Feasibility of Geophysical Monitoring of Carbon-Sequestrated Deep Saline Aquifers

Project Number DE-FE0001160

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U.S. Department of Energy

National Energy Technology Laboratory
Carbon Storage R&D Project Review Meeting
Developing the Technologies and Building the Infrastructure for CO_2 Storage

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Outline

- Benefits to the program
- Project Overview
- Technical Status
- Accomplishments to date
- Summary

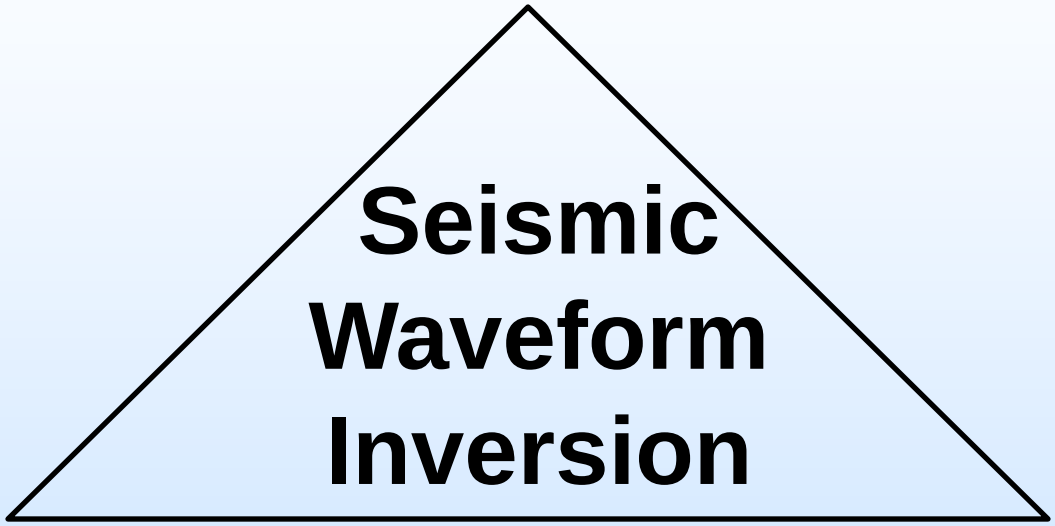
Benefit to the Program

- This research project is aimed at developing methods to monitor the CO_2 plume movements within the sequestrated reservoir volumes and account for the totality of the injected CO_2.
- It serves one of the major goals of the program:
  - Develop technologies to demonstrate that 99 percent of injected CO_2 remains within the injection zones.

Project Overview: Goals and Objectives

- Project Objectives:
  - Combine multiphase reservoir simulation with seismic modeling and inversion.
  - Verify if seismic data could be effectively used in predicting CO_2 saturation within the sequestrated reservoir volumes.
- Project Goal:
  - Develop technologies to demonstrate that 99 percent of injected CO_2 remains within the injection zones.

Technical Status

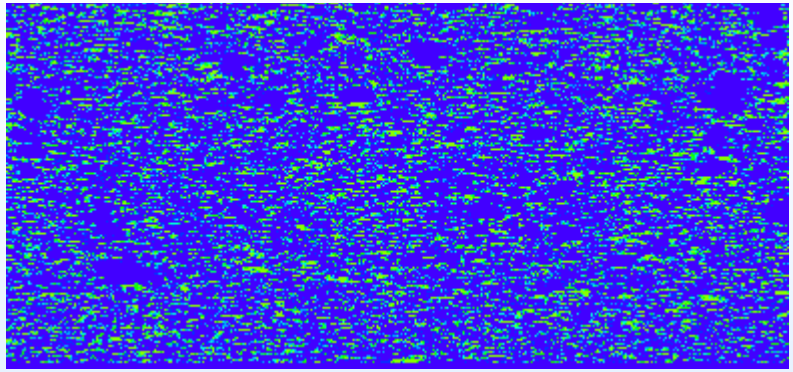


CO_2 Saturation Prediction

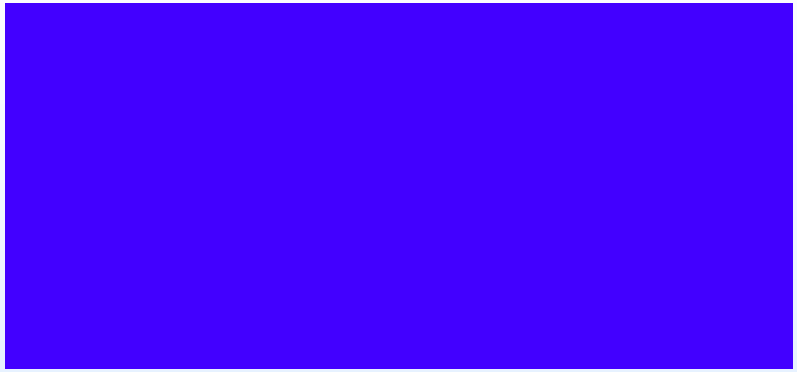
Flow simulation | **Seismic simulation**

