CO2STORE: Case Studies

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TNO innovation for life

CLIMIT Webinar: HPC-G, 22/09/2023

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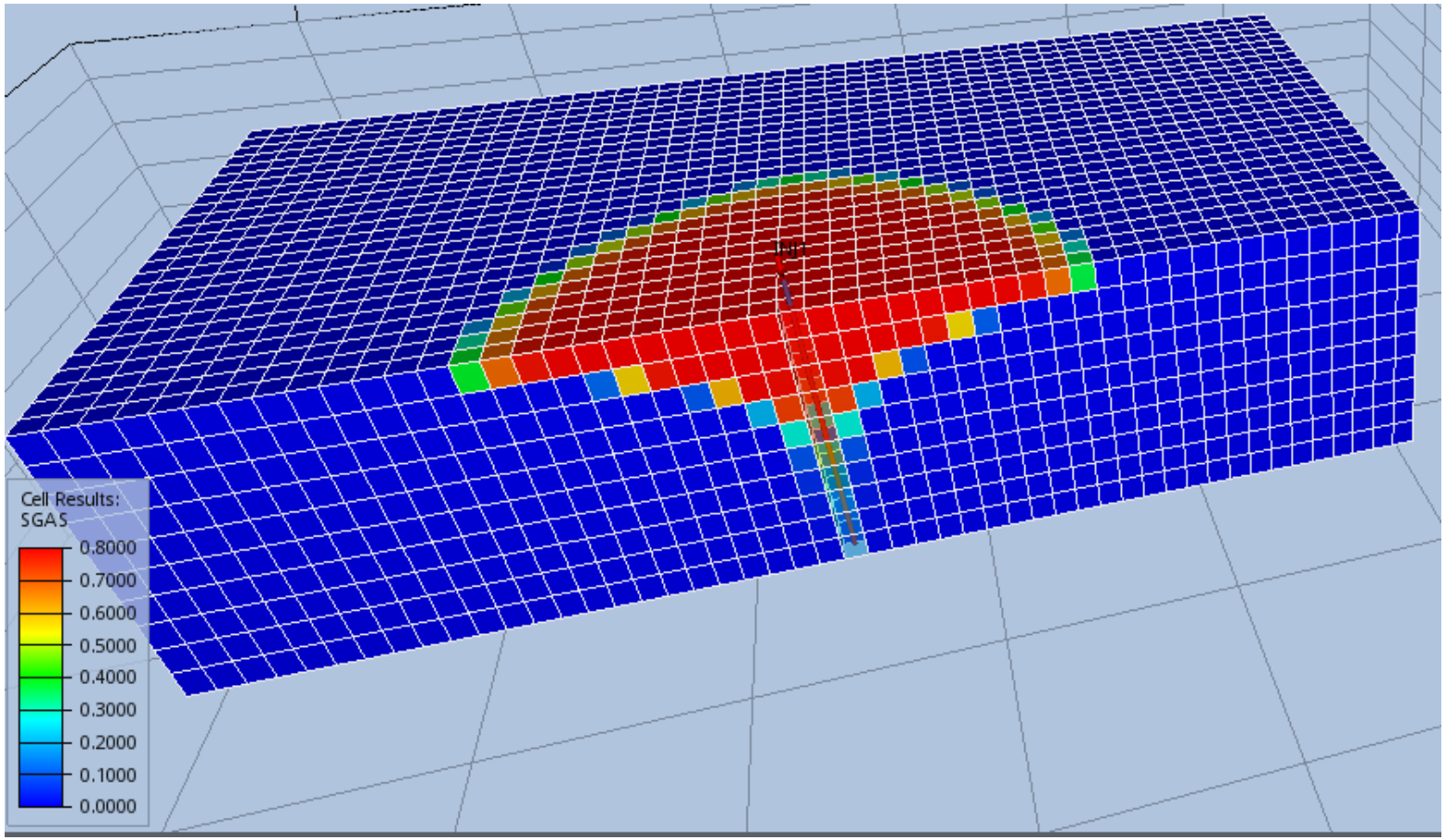
Case 1: CO2STORE in Aquifer

```
-- Test case for CO2STORE in combination with GASWAT.
-------------------------------------------------------------
RUNSPEC
-------------------------------------------------------------
TITLE

START
 1 'JAN' 2023 /

METRIC

CO2STORE
GASWAT
DISGASW


COMPS
2
/

DIMENS
   50 50 10  /
```

