Chair of Reservoir Engineering

Extension and Uncertainty Modeling of Imbibition Processes using the Morphological Method – a Reality Check

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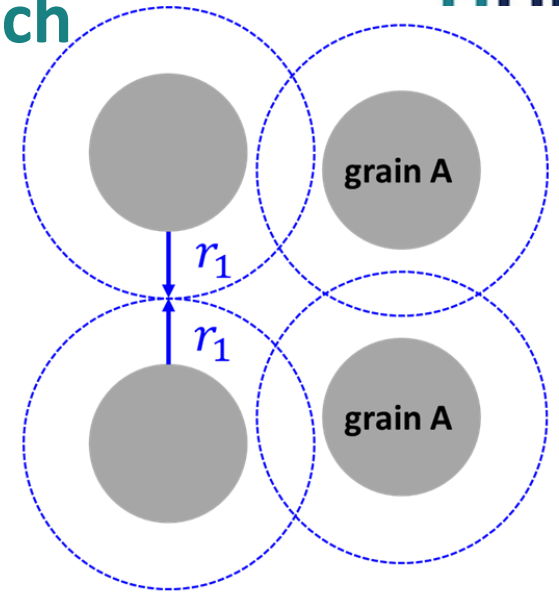
Morphological modelling approach

Basic morphological operations, i.e. dilation and erosion, on the pore space

Identification of pore throat sizes – purely geometrical



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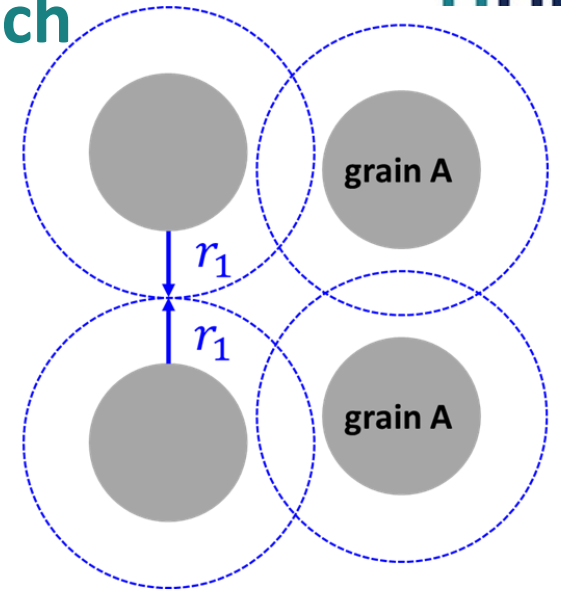

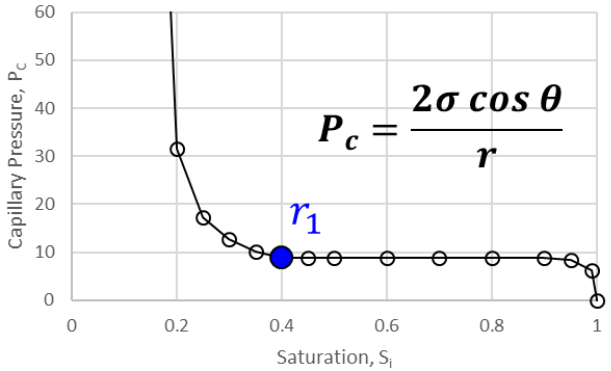

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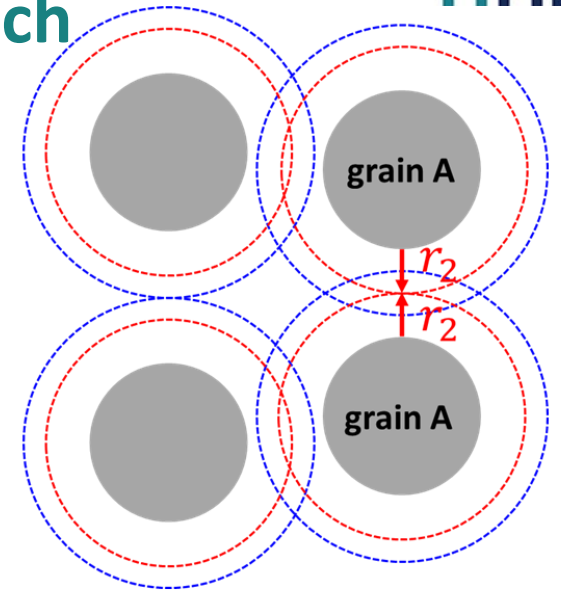

