Modeling the MT and CSEM Response to a scCO2 Plume at the Kemper CarbonSAFE Site

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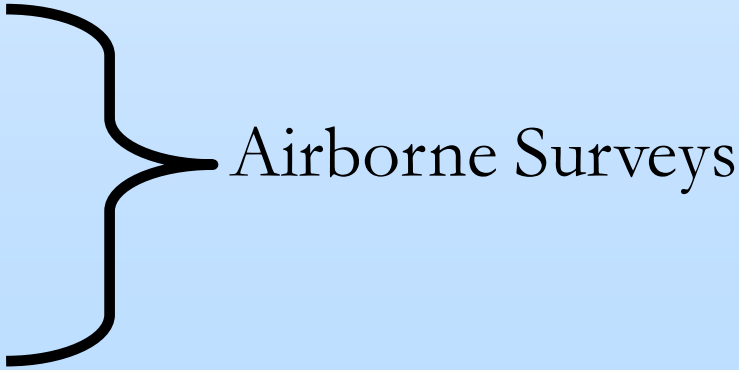
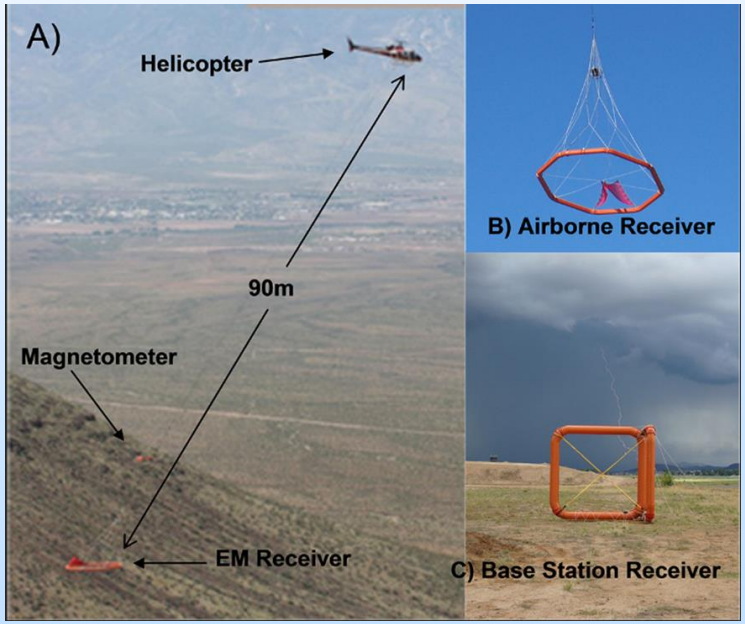
Motivation

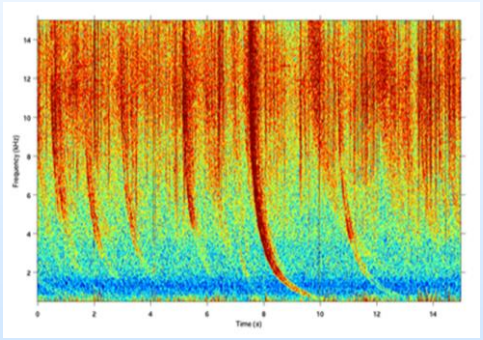
- Post-Injection Monitoring of Commercial Carbon Storage Sites (large areas, long duration)
- Limited tools
  - Monitoring wells – Poor spatial resolution
  - Repeat 3-D seismic – Poor temporal resolution
- Improvements
  - Lower Cost
  - Faster
  - Less Landowner Impact
  - AI Friendly

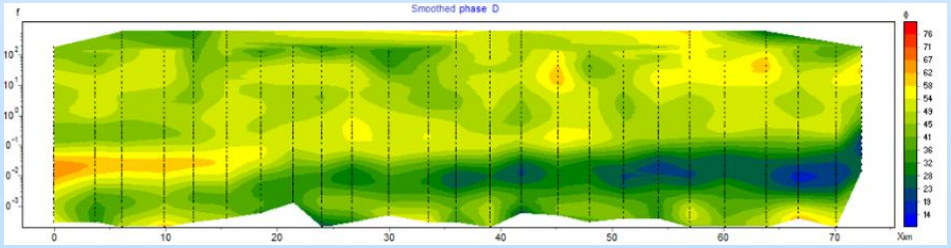


Airborne Monitoring of Carbon Storage Sites

2009 AGU – Geotech presents modeling results that suggest helicopter magnetotellurics (MT) can detect CO_2/brine boundary at 800 m depth







Approach

- Forward Model the Response of an Airborne Magnetic Sensor
  1. Magnetotellurics (MT)
  2. Controlled Source Electromagnetics (CSEM)
  3. Charged Well Casing Electromagnetics (CWCEM)

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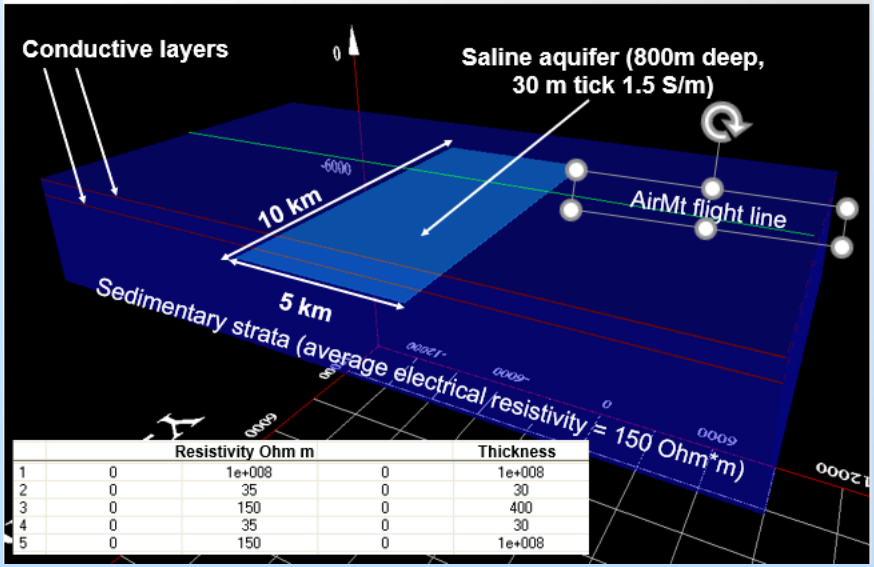
Approach

