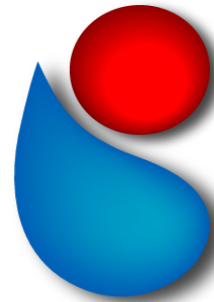




**Weatherford**<sup>®</sup>



**Sendra**



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# Sendra

A tool for proper QC of Relative permeability  
and Capillary pressure



# Sendra

- **Sendra** is a state of the art – analysis tool for your SCAL project – Relative permeability and Capillary pressure
- **Sendra** includes a modern user interface with advance plotting option. Administrate your entire SCAL project – several cases and experiments – in one file/project.
- **Sendra** can be used for analysis and quality check for individual experiments as well as analyzing all relative permeabilities determined within a project – commonly for a field or a well



# Sendra

- Sendra is a tailor-made user-friendly core-flood simulation tool for extensive study of multi-phase flow experiments
- Fully implicit, black oil formulation based on Darcy's law and the continuity equation
- Two-phase flow in 1D
- All standard SCAL flow scenarios
- All standard Relative permeability and Capillary pressure correlations

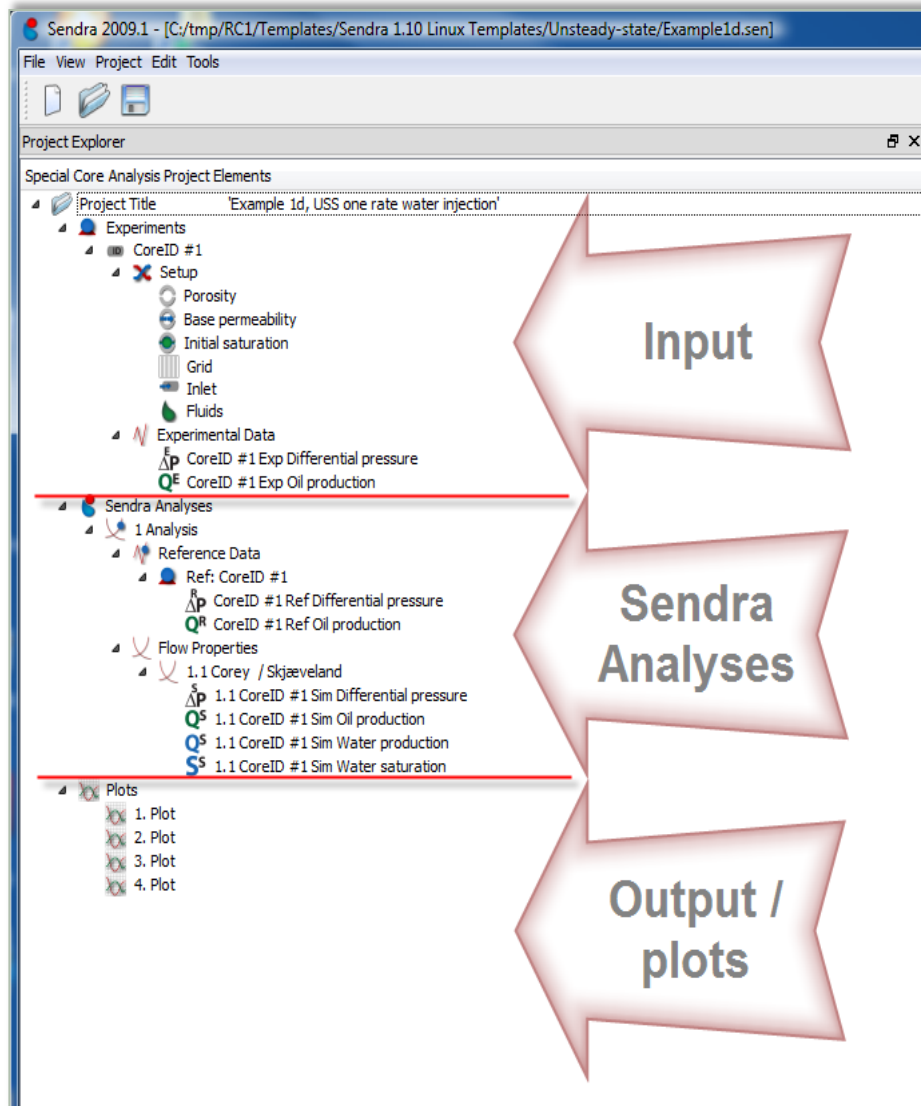
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**Sendra is based on research at IRIS, UiB and Texas A&M.  
Commercial since 1996**





