Abstract

A key challenge of modelling of flow and transport in porous media is coping with the large disparity between the scale at which flow and transport can be understood from the first principle, and the scale at which practical predictions are needed. The limitation in computational resources means that intelligent multiscale techniques are desired; however, the difficulty in obtaining both the accurate representation of pore geometry, and the actual transport coefficients make transport difficult to delineate much less in a multiscale context—no method hitherto can singlehandedly account for all these complexities. Here I present two multiscale modelling approaches: (1) a deterministic approach based on multiscale finite element method (MsFEM); and (2) a stochastic approach based on continuous time random walk (CTRW).

(1) The MsFEM method is suitable when the micro and macroscopic problems can be described by PDEs; it consists of two major ingredients: multiscale basis functions and a global numerical formulation that couples these multiscale basis functions. Multiscale basis functions are designed to capture the multiscale features of the solution, and are calculated—not modelled—on the actual geometry of the domain. I will present my works on the extension to the conventional MsFEMs by incorporating Crouzeix-Raviart, and bubble functions for advection-diffusion, Stokes and linearised Navier-Stokes problems.

(2) For cases where the possibility of obtaining complete knowledge of the pore space is ruled out a priori, transport can in general be represented by a joint probability density function $\psi(r,t)$ which describes each particle transition over a distance and direction r, in time t. This approach is called continuous time random walk (CTRW). Identification of $\psi(r,t)$ lies at the heart of the CTRW theory. At the micron level, $\psi(r,t)$ can be obtained by: (1) semi-analytical derivation from the advection-diffusion equation; or (2) by direct simulations on x-ray images of rocks. At the core level (~cm), $\psi(r,t)$ can be obtained by propagators—the probability distributions of molecular displacement measured as a function of time—measured using nuclear magnetic resonance (NMR) technologies. I will present the progress on the development of this method, which is an ongoing work in collaboration with Cambridge magnetic resonance research centre.

Biography

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