- Forward Model the Response of an Airborne Magnetic Sensor to Two Carbon Storage Scenarios:
  1. Hypothetical model used by Geotech
  2. Kemper CarbonSAFE



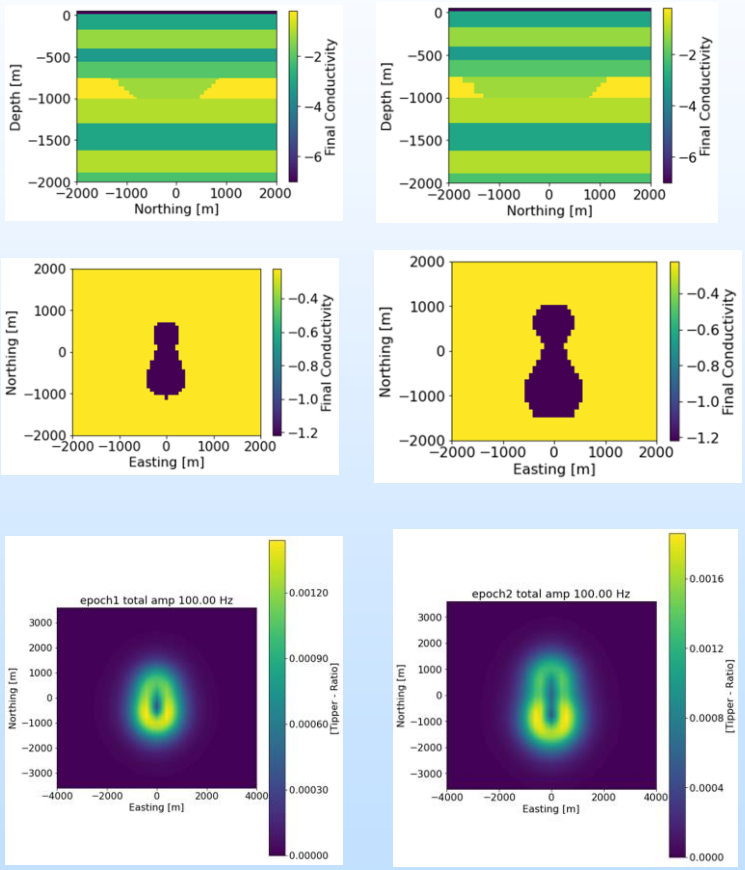
		Resistivity Ohm m		Thickness
1	0	1e+008	0	1e+008
2	0	35	0	30
3	0	150	0	400
4	0	35	0	30
5	0	150	0	1e+008

Technical Status

- Reproduce Geotech results
  - Helicopter Magnetotelluric
  - Reservoir @ 800m depth
  - Tipper

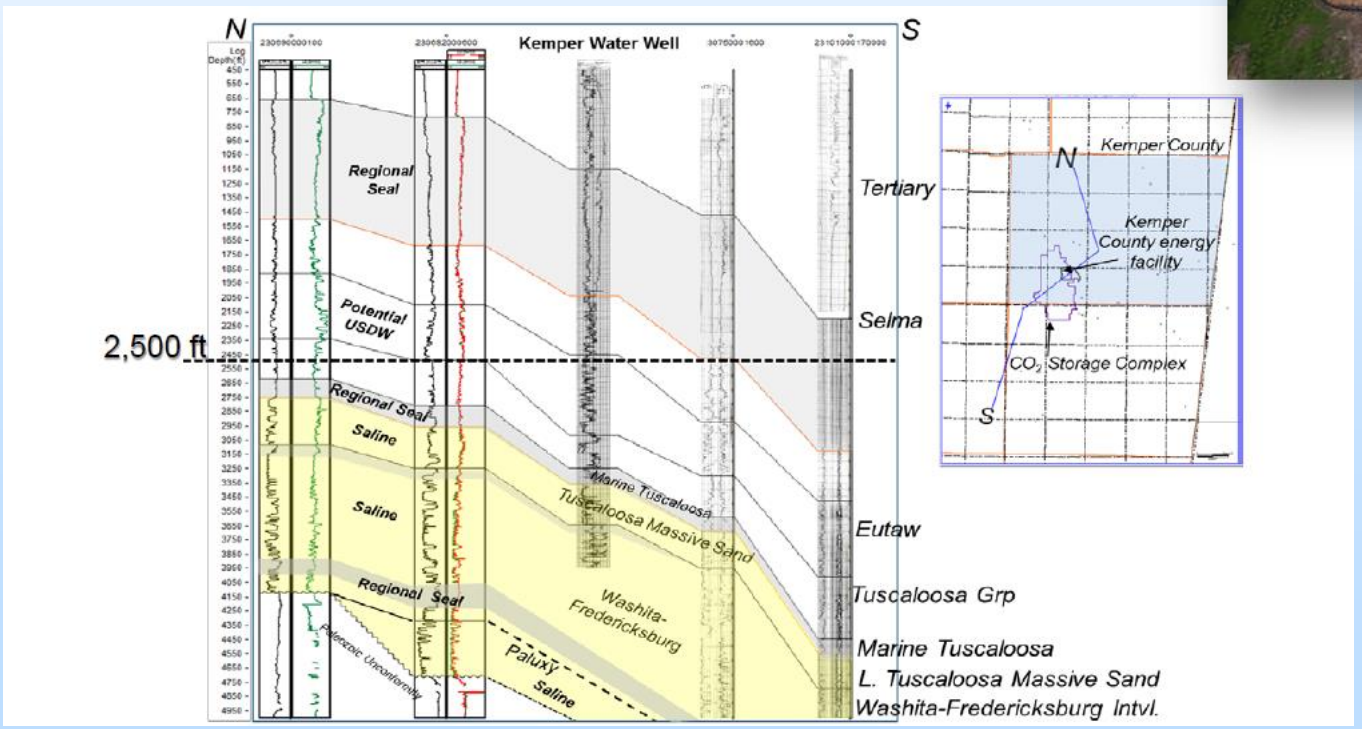
$$\boldsymbol{Tipper}: \quad \boldsymbol{H_z} = T\boldsymbol{H} = \left(T_{zx}, T_{zy}\right)\begin{pmatrix}\boldsymbol{H_x}\\ \boldsymbol{H_y}\end{pmatrix}$$

