A Note on Negative Apparent Chargeability in VOXI-DCIP

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Abstract

Negative apparent chargeabilities have been presented numerous times in the literature from IP forward modeling over specially constructed conductivity and chargeability models. In contrast, in field data negative apparent chargeabilities have often been considered to be "noise" possibly due to EM coupling, capacitive coupling, or even negative intrinsic chargeability observed in some clays. For these reasons negative apparent chargeability are often rejected prior to IP inversions, however recent studies suggest that they may contain useful information about the subsurface. In light of the growing interest in negative apparent chargeability I demonstrate that VOXI DC IP correctly computes and inverts negative apparent chargeability data.

1 Introduction

Negative apparent chargeabilities have been discussed numerous times in the literature over many decades, e.g. see Nabighian and Elliot 1976 [3] for a study using layered models through to more the recent work of Dahlin & Loke 2015 [2] for 2D models. Negative apparent chargeabilities may occur when the sensitivity of the voltage to conductivity perturbation is negative coincident with non-zero intrinsic chargeability, and more prominently when this condition occurs near the voltage measurements (usually near surface).

To paraphrase from Dahlin & Loke [2]:

> Consider a chargeability distribution with a thin chargeable top layer overlying a layer with no detectable chargeability, as illustrated by indicated zone A in Figure 1 (upper). The sensitivity distribution for longer electrode separations in this case have major zones of negative sensitivity near the surface where the chargeable zone is located, and positive sensitivity zones in the deeper parts. This means that when transmitted current is turned off all contribution to the measured signal for the deeper parts where positive sensitivity dominates disappears immediately, whereas the chargeable near surface zone produces a negative potential that decays according to its IP properties. In the case of a dipole–dipole array a chargeable zone between the current electrodes where the sensitivity is positive, in an otherwise nonchargeable environment, will give positive apparent chargeability as illustrated by zone A in Figure 1 (lower). The same applies to a chargeable zone in between the potential electrodes or at depth as indicated by zone B. If on the other hand the only chargeable zone is located in between the current and potential dipoles, zone C in Figure 1 (lower), it will produce a negative residual potential after current has been turned off.

For further details the reader is referred to Dahlin's & Loke's [2] comprehensive work including other synthetic models and a field data example. Dahlin & Loke also note other possible sources of negative IP responses including EM coupling, capacitive coupling and the reports of negative intrinsic chargeability in soft clays [1]. Figure 1 shows both the Wenner and dipole-dipole configuration sensitivity distributions and demonstrates that the location of negative apparent chargeabilities is dependent on electrode configuration.

2 Forward Modeling

To demonstrate negative apparent chargeabilities Dahlin & Loke [2] construct the 2D conductivity and chargeability models shown in Figure 2. I construct the the equivalent 3D models (referred to as DLCnd and DLChg) in VOXI-DCIP and forward model to produce the apparent resistivity and apparent chargeability and compare with the results of Dahlin & Loke [2].

The DLCnd and DLChg models with a single line of electrodes are shown in Figure 3. The simulated responses for a dipole-dipole configuration are shown in Figure 4 together with the 2D results from Dahlin and Loke[2] using

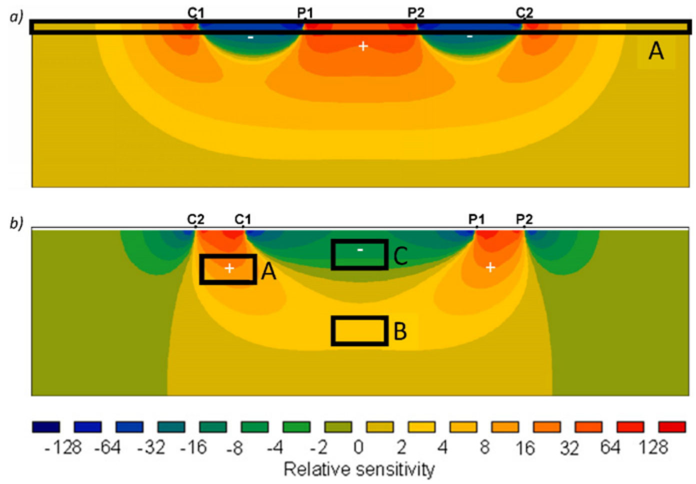

Figure 1: Sensitivity distribution with location of chargeable bodies indicated for; a) Wenner array, b) dipole-dipole array with n-factor 5.

