

Chair of Reservoir Engineering

Simultaneous Uncertainty Analysis for SCAL Data Interpretation

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11.05.22 •

Abstract ID: 468, Session: Parallel Session 2: MS14

Situation

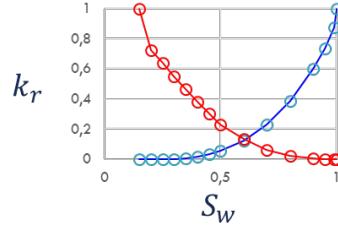
- ❑ Rock properties must be measured at great expense:
 - ❑ Water flooding for Oil production (water/oil)
 - ❑ Production of deep geothermal systems (water/steam)
 - ❑ Geological storage of CO₂ (water/CO₂)
- ❑ Concerns and limitations:
 - ❑ Takes month and delays investment decisions
 - ❑ Abundance of rock types
 - ❑ Spatial variation in the geological reservoir
 - ❑ Results from only sample under investigation without statistical variations

Two-phase Darcy:

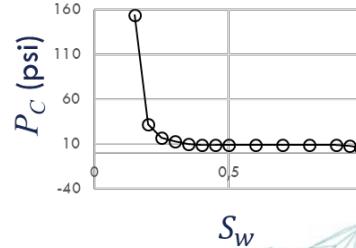
$$\vec{q}_i = -\frac{Kk_{r,i}(S_W)}{\mu_i}(\nabla P_i - \rho_i \vec{g})$$