# Project explorer



## Well organized:

- Input part
- Sendra analyses
- Output / flexible plots

**Sendra analysis:**  
**Reconciling experimental data  
for determination  $k_r$  and  $P_c$**



# Input wizard

Step-by-step wizard is used for proper input

New project...

Project Information

SCAL project: Field A

Customer: Customer A

Contractor: Service Company B

Date: 01.12.2011

Comments: Project for defining relative permeability for field applications

Experiment Information

Core ID: Core A

Depth: 3450

Field: Field C

Structure: Structure D

Well: 23-5/A8

Formation: Formation E

Fluid system:

Phases

- Water-Oil
- Oil-Gas
- Water-Gas

Process:

Imbibition

Drainage

Water-Oil description will be added here...

Scenario: Unsteady state - constant rate

Flow dir.: Horizontal

Bump flood(s)

Number of rate changes: 2

Use Wizard to fill in additional properties

Core Properties

Length: 25.000 cm

Diameter: 3.780 cm

Porosity: 0.230 frac.

Permeability: 250.000 mD

OK Cancel

Wizard - New project...

**WATER-OIL experiment**  
UNSTEADY STATE - HORIZONTAL

Fluid properties

Water viscosity: 0.360 cP

Oil viscosity: 1.230 cP

Initial conditions

Initial water saturation: 0.150 frac.

Constant rate conditions

Water injection rate: 2.000 cm3/min

Input table for rate increases

	Start time	Water injection rate	Ramp time
	min	cm3/min	min
1	1000.000	4.000	1.000
2	4500.000	5.000	2.000

Time conditions

Total simulation time: 5000.000 min

Advanced

Compressible fluids

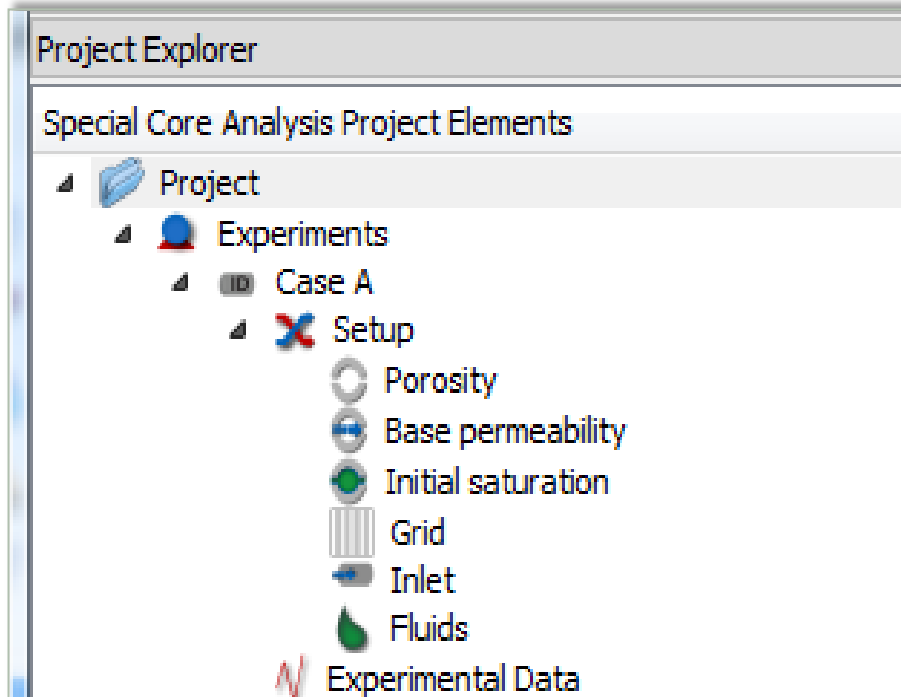
Water compressibility: 0.000000e+00 kPa-1

