Field Validation of MVA Technology for Offshore CCS: Novel Ultra-High-Resolution 3D Marine Seismic Technology (P-Cable)

Project Number DE-FE0028193

SuBTER Initiative

Tip Meckel, Ramon Trevino, & Katherine Romanak

TEXAS Geosciences
Bureau of Economic Geology
Jackson School of Geosciences
The University of Texas at Austin

Gulf Coast Carbon Center

U.S. Department of Energy
National Energy Technology Laboratory
Carbon Management and Oil and Gas Research Project Review Meeting – Carbon Storage
August 2 - 11, 2021

U.S. DEPARTMENT OF ENERGY
NETL

Program Overview

Funding: $3,123,320 DOE: $2,498,654 Cost Share: $624,666

Project Performance Dates
October 1, 2016 – September 30, 2021

Goal: Validate technologies to enhance MVA of CCS sites

Objectives:

1) Acquire UHR3D seismic dataset and validate MVA technology at operational CCS field demonstration project - FOAK
2) Validate novel positioning techniques
3) Environmental Monitoring

Project Participants

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.

MERI MARINE ECOLOGY RESEARCH INSTITUTE

RITE Research Institute of Innovative Technology for the Earth

https://www.japanccs.com/en/international/english-university-of-texas-at-austin-bureau-of-economic-geology/

Project Overview

- 1st <u>large scale</u> CCS demonstration in Japan aiming for demonstration at practical scale.
- Demonstrate and verify integrated CCS system
  - CO_2 gas separation, compression, transport, geologic storage
- Conducted by Ministry of Economy, Trade and Industry (METI), New Energy and Industrial Technology Development Organization (NEDO), and Japan CCS Co., Ltd (JCCS).
- Constructed demonstration facilities from FY12-15
- 100,000 tonnes/year rate, 3 year injection
  - April 6, 2016 to November 22, 2019
  - CO_2 is captured from offgas generated at a hydrogen production unit in refinery
  - ~70,000 tons by HR3D survey date in August 2017
  - On November 22, 2019, cumulative CO_2 injection reached the target of 300 thousand tonnes, and accordingly, injection has been suspended.
- Moebetsu Formation saline aquifer @ 1100 m
- 2 INJ; 3 OBS; Conventional 3D seismic, Seismology, Marine Geochemistry

2 reports to METI:

“Geological evaluation report of Tomakomai Area”, and

“Basic Plan of CCS demonstration project at Tomakomai Area”;

Other resources in GHGT Proceedings.

Report of Tomakomai CCS Demonstration Project at 300 thousand tonnes cumulative injection (“Summary Report”)

- Overview -

May 2020

Ministry of Economy, Trade and Industry (METI)

New Energy and Industrial Technology Development Organization (NEDO)

Japan CCS Co., Ltd. (JCCS)

