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Two-dimensional interpretation of three-dimensional magnetotelluric data: an example of limitations and resolution

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SUMMARY

Interpretation of magnetotelluric (MT) data for three-dimensional (3-D) regional conductivity structures remains uncommon, and two-dimensional (2-D) models are often considered an adequate approach. In this paper we examine 2-D interpretation of 3-D data by considering the synthetic responses of a 3-D structure chosen specifically to highlight the advantages and limitations of 2-D interpretation. 2-D models were obtained from inversion of the synthetic 3-D data set with different conditions (noise and distortion) applied to the data. We demonstrate the importance of understanding galvanic distortion of the data and show how 2-D inversion is improved when the regional data are corrected prior to modelling. When the 3-D conductive structure is located below the profile, the models obtained suggest that the effects of finite strike are not significant if the structure has a strike extent greater than about one-half of a skin depth. In this case the use of only TM-mode data determined better the horizontal extent of the 3-D anomaly. When the profiles are located away from the 3-D conductive structure the use of only TM-mode data can imagine phantom conductive structures below the profile, in this case the use of both polarizations produced a better determination of the subsurface structures. It is important to note that the main structures are identified in all the cases considered here, although in some cases the large data misfit would cause scepticism about features of the models.

Key words: electromagnetic induction, electromagnetic modelling, magnetotellurics, tensor decomposition.

INTRODUCTION

In recent years advances in computer technology have enabled the development of faster and more reliable algorithms to calculate the three-dimensional (3-D) electromagnetic response of earth models. Consequently, the current state-of-the-art for magnetotelluric (MT) data interpretation is that 3-D trial-and-error forward model fitting is being used more frequently for hypothesis testing, and 3-D inversions will become available in the near future. Data acquisition on dense 2-D grids has been undertaken to study geothermal (e.g. Takasugi *et al.* 1992) and mining-scale problems (e.g. Zhang *et al.* 1998), but regional-scale field experiments on a 2-D grid are often impractical due to high cost and inaccessibility. Accordingly, regional scale surveys are often restricted to a single profile or widely-separated profiles (e.g. southern British Columbia, Jones & Gough 1995; Ledo & Jones 2001). In such cases, researchers have to extract the maximum information possible from a data set that may be spatially undersampled. The use of additional geophysical information may allow 3-D modelling of MT data even where the data were collected along a profile (Pous *et al.* 1995; Park & Mackie 2000; Ledo *et al.* 2000).

Depending on the inductive and geological length scales of the target, 2-D interpretation of the data may be appropriate for a limited number of sites and over a limited period band. However, interpretation of 3-D data with 2-D techniques may not be able to reproduce the significant features of the subsurface; an example of this can be found in the 2-D interpretation of the Kayabe data set (Jones & Schultz 1997) by García *et al.* (1999).

In this paper, we explore some of the limitations of 2-D interpretation of 3-D MT data through the analysis of synthetic 3-D MT data with the currently available 2-D tools. Moreover, we demonstrate the importance of removing near-surface galvanic distortion on 3-D data, not only to reduce the error sources in a 2-D interpretation but also because of its importance in 3-D interpretation. Whilst this test is not aimed at reproducing all possible 3-D situations, we nevertheless follow procedures that we would undertake if these were actual field data to gain insight into the validity of 2-D modelling and interpretation of 3-D data.