Geotech Model Confirmed!



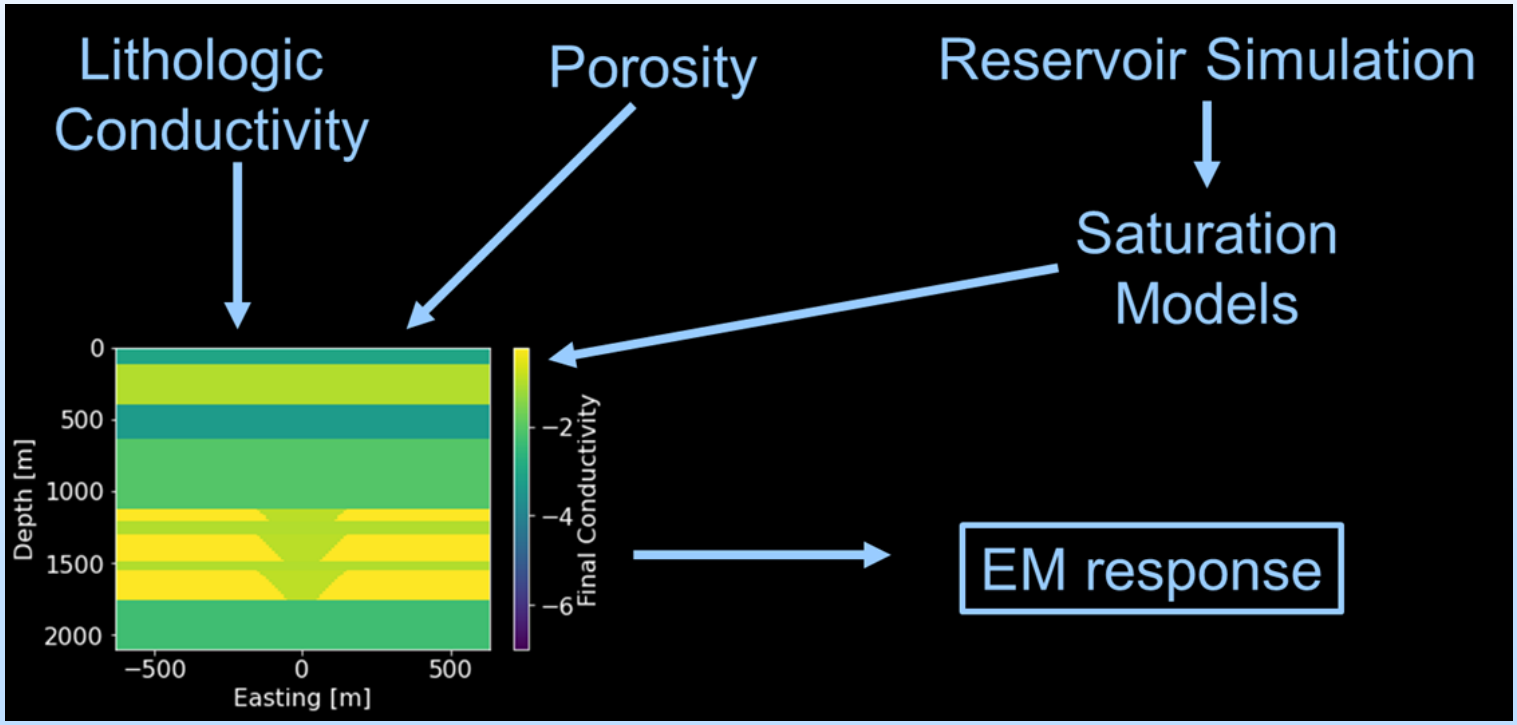
Technical Status

- Model Kemper CarbonSAFE Site
  - Shallow Reservoir
  - Thick Reservoir



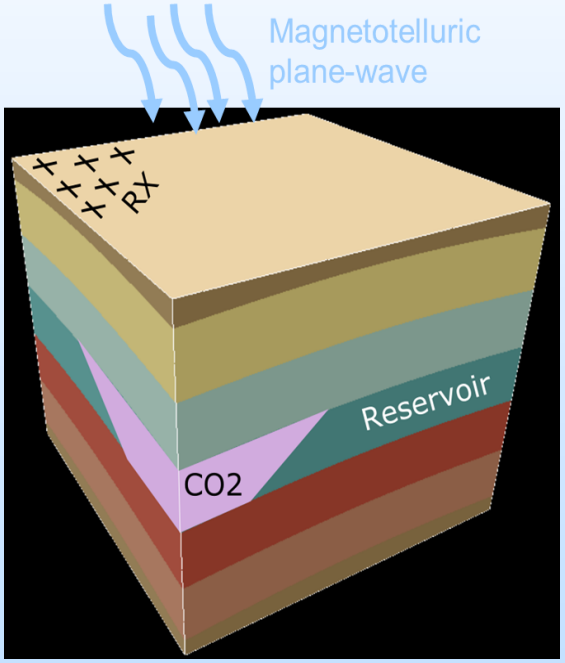
Technical Status

- Build Geoelectric Model for Kemper CarbonSAFE

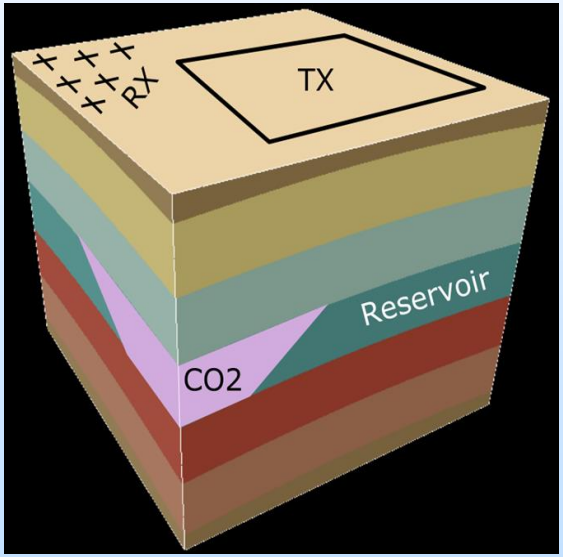


Technical Status

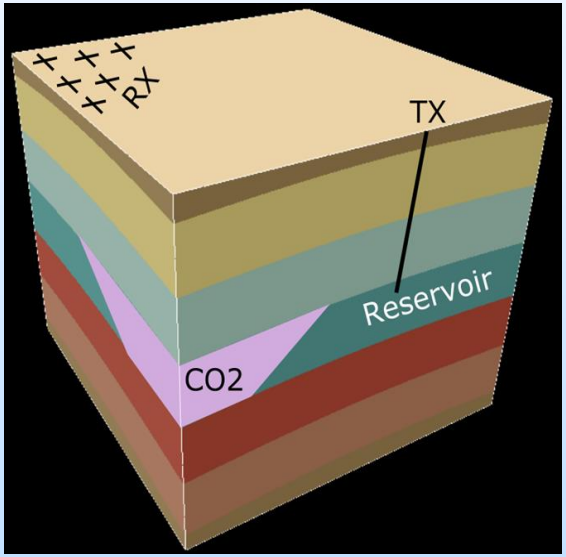
