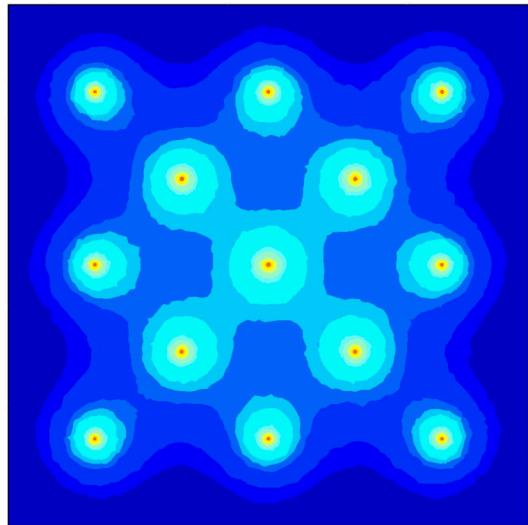


The Impact of Geologic Heterogeneity on CO₂ Injection with Simultaneous Brine Extraction and Economic Uncertainty for Large-Scale CO₂ Sequestration



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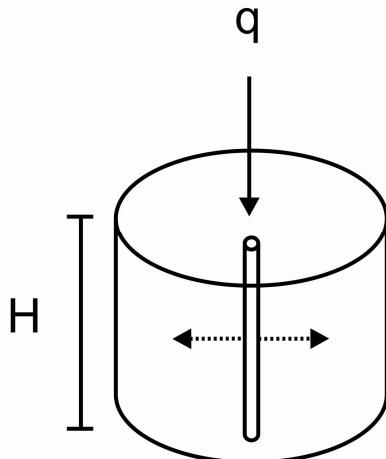
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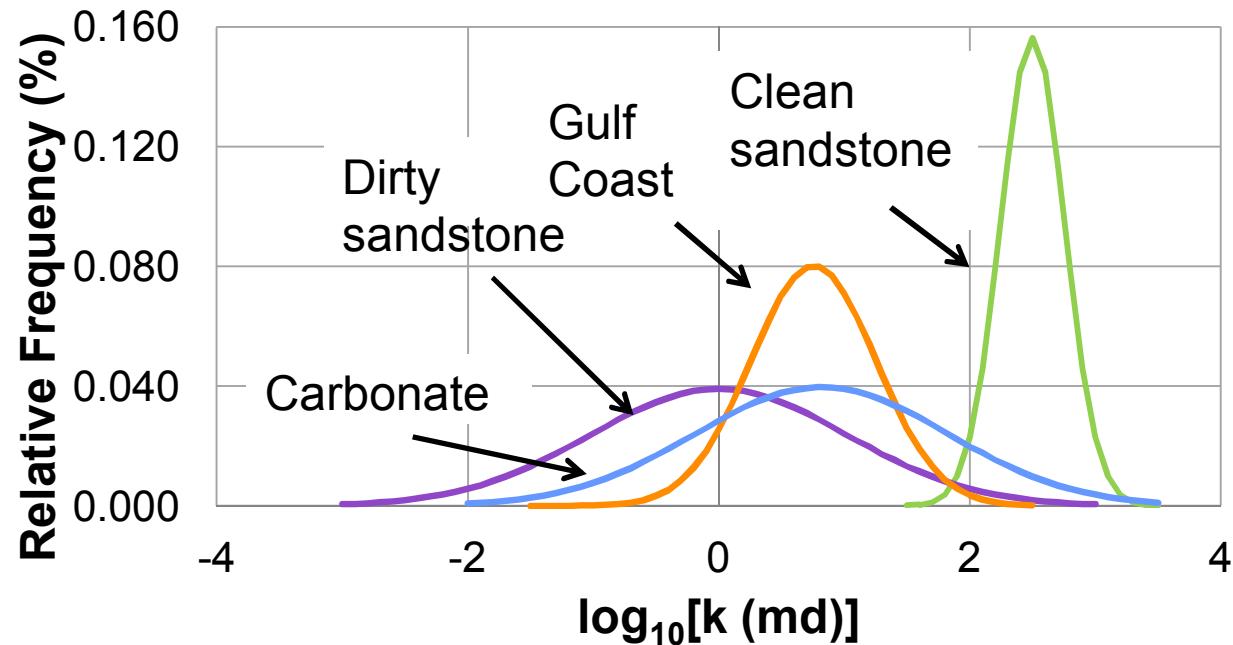
CO₂ Injectivity and Large Scale Economic and Storage Assessment

