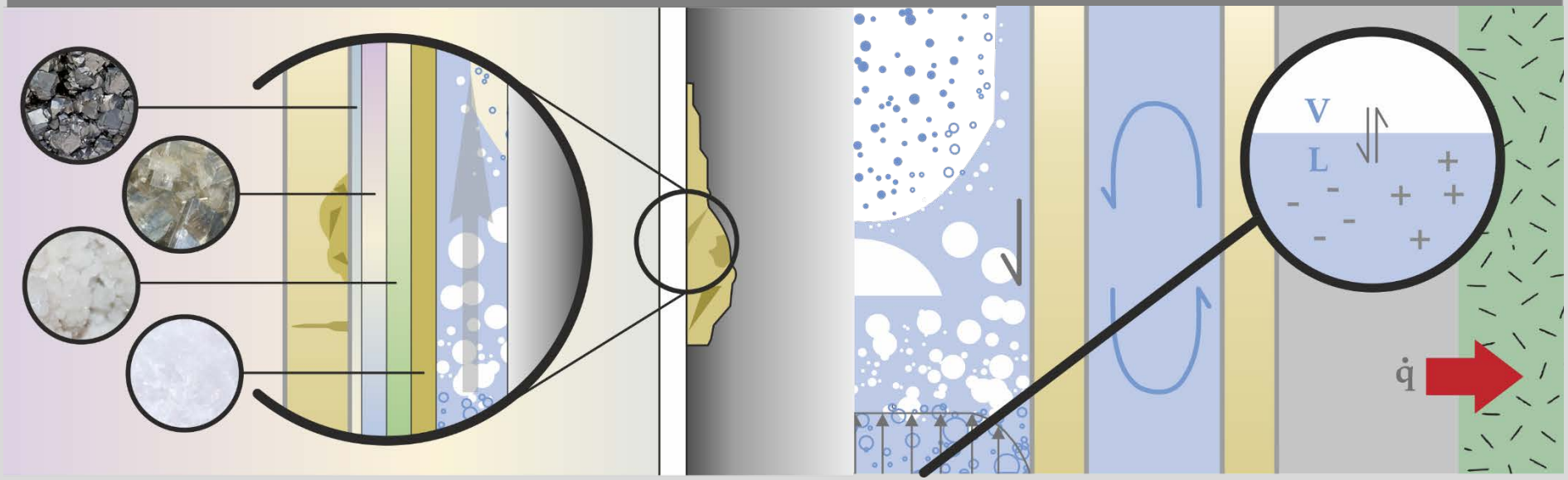
WellboreKit: A dynamic thermohydro-chemical wellbore model for two-phase multicomponent geothermal fluids

Yodha Nusiaputra, Alain Dimier, Roman Zorn and Thomas Kohl

Institute of Applied Geoscience (AGW), Karlsruhe Institute of Technology (KIT)



Outline

- Introduction
- gEOSkit: Geofluid Equation of State (EoS)
- WellboreKit: One-fluid two-phase wellbore model
- Conclusions and outlook

Introduction

- Importance of wellbore simulator
  - Downhole condition prediction during stimulation (Megel et al., 2005)
  - Wellhead temperature prognosis (Francke, 2014)
  - Mineral scaling
    - Calcite, barite, stibnite, silica, etc.
    - Halite clogging (Hesshaus, 2013)
  - Corrosion
    - Sulfide stress cracking is directly related to H_2S fugacity (Grimes, 2013)
  - Well sizing
  - Compute Productivity/Injectivity Index

