Simulation Study on the Impact of Faults as Boundary Conditions on Carbon Geological Storage Flow Dynamics

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Why modeling Fault is important

EPA Class VI permits: require reservoir simulation;

→ Boundary Condition (BC) is important in reservoir simulations;

→ Internal BC and External BC

Fault is one type of internal BC

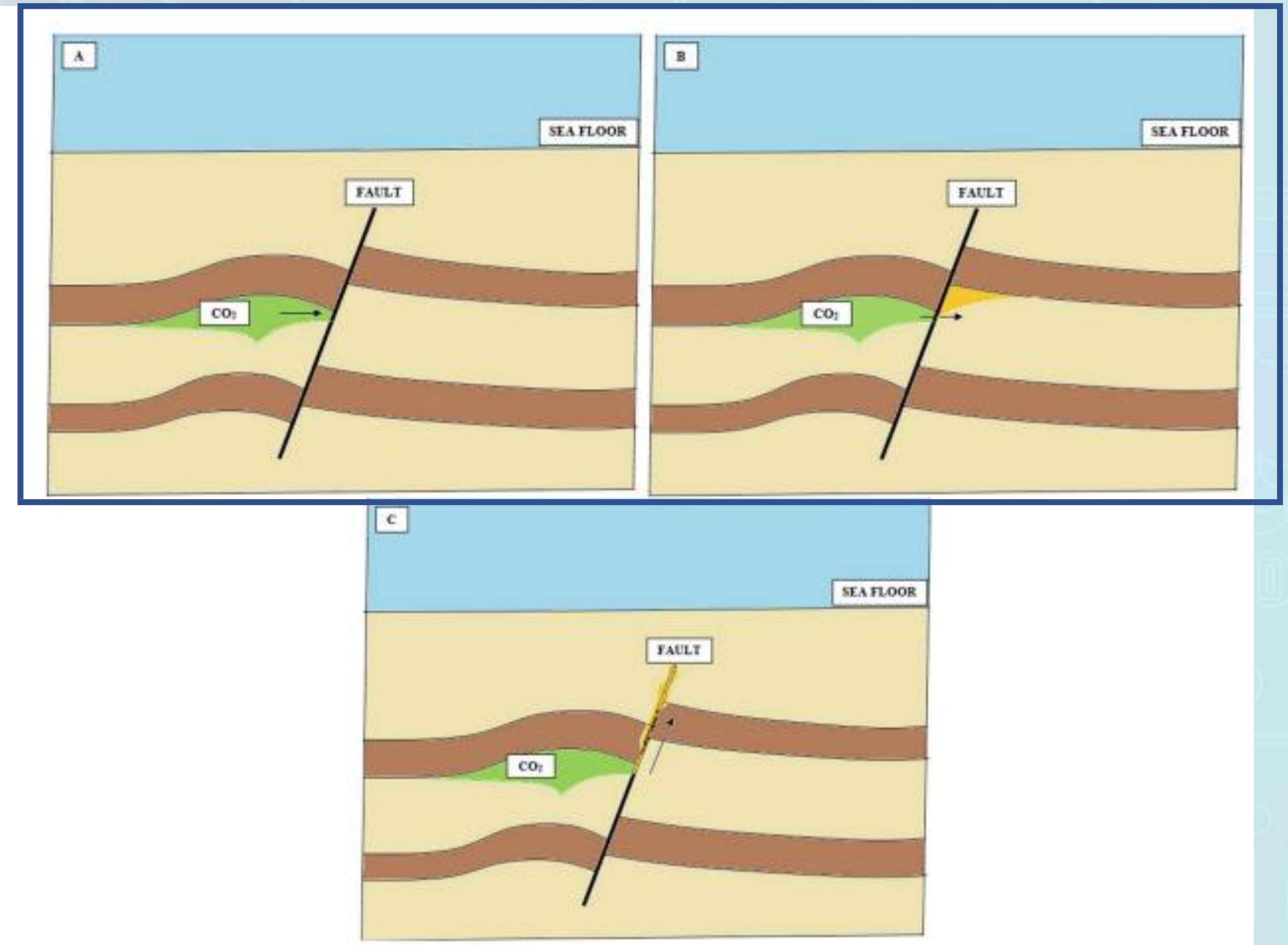
How do we model faults?

→ A gap in fault modeling in the geological model (e.g. Petrel, Decision space, etc.) vs Simulators (e.g. CMG-GEM):

→ Simulation can be different even based on the same geological model but with different fault BC implementations

Based on this uncertainty, what are the best practices, and how to select them?

