Interfacial Area Based Modelling: CO_2-Storage Simulation & Multiphysics Outlook

International Research Training Group nupus

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Motivation

Carbon Capture & Storage (CCS)

• Storage of Carbon Dioxide may be necessary for short term slowdown of climate change

Inclusion of Interfacial Area (ia)

• First step towards rational thermodynamics description of multiphase flow in porous media
• Quantification of *kinetic* energy and mass transfer between phases [1]
• Modeling hysteretic capillary pressure–saturation ($p_c(S_w)$) relationship envisaged

First Goal

• Validation of model against Benchmark 1.1 and 1.2 [2]

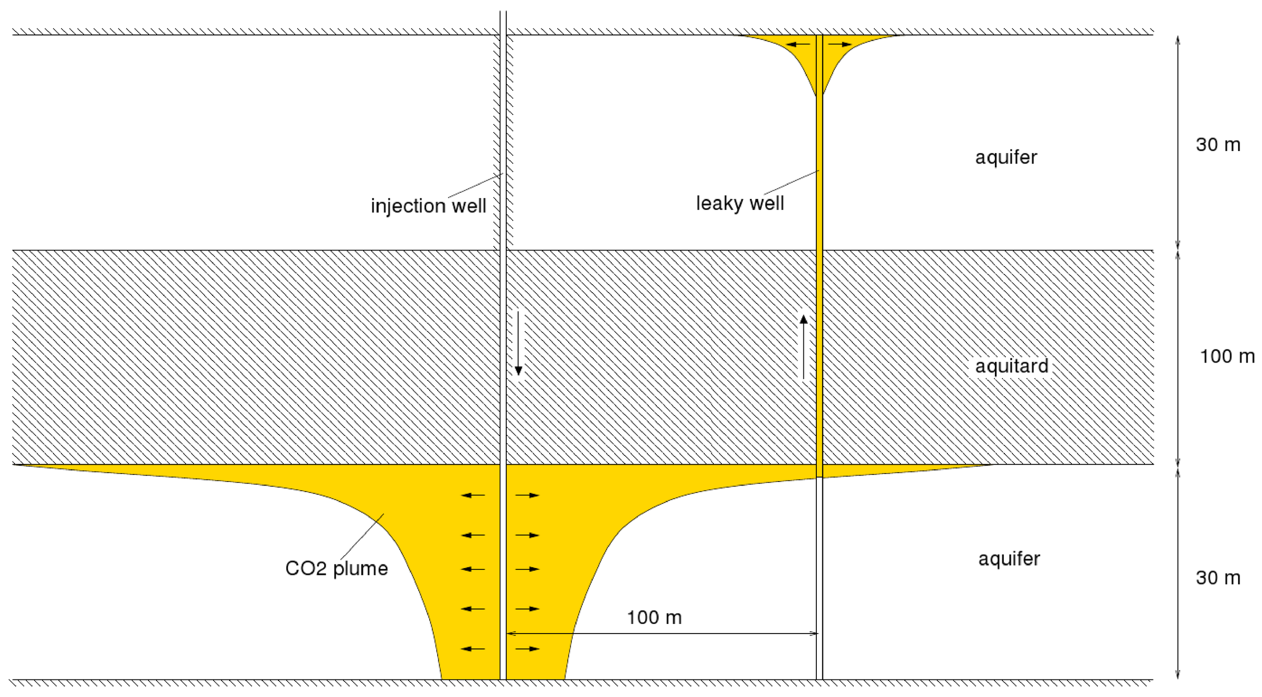

Figure 1: Schematic depiction of the leaky well scenario.

• Use of the most simple model including interfacial area
Governing Equations [3]:

$$\varphi \frac{\partial (S_\alpha \varrho_\alpha)}{\partial t} - \nabla \cdot (\varrho_\alpha \mathbf{v}_{f\alpha}) = \varrho_\alpha Q_\alpha$$

$$\frac{\partial a_{wn}}{\partial t} - \nabla \cdot (a_{wn} \mathbf{v}_{wn}) = \frac{\partial S_w}{\partial t} e_{wn}(S_w, p_c)$$

with

$$\mathbf{v}_{f\alpha} = -\mathbf{K} S_\alpha^2 \frac{\varrho_\alpha g}{\mu} \nabla \left(\frac{p_\alpha}{\varrho_\alpha g} + z \right)$$

$$\mathbf{v}_{wn} = -\mathbf{K}_{wn} \nabla a_{wn}$$

$$e_{wn} = \frac{\partial a_{wn}}{\partial S_w} + \frac{\partial a_{wn}}{\partial p_c} \frac{\partial p_c}{\partial S_w}$$