Technical Status - Flow Simulation

Fine scale



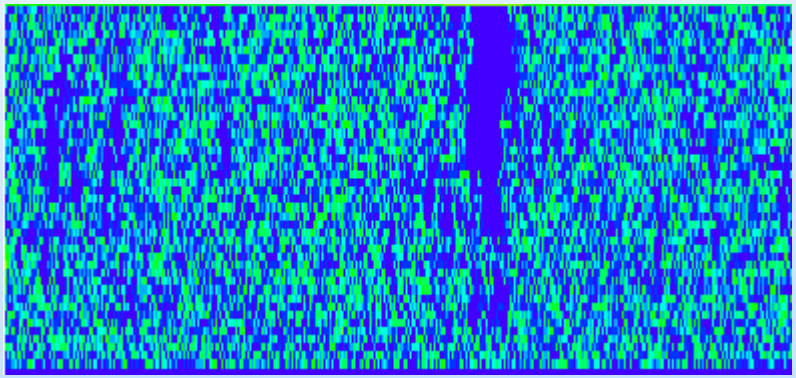
(a)



(b)

SPU

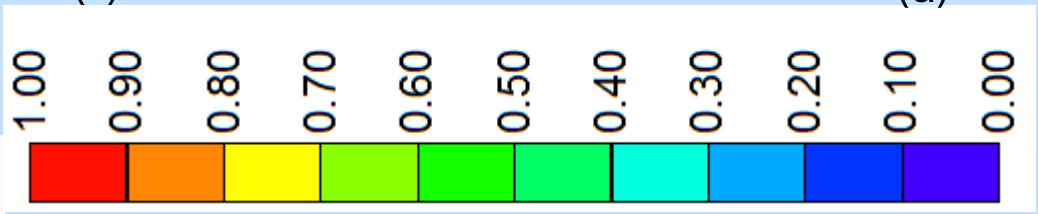
MPFU ~~Perc.~~



(c)

(d)

MPFU Perc.



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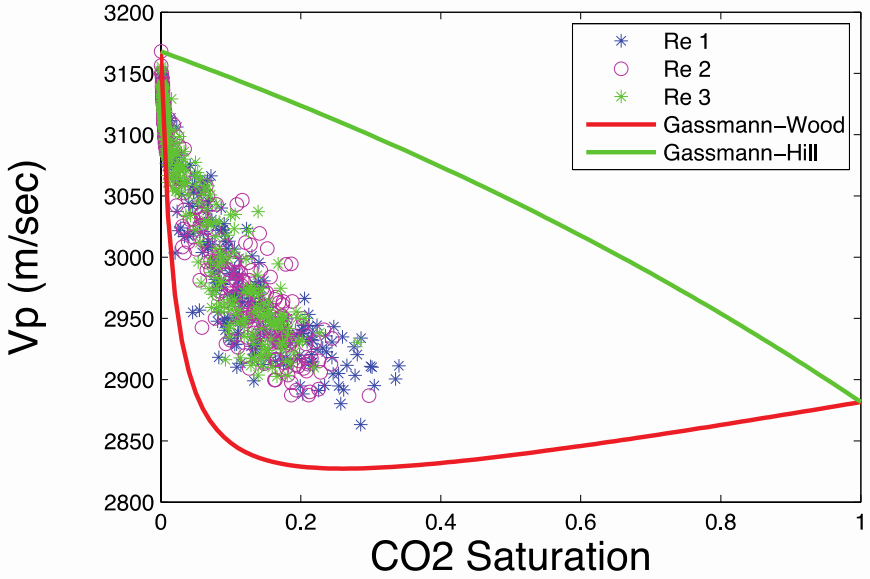
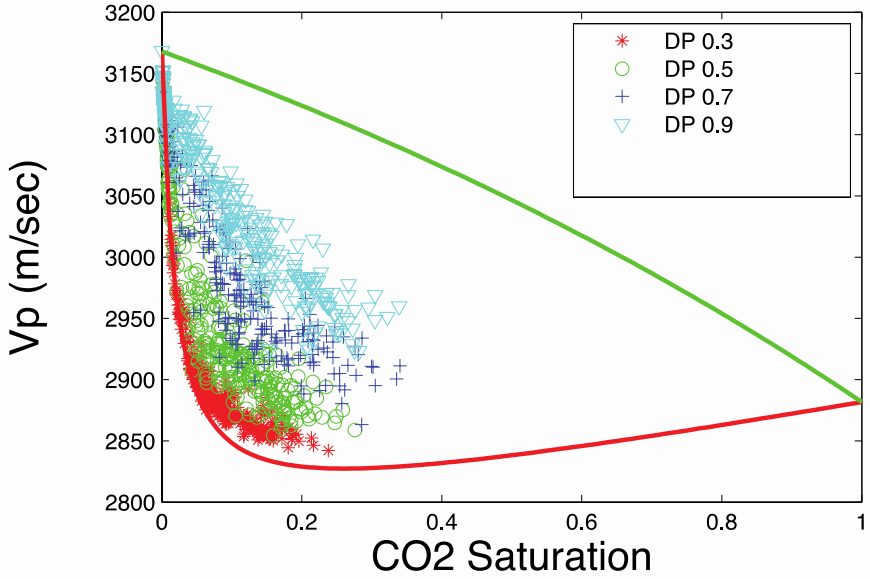
Technical Status- Flow Simulation