Potential outcomes when CO_2 reaches a fault



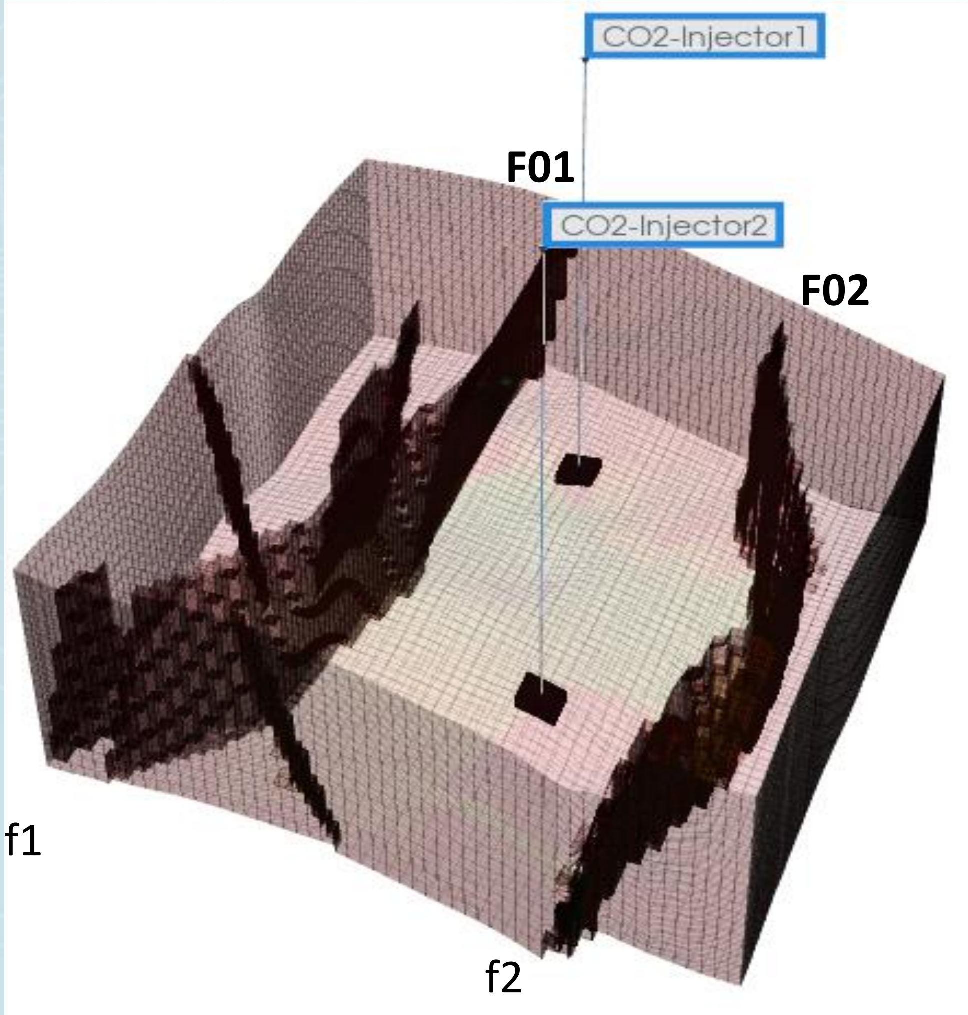
Same reservoir model, different fault BC models: different results OR similar results

- A. Ideal trap
- B. Across-fault migration
- C. Up-fault migration

- This study will focus on the across-fault migration
- Evaluated by pressure distribution, CO_2 plume, and AOR sizes.

(source: Guirola, 2022)

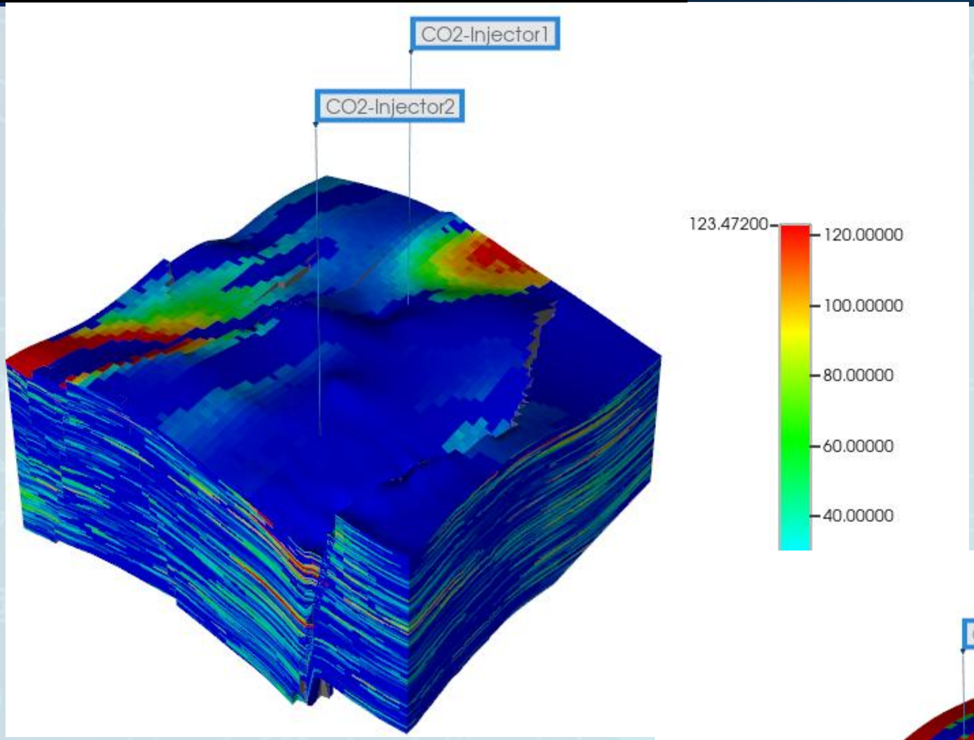
A modified reservoir model in South TX



- 2 major faults
- Reservoir size: 51,000ft by 51,000 ft by 2500ft (area of 9.7 mile by 9.7 mile)
- Miocene

