Reviewer Recommendation and Comments for Manuscript Number egusphere-2024-1044

Mapping subsea permafrost around Tuktoyaktuk Island (NWT, Canada) using electrical resistivity tomography

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The manuscript introduces marine Electrical Resistivity Tomography (ERT) as a technique for locating undersea permafrost. Using a relatively straightforward setup comprising 13 floating electrodes and an echosounder for determining water depths, multiple survey profiles around Tuktoyaktuk Island were measured. To mitigate corrupted ERT data, the cable was equipped with two GPS devices to monitor its curvature during the measurements. Various inversion methods were then tested and compared.

The manuscript demonstrates at which cable bending the geometry factor deviates significantly. These values are then filtered out. Additionally, a synthetic model was employed to investigate the impact of varying lateral and vertical smoothing constraints during the inversion process. Using the 'best-suited' inversion approach, the results indicate a slowly dipping permafrost table on the sea-facing northern side of Tuktoyaktuk Island and a more steeply dipping permafrost table on its southern side.

Overall, the manuscript is well written and easy to follow. However, to clarify the authors' approach further, a few structural adjustments could be beneficial (see general comments). When explaining the inversion process and its results, the authors could provide a more detailed introduction, analysis of the sensitivity and Depth of Investigation (DOI), as the results are primarily close to the resolution limits. Additionally, providing a brief overview of complementary methods and potential improvements to the inversion process at the end would help to properly contextualize the manuscript. These issues, along with several specific comments and technical corrections listed below, should be straightforward to address.

General comments

Structure

Beginning the “Results” chapter, Chapter 3, with uncertainties might come across as somewhat pessimistic, and readers typically expect to encounter results immediately in this section. Perhaps Section 3.1 could be relocated to the analysis chapter, Section 2.3, or alternatively, to the end of Chapter 3.

Additionally, Chapter 3.2, "Inversion and IBPT Depth," could be divided into two distinct parts: 1. Analysis and 'calibration' using synthetic data, and 2. Analysis of real data.

Presentation of inversion results

Please provide additional information on how the inversion parameters, such as DOI and inversion RMS (e.g., in comparison to data residual), are determined. A sensitivity analysis of e.g. the synthetic example would clarify how much the resistivity distribution at different depths can be expected to affect the measured data.

Including a figure that compares the synthetic model with the inversion result of the synthetic data would enhance the understanding of the synthetic study. Additionally, it would be beneficial to provide a second example of the real data inversion for comparison.

Outlook and other methods

Are there complementary methods/approaches to determine the depth of undersea permafrost? For an outlook the authors could also address possibilities to improve the inversion (e.g. 3D inversion or structural constraint inversion with different layers).

Specific comments

Line 2: comma after seawater: “Once inundated by seawater, permafrost usually begins to degrade.”

Line 11: Maybe more precise: “We discuss how marine ERT can be improved by accurately recording electrode positions, although choices made during data inversion are likely a greater source of uncertainty in the determination of the IBT position.”

Line 15: “permafrost degradation”

Line 39-40: Please give a reference for this prediction

Line 42: “sea floor” or “seafloor”? Both is used in the manuscript.

Line 47: Are “frozen fresh water saturated sediments” equivalent to permafrost? Is there a sharp boundary between these two layers, or is it more of a transition?

Line 48: “…a flexible cable in marine ERT survey relies on potentially varying electrode positions.” -> “…a flexible cable in marine ERT survey results in potentially varying electrode positions. “

Line 49: Fig. 2 mentioned before Fig. 1

Line 55 / Figure 1: Figure appears before referenced in text

Line 60: “ice bonded” -> “ice-bonded”

Line 60: “random massive ice bodies” -> “randomly distributed massive ice bodies”

Line 61: “On top of the cliff” -> “Above the cliff”

Line 67: Please explain “thermoerosion”

Line 68: Please introduce GSC

Line 86: Why reciprocal Wenner-Schlumberger array? Please discuss your choice concerning S/N ratio.

Line 87: Why did you just use 13 of 22 electrodes? Maybe give a short explanation.

Line 89: You could include 'DOI' in brackets here to clarify the abbreviation for future references. Additionally, how was the DOI determined?

Line 93: “The water depth was measured from the boat for every sounding using an echosounder.” -> Please specify a bit more: Did you measure during the ERT measurement directly on the boat (velocity?)? In that case, there would be an offset of around 50 m to the point of maximum sensitivity and DOI of the ERT measurement.

Line 104 / Figure 2:
- What model was used to determine DOI?
- Maybe add a depth scale and a label for the water body

Line 110: Figure 3a appears much later; perhaps show subpicture 3a) earlier

Line 111: How was the geometric factor k calculated? Was the full problem solved (3D electrode positions) or only the variation of electrode distances?

Line 117: Are the penalizing parameters of these four inversion types only applied to vertical resistivity contrasts or also to lateral resistivity contrasts?

Line 127: Why did you choose 10 Ohmm as the resistivity of the unfrozen sediment? Including a picture of the synthetic model could be generally helpful.

Line 141: Please introduce RMS

Line 145: Please introduce GIS.

Line 168: Here, mainly Fig. 3c)

Line 169-171: Probably only a secondary effect, should be in the range of the error linked to 2D assumption as resistivity also depends on variation of resistivity perpendicular to the profile.

Line 177:

- “were removed” with d at the end
- “Soundings for which the difference varied were removed” What was the threshold here?

Line 185: When interpreting the data without additional information, whether the boundary layer lies above or below the DOI should not be an argument. Both are valid possibilities.

Line 195: Maybe not with cm accuracy here.

Line 196: What is the grid cell size and what resolution could be expected according to the used electrode array in that depth?

Line 200: How is the data residual determined, and what is the difference compared to the inversion RMS?

Line 204: Here you could split the chapter into “Synthetic model analysis” and “Real data analysis”

Line 206: Was the water body a constraint in the inversion? Was there a variation in the CTD measurements or was it constantly 6 Ohmm?

Line 235: Couldn't the movement of the cable also be determined by the history of the GPS data, allowing you to simulate the cable's movement?

Line 254: To address this issue, you could potentially constrain the water layer within a range, e.g. between 5-6 Ohmm.

Line 269: Maybe you could provide this explanation earlier (see comment on line 185).

Line 276: First 'or' in the sentence could be replaced with a comma.

Line 285: This is the resolution of the mesh. The capability to resolve resistivity contrasts of the inversion could be in a different range depending on your electrode configuration and resistivity distribution.

Line 294: A finer grid does not necessarily improve the resolution of the measurement. An analysis of the sensitivity would be interesting to modify or adapt the electrode configuration in later studies.

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