Modelling IP in Tempest data: the first preliminary steps and insights

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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, when compared to both other geophysical data and geological data. 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.

METHODOLOGY

The synthetic experiments follow 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.

The inversions on real Tempest data 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.

RESULTS

We start with synthetic experiments, following the procedure outlined above. 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 10 m thick, with constant tau=0.1 ms, c = 0.6.

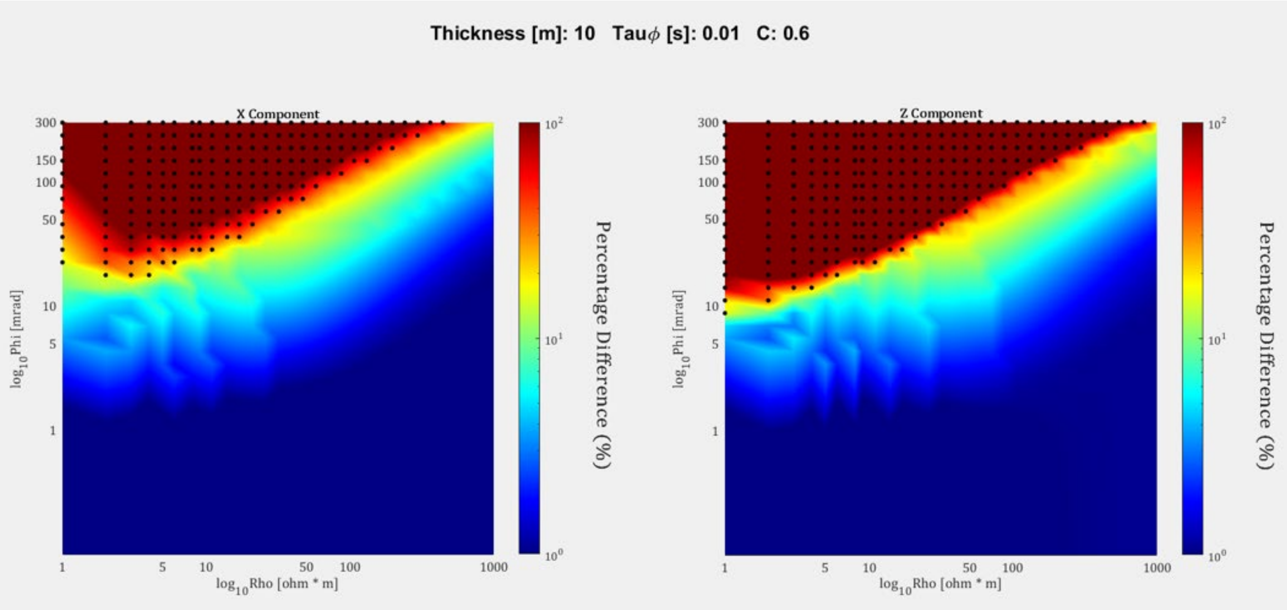

Figure 1. Distortions (expressed in %) in Tempest data, associated with IP effects, as a function of resistivity and chargeability of the first layer, over a resistive, non chargeable bedrock (X data top panel, Z data bottom panel. Black dots identify the presence of negatives data points.

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;
- Decrease both at the most conductive (only visible in X here) 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.

