Simulation of GeoCQuest Field Validation Models using GEOS

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GEOS – Comprehensive CO_2 Reservoir Simulator

- Multi-physics : coupled flow and advanced geomechanics
- Scalable : massive CPU/GPU parallelization designed to handle large CCS models
- Cost effective : no license, portable across systems from laptop to exascale
- Transparent : auditable by experts and regulators
- Distributable : open-source code under active development in a GitHub repository

TotalEnergies Lawrence Livermore National Laboratory Stanford University Chevron

Pre-injection Simulation Work

- Developed mapping algorithms to enable use of Petrel geomodels in GEOS
- Extended GEOS to treat directional relperms, and permeability anisotropy in a manner consistent with Eclipse
- Benchmarked GEOS against Eclipse 300 CO2STORE for conventional and composite rock type models
- Performed GEOS runs for 50 conventional and 50 composite rock type realizations
- Assessed impact of heterogeneity and injection options on a subset of models

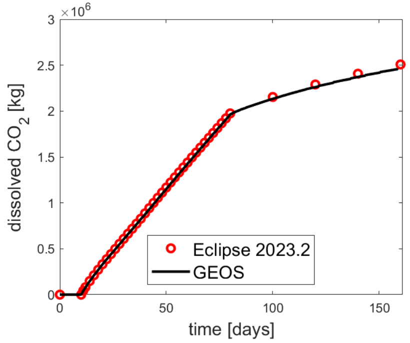
Other Flow Simulators Used in GFV

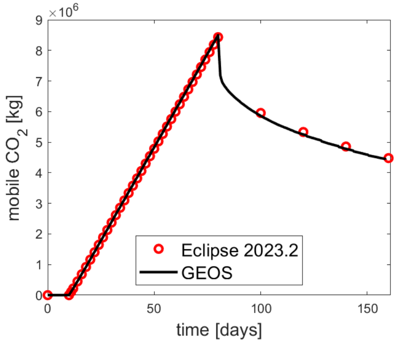
ACGSS – Australian Carbon-Geo-Sequestration Simulator

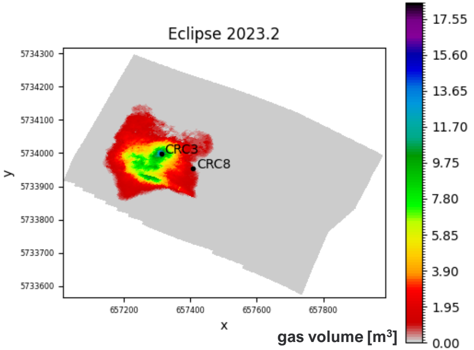
- Assess impact of various effects currently not modeled in GEOS (e.g., full-tensor permeabilities and rate-dependent relative permeability functions)

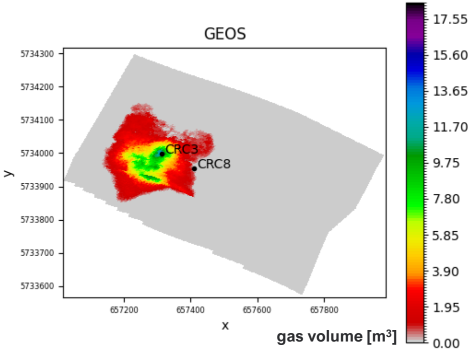
Eclipse 300 CO2STORE

- Validate GEOS in comparison with this state-of-the-art commercial simulator









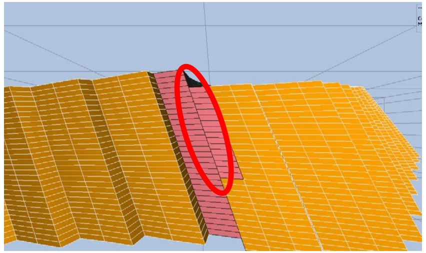
Petrel Geomodels in GEOS

Petrel's CPG (corner-point geometry) grid to GEOS VTK (visualization toolkit) grid conversion

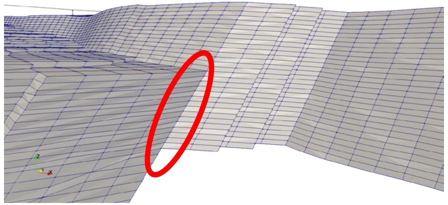
- Conformal output grid with accurate cell data sampling
- Boundary face cells to set aquifer boundary conditions

GEOS source code update

- High importance of anisotropy in GFV project
- Input data interpretation changed
  - from the global x, y, z coordinate anisotropy (default in a general unstructured grid)
  - to the local layered anisotropy (default in a hexahedral CPG grid)



