National Risk Assessment Partnership (NRAP)

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NATIONAL ENERGY TECHNOLOGY LABORATORY

CSLF Technical Group Meeting

April 26, 2019

Champaign, Illinois

Solutions for Today | Options for Tomorrow

U.S. DEPARTMENT OF ENERGY

National Risk Assessment Partnership

Objective: Building tools and improving the science base to address key questions related to environmental impacts from potential release of CO_2 or brine from the storage reservoir, and potential ground-motion impacts due to injection of CO_2

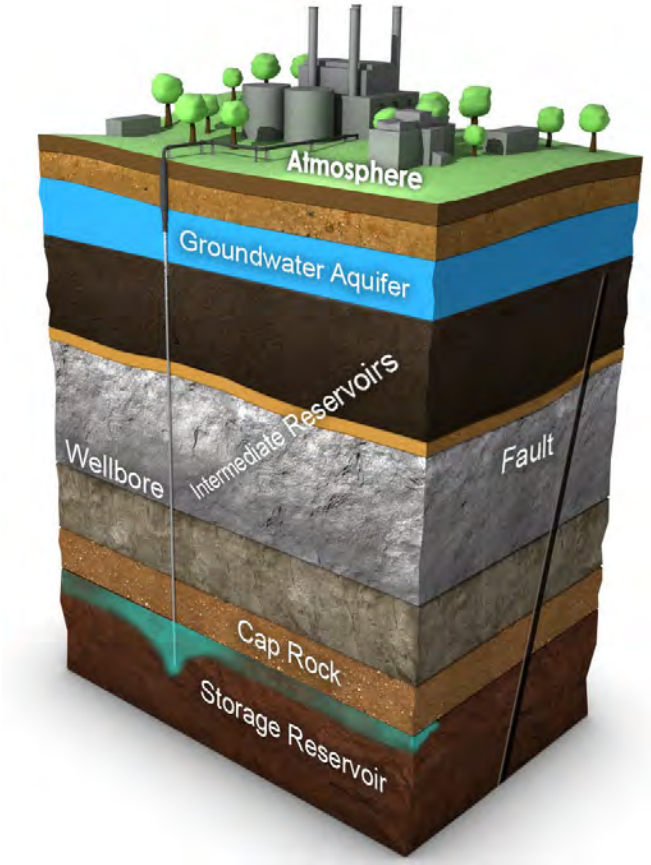
Technical Team

NATIONAL ENERGY TECHNOLOGY LABORATORY

BERKELEY LAB
Lawrence Berkeley National Laboratory

Los Alamos
NATIONAL LABORATORY
EST.1943

Pacific Northwest
NATIONAL LABORATORY



Stakeholder Group

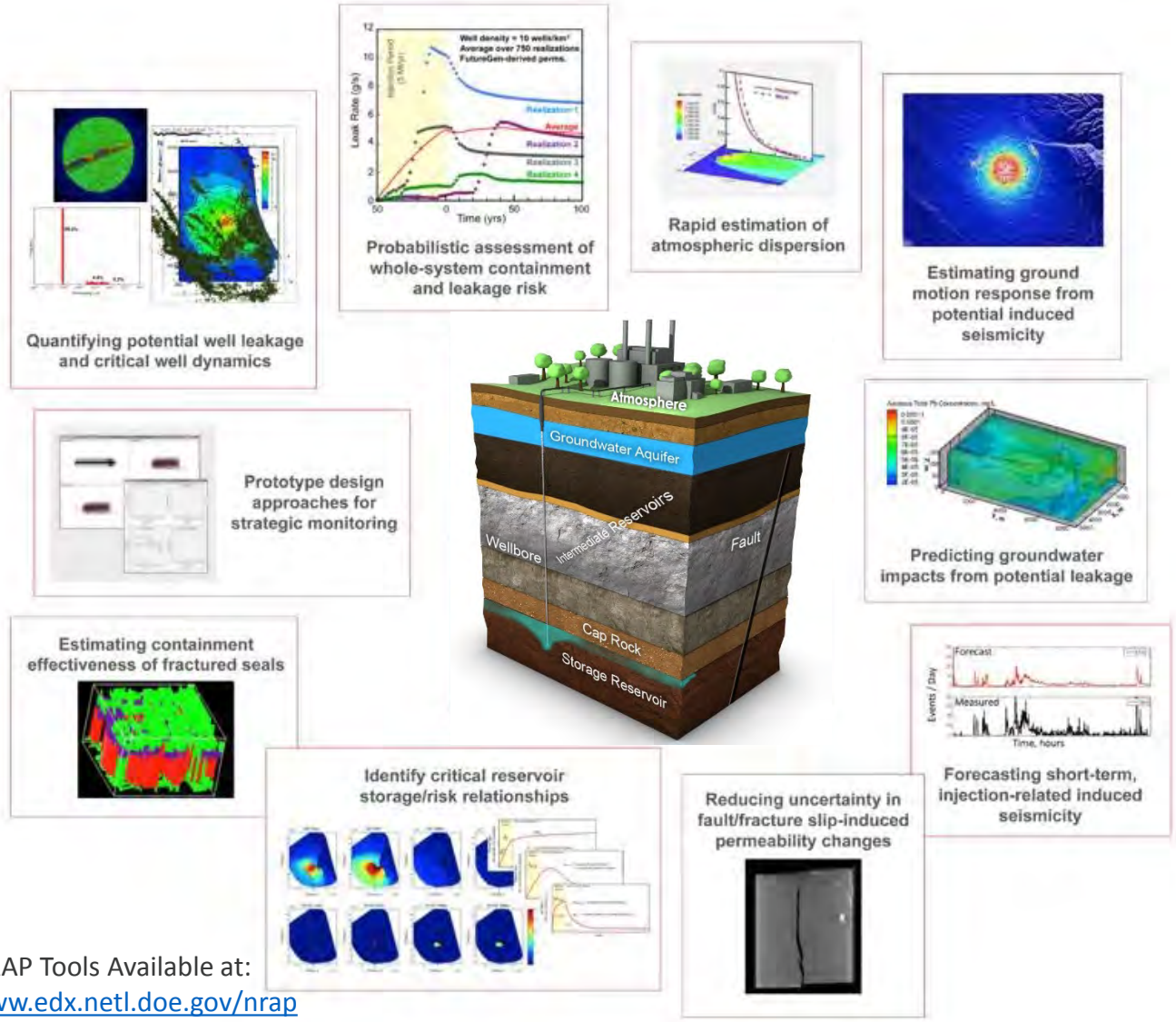
PRINCETON UNIVERSITY
THE UNIVERSITY OF UTAH
ILLINOIS
BATTELLE
USGS science for a changing world
bp
GLOBAL CCS INSTITUTE
Southern Company
ieaghg
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
NRDC
UNITED STATES Carbon Sequestration Council

NRAP Phase I Accomplishments

Assessing environmental risk and quantifying uncertainties in risk performance at CO_2 storage sites

- Generated the first publicly available quantitative, site-specific risk profiles for a complete CO_2 storage system
- Created the first comprehensive risk model for induced seismicity
- Characterized the behavior of key risk metrics associated with pressure and plume sizes for a wide variety of reservoir conditions
- Developed a toolset used to address leakage impacts and ground motion from underground storage of CO_2
- Developed and applied a novel approach for using reduced-order modeling to quantify uncertainty in subsurface systems
- Identified no-impact thresholds for groundwater quality
- Reduced uncertainty in understanding leakage pathways through experimental studies

NRAP Phase I Products

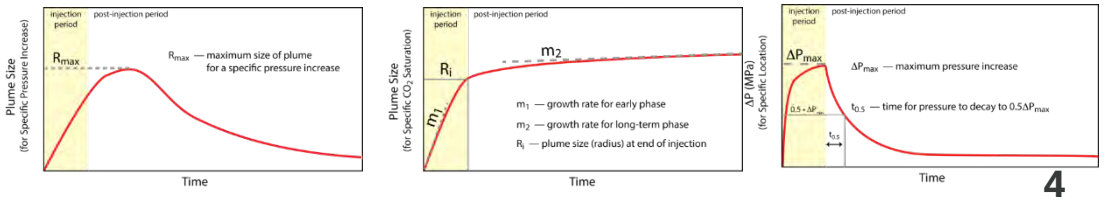


NRAP Tools Available at:
www.edx.netl.doe.gov/nrap

Virtual Special Issue of *International Journal of Greenhouse Gas Control* with 54 articles considering aspects of:

- Reservoir response and plume evolution.
- Fluid migration through leakage pathways.
- Groundwater impacts.
- Atmospheric leakage.
- System integrated assessment.
- Strategic monitoring.
- Ground motion/induced seismicity.

