A three-dimensional electromagnetic induction effect of ocean bathymetry on diurnal geomagnetic field variation in Japan

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The vertical component of diurnal geomagnetic field variation at Kakioka (KAK) and Memambetsu (MMB) geomagnetic observatories has a phase difference from that at Kanoya (KNY) one. From a spectra analysis for the observation data in 1997, the relative phase difference of the vertical component at 24 hours in period is 18.3 (KAK) and 15.7 (MMB) degrees compared with the phase of KNY. This phenomenon has been interpreted as induction by anomalous distribution of the mantle electrical conductivity or by ocean. In this presentation, three-dimensional (3-D) electromagnetic (EM) induction modeling was demonstrated for a probable mantle (electrical) conductivity model and/or a model incorporated oceanic bathymetry by using Iterative-dissipative method (IDM; Kuvshinov et al, 1999) in order to confirm whether the induced field realizes this phase difference or not.

Schmucker (1999) postulated that external field origin of diurnal variation at 24 hours in period has only specified spherical harmonic terms, the order and degree of which are (0,1), (1,1), (0,2), (1,2), (2,2), (0,3), (1,3), (2,3), (1,4), (2,4) and (2,5) and we calculated the EM field variations generated by a non-zonal source of them. With regard to the earth's interior, we tested an ocean bathymetry model and a probable mantle one for 3-D EM induction modeling. Ocean bathymetry model constitutes a thin-sheet and two-layered shell model. The thickness of the thin-sheet is 1000 m and the conductance variation is made by the ETOPO-2 data. Electrical conductivity of sea water was assumed to 3 S/m. The conductivity values of the first shell below the thin-sheet up to 600 km in depth was tested 0.02, 0.002 and 0.0002, respectively and that of the internal sphere was fixed to 2 S/m. On the other hand, we constructed a probable mantle conductivity structure realized by seismic P-wave velocity structure (Obayashi et al., 2001). Koyama (2002) and Fukao et al. (2003) revealed a 3-D mantle conductivity distribution in the Pacific region and that the thermal structure inferred from their conductivity distribution is consistent with that from seismic P-wave velocity structure in the major part of the region (The most prominent inconsistent part is under Philippine Sea region). Hence we adopted a conductivity model converted from a seismic structure to a probable mantle one. Horizontal mesh interval is 1 degree in the ocean bathymetric model and 2.8 degrees in the probable mantle model, respectively.

For the oceanic model, the phase differences at KAK and MMB are delayed rather than progressed from that at KNY by the induction effect for all the spherical terms. This feature is independent of the tested conductivity values of the first shell. The realistic mantle conductivity model makes the difference progressed by a few degree. However, this induction effect does not seem enough to explain the phase difference of the observation data. As a result, the phase difference of the diurnal geomagnetic variation generated by the EM induction of the earth's internal models did not sufficiently consistent with the observed phase difference at KAK. We can interpret this as two ways. One is that the probable mantle model does not reflect the true mantle conductivity structure. For the continents in the far east region, Ichiki et al.(2001) revealed that the stagnant slab has a high conductivity value. Therefore the conductivity structure in the continental region near Japan may not be consistent with that realized from seismic P-wave velocity structure at all. The other is that the external field shape brings about most of this phase difference. However, we confirmed that the internal and external field separation can not be correctly derived because of the non-uniform distribution of the observatory on the earth's surface. In order to determine the shape of external source field, we need to develop another three-component geomagnetic data source by using satellites and so on.