Evaluation of an iterative solver as the forward operator for three-dimensional inversion of electromagnetic data

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SUMMARY

The interpretation of controlled-source electromagnetic data through inversion requires the solution of many forward problems for the computation of electromagnetic field responses of candidate models and respective data sensitivities. Modern inversion frameworks predominately employ direct solvers as the forward engine because multiple solutions are easily accessible using inexpensive and quick forward-backward substitution after an initial resource-demanding matrix factorisation step. Iterative techniques require little resources for single forward solutions, yet are very time consuming if many solutions need computing, as is the case for calculating data sensitivities. Nonetheless, a resource-light iterative solver might be of use for large-scale inversions of multiple data sets as encountered in semi-airborne electromagnetics. It could further make inversions feasible on small-scale computing platforms such as servers or workstations. In light of this, we integrated an iterative solver as additional forward engine into the existing inverse modelling procedure of the open-source software custEM and pyGIMLi. In particular, we implemented a two-level iterative scheme where the outer solver employs a generalised conjugate residual algorithm preconditioned with a highly efficient block-based preconditioner for square blocks also known as PRESB. The inner level solver either is of the same type as the outer solver, but preconditioned with the auxiliary-space Maxwell preconditioner, or may alternatively be a direct solver. We evaluate the iterative forward operator for synthetic and real data inversions and show that using a scheme based on an outer-iterative and inner-direct approach leads to comparative time requirements for the computation of the full sensitivity matrix while reducing the memory by a factor of around two. This memory saving can have a positive impact to run, for instance, parallelised inversions of semi-airborne electromagnetic data sets requiring hundreds of GB of memory. Beyond that, we compare the iterative and direct operators in terms of computational requirements for a wide range of the data point and model parameter space that span the size of the sensitivity matrix.

Keywords: electromagnetic modelling; inversion; iterative solver