Parameters Impacting Near Wellbore Injectivity During CO2 Injection

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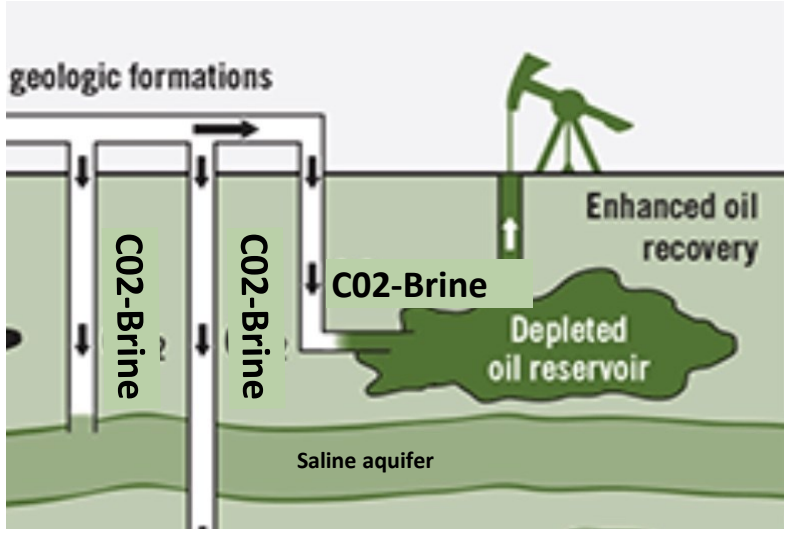
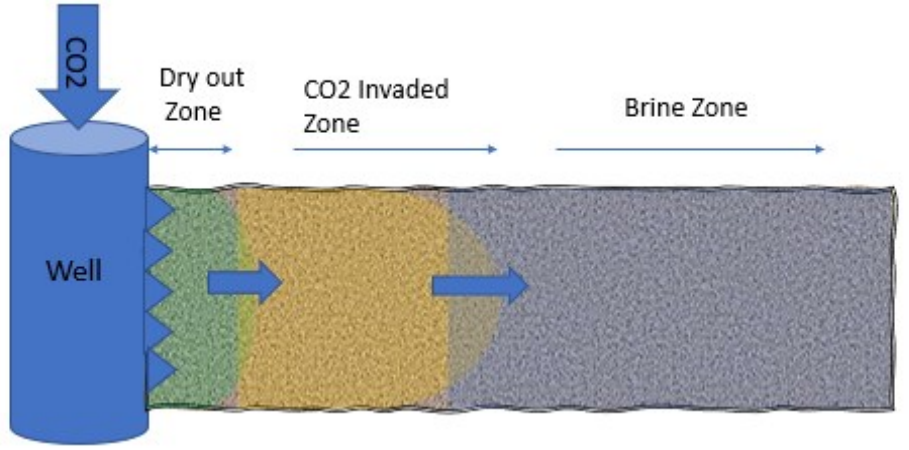




Key Concern on CO2 Geological Storage

- Injectivity is one of several key parameters that determine the effective CO2 geologic storage.

- Injectivity depends on various factors:
  - Formation permeability and thickness
  - Relative permeability
  - Salt precipitation in the dry-out zone
  - Porosity reduction due to mineral precipitation

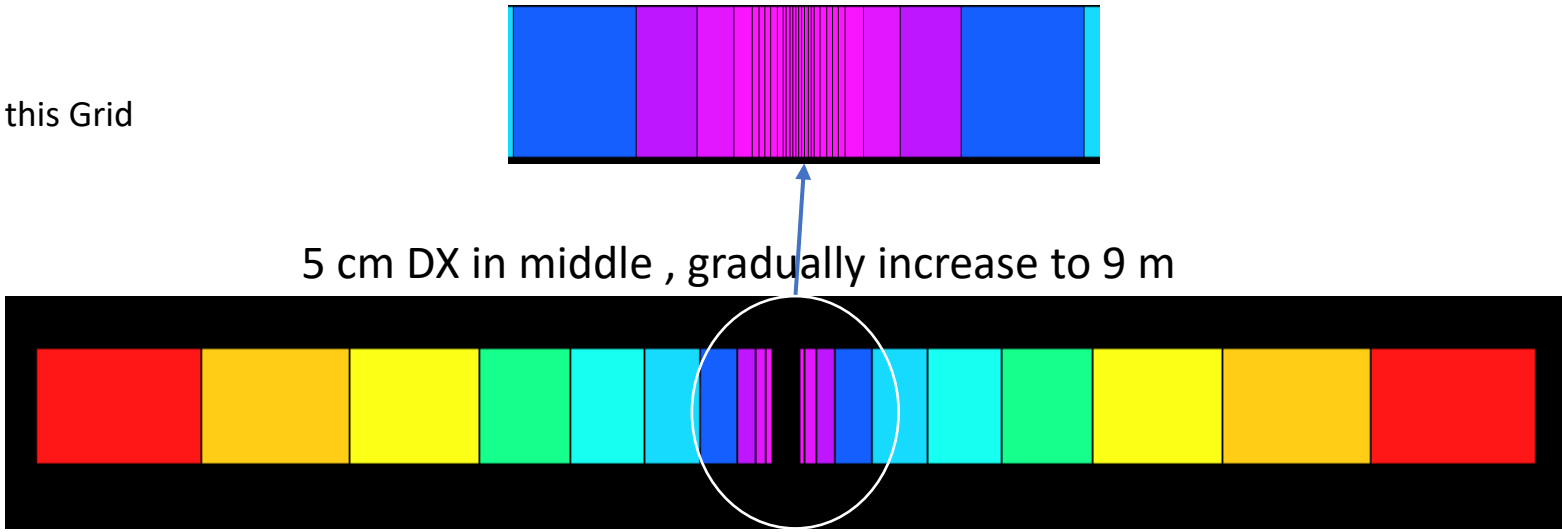
- Approach: Modeling and Simulation
  - Eclipse 300 is chosen for this study
    - Near wellbore simulation in CO2 injection (E300)

Outline

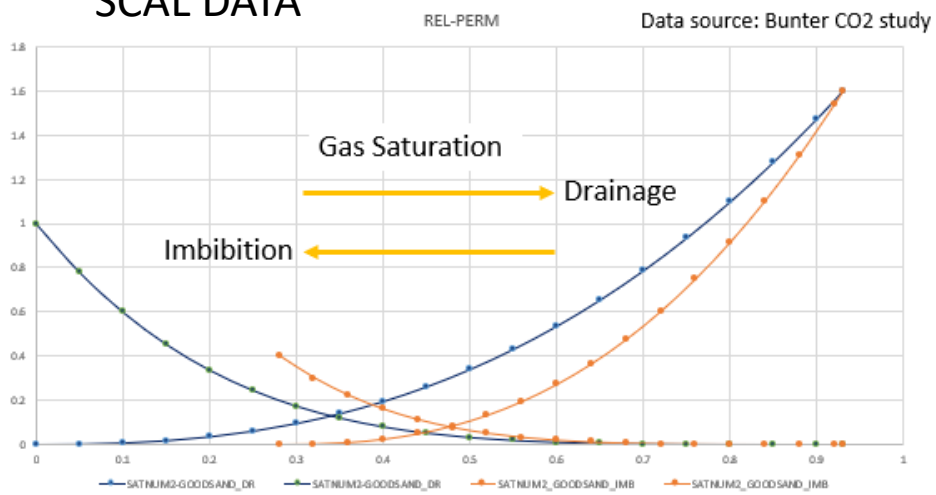
- Simulation setup E300
  - Grid
  - Injection/Production scenarios
  - Sensitivity Analysis
- Results
- Conclusion / Message

E300 Grid Setup and Simulation

- A 1D grid set up is chosen to begin
  - later more layers and dimension will be added to this Grid
- Vertical resolution is 5 cm and unisized Dy : 5 cm
- Constant Permeability in X and Y direction(500 Md)
- Constant vertical permeability (100 md)
- Constant Porosity (25%)
- The two edge grids volume is multiplied by 300



