

Enhanced Analytical Simulation Tool for CO₂ Storage Capacity Estimation

DE-FE0009301

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U.S. Department of Energy
National Energy Technology Laboratory
Carbon Storage R&D Project Review Meeting
Transforming Technology through Integration and Collaboration
August 16-18, 2016

Benefit to the Program/Goals and Objectives

- Project benefit

- Support industry's ability to predict CO₂ storage capacity in geologic saline formations to within ± 30 percent.

- Major goal


- Develop an **Enhanced Analytical Simulation Tool (EASiTool)** for simplified reservoir models to predict storage capacity of brine formations.

- Objectives



- Provide fast, reliable and science-based estimate of storage capacity.
- Integrate analytical/semi-analytical geomechanical models
- Integrate brine extraction scenarios.
- Provide sensitivity analysis.

Technical Status

EASiToolGUI



GULF COAST CARBON CENTER

1-RESERVOIR PARAMETERS

	Min	Ma
Pressure [MPa]	20	25
Temperature [C]	65	80
Thickness [m]	100	150
Salinity [mol/Kg]	2	3
Porosity	0.2	0.25
Permeability [mD]	100	250
Rock Compressibility [1/Pa]	5e-10	6.5e-10
Reservoir Area [km^2]	100	
Basin Area [km^2]	100	
Boundary Condition	Clos...	

3-SIMULATION PARAMETERS

Simulation Time [years]

Injection Well Radius [m]

Max Injection Pressure [MPa]

Estimate Max Injection Pressure Internally

Density of Porous Media [Kg/m3]

Total Stress Ratio (V/H)

Biot Coefficient

Poisson's ratio

Coefficient of Thermal Expansion [1/K]

Bottom Hole Temperature Drop [K]

Young's Modulus [GPa]

Depth [m]

Estimated Max Injection Pressure [MPa]

Max Injection Rate [ton/day/well]

Max Number of Injectors

Sensitivity Analysis (Slow)

4-NPV

Drilling Cost [\$M/well]

Operation Cost [\$K/well/year]

Monitoring Cost [\$K/year/km^2]

Tax Credit [\$/ton]

Extractors Drilling Cost [\$M/well]

Extractors Operation Cost [\$K/well/year]

5-EXTRACTION PARAMETERS

Number of Extractors

Minimum Extraction Pressure [MPa]

Maximum Extraction Rate [m^3/day/well]

Run

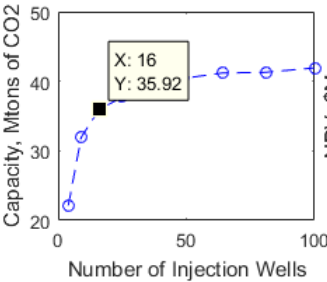
Simulation Time [sec]= 100.

6-RESULT CONTROLS

Number of Injection Wells

Export Image and Output Files (Slow)

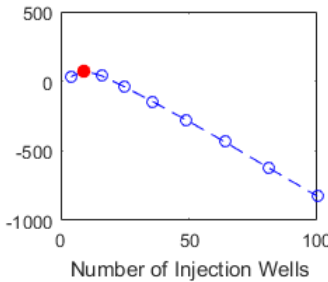
Visit our website.



Capacity, Mitons of CO2

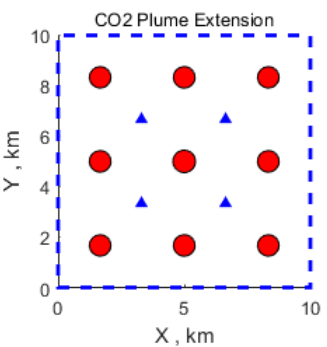
Number of Injection Wells

X: 16
Y: 35.92



NPV, \$M

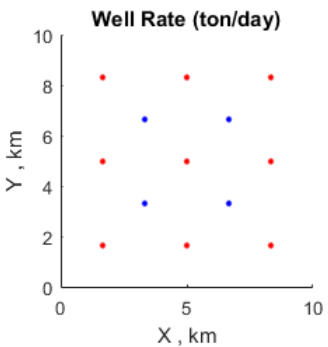
Number of Injection Wells



CO2 Plume Extension

Y, km

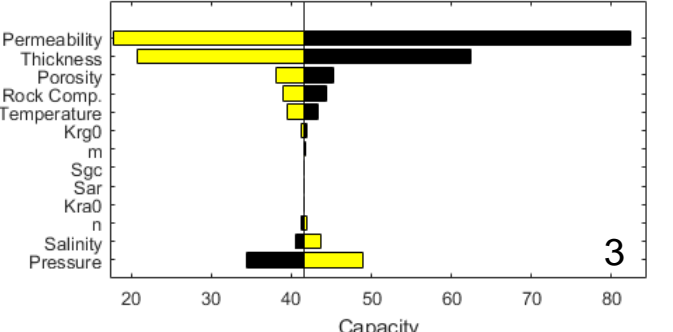
X, km



Well Rate (ton/day)

Y, km


X, km



Permeability Thickness Porosity Rock Comp. Temperature Krg0 m Sgc Sar Kra0 n Salinity Pressure

3

Capacity

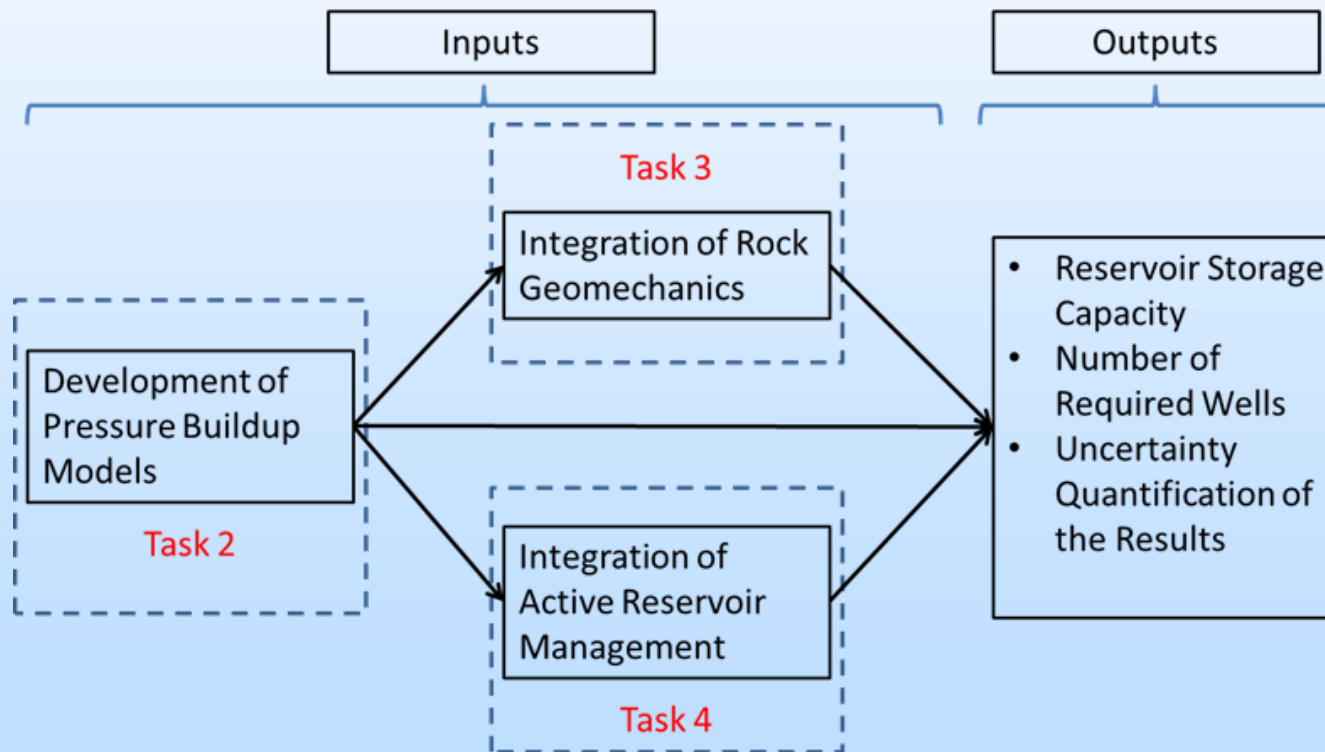


Technical Status

Tool/Approach Name	DOE/NETL	CSLF	USGS	EASiTool	Numerical Simulators
Reservoir scale	Yes	Yes	Yes	Yes	Yes
Accuracy	Low	Low	Low	Medium/High	High
Boundary conditions	No	No	No	Yes	Yes
Rock geomechanics	No	No	No	Yes	Yes
Brine management	No	No	No	Yes	Yes
Required expertise	Low	Low	Low	Low	High
Cost of use	Low	Low	Low	Low	High
Speed	High	High	High	High	Low
Dynamic	No	No	No	Yes	Yes
Sensitivity Analysis	No	No	Simple	Yes	Yes

