Compostional Simulation with OPM-flow

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Contributors

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A small history

- PT-Flash calculation — June 2022
- A pressure driven CO2 flooding 1D demonstration — Nov. 2023
- Extending fluid system to allow any number of components — Dec. 2023
  - Oil-Gas two phase
- Running simulation from DATA input file — Sep. 2024
- Summary and Restart output — Oct. 2024
- Compositional well modeling -> ongoing

Compositional reservoir simulation

- Mass balance equations for N components

$$\frac{\mathbf{M}_i^{n+1} - \mathbf{M}_i^n}{\Delta t^n} + \mathtt{div}(\mathbf{V}_i) - \mathbf{Q}_i = 0, \quad i \in \{1, \ldots, N\}.$$

$$\mathbf{M}_i = \boldsymbol{\Phi}\left(\boldsymbol{\rho}_\ell \boldsymbol{S}_\ell \boldsymbol{X}_i + \boldsymbol{\rho}_v \boldsymbol{S}_v \boldsymbol{Y}_i\right)$$

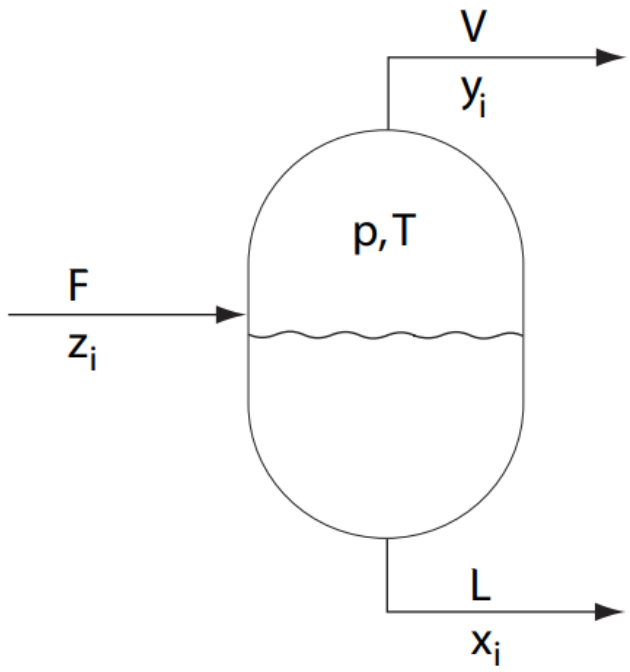
$$\mathbf{V}_i = -\mathbf{T}^f \left(\boldsymbol{\lambda}_{i,\ell}^f \boldsymbol{\Theta}_\ell + \boldsymbol{\lambda}_{i,v}^f \boldsymbol{\Theta}_v\right)$$

$$\sum_i^N \boldsymbol{x}_i = 1, \quad \sum_i^N \boldsymbol{y}_i = 1, \quad \boldsymbol{S}_\ell + \boldsymbol{S}_v = 1, \quad \boldsymbol{p}_v = \boldsymbol{p}_\ell + \boldsymbol{p}_{cv\ell}$$

Møyner O. Compositional Simulation with the AD-OO Framework. In: Lie K-A, Møyner O, eds. *Advanced Modeling with the MATLAB Reservoir Simulation Toolbox*. Cambridge University Press; 2021:324-374.

Isothermal flash calculation

- Vapor Liquid two phase
  - fugacity equilibrium
- Peng-Robinson equation of states
- Stability test
- Successive substitution iteration (SSI), Newton method and Hybrid SSI-Newton
- Automatic differentiation (AD)