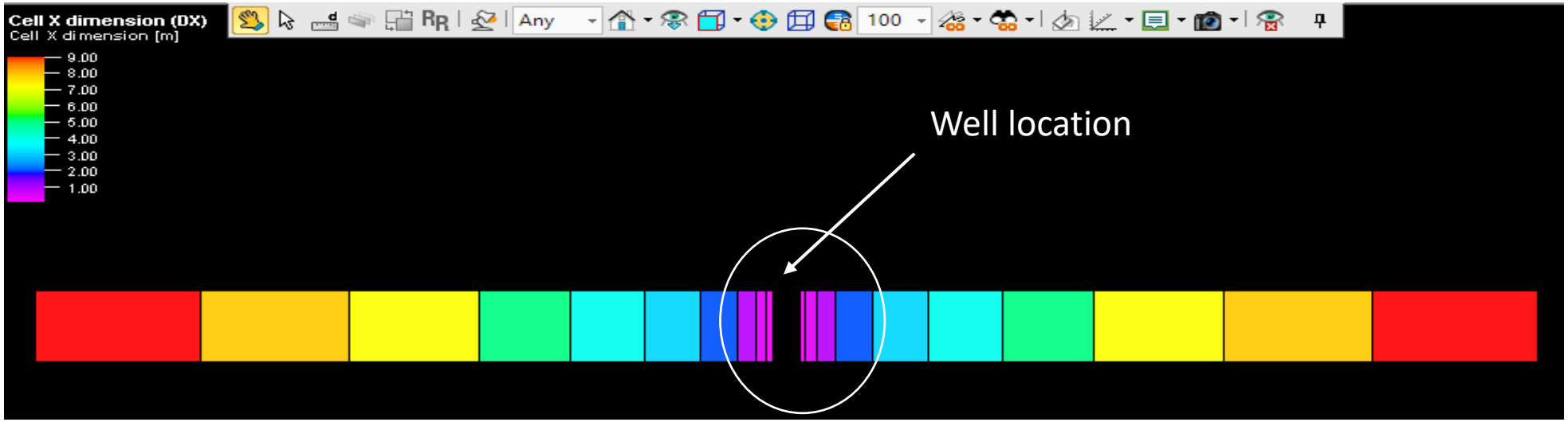
SCAL DATA



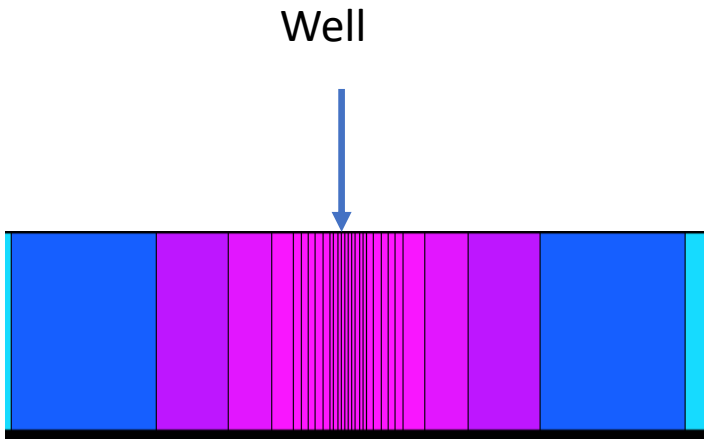
PVT Data & initialization

- grid depth set at 1100 m (Bunter field)
- Initial pressure is set as 110 bar Bunter data set
- Rock compressibility used Bunter data set
- CO2STORE option is used in Eclipse 300, in combination with SOLID option
- 5 components including ('H2O' 'CO2' 'NACL' 'CACL2' 'CACO3') are used
- There is no component gradient vertically or horizontally
- Reservoir Temperature is 37.2 C
- The injected CO2 is pure unless it is mentioned
- The diffusion is activated between all phases present
- Solid adsorption function is implemented through a table (SOLIDADS)
- Mobility multiplier as a function of adsorbed solid Saturation(SOLIDMMS)

Well Data

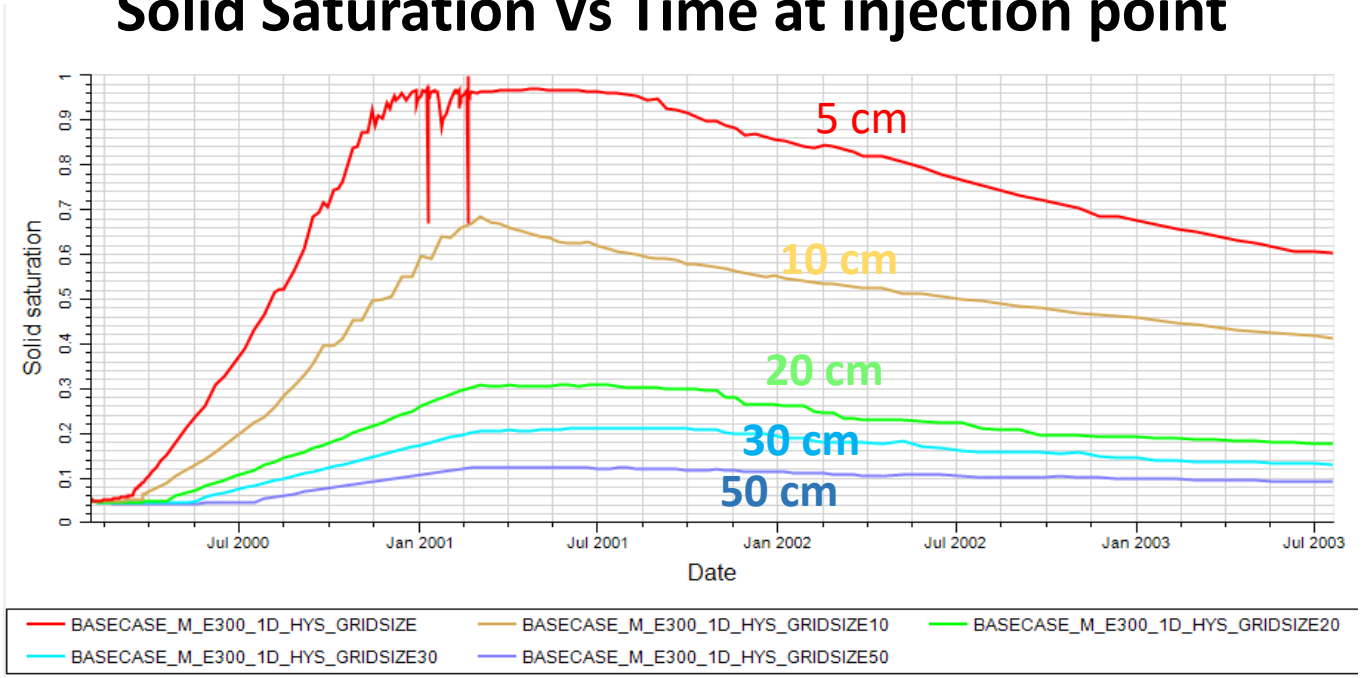


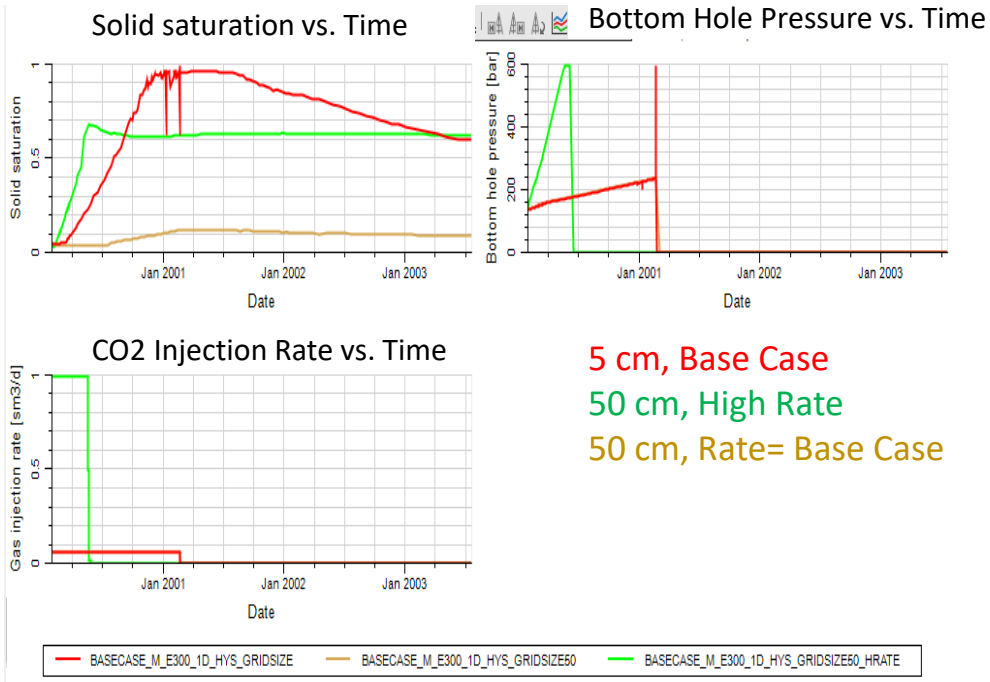
- Single Well, is located in middle (20, 1, 1)
- Pure CO2 is injected (100 %)
- Injection rate is 0.07 sm3/day (50 kg/Year)
- CO2 Injection from:1.02.2000 to: 19.02.2001 (384 days)
- Simulation runs till July 2003 (1266 days)



Grid Resolution: Why 5 cm in center ?