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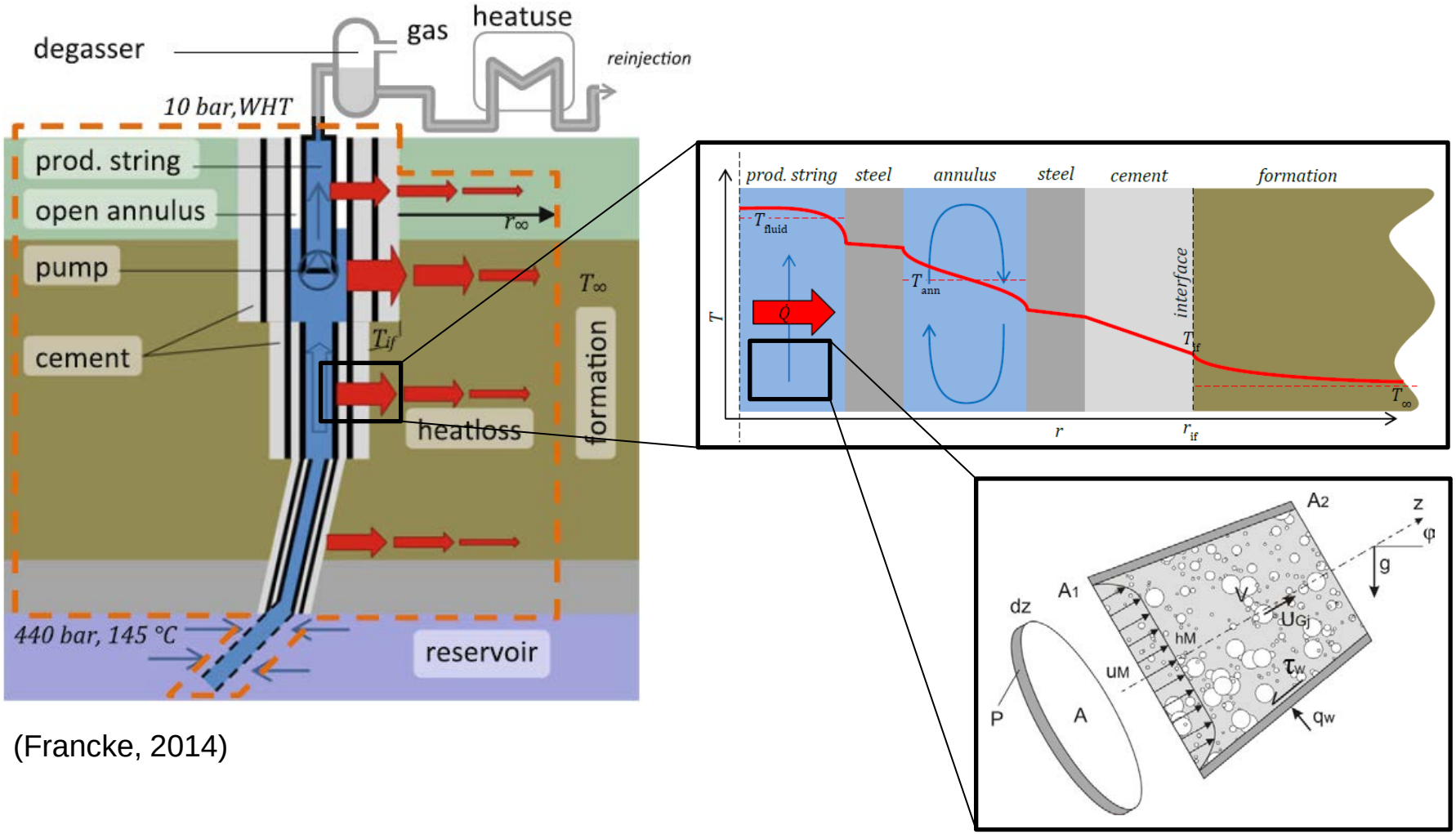
System description



(Francke, 2014)