- Electromagnetic Techniques Modeled



MT



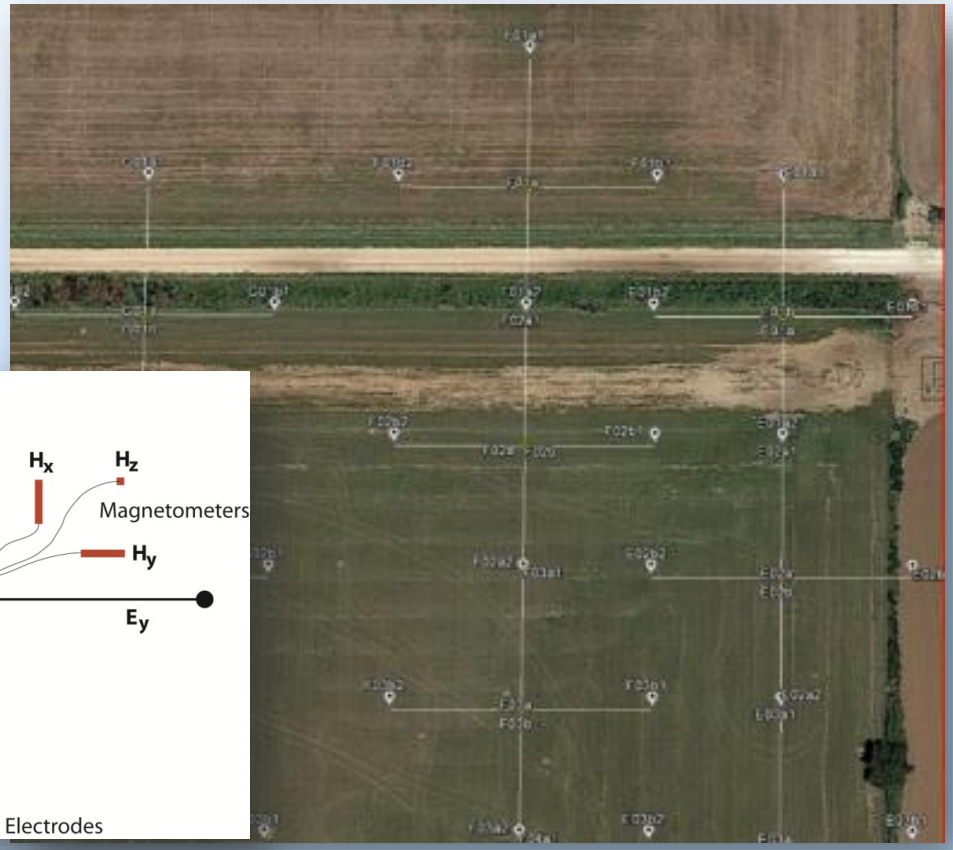
CSEM

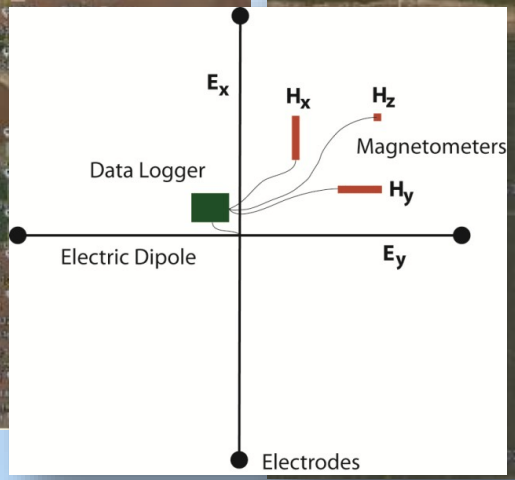


CWCEM

Technical Status

- Conventional EM techniques measure both magnetic and ~~electrical~~ fields

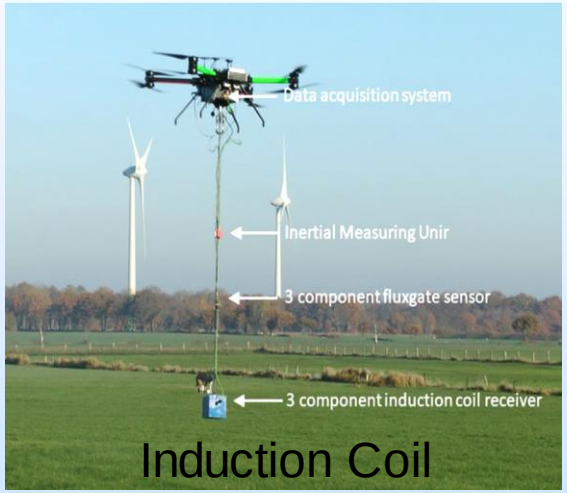




Technical Status

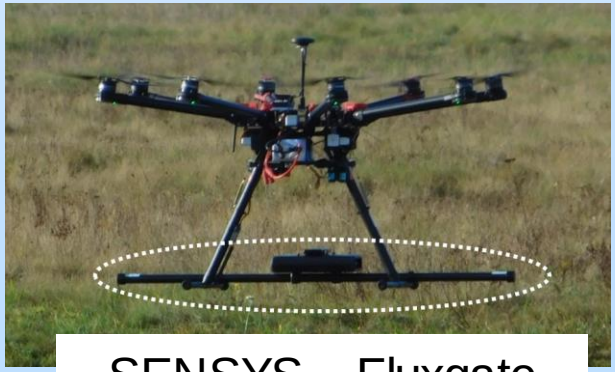