- 2 Injectors
- 1MMT for 25 years each
- 25 years post injection

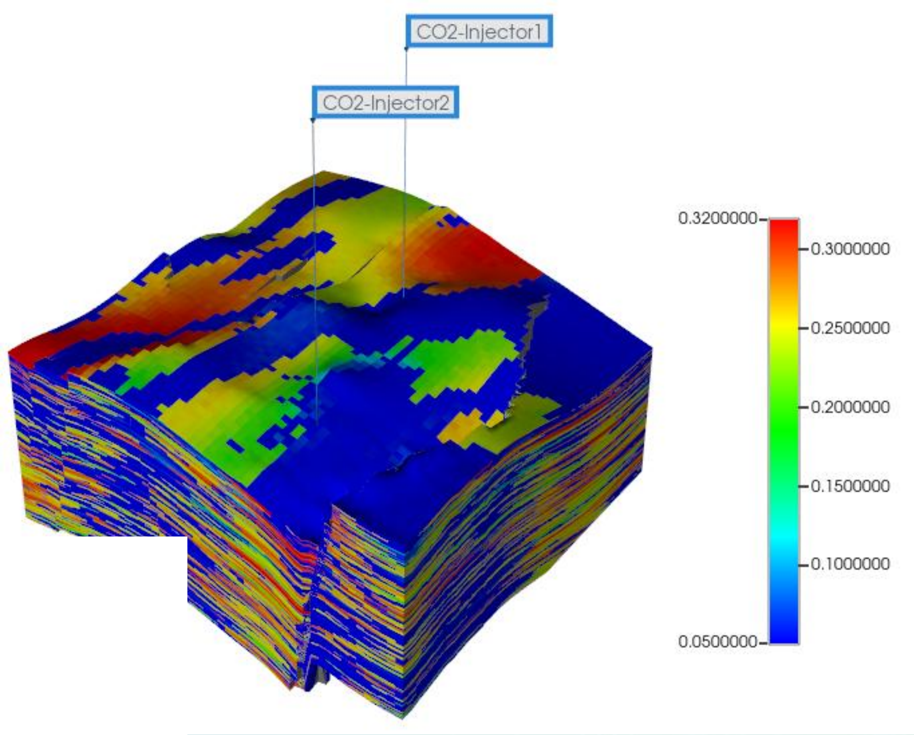
Reservoir model properties



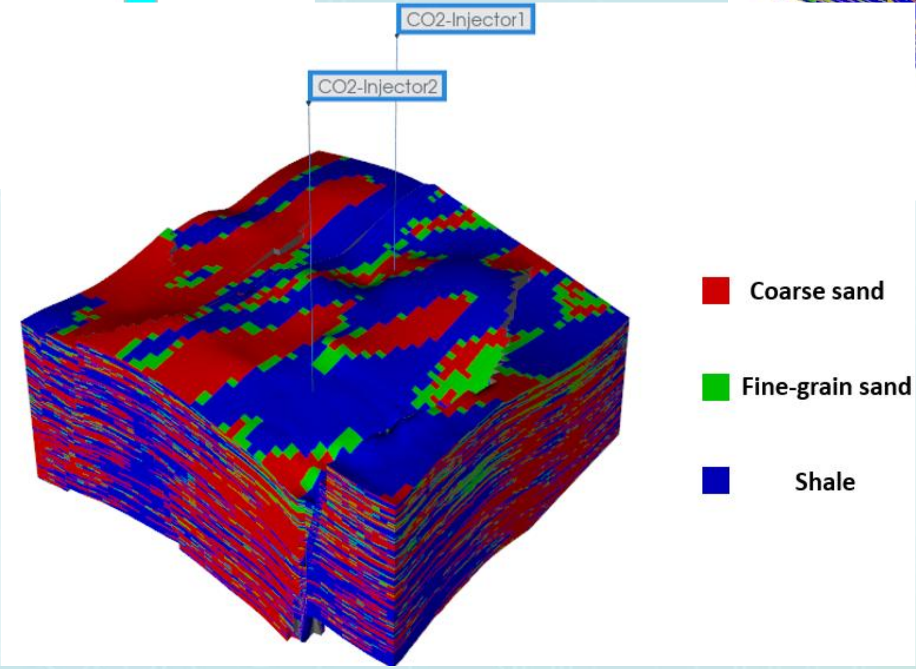
Permeability, mD

Permeability: 25-120 mD

Avg. Porosity: 21%



Porosity



Facies

Two options for fault modeling in CMG-GEM

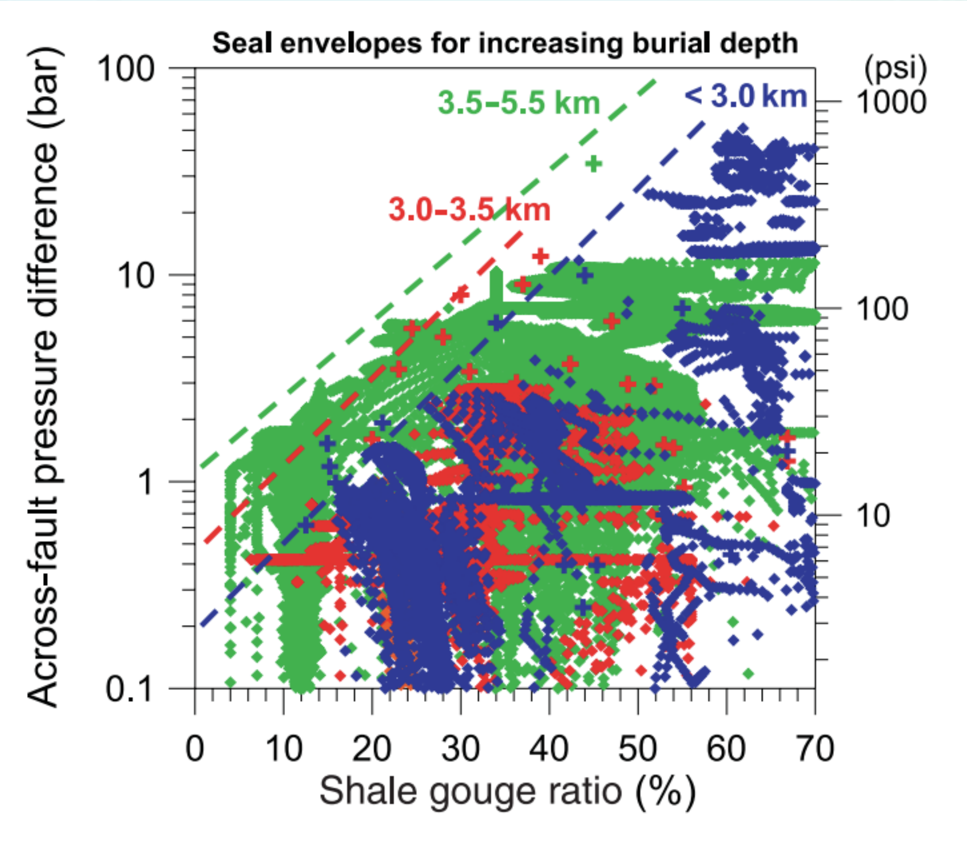
- 1. TRANSF: Transmissibility multiplier (TM)
  - Input required: damage zone permeability?

$$T_x = \frac{A_x k_x}{\mu B \Delta x}$$

