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Geologic Storage of CO_2 – Use of Computer Modeling

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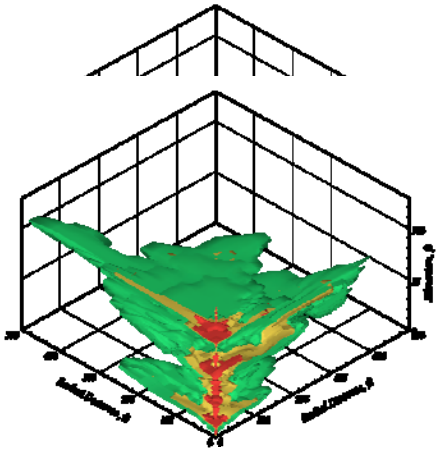
Use of CO_2 Flow and Transport Models

- Objective of this Presentation – Illustrate use of models for managing CO_2 Storage in Saline Reservoirs
- CO_2-EOR and ECBM not covered. Similar computational principles apply for these, but with additional processes
- Model uses include but are not limited to:
  - Evaluate subsurface processes – phase behavior, advection, density and viscosity effects, solubility, reactions, thermal effects, Geomechanical, etc.
  - Design of injection systems – well design, pressure profiles and fracture pressure limitations, zone of influence
  - Evaluate reservoir capacity and containment
  - Risk Assessment and Monitoring System Design
  - Mitigation if needed and site closure decisions

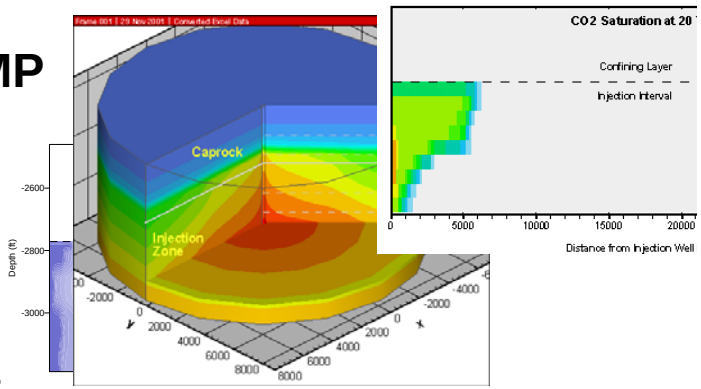
CO_2 Storage Modeling
Developing and Integrated Framework

- A number of modeling approaches have been used – analytical, semi-analytical, numerical with black oil or compositional codes.
- Field-scale projects will require sophisticated compositional models with some degree of coupling between flow, reactions, and other processes
- A number of research and commercial codes are being used, including national laboratory codes (e.g., TOUGH and STOMP families) and commercial codes (Eclipse, GEM, VIP etc).

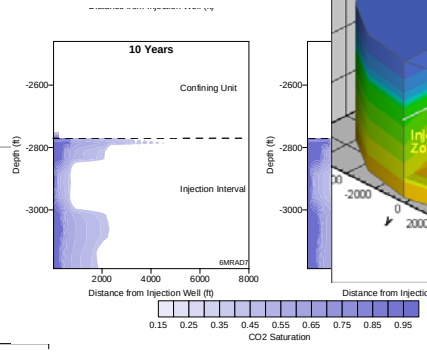
STOMPCO2



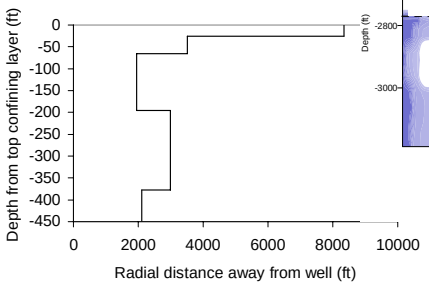
UTCOMP w/CO_2 Mod.