Using Science-Based Prediction to Probe Reservoir Behavior



NRAP Phase II Technical Focus

Managing environmental risk and reducing uncertainties in risk performance at CO_2 storage sites

- Containment assurance
- Induced seismicity risk
- Strategic monitoring for better system design
- Applying and validating risk assessment tools and methodologies using synthetic and field data

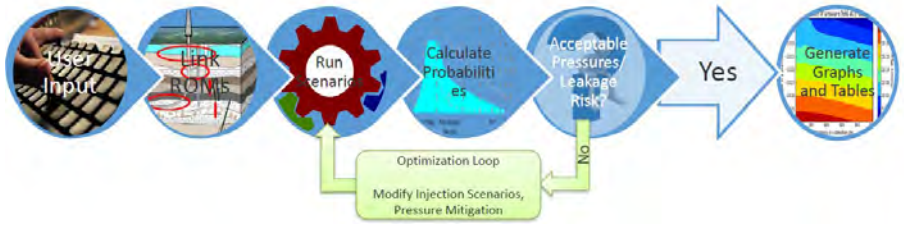
Containment Assurance

Developing robust, science-based *workflows* and *software tools* to:

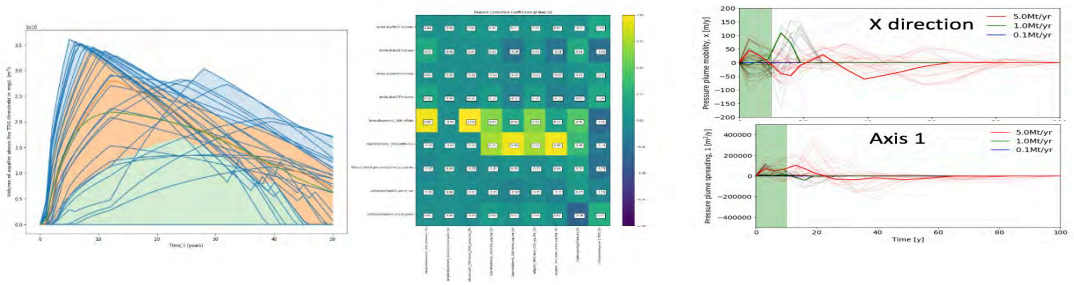
- *predict* containment effectiveness and leakage risk
- *evaluate* the effectiveness of leakage risk monitoring, management, and mitigation.

- *NRAP OpenIAM now in Beta testing.*
- *Workflows release target August 2019.*

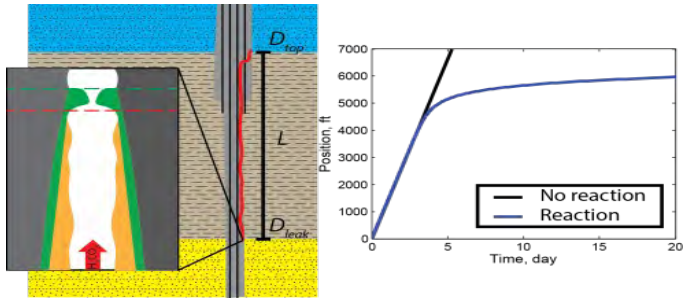
Workflows for risk assessment/risk management



NRAP OpenIAM: *Developing next-generation Integrated Assessment Model*

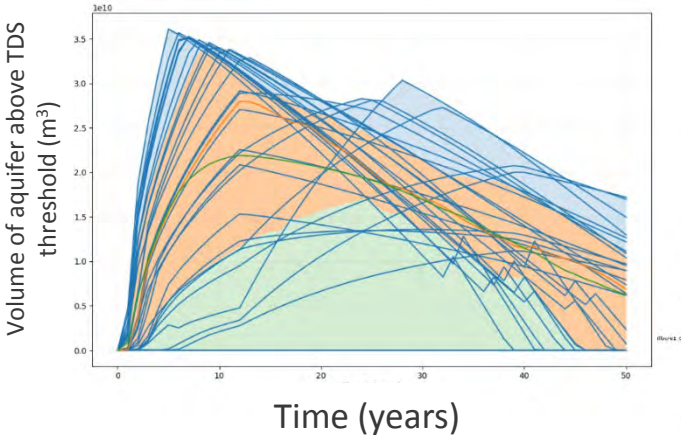


Developing improved characterizations of leakage behavior

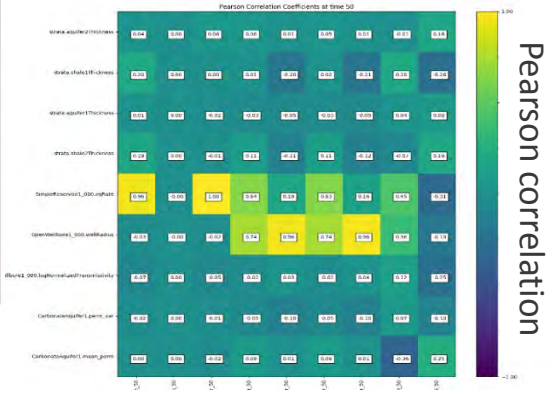


Next-generation Integrated Assessment Model (NRAP-OpenIAM)

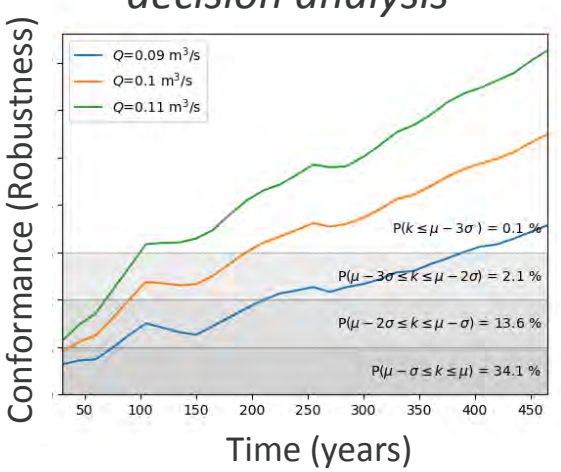
Combined ensemble and statistical visualization of system model output



Graphic representation of system model parameter/output correlations

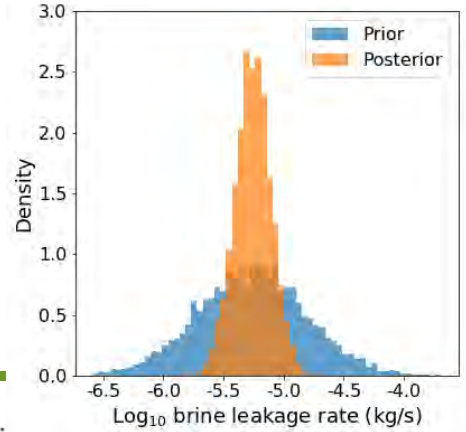


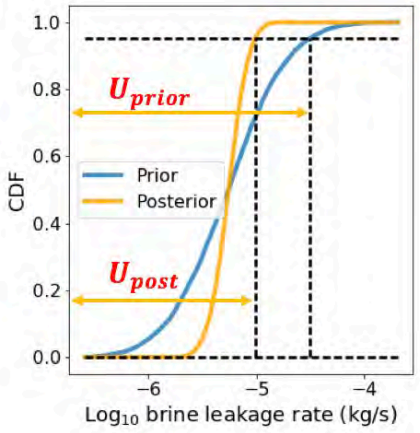
Building confidence in GCS Conformance using robust decision analysis



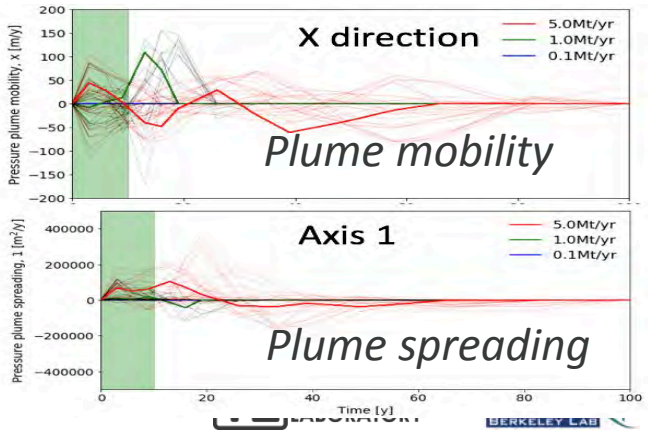
Building confidence in PISC by plume stability analysis