- Airborne 3-Component Magnetic Sensors

Geotech – Induction Coil



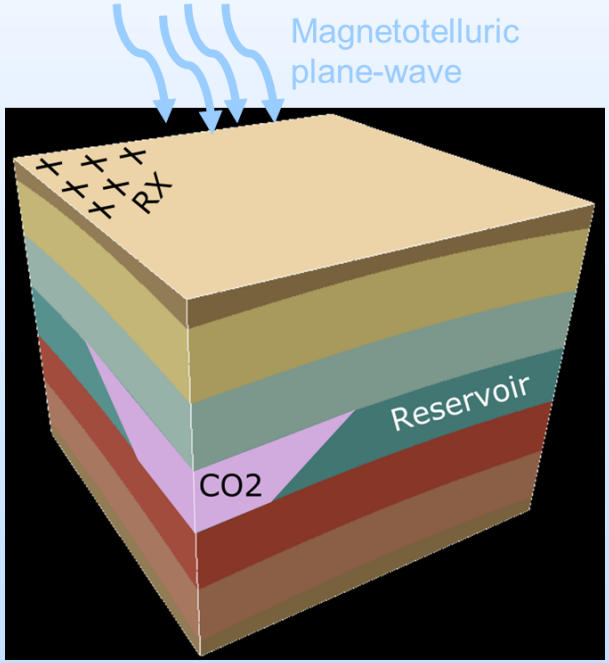
Induction Coil

Supracon – SQUID

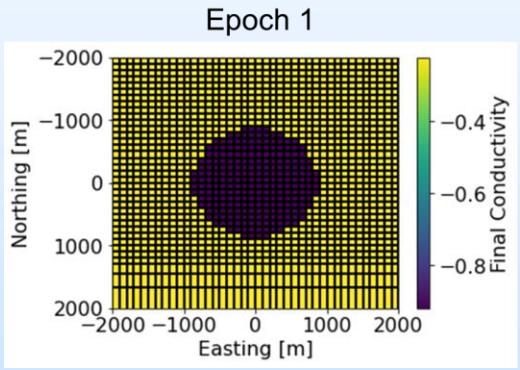

SENSYS – Fluxgate

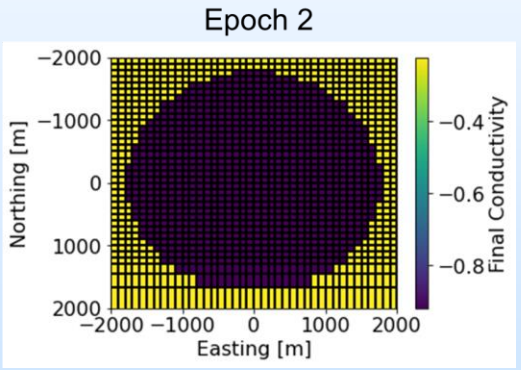
Technical Status

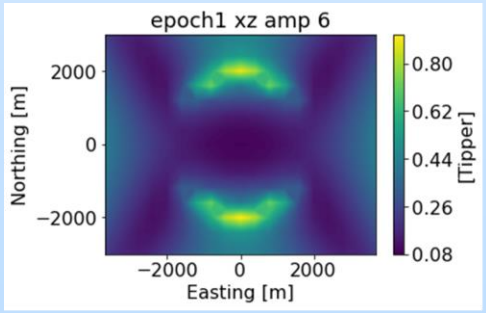
- Modeling the MT (Tipper) response using Kemper CarbonSAFE Geoelectric Model