CPG grid: non-conformal connections across the fault



VTK grid: fault cell connections made conformal

GFV Dynamic Model

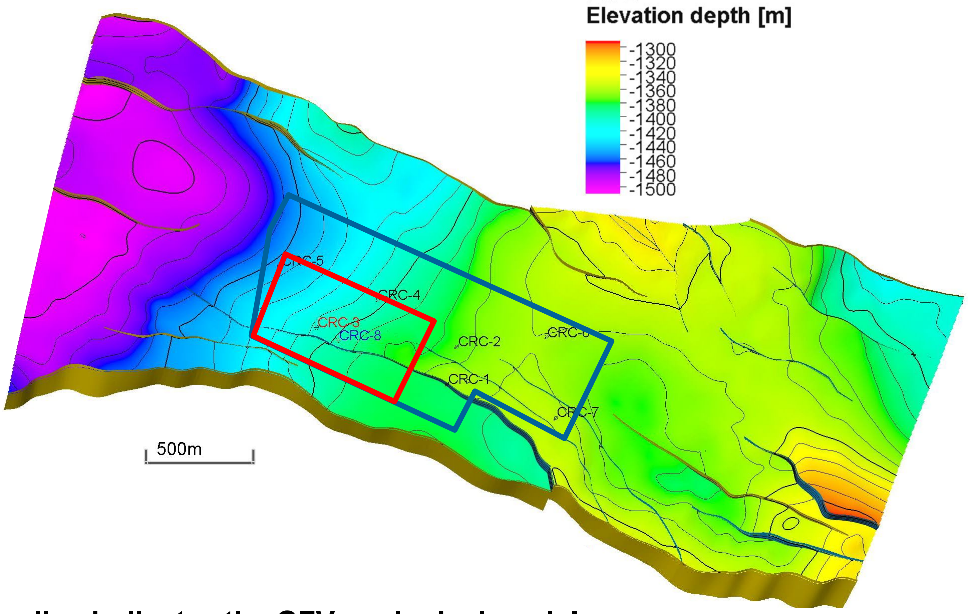
Geomodelling: CO2CRC and University of Melbourne, Australia

Grid : $4.5x10^6$ active cells of size 3.3 m x 3.3 m x 0.3 m, includes aquifer boundary conditions

Fluid model : two-component two-phase formulation compatible with Eclipse 300 CO2STORE

CO_2 injection well CRC-3

PNL monitoring well CRC-8



Blue line indicates the GFV geological model area.
Red line indicates the GFV dynamic model area.

GFV Dynamic Model Options

Geomodel ensemble (50 realizations each):

- conventional facies (single rock type)
- composite rock-type (heterogeneous anisotropic relperm)

Injection interval options :

- upper zone: 1442-1446m TVD
- lower zone: 1450-1460m TVD

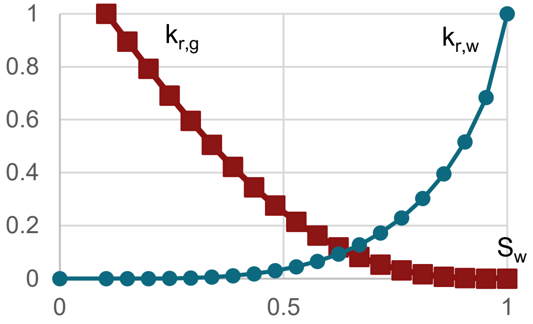
Injection rate options :

- 50 tons/day and 150 tons/day

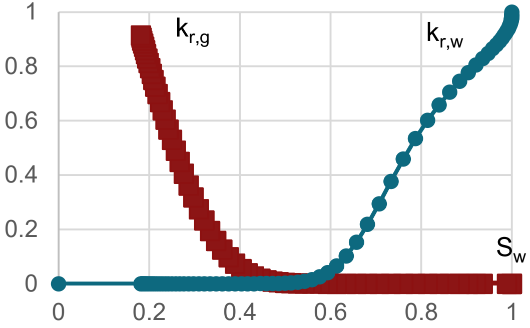
Injection volume options :