UTCOMP

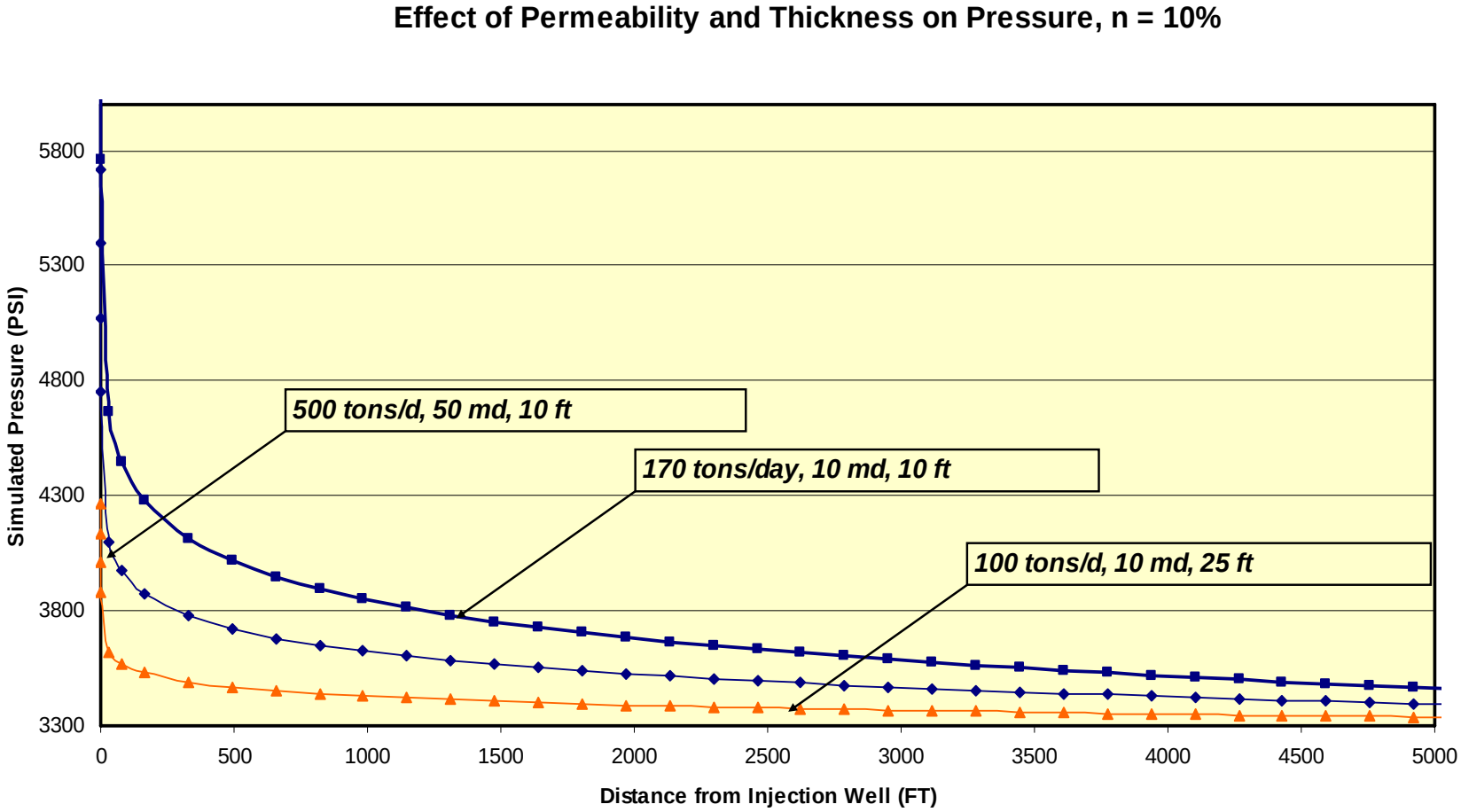


PNNLCARB



PNLCARB – A Semi-analytical Model Example

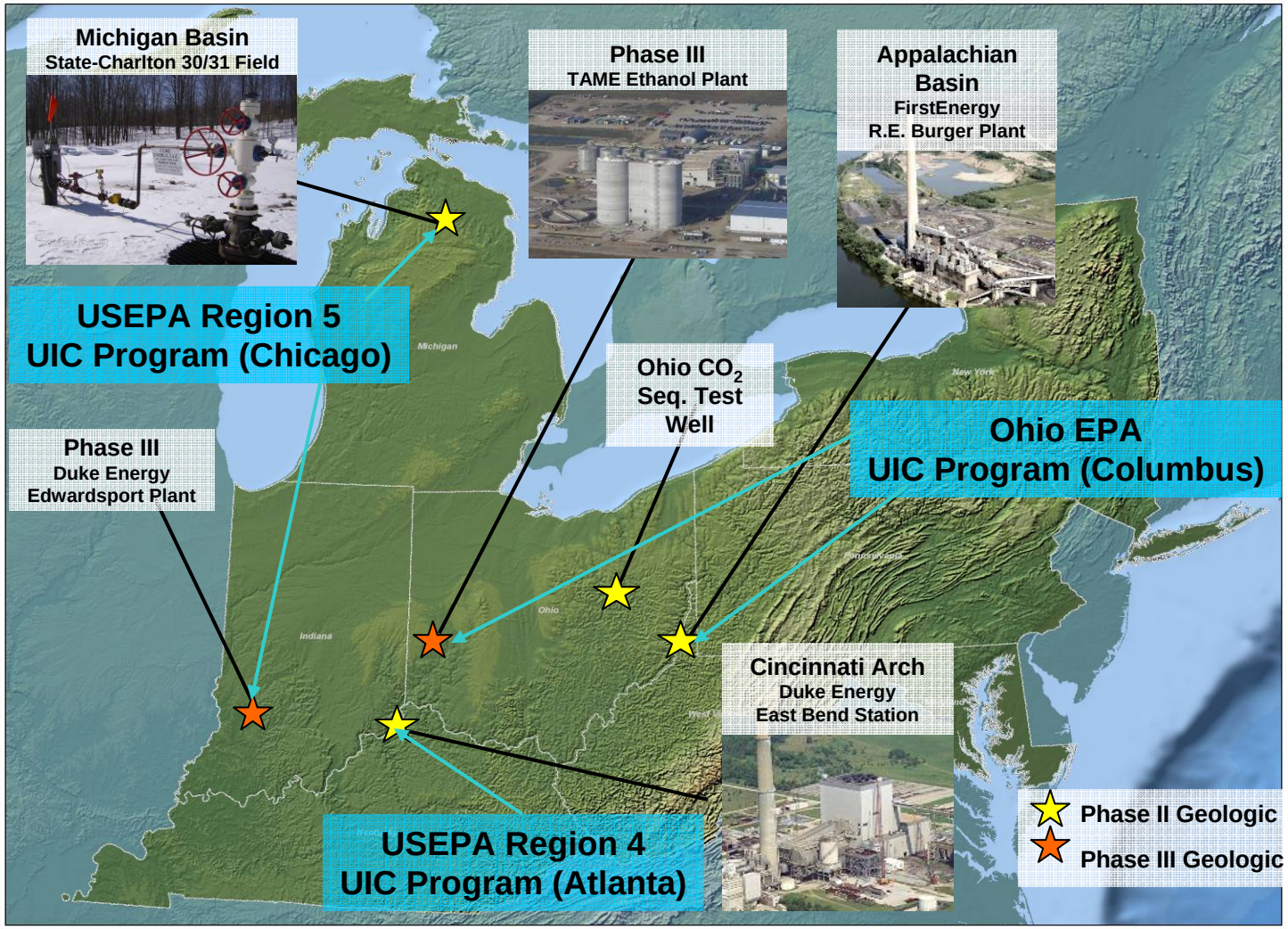
- A large number of scenarios can be evaluated quickly for sensitivity analysis, but there are many assumptions and simplifications



