Modeling Dense Phase CO_2 Decompression in Pipeline and Well Blowouts

Satartia MS, 2020

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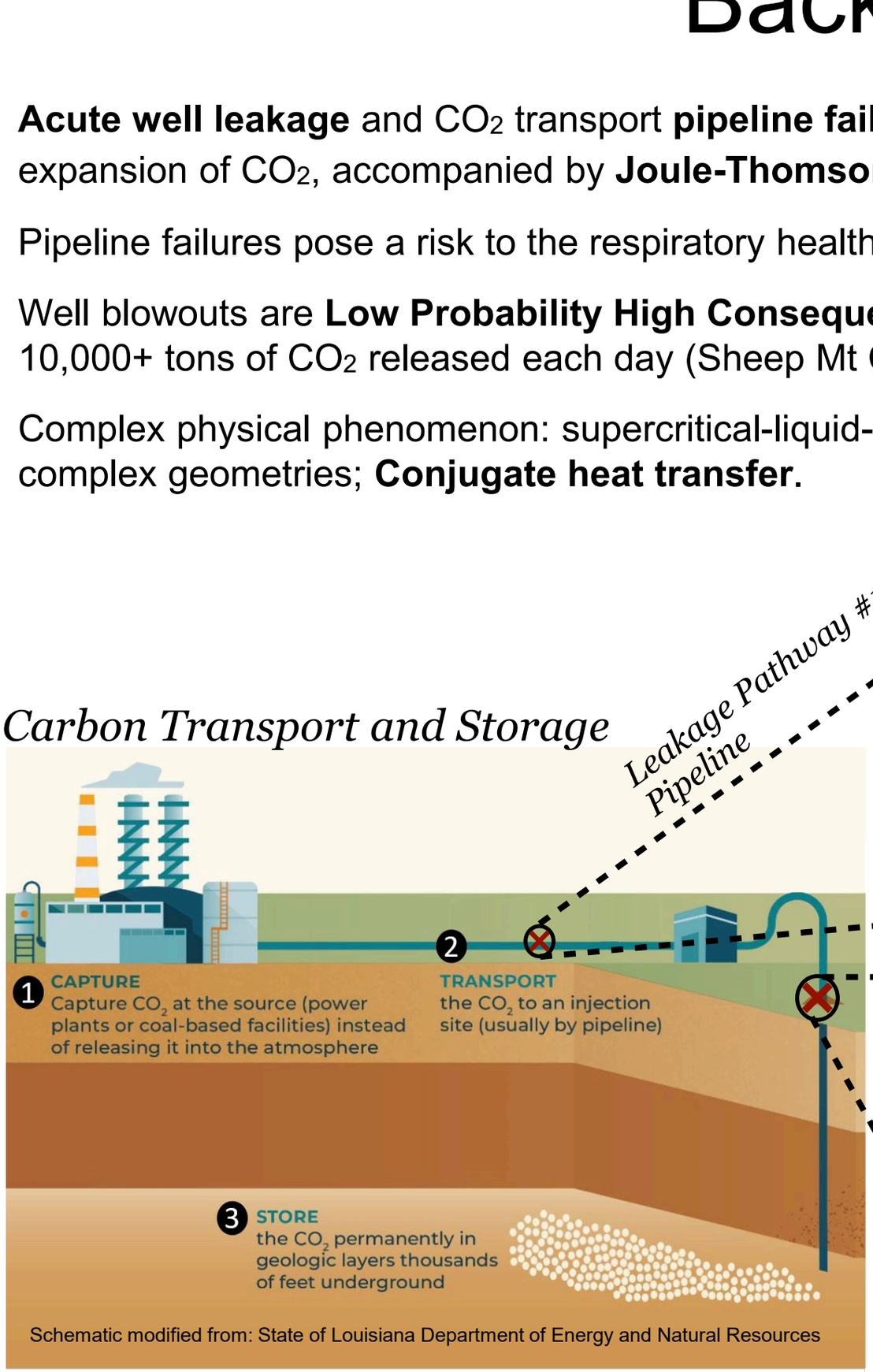
Background

