Field Validation of MVA Technology for Offshore CCS, Tomakomai, Japan

Project Number DE-FE0028193

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U.S. Department of Energy
National Energy Technology Laboratory
Mastering the Subsurface Through Technology Innovation, Partnerships and Collaboration:
Carbon Storage and Oil and Natural Gas Technologies Review Meeting
August 1-3, 2017

Acknowledgements

U.S. DEPARTMENT OF ENERGY

NETL

Thank you to our Japanese colleagues

METI Ministry of Economy, Trade and Industry

Japan CCS Co., Ltd.

JGI, Inc.

MARINE ECOLOGY RESEARCH INSTITUTE

RITE Research Institute of Innovative Technology for the Earth

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Presentation Outline

- Project Overview: Goals and Objectives
- Technical Status
  - UHR3D Seismic
  - Sediment and water column sampling
- Accomplishments to Date
- Lessons Learned
- Summary

Goals & Objectives

Goal: Validate technologies to enhance MVA

Objectives:

1) Acquire and validate UHR3D seismic dataset at operational CCS field demonstration project

2) Validate untested dynamic acoustic positioning techniques (SBL)

3) Define CO_2 plume boundaries
   - Environmental monitoring task

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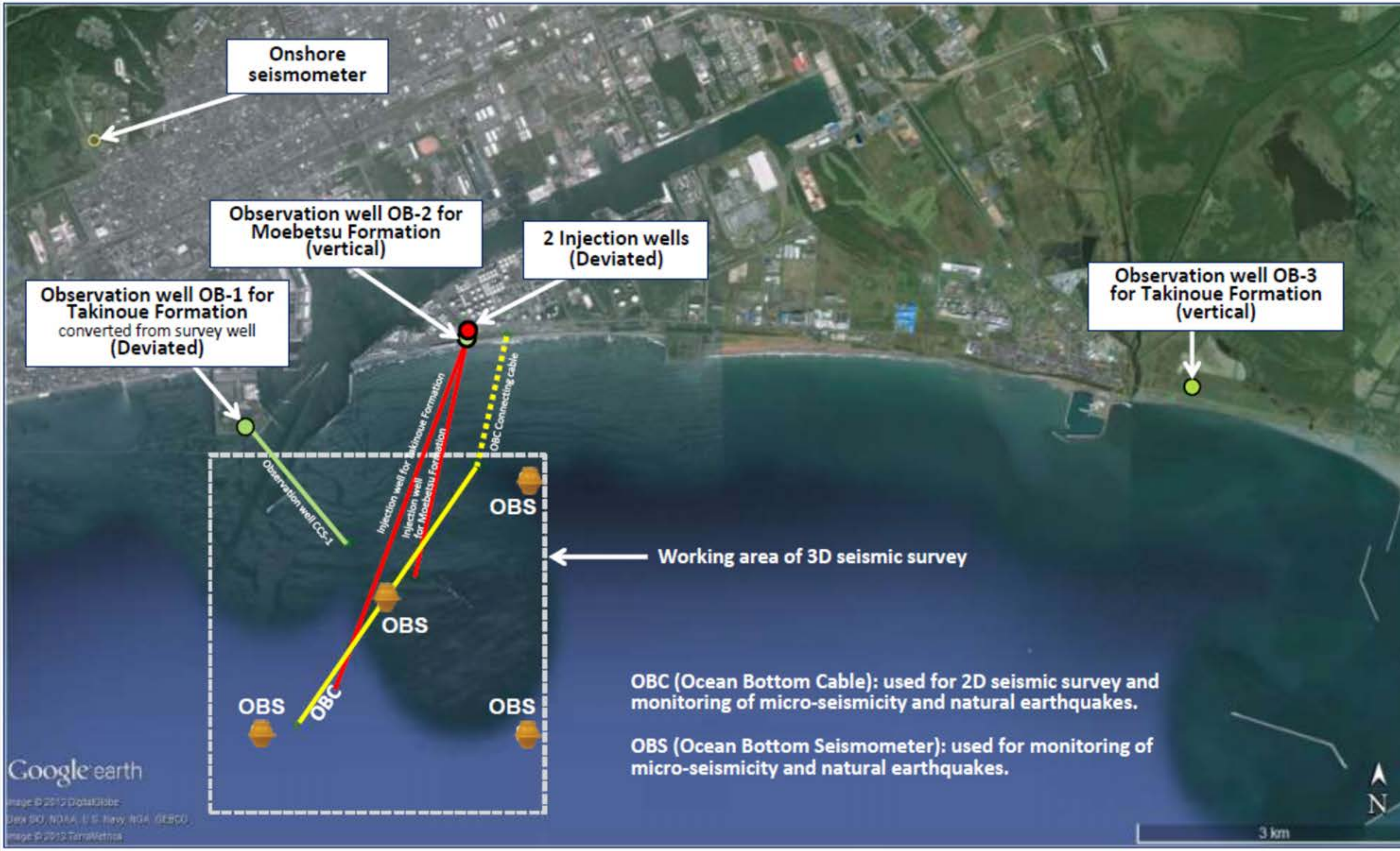
Layout of Monitoring Facilities



© **Google** Image © 2013 DigitalGlobe Data SIO, NOAA, U.S. Navy, NGA, GEBCO Image © 2013 TerraMetrics

