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導体地球の過渡応答: 理論及び観測ステップ応答の比較
Transient response of the conducting Earth: Comparison of the observed and theoretical step response

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Transient response of the Earth in time domain is very useful to delineate electrical properties of our planet down to the lower mantle depths. Among many possible configurations of the external geomagnetic field, abrupt change in the dipole filed of external origin (q_1^0) is of particular interest here because it can be actually created by variations of the magnetospheric ring current and is of significant strength in the sense that it is clearly observable. The step response, F_1^0, of the conducting Earth for the dipole field, therefore, was examined in this study for a time range from a few hundred seconds through longer than 100 hours using vector geomagnetic time-series at the time of intense geomagnetic storms such as the Halloween storm event in 2003 observed simultaneously by ground geomagnetic observatories worldwide.

In general, the so-called impulse response of a physical system is given by time derivative of its step response. A well-known example of those responses is that the first derivative of the Heaviside's step function is equal to the Dirac's delta function. Time-series of observable quantity can be expressed by a convolution of the source and the impulse response from the time origin to an instant in concern. Thus, temporal variation of the poloidal geomagnetic field, $p_n^m(t)$, at the Earth's surface is also given by a convolution of source variation, $q_n^m(t)$, and the Earth's impulse response that conveys the electrical property of our planet. Here, n and m are the degree and the order of the spherical harmonic geomagnetic field, respectively. The convolution, however, can be evaluated more easily in frequency domain rather than time domain making use of FFT. The time derivative is also replaced by i x omega in frequency domain, where omega is the angular frequency of the electromagnetic (EM) variation in concern. Temporal variation of the Earth's step response, $F_n^m(t)$, is then derived by inverse Fourier transform back into time domain.

In the present study, $F_1^0(t)$ was estimated using hourly or one-minute values of g_1^0 and q_1^0 coefficients obtained by spherical harmonic analyses of geomagnetic storms and using the relation: $p_1^0(t) = g_1^0(t) + q_1^0(t)/2$. The curve of $F_1^0(t)$ is basically an increasing function of time, which implies that the electrical conductivity of the Earth is also increasing with depth. However, $F_1^0(t)$ flattened significantly for the time range between some dozen minutes and hours indicating that there may exist a region of enhanced electrical conductivity at mantle transition zone depths. Preliminary model studies using Hamano's (2002) three-dimensional (3-D) time domain EM induction scheme yielded an estimate for the probable depth range of the enhanced electrical anomaly that was very localized around the 410km seismic discontinuity. If the localized depth estimate is true, the transient response of the conducting Earth has possibly captured the thin water filter atop the 410km discontinuity proposed by Bercovici and Karato (2003).

In this presentation, we will further examine the probable depth range for the electrical conductivity anomaly by comparing the observed step response with the theoretical step response of spherically symmetric and/or fully heterogeneous earths. A direct conversion method of the observed step response into the electrical conductivity profile based on an iterative uniform sphere approximation will be applied and compared with the model calculation as well. The effect of Sq noise on the observed step response will also be examined and argued.