Solid Saturation Vs Time at injection point

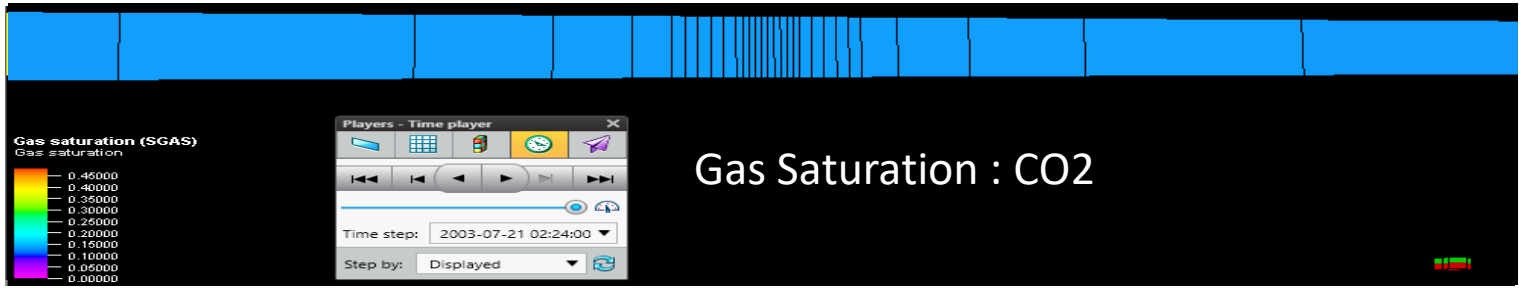




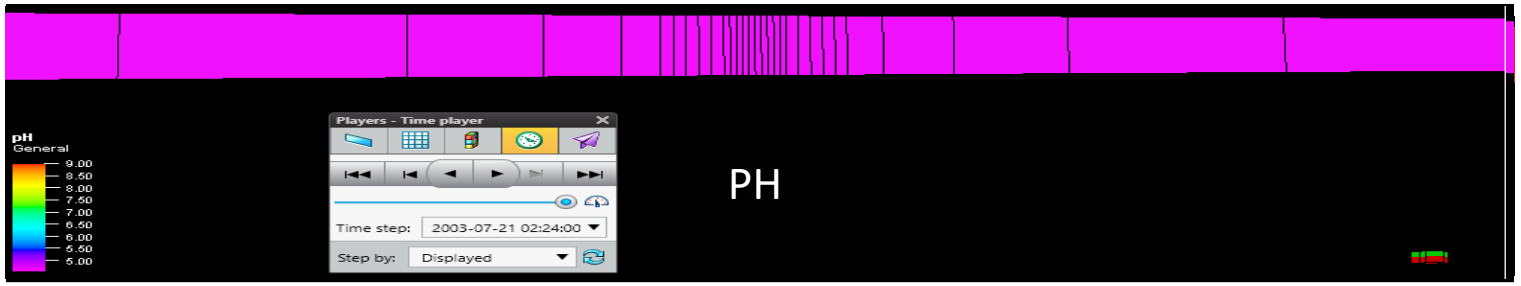
What happens near well :

- Displacement of brine
- Dissolution (evaporation) of brine into the flowing CO_2 stream,
- Segregation of CO2 due to gravity effects (buoyancy)
- Backflow of brine toward the injection point due to capillary pressure gradients
- Molecular diffusion of dissolved salt.

Simulation Results



Gas Saturation : CO2



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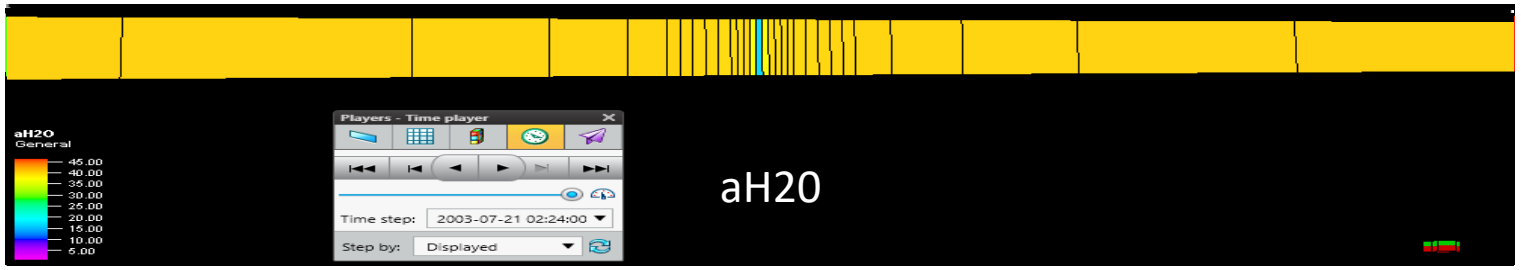

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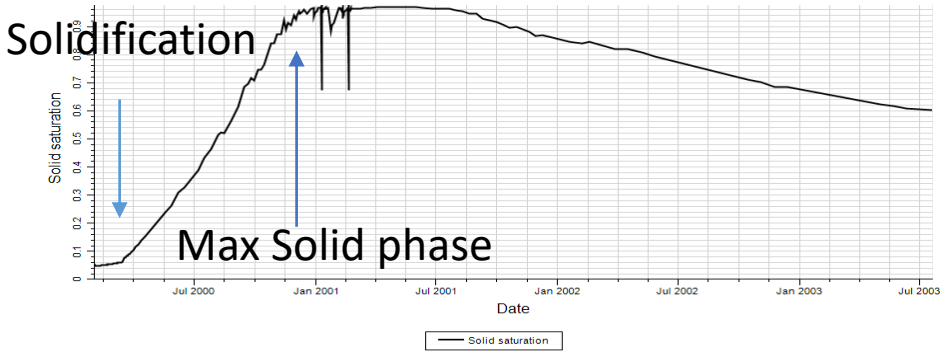
Solid Saturation

