Pore Space Conflicts: A Computational Examination of Class VI Injection Interferences

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GWPC UIC Conference 2024
Oklahoma City, OK
February 28, 2024

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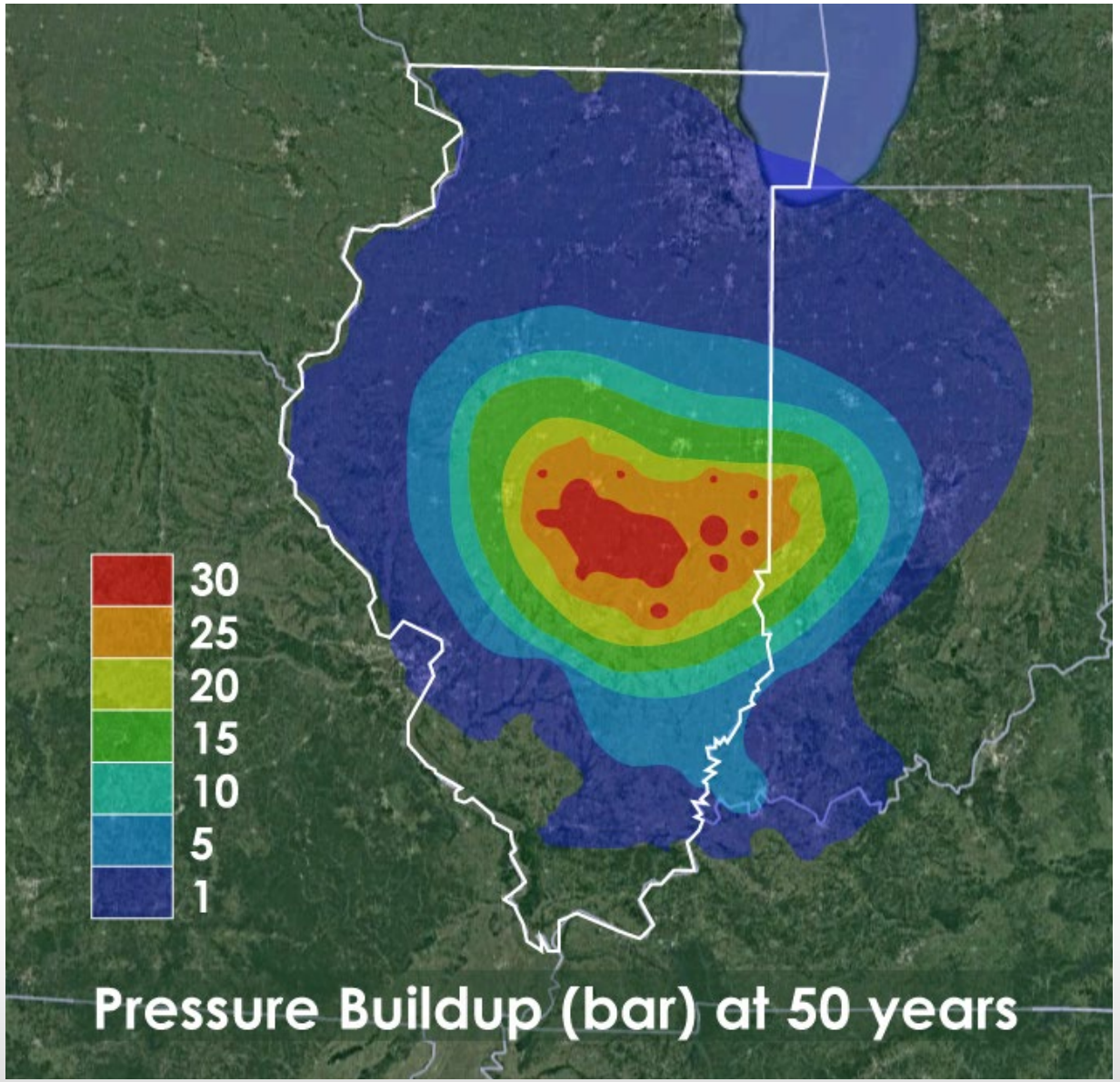
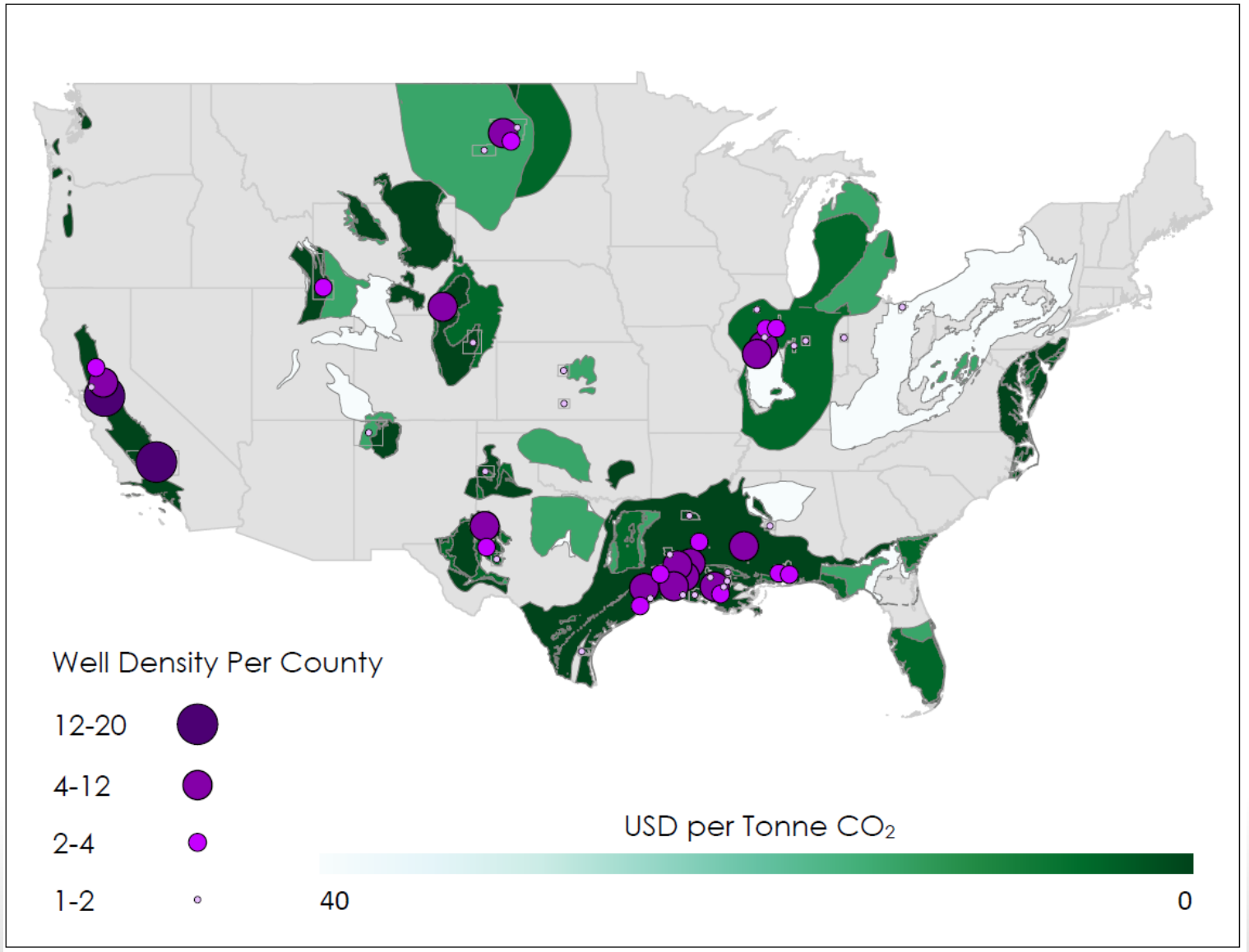
Scale of Interference – Larger-Scale Projects, or…



