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Three dimensional geomagnetic response functions for global and semi-global scale induction problems

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Electrical conductivity structure in the Earth obtained by using observed geomagnetic and geoelectric field provides important and independent information to discuss the dynamics and material in the Earth. Fukao et al. (2004) examined the first 3-D semi-global mantle conductivity model in the northern Pacific obtained by Koyama (2001) together with the global seismic velocity in the same region, and concluded that temperature anomaly cannot be the cause of anomalously high conductive region beneath Philippine Sea in 350-550 km depth. Although observationally determined electrical conductivity structures have already been employed for further interpretations (Koyama et al., 2006), the estimates have much room to improve the credibility and accuracy. Possible improvement might be brought through (1) better estimating the response functions from electromagnetic observation, (2) better understanding of the behaviors of the response functions against 3-D conductivity heterogeneity in the mantle, and (3) introducing new information (response function) which is sensitive to the 3-D structure. In this paper, we will consider (2) and (3).

1-D conductivity profiles from a number of geomagnetic stations have been often compiled to discuss 3-D structure in the mantle. However, we are going to demonstrate that such an approach will produce erroneous conductivity image if the GDS response is used for 1-D inversion. This indicates that imaging 3-D heterogeneity is only possible by real 3-D inversion.

A systematic study of the GDS responses against 1,000 km scale heterogeneous bodies was performed by 3-D forward modeling. It is shown that the GDS responses at the stations around the north and south boundary of the anomalous bodies are sensitive to the conductivity anomaly, and lateral conductivity heterogeneities of such scale may be detected if the conductivity contrast is more intense than $*2$ or $/5$ with respect to the one-dimensional reference model.

Next we look into the ratio of the geomagnetic horizontal components between two stations (horizontal transfer function; HTF hereafter), which is expected to be sensitive to lateral heterogeneities, as new information to constrain the conductivity structure. 3-D forward calculations revealed that the HTF has anomalous values above the heterogeneous bodies, and it has large enough signature to be detected compared with the estimation error of the HTFs by observations. We expect that use of HTFs together with GDS and MT responses will facilitate to obtain a more plausible 3-D mantle conductivity structure.