Southeast Regional Carbon Sequestration Partnership—Early Test at Cranfield

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National Energy Technology Laboratory

Mastering the Subsurface Through Technology Innovation, Partnerships and Collaboration:

Carbon Storage and Oil and Natural Gas Technologies Review Meeting

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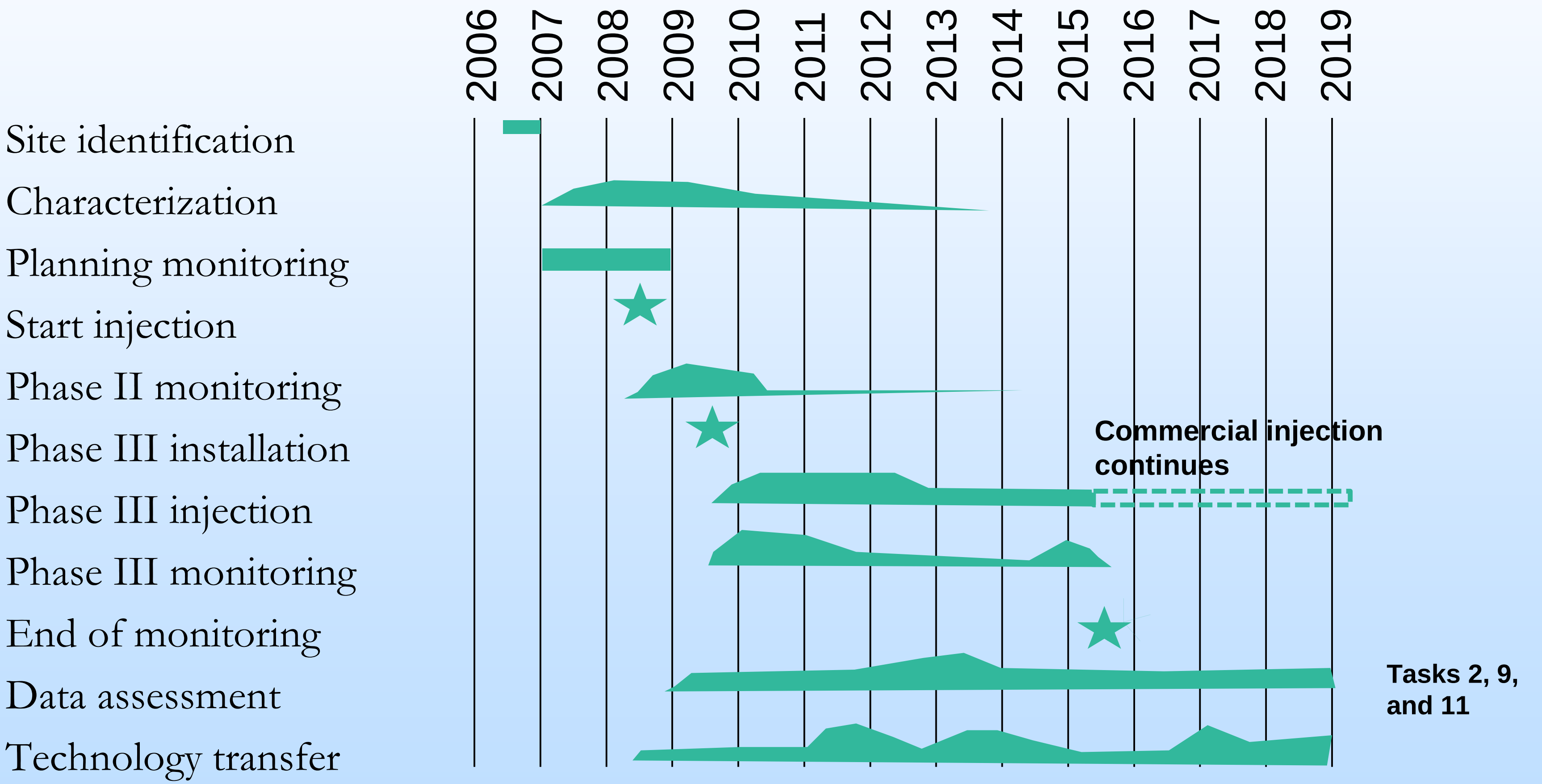
Presentation Outline

