

REASSESSMENT OF 3D MACRODISPERSION VIA GPU-BASED SIMULATIONS

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Abstract.

This work examines the behavior of macrodispersion in three-dimensional heterogeneous porous media using Random Walk Particle Tracking (RWPT) simulations of solute transport. Previous studies reported an exponential dependence of macrodispersion on medium heterogeneity, grounded in theoretical assumptions that the velocity field follows a lognormal distribution; however, this premise does not always hold. We reproduce and extend those findings with a fully GPU-based framework that couples an in-house finite-volume flow solver with a parallel RWPT implementation. This enables high-resolution simulations in three-dimensional domains across thousands of stochastic realizations. We analyze distinct transport regimes: pure advection, advection–diffusion, and advection–dispersion, as well as heterogeneity models with Gaussian and exponential covariance. In addition to estimating effective macrodispersion coefficients, we examine in detail the statistical properties of the resulting velocity fields. The results support a critical reassessment of proposed scaling laws and provide new evidence on the influence of the velocity distribution on dispersion mechanisms in 3D.