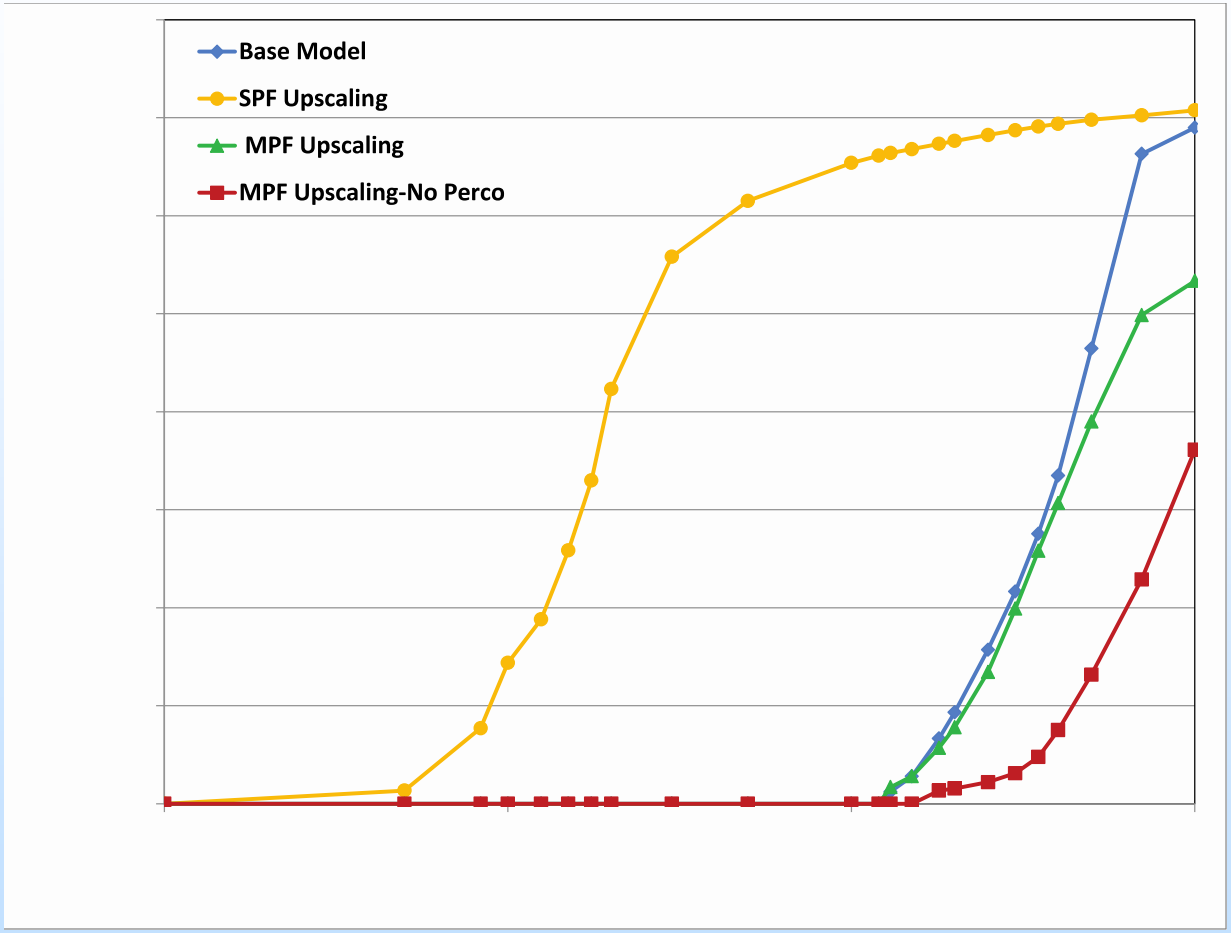




In randomly uncorrelated model:

- Vp-CO_2 relationship weakly dependent on realization
- Vp-CO_2 relationship depending on heterogeneity

