SCA Course 2019

Numerical History Matching of SCAL data

- How -

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Numerical History Matching of SCAL data

Outline

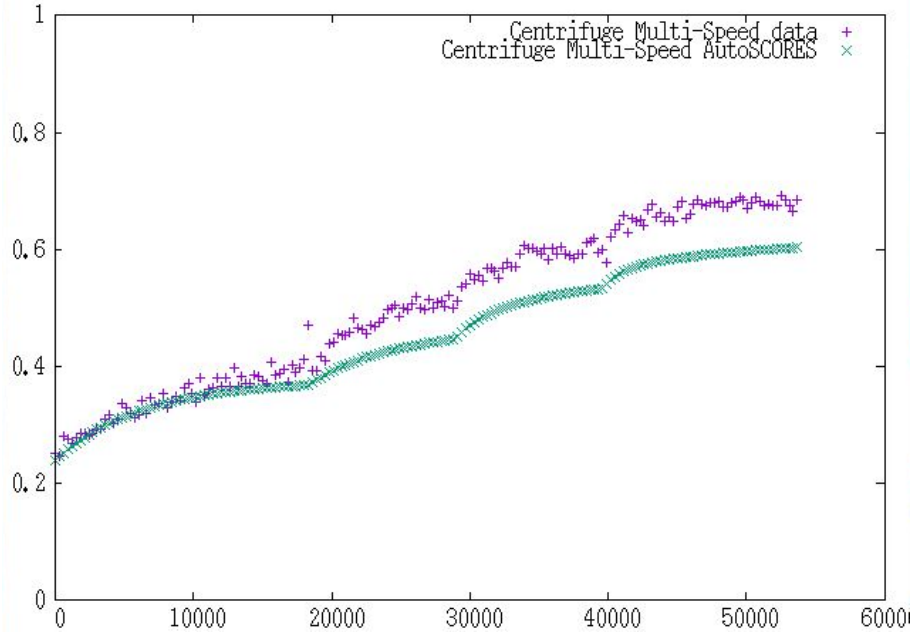
- Workflow
- Brief discussion of mathematics of automatic history matching
- Right choice of combination of experiments
- Plug selection
- Uncertainty in final results

Interpretation-by-simulation: *Workflow*

	Flow exp for krw, kro production data	**Multi-speed centr for Pc production data**
• Base analysis (analytical)	JBN or just Darcy eq. assuming Pc=0	H-B and/or Forbes assuming kr's negligible
• First iteration	include Pc from multi-speed	include kr's from flow exp
observe:	*mismatch exp prod data*	*mismatch exp prod data*

- Adjust krw, kro and Pc tables
- Second iteration with common set of kr's and Pc: rerun simulations, check match with exp prod data
- Adjust krw, kro and Pc tables
- Continue iterating until match exp prod data of each method within noise levels

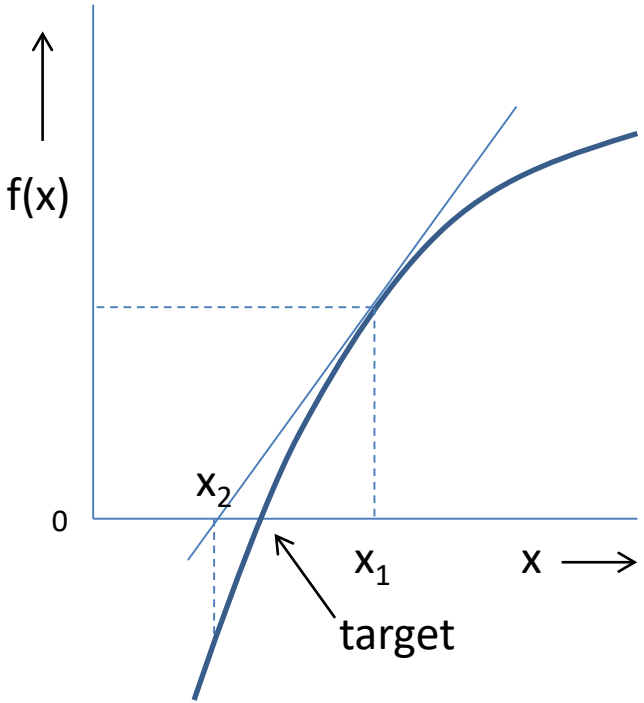
Mathematics of automatic history matching



