Carbon Capture and Offshore Storage in the Gulf of Mexico

Dr. Tip Meckel, Research Scientist

Gulf Coast Carbon Center, Bureau of Economic Geology

Jackson School of Geosciences, University of Texas at Austin


US Army Corps of Engineers®

ERDC Engineer Research and Development Center

Agenda

Coastal Resilience: The Environment, Infrastructure, and Human Systems

21-23 May 2014
New Orleans, Louisiana
Westin Canal Place

Bureau of Economic Geology

The University of Texas at Austin Jackson School of Geosciences

GCCC Gulf Coast Carbon Center

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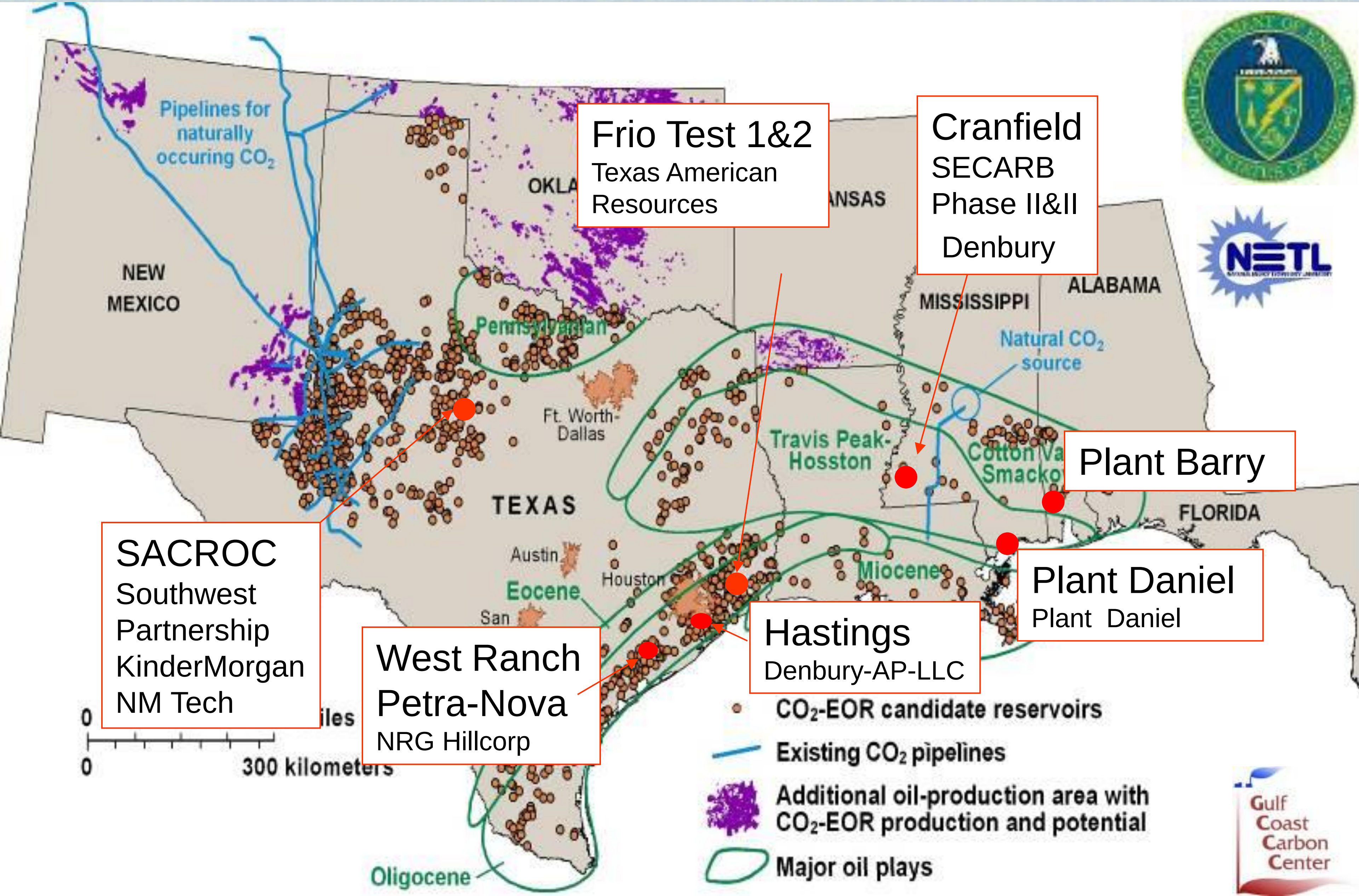
Personnel

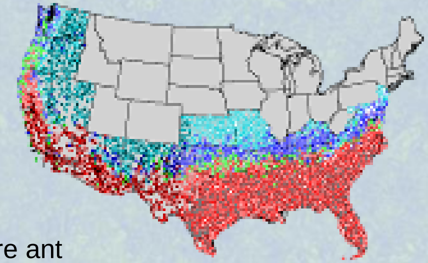
10 PhD PIs
2 RSA
2 project managers
Graduate students
Undergraduates

GCCC DOE-Funded Field Monitoring Programs

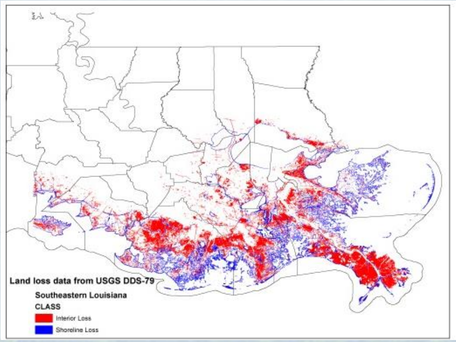


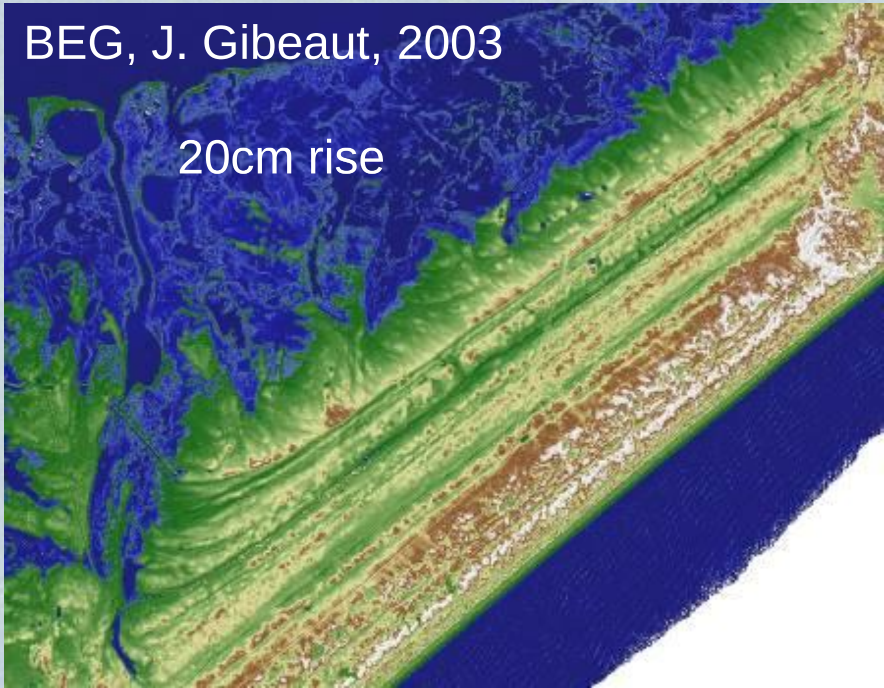
Regional Risks from increased GHG emissions

- **Southeast US is vulnerable to damage resulting from climate change**
  - **Hurricane landfall around Gulf of Mexico**
  - **Risk of tropical species invasion**
  - **Much of US low relief coastline – inundation by sea level rise**

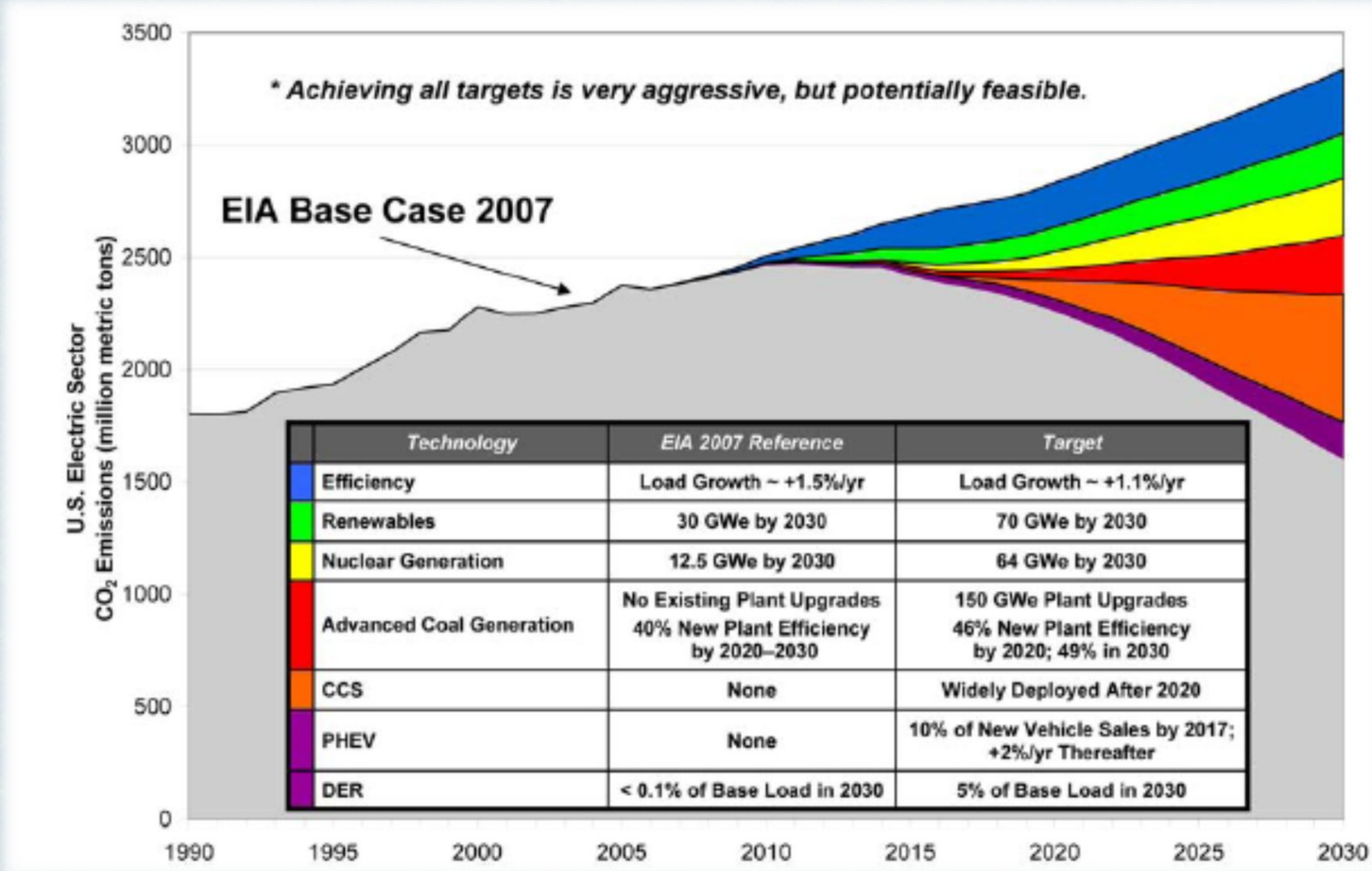


Fire ant
Invasion, USDA





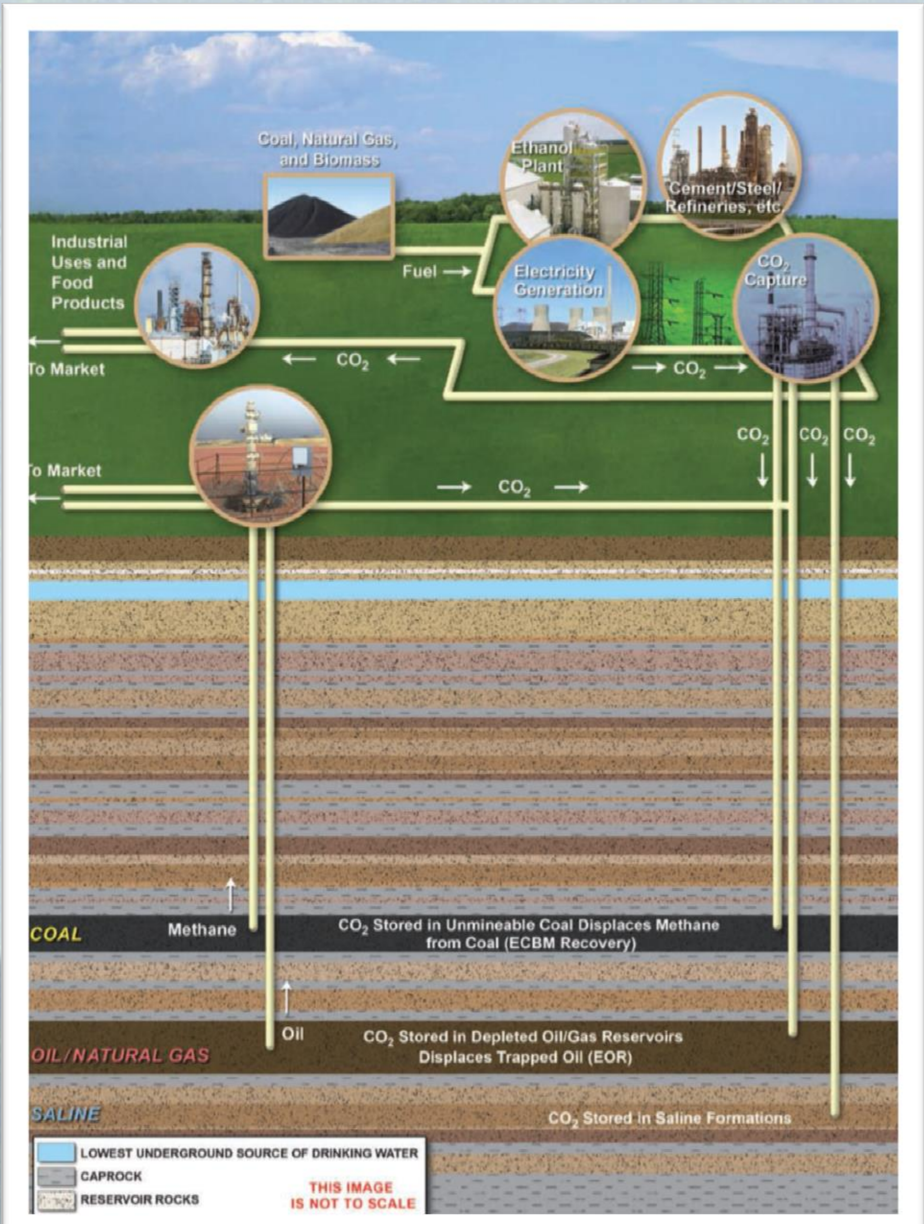
How Do the Emissions Reduction Methods Stack up?



