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Non-iterative adaptive time stepping with truncation error control for simulating variable-density flow

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Fluid density variations occur due to changes in the solute concentration, temperature and pressure of groundwater. Examples are interaction between freshwater and seawater, radioactive waste disposal, groundwater contamination, and geothermal energy production. The physical coupling between flow and transport introduces non-linearity in the governing mathematical equations, such that solving variable-density flow problems typically requires very long computational time. Computational efficiency can be attained through the use of adaptive time-stepping schemes. The aim of this work is therefore to apply a non-iterative adaptive time-stepping scheme based on local truncation error in variable-density flow problems. That new scheme is implemented into the code of the HydroGeoSphere model (Therrien et al., 2011). The new time-stepping scheme is applied to the Elder (1967) and the Shikaze et al. (1998) problem of free convection in porous and fractured-porous media, respectively.
Numerical simulations demonstrate that non-iterative time-stepping based on local truncation error control fully automates the time step size and efficiently limits the temporal discretization error to the user-defined tolerance. Results of the Elder problem show that the new time-stepping scheme presented here is significantly more efficient than uniform time-stepping when high accuracy is required. Results of the Shikaze problem reveal that the new scheme is considerably faster than conventional time-stepping where time step sizes are either constant or controlled by absolute head/concentration changes. Future research will focus on the application of the new time-stepping scheme to variable-density flow in complex real-world fractured-porous rock.