Modeling of Salinity Dependent CO_2 Solubility in the Aqueous Phase in INTERSECT

Choongyong Han, Yih-Bor Chang, Baris Guyaguler
Kevin Chambers

Chevron Technical Center

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SLB-Private

INTERSECT Reservoir Simulator

- Physics-based computer models to predict impact of production/injection operations for upstream projects
- Forecast production/injection rates, estimate ultimate recoveries, quantify impact of uncertainties, and optimize field development
- Jointly developed by Chevron and Schlumberger since 2000 with TotalEnergies as a new partner since 2012
- Utilized in all Chevron business units today
- Simulator of choice for Chevron's underground CO_2 storage projects

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Objectives

– To enhance INTERSECT functionality of isothermal CO_2 solubility in water (shortly, CSIW) to consider the well-known effect of salinity on the CSIW

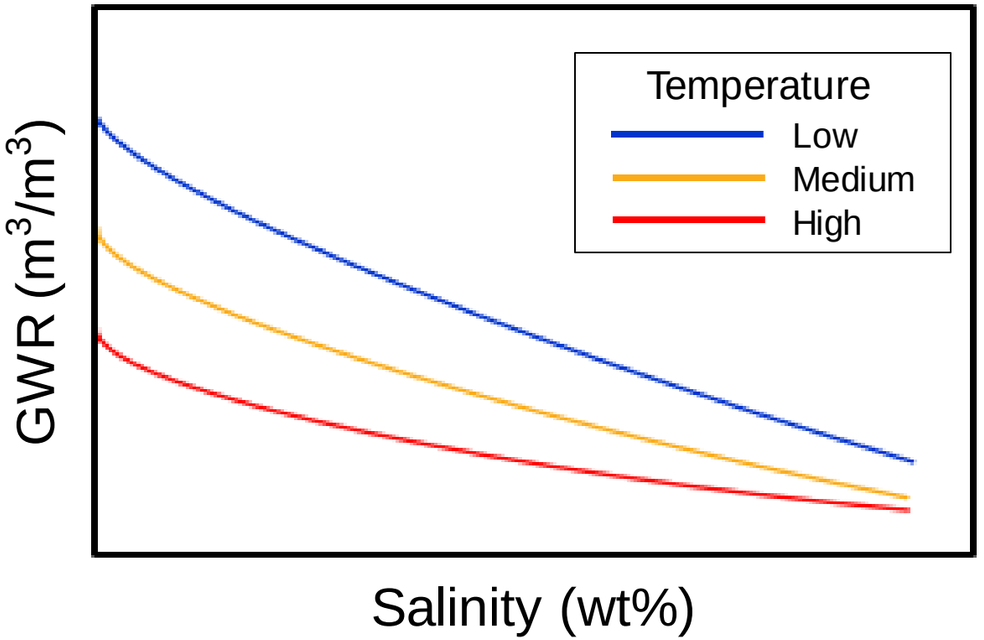


Figure 1. Typical change of solubilized CO_2 gas to water ratio (GWR) with salinity

Implementation Overview

– Definition of salinity

$$S(wt\%) = \frac{mass\ of\ salt\ (solute)}{mass\ of\ water\ (solvent)} \times 100 = \frac{\sum_{i=ion} M_i w_i}{M_w w_w} \times 100 \qquad \text{(Eq. 1)}$$

, where

w_i is the mole fraction of component i in the aqueous phase

M_i is the molecular weight of component i.

– The multi-component brine functionality has been coupled with the CSIW functionality to evaluate the salinity in a cell.

– The effect of salinity on following aqueous phase properties is considered:

- GWR
- Fugacity coefficient of CO_2
- Molar density
- Mass density
- Viscosity
- Three phase behavior

What to Update in INTERSECT CSIW Case Input

- To compute salinity
  - add brine functionality related input
  - specify initial concentration of brine components in a CO_2 storage reservoir
- To consider the salinity effect
  - have multiple CO_2 solubility tables depending on salinity
  - have multiple aqueous phase property related input depending on salinity
- To observe salinity change
  - add reporting of salinity in wt%

Simulation Examples

- Case 1: Validation
- Case 2: The effect of salinity
- Case 3: Consideration of salinity gradient

Case 1: Validation

- Storage reservoir: 450 m x 450 m x 5 m (9 x 9 x 1 cells)
- Permeability x: 500 mD, y: 500 mD, z: 50 mD, Porosity: 0.1
- One CO_2 injector and four producers
- Injection for 5 years and shut in of every well for 5 years
- Compare (CSIW + no brine having a single CSIW table) with (CSIW + 0 brine having multiple CSIW tables)

