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Distribution of electromagnetic fields induced in Japan

TOMINAGA, Hiroki[1*] ; ENDO, Arata[1] ; FUJITA, Shigeru[2] ; FUJII, Ikuko[2]

[1]Japan Meteorological Agency, [2]Meteorological College, Japan Meteorological Agency

The electric field induced by a geomagnetic field variation can be enhanced in Japan by a large conductivity contrast between seawater and rocks (the coast line effect). We should know plausible geomagnetically induced currents there when unprecedentedly large geomagnetic disturbances occur. Distributions of the electromagnetic fields induced at the surface of a realistic earth are estimated as the first step.

The electromagnetic fields induced at the surface of a 3D earth under an inducing magnetic field in the magnetosphere are computed in the frequency domain by the finite difference code developed by Uyeshima and Schultz (2000). The periods used are 200, 800 and 3600 seconds. The grid size is 12.5km x 12.5km at latitudes between 25-50^{o}N and longitudes between 125-150^{o}E and is gradually increased at the outside the region.

A 3D distribution of the electrical conductivity inside the Earth is obtained down to 12.5 km deep by using the ETOPO1 bathymetry data and the sediment thickness data by Laske and Masters (1997). A radially symmetric conductivity distribution is used at depths lower than 12.5km. The conductivities of seawater and sediment are fixed as 3 and 0.1 S/m, respectively, while the rock conductivity is used either of 0.01 or 0.0001 S/m to demonstrate the effect of a conductive or resistive lithosphere.

The inducing dipole magnetic field is given at 10 Earth radii as a boundary condition. If it is an axial dipole, the source magnetic field variation is polarized mainly in the north-south direction in Japan. We rotate the dipole every 30 degrees against the equator plane to realize other polarizations.

We pick up the maximum amplitude of the induced electric field among all source field patterns at every surface grid point to construct the distribution map of the maximum possible induced electric field in Japan. The map shows that the electric field is enhanced along the coast lines and the electric field amplitude is larger for the resistive lithosphere than that for the conductive one. The amplitude reaches twice compared to that from a homogeneous earth model. In most surface grids, the electric field amplitude at a shorter period is larger than that at a longer period. The electric field is enhanced especially at Tsugaru-Toshima peninsulas, Toyama bay, Izu peninsula, and east coasts of Kyusyu Island where offshore sea depths quickly become deeper.

The geomagnetic field at the surface also shows heterogeneity because of induction. When the source magnetic field is an axial dipole, the east-west component is generally weak and the vertical components are can be large at coastal areas. The north-south component at Tohoku and Kyusyu is similar to that of a 1D homogeneous earth, while it is weaker at areas from Kanto to Chugoku.

Distributions of the impedance tensor are also obtained. The impedance tensor substantially varies over Japan suggesting that the influence of sea on the regional induction is immense. For instance, Hokkaido could be divided into several areas following the spatial pattern of the impedance tensor, which show some similarities to the impedance tensor at Doto obtained by Uyeshima et al (2001). Similarly, several districts over Japan are recognized from the viewpoint of the spatial pattern of the impedance tensor depending on the direction of the source magnetic field.

The comparison between the computed and observed impedance tensors at Kakioka, Kanoya and Memambetsu indicates that the computed tensors qualitatively reproduce the observed ones, but the amplitudes and frequency dependencies show discrepancies. A more realistic conductivity model is necessary, if a more precise estimate of the electromagnetic field induced at the surface.

Keywords: electromagnetic induction, geomagnetically induced currents, impedance tensor