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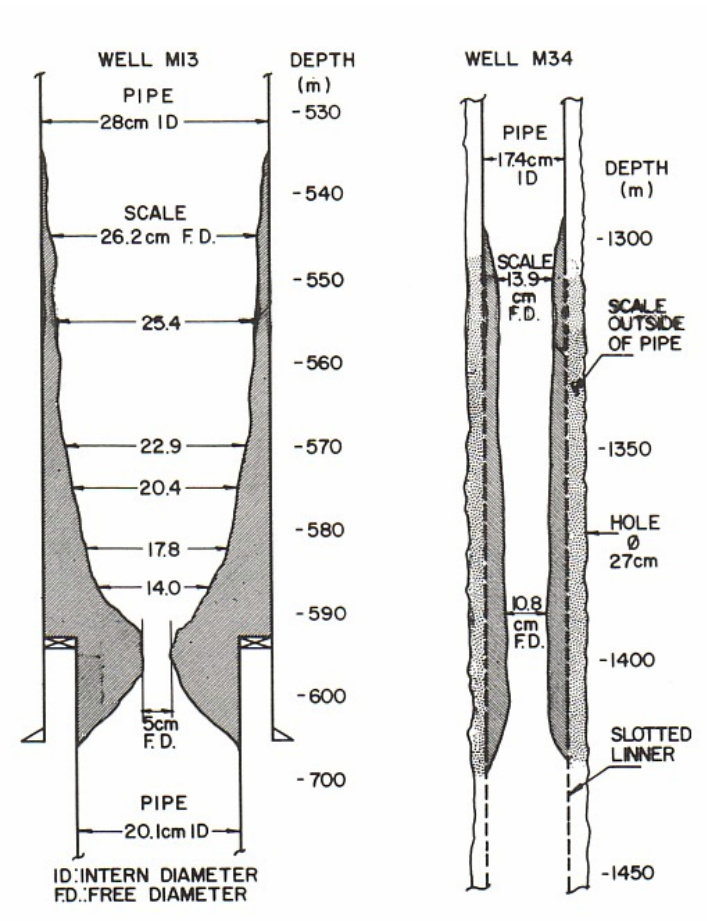
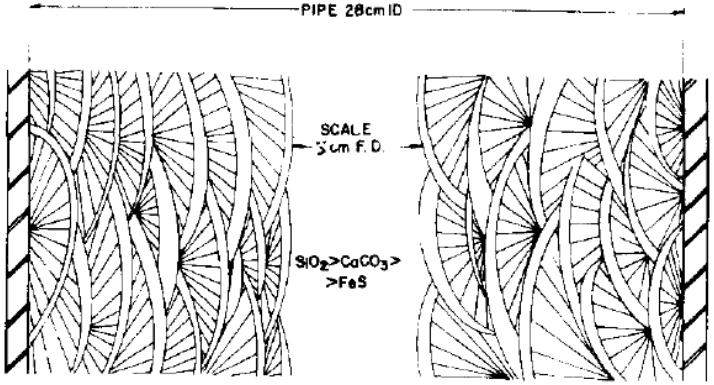
Downhole scaling in wellbores



(Ocampo et al, 2005)



(Mercado et al, 2005)

(Frick et al, 2011)

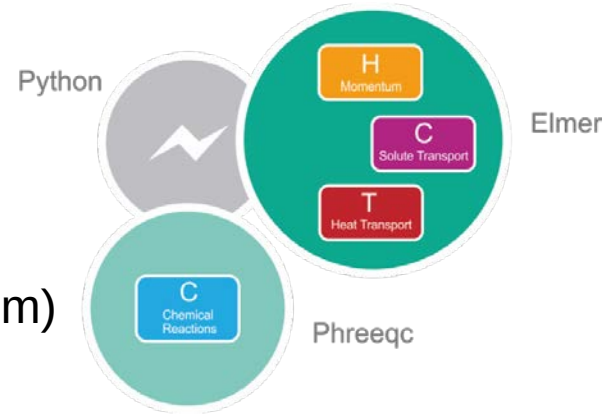
System of flow-equations to be solved

3 Equations:

$$\frac{\partial}{\partial t} A\rho + \frac{\partial}{\partial z}\dot{M} = 0 \qquad \text{(Mass)}$$

$$\frac{\partial}{\partial t}\dot{M} + \frac{\partial}{\partial z}\frac{\dot{M}^2}{A\rho} = -A\frac{\partial}{\partial z}p - P\tau_w - Ag\rho\sin\varphi \qquad \text{(Momentum)}$$

$$A\frac{\partial}{\partial t}\left(\varepsilon\rho^{NA}h^{NA} + (1-\varepsilon)\rho^{AQ}h^{AQ}\right) + \frac{\partial}{\partial z}\dot{M}\cdot h = A\frac{\partial}{\partial t}p + Pq_w \qquad \text{(Energy)}$$