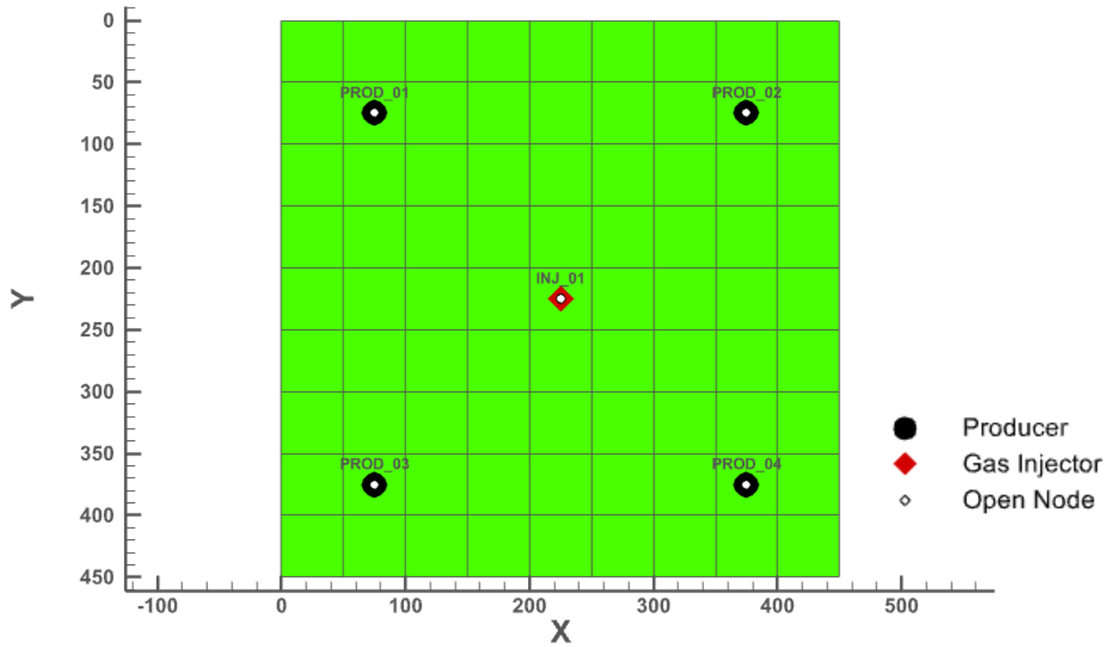
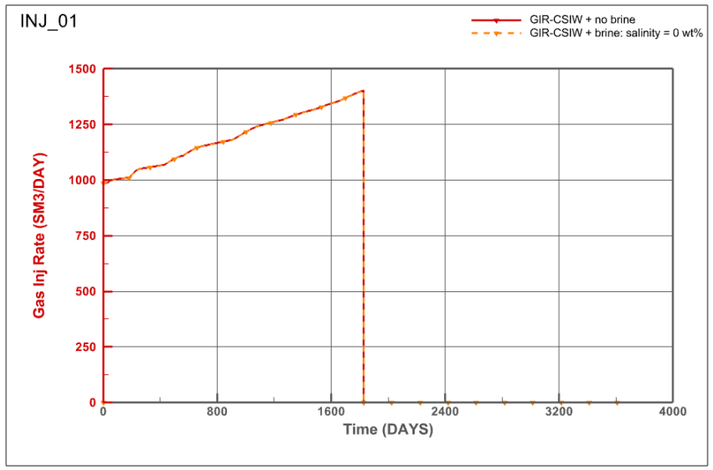
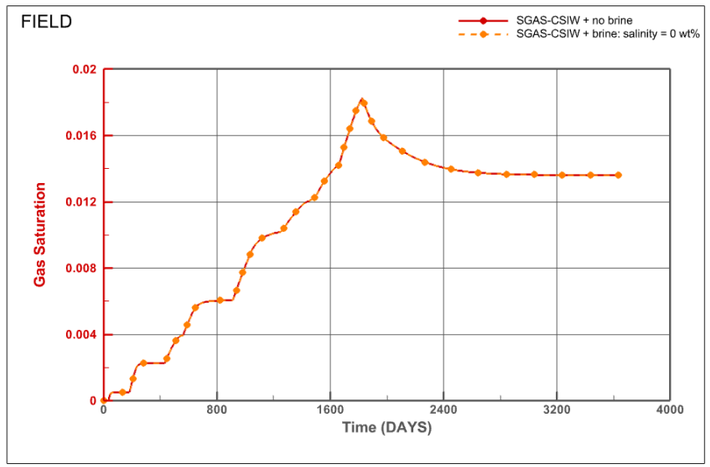


