

Evaluation of uncertainty in forward modeling of geomagnetic observatory tippers for continental-scale 3-D resistivity structure models beneath China

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SUMMARY

Comprehensively understanding China's geological structure proves challenging due to the intricate nature of its tectonic features. Our research on continental-scale 3-D resistivity structure models aims to provide insights into the properties of the crust and upper mantle, as well as the evolution of geological structures. A decade-long time series of minute means from three components of the geomagnetic field from 59 mid-latitude geomagnetic observatories was collected and then analyzed. Compared to short-term MT data prone to random disturbances, the chosen high-quality geomagnetic observatories enhanced the reliability of our findings. The estimated MT tippers from the 240s to 10000s showed spatiotemporal variations and a clear directivity in the Parkinson vector arrows for observatories close to the coastline. To account for coastal geomagnetic observatories, digital elevation model (DEM) data were incorporated, and the influence of the ocean was accounted for by fixing the conductivity in the initial model during both the forward and inversion processes.

The accuracy in the forward calculation of MT tippers is crucial to obtaining a reliable three-dimensional conductivity model by inversion. In this study, we use a simple method to evaluate the uncertainty of MT tippers' forward modeling for continental-scale 3-D resistivity structure models in a Cartesian coordinate system. The method is based on the idea that the horizontal coordinate system can be selected arbitrarily for a general 3-D structure. This study focuses on the random component of the uncertainty of forward modeling to an initial 3-D structure model that consists of a homogeneous earth and ocean surrounding the study area. To ensure both reliability and efficiency, we randomly rotated the forward model in 10 azimuth coordinate systems, including the traditional (X_N , Y_E), to compute the MT tippers' response. By synthesizing MT tippers' responses to the model in several different coordinate systems, we can compute the mean, standard deviation, and coefficient of variation. The T_x and T_y components calculated for the 10 models generally exhibited good agreement and were nearly zero during short periods (less than 1000s), indicating minimal three-dimensionality. These trends were consistent across terrestrial observatories, excluding those located along the coastline. Compare the root-mean-square (RMS) calculated for the residuals between the observed MT tippers' response and the synthesized MT tippers' responses (X_N , Y_E), normalized by observed errors, with the residuals between the observed MT tippers' response and the mean of the synthesized MT tippers' responses, both normalized by their respective standard errors.

Further application in inversion analysis involves evaluating the residuals with normalization by standard errors for both observations and forward calculations. This approach proposed above will work to avoid overfitting data in the inversion analysis by ignoring the uncertainty of the forward calculation.

Keywords: Geomagnetic Observatory; MT tippers; 3-D resistivity structure model; Forward modeling; Uncertainty