- Timeline of SECARB Early Test
- Team structure
- Early test goals
- Technical status- Advancing the state of the art
- Current activities
- Lessons learned – review publications

Outreach with China-Australia Group in Xinjian province

Timeline of SECARB Early Test



Team Structure

Gulf Coast Carbon Center
Bureau of Economic Geology
Jackson School of Geosciences
The University of Texas at Austin

Southern States Energy Board

SECARB Anthropogenic Test At Plant Barry/Citronelle

Denbury Resources
Field owner and injection system design, management, 4-D survey, HS&E

Vendors
e.g. well drilling, landmen

Sandia Technologies
Monitoring Systems Design, Installation, HS&E

50 Vendors
e.g. Schlumberger

Core Lab
UT DoG
Anchor QEA

MSU & UMiss
Hydro & hydrochem

Curtin University
3-D Seismic processing

Federal collaborators
Via FWP

LBNL
Well-based geophysics, U-tube and lab design and fabrication

LLNL
ERT

USGS
Geochemistry

Separately funded

NRAP
VSP deployment & analysis

NETL
Rock-water interaction

Model comparisons
LBNL SIM SEQ study

IPARS Modeling
CFSES M. Wheeler

4-D Seismic analysis
K. Spikes UT DoGS

Rock Mechanics
CFSES Sandia NL

Microseismic deployment
RITE, Japan

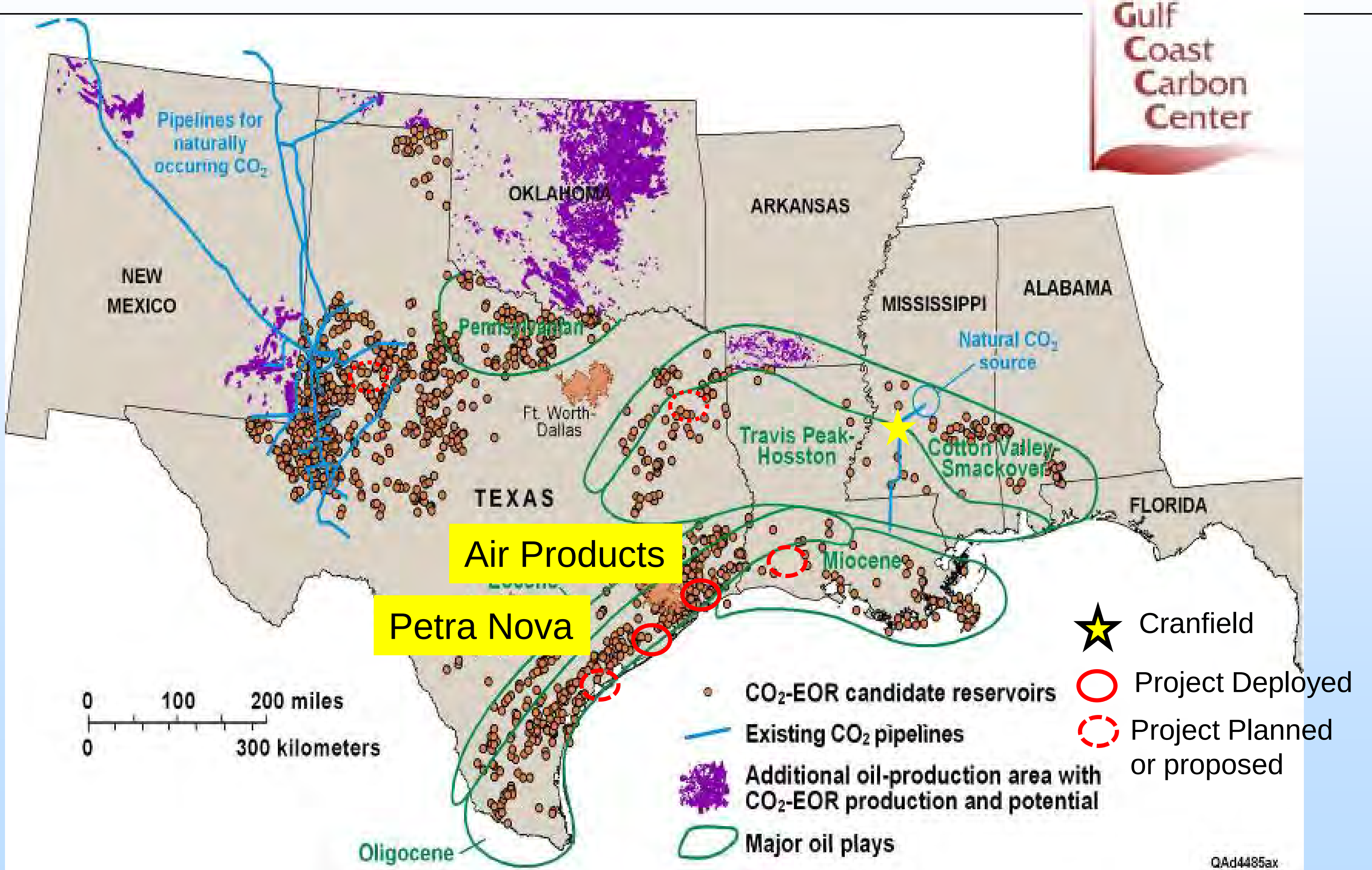
Groundwater controlled release
AWWA

Early Test Goals

- Large-scale storage demonstration
