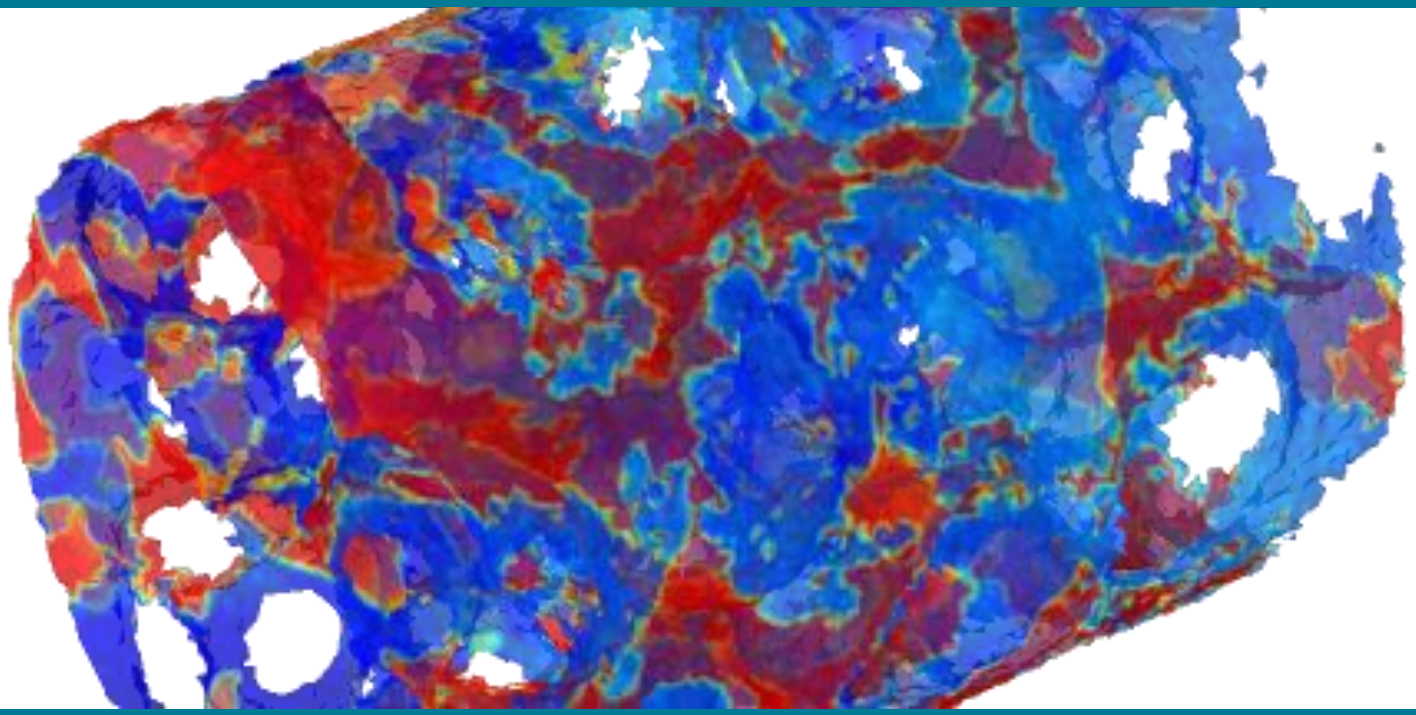

Effect of biofilm permeability on flow and transport in three-dimensional porous media: A geostatistical study