Comparing CO_2 Storage Models

- Many national laboratory and commercial codes have similar technical foundation
- Code comparison exercises have been conducted to evaluate code behavior for CO_2 storage.
  - Pruess et al (LBNL #51813, 2002) coordinated comparison of 8 problems with several codes and researchers and concluded that *"In general agreement between different simulators was satisfactory"* and the differences can be explained and understood.
  - Additional model comparison efforts are being conceived with field projects data

MRCSP Field Test Sites



At our Michigan site we completed injection of 10,000+ tonnes of CO_2 in March '08

5000 Foot Deep Test Well Drilled in November 2006

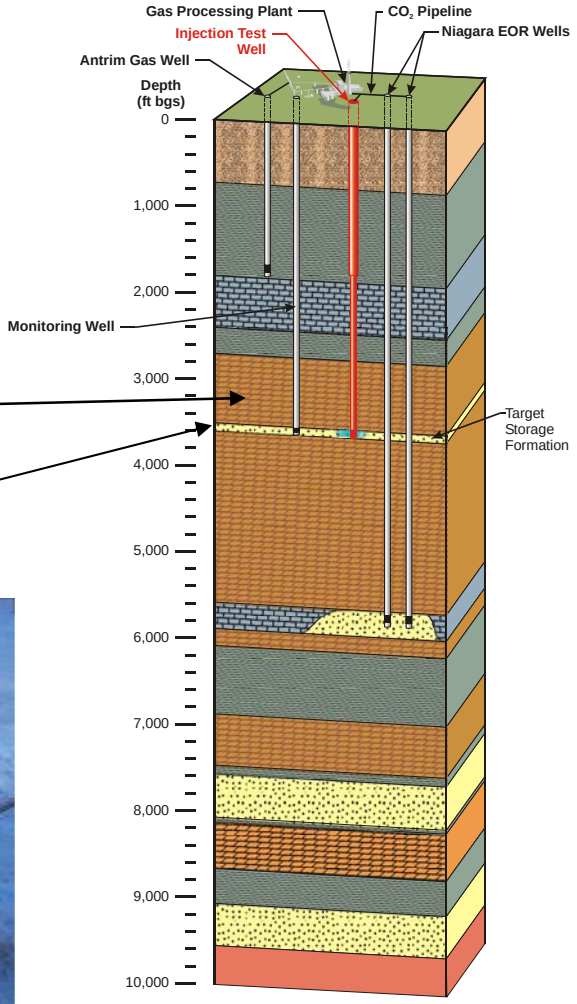
180 feet of core taken

Injection Operations

Starting Injection

Confining Layer:
Amherstburg Limestone

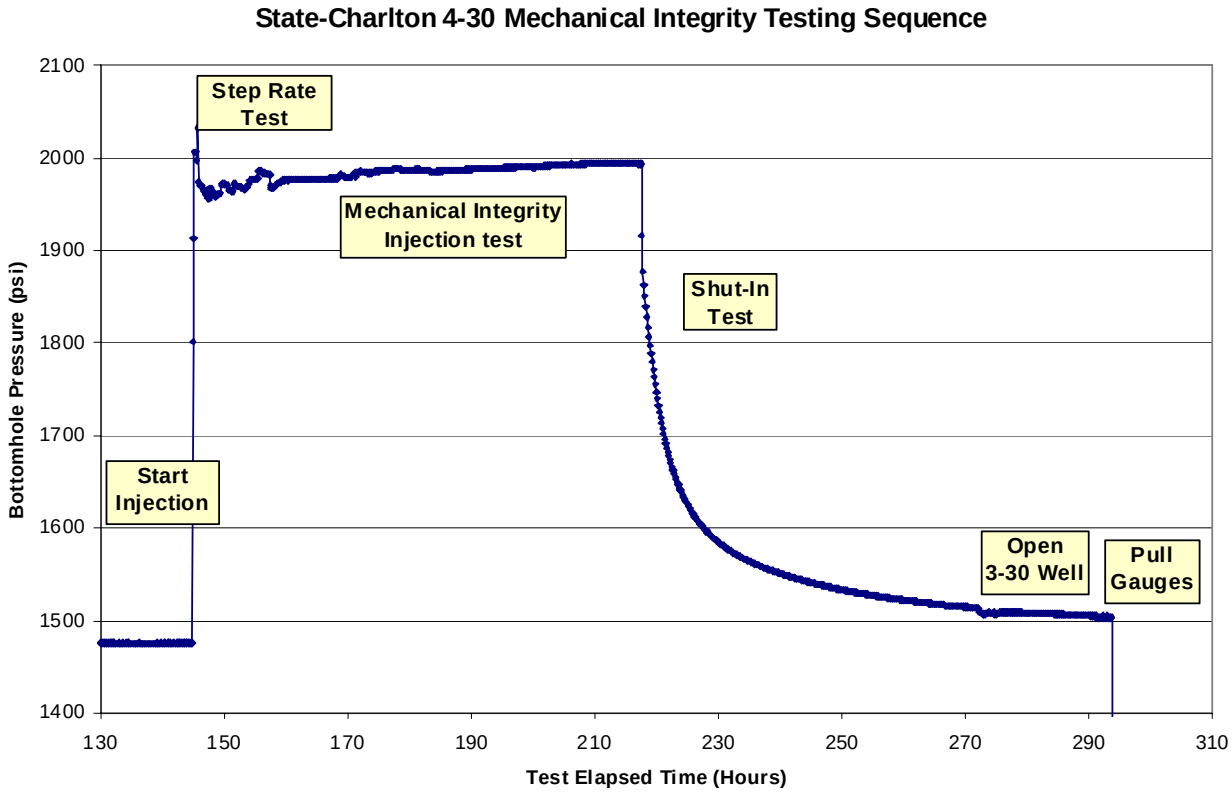
Injection Target:
Bass Islands Dolomite



Well Column

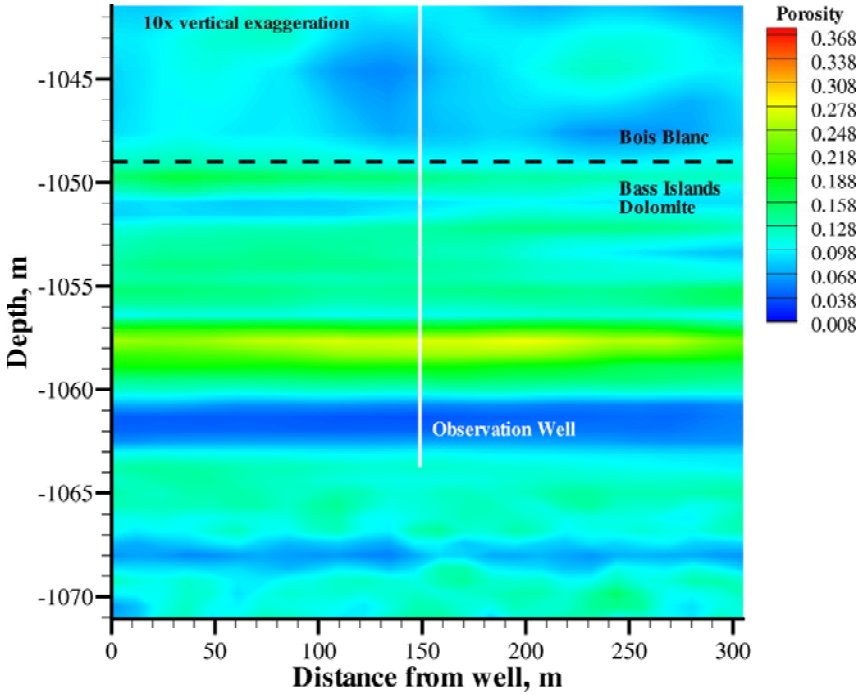
CO_2 Mechanical Integrity Testing – Example from MRCSP MI Site

- Initial step-rate test and shut-in test completed with CO_2 prior to sustained injection as part of UIC mechanical integrity testing, February 7-13, 2008.
- Testing provides data on hydraulic behavior of the reservoir system.