Solid Saturation vs. Time @ Injection Point



41 days after Injection starts solidification speeds up

296 days after Injection starts, Maximum Solid reaches

384 Injection is stopped

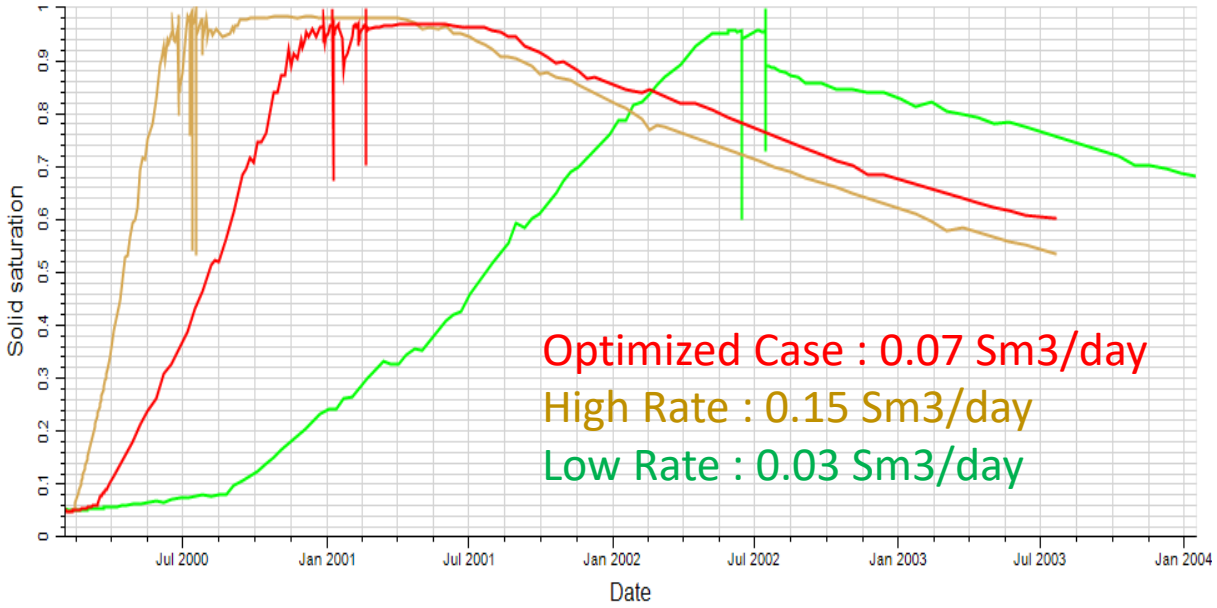
End of Simulation Day : 1266

Parameters Affecting Solid Precipitation

- Injection rate
- Reservoir temperature
- Aquifer salinity
- Injected CO2 Dryness
- Carbonated water injection impact

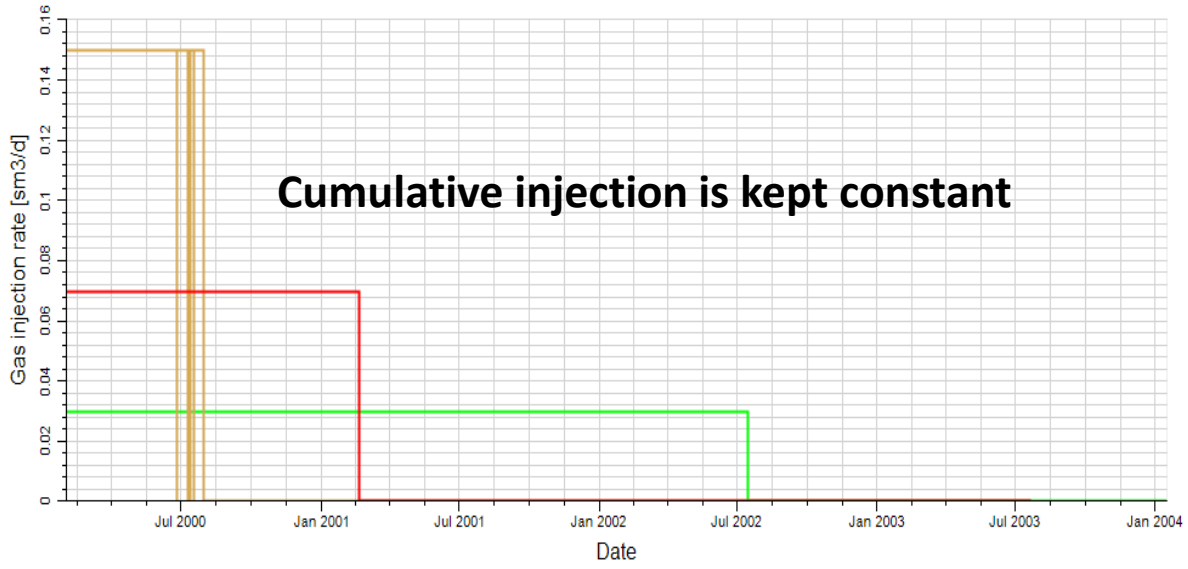
Injection Rate

Solid Saturation Vs. Time @ Injection point



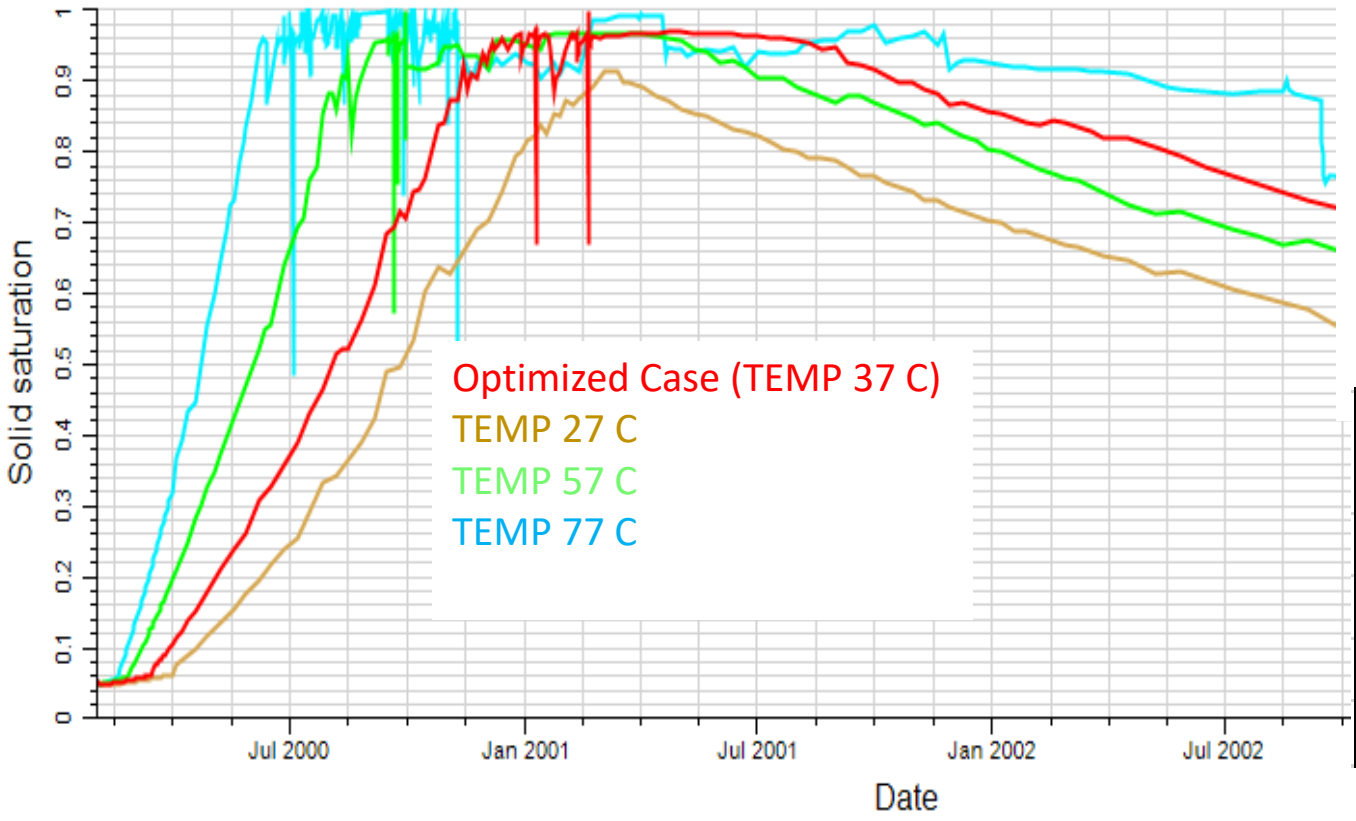
Case	Start of Solidification (day)	Maximum Solid (day)	Maximum Solid Saturation
High Rate	12	159	0.97
Optimized Case	41	296	0.97
Low Rate	206	829	0.95