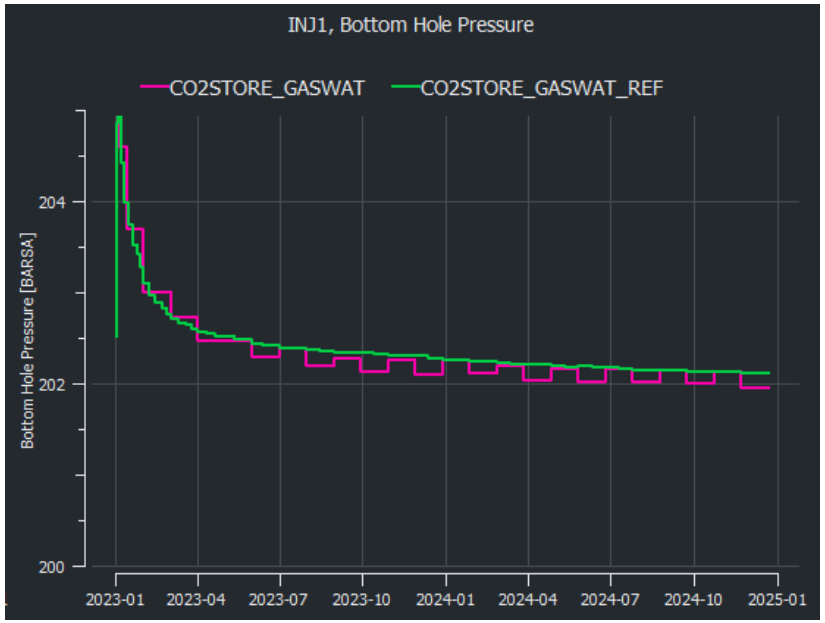
```
GRID    ============
INIT

TOPS
2500*2000/

DXV
50*20 /
DYV
50*20 /
DZV
10*5 /

EQUALS
PERMX  100   /
PERMY  100   /
PERMZ  100 /
PORO   0.25  /
/
```



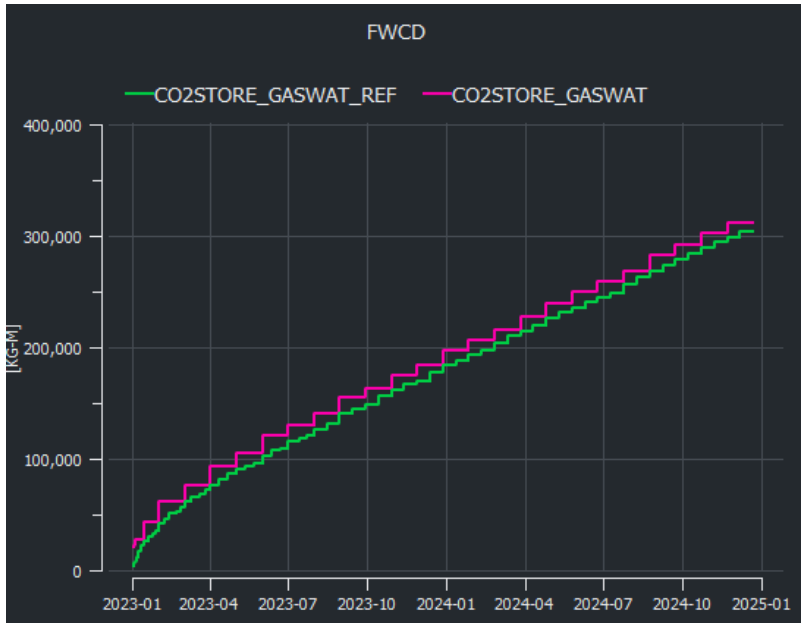
https://github.com/OPM/opm-tests/blob/master/co2store/CO2STORE_GASWAT.DATA

