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Effect of Spatially Correlated Disorder on Solute Dispersion and Mixing in Partially Saturated Porous Media

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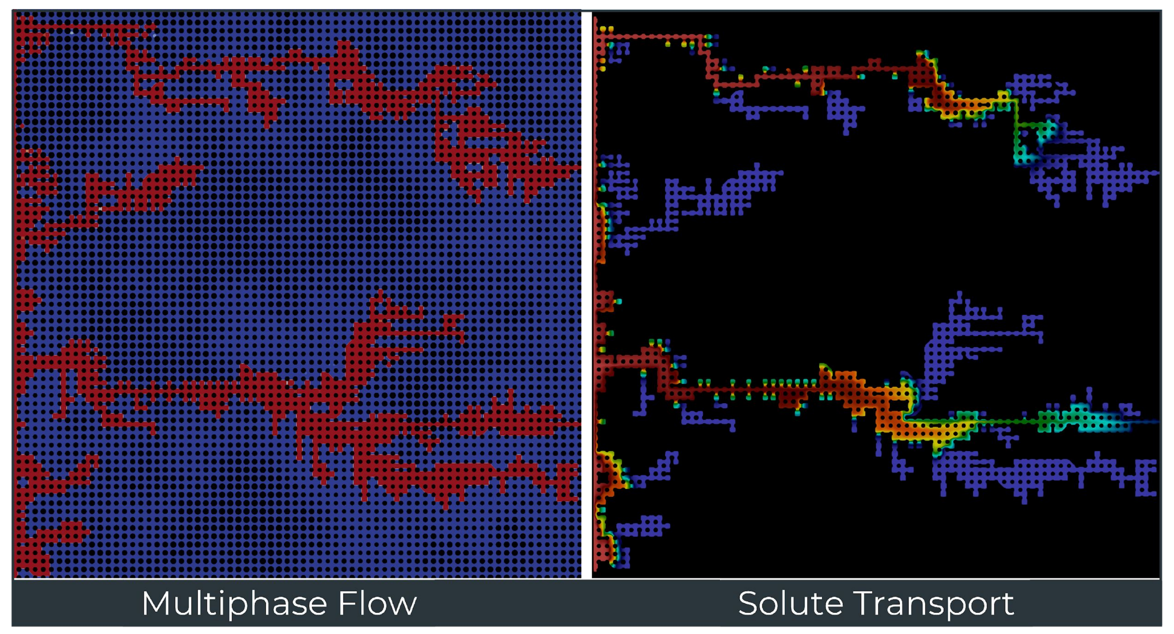
Introduction

- Transport of solute species in porous structures at multiphase conditions is a common process in subsurface systems.



Research Questions

- How correlated structures affect solute transport under multiphase viscous fingering regime?
- What is the effect of correlated disorder on solute dispersivity?
- How mass exchange between flowing and trapped regions varies with time?

Methods

The multiphase displacement pattern is captured by ***OpenFoam*** framework through solving:

- Navier-Stokes Equations
- Volume-of-Fluid Model

The Solute transport is modelled by solving the advection-diffusion equation:

$$\frac{\partial C}{\partial t} + \nabla.(uC) - \nabla.(D_m \nabla C) = 0$$

Results and Discussion

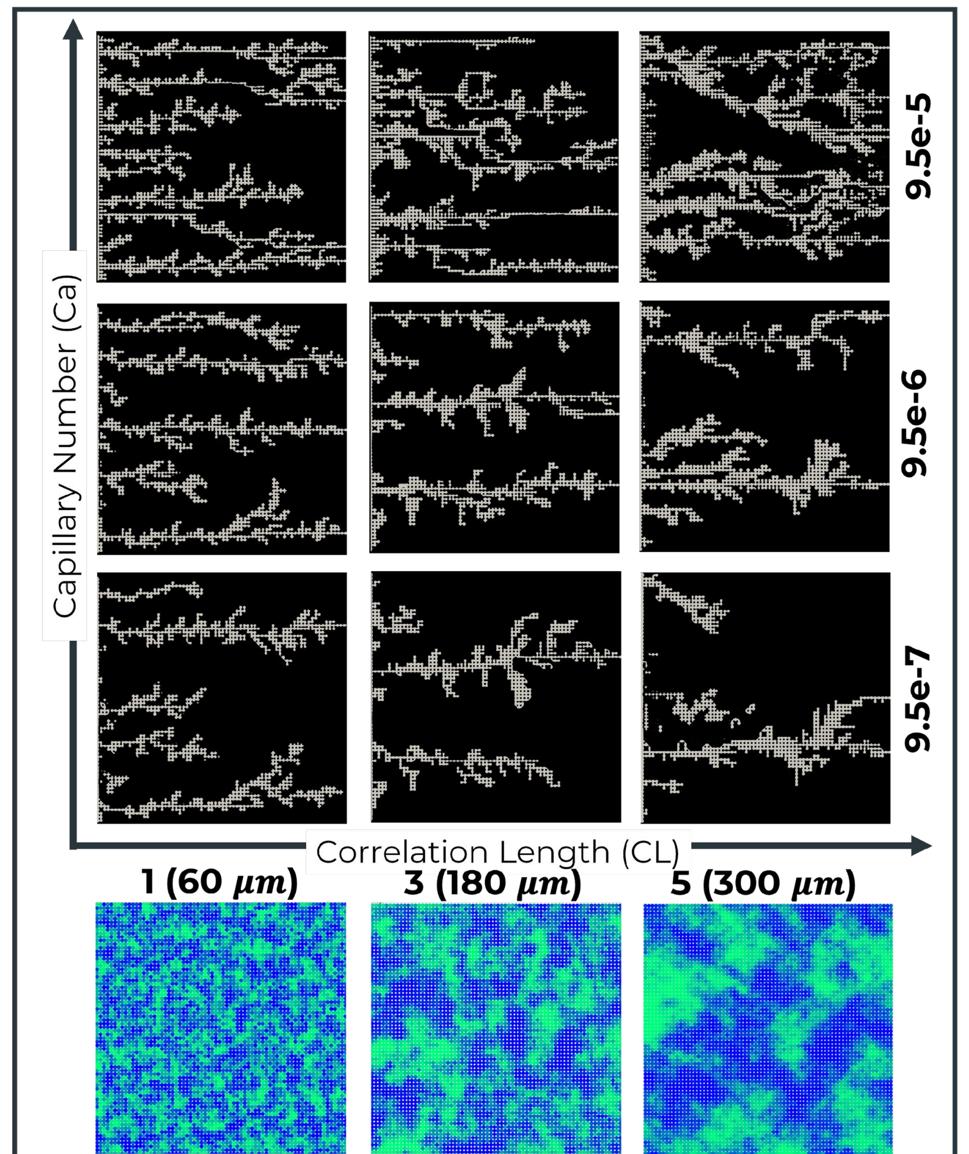


Figure 1: Displacement pattern as a function of correlation length and capillary number.

✔ The size of numerical domain needs to be at least 22 times bigger than the correlation length of medium to have realization independent modeling.

