RESEARCH PERFORMANCE PROGRESS REPORT

U.S. Department of Energy National Energy Technology Laboratory

Cooperative Agreement: DE-FE0031558

Project Title: Partnership for Offshore Carbon Storage Resources and Technology Development in the Gulf of Mexico

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Project Period: April 1, 2018 – March 31, 2023

Reporting Period End Date: December 31, 2018

Report Frequency: Quarterly

Signature Submitting Official: ____

EXECUTIVE SUMMARY OF RESEARCH DEVELOPMENTS DURING THIS QUARTER

Project management activities included the following:

- Revised / updated PMP (project management plan).
- Revised TMP (technology maturation plan).
- Revised DMP (data management plan).
- Implemented augmented Partnership SOPO and funding.
- Implement remaining sub-recipient awards from the original SOPO and funding.
- Established an LoA (letter of agreement) with the UT Petroleum and Geosystems Engineering Department.
- Continued WebEx video-conference calls with Partners.

The Louisiana Geological Survey (LGS) Partner compiled a table listing contacts for state agencies in charge of various aspects of the Louisiana State waters.

In the Chandeleur Sound Survey Area, six stratigraphic tops were interpreted. The new interpretations relied predominantly on existing interpretations of three 2D seismic lines that intersect the area.

The Partnership has access to three HR3D (high-resolution 3D) survey datasets within the greater High Island area of interest Recent research progress on a 2017 HR3D dataset from another NETL suggests that the quality of HR3D may be similarly improved by re-processing the datasets. Re-processing of the three Gulf of Mexico HR3D datasets progressed.

The PI of project Partner Lamar University began literature searches for the simulation and equation of state modeling of CO_2 stored in underground reservoirs.

LLNL (Lawrence Livermore National Laboratory) worked with GCCC on geomechanical modeling plans for the High Island 24L site. GCCC and LLNL agreed on data exchange formats to get geomodel data being developed at GCCC into LLNL's geomechanical / reservoir simulation package. Actual geo-model data should be available next quarter, when detailed modeling work can begin.

Partner, Trimeric Corp., reviewed and summarized well and pipeline data for the High Island offshore Texas state waters area. Trimeric also reviewed and summarized offshore CO_2 pipeline costs based on publically available literature.

Lamar University began planning and preparing for the February 2019 first annual Partnership meeting in Beaumont, TX. Lamar will host the meeting on the university campus.

GoMCarb staff rom Lamar University prepared for a teacher's STEM workshop to be held on 17 January, 2019) where hands-on demonstrations will be provided to southeast Texas area teachers.

Task 1.0 – Project Management, Planning, and Reporting

Revised PMP (project management plan), TMP (technology maturation plan) and DMP (data management plan) were generated and submitted to the NETL project manager (PM).

Augmented Partnership SOPO and funding was implemented. In addition to significantly augmenting Partnership's budget and scope, the period of performance was extended from four to five years.

The subcontract for Partner, TDI-Brooks, Inc., was finalized and fully executed.

Dr. Robert Finley was hired as a consultant for the Partnership.

Letters of agreement (LoA) with the University of Texas (UT) 1) Petroleum and Geosystems Engineering Department, Department of Geological Sciences and Stan Richards School of Advertising and Public Relations were established, covering non-BEG UT partners.

WebEx video-conference calls continued for various Task groups (e.g., Tasks 2, 3, 4, 5 and 6).

Recruiting of potential graduate research assistants for the fall 2019 semester began.

Plans for purchasing HR3D (high-resolution 3D) seismic equipment progressed in discussions with the manufacture/vendor, Geometics.

Task 2.0 – Offshore Storage Resource Assessment

Subtask 2.1 – Database development:

Subtask 2.1.1 – Geographic Focus Area A - Lake Jackson, Lake Charles, and Lafayette (OCS) districts

The Louisiana Geological Survey (LGS) compiled Table 2.1.1, a list of contacts for the Louisiana offshore (State waters).

Table 2.1.1 – State agencies responsible for Louisiana State Waters and the agencies', respective, primary contacts.

State/Federal Agency	Role in resource management	Contact person1 , email, phone and position	Contact person 2 e-mail phone # and positon	Date of initial contact re GoMCarb	Interest in more information? Details...	Invite to GoMCarb Meeting Feb 2019?
LA DNR- oil and gas -offshore	La DNR is responsible for all oil and gas activities in the State	David P. Elfert, Director Geologic Division. David.Elfert@la.gov 225/342-5501 Byron Miller, Administrator, Office of Mineral Resources, Geology, Engineering and Lands division, 225/342-7121 Byron.Miller@la.gov				
LA DNR – status of Class VI primacy	Injection and mining Activities in the state	Stephen Lee, Director Stephen.Lee@la.gov 225/342-5567				
BOEM –Gulf coast section	Regional Supervisor (?)	Mike Celata, Regional Director, Gulf of Mexico 1-800-299-4853				

		Mike.Celata@Boem.gov				
Corps of engineers						
Regulator pipelines	LA DNR Pipeline division	Steven Giambrone, Diretor. 225/342-2989 Steven.Giambrone@la.gov Michael Peikert, Asst. Director 225/219-3799 Michael.Peikert@la.gov				
Coastal environmental protection	Supervisor (?)	Charles Reulet, Administrator, Interagency affairs,Compliance and Field Servisces 225/342-0861 Charles.Reulet@la.gov				
Fisheries protection						
Additional contacts needed...						

Subtask 2.1.2 – Geologic Characterization of Chandeleur Sound, LA

In the Chandeleur Sound Survey Area (SA), six (6) stratigraphic tops have been interpreted, including the top of Cretaceous. The new interpretations relied predominantly on existing interpretations of three ION seismic lines that intersect the SA. Table 2.1.2.1 tabulates the currently interpreted stratigraphic tops and their associated ages per the Basin Margin Genetic Sequences defined by the GBDS (University of Texas, Gulf Basin Depositional Synthesis), and Figure 2.1.2.1shows a seismic cross-section of these interpreted stratigraphic tops.

Table 2.1.2.1 Interpreted Horizons in Chandeleur Sound SA as of December, 2018

Abbreviation	Name	Upper Age (Ma)
UM	Upper Miocene	6.05
MM	Middle Miocene	11.61
LM2	Lower Miocene 2	15.58
LM1	Lower Miocene 1	18.07
OF	Frio – Vicksburg	23.41
NT	Navarro-Taylor	66.3

Figure 2.1.2.1 removed because of proprietary data content.

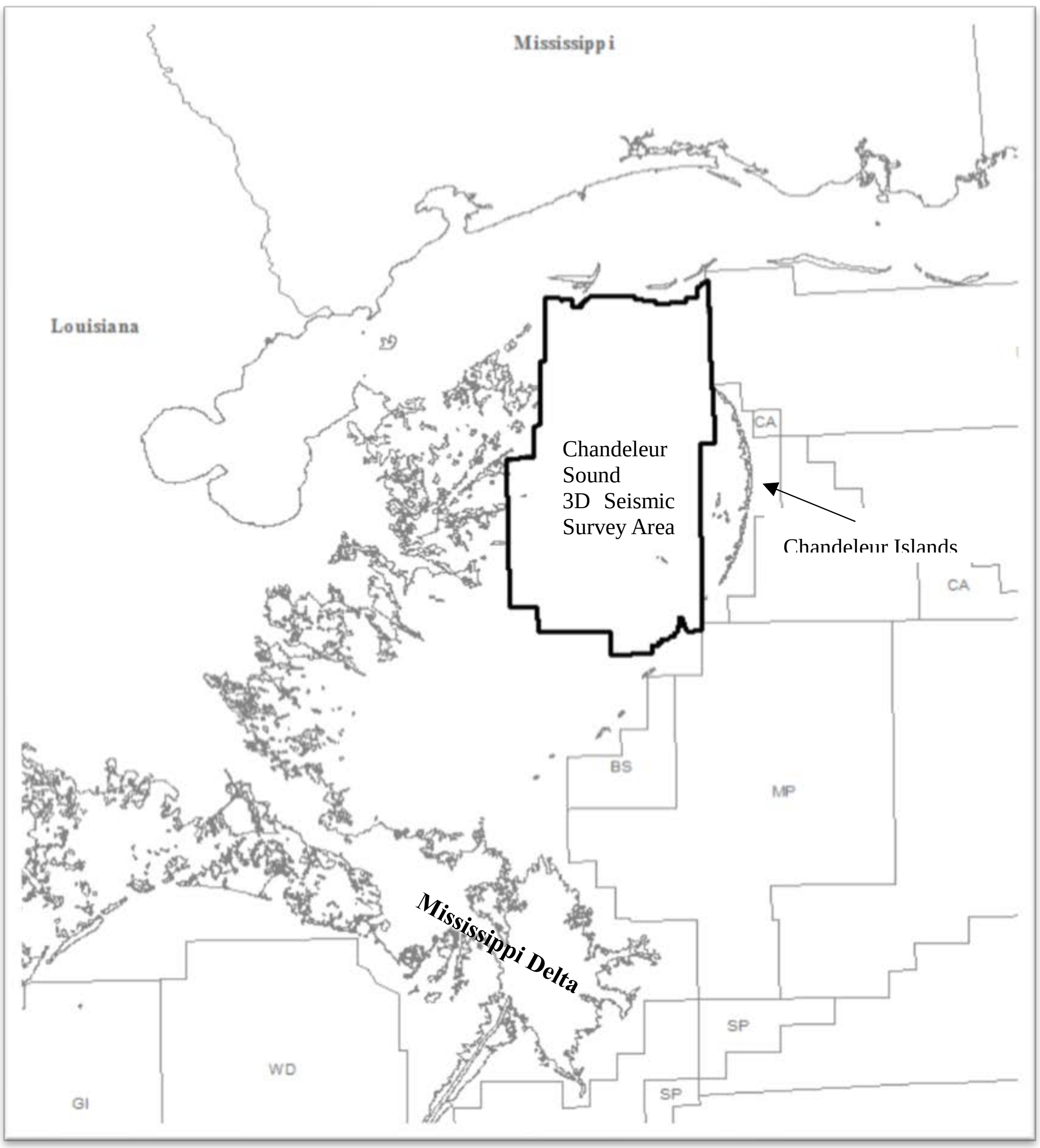
Figure 2.1.2.1 Seismic Cross section of interpreted stratigraphic boundaries as of December 2018

Literature mining & Reference library

Literature searches are continuously conducted for the Chandeleur Sound Area, and relevant publications are added to the internal GBDS library for this project. In addition to constructing a regional understanding of the SA, the publications are scanned for methodologies that may benefit the interpretation of the Chandeleur SA and overall objectives of the GoMCarb Partnership. If a previously applied method tested in Chandeleur SA proves useful, it will be incorporated into our methodology and interpretation.