Case 1: Comparison Summary

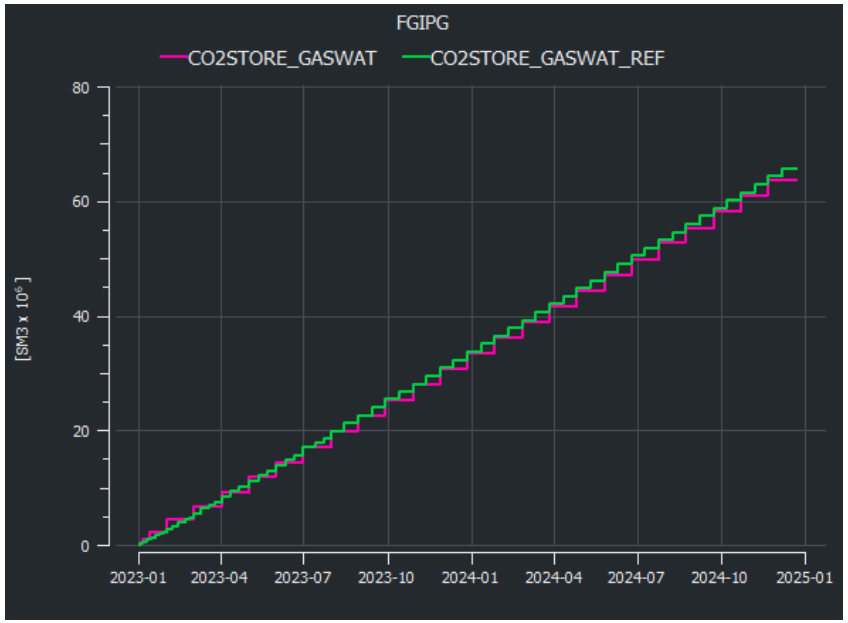
Injector BHP



CO2 Dissolved in Water

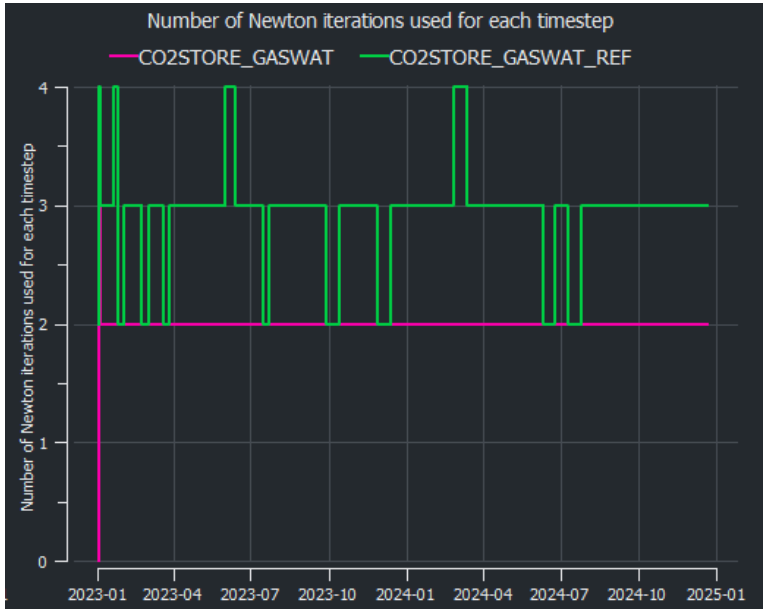


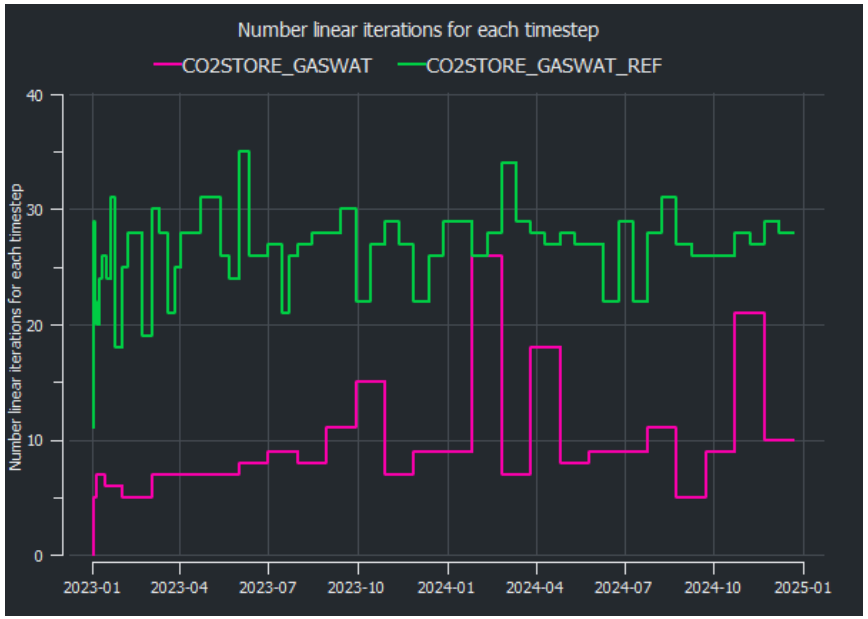
Field Gas In Place (Gas Phase)



Case 1: Comparison Performance

- Default solver and tuning parameters for both simulators, serial run
- OPM-Flow master-branch 21/09/2023 (target release 2023.10)
- Intel Core i7-8850H, 6(12) @2.60GHz, RAM 128GB