Technical Status- Flow Simulation

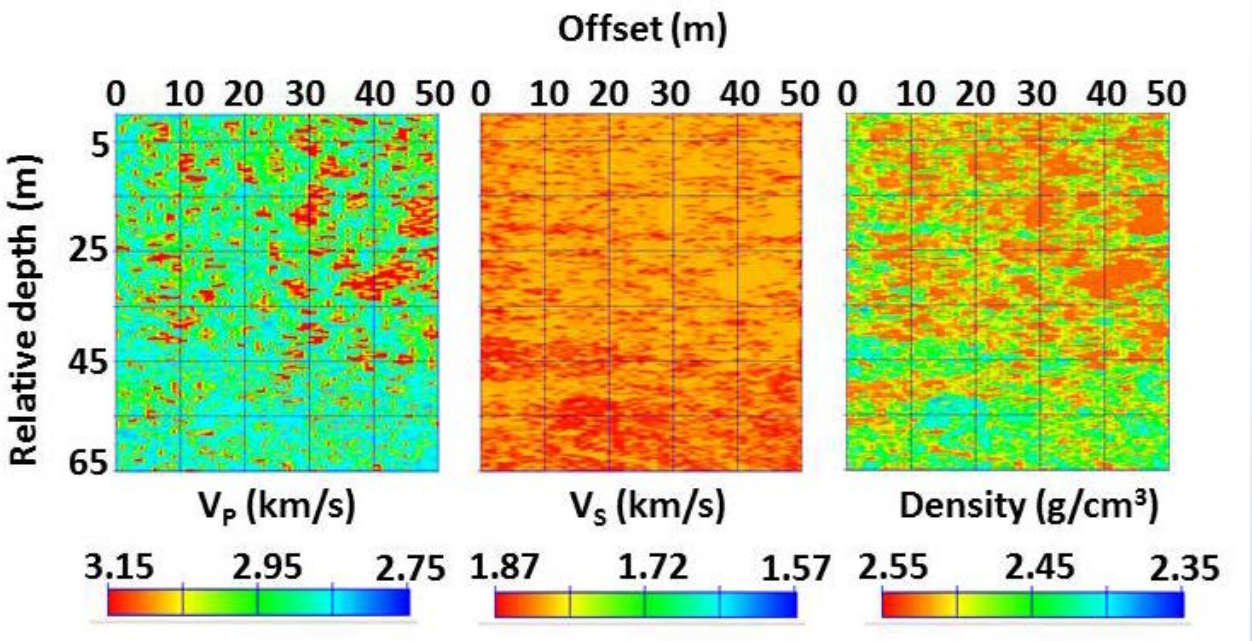


Proper upscaling that incorporates small-scale multiphase effects is necessary.

Take-away messages:

- If adequate upscaling is conducted →3D simulations useful to MVA based on seismic can be made practical with reasonable computational resources