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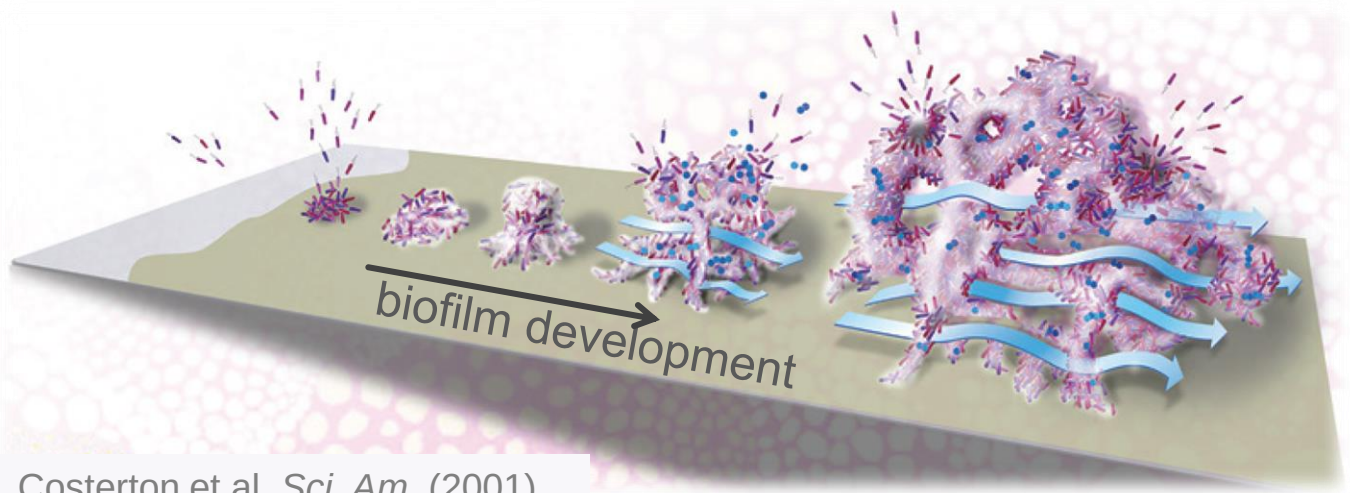
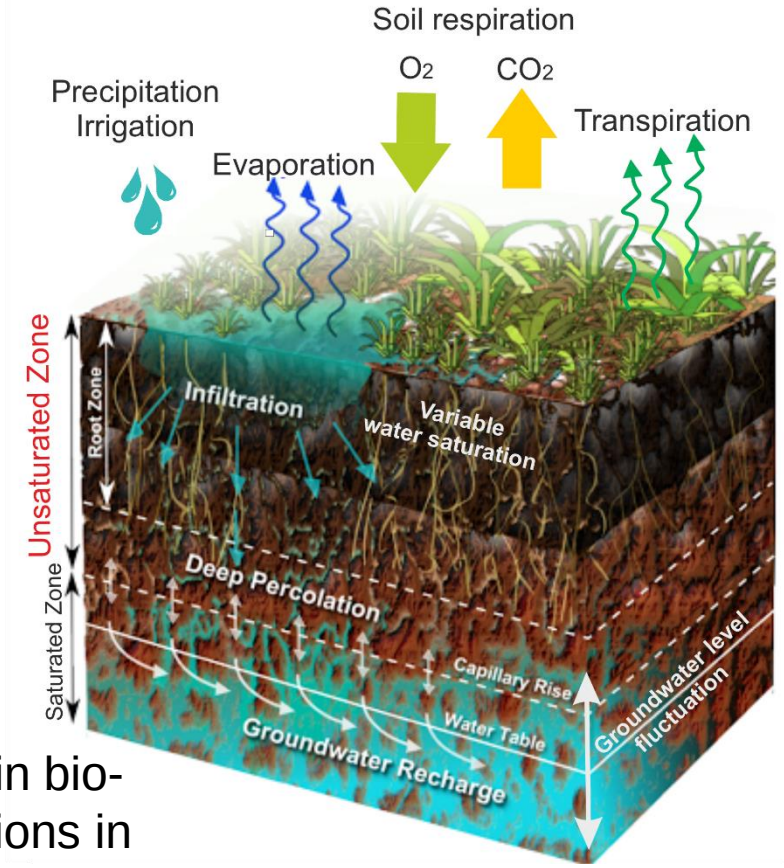
Biofilms in subsurface environments



Costerton et al. *Sci. Am.* (2001)