Technology	EIA 2007 Reference	Target
Efficiency	Load Growth ~ +1.5%/yr	Load Growth ~ +1.1%/yr
Renewables	30 GWe by 2030	70 GWe by 2030
Nuclear Generation	12.5 GWe by 2030	64 GWe by 2030
Advanced Coal Generation	No Existing Plant Upgrades 40% New Plant Efficiency by 2020–2030	150 GWe Plant Upgrades 46% New Plant Efficiency by 2020; 49% in 2030
CCS	None	Widely Deployed After 2020
PHEV	None	10% of New Vehicle Sales by 2017; +2%/yr Thereafter
DER	< 0.1% of Base Load in 2030	5% of Base Load in 2030

EPRI “Prism” report http://mydocs.epri.com/docs/public/DiscussionPaper2007.pdf

What is Geologic Carbon Sequestration?



To reduce CO_2 emissions to air from point sources, CO_2 is :

- **Captured** as concentrated high pressure fluid by one of several methods.
- **Transported** as supercritical fluid via pipeline to a selected, permitted injection site.
- **Injected** at pressure into pore space at depths below and isolated (sequestered) from potable water.
- **Stored** in pore space over geologically significant time frames.

Credit: NETL Carbon Utilization and Storage Atlas

Gulf Coast Carbon Center

Offshore CCS is a promising technology due to several key advantages:

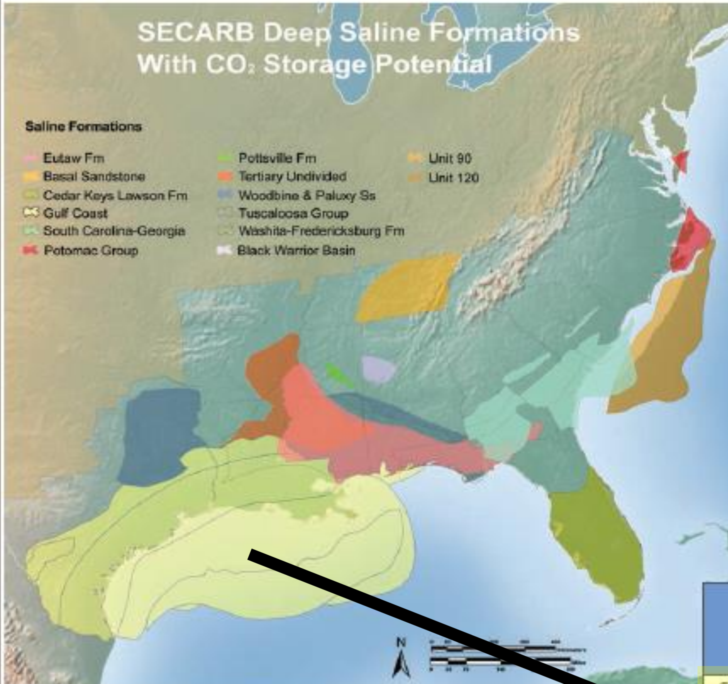
Litynski et al., (2011); Citing extensively Schrag, D., *Storage of Carbon Dioxide in Offshore Sediments*. Science 325, 1658, DOE: 10.1126/science.1175770 (2009).

- *Offshore storage provides* ***additional CO_2 storage potential*** *in the United States to supplement existing onshore capacity estimates.*
- *Reduces the difficulty of establishing surface and mineral rights at candidate storage sites =* ***single land owner****.*
- *Locating sequestration sites* ***away from heavily populated, onshore areas*** *avoids the perception of storing waste material beneath a populated area.*
- *Offshore storage* ***reduces the risk to underground sources of drinking water****.*
- *Establishing transport pipeline corridors or* ***using existing infrastructure*** *should be feasible based on already existing infrastructure for natural gas and oil.*
- *Excellent* ***source-sink matching****.*
- *The overall* ***economics*** *of offshore CCS may be more favorable compared to onshore CCS, despite higher capital costs (for drilling rigs, well manifolds, etc.). This will be especially true if offshore storage projects prove relatively easy to permit, finance, and operate, and can use* ***existing infrastructure****.*

Is geologic sequestration ready to be used as part of a greenhouse gas emissions reduction program?

- Are subsurface volumes adequate to sequester the volumes and rates needed to impact atmospheric concentrations?

- Is storage security adequate to avoid inducing hazards and to benefit atmospheric (oceanic) concentrations?
  – Experience Base



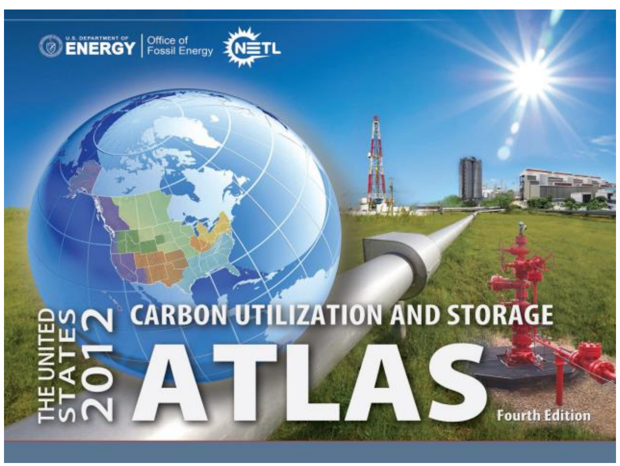
SECARB Saline Formations

Much of the CO_2 storage resource of the SECARB region lies in a thick wedge of sandstones in several sub-basins along the Gulf Coast. Sandstones of the Cretaceous Tuscaloosa Formation and the Paluxy Formation host the current SECARB large-scale field projects, providing an opportunity for scientists to further assess regional geology during detailed site characterization efforts. The Cretaceous Eutaw Formation and Washita-Fredericksburg interval are newly assessed. The Paluxy Formation resource estimate has been refined with newly collected data for Mississippi, Alabama, and Florida. The basal sandstones of Tennessee, including the Mt. Simon Formation, also have been refined. Other Cretaceous formations that provide potential storage resource include sandstones in Texas, from South Carolina to Georgia, the subseabed in the Atlantic Ocean offshore of the Carolinas and Virginia, and carbonates and sandstones in Florida. Overlying Tertiary formations extend offshore and offer additional storage potential. The current assessment establishes that the saline formations in the SECARB region have the potential to store approximately 1,376 billion–14,089 billion metric tons (1,517 billion–15,530 billion tons) of CO_2.

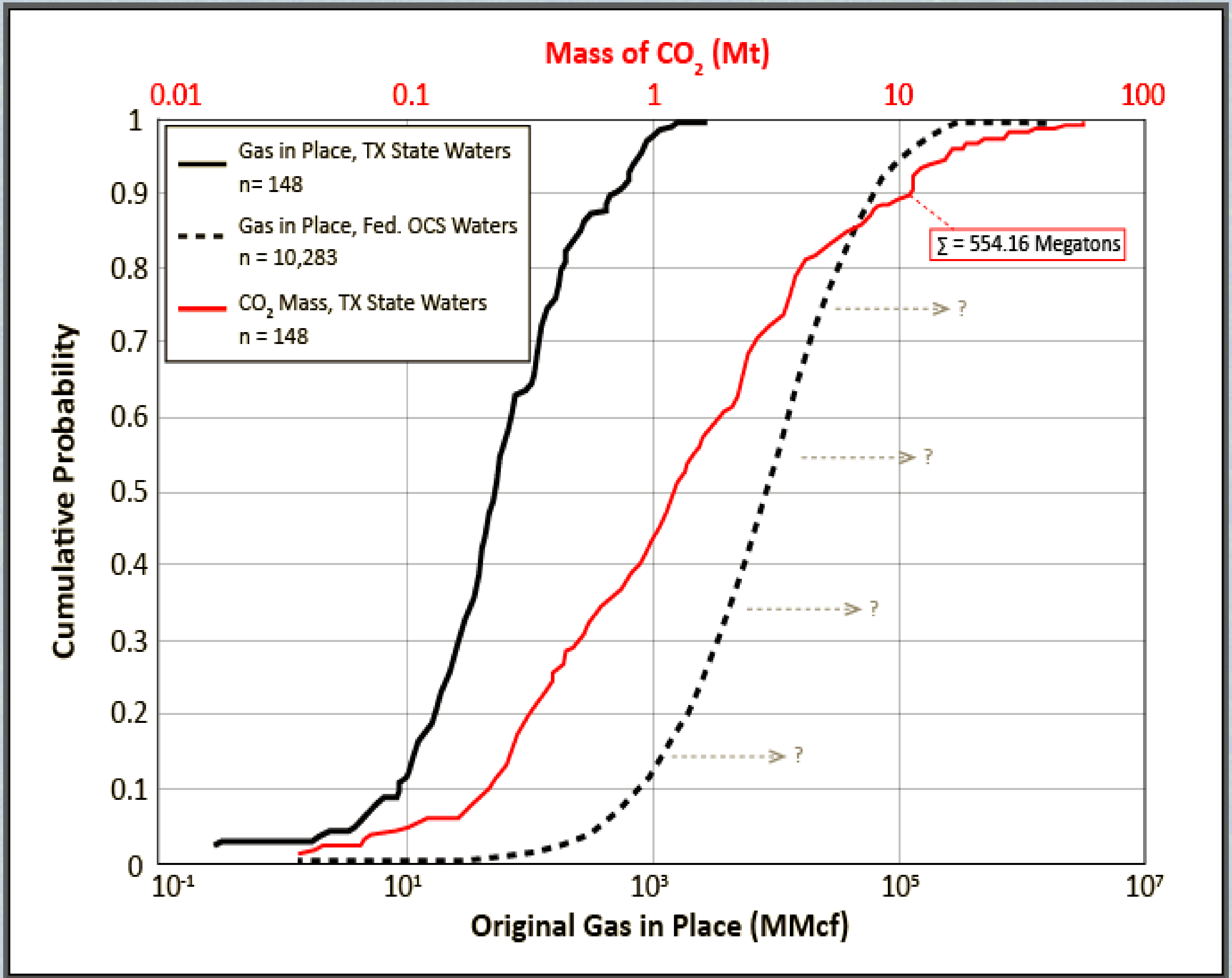
In 2011, the Savannah River National Laboratory completed a study entitled Reconnaissance Assessment of the CO_2 Sequestration Potential in the Triassic Age Rift Basin Trend of South Carolina, Georgia, and Northern Florida. They conservatively calculated a storage resource of 137 billion metric tons (151 billion tons). Based upon a revised configuration of the basins using GIS and including previous offshore estimates, the storage resource could be as much as 204 billion-244 billion metric tons (225 billion-269 billion tons). Further investigation is needed to quantify the storage potential.

