

Interactive comment on “Quasi-3-D resistivity imaging – mapping of heterogeneous frozen ground conditions using electrical resistivity tomography” by C. Kneisel et al.

Anonymous Referee #3

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The paper by C. Kneisel, A. Bast and D. Schwindt “Quasi-3D resistivity imaging - mapping of heterogeneous frozen ground conditions using electrical resistivity tomography” describes a 2.5D-ERT approach based on 17 parallel and perpendicular transects on permafrost-affected moraine material. Forward modelling is used to demonstrate the effect of transect spacing and the use of perpendicular profiles on the quality of Pseudo 3D-ERT sections. The 17 measured transects were collated to a 3D-ERT plot in Res3Dinv, that clearly shows subsurface variability and permafrost-prone material in depths of 5-25 m. The ERT data generally agree with SRT and borehole data (Fig. 6).

As the other published review has commented on the structure of the paper, I will refer

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myself to the content of the paper:

The measured 3D-ERT plot shows convincing data and provides a new and interesting insight into the accounted subsurface heterogeneity collated from an impressive amount of transects. This is a novel and important contribution to the scientific community. I see promise in the 3D data and I hope that an advanced interpolation of data in RES3Dinv as discussed below could provide a more appropriate model.

However, the outline of the forward modelling approach could be improved. The major outcome is still a little bit unclear. This partly belongs to the fact that the input data is not explained in detail. However, the input data has a high impact on the „statement 1: transect spacing“ and on the „statement 2: importance of cross profiles“. I would suggest to rethink your message, e.g.: „At the given heterogeneity of the collated 2D-resistivity sections, a transect spacing of max. 3 times the electrode spacing is still appropriate.“ However, this statement makes an exact description of the implemented data sets necessary. The paper should, thus, more explicitly focus on the technical performance of 3D inversion and forward modelling and should discuss technical approaches and problems in more detail.

Below you find a number of suggestions for revisions of your paper:

The Introduction

Should shortly refer to advancements in 3D-ERT modelling outside the permafrost community.

Could be more instructive about the problem why real 3D modelling (dipole/pole) is often difficult in permafrost environments – e.g. error levels of dipole arrays, signal to noise ratios . . . (see comments annotated copy)

Could refer to other 2.5D work in the permafrost community (see comments annotated copy)

should include a paragraph on what questions could in future be addressed by 3D

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techniques that are not covered by 2D techniques

I think, the “High-altitude alpine permafrost environments often exhibit ...” section, that is presently implemented in the conclusion, rather belongs to the introduction.

It would be nice to give a concise statement on why is it important to understand the small-scale heterogeneity and what methods are presently at hand to do this.

Site

Please state in some detail what are your systemic research questions that you aim to answer with your 3D-ERT approach.

Methods

Clarify the input data of the forward modelling: it would be nice to include a separate paragraph that explicitly describes the input data and forward modelling settings that were used to create Fig. 1 and Fig. 2.

Be more precise on the inversion modelling parameters you use and give a short statement on whether you applied – robust inversion?, reduced effect of side blocks?, altered damping factors? . . . or not and why.

Results:

„The application of only parallel arrays results in line-like structures and loss of information value with larger parallel spacings (cf. Figure 1a,b,c)“ I am not quite sure whether this is because of the data coverage and density (as you outline) or just an interpolation problem of RES3DInv that can be solved by the following procedure:

A major drawback of RES3Dinv is that (during the collation process) data of a transect at $y=0$ and a transect at $y = L$ are merged to one dataset that appears at $y=L/2$ while no data appear at $y=0$ or $y=L$. In the Krautblatter 2008 NICOP 3D dataset (p 1001) the original 2D datasets were additionally included at $y=0$ and $y=L$ or $2L$ or $3L$. This results in a much smoother model without the problem of single separate lenses that should in

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fact merge together to one larger body.

The implementation of 2D data makes sense (in your case) as high-resistivity data apparent at $y=L/2$ result from the fact that high resistivity data were measured in both, the $y=0$ and the $y=L$ transect and there is no reason to believe that they are separated by a low-resistivity body (dependent on the background resistivity) between $y=0$ and $y=L$.

The problem of single lenses is especially apparent in Figs. 1,2,3. It would be interesting to see whether the implementation of the original 2D data could change this in the forward modelling process, too.

Discussion and Conclusion:

The conclusion is too long and includes parts that belong to the Introduction

The major outcome of the forward modelling is still a little bit unclear. This partly belongs to the fact that the input data is not explained in detail. However, the input data has a high impact on the „statement 1: transect spacing“ and on the „statement 2: importance of cross profiles“. I would suggest to rethink you message: „At the **given** heterogeneity of resistivity a transect spacing of max. 3 times the electrode spacing becomes necessary“ but this message makes an exact description of the implemented data sets necessary.

„High-altitude alpine permafrost environments often exhibit a distinct small-scale heterogeneity of permafrost distribution as well as surface and subsurface characteristics. Questions arise concerning the degree of heterogeneity. Hence, knowledge of the distribution pattern and the factors determining the presence or absence of permafrost under different environmental conditions, especially at the fringe of discontinuous and sporadic permafrost occurrences, is a key to assess ongoing and future impact of climate change.“ I would include that in the introduction to state the major focus of your present work.

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Otherwise a good and very interesting paper! Good luck with the revisions.

Interactive comment on The Cryosphere Discuss., 3, 895, 2009.

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