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Characterization of Mixing and Spreading in a Bounded Stratified Medium

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Matheron and de Marsily (1980) studied transport in a perfectly stratified infinite medium as an idealized aquifer model. They observed superdiffusive solute spreading quantified by an anomalous increase of the apparent longitudinal dispersion coefficient with the square root of time. Here, we investigate solute mixing and spreading in a vertically bounded stratified random medium. Unlike for the infinite stratified medium, at asymptotically long times disorder-induced mixing and spreading is uniquely quantified by a constant Taylor dispersion coefficient. Large scale spreading and mixing is controlled by the dispersion time scale which measures the time for complete vertical mixing by local dispersion. We focus on preasymptotic times, for which solute transport is highly non-Fickian, and the transition from the preasymptotic to the asymptotic Fickian regime. The mechanisms that lead to enhanced solute spreading and mixing are studied in terms of effective dispersion coefficients that are derived from local moments, i.e., moments of the transport Green function. The impact of heterogeneity on solute spreading and mixing is quantified using a stochastic modeling approach. We study memory effects in the effective spreading and mixing dynamics for single realizations and their quantification using stochastic averaging.