Fluid mobility

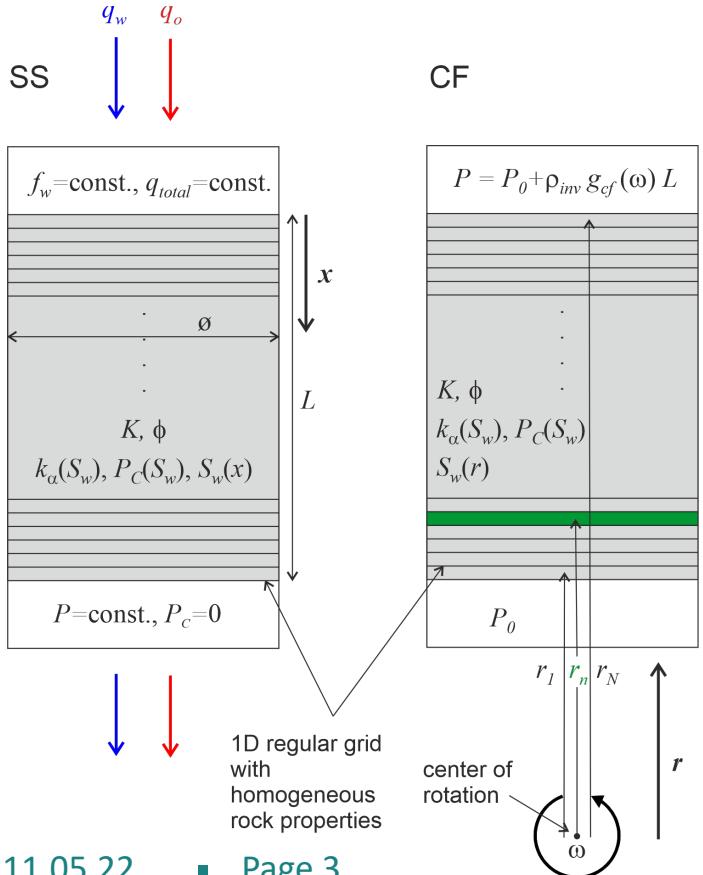
$$P_C(S_W) = P_o - P_w$$



Capillary pressure



Simulation Domain and Equations



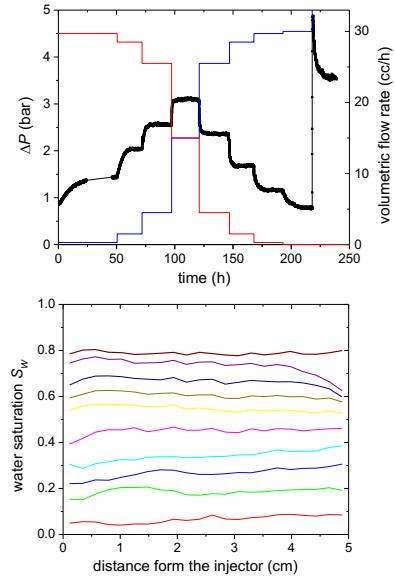
- Non-proprietary/non-commercial SCAL-data interpretation tool
- Immiscible-incompressible flow in 1D implemented in MRST

$$\phi \partial_t (S_\alpha) + \nabla \vec{q}_\alpha = Q_\alpha$$

$$\vec{q}_\alpha = - \frac{K k_{ra}}{\mu_\alpha} (\nabla p_\alpha - \rho_\alpha g) \quad \alpha = o, w$$

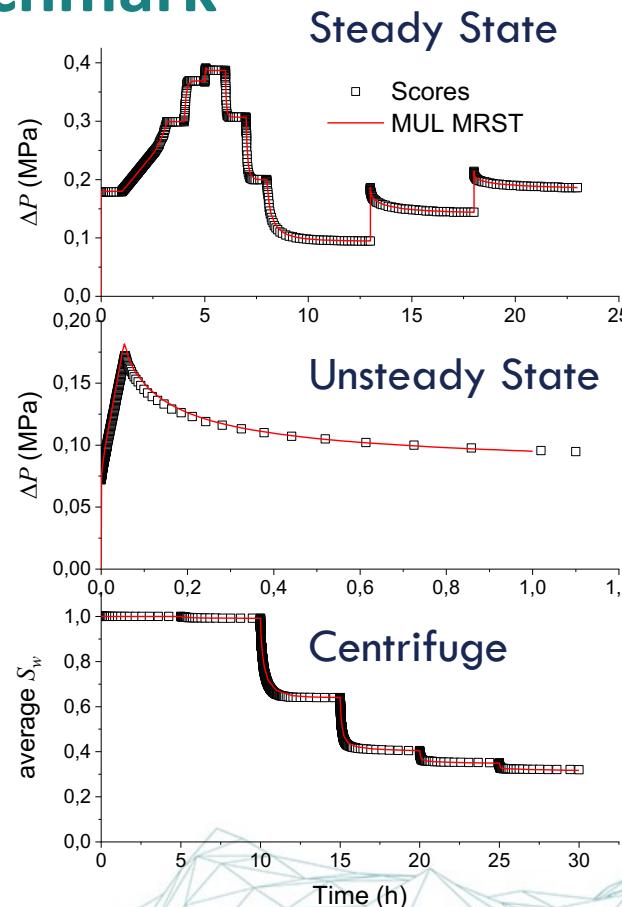
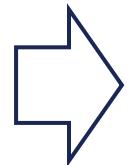
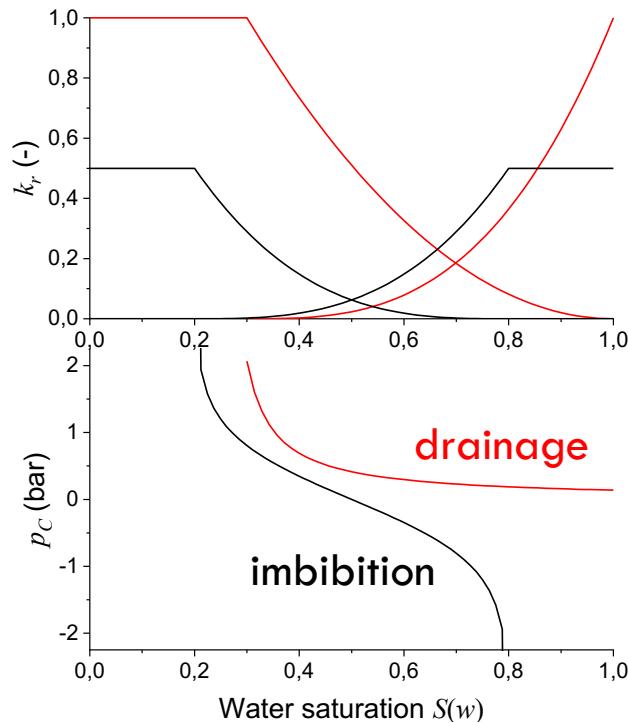
$$P_{right} = P_0 + \Delta \rho g_{CF} L$$

