2D Electrical Resistivity Modelling on highly distorted, non-smooth, rough grids

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SUMMARY

DC Resistivity method is a geophysical technique that has been widely used in subsurface investigations such as groundwater mapping, critical zone studies, and mineral exploration. In this study, we present a 2D modeling of the DC Resistivity data, keeping in mind that the constructive approach should be based on the very fundamentals of the governing physics and should be able to extend its realms for the complicated cases as well. We have developed a C++ code that aims at solving the 2D DC resistivity problem.

The novelty of our development lies in the construction of the proposed finite difference scheme (FDs) that is based on the Mimetic finite difference methods (MFDM). MFDMs are a class of numerical methods that attempts to mimic the fundamental properties of the governing physics like the conservation laws, symmetry properties, and discontinuity of the coefficients. It further enables the development of modeling algorithms based on non-orthogonal grids required to account for irregular topography. It is difficult for the FDs to accommodate non-orthogonal grids and, hence, varying topography. The finite elements (FEs) methods are generally used for modeling variable topography models. However, FDs have advantages over FEs in inverse modeling where dual discretization is not required in FDs, as is the case with FEs. The MFDM meets both of these objectives, making them a suitable scheme for DC modeling. Hence, we implemented MFDM to develop an algorithm that solved the DC resistivity problem.

A dyke model is utilized to verify the accuracy of the developed algorithm by comparing the numerically-simulated responses to the analytical solution. The benchmarking exercise is done on varying conductivity contrasts for the dyke models to establish the algorithm's accuracy. Further, the developed algorithm is tested for different 2D models by comparing its responses with a 3D modeling algorithm. The proposed algorithm is capable of handling anisotropy. Hence, the developed algorithm is suitable for analyzing DC data of anisotropy and variable topography subsurface. We have carried out a series of experiments to establish the robustness of our code when the grids become very irregular, non-smooth, and the orthogonality is violated. This is achieved by distorting the orthogonal girds using pseudo-random numbers, which follow a uniform distribution. The angles for all the grid nodes are calculated, and the ones having an angle outside 20 to 160-degree intervals are classified as highly distorted. The numerical tests are conducted on highly distorted cells ranging from 1$\%$ to 10$\%$ of the total cells. The error analysis suggests that the algorithm performs very well for non-orthogonal, non-smooth, highly distorted rough grids and the observed errors were appreciably low.

Keywords: 2D DC Resistivity Modelling, MFDM, Non-orthogonal rough grids.