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Relationship between statistical properties of permeability field and behavior of concentration in stationary fluid flow.

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In contemporary groundwater engineering heterogeneous aquifers with complex-structured permeability fields are of high interest. Heterogeneous fields create difficulties in up-scaling, increase the computation time, and may influence on selection of hydrodynamic model. A major problem us to relate permeability fields, flow and concentration behavior. Our overall goal is to investigate the correlation between permeability field and modifications of concentration.

We consider binary fields, comprised of high-permeable and low permeable zones with a varying high permeability ratio. Low-permeable zones represent a matrix and high-permeable zones represent randomly distributed inclusions in the shape of discs. In this case percolation theory is applicable and connectivity can be defined accordingly. If the intensity of inclusions is high enough, permeable areas construct cluster, that provide main fluid flow and percolation exists. Such a critical intensity is unique and percolation occurs suddenly with intensity increasing through this threshold. We are interested in cases nearby the percolation threshold.

Darcy velocity field becomes heterogeneous. Fast “channels” and almost immobile zones appear that allows us talking about dual media: dual-porosity, dual-permeability models for Darcy equation and multi-rate model for advection-dispersion equation.

We assume a stationary flow in a rectangular 2D domain with first type boundary condition. Using the resulting velocity fields we solve the advection-diffusion equation with a unit pulse of concentration at the left border. Two singularities can be observed: fast channels lead to early first-arrival times of the concentration. Secondly, almost immobile zones collect concentration at first and then give it back into clear water flow causing anormal tailing of the BTC. This is the reason why separate transport up-scaling is needed.

We calibrate multi-rate model’s parameters responsible for early arrivals (ratio between mobile and immobile porosities [U+03D5]_mob[U+2044][U+03D5]_im) and tailing (exchange coefficients of immobile zones α_min, α_max and slope of memory function) for different permeability fields with large connectivity.