Testing dimensionality of inverted models responses using WSINV3DMT code

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SUMMARY

The 3D inversion code for magnetotelluric data WSINV3DMT (Siripurnvaraporn et al., 2005) is used in this work to explore the results of several inversions, focusing on the structures and responses of the inverted models and their geoelectric dimensionality. To accomplish this, the synthetic datasets to be inverted were obtained from the model of Ledo et al. (2002), which studied the 3D effects in 2D interpretation of magnetotelluric data, and whose data analysis is well known. These datasets include the direct responses as well as some affected by galvanic distortion.
The tests performed show how the choice of the impedance components and the number of sites determine the accuracy of the inversion results, and in which cases the structures and dimensionality can be recovered.

Keywords: 3D MT inversion, geoelectric dimensionality, galvanic distortion.

INTRODUCTION

The 3D magnetotelluric inversion code WSINV3DMT (Siripurnvaraporn *et al.*, 2005) seeks, for the minimum norm model, to fit observed impedance tensor components. Based on the Occam code (Constable *et al.*, 1987), it works in data space, which significantly reduces the computing times.
In this work we use the synthetic model from Ledo et al. (2002) to perform several inversions and compare the responses and dimensionality of the models obtained.
The goals are to establish how well the structures can be retrieved from the data responses inverted, what is the weight of the different data components in the inversion, and to test whether it is possible or not to recover galvanic distortion bodies as part of the structure recovered

3D SYNTHETIC MODEL AND RESPONSES

The synthetic model considered, from which the responses to be inverted were generated, consists of a 3D conductive body embedded in a 2D structure (Figure 1).
The forward responses of this model were computed using the code RM3D code (Mackie et al., 1993), with a 99x99x50 elements mesh, at 11 periods, from 0.001 s to 1000 s.

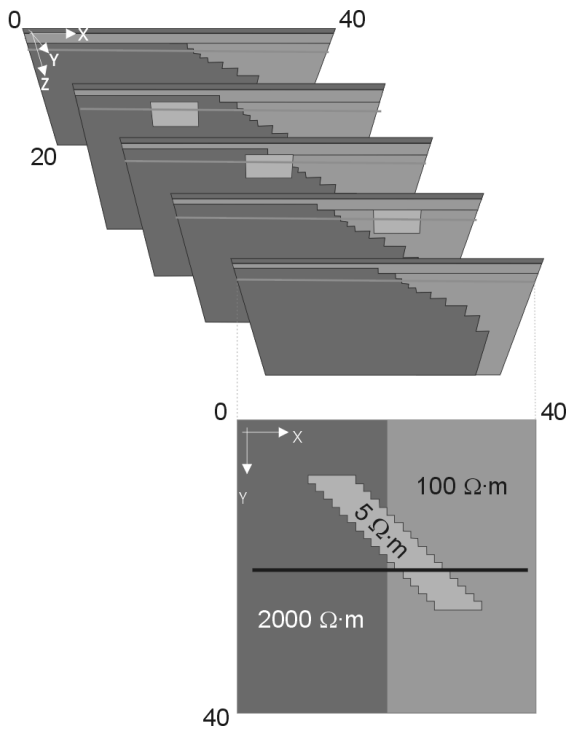

Figure 1: 3D electrical conductivity regional model used to generate synthetic responses. Distances are in km. Black line on XY view indicates the position of the profile (From Ledo *et al.*, 2002)

These responses were retrieved as three different datasets:

1) LINE: an EW line with 30 sites distributed along the width of the model (Figure 1);
2) DISTLINE: The same EW line, in which random galvanic distortion C, with site gain g = 1 and without anisotropy, was added to each site.
(Both datasets 1 and 2 are coincident with line 1 studied in Ledo *et al.*, 2002).
3) GRID: a rectangular grid with 96 sites covering the model surface (see Figure 2).

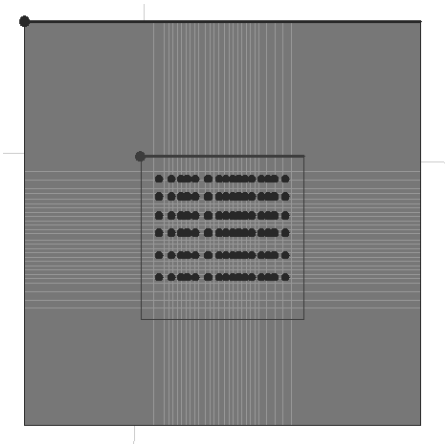

Figure 2: Plan view of the synthetic model (central frame with the 96 sites of dataset GRID. The external frame shows the extension of the model to run the inversions.

