Open-Source Landscape for Three-Dimensional Controlled-Source Electromagnetic Modeling

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Validation of large-scale 3D CSEM modelling using the open-source codes custEM, emg3d, PETGEM, and SimPEG

Numerical Results
Verification for layered model using semi-analytical solutions shows a relative amplitude error in the order of 1% or less.
Adding three resistive blocks to the layered model requires the normalised difference instead of the relative error.

Normalised Root-Mean Square Difference (NRMSD) in percent:

$$200 \frac{|R_1 - R_2|}{|R_1| + |R_2|}$$

After Dublin Test Model 1, Miensopust et al., 2013, GJI
Validation between the codes shows a normalised difference of 1–2% or less.
Marlim R3D model: Responses at receiver locations look visually the same for all relevant responses

Marlim R3D:
Correa and Menezes, 2019, Geophysics
Normalised difference to published data is mostly below 10% and very different from code to code.

- **Inline $E_x$**
- **Broadside $E_x$**
- **Broadside $E_y$**
Normalised difference between our codes is very similar and mostly below 10%
Very insightful is to look at the entire meshes and their different behaviours.
A look at the models in different mesh yields interesting insights with regards to recoverability in inversions.

<table>
<thead>
<tr>
<th>Code</th>
<th>#Procs</th>
<th>CPU (s)</th>
<th>RAM (GiB)</th>
<th>#dof</th>
</tr>
</thead>
<tbody>
<tr>
<td>custEM</td>
<td>64</td>
<td>872</td>
<td>230.1</td>
<td>1,918,106</td>
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<tr>
<td>emg3d</td>
<td>1</td>
<td>1254</td>
<td>0.6</td>
<td>5,998,992</td>
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<td>PETGEM</td>
<td>96</td>
<td>524</td>
<td>175.4</td>
<td>1,918,106</td>
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<tr>
<td>SimPEG</td>
<td>4</td>
<td>422</td>
<td>12.8</td>
<td>720,146</td>
</tr>
</tbody>
</table>
Conclusions and Outlook
A more extensive reference list can be found in:


Modelling codes: custEM, emg3d, PETGEM, SimPEG, and empymod:


Solvers PETSc, MUPMS, FEniCS, and PARDISO:


Marlim R3D model:


MT comparison study:

More Comparisons & Benchmarks
Other Scenarios, other programming languages