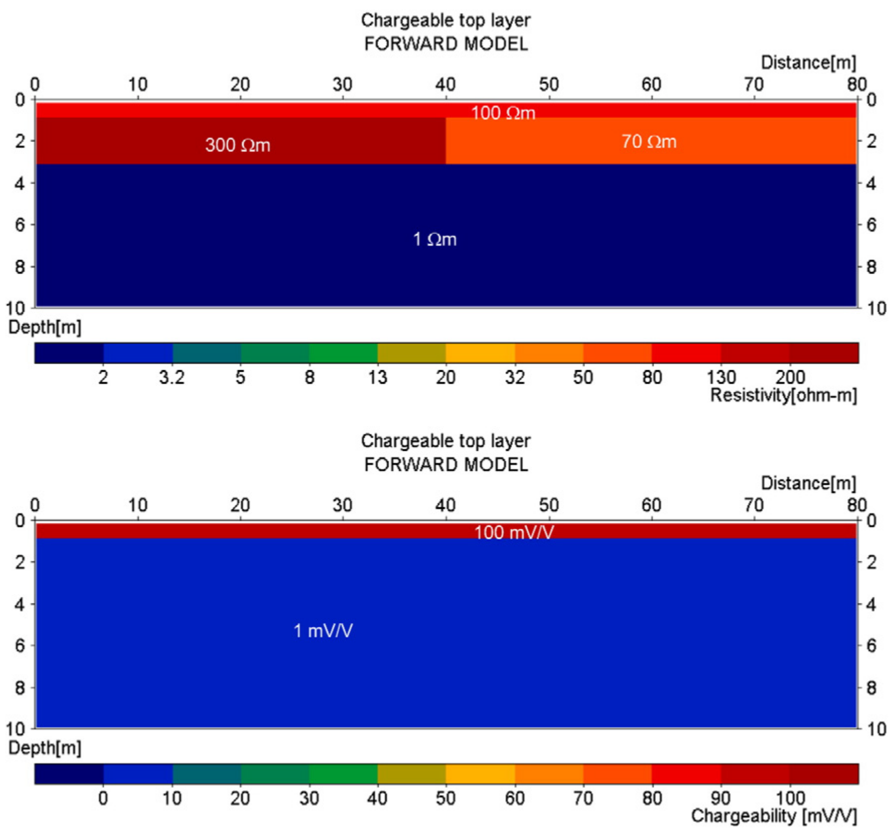

Figure 2: Synthetic layer model with resistivity (upper) and chargeability (lower).

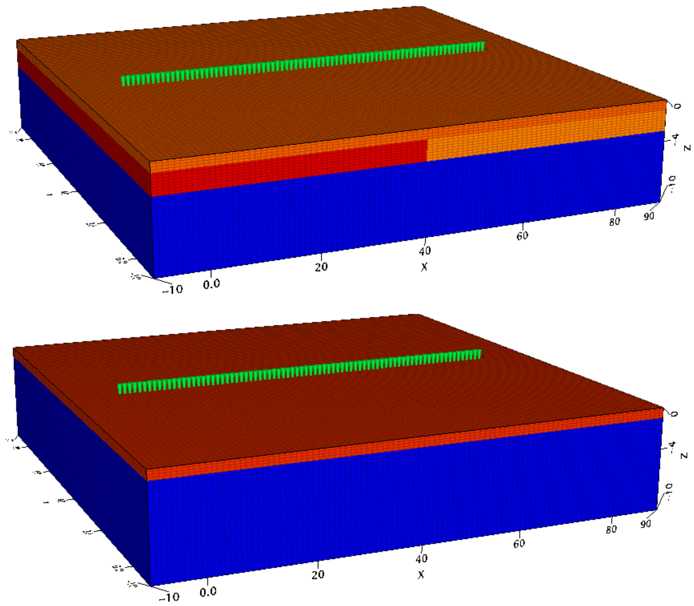

Figure 3: The 3D synthetic models corresponding those of Figure 2

Resmod2d. While the color scales for the comparison could not be matched exactly, the very good match achieved is sufficient to confirm that VOXI-DCIP is calculating *negative* apparent chargeabilities of very similar magnitude to those found independently in the literature.

