Resistivity inversion software comparison

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Introduction

The application of modern geophysics may assist in solving environmental, geotechnical and exploration problems. One commonly used method in such applications is electrical resistivity tomography (ERT). In order to interpret the results, inverse numerical modelling, inversion, is needed to create models that estimate the distribution of resistivity in the ground. The ability to invert ERT data has developed dramatically in the last few decades, which has been closely linked to the availability of affordable computing power. The development took off at the beginning of the 1990's with the affordable personal computers finding their way into many universities and companies. With this the possibility to invert ERT data became available for researchers and practitioners for near surface applications. Today, several different inversion programs are available for ERT inversion. It has however been noticed that different inversion software can result in model that appear to be significantly different. Since the plotting style differs between the programs it is difficult to make an objective comparison between them, although it is desirable. In this paper, the performances of three different inversion programs have been compared through inversion of the forward response of the same synthetic model.

All resistivity inversion programs consist of a forward modelling routine, followed by an inversion routine. The forward modelling of electrical fields may be done using either finite difference (FD) or finite element (FEM) approaches. Both approaches have their strengths and weaknesses. With the main weakness of the FD rectangular meshes being that it does not adapt very well to topography or targets that may not be well described. The FEM technique has its drawback in that it is more computationally intense. The three programs that are used in this paper represent both the FD and the FEM side. No topography is included in the modelling and the shapes that are modelled are simple to create using a rectangular mesh. The programs used are: 1) Res2Dinv (Loke et al. 1996; Loke et al. 2003), 2) Aarhusinv (Auken et al. 2015; Fiandaca et al. 2013) and 3) BERT (Rücker et al, 2006; Günther et al. 2006). The first is commercial software, the second is freely available for researchers and students, the third software is developed and used by the scientific community without cost.

Method

Two synthetic forward models used by Dahlin and Zhou (2004) served as inspiration for the inversion software comparisons in this paper. The first one is a model of an old river channel, depicted in figure 1. It can be thought of as a former stream channel with sand and gravel sediments in a surrounding of clayey sediments, being overlain by silty sediments.

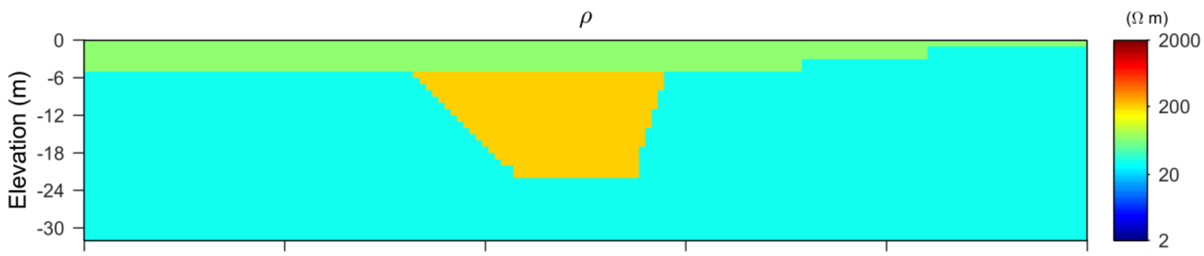

Figure 1. *Model 1, old river channel, clay environment (30 Ohm-m), sand/gravel river channel (200 Ohm-m) and silty sediments on top (70 Ohm-m).*

The second model depicts dipping layers, see figure 2. It can be seen as a sedimentary sequence that has be tilted and eroded, and eventually covered by till. The forward responses of these models are calculated using the Aarhusinv software. Voltage dependant noise was added to the forward response with a standard deviation of 2%. The simulated protocol used to sample the forward response was a multiple gradient array (Dahlin and Zhou 2006) protocol with 81 equidistant electrodes over an 80 meters long layout.

