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Fully implicit methods for Earth system models

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Major algorithmic challenges exist for the solution of Earth system problems, for example, coupled nonlinear physics, multiple disparate time scales, and scalability requirements. To address scaling, temporal parallelism is explored through implementation of the parareal method, which utilizes coarse and fine time grid operators. The fully implicit (FI) solution method is applied to the shallow water equations on a sphere as a coarse grid operator, and early results are presented. The FI solution framework allows relatively large time steps to be taken stably, within which finer time steps that resolve all the relevant physics can occur in parallel. The equations are solved within the High-order Method Modeling Environment (HOMME) model, which uses a cubed sphere grid and spectral element spatial discretization. The FI solution framework also provides a coherent nonlinear solution to all dependent variables. Enhanced accuracy with a second order FI method in time and space is illustrated with a simple fluid example. The solver implementation is occurring through the development of a Fortran interface package for the Trilinos project.