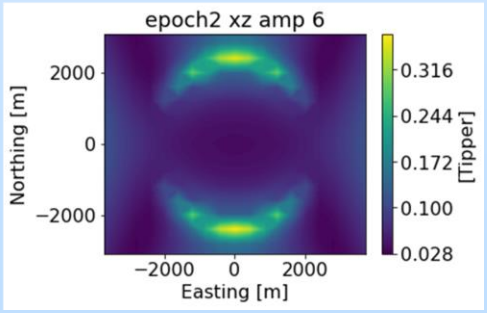


MT



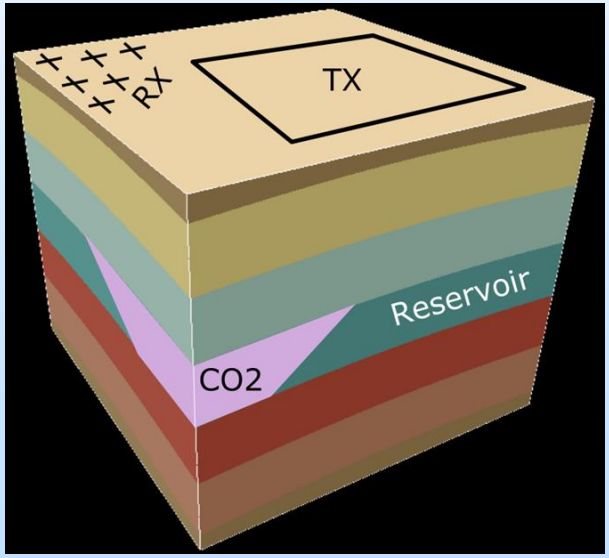




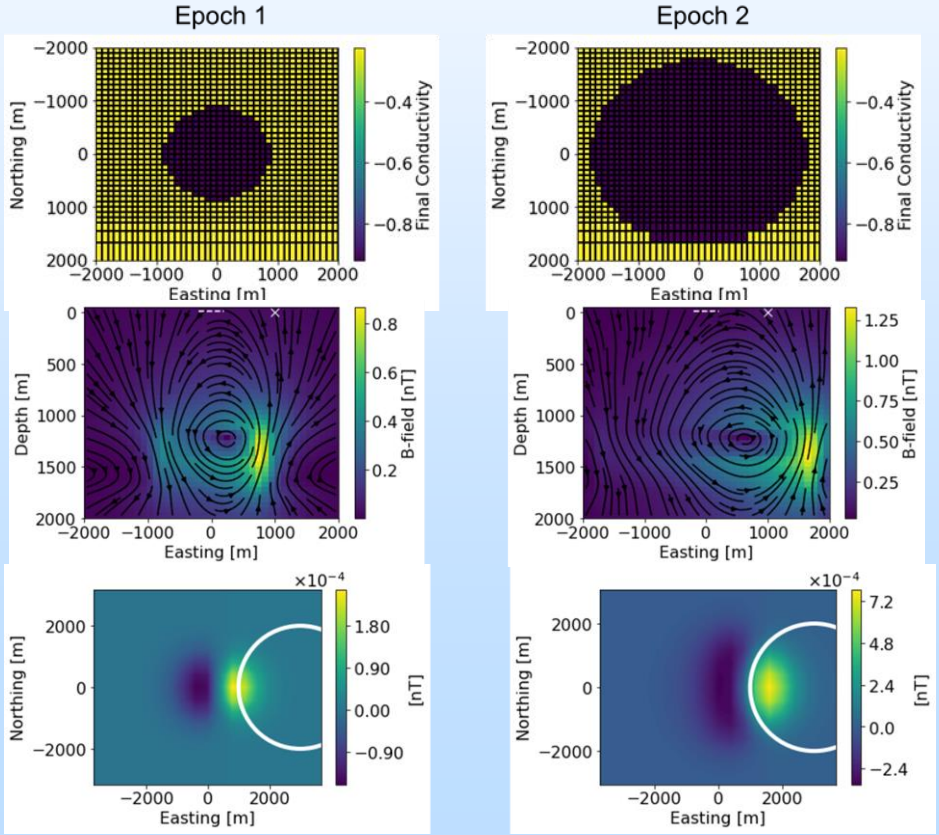


Technical Status

- Modeling the CSEM response using Kemper CarbonSAFE Geoelectric Model

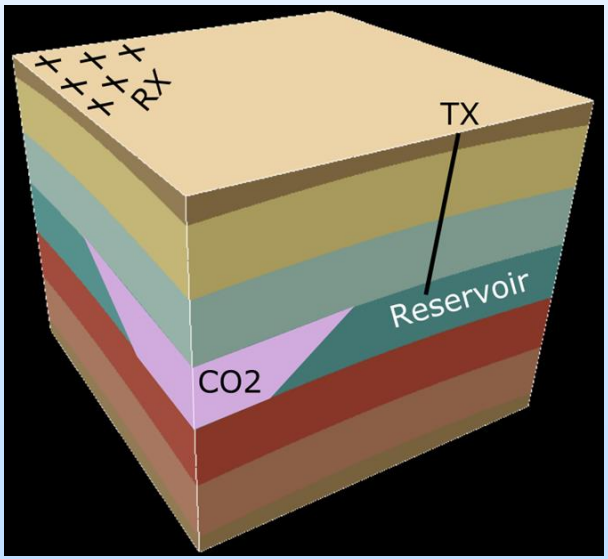


CSEM

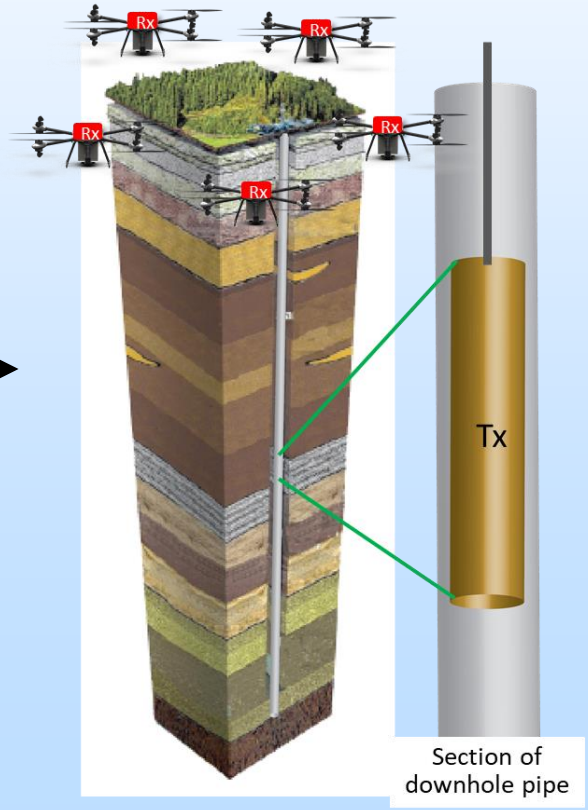


