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Transport upscaling from the pore to the Darcy scale: A representative elementary volume for non-Fickian dispersion

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The upscaling of hydrodynamic dispersion from the pore to the Darcy scale is challenging due to complex pore geometries and velocity heterogeneity. Classical upscaling approaches assume that the existence of a representative elementary volume defined in terms of medium properties such as porosity, for example, implies that dispersion is Fickian and that Darcy scale transport can described by constant hydrodynamic dispersion coefficients. This description is in contract with observations from experiments and numerical observations, which indicate the dispersion may be non-Fickian. The failure of the advection-dispersion approach is sometimes equated to the failure of the REV concept for transport. Non-Fickian transport approaches such as continuous time and time-domain random walks rely on statistical stationarity of an underlying transition time distribution or, for purely advective transport, stationarity of particle velocity statistics. Lagrangian stationarity and ergodicity can only be achieved if the flow velocities in the support volume are ergodic and thus representative for the medium. Thus, we propose a novel REV concept based on the scale at which the Eulerian velocity statistics become stationary. This stationary distribution characterizes the spatial variability of particle velocities within the REV domain and is the center piece to parameterize particle based stochastic models. We investigate the impact of diffusion, and thus of the Peclet number, on the stationarity of the Lagrangian velocity statistics and on the correlation length based on this REV concept.