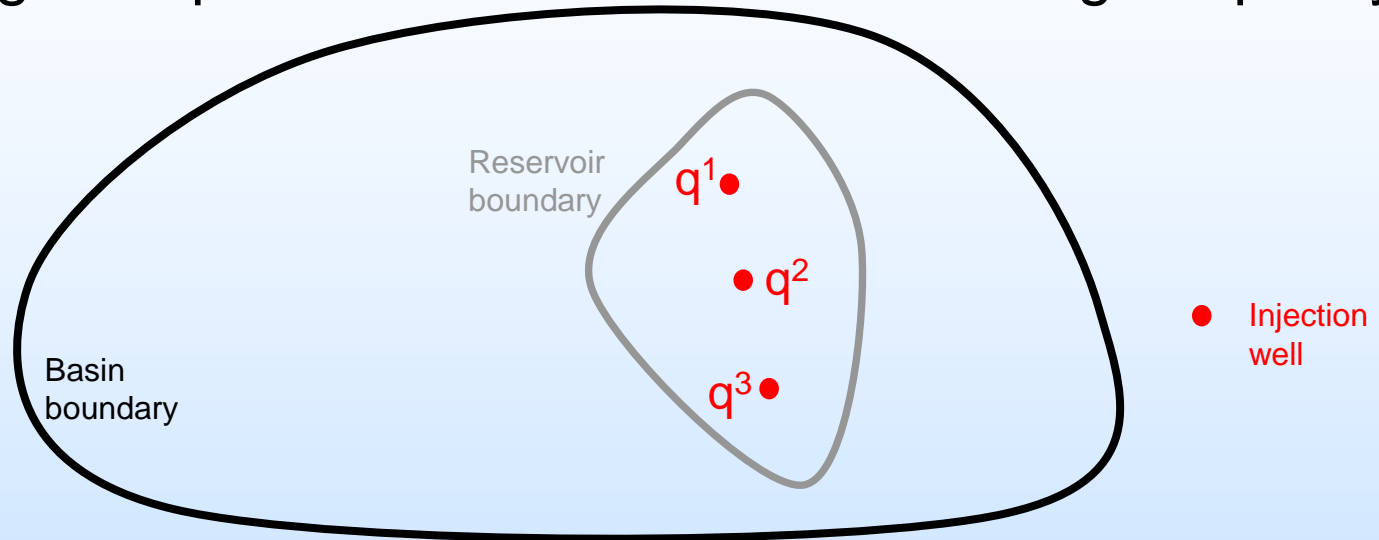
Technical Status

- Tasks 2-4 completed
- NCE
- User feedback, Verification & Application



Accomplishments to Date

- Finding the optimized rate to maximize storage capacity



$$\begin{bmatrix} \frac{1}{2}(\ln(t_D) + 0.80908) + S_a & -\frac{1}{2} \frac{\bar{\lambda}_g}{\bar{\lambda}_w} E_i \left(-\frac{r_{D1-2}^2}{4\eta_{D3} t_D} \right) & -\frac{1}{2} \frac{\bar{\lambda}_g}{\bar{\lambda}_w} E_i \left(-\frac{r_{D1-3}^2}{4\eta_{D3} t_D} \right) \\ -\frac{1}{2} \frac{\bar{\lambda}_g}{\bar{\lambda}_w} E_i \left(-\frac{r_{D2-1}^2}{4\eta_{D3} t_D} \right) & \frac{1}{2}(\ln(t_D) + 0.80908) + S_a & -\frac{1}{2} \frac{\bar{\lambda}_g}{\bar{\lambda}_w} E_i \left(-\frac{r_{D2-3}^2}{4\eta_{D3} t_D} \right) \\ -\frac{1}{2} \frac{\bar{\lambda}_g}{\bar{\lambda}_w} E_i \left(-\frac{r_{D3-1}^2}{4\eta_{D3} t_D} \right) & -\frac{1}{2} \frac{\bar{\lambda}_g}{\bar{\lambda}_w} E_i \left(-\frac{r_{D3-2}^2}{4\eta_{D3} t_D} \right) & \frac{1}{2}(\ln(t_D) + 0.80908) + S_a \end{bmatrix} \begin{Bmatrix} q^1 \\ q^2 \\ q^3 \end{Bmatrix} = \begin{Bmatrix} \frac{2\pi h k \bar{k}_{rg}}{\mu_g} \Delta P_{\max} \\ 2\pi h k \bar{k}_{rg} \Delta P_{\max} \\ \frac{2\pi h k \bar{k}_{rg}}{\mu_g} \Delta P_{\max} \end{Bmatrix}$$

Accomplishments to Date

- Normal fault system

$$P_{\max} = \frac{1}{\left[2\alpha - \beta_v - \beta_h - (\beta_v - \beta_h) \cos 2\theta + (\beta_v - \beta_h) \sin 2\theta / \mu\right]} \cdot \left[\left\{ (1+K) + (1-K) \cos 2\theta - (1-K) \sin 2\theta / \mu \right\} \sigma_{v0} - \left\{ (\beta_v + \beta_h) + (\beta_v - \beta_h) \cos 2\theta - (\beta_v - \beta_h) \sin 2\theta / \mu \right\} P_{pi} - \frac{2\alpha_T E \Delta T}{1-2\nu} \right]$$

- Reverse fault system

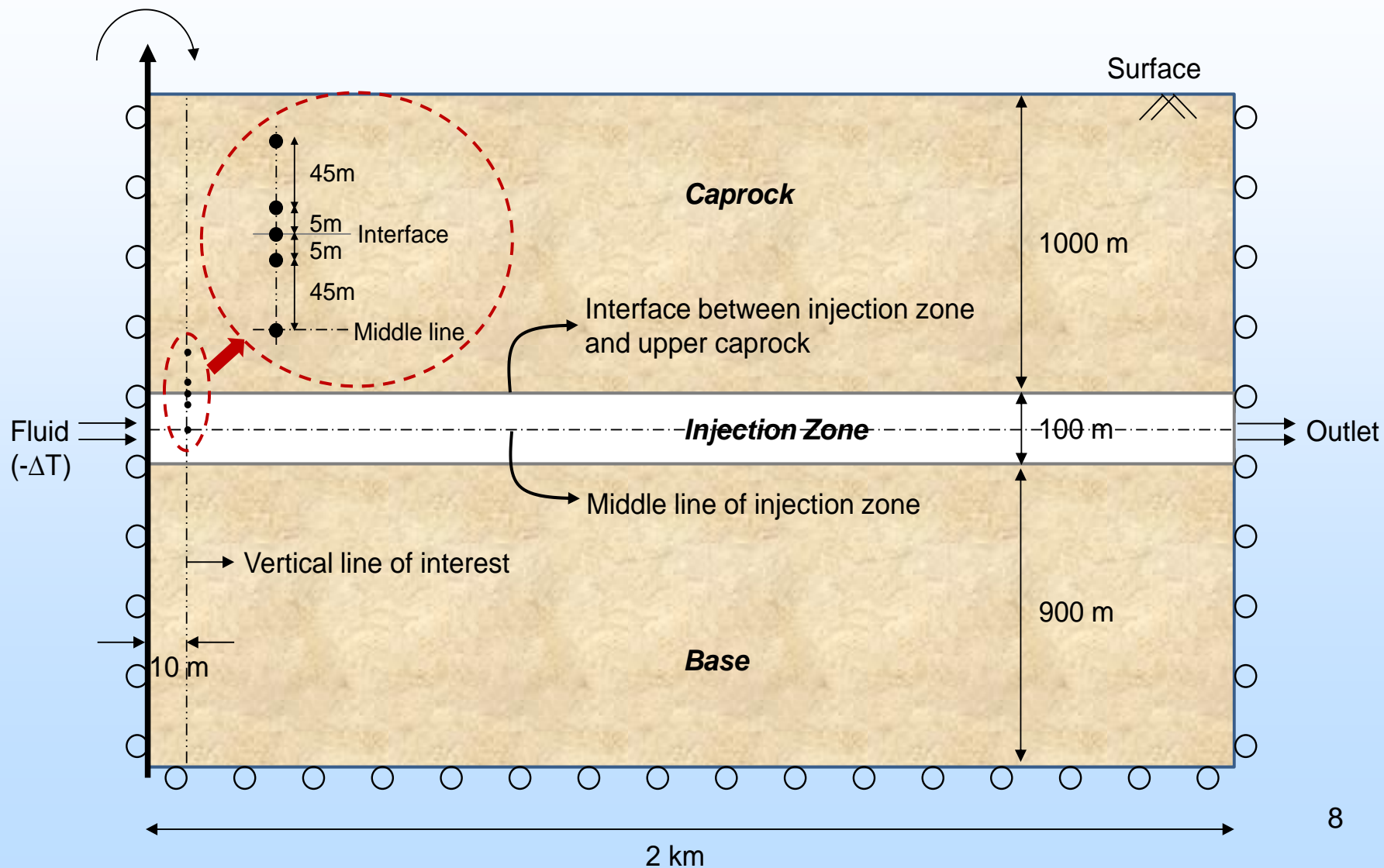
$$P_{\max} = \frac{1}{\left[2\alpha - \beta_h - \beta_v - (\beta_h - \beta_v) \cos 2\theta + (\beta_h - \beta_v) \sin 2\theta / \mu\right]} \cdot \left[\left\{ (K+1) + (K-1) \cos 2\theta - (K-1) \sin 2\theta / \mu \right\} \sigma_{v0} - \left\{ (\beta_h + \beta_v) + (\beta_h - \beta_v) \cos 2\theta - (\beta_h - \beta_v) \sin 2\theta / \mu \right\} P_{pi} - \frac{2\alpha_T E \Delta T}{1-2\nu} \right]$$

- Strike-slip fault system

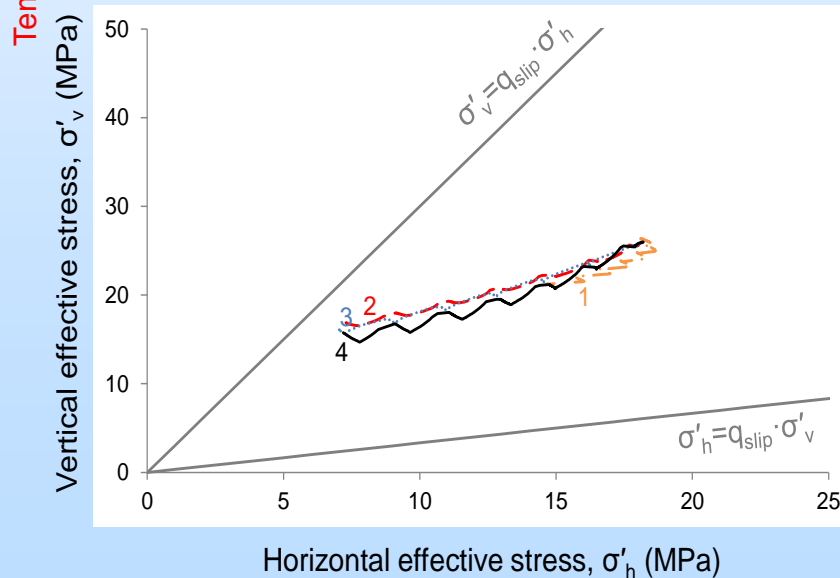
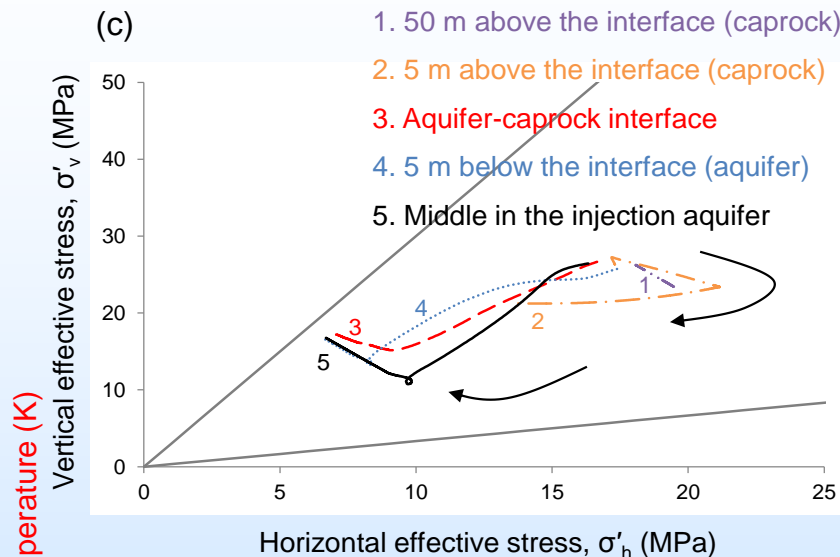
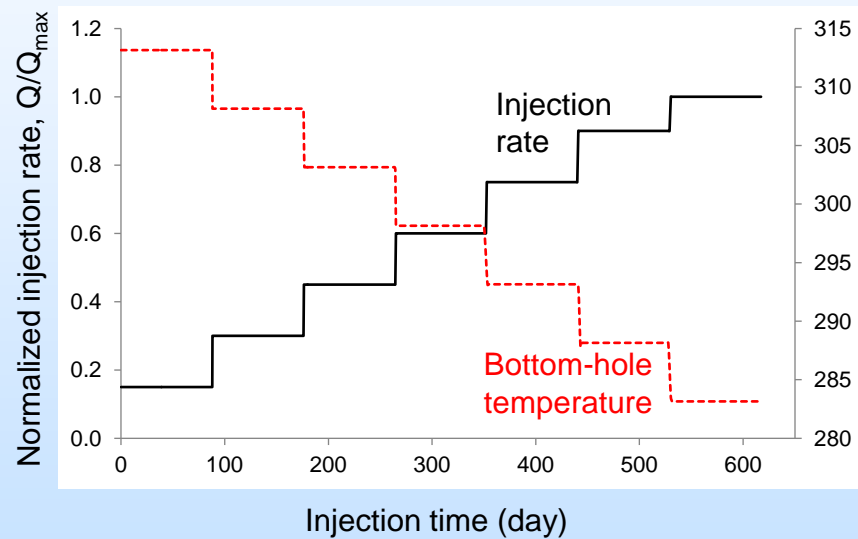
$$P_{\max} = \frac{1}{\alpha - \beta_h} \left[\left(\frac{1+K_H}{2} + \frac{1-K_H}{2} \cos 2\theta - \frac{1-K_H}{2} \sin 2\theta / \mu \right) \sigma_{H0} - \beta_h \cdot P_{pi} - \frac{\alpha_T E \Delta T}{1-2\nu} \right] \quad \Delta P_{\max} = P_{\max} - P_{pi}$$

- Kim, S, and Hosseini, S. A., 2014, Geological CO₂ storage: incorporation of pore-pressure/stress coupling and thermal effects to determine maximum sustainable pressure limit: Energy Procedia, v. 63, p. 3339-3346,
- Kim, S, and Hosseini, S. A., 2016, Study on the Ratio of Pore-Pressure/Stress Changes During Fluid Injection and Its Implications for CO₂ Geologic Storage, Journal of Petroleum Science and Engineering, in press.