Oil Compressibility: 0.000000e+00 kPa-1

Finish Cancel

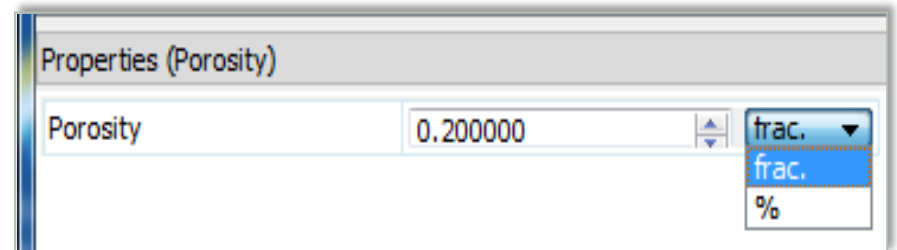
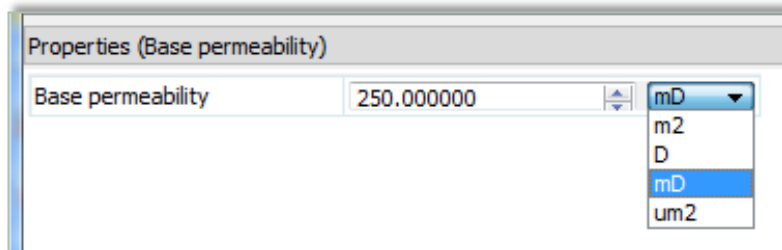


# Input



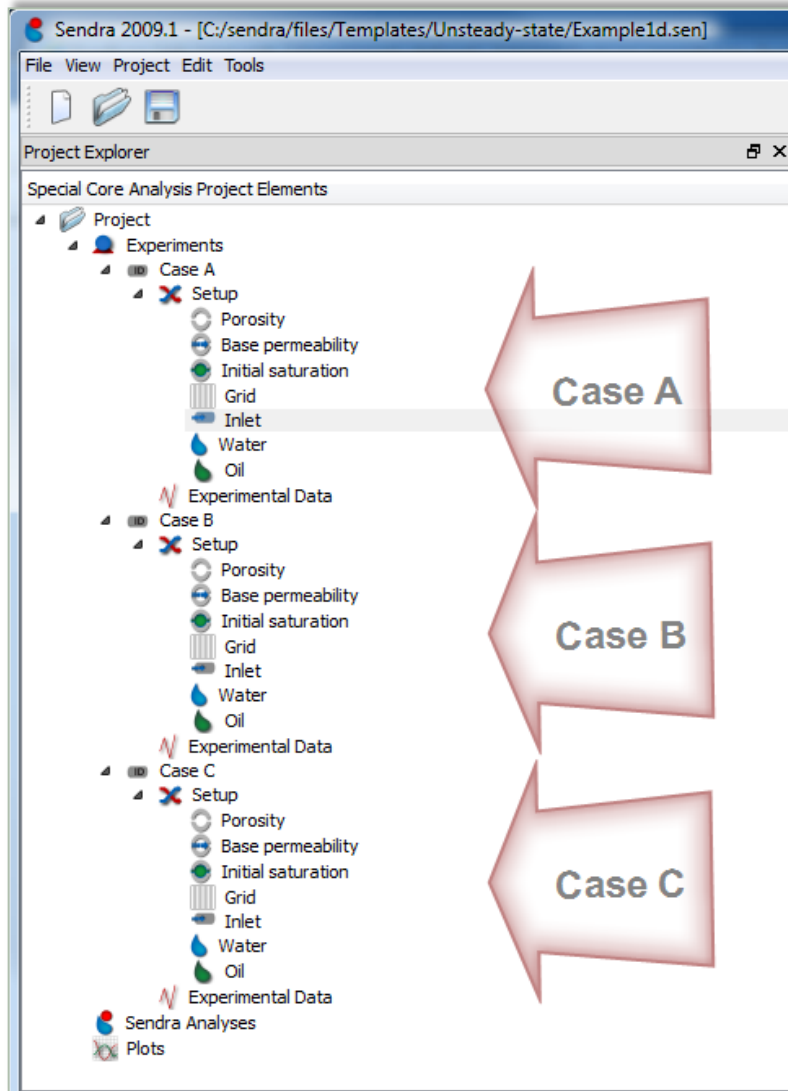
Includes all properties available from a two-phase flow experiment

