

Airborne electromagnetic modelling options and their consequences in target definition

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Abstract. Given the range of geological conditions under which airborne EM surveys are conducted, there is an expectation that the 2D and 3D methods used to extract models that are geologically meaningful would be favoured over 1D inversion and transforms. We do after all deal with an Earth that constantly undergoes, faulting, intrusions, and erosive processes that yield a subsurface morphology, which is, for most parts, dissimilar to a horizontal layered earth.

We analyse data from a survey collected in the Musgrave province, South Australia. It is of particular interest since it has been used for mineral prospecting and for a regional hydro-geological assessment. The survey comprises abrupt lateral variations, more-subtle lateral continuous sedimentary sequences and filled palaeovalleys. As consequence, we deal with several geophysical targets of contrasting conductivities, varying geometries and at different depths. We invert the observations by using several algorithms characterised by the different dimensionality of the forward operator.

Inversion of airborne EM data is known to be an ill-posed problem. We can generate a variety of models that numerically adequately fit the measured data, which makes the solution non-unique. The application of different deterministic inversion codes or transforms to the same dataset can give dissimilar results, as shown in this paper. This ambiguity suggests the choice of processes and algorithms used to interpret AEM data cannot be resolved as a matter of personal choice and preference.

The degree to which models generated by a 1D algorithm replicate/or not measured data, can be an indicator of the data's dimensionality, which per se does not imply that data that can be fitted with a 1D model cannot be multidimensional. On the other hand, it is crucial that codes that can generate 2D and 3D models do reproduce the measured data in order for them to be considered as a plausible solution. In the absence of ancillary information, it could be argued that the simplest model with the simplest physics might be preferred.

Key words: airborne, electromagnetics, exploration, inversion, target.

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Introduction

State and Federal Government agencies in Australia are developing pre-competitive databases in support of the minerals industry. They are increasingly inclined to look at airborne electromagnetic (AEM) datasets as part of the suite of data acquired to promote and support exploration. The availability of new data processing and inversion routines facilitated AEM surveying in broader geologic terrains, and the collection is no longer restricted to searching for conductors in resistive environments with no regolith cover. The more diverse use of AEM surveys includes determining areas for drilling and geochemical sampling through geological mapping, regolith characterisation and a better understanding of the groundwater and aquifer architecture. Surveys are now commissioned with particular attention being given to the different airborne system's capability of resolving geometry and complexity of the expected targets. Part of the decision

making process involves synthetic forward modelling analysis, but it should also include the direct assessment of systems and algorithm performing under real survey conditions (e.g. Christensen and Lawrie, 2012; Ley-Cooper et al., 2010; Sattel, 2009; Smith et al., 2001; and others).

Given the range of geological conditions under which airborne EM surveys are conducted, it is reasonable to expect the interpretation technique should also vary. For example, abrupt lateral variations such as faults and intrusions should be interpreted with different methods than subtle facies changes in depositional environments.

Qualitative assessment of AEM data inversions and transforms is common practice. We tend to assess results by comparing images of profiles sections and search for peaked anomalies or similar features along the time-series profiles of the streamed channels. In mineral exploration, we often compare anomalous amplitudes and shapes to the responses of simple

bodies such as thin sheets, plates, spheres and other symmetrical shapes. In some cases further analysis is done on segments of the data by parametric modelling (EMIT, 2014; Lamontagne, 2014), which allows calculation of strikes, dips and other parameters of tabular geometry.

However, standard isolated anomaly modelling, undertaken for the direct targeting of mineralisation may undervalue the full potential of AEM data collected in a particular area. Converting the data to spatially varying conductivity through inversion and/or transforms enables a quantitative and more visually intuitive way of projecting the data and then interpreting it in a contextual manner, where derived values of depth and conductivities can be related to known geology and other earth forming materials. In this paper, we focus on data interpretation of the entire survey area, as opposed to isolated anomalies, through inversions and transforms. Data were acquired with a concentric loop versatile time domain EM (VTEM) system with z-component only. We assess the results of the interpretation methods in map view, then focus on a single line, and then further restrict the comparison to three soundings acquired over distinct geological environments. The assessment is based on: (i) visual comparison of the results; (ii) comparison of the fit to the data; and (iii) calculating the residuals with a common noise model.

This dataset is of particular interest since it covers both abrupt lateral variations (mafic intrusive outcrop/sup-crop), more-subtle lateral continuous sedimentary sequences and filled palaeovalleys. Of specific interest to this work is to identify

approaches that will allow us to add geological value by means of the airborne data.

Study area

The survey was flown over part of the Musgrave Province in South Australia (Figure 1), a region of crystalline basement consisting of mainly amphibolite and granulite facies gneisses intruded by mafic dykes and granitoids where swarms of dolerite dykes are also present (Drexel and Preiss, 1993; Glikson et al., 1996). While basement crops out as isolated hills and ranges, much of the area is covered by regolith materials. The map shows a highlighted line of AEM data (in white) which we investigate in detail. The mapped surface geology shows that the line overflies both an outcropping mafic intrusive and a sand plain.

Methods

Whilst in this study we examine a range of interpretation methods, they have been limited to those to which we have ready access. The option for the future analysis of other available algorithms remains. A brief description of the codes we used to transform the VTEM data from a times-series of streamed channels to sections of conductivity and depth follows.

Conductivity depth image (CDI) transforms

EMFlow is based on a 1D method developed by Macnae et al. (1998). It employs a fast approximate transformation of AEM