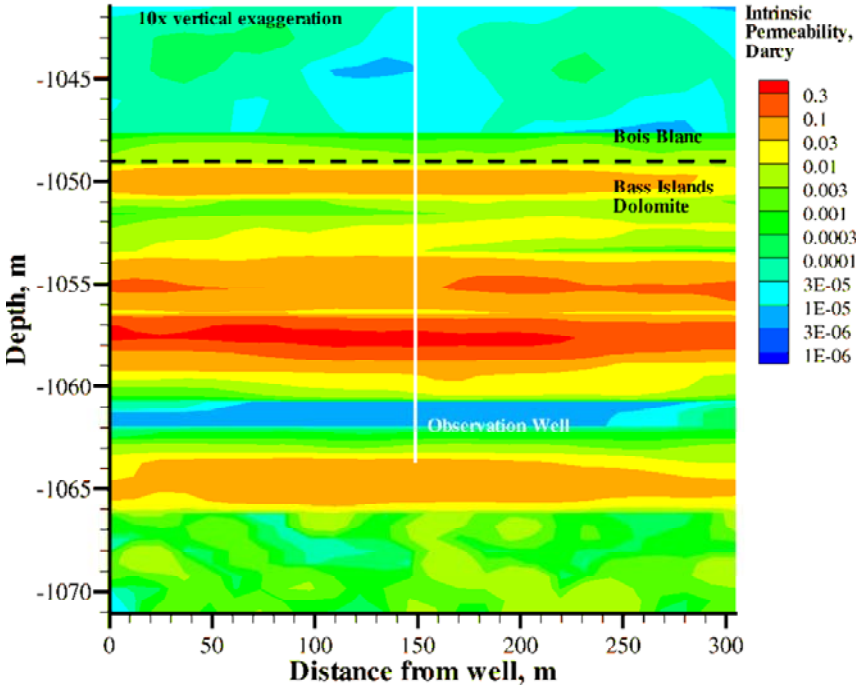


MRCSP Michigan Basin Model
Hydraulic Properties based on Well Logs

Porosity, %

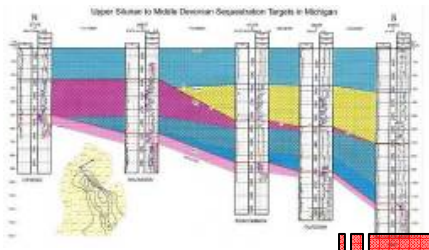


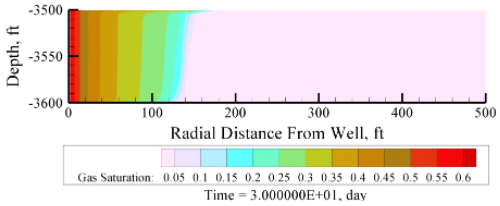
Permeability, Darcy



Example MRCSP Michigan Site – Model Evolution with Improved Site Data

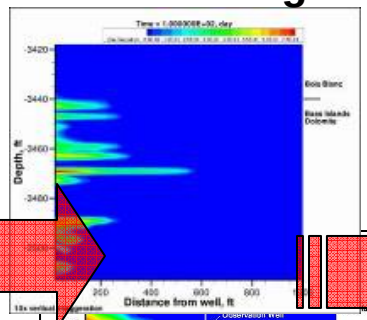
Preliminary Modeling Based on Regional Data