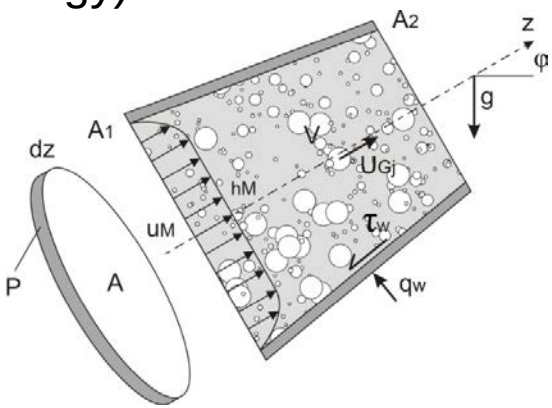


3 Unknowns:

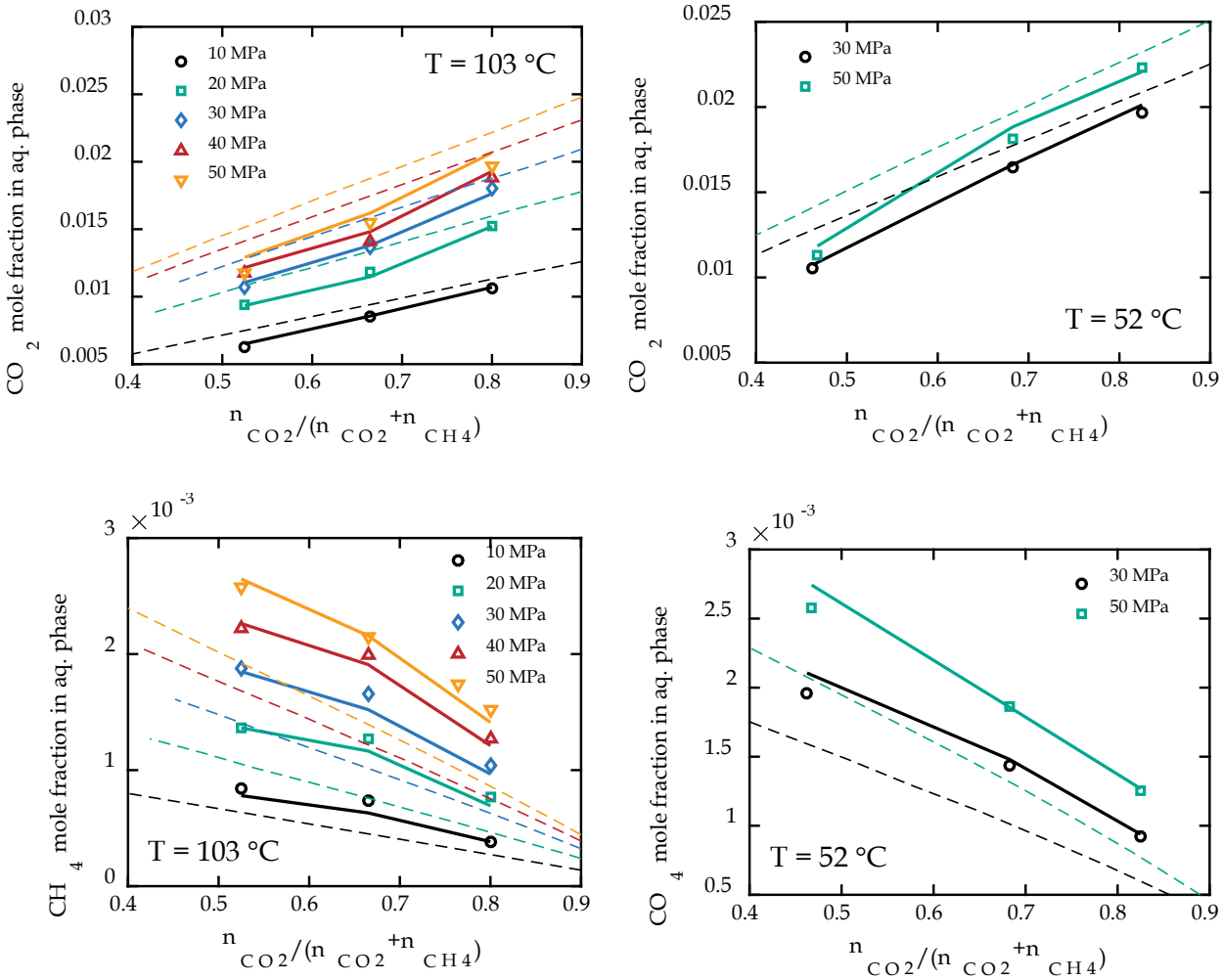
$\dot{M}, p, h$

+ solute transport

$$\boxed{\frac{\partial C_i}{\partial t} + \frac{\partial}{\partial z}uC_i = D_i\frac{\partial^2 C_i}{\partial z^2} + \cancel{S_i}}$$