• Interfacial area – capillary pressure – saturation surface $a_{wn}(S_w, p_c)$

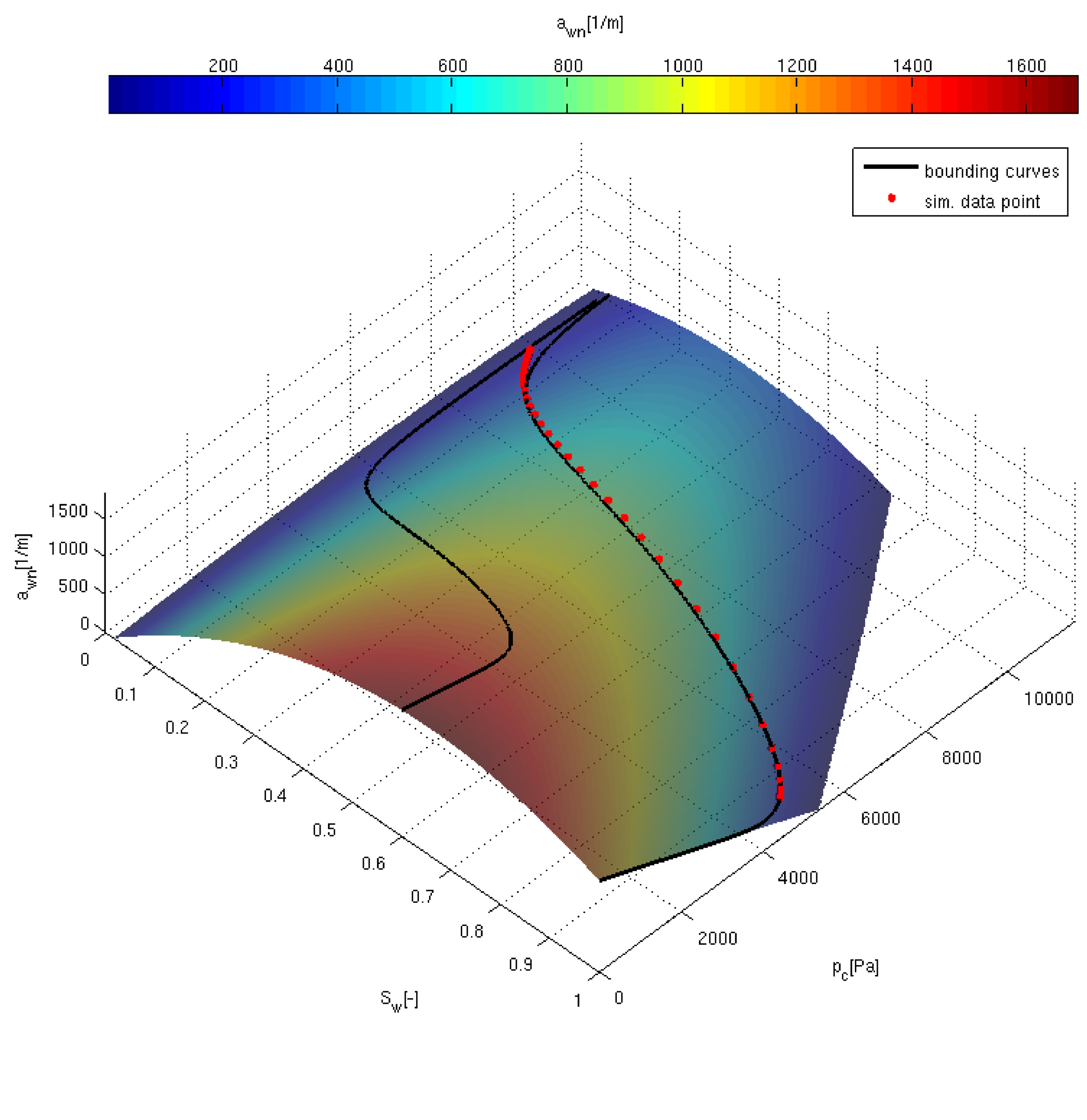

Figure 2: Constitutive relation between interfacial area, capillary pressure and saturatin. Red Points mark a point close to the injection well.

