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Effects of temporal fluctuations on mixing

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Mixing and dispersion in coastal aquifers are strongly influenced by periodic temporal flow 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- ant time-dependent flow response which induces enhanced spreading and mixing of a dissolved substance. We study effective mixing and solute transport in temporally fluctuating one-dimensional flow for a stable stratification of two fluids of different density. We derive explicit expressions for the concentration distribution and variance to identify the controls and obtain realistic predictions of the coupling between mixing and oscillatory transient flow. We find that the magnitude of transient-driven mixing is mainly controlled by the hydraulic diffusivity, the period and the initial interface location. We also find a spatial dependence of the effective dispersion coefficient which at long times causes the concentration profile to become asymmetric. Sand column experiments under well-controlled laboratory conditions are presented to validate the theoretical effective model defined. The proposed formulation is found to provide very good predictions and correctly reproduces the experimental mixing dynamics.