Technical Approach/Project Scope

DE-FE0028193

<u>Task 2.0</u>: Ultra-High Resolution 3D Marine Seismic Imaging

Subtask 2.1.1: CO_2 Sensitivity Study

Subtask 2.1.2: Vessel Subcontracting Preparation

Subtask 2.2: P-Cable acquisition survey

Subtask 2.3: P-Cable data processing

Subtask 2.3.1: 4D Repeatability Study

Subtask 2.4: P-Cable data interpretation

<u>Task 3.0</u>: Shallow Sediment Core Sampling and Geochemistry

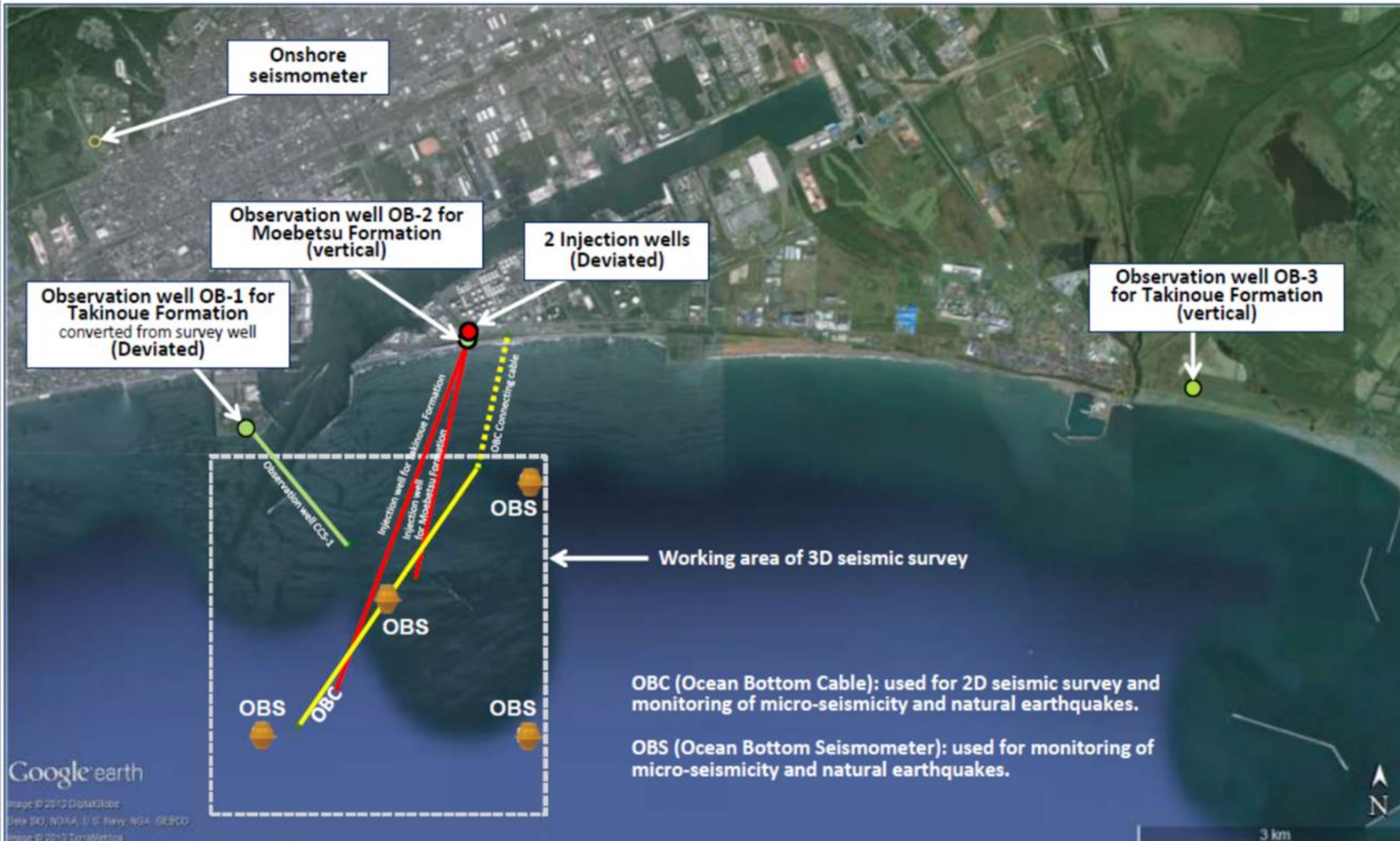
Subtask 3.1: Shallow sediment core sampling