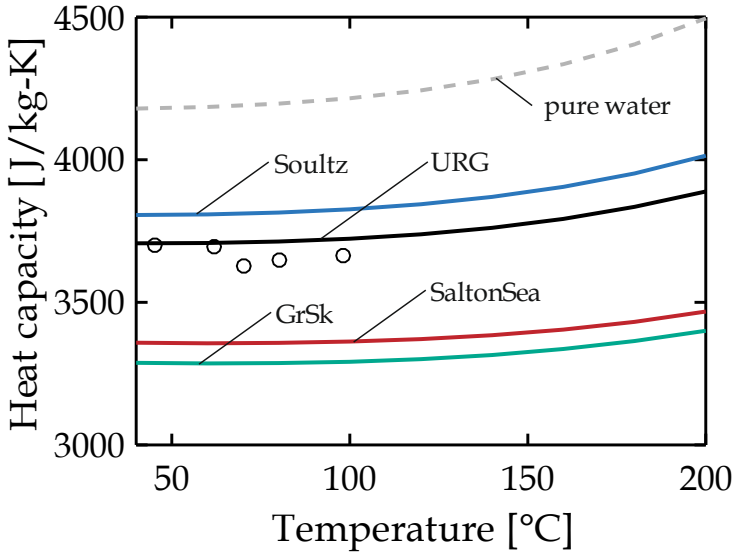


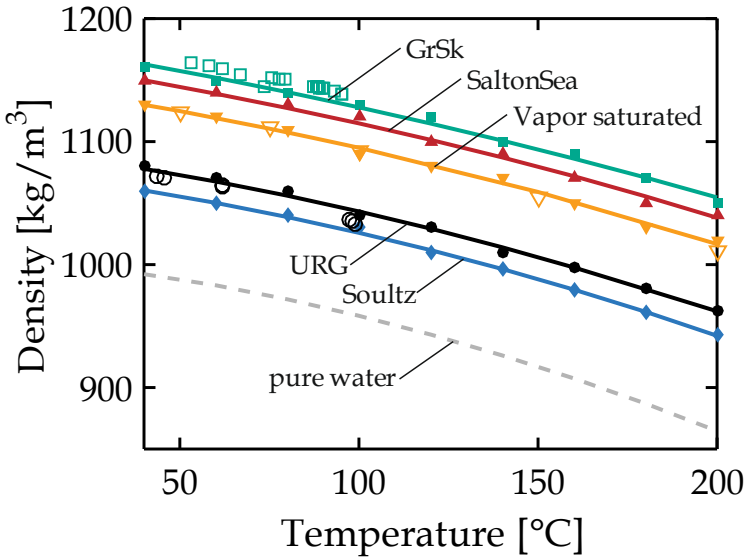
CO_2 – CH_4 – Water mutual solubility

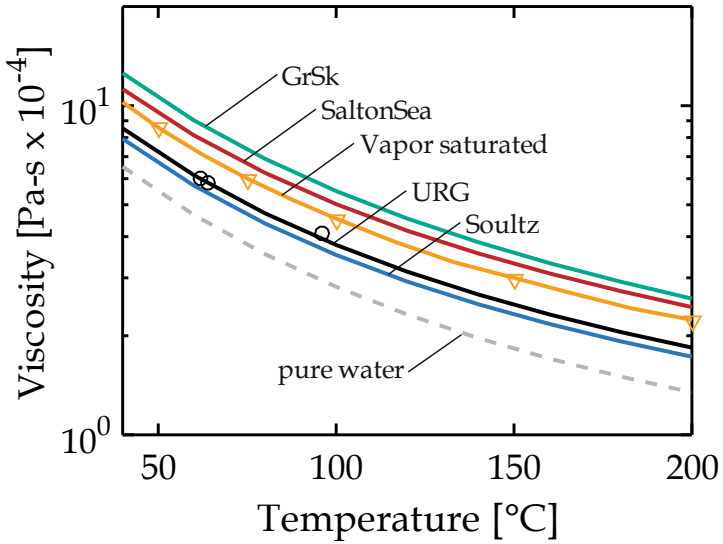


- Qin et. al., 2008
  - AAD of 3 – 4%
- gEOSkit (solid lines)
- PHREEQC 3.2 (dashed lines)

