Numerical simulation of mixing in microscale multiphase flow

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Motivation:

Solute mixing in porous media is essential to a host of industrial and natural processes, as it dictates the speed of chemical reactions by bringing reactants into contact. The mixing dynamics of steady single-phase flows through porous media are becoming well understood. However, for multiphase flows, e.g. when air and water flows together, very little is known. This partly stems from the fact that it is difficult to numerically resolve flows with strong capillary forces and low solute diffusion.

Project description:

In this project, we will employ a combined Eulerian-Lagrangian representation of two-phase flow with solute transport. We will use a finite-element formulation of a phase-field model to represent the interface between the two immiscible fluids and a (Lagrangian) diffusive strip method to resolve the solute transport. This allows us to characterise fluid stretching at unprecedented accuracy, including measuring the Lyapunov exponent which quantifies chaotic mixing. The MSc project will be tailored to the recruited student, but could include:

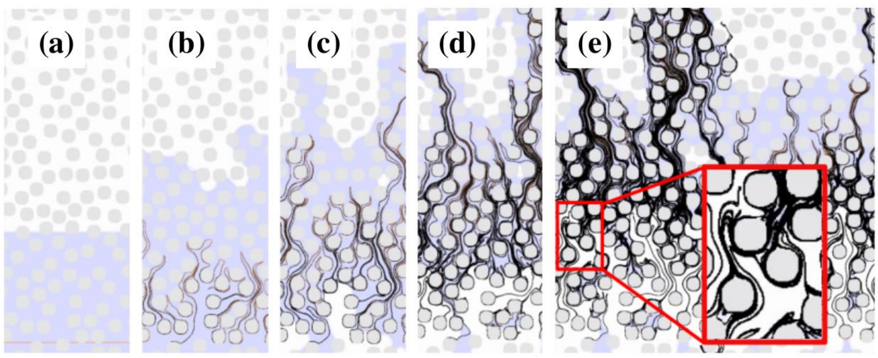
- Implementing and comparing different discretization schemes for the 3D fluid flow model. This will allow us to answer under which conditions (fully or partially) implicit schemes, with fewer but larger time steps, are advantageous over more explicit schemes, with more but smaller time steps.
- Investigate how chaotic mixing dynamics are influenced by two-phase flow in 3D periodic porous geometries and microfluidic geometries.
- Numerically and theoretically investigate how the mixing dynamics at finite Peclet number relates to the Lyapunov exponent or other flow properties.

Resources

The student will learn how to use HPC infrastructure and have access to Sigma2 and the PoreLab UiO cluster. The project will benefit from comparison to experiments carried out under similar conditions (see other project).

Required background

Strong interest and basic skills in numerical methods, scientific computing, fluid mechanics. Some knowledge of statistical mechanics is an advantage.



Simulations of chaotic mixing in two-phase flow in a 2D porous medium. (a)–(e) show a strip of solute at various instances of time as it is exponentially elongated by a net upward flow.