Graphic modified from Birkholzer and Zhou (2009) Basin-Scale Hydrologic Impacts of CO2 Storage: Regulatory and Capacity Implications; Retrieved from https://www.osti.gov/servlets/purl/951197

More Smaller Projects Clumped In Favorable Geology or Near CO_2 Sources



Data for storage potential from Roads to Removal (https://roads2removal.org/resources/)

Data for Class VI well locations downloaded from EPA Class VI Permit Tracker (https://www.epa.gov/uic/current-class-vi-projects-under-review-epa)

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Things to Consider When Investigating Class VI Interferences

Dealing with two immiscible phases

- Contrast in density
- Contrast in compressibility
- Contrast in wettability

Dealing with Different Permit Requirements

- Must explicitly calculate Area of Review (AoR) using a numerical model; AoRs are typically dominated by pressure front.
- Must consider both the footprint of the supercritical fluid and the pressure buildup in evaluating the AoR.
- "In all cases, EPA recommends that AoR delineation models account for all wells injecting into (including any injection wells associated with other UIC well classes or other Class VI operations) or pumping from the injection zone or any other zones that are hydraulically connected to the injection zone."
- Not clear that all of the information needed to evaluate cumulative impacts is publicly available.

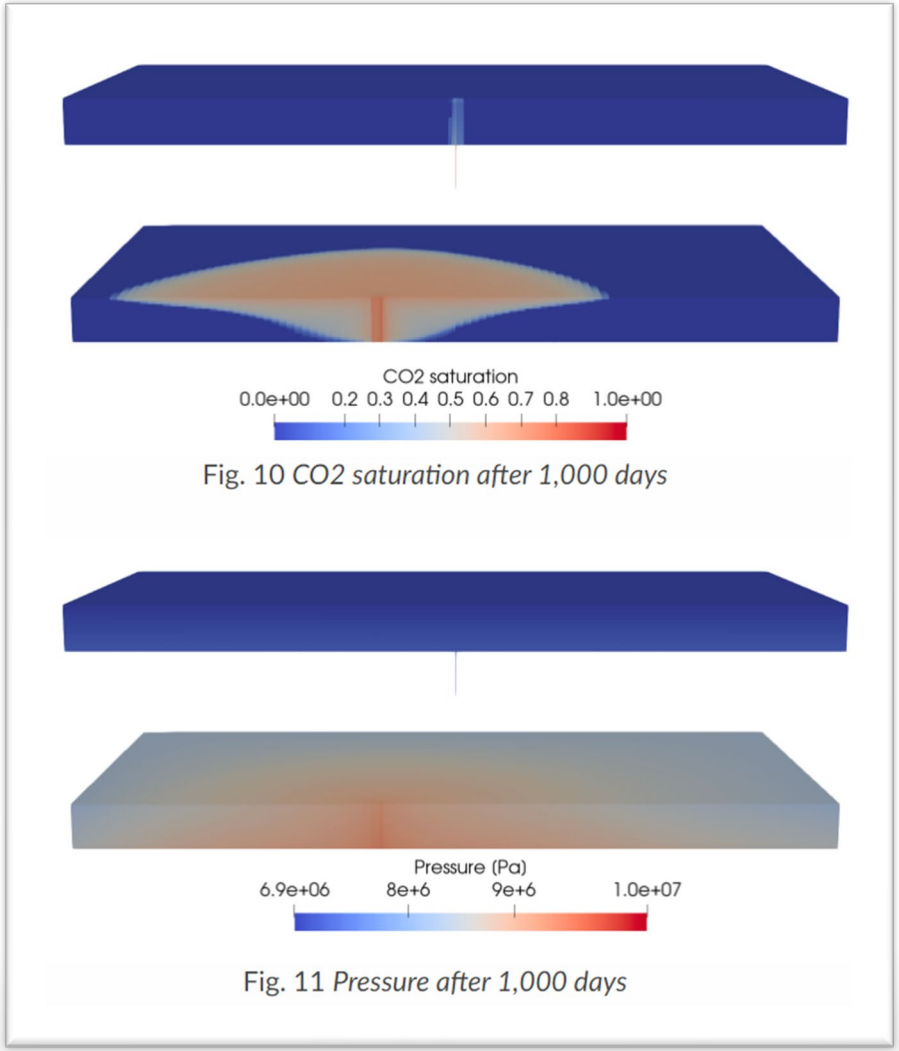

Fig. 10 *CO2 saturation after 1,000 days*

Fig. 11 *Pressure after 1,000 days*

Photo from GEOSX Documentation: Carbon Storage Non-Isothermal CO2 Plume Evolution and Leakage through an Abandoned Well (Validation and Verification Study)

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Injection-Related Pressure Buildup

Magnitude of buildup is affected by:

- Porosity and permeability of the reservoir
- Density and viscosity of the injectate and native fluids
- Thickness, depth, and lateral extent of the reservoir

What happens if pressure buildup is too high?

