Comparison of Heat and Mass Transport at the Micro-Scale

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Abstract

Phenomena of heat and mass transfer are often compared in various porous media applications. Questions of practical interest are, for example, if tracers can be used for the prediction of heat flow, or if heat can be utilized as a, possibly retarded, tracer. Using numerical modeling we compute heat and mass transport at different length and time scales, the smallest in the range of micrometer. Our model approach is as follows:

- Solution of Navier-Stokes equations in pore space (stationary)
* No slip boundary condition at pore surfaces
* Pressure difference applied by boundary conditions
- Solution of advection-diffusion equation for mass transport in pore space (transient)
* Setting of molecular diffusivity
* Concentration specified at inflow
* No diffusive flux at outflow
- Solution of convection-conduction equation for heat transport in pore space and in porous medium (two subdomains) (transient)
* Subdomain-dependent material parameters (fluid domain is made of water)
* Temperature specified at inflow; no diffusive flux at outflow

Numerical experiments are performed in 2D artificial porous media. Using MATLAB® we constructed a porous medium consisting of non-intersecting spheres of different size, using random number generator for positions and diameters. The user specifies a minimum and a maximum radius, as well as a minimum distance between two spheres. The area is filled until a specified porosity is reached. Figure 1 shows a velocity distribution in the pore space at the micro-scale, calculated by solving Navier-Stokes equations. Figure 2 shows tracer transport in the calculated velocity field (with flow from the right to the left). Figure 3 shows heat transport in the fluid/solid system. Qualitative results are:

- At the microscale heat and mass transport are quite different (as their diffusivities differ by several orders of magnitude).
- With increased length-scale the Péclet number increases (due to the fact that advection together with the velocities increases with the second power of the pore space openings, while molecular diffusion remains constant
- Dispersion is proportional to the Péclet number (as known from experiments in porous media)

Figures used in the abstract

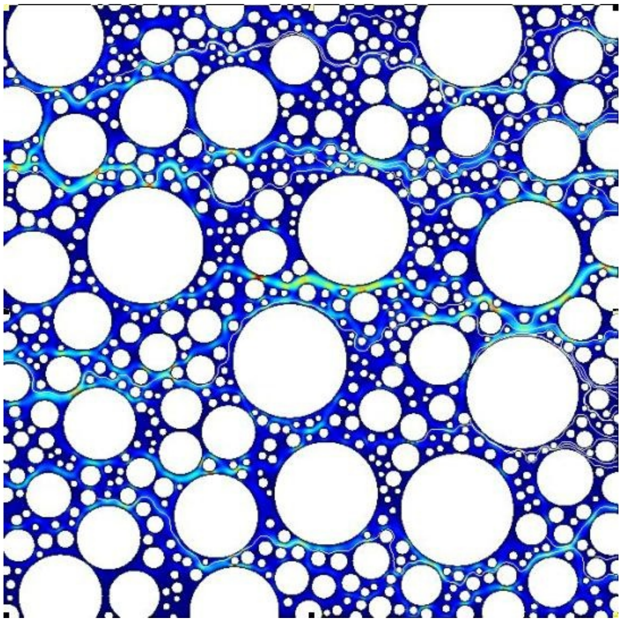

Figure 1: Laminar flow in a porous medium: velocity distribution.

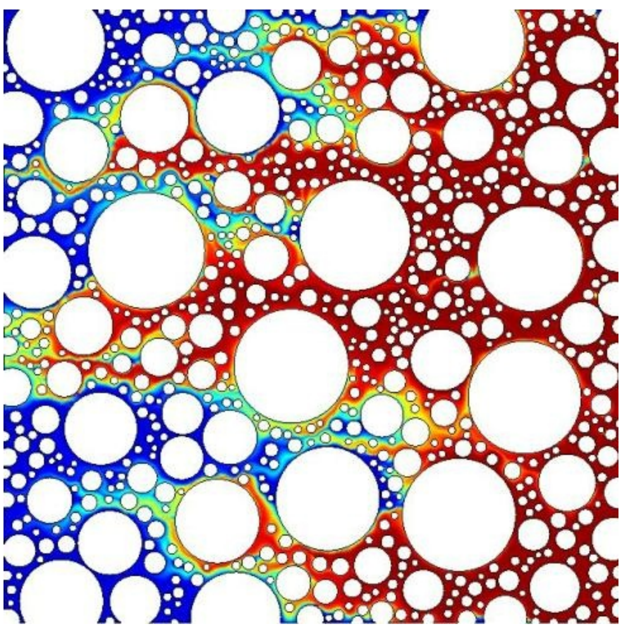

Figure 2: Tracer distribution in a porous medium.

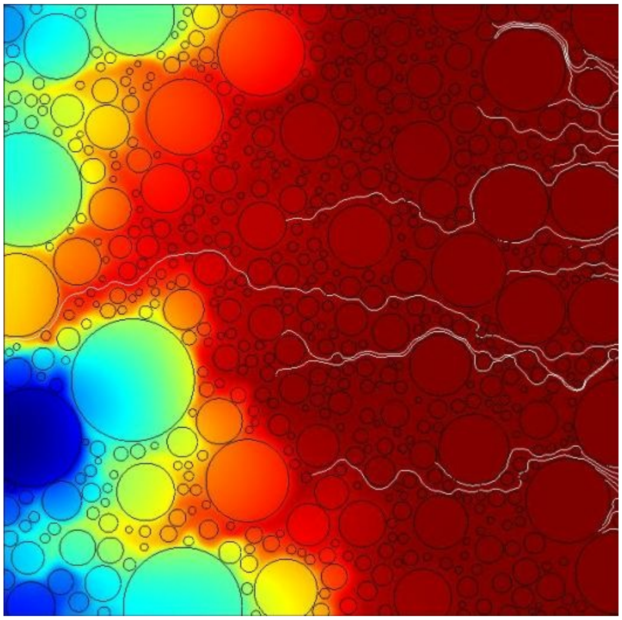

Figure 3: Heat distribution in a porous medium.