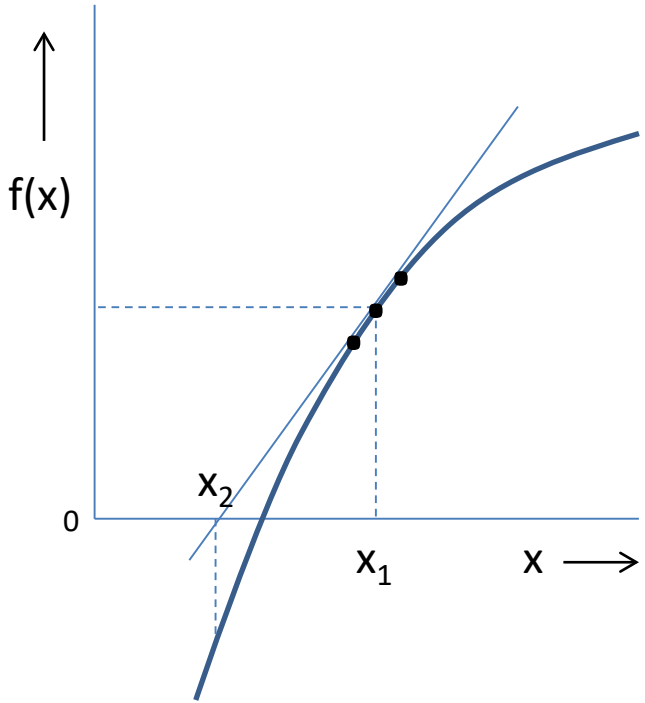
- A match corresponds to a minimal difference between the curves
- Differences along the curve are squared and summed into one number

Mathematics of automatic history matching

Principle of Newton-Raphson



Practice in history matching, simplified



X stands for {Swc, Sor, krwor, nw, ….}

• stands for one simulation

Software for automatic history matching

- AutoSCORES (PanTerra Geoconsultants)
- CYDAR (CYDAREX)
- PORLAB (D&B Ruth Enterprises)
- SENDRA (PRORES)

Numerical History Matching of SCAL data

A good match is no guarantee for a representative “true” set of relative permeabilities and capillary pressure function

- Accidentally, a local optimum can be found
- Ambiguity is large if only one experiment is analysed

Numerical History Matching of SCAL data

- Ambiguity is much reduced in practice when a combination of experiments is matched simultaneously
- Ambiguity remains for “unprobed” saturations
- Residual oil saturation is always lower than was observed in the lab

Choosing experiments to be history matched

Each experimental method has its strength and weaknesses

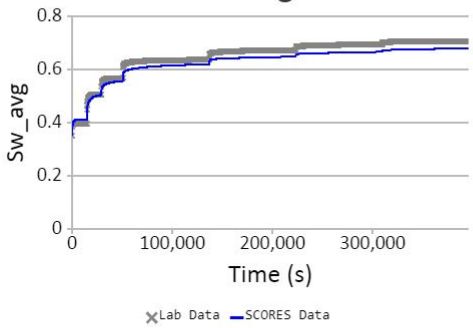
- Steady-State: probes mid-saturation range for k_{rw} and k_{ro}
- Unsteady-State (Welge): see SS, but limited to saturations above “shock front” saturation (possibly > 0.5)

Choosing experiments to be history matched

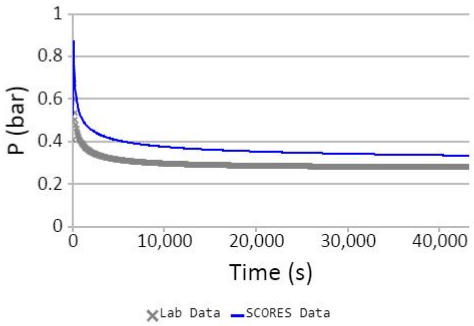
Each experimental method has its strength and weaknesses

- Multi-speed centrifuge: probes capillary pressure function for either forced imbibition or forced drainage
- Porous-Plate: probes capillary pressure function, full range, but very time consuming (3 to 6 months)
- Single-speed centrifuge: probes tail-end relative permeability of displaced phase