Saline Formations	State	CO_2 Storage Resource Million Metric Tons	
		Low Estimate	High Estimate
Gulf Coast Basins (Pliocene)	Multiple States*	136,006	1,870,083
Gulf Coast Basins (Miocene)	Multiple States*	401,185	5,516,295
Gulf Coast Basins (Oligocene)	Multiple States*	131,661	1,810,337
Gulf Coast Basins (Eocene)	Multiple States	156,551	2,152,574
Gulf Coast Basins (Tertiary Undivided)	Multiple States	17,065	234,639
Gulf Coast Basins (Olmos)	TX**	446	6,126
Eutaw Formation	Multiple States	22,564	73,179
Tuscaloosa Group	Multiple States	5,433	74,704
Washita-Fredericksburg Interval	Multiple States	225,057	729,913
Woodbine and Paluxy Formations	Multiple States	22,787	643,888
Pottsville Formation	Multiple States	1,299	17,858
Parkwood Formation	AL	20	838
Bangor Limestone	AL	3	44
Floyd Shale	AL	9	119
Tuscumbia and Fort Payne Formations	AL	19	263
Basal Sandstone (Includes Mt. Simon)	TN	407	3,894
Potomac Group	Multiple States*	1,778	24,453
South Carolina, Georgia, North Florida Basins	Multiple States*	203,753	244,248
Cedar Keys, Lawson Formations	FL	11,104	152,680
Offshore Atlantic (Unit 120)	Federal Offshore	35,624	489,830
Offshore Atlantic (Unit 90)	Federal Offshore	3,104	42,680
TOTAL*		**1,375,874**	**14,088,646**

SECARB shares KY and WV with other RCSPs. Data for these states can be found under MGSC and/or MRCSP.
* Including offshore Federal Waters
** Eastern Texas, TRRC Districts 1-6



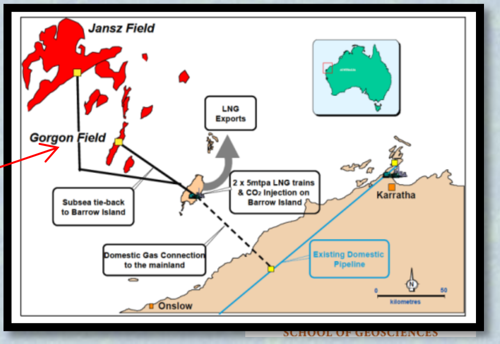
Static Gas Field Capacity



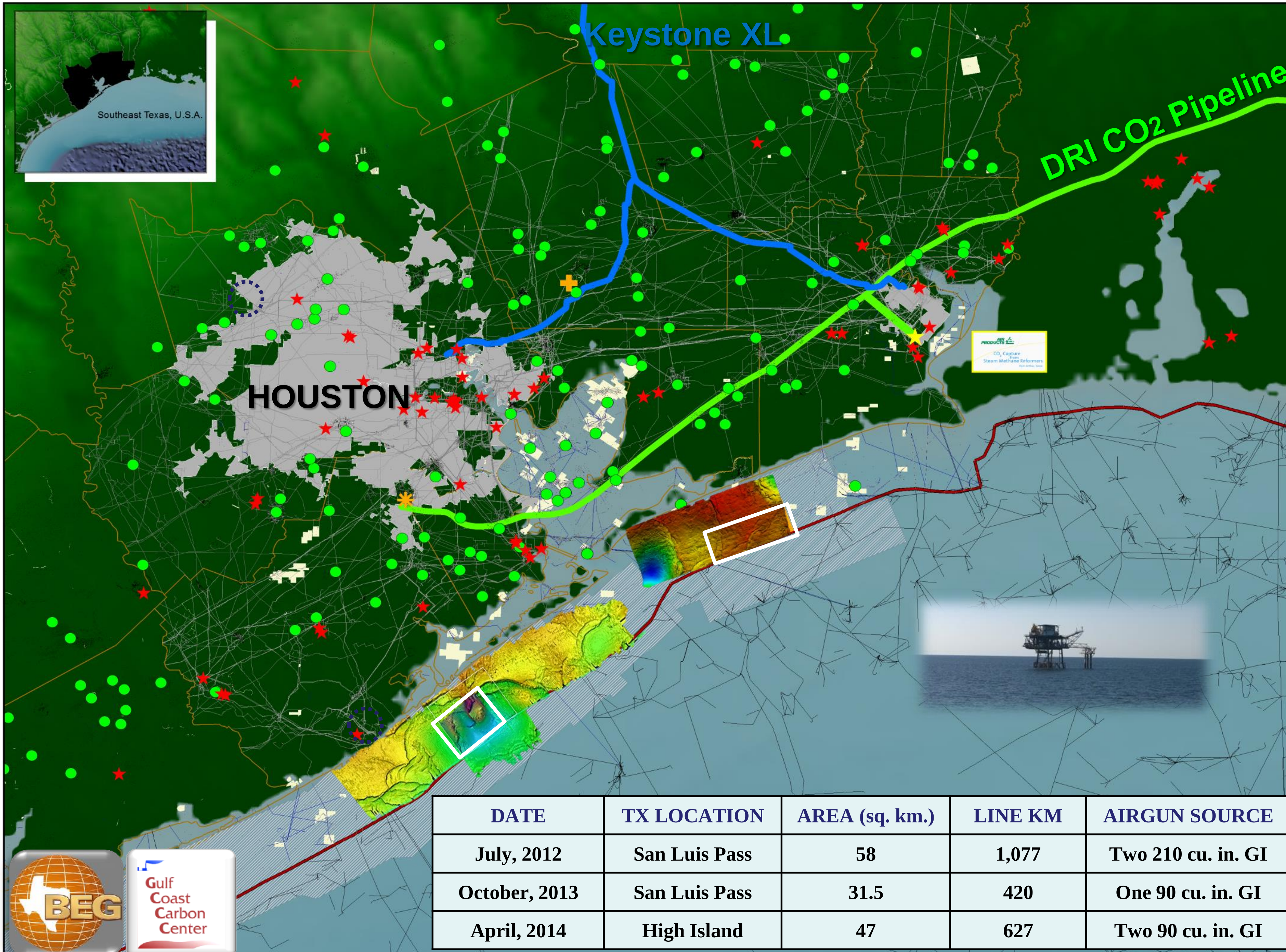
What are Some Examples of Offshore CO_2 Storage Activity?

- **Norway** – Statoil-Hydro have 13 years of operational experience in the North Sea (**Sleipner**). This facility has set the standard, including innovative EU-funded research programmes. A second sub-sea storage project is underway by Statoil at **Snovit**, utilizing CO_2 pipelines from onshore.
- **Australia** - Conceptualization for offshore storage has been completed in the **Gippsland** Basin (Offshore Victoria), and leasing has been completed. The **Gorgon** project (NW Shelf) is essentially an offshore project (although it utilizes Barrow Island for infrastructure).
- **Japan** – Currently seeking offshore storage sites at continental margins, including a planned field test at **Tomakomai**.
- **United Kingdom** - Competition is underway that features offshore sites. British Geological Survey and Scottish CCS Centre have completed feasibility studies for sub-North sea storage.
- **Netherlands** - TNO has completed several sub-sea tests of storage in depleted gas reservoirs and have plans for capacity and utilization of the Dutch segment of the sub-North Sea, as part of the ROADS project.
- **United States** – Studies underway to determine offshore CO_2 capacity in Texas and northern Gulf of Mexico. Research conducted by GCCC at The University of Texas at Austin.

ACTIVE INDUSTRIAL PROJECTS
Sleipner, Snohvit – North Sea
In-Salah – Algeria (onshore)
Gorgon, NW Shelf Australia (15% CO_2)



GULF COAST CARBON CENTER



DATE	TX LOCATION	AREA (sq. km.)	LINE KM	AIRGUN SOURCE
July, 2012	San Luis Pass	58	1,077	Two 210 cu. in. GI
October, 2013	San Luis Pass	31.5	420	One 90 cu. in. GI
April, 2014	High Island	47	627	Two 90 cu. in. GI

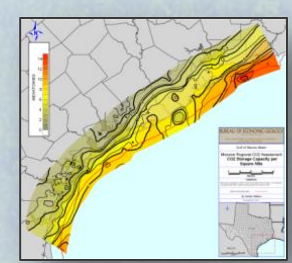
2011-2014: Gulf of Mexico Miocene CO_2 Site Characterization Study

Primary Study Objectives

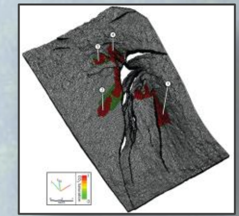
- Refine Miocene capacity estimates in TX state waters.
  - Mapping, Formation Properties Database
- Identify regional CO_2 ‘plays’ for prospective storage.
  - Atlas-style product
- Evaluate regional containment potential.
  - seal integrity; structural compartmentalization.
- Identify specific prospective 30+ Mt site(s).
- Collect additional data to reduce barriers to near-term utilization of those sites.
  - P-Cable high resolution 3D seismic surveys

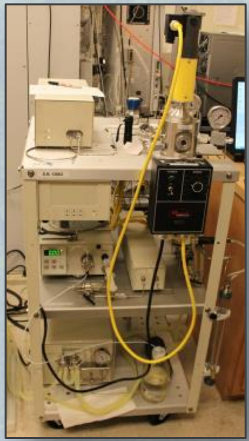
Google Earth image

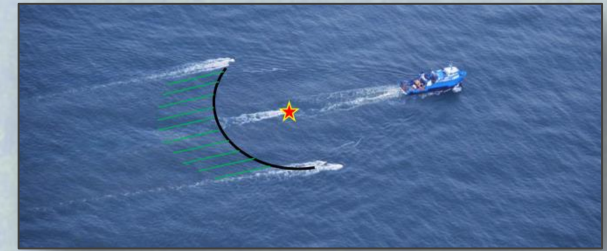
Geoscience Research Scope

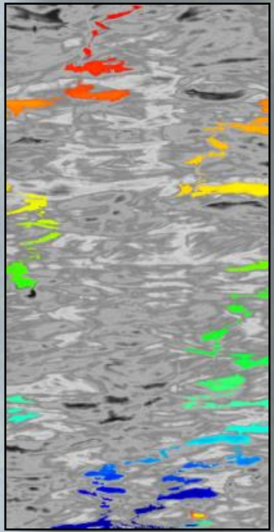


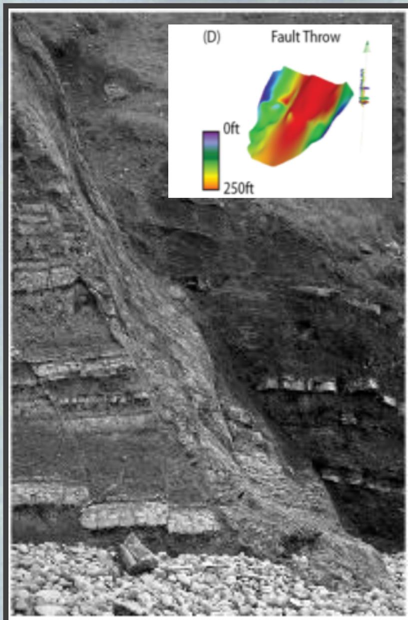
- Static capacity calculations
- Dynamic capacity calculations
  - Analytical & geocellular modeling
- Geochemistry
- Mudrock sealing capacity
- Fluid migration, saturation
- Fault seal
- Seismics











Draft: Environmental Aspects

T. O'Connor, S. Anderson, M. Odom and J. Marston

"…with appropriate site selection, operational safeguards, and compliance with existing regulatory requirements and best practice methodology for monitoring, offshore CCS can be performed in Texas state waters safely and effectively, and with limited risk to the coastal environment".

Monitoring / reporting practices critical to ensure against environmental risks

Practices utilized must:

- Prevent problems from occurring
- Identify problems if they arise
- Cease and mitigate any damages

10 recommendations: avoiding direct/indirect impacts, precautionary approach, site-specific evaluation, brine focused, maximum distance from shoreline, AoR, utilize existing infrastructure, MVAR plan, Contingency & remediation plan.

IDENTIFIED RISKS FROM SEQUESTRATION OF CO_2

- Transport (pipeline)
- Injection
  - Overpressure, well integrity
- Leakage from the confining zone to the seafloor-sediments-water column.
  - Wells, faults
- Groundwater interaction
  - Saltwater incursion
- Potential impacts on fauna

Regulations and Jurisdictions Governing Near-shore CCS – working document

	State		Federal		
Topic	Offshore Permitting	Pipeline transportation	GHG monitoring & reporting	GS site selection, operation & monitoring	Pipeline transportation
Law/Rule	Texas Coastal Management Program	Texas State Pipeline Regulations	GHG Reporting Rule (12/2010)	UIC Class VI Regulations (12/2010)	Pipeline Inspection Protection Enforcement and Safety (PIPES) Act of 2006 *
Organization	TX Coastal Coordination Council (CCC)	Railroad Commission (RRC)	EPA	EPA	DOT Pipeline Hazardous Material Safety Agency
Authority	Coastal Zone Management Act (applies to submerged offshore state lands)	49 CFR Parts 190-199	Clean Air Act	Safe Drinking Water Act	49 CFR Parts 190-199
Key points	Governs issuance of coastal area permits by RRC		• Specifies protocol for monitoring and measurement of CO2 storage and emissions • Requires operators submit plan for responding to and stopping leaks • Uses "mass balance" equation for calculating CO2 sequestered • Does not mandate storage of CO2, only proper accounting • BEG project may qualify for an exemption as R&D well	• Covers protocol for all aspects of onshore and offshore geological storage • Site selection, operation, testing & monitoring, financial responsibility and more • Unique in the UIC program in that it requires permit applicant to submit detailed MRV plan with application • Offshore wells must be equipped with automatic downhole shut-off systems	• Provides guidance on safety measures, quality and materials standards.

Is storage security adequate to avoid inducing hazards and to benefit atmospheric/oceanic concentrations?