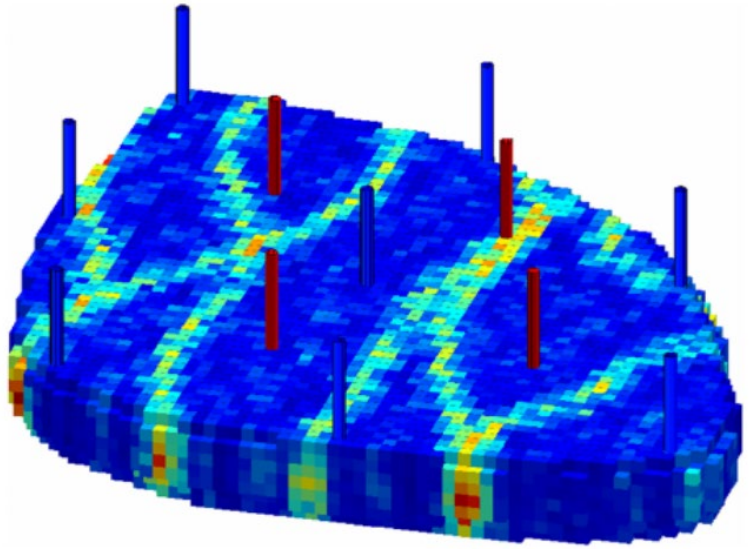
- Fluid migration through improperly plugged artificial penetrations or caprock flaws
- CO_2 migration through improperly plugged artificial penetrations or caprock flaws
- Fracturing in the injection or confining zones

GEOS Overview

GEOS = open-source, multi-physics simulator developed* for modeling carbon storage and other subsurface energy systems

What makes it state-of-the-art?

- Explicit injection well modeling capability with pressure control
- Computational scaling for large areas and complex site geology
- Previous modeling codes are practically limited to ~ 10^5 nodes, while GEOS can run problems with ≥10^6 nodes



**Developed by Lawrence Livermore National Laboratory, Stanford University, TotalEnergies, and Chevron. Photo from GEOSX Documentation.*

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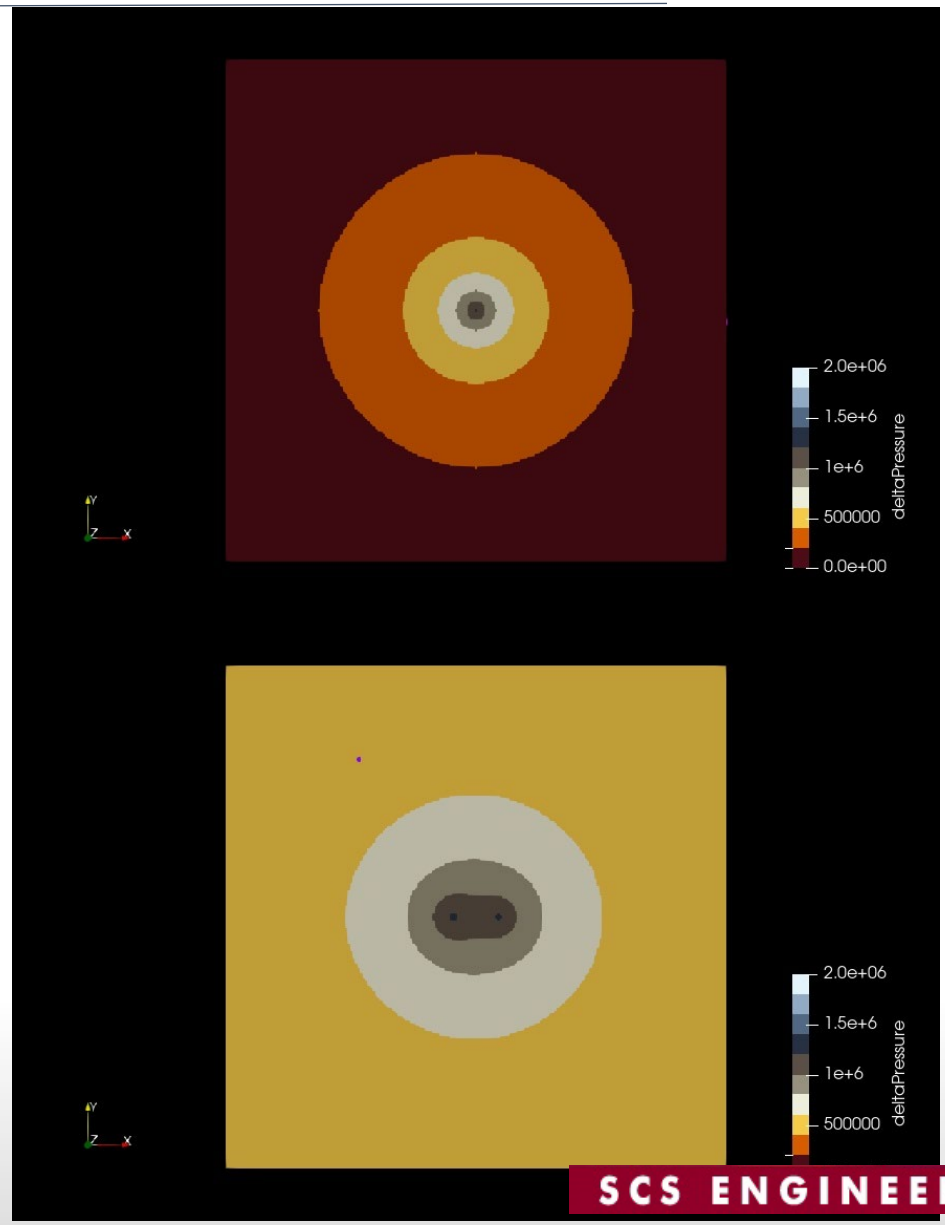
Model Setup – Domain, Geology, Initial Conditions