Constraining system model output and reducing uncertainty by model updating using MCMC





Evaluating the uncertainty of plume stability through ensemble analysis



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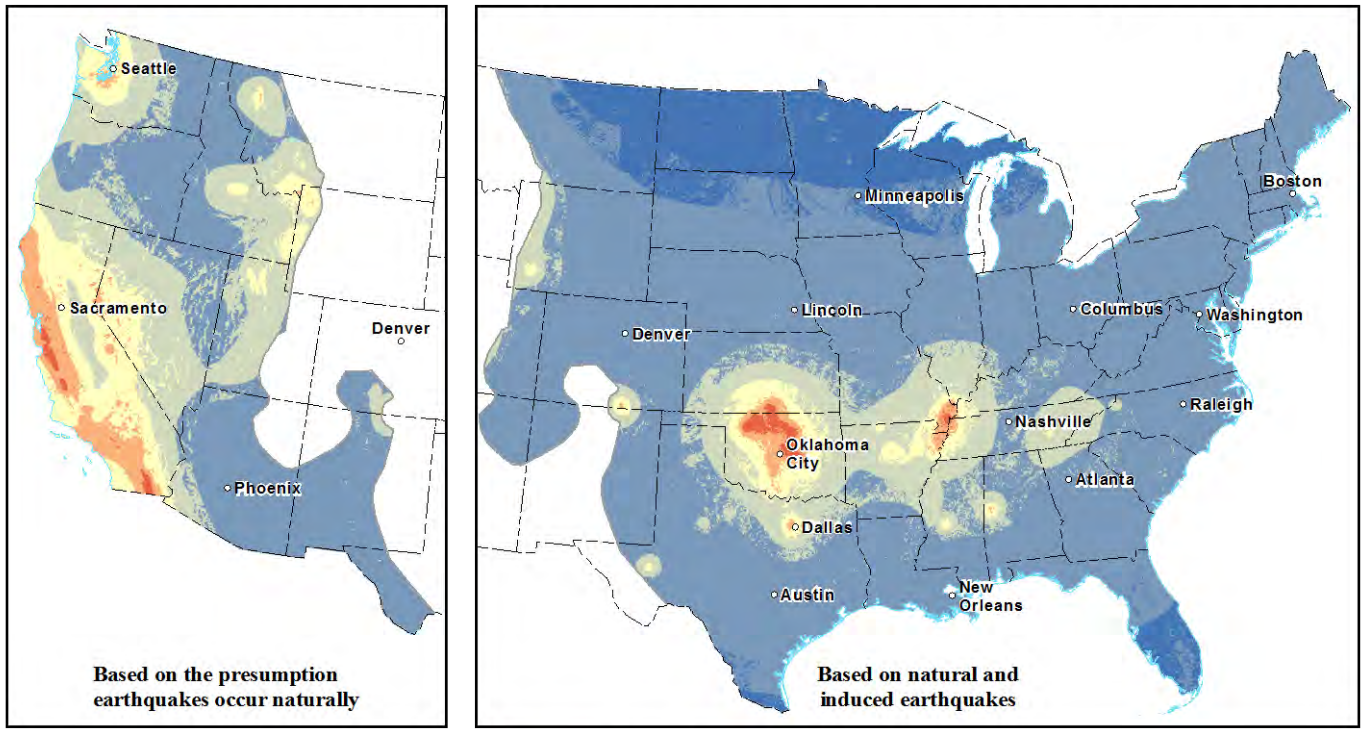
Induced Seismicity Risk

Developing practical tools to assess and manage induced seismicity risk at carbon storage sites and identify site characteristics and operational approaches to lower seismic risk.

- *Probabilistic seismic risk forecasting tool generated.*
- *State of Stress tool available.*
- *IS Protocol Document for Carbon Storage target by 2020.*

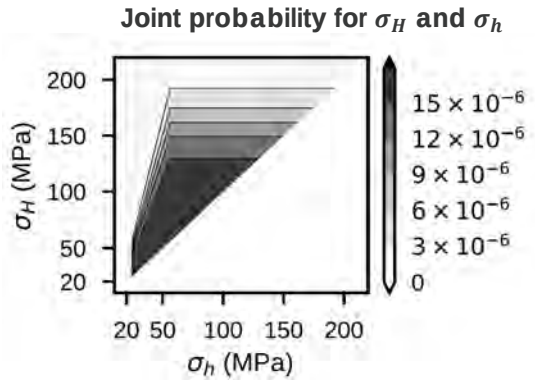
USGS Forecast for Ground Shaking Intensity from Natural and Induced Earthquakes in 2016

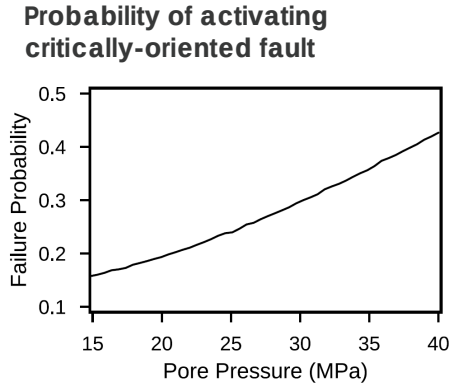


USGS map displaying intensity of potential ground shaking from natural and human-induced earthquakes. There is a small chance (one percent) that ground shaking intensity will occur at this level or higher. There is a greater chance (99 percent) that ground shaking will be lower than what is displayed in these maps.