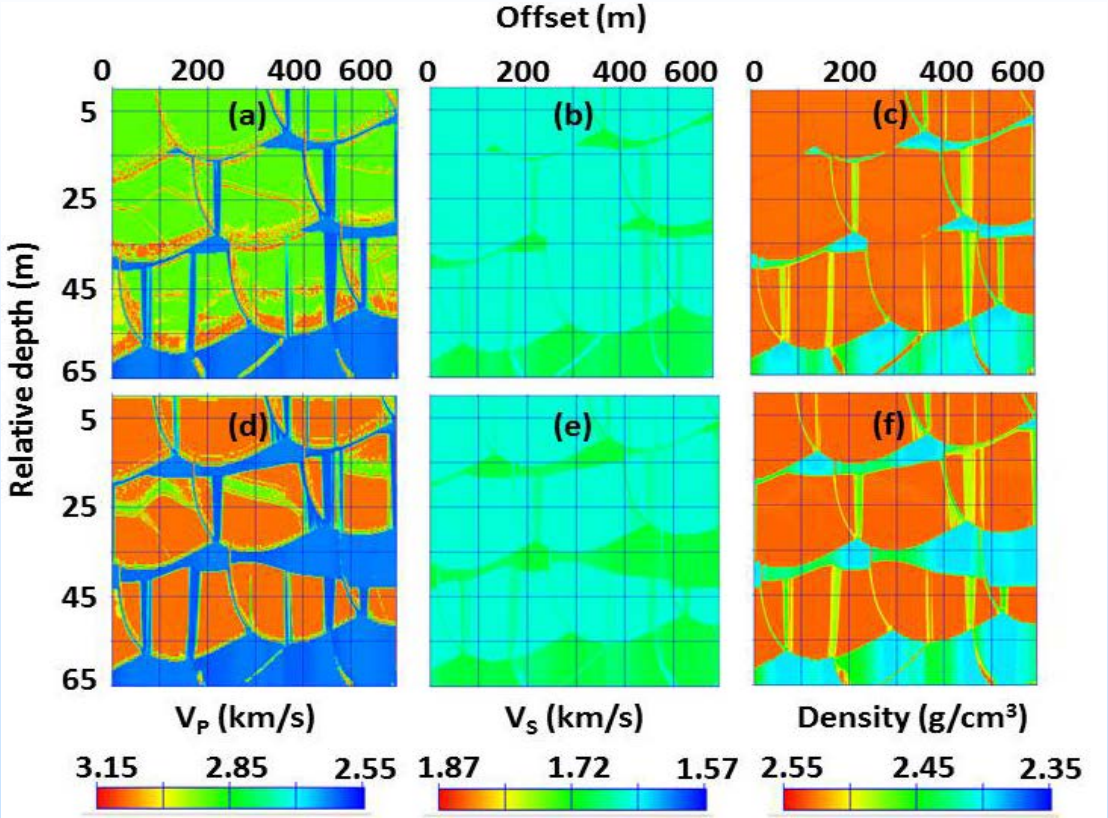
Technical Status- Flow Simulation



Randomly uncorrelated model:

- CO_2 sequestrated at the bottom of the reservoir
- The model shown is 25 years after sequestration

Technical Status - Flow Simulation



Eolian sand depositional system:

- CO_2 sequestrated from the bottom of the reservoir
- (a)-(c) the model 5 years after sequestration
- (d)-(f) the model 55 years after sequestration.

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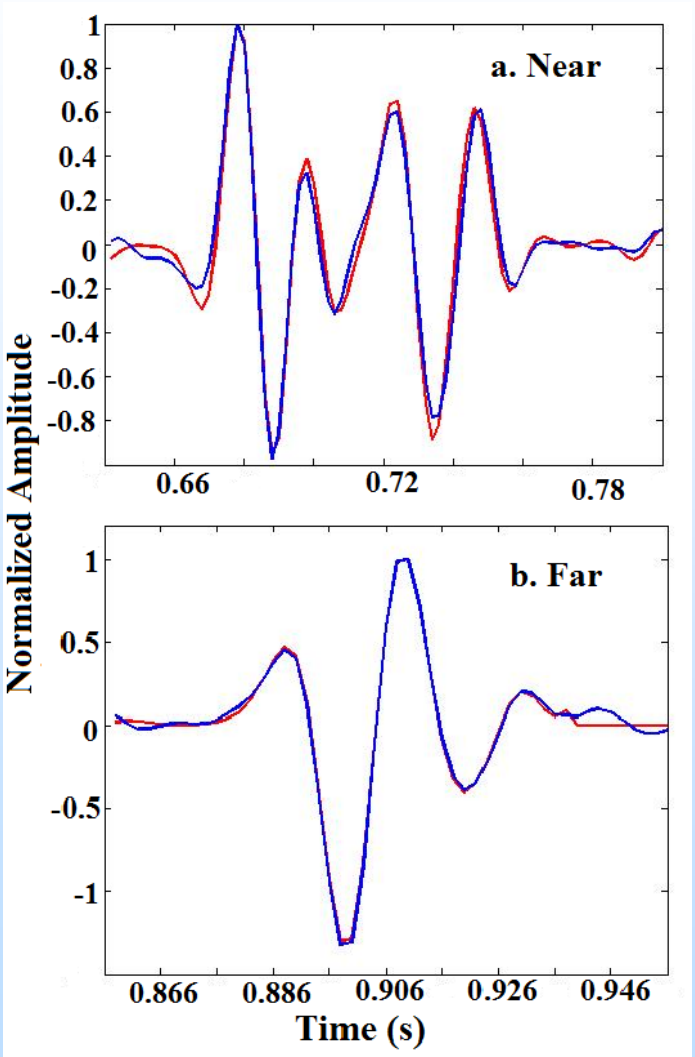
Technical Status – Seismic Simulation



Seismic Modeling of the random system:

- The red curve is the finite-difference computed seismic response from the reservoir using the exact reservoir model.
- The blue curve is the computed response where the exact reservoir model is replaced by an equivalent model of a few homogeneous layers.
- For the random system, the equivalent layers were all isotropic.

