A Streamline Splitting Pore-Network Approach for Accurate Simulation of Species Transport in Porous Media

Scientific Achievement

Developed a new pore-network approach to model species transport that accurately models mixing at pores over in both advection and dispersion dominated flows

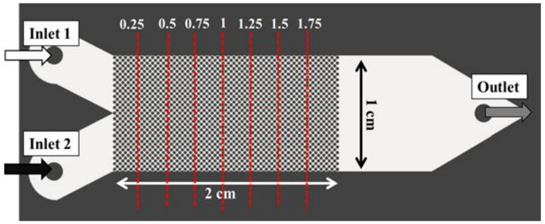
Significance and Impact

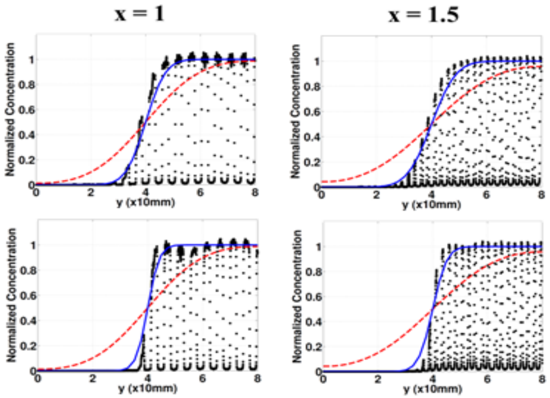
Models can quickly and accurately upscale transverse dispersion coefficients in porous media, which can be directly substituted into macroscopic simulators of CO_2 flow and transport

Research Details

- High concentration gradients at moderate to high Peclet regimes are not captured by traditional pore-network modeling approaches, i.e. MCM (mixed cell method)
- This model considers *a priori* splitting of streamlines using an optimization problem. Algorithm was verified against direct CFD simulations
- Diffusion between the streamlines accounted via solution of Riemann problem
- Model validated against numerous micromodel experiments, the predictions of which were excellent
- Transport in 3D disordered sphere packs were studied using the model and the importance of pore-level mixing determined: very low due to high tortuosity of the medium.

Mehmani, Y., Oostrom, M., Balhoff, M.T., "A Streamline Splitting Pore-Network Approach for Computationally Inexpensive and Accurate Simulation of Species Transport in Porous Media," *Water Resources Research*, in review.





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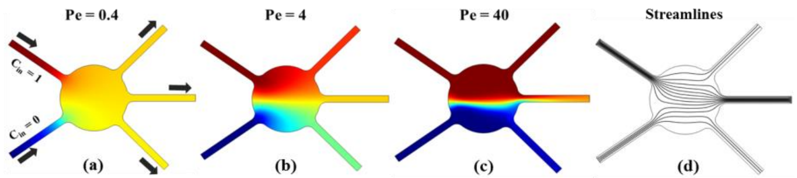
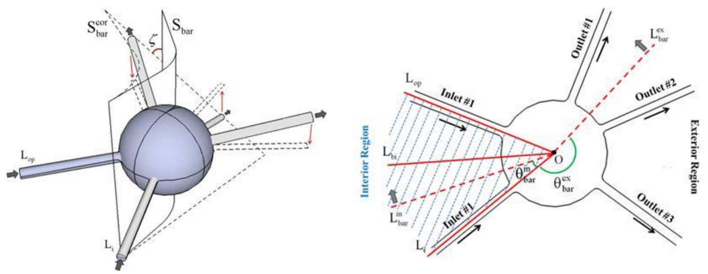
Motivation



Schematic of steady state concentration fields for a typical pore at different Pe and streamline field obtained from flow equation.

Streamline Splitting Approach



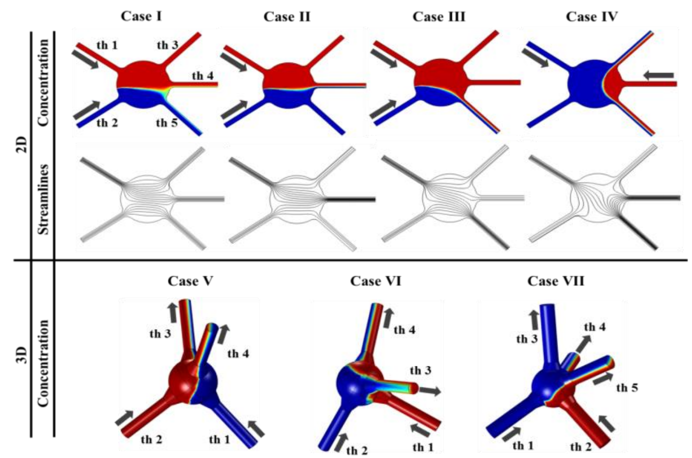
(a) 3D schematic of the pore, projection of the outflowing throats onto the *flowing plane*, the *barrier surface*, and the *transverse angle* corresponding to the twisting of the *barrier surface*. (b) 2D projection of all throats on the *flowing plane* (on P_{fl})

$$F_i(\vec{y}_{io}) := \sum_{i=1}^{N_i}\sum_{o=1}^{N_o}\omega_{io}y_{io}^2 \qquad \sum_{o=1}^{N_o}(-1)^{\beta_{io}}\, y_{io}\,|q_o| = C_i \qquad i=1,\dots,N_i$$

$$\sum_{i=1}^{N_i}(-1)^{\beta_{io}}\, y_{io} = C_o \qquad o=1,\dots,N_o$$

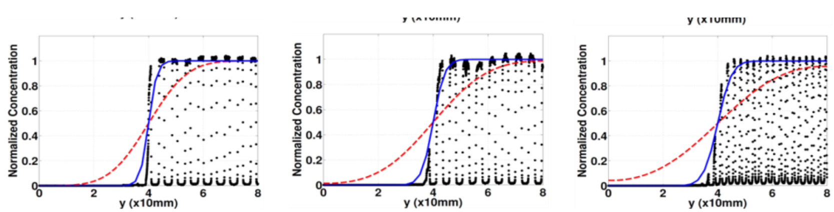
$$y_{io}(\in[0,1]) = \begin{cases} x_{io} & if \quad o\in Pr_i^c \\ 1-x_{io} & if \quad o\in Pr_i \end{cases} \qquad \beta_{io} = \begin{cases} 1 & o\in Pr_i \\ 0 & o\in Pr_i^c \end{cases}$$

Verification with CFD models



Concentration fields of a dummy tracer (injected through one inlet) obtained from COMSOL simulations on one 2D pore and three distinct 3D pores.

Validation with Experiments



Concentration profiles along the 0.5, 1 and 1.5 cm transect lines including experimental data (dots), *SSM* transects (solid blue line), and *MCM* transects (dashed red line)

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