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Impact of Time-domain IP Pulse Length on Measured Data and Inverted Models

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SUMMARY

The duration of time domain (TD) induced polarization (IP) current injections has significant impact on the acquired IP data as well as on the inversion models, if the standard evaluation procedure is followed. However, it is still possible to retrieve similar inversion models if the waveform of the injected current and the IP response waveform are included in the inversion. The on-time also generally affects the signal-to-noise ratio (SNR) where an increased on-time gives higher SNR for the IP data.

Introduction

Direct current resistivity and time domain induced polarization (DCIP) is a versatile geophysical method which has been developed for over 100 years. Alongside with this development, the use and understanding of time domain induced polarisation (TDIP) have increased in academia as well as in the engineering industry. Some aspects of the TDIP are however generally neglected when conducting DCIP surveys for engineering applications. Specifically, the effect of varying duration of the current injections and the duration of the IP decays are normally not accounted for in the standard procedures. Furthermore, to the knowledge of the authors, there has up to date been only few studies on how the duration of the injected current affects the results retrieved from TDIP measurements (with notable exception of Gazoty et al., 2013).

In this paper we show that the duration of current injections in fact has significant impact on the acquired induced polarization data as well as on the inversion models, if the standard evaluation procedure is followed. The commonly applied inversion of the induced polarization data is only considering the integral chargeability, without taking the waveform of the injected current or the waveform of the IP response into account. Our results show that, with these full waveform considerations included in the inversion, it is possible to retrieve similar inversion models for the induced polarization, independent of the on-time duration. Our results also show that the signal-to-noise ratio (SNR) for the IP information increases with increasing duration of the current injections.

Methods

A field test was conducted using an ABEM Terrameter LS for transmitting current and measuring potentials. Four field data sets were acquired on the same measurement line, using a 50% duty cycle current injection waveform with different on-time and off-time durations: half second, on second, two seconds and four seconds. The retrieved IP decays were gated with approximately log-increasing IP-gates with the same temporal distribution, but with larger number of gates for the longer on-time acquisitions. All other data acquisition parameters were identical. The field data were inverted for resistivity, integral chargeability (Res2dinv) and phase shift (Aarhusinv).

For simplicity, and in order to compare the same amount of parameters for both inversion methods, the constant phase angle (CPA) model was used for the Aarhusinv inversions (Fiandaca et al., 2013, 2012). This model contains only two parameters, in contrast to the more general Cole-Cole model which contains four parameters.

Results and Discussion

Figure 1 shows acquired field IP decays for the same quadruple from the four different on-time data sets. As seen in Figure 1, the starting values of the measured IP decays are increasing with increasing on-time. Furthermore, the magnitudes of the longer on-time decays are higher than for the shorter on-times for the full length of the decays. One direct effect of this is, assuming that noise levels are independent of on-time, is an increase in SNR with increasing on-time.

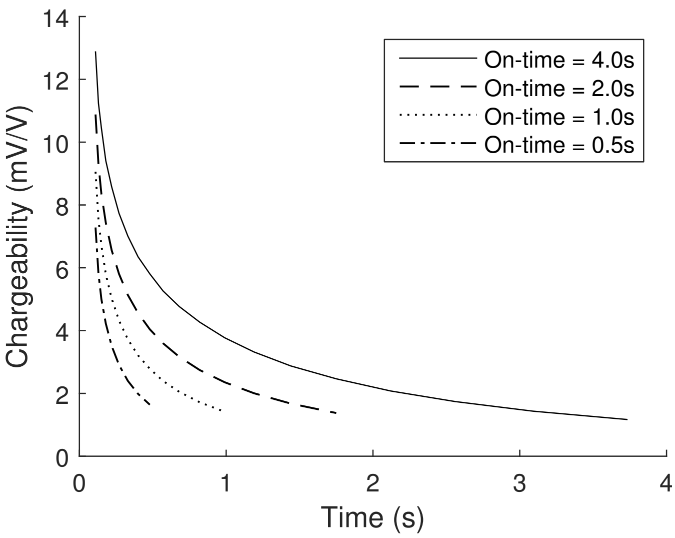

Figure 1 *Acquired field IP decays corresponding to the same quadruple from each of the four data sets with different on-time. Note that the magnitude of the decays are increasing with longer on-time.*

Figure 2 shows pseudosections of apparent chargeability for the 3rd IP-window for three data sets with different on-time. Clearly data space is different for the three data sets even if they were acquired on the same measurement line. More specific, is the apparent chargeability generally increasing when on-time is increased, which is also shown by the individual full decays in Figure 1. One effect of this difference in data space is that inversions not considering the full waveform will produce different inversion models for data acquired with different on-time. Since not only decay duration but also magnitude is different it is not enough to only fix the integration time to for example the Newmont polarization standard (Van Voorhis et al., 1973; Zonge et al., 1972), but full waveform inversion is needed.

