An introductory step towards modelling IP in Tempest data

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BIOGRAPHY

Francesco Dauti is a Ph.D. student in exploration geophysics at University La Statale of Milan. He took a bachelor and a master's degree at University of Pisa, respectively in geological sciences and in exploration and applied geophysics. His current research project is about the integration of galvanic and inductive Induced Polarization techniques for mineral exploration, both in terms of modelling, inversion, and interpretation

SUMMARY

IP effects are to be expected in Tempest AEM data, similarly to other systems'. We carry out extensive synthetic modelling that confirms it. We then present modelling of IP in delivered B field data and show that an improved result is obtained compared to those obtained without taking IP into account. The recovered chargeability seems largely associated with a near surface response. We anticipate that IP modelling may produce more accurate results if applied to data that is differently processed.

Key words: Tempest, modelling, AIP, chargeability, B field.

INTRODUCTION

Tempest is a very successful AEM system, used over the last 2 decades for mapping changes in subsurface conductivity from tenement to regional scales (Lane et al, 2000). It delivers B field 100 % duty cycle data for X and Z components. It has been the subject of extensive research and development from both internal and third parties (e.g., Mulè and Smiarowski, 2013; Brodie and Ley Cooper, 2019). This paper focuses on a rather novel aspect: its sensitivity to IP effects and the relevance of modelling IP in its data. Airborne IP (AIP) modelling has been researched extensively over recent years, mainly in Helicopter Time Domain EM data. Both the industry and the academic community (Oldenburg and Kang, 2015, Macnae, 2016, Viezzoli et al., 2017, Cox et al., 2022,) have come to accept AIP as an important part of HTEM data. We now wish to take a similar approach for the Tempest Fixed-wing Time Domain EM (FTEM) system.

METHOD AND RESULTS

We start with synthetic experiments, following closely the methodology we adopted in previous studies (cfr Viezzoli et al., 2021). We define a series of layered earth models, assign a range of electrical properties to them and produce two pairs of forward responses for each model, one with 0 chargeability and one with non-zero chargeability. For this purpose, we use the EEMverter code (Fiandaca et al., 2023) with the model of Maximum Phase Angle (a re-parametrisation of Cole-Cole). We then compute the signal above noise levels across IP and non-IP forward models and express it as a scalar "distortion" measure.

Here, we present (Figure 1) only one of hundreds of similar 2D plots that show the strength of the IP distortion as a function of 2 variables while keeping all others constant. The example is for a 2 layer model. The first layer is 35 m thick, with constant tau=1 ms, c = 0.6.