https://skoge.folk.ntnu.no/bok/mer/flash_english_edition_2009

Supported compositional keywords

- COMPS
- EOS
- CNAMES
- ACF, MW, PCRIT, TCRIT, VCRIT, BIC

- XMF, YMF, ZMF

Demonstration

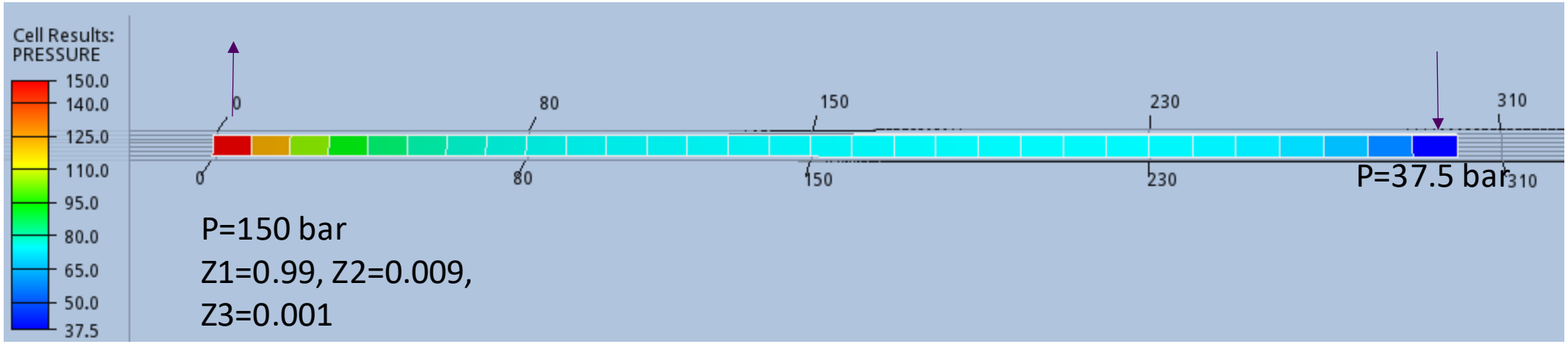
- flowexp_comp

- arguments:
  - --ecl-deck-file-name (input file)
  - --output-dir (output path)
  - --enable-vtk-output (false by default)
  - --flash-two-phase-method (ssi, newton and ssi+newton, ssi by default)
  - --flash-verbosity (0 by default)

- flowexp_comp --ecl-deck-file-name=SIMPLE_COMP_SMALLZ.DATA --output-dir=outputdir --enable-vtk-output=true