- 2. PTHRESH: Across-fault Pressure Difference (AFPD):
  - Input required: Shale Gouge Ratio (SGR)
  - However, how to get SGR? Perforation zone, or overall?

$$AFPD = 10^{SGR/27-C}$$

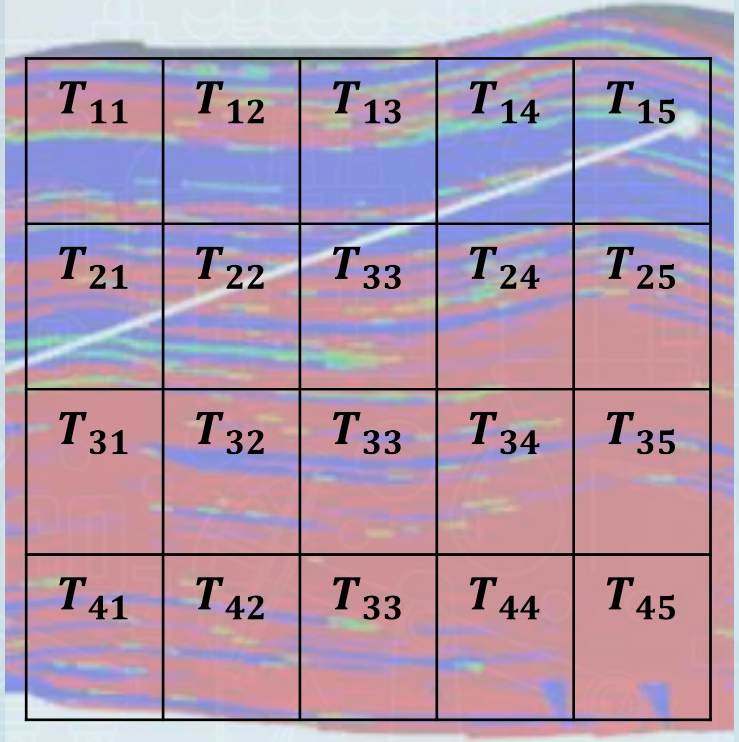
C is constant, depends on the depth



(Bretan et al., 2003)

Main difference between two approaches

TRANSF approach



T_{11}	T_{12}	T_{13}	T_{14}	T_{15}
T_{21}	T_{22}	T_{33}	T_{24}	T_{25}
T_{31}	T_{32}	T_{33}	T_{34}	T_{35}
T_{41}	T_{42}	T_{33}	T_{44}	T_{45}