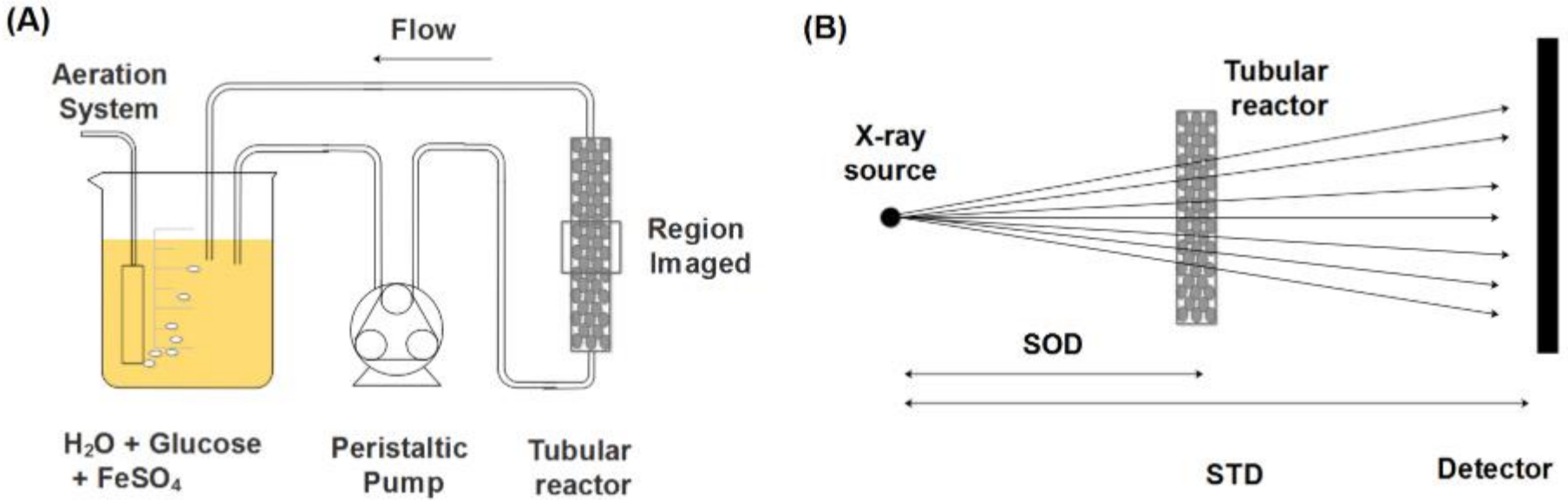


Communities of bacterial cells embedded in a porous extracellular matrix

Play a critical role in bio-geochemical reactions in subsurface

- Drive contaminant transport for bioremediation
- Wastewater treatment
- Enhanced oil recovery