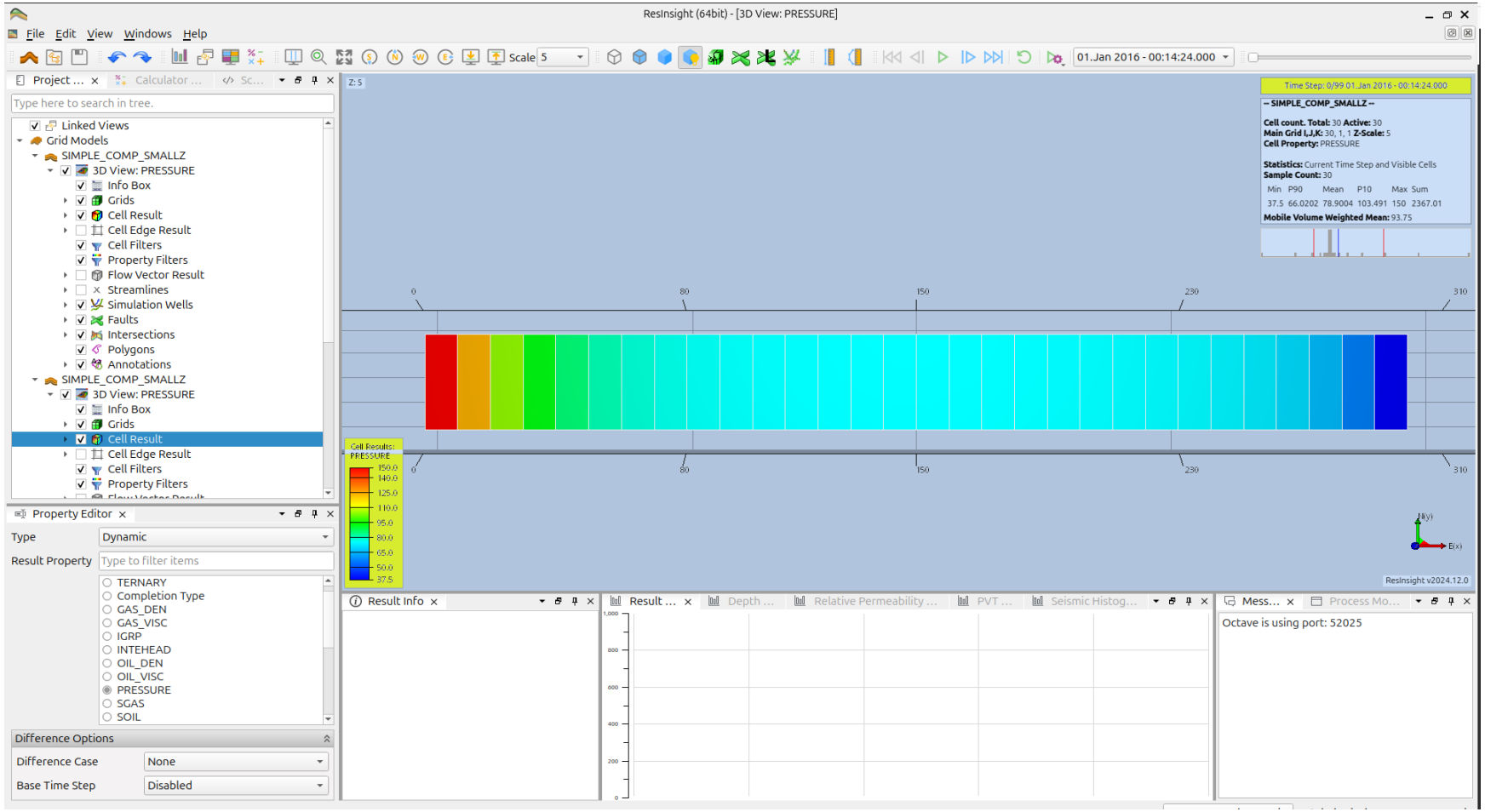
Test Case

- 1-D model (30x1x1)
- K=100 mD, Phi=0.1, P_{res}=75 bar, S_{Gas}=1, T_{res}=150 °C,
- Components (CO2(1), CH4(2), Decane(3)), Z_1=0.5, Z_2=0.3, Z_3=0.2
- Cell(1,1,1) and cell(30,1,1) are assigned with much bigger pore volume to mimic source and sink with constant pressure and compositions