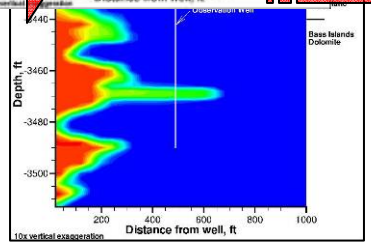




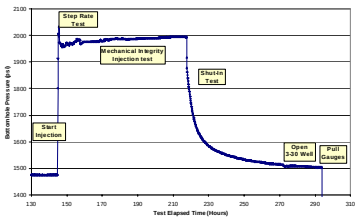
Site Drilling and Testing

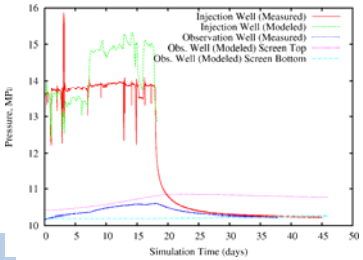
Site Specific Modeling





Post-Injection Calibration/Validation





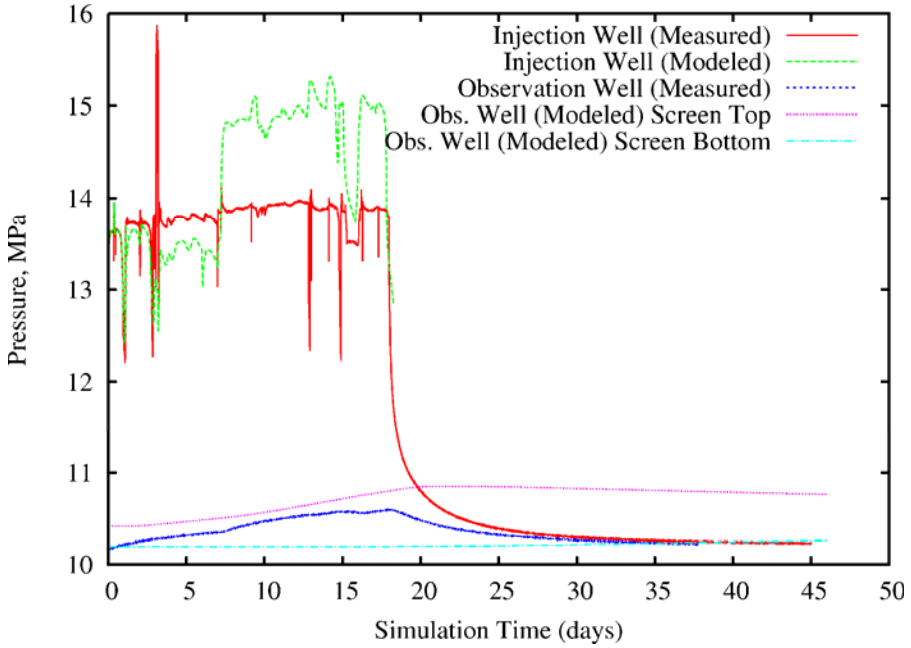
Conceptualize → Design → Calibrate →

Characterize → Monitor → Validate

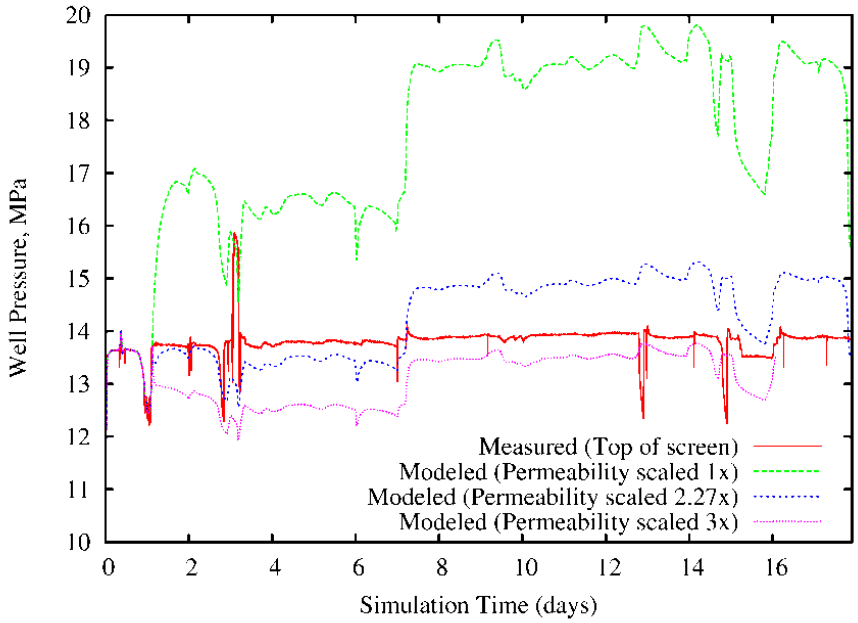
----------Communicate----------

Model Calibration

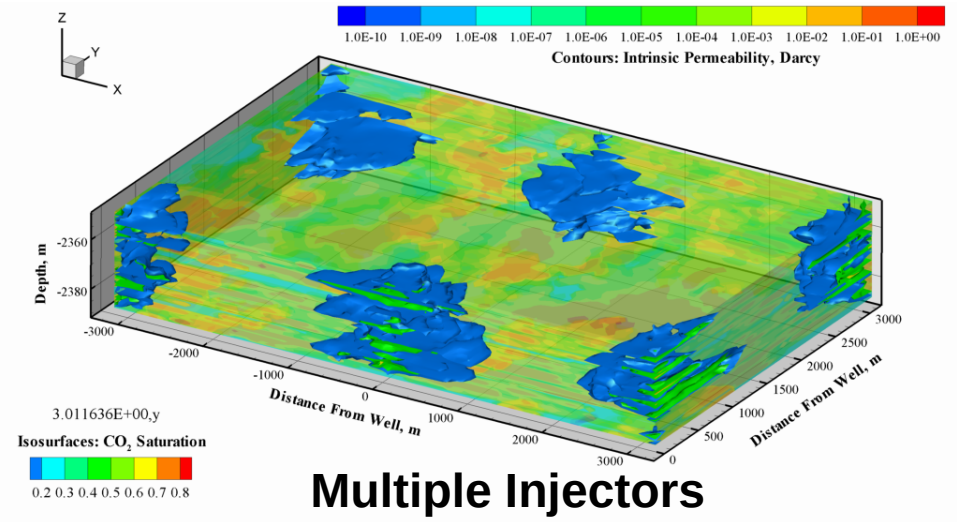