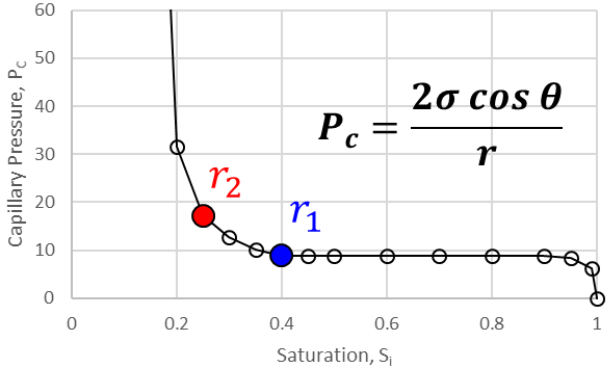

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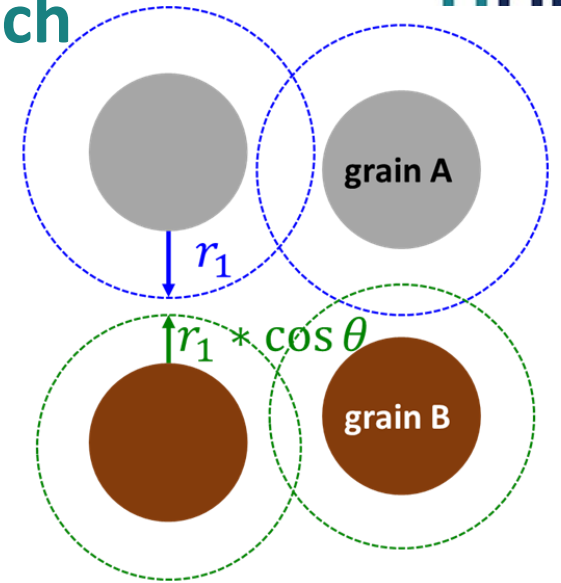
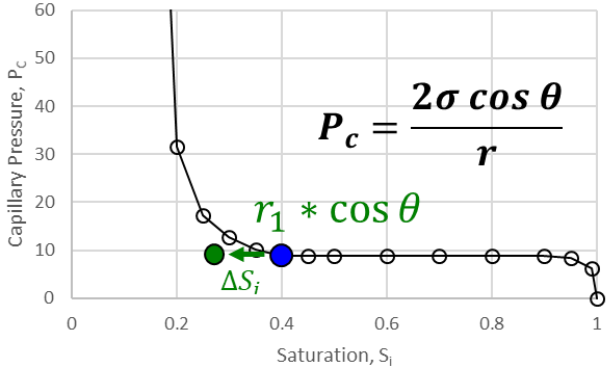
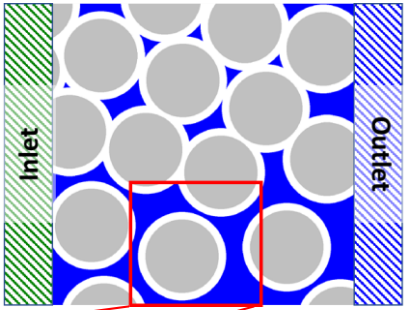
Different pathways by applying multiple contact angles, θ