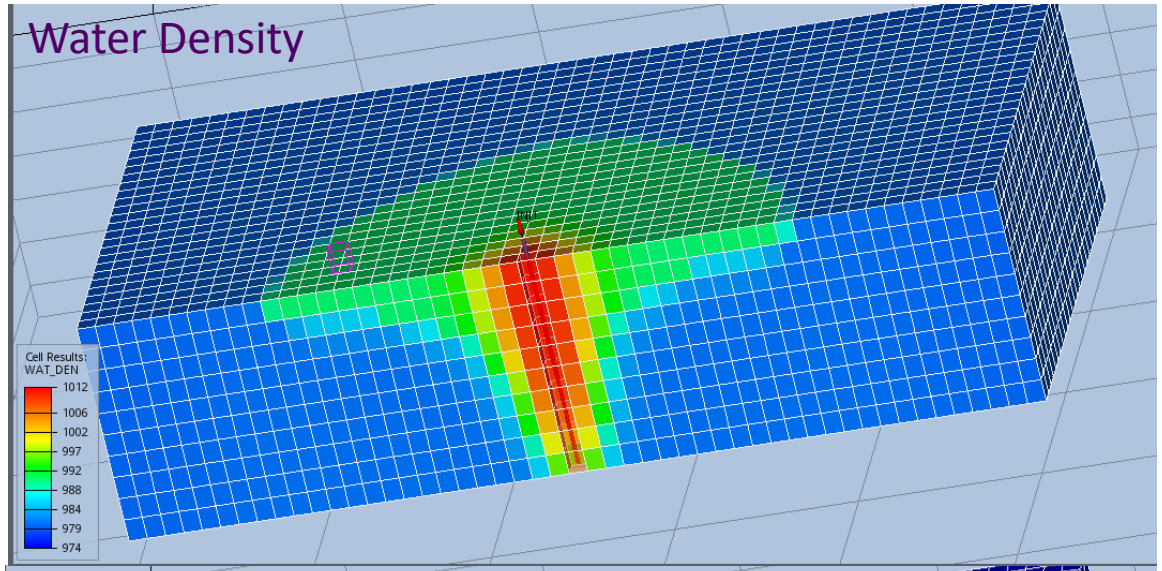


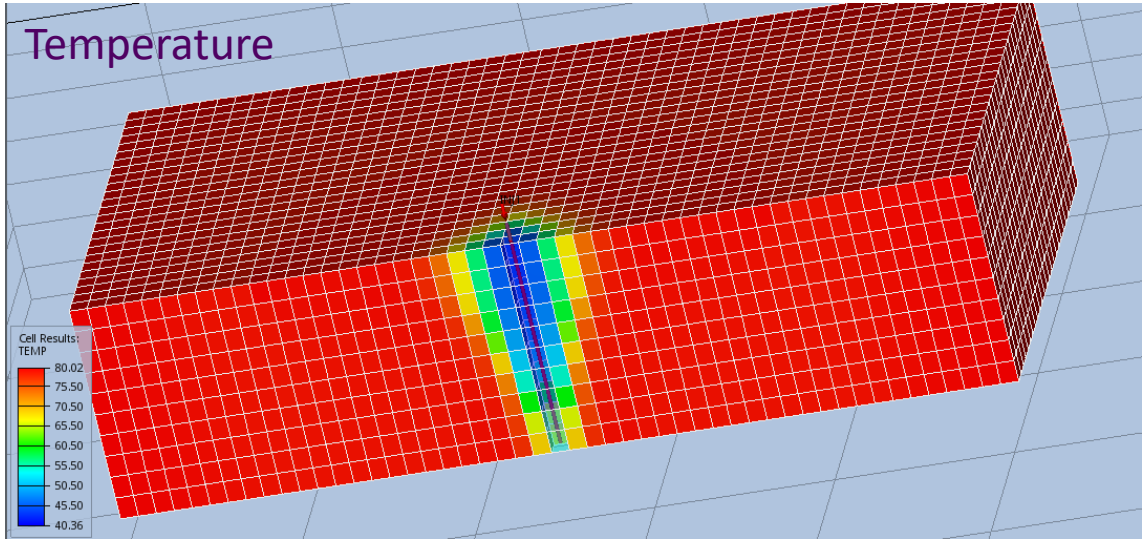


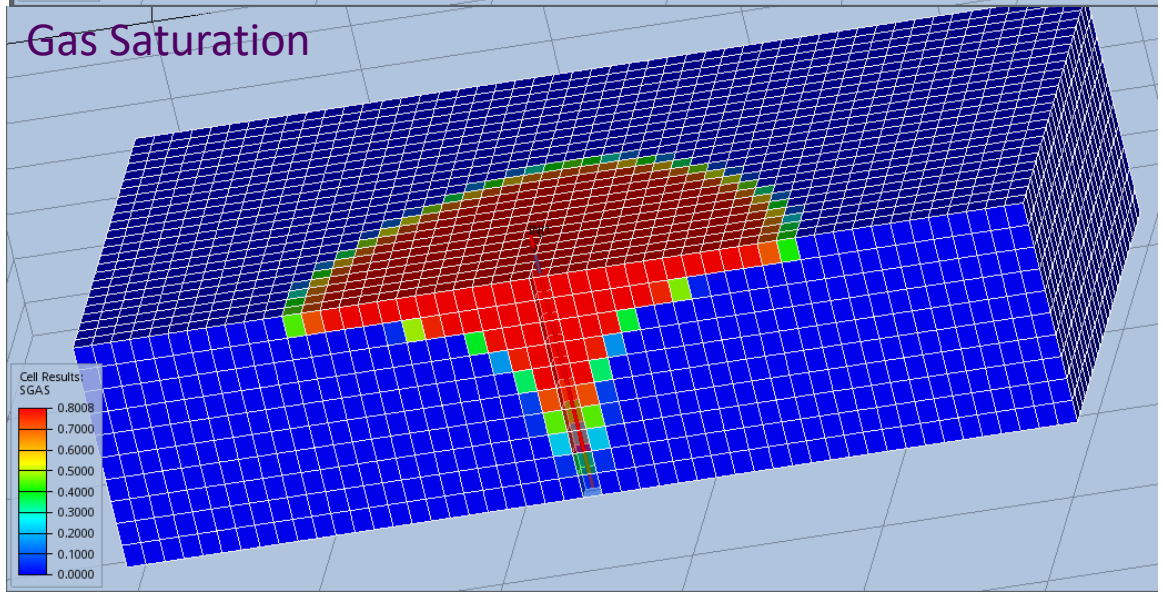
Case 2: CO2STORE + THERMAL in Aquifer

```
-- Test case for CO2STORE in combination with THERMAL.

----------------------------------------------------------
RUNSPEC
----------------------------------------------------------
TITLE
   CO2STORE

START
 1 'JAN' 2023 /

METRIC

CO2STORE
THERMAL
GAS
WATER
DISGASW
```