$$I \equiv \frac{q}{\Delta P}$$



Reservoir volume

Radial flow from the well

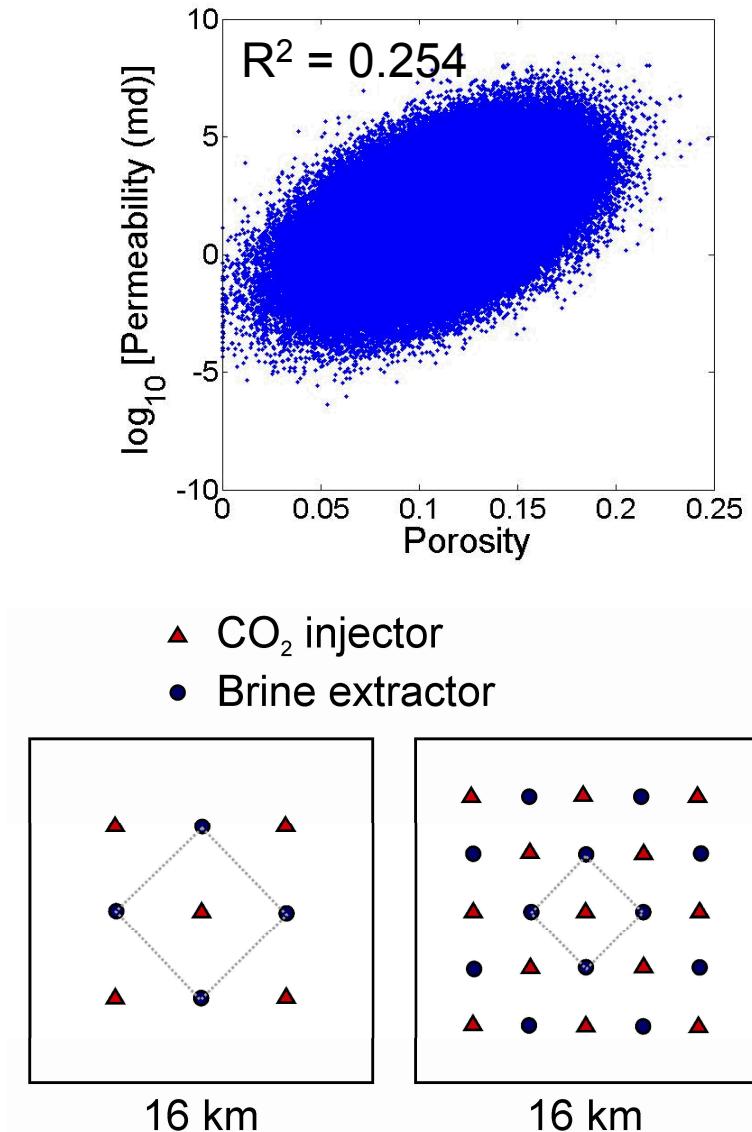


(Kobos et al., 2011)

Examples: Eccles et al., 2012; Keating et al., 2011; Cinar et al., 2008; Stauffer et al., 2009; Zakrisson et al., 2008; and many others

Digging into Common Assumptions

1. How does correlation between permeability and porosity affect injectivity?
2. How different in terms of injection rates are the homogeneous versus heterogeneous cases?
3. How does heterogeneity impact well numbers and associated costs?