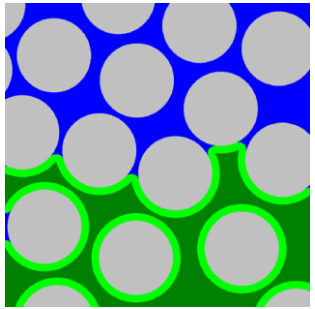


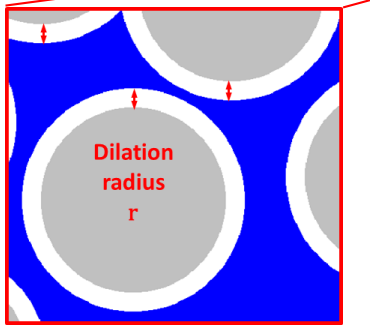


MM population to relative permeability

MM population

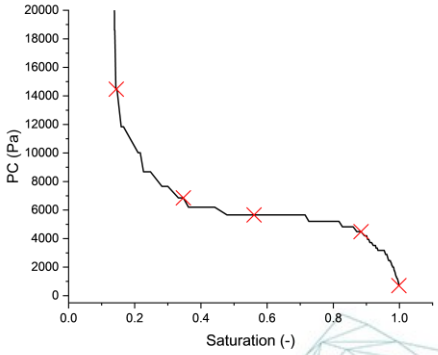






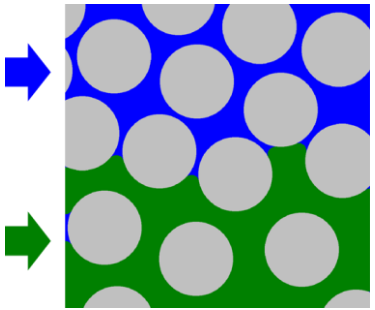
Morphological Invasion Step

$$P_c = \frac{2\sigma \cos\theta}{r}$$



Navier-Stokes Simulations

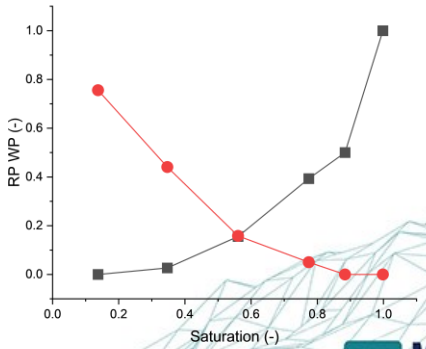
Connected Phase Flow



Connected Phase Flow

Effective permeability simulation on connected path ways

$$k_{r,i} = \frac{k_{eff,i}}{k_{abs}}$$

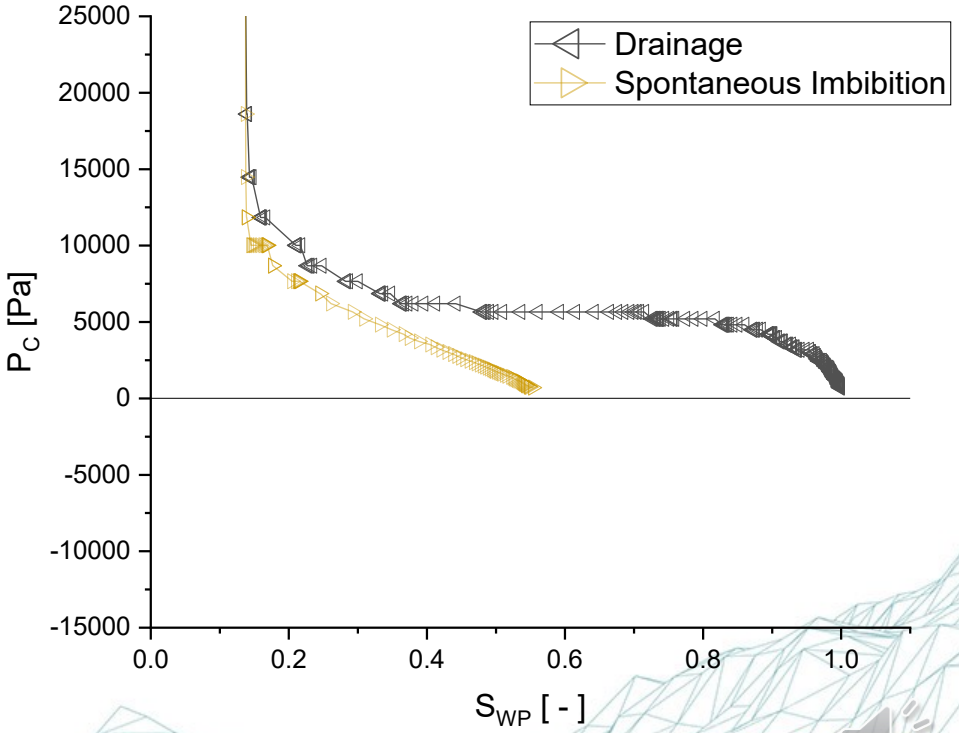


But what about imbibition?