  - 1 MMT/year over >1.5 years
    - Periods of high injection rates
    - Result >5 years monitoring with >5 MMT CO_2 stored
- Measurement, monitoring and verification
  - Tool testing and optimization approach
  - Deploy as many tools, analysis methods, and models as possible
- Stacked EOR and saline storage
- Commercial technology transfer
  - Uploaded data to EDX

Current major effort

Commercialization of learnings at SECARB Early Test Accomplishments to Date



Commercialization of Monitoring

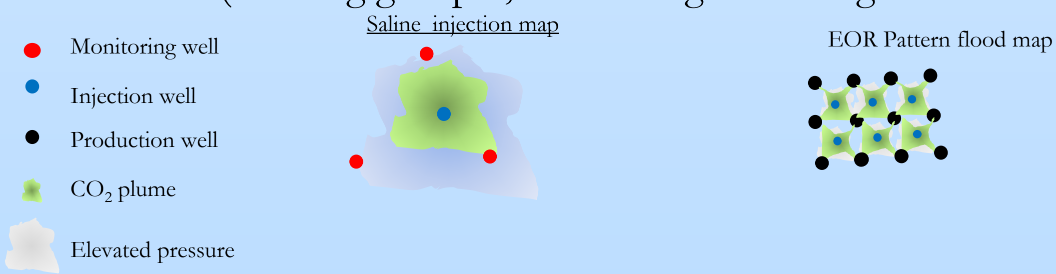
	Mass balance	soil gas	groundwater chem	AZMI chem	AZMI pressure	3D seismic	VSP	ERT	EM	gravity	u-tube	IZ chem	tracers
Frio	x	x	x	x			x		x		x	x	x
SECARB Early test at Cranfield	x	x	x	x	x	x	x	x		x	x	x	x
Industrial capture Air Products - Hastings	x	x	x		x	x	x						
Clean Coal Power initiative Petra Nova/ West Ranch	x	x	x	x	x								

Major Contributions

- Early Test Developed monitoring approaches for later commercial projects
  - Process-based soil gas method
  - Effectiveness of groundwater surveillance
  - Pressure and fluid chemistry monitoring in Above-Zone Monitoring Interval (AZMI)
  - ERT for deep CO_2 plume
  - Limitations of 4-D seismic
- Published and propagated techniques for widespread application
- Advanced to commercialization

