simpegEM: An open-source resource for simulation and parameter estimation problems in electromagnetic geophysics

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Abstract:
A large suite of problems in applied geophysics can be tackled by simulating and inverting electromagnetic (EM) data. Problems can be treated in the time- or frequency-domain, sources can be magnetic or electric and either natural or controlled, techniques such as primary-secondary may be employed and different problem dimensionalities, including 1D, 2D and 3D, may be considered. To address the inverse problem, derivatives of each of these element must be readily accessible so they may be composed to form the sensitivity for the approach taken. For many applications, efficient algorithms have been designed and implemented. However, inconsistencies between implementations of different problem-types and modeling techniques often limits extensibility and interoperability, particularly when addressing the inverse problem. Building on top of the open-source simulation and gradient based parameter estimation framework, SimPEG (http://simpeg.xyz), we have developed simpegEM to be a modular framework for geophysical problems in electromagnetics.

The SimPEG implementation in Python provides finite-volume discretizations for both structured and semi-structured meshes, along with machinery for the inversion, including optimization and regularization routines. The elements of the EM simulation, including the formulation of Maxwell's equations and definitions of the sources and receivers as well as their derivatives are implemented in a modular, object-oriented manner. This structure and organization of the code allow elements to be readily interchanged and extensions made.

In this presentation, we discuss an example with steel-cased wells. Steel is highly conductive, has a significant magnetic permeability and is very thin compared to its length, making it a challenging structure to model. Using the open-source frameworks of SimPEG and simpegEM, we solve this using a primary-secondary approach that employs multiple formulations of Maxwell's equations and both a 2D cylindrically symmetric mesh and a 3D tensor mesh. We explore results from these numerical experiments and discuss our goals for the ongoing construction of a platform to support a community of researchers using EM geophysical simulations and inversions.