Initial imbibition modelling

Single process only (drainage or spontaneous imbition)

Forced imbibition = ?



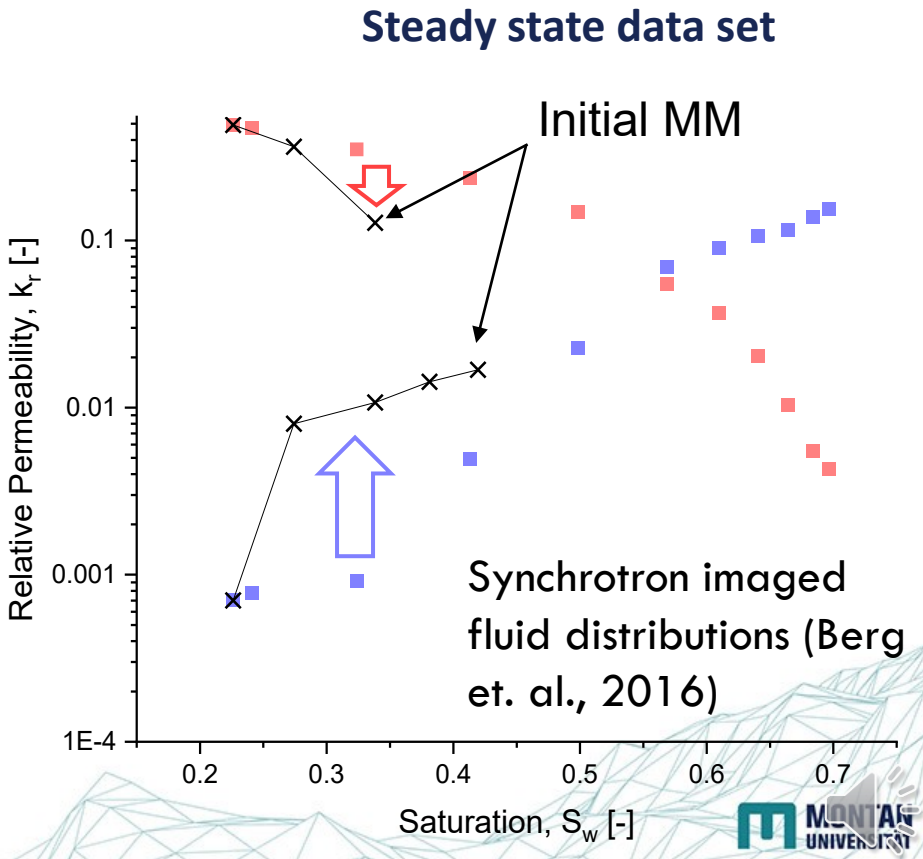
Problem

Limited saturation range for P_c and k_r:

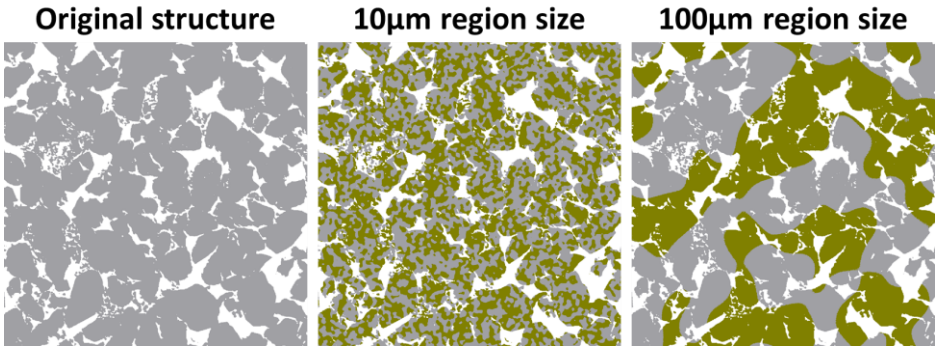
→ Early cutoff of relative permeability data and mismatch