Subtask 3.2: Core geochemistry

Subtask 3.3: Interpretation and integration

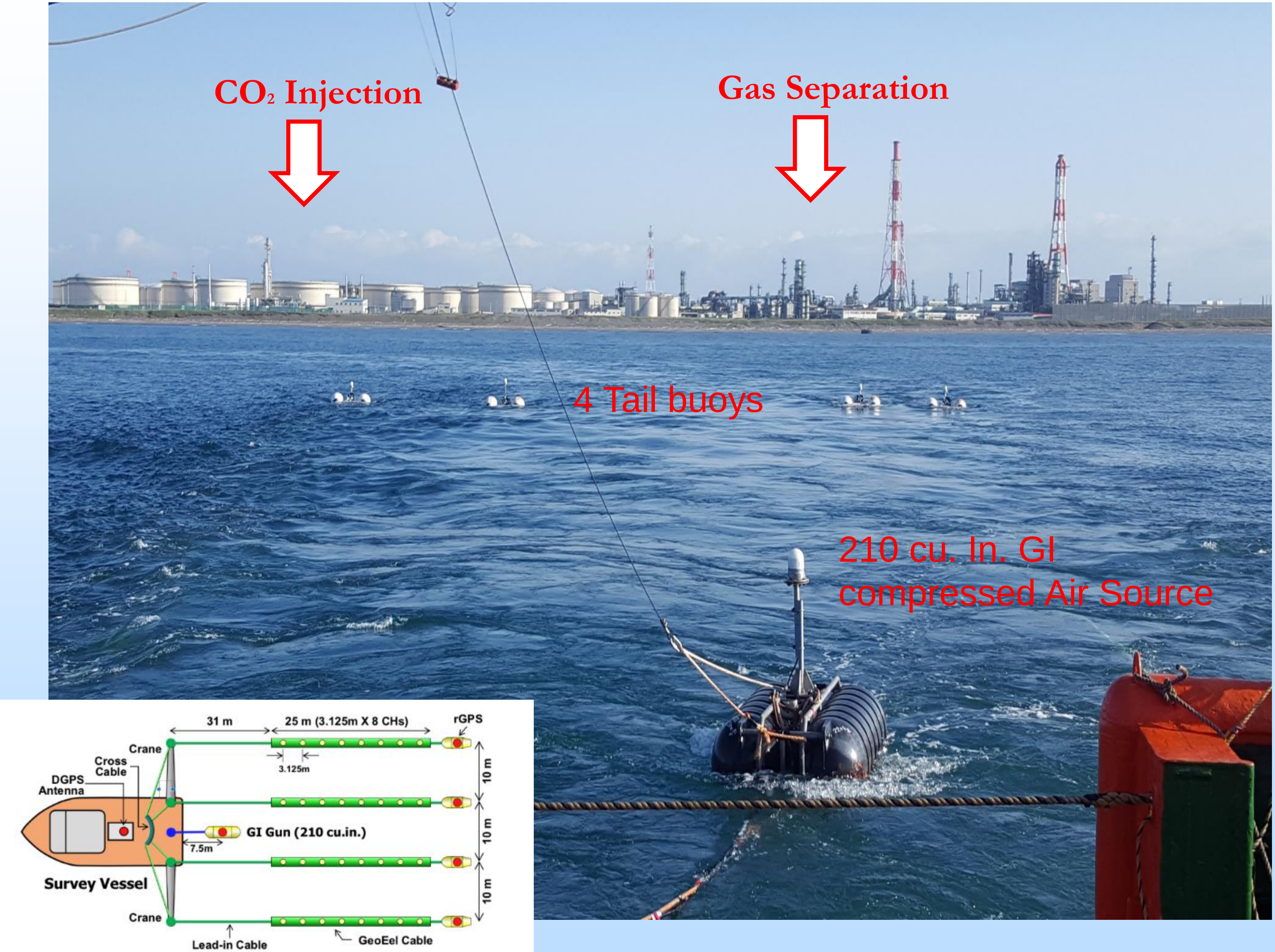
Tomakomai Port, Hokkaido Japan