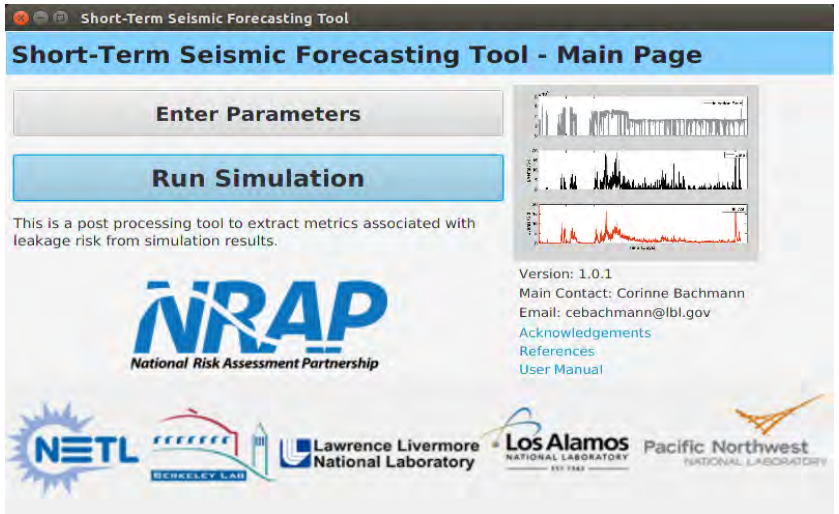
Induced Seismicity Risk Tool Catalog

State-of-Stress Assessment Tool

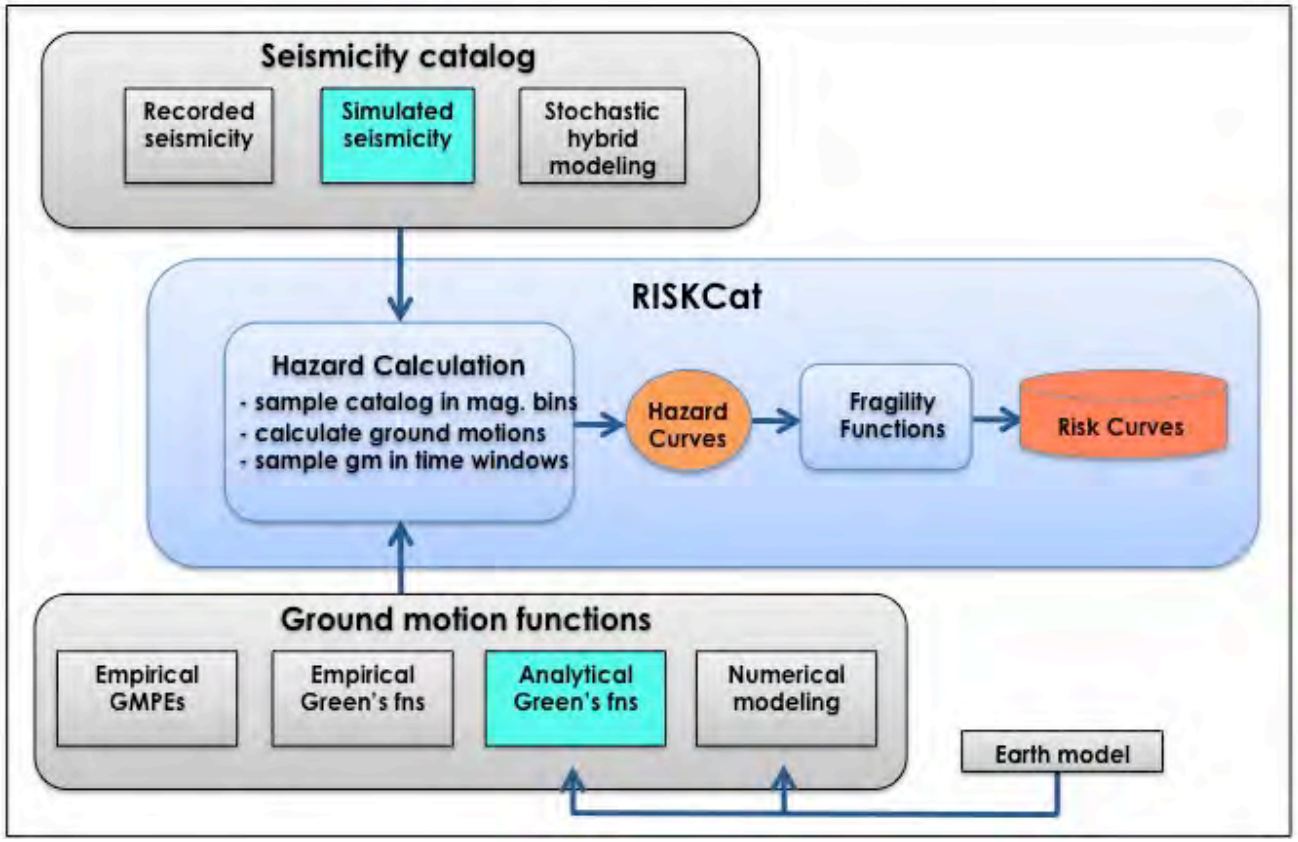




Short Term Seismic Forecasting (STSF) Tool



Probabilistic Seismic Risk Assessment Tool

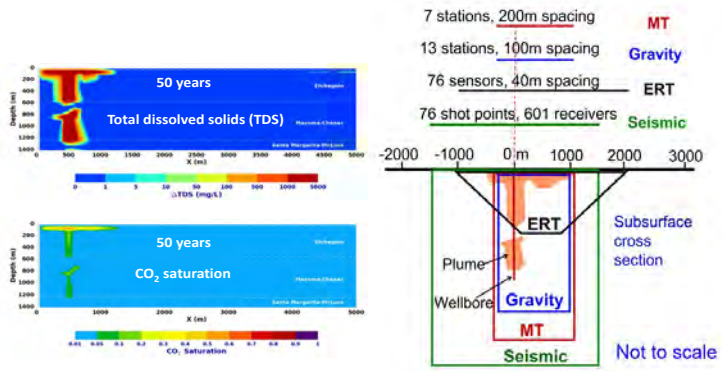


Strategic Monitoring for Uncertainty Reduction

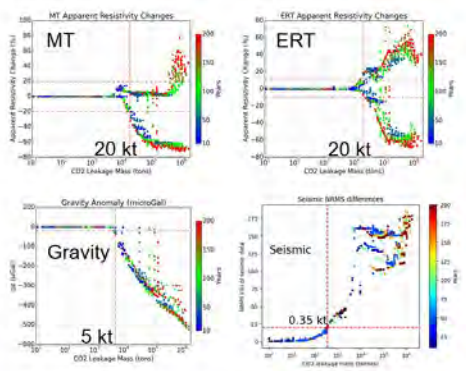
Developing insights, methods, and tools to understand the ability of monitoring technologies to detect system behavior, in the context of uncertainties in system features, events, and processes.

- *Version 2 monitoring design tool DREAM (beta) released.*

Modeling of Geophysical Monitoring

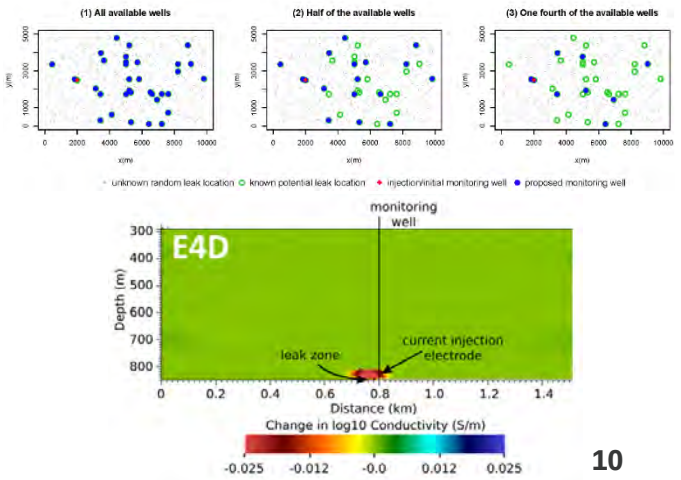


Layout of Surface Geophysical Methods

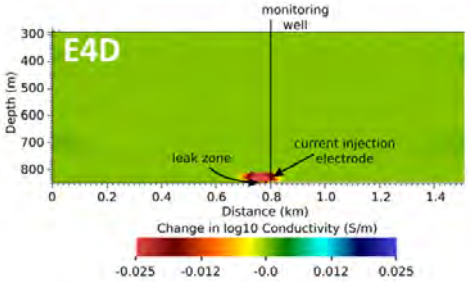


Geophysical signals versus CO_2 leakage mass

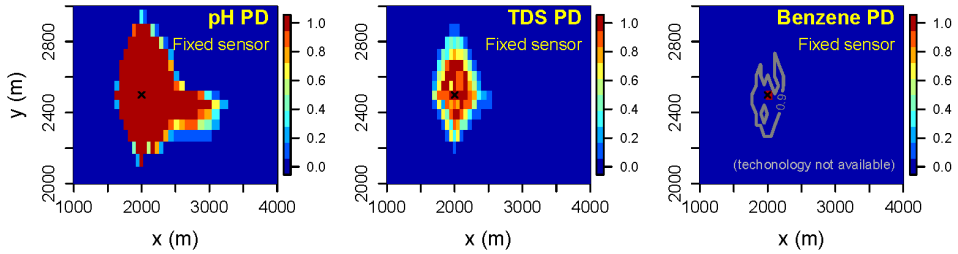
Risk-Based Monitoring Network Design Tools



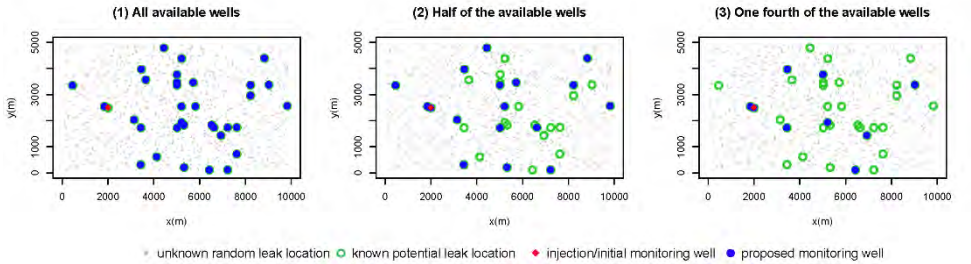
Risk-Based Monitoring Network Design



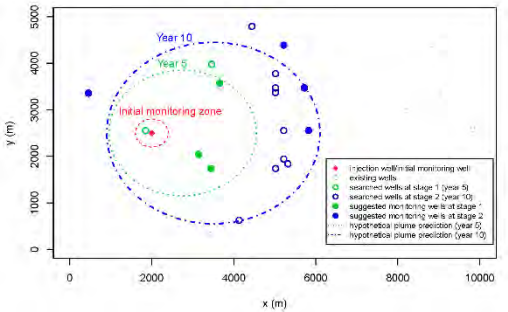
- DREAM v2 ERT module Beta released
- Considers both remote and point source monitoring parameters
- More flexible user input including compatibility with NRAP-OpenIAM output