Figure 2. CO_2 storage reservoir used for Case 1

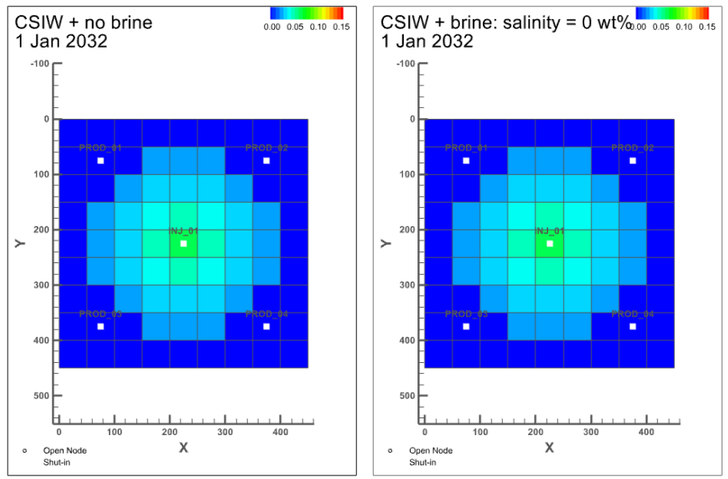
Case 1: Validation - *continued*



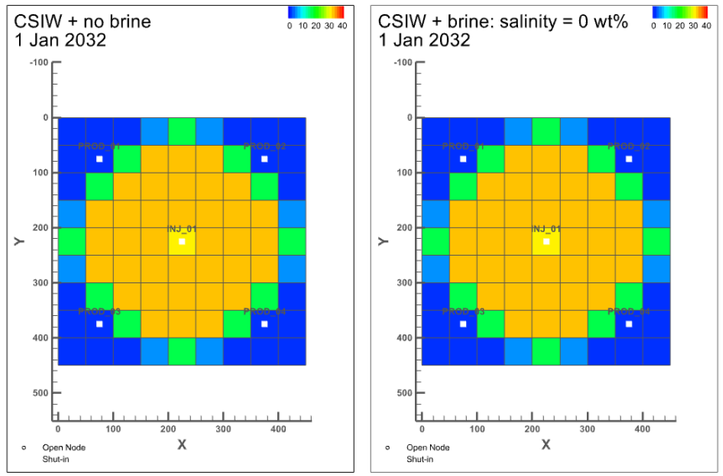
a) CO_2 injection rate over time



b) CO_2 gas saturation in the reservoir over time



c) CO_2 gas saturation at 10 year



d) GWR at 10 year

Figure 3. Comparison between (CSIW + no brine) and (CSIW + 0 brine)

Case 2: The Effect of Salinity

- The same model as Case 1 CSIW + brine (having multiple CSIW tables depending on salinity)
- Three models of different constant initial salinities to investigate the salinity effect (0, 15, and 30 wt%)