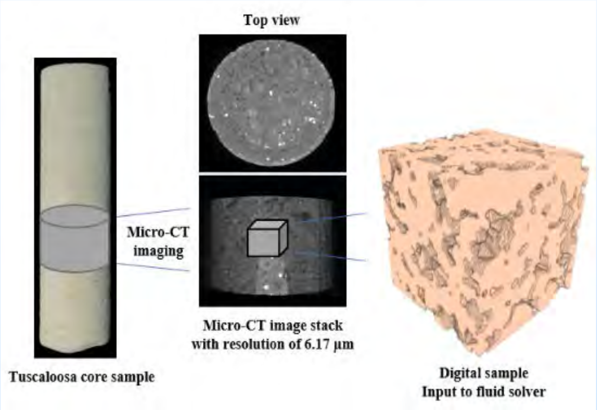
Technical Status - Advancing the state-of-the-art

- Injection scale-up – pushing the limit of injection
  - Assessing what is rate-limiting issue – overpressure or overfill?
- CCUS monitoring and accounting
  - Unique issues in a proven trap with production history – but complex fluids and many wells
- Maximize monitoring testing to minimize commercial monitoring
  - SECARB early test – extensive monitoring – many experiments
  - Commercial monitoring – focus on key issues –ALPMI method
  - Advising California Air Resources Board on their new Carbon Capture and Sequestration Protocol under the Low Carbon Fuel Standard
  - Advising International Standards (working group 6, accounting for storage associated with EOR.

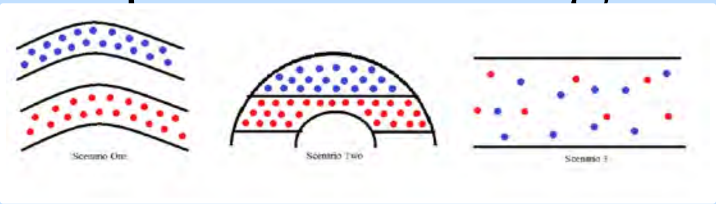


Active and continuing elements

- Pore scale modeling to extend laboratory multiphase parameter measurement – key model input
- Fault stress change from injection
- Post injection fate of CO_2
- RST logs – changes in porosity
- Management of methane impacts on miscibility
- Regional and global impact of findings



Micro CT-Imaging Espinoza, CFSES

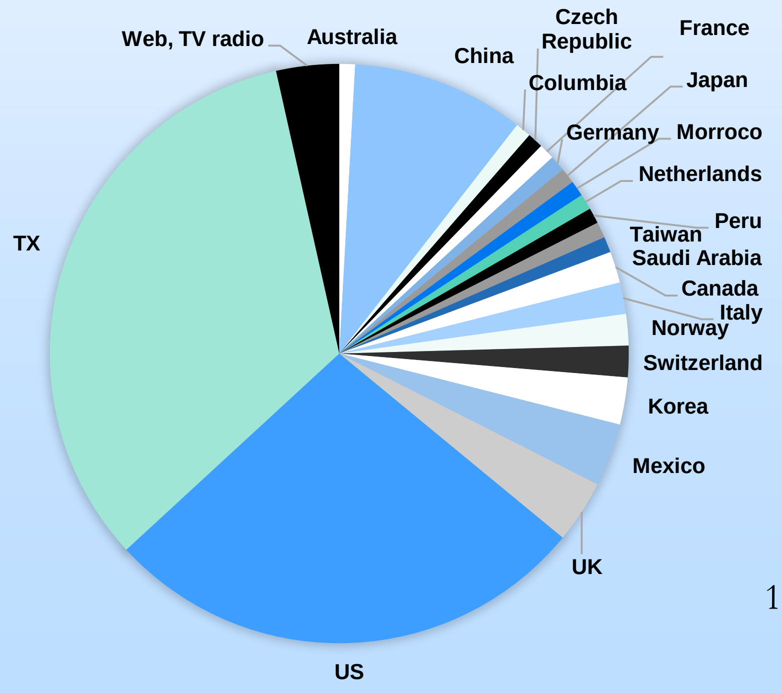


Methane and oil distributions Prentise

(Selected) Lessons Learned

- Value and methods for down-selection of monitoring tools
- Benefits of pressure monitoring
- Limitation of groundwater and soil gas monitoring

Distribution of GCCC presentation 2014-18



Value and methods for down-selection of monitoring tools

- Optimized tool selection (Assessment of low probability material impact: ALPMI)

Risk assessment method as usual

- Avoid subjective terms like safe and effective.
- E.g. : Specify mass of leakage at identified horizon or magnitude of seismicity.
- Specify certainty with which assurance is needed

Quantify risks to define material impact

Specify magnitude, duration, location, rate of material impact

Explicitly model unacceptable outcomes showing leakage cases.