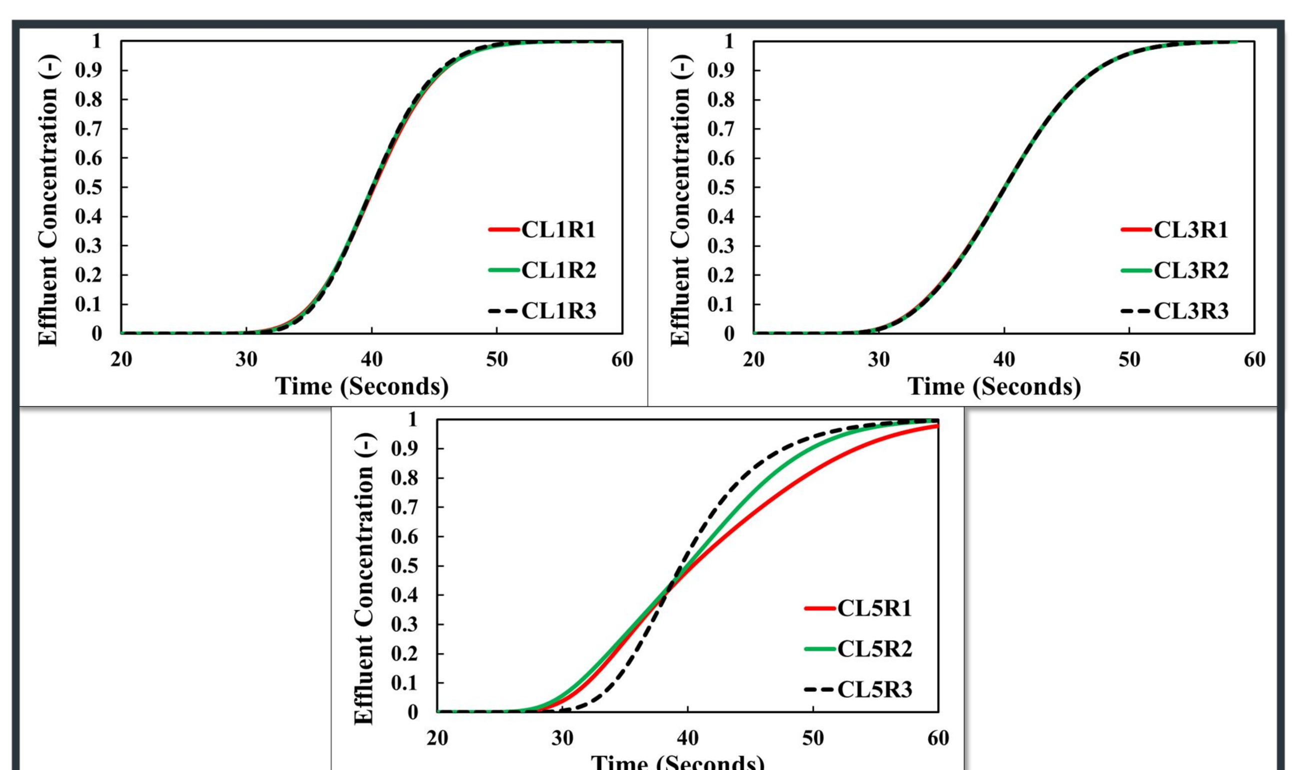


Figure 2: Single-phase solute breakthrough curves for three correlation lengths at three different realisations.

The presence of a second phase alters transport behavior by the creation of two different regions, Zone 1 being advective controlled and Zone 2 being diffusive controlled.