1. ~40 mi x 40 mi area with a simple cartesian mesh
2. Injection Zone with constant porosity and permeability
3. No-flow boundaries on all model faces
4. Initial geothermal gradient and hydrostatic gradient
5. One or two fully penetrating injection well(s) perforated throughout injection zone
6. Injecting 1 million metric tons/well for 20 years
7. Examined two different critical pressures
    1. 0.2MPa
    2. 1 MPa



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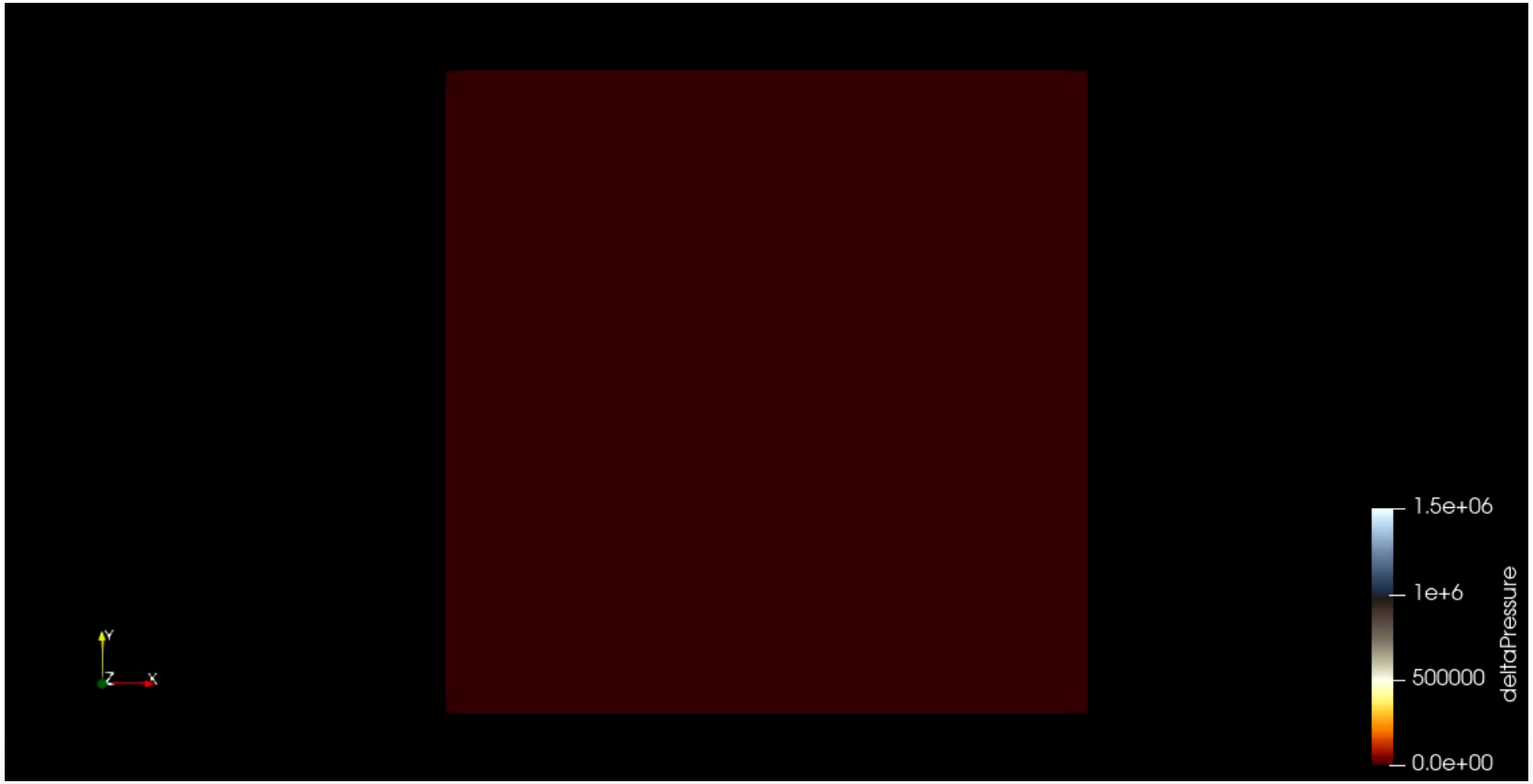
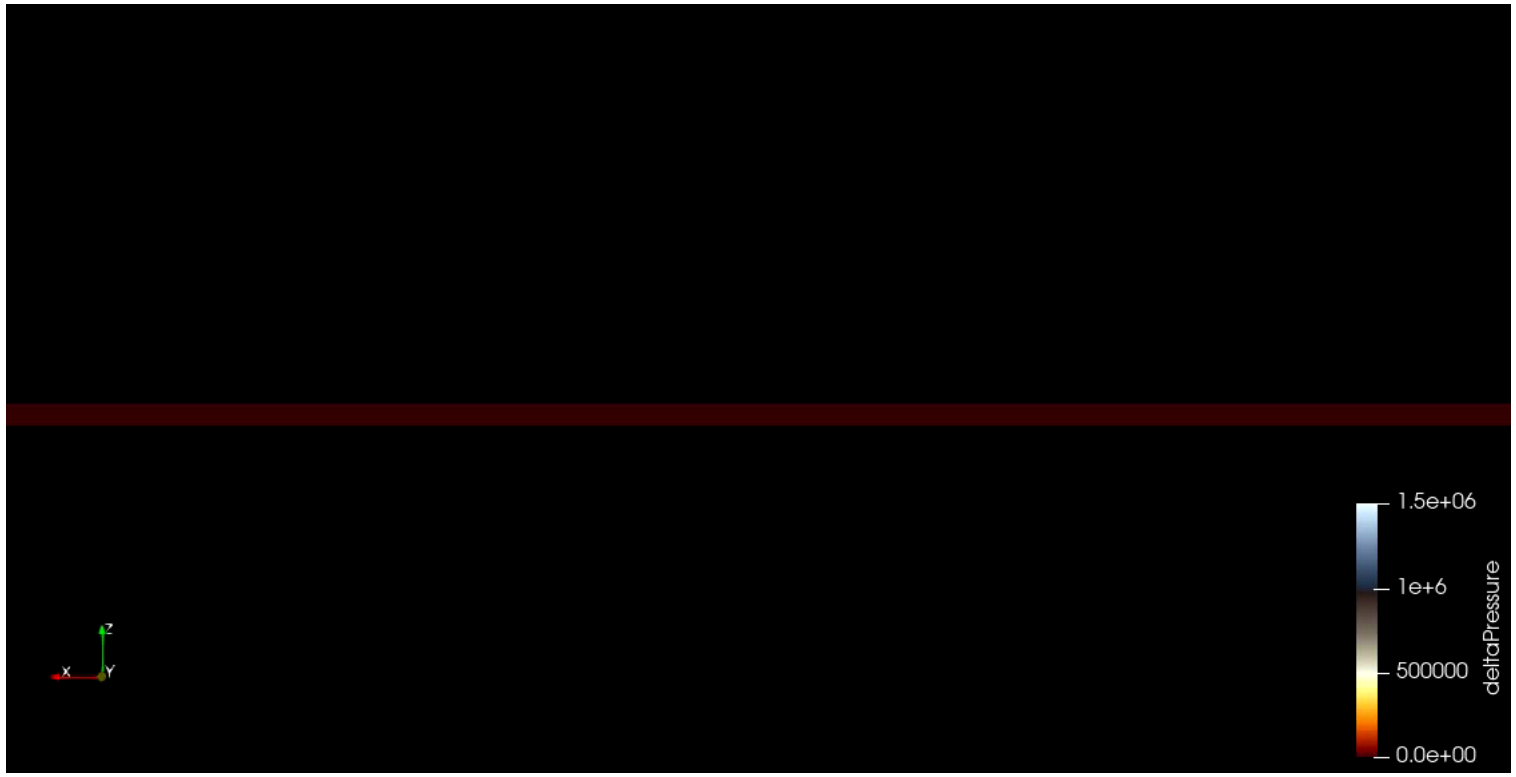
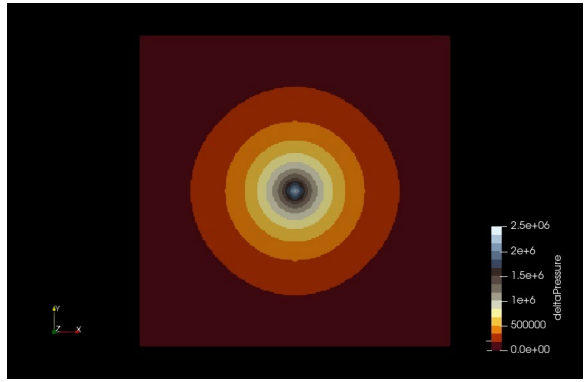
Single Well Model – Top View