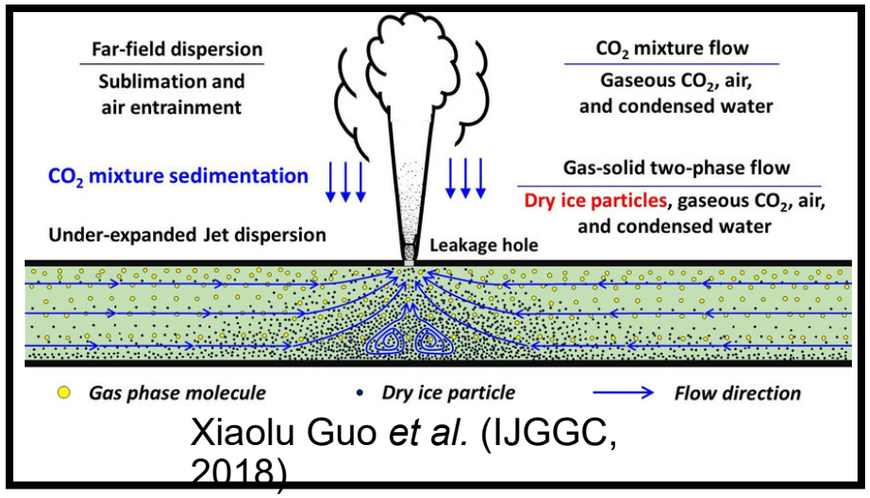
- **Acute well leakage** and CO_2 transport **pipeline failure** result in dense-phase CO_2 decompression: Rapid expansion of CO_2, accompanied by **Joule-Thomson cooling** ($T \leq -56.7^{o}C$).
- Pipeline failures pose a risk to the respiratory health of nearby populations (Satartia MS, 2020).
- Well blowouts are **Low Probability High Consequence** (LPHC) events (Oldenburg & Budnitz 2016), with 10,000+ tons of CO_2 released each day (Sheep Mt CO, 1984).
- Complex physical phenomenon: supercritical-liquid-gas-solid **phase change** of CO_2; **Near-sonic flow** around complex geometries; **Conjugate heat transfer**.

Carbon Transport and Storage



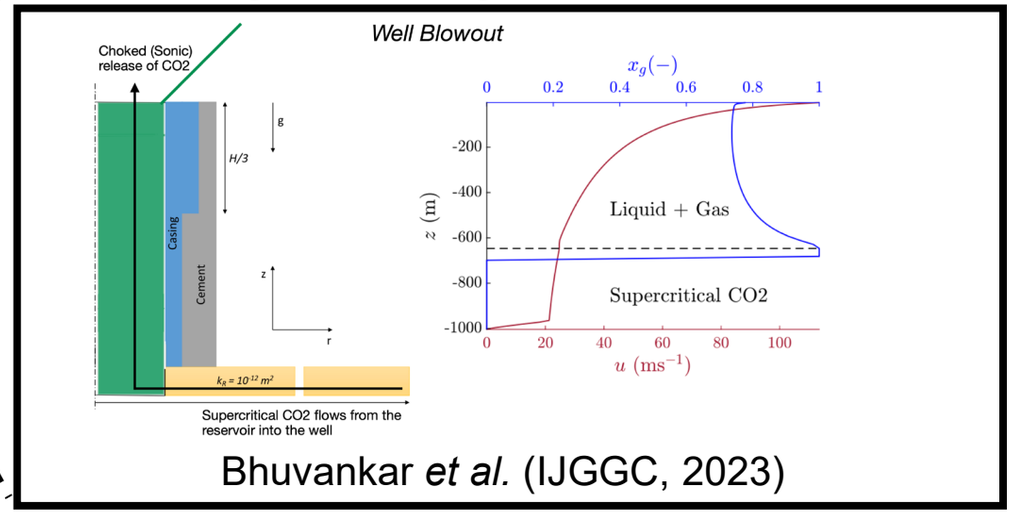
Schematic modified from: State of Louisiana Department of Energy and Natural Resources

Leakage Pathway #1: Pipeline



Xiaolu Guo *et al.* (IJGGC, 2018)