Probability of detection using monitoring response



Proposed monitoring well locations



Two-stage monitoring design solution

Toward an adaptive monitoring design for leakage risk – Closing the loop of monitoring and modeling

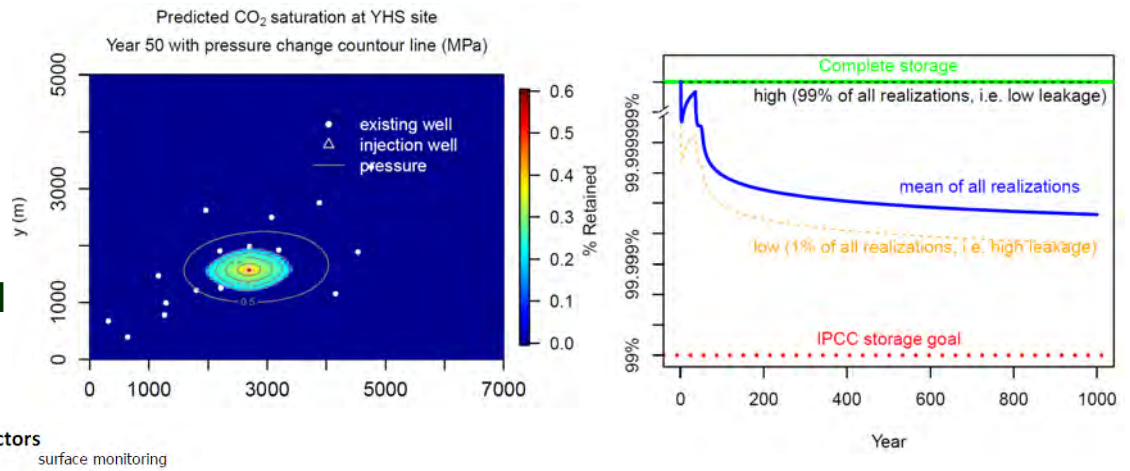
Ya-Mei Yang[a,c,*], Robert M. Dilmore[a], Grant S. Bromhal[a], Mitchell J. Small[b]

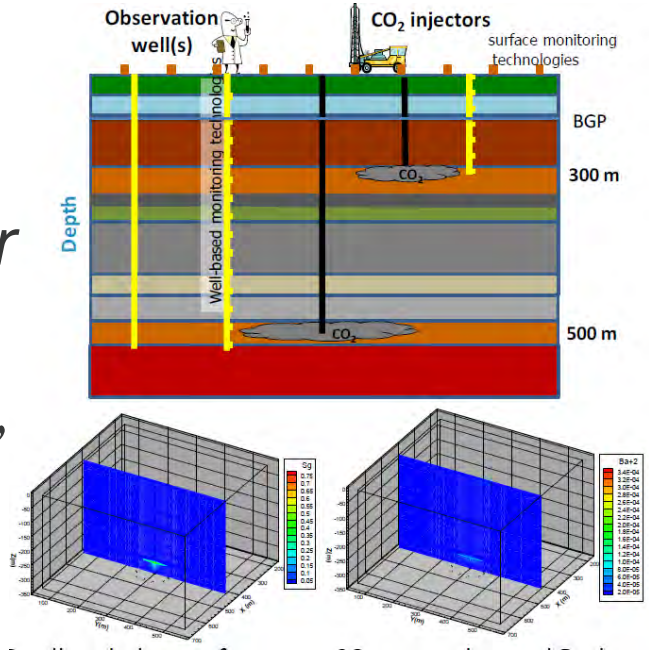
Validation and Use of Risk Assessment Tools and Methodologies

Enabling the adoption of NRAP tools and methods for large-field demonstration projects and validating the tools and the science-based risk assessment approach.

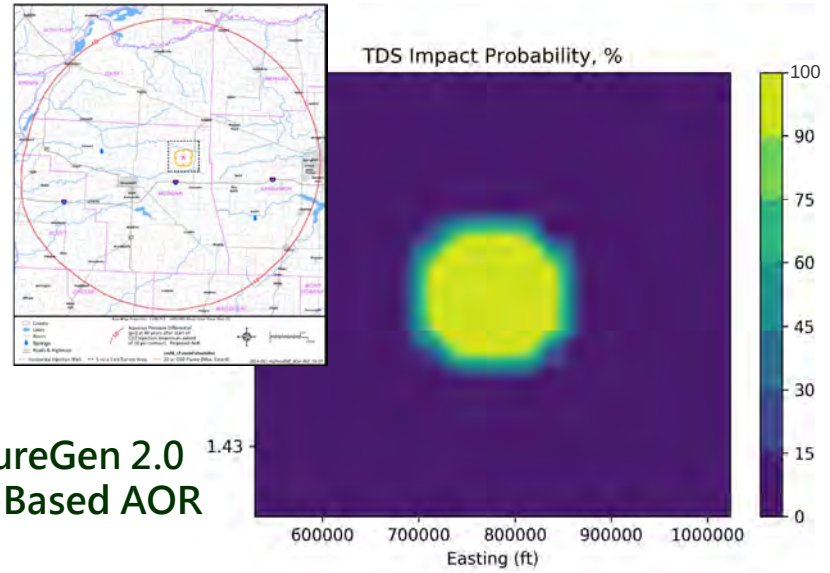
- *Tools used in >15 planned or existing projects*
  - *7 CarbonSAFE projects; CaMi, IBDP, Farnsworth, OK water injection, ITRI, and more*

CaMI Field Test Site





FutureGen 2.0 Risk-Based AOR

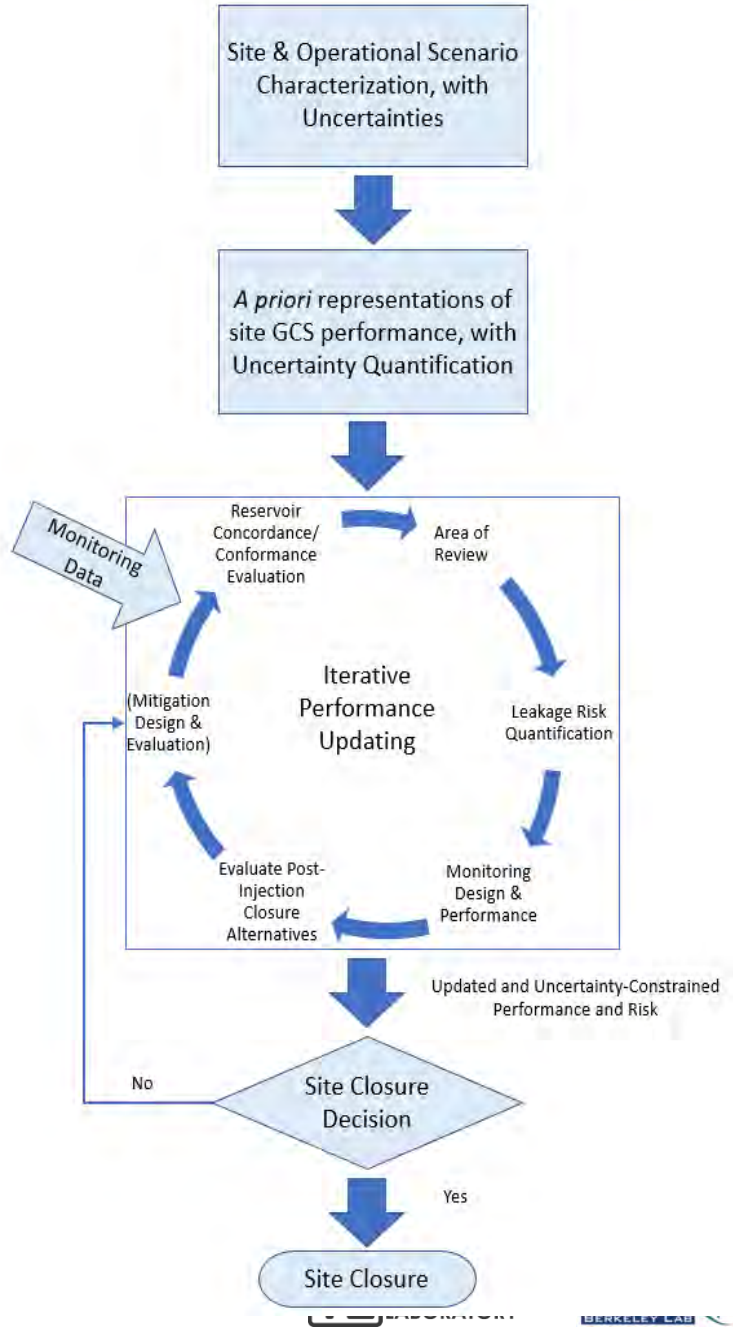


Using a risk-based approach to justify closure at a GCS site

Purpose: To provide a technical basis for a cost-effective and safe closure of GCS projects, using a risk-based approach as opposed to a default monitoring period.