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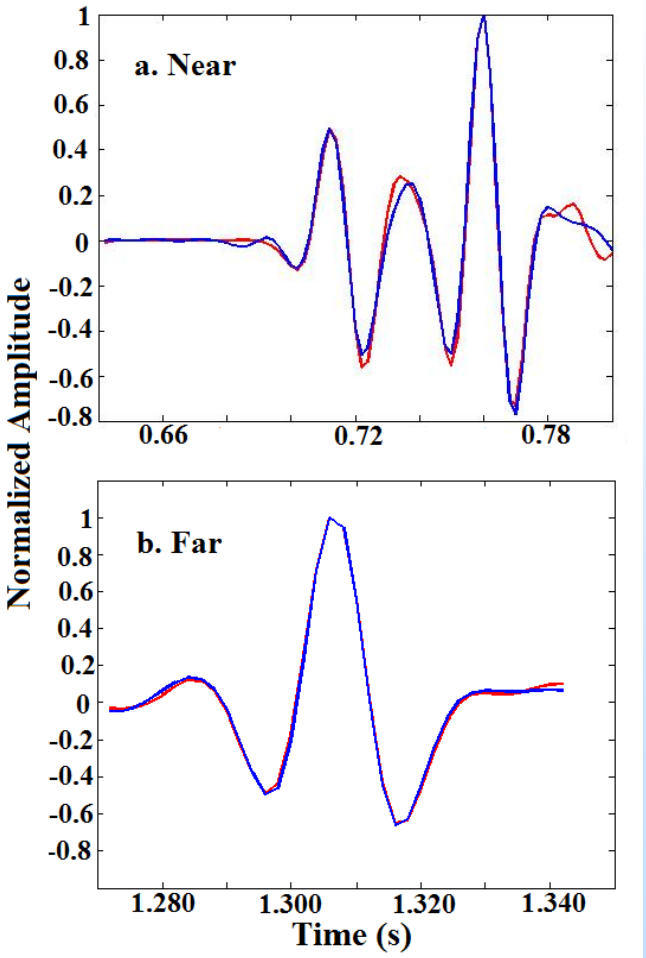
Technical Status – Seismic Simulation



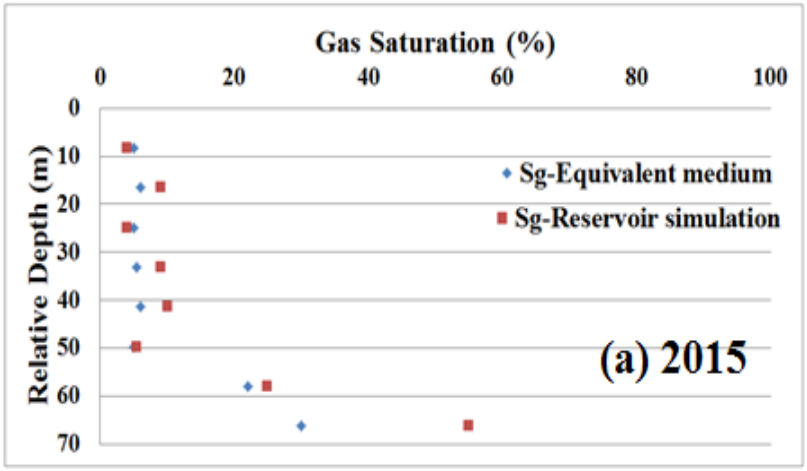
Seismic Modeling of the eolian system:

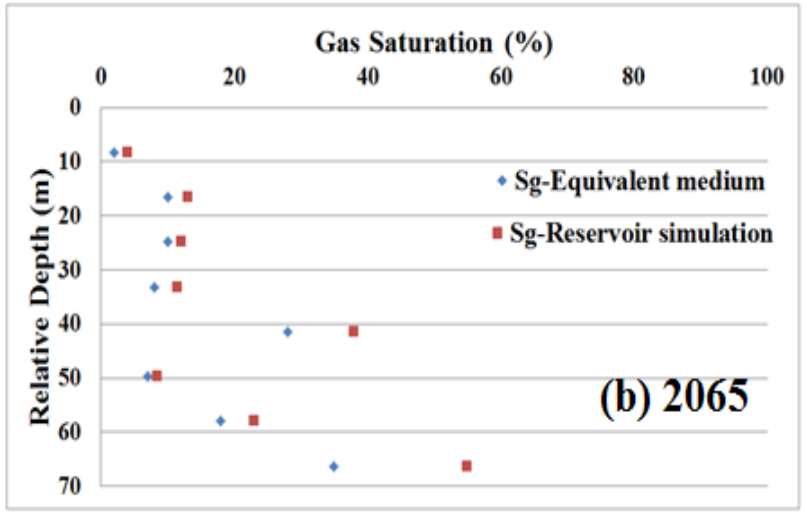
- The red and blue curves are the same as they were for the random
- The equivalent layers needed to be anisotropic.

Take-away message:

- CO_2 sequestration into realistic reservoir systems induce apparent anisotropy in the observed time-lapse seismic responses.
- For an accurate strategy for MVA, the seismic anisotropy cannot be ignored.

Technical Status – Seismic Simulation





Equivalent anisotropic models could reasonably predict CO_2 saturation.