Leakage Pathway #2: Well Blowout

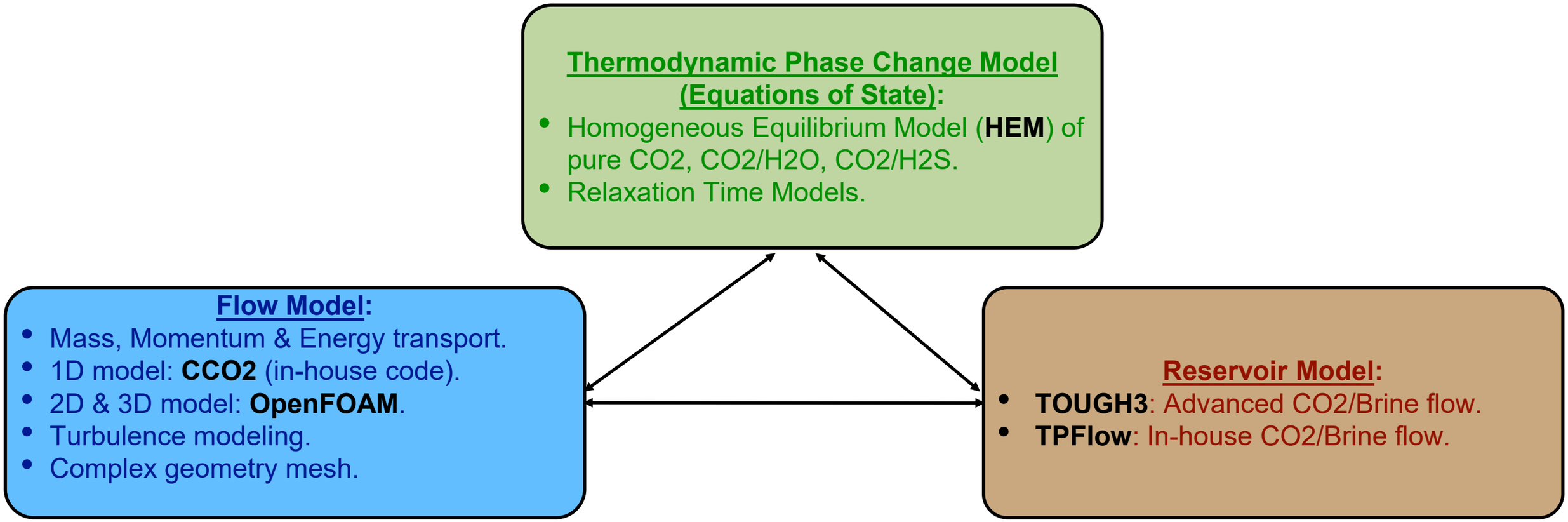


Bhuvankar *et al.* (IJGGC, 2023)

Objectives

- Building an **easily accessible**, **physics-based** modeling tool to predict:
  1. Local temperature & pressure changes near a leakage point during the **pipeline** leakage of CO_2-rich mixtures.
  2. Downhole, wellhead temperature & pressure in a **well** during the uncontrolled depressurization of CO_2-rich mixtures from a *reservoir*.
- To help in the design of experiments on CO_2 depressurization & to validate thermodynamic models.