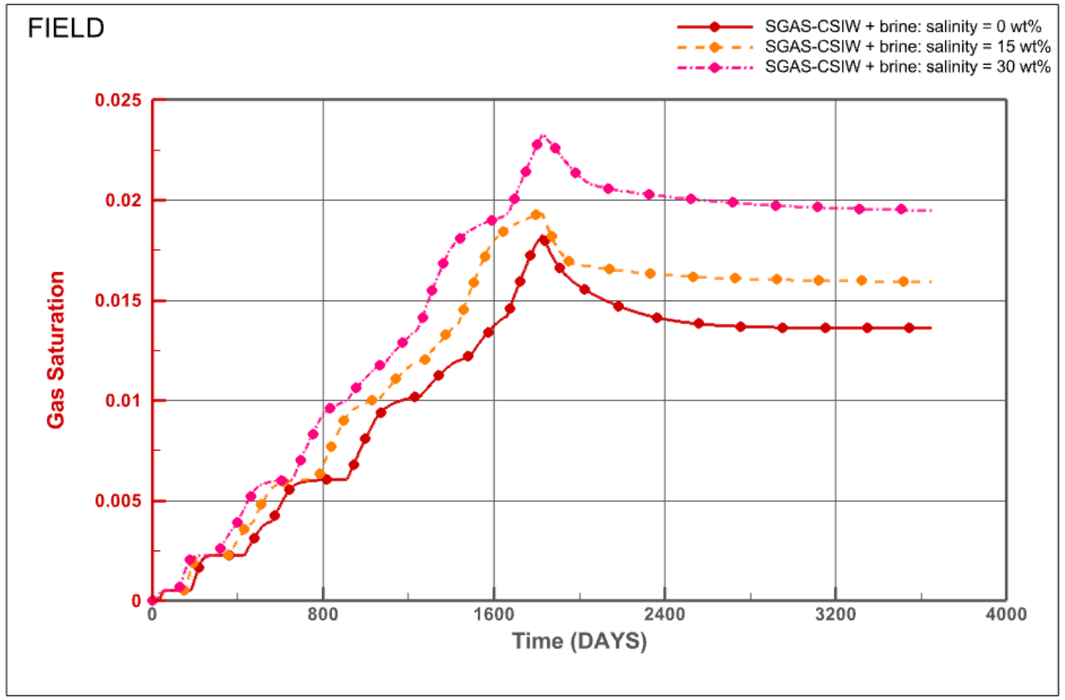


Figure 4. The change of CO_2 gas saturation over time depending on salinity in the reservoir

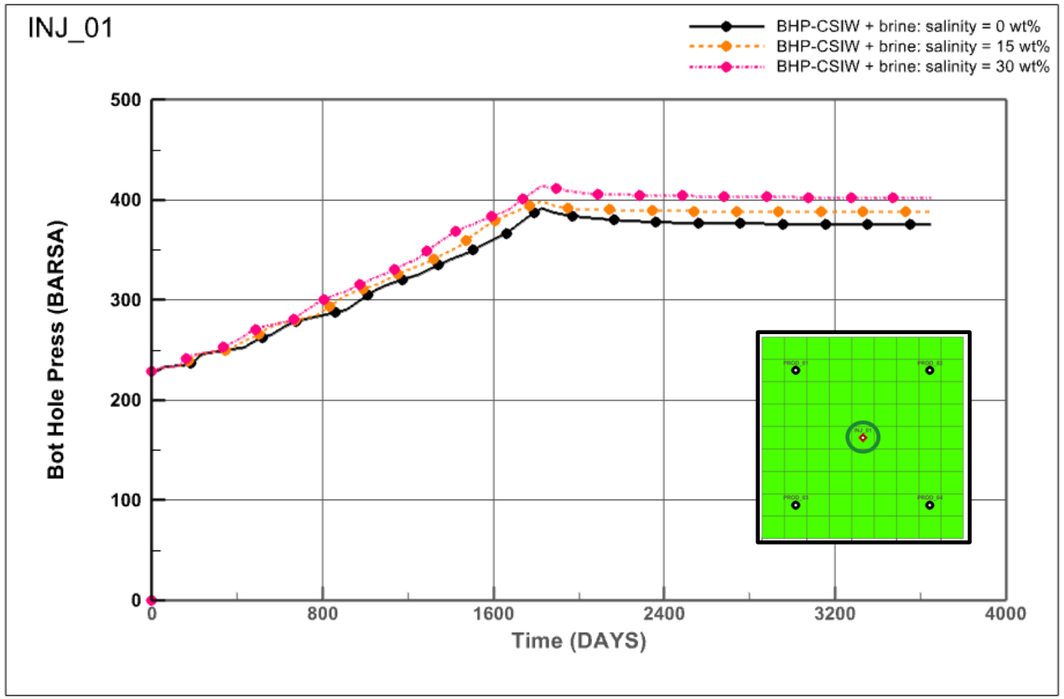


Figure 5. The change bottomhole pressure of injection well over time depending on salinity