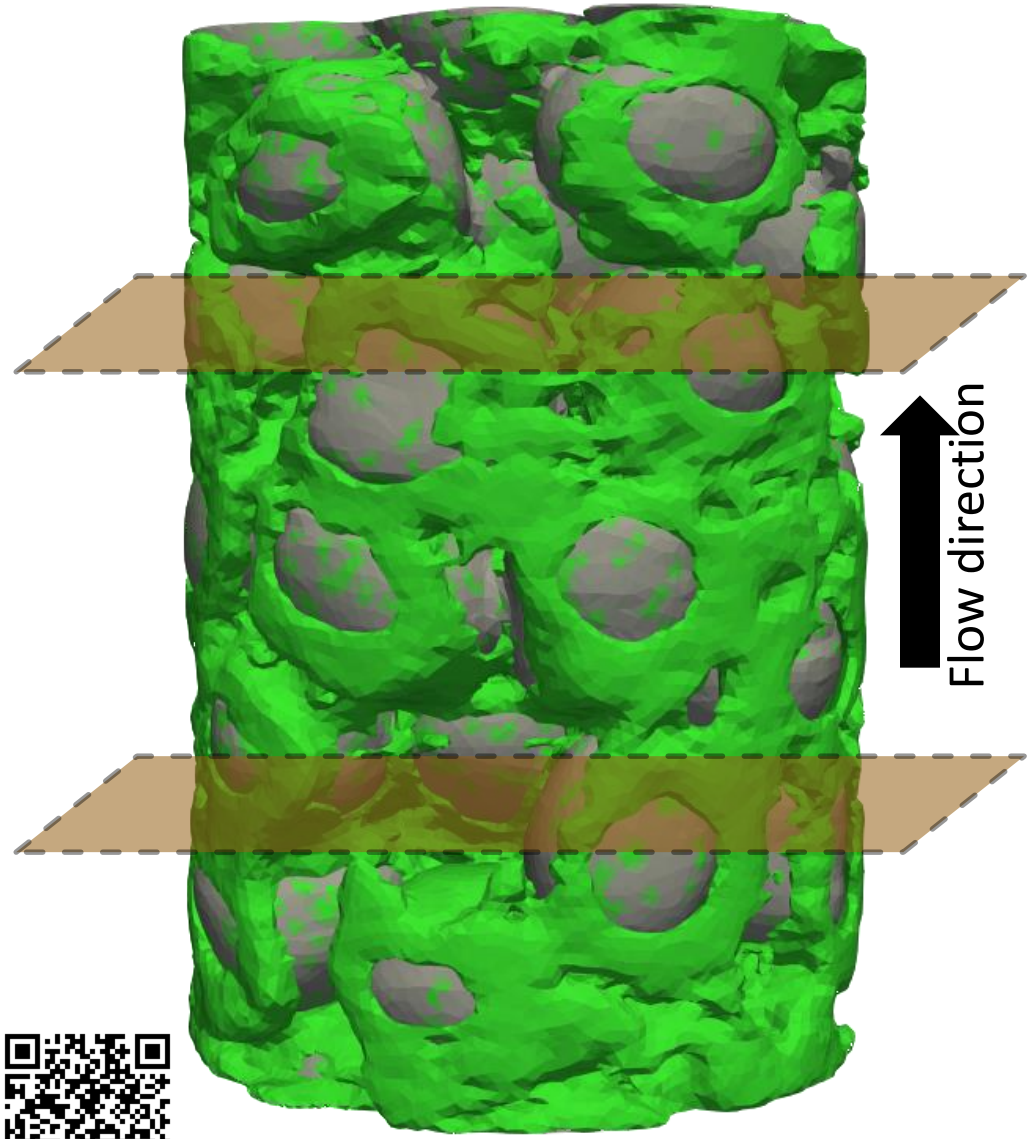
Quantification of biofilm distribution is challenging

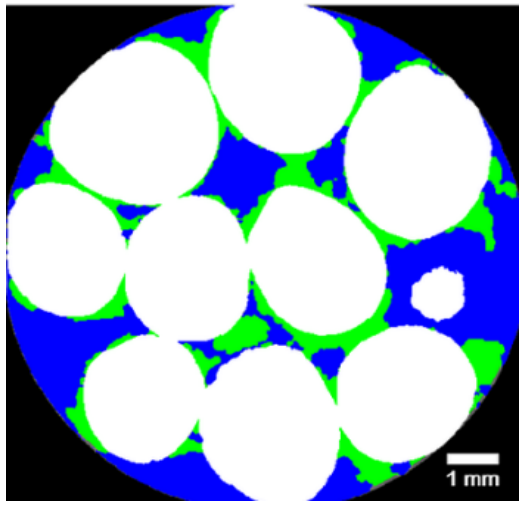


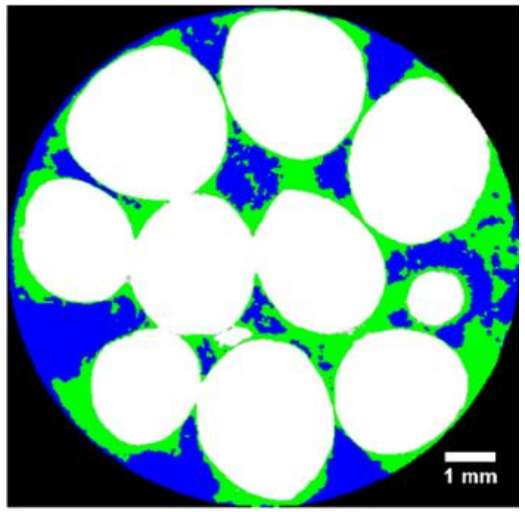
Carrel et al., *PLoS One* (2017)

- X-ray lab source
- $FeSO_4$: non-toxic inorganic compound as contrast agent
- Biofilm morphology in 3D