Approach

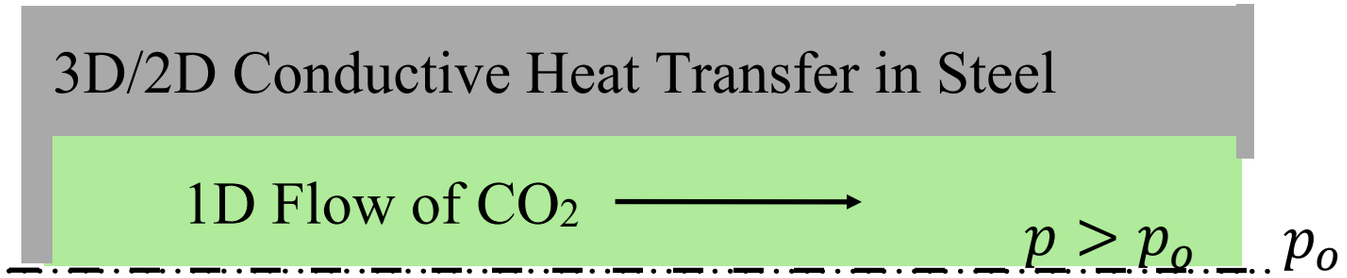


State of Research: Pipeline Failure

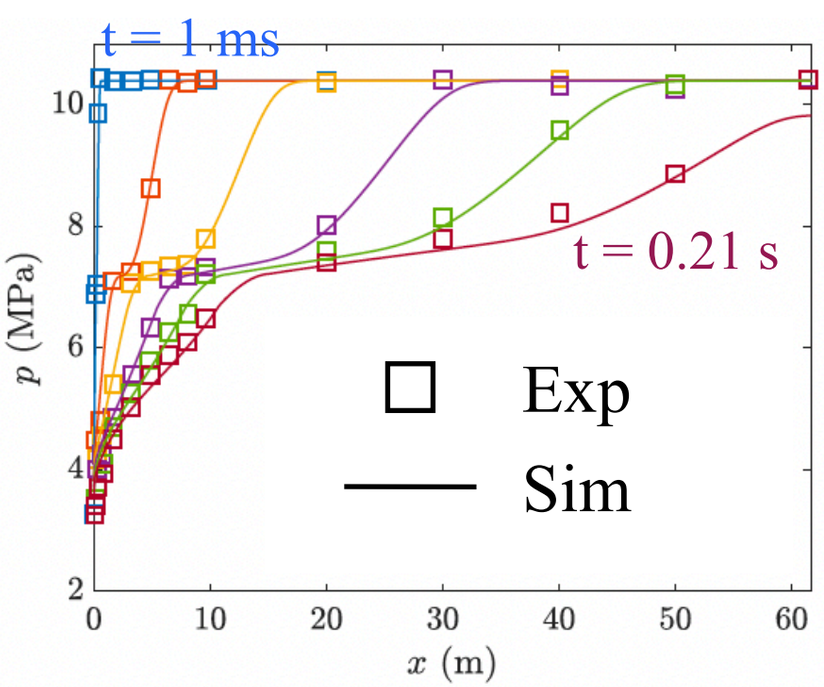
Capability to Predict Temperature & Pressure along Pipeline during Dense Phase CO_2 Decompression

- Supercritical-Liquid-Gas-Solid Phase transitions using Homogeneous Equilibrium Model
- Capturing shocks and sonic flows

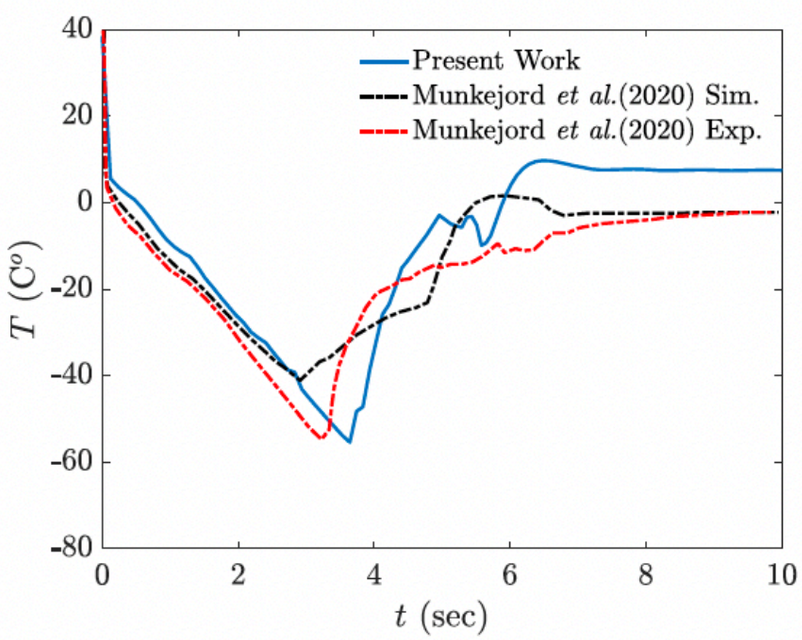
Munkejord *et al.* (2020)



Bhuvankar, Cihan & Birkholzer (2023)



Axial pressure dist.

