A high-performance lattice Boltzmann solver with applications to multiphase flow in porous media

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Background

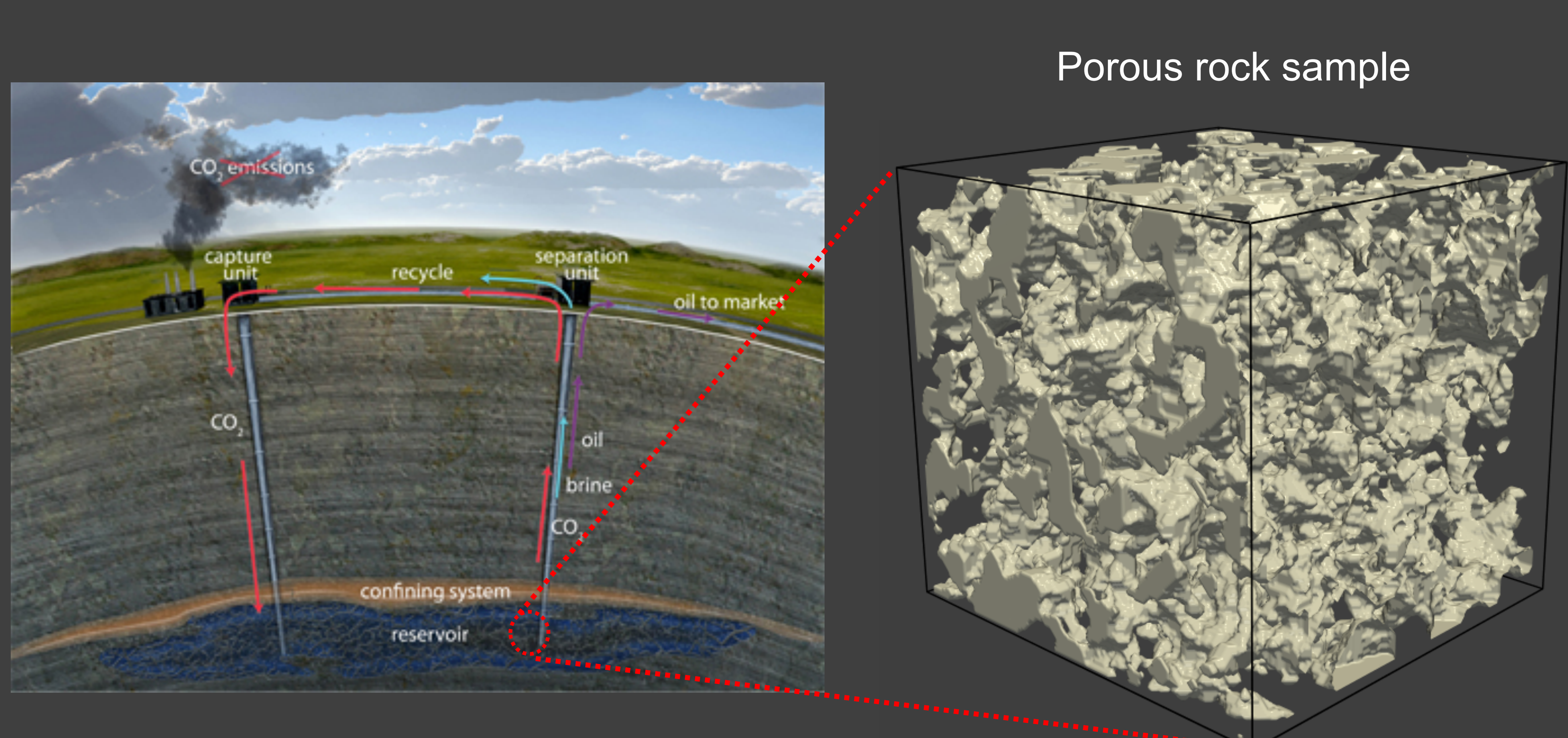
- Multiphase flow is significant to many industrial processes such as the geologic storage of CO_2 and oil recovery
- Understanding the physics of pore-scale phenomena is critical to all fluid-rock interactions, including core-scale and reservoir-scale
- Pore-scale modeling considers microscopic details of fluid flow so that we can predict configuration of fluids and understand small-scale heterogeneity of the rock
- Complex pore geometry and phase distribution can affect macroscopic flow patterns and properties like permeability and capillary pressure
- Microscale simulation of multiphase flow using traditional computational fluid dynamics (CFD) methods is a challenging task with high computational demand
- The goal of our study is to overcome high computational demand of multiphase flow simulations by using high performance computing