Geologic Setting of Chandeleur Sound

The Chandeleur Sound 3D Seismic Survey Area is located in state waters offshore eastern Louisiana loosely bound by the southern coast of Mississippi to the North, the Chandeleur Islands to the East, and the modern



Mississippi delta to the South (Figure 2.1.2.2). The Survey Area is bisected by the NW/SE trending Albian Shelf Margin (also referred to as the mid-Cretaceous Louann Salt Detachment) characterized by extensive faulting. The northern half of the SA is on the continental shelf characterized by low-relief geologic structures and stratigraphy with little-to-no faulting. The southern half of the SA is characterized by isolated salt canopies and mini basins resulting in localized disturbance of stratigraphy (Figure 2.1.2.3).

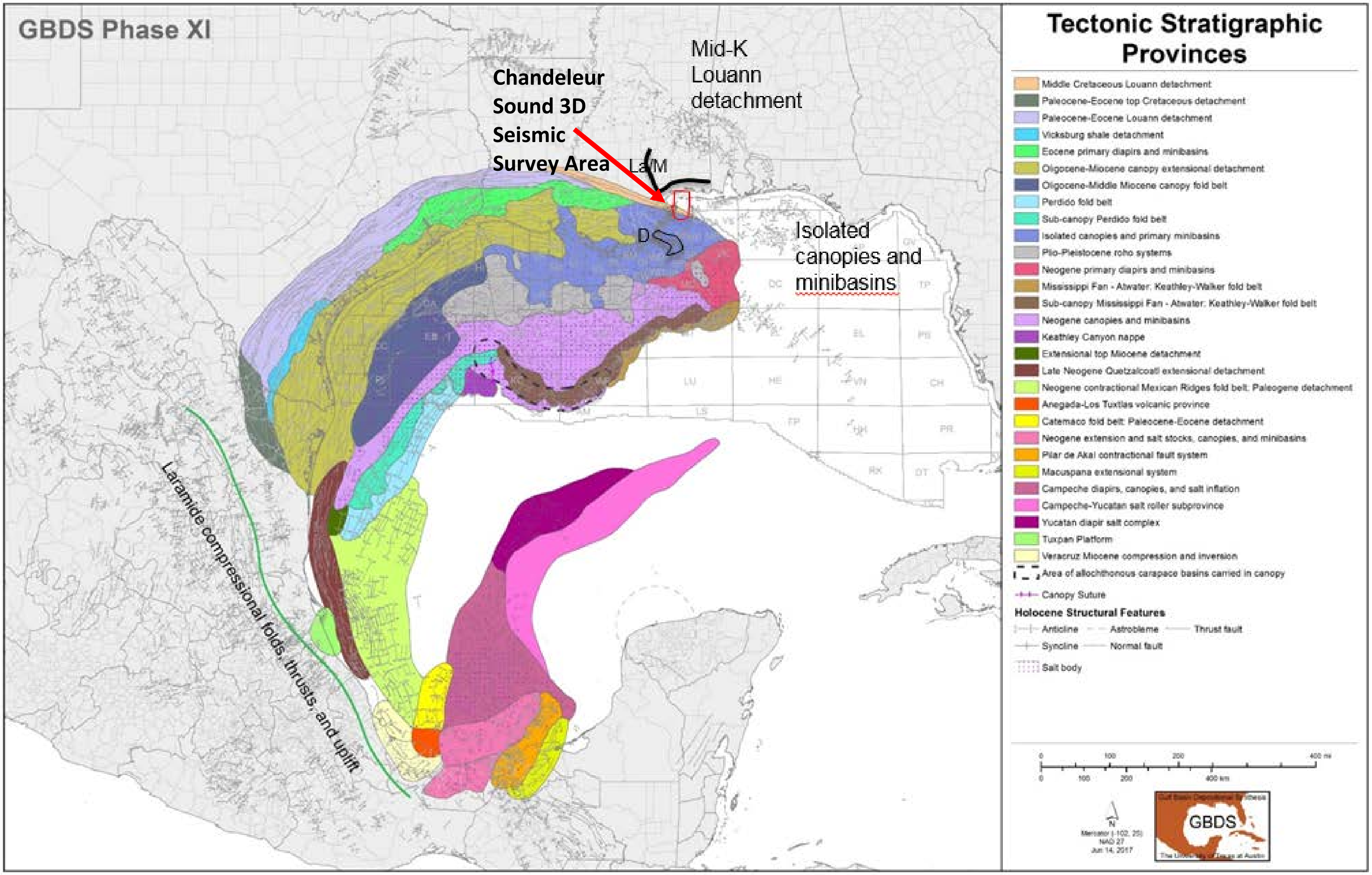


Figure 2.1.2.3 Regional interpretation of Tectonic Stratigraphic Provinces in the GoM. Produced by the GBDS, Phase XI, 2017

Subtask 2.1.3 Geologic Characterization of High Island, TX

General progress on re-processing and improving the utility of HR3D survey

The Partnership has access to three HR3D (high-resolution 3D) survey datasets within the greater High Island area of interest (Figure 2.1.3.1). Internally, the datasets are informally named GOM2012, GOM2013, and GOM2014 because they were acquired in the Gulf of Mexico (GOM) in 2012, 2013 and 2014, respectively. Recent research progress on a 2017 HR3D dataset from project DE-FE 0028193 “DOE-Field Validation of MVA Technology for Offshore CCS: Novel Ultra-High-Resolution 3D Marine Seismic Technology” (aka “Tomakomai”) suggests that the quality of HR3D GOM datasets may be similarly improved by re-processing the datasets.

The re-processing efforts on the GOM datasets follow some of the new methods developed for the Tomakomai survey. In fact, the major problem with increasing resolution in each survey is an uncertainty problem related to the position of the hydrophones within each shot. These error are post GPS processing and account for small errors due to the hydrophone either being out of line (feathering) or diving and resurfacing motions (i.e., in the water column) caused by the tow line geometry. Work is ongoing in this area.

In addition, signal-processing methods were developed to remove electrical noise using Weiner filters as opposed to using conventional notch filters. Surprisingly, Weiner filtering produces much better spatial resolution. Most of the work in this subject area is well understood and will be integrated into the processing flow at a later time.

Work to be done after positional uncertainty is corrected includes

- 3D Statics
- 3D Balancing
- 3D Deconvolution
- FXY Filtering
- Interpolation (Madagascar)
- Fault and feature enhancement

Positional uncertainty

To date, all HR3D surveys have some issues related to the calculation of receiver positions. As experience with the HR3D wide array layout progressed over the course of the three GoM HR3D surveys, the coordinate problems were recognized and successively minimized. However, remaining positional uncertainty relates to actual XY positions versus calculations, thereof. Usually the GPS coordinates are measured on key areas of the spread, and each individual hydrophone’s XY coordinates are interpolated. What was found in Tomakomai and confirmed in the GoM HR3D datasets is that minor variations in XY position occurred frequently throughout all surveys.