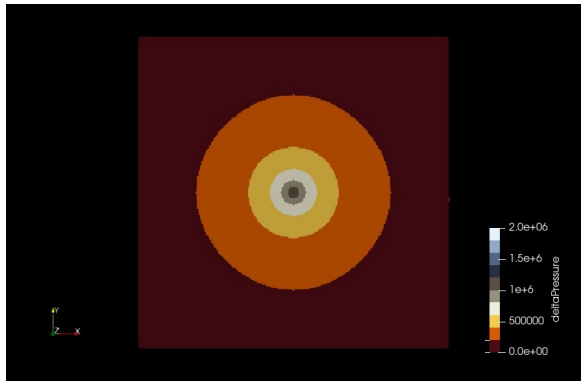
Single Well Model – Side View



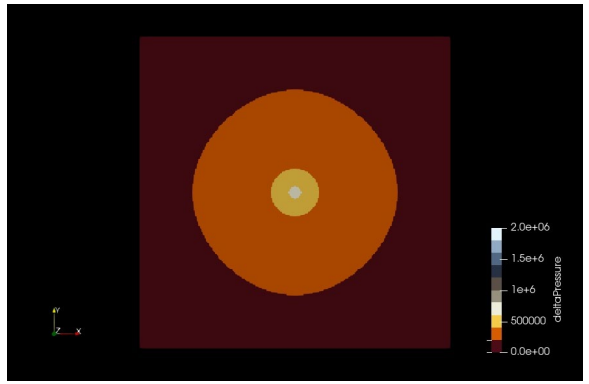
Single Well Model – Pressure Buildup



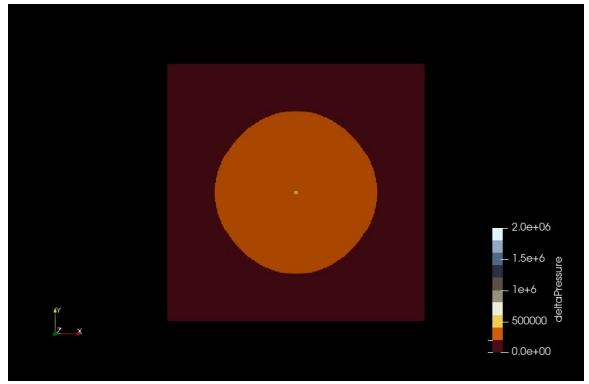
50 mD



100mD

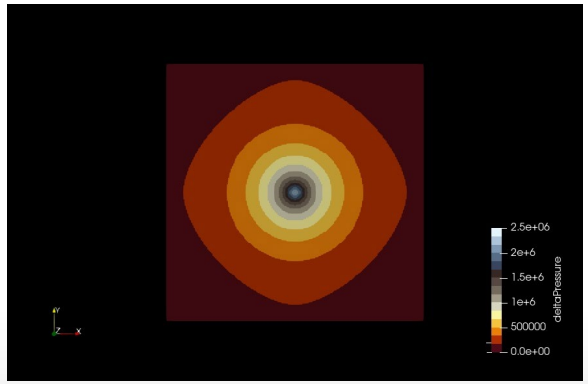


200 mD

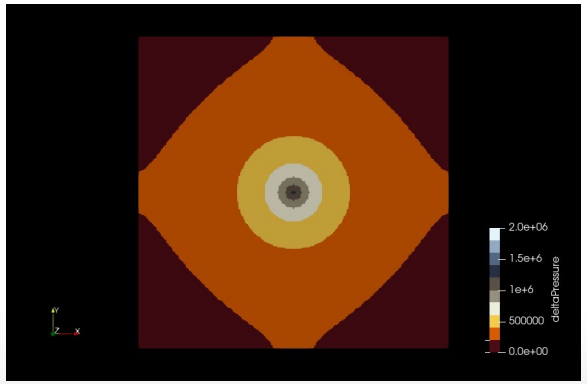


