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Modeling capillary fluctuations for fluid flow with lattice Boltzmann methods using LBPM

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Capillary phenomena have important consequences for fluid flow in geological systems, with relevant applications including carbon sequestration, recovery of oil and gas, and management of water resources. In capillary dominated systems where multiple length scales are present, accompanying timescales will also arise when considering the system dynamics. In these systems, the available thermal energy is insufficient to overcome internal energy barriers, which inhibits mixing and prevents the system from exploring all possible micro-states within the timescale of interest. Multiscale fluctuation terms arise in the non-equilibrium energy dynamics due to spatial and temporal deviations associated with intensive thermodynamic variables. How to characterize and interpret these fluctuations has been a long-standing problem for immiscible fluid flow in porous media.

In this study, 3D pore structure extracted from micro-CT images of Bentheimer sandstone were used to define interior boundary conditions of flow modeling in a pore-scale lattice Boltzmann simulator, LBPM, to simulate multiphase flow within the pore space. LBPM is an open source software package that has been developed to simulate fluid flows through porous media (McClure et al. 2020).

Non-equilibrium thermodynamic equations for immiscible fluid flow in porous media were derived using time-and-space averaging (McClure et al. 2021). In the context of this theory, capillary fluctuation terms are assessed during steady-state displacement. We investigate the influence of representative elementary volume (REV) effect on capillary fluctuations that are due to typical pore-scale events for drainage and imbibition process in porous media. The results indicate that capillary fluctuations are an essential consideration to determine REV for immiscible fluid flow.

Reference:

McClure, J. E., Li, Z., Berrill, M., & Ramstad, T. (2020). The LBPM software package for simulating multiphase flow on digital images of porous rocks. Computational Geosciences, 1-25.

McClure, J. E., Berg, S., & Armstrong, R. T. (2021). Capillary fluctuations and energy dynamics for flow in porous media. arXiv preprint arXiv:2012.09206.

Time Block Preference

Time Block C (18:00-21:00 CET)

References

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