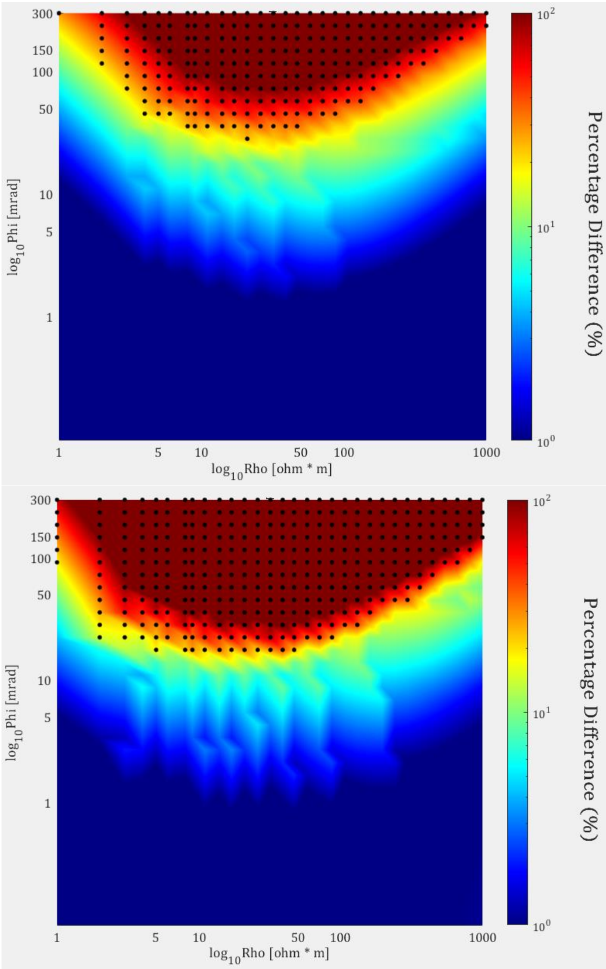

Figure 1. Distortions (expressed in %) in Tempest data, associated with IP effects, as a function of resistivity and chargeability of the first layer, over a

resistive, non chargeable bedrock (X data top panel, Z data bottom panel. Black dots identify the presence of negatives data points.

The plot shows how distortions:

- Are present over a large portion of the model space described in both the horizontal and vertical axis;
- Are much more prevalent than negatives;
- Can be associated with moderate chargeabilities;
- Seem to be slightly more pervasive in the X component data
- Decrease both at the most conductive and most resistive end of the scale.

The latter point can be explained by the predominance of the pure EM response over the IP one (at the conductive end) and by the fall of signal into noise (at the resistive end).

From our extensive series of models, we conclude that IP effects are measurable by Tempest over a wide range of situations. It is, therefore, worth attempting to model IP in real Tempest data. We chose the dataset from the Musgraves, South Australia, commissioned by CSIRO. This line was chosen since we have concurrent SkyTEM data from the same location. As mentioned in the introduction, AIP modelling of HTEM data is presently more advanced, and we therefore use SkyTEM's AIP inversion results as a benchmark. SkyTEM's data contains some late time negatives in the Z channel. The Tempest data also contains negatives, although they are less clear and closer to noise levels.

The inversions were carried out using EEMverter. The model space has been described with the Maximum Phase Angle Cole & Cole parametrisation, and the model parameters are mapped in two different model meshes, as proposed by Fiandaca (2019) and Dauti (2023), with respectively different geometries and regularisations. Here, the resistivity and chargeability are mapped in a 2D (X-Z) model mesh and are vertically and laterally regularised with loose constraints (200%-300% of consecutive allowed variation). Given the small spectral content of the AEM data (limited to 2 decades), the spectral parameters ($\tau\varphi$ and C) are kept fixed with depth and are free to change only laterally. This regularisation aims to reduce the correlations between the parameters and to increase the sensitivity of the chargeability at depth, as shown by Fiandaca & Viezzoli 2020, during the inversion procedure.

Figure 2 compares inversion results of SkyTEM's data, with IP, against Tempest's (Z only), with and without IP. The global misfit when modelling IP was for 1.4 SkyTEM and 0.9 for Tempest, compared to 2.4 and 1.5 respectively when IP was not modelled.

Modelling IP in Tempest

- Improves data fit
- Increases the coherence with SkyTEM's resistivities obtained with IP
- Chargeabilities obtained from the two systems have similar spatial patterns
- The main AIP response seems to be from chargeable cover.

Further work is underway to assess the possibility of simultaneously fitting Tempest's X and Z while modelling IP. Additionally, comparisons between stratigraphical information from drilling and resistivities obtained from Tempest with and without IP are currently underway. Beside direct targeting, the methodology is expected to improve general geological mapping derived from Tempest data.

CONCLUSIONS

This work confirms that Tempest is sensitive to IP effects. It also shows that IP effects can be modelled in real Tempest data, improving data fit and coherence with ancillary, IP-corrected models. Work is underway to confirm the relevance of Tempest IP modelling towards mapping. The authors also believe the standard Tempest processing may alter the IP response measured by the Tempest receivers and are engaging in further research on this topic.

