Geophysical Research Abstracts
Vol. 13, EGU2011-2407, 2011
EGU General Assembly 2011

Measurements of submarine cable electrical voltages to probe the Earth's deep interior

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During past a few decades, we have been conducting electrical voltage measurements using thousand-kilometer-scale trans-oceanic submarine cables in order to understand dynamic processes in the Earth's deep interior.
The geomagnetic main field is generated in the electrically conducting Earth's fluid outer core by dynamo action. It is well known that both the poloidal and toroidal magnetic modes are necessary to sustain a self exciting dynamo. However, only the poloidal magnetic field can be observed at the Earth's surface through geomagnetic observations. The toloidal magnetic field is confined within the Earth, and therefore its direct observation is thought impossible. Nevertheless, it is desirable to constrain the size and distribution of the toroidal magnetic field observationally to understand the geodynamo and related dynamical processes. If a toroidal magnetic field exists at the core-mantle boundary (CMB), the signature of the field arises as an electric field at the Earth's surface. Although the intensity of the electric field of the toroidal magnetic mode is expected to be weak, the electrical signature can be observed if a very long cable such as a trans-oceanic submarine cable is used (e.g. Runcorn, 1964).
The geomagnetic main field changes with various time scales. Among them, we consider two shortest time scales: decades and about one year. The dipole and some other low degree magnetic field vary with time scale of about 30 and 60 years. Toroidal field variation corresponding to the field variation at the surface should exist in the core, and it can be detected from long-term variation in the submarine cable voltages. The field variation with about one year time scale is known as a geomagnetic jerk, in which sudden change of second time derivatives of magnetic field components are observed. The cause of the geomagnetic jerks is believed to be in the geodynamo, but it is not well understood that the sudden variation is a signature of the poloidal field variation in the core or that of the toroidal field variation which is interacted with heterogeneous layer at the bottom of the mantle through electromagnetic induction. Electric potential observed by submarine cables has potential to discriminate the origin of the geomagnetic jerk.
In this paper, we present recent estimates of long-term variation of the electric potential observed by submarine cables in the western Pacific and discuss the toroidal field variation of decadal time scale at the CMB. Also, characteristics of the electric potential variation caused by short time scale poloidal and toroidal magnetic field variations are summarized to discuss the possible cause of the geomagnetic jerk.