Methods

- Developed a multiphase lattice Boltzmann (LB) solver using an extended Color-Gradient approach
- Applied the LB model to a parallel scheme written in C++ using the Message Passing Interface (MPI)
- Computed multiphase flow simulations by performing highly parallel runs on the HPC system at the Texas Advanced Computing Center at the University of Texas at Austin

Research Objectives

- Understanding the pore-scale phenomena of multiphase flow (CO_2/Brine) in subsurface reservoir
- Study different mechanisms of CO_2 trapping in the formation
- Studying the morphology and distribution of trapped CO_2 clusters in a rock with different wetting conditions
- Capture the effect of wettability on relative permeability curves to incorporate the pore-scale effects to reservoir-scale analysis



Red lines show the flow of carbon dioxide captured from an industrial facility and injected into deep geological reservoirs where it can no longer impact oceans or climate.

References

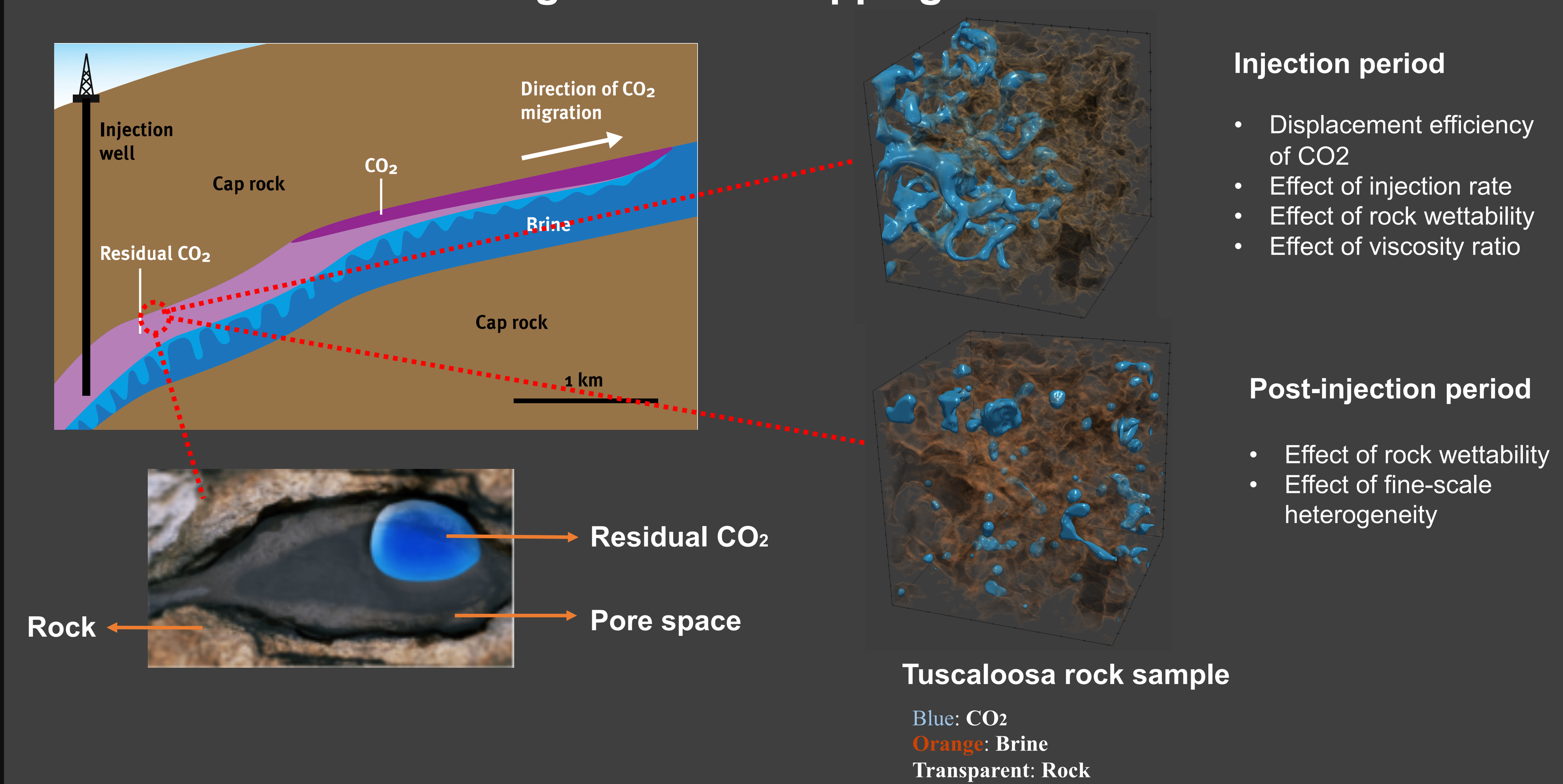
1- Bakhshian, S., Hosseini, S.A., Shokri, N., 2019, Pore-scale characteristics of multiphase flow in heterogeneous porous media Using the lattice Boltzmann method. Sci. Rep. v. 9, Article number: 3377.