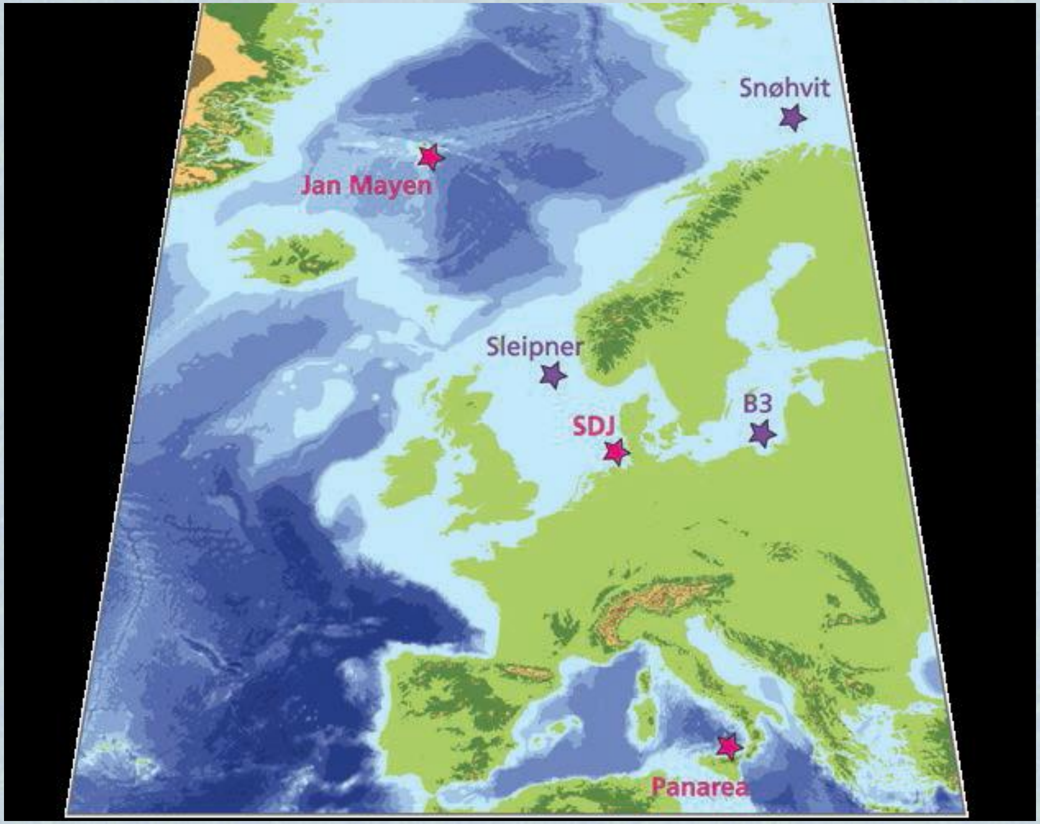
WIDE ARRAY OF LEAKAGE DETECTION STRATEGIES AND ANALYTICS AVAILABLE

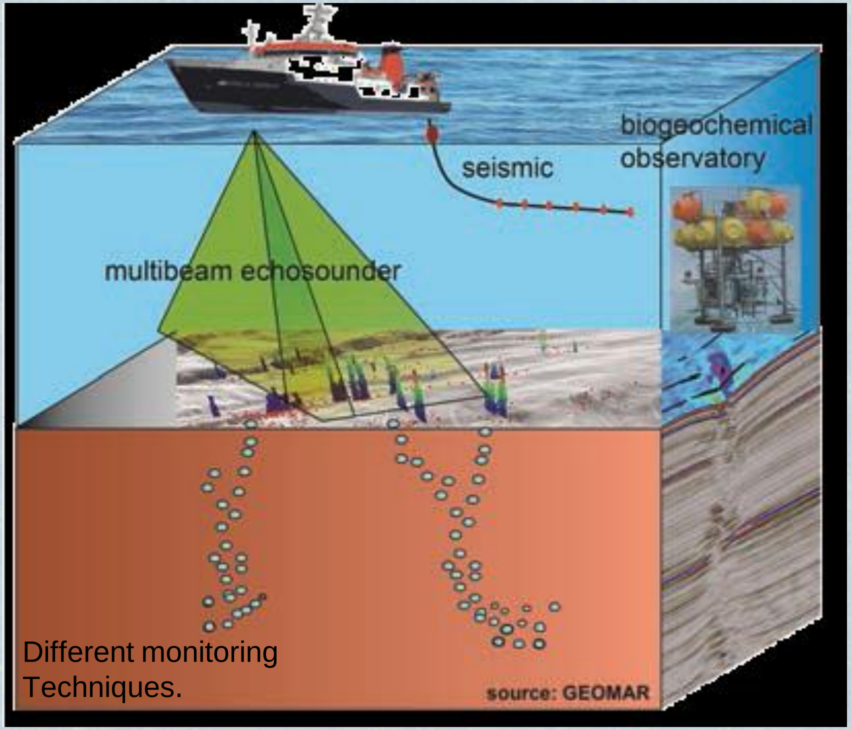
.

QICS controlled release, Scotland

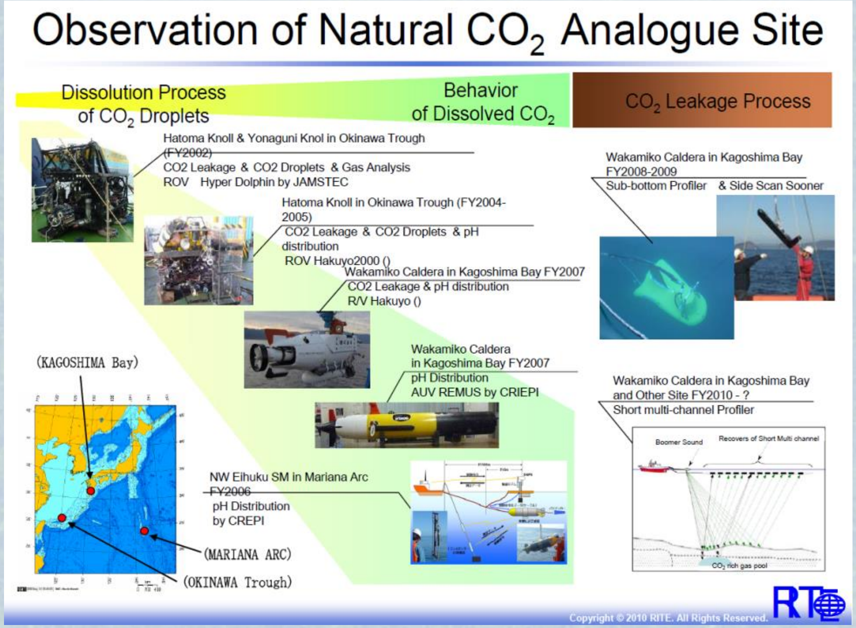
Natural Analogs: Eco_2

Klaus Wallmann, GEOMAR & others





Different monitoring Techniques.

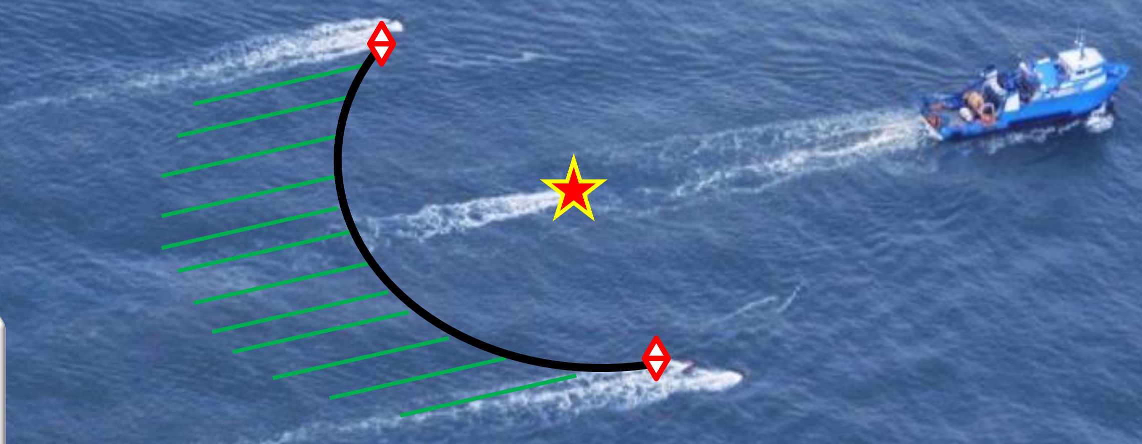


Based on available literature, research on CO_2 seeps, vents and discharges is ongoing or completed at the following sites:

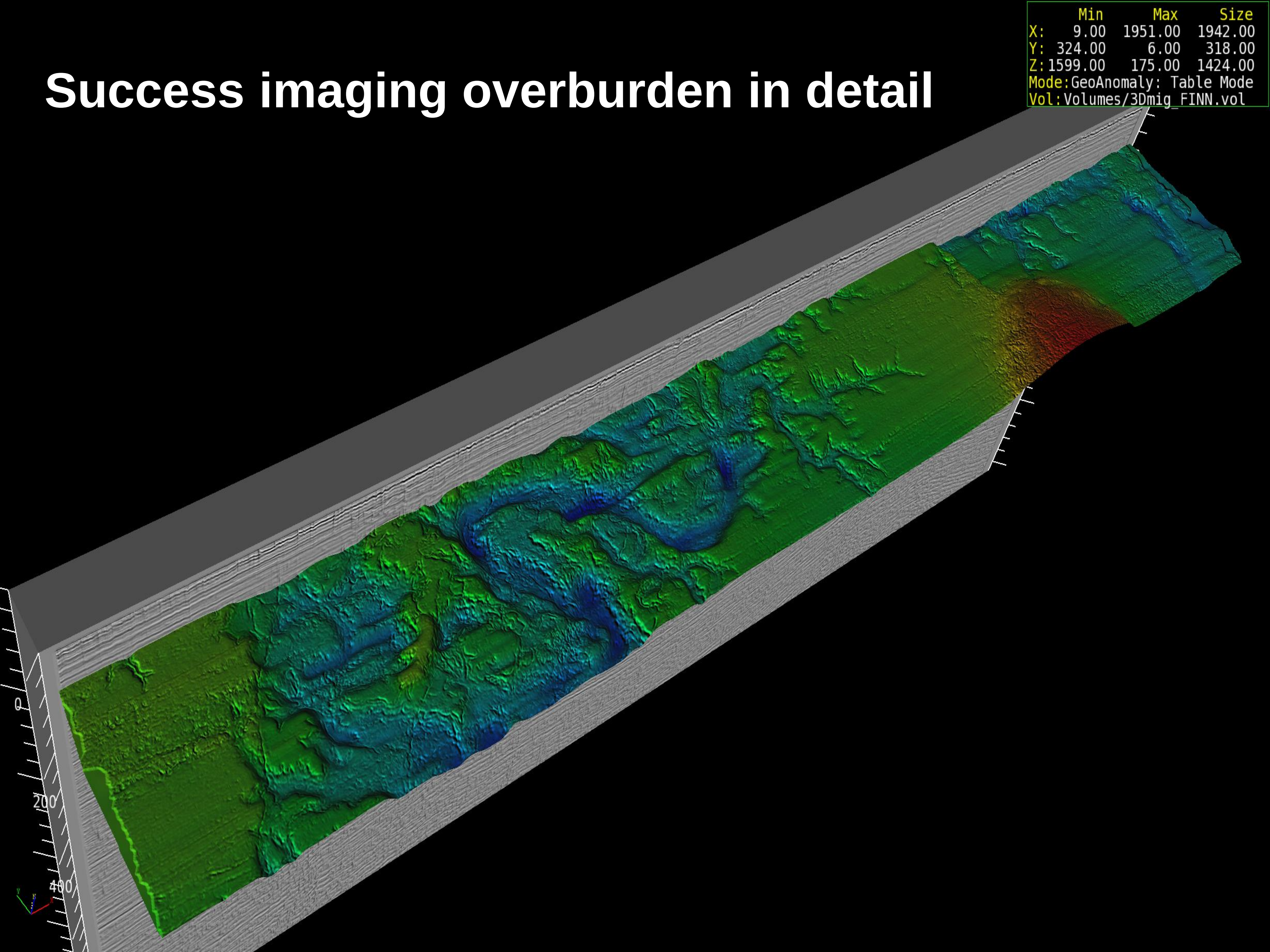
- Norwegian offshore CO2 storage Sleipner;
- Norwegian offshore CO2 storage Snøhvit;
- B3 field in the Polish Baltic Sea;
- Natural CO2 seeps off:
    - Italy (Panarea);
    - Japan (Okinawa Trough);
    - Germany (Salt dome Juist, Lake Kaach);
    - Norway (Jan Mayen).

Photo by Eddie Tausch, courtesy of TDI-Brooks, Int.

