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Understand Advection-Dispersion and their Relationship with the Scales of Heterogeneity through Lattice Boltzmann simulations

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The classical advection-dispersion equation has been a cornerstone in aquifer solute migration studies for decades. However, prevailing misunderstandings regarding advection-dispersion dynamics, their interplay with heterogeneity scales, the nature of ensemble averages, and their observational implications have sparked intense debate concerning the equation's conceptual validity. Addressing these controversies is critical for demystifying phenomena such as macrodispersion, anomalous dispersion, and scale-dependent transport, as well as for evaluating contemporary models like the dual-domain dispersion model for solute movement in aquifers. This investigation employs the Lattice Boltzmann Method (LBM) for simulating solute transport within heterogeneous porous media. Our study delineates the evolution of the dispersion concept from molecular diffusion to encompass fluid dynamic effects caused by variations in scale-specific velocities and discusses the limitations of extending Fick's law for molecular-scale velocity variations to describe the effects of large-scale velocity variations.

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