**Introduction:** Viscous coupling results in a reduction of CO₂/brine relative permeability during counter-current flow relative to what is measured in co-current flow experiments. The significance of the viscous coupling for two-phase flow in a cylindrical pore can be illustrated via a generalized form of Darcy’s equation:

\[
\frac{Q_{nw}}{Q_w} = c_{11} c_{12} c_{21} c_{22} \frac{\partial p_{nw}}{\partial x}
\]

Viscous coupling during two-phase CO₂/brine flow in a cylindrical pore.

To represent this effect in numerical calculations, we use two sets of bounding relative permeability curves (1: co-current and 2: counter-current) in a modified version of GPRS. The relative permeability of each phase is calculated from the velocity of both phases in each cell. We call this model the “mixed” model, as opposed to the co-current model (current standard) that relies on a single set of bounding relative permeability functions.

**Example I: 2D Simulation of CO₂ injection**

- **Aquifer:** 5000*500 ft (50*40 cells); Permeability: \( k_r = 50 \text{ mD}, k_i = 20 \text{ mD} \)
- **Injection (left):** 11K tonne CO₂/100ft²/yr; Open hydrostatic boundary (right)
- **CO₂ Saturation (co-current)**
- **CO₂ Saturation (mixed)**
- **CO₂ Trapped Saturation (co-current)**
- **CO₂ Trapped Saturation (mixed)**

**Observations:**
- No change in pressures (cells and bottom-hole pressures) and injection and production rates
- Negligible decrease in time step size and little increase in total simulation time

**Example II: 3D Simulation of CO₂ injection**

- **Aquifer:** 5000*5000*500 ft (100*100*10 cells)
- **Permeability:** Heterogeneous (\( k_{r,avg} = 90 \text{ mD}, k_{i,avg} = 9 \text{ mD} \))
- **Injection well in the middle of the domain:** 0.22 Mdyr for 2500 days
- **Open and hydrostatic boundaries (simulated via production wells)**

**Conclusions:** For accurate modeling and simulation of CO₂ injection into saline aquifers, the effect of flow transitions from co-current to counter-current (and vice versa) must be considered. This will modify the relative permeability functions (viscous coupling) and affect dynamics of plume migration and CO₂ entrapment.

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