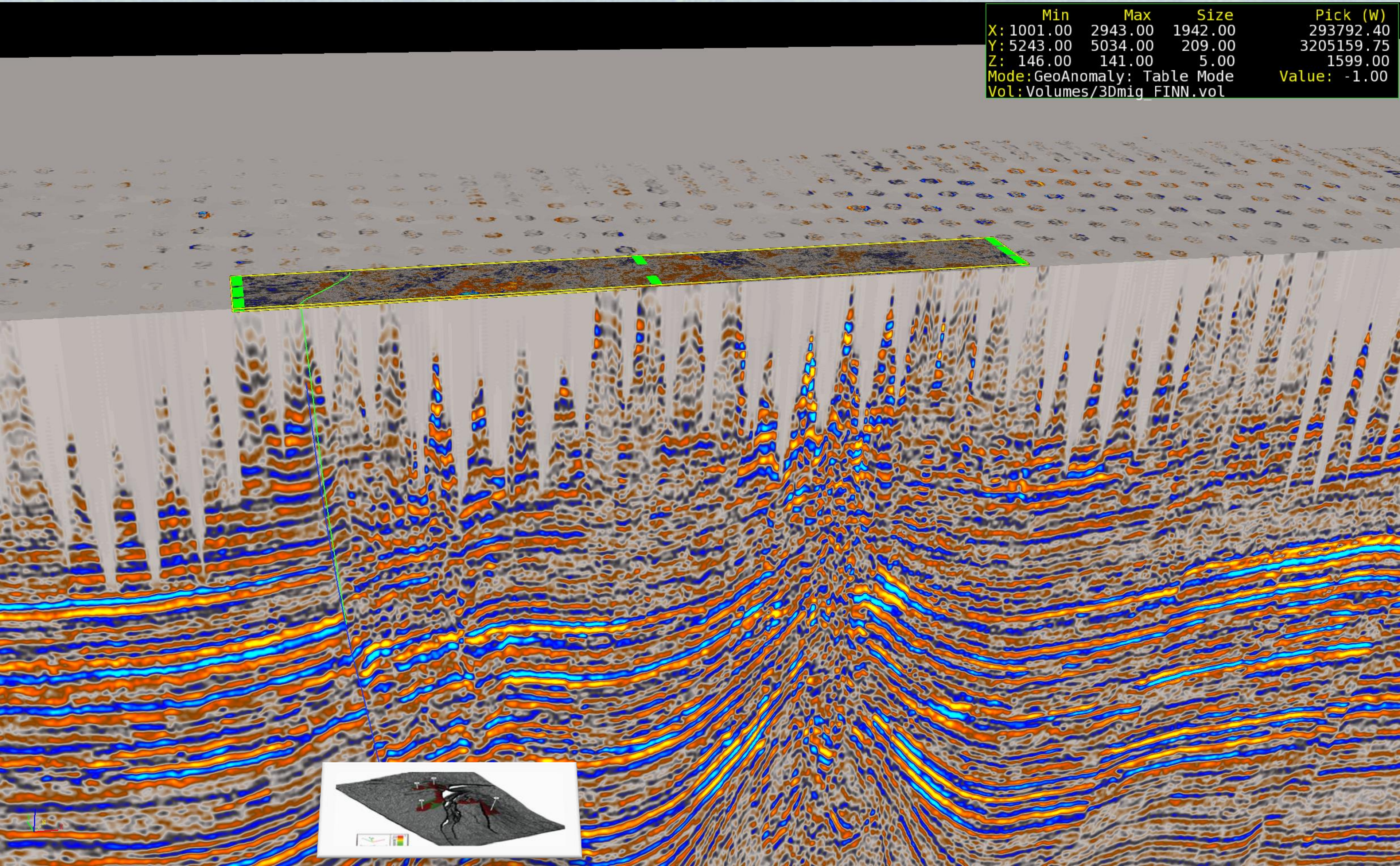
First 3 deployments in GoM



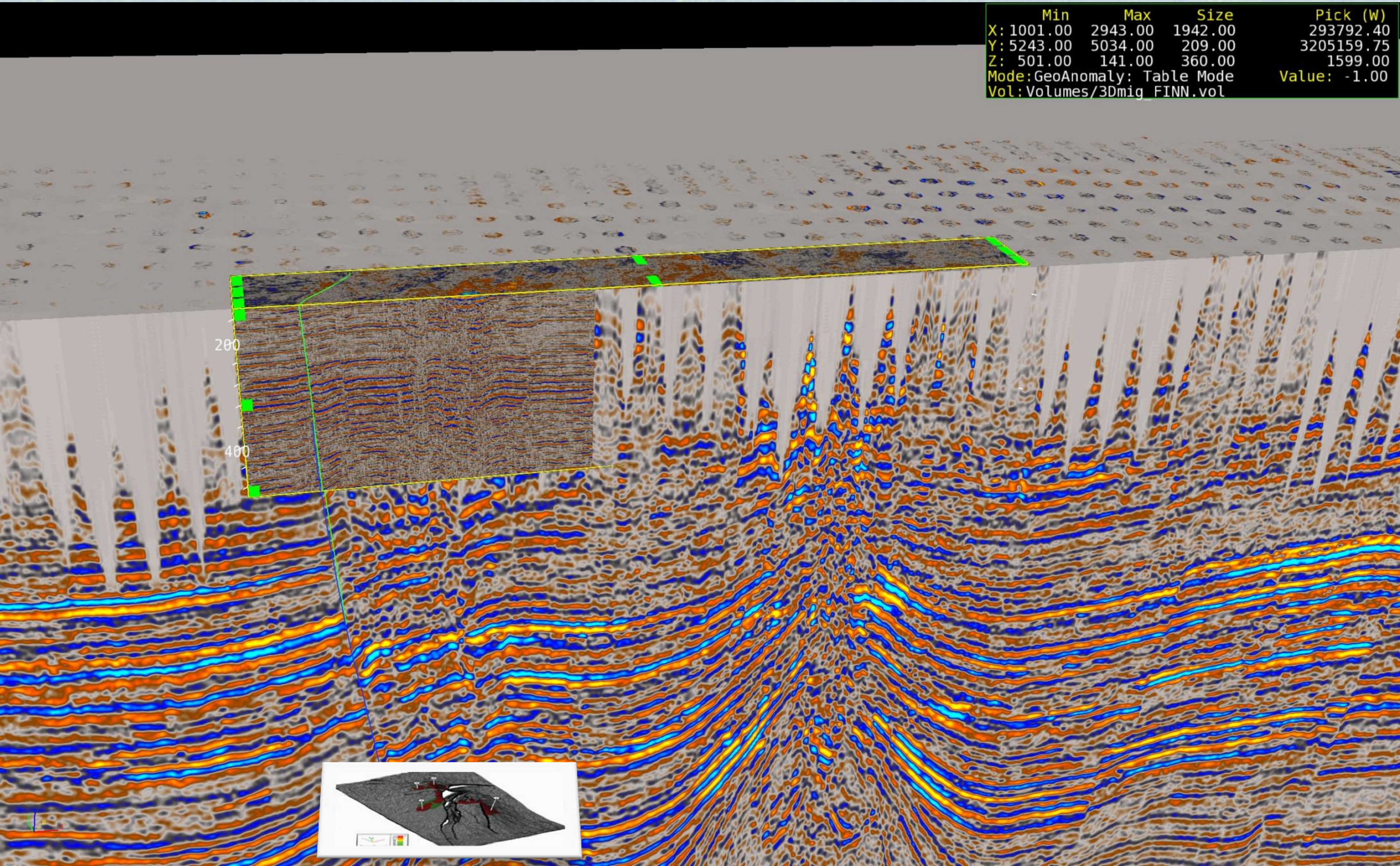
Success imaging overburden in detail



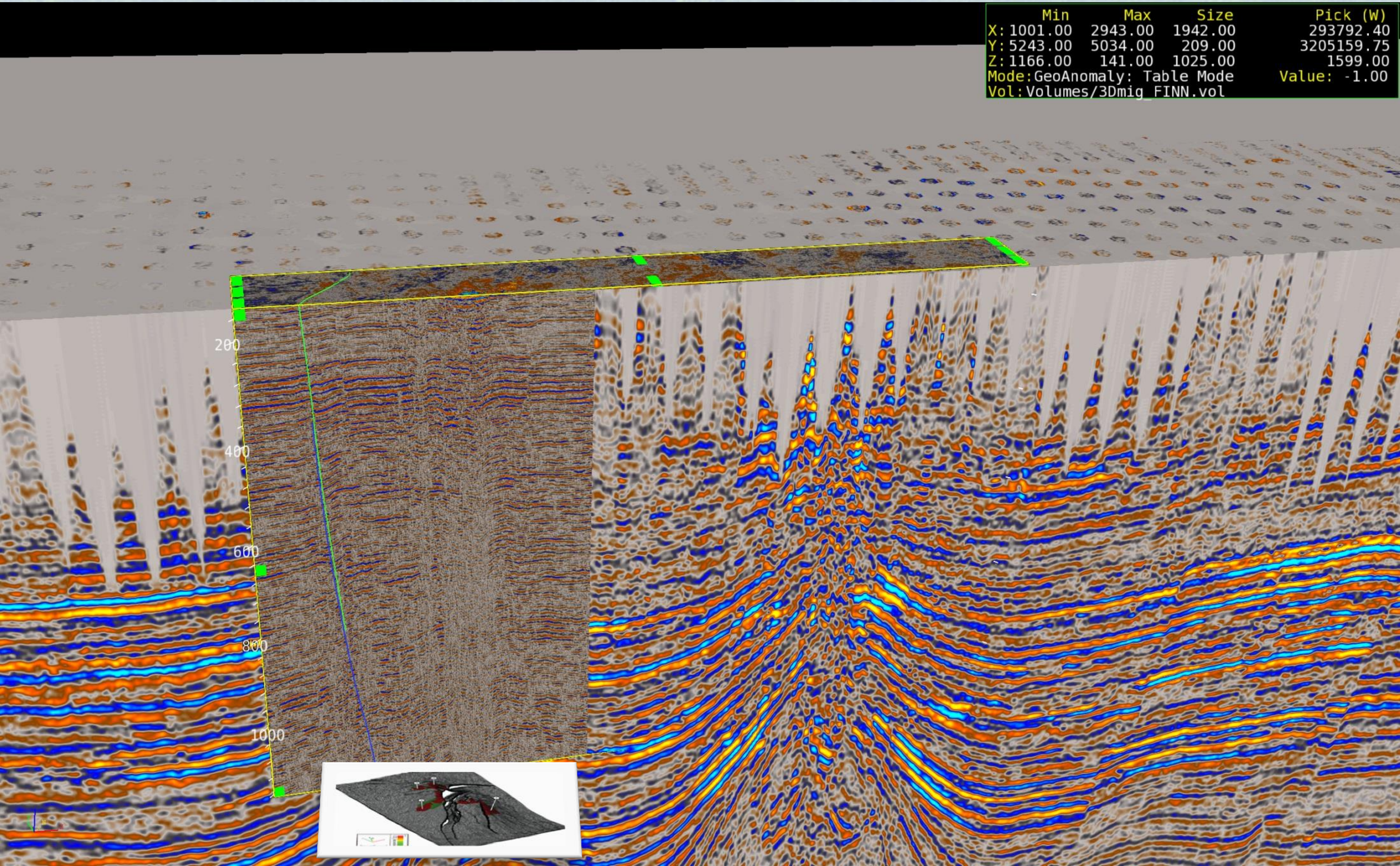
The benefit of HR3D for overburden characterization

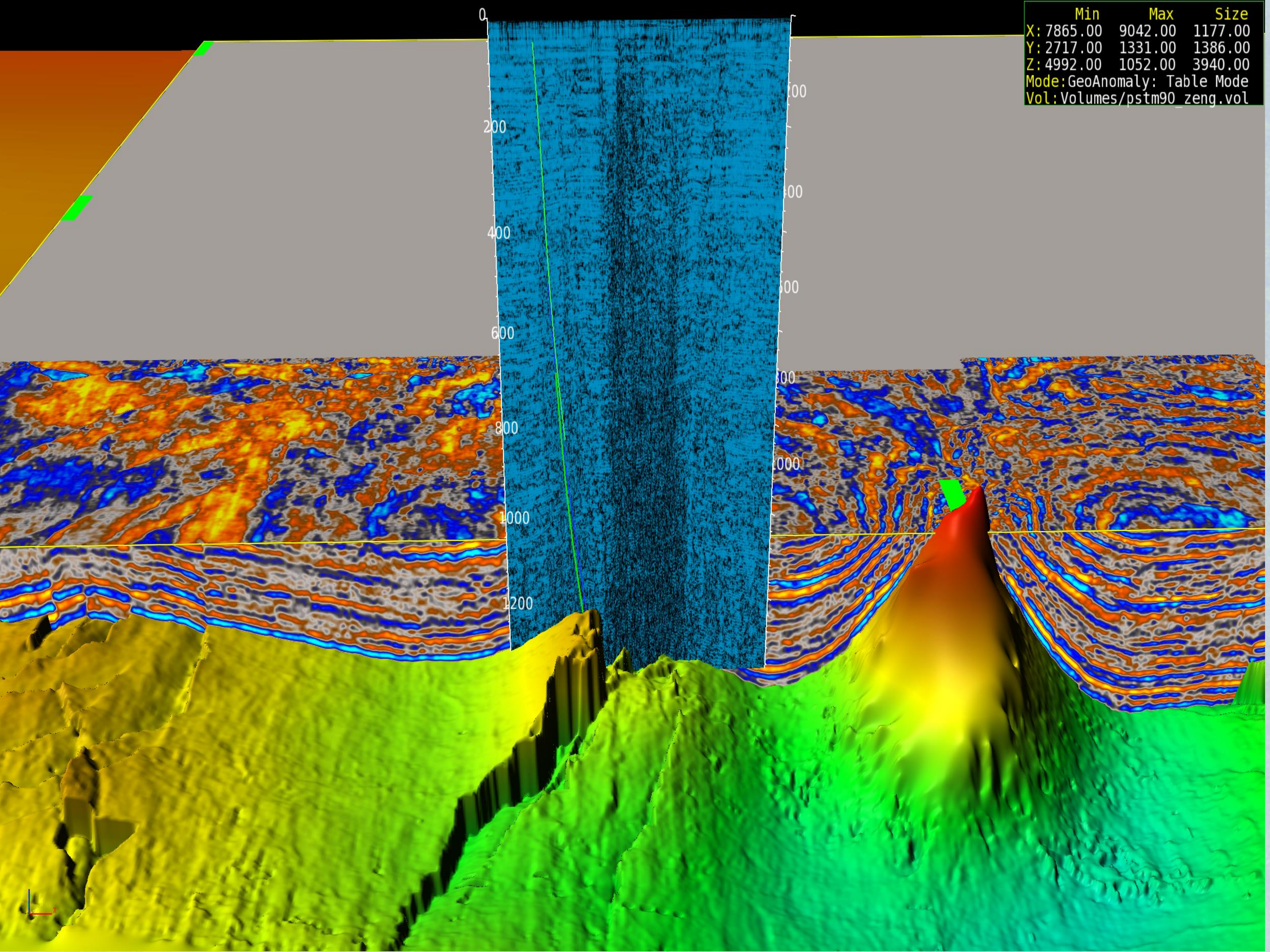


The benefit of HR3D for overburden characterization



The benefit of HR3D for overburden characterization

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Coastal resilience?