3 Inversion of Negative Apparent Chargeability Data

Given the simulated negative apparent chargeability response observed in the Section 2 we can investigate inversion of *negative* apparent chargeability data with VOXI-DCIP. The purpose of this test is to ensure that VOXI-DCIP can produce the correct *positive* intrinsic chargeabilities from *negative* apparent chargeability data. I begin by simulating the chargeability for 7 EW dipole-dipole lines over the DLCnd and DLChg models analogous to the Line shown in Section 2. Lines were created at $Y = \{4., 16., 28., 40., 52., 64., 76.\}$

Inverting the apparent chargeability data (including negatives) produced the 3D chargeability model with the 2D structure shown in section view at $Y = 40$ in Figure 5 (lower), under the true chargeability model (upper). The true and the recovered apparent chargeabilities are shown in Figure 6. (Note the correct fit to negative apparent chargeabilities). This example confirms that VOXI-DCIP has the ability to recover the correct positive intrinsic chargeabilities regardless of the sign of the input data.

4 Conclusions

Recent interest in the exploration value of negative apparent chargeability data in IP inversion prompted this Note to confirm that VOXI-DCIP correctly simulates negative apparent chargeability data for situations where such data are expected over positive intrinsic chargeability models, and furthermore, that VOXI-DCIP can correctly invert negative apparent chargeability to produce a positive intrinsic chargeability model. This means that negative apparent chargeability data should not necessarily or automatically be discarded as “noise” prior to inversion but should be assessed for validity relative to the likelihood of being due to other effects, particularly in the situation where shallow chargeable material dominates. The inversion tests in this Note provide further evidence that VOXI-DCIP is a valuable aid for the interpretation of induced polarization data regardless of data sign.

Acknowledgment

I thank Julien Gance of IRIS Instruments for bringing recent work on negative apparent chargeabilities in field data to my attention.