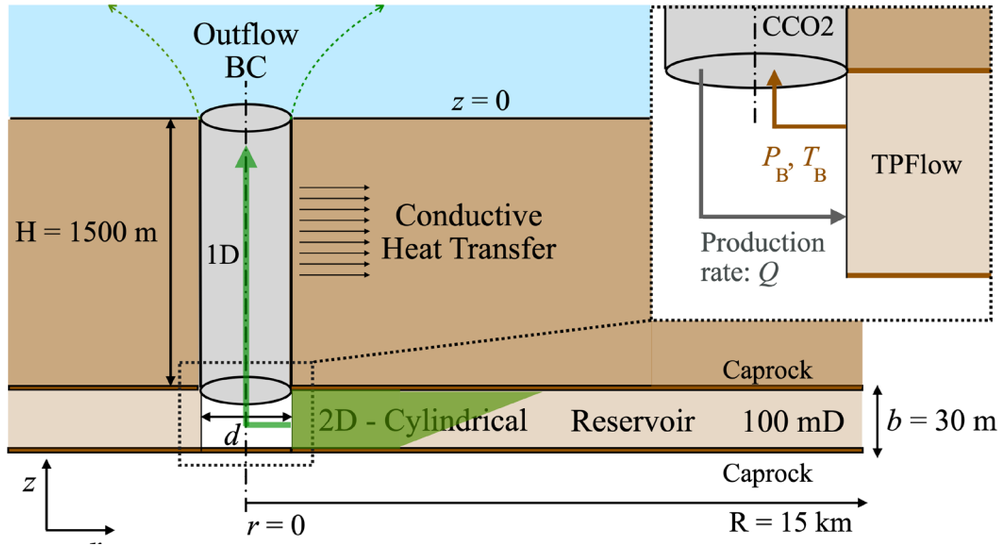


Transient outlet temperature

State of Research: Well Blowout

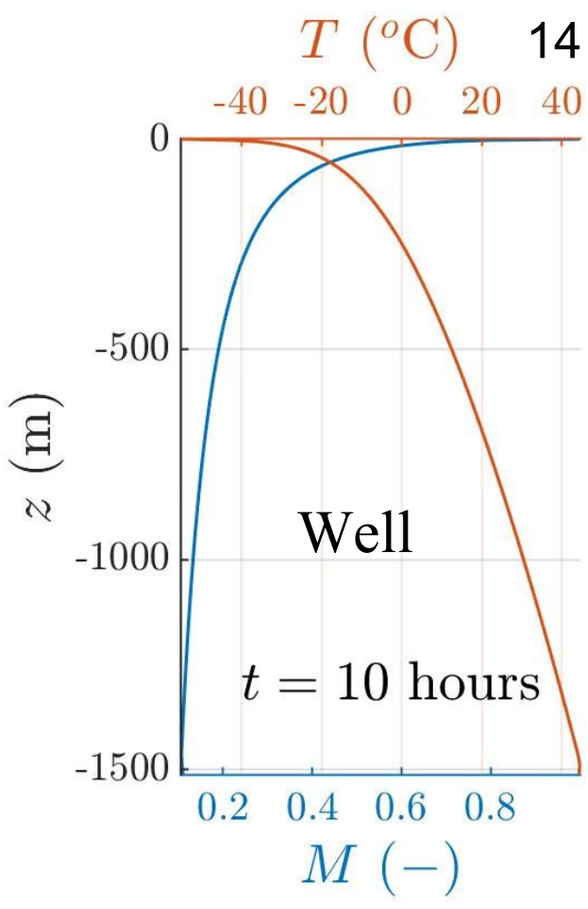
Coupled Well-Reservoir Flow Simulation Capabilities: Axial Temperature & Pressure Profile

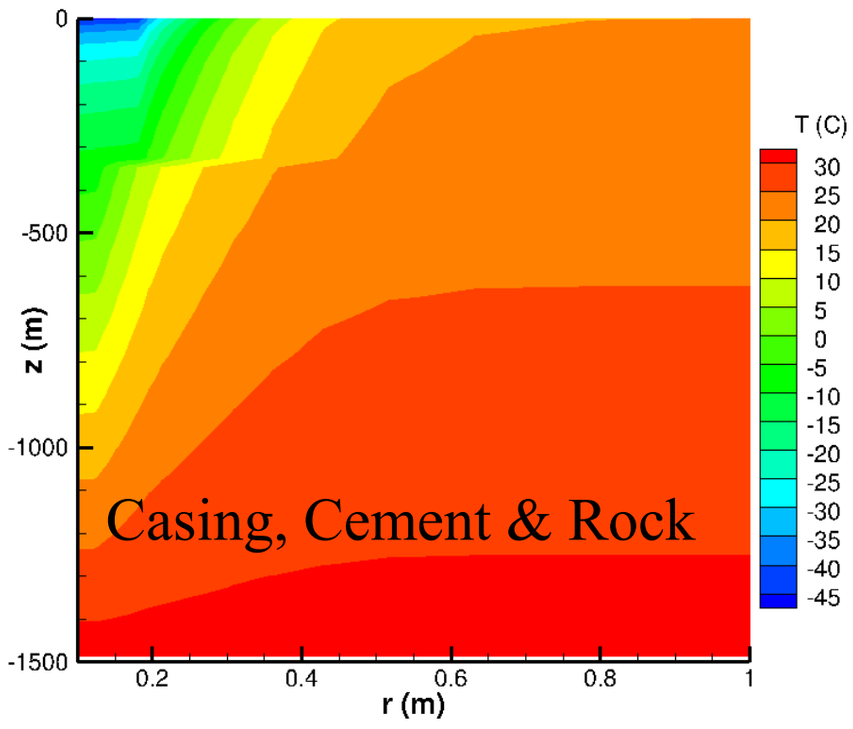
- In-house well model: CCO2
- Reservoir model: TPFlow