$$g_{CF} = \omega^2 r_m$$



Synthetic Data Set – Benchmark

Synthetic input → forward simulation



Benchmarked
against synthetic
dataset from
Lenormand et al.
(2017)

- Scores
- Sendra
- ...



Implementation in
MRST



Simulation Strategy

Experiment

e.g. SS and centrifuge

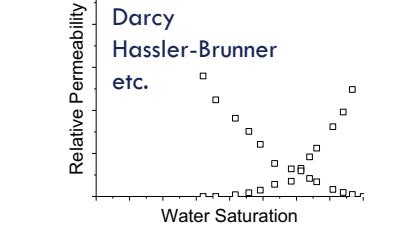


Compute analytical solutions

Initial
 $k_r(S_w), p_c(S_w)$

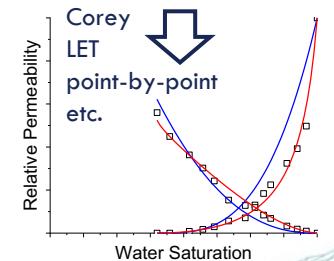
Compare and choose representation of $f(S_w)$

Starting point
for numerical simulation
 $k_r(S_w), p_c(S_w)$ parametrized



$$k_{rw} = k_{rw}(S_{or}) \left(\frac{S_w - S_{wc}}{1 - S_{wc} - S_{or}} \right)^{nw}$$

$$k_{ro} = k_{ro}(S_{wc}) \left(\frac{1 - S_w - S_{or}}{1 - S_{wc} - S_{or}} \right)^{no}$$



Simulation Strategy

Experiment

e.g. SS and centrifuge



Compute analytical solutions

Initial
 $k_r(S_w), p_c(S_w)$

Compare and choose representation of $f(S_w)$

History matching

Minimizing objective function
simultaneous for multiple data sets

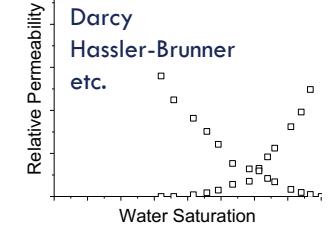
Starting point
for numerical simulation
 $k_r(S_w), p_c(S_w)$ parametrized

MRST

MATLAB

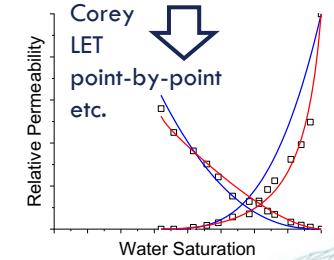
Optimization
Toolbox

$$J = \frac{\sum_{i=1}^{N_{obs}} \left(\frac{d_i - y_i}{d_i} \right)^2}{N_{obs}}$$