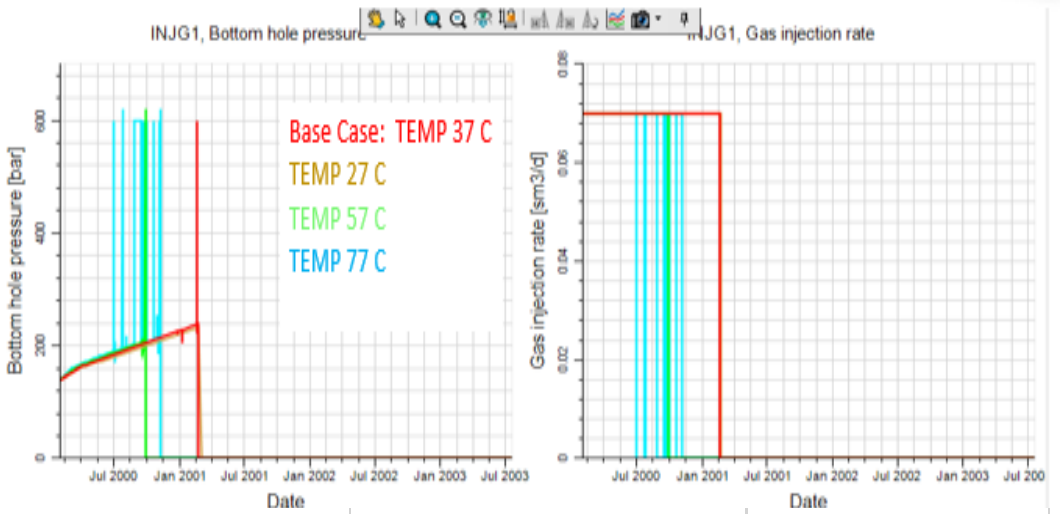
CO2 Injection Rate Vs. Time



Temperature Impact on Solid Saturation

Solid Saturation Vs. Time @ Injection Point

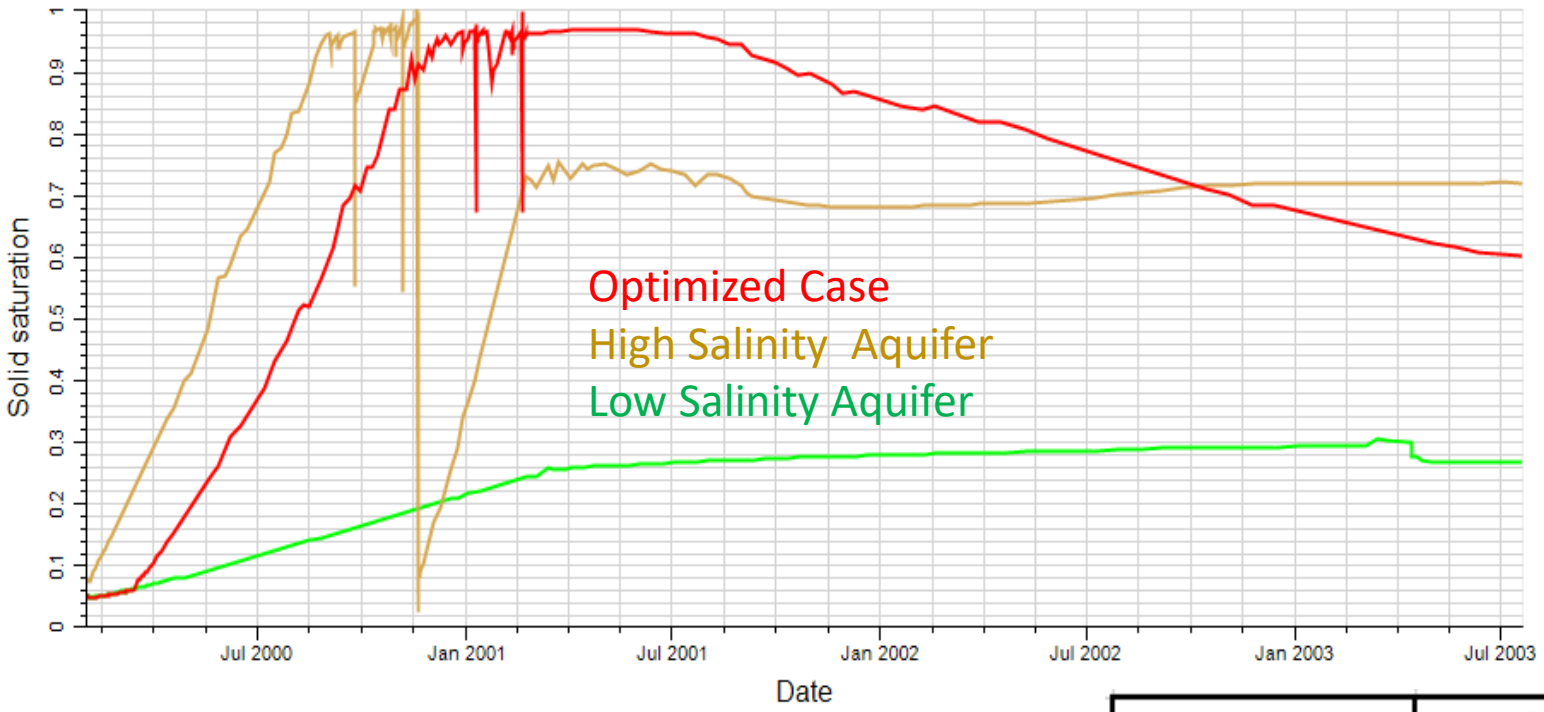


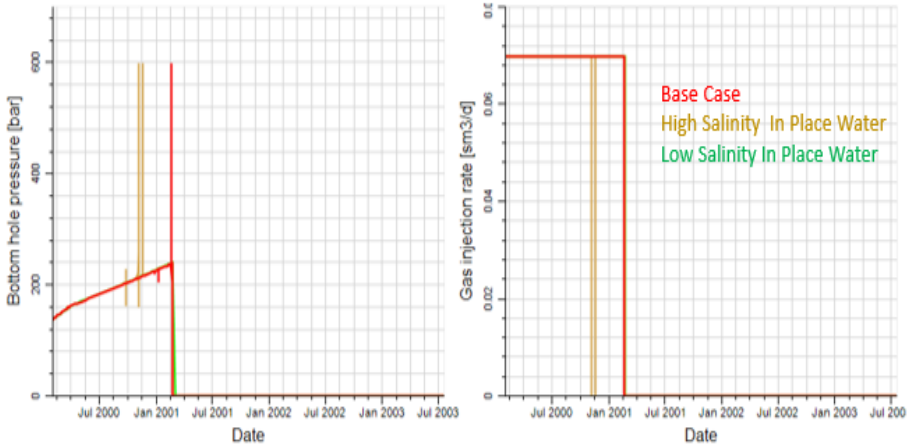


Case	Start of Solidification (day)	Maximum Solid (day)
Temprature 27	58	403
Temprature 37	41	296
Temprature 57	25	234
Temprature 77	16	159

Aquifer Salinity

Solid Saturation Vs. Time @ Injection Point





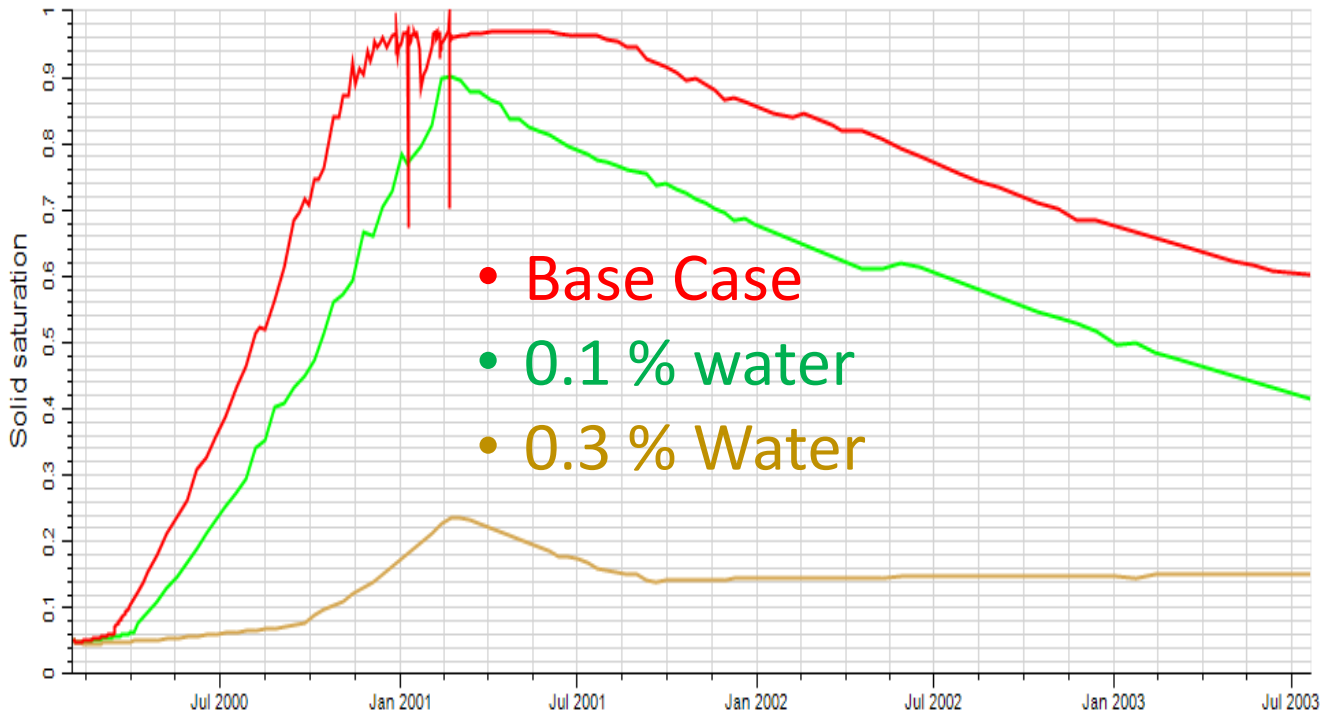
- Initial solid saturation : 0.0932
- Initial solid saturation : 0.0653
- Base case: 0.0643