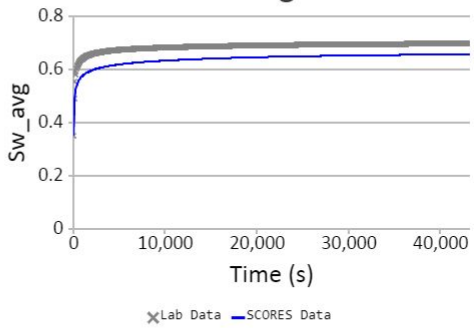
AutoSCORES Multi-Speed Centrifuge



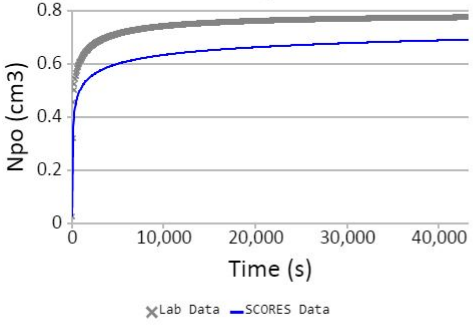
AutoSCORES Unsteady-State dP



AutoSCORES Single-Speed Centrifuge



AutoSCORES Unsteady-State Cum. Oil prod.



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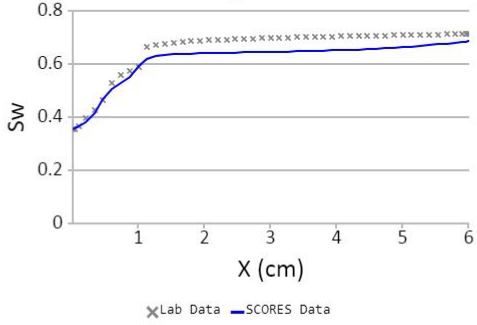

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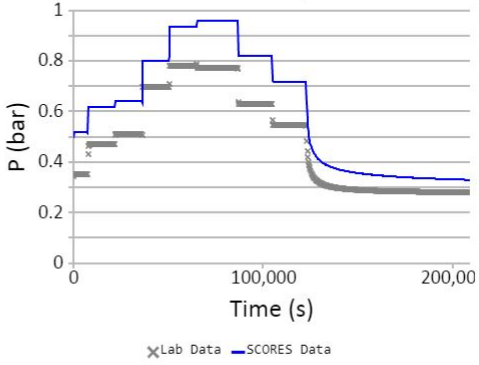

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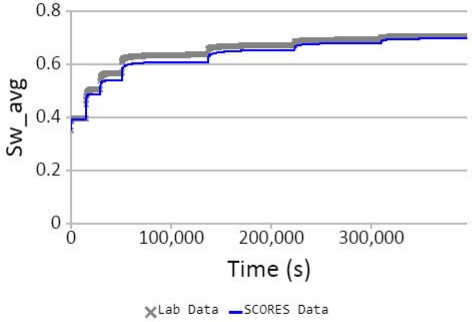

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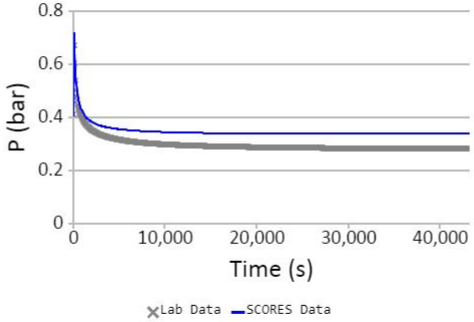

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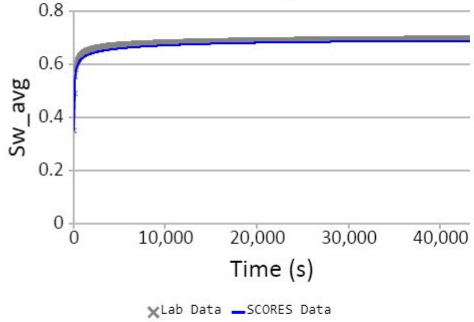