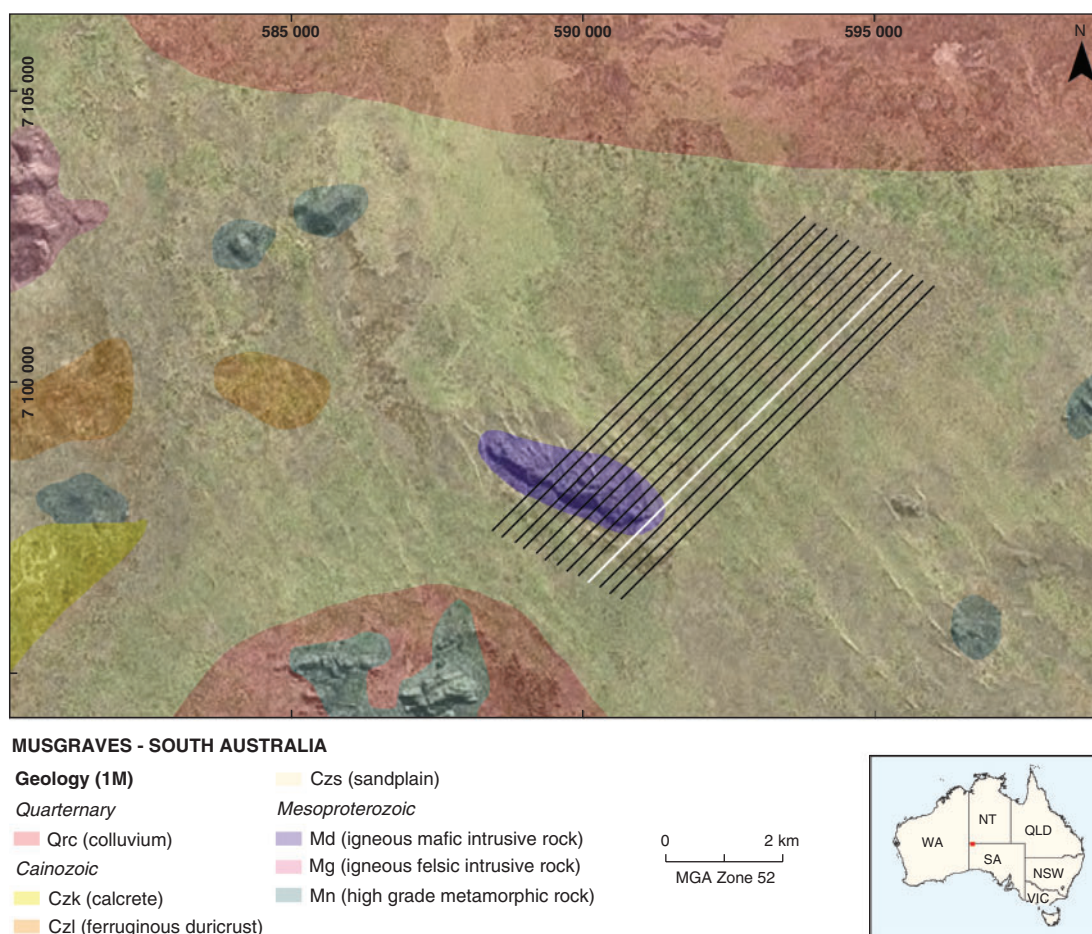


Fig. 1. Geological map of the Musgrave Province of South Australia overlaid by flight lines of data acquired using a central-loop helicopter time-domain EM system. The highlighted line in red is of interest as it was flown over at least two geological environments: an igneous intrusive outcrop of resistive basement and what appear to be sand plain materials, at surface.

data to conductivity estimates of a quasi-layered earth, using Maxwell's analytic receding-image solution for an individual transient decay.

1D inversion sample by sample

Geoscience Australia's 1D layered-earth inversion (GA-LEI) algorithm was conceptualised by Lane et al. (2004) and has continuously been developed by Brodie (2012). The algorithm has been designed to solve the non-linear problem of obtaining subsurface values of conductivity from a measured AEM response while accounting for geometric unknowns also known as system geometry (Ley-Cooper and Brodie, 2013). The algorithm based on an idealised layered-earth model calculation at each sounding assumes individual layers that are laterally homogenous. For this example, we have used an 80-layer and 30-layer sample-by-sample, fixed thickness smooth model.

Sample by sample, laterally constrained, spatially constrained and sharp 1D inversions

We processed and inverted the AEM data with different approaches using the AarhusInv (Auken et al., 2014) inversion kernel: applying sample by sample (SBS), using lateral and spatial constraints in the inversion (LCI and SCI) (Auken and Christiansen, 2004; Viezzoli et al., 2008), and also by using a sharp LCI (Vignoli et al., 2014) regularisation. The latter process extends the existing concept of the LCI/SCI using a focused regularisation designed to preserve abrupt (vertical and lateral) transitions in the model reconstruction (Last and Kubik, 1983; Portniaguine and Zhdanov, 1999; Vignoli et al., 2011; Zhdanov, 2002; Zhdanov et al., 2006).

2D inversion

We applied an empirical 2D sensitivity transform (The École et Observatoire des Sciences de la Terre, EOST) of the data developed by Guilleminot et al. (2012). This transform is a 2D linear inversion using a standard regularisation scheme (data weight and smoothness constraints) in which the Frechet kernels has been inspired from 2.5D finite element modelling. The Frechet kernel model is an empirical 2D function that depends on the time windows and the apparent conductivity similarly to the 1D adaptive born forward mapping (ABFM) presented in Christensen (2002).

3D inversion

Finally we also used a 3D moving sensitivity domain algorithm described in Cox and Zhdanov (2007) and Cox et al. (2010) to invert the data. This algorithm uses full 3D modelling and sensitivity calculations based on the integral equation method (Zhdanov, 2009). The moving sensitivity domain method makes full 3D modelling practical on this small survey area.

Results

We have been diligent to separate the description of the results of the algorithms from the discussion. The former is numerical, while the latter includes some speculation and is necessarily biased with our opinions. Figure 2 compares the conductivity spatial distribution at three different elevations from five of the nine conductivity-depth products. The location of the detailed flight line comparison is shown as the yellow line (line 30390), and point soundings from three different geological regimes are lettered. Each inversion shows very similar large-scale features and general trends, major discrepancies arise at depth. Fine

scale features vary from one image to the next, but without a drilling campaign designed to test these targets or in the absence of other independent information, it is not possible to say which methods provide models that are more accurate.

In Figure 3, we display streamed channels of the measured VTEM data and predicted/modelled data from line 30390. The measured data are shown as the black lines and the predicted data vary with the interpretation method by colour. Note that EMFlow produces only the final models of conductivity distribution with depth, so although we could have estimated a forward response for the proposed model using another code, this would not truly reflect the way the transform is calculated hence the absence of results in the comparison plots between measured and predicted data.