500 mD

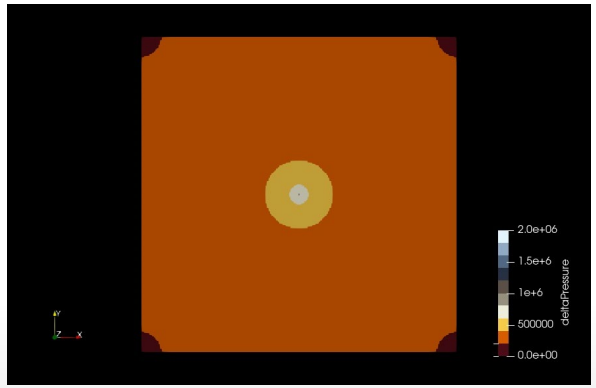
25% Porosity



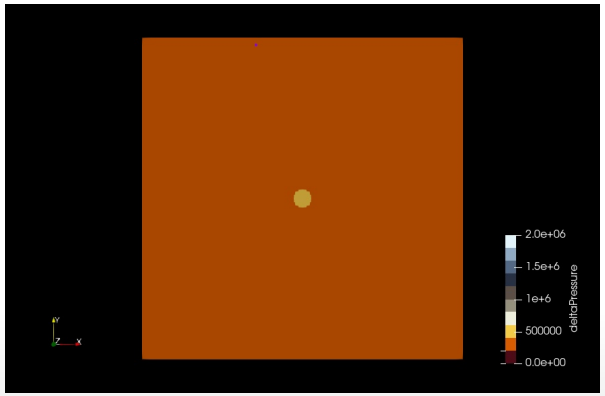
50 mD



100mD



200 mD



500 mD

20% Porosity

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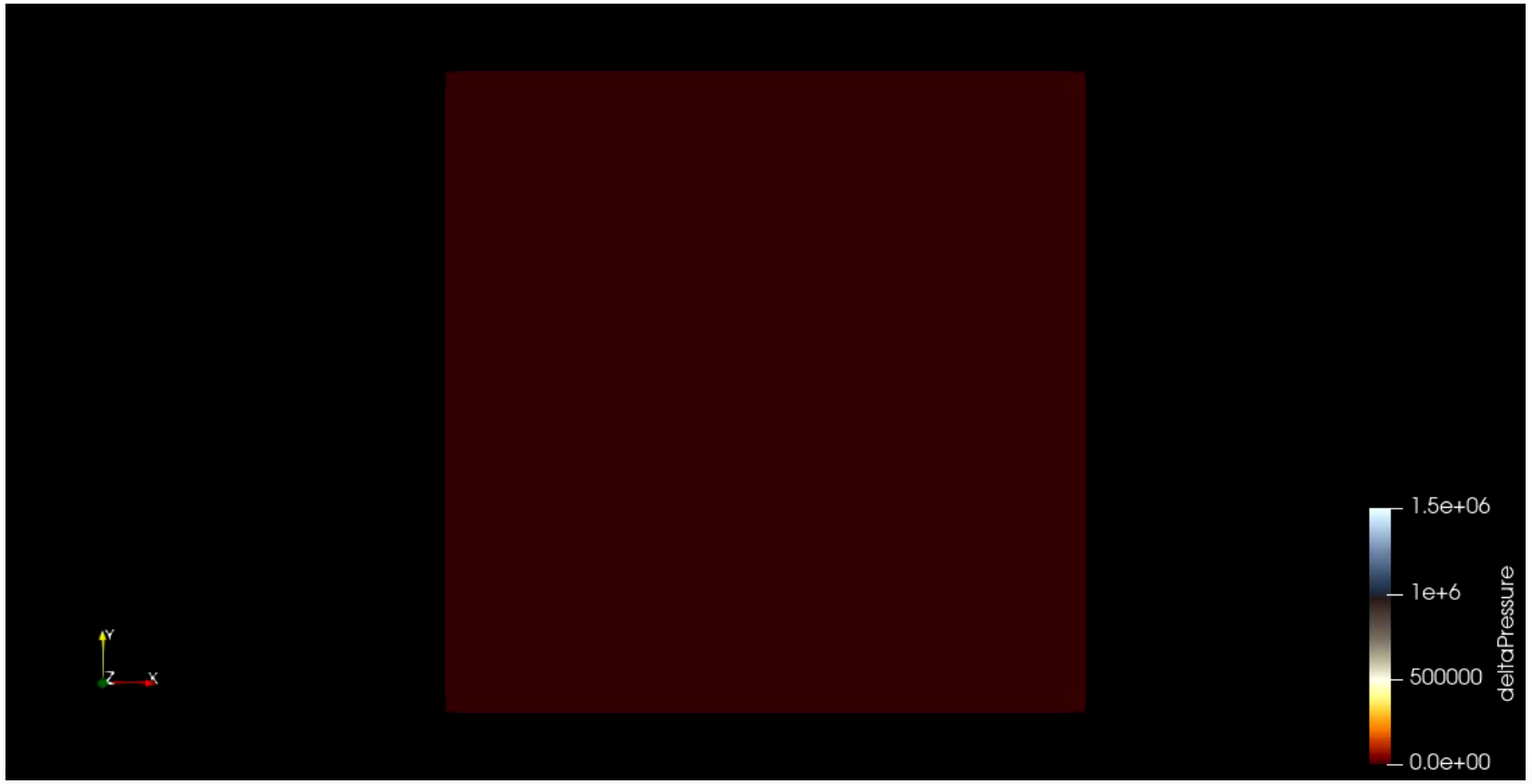
Observations on the Single Well Models

