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Benchmarking variable-density flow in saturated and unsaturated porous media

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In natural environments, fluid density and viscosity can be affected by spatial and temporal variations of solute concentration and/or temperature. These variations can occur, for example, due to salt water intrusion in coastal aquifers, leachate infiltration from waste disposal sites and upconing of saline water from deep aquifers. As a consequence, potentially unstable situations may exist in which a dense fluid overlies a less dense fluid. This situation can produce instabilities that manifest as dense plume fingers that move vertically downwards counterbalanced by vertical upwards flow of the less dense fluid. Resulting free convection increases solute transport rates over large distances and times relative to constant-density flow. Therefore, the understanding of free convection is relevant for the protection of freshwater aquifer systems.

The results from a laboratory experiment of saturated and unsaturated variable-density flow and solute transport (Simmons et al., Transp. Porous Medium, 2002) are used as the physical basis to define a mathematical benchmark. The HydroGeoSphere code coupled with PEST are used to estimate the optimal parameter set capable of reproducing the physical model. A grid convergency analysis (in space and time) is also undertaken in order to obtain the adequate spatial and temporal discretizations. The new mathematical benchmark is useful for model comparison and testing of variable-density variably saturated flow in porous media.