- Subsidence

GEOPHYSICAL RESEARCH LETTERS, VOL. 33, L11403, doi:10.1029/2006GL026300, 2006

Current subsidence rates due to compaction of Holocene sediments in southern Louisiana

T. A. Meckel,[1] U. S. ten Brink,[1] and S. Jeffress Williams[1]

Basin Research (2007) **19**, 19–31, doi: 10.1111/j.1365-2117.2006.00310.x

Sediment compaction rates and subsidence in deltaic plains: numerical constraints and stratigraphic influences

T. A. Meckel,[1] U. S. Ten Brink and S. J. Williams

United States Geological Survey, Woods Hole, MA, USA

Contents lists available at ScienceDirect

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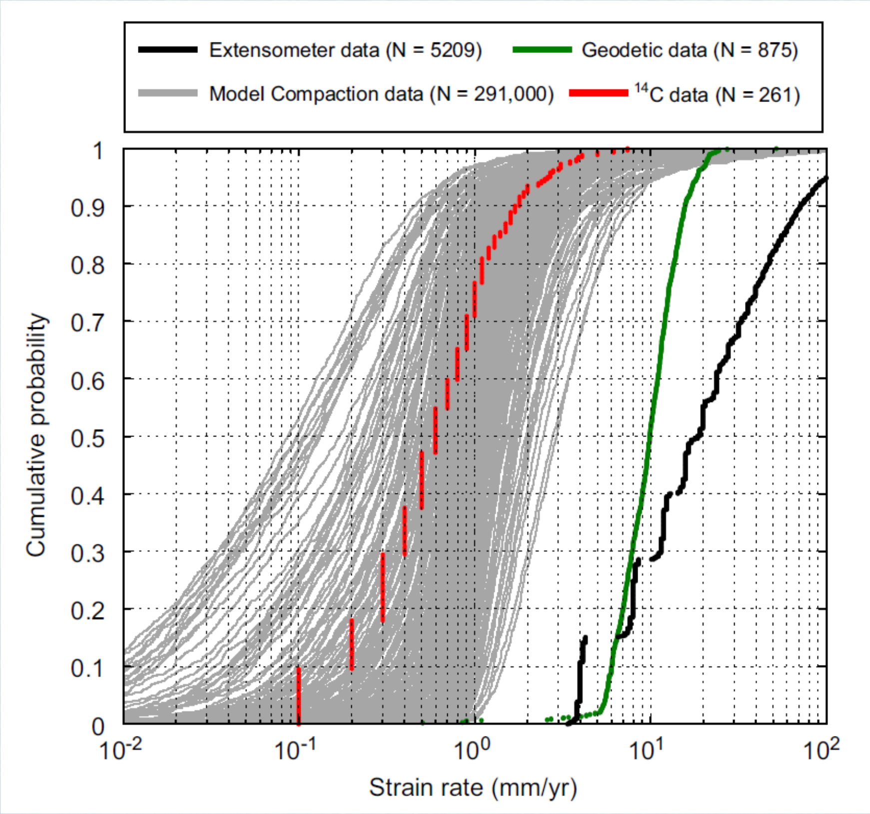
ELSEVIER

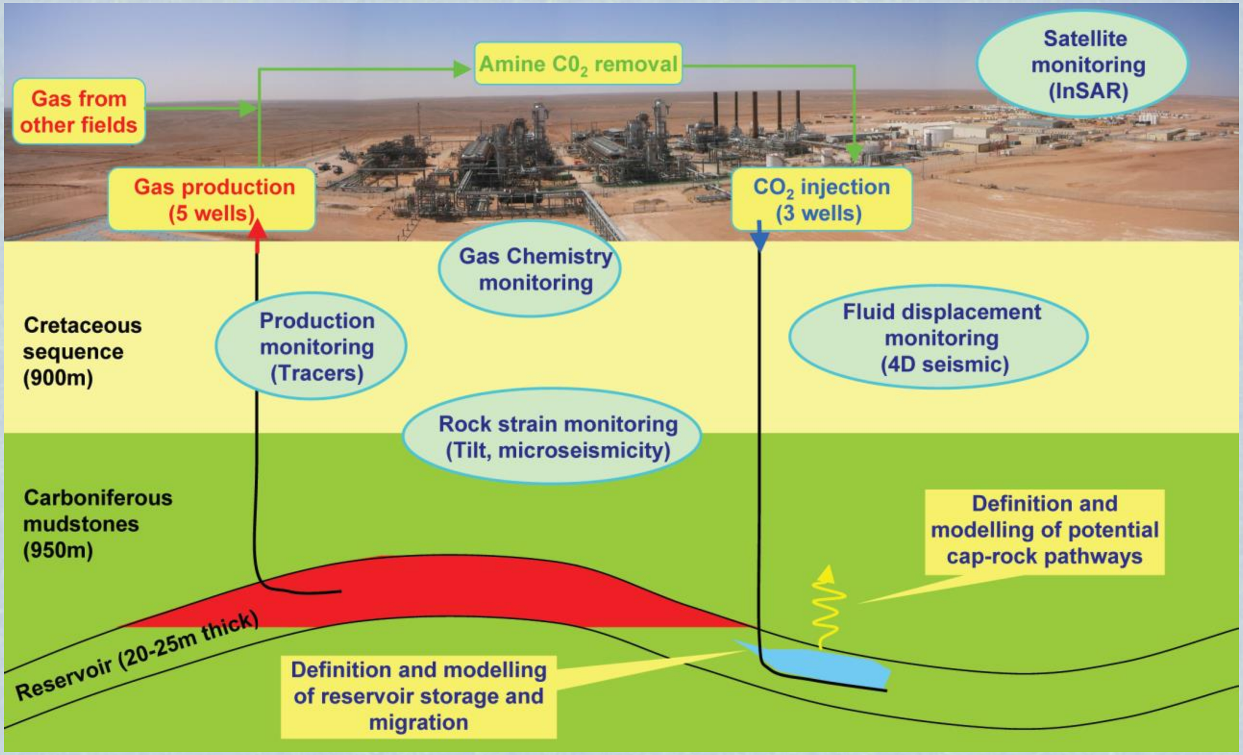
An attempt to reconcile subsidence rates determined from various techniques in southern Louisiana

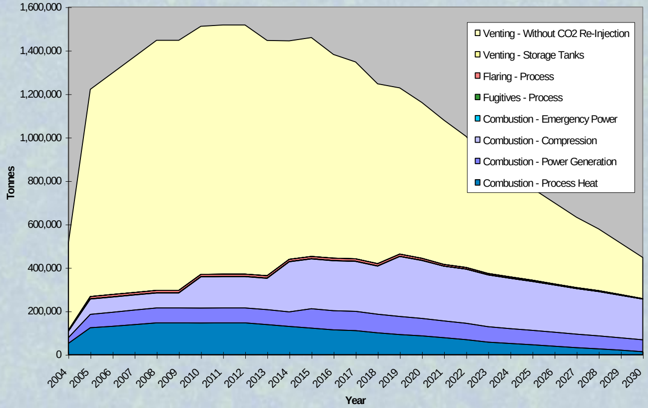
T.A. Meckel *

Bureau of Economic Geology, John A. and Katherine G. Jackson School of Geosciences, The University of Texas at Austin, 10100 Burnet Road, Austin, TX 78713-8924, USA



In Salah Gas Project





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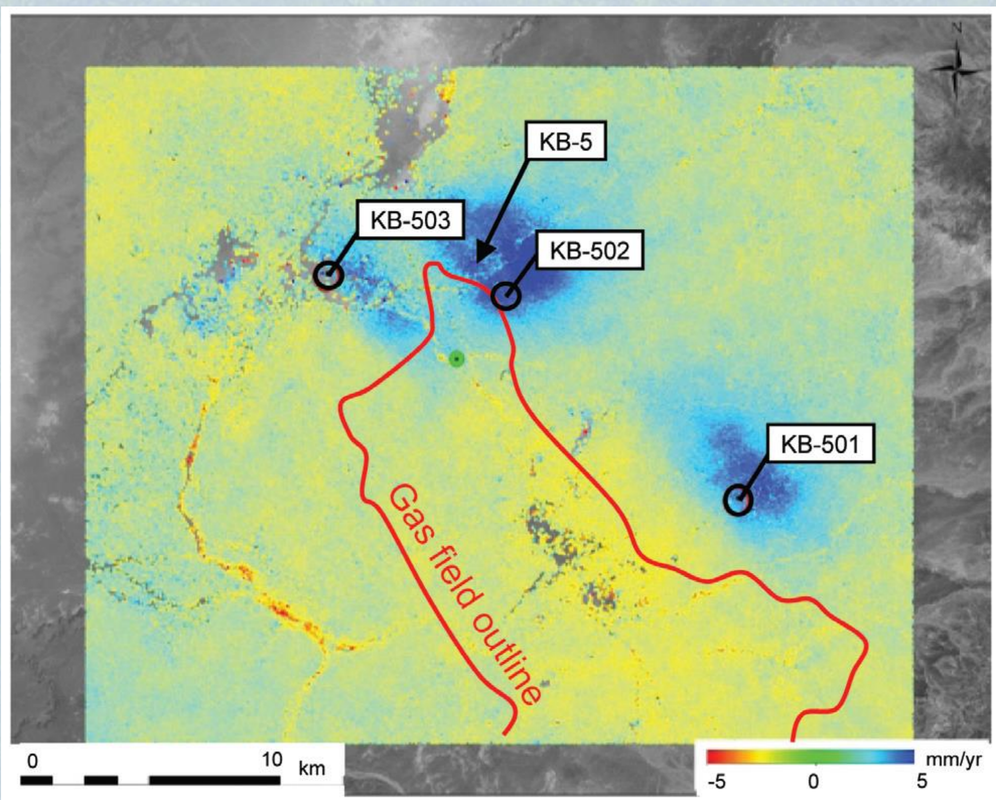
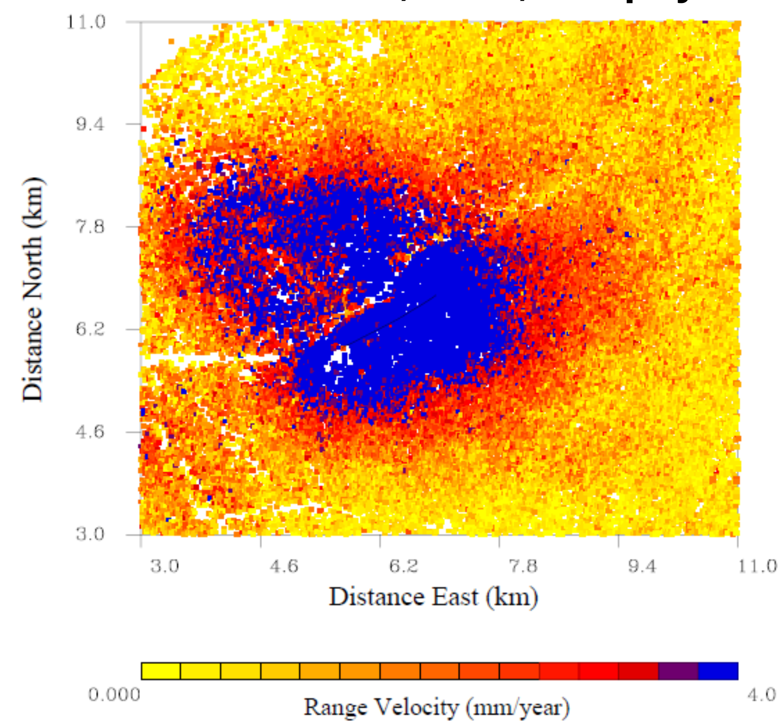
first break volume 27, January 2009

Plume development around well KB-502 at the In Salah CO_2 storage site

Philip Ringrose,[1*] Mansour Atbi,[2] David Mason,[2] Marianne Espinassous,[2] Øyvind Myhrer,[2] Martin Iding,[1] Allan Mathieson,[3] and Iain Wright[3] report on the lessons learned so far from early phase monitoring of the pioneering In Salah CO_2 storage project in Algeria by joint venture partners BP, Sonatrach, and StatoilHydro which has a planned operational lifetime of more than 20 years.



Vasco et al., 2008, Geophysics



Is geologic sequestration ready to be used as part of a greenhouse gas emissions reduction program?

- Are subsurface volumes adequate to sequester the volumes and rates needed to impact atmospheric concentrations?

- Is storage security adequate to avoid inducing hazards and to benefit atmospheric (oceanic) concentrations?
  - Risks vs. Benefits