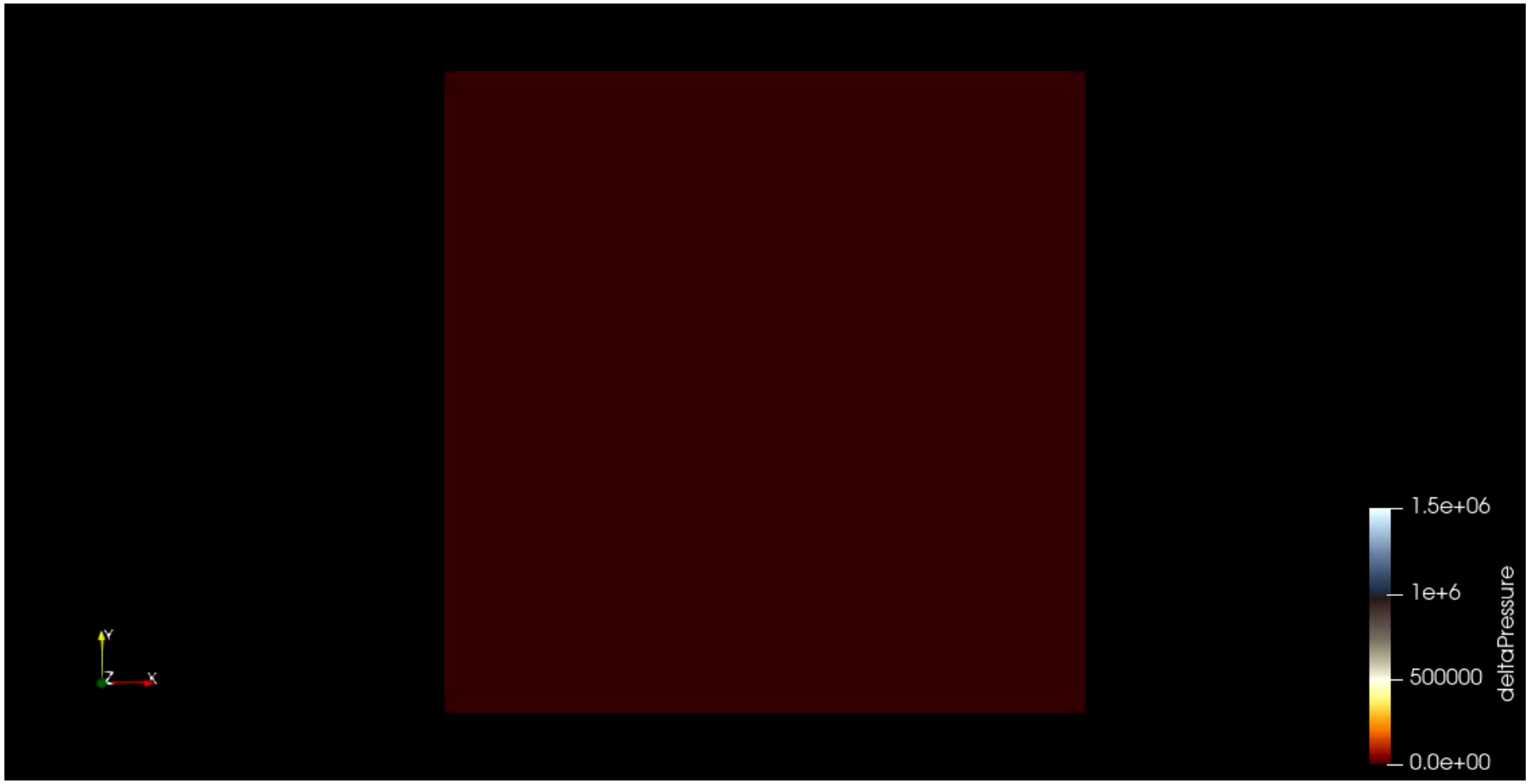
- **Plume Behavior:**
  - For a given porosity, increasing permeability leads to a more diffuse pressure buildup
  - This effect is more pronounced for the less porous injection zone
- **Impacts on Area of Review; 0.2 MPa critical pressure:**
  - At higher porosity (25%), a pressure dominated AoR expands slowly with permeability
  - At lower porosity (20%), a pressure dominated AoR expands rapidly with permeability
- **Impacts on Area of Review; 1.0 MPa critical pressure:**
  - At higher porosity (25%), a pressure dominated AoR decreases rapidly with permeability
  - At lower porosity (20%), a pressure dominated AoR decreases rapidly with permeability
- **Modeling notes:**
  - For a 1 million metric ton per year injection for 20 years, there is significant interaction of the pressure front with the model edges at 20% porosity at all permeabilities that we investigated