2- Bakhshian, S., Hosseini, S.A., 2019, Pore–scale analysis of supercritical CO2-brine immiscible displacement under fractional-wettability conditions. Adv. Water Resour. V. 126, p. 96-107.

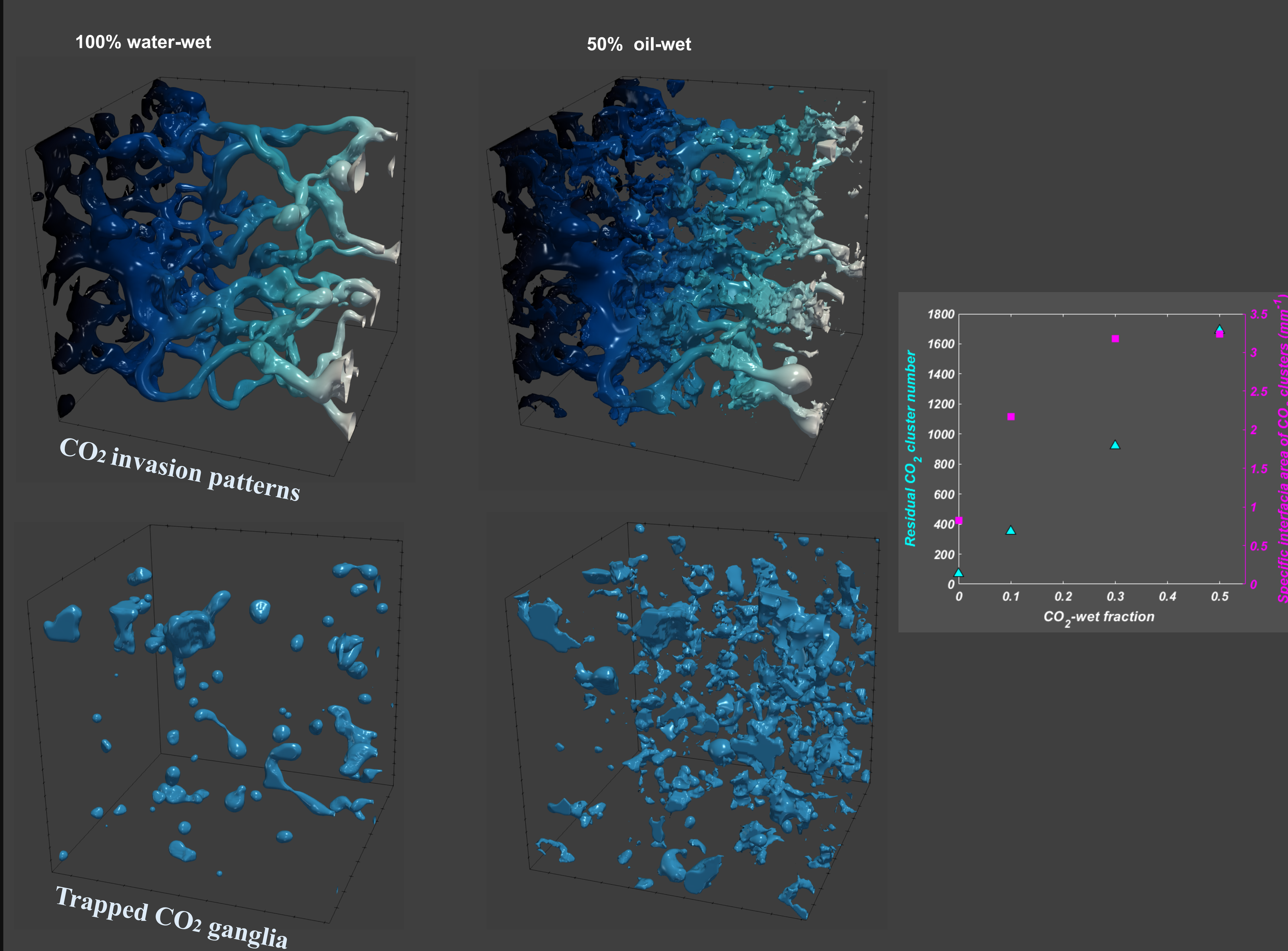
3- H. Dashtian, S. Bakhshian, S. A. Hosseini, and J. P. Nicot, 2018, Convection-diffusion-reaction of CO2-enriched brine in porous media: A pore-scale study, Computer & Geoscience, 125, 19-29.