Take-away messages:

- If time lapse seismic data could be inverted for anisotropic elastic properties →
  - Equivalent anisotropic properties can potentially predict the CO_2 saturation
- Important elements to a successful MVA →
  - Anisotropic seismic inversion
  - Calibration of seismic inversion with flow simulation

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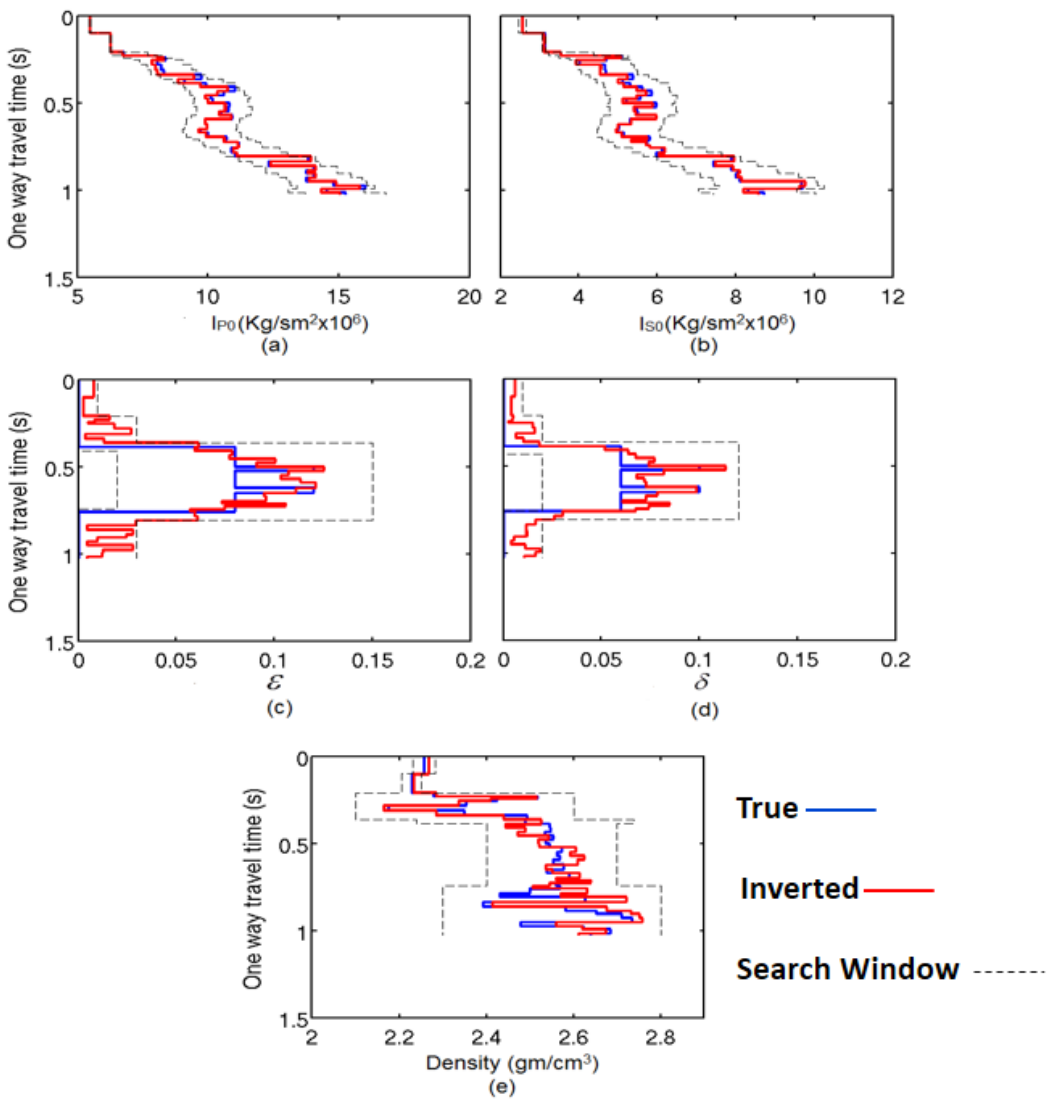
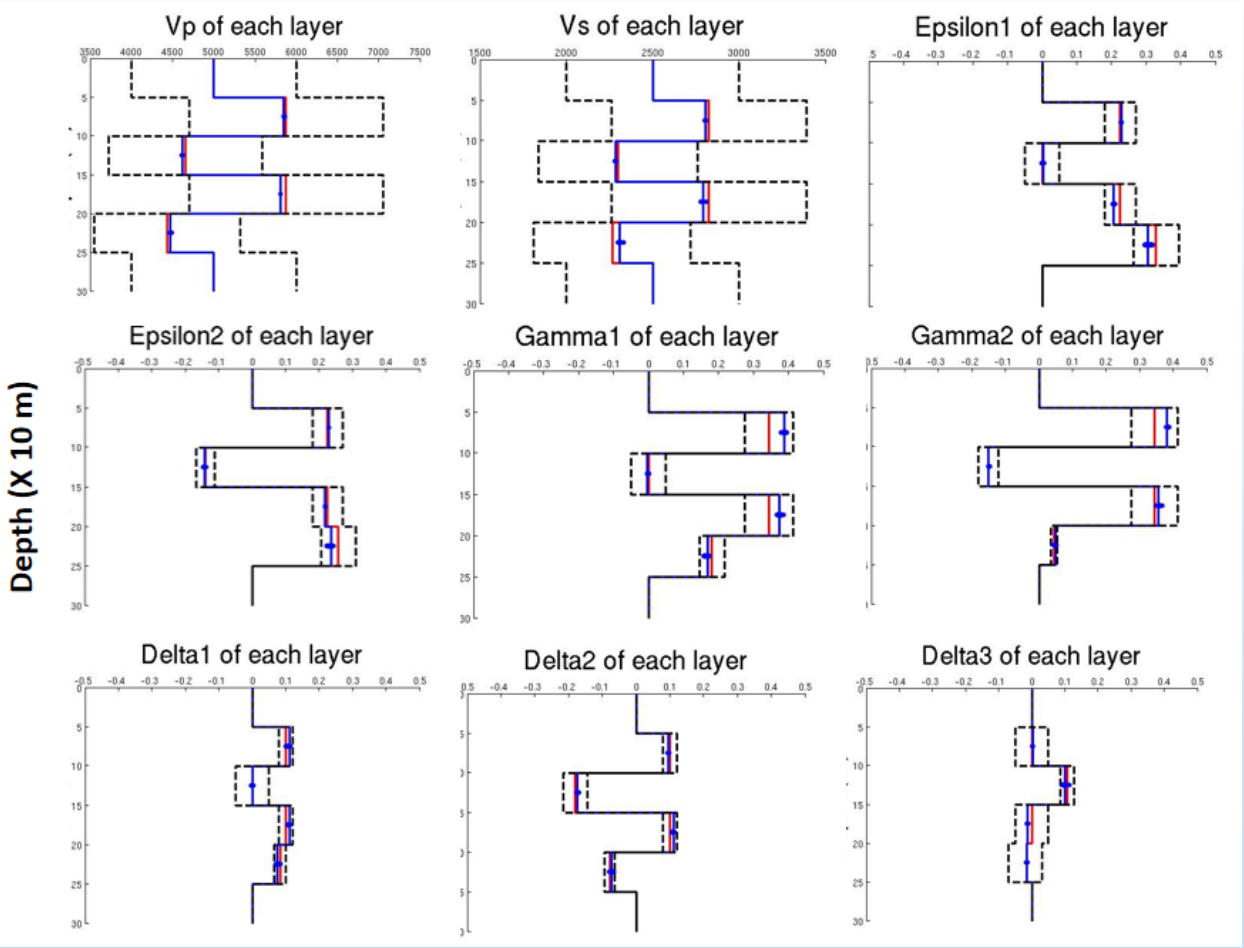
Technical Status – Anisotropic Inversion