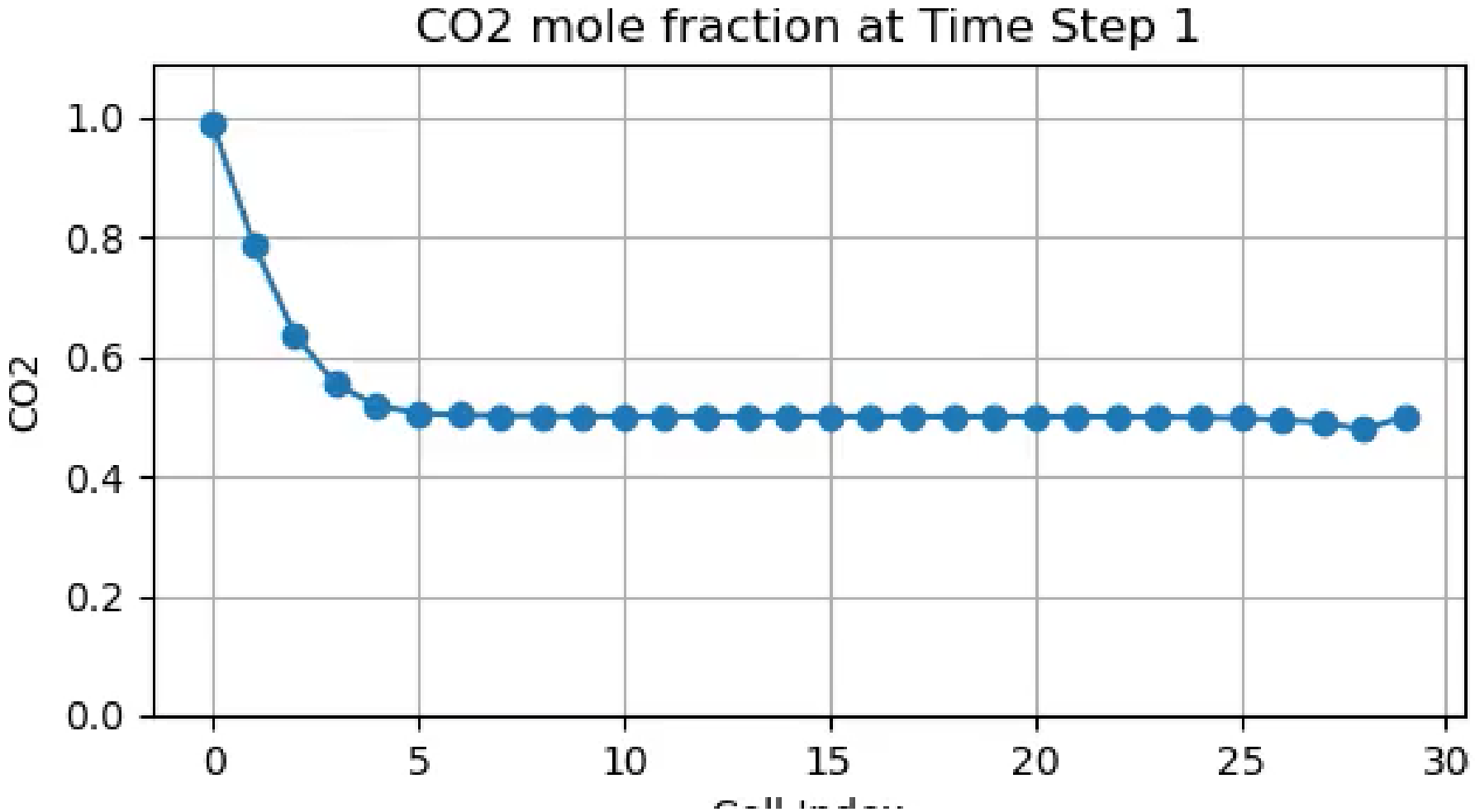


Visualization

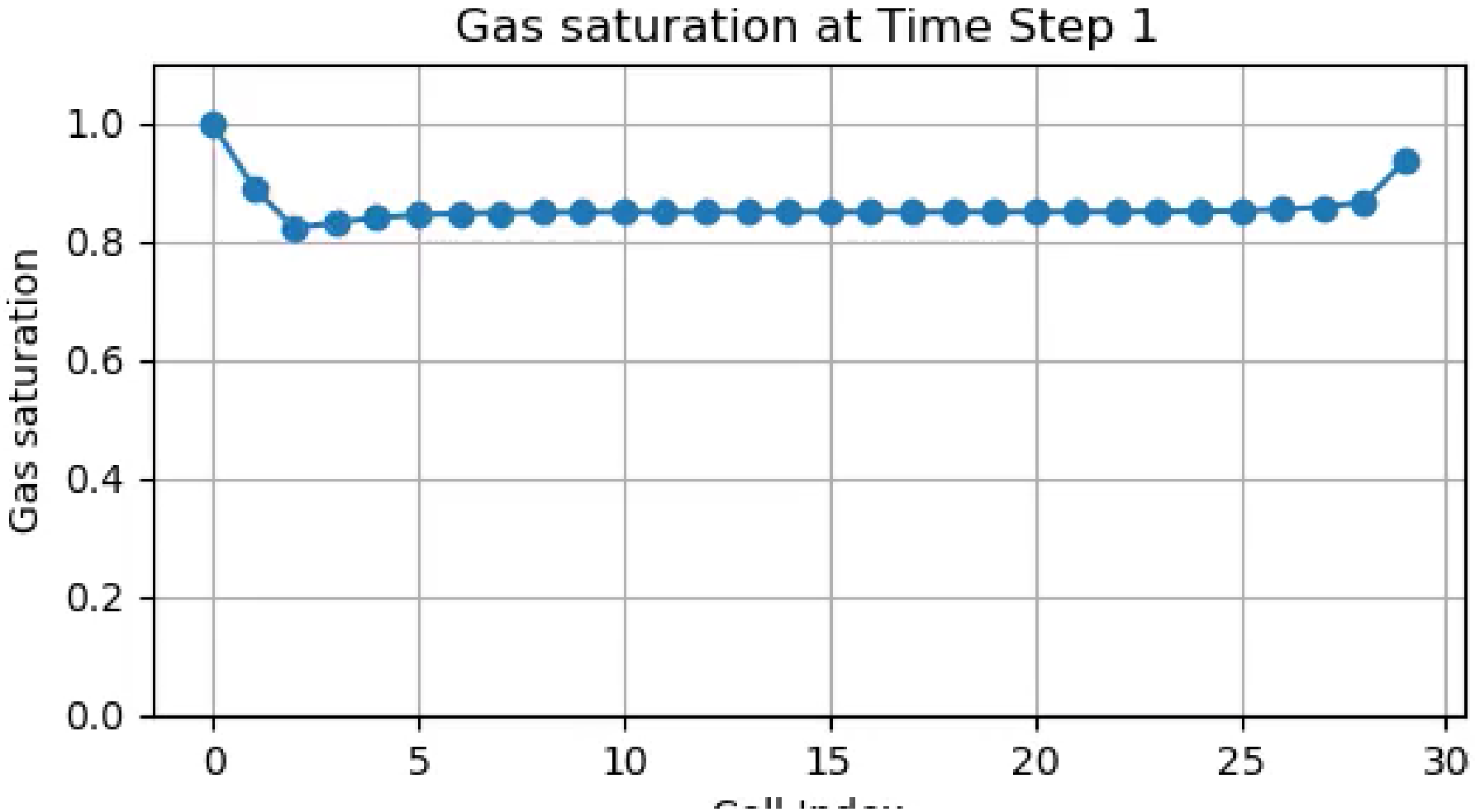
- ResInsight and Paraview can be used to visualize the output



