Reliability estimation of magnetotelluric inversion result based on the Principle Component Analysis and Markov Chain Monte-Carlo method

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Magnetotelluric (MT) method is used for detection of electrical conductive materials such as fluid, clay, partial melt and so on. Subsurface resistivity structure is generally estimated by an inverse algorism, based on the least-square scheme using observed apparent resistivity and phase. The reliability of the optimal model in the inversion procedure should be discussed together with seeking the "better" model having the lower data misfit than the optimal model. However, the sophisticated method is not well developed for the magnetotelluric survey, except for the simple test based on a number of forward modeling, constrained inversions and so on, or simple visualization of sensitivity of model parameters. In this study, for a quantitative visualization of reliability of optimal model parameters, we propose a new way of the numerical test of the model based on the Markov Chain Monte-Carlo (MCMC) methods. Since the MCMC cannot solve a number of unknowns in model parameters, we adopted the principle component analysis (PCA) to reduce unknowns in the model obtained by MT inversion code. First, for testing the PCA ability in subsurface image analysis, various two-dimensional (2-D) resistivity models are decomposed by PCA. As a result, we succeeded to extract the "major features" of 2-D resistivity model, especially by using first to third principle components. Then, we tested the MCMC algorithm with changing parameters of "major features" of 2-D model, such as its resistivity, width, thickness, horizontal and vertical locations. In a case of a simple two-prism model, we confirmed that the reliability of low and high resistive anomalies are shown in the probability density functions obtained by MCMC. We also found that some parameters (e.g., thickness and resistivity of an anomalous body) indicate a tread-off relationship as mentioned in the previous studies, and also found the reliable range of parameters even under the trade-off. We then applied this technique to the magnetotelluric data obtained at a field experiment. In consequence, anomalies in the optimal model are detected properly by PCA, and the reliable range of model parameters based on the MCMC method are similar to those inferred by the conventional forward calculations. We conclude that our proposed method can be widely applied to magnetotelluric exploration, even to the three-dimensional inversion.

Keywords: Principle Component Analysis, Markov Chain Monte-Carlo method, Magnetotelluric Inversion