Still heterogenous

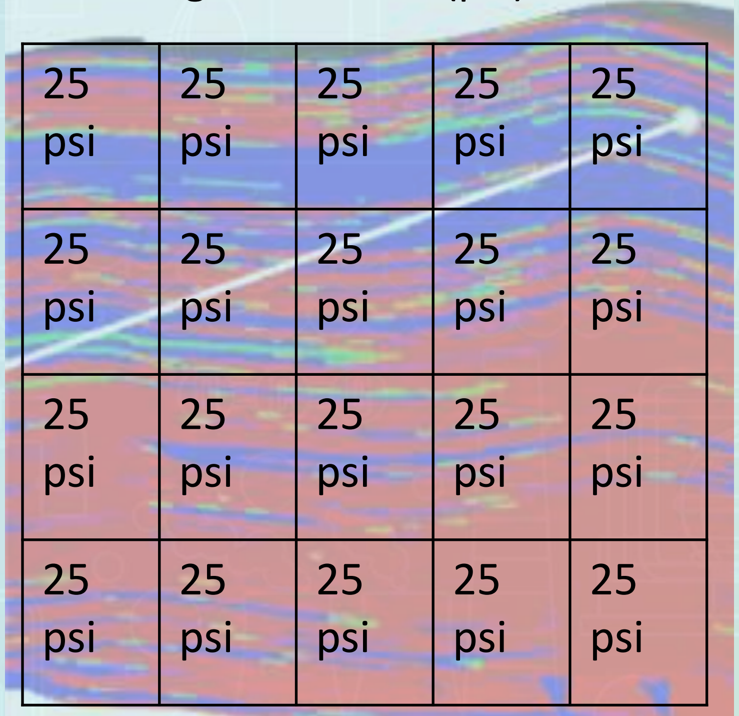
TRANSF

$\times\, 0.1$

V.S.

PHTRESH approach

Assign one AFPD (psi)



25 psi	25 psi	25 psi	25 psi	25 psi
25 psi	25 psi	25 psi	25 psi	25 psi
25 psi	25 psi	25 psi	25 psi	25 psi
25 psi	25 psi	25 psi	25 psi	25 psi

…

Homogenous, unless cut in section

Option 1: Using TRANSF

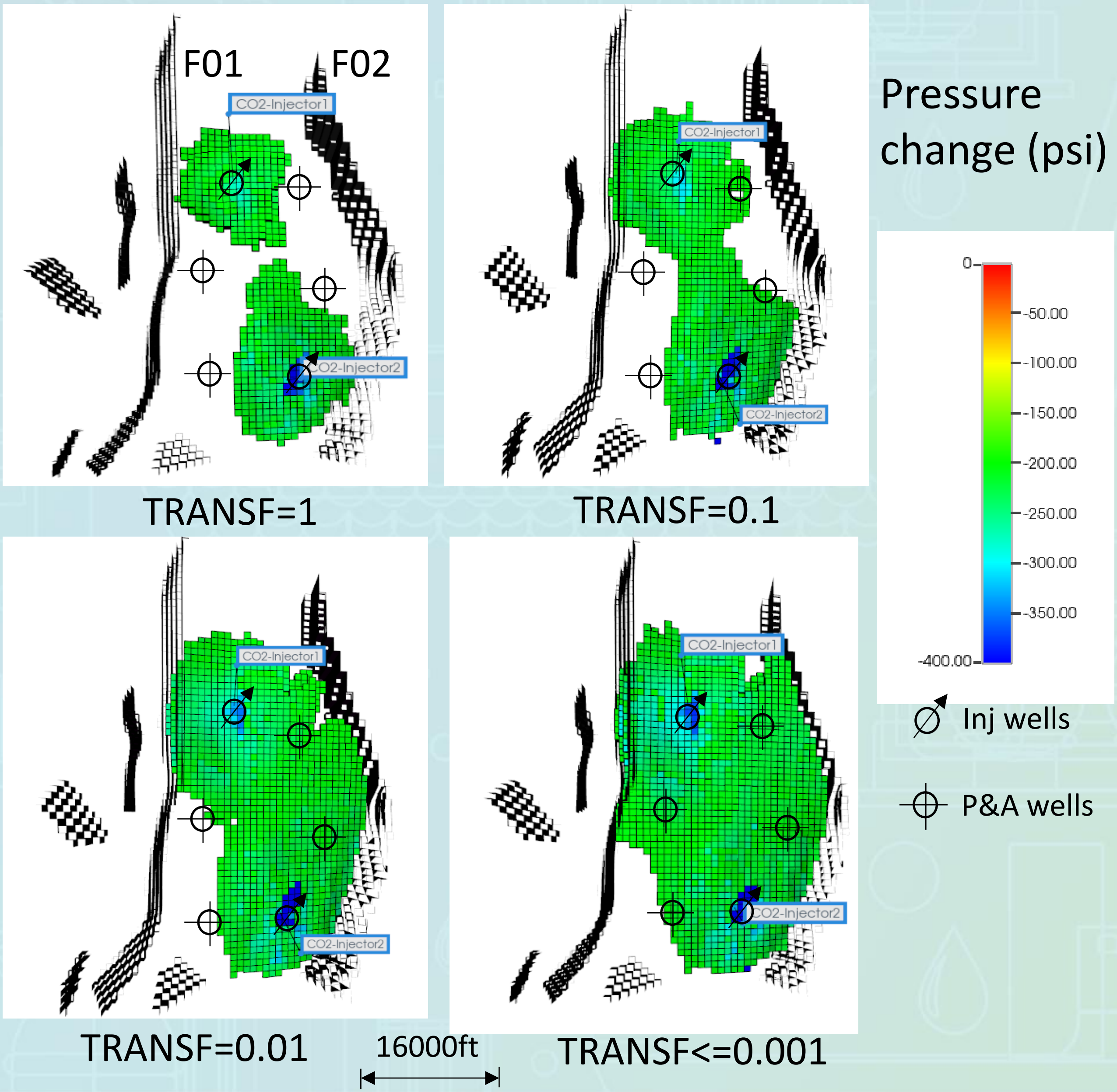
TRANSF should follow the logarithmic relationship (Fossen et al., 2007)