- 5,000 tons and 10,000 tons

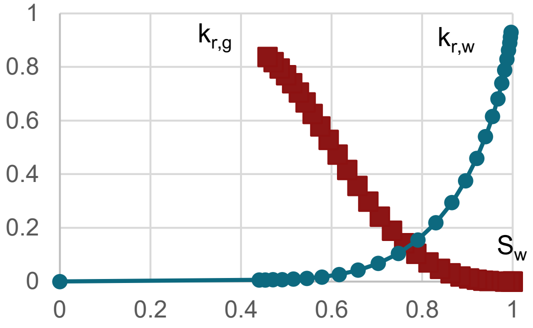
homogeneous coarse sandstone



composite siltstone & fine sandstone vertical



composite siltstone & fine sandstone horizontal



Geomodel Realizations

Plume arrival time to CRC-8

50 conventional facies models

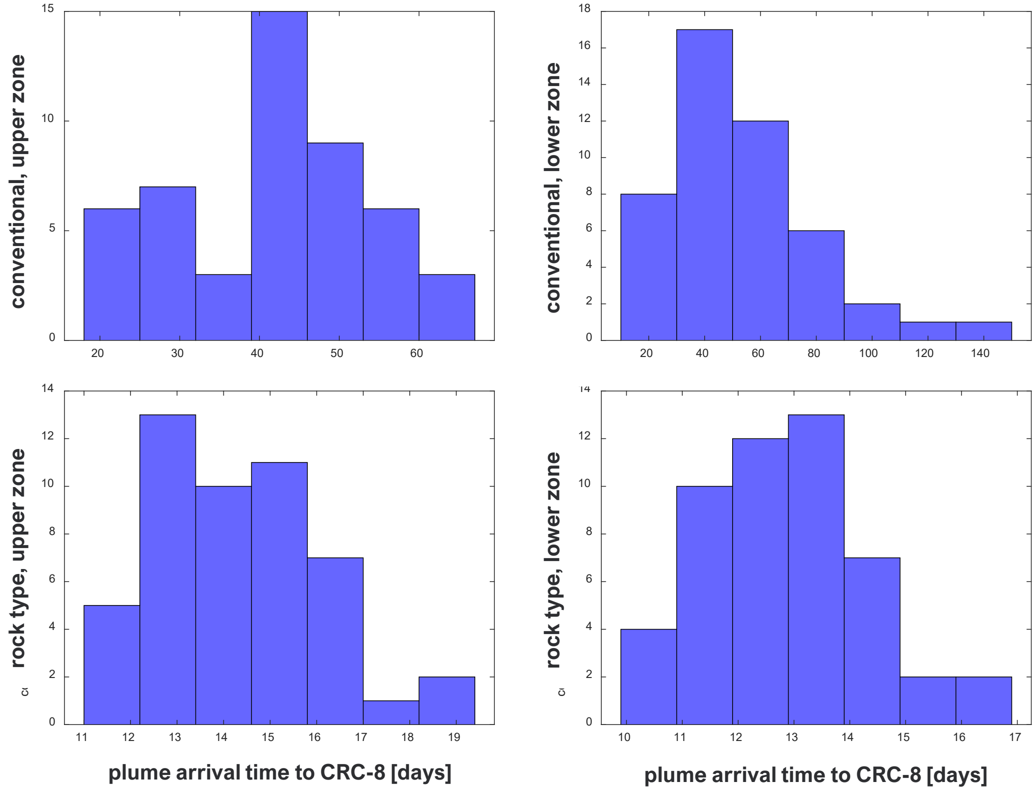
- 20-64 days, upper zone
- 20-149 days, lower zone

50 composite rock type models

- 11-19 days, upper zone
- 10-16.5 days, lower zone

Representative subset selection

Ongoing comparison work



Relperm Heterogeneity Study (Median Arrival Time)

Same absolute permeability distribution

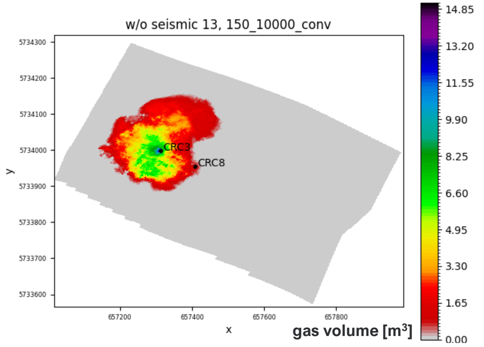
Conventional facies model

- homogeneous isotropic relative permeability and capillary pressure

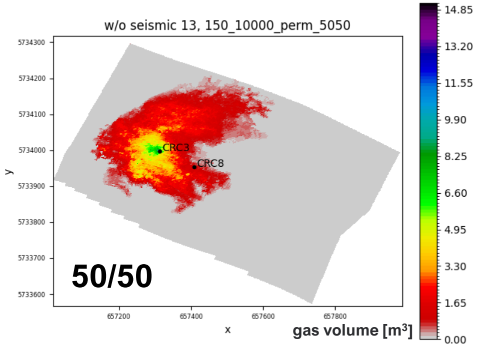
Composite rock-type model

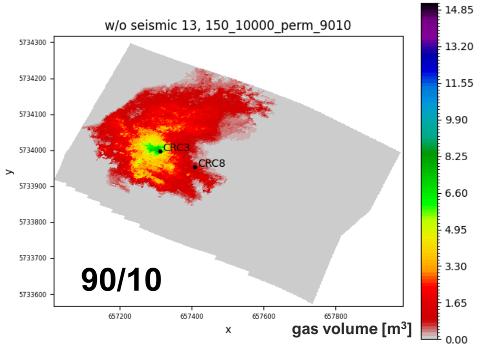
- heterogeneous relative permeability and capillary pressure
- anisotropic relative permeability
- composition options : 50/50 and 90/10