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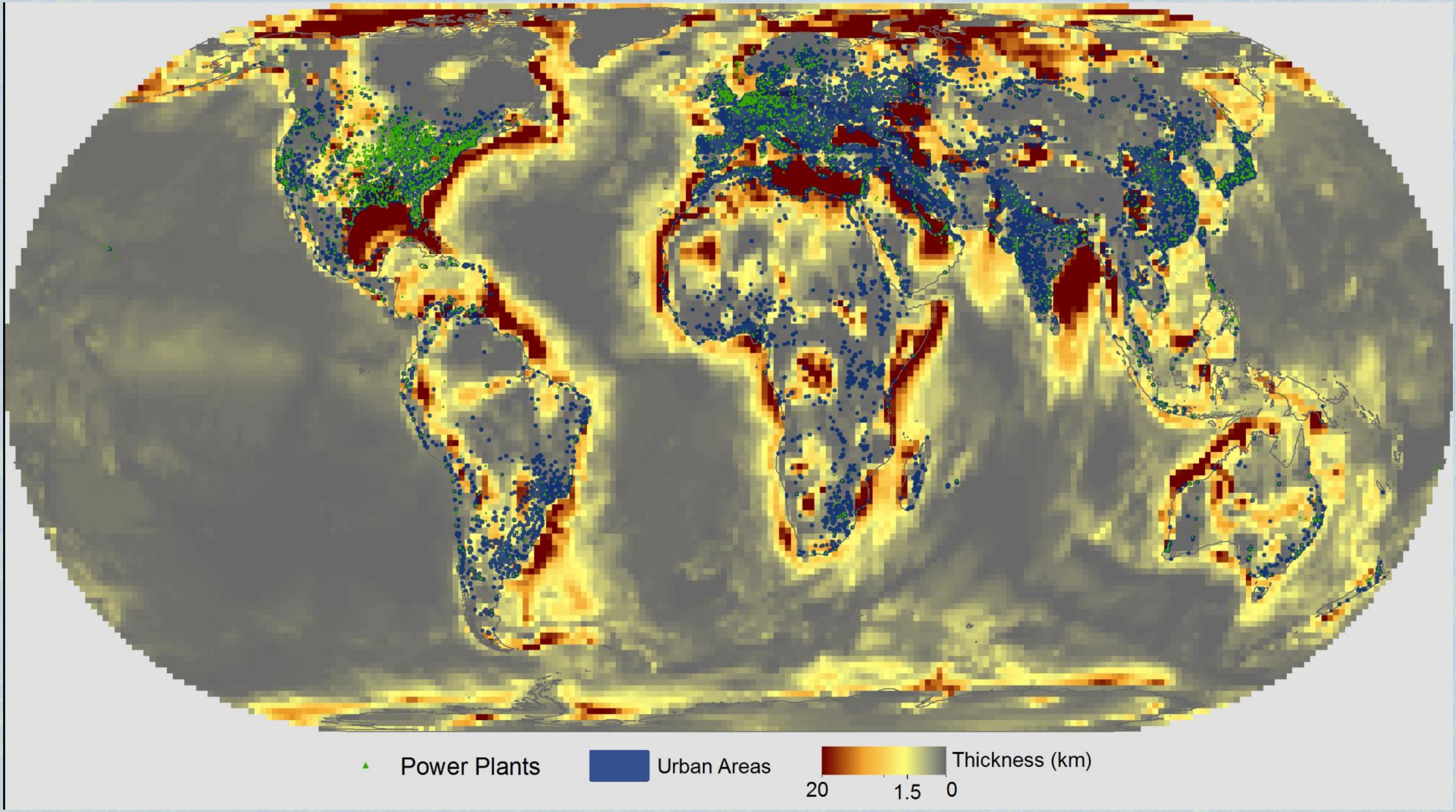
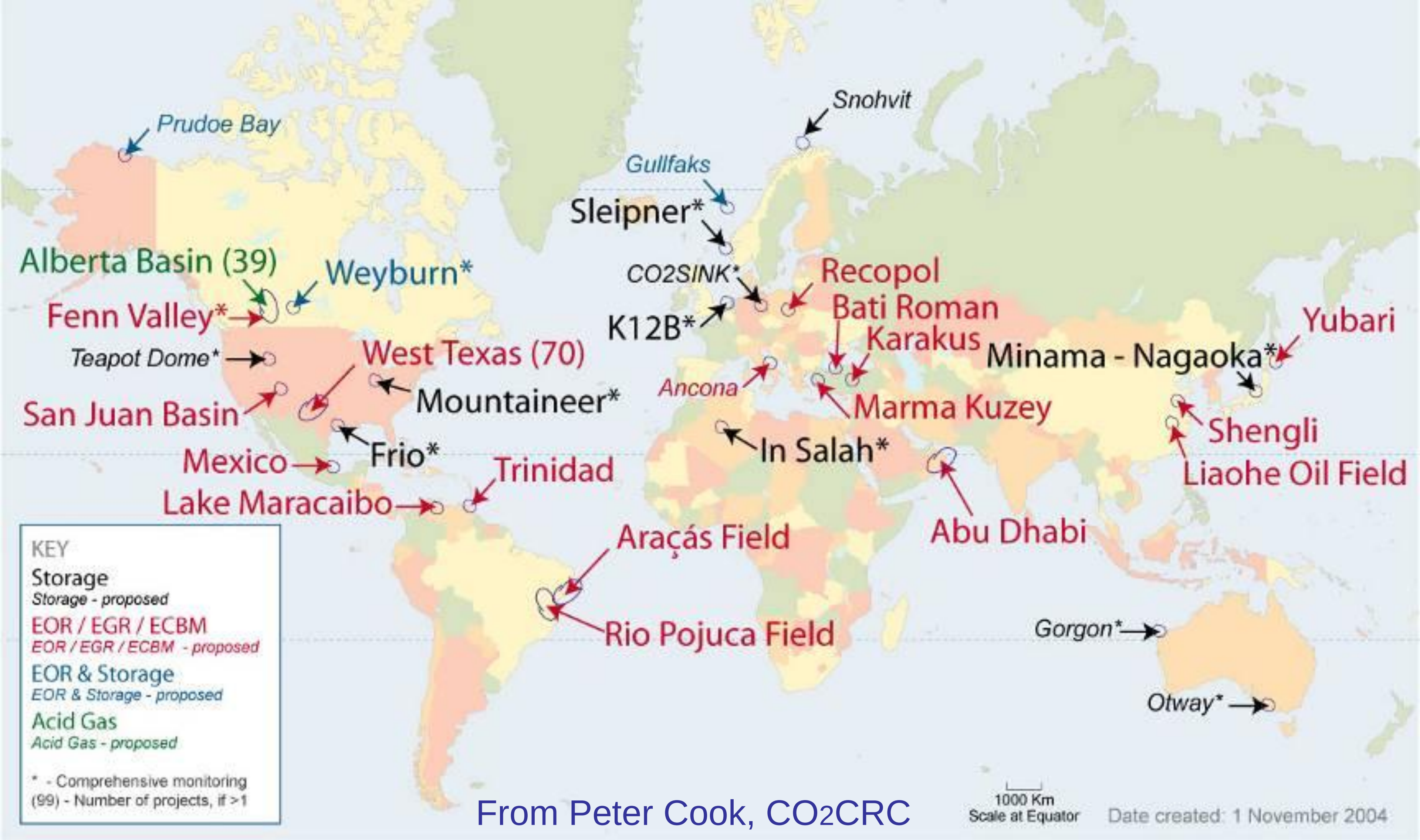
Offshore Potential
Relative to Population Centers & CO2 Sources



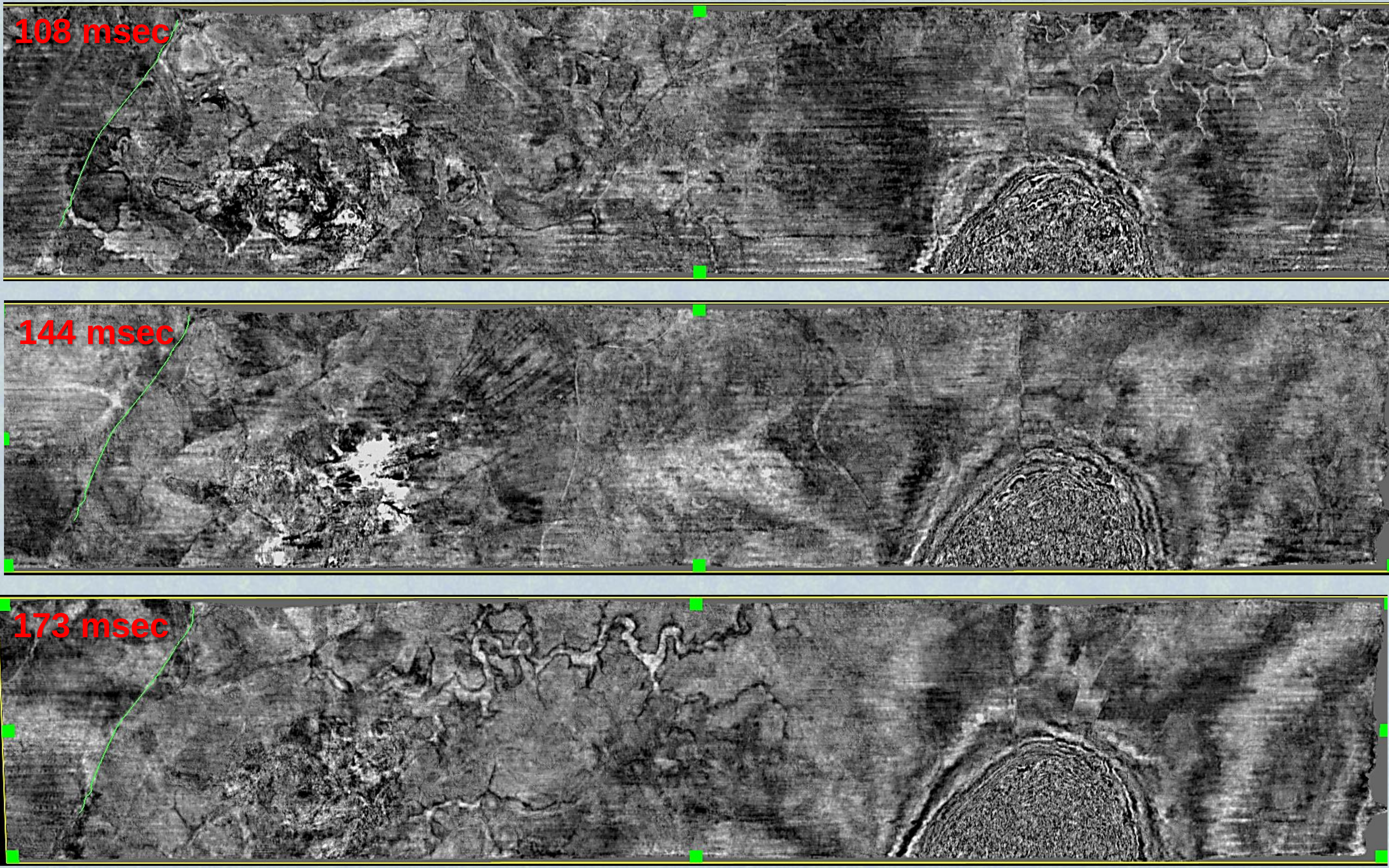
Exxon Production Research Company,
W.M.P.A.A.o.P.G.F., 1985
Laske and Masters, 1997
Schneider, et al., 2003

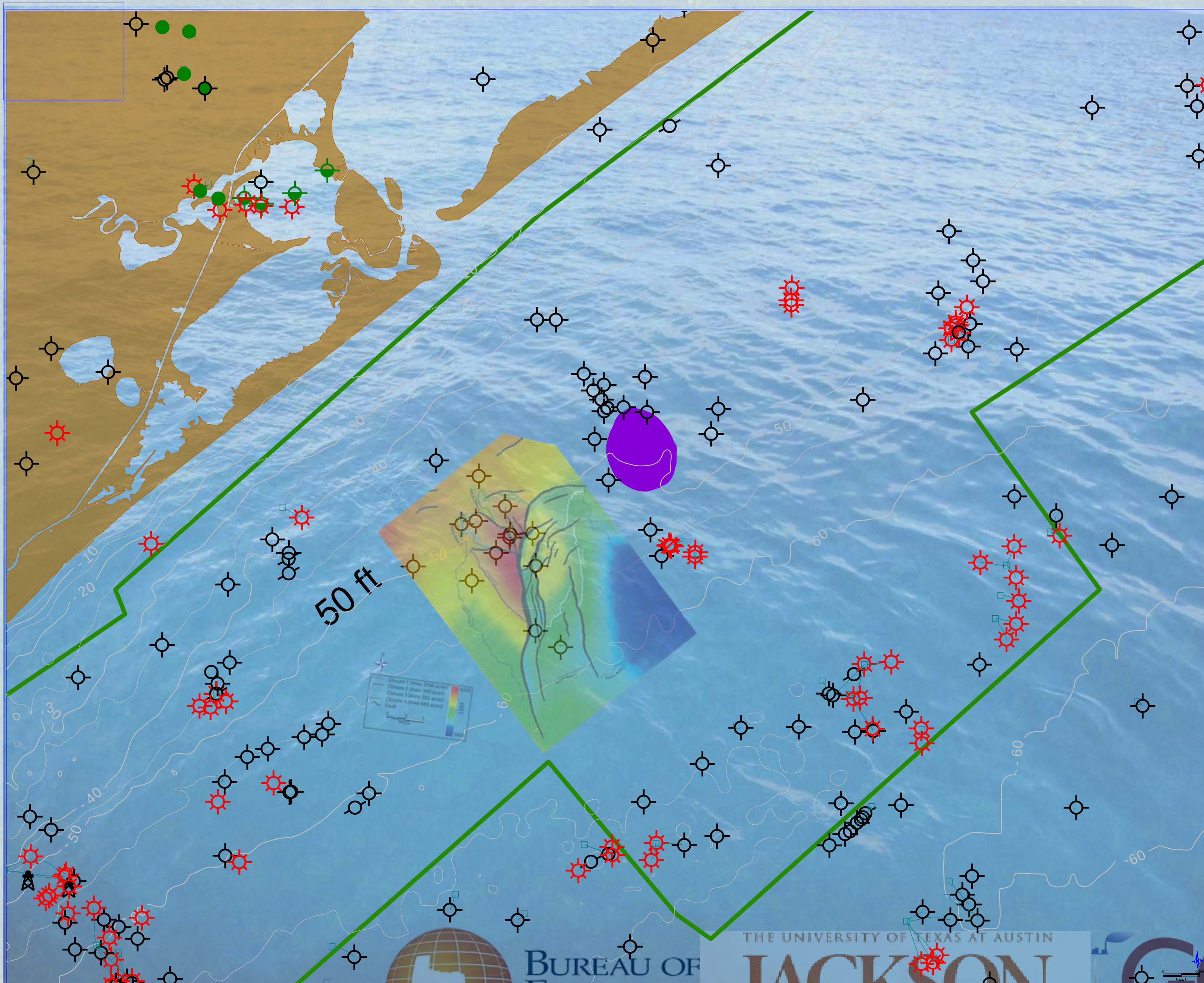
System mature enough to proceed: Global experience in CO_2 injection