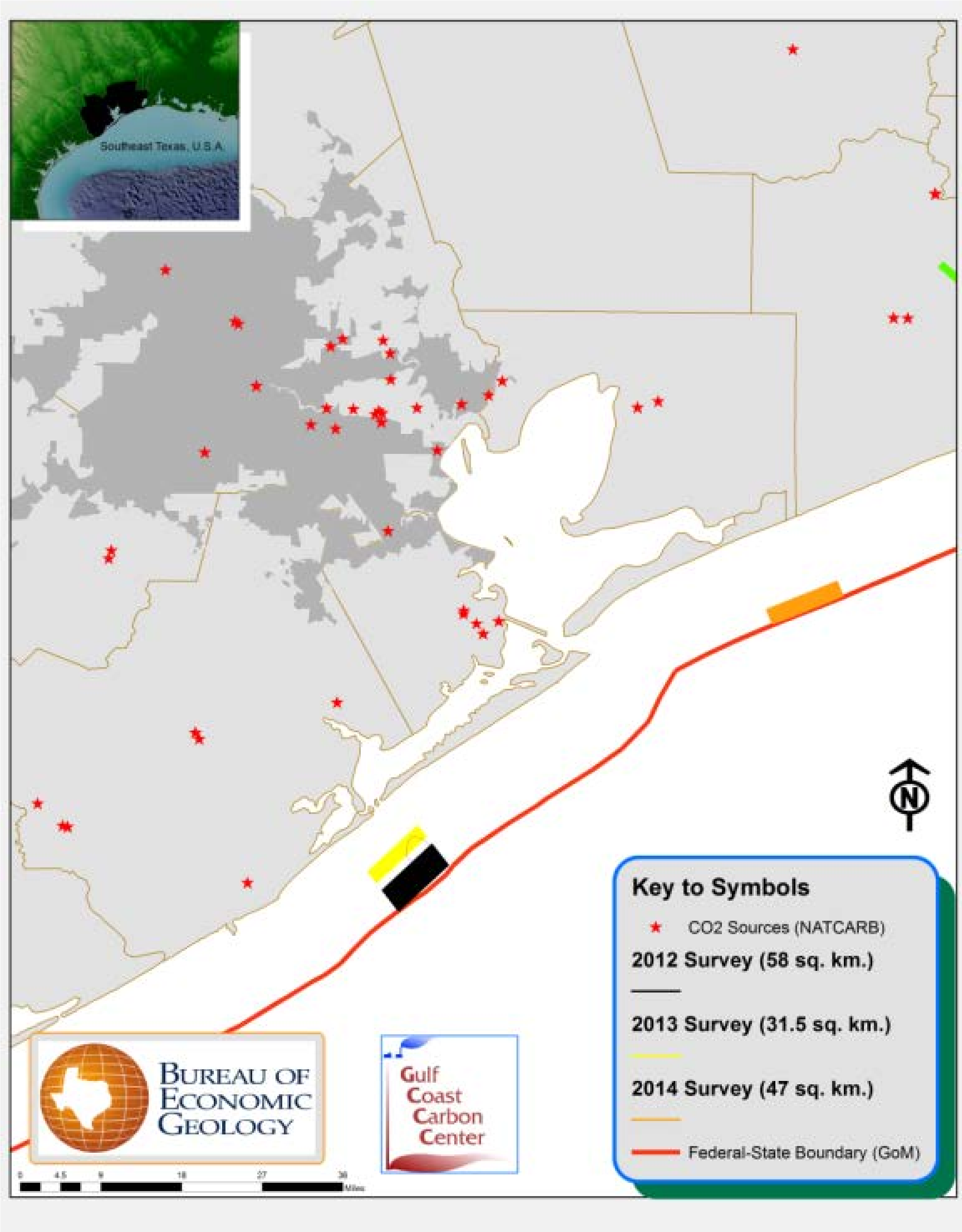


Figure 2.1.3.1 - Map of the southeast Texas coastal region showing the locations of three HR3D (P-Cable) surveys within the study area. The outline of the 2012 survey is shown in black, the 2013 survey in yellow and the 2014 survey in orange. Note the outline of the city of Houston in dark gray and the boundary (red line) between State and Federal waters.

These minor positional errors are most likely due to the currents, tow speed and wave levels. We believe that the hydrophones may also have developed a diving and rising harmonic pattern despite the use of stabilizers.

Feathering is the error of position when a cable of hydrophones does not properly align due to the above factors. It is a term usually reserved for long arrays with high currents and turns during acquisition. In the HR3D surveys with shorter cables, the problem does exist, and since the survey is so high resolution in time and space, the small errors matter more.

Machine Learning and Refractor Flattening

Picking events in noisy data is a common problem in geophysics, and we are pursuing two solutions. The older neural net method of picking arrivals and shifting their positions to account for an isotropic velocity arrival distorted by positional uncertainty (Figure 2.1.3.2) is somewhat successful in these datasets. This method requires modifying refraction statics techniques for the problem. Large time shifts (shot delays) need to be handled separately.

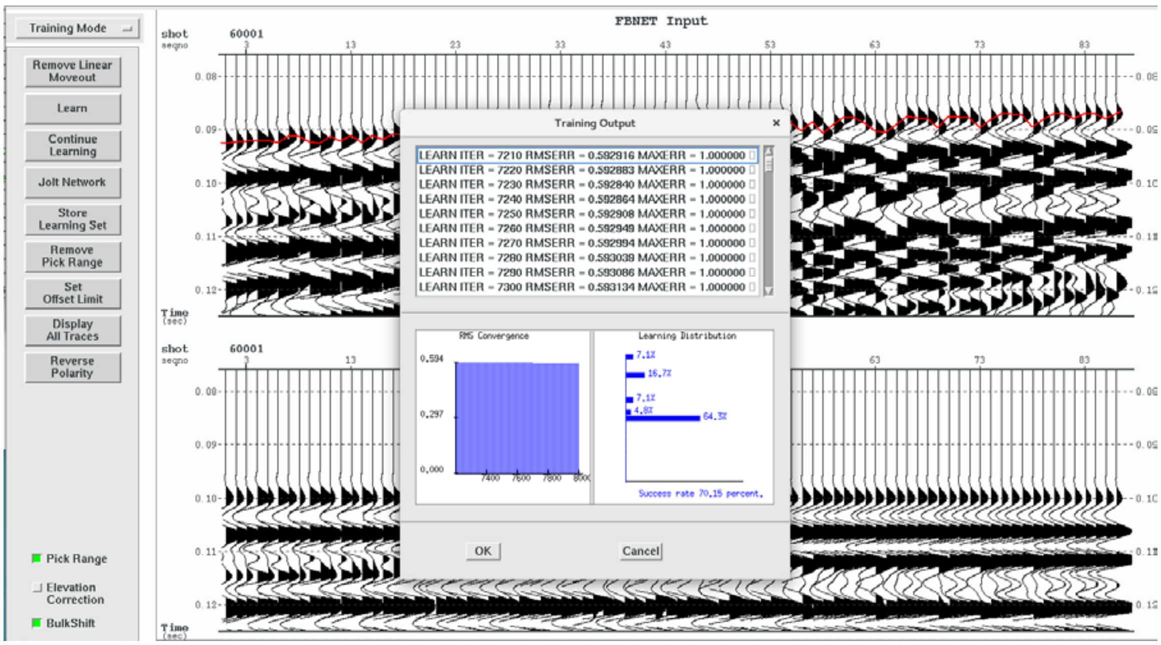


Figure 2.1.3.2 – Screen capture of a neural network learning set being saved after successfully picking and flattening the first arrival. Statistics in the center window show the various iterations level of success. The lower panel shows flattened first arrival with the proposed solution. After learning occurs on a training set, the software picks the entire dataset.

Unique to the HR3D datasets is sampling of refraction energy due to the relatively long, for HR3D (50m+), acquisition style. Using any first arrival method, we use a simple flattening and shifting of the traces by the velocity of the water bottom back to a more reasonable position (offset) This method also has some drawbacks, but it does handle large shot variations. Figure 2.1.3.3 shows some flattened and shifted shots using this method. The uncertainty in the refract intercept time has been solved.

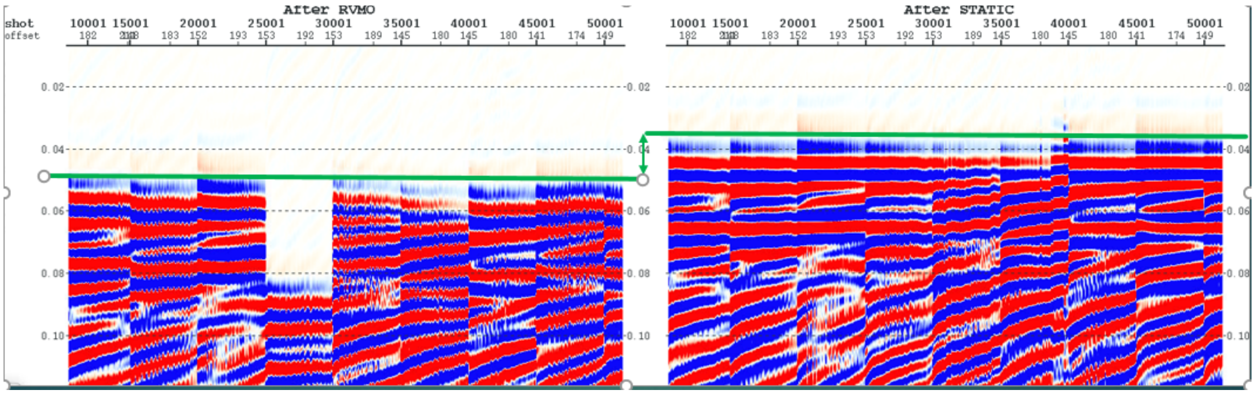


Figure 2.1.3.3 - Refractor flattening method handles large shot timing issues. Left panel shows 8 shots flattened using a constant velocity for the water bottom. The right side show large and small shifts in the shots to be flattened to T = 0 ms (milliseconds). The bulk shift of the shots is an issue similar to re-datuming and can be handled with a shift based on the left panel's flattened intercept time with averaging to remove the large shifts.

Shot Timing Issues

Shot timing issues are large (40+ ms) and affect entire shots. These errors result in a "rectangular band" occurring on time slices of the data volume (Figure 2.1.3.4). Work is ongoing to automate solutions to these issues.

