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# When do diffusing particles forget their initial positions?

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The finding that the variance of the displacements can generally be decomposed as sum of dispersion and memory terms shows that diffusing particles always remember their itinerary in spatially inhomogeneous environments. The memory-free diffusive behavior linear in time of the dispersion can only occur after the extinction of the memory terms produced by correlations between velocity fluctuations and initial positions of the particles. For random initial conditions outcome of the evolution of the process, as for instance solute plumes observed after the beginning of contaminant events in natural aquifers, the memory terms quantify the transitory or persistent anomalous behavior of the transport. In environments with finite spatial correlation ranges, particles forget memory and normal diffusion occurs in the long-time limit. In case of infinite correlation ranges, e.g. perfectly stratified flows, indefinitely persistent memory can be observed and memory terms have the same nonlinear scaling with the time as the anomalous diffusion. For deterministic initial conditions independent of velocity statistics, like those designed for tracer experiments, the memory terms quantify the strong dependence of the macroscopic observables of the transport processes on the shape and dimension of the source. Global Random Walk simulations of transport in heterogeneous aquifers show that the standard deviation of the memory terms is a good measure of the large sample-to-sample fluctuations of the variance caused by large asymmetric sources. The simulations indicate that if the random velocity field has finite correlation range the particles forget the deterministic initial positions in the long-time limit and the variance is self-averaging, with clear tendency toward normal diffusion. If in addition, the Lagrangian velocity field is statistically homogeneous, or equivalently if the mean Green function of the transport problem is invariant to spatial translations, then the ensemble averaged memory terms necessarily vanish. Consequently, the spatial moments of the mean Green function, independent of deterministic initial conditions, supply an "ergodic" description of the pre-asymptotic behavior of the mean concentration. On the contrary, for random initial conditions, the mean memory terms are non-vanishing whenever the velocity field has non-zero correlation lengths and the translation-invariance of the mean Green function as well as the ergodic description break down.