Model material impact scenarios

ALPMI uses models differently than the typical history matching the expected performance

Identify signals in the earth system that indicate or preferably precede material impact

Method down selects only signals that indicate material impact may occur or may be occurring

Approaches like those normally used for seismic survey design should be deployed for all modeling tools

Select monitoring tools that can detect these signals at required sensitivity

Forward modeling tool response is essential to developing the expected negative finding: “No material impact was detected by a system that could detect this impact.”

This activity as traditionally conducted. Include all the expected components, such as attribution, updating as needed, feedback , etc.

Deploy tools; collect and analyze data

Via this ALPMI process can a finding that the material impact did not occur be robustly documented

Report if material impact did/did not occur

Value and methods for down-selection of monitoring tools

You can't have everything! Example limitations:

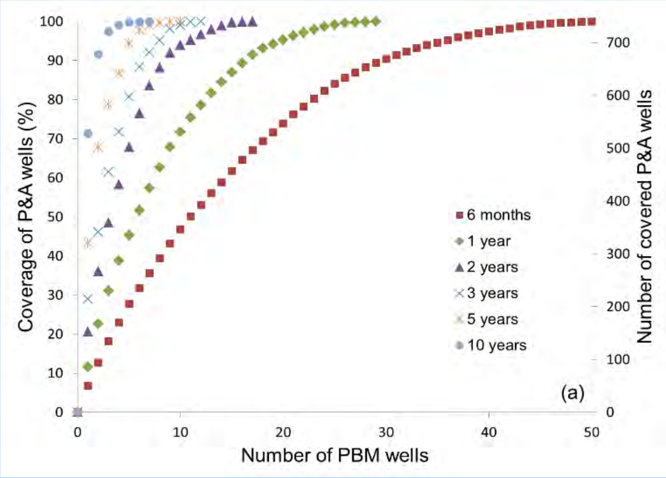
- Tool interference

  e.g. "jewelry" on casing interferes with log response

  Perforated well – geochemical and geophysical tool deployment interference

- Tool limitations – cost, cost of analysis

  Paper on cost/value in preparation



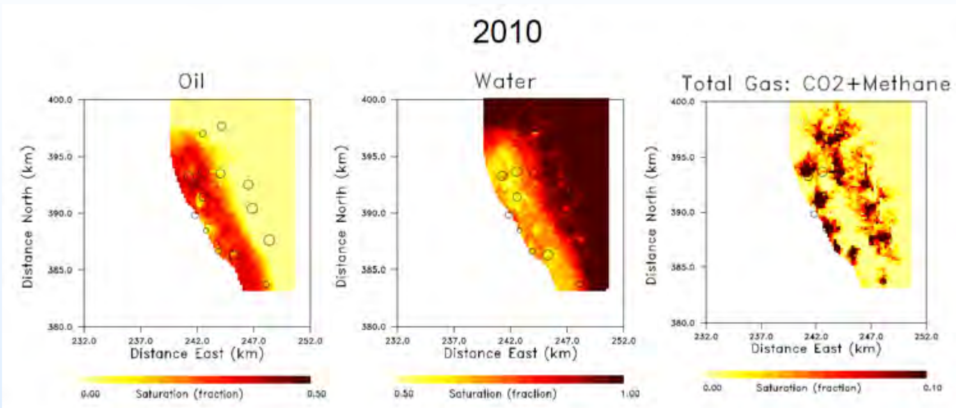
Sensitivity of time until detection of leakage on number of wells installed, Bolhassani (*in prep.)*