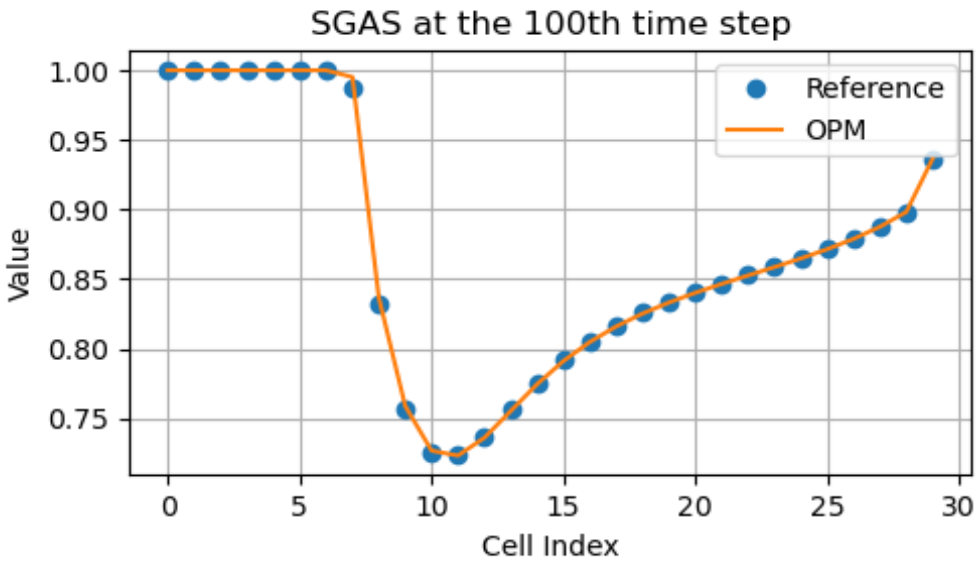
Resulting CO2 mole fraction evolution

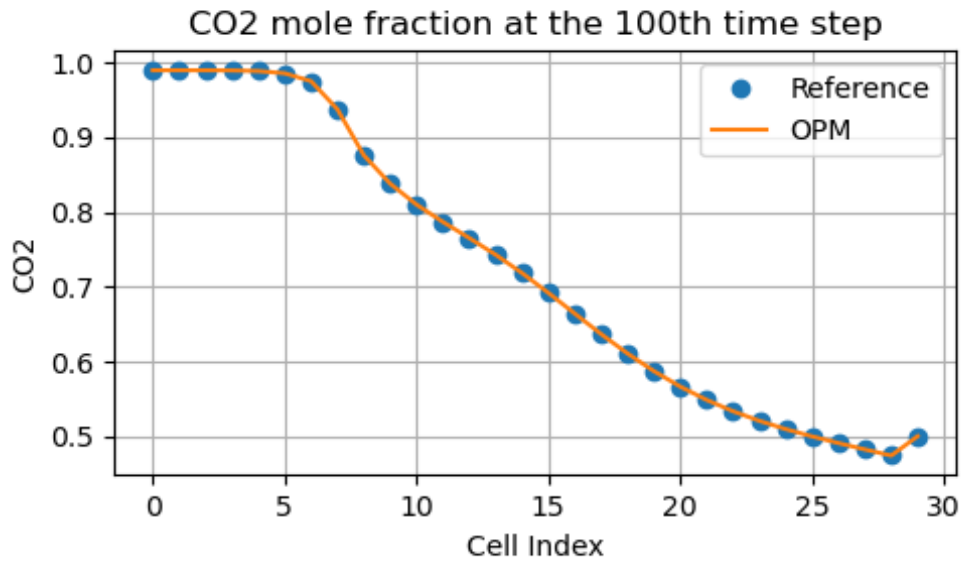


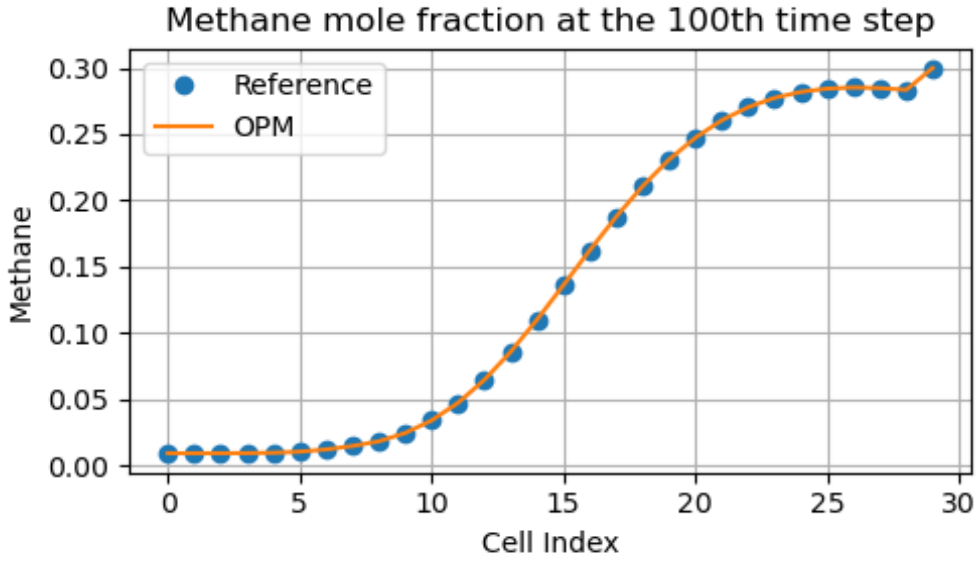
Resulting gas saturation evolution

