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Effects of temporal fluctuations, fluid density effects and heterogeneity on mixing of two fluids for a stable stratification

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Mixing and dispersion in coastal aquifers are controlled by density variations, which are influenced by temporal fluctuations on multiple time-scales ranging from days (tides), seasons (pumping and recharge) to glacial cycles (regression and transgressions). Transient forcing effects lead to a complex space and time dependent flow response which induces enhanced spreading and mixing of dissolved substances. We study effective mixing and solute transport in temporally fluctuating flow for a stable stratification of two fluids of different density using detailed numerical simulation as well as accurate column experiments. For the homogeneous case, we quantify the observed transport behaviors and interface evolution by a time-averaged model that is obtained from a two-scale expansion of the full transport problem, and derive explicit expressions for the center of mass and width of the mixing zone between the two fluids (Pool et al., 2016). We find that the magnitude of transient-driven mixing is mainly controlled by the hydraulic diffusivity, the period, and the initial interface location. For the heterogeneous case, transient forcing and density-dependent transport is investigated considering multigaussian random log conductivity fields and more complex heterogeneous fields characterized by connected patterns of high and low conductivity. We find that the mixing potential and 'hot spots' are directly related to the deformation properties and topology of the flow field, specifically its stretching behavior in response to temporal fluctuations. We also find that gravity forces due to density variations cause smoother concentration distribution leading to a decrease in the width of the transition zone. However the mixing potential is similar as the one obtained with constant density.

Reference:
Pool, M., M. Dentz, and V.E.A. Post (2016), Transient forcing effects on mixing of two fluids for a stable stratification, Water Resour. Res., 52, 7178–7197, doi:10.1002/2016WR019181.