On the top row I, red curves correspond to forward-model responses from the GA-LEI using a 30-layer model. On the right, we show an enlargement of a feature of interest (location B) which is a late-time channel (200 m wide) anomaly present throughout adjacent soundings. The whole-line and the enlarged forward responses from the AarhusInv kernel using spatial constraints are shown in magenta (Figure 3 panels, row II). We then show responses from the 2D empirical transform in brown (row III) and from the moving footprint 3D inversion in green (row IV).

Strong signals in early and middle time channels from shallow conductive features can be of amplitudes of up to two orders of magnitude greater than those same time channels measured over a resistive host.

Figure 4 shows the recovered conductivity section under line 30390. The results of all nine methods are plotted. The near surface features are similar between all of the methods, but they begin to diverge at depth. Figure 5 shows an enlargement of these results to a shallower depth from the surface to 250 m depth. It illustrates the subtle variations in the recovered models in the near surface.

Figure 6 highlights differences in shape and magnitude of the response for three soundings recorded over varying geological settings:

- A. Resistive bedrock hosting a deep (> 500 m) conductor or a near surface super paramagnetic (SP) source;
- B. Confined late time channel anomaly, prospective steeply dipping conductor; and
- C. High amplitude mid to early channel responses, interpreted as a broad shallow conductor.

To assess depth, conductivity and level of fit from the three individual soundings (A, B and C), we plot the measured data and their respective forward responses (Figure 7, left column). These responses we have generated using the final proposed conductivity-depth model from each inversion (Figure 7, right column). Individual curves represent one of the nine different modelling approaches used in this study.

Discussion

The original employment of strong lateral constraints and the use of a high noise threshold assigned to the data, initially hindered the AarhusInv and EOST 2D algorithms' ability to appropriately model the confined conductive target (sounding B). In a second stage, the data were processed using standard lateral filtering as described in Auken et al. (2009), deep layers were added to the original model parameterisation, and noise thresholds were redefined. These changes allowed a better data fit. Data culling is a good way of ensuring anthropogenic noise does not contaminate the data, which in turn will and introduce

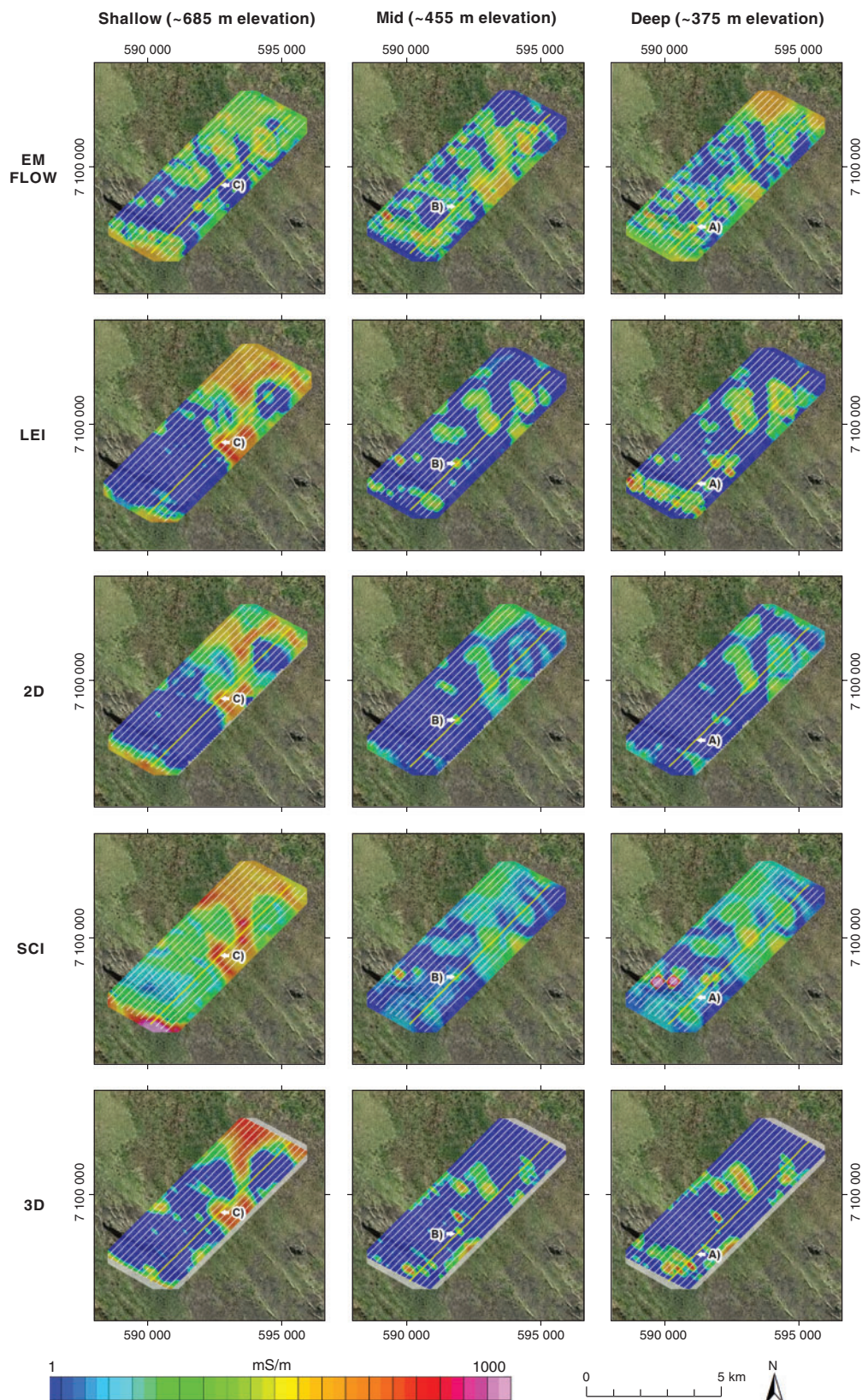


Fig. 2. Conductivity slices at different elevations, showing the location and lateral spatial distribution of soundings A, B and C, for four different conductivity-depth inversions or transforms.

artefacts in the inversions, but it is not an approach we recommend for use as an automated process.

The 3D inversion also suffered from issues on the first runs of the code, with the deep conductor at location B absent from the inversion results and a poor data fit at this location. This was

caused by inadequate selection of the noise model, background conductivity and the model being poorly discretised. Adjusting these parameters plus using a combined regularisation of minimum norm and second derivative in the horizontal directions significantly improved the results.

