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Comparative Depth Performance Analysis of ERT Electrode Arrays

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Introduction

This study presents a sensitivity and resolution analysis of different electrode arrays used in Electrical Resistivity Tomography (ERT), a geophysical technique that investigates subsurface structures based on resistivity distribution. Synthetic data were employed to evaluate the pole-pole, dipole-dipole, and pole-dipole arrays, aiming to assess their advantages and limitations in detecting specific subsurface features. Through numerical modeling, we compare the performance of these arrays in terms of depth of investigation, resolution, and sensitivity.

Method

The methodology employs a systematic numerical modeling using pyGIMLi, an open-source Python library for geophysical inversion and 2D modeling, to conduct a comprehensive evaluation of electrode arrays (pole-pole, dipole-dipole, and pole-dipole) for specific ERT applications, particularly for hydrogeological investigations at significant depths. This approach involves generating synthetic models that replicate realistic subsurface scenarios, including aquifer systems, saltwater intrusion interfaces, and deep fracture zones, while progressively varying both geometric parameters and physical parameters to assess each array's detection capabilities under controlled conditions. By implementing a reference model comparison framework, we quantitatively analyze the numerical solution variation rates, focusing specifically on depth-dependent performance metrics such as signal attenuation patterns, depth-normalized resolution decay, and sensitivity thresholds for different target geometries. The controlled simulations enable direct comparison of array performance, where preliminary results align with established literature - the dipole-dipole array demonstrates superior lateral resolution for vertical structures but limited depth penetration, the pole-dipole configuration offers an optimal balance between resolution and investigation depth, while the pole-pole array achieves maximum depth penetration albeit with reduced spatial resolution, particularly crucial for deep target characterization where detection of subtle resistivity variations becomes critical.

Conclusions

By varying model parameters, this study contributes to a better understanding of each array's behavior in different scenarios, aiding in the selection of optimal configurations for specific survey objectives. The results support more reliable and efficient interpretations in real-world geophysical applications.