Solution:

Stopping criteria to avoid total disconnection before starting to couple forced process

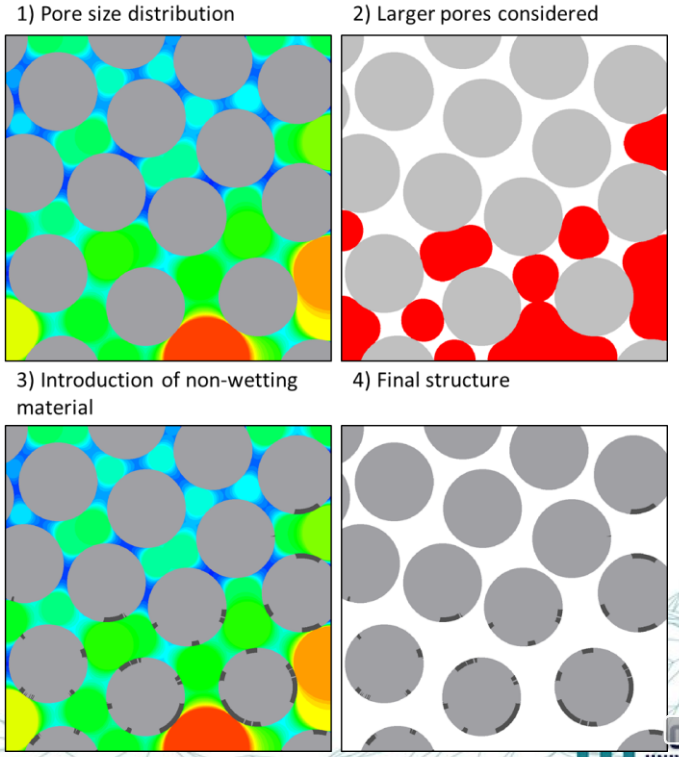


Implementation of non-wetting material
Stochastic vs. Deterministic

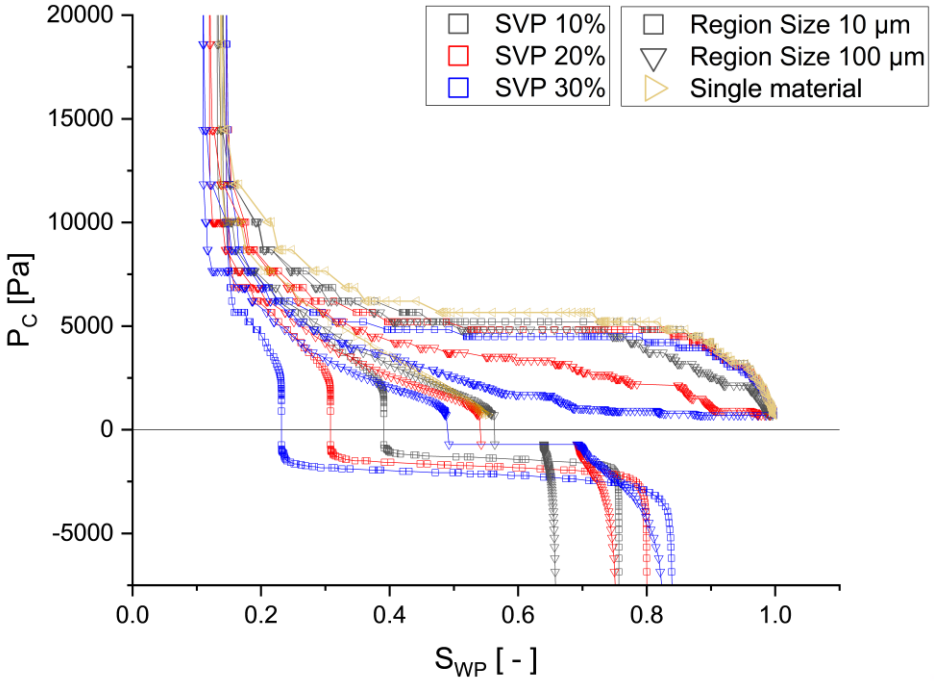


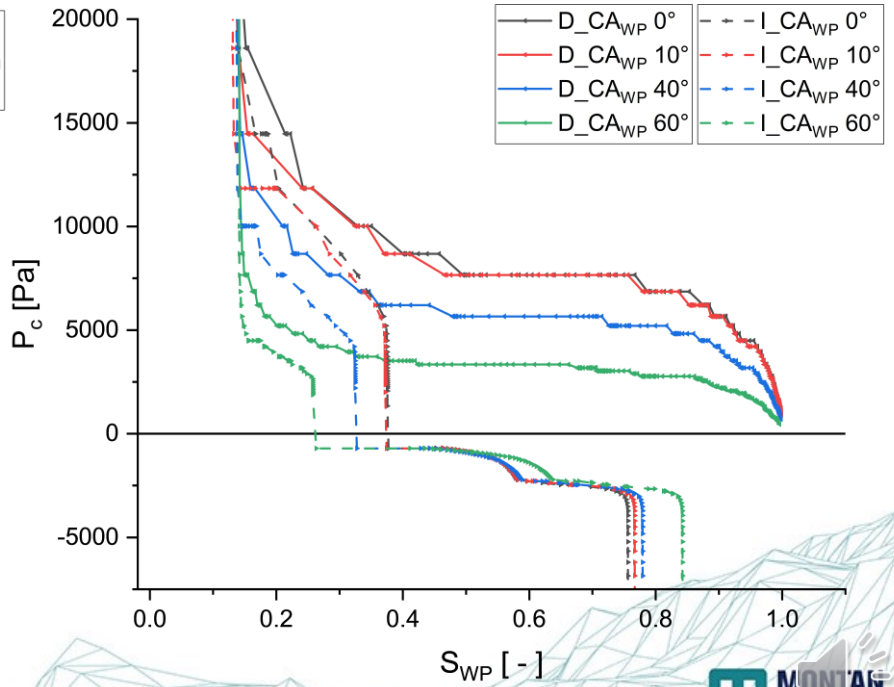
