Numerical modeling of the electric and magnetic fields induced by ocean currents - a study aiming to use on volcanic islands

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Magnetic variations caused by ocean currents appear as noise in magnetic observations on volcanic islands near the Kuroshio such as Miyakejima. Since the magnitude of the magnetic variation originating from the ocean current is close to those from volcanoes, it causes disturbances in volcanic electromagnetic observations. In this study, we developed a numerical code to model the electromagnetic variations caused by the ocean current and estimated effects of large-scale ocean currents around Japan by using flow velocity data from an ocean model.

The code by Uyeshima and Schultz (2000), which calculates the induced electromagnetic field on three-dimensional spherical coordinates, was modified so as to incorporate source terms derived from ocean currents. The source term caused by the ocean current consists of the flow velocity and electric conductivity of sea water and the Earth's main magnetic field.

The data of the flow velocity, salinity and seawater temperature were obtained from the high-resolution ocean model around Japan, “Meteorological Research Institute multivariate ocean variational estimation (MOVE) system” (Usui et al., 2006). The electric conductivity of sea water was calculated from the salinity, seawater temperature and water pressure. “International Geomagnetic Reference Field the tenth generation (IGRF10)” (Macmillan and Maus, 2005) was used to compute the Earth’s main magnetic field. These data are given every 10 days from April 2001 to September 2001, with the horizontal resolution of 0.1 degrees. The bathymetry and the sediment thickness were taken from the data sets of ETOPO2 and Laske & Masters (1997).

The sea is split into six layers in the vertical direction of the model space, representing three-dimensional structures of the ocean current and the bathymetry. Expressing the sea with multiple layers instead of one thin layer enabled us to include the electric field generated in the vertical direction and thus calculate the magnetic field variation of all vector components including the horizontal ones.

Calculated amplitudes of the induced magnetic field at the surface of the Earth showed particularly large values on the area between the offshore of Tohoku region and Izu Islands. Around the Japan Trench, the maximum estimated amplitude was about 10 nT, due to the effect of the seafloor topography. The variation of the total force estimated on the position of Miyakejima has the amplitude of about 3 nT which is roughly consistent with the observed one when the Kuroshio closed to the island.

The calculation scheme developed in this study can be applied to other high-resolution ocean current models, so a next challenge would be to incorporate smaller-scale ocean currents around the islands in order to model the geomagnetic field at each actual observation point on volcanic islands.

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