EFFICIENT DETECTION OF UNINTENDED LATERAL MIGRATION OF CO_2 PLUME IN ONSHORE GULF OF MEXICO (TEXAS, USA)

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ABSTRACT

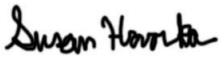
Carbon capture and storage (CCS) is a key technology for mitigating climate change, and the industrialized Gulf Coast is a prime location. However, many industries that need CCS also compete with it. Fractured surface ownership creates complex negotiations and often irregular storage leases that must be mapped to avoid ~1M legacy wells. Combined with geologic complexity and uncertain CO_2 plume migration, these create significant risks to storage operators, including trespass and potential leakage if CO_2 contacts unremediated wells. Effective and cost-efficient monitoring of injected CO_2 is critical for long-term storage assurance.

Time-lapse seismic is a proven monitoring tool, but often expensive. This study explores novel deployment strategies to minimize monitoring costs. We simulated seismic responses under varying geological and fluid conditions using wedge modeling to understand detection thresholds. Static properties like porosity and clay content, along with dynamic factors such as CO_2 saturation and patchiness, were tested across a range of frequencies. Results show that a 28 Hz seismic signal can detect plume thicknesses as small as ~28.3 meters. Among the parameters tested, patchiness had the strongest influence on reflectivity, followed by saturation and frequency, while clay content had minimal impact. These findings inform the design of cost-effective, site-specific monitoring plans.

We analyze seismic monitoring options including repeat 3D ($50k–$100k per square mile) and repeat 2D ($5k–$20k per linear mile). This work demonstrates the potential of sparse 2D and other lower-cost seismic approaches to detect lateral plume migration, offering a practical alternative to more expensive methods. By combining geophysical sensitivity analysis with cost modeling, the study highlights trade-offs in detectability and economics—providing data-driven insights to guide operator decisions and evolving EPA Class VI expectations.

Acknowledgment to GCCC and colleagues for the opportunity to work on the project, with thanks to Shuvajit Bhattacharya and Chao Li for rock physics modeling guidance, and Sergey Fomel and Rebecca Gao for geophysical modeling.’

(Alexander Bump)



(Susan Hovorka)