After 3 year of injection



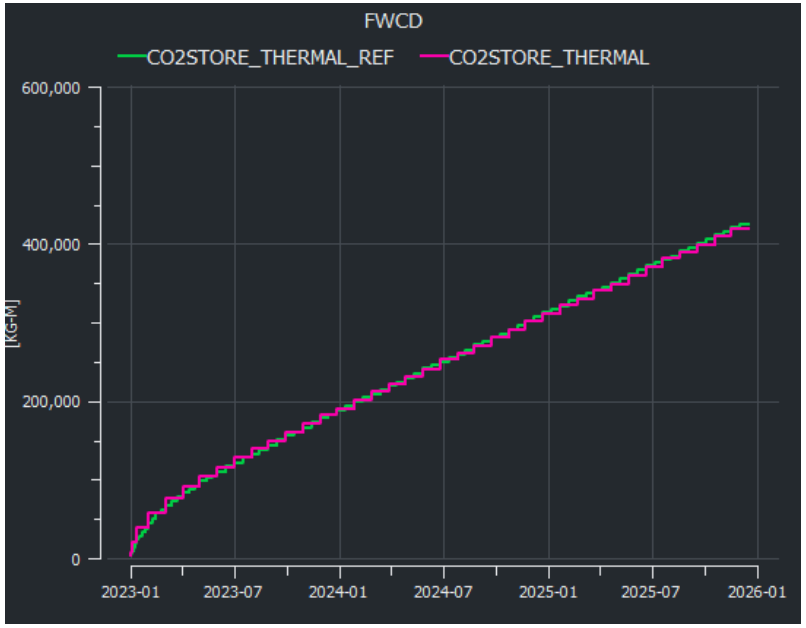




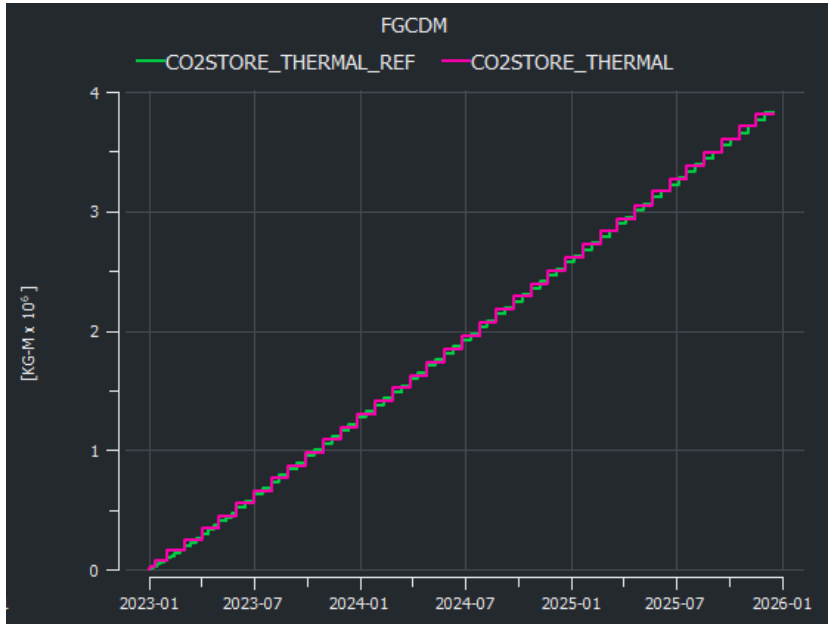
https://github.com/OPM/opm-tests/blob/master/co2store/CO2STORE_THERMAL.DATA