All the inversions of these datasets were performed using the default inversion parameters provided with the code. Five or eleven periods were inverted (between 0.01 s and 100 s), using either the 4 complex components of the impedance tensor or only the 2 off-diagonal ones. The assumed error was set to 5% in the off-diagonal components and the same value was then applied to the diagonal components (following Siripurnvaraporn et al., 2005, test example). The initial model consisted of a homogeneous half-space. The mesh for inversion was reduced to 28x28x20 cells, given limitations in computing time and space. The lateral cells were extended horizontally (see Figure 2) to avoid problems with the boundary conditions.
Although the WSINV3DMT code provides the responses of the inverted model, these were retrieved using RM3D code to make their further analyses and comparisons easier.
Dimensionality analysis was carried out using the WALDIM program (Martí et al., 2004), following WAL invariants criteria (Weaver et al., 2000).

LINE AND DISTLINE INVERSIONS

Both the original line (LINE) and the distorted one (DISTLINE) were inverted including all the sites, 11 periods and the 4 complex (8 valued) tensor components.
In the first case, rms reduced from an initial value of 3.3 to 2.9 by the 5th iteration. Both diagonal and off-diagonal components fits are good, except in the range between 0.0312 s and 3.2 s where the inverted model mesh probably lacks sufficient discretization.
Although all four components were inverted, the recovered model is mainly 2D, and not even the structures below the inverted sites are well recovered.
Comparison between the dimensionality obtained for the original and inverted datasets shows an agreement at short periods, up to 1 s. At longest periods, the inverted model images as 1D or 2D features that in the original data are seen as 3D.
For the distorted dataset, rms started at 129 and significantly reduced to 17 by the 5th iteration, which is still a poor fit. The resulting model shows abrupt resistivity changes at all periods, and the structures extend laterally out of the inverted profile.
In order to better characterise the uppermost structure further work will consist of refining the first layers mesh, inverting only the shortest periods with a better resolution, and fixing the resulting model to invert the rest of the periods.

GRID INVERSIONS

In order to obtain a better representation of the model, a rectangular grid dataset was created (see Figure 2).
A first inversion was performed considering 5 periods between 0.01 s and 10 s, and only 2 components of the impedance tensor.
Rms changed from 3.6 in the first iteration to 2.5 by the 7th. Even if only the off-diagonal components were inverted, the shorter spacing between sites allowed for a better retrieval of the original structures in the final inverted model (Figure 3).

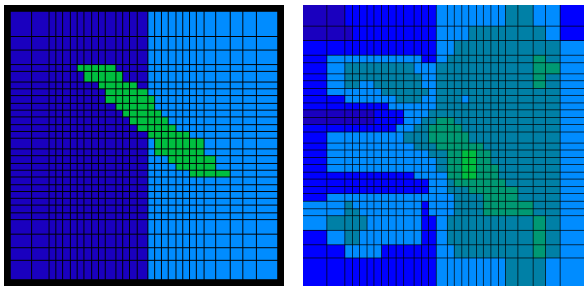

Figure 3: Depth slices of the synthetic model and the inverted model at z=2 km.

As for the model responses computed using RM3D, the diagonal components were significant, and the dimensionality analysis gave results similar to the original dataset: 1D at short periods and 2D and 3D for the rest. The dimensionality information may be used then to invert only 4 components at short periods and 8 components for the others, fixing the uppermost layers of the model.

ERRORS OF THE RESPONSES

One of the issues yet to be solved concerns the errors in the diagonal and off-diagonal components. The performed tests show how, when both diagonal and non-diagonal have the same error percentage, the inverted model does seldom change with iteration.
Following the same procedure as in the code testrun example (% in the non-diagonals, and same value in the diagonals), the model changes and the responses misfits reduce. However, the diagonal responses have a very low weight, which is almost equivalent to inverting only the off-diagonal components.
Even if affected by 3D effects, in general, the diagonal values of the responses are low compared to the non-diagonal. A further test will consist of rotating 45º the responses and the dataset GRID, in order to invert responses with all the components of the same order of magnitude.

CONCLUSIONS

The choice of the sites to be inverted seems to be of much more importance in the resulting model than the number of impedance components. When the dataset is dense enough, the model structures are recovered to within a reasonable degree, as shown also in the model responses and dimensionality. Data affected by galvanic distortion must be inverted using a finer grid at the uppermost model layers. Further tests must be performed to solve the error weights.

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