Captur akomai

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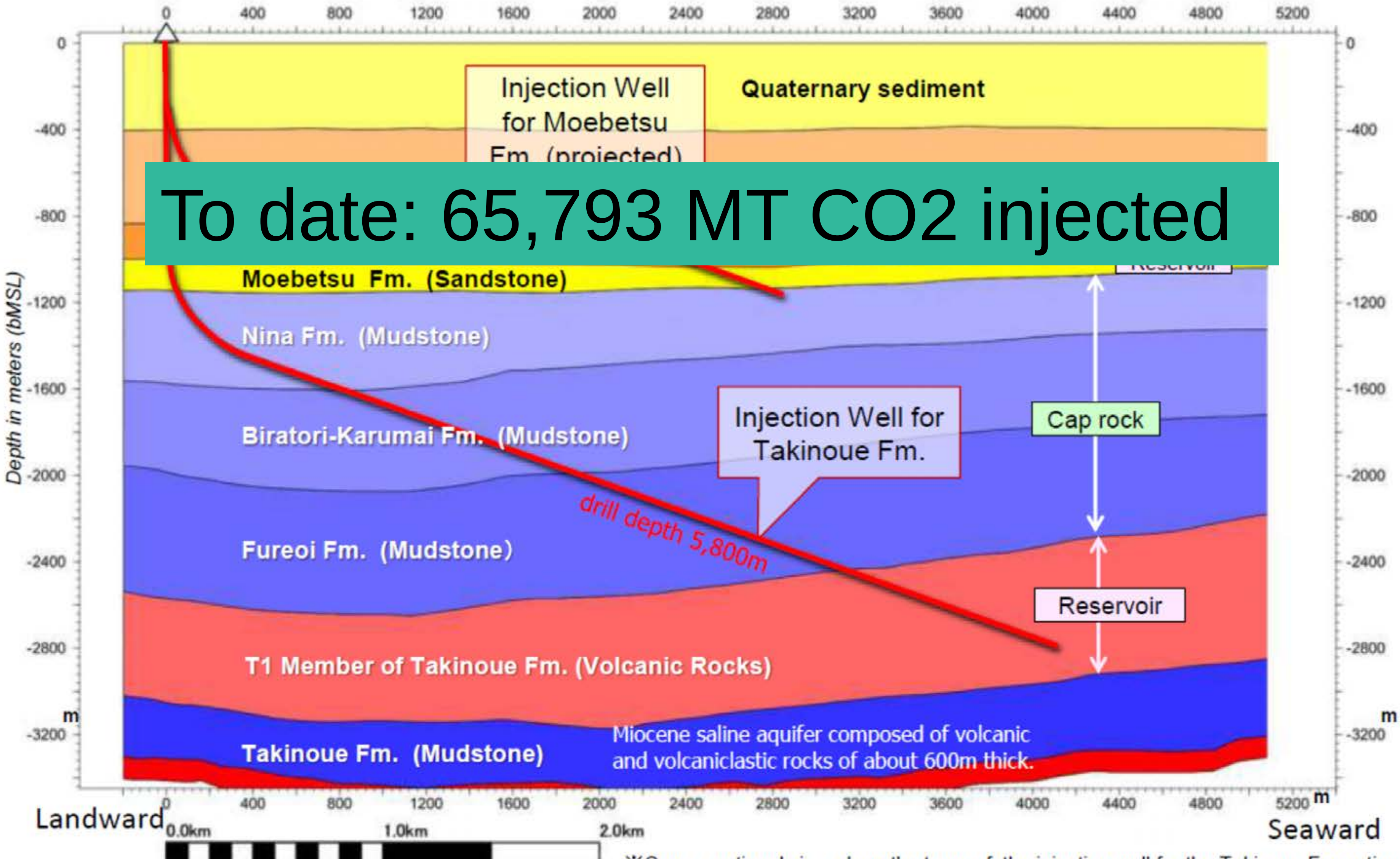
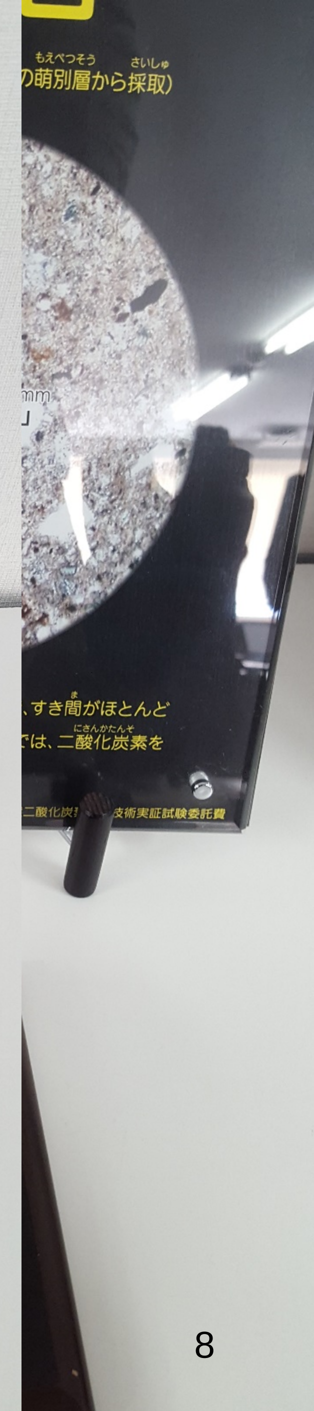
Schematic Geological Section



To date: 65,793 MT CO_2 injected

※Cross-sectional view along the trace of the injection well for the Takinoue Formation

顕微鏡写真
砂岩
(苫小牧 CCS-2 号井 深度1102mの萌別層から採取)
0
0.5mm
1mm
砂が固まったもので、すき間(青いところ)がたくさんあります。
CCSでは、二酸化炭素をためる貯留層となります。
経済産業省 平成23年度二酸化

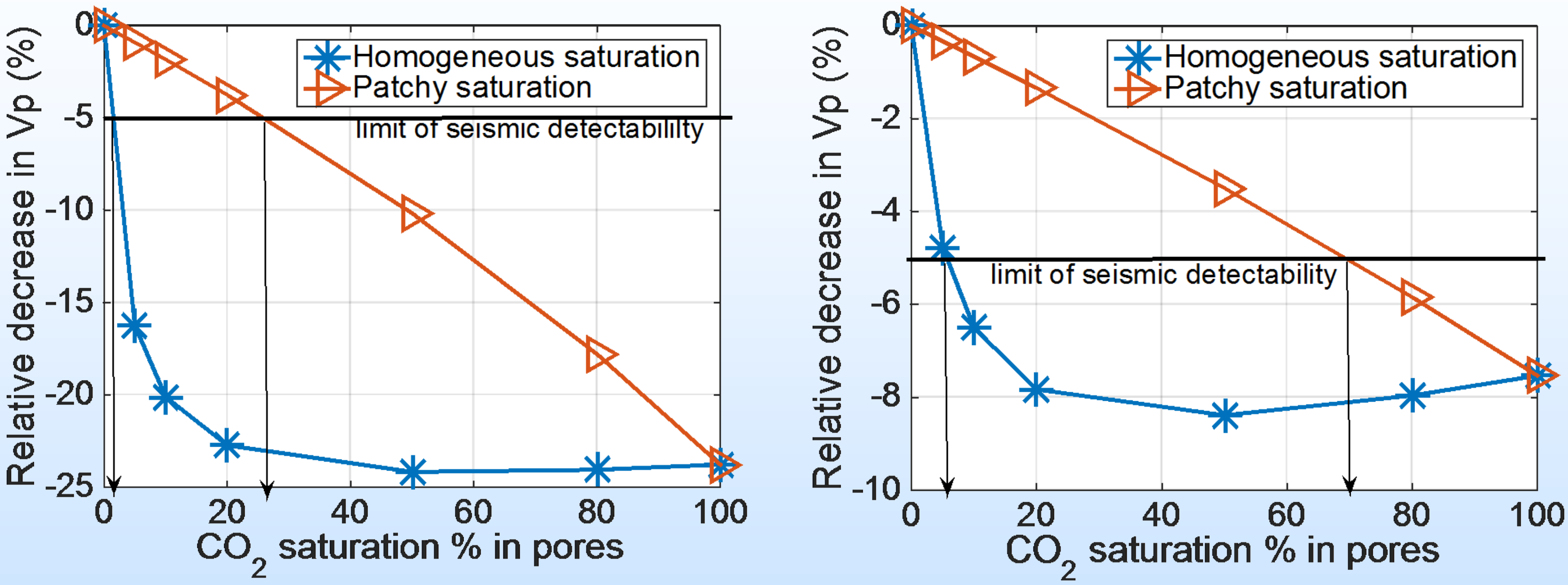


Sensitivity Study

Rock Physics Modeling Theoretical Seismic Response (Moebetsu Fm.)