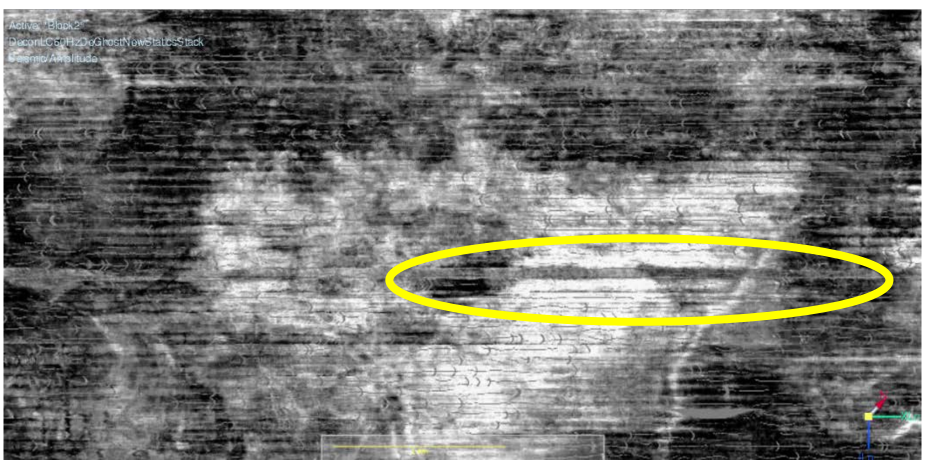


Figure 2.1.3.4 – Example of a banded shift (within yellow oval) seen on time slice due to shot timing issues. This is possibly occurring along a sail line (series of shots in row) and may be in the original GPS data or simply a constant time delay.

Overall Quality

The quality of the data improves greatly with static shifts accounting for positional problems. The problem with implementing such a correction is getting a robust picking method. We are beginning to see geological features much earlier in time slice views, and in 2D sections fault resolution is enhanced.

Depth of Resolution

Both the machine learning and refractor shift methods enhance coherency enough to increase the resolution with depth. Note: in figure 2.1.3.5 there is a time shift in the sections due to the refractor flattening. The left side shows increased reflection coherency; the right side is without the statics shifts (positional uncertainty).

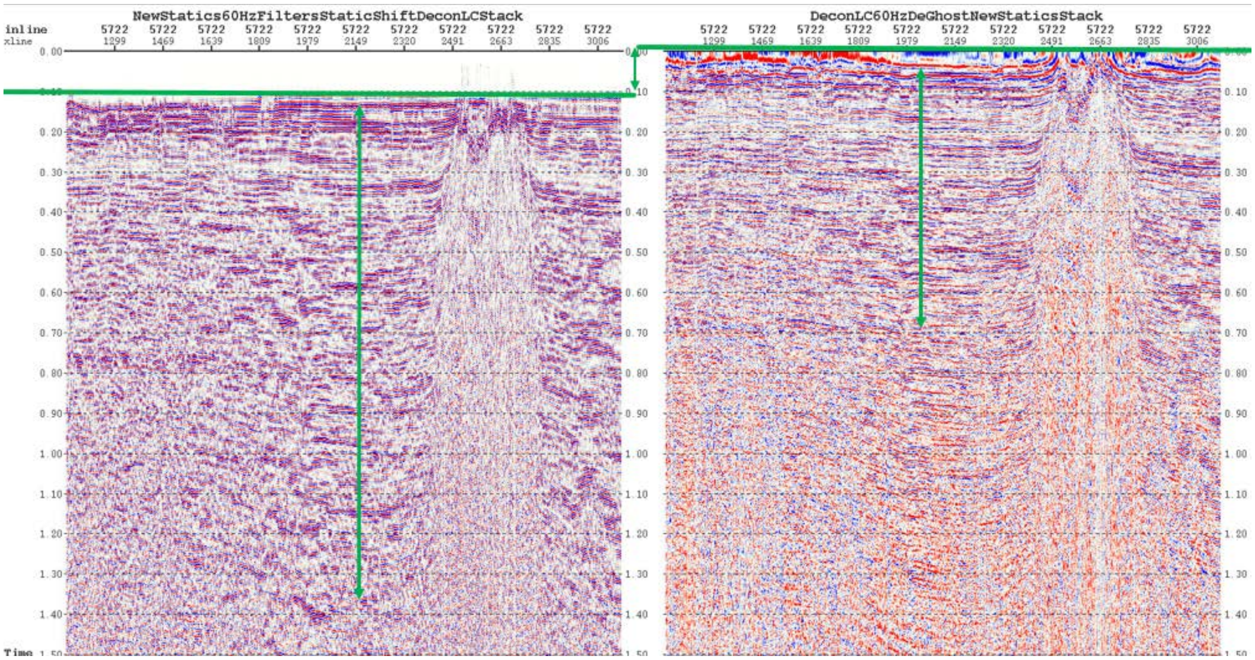


Figure 2.1.3.5 – Panels showing the effect of adding statics correction; left panel shows new statics; right is without statics correction. Since the reflections line up better after the statics correction, they stack together more strongly and appear to have greater coherency with increasing time.

Positional uncertainty corrections also enhance fault resolution. In figure 2.1.3.6 the fault enhancement is seen following the green arrows. In the previous work (bulk shift as before) on the right, the fault edges are not as well defined.

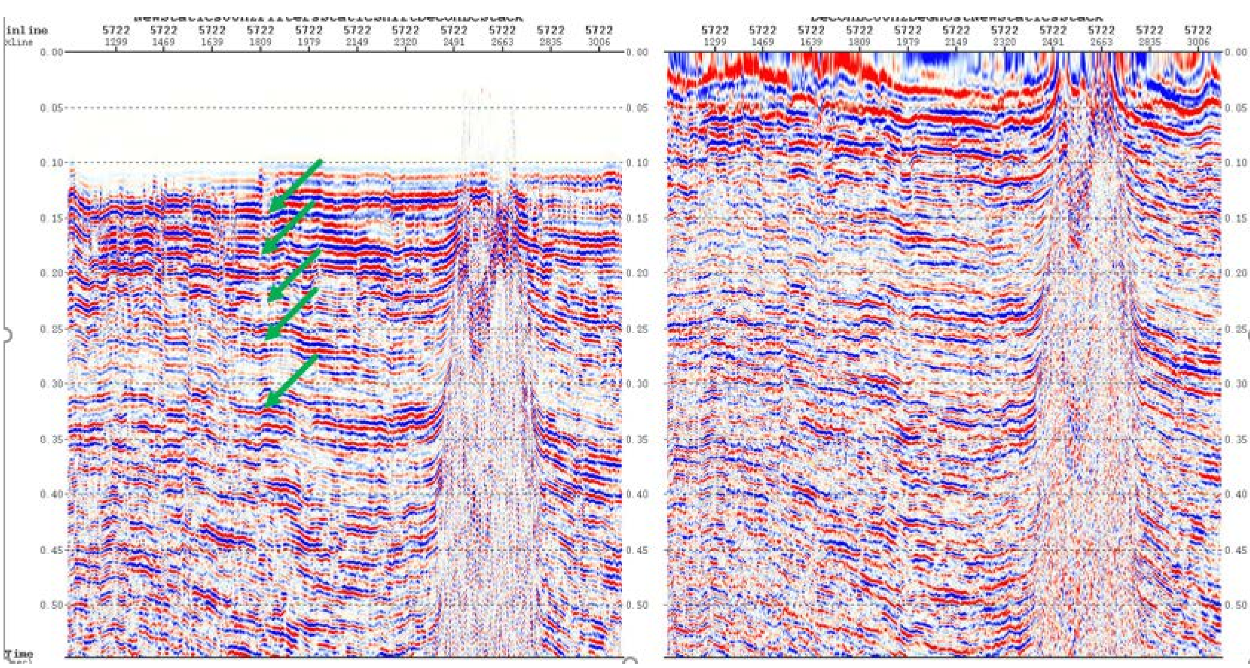


Figure 2.1.3.6 – Panel showing effects of positional uncertainty corrections. Resolution around faults is greater on the left than on the right. Green arrows outline the fault edge which is not as defined in uncorrected data.

Current challenges

Current challenges include fixing the shot timing issues and fixing "footprint" like static shifts, which appear throughout the data. In figure 2.1.3.7, "C" shaped artifacts (catenaries) are visible. They are possibly due to shot layout. Determination of the root cause and the subsequent fix are in progress.

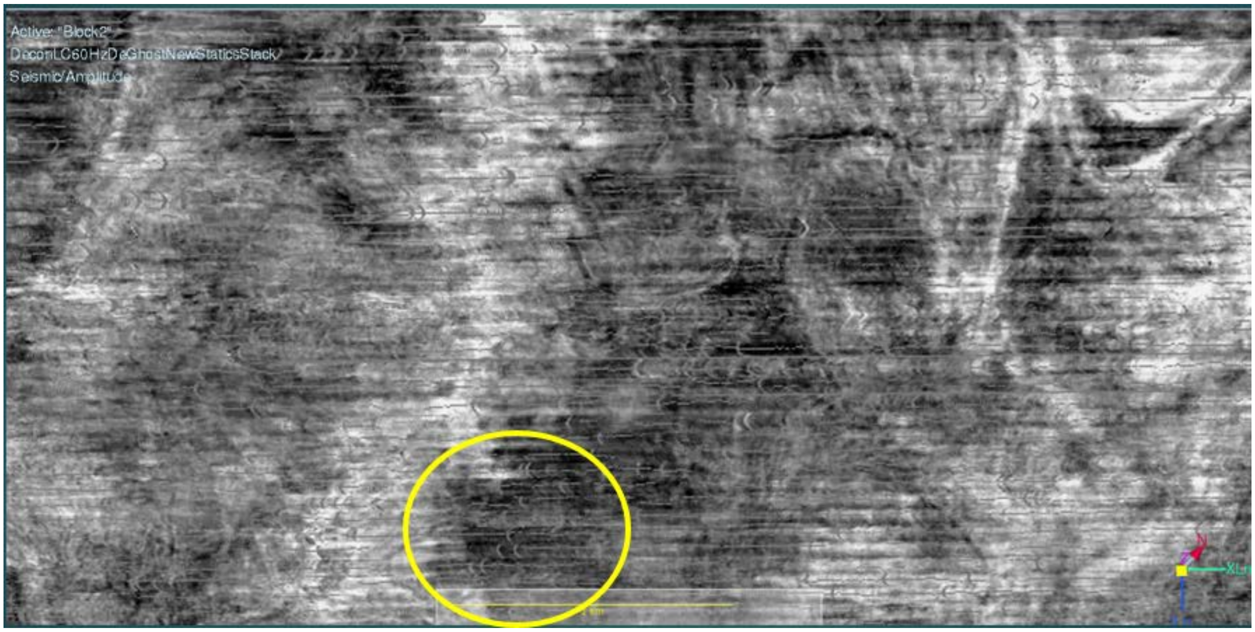


Figure 2.1.3.7 – Time slice showing "C" shaped artifacts (aka catenaries), which are the shot layout that need to be removed by improved processing. These "footprints" may be a shot static issue or a slight phase shift. Work is ongoing.