Key Learnings:

- Monitoring during injection yields a better understanding of reservoir performance and builds confidence in safe, long-term storage.
- Drivers for leakage decrease once injection stops.
- PISC period can be reduced for many storage reservoir systems.



Thanks!

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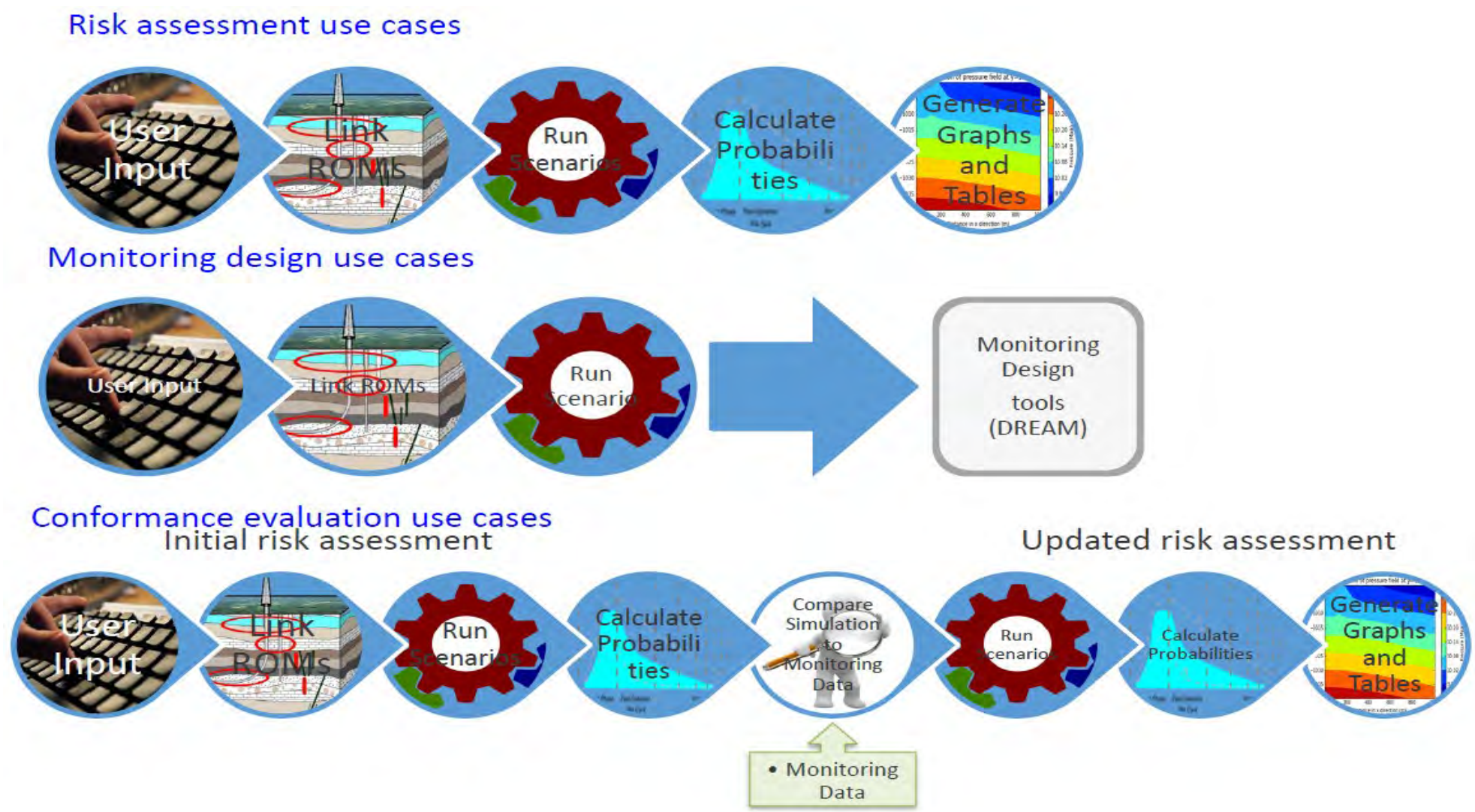
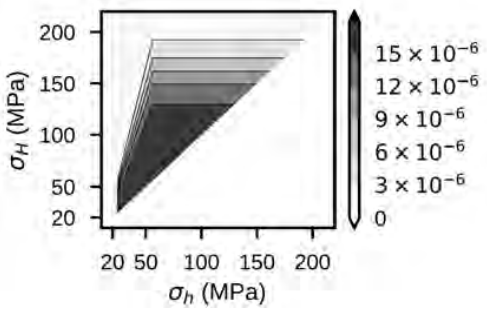
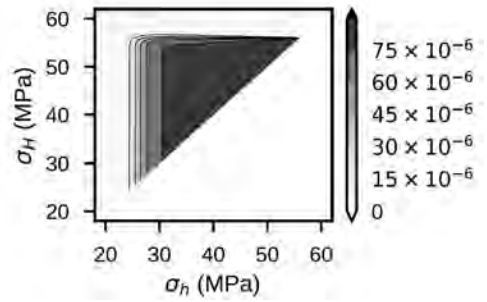
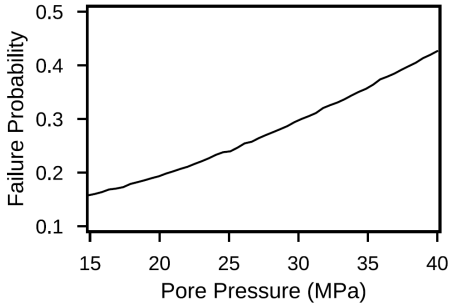
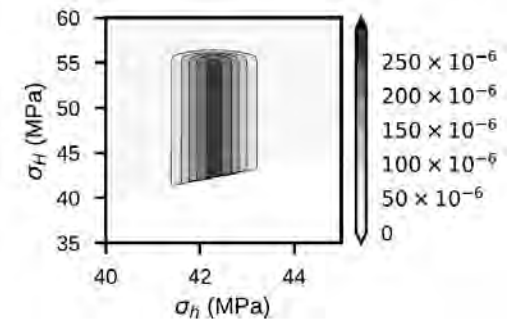
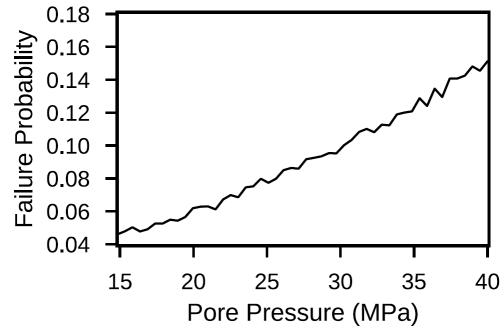
NRAP@netl.doe.gov