New assessment forward modeling seismic response

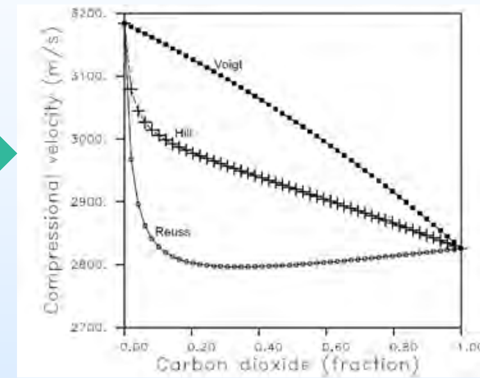
- Calibrated compositional fluid flow model of northeast quadrant of field (BEG team)
- Another look at seismic processing by Don Vasco, LBNL
- Seismic modeling of expected response
- Identify signal reduction related to hydrocarbons

Seismic forward modeling study outcomes

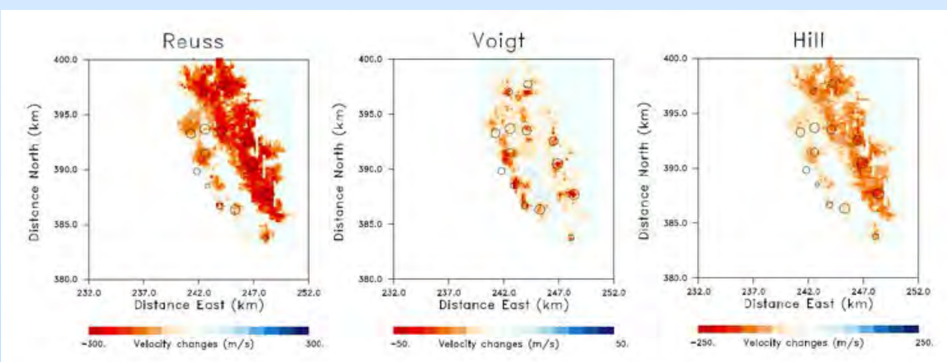
Fluid flow model outcomes



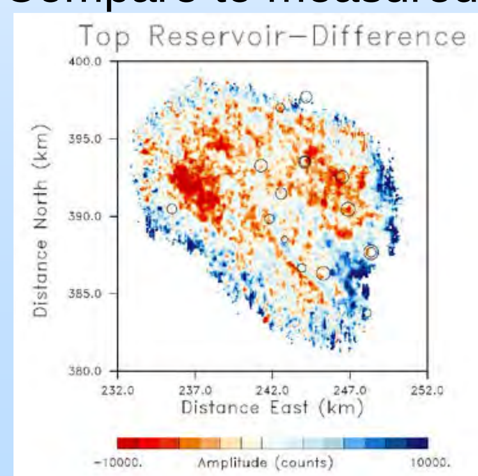
Rock physics models



Forward model seismic response to fluid substitutions



Compare to measured response

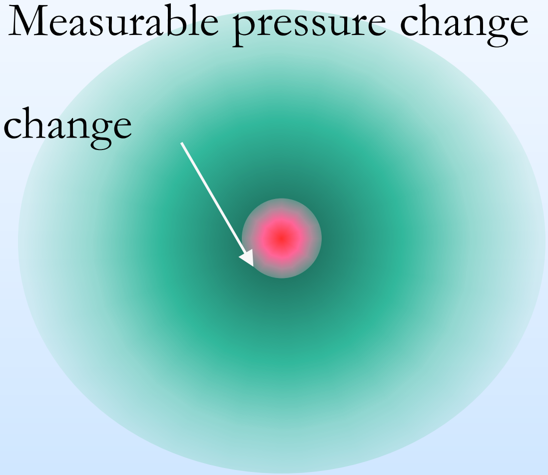


Vasco et al

Benefits of pressure monitoring

– Pressure is a key parameter in risk reduction

– Diffusive parameter



– Robust history matching-

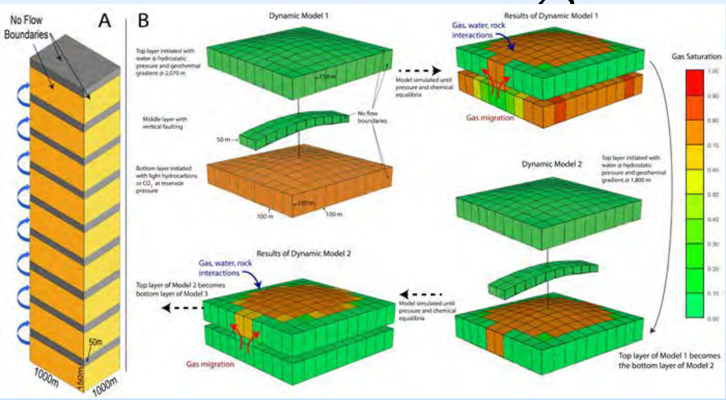
- Model validation
- Plume conformance to model

– Above-zone diagnostic

