Submission code: DPZRGN9APL

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Meshless Generalized Finite-Differences Method applied to 2D Magnetotelluric Foward-Modeling

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Introduction

Numerical methods for solving differential equations (DE) are some of the most used electromagnetic (EM) modeling techniques in geophysics. (i.e Finite Elements - FE; Finite Difference - FD and Finite Volume - FV.). This research presents the application of the Meshless Generalized Finite-Difference (MGFD) method in a 2D magnetotelluric modeling for geophysical studies. The technique is a numerical modeling that solves partial differential equations (PDEs) without the need for generating structured meshes, making it particularly useful for modeling complex geological structures. The 2D magnetotelluric (MT) modeling is applied to study the electromagnetic response of the subsurface, considering the transverse electric (TE) and transverse magnetic (TM) modes. The governing equations are derived from Maxwell's equations, and boundary conditions are defined to ensure the continuity of the solution.

Method and/or Theory

The method is based on the expansion of the Taylor series combined with the weighted least squares method. Unlike traditional finite difference (FD) or finite element (FE) methods, the MGFD uses a freely distributed point cloud, simplifying the discretization of regions with complex geometries. The main advantage of the method is the flexibility in the distribution of points, eliminating the need for interpolation functions and numerical integrals, which increases computational efficiency. Furthermore, the method proposes an analytical solution for the inversion of $\mathbf{A}^{\ell\top}\mathbf{W}^{\ell}\mathbf{A}^{\ell}$ using the Banachiewicz-Schur form, which significantly enhances computational performance.

Results and Conclusions

The MGFD method has proven to be efficient and flexible for 2D MT modeling, especially in regions with complex geometries. The proposed analytical solution for matrix inversion reduces computational costs, making the method a viable alternative for large-scale geophysical studies.

As a test of the methodology, we used an electrical resistivity profile extracted from the Marlim R3D model. Using the method for constructing point clouds, we calculated the electric and magnetic fields, with which we obtained the amplitude and phase curves of the apparent resistivity for the TE and TM modes.