Replies to Editor comments

09 Aug 2024
Editor decision: Publish subject to revisions (further review by editor and referees)
by Andreas Hördt

Public justification (visible to the public if the article is accepted and published):

Dear authors,

I agree with both reviewers, who express their positive opinion on the manuscript, but at the same time suggest revisions that will require structural changes and additional figures.
I anticipate no significant difficulties and ask you to carry out the revisions along the reviewers' recommendations and your replies.

Response: We relocated section 3.1 to the end of chapter 3 and section 4.1 to the end of chapter four. To introduce section 3.1 (now 3.2), we added the following sentence:

> *Marine electrical resistivity surveys using a floating cable towed behind a boat can introduce uncertainties in the positions of the electrodes. Because the cable is flexible, it may curve under conditions such as the boat's path, wind or currents. This curvature leads to two sources of uncertainty: 1) a deviation in the geometric factor compared to a straight cable, due to changes in the relative distances between the electrodes and 2) a lateral deviation of the cable center (Fig. 7).*

I have one major issue, however: Both reviewers independently asked you to provide more information on the resistivity results, in particular to discuss more profiles. I totally agree with this recommendation, and from the author's comments I see that the necessary material already exists.
At the moment, you suggest to provide this as "supplementary" material, to avoid the paper to become "excessively long" or "stick to not more than 5 figures". I do not see the paper becoming "excessively long" if it has more than 5 figures, or why this should be important. Therefore, I strongly advise you to include part of the material into the main body, instead of the supplementary section. This refers to supplementary figure 2 and 3, and a selection of 2-3 additional 2-D profiles.

Response: Thank you for the suggestion. We adapted this comment by moving the previous supplemental figures into the main text. The revised manuscript now includes a figure of the synthetic model (Fig. 3), a figure of the inversion of the synthetic model (Fig. 4) and four 2-D profiles (Fig. 5). Three profiles were located roughly perpendicular to the coastline from the north and south side of the island, and one profile parallel to the island. The positions of these profiles are highlighted in the upper panel of Fig. 6 and inferred IBPTs are shown in the lower panel.
In the methods section, we have added a reference to Fig. 3 to the description of the synthetic model and we have added the following caption to the figure:

Figure 3. Synthetic model used to infer the most suitable inversion technique for this specific setting. The model consists of three layers: The upper layer represents the water body with a depth of 5 m and a resistivity of 6.1 Ωm. The second and third layers have resistivities of 10 Ωm and 1000 Ωm, representing unfrozen and frozen sediment, respectively. The boundary between the two layers ranges from depths of 7 to 30 m and dips at varying angles, which is a plausible scenario for the IBPT in a profile perpendicular to the shoreline of Tuktoyaktuk Island.

In the results section, we have added a description of Fig. 4 to the text:

The inverted models for medium vertical and medium lateral/thickness constraints are shown in Fig. 4 and illustrate the differences between the inversion types. The smooth inversion produces a model with a constant or only slightly varying resistivity gradient, which makes the determination of the highest vertical resistivity gradient ambiguous. In contrast, the layered model provides a defined boundary between the unfrozen and frozen layer. However, the resistivity and thickness of the unfrozen layer are strongly correlated, producing unrealistic models for most of the constraint combinations. The blocky and sharp inversions represent compromises between the smooth and layered inversion. Blocky inversions tend to show resistivity variations within the frozen layer, while sharp inversion models exhibit fewer variations within the layers but often display strong artifacts at the seabed boundary.

And the following caption to Fig. 4:

Figure 4. Comparison between the smooth, blocky, sharp and layered inversions (with medium vertical and lateral/thickness constraints) of the simulated ERT data from the synthetic model. The models show different transitions between the second and the third layer (representing unfrozen and frozen sediment in Fig. 3). The inferred IBPT, identified as the highest vertical resistivity gradient in logarithmic space, is close to the DOI in all four models. The blocky model's inferred IBPT is closest to the actual boundary in the synthetic model.