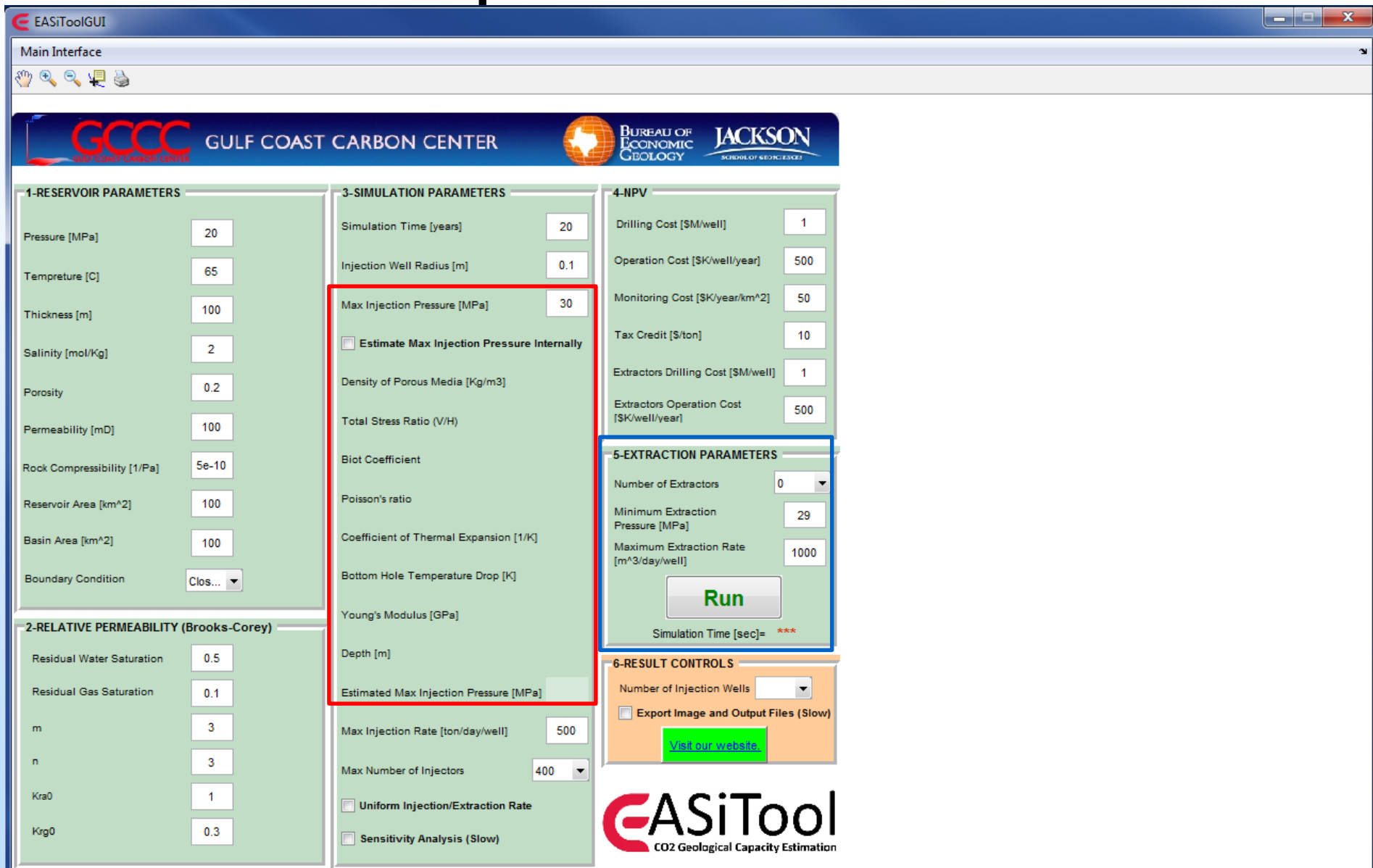
Accomplishments to Date



Accomplishments to Date



Accomplishments to Date



The screenshot displays the EASiToolGUI software interface, which is used for CO2 Geological Capacity Estimation. The interface is divided into several sections for parameter input:

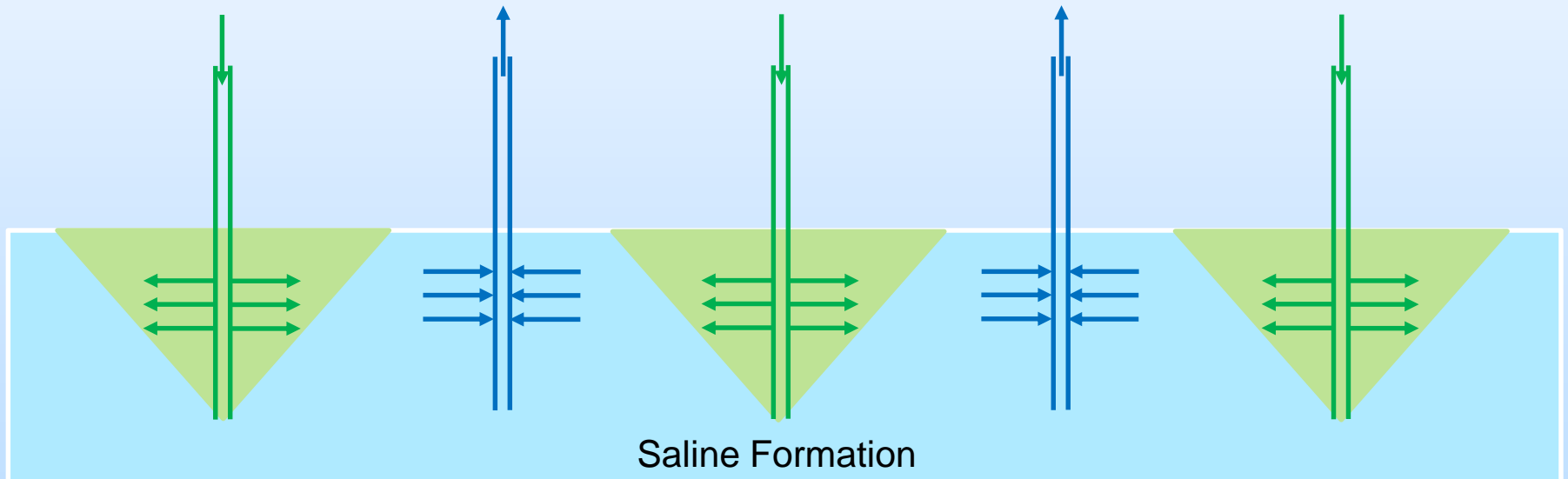
- 1-RESERVOIR PARAMETERS:**
 - Pressure [MPa]: 20
 - Temperature [C]: 65
 - Thickness [m]: 100
 - Salinity [mol/Kg]: 2
 - Porosity: 0.2
 - Permeability [mD]: 100
 - Rock Compressibility [1/Pa]: 5e-10
 - Reservoir Area [km^2]: 100
 - Basin Area [km^2]: 100
 - Boundary Condition: Clos...
- 2-RELATIVE PERMEABILITY (Brooks-Corey):**
 - Residual Water Saturation: 0.5
 - Residual Gas Saturation: 0.1
 - m: 3
 - n: 3
 - Kra0: 1
 - Krg0: 0.3
- 3-SIMULATION PARAMETERS:**
 - Simulation Time [years]: 20
 - Injection Well Radius [m]: 0.1
 - Max Injection Pressure [MPa]: 30
 - Estimate Max Injection Pressure Internally
 - Density of Porous Media [Kg/m3]:
 - Total Stress Ratio (V/H):
 - Biot Coefficient:
 - Poisson's ratio:
 - Coefficient of Thermal Expansion [1/K]:
 - Bottom Hole Temperature Drop [K]:
 - Young's Modulus [GPa]:
 - Depth [m]:
 - Estimated Max Injection Pressure [MPa]:
 - Max Injection Rate [ton/day/well]: 500
 - Max Number of Injectors: 400
 - Uniform Injection/Extraction Rate
 - Sensitivity Analysis (Slow)
- 4-NPV:**
 - Drilling Cost [\$M/well]: 1
 - Operation Cost [\$K/well/year]: 500
 - Monitoring Cost [\$K/year/km^2]: 50
 - Tax Credit [\$/ton]: 10
 - Extractors Drilling Cost [\$M/well]: 1
 - Extractors Operation Cost [\$K/well/year]: 500
- 5-EXTRACTION PARAMETERS:**
 - Number of Extractors: 0
 - Minimum Extraction Pressure [MPa]: 29
 - Maximum Extraction Rate [m^3/day/well]: 1000
 - Run** button
 - Simulation Time [sec]= ***
- 6-RESULT CONTROLS:**
 - Number of Injection Wells:
 - Export Image and Output Files (Slow)
 - [Visit our website.](#)

The interface also features logos for the Gulf Coast Carbon Center, Bureau of Economic Geology, and Jackson School of Geosciences. The EASiTool logo at the bottom identifies the software as "CO2 Geological Capacity Estimation".

Brine Extraction

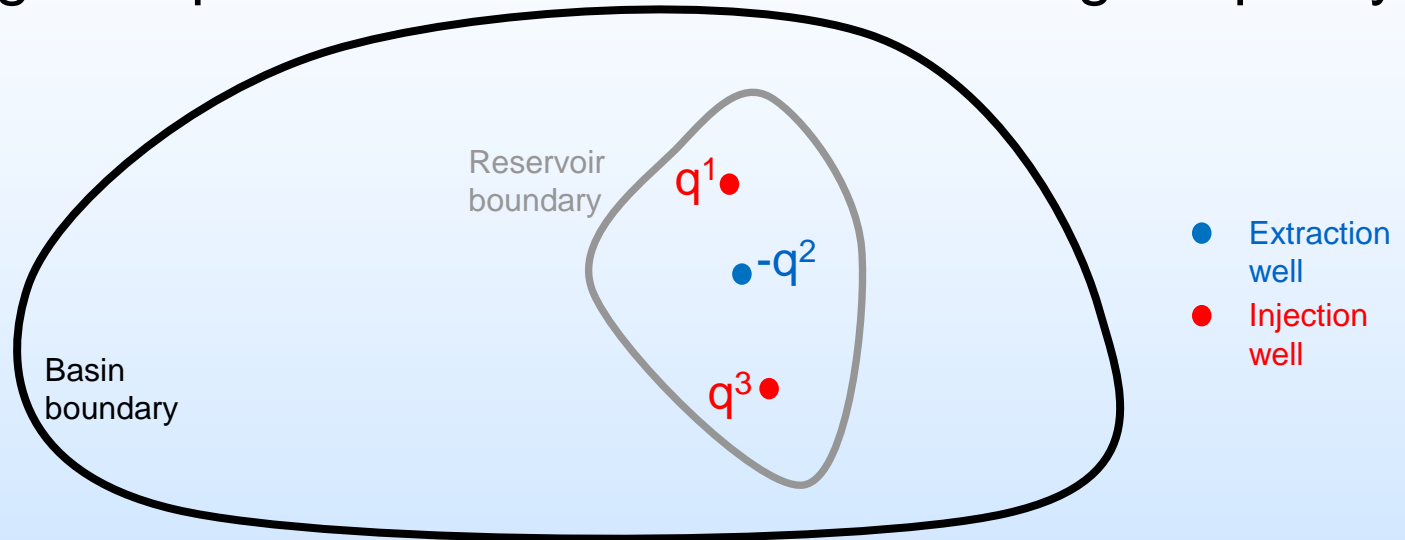
- Brine extraction improves injectivity (capacity) and reduce the risk of exceeding the fracture pressure.