Work to be done on all HR3D datasets will go relatively quickly once a final position error methodology is complete. This stage will probably be completed within the first quarter 2019.

Subtask 2.2 – Data Gap Assessment

No activity this quarter

Subtask 2.2.1: Data gap assessments will focus on regionally relevant analog settings

No activity this quarter

Subtask 2.3 – Offshore and reservoir storage Enhanced Oil Recovery (EOR) Potential

No activity this quarter

Subtask 2.3.1 Texas (High Island area of Lake Jackson district) and Louisiana (Lake Charles and Lafayette districts)

Task 3.0 – Risk Assessment, Simulation and Modeling

Subtask 3.1 – Risk Assessment and Mitigation Strategies

Project partner PI, Dr. Tracy Benson (Lamar University) began literature searches for the simulation and equation of state modeling of CO_2 stored in underground reservoirs.

Subtask 3.1.1 Assess the adaptation of existing tools to offshore settings

No activity this quarter.

Subtask 3.1.2 Extend geomechanical assessment to additional areas of the basin

No activity this quarter.

Subtask 3.1.3 Dissolution and bubbling in water column

No activity this quarter.

Subtask 3.1.4 Numerical modeling of heterogeneous reservoirs

No activity this quarter.

Subtask 3.2 – Geologic Modeling

LLNL (Lawrence Livermore National Laboratory) worked with GCCC on geomechanical modeling plans for the High Island 24L site. GCCC and LLNL agreed on data exchange formats to get geomodel data being developed at GCCC into LLNL's geomechanical / reservoir simulation package. Actual geomodel data should be available next quarter, when detailed modeling work can begin.

Subtask 3.2.1 – Reservoir modeling

No activity during this quarter.

Subtask 3.2.2 Sub-basinal scale modeling

No activity during this quarter.

Subtask 3.2.3 History matching experiment via modeling

No activity during this quarter.

Subtask 3.2.4 Economic modeling

No activity during this quarter.

TASK 4.0: Monitoring, Verification, and Assessment (MVA)

Subtask 4.1: MVA Technologies and Methodologies

No activity during this quarter.

Subtask 4.1.1 Geochemical Monitoring of Seabed Sediments

No activity during this quarter.

Subtask 4.1.2 Geochemical Monitoring of Seawater Column

No activity during this quarter.

Subtask 4.1.3 UHR3D Seismic

No activity during this quarter.

Subtask 4.1.4 Distributed Acoustic Sensors

No activity during this quarter.

Subtask 4.1.5 Pipeline MVA

Co-PI, Dr. Daniel Chen, (Project Partner Lamar University) performed literature searches for CO2 pipeline transport and prepared a manuscript to be presented in OTC (Offshore Technology Conference) May 9, 2019 Houston, TX. The manuscript was submitted to and accepted.

Subtask 4.2: Plans for Testing of MVA Technologies

Subtask 4.2.1 Priority list for MVA Technologies and testing methods

No activity during this quarter.

TASK 5.0: Infrastructure, Operations and Permitting

The following summarizes the results of the work Trimeric Corporation performed for the University of Texas, Bureau of Economic Geology (UT BEG) as part of the DOE-sponsored Gulf of Mexico Partnership for Offshore Carbon Storage (GoMCarb) program for the period from October – December 2018.

Subtask 5.1: CO_2 Transport and Delivery

Subtask 5.1.1 Data assessment near-shore sites

Review of well and pipeline data in High Island offshore state waters

The Infrastructure task will include defining source to sink connections in order to define the full CO_2 transport chain. As noted previously, the High Island region is an initial template or proxy region where the project will focus in order to develop methods and approaches that will be used across the broader regional project. An initial step for the High Island regional evaluation is to identify existing infrastructure in the region in order to define a method and approach for evaluating infrastructure for its potential to be re-used as part of a CO_2 storage project.

The Texas Railroad Commission (RRC) maintains a database of wells and pipelines in lease blocks within Texas state waters. An initial review of data was conducted in High Island Block 10-L. Figure 5.1.1 depicts a map of High Island Block 10 with wells and pipelines depicted for the block.

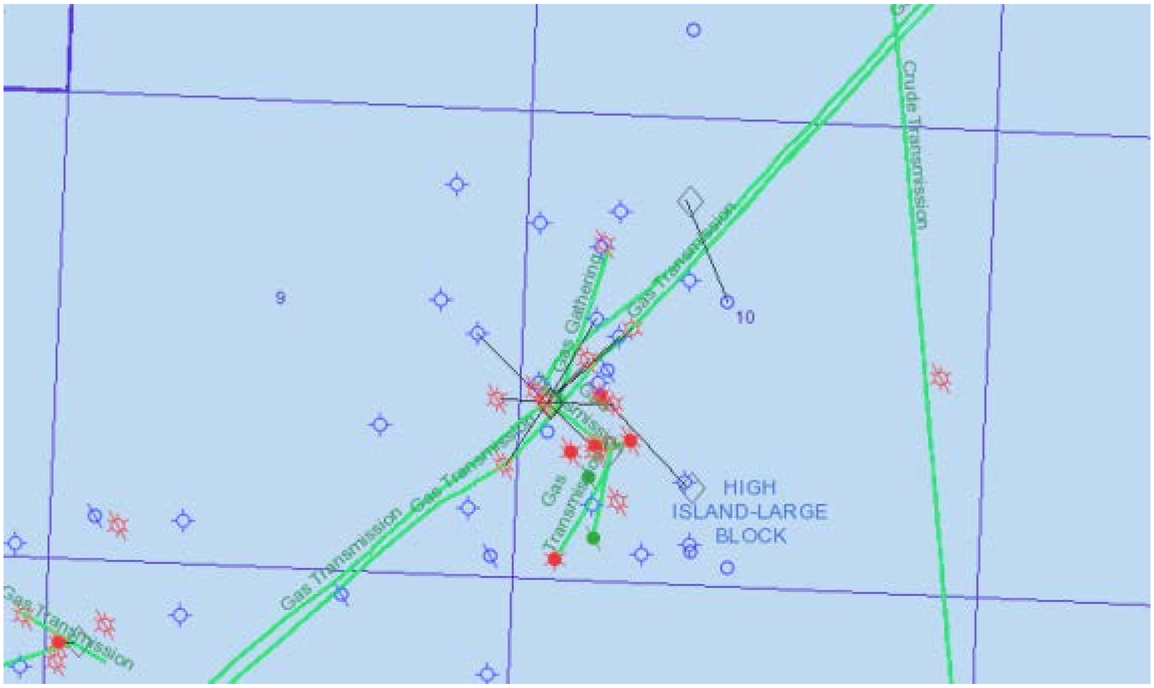


Figure 5.1.1: High Island Block 10-L Map with Wells and Pipelines (from Texas Railroad Commission http://wwwgisp.rrc.texas.gov/GISViewer2/)

The associated legend with the map was used to define the terms in Table 5.1.1 for wells in the lease block.

Table 5.1.1: Glossary of Terms for Wells in the Texas RRC Database

Term	Definition
Cancelled/Abandoned Location	Well location for which the permit has expired or been cancelled
Dry Hole	A plugged well that never produced oil or gas
Gas Well	Any well which produces natural gas; formal definition has limits set on the amount of petroleum oil
Oil/Gas Well	A completed well with a history of both oil and gas production based on reported test data.
Permitted Location	Proposed location of a well for which the Railroad Commission of Texas has granted a drilling permit.
Plugged Gas Well	A well with a history of gas production that has been plugged
Plugged Oil Well	A well with a history of oil production that has been plugged.
Plugged Oil/Gas Well	A well with a history of oil and gas production that has been plugged.

Using the data associated with the map in Figure 5.1.1, Table 5.1.2 (pipelines) and Table 5.1.3 (wells) were generated.