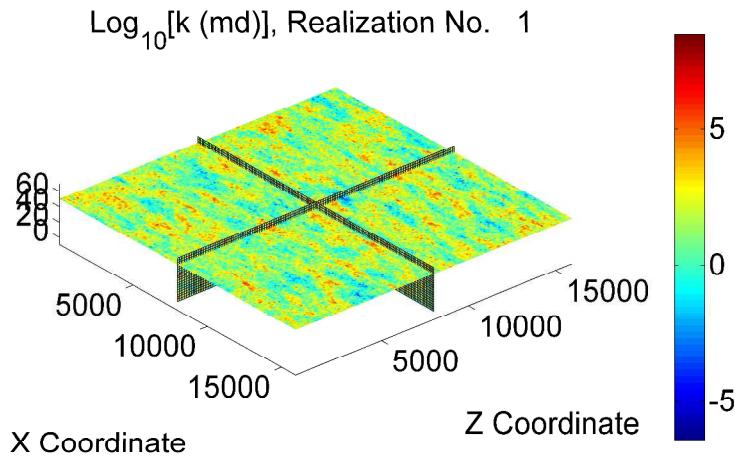
Methods

1. Geostatistics:

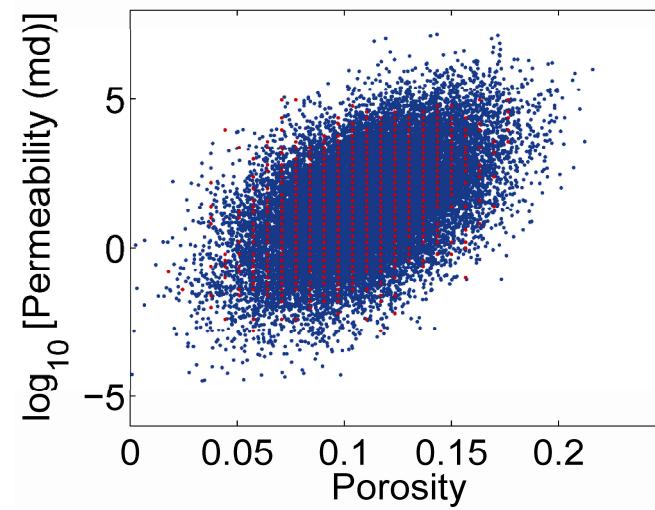
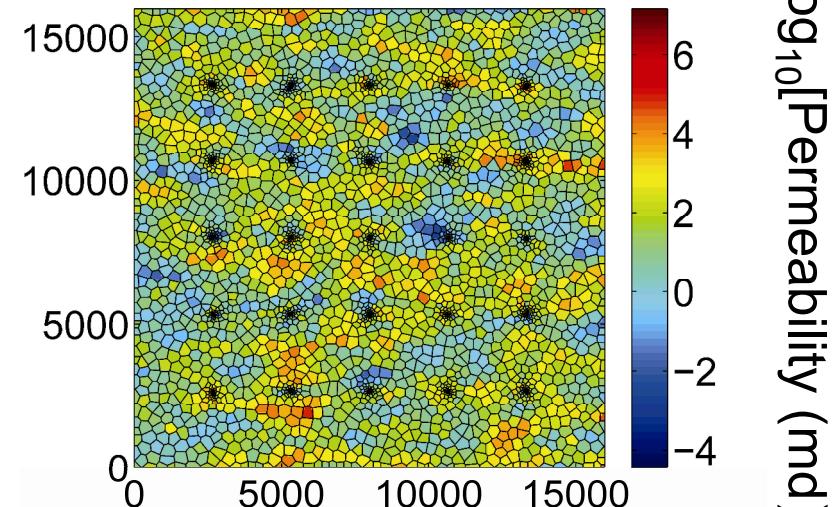
Coregionalization and SGSIM

(Rautman and McKenna, 1997;
Deutsch and Journel 1992)

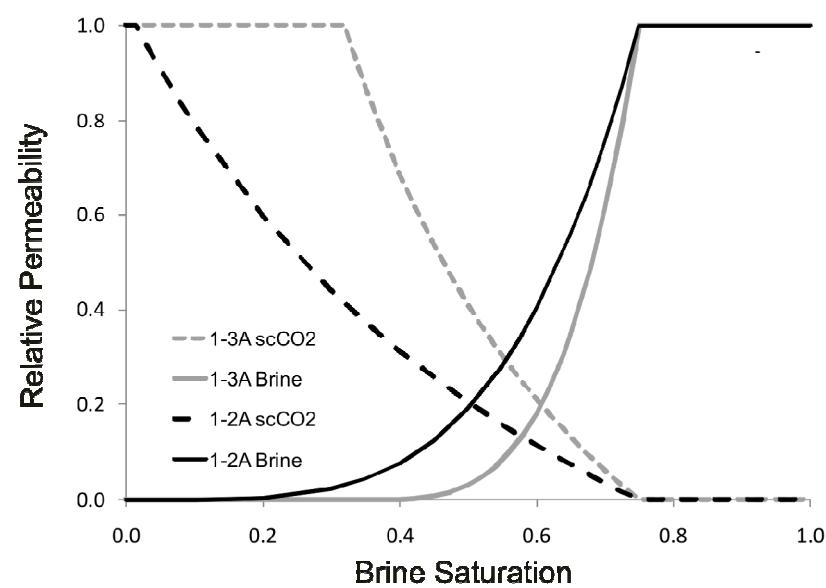
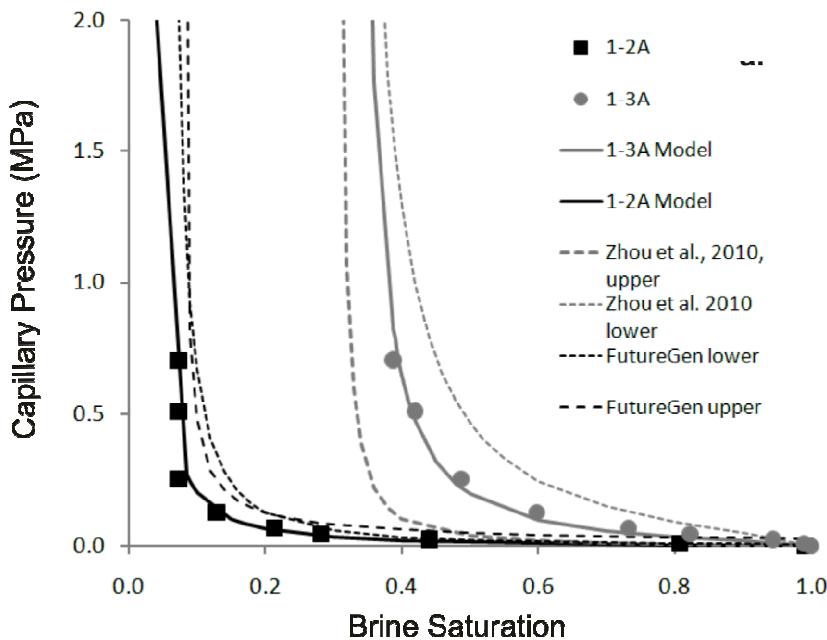
$$r^2 = \underline{0.25 \text{ or } 0.75}$$