- STOMP-CO_2 Model was calibrated actual injection rates and downhole pressures.
- Results suggest somewhat higher reservoir permeability than initially input.
- Very good calibration to post injection fall-off in the injection well.
- Pressures declined faster than simulation in the monitoring well.



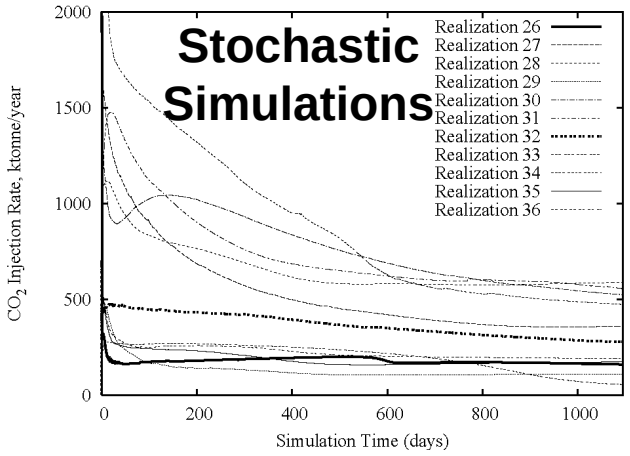
Sensitivity of model to permeability

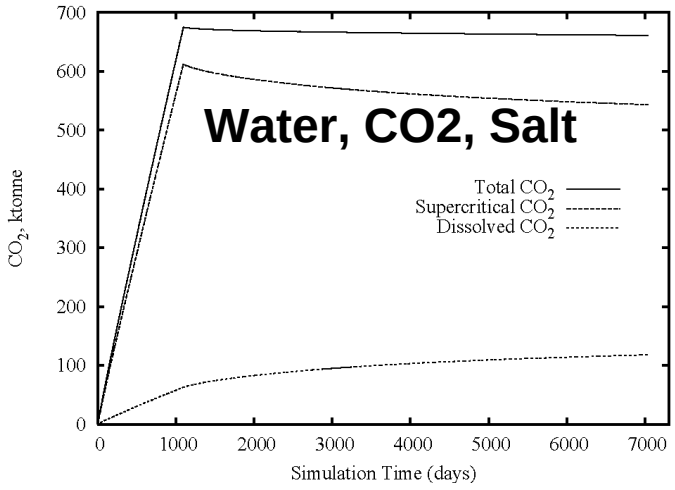


Advanced simulations for permitting, outreach, MMV, and facility design – Accounting for geologic uncertainty