Stochastic field modelling – region size and solid volume percentage (SVP) are defined

Deterministic modelling – pore space considered (PSC) for implementation of non-wetting material is defined



Capillary Pressure Curves
Stochastic vs. Deterministic





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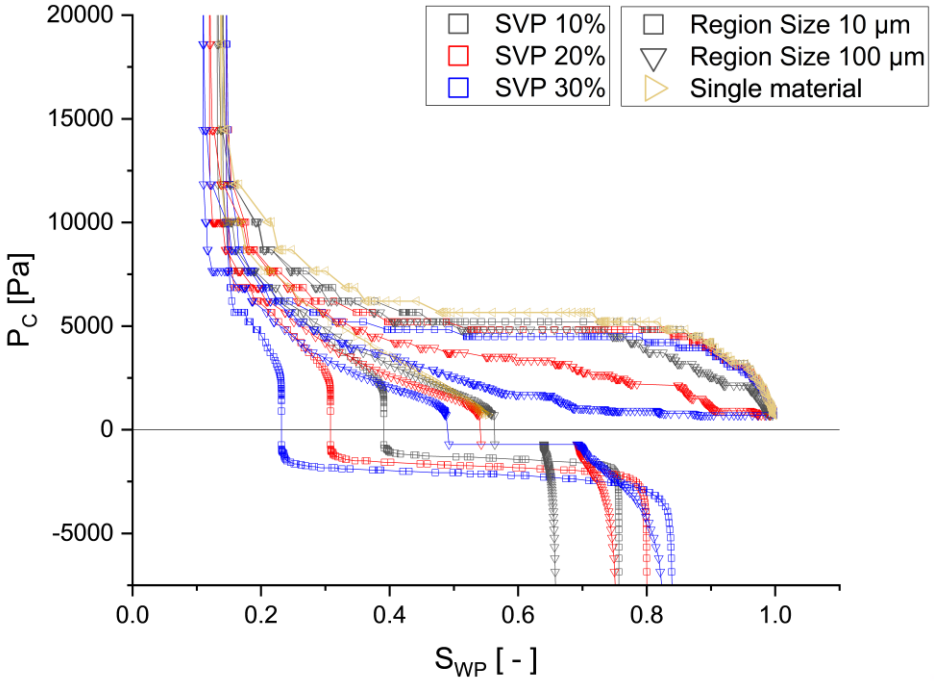