- Each item can be edited
- Units can be changed





# Input – several cases

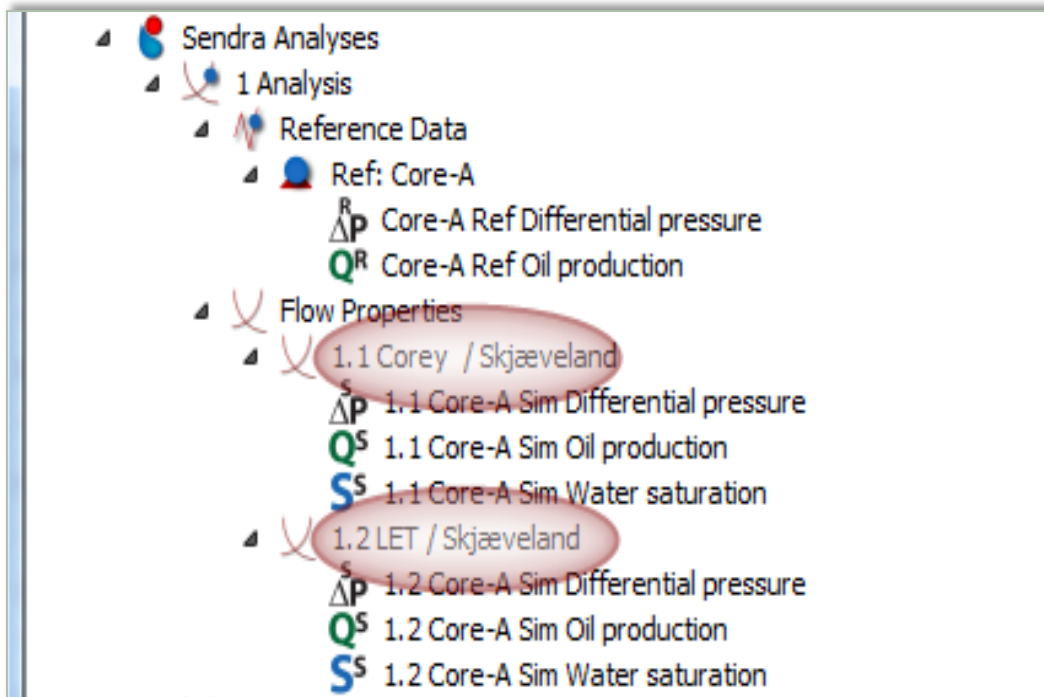


- Several experiment/cases can be included in one project
- Enable you to administrate all cases in the entire SCAL project
- Easy comparison of result among individual cases



# Sendra analyses

Where you perform the analysis – either simulation or estimation – based upon the data given in the upper part of the project explorer



Several correlations can be utilized for:

- Relative permeability
- Capillary pressure



# Flow properties

The correlation for Relative permeability and Capillary pressure are selected from a drop-down list