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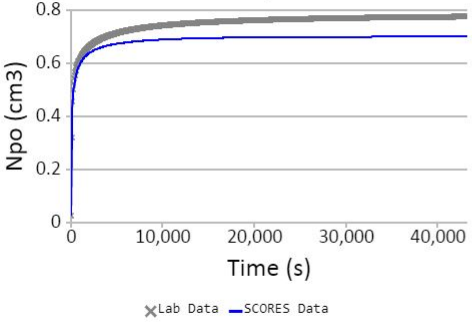

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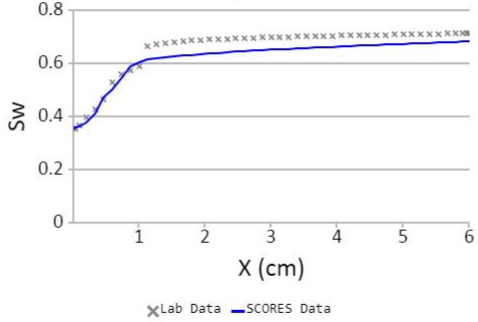

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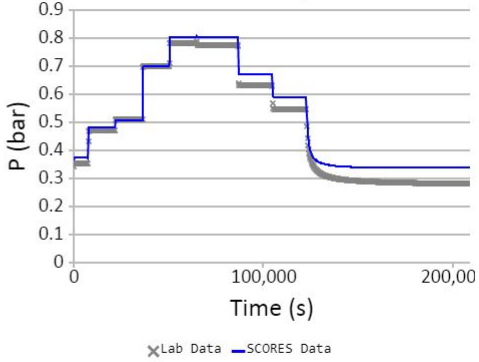

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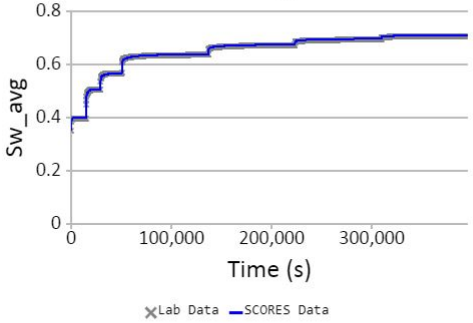

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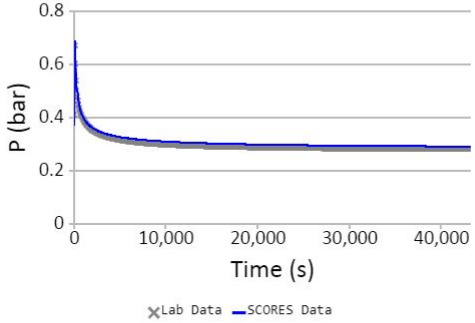

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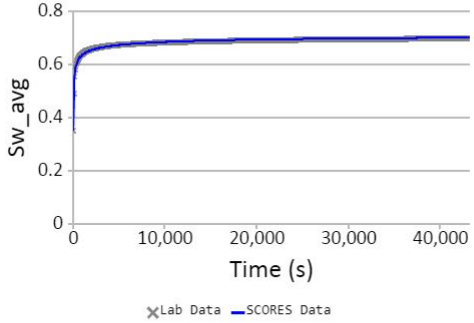

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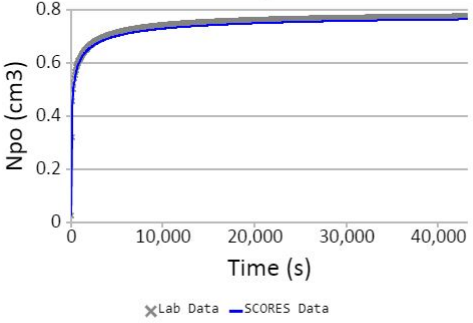

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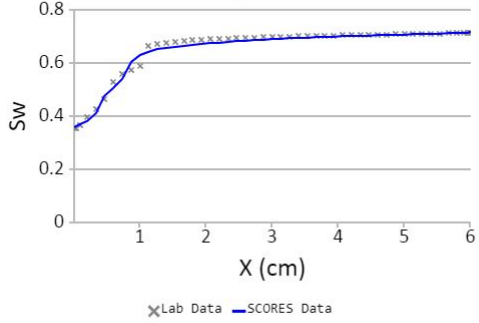