CO₂ Injectors Brine Extractors



Accomplishments to Date


- Finding the optimized rate to maximize storage capacity






$$\begin{bmatrix} \frac{1}{2}(\ln(t_D) + 0.80908) + S_a & -\frac{1}{2} \frac{\bar{\lambda}_g}{\lambda_w} E_i \left(-\frac{r_{D1-2}^2}{4\eta_{D3} t_D} \right) & -\frac{1}{2} \frac{\bar{\lambda}_g}{\lambda_w} E_i \left(-\frac{r_{D1-3}^2}{4\eta_{D3} t_D} \right) \\ -\frac{1}{2} \frac{\bar{\lambda}_g}{\lambda_w} E_i \left(-\frac{r_{D2-1}^2}{4\eta_{D3} t_D} \right) & \frac{1}{2}(\ln(t_D) + 0.80908) + S_a & -\frac{1}{2} \frac{\bar{\lambda}_g}{\lambda_w} E_i \left(-\frac{r_{D2-3}^2}{4\eta_{D3} t_D} \right) \\ -\frac{1}{2} \frac{\bar{\lambda}_g}{\lambda_w} E_i \left(-\frac{r_{D3-1}^2}{4\eta_{D3} t_D} \right) & -\frac{1}{2} \frac{\bar{\lambda}_g}{\lambda_w} E_i \left(-\frac{r_{D3-2}^2}{4\eta_{D3} t_D} \right) & \frac{1}{2}(\ln(t_D) + 0.80908) + S_a \end{bmatrix} \begin{Bmatrix} q^1 \\ -q^2 \\ q^3 \end{Bmatrix} = \begin{Bmatrix} \frac{2\pi h k \bar{k}_{rg}}{\mu_g} \Delta P_{\max} \\ \frac{2\pi h k \bar{k}_{rg}}{\mu_g} \Delta P_{\min} \\ \frac{2\pi h k \bar{k}_{rg}}{\mu_g} \Delta P_{\max} \end{Bmatrix}$$

Closed Boundary, 4 Extractors

EASiToolGUI




GULF COAST CARBON CENTER

BUREAU OF ECONOMIC GEOLOGY


1-RESERVOIR PARAMETERS

	Min	Ma	
Pressure [MPa]	20	15	25
Temperature [C]	65	50	80
Thickness [m]	100	50	150
Salinity [mol/Kg]	2	1	3
Porosity	0.2	0.15	0.25
Permeability [mD]	100	10	250
Rock Compressibility [1/K]	5e-10	3.5e-10	6.5e-10
Reservoir Area [km^2]	100		
Basin Area [km^2]	100		
Boundary Condition	Clos... ▾		

3-SIMULATION PARAMETERS

Simulation Time [years]

Injection Well Radius [m]

Max Injection Pressure [MPa]

Estimate Max Injection Pressure Internally

Density of Porous Media [Kg/m3]

Total Stress Ratio (V/H)

Biot Coefficient

Poisson's ratio

Coefficient of Thermal Expansion [1/K]

Bottom Hole Temperature Drop [K]

Young's Modulus [GPa]

Depth [m]

Estimated Max Injection Pressure [MPa]

Max Injection Rate [ton/day/well]

Max Number of Injectors

Sensitivity Analysis (Slow)

4-NPV

Drilling Cost [\$M/well]

Operation Cost [\$K/well/year]

Monitoring Cost [\$K/year/km^2]

Tax Credit [\$/ton]

Extractors Drilling Cost [\$M/well]

Extractors Operation Cost [\$K/well/year]

5-EXTRACTION PARAMETERS

Number of Extractors

Minimum Extraction Pressure [MPa]

Maximum Extraction Rate [m^3/day/well]

Run

Simulation Time [sec]= 100.

6-RESULT CONTROLS

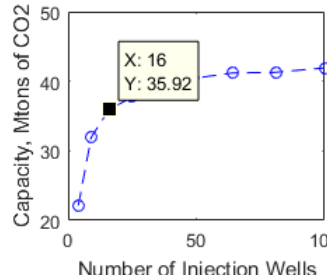
Number of Injection Wells

Export Image and Output Files (Slow)

Visit our website.

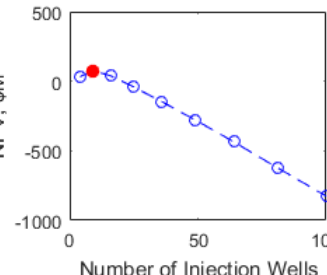
2-RELATIVE PERMEABILITY (Brooks-Corey)

Residual Water Saturation	0.5	0.3	0.7
Residual Gas Saturation	0.05	0	0.1
m	3	2	4
n	3	2	4
Kra0	1	1	1
Krg0	0.3	0.20	0.4

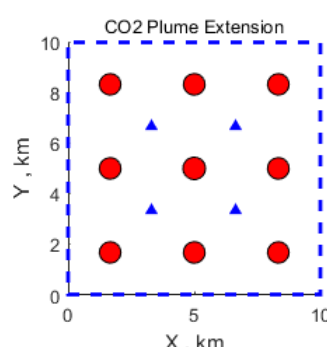


Capacity, Mitons of CO2 vs Number of Injection Wells

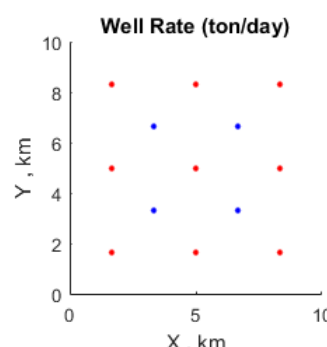
Point: X: 16, Y: 35.92



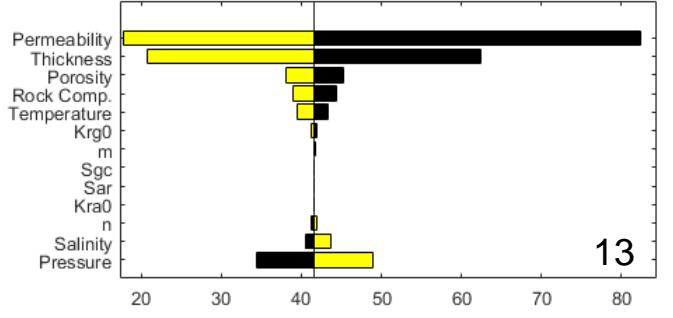
NPV, \$M vs Number of Injection Wells



CO2 Plume Extension




Well Rate (ton/day)



Permeability Thickness Porosity Rock Comp. Temperature Krg0 m Sgc Sar Kra0 n Salinity Pressure

13



Closed Boundary, 8 Extractors

EASIToolGUI

— □ ✕

GCCC GULF COAST CARBON CENTER

1-RESERVOIR PARAMETERS

	Min	Ma	
Pressure [MPa]	20	15	25
Temperature [C]	65	50	80
Thickness [m]	100	50	150
Salinity [mol/Kg]	2	1	3
Porosity	0.2	0.15	0.25
Permeability [mD]	100	10	250
Rock Compressibility [1/Pa]	5e-10	3.5e-10	6.5e-10
Reservoir Area [km ²]	100		
Basin Area [km ²]	100		
Boundary Condition	Clos... ▾		

3-SIMULATION PARAMETERS

Simulation Time [years]

Injection Well Radius [m]

Max Injection Pressure [MPa]

Estimate Max Injection Pressure Internally

Density of Porous Media [Kg/m³]

Total Stress Ratio (V/H)

Biot Coefficient

Poisson's ratio

Coefficient of Thermal Expansion [1/K]

Bottom Hole Temperature Drop [K]

Young's Modulus [GPa]

Depth [m]

Estimated Max Injection Pressure [MPa]

Max Injection Rate [ton/day/well]

Max Number of Injectors

Sensitivity Analysis (Slow)

4-NPV

Drilling Cost [\$M/well]

Operation Cost [\$K/well/year]

Monitoring Cost [\$K/year/km²]

Tax Credit [\$/ton]

Extractors Drilling Cost [\$M/well]

Extractors Operation Cost [\$K/well/year]

5-EXTRACTION PARAMETERS

Number of Extractors

Minimum Extraction Pressure [MPa]

Maximum Extraction Rate [m³/day/well]

Run

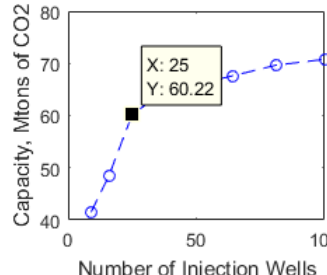
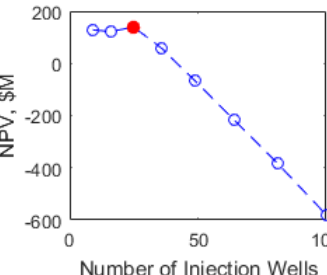
Simulation Time [sec]= 100.

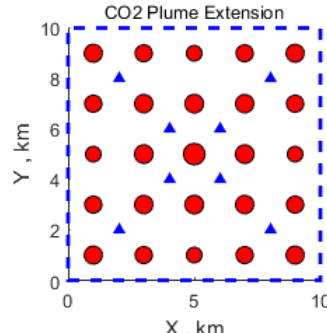
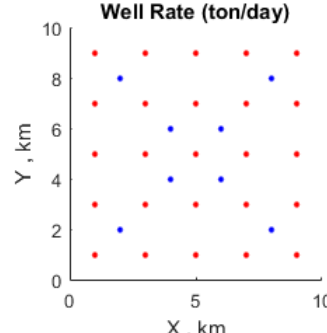
6-RESULT CONTROLS

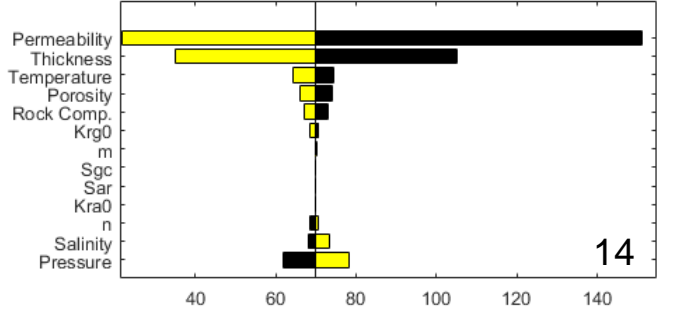
Number of Injection Wells

Export Image and Output Files (Slow)

Visit our website.



