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Breakthrough curves tailing development during convergent flow tracer tests in 3D heterogeneous aquifers

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Breakthrough curves (BTCs) usually show asymmetric shapes, with marked tailing. This is particularly relevant in convergent-flow tracer tests (CFTTs). It is found that late-time BTCs frequently scales as a power-law function with a slope of -1 in a log-log plot. In tests performed in heterogeneous sandy aquifers with conservative tracers, the key link relating BTC shape and physical soil parameters is still missing. Here we develop a numerical analysis based on individual realizations of 3D fields under radial convergent flow conditions. Such realizations are drawn from an unconditional multigaussian models. We show that non symmetric BTCs naturally arise without the need for data conditioning. We further find that late-time BTCs tend to scale as a power-law with unit slope when a number of conditions are met, those being: intermediate injection distances, high variance of log-normal hydraulic conductivity and high vertical variability or flux stratification. This behavior can be physically explained by noticing that due to the vertical variability of aquifer properties, injections during a CFTT follow a flux-averaged injection scheme. For high variances the stratification determines that solute mass is mainly transported from a few layers, but a resting mass, trapped in low conductivity layer, migrate according to an equivalent stratified homogeneous medium.