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Estimating the distribution of electrical conductivity in the earth with the maximum-likelihood method

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We estimated radial electrical conductivity distribution in the Earth by solving an inversion problem with an objective function that allows errors in the model. In general, geophysical inverse problems are solved by the least squares method that minimizes the objective function consisting of linear combination of the data misfit and the regularization term. The predicted data is obtained by a forward calculation for the set of optimized model parameters. However, this method implicitly premises that the model has no error.

We tried to solve an inversion problem without the premise. Solutions by the maximum-likelihood method are not necessarily equal to those by the least square method. Specifically, We applied this method to the vector geomagnetic observatory data all around the globe in November, 2003 and estimated the radial electrical conductivity profile. A heterogeneously conducting shell was placed at the top of the radially symmetric sphere. We worked with the data per minute at 69 observatories during the large geomagnetic storm and subtracted the vector average for 5 quietest days. We then separated the corrected time-series into internal and external origin. The separated internal magnetic field can be reproduced by our maximum-likelihood method using forward response of the radially symmetric conducting sphere to the separated external magnetic field.

It was revealed that the maximum-likelihood method led to the different solution from that by the least squares method and that the maximum-likelihood method gave us appropriate information on model choice. However, it was necessary to apply a priori information on the model parameters as much as possible (e.g., all electrical conductivities must be positive) and to add a regularization term to the objective function. We will also discuss the pertinent way of adding errors to the synthetic data and the effect of initial models on the final model.

Keywords: electrical conductivity, magnetic storm, inversion