Experimental reconstruction of biofilm morphology

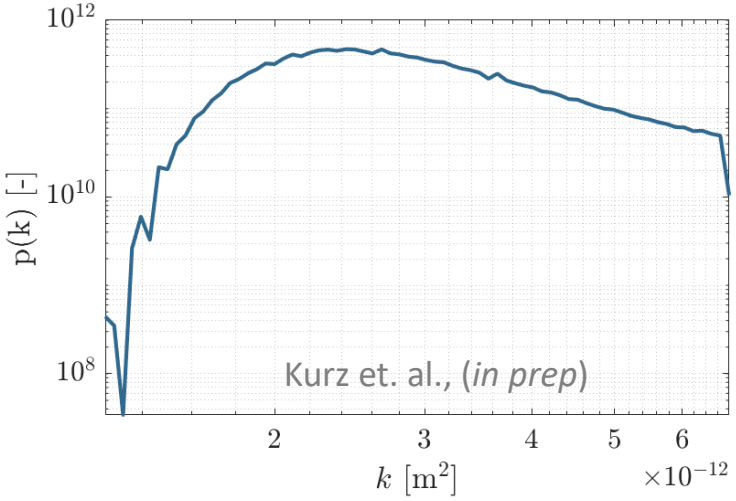




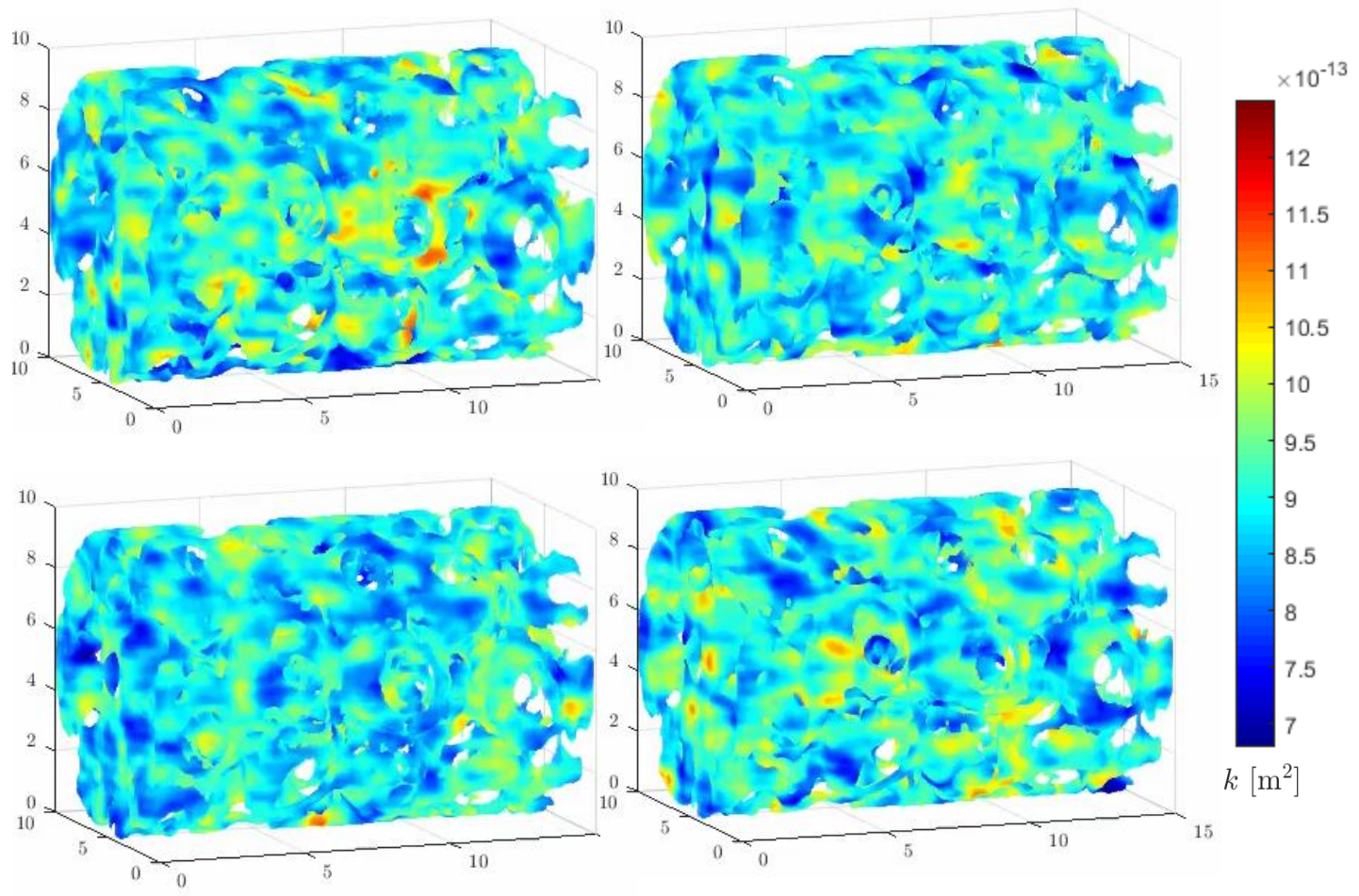


- Current biofilm models in porous media
  - Impermeable or constant permeability in biofilm
  - Solute transport is not accurately predicted
- Locally varying physical properties from experimental images

Biofilm permeability in porous media is heterogeneous



FFT applied on sampling grid