Two Well Model – Top View



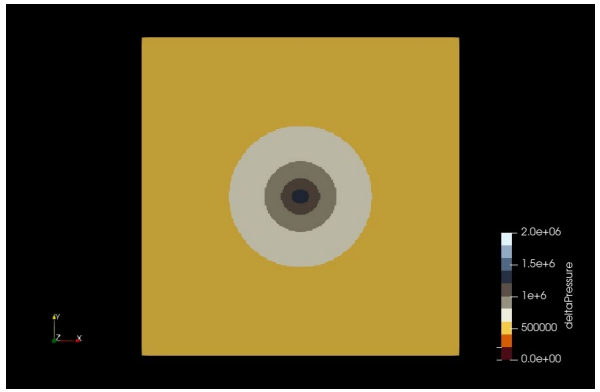
Two Well Model – Side View

Two Well Model – Top View

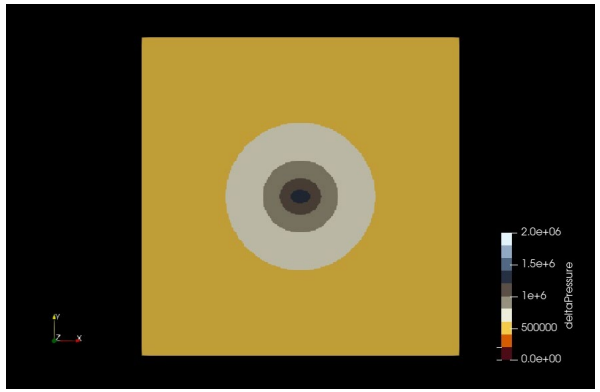


Two Well Model – Side View

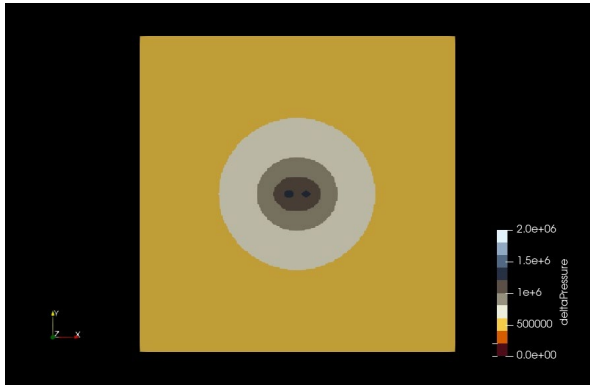
Two Well Model – Pressure Buildup



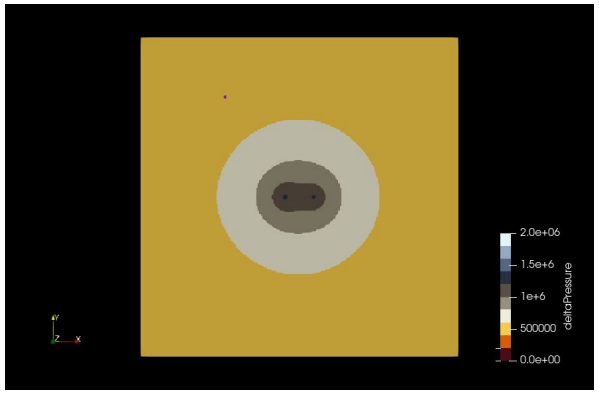
1 Km



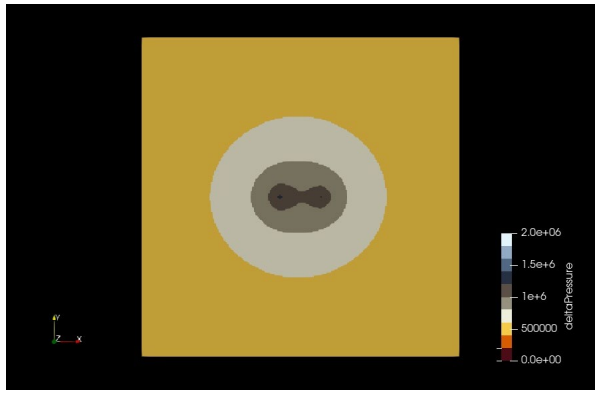
2 Km



4 Km

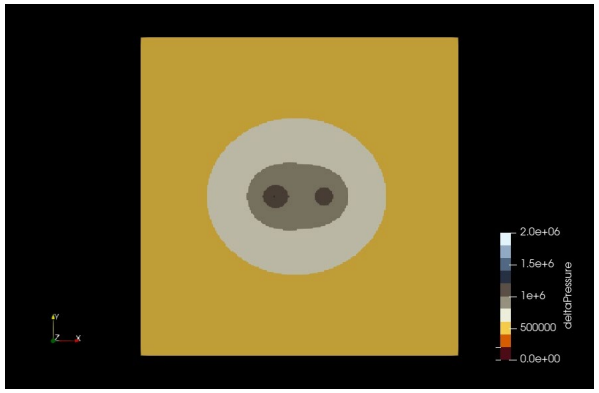


6 Km



8 Km

200 mD; Porosity = 20%



10 Km

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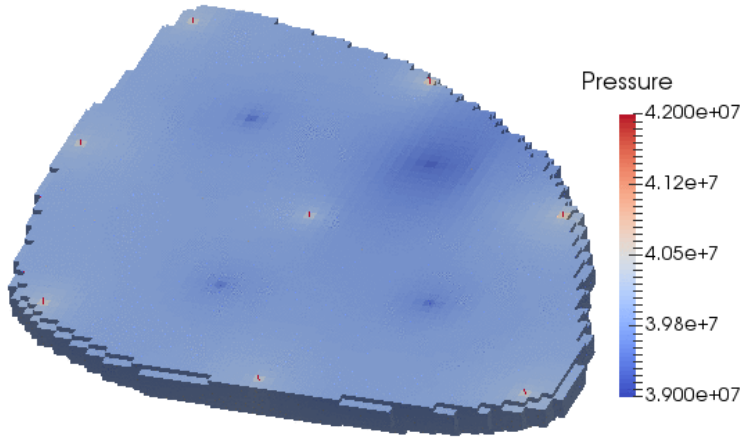
Observations on the Two Well Models

- **Plume Behavior:**
  - For the porosity and permeability we examined (20% and 200 mD), relatively close well spacing (1 to 2 Km) leads to a tightly peaked pressure buildup
  - Separation into two distinct pressure peaks occurs at spacings on the order of 4 Km
- **Impacts on Area of Review; 0.2 MPa critical pressure:**
  - The AoR cannot be determined because of interaction of the pressure front with the boundary conditions
- **Impacts on Area of Review; 1.0 MPa critical pressure:**
  - At close well spacings (1 to 2 Km) the AoR is less than 2x a single well (more efficient use of pore space)
  - At larger well spacings the AoR looks more like 2 single wells
- **Modeling notes:**
  - For two 1 million metric ton per year injections for 20 years, there is significant interaction of the pressure front at all well spacings that we investigated

Summary and Recommendations

1. **Our findings suggest that it is a prudent practice to develop sensitivities around the size of the model domain to ensure the pressure front is not interacting with the boundary conditions**
2. **Our findings suggest that multiple wells can, in some cases, lead to more efficient use of pore space (smaller AoRs for a given amount of injection)**
3. **Our findings also suggest that project interferences can be possible if projects locations are within 10 Km and injecting into the same formation**



From GEOSX Documentation: Multiphase Flow with Wells

Thank you!

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