Aqueous density, heat capacity and viscosity







- Measurement data
  - PETher (KIT, 2014)
  - FluMo (GFZ, 2013)
- Good agreement with AARD within 1 – 2 %

* URG = Upper Rhine Graben

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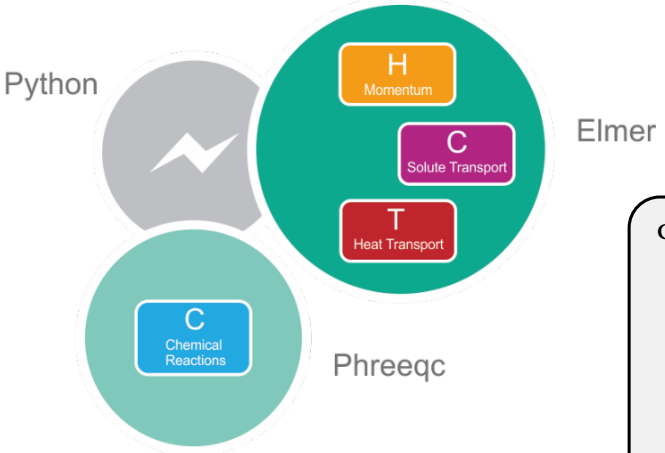
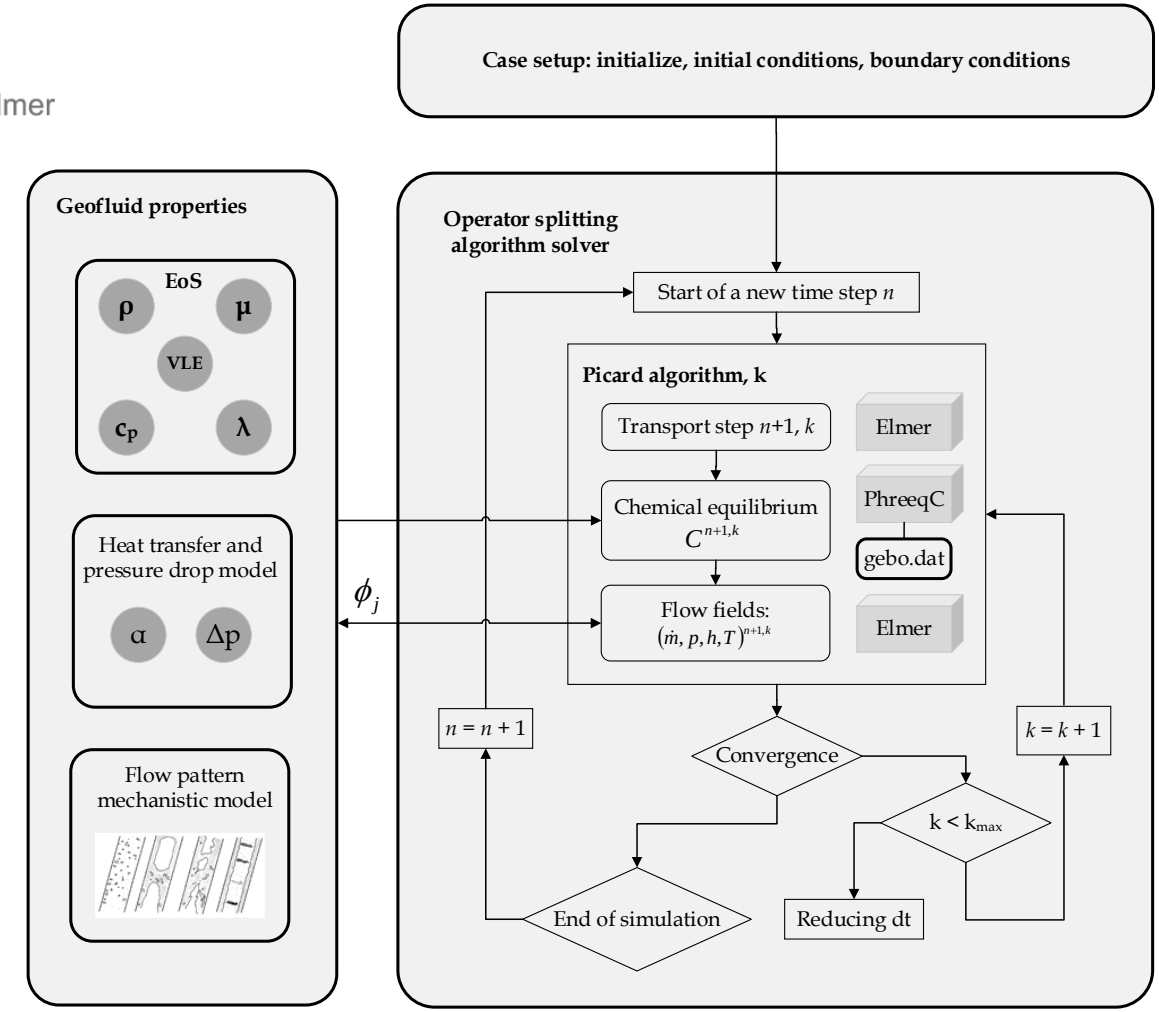
Numerical procedure