Results

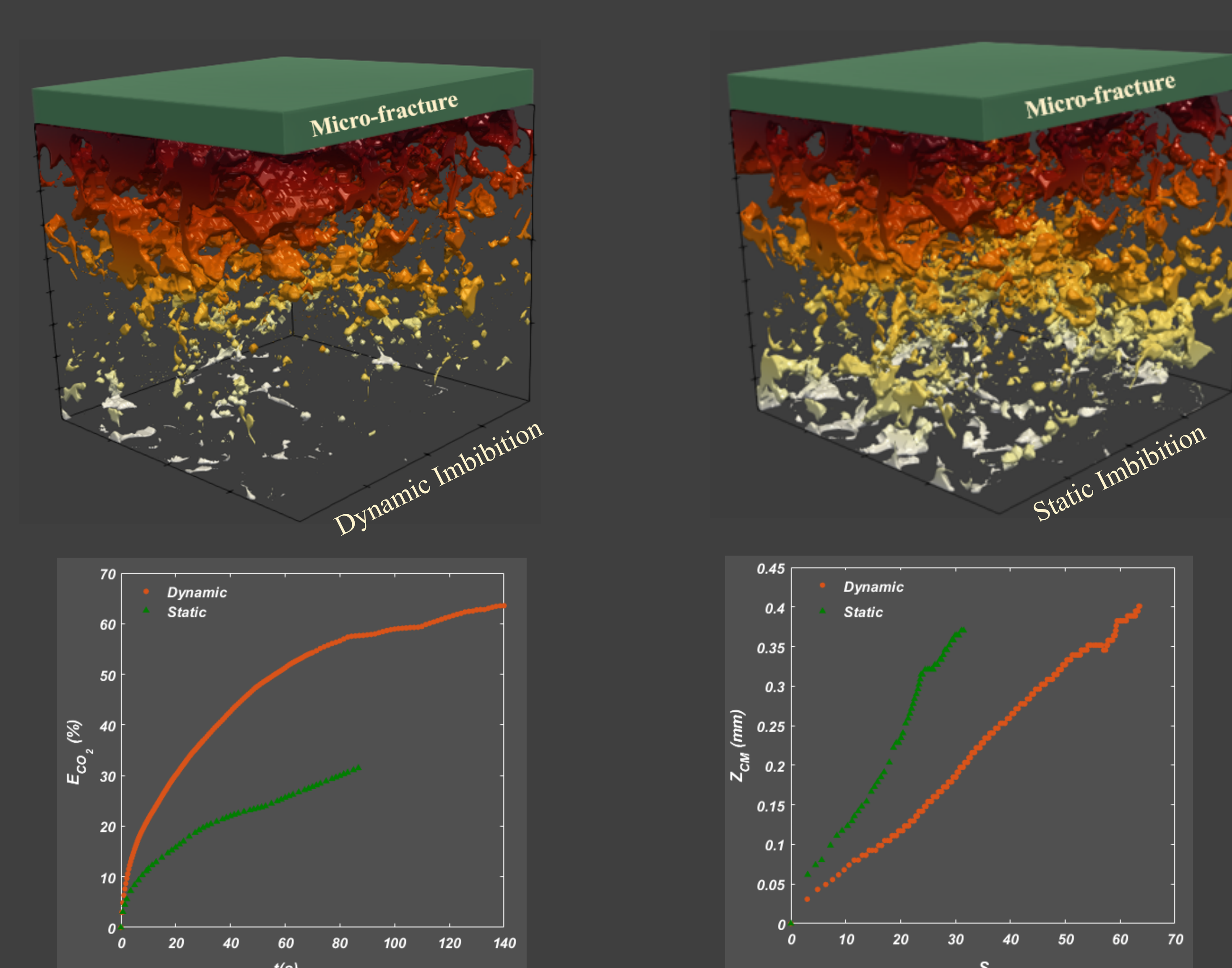
- **Mechanism of CO_2 migration and trapping**



- **Effect of wettability on CO_2 migration pathway and its residual trapping**



- **Matrix-fracture interaction**



Conclusions

- The LB model is a promising scheme for the application of CO2 sequestration and can be used fro the evaluation of CO2 sweep efficiency and storage capacity of reservoirs with various wetting conditions.
- We successfully applied our parallel tool to study CO2 trapping mechanism in fractured rock samples.

Acknowledgments

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