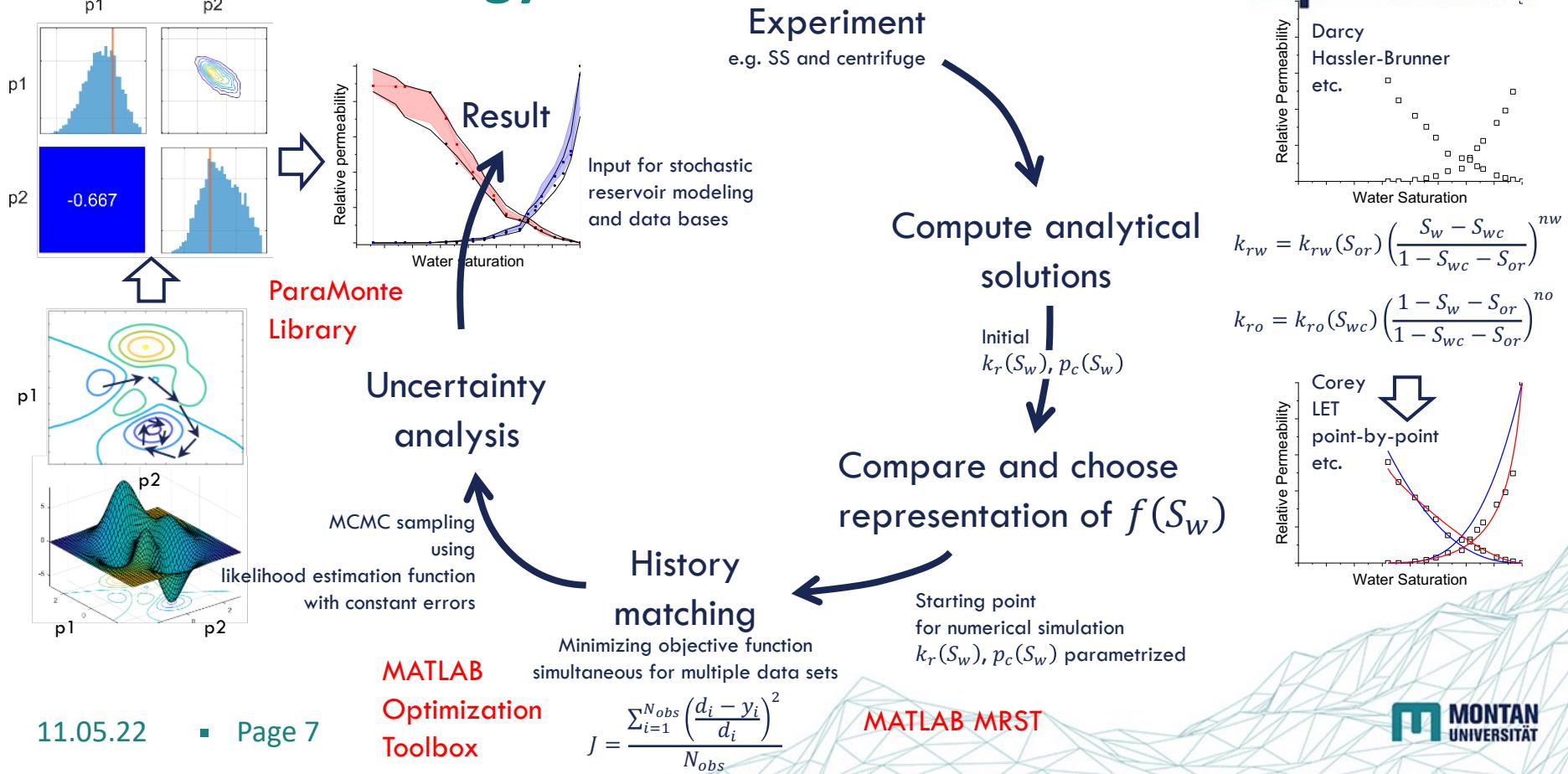


$$k_{rw} = k_{rw}(S_{or}) \left(\frac{S_w - S_{wc}}{1 - S_{wc} - S_{or}} \right)^{nw}$$