Case 2: The Effect of Salinity - *continued*

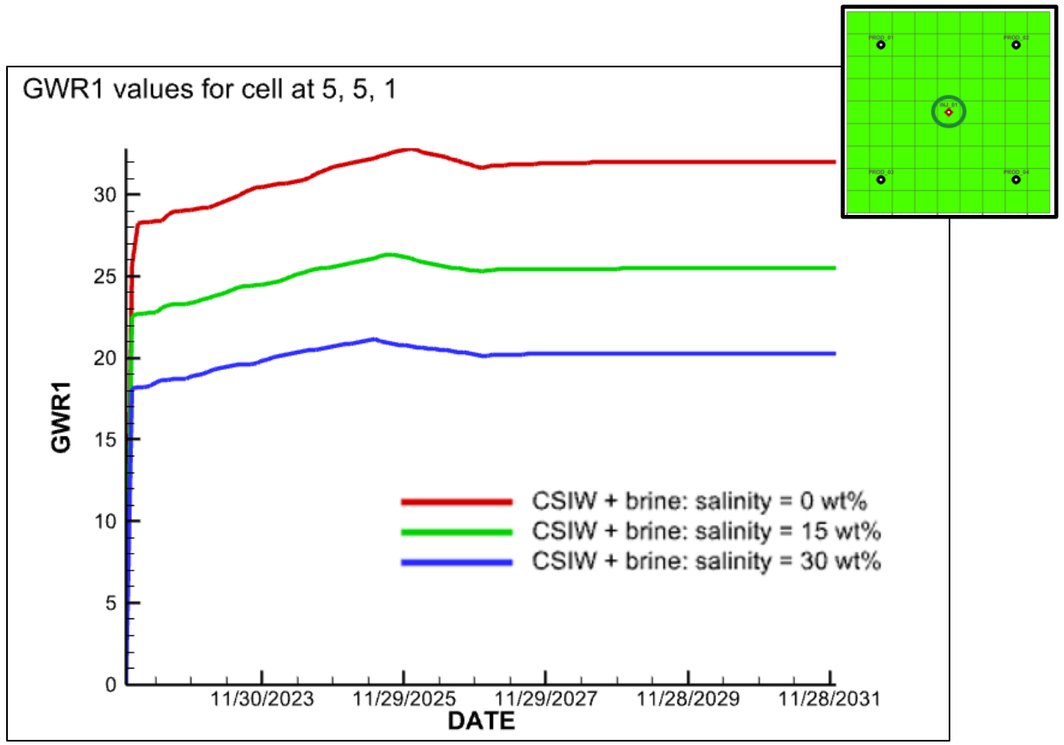


Figure 6. The change of GWR over time depending on salinity **at injection cell**

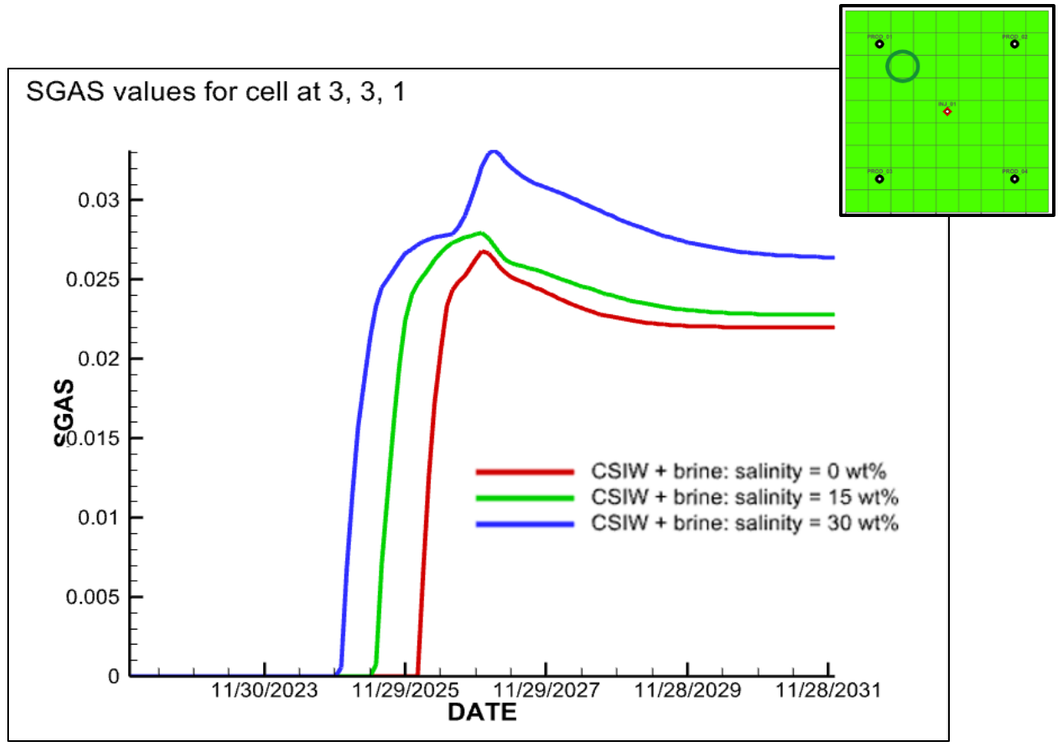


Figure 7. The change of CO_2 gas saturation over time depending on salinity **near production well**