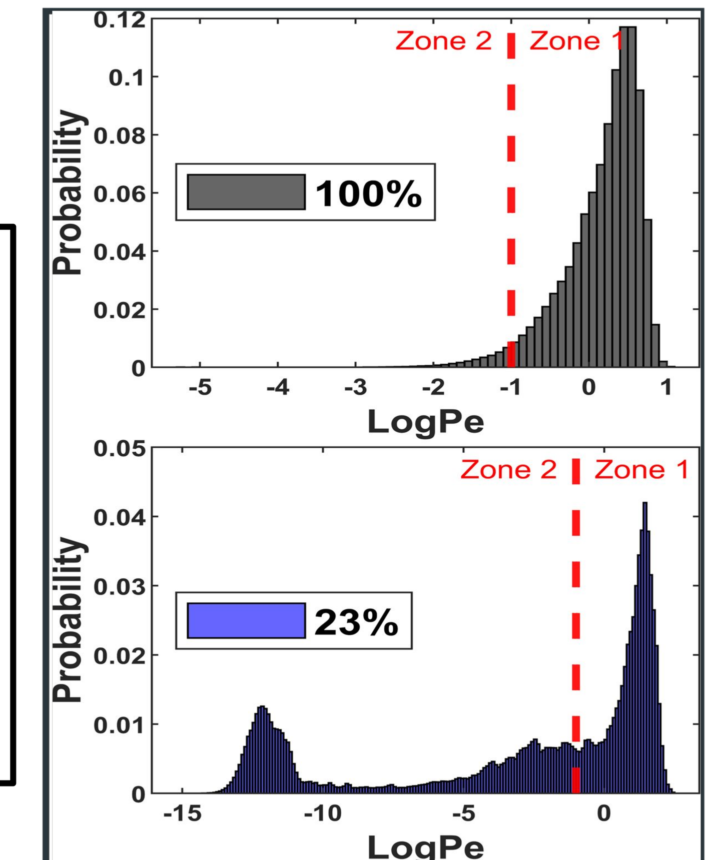


Figure 3: Probability distribution of pore-scale Peclet number at two different saturation.

✔ A unimodal variation can be seen for saturated case with the most of transport happens under the advection, while there is a bimodal variation for partially saturated domain with both advective and diffusive forces affecting transport.

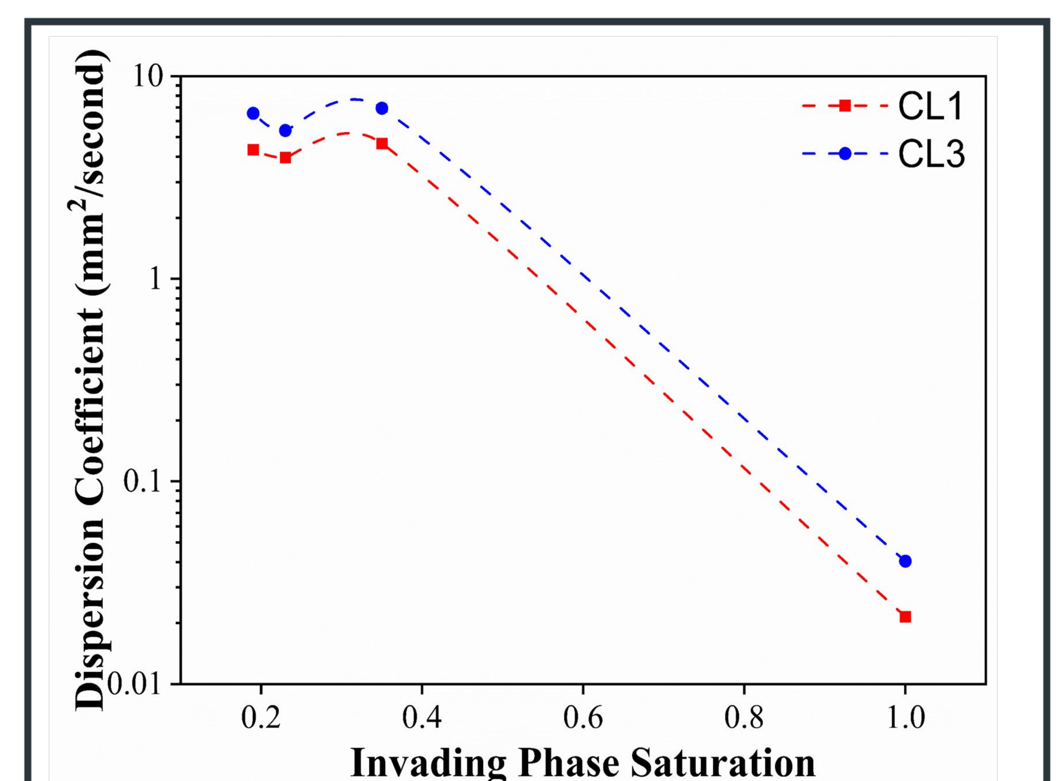


Figure 4: Dispersion saturation relation at two different correlation length.