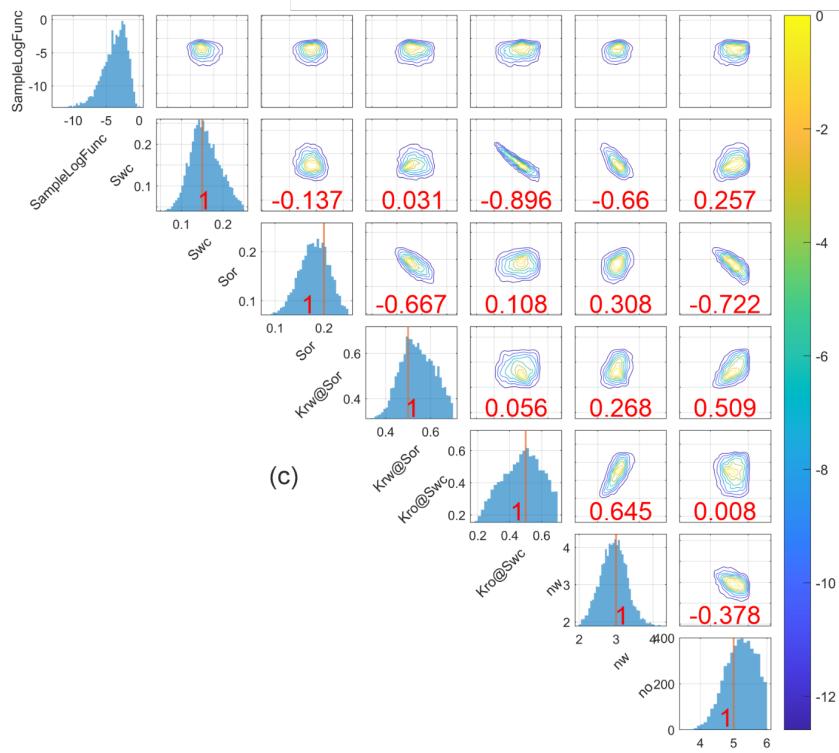
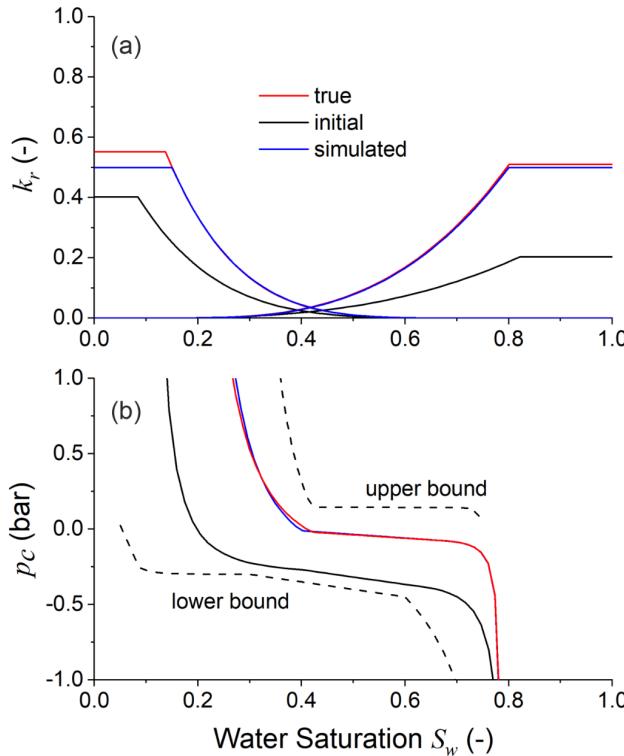
$$k_{ro} = k_{ro}(S_{wc}) \left(\frac{1 - S_w - S_{or}}{1 - S_{wc} - S_{or}} \right)^{no}$$



Simulation Strategy



Synthetic Data Set – Benchmark (History match)