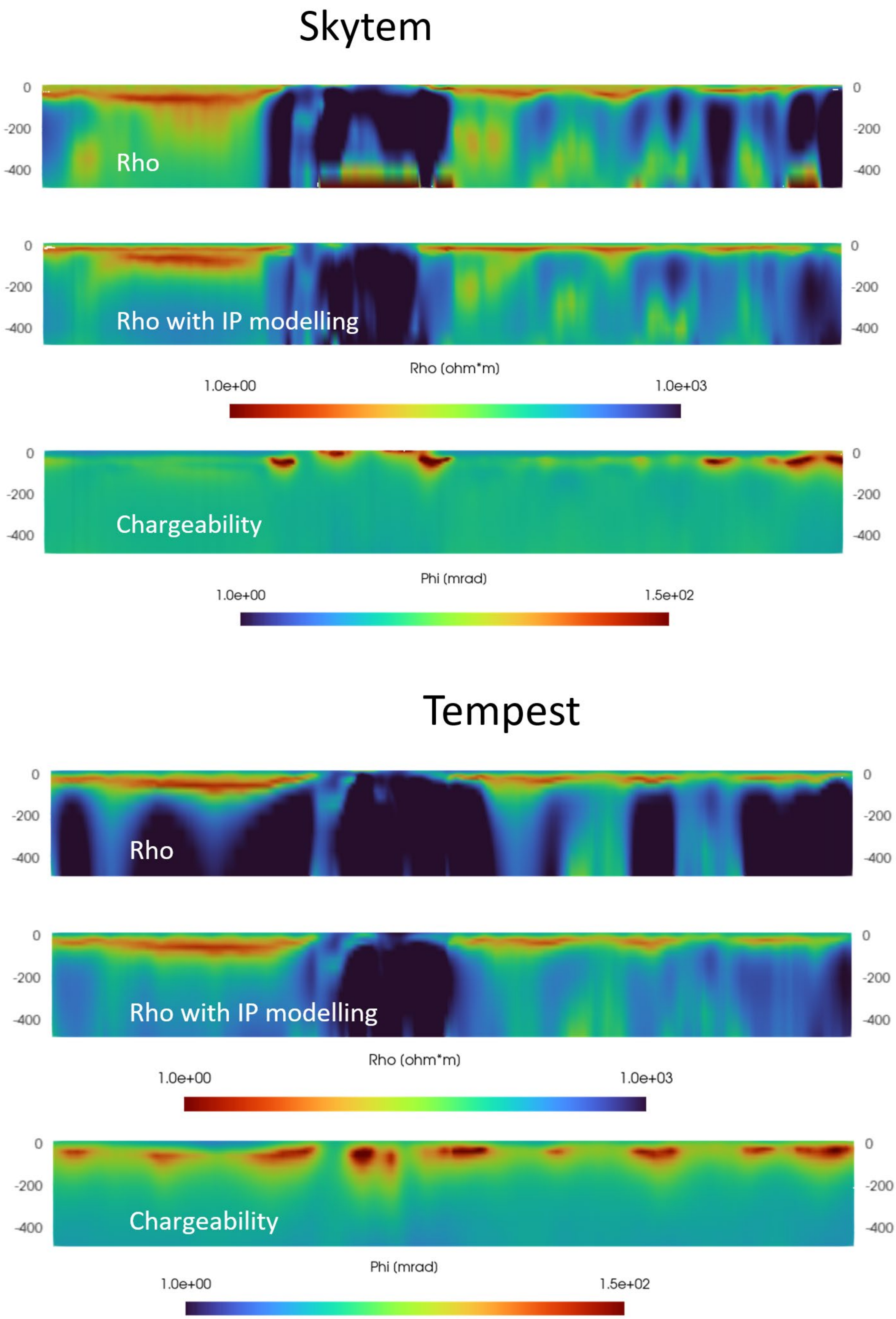

Figure 2. Comparison between SkyTEM and Tempest (Z only) inversion, without IP (from the top, panel 1 and 4) and with IP (panels 2, 3, 5, and 6).

The results presented in Figure 2 show that 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.

In this last example we compare AIP Tempest (AusAEM surveys) modelling results against information from drilling. A selection of the drilling data was compiled from the publicly available databases on the Geoscience Australia and Government of Western Australia-Department of Mines, Industry Regulation and Safety websites. The minimum criteria adopted in the selection were proximity (within 250m) to flight lines of the AusAEM program and presence of stratigraphical/mineralization information. In some locations they are also accompanied by other geophysical data (e.g., ground IP, AEM). The procedure returned approximately 200 drillings, from all over Australia. A strip of data of approximately 1 km, centred around the drillings, was then processed and inverted, with and without IP modelling. A thorough review of the results is underway. Here we present one example (Figure 3) from WA.