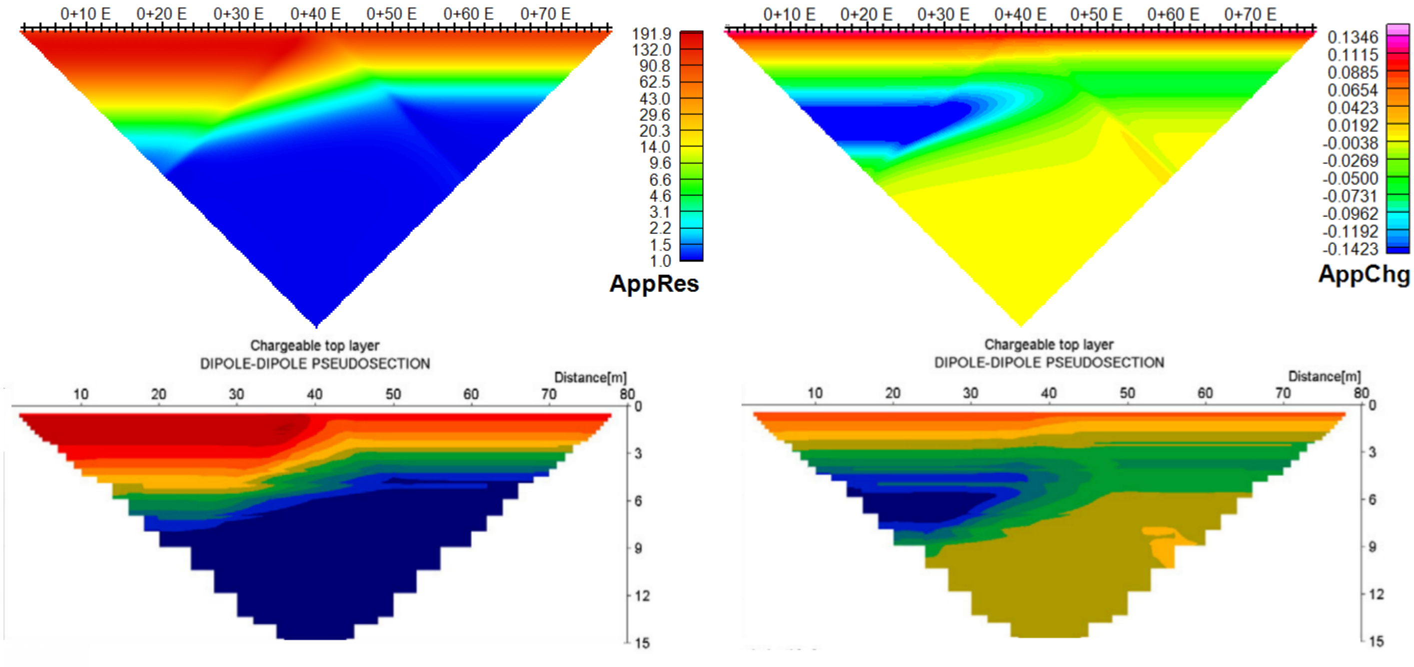

Figure 4: A comparison of the apparent resistivity (left) and apparent chargeability (right) for VOXI-DCIP (upper) and from Loke Resmod2d [2]. The color stretch is similar for VOXI-DCIP and Resmod2d.

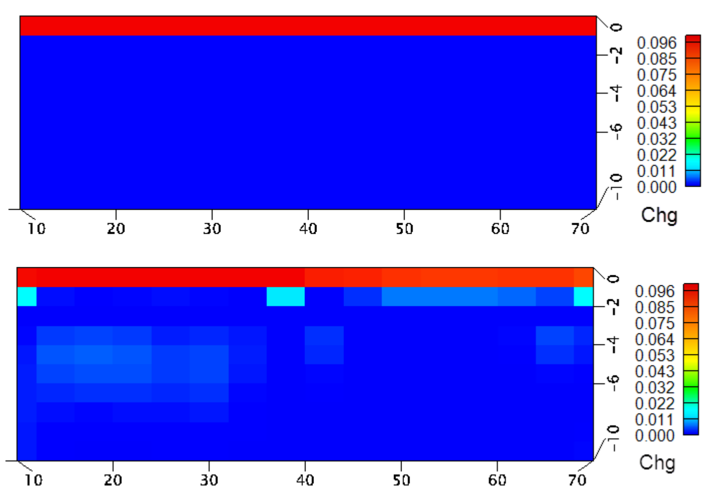

Figure 5: Sections at $Y = 40$ through the true 3D chargeability model (upper) and the VOXI-DCIP inversion model (lower).

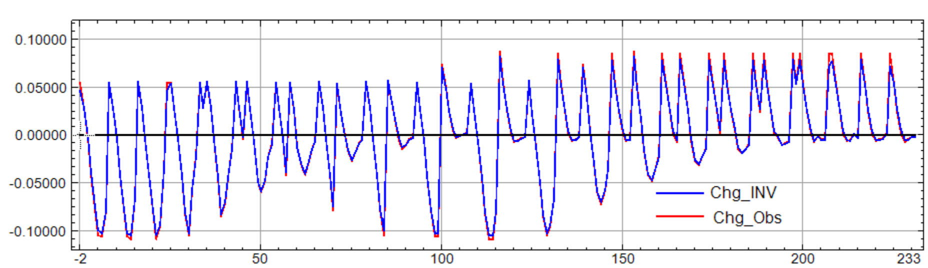

Figure 6: The observed and predicted apparent chargeability for the central Line $Y = 40$. Note the negative apparent chargeabilities.

References

[1] Brandes, I., Acworth, R.I., 2003, Intrinsic Negative Chargeability of Soft Clays. Procs. ASEG 16th Geophysical Conference and Exhibition, February 2003, Adelaide.

[2] Dahlin, T., Loke, M. H., 2015, Negative apparent chargeability in time-domain induced polarisation data. Journal of Applied Geophysics, 123, 322-332. DOI: 10.1016/j.jappgeo.2015.08.012

[3] Nabigihan, M.N., Elliot, C.L., 1976, Negative induced-polarization effects from layered media, Geophysics 41, 1236-1255