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ACCURACY AND PERFORMANCE ENHANCEMENT OF LINEAR SOLVERS FOR THE INTEGRATED WATER FLOW MODEL

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Summary. We describe the accuracy control and performance enhancement of linear solvers for the Integrated Water Flow Model (IWFM). This model is used by the State of California Department of Water Resources to assess the impact of climate change on water resources and the analysis of different conjunctive use scenarios across California. IWFM simulates groundwater, surface water and surface-groundwater interaction using an implicitly formulated Galerkin finite element approximation of the groundwater head in a multi-layer aquifer system. The computational efficiency of the simulation is governed by the efficiency of linear solvers for sequences of large-scale sparse linearized systems of equations.

We firstly understand how multi-layer aquifer flow and stream-groundwater interaction affects the scaling, conditioning and sparsity structure of the linear systems. These properties guide the choice of scaling which, together with preconditioning, not only offset the ill-conditioning effects of multi-scale flow, but significantly improve the control of the linear solver forward error. Improved error control ensures that the accuracy of the solver is consistent with the accuracy of the initial data. We implemented a preconditioned Krylov subspace linear solver based on the Generalized Minimum RESidual (GMRES) algorithm and incomplete LU preconditioners and demonstrate how scaling improves forward error control in IWFM. We also performance benchmarked the new linear solver against the SOR method, a classical stationary iterative linear solver used in IWFM, and find an overall 7.7x speedup for the largest tested dataset. Further performance profiling shows that the new linear solver removes a major performance bottleneck in IWFM for the other datasets.