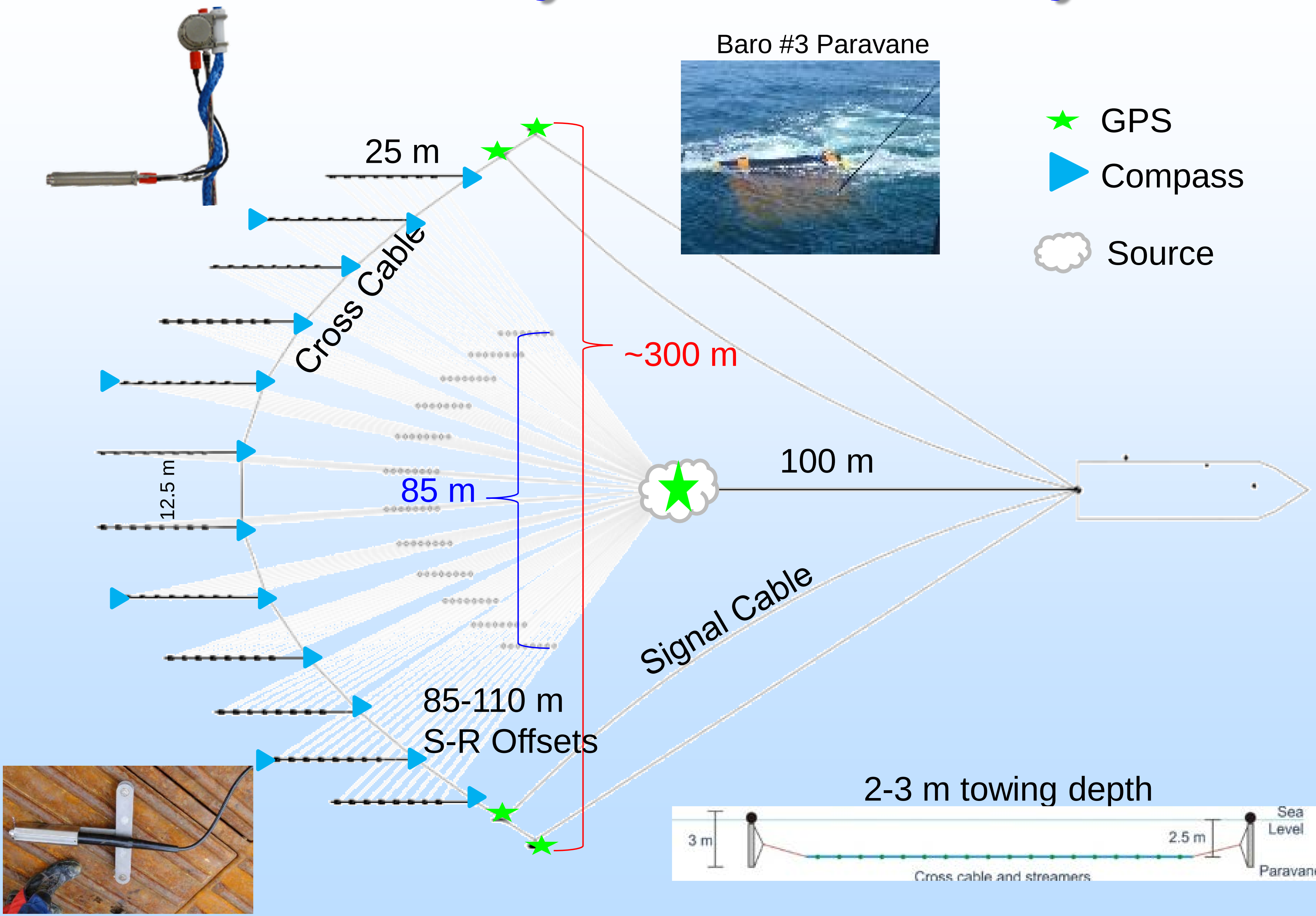
- Poorly consolidated, low velocity high porosity sandstone
- Changing pore fluid (CO_2 and methane) with injection
- Conditions favor seismic response (Gassmann (1951) theory)
- Both acoustic impedance (P impedance) and P-wave velocity decrease with increasing CO_2 saturation
- Assumed homogeneous & patchy saturation models
- With:
  - absence of residual methane &
  - high signal-to-noise ratio seismic data
  - CO_2 should be identifiable in the Moebetsu Formation

Residual gas saturation is set to 0.5%. **Residual gas saturation is set to 2%.**

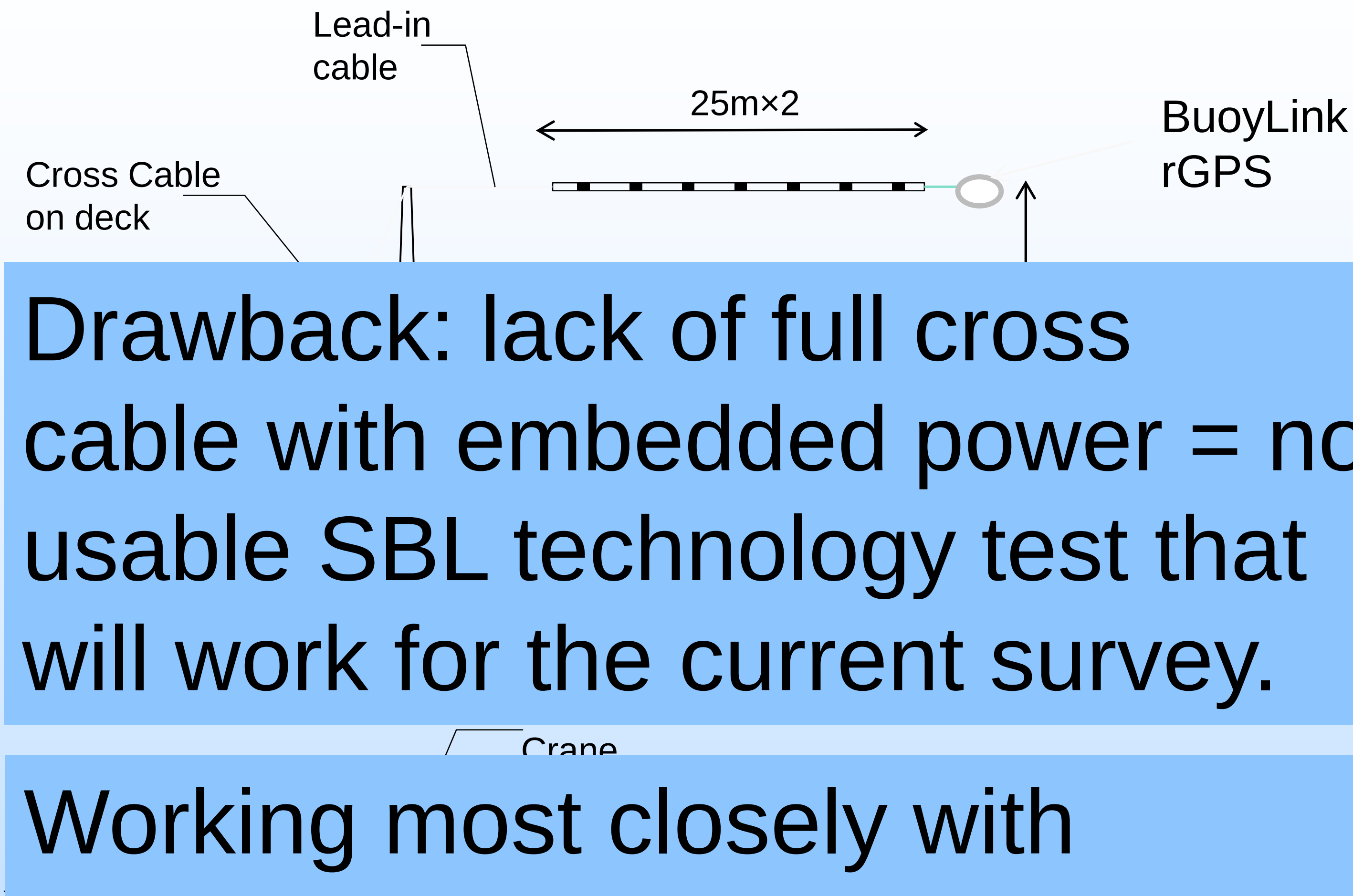


Relative decrease in P-wave velocity as a function of CO_2 saturation in pores for homogeneous saturation and patchy saturation assumptions. Superimposed on the figures is a line at -5% decrease in Vp, as the limit for seismic detectability.