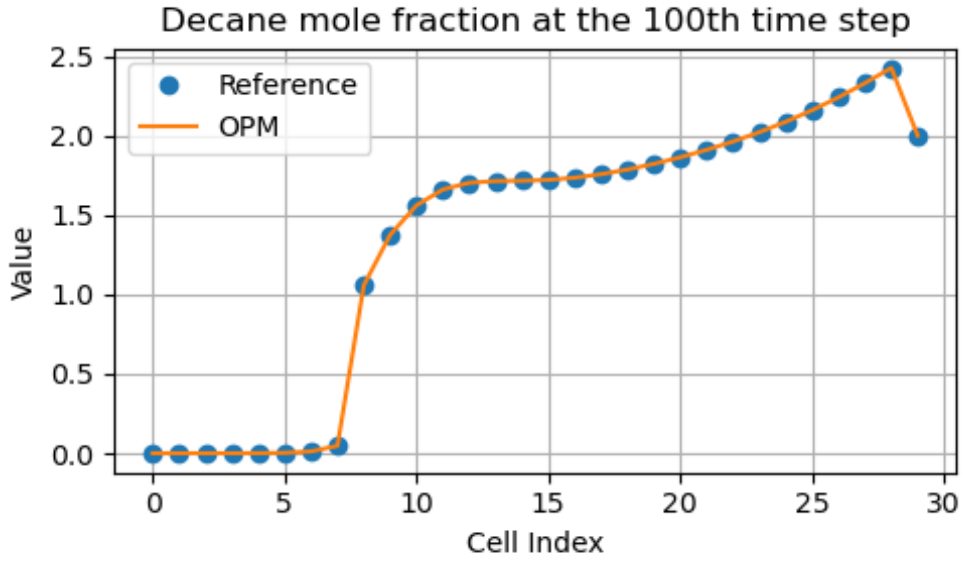


Validation against reference result









Features expected for OPM Release 25.04

- Compositional Standard Well model (working in process)