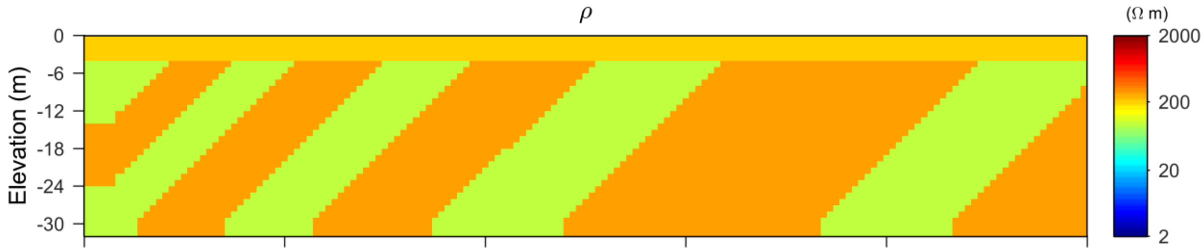

Figure 2. *Model 2, dipping blocks sandstone (300 Ohm) and siltstone (100 Ohm-m) dipping blocks covered by till (200 Ohm-m).*

In order to keep things as similar as possible between the inversion approaches for the compared programs, the L1-norm inversion scheme was used. In the Res2Dinv inversions, the depth of the model grid was increased compared to the default settings and extended model grid was used. Furthermore, model blocks with half the unit electrode spacing were used and the numbers of iterations were increased. For the BERT inversion, the depth of the model was set to the same as Res2Dinv.

Results

The results from the model 1 inversion clearly show that all three programs invert the data with a reasonable result, see figure 3. It should, however, be noted that the diagrams present approximately 3 times the median depth of investigation which is often used as the lower limit when presenting inverted models.