Additionally, we have changed the description of the profiles:

The LCI of field data are shown in Fig. 5 for a selection of profiles around Tuktoyaktuk Island. In each tomogram, the IBPT calculated in linear and logarithmic space was compared to the DOI. Gray dots represent the data points of the inversion and show the cell thickness. The water layer in each model was constrained by the CTD measurements taken closest to the profiles on the day of the ERT surveying. As the water column showed no stratification, the water resistivity of the model was constrained uniformly throughout the layer. The profile corresponding to Fig. 5a lay north of the island and extended from NNW' to SSE'. The IBPT inferred from the model was extended based on borehole information (Dallimore et al., 2018) and permafrost probe measurements conducted in September 2021. The water layer and the unfrozen sediment layer had a similar resistivity with slight variations that could be interpreted as compensation for a slight spatial variation in water resistivity. The transition from unfrozen to frozen layer (as identified by the highest logarithmic resistivity gradient) occurred between 10 and 50 Ωm and the permafrost below

showed resistivities of 50 to several hundreds Ωm. The depth of the IBPT was shallow (5 to 10 m bsl) at a distance up to 250 m from the shoreline and descended to a stable level around 20 m bsl further offshore (250 to 600 m from the shore). The mean data residual was 1.54 (RMS=3.4%).
The profile corresponding to Fig. 5b lay perpendicular to the northern shoreline and extended from N' (offshore) to S' (around 130 m from the coast). The water depth was around 4 to 5 m and the IBPT was inferred at around 13 to 17 m bsl, close to the DOI. The dipping of the IBPT from S' to N' was not as pronounced as for the profile shown in Fig. 5a, but rather at a constant depth below the slightly northwards dipping seafloor. The mean data residual was 1.47 (RMS=3.4%).
The profile corresponding to Fig. 5c lay south of Tuktoyaktuk Island and extended from NW' (close to the coast) to SE' (towards the harbor basin). The water depth ranged from 2 m close to the coast to around 10 m. In the deep water, the resistivity below and slightly above the seabed is very low (below 1 Ωm) which could be an artifact compensating for changes in the resistivity of the deeper water. The IBPT ranged from 12 m bsl close to the coast to around 35 m bsl where the water is deeper. A significant stretch of the IBPT lay several meters below the DOI, where the sensitivity was very low and the IBPT depth should be treated with caution. However, we expected a deeper IBPT south of Tuktoyaktuk Island due to deeper water and slower coastal retreat rates that imply longer inundation times at similar distances from the coast and thus a longer period of subsea permafrost degradation. The mean data residual was 1.70 (RMS=13.8%).
The profile corresponding to Fig. 5d lay parallel to the northern shoreline and extended from WNW' to ENE' at around 150 m from the shore. The water depth varied between 3 and 7 m and the IBPT was inferred to be mostly horizontal between 12 and 16 m bsl, close to the DOI. The resistivity ranges were similar to the profile in Fig. 5a. The mean data residual was 1.93 (RMS=3.8%).

Accordingly, we have changed the figure caption:

Figure 5. Comparison of IBPT calculations (linear and logarithmic) and DOI across selected inverted resistivity models. The locations of the selected profiles are indicated in Fig. 6. (a) The profile was located north of the island, perpendicular to the shoreline. The IBPT dipped towards the offshore part where it remained constant for several hundred meters. Towards the shore, the IBPT was extended based on borehole information (Dallimore et al., 2018) and permafrost probe measurements. (b) The profile lay perpendicular to the northern shoreline, east of the profile in (a). The IBPT dipped from S' to N' but was pronounced as for the profile shown in (a). (c) The profile lay south of Tuktoyaktuk Island and extended from NW' (close to the coast) to SE' (towards the harbor basin). The IBPT dipped steeply and lay deeper compared to the other profiles; however, the section lying several grid cells below the DOI should be treated with caution. (d) The profile ran parallel to the northern shoreline at around 150 m from the shore. The IBPT was mostly horizontal.

A few minor issues: You agreed with rev. 1 that permafrost depth and IBPT should be distinguished, but the caption of supplement fig. 4 refers to IBPT, whereas the corresponding colur scale is labelled "permafrost depth", indicating that the two are not being distinguished. Please check for consistency throughout the entire paper.

Response: Thanks for noting this inconsistency. We have corrected the labels throughout the paper to ensure a consistent terminology.

In that same figure, the choice of the colour to highlight the profiles is unfortunate, because it overlaps with the colour bar.

Response: We have changed the highlight color to blue for a bigger contrast to the color scale.

I look forward to receiving the revised manuscript, which will be sent to both reviewers.
Sincerely,
Andreas Hördt

We have additionally made minor corrections, including spelling, abbreviations, figure captions, and adjustments to figures that do not impact the text.