Relative permeability: LET

Capillary pressure: Skj

Parameters for relative permeability

			Min	Max
$L_w$	5	<input checked="" type="checkbox"/>	1	inf
$E_w$	1.8	<input checked="" type="checkbox"/>	0.5	inf
$T_w$	0.8	<input type="checkbox"/>	0.5	inf
$L_o$	3.5	<input checked="" type="checkbox"/>	1	inf
$E_o$	1.5	<input checked="" type="checkbox"/>	0.5	inf
$T_o$	0.7	<input checked="" type="checkbox"/>	0.5	inf
$k_{rw}(S_{or})$	0.6	<input checked="" type="checkbox"/>	0	1
$k_{ro}(S_{wr})$	1	<input type="checkbox"/>	0	1

Saturation values

	Value		Min	Max
$S_{wr}$	0.15	<input type="checkbox"/>	0	1
$S_{or}$	0.1	<input checked="" type="checkbox"/>	0	1

Relative permeability: LET

Capillary pressure: Skjæveland

Parameters for relative permeability

			Min	Max
$L_w$				
$E_w$				
$T_w$	0.8	<input type="checkbox"/>	0.5	inf
$L_o$	3.5	<input checked="" type="checkbox"/>	1	inf
$E_o$	1.5	<input checked="" type="checkbox"/>	0.5	inf
$T_o$	0.7	<input checked="" type="checkbox"/>	0.5	inf
$k_{rw}(S_{or})$	0.6	<input checked="" type="checkbox"/>	0	1
$k_{ro}(S_{wr})$	1	<input type="checkbox"/>	0	1

