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Non-ergodic behavior of "ergodic plumes"

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In stochastic approaches to transport in heterogeneous aquifers, large initial solute plumes are often called "ergodic plumes". The underlying assumption is that, by sampling the heterogeneity of the velocity field, the observables of transport processes starting from extended concentration distributions behave like their average over a statistical ensemble of velocity fields. The latter cannot be obtained from field-scale experiments (done for given velocity realizations) and are provided by stochastic models such as the one-particle displacement covariance or the "macrodispersion" upscaled Gaussian process. Therefore, instead of simply checking the self-averaging of the observables, one needs to estimate "ergodicity ranges", quantified by mean square deviations from theoretical predictions. We computed ergodicity ranges with respect to one-particle variances and macrodispersion model from two-dimensional simulations of advection-dispersion process for Darcy velocity fields with finite correlation lengths [1], based on reliable numerical methods [2,3,4]. Our results show that the ergodicity ranges do not decrease monotonously and uniformly in time with increasing dimension of initial plumes. Thus, strictly speaking, large initial plumes do not ensure ergodic behavior of transport. Nevertheless, the process is asymptotically ergodic with respect to the macrodispersion model. But, in real life problems, the ergodicity timescale is often too large for realistic contamination risk assessments. As for the pre-asymptotic regime, we found that ergodic behavior with respect to the one-particle variances can be expected for longitudinal dispersion, if the initial condition is a narrow transverse plume, and for transverse dispersion, for a longitudinal initial plume. Otherwise, the dispersion shows large ergodicity ranges which increase with the plume dimension.

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