✔ There is a saturation in which the velocity streamlines are the most heterogenous, which corresponds to the maximum value of dispersivity.

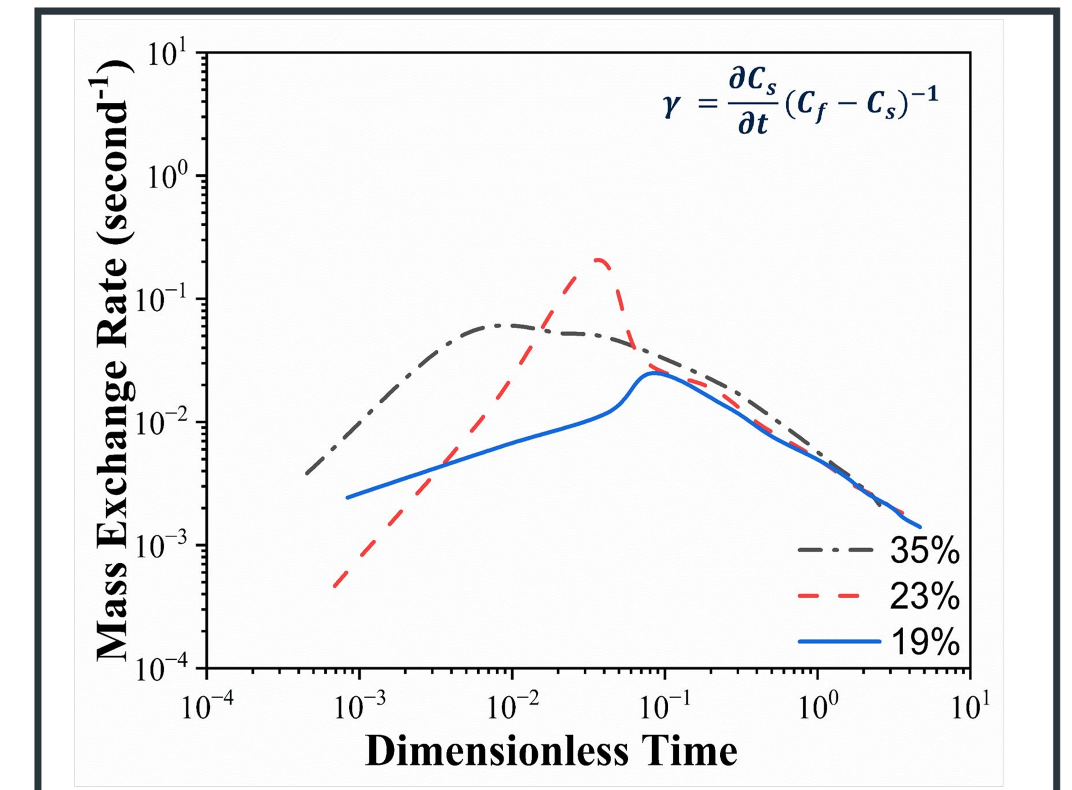


Figure 5: Variation of mass exchange rate between flowing and trapped region at different saturation for correlation length 1.

✔ Mass exchange rate between flowing and trapped regions experiences a non-monotonic variation with two stages for transport.

Conclusion

- A non-monotonic behavior is observed for dispersion coefficient with an increase in its values against correlation length.
- Transport is mainly under the influence of advective forces for saturated porous media, whereas there are purely diffusive zones at multiphase case.
- The diffusive mass flux among flowing and trapped regions enhances over time and peaks at a value followed by a decrease due to gradual fading of concentration gradient.

Future Works

- Investigating the effect of a wider range of porous media characteristics, such as wettability, on multiphase flow and followed solute transport at correlated structure.
- Analyzing solute migration at other types of engineered porous media.