Geometry Detail: UT System



Survey Layout (P-Cable Plan - Tomakomai)

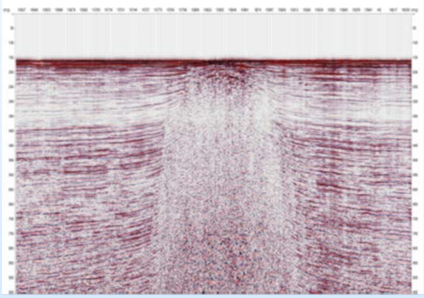


Drawback: lack of full cross cable with embedded power = no usable SBL technology test that will work for the current survey.

Working most closely with Sonardyne to resolve this challenge. Hopeful for next year.

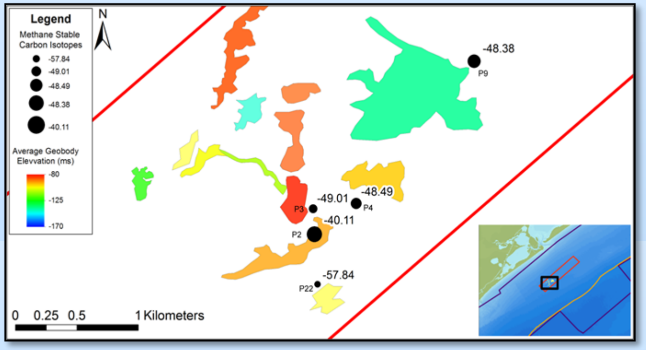
Task 3- Environmental Monitoring Objectives

- Provide insight into subsurface field conditions informed by high resolution 3D seismic survey (P-Cable) at Tomakomai.



Tip Meckel, P-Cable seismic image GOM

- Augment existing monitoring activities with additional analyses/techniques
- Learn marine monitoring techniques



Example of light hydrocarbon assessment of submarine anomalies, San Luis Pass, Gulf of Mexico (Anderson et al., in preparation)

Tomakomai Injection Postponed

- 7,163 tonnes of CO_2 was injected April 6th to May 24th, 2016.
- The CO_2 injection was temporarily postponed due to high CO_2 levels observed in the marine monitoring.

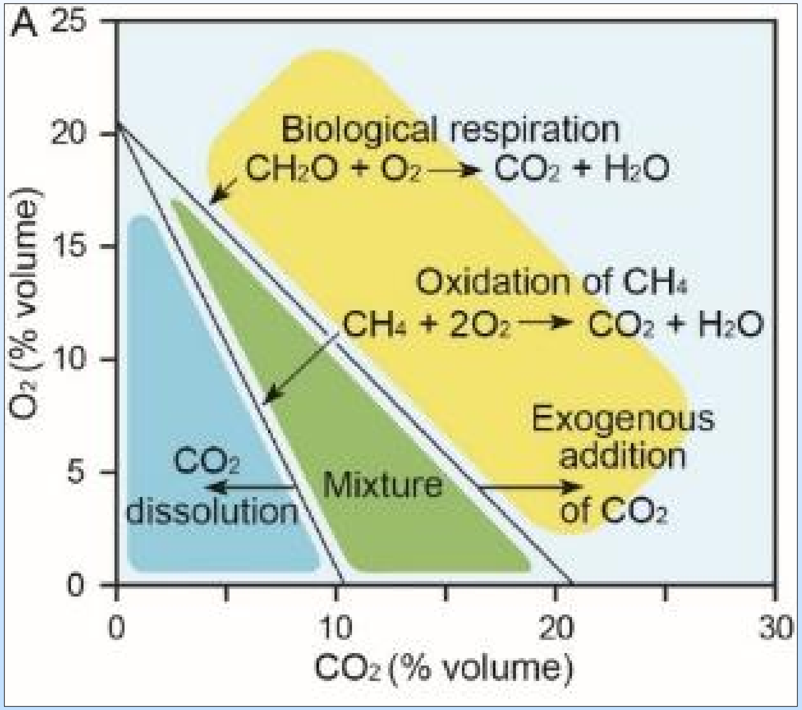
Slide courtesy of Jun Kita, RITE

Task 3- Additional Monitoring Objectives

- Help address source attribution of current data to aid decisions on CO_2 injection
- Advance “bio-oceanographic” source attribution methodology
  - Aims to use geochemical relationships to attribute the source of anomalies rather than concentrations

Process-Based Monitoring

- Uses simple stoichiometric relationships to identify processes for attribution
  - Respiration, methane oxidation, dissolution, leakage
- No need for years of baseline.
- Universal trigger point
- Stakeholder engagement



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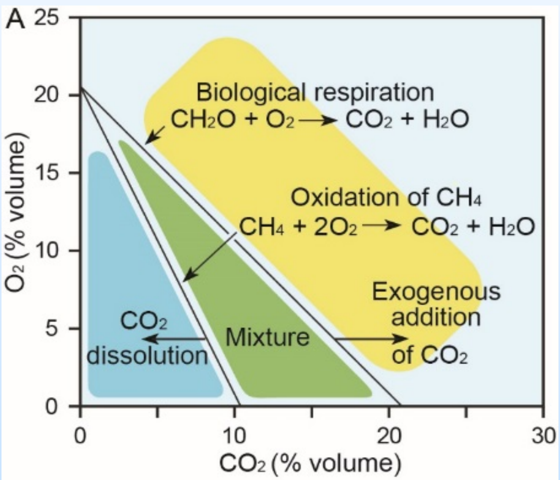
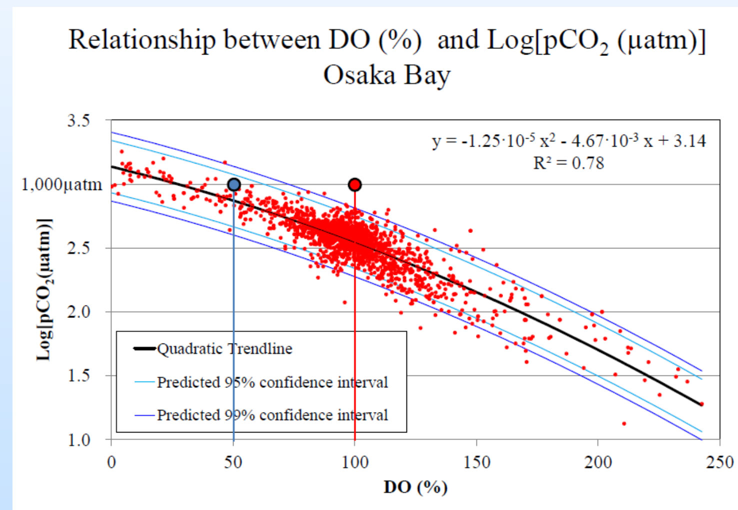
Bio-oceanographic source attribution