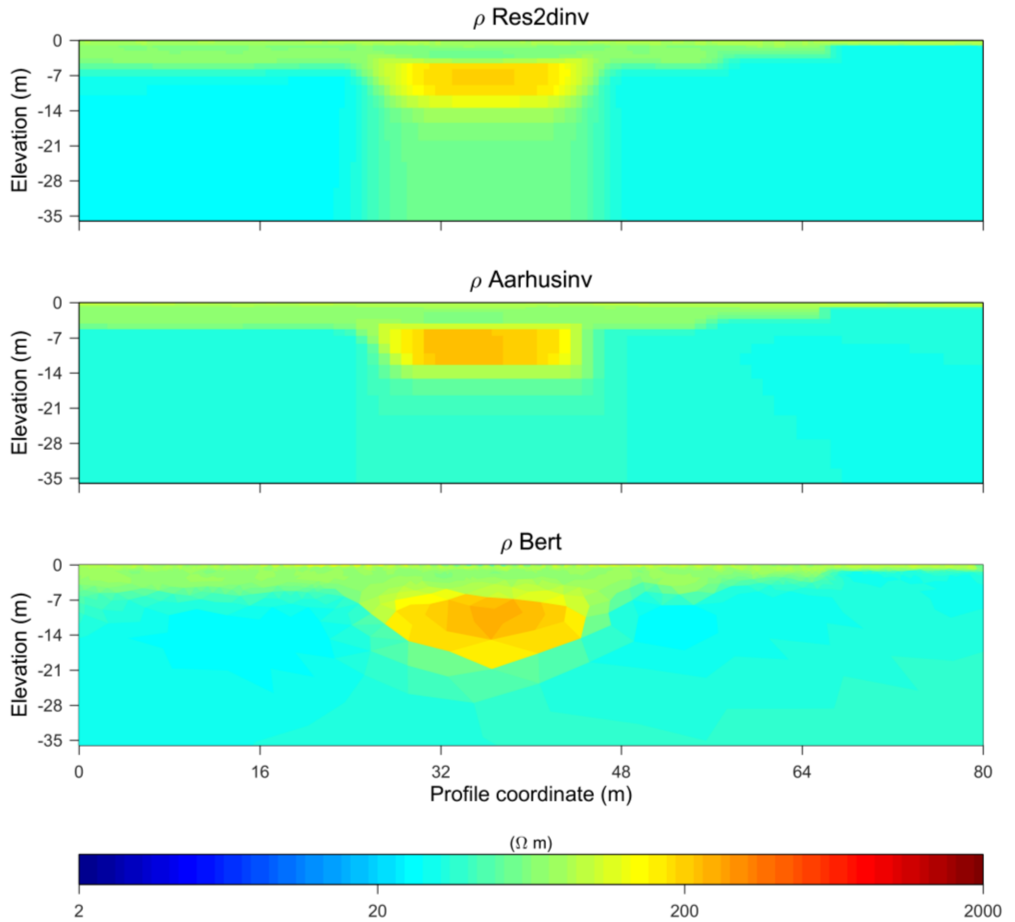

Figure 3. *Model 1 inversion results.*

There is a small underestimation of the depth of the river channel in all inversion models except the BERT one. On the other hand, the edges of the dyke are rounded in the BERT model in contradiction to the synthetic forward model (depicted in figure 1) and the Res2Dinv and AarhusInv models. It can also be noted that there is shadow of increased resistivity below the river channel in the Res2Dinv model, but this is below the median depth of investigation and would normally not be presented by the software.

The results from the model 2 inversion clearly shows that the dipping blocks model is not so well resolved, see figure 4, at least not below the median depth of investigation. Res2Dinv tends to extend the blocks vertically with hardly any indication of dipping, whereas Aarhusinv conversely produces horizontal rectangular blocks. BERT seems to pick up some minor dipping in the structures. A general problem when trying to invert the dipping block model in figure 2 is that the data coverage at depth is insufficient with the modelled array.