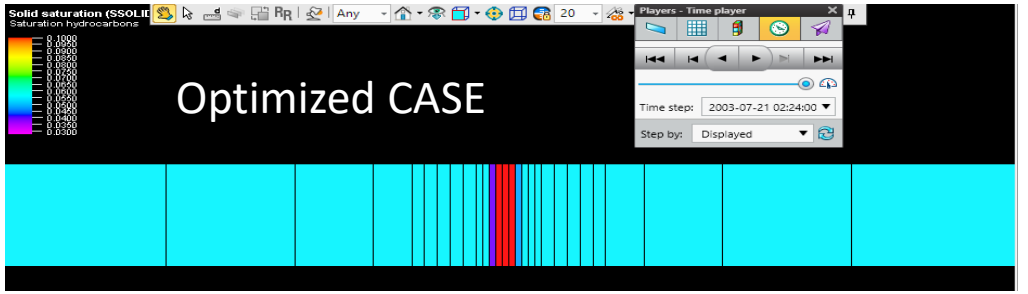
	Mole %		
Component Name	Low salinity	Base Case	High Salinity
H2O	0.9509	0.9009	0.88
CO2	0	0	0
NACL	0.0291	0.0741	0.085
CACL2	0.01	0.015	0.02
CACO3	0.01	0.01	0.015

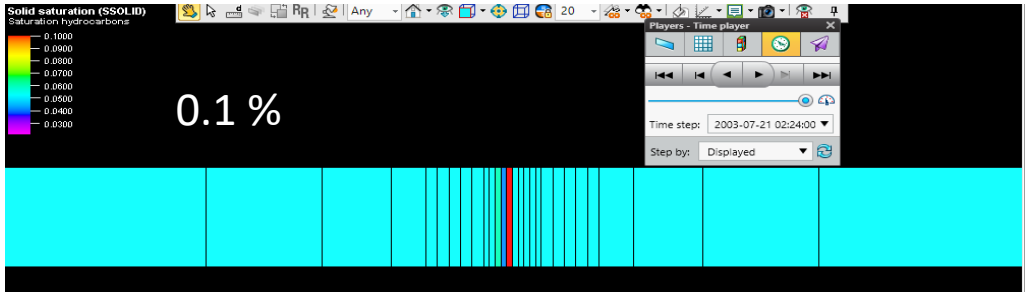
Case	Start of Solidification (day)	Maximum Solid (day)	Maximum Solid Saturation
High Salinity	0	214	0.97
Optimized Case	41	296	0.97
Low Salinity	-	401	0.26

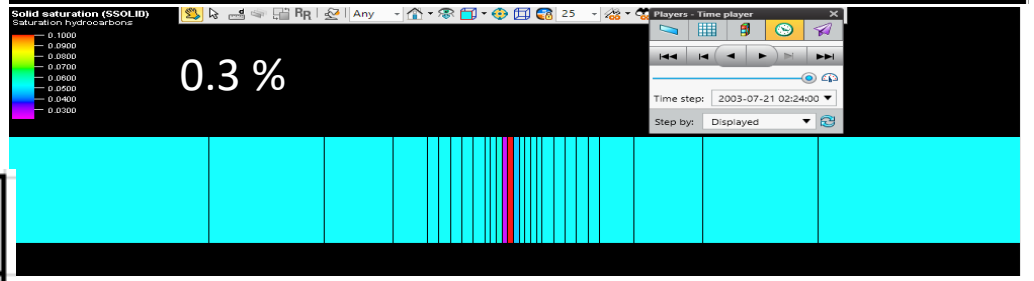
Adding Water to Injection Stream (CO2)

