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The Impact of the Injection and Detection Modes on Solute Transport in Heterogeneous Aquifers with Application to MADE

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The seminal paper of Kreft and Zuber (1978) presented the solution of the 1D advection-dispersion equation with constant coefficients (velocity, dispersivity) under different modes of injection and detection: the common resident concentration C(x,t) and the flux proportional one CF(x,t) (the breakthrough curve). Thus, among the 4 combinations of modes, for resident injection and detection of an instantaneous pulse, C has the common Gaussian spatial shape, whereas for flux proportional injection and detection CF distribution is Inverse Gaussian.

The same modes are considered for transport at aquifer scale, the spreading mechanism being related to the spatially variable velocity field, due to the random hydraulic conductivity. A solute plume is injected instantaneously along a plane normal to the mean Eulerian velocity U, over a large area relative to the logconductivity integral scale I (ergodic plume). With similar definitions of C and CF, the presentation is focused on the mixed mode of flux proportional injection and resident detection, the one encountered typically in field experiments e.g. Borden Site, Cape Cod and MADE. It is shown that the mean velocity of the centroid is larger than U (depending on the degree of heterogeneity) near the injection plane and tends asymptotically to it. The longitudinal plume mass distribution is skewed and different from the Gaussian one. These effects are negligible for weakly heterogeneous aquifers, but significant for highly heterogeneous ones like MADE. The comparison between measured snapshots of plume longitudinal mass distribution at MADE and the theoretical ones are in fair agreement. Thus, adopting the appropriate modes of injection and detection offers a physically based explanation to the non-Gaussian shape of MADE plume, a topic of intense debate in the literature.