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Effective dispersion for 2D highly heterogeneous permeability fields under temporally fluctuating flow conditions

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Ground water flow fluctuates in space, due to medium heterogeneities, and time, due to the variability of boundary conditions. These fluctuations act concurrently to cause dispersion. The issue has been analyzed, largely analytically, because of the severe computational effort required to for numerical analyses. However, analytical results obtained by different authors are somewhat inconsistent. Therefore, the objective of this work is to use detailed numerical simulations to study in detail the values of effective dispersion coefficients for transport through highly heterogeneous media, when the mean flow fluctuates both longitudinally and transversally. We simulate transport through highly heterogeneous media using a random walk approach on a 2D domain, where permeability is a multigaussian random field. The domain spans several 1000's of integral distances both in the mean flow and in the transverse directions. Time fluctuations are simulated by imposing Gaussian random time series for both the mean and transverse (zero mean) head gradients. Ground water fluxes are divergence free (quasi steady state flux), which should be appropriate for slow fluctuations in confined aquifers. Dispersion coefficients are obtained from the time evolution of the moments of the particles distribution. Consistently with analytical results derived using perturbation methods, we find that transverse dispersion increases dramatically with the variance of the temporal fluctuations in the transverse head gradient. However, our numerical results differ from analytical ones in two respects. First, we find a small but significant reduction in the longitudinal asymptotic dispersion coefficient where analytical results show a reduction. Second, contrary to analytical results, we find that longitudinal fluctuations display a minor effect on macrodispersion coefficients. We discuss these differences.