3D CSEM Forward Modelling: Testing Adaptive Mesh Refinement Approaches on an Ore Body Model

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Key Features of the Modelling Code

- 3D controlled-source electromagnetic (CSEM) modelling in frequency domain
- Using unstructured tetrahedral meshes of finite-elements
- First order Nédélec basis functions - vector edge interpolation functions [1]
- Distinct boundary conditions
- Model parameters: electric resistivity and magnetic permeability

Model:

- Calculation of the electric fields in an edge-based manner
- Curl-Curl Equation for the electric field \( \mathbf{E} \) with time dependency of \( e^{i\omega t} \):
  \[
  \nabla \times \left( \mu \nabla \times \mathbf{E} \right) = \rho \varepsilon_0 \frac{d}{dt} \nabla \times \mathbf{H} + \nabla \psi
  \]
- Latest addition: goal-oriented adaptive mesh refinement
- Planned to be incorporated in the inversion framework EMMILIA [2] as a 3D module

Refinement Validation

- Improved result after refinement:

Permeable Subsurface

- To find the optimal error estimator for models with contrasts in electric resistivity and magnetic permeability, we run a few refinement steps for a homogeneous half-space model discreted with a low quality factor of 1:8 and investigate the behaviour of the two average error estimators \( \xi_0 \) and \( \xi_3 \) for three cases: the approach based on residuals, face jumps in normal current density and face jumps in tangential magnetic field. (Figure 6.)

- The error estimation approach based on only face jumps in current density \( \xi_0 \) and the one based on residuals and face jumps in current density \( \xi_3 \).

- The \( \xi_0 \) approach causes both average error estimators to decrease most continuously and results in the lowest average error estimators after 12 refinement steps.

Detectability

- Amplitudes and phases of the strongest field components at a receivers above the ore body for the homogeneous half-space model and three different ore body resistivity scenarios.

- Detectability anomalies are numerically detectable with the planned measurement setup. Ambiguities of amplitudes at the CSEM frequencies in the measurement area are needed to make meaningful statements about the detectability with real measurements.

References


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