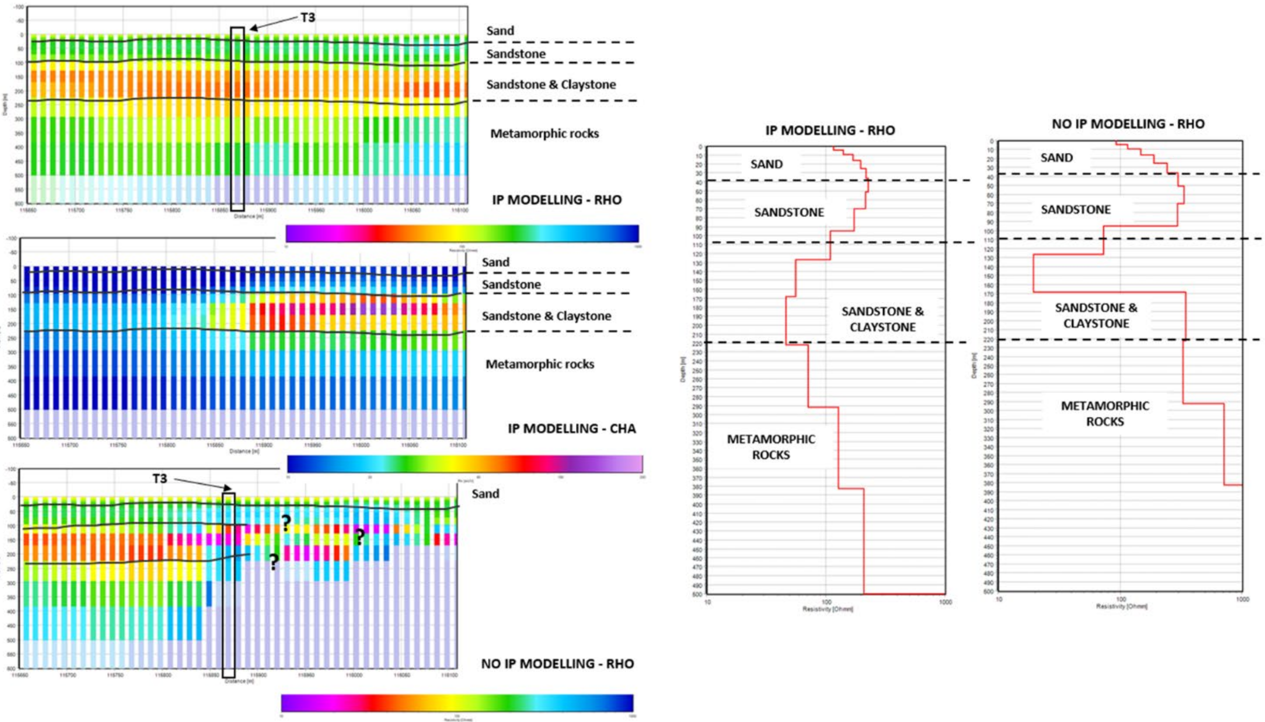

Figure 3. An example of the effect of modelling IP in Tempest data when correlating resistivity and chargeability with stratigraphy

Figure 3 shows the correlation between stratigraphy and resistivity with (top 2D vertical section, and 1D model to the left) and without IP modelling (bottom 2D vertical section and 1D model to the right) and with chargeability (2D middle vertical section). Notice the overall good correlation between the IP modelling (in terms of both chargeable and conductive) and the stratigraphy. The resistivity obtained without IP correlates worse with the stratigraphical information. Main differences correspond with the thickness of the sandstone-claystone and, therefore, depth to the resistor associated with the metamorphic rocks. Reconciling the drilling information with the non-IP, 2D resistivity is problematic, as shown in an attempt to interpret geology (black lines over the section). The IP modelling sections, on the contrary, allow deriving a coherent geological interpretation (black lines over the sections) across the entire line.

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 thoroughly describe the relevance of Tempest IP modelling towards mapping and exploration. Preliminary results show that, in some circumstances, modelling IP improves the correlation with stratigraphical information and can improve geological interpretability. 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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