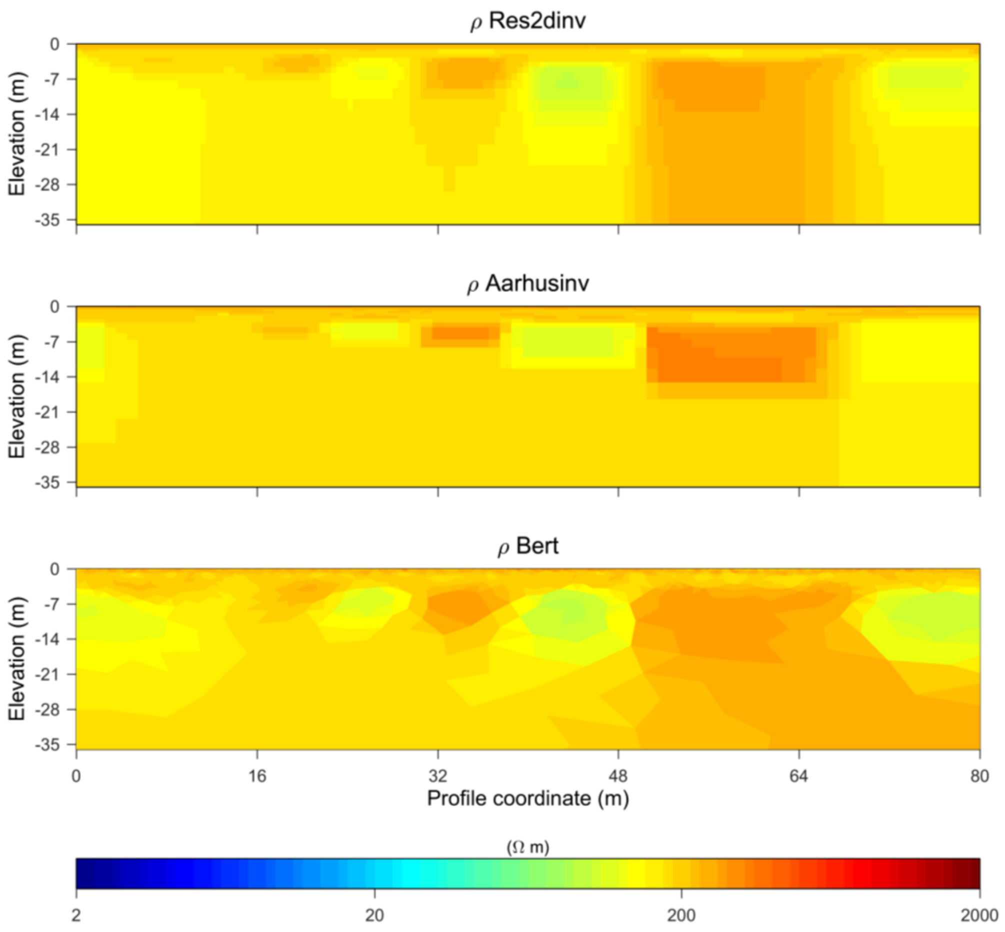

Figure 4. *Model 2 inversion results.*

Discussion and conclusion

There are major challenges in trying to compare different resistivity inversion software packages. It is difficult to plot all the results in such a way that they attain the same colour scale. An explanation to the differences between the inverted models may be found in the fact that they use different discretization algorithms. These discretization differences may play an especially large role for the results when comparing FD with FEM based inversion software. As expected, Res2Dinv generally tends to exaggerate structures vertically and Aarhusinv to exaggerate their horizontal character. BERT seems to be somewhere in between the two other programs, but does not resolve sharp features so well and result in rounded anomalies.

Despite the discretization differences among the inversion softwares, it is worth noting that the inverted results from the buried channel model are very similar and would most likely lead to an almost identical geological interpretation. The inverted values for the river channel model are pretty much spot on for all three inversions, and the shapes of the features in the synthetic forward model are well resolved with all three.

For the dipping blocks model, the upper parts of the thin blocks in the left part of the model are poorly resolved in comparison with the wider blocks in the right part. This applies to all three dipping blocks inversions. The resistivity values of the inverted models generally seem to obtain a value in between the values of the blocks in the synthetic model. Furthermore, is not possible to distinguish the inclination of the blocks in any of the inversions. Possible explanations might be poor data coverage at larger depths in the model and model discretization that cannot resolve inclined geometries.

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References

Auken, E., Christiansen, A.V., Kirkegaard, C., Fiandaca, G., Schamper, C., Behroozmand, A.A., Binley, A., Nielsen, E., Effersø, F., Christensen, N.B., Sørensen, K., Foged, N., Vignoli, G., [2015]. An overview of a highly versatile forward and stable inverse algorithm for airborne, ground-based and borehole electromagnetic and electric data. *Exploration Geophysics.* 46, 223.

Dahlin, T. and Zhou, B. [2006] Multiple-gradient array measurements for multichannel 2D resistivity imaging, *Near Surface Geophysics*, 4, 113-123.

Dahlin, T and Zhou, B. [2004] A Numerical Comparison of 2D Resistivity Imaging with Ten Electrode Arrays, *Geophysical Prospecting*, 52, 379-398.

Loke, M.H., Acworth, I. and Dahlin, T. [2003] A comparison of smooth and blocky inversion methods in 2-D electrical imaging surveys, *Exploration Geophysics*, 34(3), 182-187.

Loke, M.H., Barker, R.D. [1996] Rapid least-squares inversion of apparent resistivity pseudosections by a quasi-Newton method1. *Geophysical Prospecting.*, 44, 131–152.

Fiandaca, G., Ramm, J., Binley, A., Gazoty, A., Christiansen, A.V. and Auken, E. [2013] Resolving spectral information from time domain induced polarization data through 2-D inversion. *Geophys. J. Int.*, 192, 631–646.

Rücker, C., Günther, T. and Spitzer, K. [2006] Three-dimensional modelling and inversion of dc resistivity data incorporating topography–I. Modelling. *Geophys. J. Int.*, 166, 495–505.

Günther, T., Rücker, C. and Spitzer, K. [2006] Three-dimensional modelling and inversion of dc resistivity data incorporating topography–II. Inversion. *Geophys. J. Int.*, 166, 506–517.