– Not especially sensitive in post-injection context

Limitation of groundwater and soil gas monitoring

- Extensive published work by Katherine Romanak, Changbing Yang, Sean Porse, Jacob Anderson
- Leakage signal changed and attenuated during lateral and vertical transport



Anderson et al, 2018

- Issue of noise and trend in near-surface signal
- CO_2 is non-unique signal

Synergies

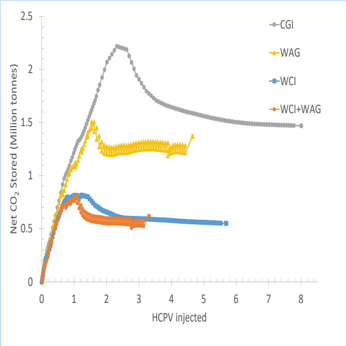
Field data collection
Microseismic – RITE
CO_2 Geothermal – LBNL
PIDAS – Sun
CCP-BP gravity
Microbes – U KY
NRAP 3-D VSP
Borehole seismic – Ground metrics
Nobles gasses U. Edinburgh
Fluid Chem – Ohio State
Well integrity – Schlumberger/Battelle

Additional analyses
NETL- EOR accounting Mei/Dilmore
NETL- Rock-water reaction BES – LLNL

Modeling efforts
SIMSEQ –LBNL
15 teams
CFSES – UT/ SNL
IPARS --Wheeler
NRAP
NCNO
LBNL
CCP3
UT- LBNL Zhang
LLNL
LBNL – Don Vasco study