Observations:

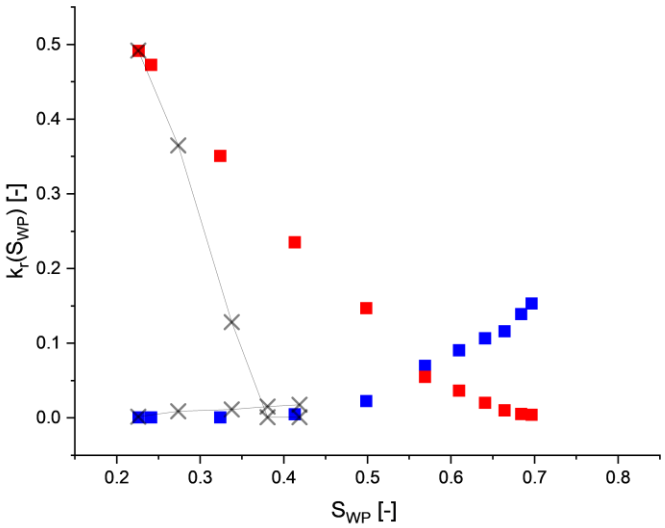
Stochastic: change of drainage as well
Deterministic: more like an aging process

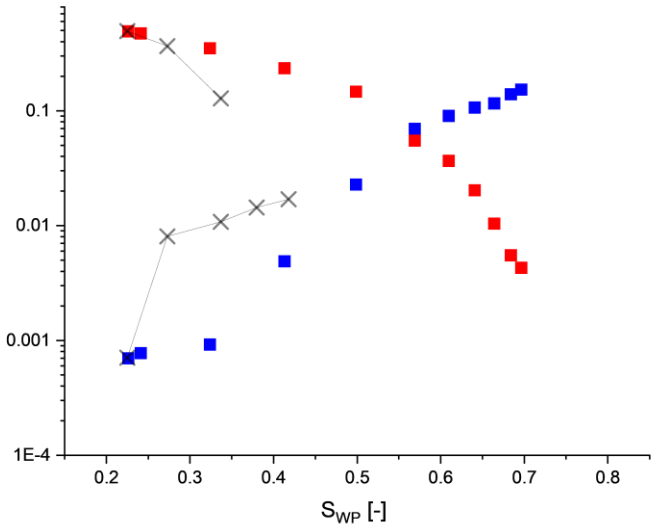
Uncertainty modeling by variation of pathways

Both methods show right physical trends ✓

But: Comparison to reality ?