CO2 Geological Capacity Estimation

Closed Boundary, 16 Extractors

EASiToolGUI

Main Interface

GCCC GULF COAST CARBON CENTER

BUREAU OF ECONOMIC GEOLOGY JACKSON SCHOOL OF GEOSCIENCES

1-RESERVOIR PARAMETERS

	Min	Ma	
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Rock Compressibility [1/Pa]	5e-10	3.5e-10	6.5e-10
Reservoir Area [km ²]	100		
Basin Area [km ²]	100		
Boundary Condition	Clos...		

2-RELATIVE PERMEABILITY (Brooks-Corey)

Residual Water Saturation	0.5	0.3	0.7
Residual Gas Saturation	0.05	0	0.1
m	3	2	4
n	3	2	4
Kra0	1	1	1
Krg0	0.3	0.20	0.4

3-SIMULATION PARAMETERS

Simulation Time [years]

Injection Well Radius [m]

Max Injection Pressure [MPa]

Estimate Max Injection Pressure Internally

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Total Stress Ratio (V/H)

Biot Coefficient

Poisson's ratio

Coefficient of Thermal Expansion [1/K]

Bottom Hole Temperature Drop [K]

Young's Modulus [GPa]

Depth [m]

Estimated Max Injection Pressure [MPa]

Max Injection Rate [ton/day/well]

Max Number of Injectors

Sensitivity Analysis (Slow)

4-NPV

Drilling Cost [\$M/well]

Operation Cost [\$K/well/year]

Monitoring Cost [\$K/year/km²]

Tax Credit [\$/ton]

Extractors Drilling Cost [\$M/well]

Extractors Operation Cost [\$K/well/year]

5-EXTRACTION PARAMETERS

Number of Extractors

Minimum Extraction Pressure [MPa]

Maximum Extraction Rate [m³/day/well]

Run

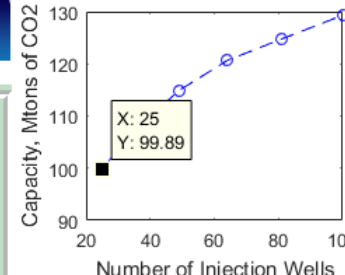
Simulation Time [sec]= 103.

6-RESULT CONTROLS

Number of Injection Wells

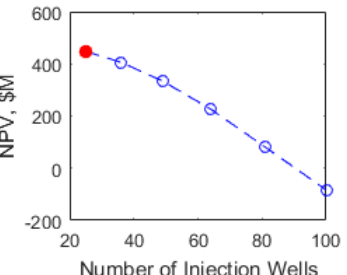
Export Image and Output Files (Slow)

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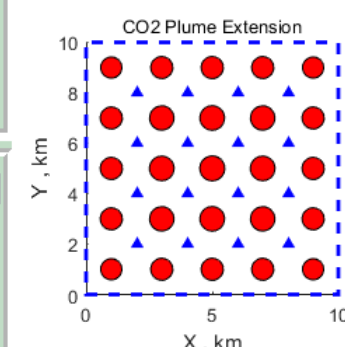
Capacity, Mtons of CO₂

Number of Injection Wells



NPV, \$M

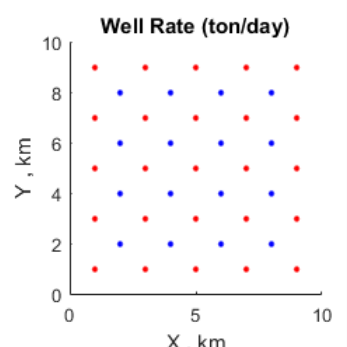
Number of Injection Wells



CO₂ Plume Extension

Y, km

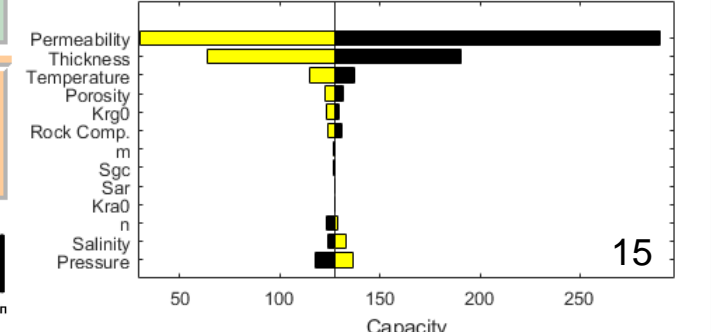
X, km



Well Rate (ton/day)

Y, km

X, km



Permeability Thickness

Temperature

Porosity

Krg0

Rock Comp.

m

Sgc

Sar

Kra0


n

Salinity

Pressure

Capacity


15






EASiTool
CO₂ Geological Capacity Estimation

Closed Boundary, 16 Extractors

EASiToolGUI




GULF COAST CARBON CENTER

BUREAU OF ECONOMIC GEOLOGY


1-RESERVOIR PARAMETERS

	Min	Ma	
Pressure [MPa]	20	15	25
Temperature [C]	65	50	80
Thickness [m]	100	50	150
Salinity [mol/Kg]	2	1	3
Porosity	0.2	0.15	0.25
Permeability [mD]	100	10	250
Rock Compressibility [1/Pa]	5e-10	3.5e-10	6.5e-10
Reservoir Area [km ²]	100		
Basin Area [km ²]	100		
Boundary Condition	Clos... ▾		

3-SIMULATION PARAMETERS

Simulation Time [years]

Injection Well Radius [m]

Max Injection Pressure [MPa]

Estimate Max Injection Pressure Internally

Density of Porous Media [Kg/m³]

Total Stress Ratio (V/H)

Biot Coefficient

Poisson's ratio

Coefficient of Thermal Expansion [1/K]

Bottom Hole Temperature Drop [K]

Young's Modulus [GPa]

Depth [m]

Estimated Max Injection Pressure [MPa]

Max Injection Rate [ton/day/well]

Max Number of Injectors

Sensitivity Analysis (Slow)

4-NPV

Drilling Cost [\$M/well]

Operation Cost [\$K/well/year]

Monitoring Cost [\$K/year/km²]

Tax Credit [\$/ton]

Extractors Drilling Cost [\$M/well]

Extractors Operation Cost [\$K/well/year]

2-RELATIVE PERMEABILITY (Brooks-Corey)

Residual Water Saturation	0.5	0.3	0.7
Residual Gas Saturation	0.05	0	0.1
m	3	2	4
n	3	2	4
Kra0	1	1	1
Krg0	0.3	0.20	0.4

5-EXTRACTION PARAMETERS

Number of Extractors

Minimum Extraction Pressure [MPa]

Maximum Extraction Rate [m³/day/well]

Run

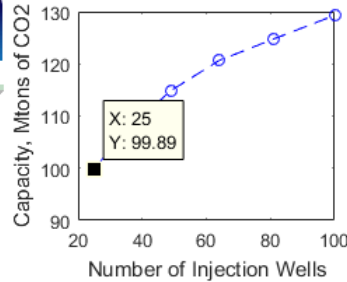
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6-RESULT CONTROLS

Number of Injection Wells

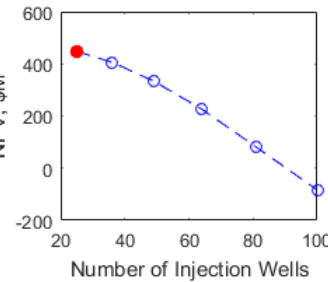
Export Image and Output Files (Slow)

Visit our website.



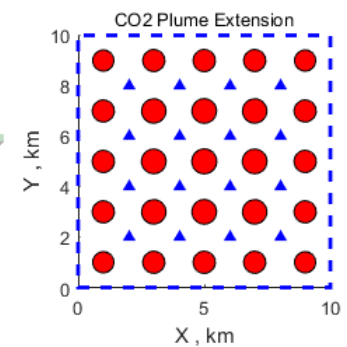
Capacity, Mtons of CO₂

Number of Injection Wells



NPV, \$M

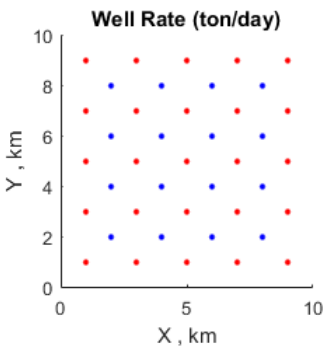
Number of Injection Wells



CO₂ Plume Extension

Y, km

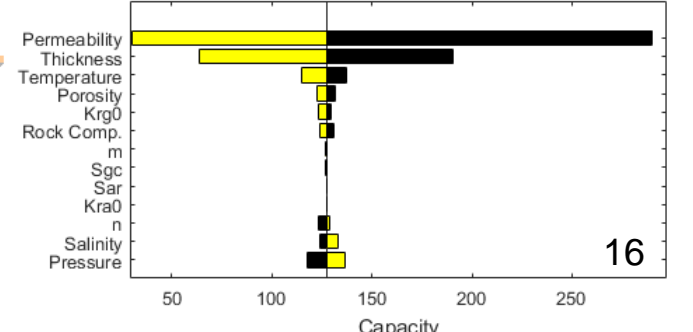
X, km



Well Rate (ton/day)


