Sensitivity of phase tensors to absolute resistivities in a 3-D world

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SUMMARY

Galvanic distortions represent one of the greatest challenges when dealing with magnetotelluric datasets. Several methods exist that try to mitigate the effect of distortions on inversion. One solution to avoid this major issue was provided with the introduction of the phase tensor, a transfer function that is free of galvanic distortion. However, the nature of the phase tensor makes it predominantly sensitive to relative changes of resistivity and its ability to constrain absolute resistivities is still under debate. So far, case studies have shown that phase tensor inversion works effectively if (i) the subsurface resistivity distribution has significant 3-D heterogeneities, (ii) MT site spacing is sufficiently dense, and (iii) data-constrained starting models are employed. There is presently a lack of systematic investigations to what extent phase tensors constrain absolute resistivity values in 3-D subsurface models.

To shed light on this discussion we systematically analyse to what degree variations of absolute resistivities influence the fit of phase tensor data. We use a dataset with measurements from 127 MT stations in an area of about 340 km^2 covering a volcanic geothermal field in the Main Ethiopian Rift. To ensure the eligibility of the dataset for 3-D phase tensor inversion we introduce a quantitative criterion for “sufficiently” dense station spacing. Using a homogenous starting model derived from the average apparent resistivity we retrieve a model with a good data fit, that acts as a reference model.

In a first test the fit of the reference model is compared to models obtained from inversion using arbitrary (i.e. not data-constrained) starting models consisting of homogenous halfspace models of 20, 50, 100 and 1000 Ωm. This results in poorer data fit and less geologically plausible models, thereby demonstrating the importance of using starting models that are constrained by data. In a second test we use the reference model and vary the resistivity values using algorithms from image processing such as contrast adjustment and linear stretching. Detailed analysis of the modelled responses and residuals reveals significant changes in the misfit relative to the reference model.

We conclude that in a realistic 3-D settings with sufficiently dense MT site spacing phase tensor inversion can be considered as a reliable method to recover true subsurface resistivities. If performed properly, phase tensor inversion is an elegant and straight-forward method to obtain models not affected by galvanic distortion.

Keywords: Magnetotellurics, Phase tensor, 3-D inversion, Galvanic distortion