Relative Permeabilities
Initial Implementation vs. experimental data





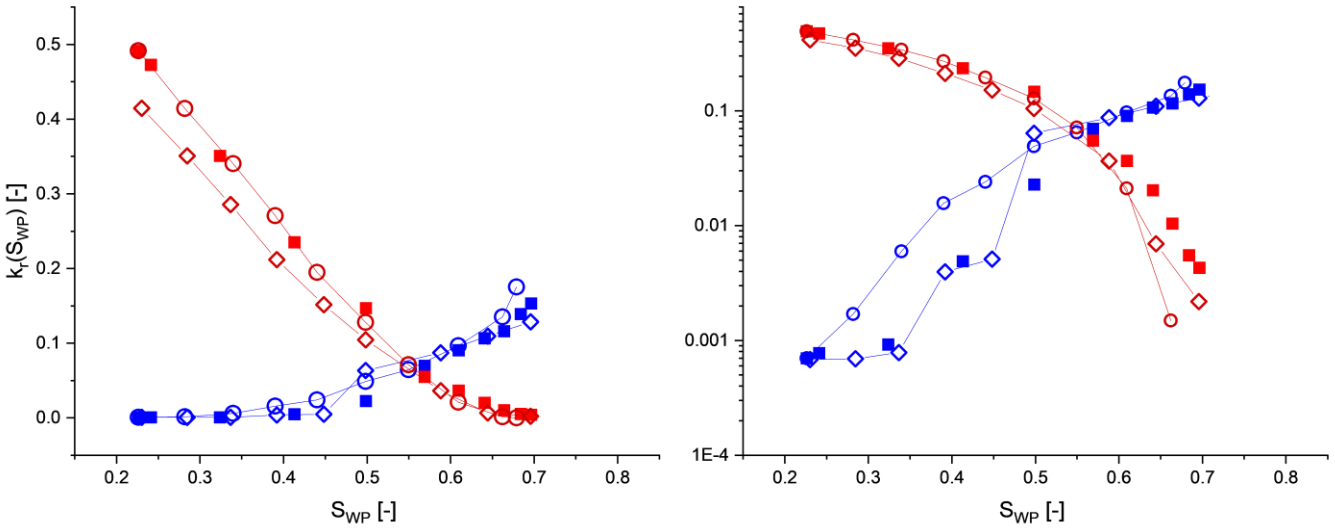
Berg et. al, 2016

Synchrotron Data = actual fluid distributions

NS Simulation on MM populated vs. experimental measured

→ Mismatch

Relative Permeabilities
Full imbibition modelling vs. experimental data

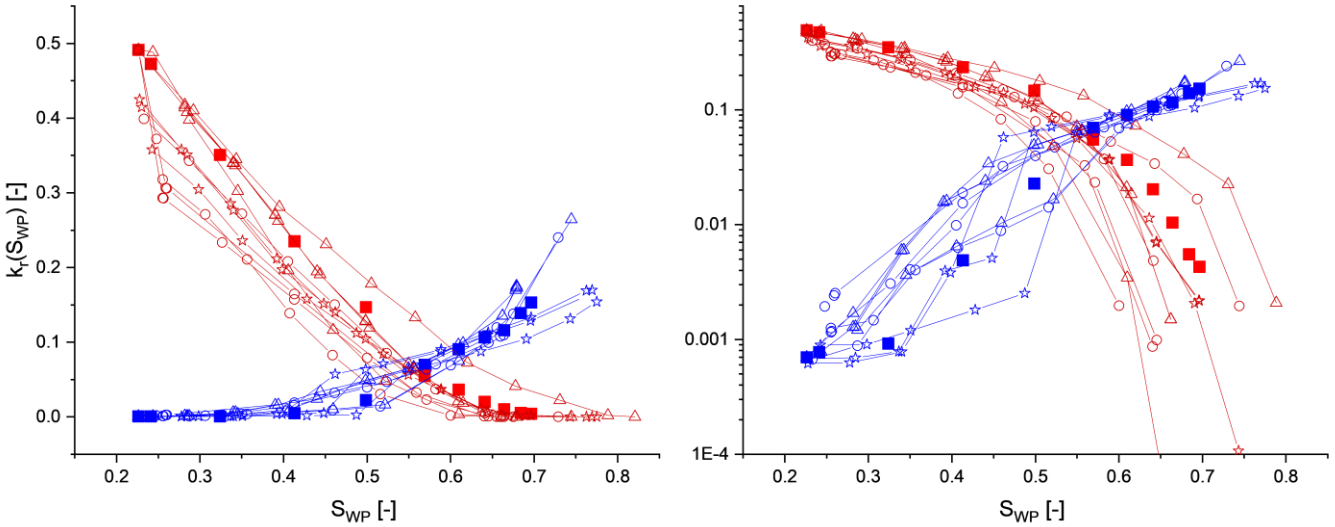


Best Match:

- Deterministic
- Stochastic

- Simulating forced imbibition only
- Not using strong wetting conditions ($\theta = 40°$)

Relative Permeabilities
Full imbibition modelling vs. experimental data



Uncertainty Modelling by:

- Varying contact angles
- Changing size and volume of non-wetting material

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Questions?

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