparison. Moreover, defining a consistent ER threshold to delineate permafrost boundaries remains challenging, as ER is controlled by factors such as ice or water content and rock type. These limitations that need to be overcome increase the error and uncertainty in the results. Nevertheless, our results revealed the permafrost structure and talik morphologies and the effect of thermokarst lake on permafrost. In the future, more transects and borehole data can be considered for a comprehensive and long-term measurement of the permafrost and taliks. The development of more applicable calculated methods and convenient-to-use instruments with high precision, high resolution, and strong applicability can be another research direction.*