We have tested

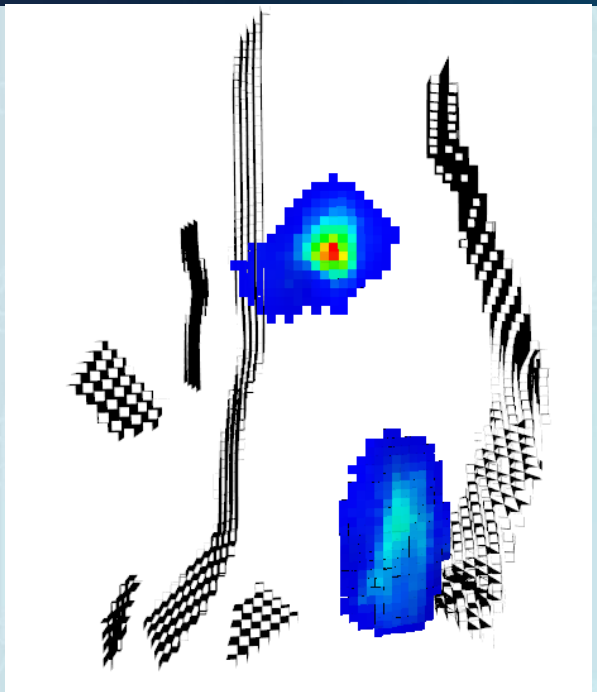
$$TRANSF = 1, 0.1, 0.01, 0.001, 0.0001, 0$$

However, when $TRANSF < 0.01$, difference was not obvious

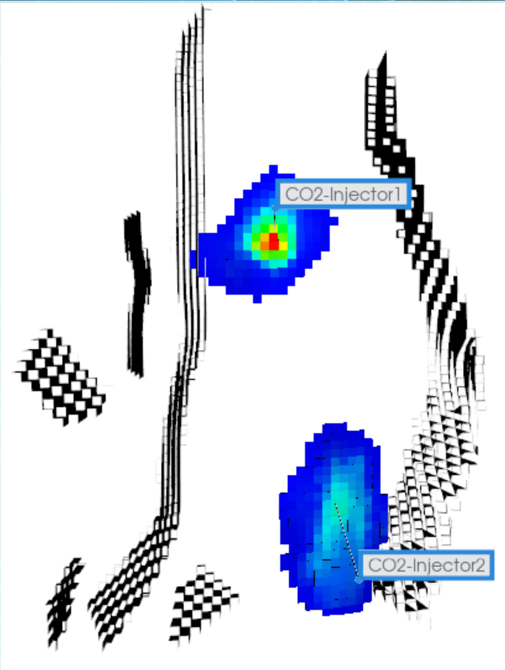
Varying the value of TRANSF from 1 to 0 could potentially quadruple the size of AOR (critical pressure = 200psi)!



However, in terms of the plume size, only limited visual differences.