Transversely Isotropic Medium with a Vertical Symmetry axis (VTI)

Model based on the Rock Springs Uplift (RSU-1) well

Technical Status – Anisotropic Inversion



Orthorhombic (ORT) Medium

Search Window — True — Inverted

Technical Status – Anisotropic Inversion

Take-away messages:

- Time-lapse seismic data could be inverted for anisotropic properties of the sequestrated reservoir volumes.
- These extracted anisotropic properties could then be used to predict CO_2 saturation within the reservoirs.
- Multicomponent seismic data are required for an accurate extraction of elastic parameters and density from data.

Accomplishments to Date

- Developed prestack waveform inversion (PWI) methodology:
  - Isotropic and VTI PWI is complete.
  - A prototype anisotropic PWI up to ORT is developed and is being tested.
- Demonstrated a complete workflow of calibrating seismic simulations with reservoir flow modeling in predicting the saturation of the injected CO_2 during the post-sequestration phases.

Summary

- Key Findings
  - Saturation of the injected CO_2 could be predicted by a proper calibration of seismic simulations with reservoir flow modeling.
- Lessons Learned
  - CO_2 injection induces anisotropy in observed seismic responses
  - A correct MVA strategy should include:
    - Acquisition and inversion of multicomponent seismic data
    - Flow modeling and calibration of seismic data with simulation models.
    - Anisotropic inversion for prediction of CO_2 saturation

Summary

- Future Plans
  - Flow modeling on Rock-Springs reservoir models.
  - Seismic simulations on Rock-Springs reservoir models and calibrate observed responses with the CO_2 saturation within the reservoir.
  - Complete the development of the anisotropic PWI.

Acknowledgements

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Thank You

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