2. Multiphase Flow: TOUGH2-ECO2N



Relative Permeability & Capillary Pressure

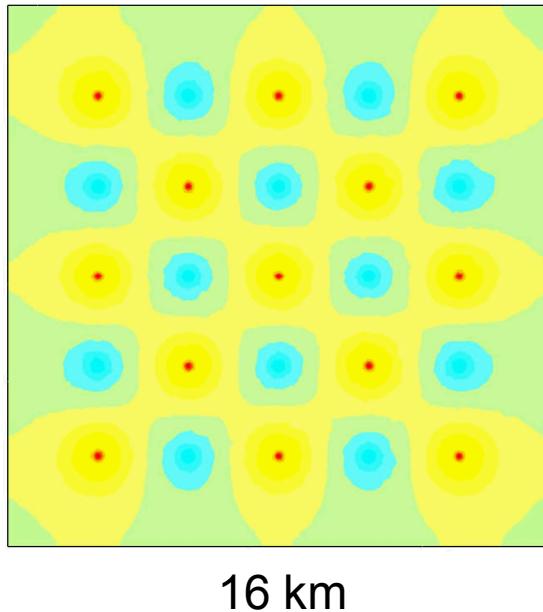


(Heath et al., 2012)

Methods: Base Cases

Time = 36 days

Injection and Extraction



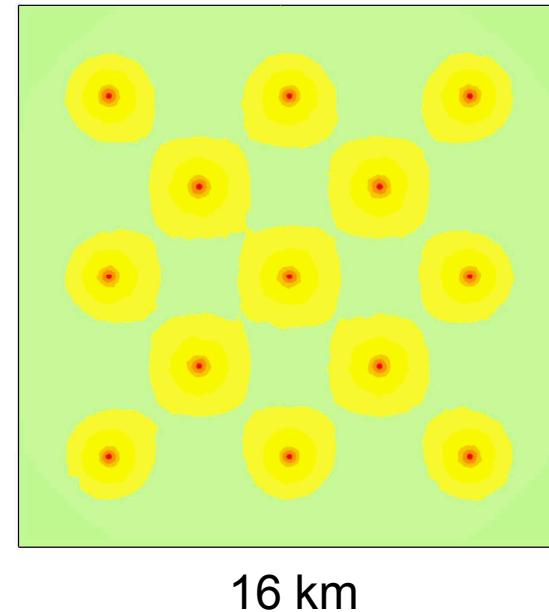
Press. (Mpa)

2.83e7

1.44e7

16 km

Injection only



16 km

- Permeability = 29.7 md; porosity = 11.1 % (Finley, 2005)
- CO₂ injection with or without brine extraction
- Maximize flow rates: constant pressure at wells
- Closed reservoir
- Homogenous and heterogeneous cases