Y, km

X, km



Capacity

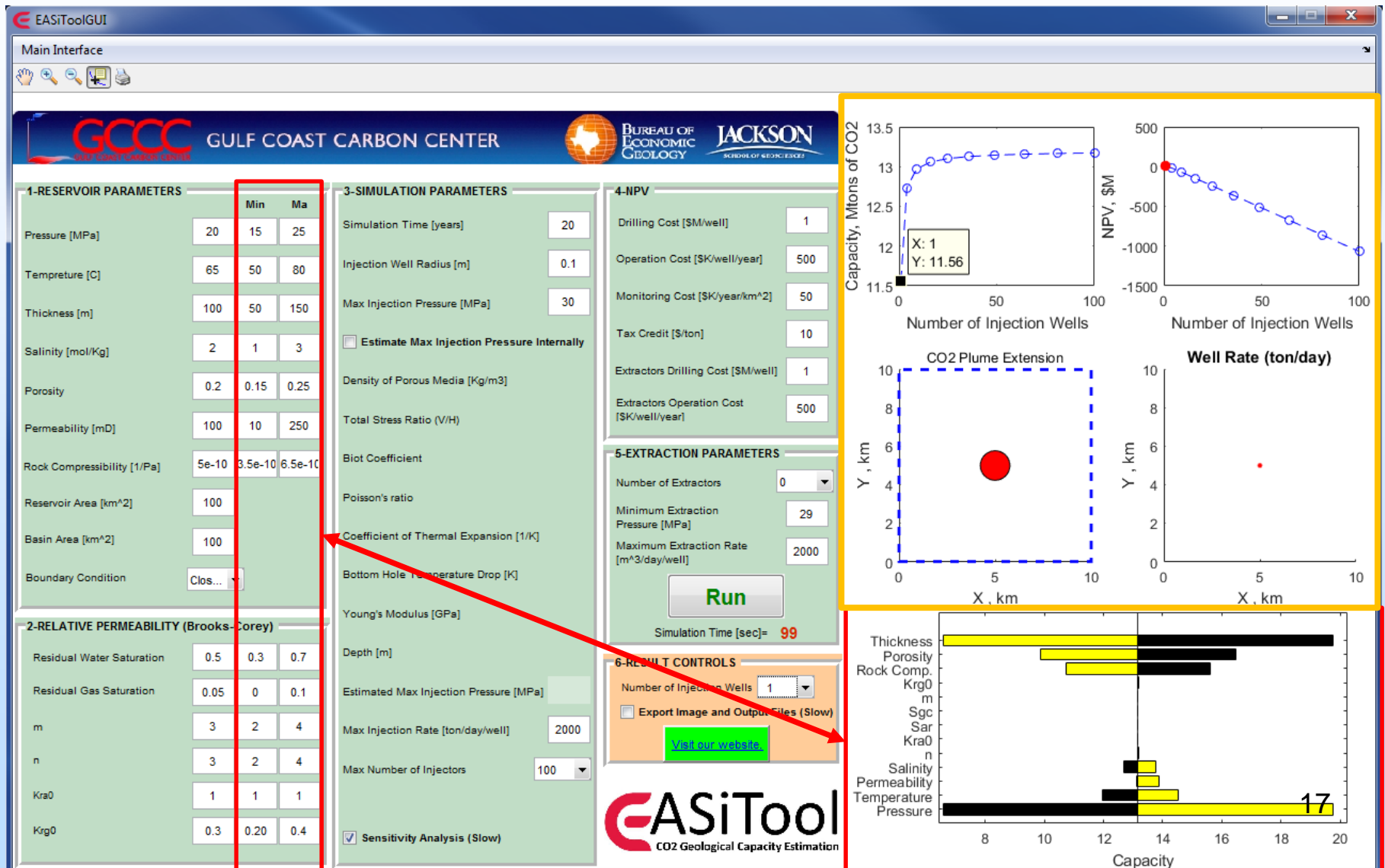
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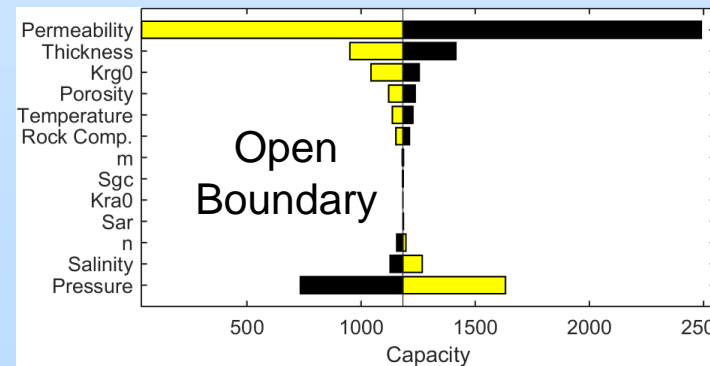
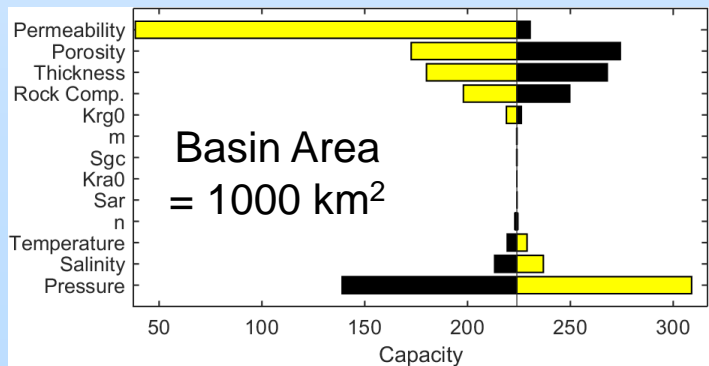
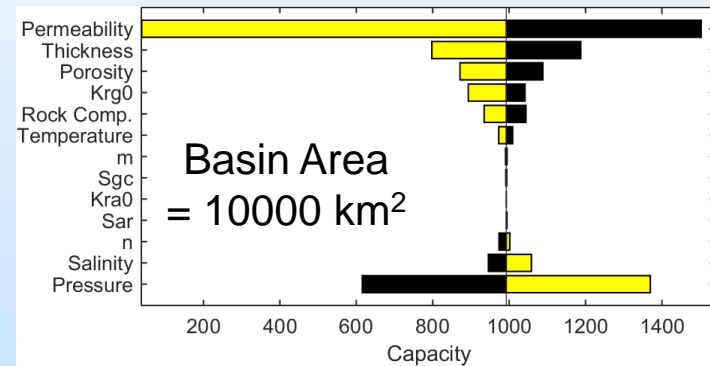
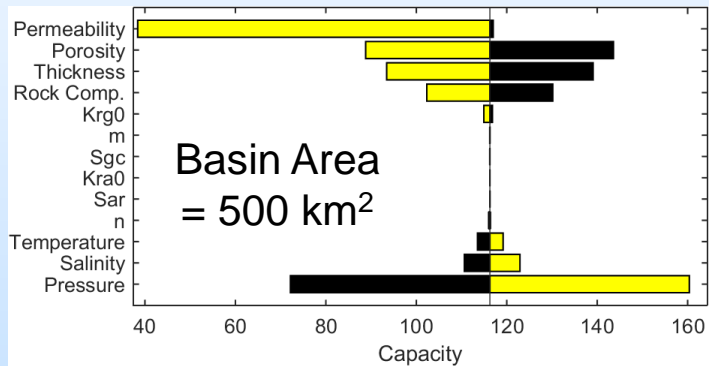
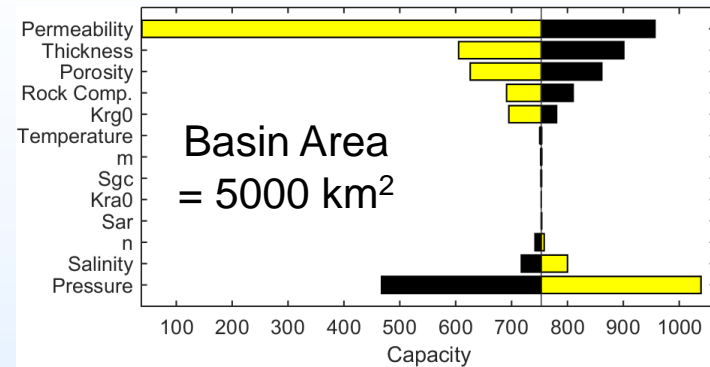
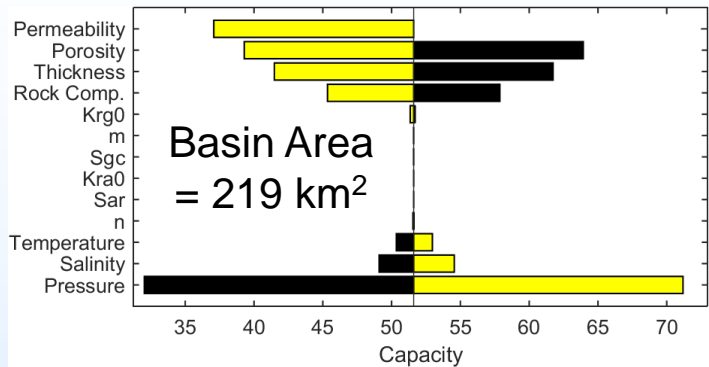
EASiTool

CO₂ Geological Capacity Estimation

Sensitivity Analysis



Reservoir Area = 219 km²



Synergy Opportunities

- EASiTool is an analytical simulation tool for capacity estimation in **saline** aquifers.
- Input data required for EASiTool is typically available for most of the projects.
- EASiTool results can be compared with the results obtain in other projects via other methods (static, simulation, etc).

Future Plans

- User defined locations for injection and extraction wells
 - Adding multiple reservoirs within the same basin
 - Pressure maps
- Improving the user interface
- Improving sensitivity analysis
- Application of to USGS database (36 Basins)
- Funding to maintain and further develop EASiTool

Summary

- Third version of EASiTool has been released.
- Calculations for maximum injection pressure.
 - Integrates thermal and pore pressure stresses.
- Brine extraction option.
- Constant rate injection option.
- Sensitivity analysis.
- EASiTool is available for download:
 - <http://www.beg.utexas.edu/gccc/EASiTool/>

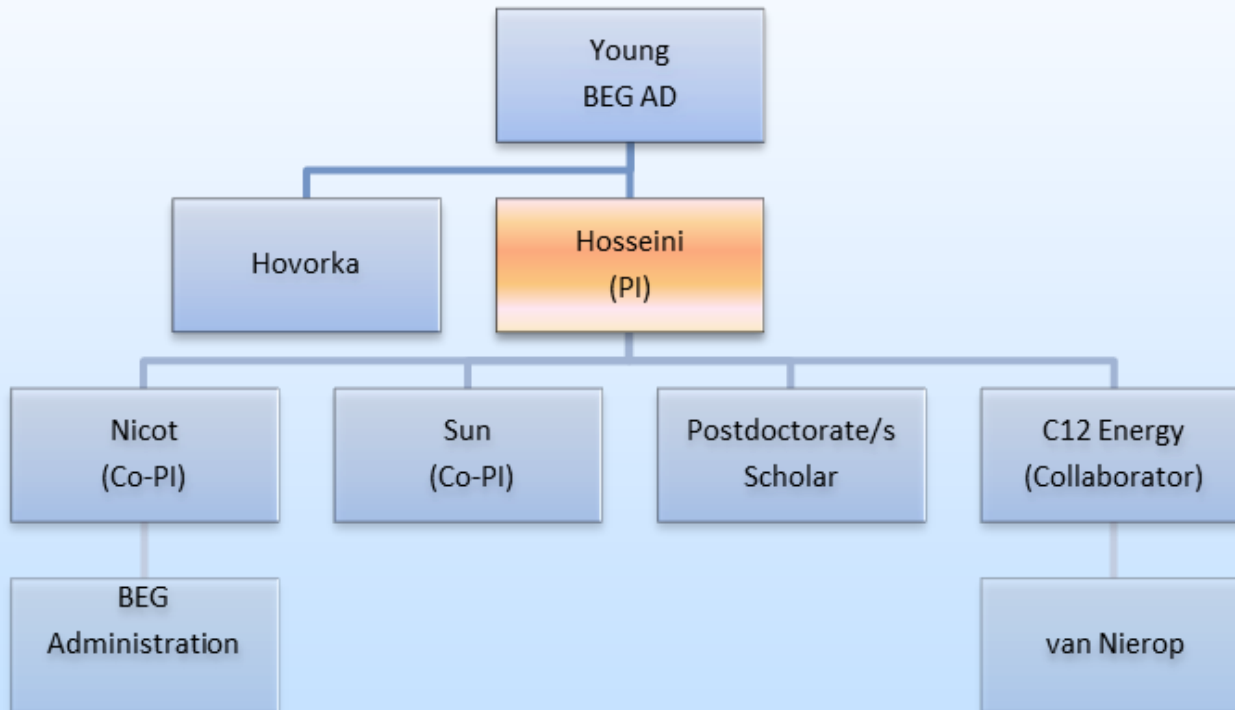
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» Questions/Comments