WellboreKit

Karlsruhe Institute of Technology





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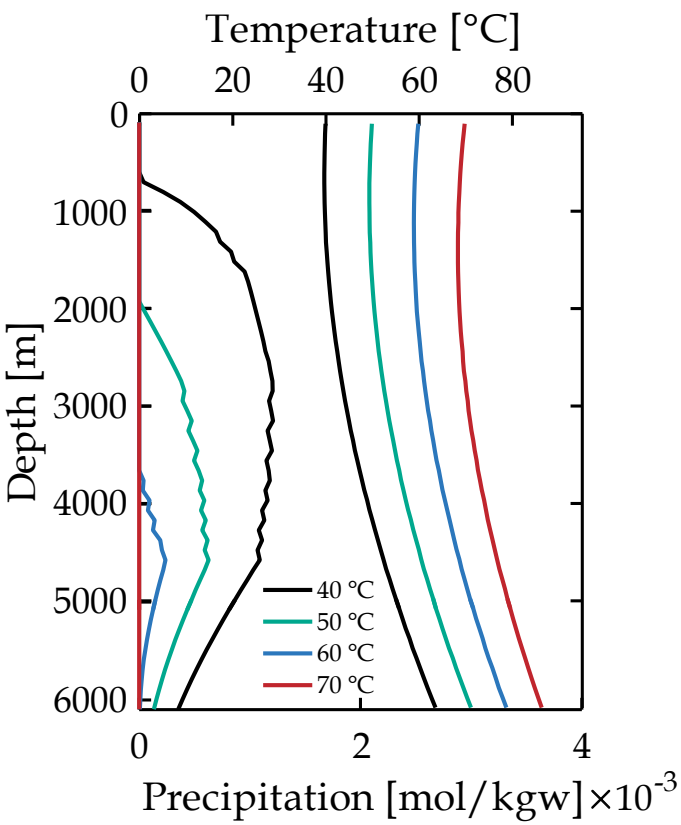
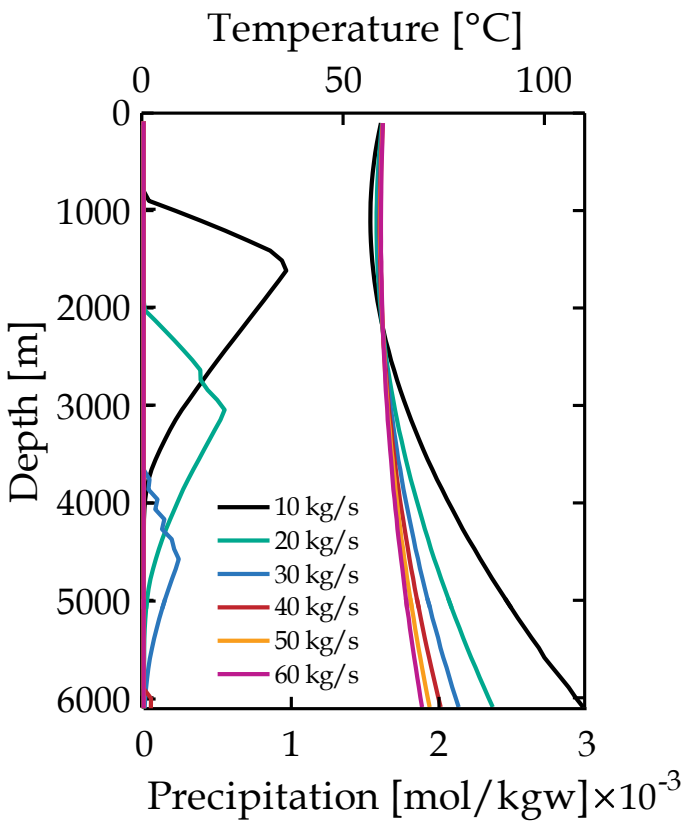
Reinjection with barite ($BaSO_4$) scaling