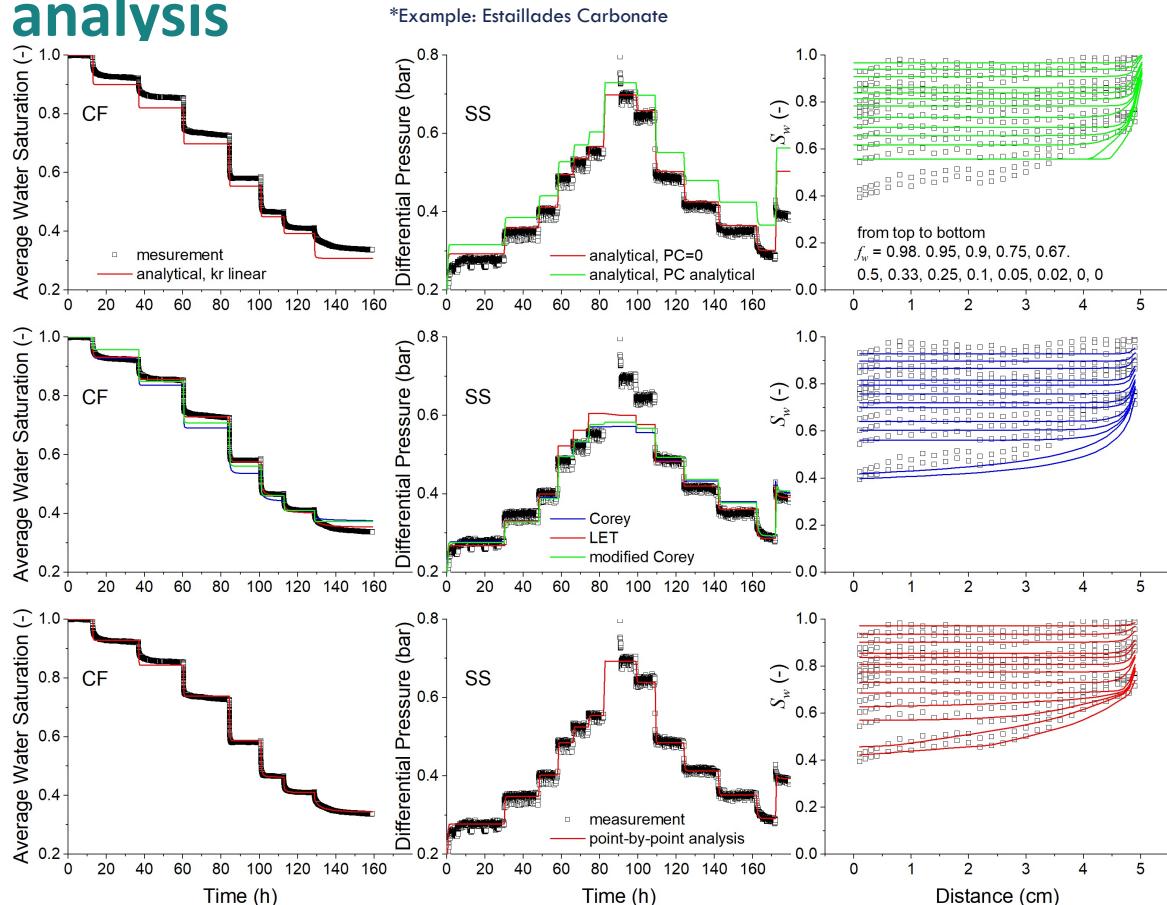
Benchmarked
against synthetic
dataset from Loeve,
et al., 2011

- Simultaneous USS and Centrifuge imbibition
- Corey for kr and Skjæveland for pc