Conventional facies model



Composite rock-type model

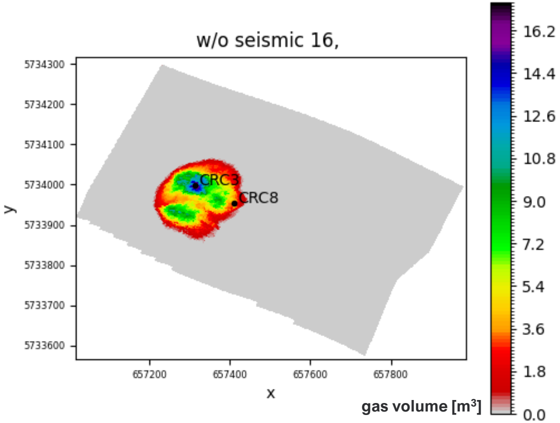




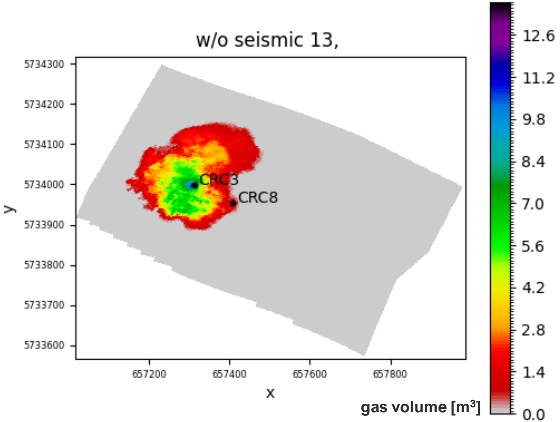
Injection Interval Study (Median Arrival Time)

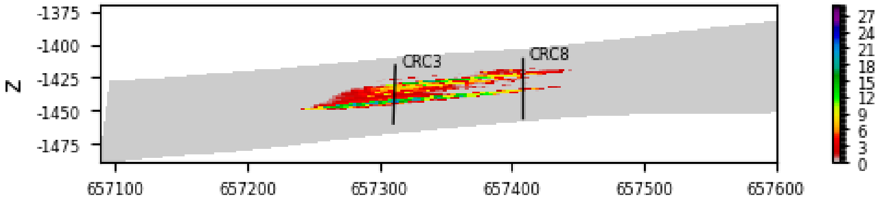
More extensive plume dynamics with lower injection zone

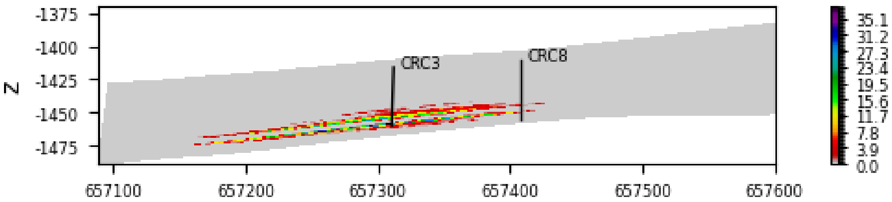
Upper injection zone
Conventional model
10,050 tons injected