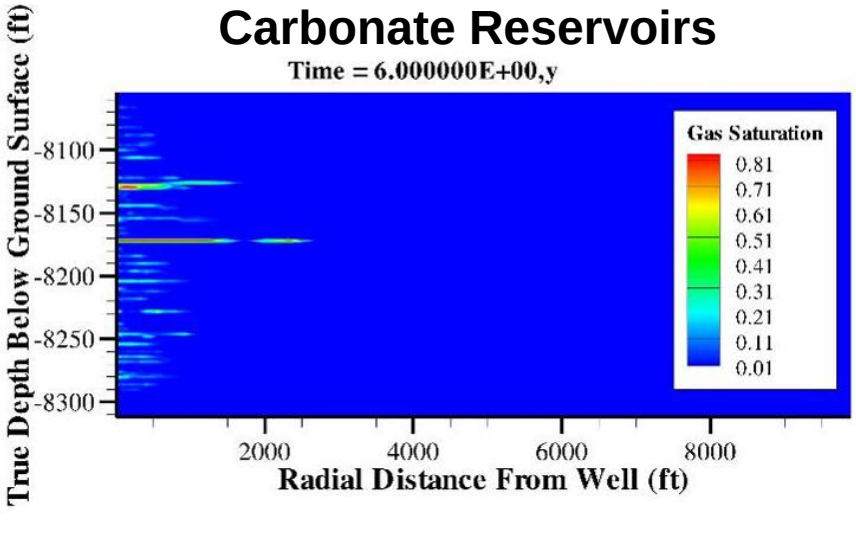


Multiple Injectors





Carbonate Reservoirs

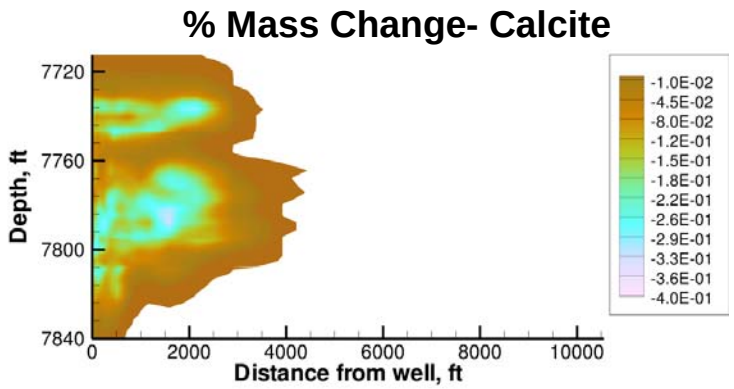


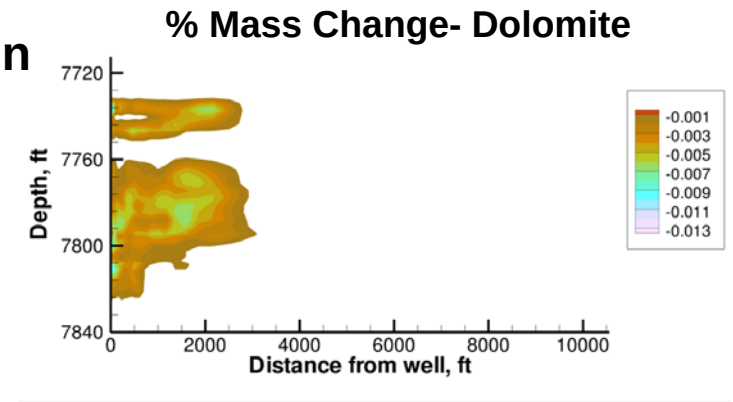
Reactive Transport Simulations

Example from Injection in Sandstone and Dolomite Layers

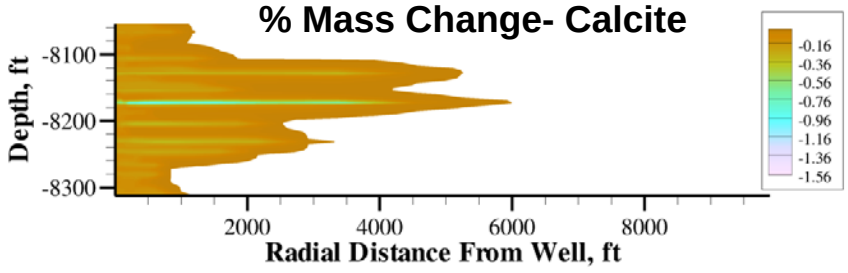
- Reactive transport simulations with equilibrium and kinetic reactions were conducted with STOMP/ECKEChem.
- During the 4-year injection and 6-year recovery period, carbonate dissolution does not significantly affect the rate of injection based on this scenario.