Case 3: Consideration of Salinity Gradient

- Storage reservoir: 2250 m x 2250 m x 400 m (45 x 45 x 40 cells) having gravity effect
- Permeability x: 500 mD, y: 500 mD, z: 50 mD, Porosity: 0.1
- One CO_2 injector and four producers with completions near bottom of the reservoir
- Injection for 5 years and shut in of every well for 5 years
- Increase of initial salinity along depth (5 to 15 wt% along 400 m, with gradient of 0.025 wt% per m)

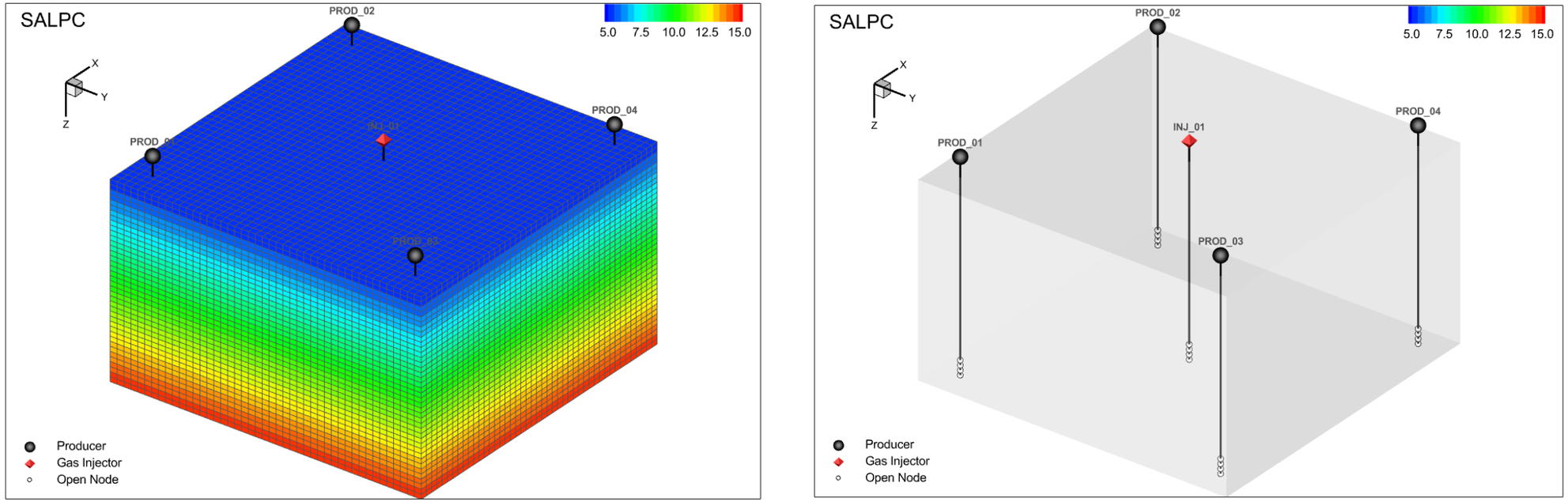
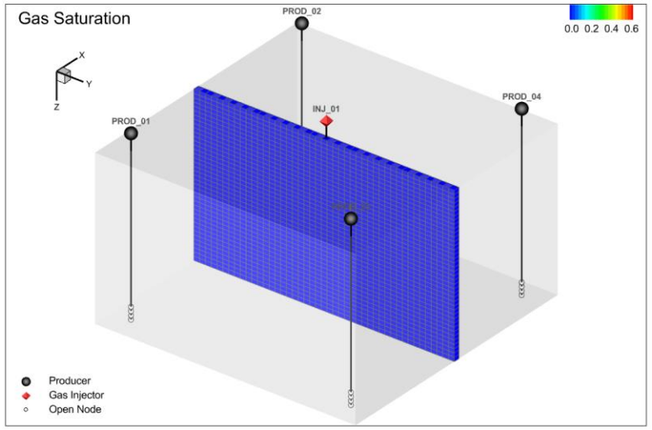
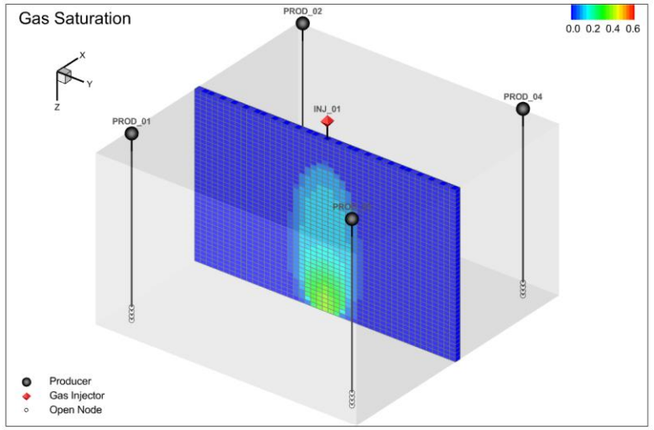