Onshore:
Process-Based Method



IEAGHG Meetings

Offshore:
Bio-Oceanographic Method



Katherine Romanak, BEG, USA
Romanak et al., 2012, 2014
Dixon and Romanak, 2015

Jun Kita, MERI, Japan

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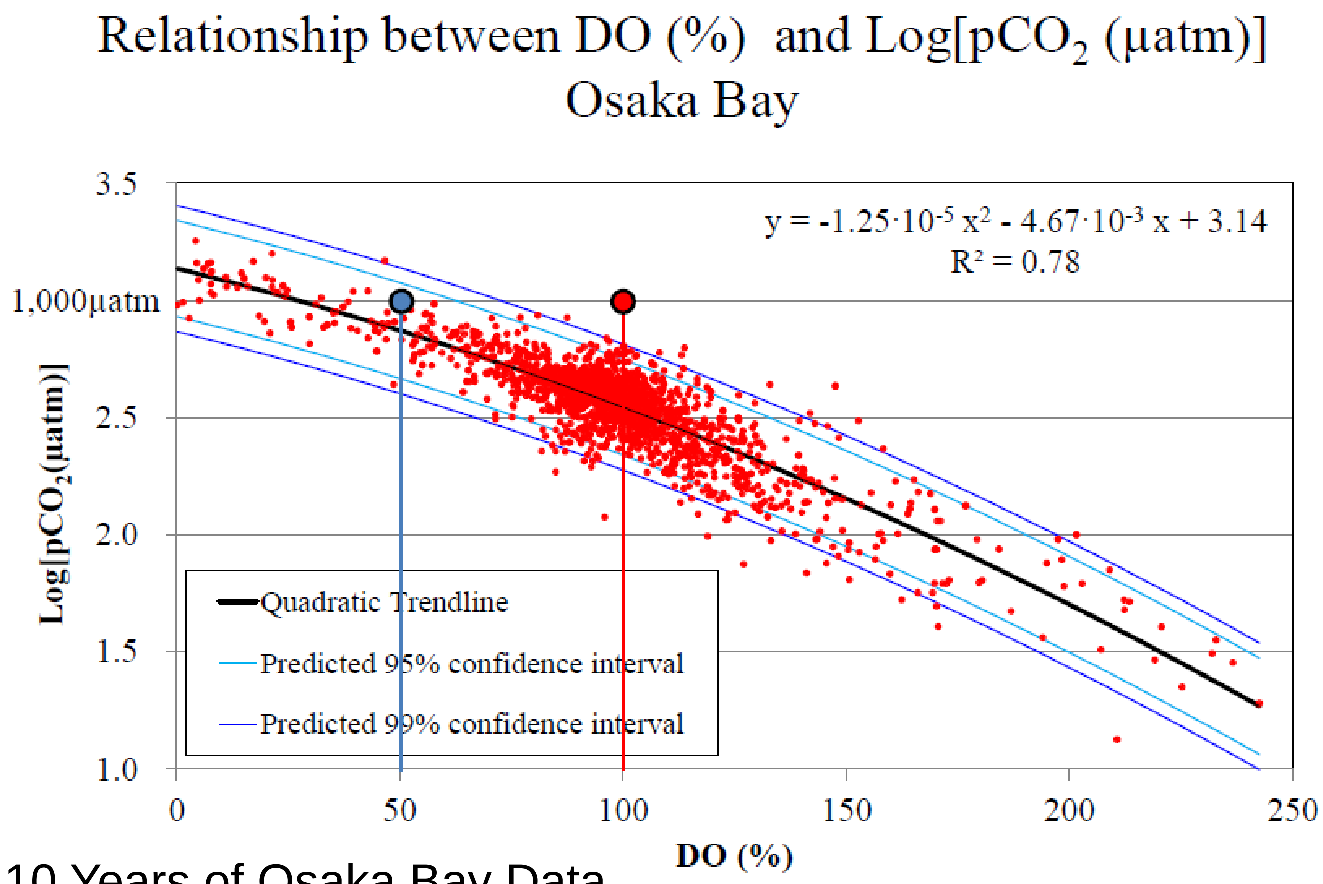
Bio-oceanographic Method



10 Years of Osaka Bay Data

Jun Kita, MERI, Japan
Uchimoto et al., in review

Tomakomai Environmental Monitoring

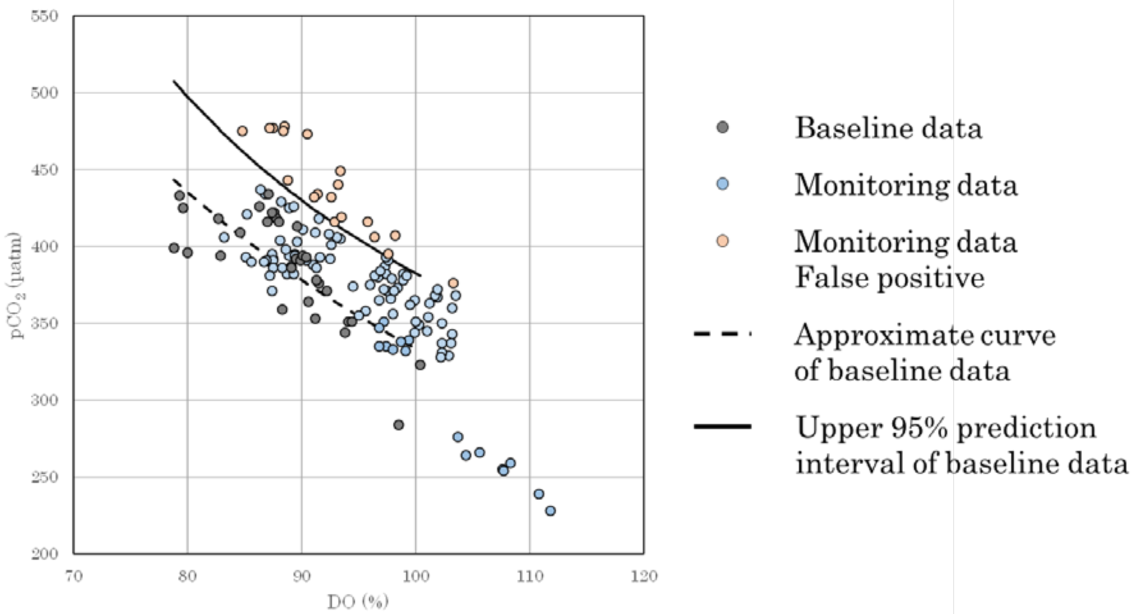
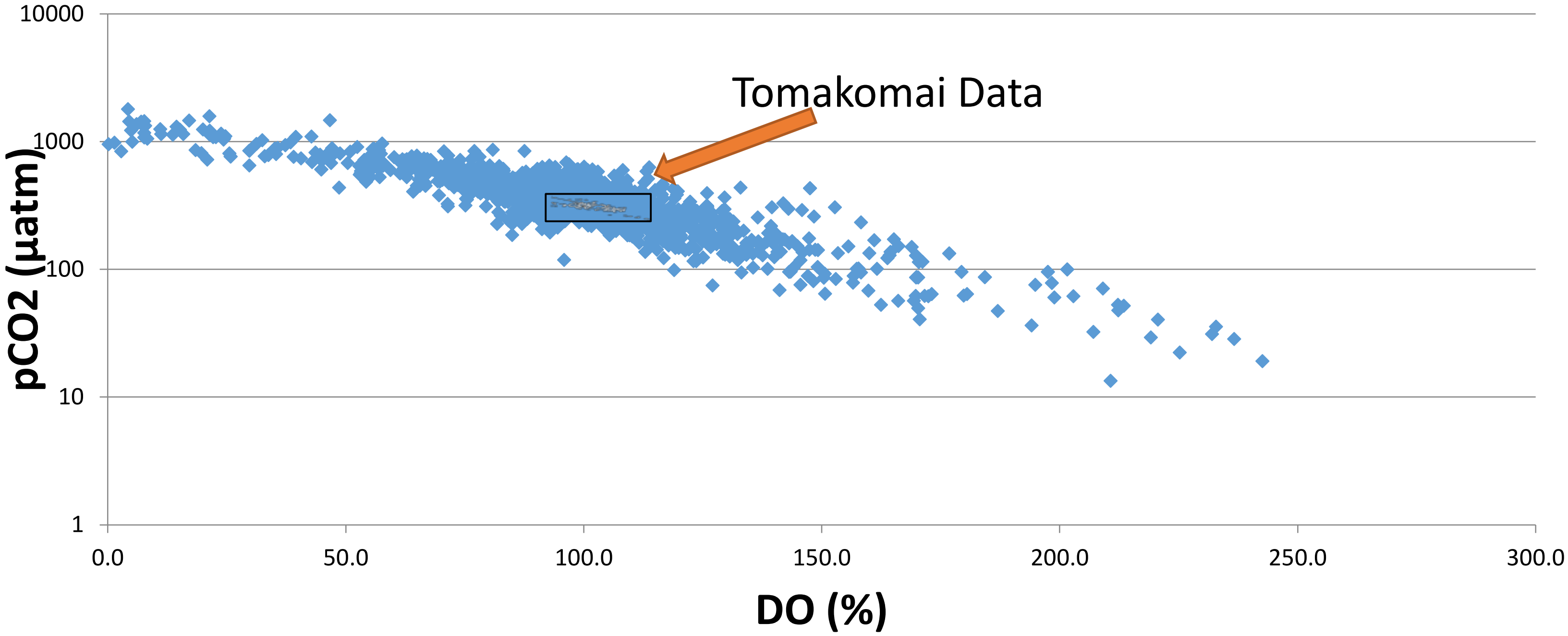