Technical Status

- Modeling the CWCEM response using Kemper CarbonSAFE Geoelectric Model



CWCEM

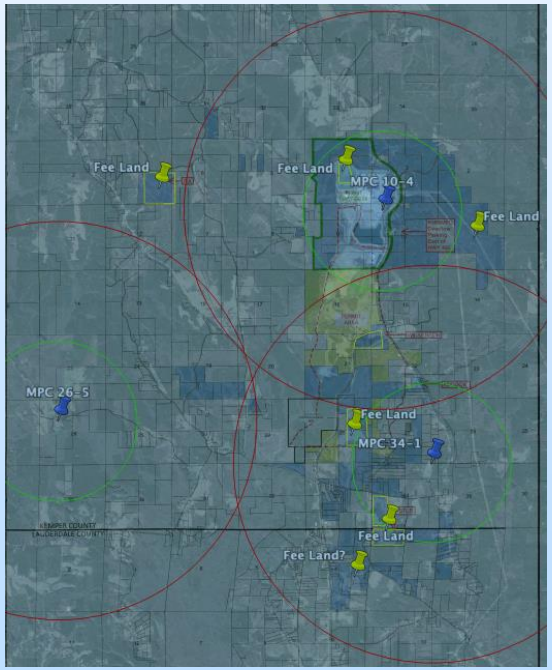


Downhole Source

C- eBeam Source

Technical Status

- Near-Term Work
  - Modeling Downhole EM Sources
  - Baseline MT and CSEM Surveys at Kempton