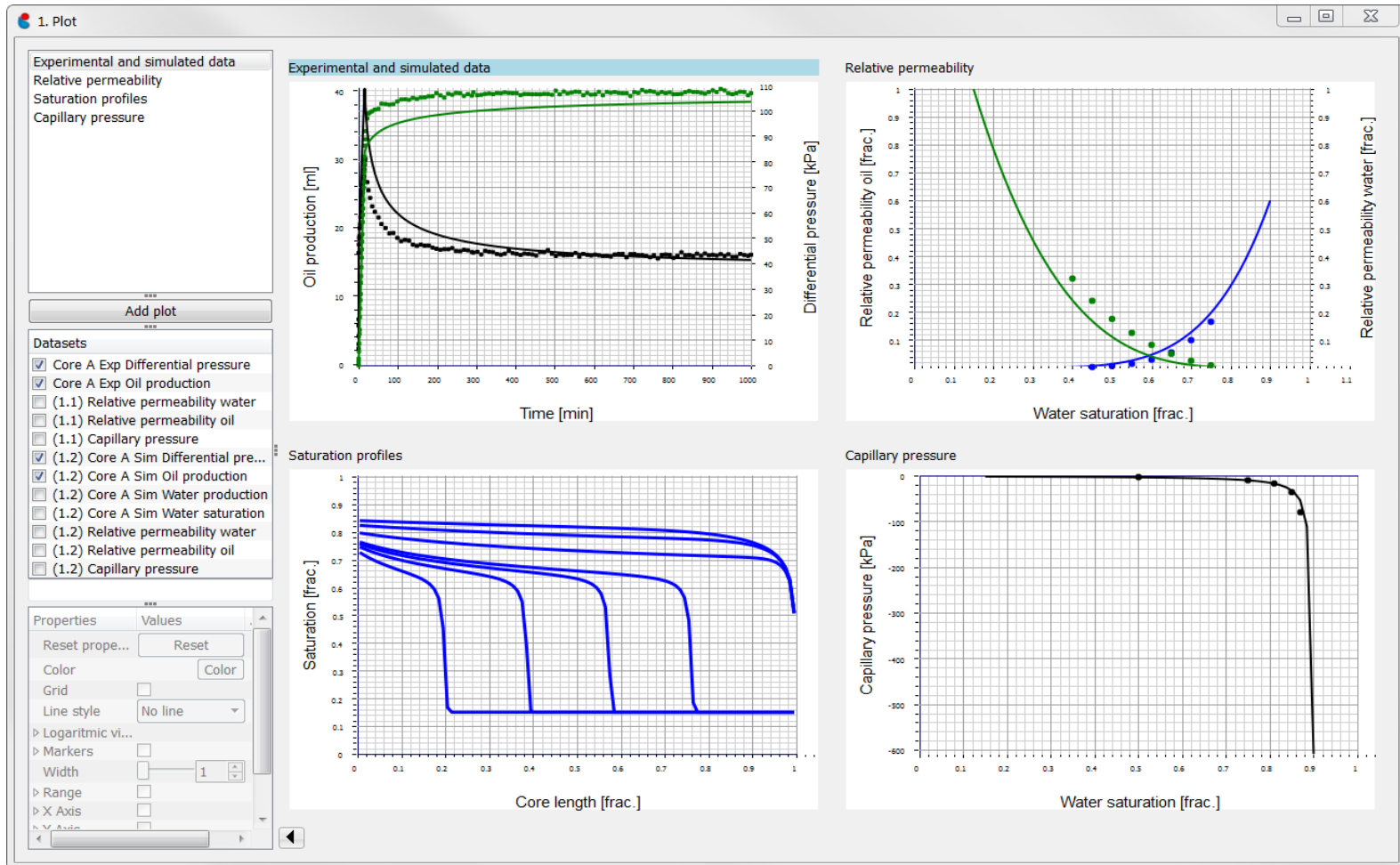
Saturation values

	Value		Min	Max
$S_{wr}$	0.15	<input type="checkbox"/>	0	1
$S_{or}$	0.1	<input checked="" type="checkbox"/>	0	1



# Plot feature

Flexible and easy to use – a number of properties can be plotted and compared





# Flexibility

Project Explorer

Special Core Analysis Project Elements

- Project Title 'Example 1d, USS one rate water injection'
- Experiments
  - Unsteady-state
    - Setup
      - Porosity
      - Base permeability
      - Initial saturation
      - Grid
      - Inlet
      - Fluids
    - Experimental Data
      - Unsteady-state Exp Differential pressure
      - Unsteady-state Exp Oil production
  - SS centrifuge
    - Setup
      - Porosity
      - Base permeability
      - Initial saturation
      - Grid
      - Inlet
      - Fluids
    - Experimental Data
      - SS centrifuge Exp Oil production
  - MS centrifuge
    - Setup
      - Porosity
      - Base permeability
      - Initial saturation
      - Grid
      - Inlet
      - Fluids
    - Experimental Data
      - MS centrifuge Exp Oil production
- Sendra Analyses

Several experiments/cases

Several Sendra analyses

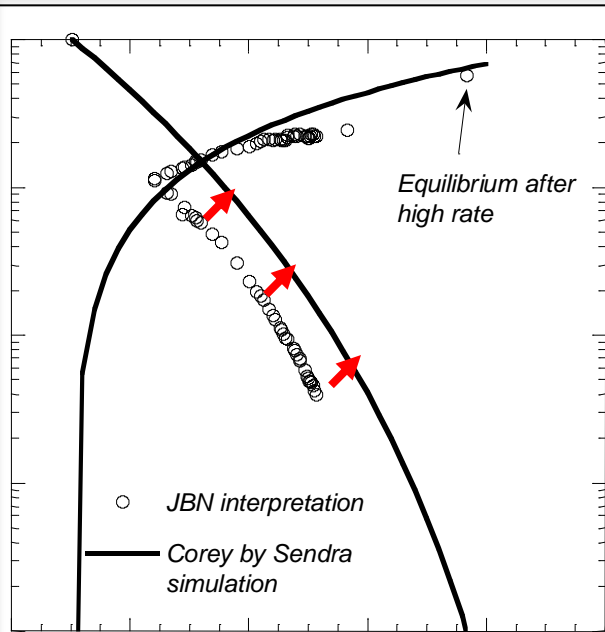
Sendra Analyses

- 1 Analysis
  - Reference Data
    - Ref: Unsteady-state
  - Flow Properties
    - 1.1 Corey / Skjæveland
    - 1.2 LET / LET - imbibition
- 2 Analysis
  - Reference Data
    - Ref: Unsteady-state
    - Ref: SS centrifuge
  - Flow Properties
    - 2.1 Corey / Skjæveland
    - 2.2 LET / Skjæveland
- 3 Analysis
  - Reference Data
    - Ref: Unsteady-state
    - Ref: SS centrifuge
    - Ref: MS centrifuge
  - Flow Properties
    - 3.1 Corey / Skjæveland
    - 3.2 LET / Skjæveland