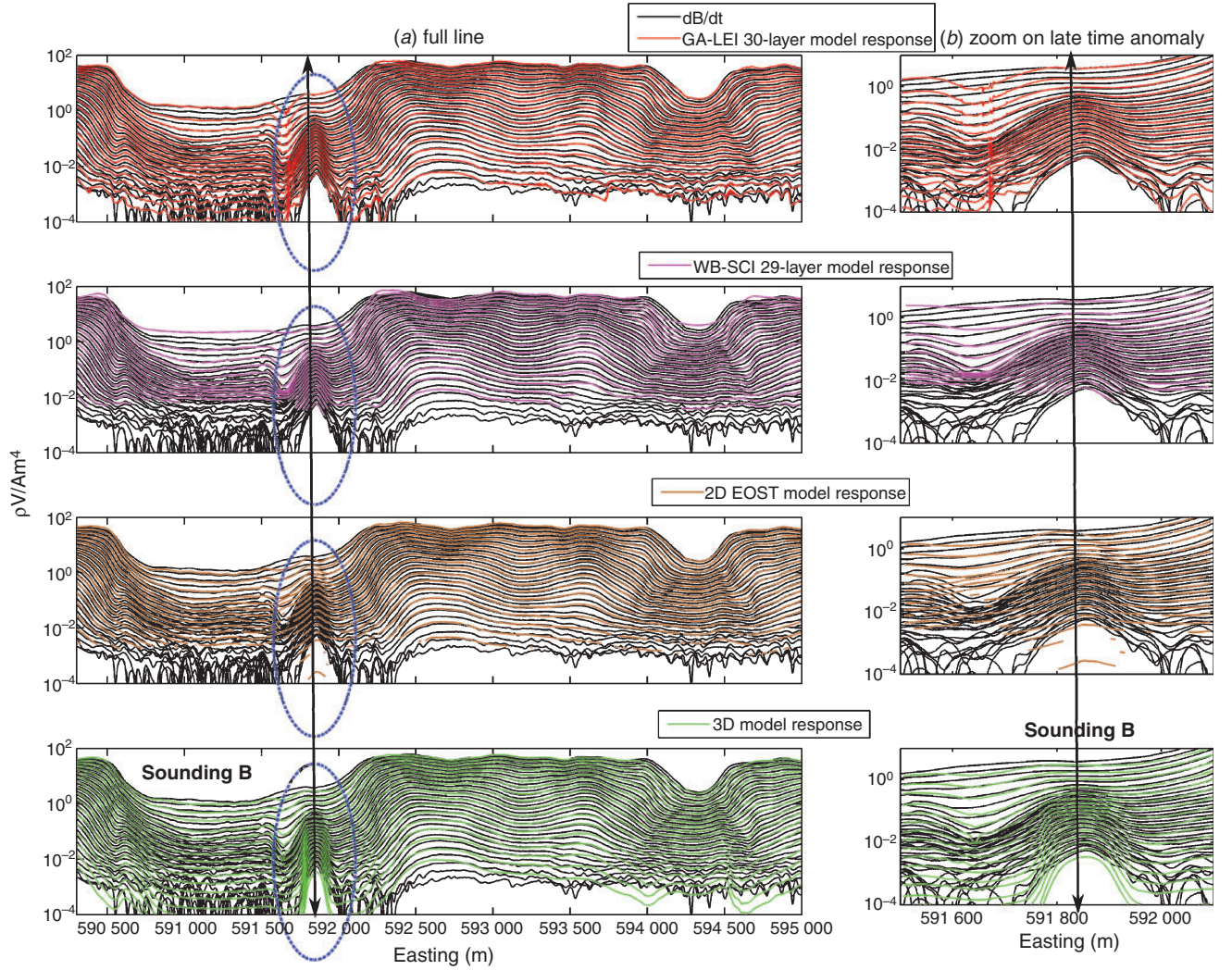


Fig. 3. (a) We have overlaid a line of measured VTEM data displayed as a time series of streamed channels (in black), by every second channel of predicted model responses from different inversions, results are shown in distinct colours. (b) Zoom on a single peak anomaly highlighted by blue ellipses. We will refer to this as the feature of interest (FOI) which, because of its location and shape, corresponds to a late-time channel response commonly of interest to mineral prospectors.

As shown in Figure 5 the near surface is similar for all methods (even if, for example, for hydrogeological mapping applications, these ‘slight’ differences may lead to very different geological interpretations). Likely, all are performing well and differences in regularisation and noise models can account for the variations. At increased depth, the presence of the strong conductor (feature B) appears in all results, although there are differences, which are discussed below. The conductive anomalies at depth around 7 097 200 mN and 7 108 000 mN–7 101 400 mN, particularly prominent on pane X in Figure 5, are especially different when comparing the codes with different dimensionality. At these depths, the signal-to-noise ratio has decreased substantially and effects of noise floors and regularisation can make a significant difference. Without drilling, it is impossible to tell which models are more accurate. In principle, 2D and 3D inversion algorithms have a better capability to model the lateral conductivity variations that 1D inversion schemes can try to retrieve via regularisation strategies. This superior capability of 2D and 3D algorithms is clearly an advantage, as, for example, the peak response of a dipping conductor is not necessarily centred on the conductor and the feature can be located correctly. However, this also leads to more non-uniqueness issues as the ill-posedness of the problem is also

related to its dimensionality. In these cases, the inclusion of an x -component would potentially help reduce non-uniqueness in the inversion.

Model assessment

As a way of quantitatively assessing each of the proposed models, we compare the final forward d^{mod} against the measured data d^{obs} , and using a common noise model ($noise^{err}$) for each sounding of data, we calculate the residual:

$$Residual = \frac{1}{N_D} \sum_{k=1}^{N_D} \left(\frac{d_k^{obs} - d_k^{mod}}{noise_k^{err}} \right)^2, \quad (1)$$

where N_D is the number of channels.

The employed noise model is composed of an additive and multiplicative component derived from a procedure suggested by Green and Lane (2003). The values we used are reported in Table 1.

