Sensitivity of local electromagnetic response functions from Sq field to the electrical conductivity in the upper mantle

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Solar quiet daily variations of the Earth’ s magnetic field, Sq field variations, are composed of externally inducing electric current system in the ionosphere and internally induced current system within conductive Earth. Spherical harmonic analysis of magnetic field on quiet days showed that dominant spherical harmonic modes are those with spherical harmonic degree n=p+1 and order m=p for a period 24/p hours up to p=4. Schmucker (1999a) named them as the principal modes of Sq. It is possible to separate the scalar magnetic field potential at each of these periods into external and internal parts by spectral and spherical harmonic analyses, and the responses obtained from them may be used to study the electrical conductivity in the upper mantle. Ratios of the internal to external coefficients, q-response, of the spherical harmonic expansion, global responses, may be useful when Earth is radially symmetric. However, for a realistic three-dimensional (3-d) Earth, one external spherical harmonic mode generates various internal modes due to lateral heterogeneities like land-ocean distribution and heterogeneity in the upper mantle, and each internal term has to be related to all existing external terms. This implies that a global response such as the q-response is difficult to apply for estimating 3-d structure (Schmucker, 1999b). In this study, we consider local electromagnetic responses such as Bz/Bx, Bz/By, magnetotelluric (MT), and corresponding quantities, where x, y and z are northward, eastward and vertically downward components, respectively. We investigate the sensitivity of these responses with respect to the electrical conductivity of the upper mantle by forward modeling of electromagnetic field.

Here theoretical responses were evaluated at the depth of seafloor in order to apply the results on the electromagnetic field observed there. We first examine the sensitivity of the response functions for 1-d radially symmetric conductivity structure modified according to Olsen (1998). The responses for the Sq's principal modes are calculated using a method based on Banks (1969). In addition to showing the responses have sensitivity to 1-d structure, apparent resistivity calculated from Ex/By and Ey/Bx due to the principal modes are compared with those calculated assuming source field with spherical harmonic mode of n=1 and m=0 to discuss the influence of source field that has spatial structure. Then, we evaluate the influence of 3-d conductivity structure on the responses using forward modeling code by Uyeshima and Schultz (2000). Influence of land-sea conductivity contrast on the responses are shown. Also, sensitivity of the responses to a rectangular heterogeneous body (in a spherical coordinate) in the upper mantle is discussed by evaluating the responses by changing the size, depth, and conductivity of the heterogeneous body.

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