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Solute dispersion for stable density-driven flow in randomly heterogeneous porous media

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We present a theoretical investigation on the processes underpinning the reduced longitudinal spreading documented in stable variable density flows, as opposed to constant density settings, within heterogeneous porous media. We do so by decomposing velocity and pressure in terms of stationary and dynamic components. The former corresponds to the solution of the constant density flow problem, while the latter accounts for the effects induced by density variability. We focus on a stable flow configuration and analyze the longitudinal spread of saltwater injected from the bottom of a column formed by a heterogeneous porous medium initially fully saturated by freshwater. We adopt a perturbation expansion approach and derive the equations satisfied by section-averaged concentrations and their ensemble mean values. These formulations are respectively characterized by a single realization and an ensemble dispersive flux, which we determine through appropriate closure equations. The latter are solved via semi-analytical and numerical approaches. Our formulations and associated results enable us to discriminate the relative impact on the density-driven solute displacement of (a) covariance of the permeability of the porous medium, (b) cross-covariance between permeability and concentration, which is in turn linked to the coupling of flow and transport problems, and (c) cross-covariance between the dynamic and stationary velocities.

References

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