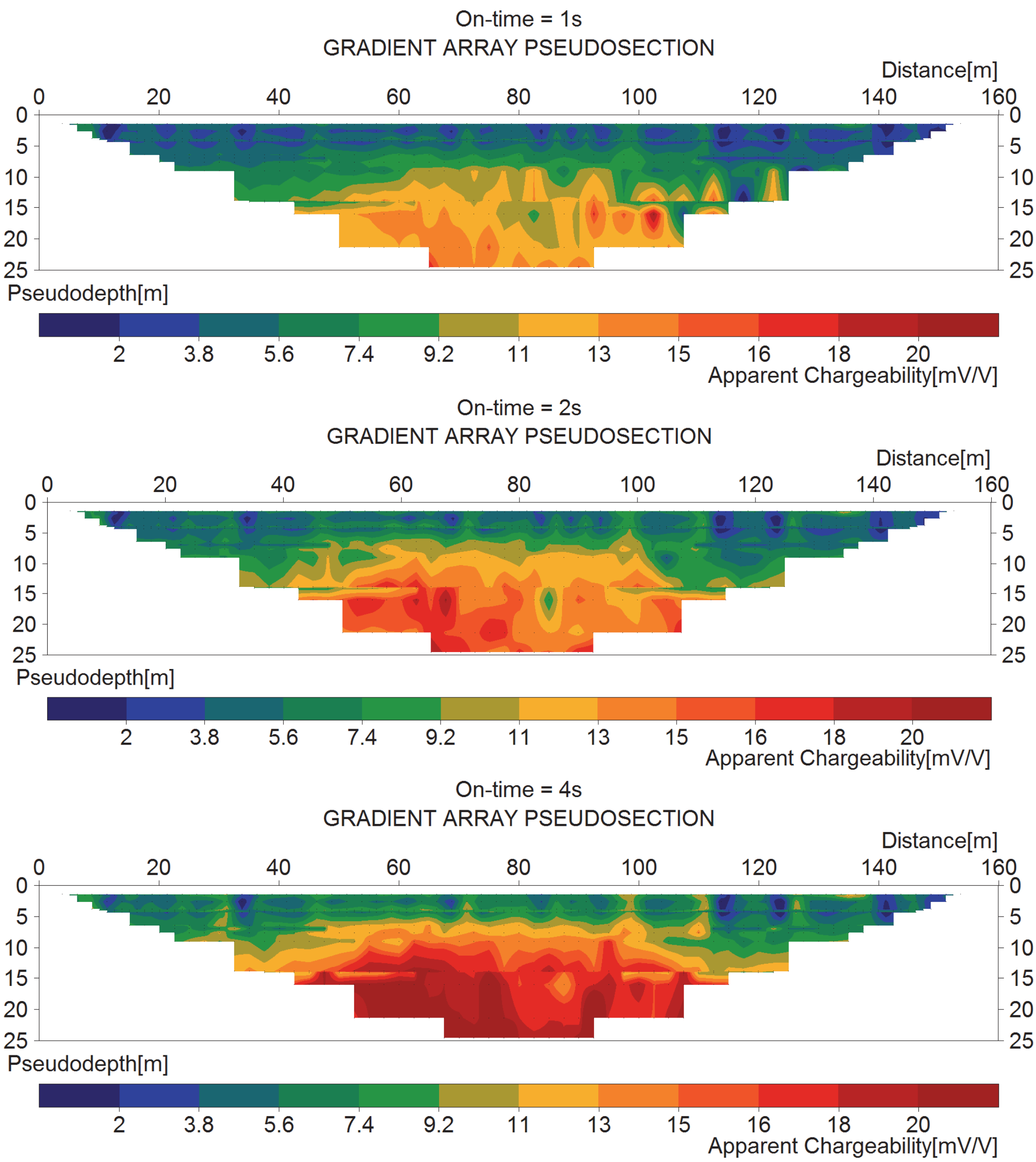

Figure 2 *Pseudosections for apparent chargeability (3rd IP-window) of three different field data sets (on-time=1, 2 and 4 seconds). As seen in the figure is the magnitude of the apparent chargeability increasing with increasing on-time (from top to bottom). This effect can also be seen in the full decays shown in Figure 1.*

Figure 3 shows inversion models retrieved with Res2dinv and Aarhusinv for three data sets acquired on the same measurement line but with different on-time. The resistivity sections are similar for all data sets independent on inversion software. However, as expected when considering the difference in data space, the chargeability models retrieved from the integral chargeability inversions are quite different (Figure 3, 2nd profile from top). On the contrary, more similar inversion models are retrieved when inverting for the CPA-model and taking the waveform of the injected current into account (Figure 3, bottom profile).