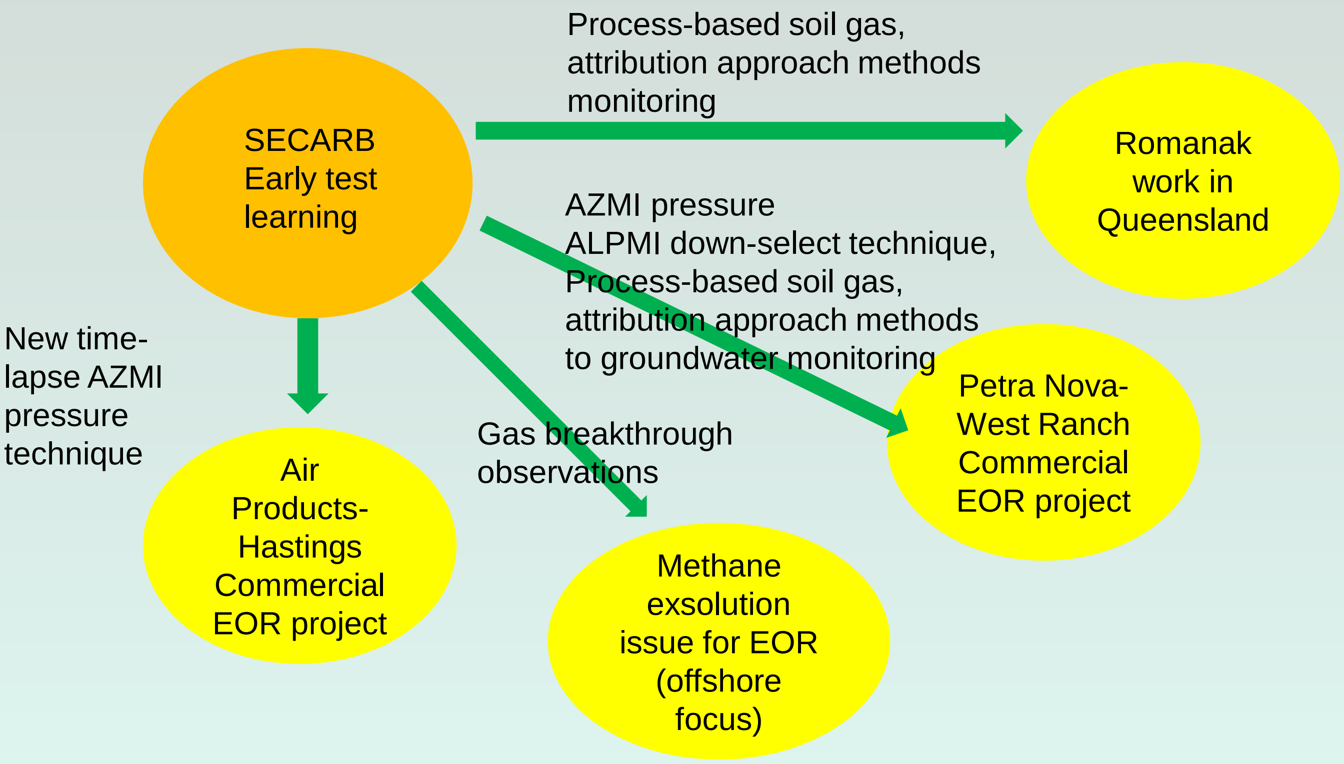
119 history match efforts

Support other studies
NCNO



Nunez- Cranfield data supporting NCNO study

Technology transfer from SECARB early test to other projects



Recent submissions and publications (108 total)

- Uploads to EDX (data) https://edx.netl.doe.gov
- Texas Scholar Works https://repositories.lib.utexas.edu
- Hovorka, S. D., Case study – testing geophysical methods for assessing CO_2 migration at the SECARB early test, Cranfield Mississippi "Geophysical Monitoring for Geologic Carbon Storage and Utilization" to be published by Wiley for the American Geophysical Union.
- D. W. Vasco, Masoud Alfi, Seyyed A. Hosseini, Rui Zhang, Thomas Daley, Jonathan B. Ajo-Franklin, and Susan D. Hovorka "The seismic response to injected carbon dioxide: Comparing observations to estimates based upon fluid flow modeling"
- Hosseini, S. A., Masoud Alfi, Donald Vasco, Susan Hovorka, Timothy Meckel, Validating compositional fluid flow simulations using 4D seismic interpretation and vice versa in the SECARB Early Test—A critical review
- Anderson, Jacob; Romanak, Katherine; Alfi, Masoud; Hovorka, Susan, Light Hydrocarbon and Noble Gas Migration as an Analog for Potential CO_2 leakage: Numerical Simulations and Field Data from Three Hydrocarbon Systems
- Fietz and Hovorka, Capturing the magic of carbon dioxide
- Hovorka, S.D. and Lu, J., Field observation of geochemical response to CO_2 injection at the reservoir scale, in Newel and Ilgen, Science of Carbon Storage in Deep Saline Formations , Elsevier

Appendix

Benefit to the Program

Development of large-scale (>1 million tons of CO_2) Carbon Capture and Storage (CCS) projects, which will demonstrate that large volumes of CO_2 can be injected safely, permanently, and economically into geologic formations representative of large storage capacity.

Project Overview

Goals and Objectives

The Southeast Regional Carbon Sequestration Partnership's (SECARB) Phase III work focuses on the large scale demonstration of safe, long-term injection and storage of CO_2 in a saline reservoir that holds significant promise for future development within the SECARB region. The project will promote the building of experience necessary for the validation and deployment of carbon sequestration technologies in the region. Phase III will continue refining Phase II sequestration activities, sequestration demonstrations and will begin to validate sequestration technologies related to regulatory, permitting and outreach. The multi-partner collaborations that developed during Phase I and Phase II will continue in Phase III with additional support from resources necessary to implement strong and timely field projects.