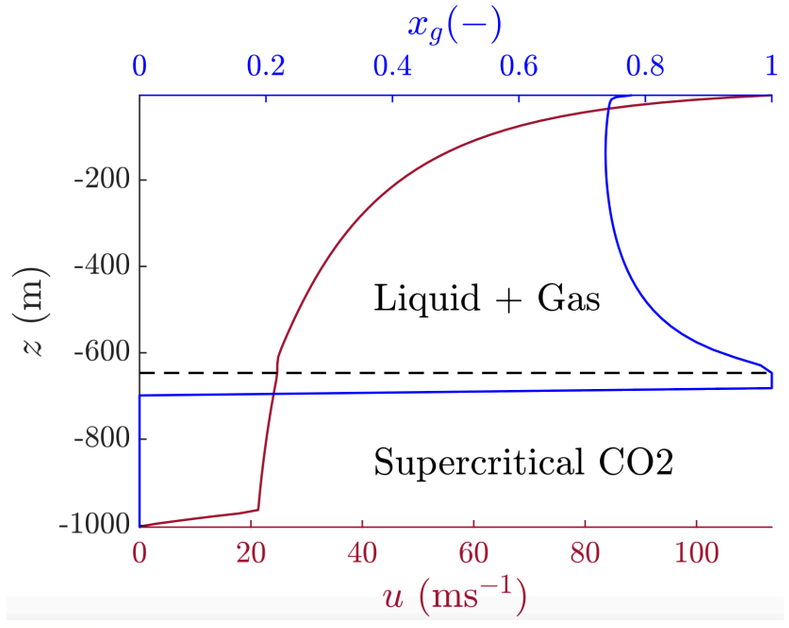


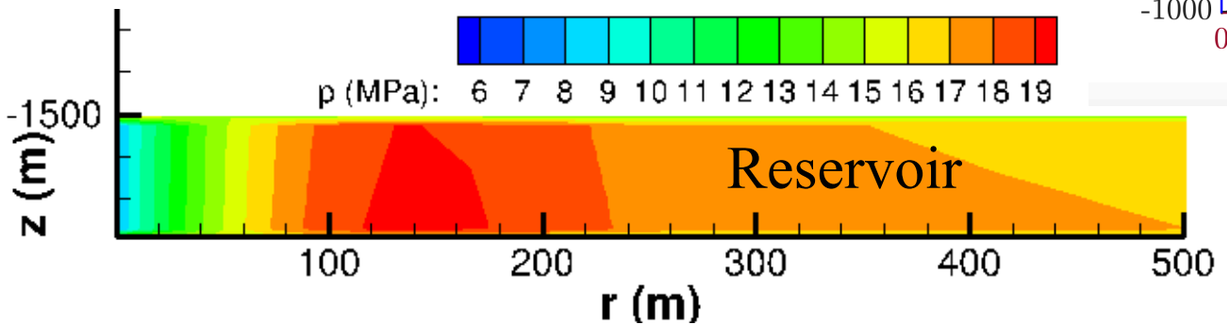
Bhuvankar, Cihan & Dilmore (under prep.)

14 day blowout after 1 year of injection.









Planned Timeline

Year 1: Simulator Development/Enhancement

- Flow model selection:
  - OpenFOAM - Complex mesh (Snappy Hex-mesh), extensive user base, turbulence models, MPI-parallelized, Conjugate heat transfer, open-source.
- Coupling Flow model with existing pure-CO_2 HEM.
- Application of the 3D model to perform preliminary simulations & assist in experimental design.

Year 1 deliverables:

- Preliminary 3D simulator of pure CO_2 depressurization in pipeline & well flows.

Year 2: Complex Geometries & CO_2-H2O Mixture Models

- Review various geometries & pathways encountered downhole during well blowouts.
- Implement CO_2-H_2O mixture model into code. Deliverable: 3D simulator with CO_2-H_2O capability.

Year 3: Simulating Temperature & Pressures in Pipeline Failure

- Perform coupled reservoir-well & pipeline leakage simulations with CO_2 mixtures & complex geometries.
- Deliverable: 3D simulator with CO_2-H_2O depressurization capability for complex geometries coupled with reservoir.

Acknowledgments

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