Table 5.1.2: Pipelines in High Island Block 10-L (from Texas Railroad Commission http://wwwgisp.rrc.texas.gov/GISViewer2/)

Commodity	Operator	Type		
Natural Gas FWS	Tri-C Resources LLC	Gas Gathering		
Natural Gas	Transcontinental Gas P.L. Corp.	Gas Transmission		

Table 5.1.3: Wells in High Island Block 10-L (from Texas Railroad Commission http://wwwgisp.rrc.texas.gov/GISViewer2/)

Feature Label on Map	Feature Type	API Number	Last Permit Operator	Wellbore Status
12 - 30245	Cancelled/Abandoned Location	70830245	Centex Oil and Gas, Incorporated	“Location” ??
1 - 30268	Dry Hole	70830268	McMoran Exploration Co.	Dry
1 - 30359	Dry Hole	70830359	Apache Corporation	Dry
12 - 30293	Dry Hole	70830293	Cenergy Exploration Company	Dry
9 - 30288	Dry Hole	70830288	Cenergy Exploration Company	Dry
1 - 30264	Dry Hole	70830264	McMoran Exploration Co	Dry
A7	Dry Hole	708 (no other number)	None listed	No status listed
A8	Dry Hole	708 (no other number)	None listed	No status listed
B1	Dry Hole	708 (no other number)	None listed	No status listed
C1	Dry Hole	708 (no other number)	None listed	No status listed
1 - 30298	Dry Hole	70830298	Pend Oreille Oil & Gas Co	Dry

Feature Label on Map	Feature Type	API Number	Last Permit Operator	Wellbore Status
1 - 30343	Dry Hole	70830343	Zilkha Energy Company	Dry
1 - 30358	Dry Hole	70830358	Zilkha Energy Company	Dry
A5 - 30230	Gas Well	70830230	Cenergy Exploration Company	Plug
A9	Gas Well	708 (no other number)	None listed	No status listed
7 - 30240	Oil/Gas Well	70830240	Centex Oil & Gas, Incorporated	Plug
1 – "north"	Permitted Location	708 (no other number)	None listed	Two "1" markers listed on map; Delineated as "North" and "South"
1 – "south"	Permitted Location	708 (no other number)	None listed	Two "1" markers listed on map; Delineated as "North" and "South"
2B	Permitted Location	708 (no other number)	None listed	
2 - 30345	Permitted Location	70830345	Zilkha Energy Company	"location"
1 - 30108	Plugged Gas Well	70830108	Centex Oil & Gas, Incorporated	
4 - 30225	Plugged Gas Well	70830225	Conquest Exploration Company	
A1	Plugged Gas Well	606 (no other number)	None listed	
A3	Plugged Gas Well	708 (no other number)	None listed	
A4	Plugged Gas Well	708 (no other number)	None listed	
A5	Plugged Gas Well	708 (no other number)	None listed	
1 - 30369	Plugged Gas Well	70830369	Shell Offshore Inc.	
1 - 30386	Plugged Gas Well	70830386	TRI-C Resources, Inc.	
8 - 30248	Plugged Oil Well	70830248	Cenergy Exploration Company	
10 - 30287	Plugged Oil Well	70830287	Conquest Exploration	

Feature Label on Map	Feature Type	API Number	Last Permit Operator	Wellbore Status
			Company	
11 - 30289	Plugged Oil/Gas	70830289	Cenergy Exploration Company	
2 - 30224	Plugged Oil/Gas	70830224	Cenergy Exploration Company	
3 - 30237	Plugged Oil/Gas	70830237	Cenergy Exploration Company	
6 - 30236	Plugged Oil/Gas	70830236	Centex Oil and Gas, Incorporated	

Note that in the pipeline list, the crude pipeline depicted in Figure 5.1.1 did not appear. However, for the purposes of the GoMCarb effort, crude pipelines are highly unlikely to be re-used due to material integrity concerns and pressure rating of the pipelines.

For the well data, Trimeric has initiated interviews with industry experts to understand the circumstances and requirements of re-using wells. The list from High-Island Block 10-L will be screened based on the input from these experts with the goal of developing a methodology that can readily be applied to other regions. For any high priority wells, the last known operator/owner of the well may be contacted as a source of additional information. One potential outcome may be that wells will not be re-used at all, but the infrastructure group will seek to reach that (or any other conclusion) based on a systematic review of literature and industry knowledge.

Review of Offshore CO_2 Pipeline Costs in Literature

Part of the broader effort of the Infrastructure task is to identify gaps in data that could present obstacles or challenges in deployment of a large-scale CO_2 storage project in the Gulf of Mexico region. To that end, understanding the major infrastructure cost centers and the uncertainty in those costs will be an important activity.

Pipelines are a major component of the cost for large-scale offshore CO_2 transport. Pipeline transport is already extensively used for natural gas transport onshore and offshore and CO_2 pipelines are common onshore for EOR projects. There are over 4,000 miles of CO_2 pipeline in the U.S. (Plains CO2 Reduction Partnership (PCOR) 2011). However, global experience with offshore CO_2 pipelines is limited (i.e., one major project, Snøhvit, in offshore Norway). Cost data for offshore pipelines is scattered and varies widely by source. In addition, pipeline costs have changed significantly over time (beyond what may be captured in typical cost indices) and can scale non-linearly with length and diameter, making it difficult to compare cost data points without finding ways to normalize the data. The following approach was proposed to initially assess offshore pipeline costs:

1) Use literature data sources where onshore and offshore pipeline data are both presented (i.e., common reference for both sets of data)
2) Calculate an approximate factor to scale from onshore to offshore pipeline costs.
3) Use developed correlations for onshore CO_2 pipeline costs to estimate offshore costs via the scaling factor developed in step 2.

Table 5.1.4 summarizes the literature data and estimated offshore pipeline cost scaling factors. Additional data points for offshore pipeline costs are also included for reference.

Table 5.1.4: CO_2 Pipeline Cost Estimates – Literature Review

Source	Fluid	Cost ($/in-mile)		Offshore Multiplier	Notes
		Onshore	Offshore		
NATGAS.INFO website (Chandra n.d.)	Natural Gas		$40,000 - $64,000		
(Kaiser 2016)	Oil, Natural Gas		$45,000 - $418,333		Pipe sizes from 4" - 30". Data varies as a function of water depth, function (export vs. infield), piping type (flexible piping, pipe-in-pipe, rigid pipe). The average inflation-adjusted cost to install deepwater pipelines in the U.S. Gulf of Mexico is estimated at **$3.1 MM/mi.**
(Mallon, et al. 2013) via JRC (Serpa, Morbee and Tzimas 2011)	CO_2		$67,600 - $89,600		
(USAID and SARI/Energy 2006)	Oil, Natural Gas			1.96	Costs Provided as $/mile of pipeline without informaiton on length or diameter: **Offshore: $2,578,413 / mile** **Onshore: $1,316,164 / mile**
(Brito and Sheshinski 1997)	Natural Gas	$40,000	$100,000	2.50	Approximate numbers used in analysis - reflects a rule of thumb, not data.
(Mallon, et al. 2013) via Global CCS (Vermeulen 2011)	CO_2	$103,000	$144,800	1.41	Reference indicates costs reflect high pressure pipeline
(Mallon, et al. 2013) via Scottish Power Longannet	CO_2	$12,900	$49,900	3.87	Costs for re-use of existing pipeline, not new build costs.
(Rubin, Davison and Herzog 2015) via (Intergovernmental Panel on Climate Change 2005)	CO_2			2	Costs in 2013 USD/t CO2/250km. Numbers are average of 3 cases (3, 10, 30 Mt CO2/yr): **Offshore: $4.2 - 5.2 /t CO2/250km** **Onshore: $2.6 - 4.4 /t CO2/250km** **Ratio is high offshore (5.2) to low onshore (2.6).**
(Rubin, Davison and Herzog 2015) via (Zero Emissions Platform - ZEP 2011)	CO_2			1.38	Costs Provided as 2013 USD/t CO2/250km. Numbers are average of 2 cases (3, 10 Mt CO2/yr): **Offshore: $9.8 /t CO2/250km** **Onshore: $7.1 /t CO2/250km**

JRC (Serpa, Morbee and Tzimas 2011)	CO_2			2	Factor of 2 between onshore and offshore via IEA GHG report. (IEA GHG R&D Programme 2002)
(NETL 2013) via Kinder Morgan	CO_2	$50,000	$700,000	14	Based on NETL correspondence with Kinder-Morgan. Onshore pipe flat terrain vs 150’ of offshore at 200’ depth.
			Average	**3.64**	
			Median	**2.00**	

Average and median values are reported for the offshore-to-onshore scaling factor – the difference in these values is primarily driven by the outlier from the NETL document citing data from Kinder Morgan (scaling factor = 14). If this is removed from the dataset, the median and average scaling factors are both approximately 2. The review above is not exhaustive, the data in literature is limited in general, and pipeline costs vary as a function of many factors (length, depth, diameter, route, pressure, etc.), so the scaling factor is likely only useful for initial, screening-level evaluation.

Table 5.1.4 also illustrates the wide range of offshore cost estimates in literature ($40,000/in-mile to $700,000/in-mile). This reflects a critical data gap/source of uncertainty that must be addressed when assessing the viability of CO_2 transport costs.

Subtask 5.2: Scenario Optimization

CO_2 Source Mapping for Large-Scale Storage Projects

While the primary focus of the GoMCarb work is not CO_2 sources or development of end-to-end capture and storage projects, the sources do have potentially significant impacts on the downstream transport processes, and source-sink optimization/evaluation will be an important part of defining transport strategies. Therefore, some CO_2 source evaluation is an important initial step of evaluating CO_2 transport infrastructure.

The first step to expanding the list of sources was to use publicly available data on CO_2 sources. The EPA Greenhouse Gas Reporting Program database was used to identify CO_2 sources along the Texas Gulf Coast. Figure 5.2.1 was generated from the dataset using screening for large-scale sources (defined as >400,000 tonnes CO_2/yr).