Additional Workflows

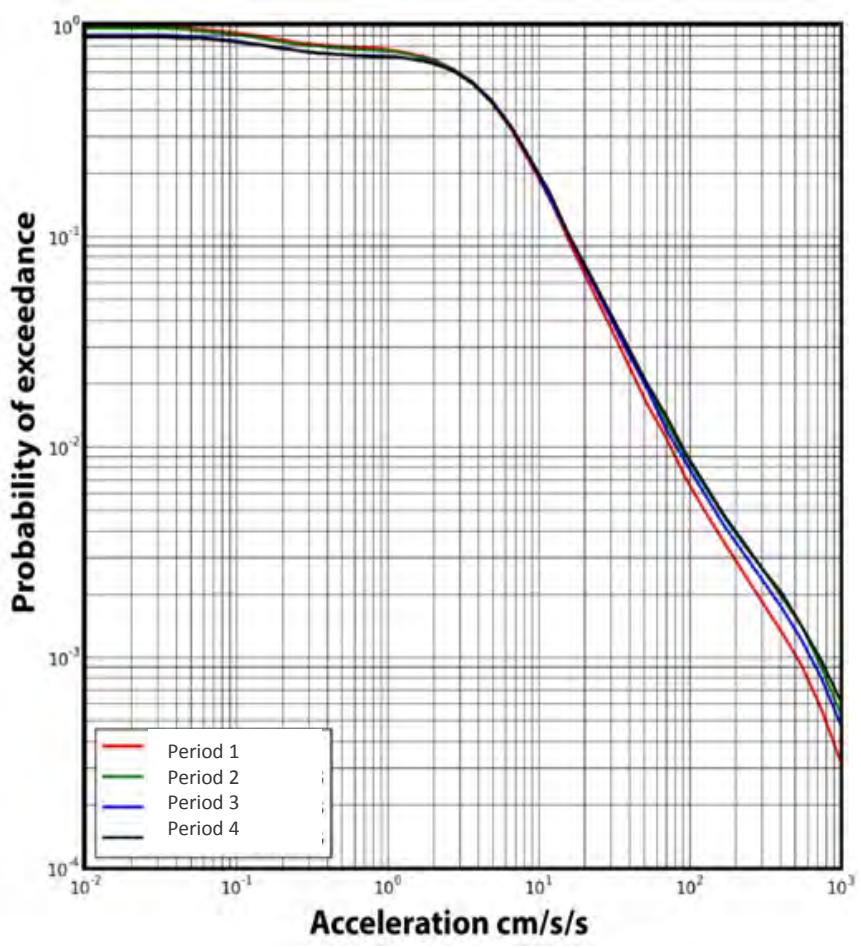


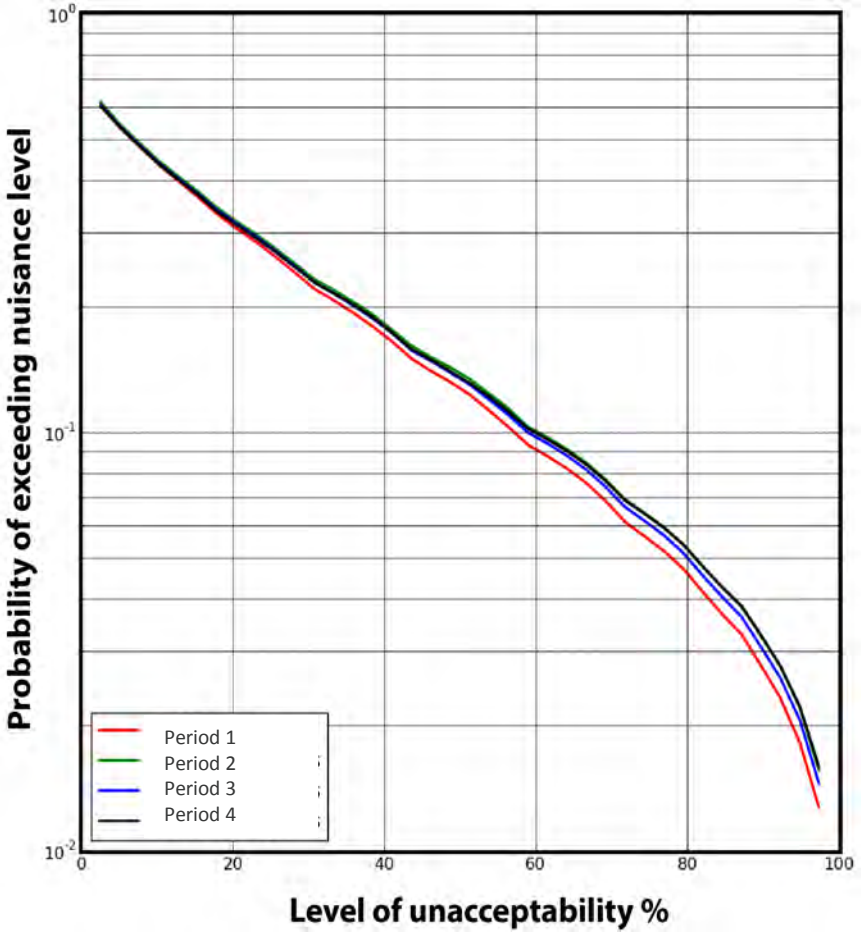
State-of-Stress Assessment Tool (SoSAT)

Input data available	Joint probability for σ_H and σ_h	Probability of activating critically-oriented fault
• Pore pressure • Overburden density		
• Regional stress indicators • Geodetic data		
• Local measurement of σ_h		

Reference: Jeff Burghardt (2018) SOSAT User's Manual.

Probabilistic Seismic Risk Assessment Tool (RiskCat)





Reference: Jean Savy and Bill Foxall (2018) RiskCAT User's Manual.

Carbon Storage Program

NATIONAL ENERGY TECHNOLOGY LABORATORY

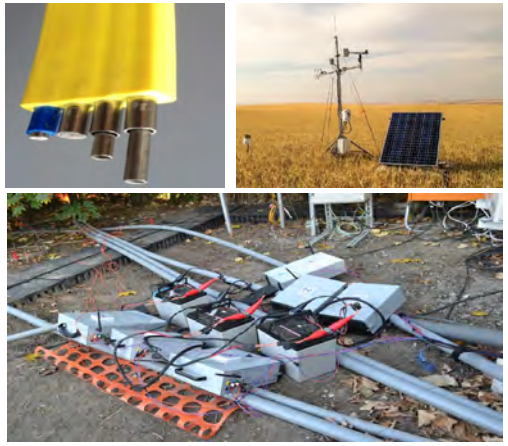
MISSION

Ensure Permanence – Protect Environment – Facilitate Awareness – Improve Storage Efficiency – Commercial-Readiness by 2030

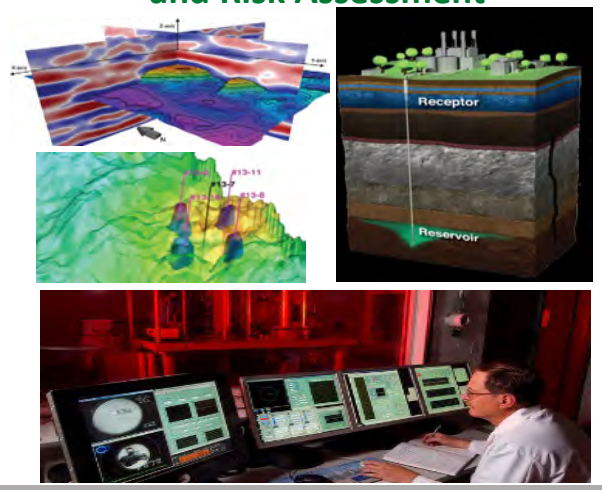
Program Approach & Technical Accomplishments

ADVANCED STORAGE

Monitoring, Verification, and Accounting



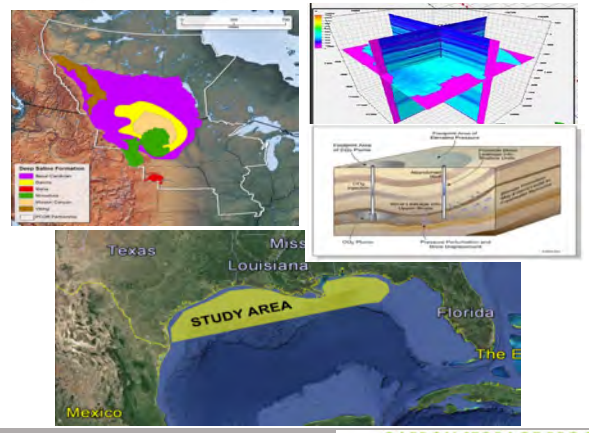
Geologic Storage, Simulation, and Risk Assessment



STORAGE INFRASTRUCTURE

Regional Carbon Sequestration Partnership Initiative

Onshore and Offshore Characterization, Brine Extraction Storage Tests (BEST), and CarbonSAFE



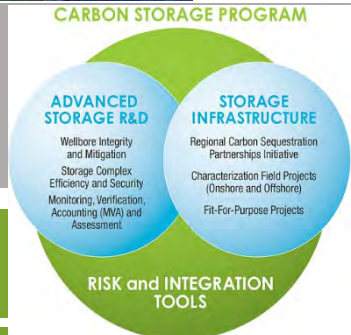
Risk and Integration Tools

CO2 SCREEN

EDX Energy Data eXchange

NRAP National Risk Assessment Partnership

For more information, please visit the Carbon Storage Program web page at: https://www.netl.doe.gov/coal/carbon-storage