Heterogeneous Example

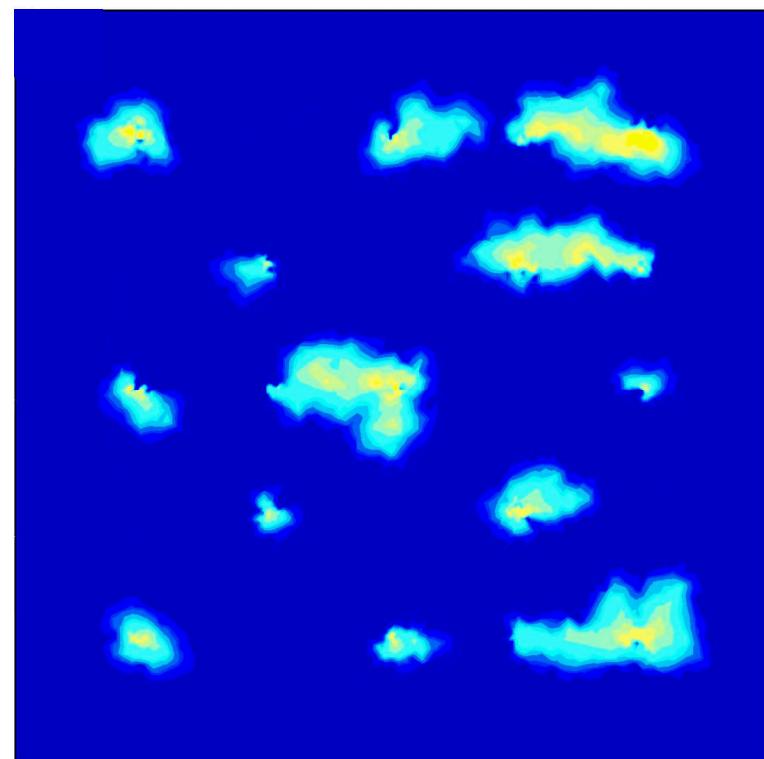
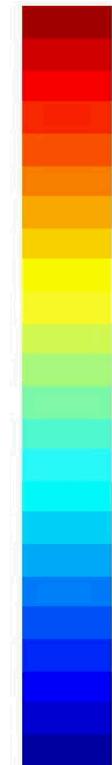
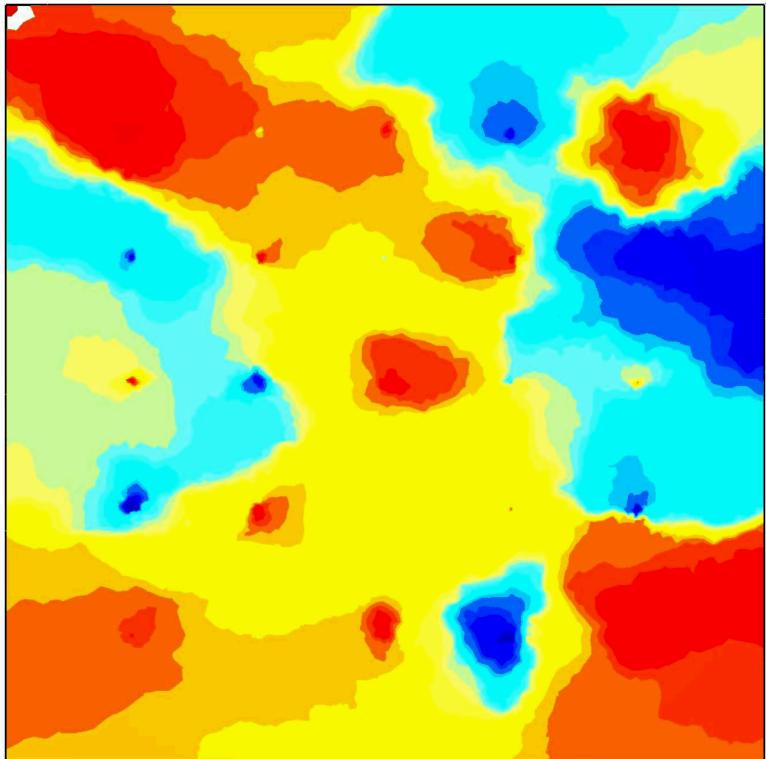
Time = 6 years

Press. (MPa)