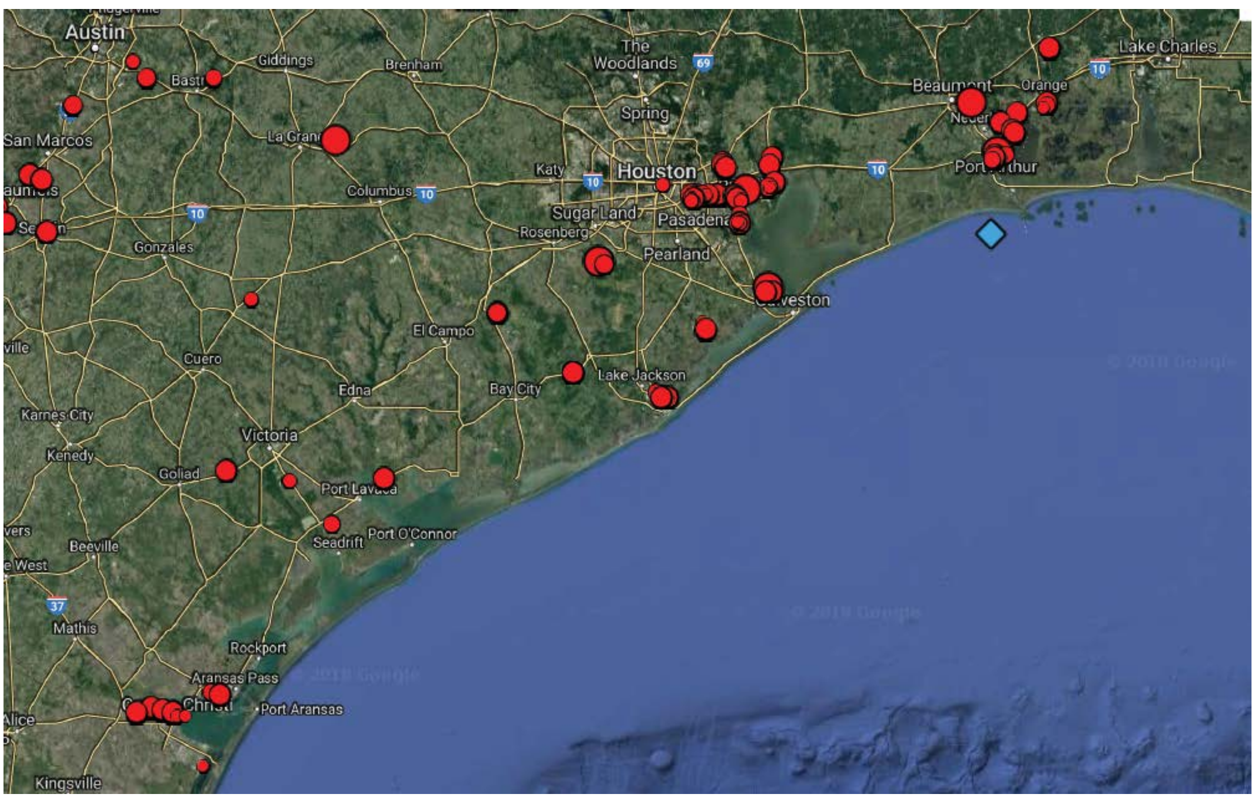


Figure 5.2.1. CO_2 Emissions Sources, Texas Gulf Coast Region (> 400k tonnes/yr CO_2 emissions). Larger circles correspond to larger emissions rates. Blue diamond = High Island offshore lease region. Data from EPA GHGRP dataset for 2017 (U.S. Environmental Protection Agency 2017)

In Texas as a whole, 148 sources meet the criteria of 400,000 tonnes/yr CO_2 emitted. If the list is further filtered to only include sources within 50 miles of the Texas coastline, the list is reduced to 75 sources. These coastal sources are heavily clustered in three regions along the Texas coast:

1) Beaumont/Port Arthur Region
2) Houston/Galveston Region (extending west to Freeport/Lake Jackson)
3) Corpus Christi Region

The sources in the region include power plants, refineries, and petrochemical facilities. Further refinement of these sources will include the following:

1) Capture/CO_2 separation process in-place or new process required
2) Purity of CO_2 available
3) Existing use of CO_2 from the site (vented, sold for other applications, etc.)

The additional screening will help prioritize sources. For example, several sources among the 75 are steam methane reformers at petrochemical facilities. In general, steam methane reformers represent a good CO_2 sources opportunity because CO_2 is separated from hydrogen as part of the process, producing a potentially high purity CO_2 stream (minimizing capture/purification costs). In some of these cases, purge gas from pressure swing adsorption process is recycled to the furnace in the process as fuel gas for combustion. This creates added complexity and potential modifications at the site where the CO_2 is generated, and may make the sources low probability or completely infeasible for capture and storage projects.

In addition, Figure 5.2.1 includes a blue diamond offshore near the Beaumont/Port Arthur region. This represents the approximate position of the High Island oil and gas lease blocks that are managed by the Texas Railroad Commission (state waters) and the U.S Bureau of Ocean Energy Management (federal waters). The GoMCarb partnership will use the High Island region as an initial analog to develop a methodology to apply for the larger regional evaluation that will occur along the Gulf Coast.

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Subtask 5.2.1 Analog Site Optimization

No activity during this quarter

Subtask 5.3: Communication

No activity during this quarter

TASK 6.0: Knowledge Dissemination

No activity during this quarter

Subtask 6.1: Stakeholder Outreach

Lamar University began planning and preparing for the February 2019 first annual Partnership meeting in Beaumont, TX. Lamar will host the meeting on the university campus.

GoMCarb staff from Lamar University prepared for a teacher's STEM workshop to be held on 17 January, 2019) where hands-on demonstrations will be provided to southeast Texas area teachers. Specifically, a teacher module developed by University of Texas at Austin project PI, Dr. Susan Hovorka and project staff Hilary Olson, "CO2 – Too much of a Good Thing?" will be presented.

Subtask 6.2: Technical Outreach

No activity during this quarter

Subtask 6.3: Advisory Committee

Advisory committee chair, Tim Dixon mentioned the GoMCarb Partnership at the London Convention meeting on November 7, 2018. Meeting attendees included representatives from U.S. EPA and DOE.

PLANS FOR THE NEXT PROJECT QUARTER

In the next quarter, work will continue on:

Task 1

- Amending Partners' subcontracts with augmented funding and scope.

Task 2

- Subtask 2.1.3: Finalize geologic model for the High Island area and provide it to LLNL (Lawrence Livermore National Laboratory).

Task 3 Risk Assessment, Simulation and Modeling

- Subtask 3.2: Begin detailed geomechanical modeling after geologic model is delivered.

Task 5

- Subtask 5.1: Continued development of existing infrastructure "database" for project region, starting in the High Island region
- Subtask 5.1: Development of methodology to evaluate existing infrastructure for re-use in CO_2 transportation with a focus of gathering and assessing industry expertise/experience on the subject (particularly leveraging knowledge internationally, e.g., North Sea)
- Subtask 5.2: Continued development of CO_2 source list along the Texas coast, including outreach and education of industry in the region

Task 6

- Hold first annual Partnership meeting.

STATUS OF PROJECT SCHEDULE AND MAJOR GOALS/MILESTONES OF PROJECT

Schedule/Timeline

The project schedule/timeline is shown in the following Gantt chart.

Task	Partnership for Offshore Carbon Storage Resources and Technology Development in the Gulf of Mexico	BUDGET PERIOD 1																			
									BUDGET PERIOD 2												
		2018			2019				2020				2021				2022				2023
Task	Tasks	qtr2	qtr3	qtr4	qtr 1	qtr2	qtr3	qtr4	qtr 1	qtr2	qtr3	qtr4	qtr 1	qtr2	qtr3	qtr4	qtr 1	qtr2	qtr3	qtr4	qtr 1
		A-M-J	J-A-S	O-N-D	J-F-M	A-M-J	J-A-S	O-N-D	J-F-M	A-M-J	J-A-S	O-N-D	J-F-M	A-M-J	J-A-S	O-N-D	J-F-M	A-M-J	J-A-S	O-N-D	J-F-M
1	**Project Management, Planning, and Reporting**	**M1**		**M2**																	**M11**
	Revision and Maintenance of Project Management Plan	D1a-c							**G-NG**												
	Progress Report	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q
2	**Offshore Storage Resources Characterization**						**M4**	D2a				D2b			**M8**	D2c				D2d	
2.1	Database Development				**M3**																
2.2	Data Gap Assessment																				
2.3	Offshore EOR Potential																				
3	**Risk Assessment, Simulation and Modeling**				D3a				**M5** D3b		**M6**		D3c				D3d				D3e
3.1	Risk Assessment and Mitigation Strategies																				
3.2	Geologic Modeling																				
4	**Monitoring, Verification, Accounting (MVA) and Assessment**					D4a				D4b			**M7**	D4c				D4d			
4.1	MVA Technologies and Methodologies																				
4.2	Plans for Field Testing of MVA Technologies																				
4.3	Testing MVA Technologies																				
5	**Infrastructure, Operations, and Permitting**						D5a				D5b				D5c				D5d		
5.1	CO2 Transport and Delivery																				
5.2	Scenario Optimization																				
5.3	Communication																				
6	**Knowledge Dissemination**			D6a				D6b				D6c				D6d	**M9**		**M10**		D6e
6.1	Stakeholder Outreach																				
6.2	Technical Outreach																				
6.3	Advisory Panel																				

Q = Quarterly Report; A = Annual Report; M = Milestone; DP = Decision Point; D = Deliverable; G-NG = Go/no-go decision point; FR = Final Report

MAJOR GOALS / MILESTONES

Task/ Subtask	Milestone Number and Title	Planned Completion Date	Verification method
1	M1: Attend Kickoff meeting	4/30/2018	Submit Presentation File
1	M2-1: Partnership Fact Sheet	8/31/2018	Fact Sheet file
2	M3: Data submitted to NETL-EDX	1/31/2019	List of data submitted
2	M4: Identification of geologic storage prospects & data gaps	9/30/2019	Summary Report
3	M5: Risk assessment, simulation and modeling of prospects	3/13/2020	Summary Report
3	M6: Modified risk assessment, simulation and modeling of prospects	9/30/2020	Summary Report
4	M7: Modified MVA technologies and testing plan identified for prospects	2/26/2021	Summary Report
2	M8: Refinement of geologic storage prospects & data gaps	9/30/2021	Summary Report
6	M9: Summary of Advisory Committee recommendations	3/31/2022	Letter Report
6	M10: Outcomes of public acceptance studies	9/30/2022	Letter Report
1	M11: Upload results to EDX	3/3/2023	Summary Report

3. PRODUCTS

Publications, conference papers, and presentations.