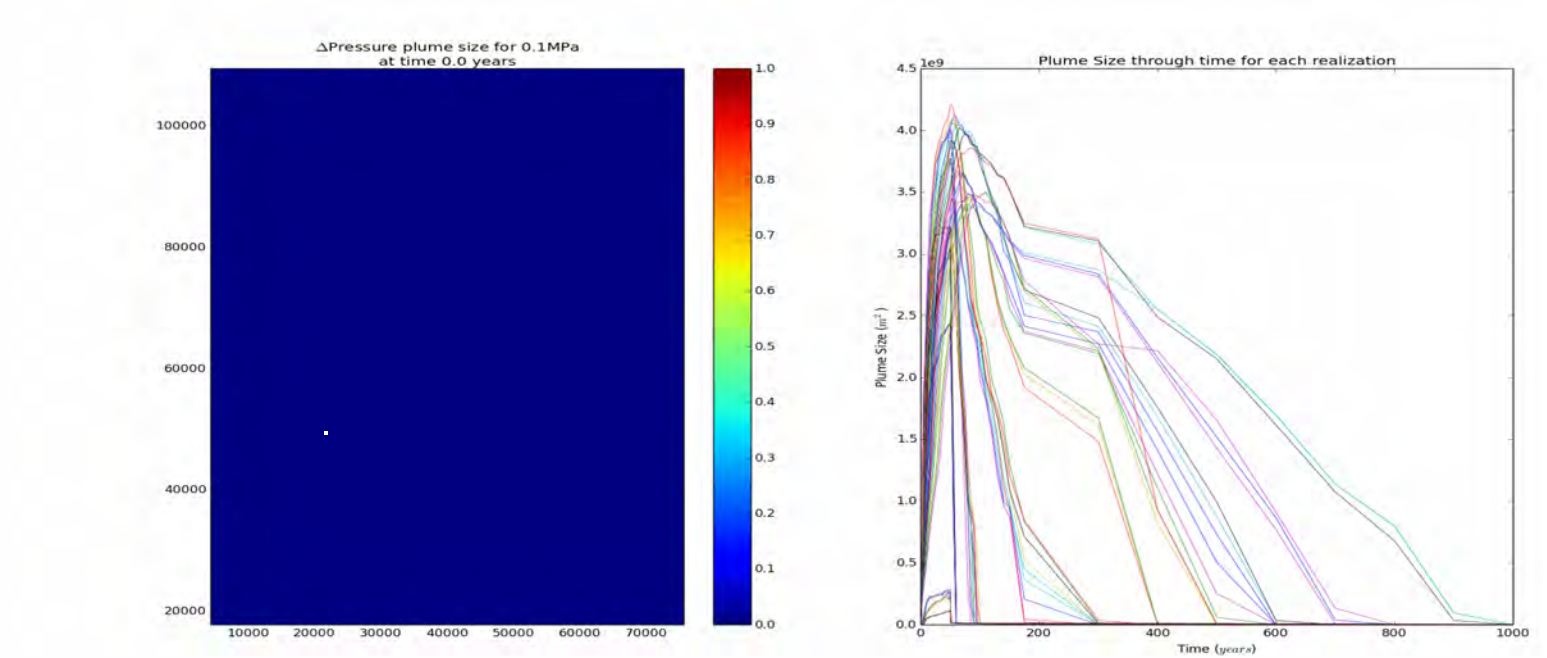


U.S. DEPARTMENT OF ENERGY

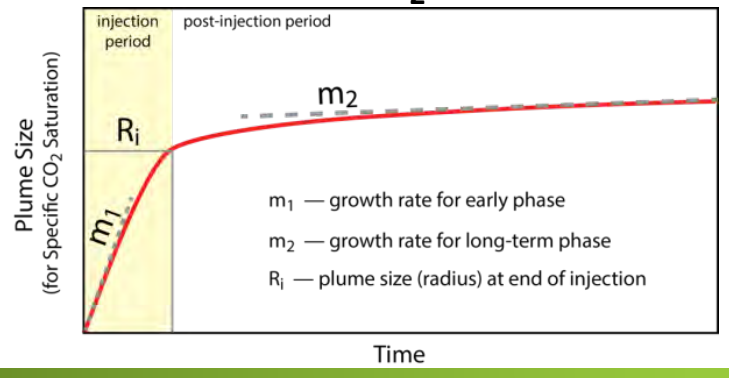
– NETL – Industry – Universities – National Labs –

Using Science-Based Prediction to Probe Reservoir Behavior and the Reservoir Evaluation and Visualization (REV) tool

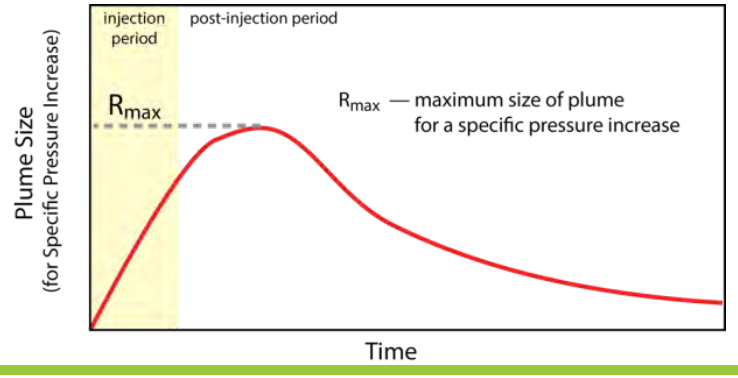
- **Size of CO_2 plume injection**
  - Rate of growth for early phase
  - Rate of growth for long-term phase
  - Plume radius at end of injection
- **Size of pressure plume**
  - Maximum size of plume
  - Various pressure thresholds, relevant
    - Brine rise
    - Fault-slip criteria
- **Pressure at a location**
  - Maximum pressure increase



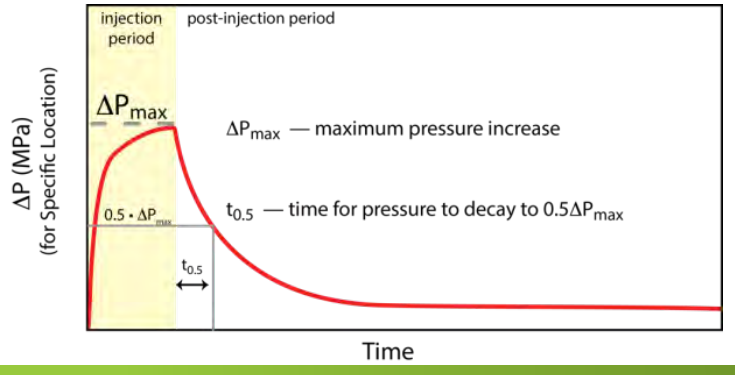
Size of CO_2 Plume



Size of Pressure Plume



Pressure at a Location



GCS Site Closure Products

- Demirkanli, Bacon, White, Risk-based Area of Review (AoR) Determination for a Deep-Saline Carbon Storage Site Using National Risk Assessment Partnership's Open-Source Integrated Assessment Model (NRAP-IAM-CS v2)." submitted to IJGGC
- Bacon, Yonkofski, Brown, Demirkanli, Whiting. Risk-based Post Injection Site Care and Monitoring for Commercial-Scale Carbon Storage: Reevaluation of the FutureGen 2.0 Site using NRAP-IAM-CS v2 and DREAM. submitted to IJGGC
- Yang, X., Buscheck, T. A., Mansoor, K., Carroll, S. A. Assessment of Geophysical Monitoring Methods for Detection of Brine and CO_2 Leakage in Drinking Aquifers. submitted to IJGGC
- Carroll, Yang, Mansoor, Buscheck, Wang, Huang, Appriou, "Integration of monitoring data to reduce risk uncertainty and to define site closure. International J. Greenhouse Gas Control, planned submission
- Harp, D., Oldenburg, C., Pawar, R. A metric for evaluating conformance robustness during geologic CO_2 sequestration operations. accepted by IJGGC
- Pawar, R., Chu, S., Makedonska, N., Onishi, T., Harp, D. Assessment of relationship between post-injection plume migration and leakage risks at geologic CO_2 storage sites. submitted to IJGGC
- Harp, D., Ohishi, T., Chu, S., Chen, S., Pawar, R. Development of quantitative metrics of plume migration at geologic CO_2 storage sites. submitted to Greenhouse Gas Science
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