Tide-induced magnetic field constrain the three-dimensional electrical structure of the Earth's upper mantle

Cong Yang[1], Zhengyong Ren[1], Chaojian Chen[2], Hongbo Yao[3], Yu Gu[1], Jingtian Tang[1], Keke Zhang[3]

1 Central South University, Changsha, Hunan, China
2 Ludwig Maximilian University of Munich, Munich, Germany
3 Macau Institute of Space Technology and Application, Macao, China

Abstract: Using magnetotelluric (MT) and geomagnetic deep sounding (GDS) methods, one can obtain the electrical structure beneath continents, including the lithosphere and asthenosphere. However, the lack of information on the conductivity structure beneath the ocean hinders a comprehensive understanding of the Earth's internal conductivity structure. In recent years, with the increase in the number of geomagnetic satellites launched by major countries such as China and those in Europe and the United States, the utilization of satellite magnetic field data for deep Earth conductivity structure studies has become increasingly popular. Notably, Magnetic field signals from tidal currents have proven effective in constraining the electrical structure of the lithosphere and asthenosphere beneath the ocean. Electromagnetic induced data contain information about the Earth's deep conductivity structure, which reflects the thermal state and compositional constituent of the Earth's matter. Those data can provide unique insights that are not obtainable through seismology. This paper builds on a previously developed tidal induction magnetic field modeling algorithm based on the tetrahedral finite element method, to realize a 3D conductivity inversion algorithm using the L-BFGS method. Due to the globally uniform distribution of tidal signals extracted from satellite magnetic field data, spherical harmonic expansion is particularly suitable for model parameterization in satellite data inversion. To improve computational efficiency in solving large-scale problems, domain decomposition techniques are employed for solving the system of equations, with MPI communication technology used for information exchange and reception during the solution process. The correctness of the program is verified by inversion of the synthetic data generated by the tidal induction electromagnetic theoretical model. Subsequently, the tidal induction magnetic field signals extracted at satellite altitude are used for the first-time inversion to obtain the 3D electrical conductivity structure of the Earth's interior, particularly beneath the oceans' lithosphere and asthenosphere.

Keywords: Inversion; Tide; Conductivity; Geomagnetic satellites