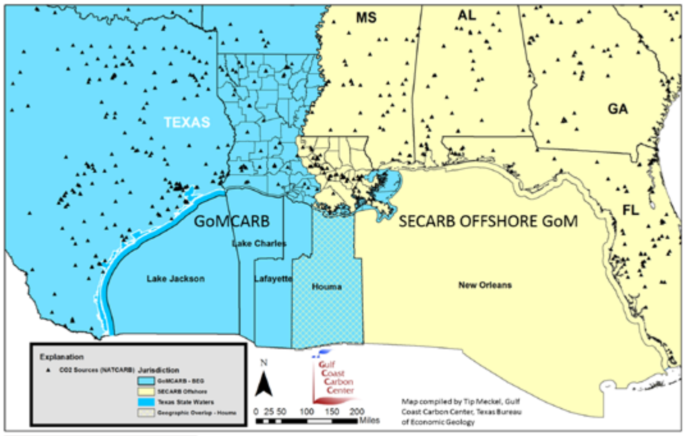
Dr. Sean Brennan (USGS) presented a poster at the GHGT 14 (Greenhouse Gas Control Technologies) international conference in Melbourne, Australia.

Overview of future USGS Gulf of Mexico buoyant storage assessment project

Sean T. Brennan

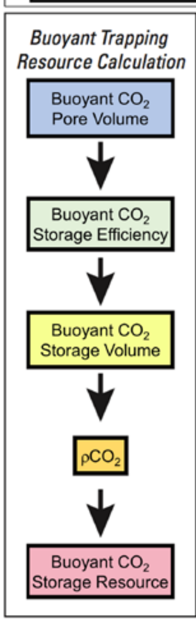
U.S. Geological Survey, Eastern Energy Resources Science Center, 12201 Sunrise Valley Dr., Reston, VA 20120

The United States Geological Survey (USGS) is a member of GoMCARB, a U.S. Department of Energy-funded partnership headed by the University of Texas Bureau of Economic Geology that is working to assess the feasibility of offshore geologic carbon dioxide (CO_2) storage in the Gulf of Mexico. The role of the USGS is to assess the buoyant geologic CO_2 storage resource of the western half of the offshore Gulf of Mexico (GoM). Buoyant CO_2 storage is the CO_2 held in place by a top and lateral seal (either a sealing formation or a sealing fault), that creates a column of CO_2 in communication across pore space in a geologic reservoir. This assessment will be similar to the USGS assessment of onshore buoyant geologic CO_2 storage [1] and will employ a modified version of existing USGS methodology [2] to assess the buoyant CO_2 storage capacity in the GoM.



The initial step of the USGS CO_2 storage resource assessment method was to identify storage assessment units (SAUs). The SAUs were defined by a regional seal formation that overlies a porous storage formation, or multiple porous storage formations. This regional seal was to ensure that the residual and buoyantly stored CO_2 would be kept within the storage formation.

The focus of this storage assessment is only on buoyant storage. Therefore, the seal formation does not need to be regionally persistent, it only needs to be present over the traps. This assessment will identify assessment units based on extensive porous units within the area of interest, shown in light blue on the map to the left, and the presence of a seal formation across the structural highs or other trapping mechanisms within the storage formation.



This probabilistic assessment method uses distribution functions to determine input values. The first input value is the buoyant pore volume. To determine the potential total buoyant CO_2 pore volume, a truncated log normal distribution is created using a minimum value based on the total hydrocarbon production within an assessment unit, a most likely value based on the production plus the undiscovered hydrocarbon estimates from published assessments, and a maximum value based on structural maps, porous interval thickness, and porosity estimates. Further discussion of the buoyant CO_2 pore volume estimates can be found in Blondes, et al. [2].

For this method we will use production values from proprietary databases [3-5], undiscovered estimates from the U.S. Bureau of Ocean Management assessments, structural maps and porous interval estimates from GoMCARB partners, and porosity estimates from proprietary sources and GoMCARB partners.

The buoyant CO_2 storage efficiency in this project will be the same as was used in the USGS onshore CO_2 storage resource assessment [1]. Those values are discussed in Blondes, et al. [2] as well. A form of a log normal distribution (beta-PERT) is used, and is defined by a minimum of 20%, and most likely value of 30%, and a maximum of 40%.

A distribution of the buoyant CO_2 storage volume is created by multiplying values sampled (10,000 iterations) from the buoyant pore volume and the buoyant storage efficiency distributions.

The density of CO_2 (ρCO_2) is determined based on the thermal and pressure gradients within an assessment unit. These gradients can be simulated by depth, pressure, and temperature values from hydrocarbon reservoirs. For this project, we will use data primarily from proprietary databases [3-5] as well as estimates from literature [6-9]

The buoyant CO_2 storage resource is then calculated by multiplying values sampled from the buoyant CO_2 storage volume and the CO_2 density distributions. The resulting distribution then provides a range of potential values estimating the total buoyant CO_2 storage resource. The storage resource values for each assessment unit will then be aggregated to an overall buoyant storage resource range of values for the western GoM study area.

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Websites

http://www.beg.utexas.edu/gccc/research/gomcarb

Technologies or techniques

None generated to date.

Inventions, patent applications, and/or licenses

None generated to date.

Other products

None to date.

4. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

The University of Texas at Austin

Bureau of Economic Geology, GCCC (Gulf Coast Carbon Center)
Name: Susan Hovorka, PhD
Project Role: Principal Investigator
Nearest person month worked: 1
Contribution to Project: Leadership in planning and negotiating

Name: Tip Meckel, PhD
Project Role: Co-Principal Investigator
Nearest person month worked: 1
Contribution to Project: Dr. Meckel presented the overview at the kick-off meeting

Name: Ramón Treviño
Project Role: Co-Principal Investigator (project manager)
Nearest person month worked: 1
Contribution to Project: Mr. Treviño provided project management and project reporting; he acted at the primary contact for the DOE project manager and contracting specialist.

Name: Michael DeAngelo
Project Role: Researcher (geophysicist seismic interpreter)
Contribution to Project: Mr. DeAngelo conducted structural interpretation of the "TexLa Merge" and "Texas OBS" regional 3D seismic datasets.

Name: Katherine Romanak, PhD
Project Role: sediment geochemist
Nearest person month worked: 1
Contribution to Project: Liaison with Texas A&M GERG

UT Institute for Geophysics, GBDS (Gulf Basin Depositional Synthesis) Industrial Associates Program

Name: John Snedden
Project Role: Senior Research Scientist
Nearest person month worked: 1
Contribution to Project: Dr. Snedden provided expertise in seismic stratigraphy and siliciclastic depositional systems.

Name: Jon Virdell
Project Role: Project Manager
Nearest person month worked: 1
Contribution to Project: Mr. Virdell provided project and GIS data management support.

Name: Marcie Purkey Phillips
Project Role: Biostratigrapher
Nearest person month worked: 1
Contribution to Project: Mrs. Purkey Phillips contributed expertise in biostratigraphy and integrated well and seismic data in the Chandeleur 3D survey area.

Lamar University

Louisiana Geological Survey

TDI-Brooks, Inc.

Trimeric Corp.

U.S. Geological Survey (USGS)

Lawrence Berkeley National Laboratory

Lawrence Livermore National Laboratory

5. IMPACT:

6. CHANGES/PROBLEMS

Changes in approach and reasons for change: **None**

Actual or anticipated problems or delays and actions or plans to resolve them:

1. **Negotiations between NETL and The University of Texas at Austin (UT) were completed (i.e., related to the Partnership's augmented scope additional funding ($10 million)). Amending existing Partners' subcontracts and adding new Partners commenced. The efforts necessarily**

diverted time and energy away from usual early-project start-up activities and somewhat slowed progress on the original scope and project management.

Changes that have a significant impact on expenditures: **Per item #1 above, expenditures were less than planned.**

Change of primary performance site location from that originally proposed: **None**.

7. SPECIAL REPORTING REQUIREMENTS

Respond to any special reporting requirements specified in the award terms and conditions, as well as any award specific requirements. **None**

8. BUDGETARY INFORMATION

Cost Plan Status Report