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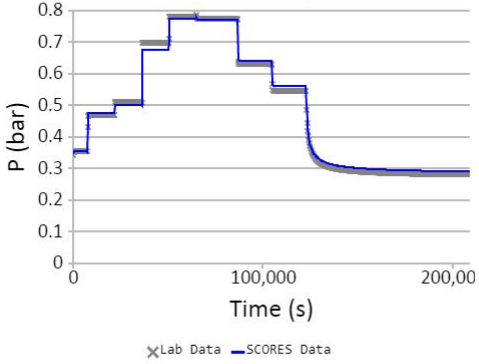

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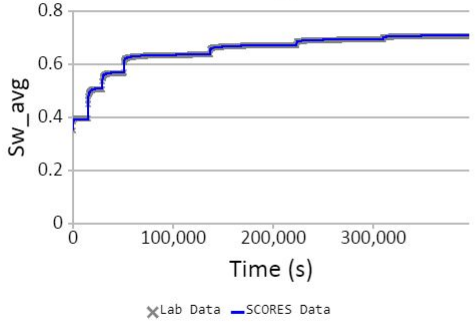

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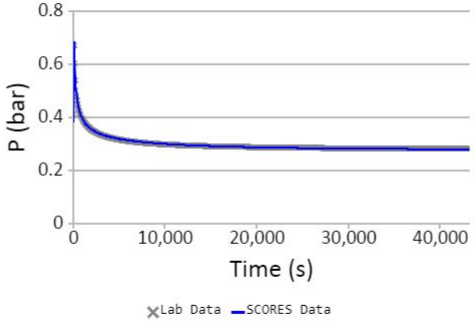

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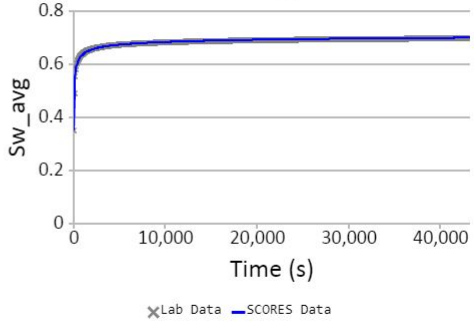

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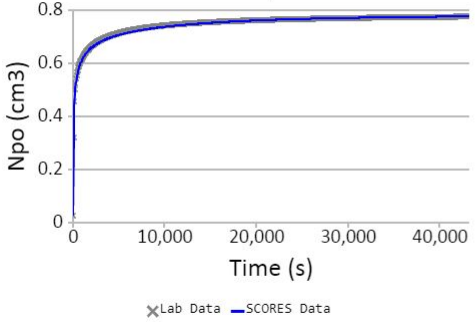

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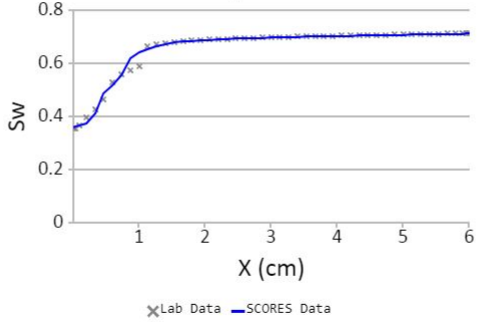

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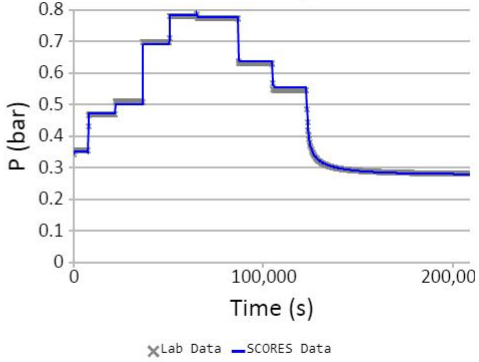

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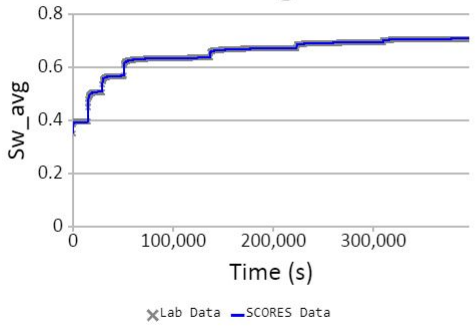