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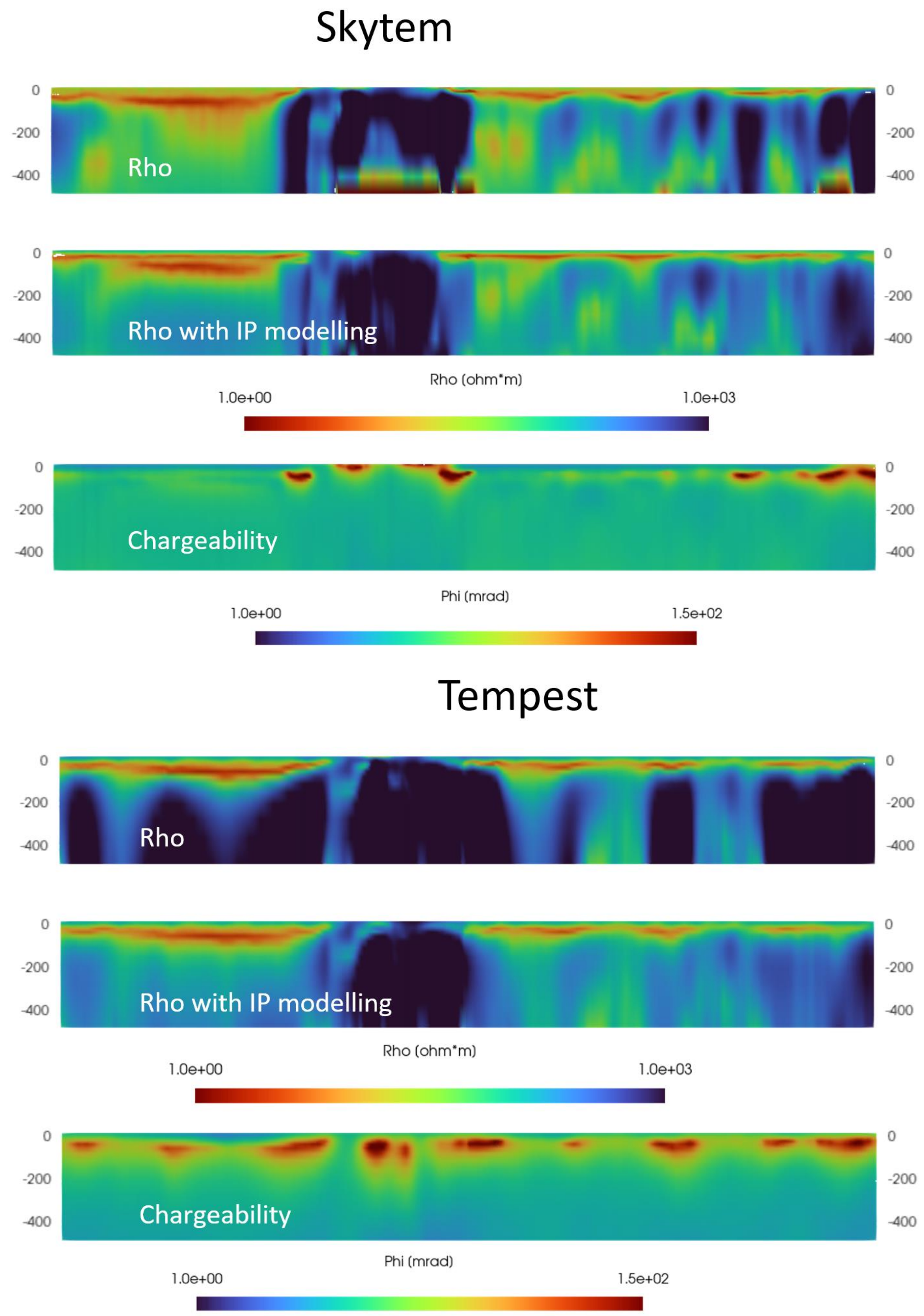

Figure 2. Comparison between SkyTEM and Tempest (Z only) inversion, without IP (panel 1 and 4) and with IP (panels 2, 3, 5, and 6).