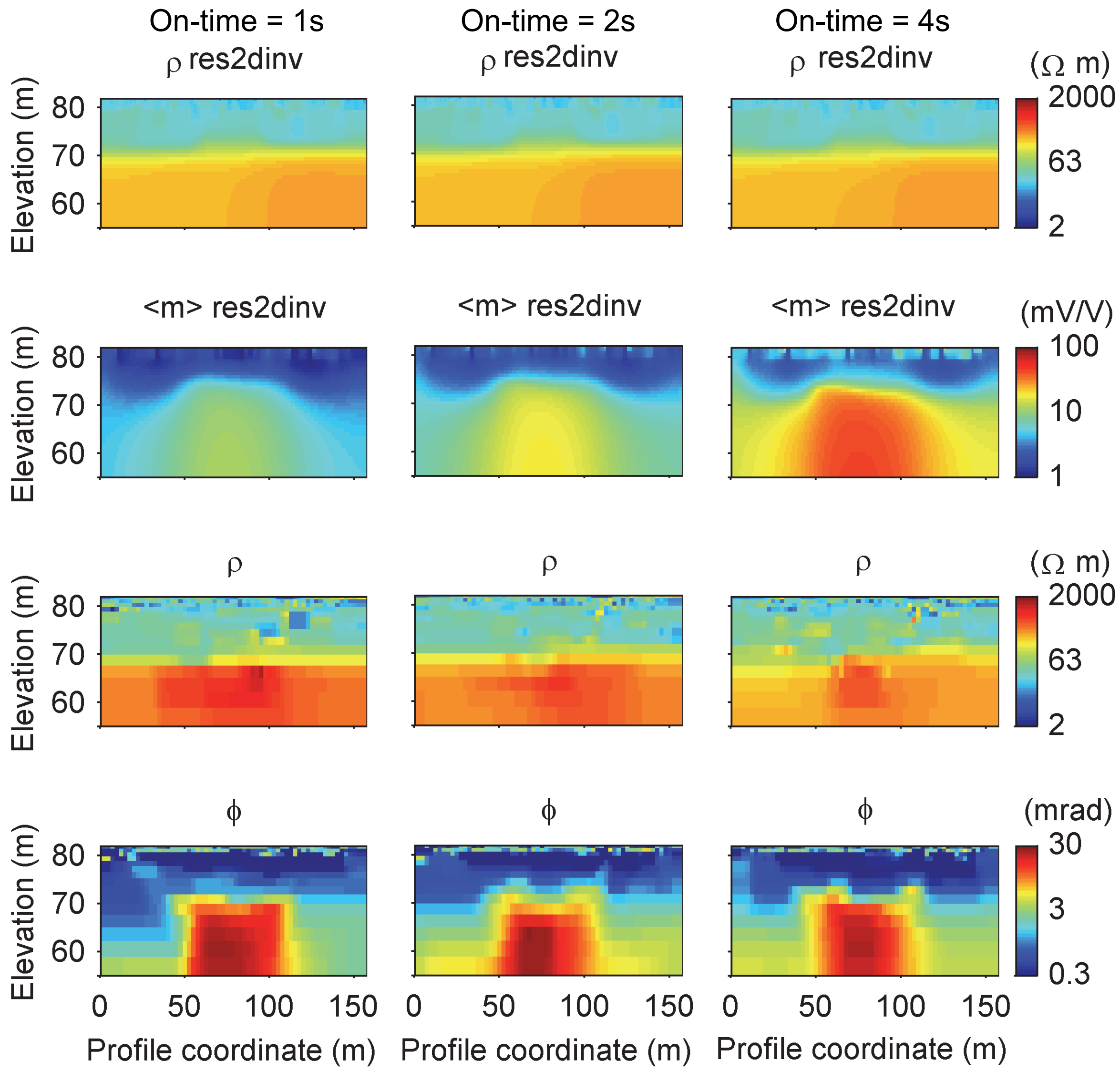

Figure 3 *Inversion models of field data from the same measurement line but with different on-time/off-time. Sections shown are (from top to bottom): resistivity (Res2dinv), integral chargeability (Res2dinv), resistivity (Aarhusinv) and CPA phase shift (Aarhusinv). Clearly, the resulting inversion models for integral chargeability are very different from each other even if they represent inversion of data acquired on the same profile. In contrast, similar inversion models are retrieved when inverting for phase shift and including the waveform of the injected current in the inversion.*

Conclusion

Our results show, that the on-time of the injected current has a substantial effect on retrieved induced polarization field data. It is clear from the results that this difference in data also effects the inverted subsurface IP models when using an inversion software that only considers integral chargeability. However, we have also shown that it is in fact possible to retrieve similar inversion models if the waveform of the injected current and the IP response waveform are included in the inversion and that increasing on-time gives higher SNR for the IP data.

Only considering the integral chargeability can be misleading and likely makes it more ambiguous when trying to relate the IP models to geology building tabular reference data. Furthermore, if not including the full waveform in the inversion, care need to be taken that the same acquisition settings are used when making complimentary or verification measurements so that different data sets will be comparable in data and model space.

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