Fig. Relationship between oxygen saturation (DO) and CO_2 partial pressure (pCO_2) of bottom seawater (2 m above the seafloor).

“Regulatory authority urged strongly to use the relationship between concentrations of oxygen and carbon dioxide to detect leakage. Since the baseline data did not fully reflect the natural variation, false positive occurred. Ultimately, the observed value (false positives) were judged to be within the range or natural variation by the expert judge. In other words, no leakage was observed”.

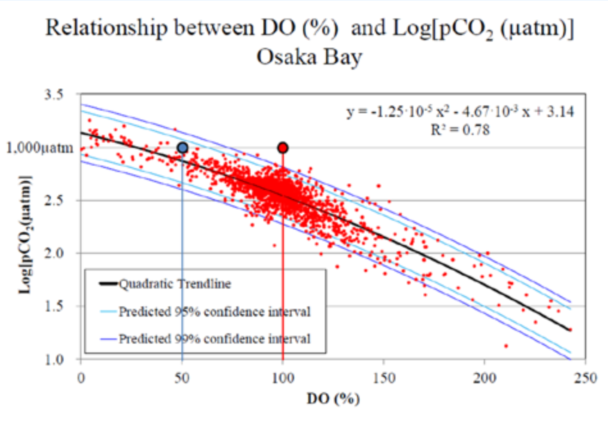
Jun Kita, 2017, 2nd International Workshop on Offshore Geologic CO2 storage

10 Years of Osaka Bay Data
1 year Tomakomai Data



Plans for Method Advancement

- Current bio-oceanographic method is still <u>baseline-dependent</u>
- Instead we will attempt to:
  - Use <u>stoichiometric relationships</u>
  - Reduce scatter arising from differences in gas solubility
    - Salinity (34-7 psu)
    - Temperature (6-31C)
    - Depth (0-67 m)
- Osaka Bay data
- CO2sys program
- Weiss equation linking concentration to salinity and temperature



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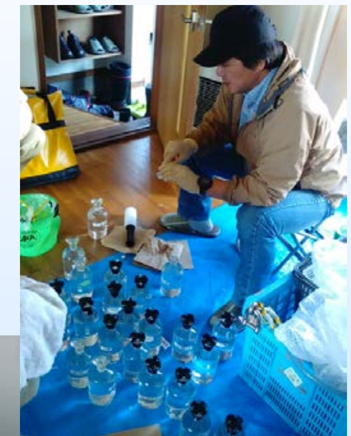
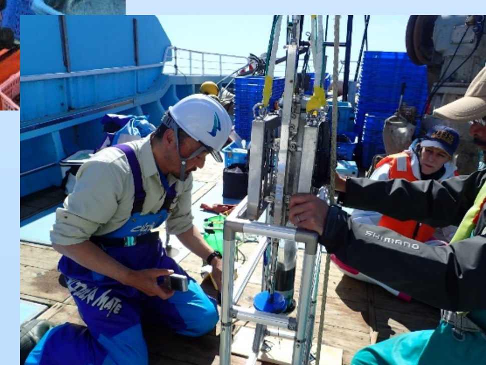
Sediment and Water Sampling

- Accompany environmental sampling team on a routine monitoring trip
- Add sediment pore water analysis
- Add ^{14}C and hydrocarbons to analytical suite
- Collaborate to integrate analyses with current monitoring parameters and methods





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Accomplishments to Date

- Sediment sampling completed ahead of schedule- Analyses nearly complete
- Acquired data sets for advancing marine attribution methods
- Input additional analyses and methods
- Learned marine sampling methods
- UHR3D Sensitivity study completed on time
- Seismic system now at port of Tomakomai, Japan
- First seismic survey on schedule – starts 2 weeks

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Lessons Learned

- Environmental monitoring and sediment sampling
  - Learned marine sample collection methods.
  - Gained insights onto advancing marine attribution
- Allow extra time for data agreements / data transfer
  - Well data late arrival delayed:
    - Geomechanical seismic sensitivity study
    - New equipment purchase
    - Trans-Pacific shipment of system (commitment)
    - Go, no-go decision / BP1 → BP2 continuation, etc.

Synergy Opportunities

- Last frontier – Overburden:
  - Plume mapping in the overburden and link to environmental risk- offshore and onshore.
    - Risk of overburden features- what do they really mean?
    - Link subsurface features to environmental outcomes LBNL in-situ continuous geophysics.
    - Parameters for feeding NRAP models (LBNL and others)
    - Location, attribution, quantification (IOS and LANL)
- Offshore:
  - Synergy with NW GOM CarbonSAFE , STEMM-CCS (UK)

Goals & Objectives

Goal: Validate technologies to enhance MVA

Objectives

1) Acquire and validate UHR3D seismic dataset at operational CCS field demonstration project

2) Validate untested dynamic acoustic positioning technique

3) Define CO_2 plume boundaries
   - Advance attribution to track the plume apart from background CO_2 in shallow environments

Project Summary

- Key Findings
  - Sensitivity study indicates CO_2 should be imageable using UHR3D
  - Learned marine monitoring techniques
- Next Steps.
  - Acquire UHR3D seismic survey
  - Update bio-oceanographic method
  - Assess sediment/water column data when completed