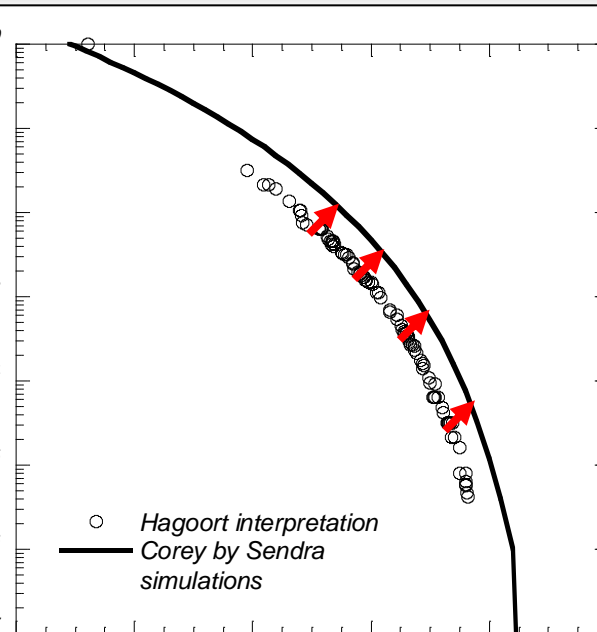


# Benefits by Sendra

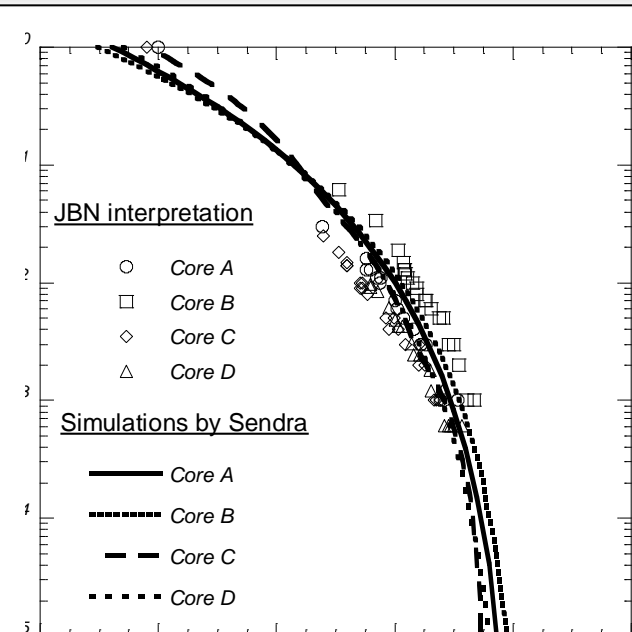
## Unsteady-state



## Single-speed centrifuge



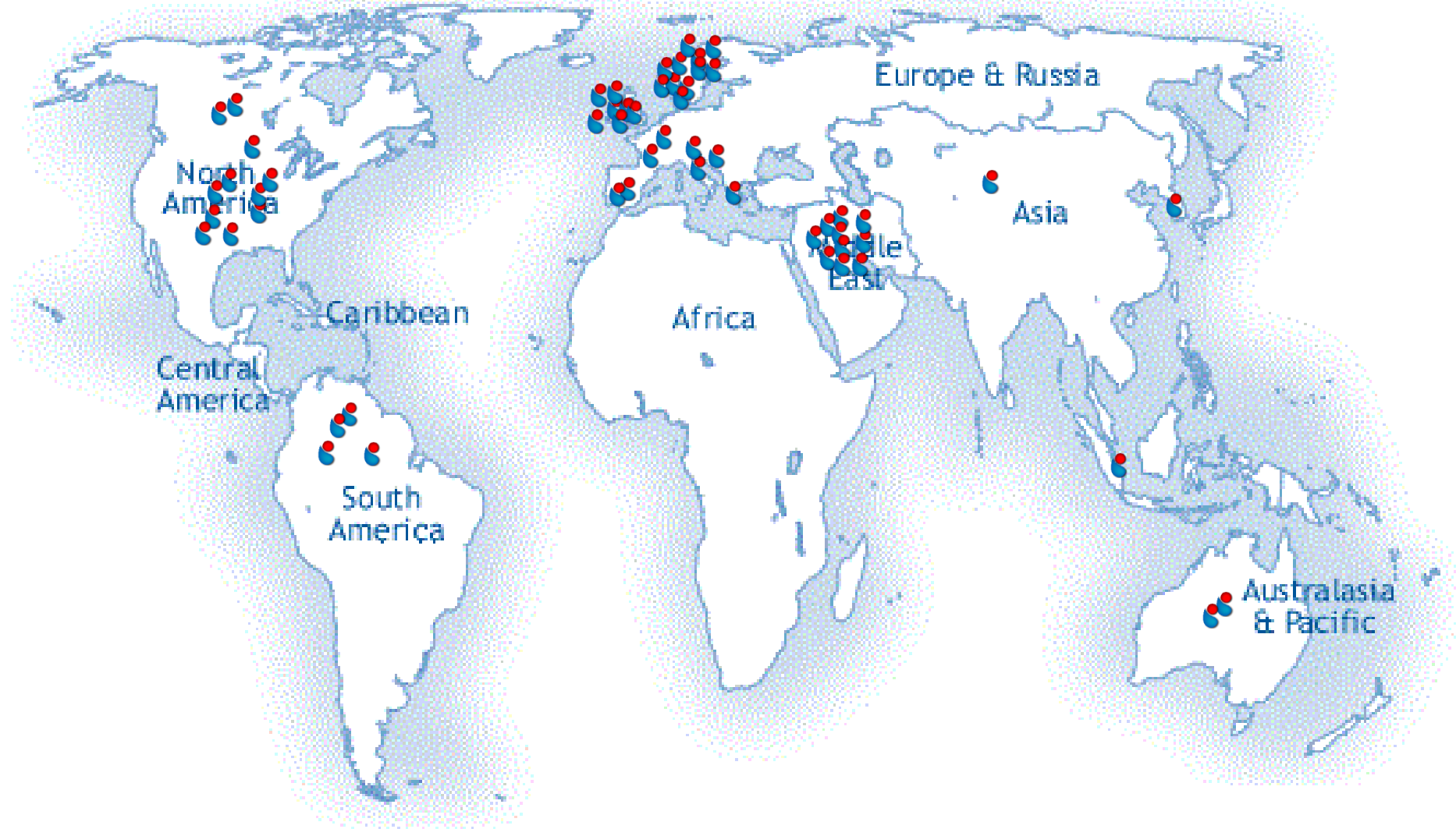
## 4 Unsteady-state

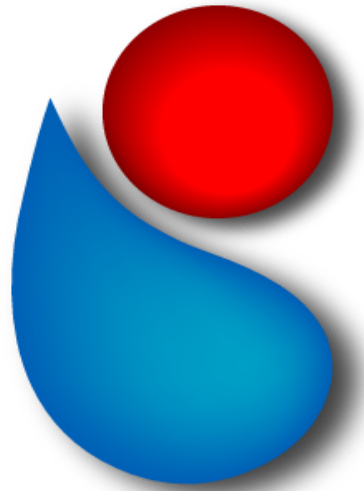


- Accounting for  $P_c$  may improve  $k_{r0}$  toward  $S_{or}$
- Simulations may reduce the uncertainty of final  $k_r$



# Sendra Worldwide





# Sendra

A tool suitable for reservoir engineers  
as well as SCAL analysts

We would like to make reservoir engineers **happy and comfortable** when  
using relative permeability and capillary pressure for full-field simulations