Development of DPE SCAL simulator

Conventional laboratory analysis

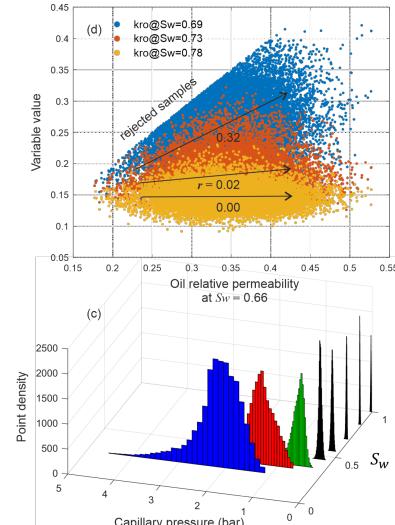
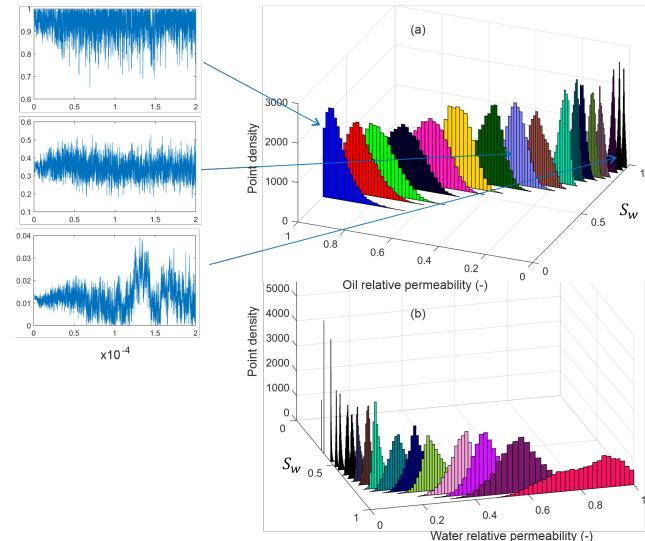
- ❑ Analytical data evaluation = insufficient
- ❑ Analysis done in sequence causing inconsistent results
- ❑ Different representations for complex saturation functions
- ❑ Uncertainty modeling → robust input to stochastic RE modeling



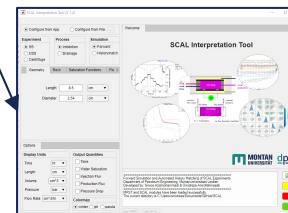
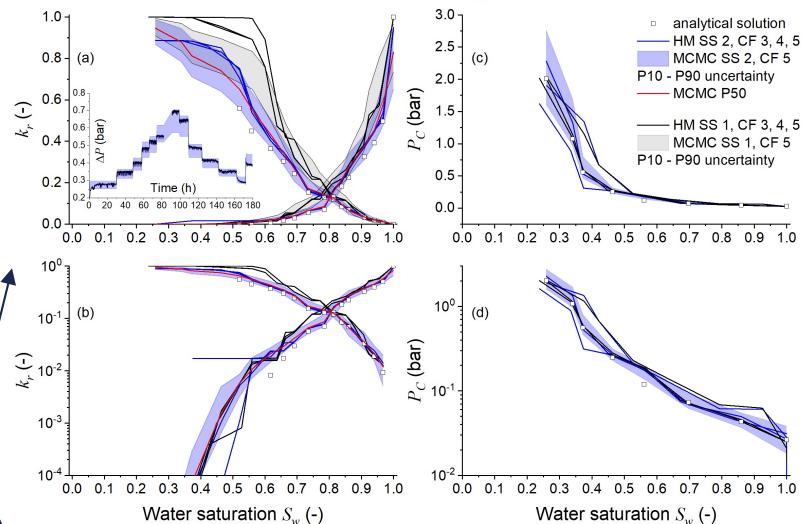
Development of DPE SCAL simulator

Conventional laboratory analysis

Estailles Carbonate



*Example: Estailles Carbonate



Simultaneous Interpretation of SCAL Data with Different Degrees of Freedom and Uncertainty Analysis

Omideza Amrollahinasab, Siroos Azizmohammadi and Holger Ott* - Under review

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*Open source to be a part of the main
MRST package



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Questions?

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