&

Permeability correlation lengths in transverse and longitudinal directions

Multiple realizations of 3D permeability field

Influence on pore scale statistics

Navier-Stokes formulation

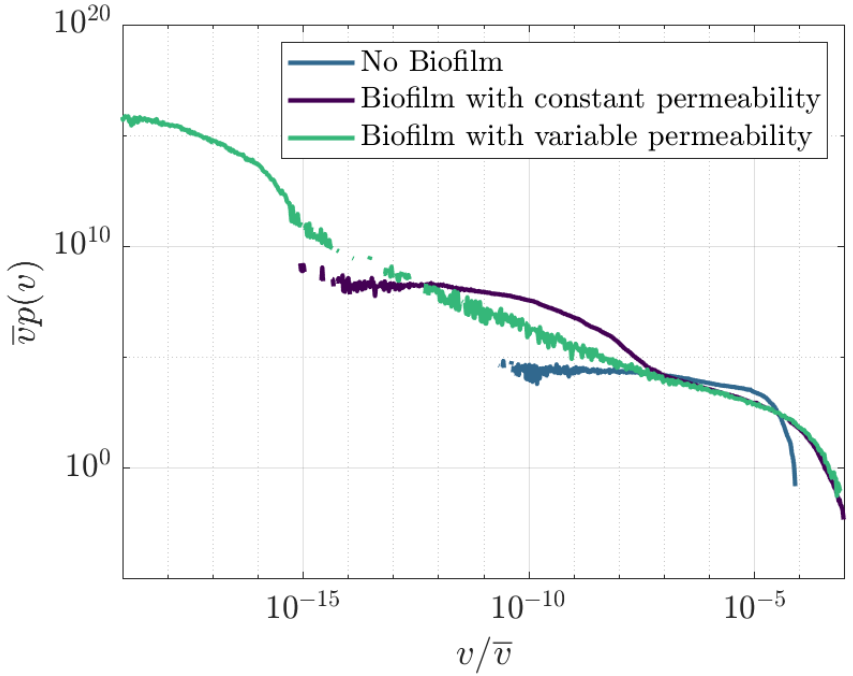
$$\nabla \cdot \mathbf{u} = \mathbf{0}$$

$$\rho(\mathbf{u} \cdot \nabla)\mathbf{u} = \nabla \cdot [-p\mathbf{I} + \mu(\nabla \mathbf{u}) + (\nabla \mathbf{u})^{\mathbf{T}}]$$