This comparison is not ideal, since the suggested noise values have not been used in all the algorithms. Nevertheless, it is an attempt to calculate a single value residual, for soundings A, B and C and quantitatively assess the performances of the different algorithms. The process and final values we have resumed in

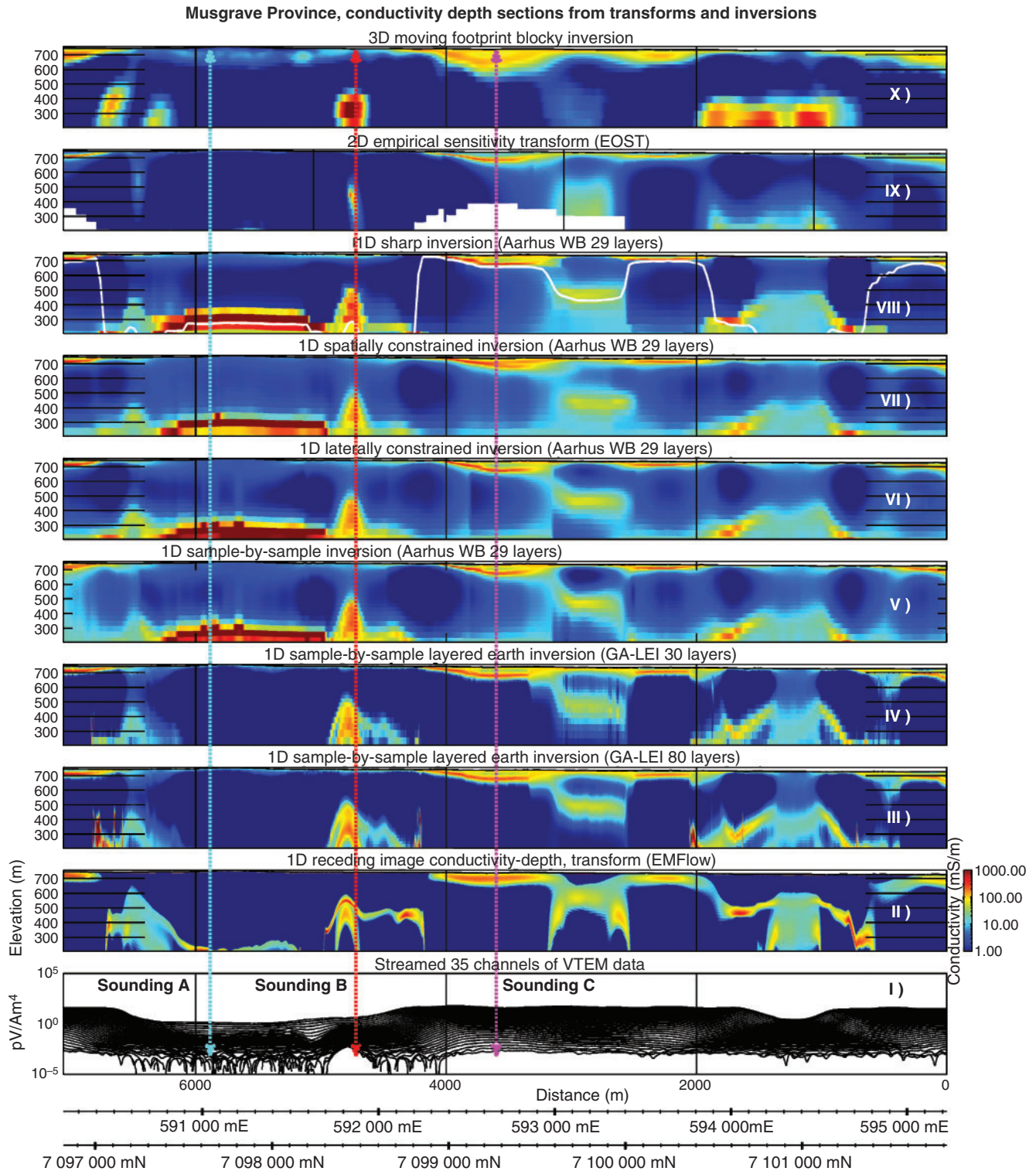


Fig. 4. Conductivity depth sections from nine different inversions and approximate transforms displayed as a stack of panels (from II to X). The cyan arrow (sounding A) points to a resistive area where EMFlow and the AarhusInv codes suggest a deep conductor can be modelled. The red arrow (sounding B) highlights a segment of the data with a confined late-time channel anomaly (FOI). The magenta arrow (sounding C) highlights a sounding from a shallow-conductive palaeovalley structure. An estimated depth of investigation, calculated following the method of Christiansen and Auken (2012), is shown as a discontinuous undulating grey line on panel VIII.

Table 2. In order to estimate the importance of the different noise values actually used during the inversions, the figures in Table 2 should be evaluated together with the corresponding observed and calculated decay curves in Figure 7. Moreover, it is, of course, fundamental to take into account that the different methods minimise different objective functionals. For example,

lateral/spatially constrained inversions and 2D/3D schemes minimise global functionals, while the sounding-by-sounding algorithms try to decrease a functional value depending solely on the local conductivity and decay curve. In this respect, a comparison based on a single sounding can be misleading. However, the variance on the residual values for each of the

