Geophysical Research Abstracts,
Vol. 10, EGU2008-A-06117, 2008
SRef-ID: 1607-7962/gra/EGU2008-A-06117
EGU General Assembly 2008

Lagrangian stationarity and memory effects for dispersion in ergodic velocity fields

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Statistically homogeneous velocity fields with finite correlation range are ergodic. If, besides conditions for existence and uniqueness of the solutions of the transport equations, the sample velocity fields are also continuously differentiable space functions with divergence zero, a “Lagrangian” random velocity field can be constructed for every fixed realization of the local dispersion, which has the same one-point statistics as the Eulerian field and is statistically stationary in space and time. Numerical results show that for ergodic Gaussian velocity fields the corresponding Lagrangian fields are ergodic as well. For large solute plumes, the uncertainty quantified by the variance of the center of mass is negligibly small and the dispersion of single realization plumes about the ensemble average center of mass approximates the one-particle dispersion, as a consequence of Lagrangian stationarity and ergodicity. However, the dispersion with respect to the actual plume center of mass along a given space direction, which is the observable quantity in practice, shows memory effects which increase with the extension of the initial plume in the same direction. Its deviation from the one-particle dispersion is shown to be a consequence of persistent correlations between initial positions and displacements of solute molecules. Only when such correlations are destroyed, can the idealized one-particle dispersion be used to quantify contamination by groundwater transport in real cases. The decay of memory effects after hundreds of heterogeneity scales was observed in simulations of transport driven by a local dis-

persion process and by ergodic Gaussian advection velocity fields. On the other side, simulations done in the past of strictly advective transport in sample velocity fields obeying Darcy law indicate indefinite persistence of memory effects. The most likely explanation for that seems to be the lack of ergodicity of dynamical systems associated to Darcy flows, for which displacements never forget the memory of initial positions. These facts support the conjecture that the decay or the persistence of memory effects are governed rather by the ergodic properties of the stochastic process governing the trajectories of the solute molecules than by those of the random field model for heterogeneity of flow in groundwater.