Solid Saturation Vs. Time @ Injection Point





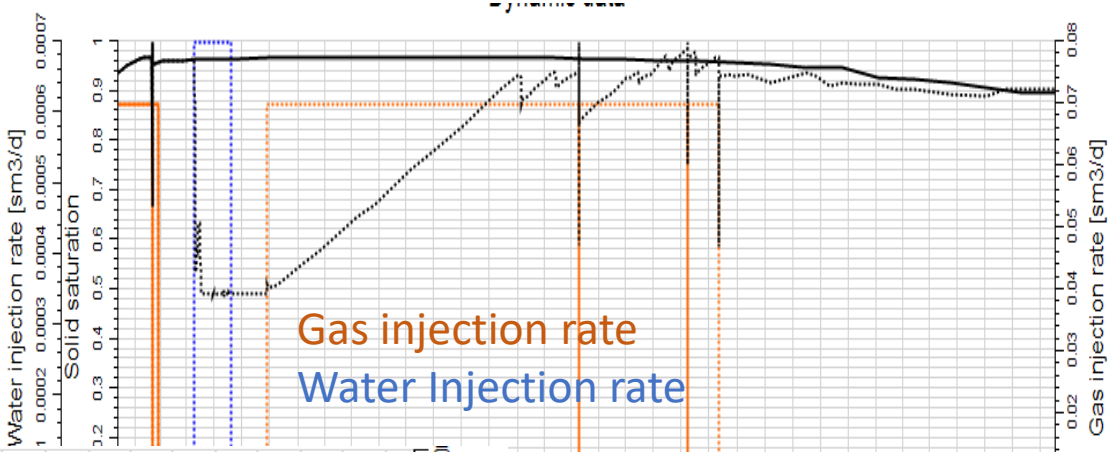


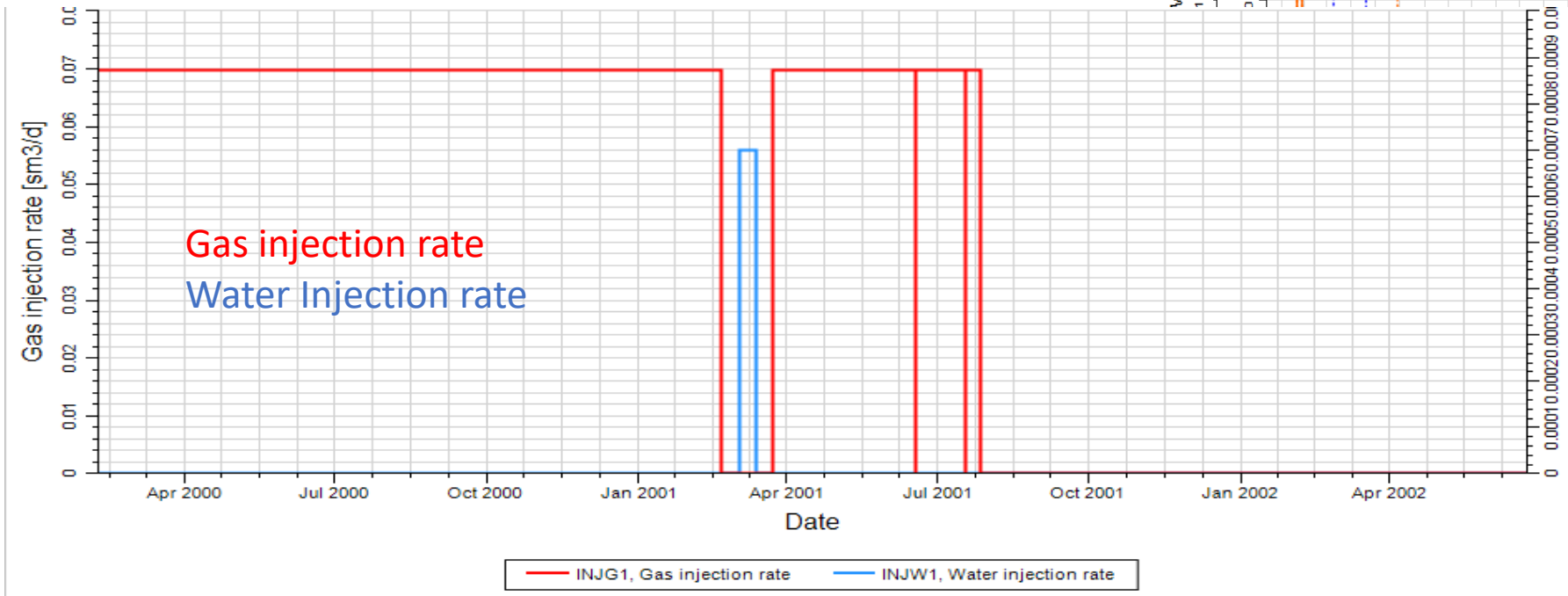


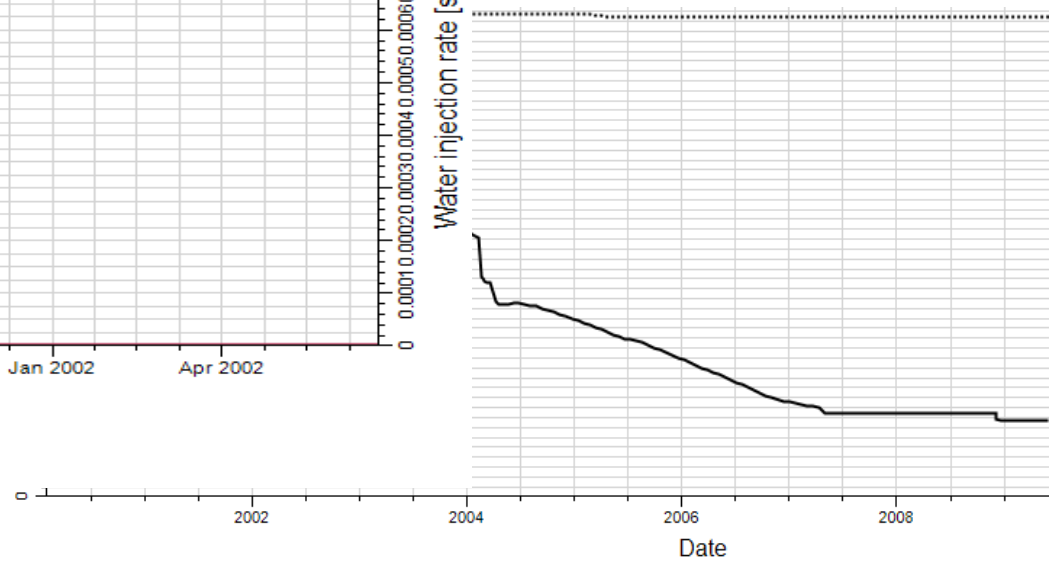
Case	Start of Solidification (day)	Maximum Solid (day)	Maximum Solid Saturation
0.3 % water content	237	385	0.237
Optimized Case	41	296	0.97
0.1 % water content	60	375	0.89

Simulation Set Up for Carbonated Water Injection

- The CO2 injection will stop after 384 days
- After 10 days the well is converted to water injector (Carbonated Water)
- Carbonated water Injection for 10 days then shutting the well
- After 10 days well converted back to gas Injector
- Gas injection continues for 120 more days