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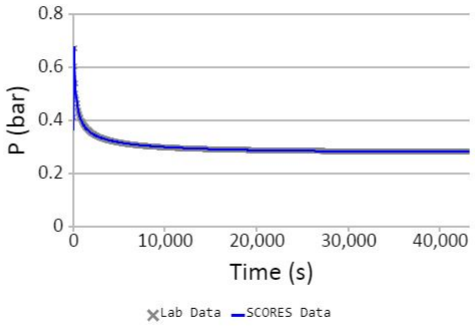

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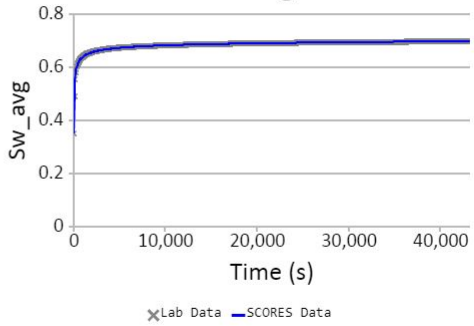

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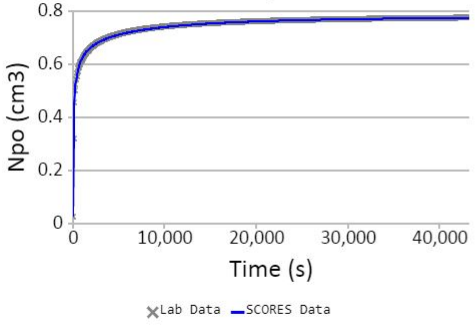

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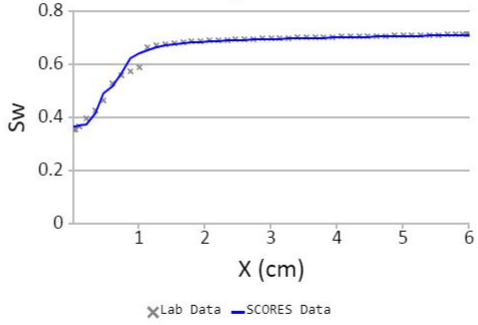

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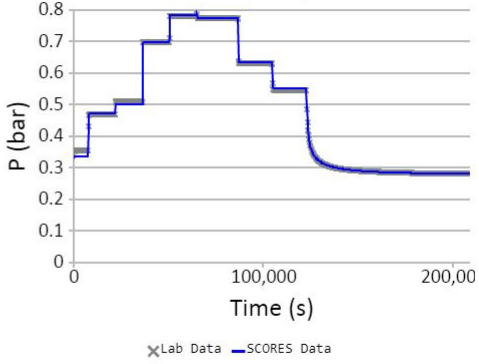

Representative data require representative core plugs

Representative plugs

- For the reservoir
  - Flow zone
  - Wettability
- For data analysis: Homogeneity
  - Local features, e.g. streaks in a plug, may dominate the flow in the laboratory. Early water breakthrough in the lab may well be translated into early water breakthrough in field forecasts
  - Assess with X-ray CT, quantitatively. Cut-off explained in SCA2019-024

Uncertainty in final results

- Uncertainty is indicated by standard deviation in final Corey parameters, and may be estimated/reported by the history matching algorithm (AutoSCORES, CYDAR, PORLAB, SENDRA)
- Only valid if proper convergence has been reached in HM
- Only valid if at least two experiments were matched simultaneously
- Hidden important uncertainties due to sample selection
  - Need at least 3 plug samples per flow unit (SCA2019-024)
  - Value Of Information may drive larger number of samples

Conclusions

- Capillary end effects in the laboratory will bring about significantly higher apparent residual oil saturation than is actually the case
- True residual oil is usually 10 to 15 saturation units lower than reported after analytical interpretation
- Mature fields and EOR projects will be affected most by wrong S_{or} estimates

Conclusions

- Heterogeneities in core plugs can and should be managed
- Mutual interference of relative permeabilities and capillary pressure can only be unraveled by numerical history matching of the experiments

Numerical History Matching is the other half of the experimental work