S4-001 Room: C405 Time: June 6 9:00-9:15

On the simulation of the electromagnetic induction process in 3D heterogeneous earth

Yozo Hamano[1]

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

We present a new time-domain approach to the forward modeling of 3-D electromagnetic induction in a heterogeneous conducting sphere. This method utilize the standard decomposition of the magnetic field into toroidal and poloidal mode, and spherical harmonic expansions of both the magnetic field and the conductivity heterogeneity. Resulting induction equations for the expansion coefficients are solved simultaneously in time domain. Coupling terms of the two modes (toroidal and poloidal) with the conductivity structure are analytically solved, so that the terms can be calculated by the matrix multiplications at each step of the computation. Finite difference approximation was used to solve a set of the diffusion equations up to degree 12.

We present a new time-domain approach to the forward modeling of 3-D electromagnetic induction in a heterogeneous conducting sphere excited by external and internal sources. This method utilize the standard decomposition of the magnetic field into toroidal and poloidal magnetic field, and spherical harmonic expansions of both the magnetic field and the conductivity heterogeneity. Resulting induction equations for the expansion coefficients are solved simultaneously in time domain. Coupling terms of the two modes (toroidal and poloidal) and of the electromagnetic fields with the conductivity structure are analytically solved, and re-expanded by the spherical harmonics, so that the terms can be calculated by the matrix multiplications at each step of the computation. Finite difference approximation was used to solve a set of the diffusion equations up to degree 12. This method can be efficiently used to analyze transient geomagnetic variations to infer the 3-D conductivity structure of the earth.

In order to validate the present approach, we solved an induction problem in a simple three layer mantle model, where the thin top layer (thickness: 25 km) has an electrical conductivity heterogeneity. Two models, in which depths of the bottom of the second layer (simulating the upper mantle) are 400 km and 700km, are calculated to estimate the effect of the depth of the conductivity jump. The third layer extends from the bottom of the second layer to the core-mantle boundary. The electrical resistivity of the second and the third layer is assumed to be 100 ohm-m and 1 ohm-m, respectively, where the resistivity of the top layer has P11 type heterogeneity.. For these two models, temporal variations of the internal Gauss coefficients in response to a sudden application of P10-type external field were calculated, and the impulse response function of each harmonic component was obtained by differentiation with time.

The response function of the primary induced components, g10 and g21, have large initial values, and monotonously decays with time, whereas other secondary induced components are initially zero and have two peaks during the later period. The first peaks are about 0.01 hours after the application of the external field, and the second peaks are at around 10-20 hours after the onset. Differences of the response functions between two models are detected after about an hour elapsed. These differences in the amplitude and the peak time can be used to infer the depth of the conductivity jump. Since all these induced components are generated by the surface heterogeneous layer simulating the distributions of the ocean and land, and the responses remains even after several days, it is to be said that the effect of the surface layer should be considered even for the long period responses of more than several days. Fourier transforms of the time-domain response of the Gauss coefficient give the response function in the frequency domain, which can be compared with the previously available solutions. Real and imaginary parts of the spatial distribution of the induce magnetic field (Bz and By) in frequency domain at some periods were calculated from the present results, and compared with those calculated based on the finite difference method with the staggered grids (see Uyeshima and Schults, 1999) This comparison indicates that the surface induce phases are also detected in the frequency-domain response functions with the period ranging from 1 hour to 10 days, and with the different methods of the calculation.