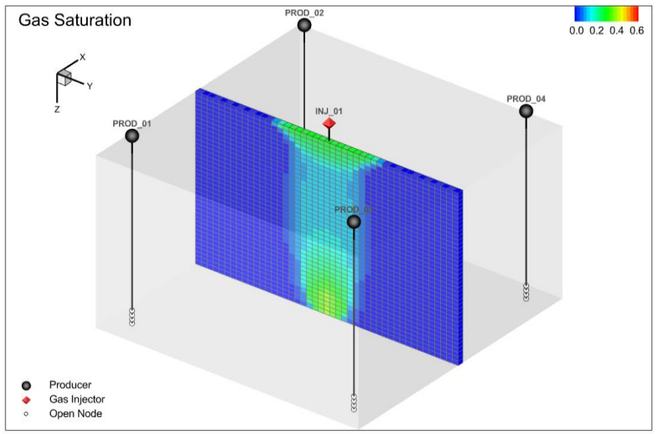
Figure 8. CO_2 storage reservoir used for Case 3



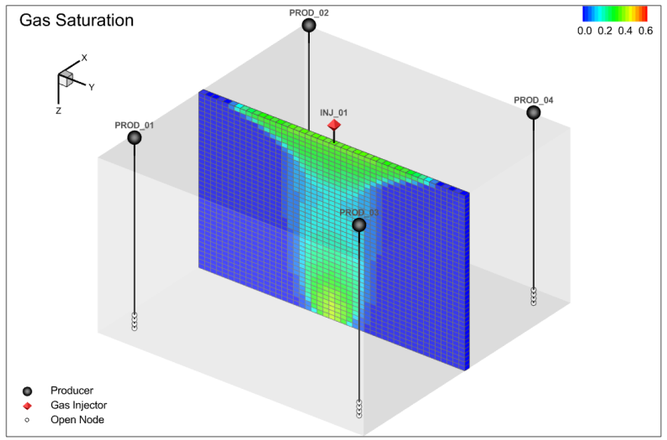
Time = 0 year (start of CO_2 injection)



