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Three-dimensional forward calculation of magnetotelluric responses using a mesh-free particle method.

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Accurate forward calculation of electromagnetic induction in the earth is essential for quantitative modeling of subsurface resistivity structure. The expression of complicated topography and bathymetry in the three-dimensional (3D) model should be carefully handled for accurate numerical calculations, but frequently ignored, unfortunately. For example, a widely-used 3D inversion code of magnetotelluric (MT) data is based on the finite difference method (FDM), in which the 3D model consists of assembly of rectangular blocks. Therefore, a smooth relief on the ground can be expressed as stair-like hills and valleys. Previous studies indicated that such step-wise approximation of topography yields large calculation error of MT responses. The finite element method (FEM) can include the smooth topographic relief in the 3D model, while the selection of proper mesh configuration for FEM is a hard task for users.

In this research, I developed an new 3D MT forward calculation method with the MPS (Moving Particle Semi-implicit) method, one of the mesh-free calculation methods. The main purpose is the proper expression of topography / bathymetry in the 3D resistivity model. The MPS method is a particle method and is developed for the simulation of incompressible flow by Koshizuka and Oka (1996), and has been applied for the one and two-dimensional MT problems. I use the MPS method for the 3D simulation of electromagnetic induction in this study. In the forward calculation, electric and magnetic fields can be defined at each particle in a calculation model. Then, MT responses are calculated on an arbitrary point in the 3D model (on the surface, on the seafloor, and even in the earth). The results of MT forward calculation indicate enough accuracy, implying capability to application to the inversion procedure of MT responses with complicated topography.

Keywords: particle method, magnetotellurics, forward calculation, numerical calculation, mesh-free