2.83e7

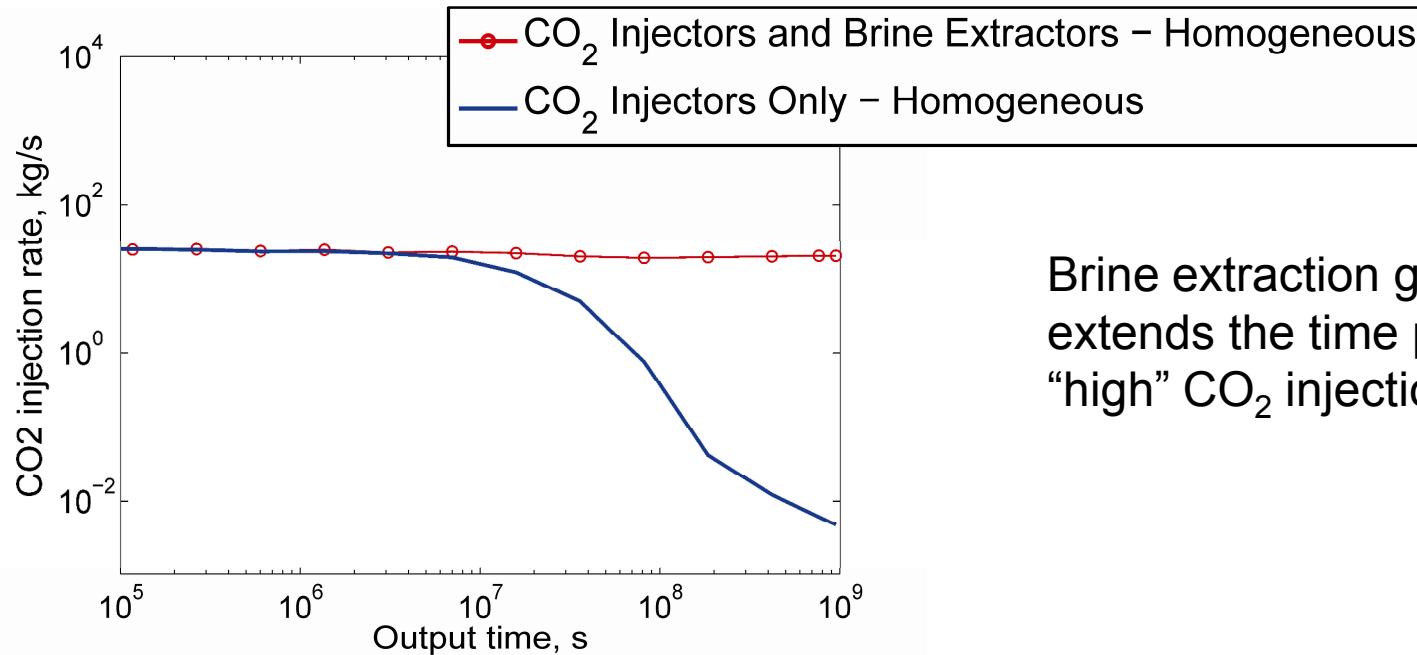
S_{CO_2}

1

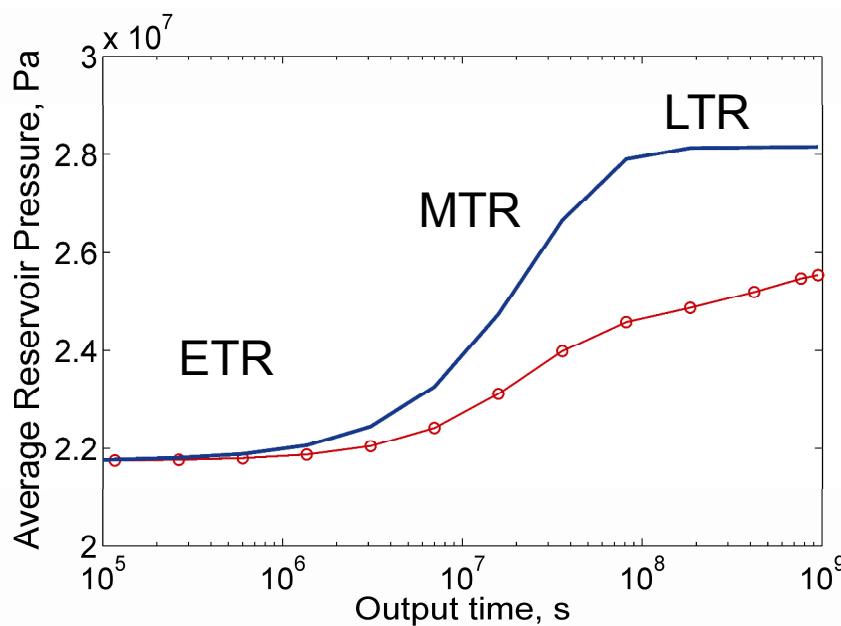


1.44e7

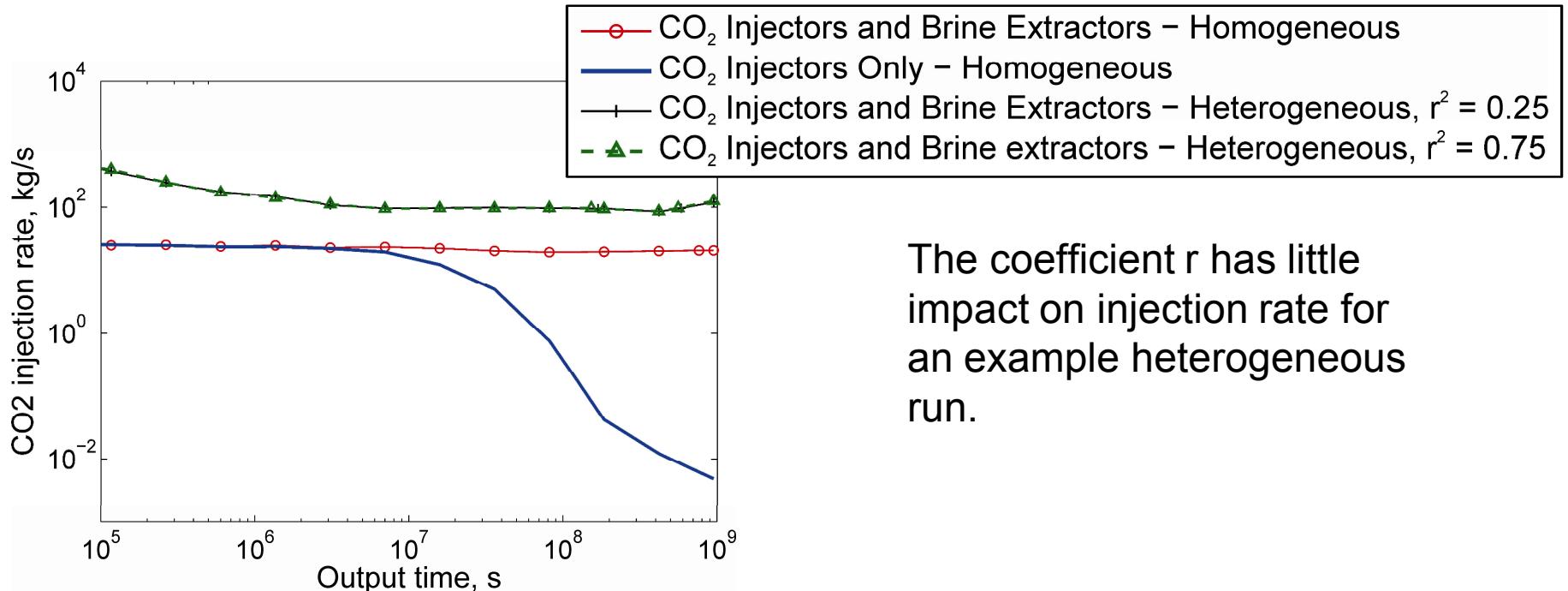
0



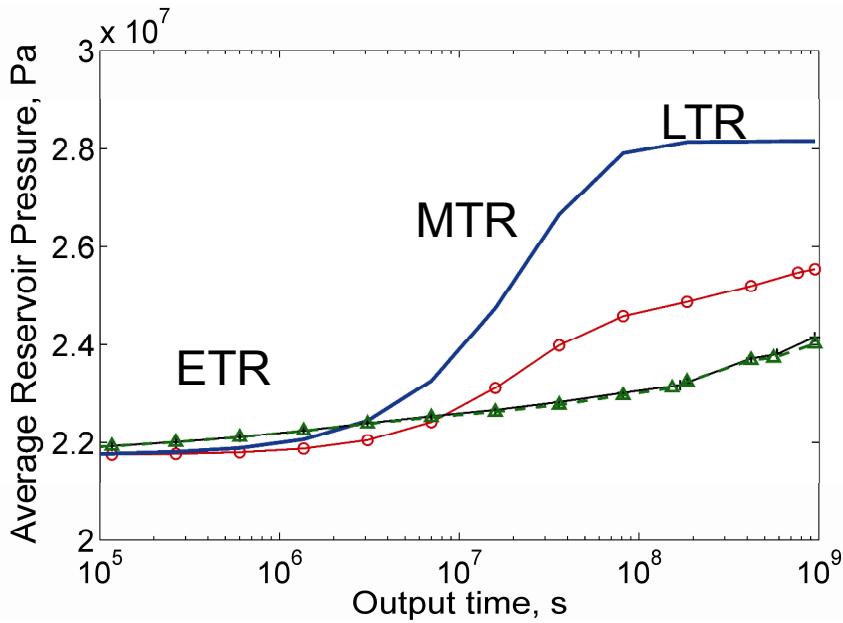