- Three phase with water
  - water is not involved in flash calculation

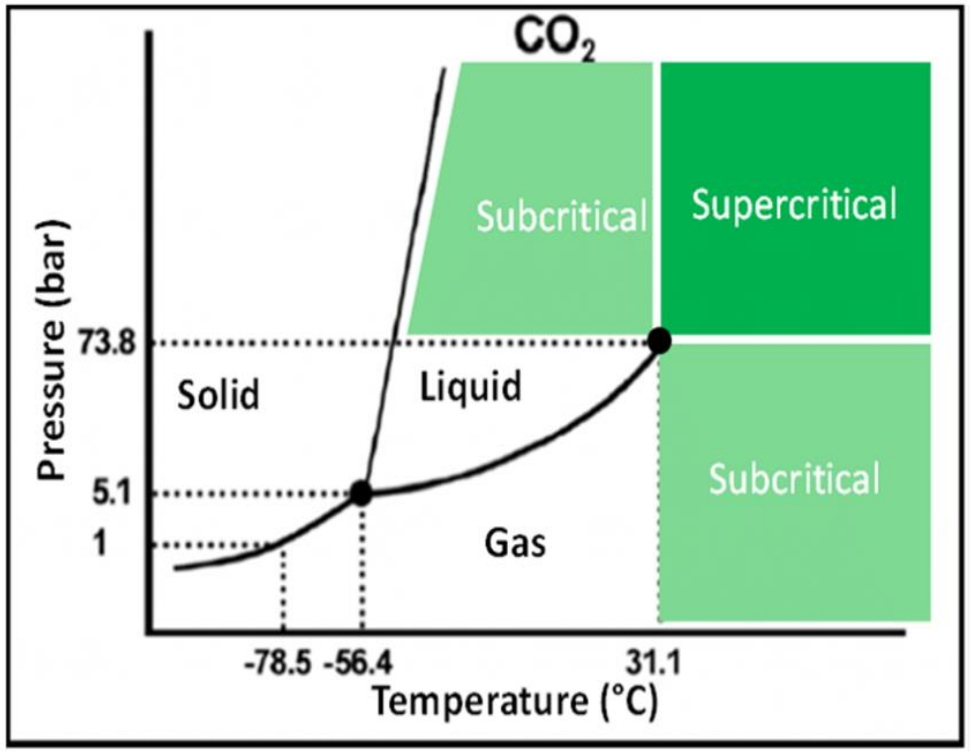
- Equilibration initialization

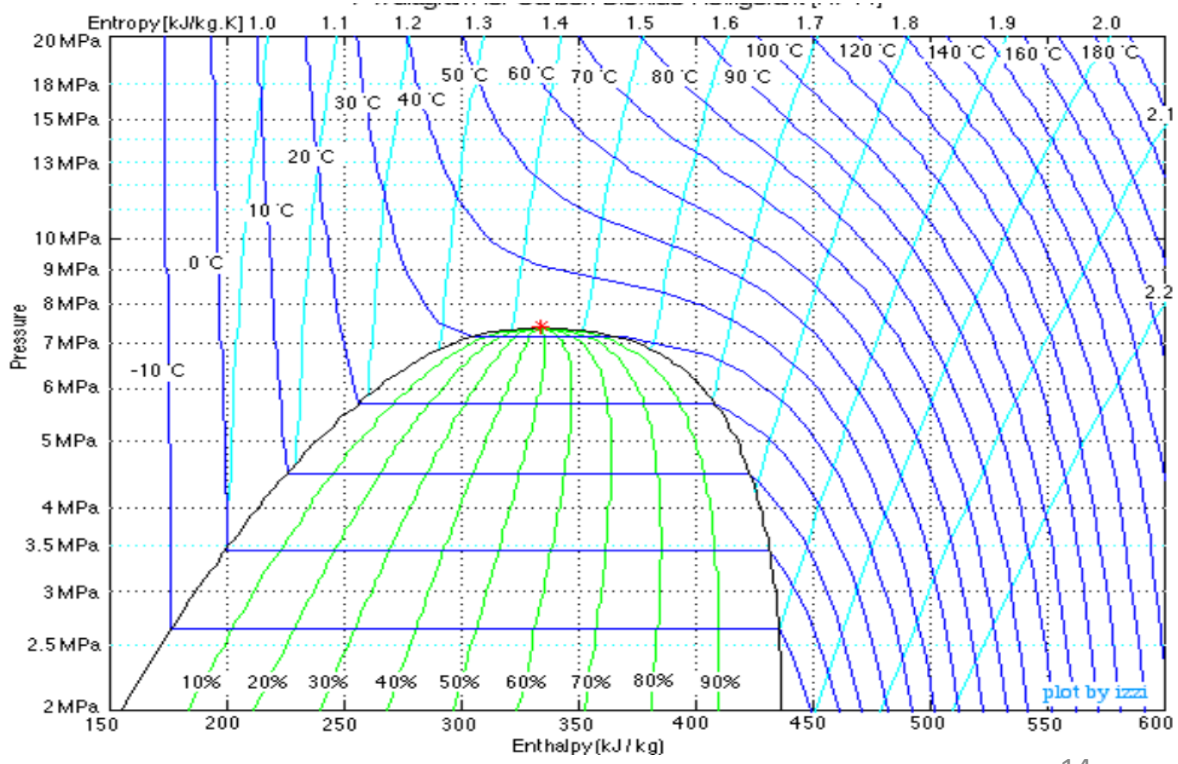
Hopefully

- Testing with bigger models for CO2 injection
- Thermal

EOS Based Thermal Compositional Energy Balance Formulation - Enthalpy Formulation

$$\frac{\partial}{\partial t}\left[\phi\left(\sum_{j=1}^{np}\rho_j S_j U_j\right)+(1-\phi)\rho_r U_r\right]=-\nabla\cdot\left(\sum_{j=1}^{np}\rho_j h_j u_j\right)+\nabla\cdot\left(K_T\nabla T\right)+q_H$$





$P,H,Z_1,Z_2,\ldots,Z_n$

Summary

- It is still in the early stage.
  - Testing, refactoring, optimization, adding features
- It can be readily elevated by incorporating existing capacities from flow simulator
  - Parsing, schedule, grid, parallelization, linear solvers, input/output facility, etc.
- It is on the way to be ready for future research and application.

Thank you!