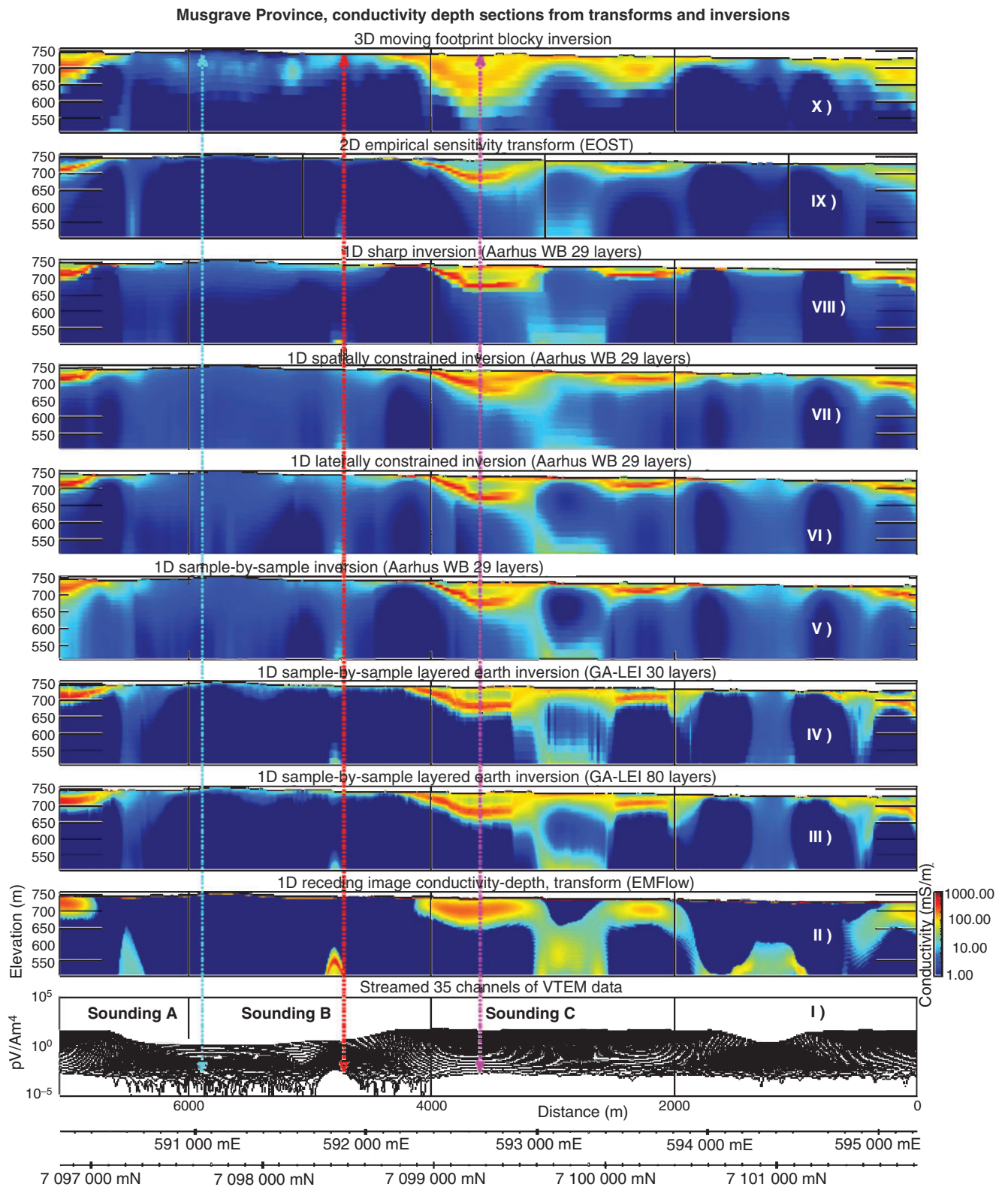


Fig. 5. Stack of nine conductivity-depth profiles focusing on shallow features in a depth range of 0 to 250 m below surface.

three soundings does identify areas of superior and inferior convergence for the different algorithms, and potential areas where plate modelling might be better suited.

In addition, the assumptions and approximations of each of these modelling schemes when comparing the data, each having their own drawbacks and advantages, should not be disregarded. The predicted data from the 1D algorithm assume a laterally invariant earth determined at each sounding position. The actual

(3D) response from the stitched section may be significantly different from the 1D predicted data as has been suggested by Ellis (1998). The 2D code uses an empirical approximation to forward model the response. The 3D code uses a 1D solution for background fields, but assumes that the scattered electric field is a constant within each cell. In short, the predicted data for each model approximates the true response for the recovered conductivity section.

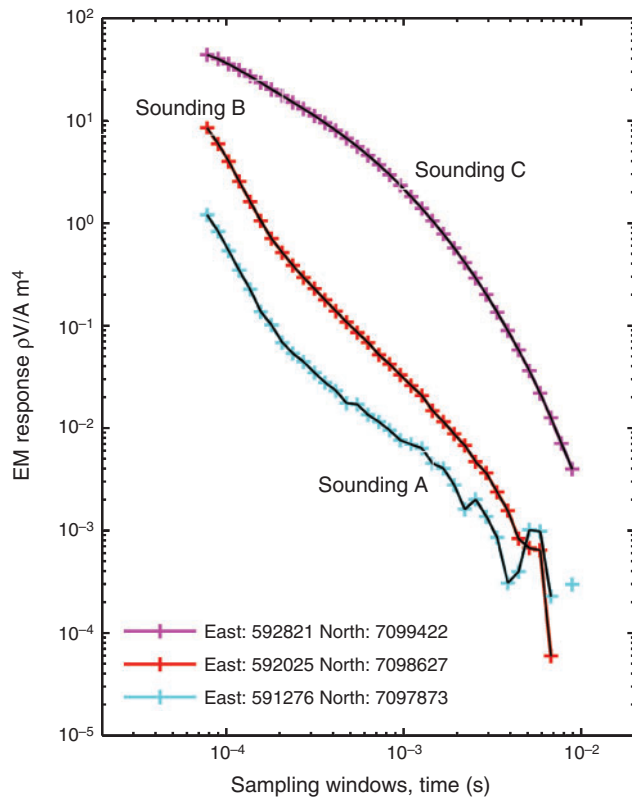


Fig. 6. Single decay responses over the central sounding of feature of interest (sounding B in red) and further east over an area with strong conductive cover (sounding C in magenta). The non-monotonic decay (sounding A in cyan) corresponds to a sounding acquired over very resistive ground, where arguably a very deep (> 500 m) conductor may be found.

Sounding A

The raw decay curves (sounding A, Figure 6) on the western most part of Figure 4 have a decay rate approximating $1/t$ after ~ 1 ms. This $1/t$ decay rate, with an amplitude appropriate for a deep conductor, might be related to a superparamagnetic (SPM) source in the near surface (Kratzer et al., 2013) rather than a deep conductor. None of the inversion codes applied here have the ability to fit SPM decays, so, even if they provide a conductivity model that fits the data, the ~ 500 m deep conductor as shown to the west on Figure 4 might be an artefact.

In these situations where a depth of investigation or a credible recovered depth of penetration can be useful as a potential marker, there are several suggested ways of how to calculate this depth (Christiansen and Auken, 2012; Hutchinson et al., 2010; Oldenburg and Li, 1999), all of which are model dependent, and will vary with the assigned noise level and rely on a predetermined, subjective threshold. For sounding A, the depth of investigation (white solid line in Figure 4, pane VIII), calculated by using the method proposed by Christiansen and Auken (2012), has been estimated to be of 480 m below the surface which would suggest a conductive layer at depth is detectable and would be warranted by some of the inversion methods.