Brinkman formulation

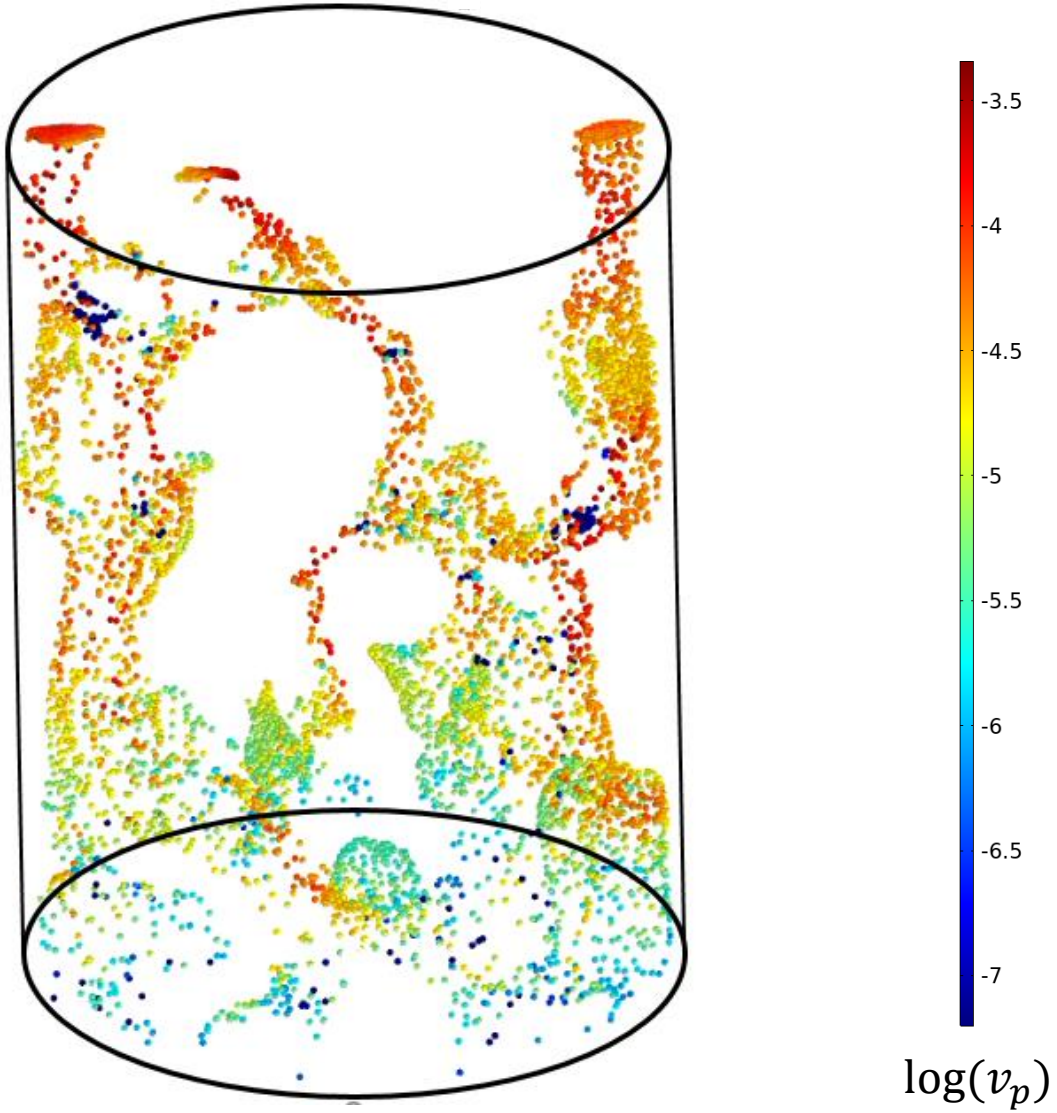
$$\nabla \cdot \mathbf{u_{br}} = \mathbf{0}$$

$$\frac{\rho}{\varepsilon_{\mathbf{P}}}\left((\mathbf{u_{br}} \cdot \nabla)\frac{\mathbf{u_{br}}}{\varepsilon_{\mathbf{P}}}\right) = -\nabla \cdot [-p\mathbf{I}] + \nabla \cdot \frac{\mu}{\varepsilon_{\mathbf{P}}}\left(\nabla \mathbf{u_{br}} + (\nabla \mathbf{u_{br}})^{\mathbf{T}}\right) - \frac{\mu}{\mathbf{k_{br}}}\mathbf{u_{br}}$$



Biofilm influence on transport

Particle Tracking



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