Case 2: Comparison Field Summary

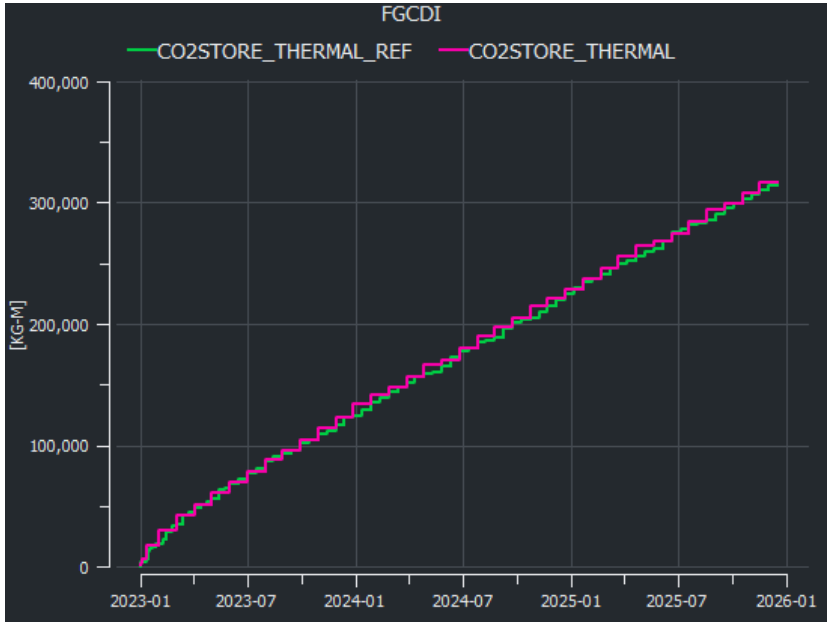
CO2 Dissolved in Water



CO2 Mobile as Gas Phase



CO2 Trapped as Gas Phase



Case 2: Comparison Performance

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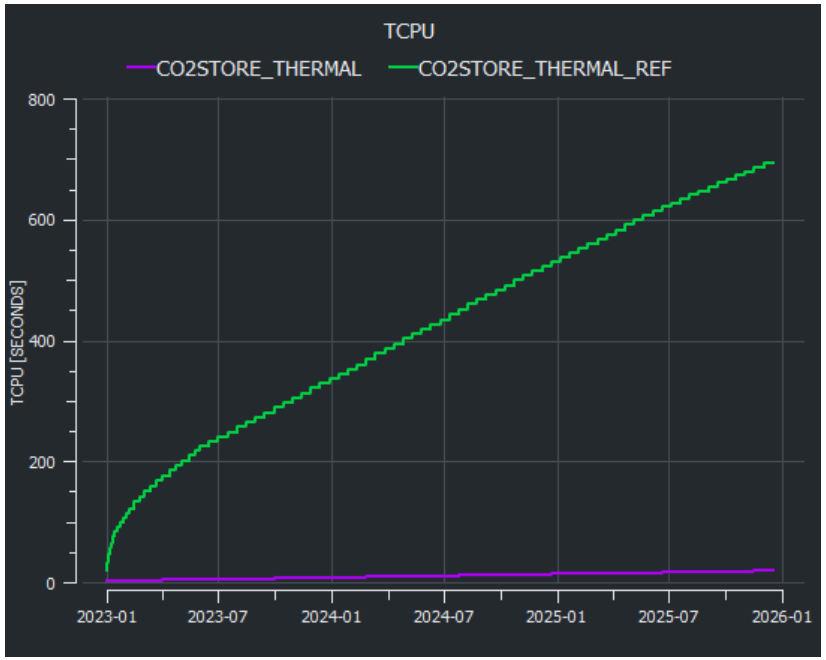
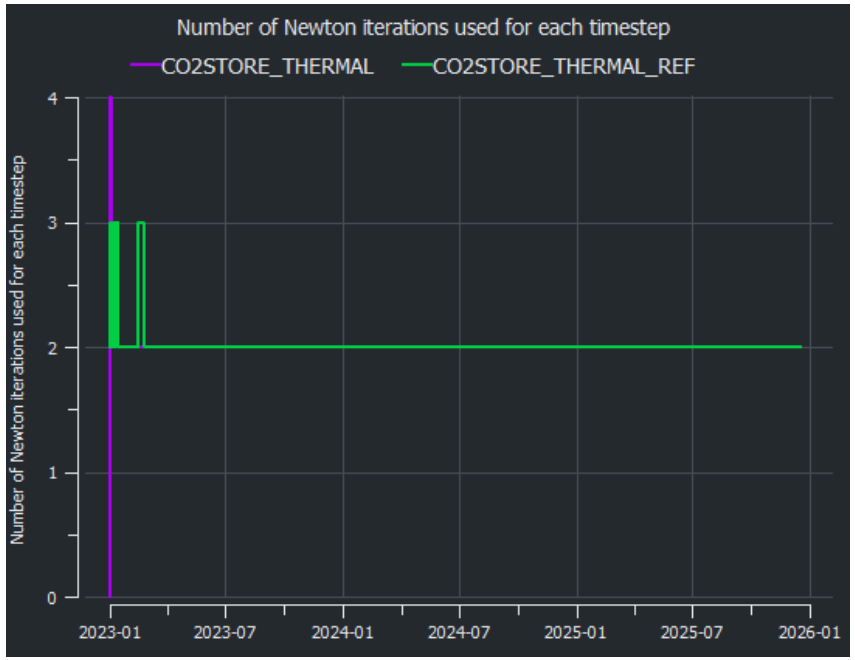
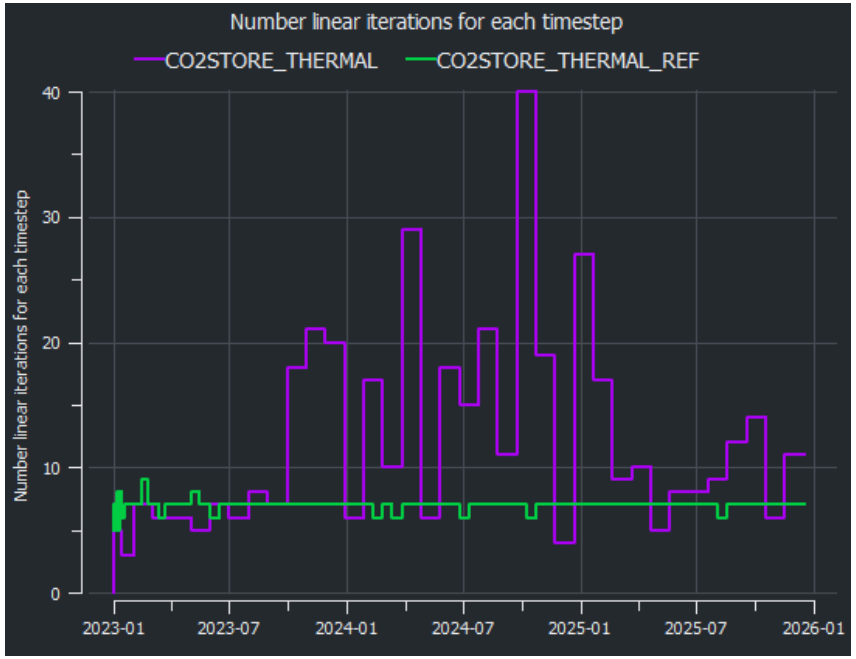