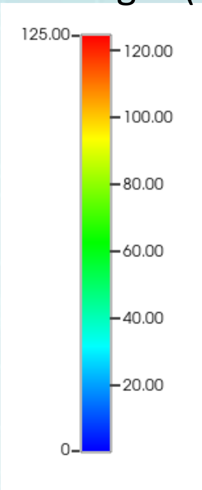


TRANSF = 1

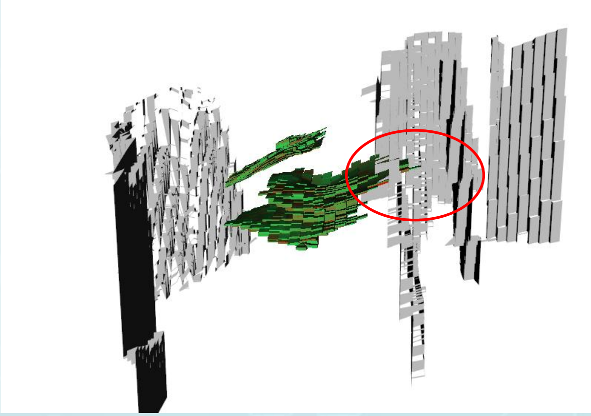


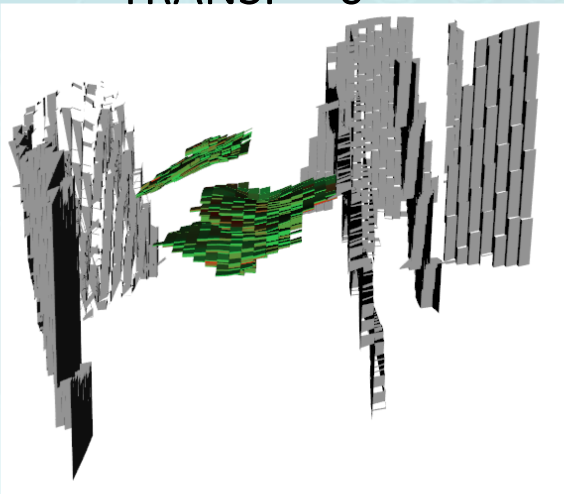
TRANSF = 0

CO_2 plume column height (ft)

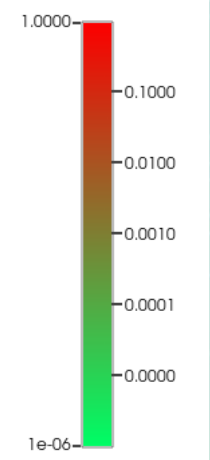


And the plume could cross the fault!





