A parallel adaptive finite element solver for global electromagnetic induction modeling using hierarchal tetrahedral meshes

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We present an accurate and fast finite element solver for global electromagnetic induction forward modeling problems in spherical Earth. We solve for the electric field equation using the first-order Nedelec elements. The magnetic field is then obtained by computing the curl of the electric field. The computational domain composed of the air space and the conductive Earth is discretized by disjoint unstructured tetrahedral elements. To improve the accuracy with an optimal number of unknowns, we propose a simple two-step goal-oriented adaptive mesh refinement (AMR) strategy. In the first step, an h-type AMR procedure is used to obtain an optimal finite element mesh. The mesh refinement is accomplished by bisection to generate a set of hierarchal tetrahedral meshes. The AMR procedure is driven by a goal-oriented error estimator, which is based on face jumps of normal components of current density. In the second step, we adopt the high-order finite elements at the last iteration to update the accuracy of final numerical solutions. This simple two-step adaptive strategy takes advantage of both h-type AMR and high-order basis functions, and in the meanwhile, it is also computationally economical. To improve efficiency, the solver is parallelized with an MPI-based domain decomposition technique. The sophisticated auxiliary space preconditioned linear solver is adopted to efficiently solve the linear system of equations. This new solver is verified on both semi-analytic and realistic 3-D Earth models. It can be used as a core to derive the inversion of global electromagnetic induction data.