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A Comparison of DCIP Inversion Software

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SUMMARY

Electrical resistivity tomography (ERT) is a commonly used geophysical method, which can conveniently be combined with measuring time-domain induced polarization. The combined measurement can be termed DCIP, and can be employed in a wide range of situations such as pre-investigations for construction, or contaminant monitoring to name a few. An integral part of a DCIP survey is the software used for processing and interpretation. There exists many such software packages. We compare the ubiquitous, commercial software, Res2DInv and two other common alternatives; the semi-academic AarhusInv and the academic, open source, BERT/GIMLi. The comparison is done by simulating measurements of resistivity and IP with a multiple gradient protocol over a model that represents a waste pond setting. The results show that there are quite a few similarities between the different softwares, but also some notable differences that one should be aware of during interpretation. This work is the first step towards an exhaustive comparison.
**Introduction**

Electrical resistivity tomography (ERT) is a commonly used geophysical method, which can conveniently be combined with measurement of time-domain induced polarization. DCIP can be used as a term for the combination and it can be employed in many situations, ranging from pre-investigations for construction projects (Danielsen, 2011) to monitoring contaminations and remediation efforts (Johansson et al., 2014) to mention a few. ERT is versatile and generally accepted and the results are often very useful, and the use of DCIP is expected to increase. One important aspect of any DCIP survey, apart from the actual hardware, is the software used for processing and interpretation. The commercial software Res2DInv is the inversion program that has become one of the most commonly used in the industry, but it is by no means the only one in existence. Two other common software suites that are used to invert DCIP data are the semi-academic AarhusInv and the academic, open source, BERT/GIMLi. These three all take different approaches to inverting the data, and comparing the output in a systematic way could be very enlightening and highlight the strengths and weaknesses in each approach. Such an extensive and systematic comparison does not seem to exist, although there have been some case studies presented by (Bazin et al., 2015), (Kydland Lysdahl et al., 2014) and (Christiansen and Auken, 2003).

**The synthetic model**

In order to study the impact of the inversion scheme on the results, we use synthetic models to be able to evaluate the performance of each program. One such model was selected as an example for this paper. From the model consisting of subsurface resistivity and Cole-Cole parameters, a simulated data set

![Figure 1](image)

*Figure 1* The subsurface model used in this comparison consists of two materials. It is the same model that was used in (Dahlin and Zhou, 2004) and represents a waste pond setting. We have assigned Cole-Cole-parameters in addition to the resistivity values of the two material types. At the bottom is the integral chargeability. The numerical values are for the anomalies: rho=10 Ohm-m, m0=150 mV/V, tau=1s and c=0.4 giving intM=58 mV/V. Corresponding values for the surroundings are: rho=100 Ohm-m, m0=10 mV/V, tau=0.5s and c=0.2 giving intM=4 mV/V.
(forward response) is computed. Noise is then added to the synthetic apparent resistivity and IP response. Figure 1 shows the model that was chosen for this comparison. The simulated measurements were done using a multiple gradient array protocol with 81 electrodes at spacing of 1 meter, on-time of 4 seconds, three stacks and twelve, approximately log-increasing, IP gates, yielding a total of 1302 data points. Voltage dependant noise (Gazoty et al., 2013) was added to the forward response with relative standard deviation on resistivity of 2%, and 5% for IP, and using a voltage threshold of 1 mV for a nominal integration time of 0.01 s and one stack. According to our experience a voltage threshold of 0.1-0.5 mV is normally representative of field-condition noise with an electrode spacing of 5 meters. To compensate for the unusually short electrode spacing thus we did choose to use a higher voltage threshold. All inversions are done using robust (L1) norms. The various other inversion settings have been adjusted in each software, without regard to the others, to get good results. Hence, the settings are not the same.

**Resistivity results**

Figure 2 shows the results from the three inversions. The three resistivity results are mostly similar and correspond quite well with the synthetic model. Both quantitatively and qualitatively (structurally), BERT/GIMLi may hint at it, but all inversions struggle to detect the deepest, rightmost anomaly. They are otherwise reasonably accurate. Res2DInv tends to stretch features downward, while the other two smoothes the features more uniformly. It appears that lateral smoothing in AarhusInv has merged the two or three rightmost anomalies into one. This part is also difficult because the depth penetration is worse towards the edges.

*Figure 2 The synthetic resistivity model (top) and the three inverted models.*
IP results

All three inversion packages take different approaches to inverting IP, and give different outputs. AarhusInv’s greatest selling point is its ability to invert for spectral (in this case Cole-Cole) parameters. Res2DInv inverts for integral chargeability, whereas BERT/GIMLi outputs the phase angle instead. All these types of IP results are qualitatively connected, but the differences make it difficult to do a quantitative comparison. Consequently we will limit the IP comparison to a qualitative one at this stage, and only look at the recovered structures.

Figure 3 shows the IP results. There are more differences between the programs when dealing with IP than resistivity. BERT/GIMLi is able to detect the upper part of the anomalies, but they appear to spread downwards much further than they should, and the result appears noisy. Again, AarhusInv blends the rightmost anomalies together, as do Res2DInv. Overall, these two are quite similar, but it is worth noting that AarhusInv is quantitatively much closer to the synthetic model than Res2DInv.

Figure 3 The synthetic integral chargeability IP model (top) and the three inverted models. Please note the different units and color scales.
Conclusions

We have shown that there are differences between the results obtained depending on the inversion software, which one should be aware of when interpreting them. The different software may have different strengths and weaknesses and could be more or less suited for a particular geological setting. To fully address this, an extensive systematic comparison is needed. Such a study would need to look at different geological settings and simulate measurements from various protocols etc. Also, a more objective way of assessing the accuracy of the inversions must be employed. This comparison is merely the first step.

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