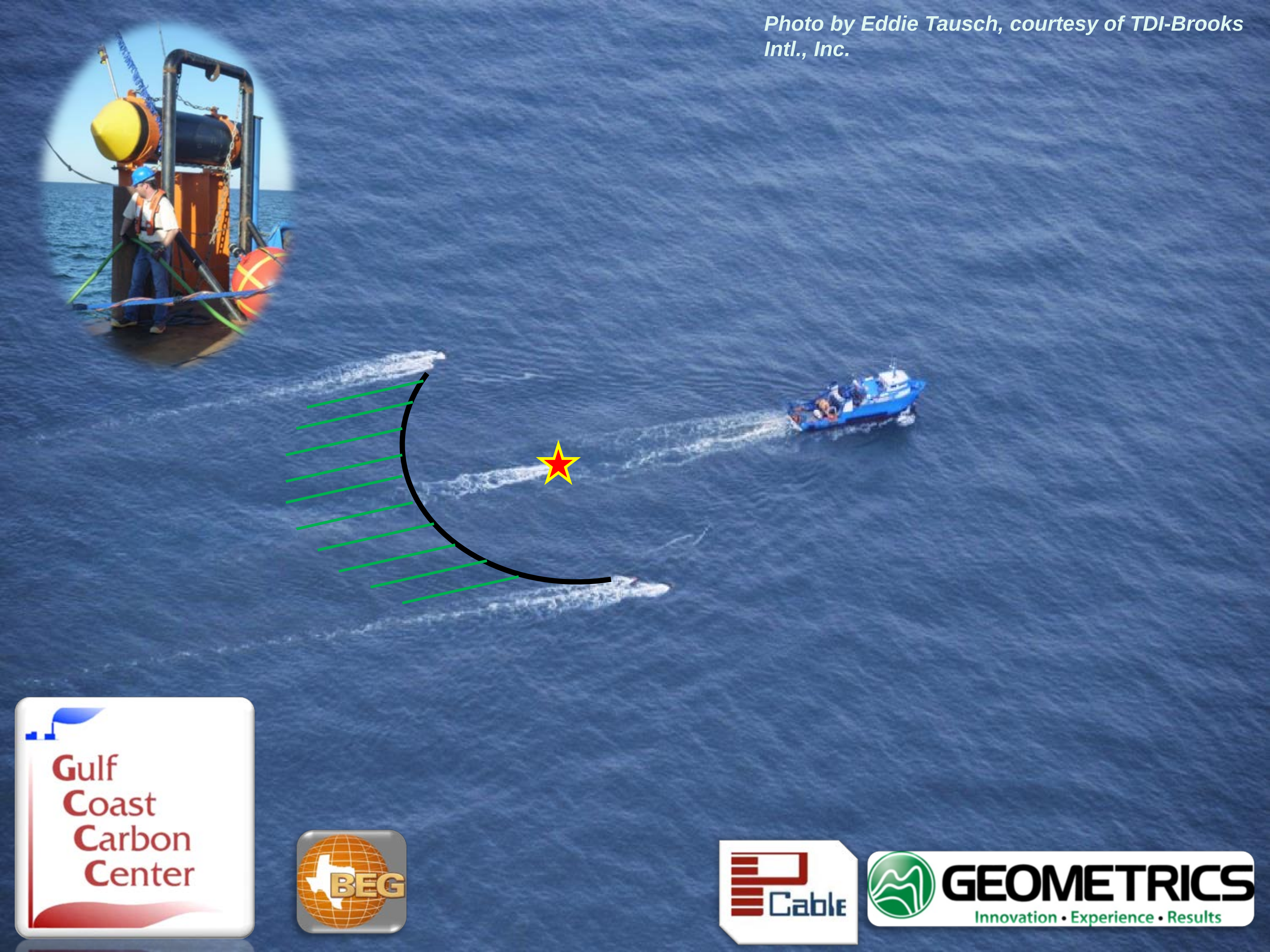


Photo by Eddie Tausch, courtesy of TDI-Brooks Intl., Inc.

Appendix

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

Benefit to the Program

Program goal being addressed:

- This study supports SubTER pillar 4 (new subsurface signals) and advances the long-term Carbon Storage program goal of developing technologies to ensure 99 percent storage permanence.

Benefits statement:

- The project will conduct research under Area of Interest 1, Field Demonstration of MVA Technologies, by deploying and validating novel ultra-high resolution 3D seismic technology for CCS MVA at an active operational field site. This research will advance the MVA technology development pathway to TRL 7 by validating a fully integrated prototype seismic imaging system including untested dynamic acoustic positioning. The technology will demonstrate significantly improved spatial resolution over a commercially-meaningful area with improved accuracy and economic viability, decreasing the cost and uncertainty in measurements needed to satisfy regulations for tracking the subsurface fate of CO_2.

Project Overview
Goals and Objectives

The primary goal of this study is to validate technologies to enhance the monitoring, verification, and accounting (MVA) of CO2 injected underground for the purpose of long-term geologic storage and/or for enhanced recovery of oil and gas reserves.

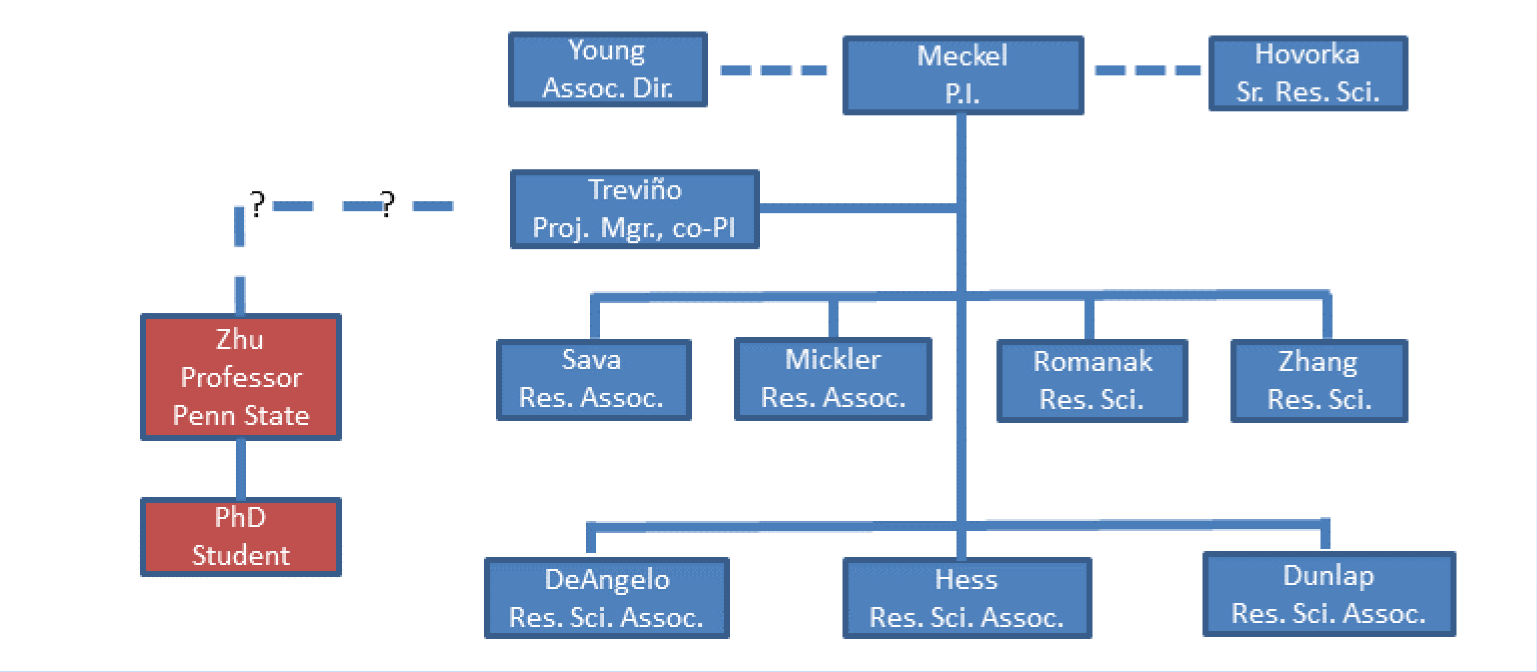
The objectives are to:

1) Acquire and validate at least one UHR3D seismic dataset at an operational CCS field demonstration project,

2) Validate untested dynamic acoustic positioning techniques during UHR3D data acquisition, and

3) Define the lateral extent and boundaries of the CO2 plume, and to track and quantify uncertainty of spatial and temporal movement of CO2 through the storage reservoir.