Lower injection zone
Conventional model
10,050 tons injected

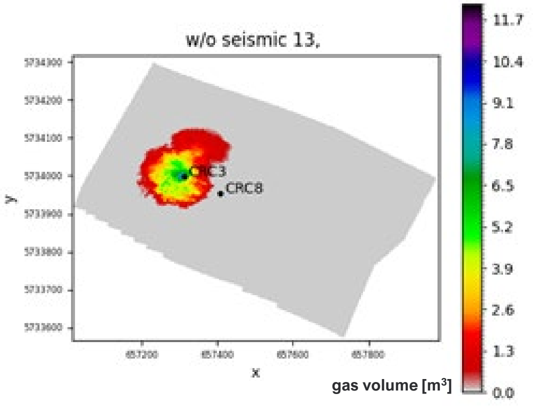




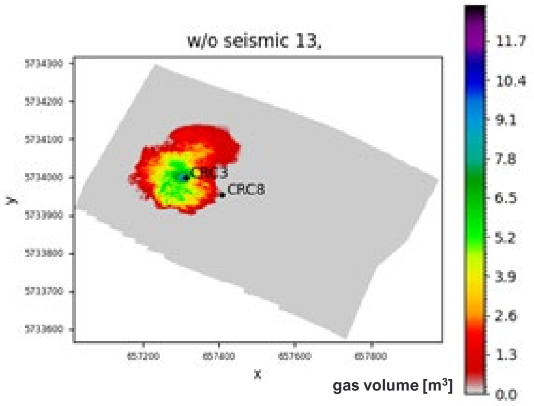


Injection Volume Study (Median Arrival Time)

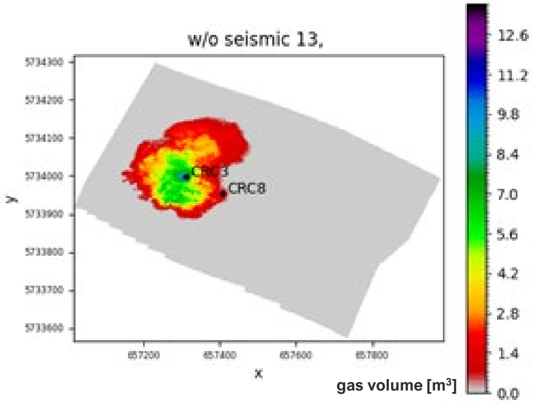
Plume extend for different injection volumes



5,000 tons injected



arrival at CRC-8

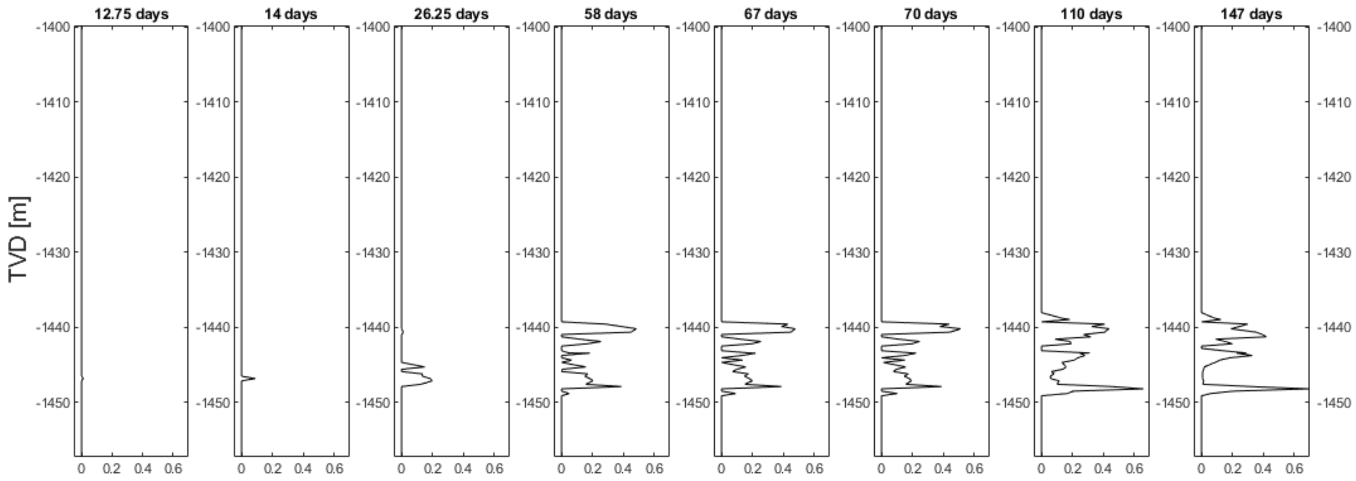


10,050 tons injected

Conventional model for lower injection zone: more extensive spread and more activity in CRC-8 with ~10,000 tons

Monitoring Well Data Study (Median Arrival Time)

Gas saturation output in CRC-8 to be compared to the PNL



gas saturation from breakthrough time to the end of injection
composite rock-type model with the injection rate of 150 tons/day

Current and Future Work

Current deployment of GEOS

- Simulation of composite rock type realizations to gauge uncertainty and assess GFV contingency plan
- Cost benefit analysis in the GeoCQuest project
- Sensitivity analysis and testing of history matching approaches
- Development and testing of deep-learning surrogate modeling approaches in application to uncertainty quantification and history matching

Future work

- Assessing the impact of rate-dependent relative permeabilities through comparison with ACGSS