Appendix

- Organization Chart
- Gantt Chart
- Bibliography
- Extra Slides

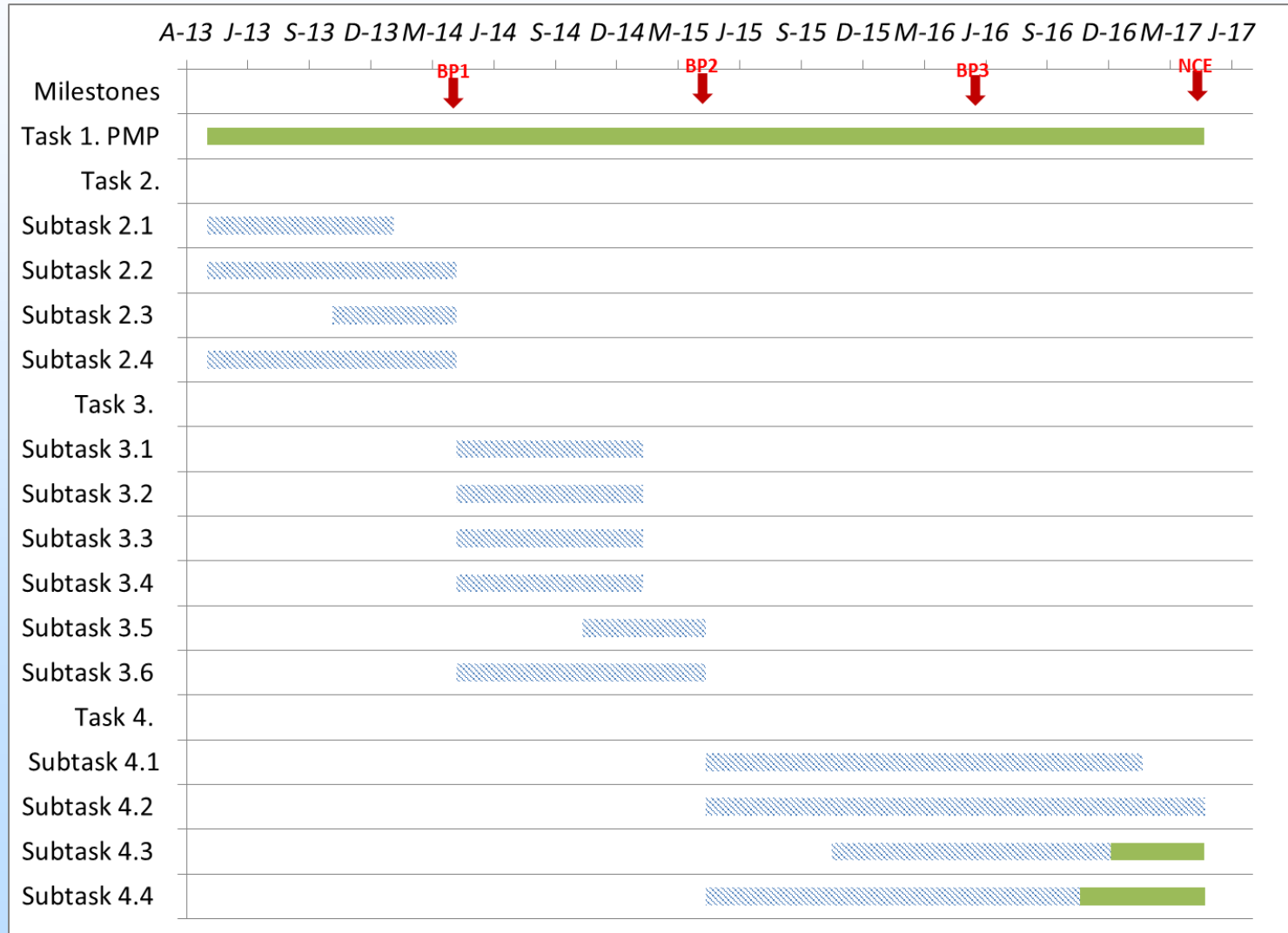
Organization Chart



Organization Chart

Project PI: Seyyed A. Hosseini			
Task 1 Project Management and Planning	Task 2 Development of Analytical Solutions for Pressure Buildup	Task 3 Rock Geomechanics Impact on Pressure Buildup and Capacity Estimation	Task 4 Brine-Management Impact on CO ₂ Injectivity and Storage Capacity
Task Leader/Backup Nicot/Hosseini	Task Leader/Backup Hosseini/Sun	Task Leader/Backup Hosseini/Sun	Task Leader/Backup Hosseini/Sun
Task 1 Team Nicot/Hosseini/ Young/Hovorka	Task 2 Team Subtask 2.1 Hosseini/Sun/ Postdoc/s Subtask 2.2 Hosseini/Sun/C12 Energy Subtask 2.3 Sun/Hosseini Subtask 2.4 Sun/Hosseini	Task 3 Team Subtask 3.1 Hosseini/Sun/ Postdoc/s Subtask 3.2 Hosseini/Sun/ Postdoc/s Subtask 3.3 Sun/Hosseini Subtask 3.4 Hosseini/Sun Subtask 3.5 Sun/Hosseini Subtask 3.6 Sun/Hosseini	Task 4 Team Subtask 4.1 Hosseini/Sun/ Postdoc/s Subtask 4.2 Sun/Hosseini/ Postdoc/s Subtask 4.3 Sun/Hosseini Subtask 4.4 Sun/Hosseini

Gantt Chart



Bibliography

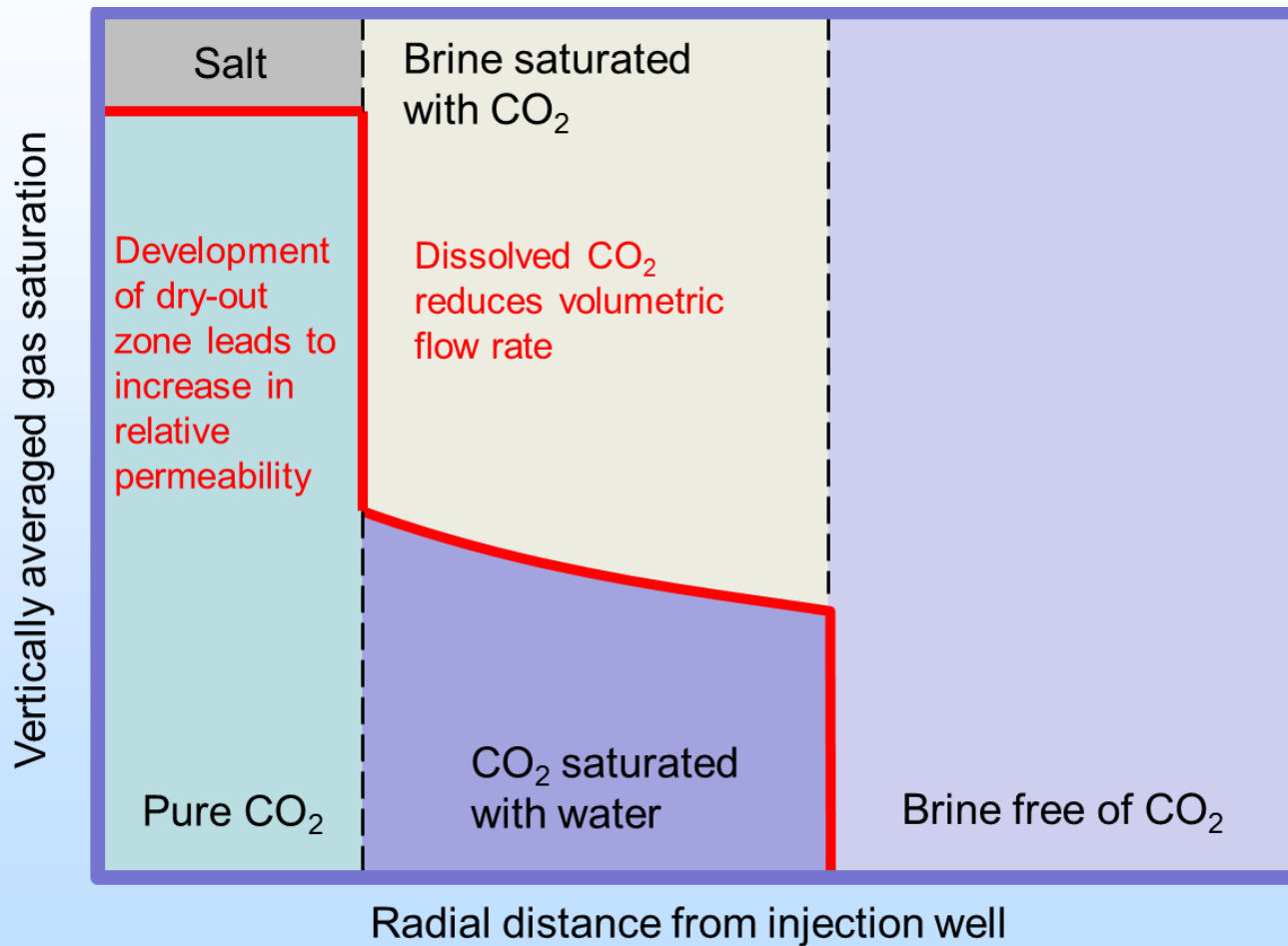
– Journals

- Kim, S., Hosseini, S.A, 2013, Above-zone pressure monitoring and geomechanical analyses for a field-scale CO₂ injection project in Cranfield, MS, Greenhouse Gases: Science and Technology, 4 (1), 81-98, DOI: 10.1002/ghg.1388

– Conferences

- Kim, Seunghee, Hosseini, S. A., and Hovorka, S. D., 2013, Numerical Simulation: Field Scale Fluid Injection to a Porous Layer in relevance to CO₂ Geological Storage: Proceedings of the 2013 COMSOL Conference, Boston, Massachusetts.
- Kim, Seunghee, Hosseini, S. A., 2014, Optimization of Injection Rates for Geological CO₂ Storage in Brine Formations, 13th Annual Conference on Carbon Capture Utilization & Storage.
- Kim, Seunghee, Hosseini, S. A., 2014, Effect of Pore Pressure/Stress Coupling on Geological CO₂ Storage, 13th Annual Conference on Carbon Capture Utilization & Storage. 27

Analytical model

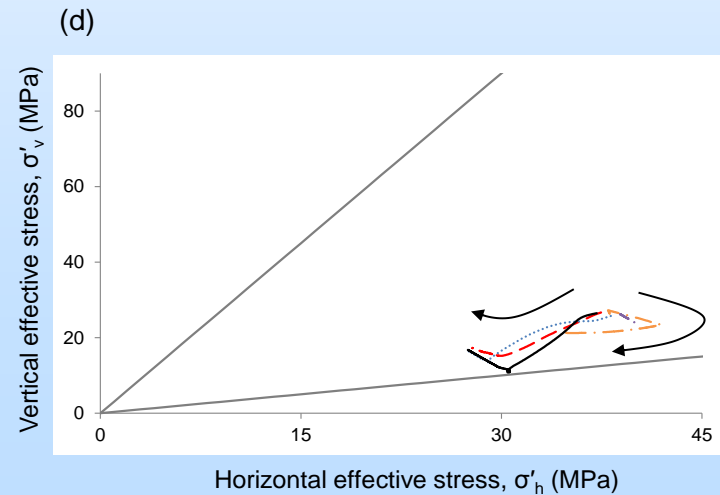
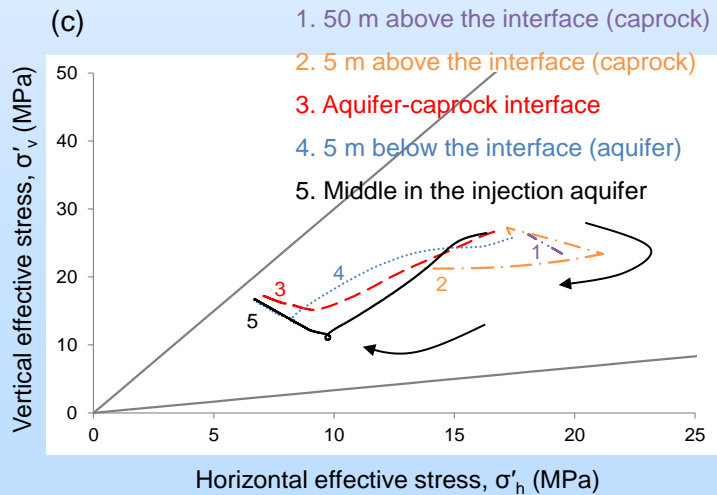
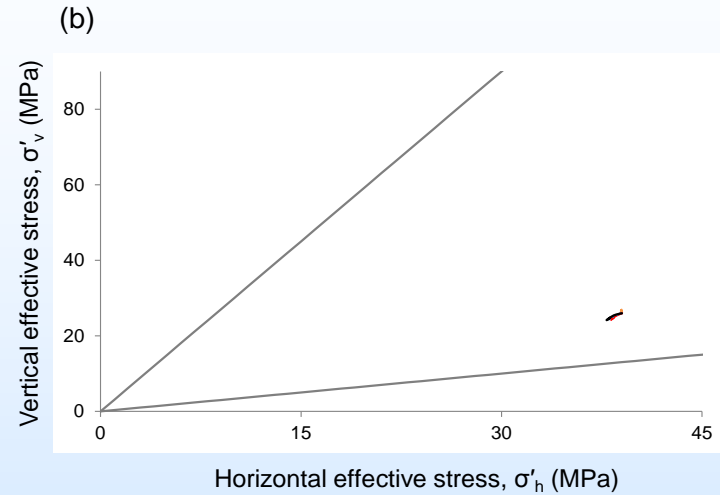
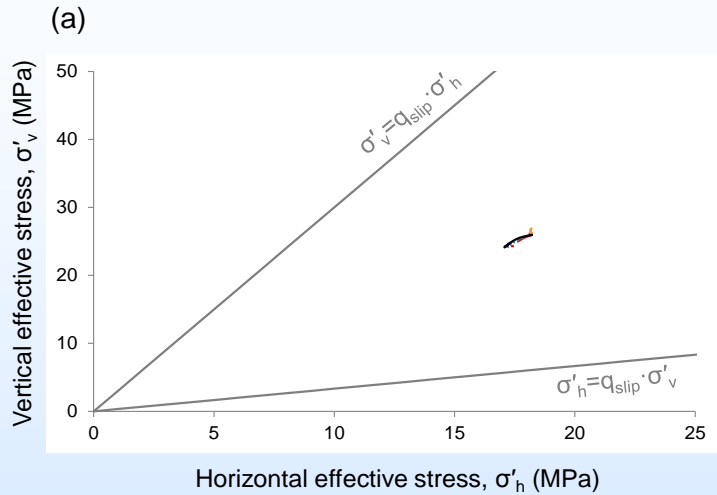