From Peter Cook, CO2CRC

Stratigraphic morphologies





San Luis Pass Salt Dome

P-Cable Surveys 2012 & 2013

Map produced by Dave Carr

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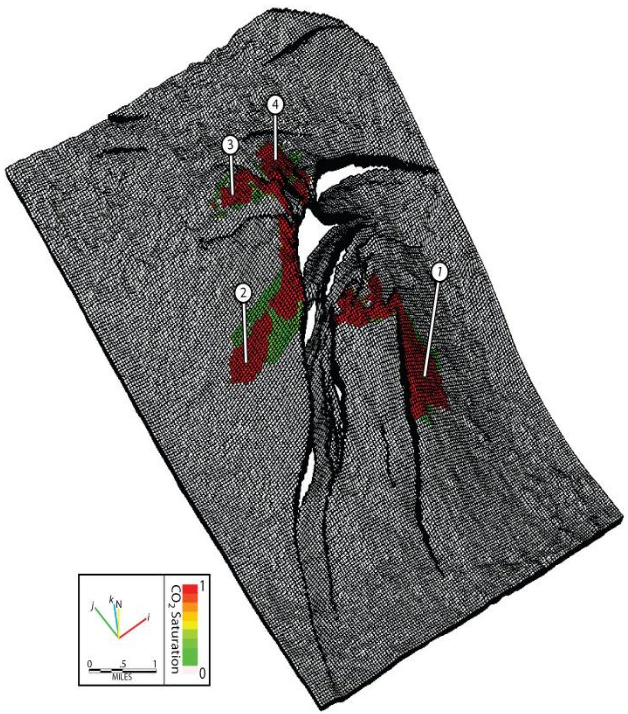
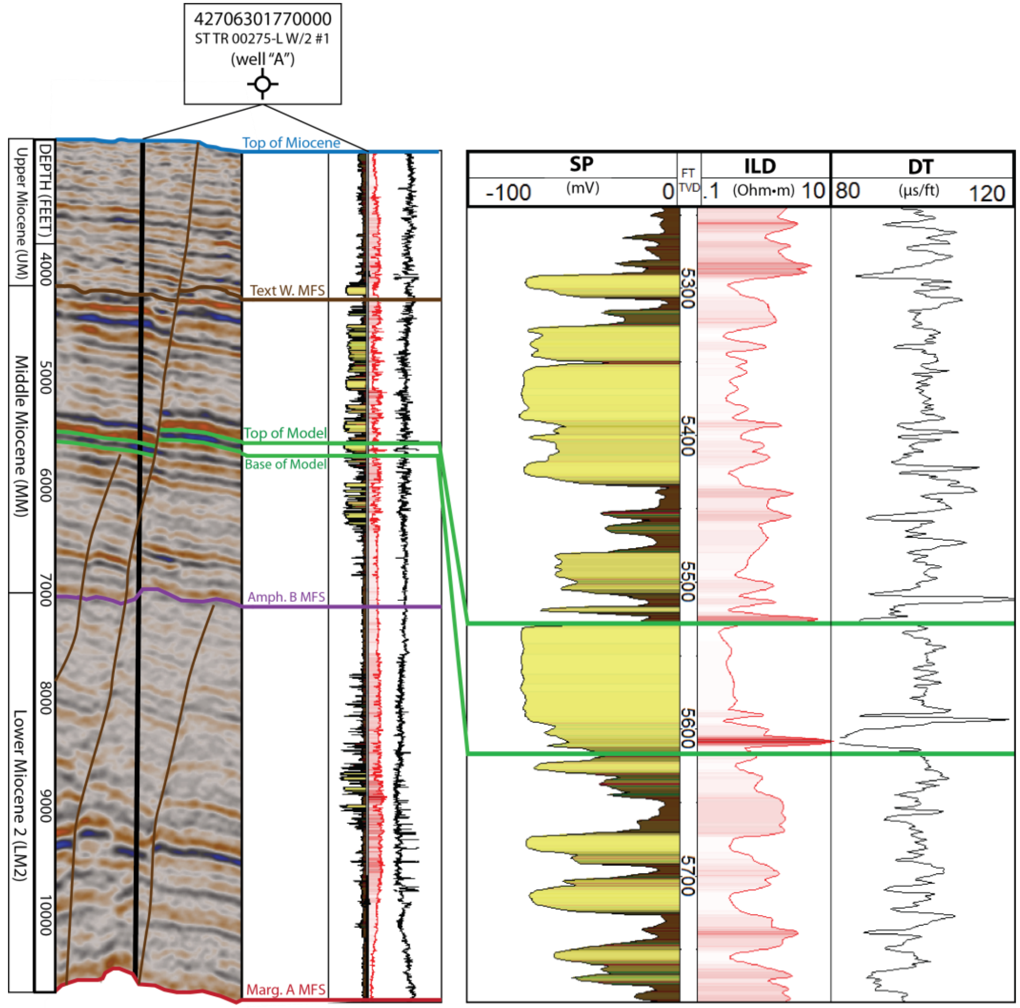
GCCC Gulf Coast Carbon Center

Reservoir characterization and modeling



Kerstan Wallace
MS Thesis, 2013



Φ Derived from DT

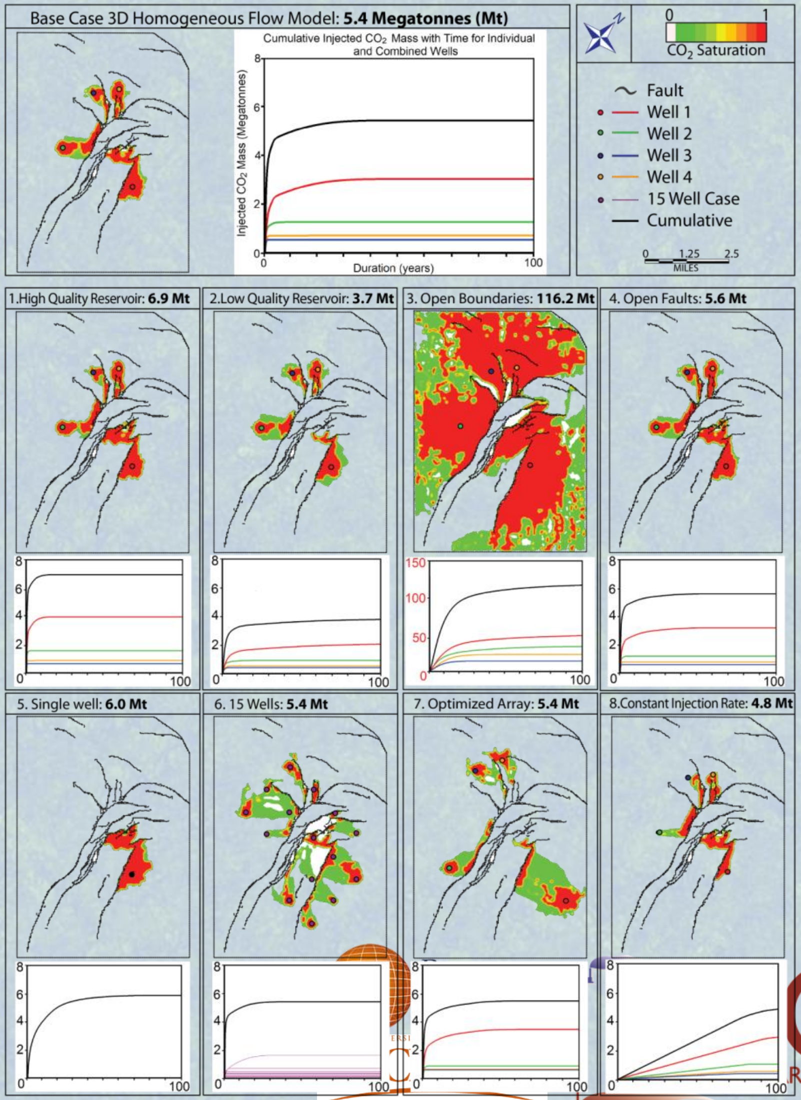
Reservoir Interval

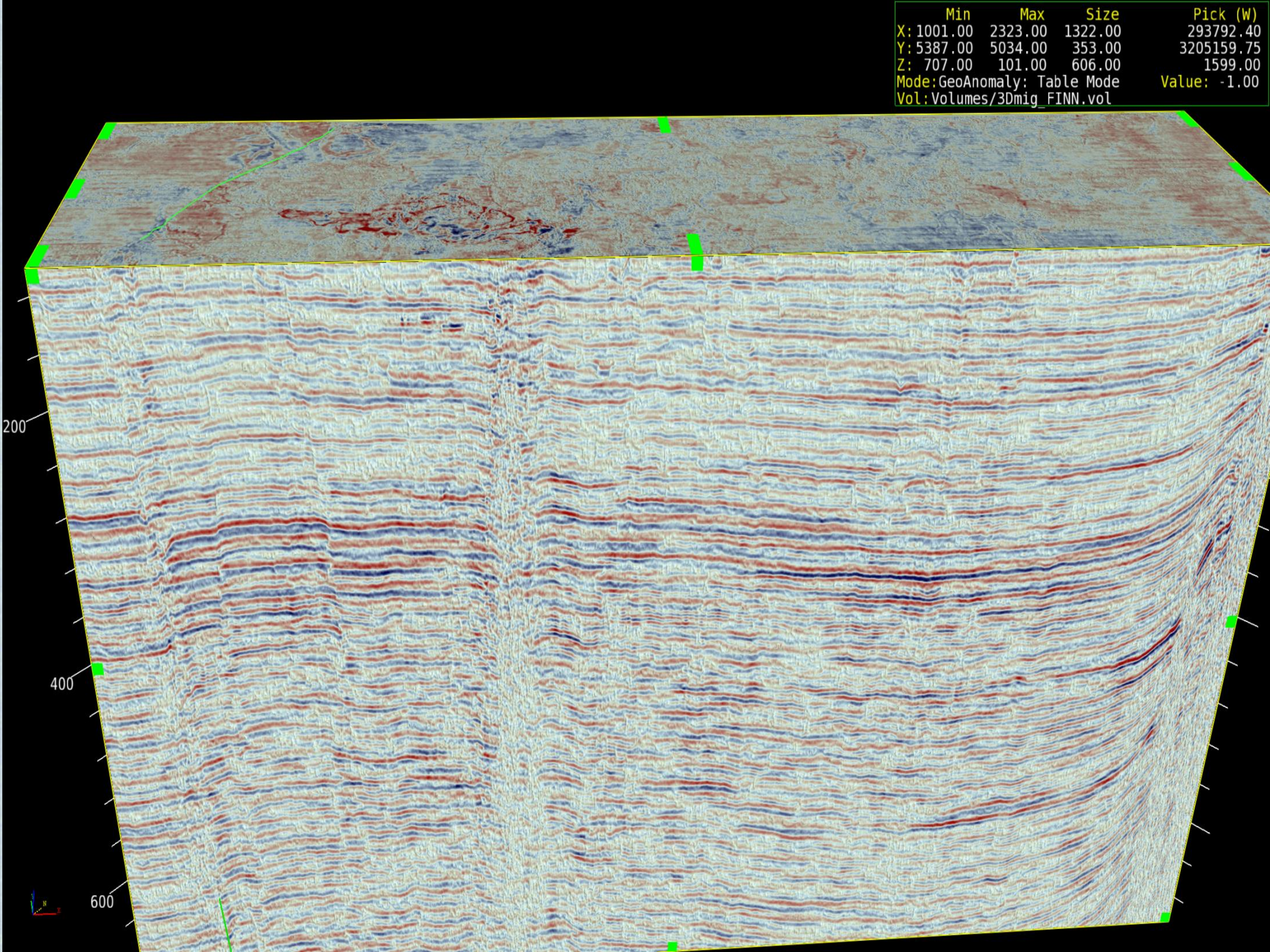
*Stratigraphic interpretation by David L. Carr
**Seismic data owned or controlled by Seismic Exchange, Inc.; interpretation is that of Kerstan Wallace

Homogeneous 3D Flow Model Scenario
Geologic sensitivities

- Cases 1-8 final plume geometries

Open boundaries effect (case #3) ***by far*** the most significant variable parameter.





Min Max Size Pick (W)
X: 1001.00 2323.00 1322.00 293792.40
Y: 5387.00 5034.00 353.00 3205159.75
Z: 707.00 101.00 606.00 1599.00
Mode: GeoAnomaly: Table Mode Value: -1.00
Vol: Volumes/3Dmig_FINN.vol
200
400
600

SUMMARY

- **Subsurface storage capacity is there.**
- **Storage security appears adequate to pursue further.**
  - **Capability to characterize and monitor reservoir to surface**

- **HR3D Seismic Datasets achieve 2 benchmark goals for CCS:**

1. **Characterization: Success imaging overburden in detail**
   - **Well-resolved faults and stratigraphy down to 1 second (~800 m)**
     - **Not seen in conventional data.**
   - **ID naturally leaky/non-leaky geo-systems**
     - **Shallow salt dome feature appears non-leaky/uncharged; deeper salt structure apparently is.**
2. **Monitoring: Verification that fluid migration is likely to be observable (3D & 4D)**
   - **Fluid chimney identified, now need to understand migration processes & integrate expected saturations with seismic response.**
   - **Opportunity to integrate shallow sediment coring.**

POTENTIAL IMPACTS ON FAUNA

Arthropods	Description	CO_2 System Parameter	Sensitivity	Reference
Acartia steueri	Copepod	0.2-1%CO_2,	Decrease in egg hatching success; increase in nauplius mortality rate	Kurihara et al. (2004)
Acartia erythraea	Copepod	~2000–10 000 ppmv		
Copepods	Pacific, deep vs. shallow	~860–22 000 ppmv CO_2	Increasing mortality with increasing CO_2 concentration and duration of exposure	Watanabe et al. (2006)
Euphausia pacifica Paraeuchaeta elongata	Krill Mesopelagic copepod	pH < 7.6	Mortality increased with increasing exposure time and decreasing pH	Yamada and Ikeda (1999)
Conchoecia sp.	Ostracod			
Cancer pagurus 1	Crab	1% CO_2, ~10 000 ppmv	Reduced thermal tolerance, aerobic scope	Metzger et al. (2007)

Figure 14: Effect of hypercapnia on various arthropod species, including the edible crab Cancer pagurus.[104]

Effect of contact with CO_2 leaked locally into the water column will vary significantly depending on the animal group, age, and level of exposure.