- Temperature and precipitation profile at 1 month





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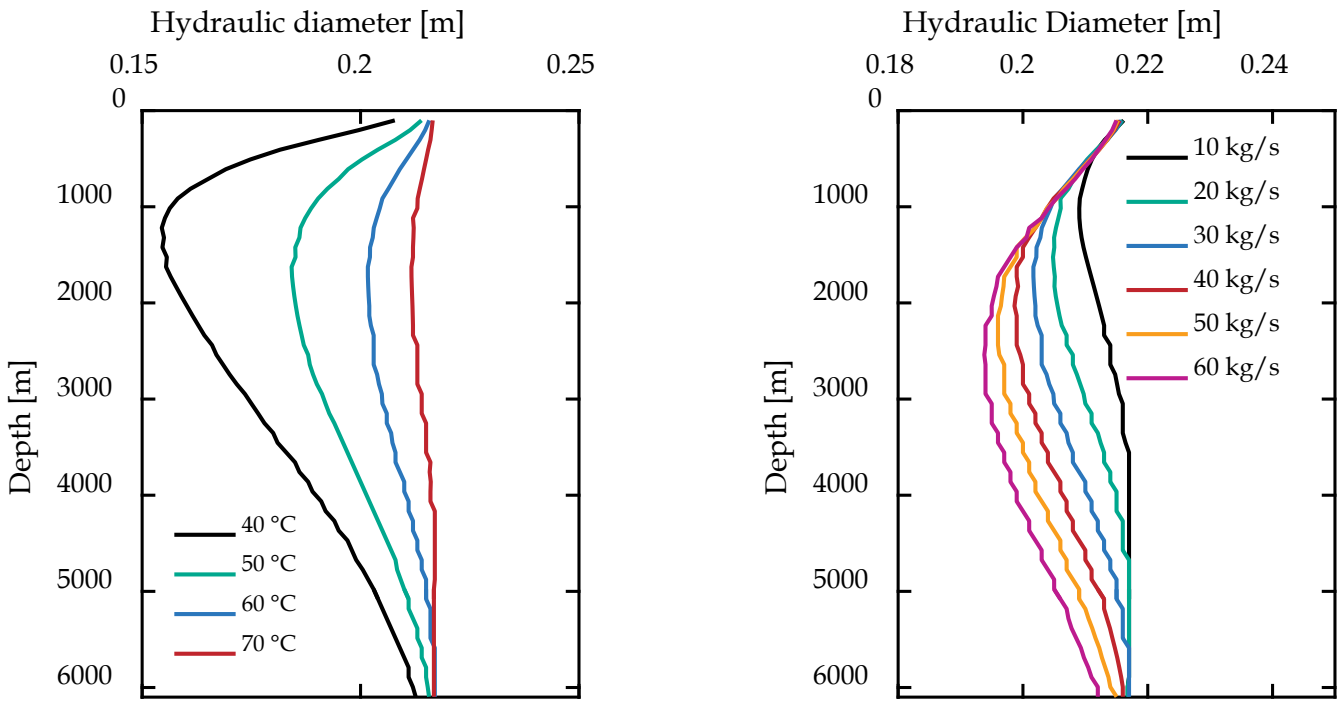
Reinjection with barite ($BaSO_4$) scaling

- Hydraulic diameter reduction at 1 month



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Conclusions

- Geofluid equation of state (gEOSkit) has been developed and validated
- Injection simulation for aqueous barium and sulphate at equilibrium condition shows downhole scaling and hydraulic diameter reductions
- WellboreKit is a unique tool that is useful to optimize plants design and operation in geothermal industry worldwide

Outlook

- Kinetics of amorphous silica (SiO2(a)), barite (BaSO4), calcite (CaCO3), and galena (PbS) scales
- Two-phase case validation

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