Case 3: CO2STORE + THERMAL + PRECSALT

Salt precipitation and dissolution assuming instantaneous equilibrium:

$$\frac{\partial}{\partial \mathrm{t}}\left[\varphi b_w s_w c_w^{salt} + m_\varphi \varphi_0 s_s \rho^{salt}\right] + \nabla \cdot \left(c_w^{salt} b_w v_w\right) + c_w^{salt} q_w = 0$$

- ρ^{salt} : Density of solid salt [kg/m^3]
- s_s : (Volume) saturation of precipitated salt, assumed to be immobile
- c_w^{salt} : Salt concentration in water [kg/Sm^3]

- Change in porosity: $\varphi = (1 - s_s) m_\varphi \varphi_0$, with $m_\varphi(p)$
- Change in permeability: $k = k_0(\phi/\phi_0)^\lambda$ (or any user-defined input table)

Extension of primary variable switching logic

- Salt precipitation and dissolution:
  - If c_w^{salt} exceeds solubility limit, s_s becomes primary variable
  - If $s_s \leq 0$, then c_w^{salt} becomes the primary variable

* Machado, C. G., Egberts, P., Alvestad, J., Hustad, O. S. , Salt Precipitation and Water Evaporation Modelling in a Black-Oil Reservoir Simulator, SPE RSC 2023. SPE-212257-MS.

Case 3: Brine-CO2 System

- Black-oil formulation internally, but
  - PVT and solubility computed dynamically as function of temperature, pressure, composition and salinity.
  - Molar fractions of components are computed and output
- This setup for CSS is straightforward for the user
- CO2STORE can be combined with THERMAL and PRECSALT

CO2STORE: CO2-Brine properties

Density	Brine	Water	Hu, J., Duan, Z., Zhu, C., & Chou, I. M. (2007), Wagner, W., & Pruß, A. (2002).
		Salinity	Batzle, M., & Wang, Z. (1992).
		Dissolved CO2	Garcia, J. E. (2001).
	CO2		Span, R., & Wagner, W. (1996)
Viscosity	Brine		Batzle, M., & Wang, Z. (1992).
	CO2		Fenghour, A., Wakeham, W. A., & Vesovic, V. (1998).
Solubility			Spycher, N., Pruess, K., & Ennis-King, J. (2003). Duan, Z., & Sun, R. (2003)
Enthalpy	Brine	Water	Wagner, W., & Kruse, A. (2013).
		Salinity	Daubert, T. E., Daubert, T. E., & Danner, R. P. (1989)
		Dissolved CO2	Duan, Z., & Sun, R. (2003)
	CO2		Span, R., & Wagner, W. (1996).

Diffusivity	Water	McLachlan, C. N. S., & Danckwerts, P. V. (1972).
	Salinity	Ratcliff, G. A., & Holdcroft, J. G. (1963)
	Tortuosity	Millington, R. J., & Quirk, J. P. (1961).

* Sandve, T. H., Gasda, S. E., Rasmussen, A., & Rustad, A. B. (2021). Convective Dissolution in Field Scale Co2 Storage Simulations Using the OPM Flow Simulator. In TCCS–11. CO2 Capture, Transport and Storage. Short Papers from the 11th International Trondheim CCS Conference 2021. SINTEF Academic Press.