First Results

Simulation Description

• Injection of CO_2 in the middle of the domain
• Leakage through a second well
• Hydrostatic Dirichlet conditions on the lateral sides
• No-flow conditions at top / bottom

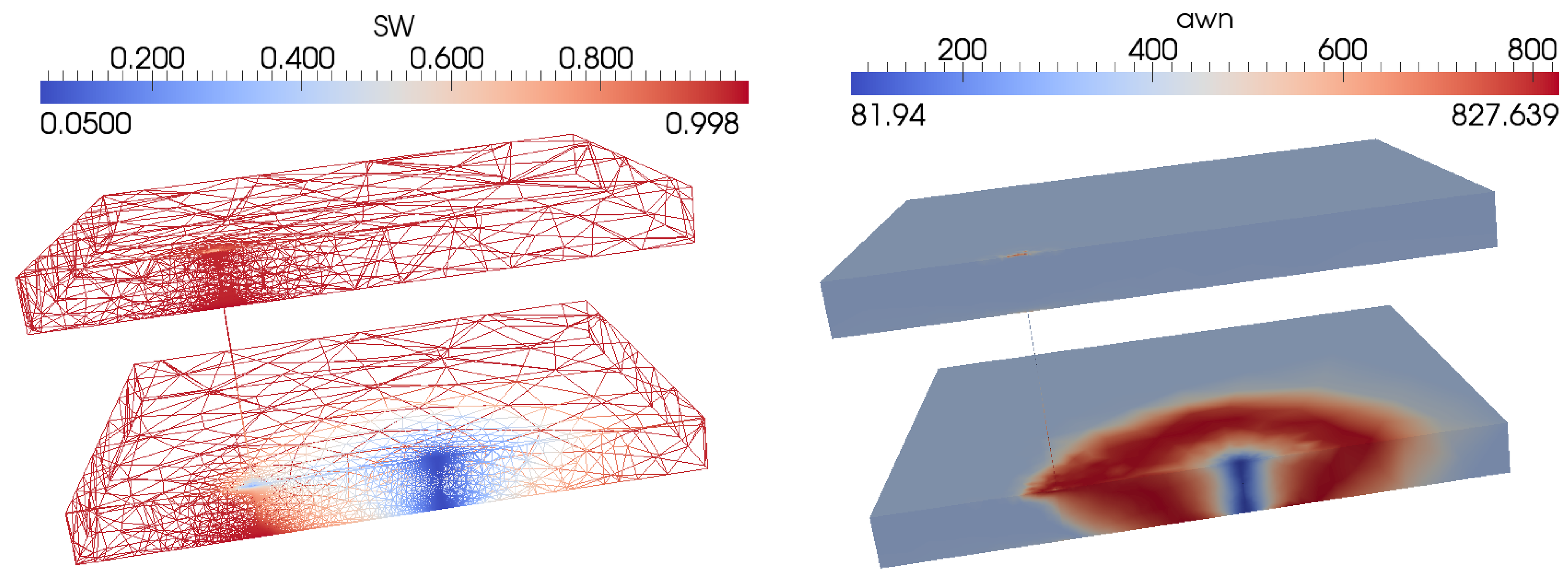

*Figure 3: Modelling results showing saturation (**left**) and interfacial area (**right**). Depicted region is a 250m·350m zoom of the 1000m·1000m base area.*

Future Work

Obstacle

• Root of partial derivative of interfacial area w.r.t. capillary pressure
• Model breaks down at those nodes hitting the root

⇒ Deal with the occuring problems numerically
⇒ Use thermodynamically motivated E_{wn}
⇒ description of hysteresis