Accomplishments to Date

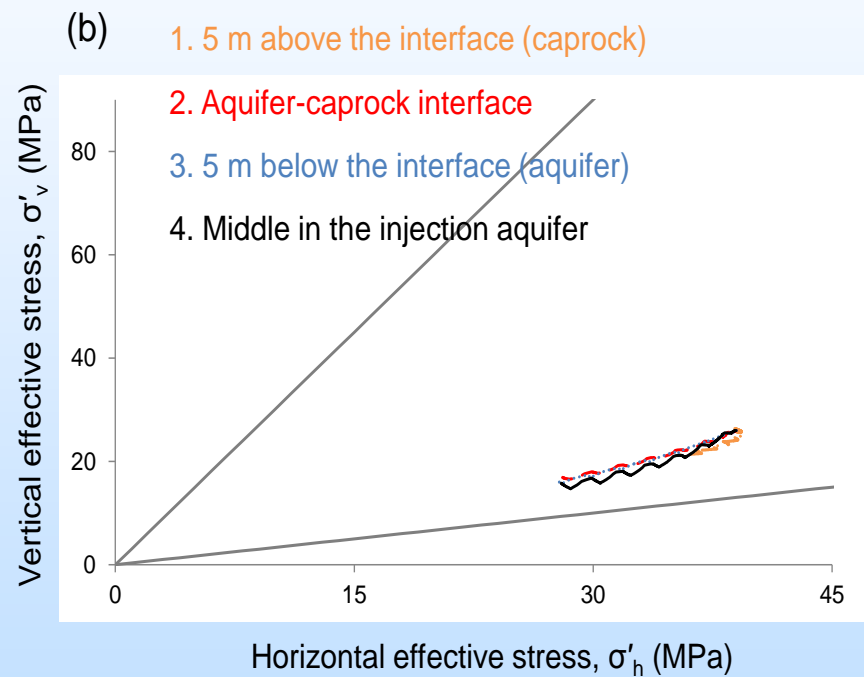
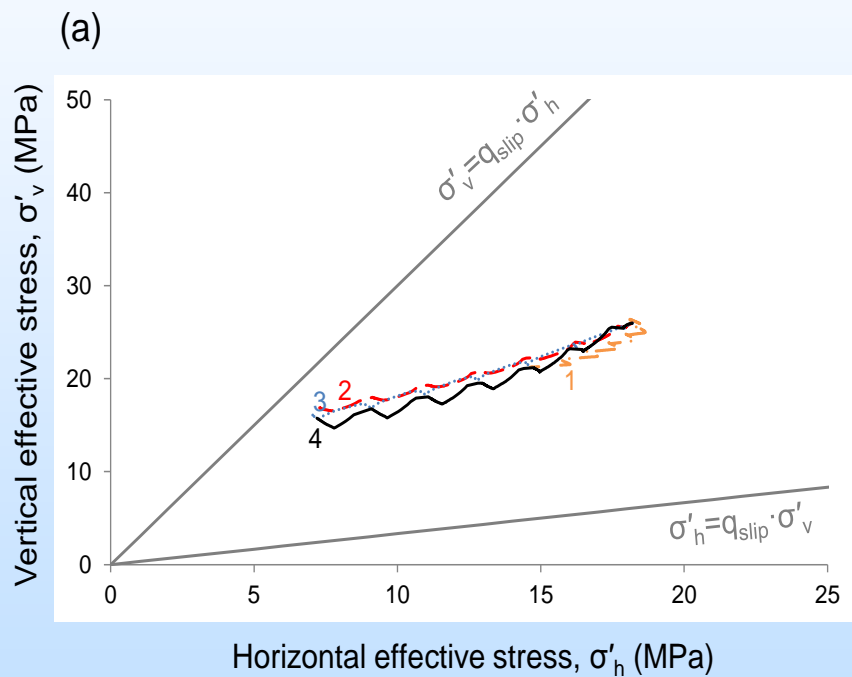
- Pore pressure stress coupling
 - Change in total stress ($\Delta\sigma$) is coupled with change in pore pressure (ΔP).
 - We define $\beta_h = \Delta\sigma_h / \Delta P$ and $\beta_v = \Delta\sigma_v / \Delta P$ & typically $\beta_h > \beta_v$
- Thermal stress
 - Injected CO_2 is generally colder than formation brine.
 - shrinkage of the rock formation (specially near the injection well) by $\sigma^{\Delta T} = 2\alpha_T E \Delta T / (1 - 2\nu)$
- Mohr-Coulomb shear failure criterion

$$\tau = c + (\sigma_n - \alpha \cdot P_{max}) \mu$$

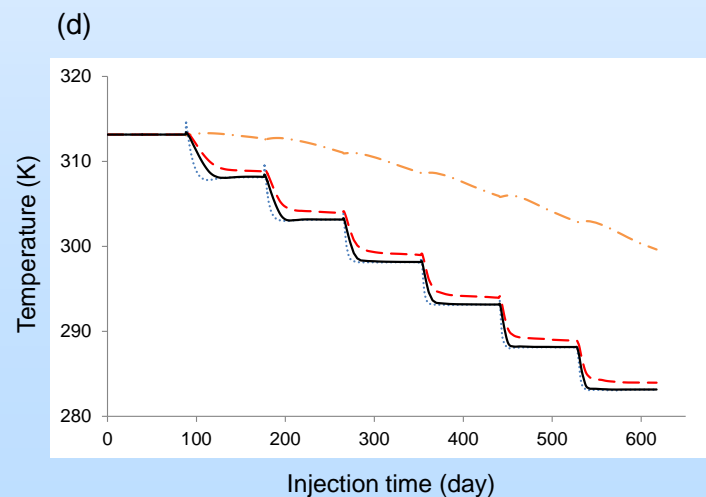
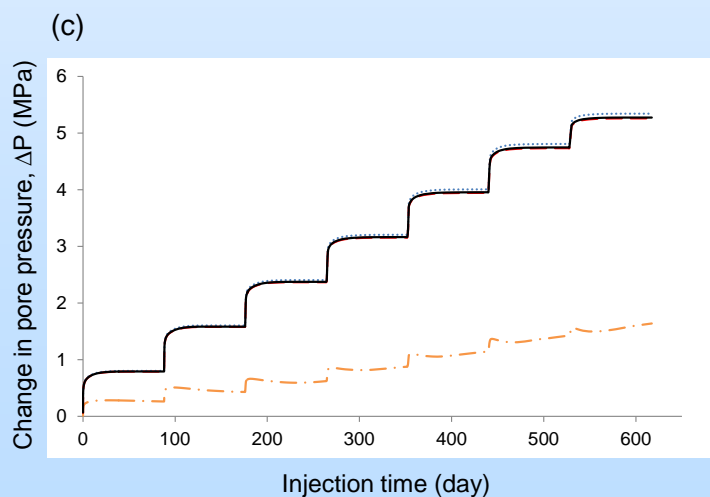
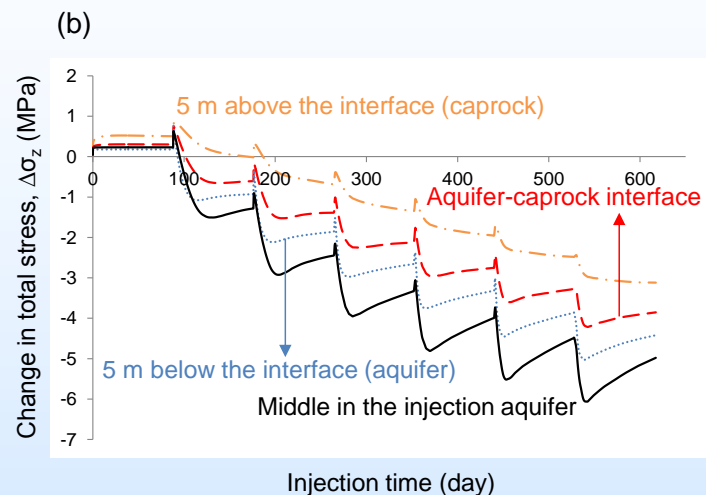
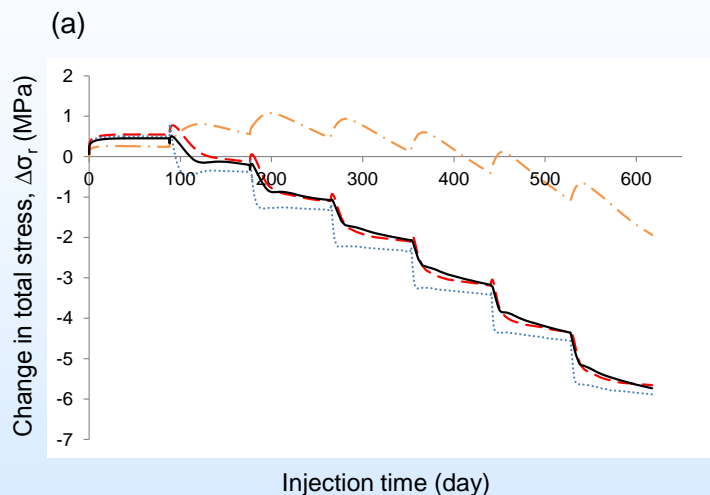
Accomplishments to Date



Accomplishments to Date-10



Accomplishments to Date-9



Verification of EASiTool Models