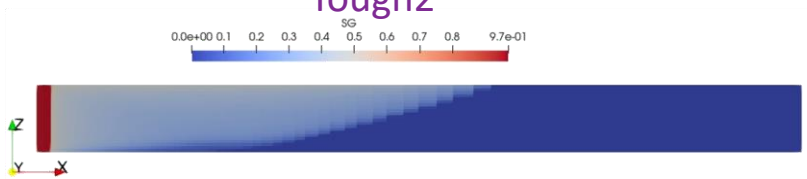
Case 3: Benchmark

Release version 2023.04

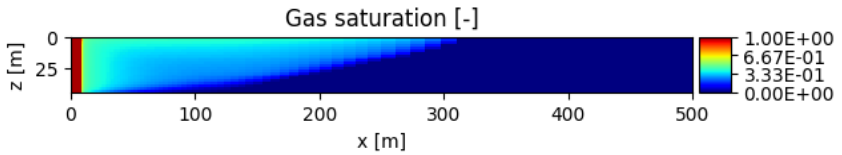
OPM OPEN POROUS MEDIA

CO2

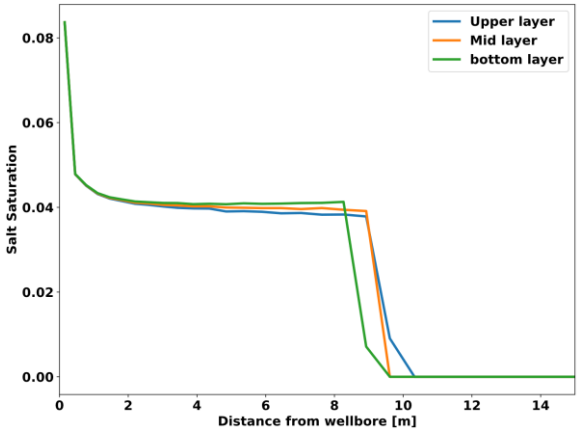
Tough2

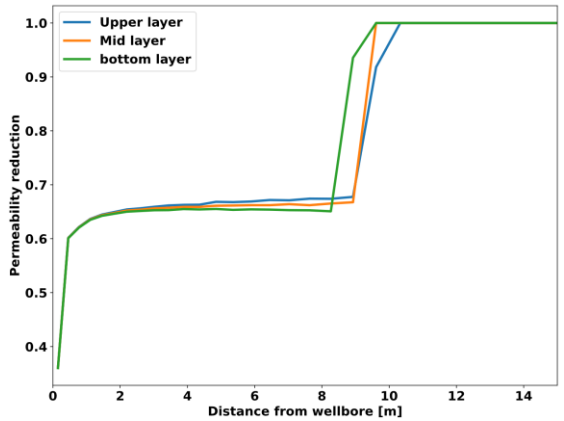


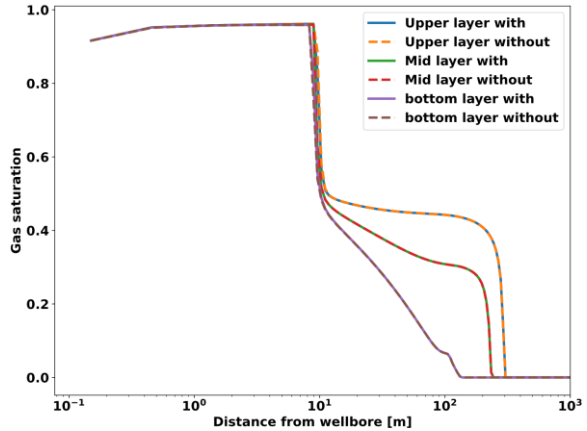
Opm-Flow



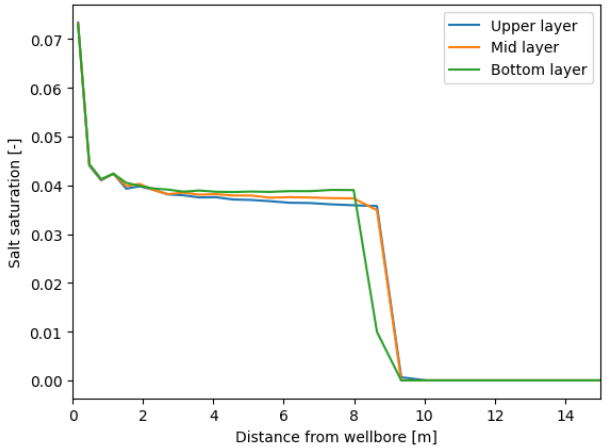
Tough2

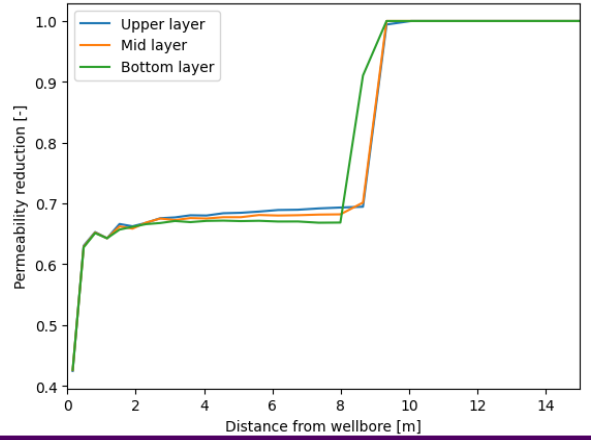


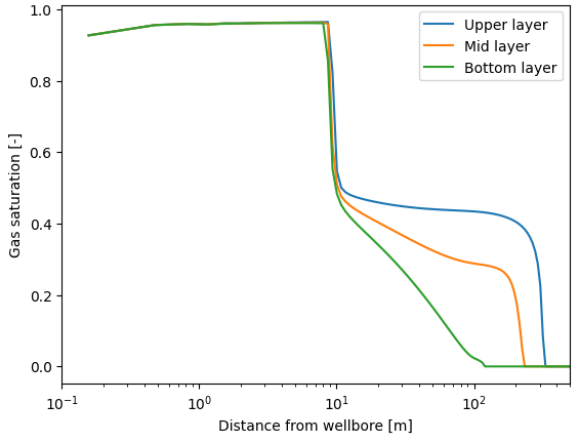




Opm-Flow







* Sarah Gasda, Nematollah Zamani and David Landa Marban. ”Management of salt precipitation for large-scale CO2 storage projects.” InterPore2023

Thank you!

Contact: Dr. Cintia Machado (cintia.machado@tno.nl)