Proposed MT/CSEM Survey Areas

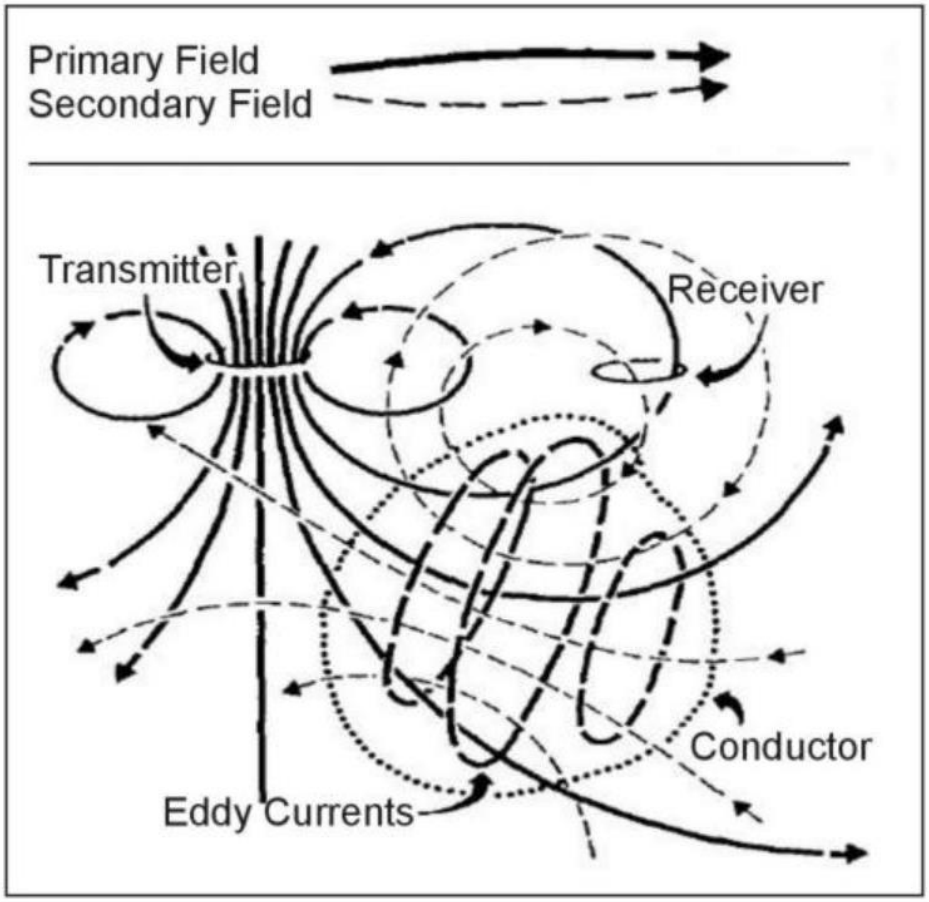
Supracon SQUID Magnetometer

Accomplishments to Date

- Confirmed Geotech Modeling Results of 2009
- Prepared geoelectric models for Kemper CarbonSAFE
- Modeled MT "tipper" response for Kemper CarbonSAFE
- Modeled CSEM response for Kemper CarbonSAFE

Lessons Learned

– For CSEM, the transmitter should not be located directly over the CO_2 plume



Synergy Opportunities

- Kemper CarbonSAFE team
- Illinois CarbonSAFE team
- Enig Associates- development of downhole C-eBeam source

Project Summary

- **Key Findings**
  - MT can distinguish CO_2 vs. brine-filled pore space at 800 m depth
  - MT tipper should be excellent for mapping the CO_2/brine interface at Kemper CarbonSAFE
  - CSEM can map the CO_2 plume extent with multiple transmitter locations
- **Next Steps**
  - Ground MT and CSEM surveys at Kemper CarbonSAFE using SQUID magnetometer
  - Modeling the surface magnetic response to downhole transmitters- determine optimum transmitter depth WRT injection formation.

Appendix

- These slides will not be discussed during the presentation but are mandatory.

Benefit to the Program

- Program Goals Being Addressed
  - Insuring CO_2 storage permanence

- Program Benefits
  - Lowers the cost of post-injection monitoring at commercial-scale CO_2 storage sites
  - Minimizes impact to surface landowners because surveys are done by aircraft-manned or drone
  - Method is sensitive to all CO_2 saturations; seismic is only sensitive to CO_2 concentration below 40%

Project Overview

Goals and Objectives

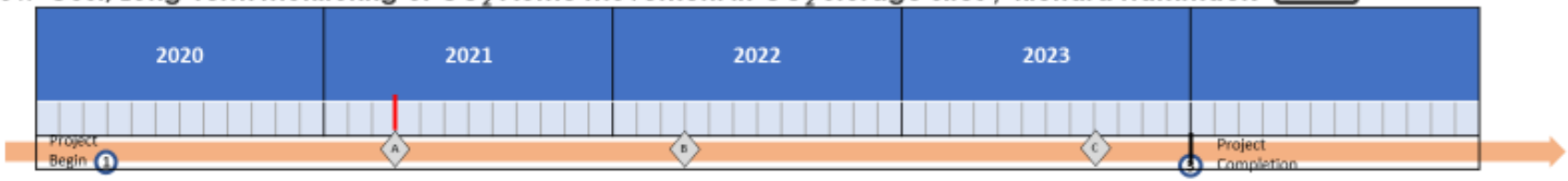
- Describe the project goals and objectives in the Statement of Project Objectives.
  - How the project goals and objectives relate to the program goals and objectives.
  - Identify the success criteria for determining if a goal or objective has been met. These generally are discrete metrics to assess the progress of the project and used as decision points throughout the project.

Gantt Chart

NEW Task 34: Project Timeline Overview

NATIONAL ENERGY TECHNOLOGY LABORATORY

Low-Cost, Long-Term Monitoring of CO_2 Plume Movement in CO_2 Storage Sites / Richard Hammack



Milestones

A. Complete feasibility study on the use of drone electromagnetic methods to detect the CO_2 plume in storage formations. (March 31, 2021).

Go/No Go Decision Point. (March 31, 2021) Success Criterion – Modeling predicts that geophysical sensor/drone combination(s) will detect CO_2 plume in typical storage scenario.

B. Baseline MT and CSEM testing at Kempton CarbonSAFE complete (March 31, 2022)

C. Drone/sensor system field tested at well-characterized CO_2 storage location. (Sep. 30, 2023)

Requested Funding

EY 20	$110K
EY 21	$200K
EY 22	$200K
EY 23	$200K
Total	$710K

Impact

Key Accomplishments/Deliverables	Value Delivered
1. Scoping report describing opportunities to use drone aircraft for CO_2 storage site monitoring (3/31/2021). 2. Airworthiness report for drone-mounted sensor. (3/31/2022). 3. Report comparing drone plume location with borehole results (12/31/2023).	• Rapid mapping of CO_2 plume in storage reservoir. • Low-cost monitoring of CO_2 storage site, facilitating frequent repeat surveys and ensuring excellent temporal resolution of reservoir changes. • Surveys are designed to be inobtrusive to surface landowner.

U.S. DEPARTMENT OF ENERGY

(#) TRL Score | Go / No-Go Timeframe | Project Completion | Milestone | Chart Key

14

Bibliography

- Publication in Conference Proceedings:
  - Kohnke, C., Li, Y., and R. Hammack, 2021, The Feasibility of MT tipper data to monitor CO_2 storage sites, Proceedings of the 2021 SEG Annual Meeting, Denver, CO, Sept 26-Oct 1, 2021.