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Fully coupled implicit discretization for large-scale simulation of miscible multiphase flow in heterogenous porous media

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To comprehensively understand and predict the behavior of CO2 storage, the development of precise mathematical models and advanced numerical schemes for large-scale simulations is demanding. The advection and diffusion or even interaction between injected supercritical CO2 and other fluids in the storage reservoirs should be able to be described by multiphase flow models. Notably, the consideration of CO2 dissolution introduces dynamic changes in the density of fluid phases, instigating density-driven flows. Most discretization schemes are explicit or semi-implicit which restricts the time step size of the simulations. In this work, a fully coupled and fully implicit scheme for large-scale simulations of miscible multiphase flow in heterogeneous porous media is proposed. Vertex Centered Finite Volume Method is employed for the spatial discretization. The linearly implicit extrapolation method (LIMEX) is adapted for temporal discretization. The arising linear system of equations is solved by BiCGSTAB with Geometric Multigrid (GMG) preconditioner. The parallel implementations are based on the open-source software: UG4. The validation of the proposed scheme is verified by the comparisons with analytical solutions in benchmark cases. The weak and strong scaling tests are performed on the supercomputer Shaheen II with up to 4096 processor cores. Due to the stable numerical treatment and efficient implementation, the proposed scalable solution is suitable for large-scale simulation over long periods.

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