

Results and insights on the three-dimensional inversion of tipper measurements

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SUMMARY

Magnetotelluric (MT) impedance tensor and tipper are fundamental components in modern MT surveys. However, localized surface inhomogeneities can introduce galvanic distortions that significantly affect the MT impedance tensor, particularly impacting the three-dimensional (3D) inversion models (Jones, 2011). When compounded with the topographical effects, these distortions probably can render MT impedance useless (Usui, 2015). In contrast, tipper data are immune to the galvanic distortions in the electric field. But, broadband tipper data often exhibit lower signal-to-noise ratios due to difficulties in burying vertical magnetic coils in the field and the relatively low intensity of the natural vertical magnetic field. Challenges also arise in effectively balancing the weights of impedance and tipper in the joint inversion objective functions. Consequently, these shortcomings and challenges in practice are commonly cited as reasons why incorporating tipper data into joint inversions may degrade the fit of MT impedance data manifested by increasing misfits. This study presents findings from several three-dimensional inversions of MT measurements, both separately and jointly inverting MT impedance and tipper data collected along a profile and on a 2D grid. Comparison of resulting models indicates that integrating tipper measurements into 3D inversions of profile MT data notably enhances the resolution of active fault geometries in the upper crust. Moreover, a preferred tipper-only 3D inversion model derived from a 2D grid dataset effectively identifies geological boundaries at depth, with resistivity distributions aligning well with lateral variations indicated by observed phase tensors (Caldwell et al., 2004). A detailed comparison of root mean square (r.m.s.) misfits across the different models, including those with and without tipper data, reveals that high-quality impedance tensors generally do not show increased misfits. Any observed increases in r.m.s. misfits in MT impedance data typically occur at period ranges of 10-0.1 Hz and occasionally at the longest periods, at which noise levels are relatively higher. This suggests that elevated misfits in impedance data during joint inversion may be attributed to higher noise levels or inaccurately estimated error floors in the data points. This implies that integrating tipper measurements could somewhat mitigate model fitting errors in MT impedance. In conclusion, extensive three-dimensional inversions across profile and 2D grid MT datasets underscore the advantages of incorporating galvanic distortion-free tipper data. This approach enhances the resolution of resistivity boundaries at depth and reduces the risk of fitting errors in MT impedance tensors, thereby ultimately improving the reliability of 3D MT models.

Keywords: Magnetotellurics, Tipper data, Three-dimensional, Inversion