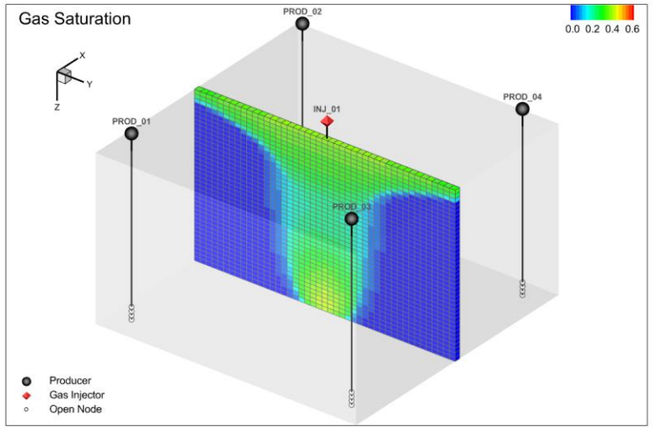
Time = 0.5 year



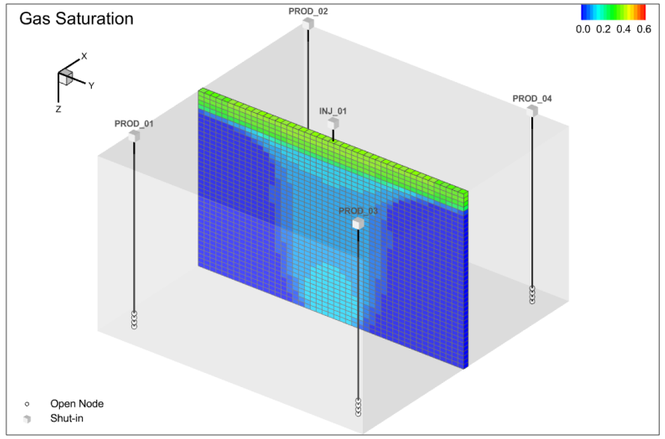
Time = 1 year



Time = 2 year



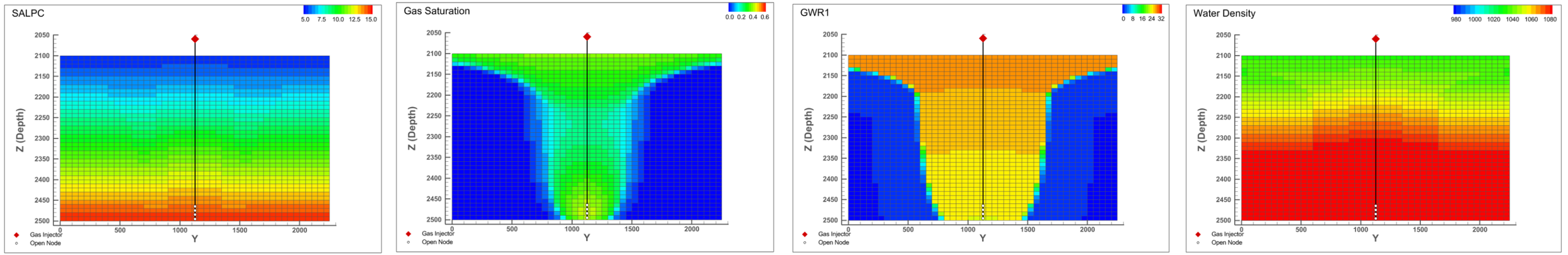
Time = 5 year (well shut-in)



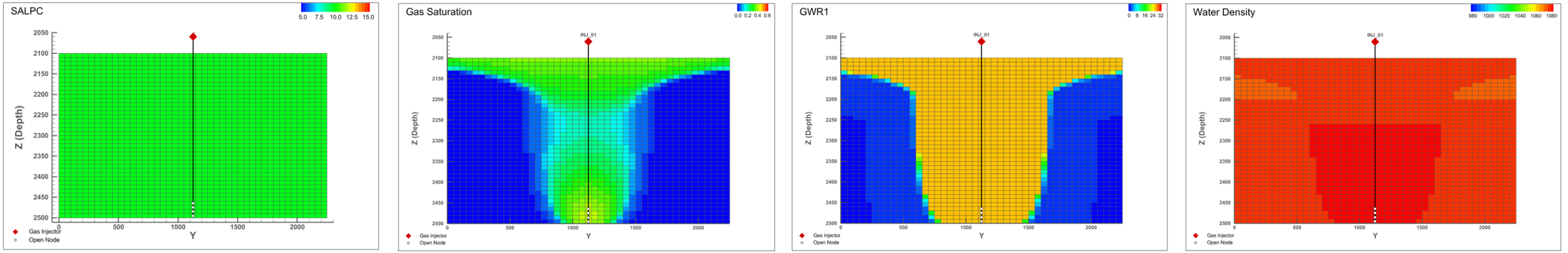
Time = 10 year

Figure 9. The change of CO_2 gas saturation over time

Salinity | CO_2 gas saturation | GWR | Aqueous phase density



(a) **Variable** salinity case



(b) **Constant** salinity case

Figure 10. Comparison of properties between **variable** and **constant** salinity cases at 5 year (well shut-in)

Summary

- The INTERSECT isothermal CSIW functionality has been enhanced with coupling of the multi-component brine option to simulate salinity effect on CO_2 solubility in the aqueous phase.
- The salinity effect on CO_2 solubility, three phase flash, and aqueous phase properties such as CO_2 fugacity, density, and viscosity has been implemented.
- The enhancement has been validated by comparing CSIW + 0 brine with CSIW + no brine cases.
- Simulation examples show expected results of less CO_2 solubility and more CO_2 gas saturation with increasing salinity.