Simulating Three-Dimensional Fluid Flow in Porous Media

C. Larrabee Winter*
University of Arizona, Department of Hydrology and Water Resources, Program in Applied Mathematics, Tucson, AZ 85721-0011, USA

Jeffrey D. Hyman†
University of Arizona, Program in Applied Mathematics, Tucson, AZ 85721-0089, USA

Piotr K. Smolarkiewicz‡
National Center for Atmospheric Research, Boulder, CO 80307, USA
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Numerically modeling fluid flow through explicit porous media is computationally expensive. However, a modification of the multiscale computational fluid dynamics modeling tool EULAG [Prusa et al., Comput. Fluids, 2008] allows us to efficiently simulate fluid flow through samples of explicit pore-spaces, both real and synthetic. Allowing the fluid to reach steady state in a given porous medium, the resulting velocity field is analyzed to approximate permeability of the porous medium and relate it to specific properties of the pore-space. Our results indicate that power law alternatives can accurately estimate permeabilities across a wide range of porous media. Since the power laws depend on porosity and hydraulic radius, which can be measured in bulk, they may extend to continuum representations of permeability. We compute statistics of streamline lengths and corresponding breakthrough curves. Based on these microscopic statistics we observe that streamlines fall into two classes: (1) normal streamlines of particles that remain near their neighbors throughout the flow field, i.e., streamlines with low Lyapunov exponents, and (2) streamlines with high Lyapunov exponents that exhibit chaotic behavior by swiftly moving away from their initial neighbors.

*Corresponding author: `winter@email.arizona.edu`
†`jhyman@math.arizona.edu`
‡`smolar@ucar.edu`