Investigation on the dynamical structure in the region of core-mantle boundary by using the method of EM tomography

Yozo Hamano[1]

[1] Dept. Earth & Planetary Physics, Univ. of Tokyo

In the present work, we present a new approach for investigating the electromagnetic heterogeneous structure near the core-mantle boundary. This method employs a time domain analysis of the induction equations, and calculates the temporal variation of the magnetic field at the surface, which is induced by the variation of the geomagnetic field in the core. Most of the previous approach for the global earth modeling calculate the induction in frequency domain in order to investigate a steady-state part of geomagnetic variation with a strictly periodic current system flowing in the earth. We would like to show here that the calculation of the transient response in time-domain is also a useful and powerful tool to detect the conductivity structure in the lower mantle.

Global seismic tomography shows the existence of horizontal variations of the seismic wave velocities in the mantle. The lateral heterogeneities are large in the upper mantle and near the core-mantle boundary. Causes of these lateral heterogeneities are attributed to the temperature and/or compositional variations. Hence, the electrical conductivity heterogeneity is also expected associated with the above heterogeneities. Although the strong lateral heterogeneity in electrical conductivity has been observed in the crust and the upper mantle, direct observations of the electrical conductivity heterogeneity in the lower mantle are not available. External geomagnetic signals generated by the electric current in the ionosphere and magnetosphere largely attenuates through the upper mantle, and the observations of the induced field due to the external sources are not sensitive enough to detect the electrical conductivity of the lower mantle. Even an average conductivity in the D" layer is still controversial. In order to estimate the conductivity structure in the lower mantle, we need to use the geomagnetic signals generated in the core.

In the present work, we present a new approach for investigating the electromagnetic heterogeneous structure near the core-mantle boundary. This method employs a time domain analysis of the induction equations, and calculates the temporal variation of the magnetic field at the surface, which is induced by the variation of the geomagnetic field in the core. Most of the previous approach for the global earth modeling calculate the induction in frequency domain in order to investigate a steady-state part of geomagnetic variation with a strictly periodic current system flowing in the Earth. On the other hand, in electromagnetic exploration field, time domain approach is commonly used to estimate the shallow structure of the earth's crust. We would like to show here that the calculation of the transient response in time-domain is also a useful and powerful tool to detect the conductivity structure in the lower mantle.

In the conductive earth, geomagnetic field can be decomposed into poloidal and toroidal modes. We solved the magnetic induction equations for the two modes simultaneously, since the two modes are mutually coupled. Time integration starts when a given core field is suddenly applied at t=0. Time derivative of the induced field generated by this abrupt change of the core field gives the impulse response function of the induced field.

Results of the calculation on a simple 2-layer mantle model, in which the bottom layer has a lateral conductivity heterogeneity, revealed a very interesting feature when the zonal toroidal field is used as an inducing source field in the core. In this case, time variation of the response function of the induced poloidal field has a shape of ramp function, where each component of the response monotonously increases (or decreases) from zero, and approaches to a certain finite value. This indicates that the permanent poloidal field exists associated with the toroidal field in the core. Since the toroidal magnetic field is accompanied with the poloidal electric field, existence of the toroidal magnetic field at CMB generates the electric current flowing into the lowermost part of the mantle. This current flows the conductive part of the mantle, and returns to the core. If the conductive part of the mantle is laterally homogeneous, this current system does not generate the poloidal magnetic field. However, if the lowermost part of the mantle, i.e. D" layer, is laterally heterogeneous, the horizontal current concentrates to the relatively conductive part within the D" layer, and this current flow produces the poloidal field, which can be observed at the earth's surface. This feature of the toroidal induction suggests the possibility of estimating the toroidal field in the core from the surface observation of the geomagnetic field.