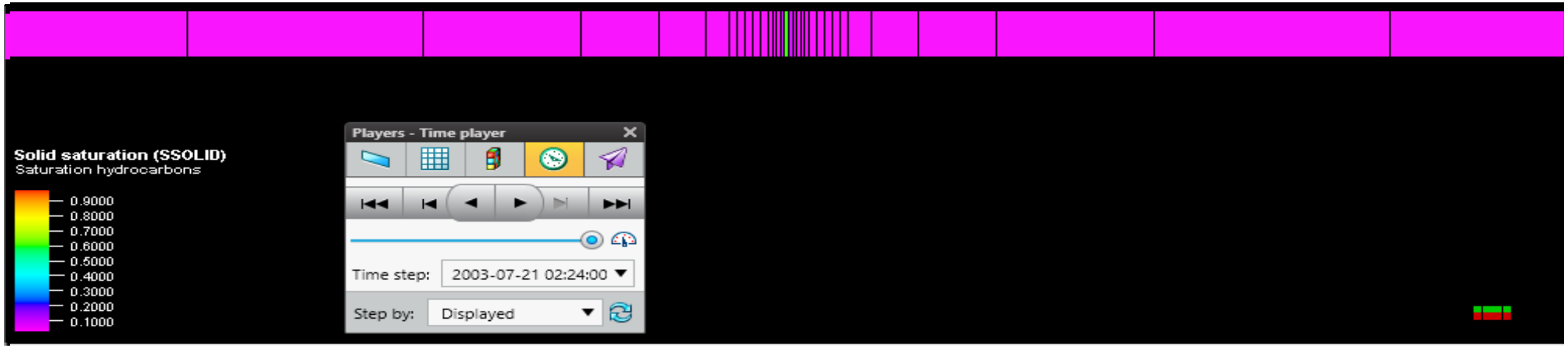




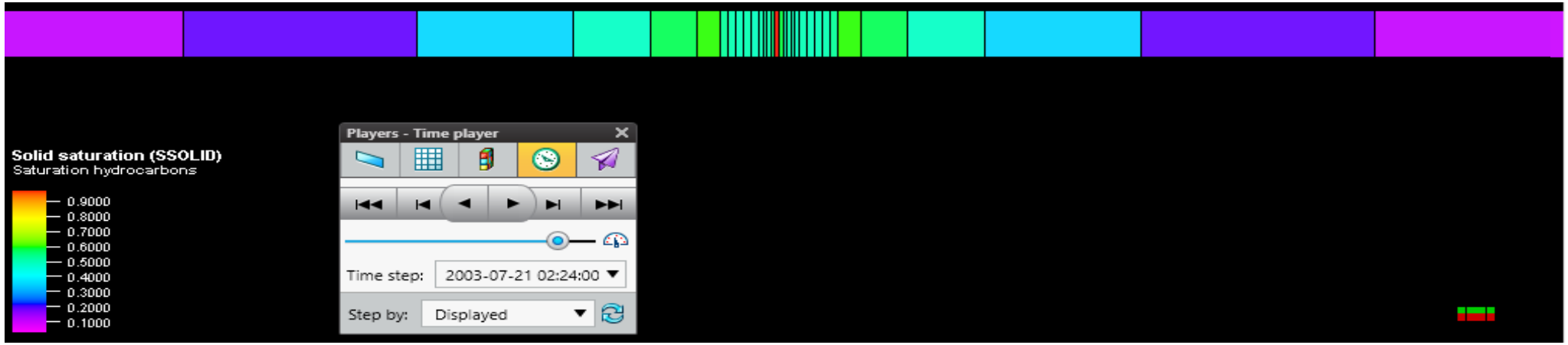


Carbonated Water Injection Solid Saturation Map

Optimized Case



Carbonated Water Injection Case

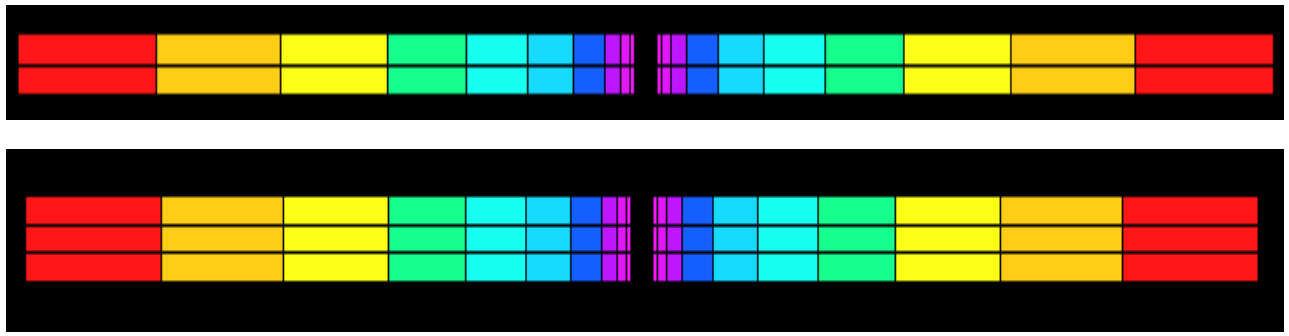


Solid saturation map after 10 days carbonated water injection

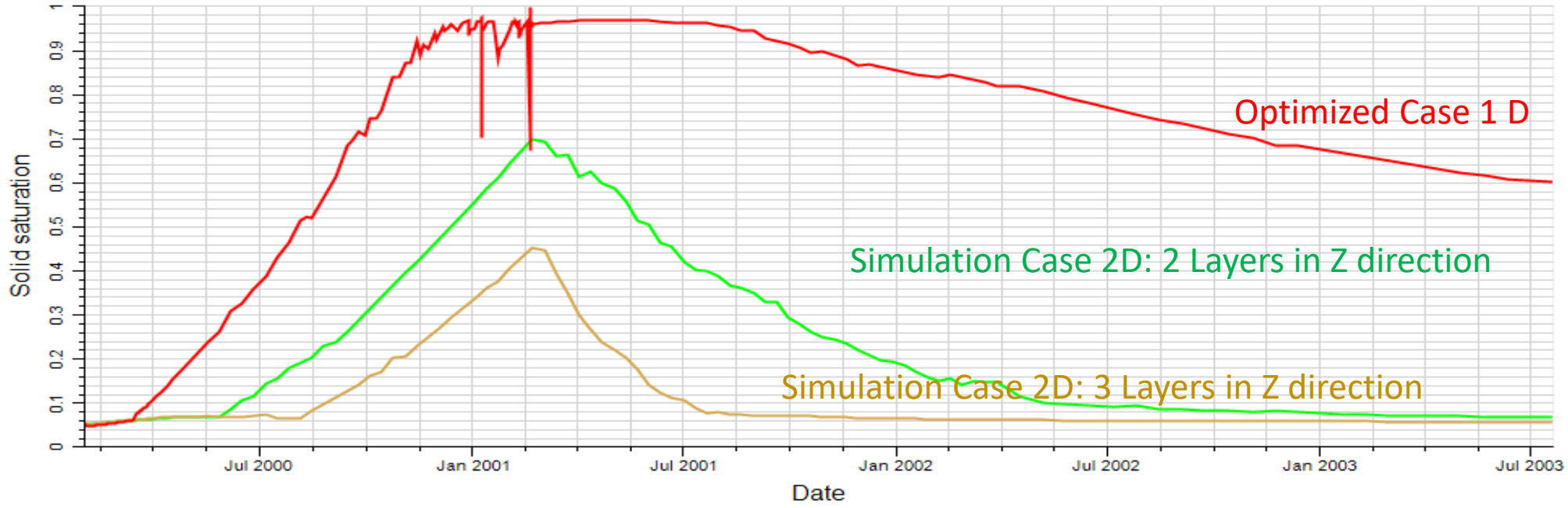
Impact of The Model Scale on The Simulation Results

2D Grid Set Up

- 2D model is built on the 1D model for sake of comparison:
- Dx: 40 , Dy: 1 , DZ: 2 and 3
- Grid size in all dimensions are the same
- Properties are the same
- Model input are identical

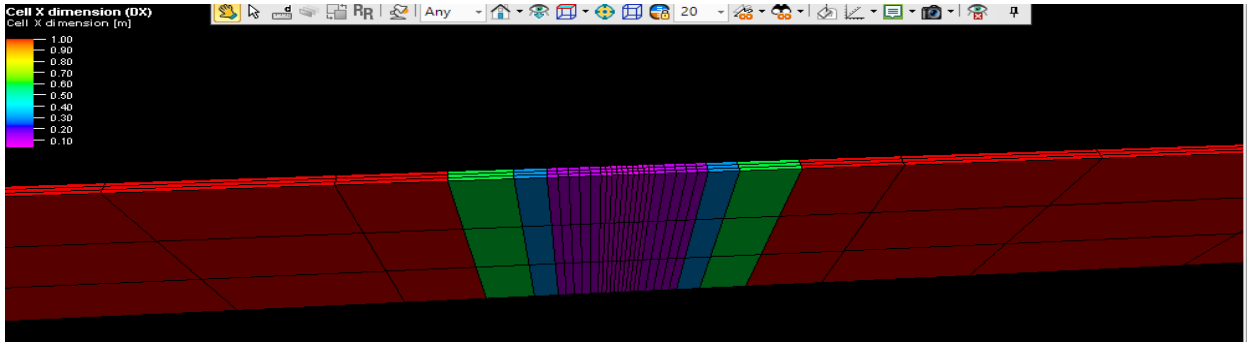


Solid Saturation Vs. Time @ Injection Point

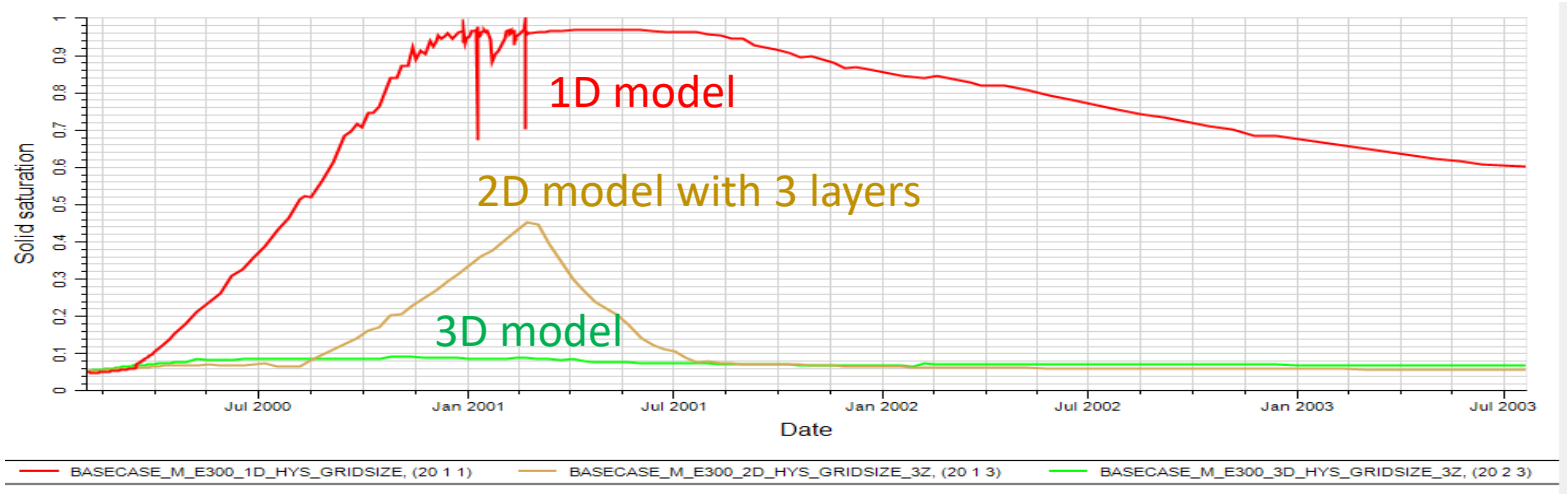


3D Grid Set Up

- 3D model is built on the 1D model for sake of comparison:
- Dx: 40 , Dy: 3 , DZ: 3
- Grid size is the same
- Properties are the same
- Model input are identical



Solid Saturation Vs. Time @ Injection Point



Message

- This study shows the CO2 storage can be optimized not only regarding storage capacity but also well performance

- Using nonreactive transport simulator for near wellbore modeling in 3D radial flow is not advisable.
  - Most important reason is that impact of solid presence in the model is introduced to the model as tabulated data linked to the solid saturation eventually injected gas saturation
  - Hens it is not straight forward to use lab data (1D) directly for well data (3D) due to buoyancy and segregation impact

- Is it possible to predict when CO2 injector will need stimulation by the E300 simulator?
  - Providing representative data to use in tool is a big challenge

- Injecting Carbonated water improves CO2 containment through enhancing the chemical reaction

THANK YOU