地表で観測される地磁気ジャークに対する下部マントルの電気伝導度不均質の影響

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Effect of an electrically heterogeneous lower mantle on the geomagnetic jerks observed at the Earth's surface

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Most of the geomagnetic field observed at the surface of the earth is generated in the fluid outer core. The main field changes with time, which is denoted as secular variation. Geomagnetic jerks are abrupt changes in the linear trend of this secular variation, and are surface observable shortest-period components of the geomagnetic field variation of core origin. Hence, the jerks have been studied by many authors to infer the dynamics of the core and the electrical conductivity of the lower mantle in the last few decades. Geomagnetic jerks are traditionally studied using time series of the magnetic field recorded in geomagnetic observatories. The uneven distribution of the observatory network precludes the investigation of global distribution of the geomagnetic jerks, and internal origin of the jerks have been questioned by a number of authors. Recently, as a result of continuous satellite measurements since 1999, the magnetic fields and their variations can now be described with high resolution in space and time, and the internal origin of most of the known jerks and their global nature are now firmly established. However, even now, little is understood of their physical origin.

Since jerks are generated in the core, they will pass through the electrical conducting mantle, before arriving at the surface. Consequently, the geomagnetic field observed at the surface will correspond to a filtered version of the original field generated in the core. Even an 1D electrical conductivity distribution in the mantle exerts screening effects such as delaying and smoothing of signals on the surface observed geomagnetic field. Moreover, a laterally heterogeneous electrical conductivity structure causes more dramatic changes in time and space on the magnetic fields come through the heterogeneous layer. In this case, an uniform change of the magnetic field over the core surface may generate complex variations of the surface observed geomagnetic field. Changes of the toroidal magnetic field in the core, which is not detectable at the insulating surface of a 1D earth, generates poloidal magnetic field in the laterally heterogeneous layer, and can be detected at the surface. Recent discovery of the post-perovskite phase change at the lowermost mantle, and the measurements of the electrical conductivity in the high P and high T condition expected at the bottom of the mantle, predict very high and heterogeneous electrical conductivity structure in the lowermost mantle adjacent to the core surface. Hence, understanding of the filtering effect of an electrical heterogeneous layer on the geomagnetic field is indispensable to investigate the origin of the geomagnetic jerks and other geomagnetic phenomena of core origin.

In the present study, modification effect of the geomagnetic field due to an electrically heterogeneous layer is examined by using newly formulated induction equations in a 3D heterogeneous mantle. Assuming an electrical heterogeneous layer above the CMB, results of the numerical calculation indicate that uniform changes of the geomagnetic field at the core surface causes very complicated variation of the surface geomagnetic field in space and time. As a source field at the core surface, T20 component of the toroidal field, and P10 poloidal field are provided. Corresponding to the abrupt change of these source fields at the core surface, surface observed magnetic field varies with time in very similar manner to the observed geomagnetic jerks. Time scale of the change of the secular variation and the surface morphology of the secular acceleration jump of the calculated geomagnetic variation suggest that the change of the toroidal T20 field at the core surface is more plausible as a source of the actual geomagnetic jerks. The origin of the toroidal field change can be attributed to the torsional oscillation in the core, that is expected by theoretical grounds and observed in MHD dynamo simulation models.