Brine extraction greatly extends the time period of “high” CO₂ injection rates.



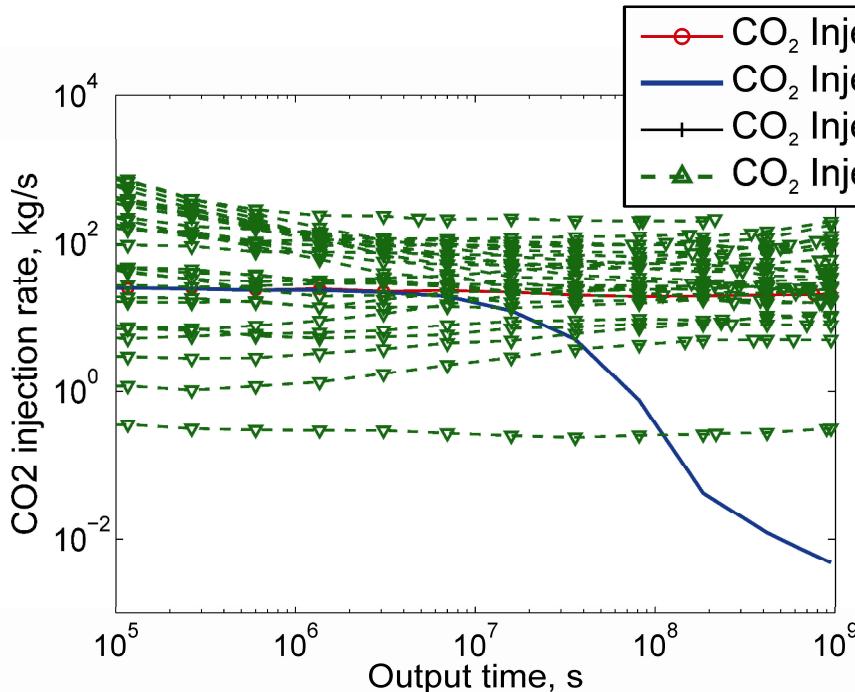
Clear early, middle, and late time regions occur during CO₂-only-homogeneous case