Sounding B

From analysis of the responses (sounding B), in Figure 7, we can see that the proposed models recover a relatively conductive (~ 250 mS/m) layer which starts at a depth of (~ 200 m). Other subtle variations between the constrained and the sample-by-sample models are observed, but overall they all appear to be

consistent. The conductive feature appears slightly deeper and more conductive in the 3D inversion (~ 1000 mS/m). The 2D inversion algorithm retrieves an inclusion that is significantly more compact than the others, while the same conductive feature is reconstructed by, EMFlow as two layers and at shallower depths with respect to the 1D inversions.

On an individual sounding basis, the 1D-inversion models have an overall good fit, but show the ‘pant leg’ artefact on profile (Figure 4). Pant legs are not surprising since they are well known 2D effects characteristic of conductive bodies embedded in a resistivity background when inverted with 1D forward operators. They are generally detectable by skilled interpreters and largely discussed in literature (e.g. Ley-Cooper et al., 2010 and Guillemoteau et al., 2011). Clearly, the 2D and 3D algorithms should be able to model edge effects more correctly, however, they are also characterised by worse local data fits that, in turn, manifest themselves in 2D data fit profiles (Figure 3). While the 3D scheme tends to have a too low response aside the anomaly peak (Figure 3, right side), the reconstruction based on the 2D forward modelling returns a response maximum slightly migrated towards the first gates (Figure 3 and Figure 7b).

The discrepancy in the conductivity value between the 3D and 1D is likely due to two factors. The 1D inversion is assuming an infinite layer for this discrete conductor, which means the conductivity of the infinite layer needs to be less conductive to match the magnitude of the response than would a discrete conductor. On the other hand, the 3D algorithm will underestimate the response of highly conductive bodies embedded in resistive material, thereby over-inflating the conductivity to counter this effect. The true resistivity of the target is likely between the estimates of two methods.

The 1D inversions fit the observed data well for individual soundings, that is to say, only for the time dimension. But even when lateral (2D) or spatial (3D) constraints are applied, and a global data misfit is minimised, the agreement with the data is still good. The 2D has a good global data misfit. In a quasi-tabular context, it fits the data well. However, for a big lateral contrast, the local data misfit (in time) is not very good (Table 2 and Figure 7b). But by considering windows of data comparable to the footprint of the method (several hundred metres for late times), the modelled data is reasonable (see Figure 3) as it tends to reproduce the shape of the anomaly in (x, t) . Under these conditions, the 3D should have a similar or even greater problem in fitting the data because the inversion should take into account the cumulative effect of the entire model in every receiver position, as discussed in Cox et al. (2012), but still produce a reasonable global misfit.

Sounding C

Sounding C in Figure 7 appears to be a simple monotonically decaying response from which not much structure can be extracted. However, on closer scrutiny, the sounding actually turns out to have quite complex structure of shallow features in a depth range of 0 to 250 m below surface, as can be seen in all nine sections of Figure 5. When focus on the near surface, the image of this same line of data unveils and hides features that we outlined in Figure 4 and discussed previously.

As a general consideration, a comparison between the reconstructed models from all codes, using a unique rigorous 3D forward modelling operator and a common noise model, would be a natural succession of the findings of this paper.