CO_2 plume saturation

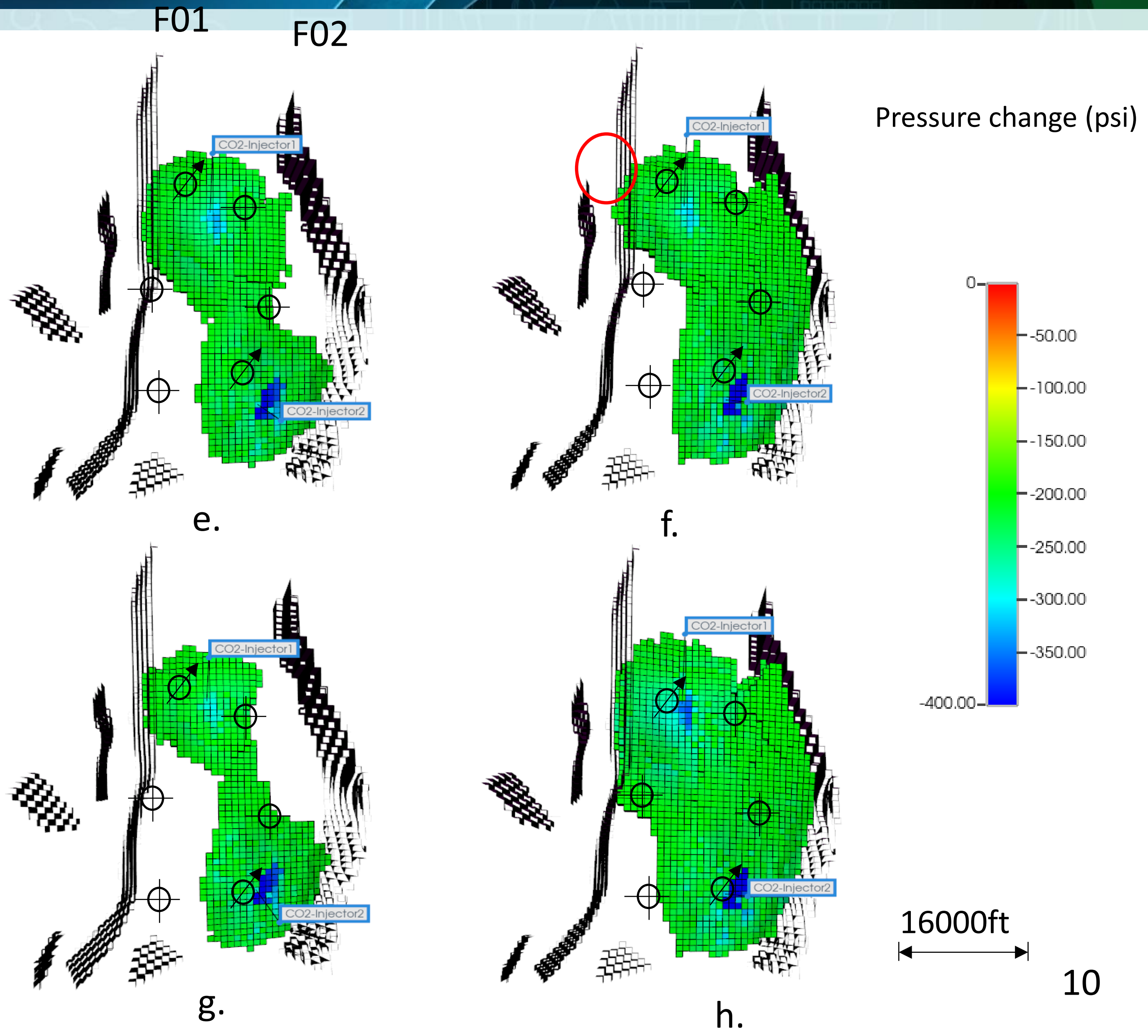


Option 2: Using PTHRESH

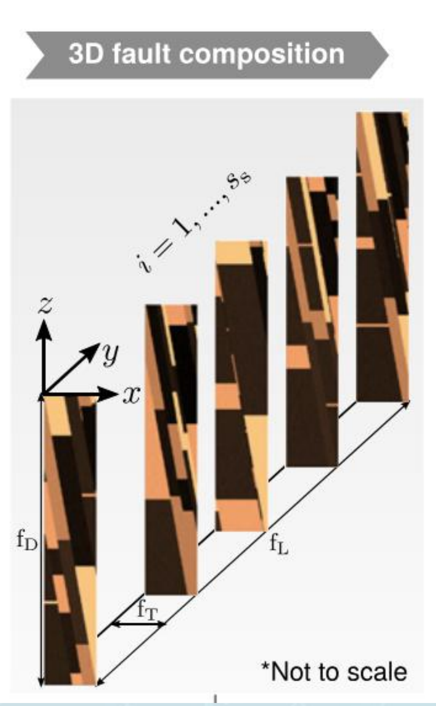
Scenarios	Keywords	F01 SGR	F02 SGR	AFPD (psi)	AFPD (psi)
e	PTHRESH	0.4	0.2	138.94	25.24
f	PTHRESH	0.2	0.45	25.24	212.83
g	PTHRESH	0.2	0.2	25.24	25.24
h	PTHRESH	0.45	0.45	212.83	212.83

$$AFPD = 10^{SGR/27-C}$$

1. Problem: how to select the SGR value? Overall fault average, or only average among the perforation layers?
2. The selection of SGR value is very sensitive: different choices could impact the AOR size (critical pressure = 200psi)
3. Correlation between TRASNF and SGR?

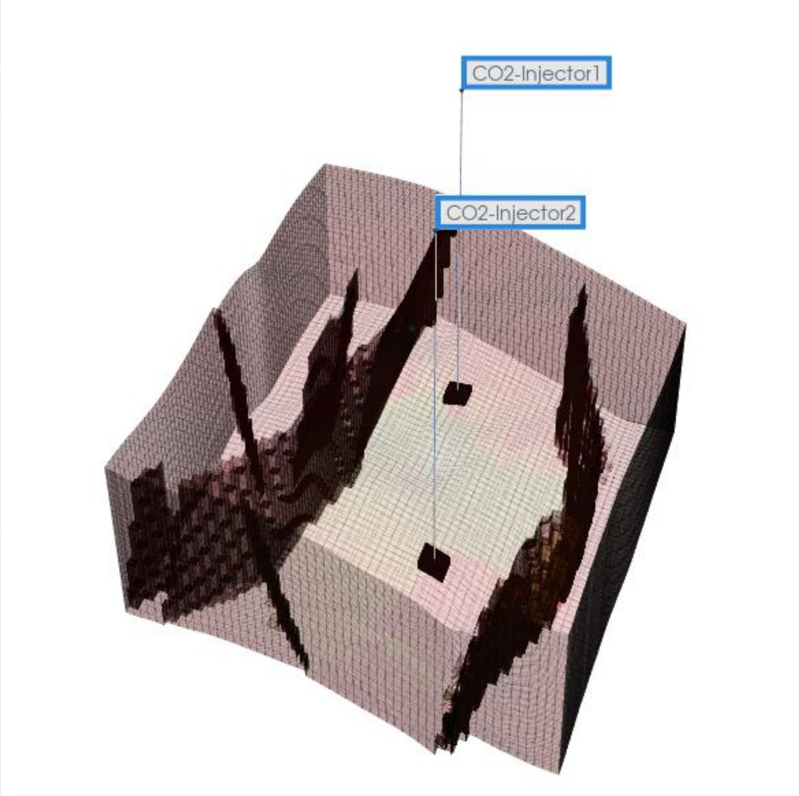


Options for model across-fault migration



Option 1:
Dual permeable zone, set up as a several-layer section in the model

e.g. Salagado & Juanes, 2022 (PREDICT from MIT)



Option 2:
As an interface between two sections of the reservoir model (a ‘membrane’)

Lessons learnt

- There is a big gap between fault representation in reservoir simulations and geological model
  - If need to represent heterogeneity among the faults: ‘cut’ the fault into pieces, or use the more complex ‘layer-method’

- Selection of the fault model parameters could impact the simulation results; the pressure distribution is more sensitive than CO_2 plume

- The TRANSF approach is easier to use; while the PTHRESH approach based on local SGR is truer to reality; selection depends on needs and assumptions; we have some preliminary results to bridge and correlation between these two approaches.

- Sidenote: During software data transfer, some fault data corrupted, or not well defined, leads to ‘holes’ in the fault. Even ‘small holes’ could potentially lead to a big pressure drop, as a ‘Teapot effect’. Simulations needs another round of QC.

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