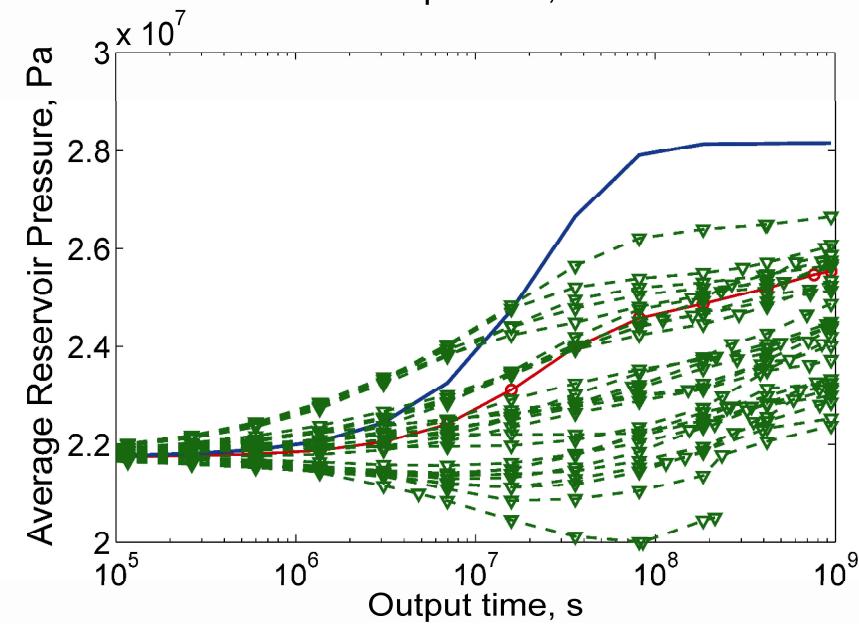
The coefficient r has little impact on injection rate for an example heterogeneous run.



The heterogeneous case differs in behavior from the injection-extraction homogeneous case.



The coefficient r has little impact on injection rate for an example heterogeneous run.



Heterogeneous cases display a range of behaviors.

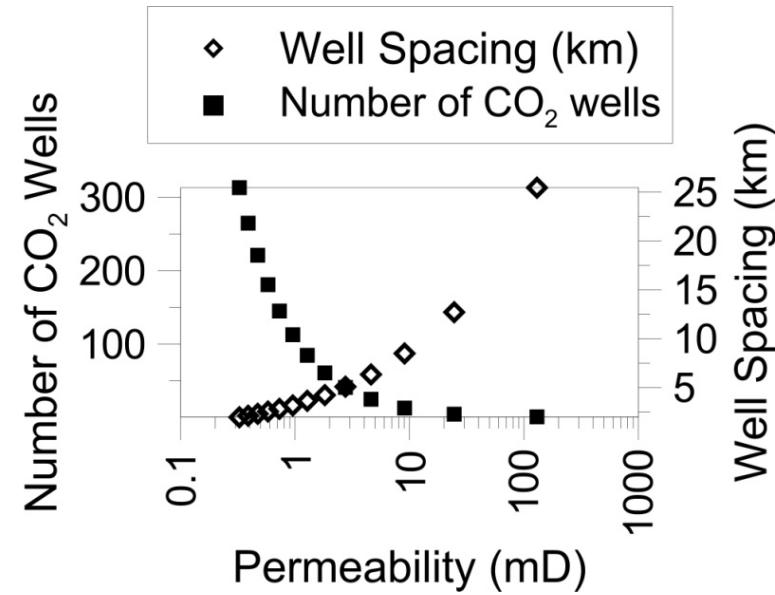
30 geostatistical realizations

Conclusions

Brine extraction greatly extends the time period of high injectivity in closed reservoirs

Brine extraction, however, may be limited by breakthrough for higher permeability cases

Heterogeneity provides a mix of high and low injectivity wells, thus making simple analytical solutions difficult



Ongoing Work

Investigating impact of permeability-porosity coefficient r on:

- Sweep efficiency
- Breakthrough
- Storage capacity (probably most import here?)

Acknowledgements

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