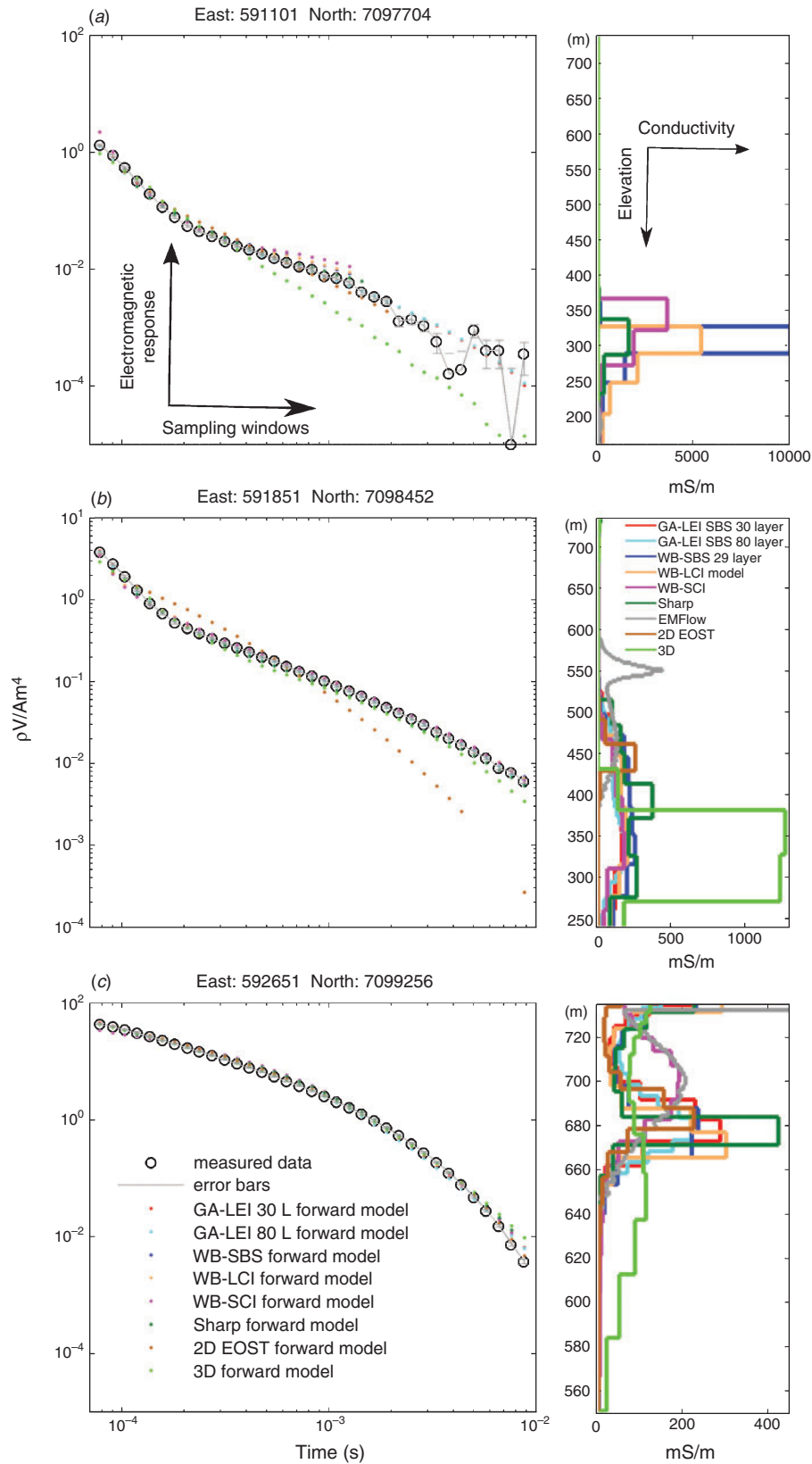


Fig. 7. Measured data from soundings (a) A, (b) B and (c) C (in black circles) overlaid by modelled forward responses (dots of different colours), produced by nine different inversions and transform codes.

Conclusions

Inversion of airborne EM data is known to be an ill-posed problem, which by its mere nature will give us non-unique solutions, hence, the potential to generate a variety of models

that can fit the measured data equally well. The application of different inversion codes or transforms to the same dataset can give dissimilar results as shown throughout this paper. This ambiguity suggests the choice of processes and

Table 1. Noise levels for each sampling wind.

Number	Sampling gates		Noise	
	start (s)	end (s)	additive	multiplicative
1	0.000078	0.000090	0.008194	3.60%
2	0.000090	0.000103	0.005067	3.60%
3	0.000103	0.000118	0.003395	3.60%
4	0.000118	0.000136	0.002301	3.60%
5	0.000136	0.000156	0.001758	3.60%
6	0.000156	0.000179	0.001315	3.60%
7	0.000179	0.000206	0.001035	3.60%
8	0.000206	0.000236	0.000803	3.60%
9	0.000236	0.000271	0.000689	3.60%
10	0.000271	0.000312	0.000611	3.60%
11	0.000312	0.000358	0.000504	3.60%
12	0.000358	0.000411	0.000442	3.60%
13	0.000411	0.000472	0.000391	3.60%
14	0.000472	0.000543	0.000362	3.60%
15	0.000543	0.000623	0.000323	3.60%
16	0.000623	0.000716	0.000299	3.60%
17	0.000716	0.000823	0.000277	3.60%
18	0.000823	0.000945	0.000269	3.60%
19	0.000945	0.001086	0.000245	3.60%
20	0.001086	0.001247	0.000236	3.60%
21	0.001247	0.001432	0.000225	3.60%
22	0.001432	0.001646	0.000223	3.60%
23	0.001646	0.001891	0.000215	3.60%
24	0.001891	0.002172	0.000209	3.60%
25	0.002172	0.002495	0.000200	3.60%
26	0.002495	0.002865	0.000194	3.60%
27	0.002865	0.003292	0.000194	3.60%
28	0.003292	0.003781	0.000193	3.60%
29	0.003781	0.004341	0.000192	3.60%
30	0.004341	0.004987	0.000191	3.60%
31	0.004987	0.005729	0.00019	3.60%
32	0.005729	0.006581	0.000189	3.60%
33	0.006581	0.00756	0.000188	3.60%
34	0.00756	0.008685	0.000187	3.60%
35	0.008685	0.009977	0.000186	3.60%

Table 2. Calculated residuals using a common noise model.

	Sounding A residual	Sounding B residual	Sounding C residual
WB SBS	19.84	7.52	15.22
WB LCI	17.84	7.00	15.43
WB SCI	33.63	7.97	20.55
Sharp	61.67	6.55	154.19
GA-LEI SBS	3.44	0.76	10.20
2D	15.65	136.47	3.81
3D	35.34	22.03	24.921

algorithms used to interpret AEM data requires more thought than just being a matter of personal choice and preference, particularly if the findings are to be transferred to other surveys in other areas.

Inversions that enforce horizontal continuity in its models are favoured in the more laterally continuous environments, while tight (smooth) lateral constraints and automated filtering should be avoided when horizontal variations such as faults and confined targets are expected. The choice of algorithm and regularisation must reflect the environment being studied.

AEM data are distributed over space and time as a function of depth (x , y , $t(z)$). The collected data can be inverted by using strategies that are different in terms of: (i) dimensionality of the forward operator; and (ii) *a priori* information formalised via the regularisation terms. Hence, a rough classification can consist of:

- 1D algorithms, modelling the data as a function of depth/time: ($t(z)$)
- 2D algorithms, modelling the data as a function of the depth and the distance along the line of flight: (in-line coordinate, $t(z)$)
- 3D algorithms, modelling the data as a function of all the spatial coordinates: (x , y , $t(z)$).

To these categories, we should also add the codes having intermediate characteristics. For example, the laterally/spatially constrained inversion is characterised by a 1D forward operator, but includes stabiliser terms connecting several soundings, and is actually capable to provide (pseudo-)2D/3D results.

In the present research, we have reviewed and compared several inversion schemes belonging to these categories.

When comparing models from different inversion of AEM data common noise model is desirable. The 1D inversions fit well the observed data for individual soundings that is to say only for the time dimension. The 2D and 3D have a good global data misfit. In a quasi-tabular context, they fit the data locally as well, but in certain locations fail to replicate the measured data. Note that to assess the misfit of each method, the final product (stitched or merged sections as shown in Figure 4) should be forward modelled by an independent and rigorous 3D modelling code capable of emulating the measured data. This will be left to future research.

Confined conductive responses detectable in the late-time channels are commonly obliterated by the high-amplitude response from conductive cover, which are in some cases two orders of magnitude higher. Advances in inversion and processing of AEM data will continue to be crucial in understanding regolith architecture and its geo-electrical structure, but in order to unveil targets under conductive cover, algorithms that provided statistical information on the level of ambiguity and uncertainty of our models are needed, as are the next generation of systems with lower base-frequencies, improved signal-to-noise ratios and more precise sensors to monitor system geometry will need to be built.

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