Organization Chart



Gantt Chart

		BUDGET PERIOD 1			BUDGET PERIOD 2			BUDGET PERIOD 3					
		YEAR 1				YEAR 2				YEAR 3			
Task	Tasks	qtr 1	qtr2	qtr3	qtr4	qtr 1	qtr2	qtr3	qtr4	qtr 1	qtr2	qtr3	qtr4
Field Validation of MVA Technology for Offshore CCS: Novel Ultra-High-Resolution 3D Marine Seismic Technology (P-Cable)													
1) PROJECT MANAGEMENT, PLANNING, and REPORTING													
1.1	PMP, TMP, DMP	D1 D2 D3											
1.2	Meetings												
1.3	Reporting	Q	Q	Q	Q A	Q	Q	Q	Q A	Q	Q	Q	Q A F
1,4	Project Management												
2) UHR3D SEISMIC IMAGING													
2.1	CO2 SENSITIVITY STUDY	M1		D4 DP1									
2.2	P-Cable ACQUISITION				M2 M3			M5	M6				
2.3	P-Cable PROCESSING					D5	M4 D6 DP2				M8		
2.4	P-Cable INTERPRETATION								D7			D9	M10
3) SHALLOW SEDIMENT CORE SAMPLING AND GEOCHEMISTRY													
3.1	Shallow Sediment Core Sampling									M7			
3.2	Core Geochemistry										M9		
3.3	Interpretation & Integration											D8	

Bibliography

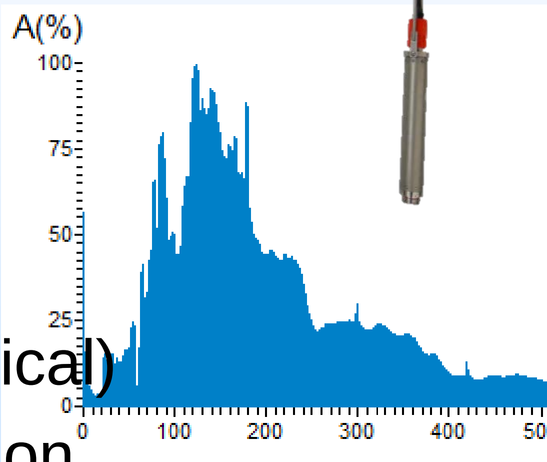
– List peer reviewed publications generated from the project per the format of the examples below.

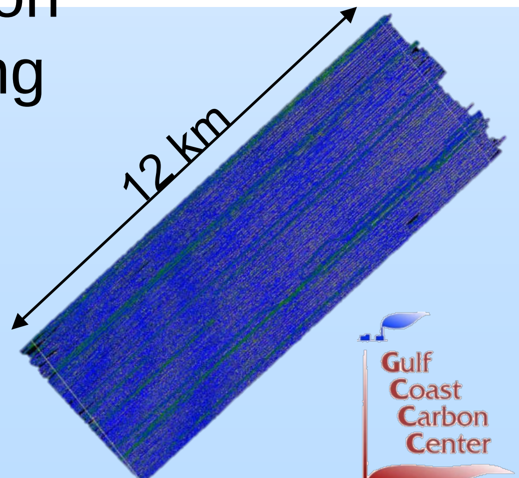
- None to - date

Extra Slides

System/Survey Specifications

- 12 active sections (streamers): GeoEel Solid
- 25 m streamer length (short offset, low fold)
- 8 Channels per streamer (96 total)
- Streamer separation: 12.5m
- Source: One 90 in^3 Sercel GI
- 12.5 m shot spacing (6.25 m^2 bins)
- Dominant frequency: 150 Hz (50-250 Hz typical)
- Navigation and positioning: 3rd party navigation hardware/software with proprietary processing





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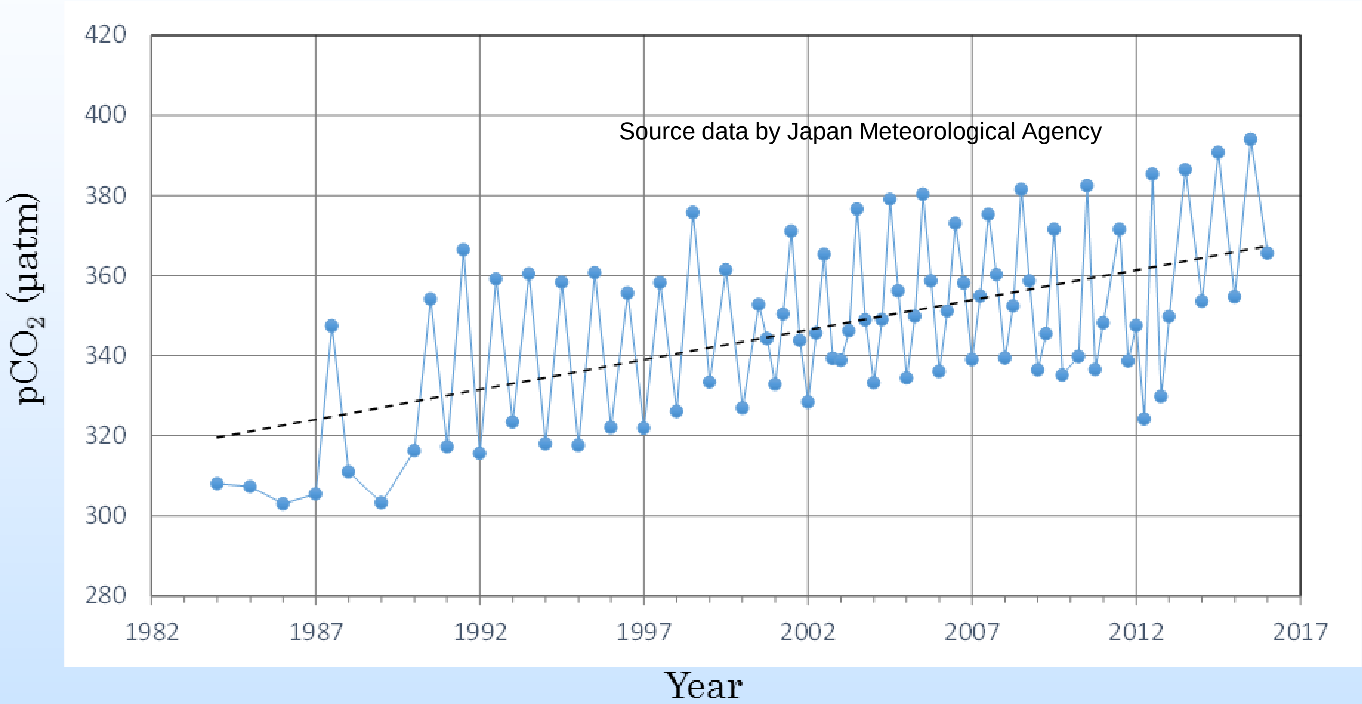
Baselines are Shifting in the Offshore



Time series of surface seawater CO_2 level near Japan (137 degrees East longitude, 3-34 degrees North latitude)

Courtesy of Jun Kita, MERI

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