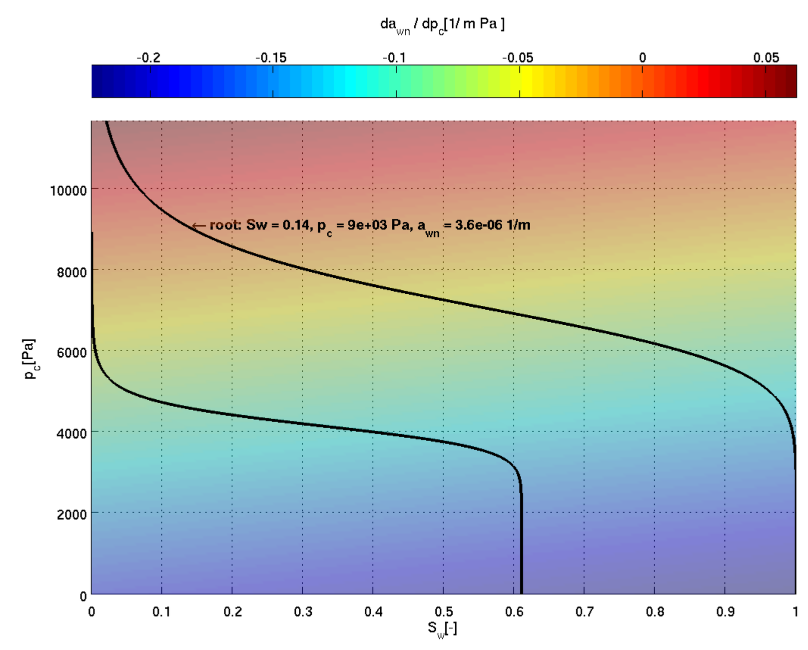

Figure 4: Partial derivative of $a_{wn}(S_w, p_c)$ w.r.t. capillary pressure. The root of the primary drainage curve is highlighted.

Increase Model complexity

• Inclusion of compositional (2c) effects
• Inclusion of non-isothermal (ni) effects

Multiphysics Approach

• Adjust model complexity to occuring processes
• Save computational time

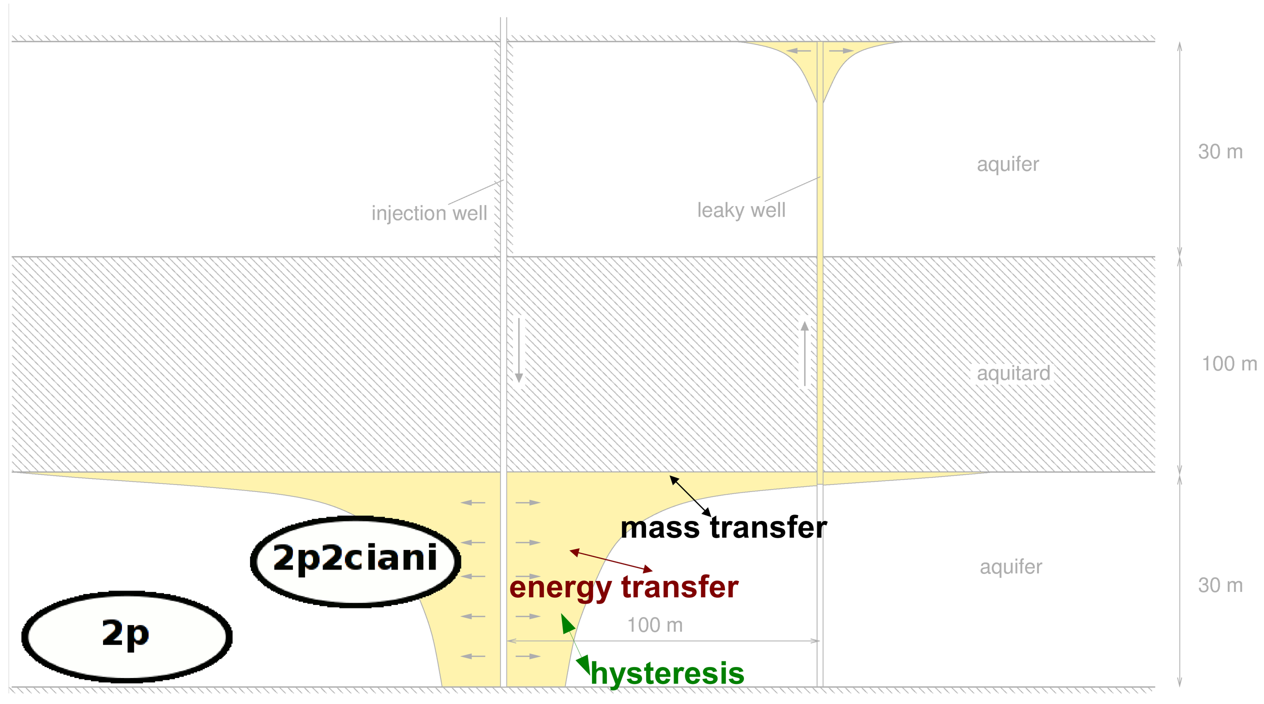

Figure 5: Conceptual model for multiphysics appoach.

Literature

[1] *Niessner, J.; Hassanizadeh, S.M.:* Modeling kinetic interphase mass transfer for two-phase flow in porous media including fluid-fluid interfacial area. *Transport in Porous Media 80 (2009)*

[2] *Class et al.:* A benchmark-study on problems related to CO2 storage in geologic formations. *Computational Geosciences* 13 (2009), p. 409-434

[3] *Niessner, J.; Hassanizadeh, S. M.:* A model for two-phase flow in porous media including fluid-fluid interfacial area. *Water Resources Research 44 (2008)*

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