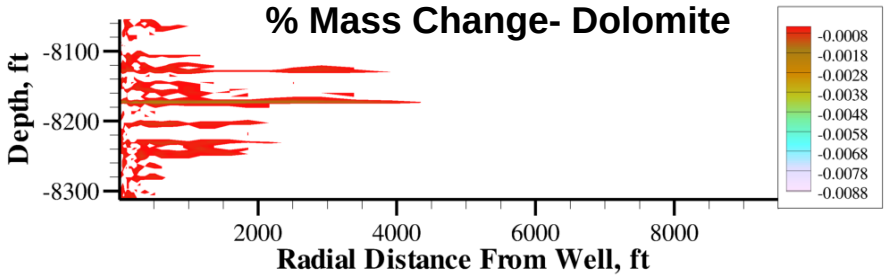
Rose Run





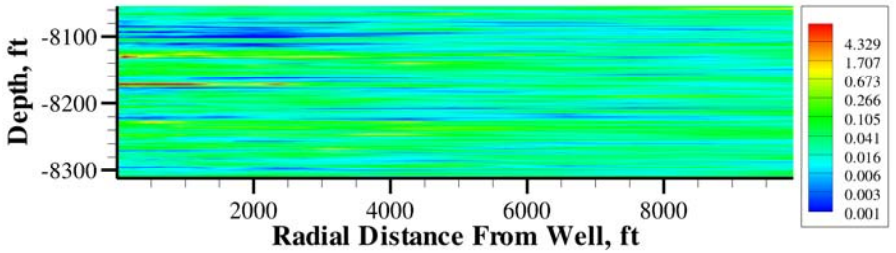
Copper Ridge

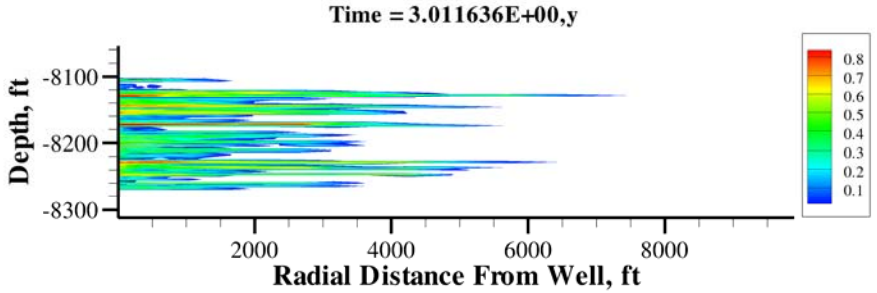


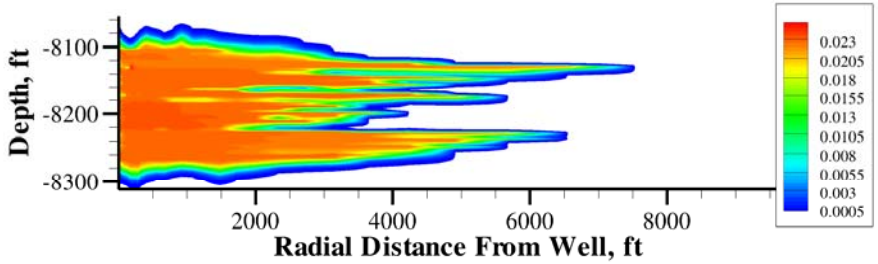


Mapping and Modeling Storage in Carbonate Zones

- Example – Copper Ridge/Knox Dolomite in the Midwest
- Potentially thin but very high permeability zones in carbonates throughout the region
- Need to understand geologic continuity and geochemical behavior
- Estimating capacity in discontinuous carbonates can be difficult

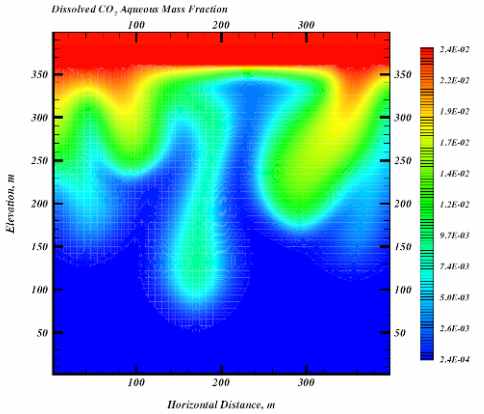




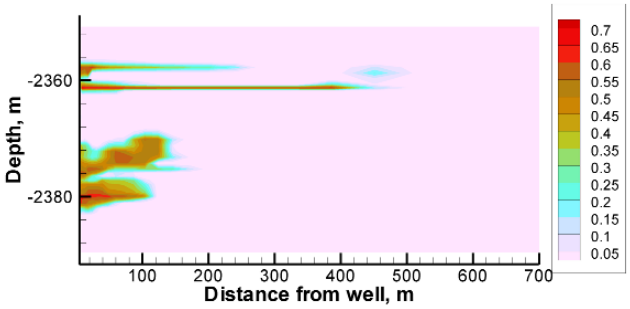


CO_2 Simulations at Multiple Scales

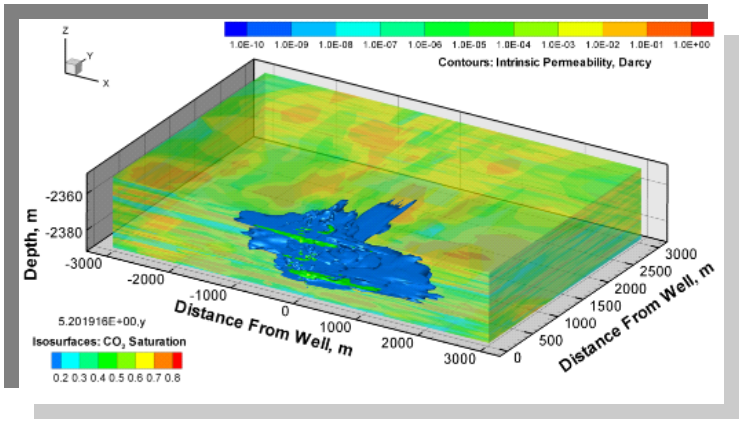
Fundamental process modeling



Pilot Test Scale 10,000s tonne/yr



Industrial-Scale 100,000s tonne/year



Challenge – Development of methods that model multiple scales (pore-scale to basin-scale) simultaneously is desirable.

Summary

- Reservoir modeling is an essential and highly useful part of CO_2 Storage research and implementation
- Special properties of CO_2, including phase behavior, density, solubility, viscosity etc. are incorporated in current models. Continued innovation is underway to incorporate even more processes.
- A number of modeling codes are available and many more could be developed or improved during next few years
- Modeling injection fields over CO_2 storage areas for long-term will require large computational resources
- Geochemical and geomechanical factors need to be addressed in the models, either coupled or uncoupled.