The plane-wave and gradient modes of geomagnetic diurnal variations

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SUMMARY

Our previous study used geomagnetic diurnal variations (DV) recorded by observatories to study the mantle electrical conductivity by combining physics-based ionospheric model and principal components analysis (PCA). However, both synthetic and observed data show that the vertical magnetic field is highly sensitive to the lateral variations of mantle conductivity, making the conventional 1-D regional interpretation sometimes unreliable. In order to better reconstruct local background structure beneath observatories, we have developed a new method to decompose the DV signals into various components and select appropriate mode for interpretation. According to The Taylor series expansion for the magnetic scalar potential, the source of geomagnetic field can be defined as 5 idealized types of excitations locally: 2 uniform polarized plane-wave modes, and 3 curl-free gradients modes. While the vertical magnetic field associated with plane-wave modes is equivalent to the tipper vector that better delineates the vertical contrast of conductivity, the one induced by the first gradients modes corresponds to the generalized C response which are more relevant to background conductivity. These 5 idealized sources could be approximated by linear combination of the spatial modes of DV derived from PCA, assumed that the source model is accurate enough. Here we utilize 3D synthetic data generated by checkerboard models to validate the method of plane-wave and gradient (PWG) modes decomposition of DV signals. The result shows that when the domain wavelength of conductivity structure is larger than the span of observatory array, the PWG decomposition could reasonably separate the vertical field determined by regional background conductivity underneath the observatory from the one influence more by 3D effect, but the inhomogeneous surface layer based on earth sediment and bathymetry would significantly affect the performance, which needs to be explored in the future.

Keywords: Geomagnetic diurnal variations, 3D effect, Field decomposition