Layout of Monitoring Facilities

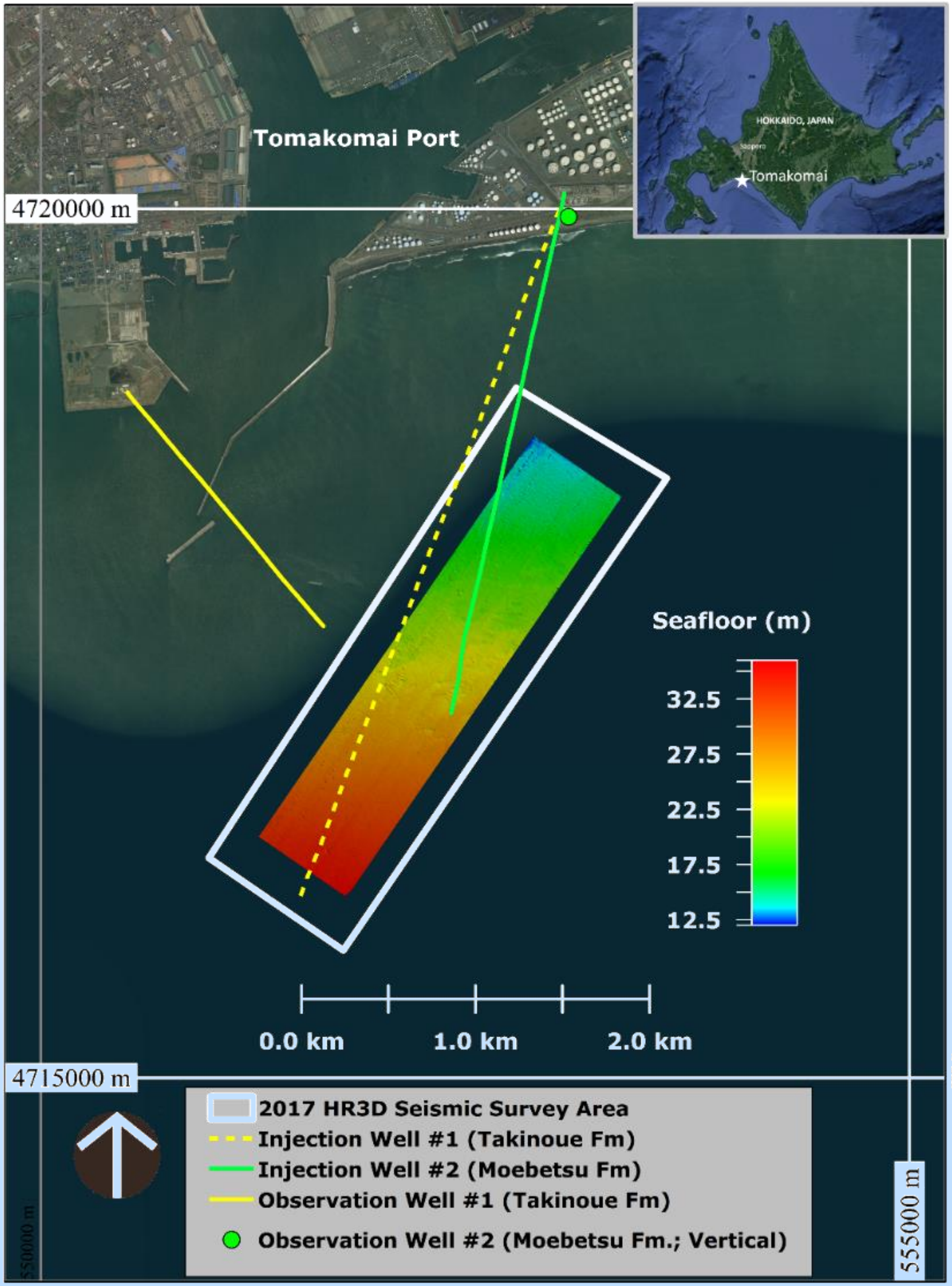


JCCS

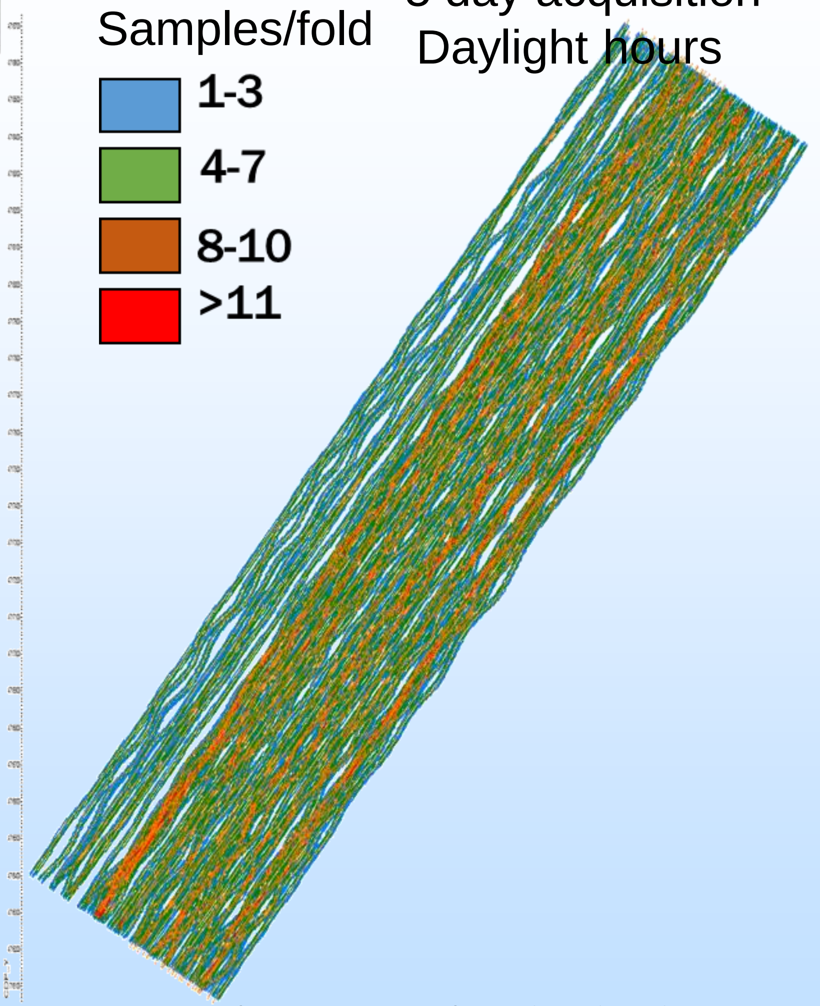
HR3D acquisition August 2017



CDP Binning



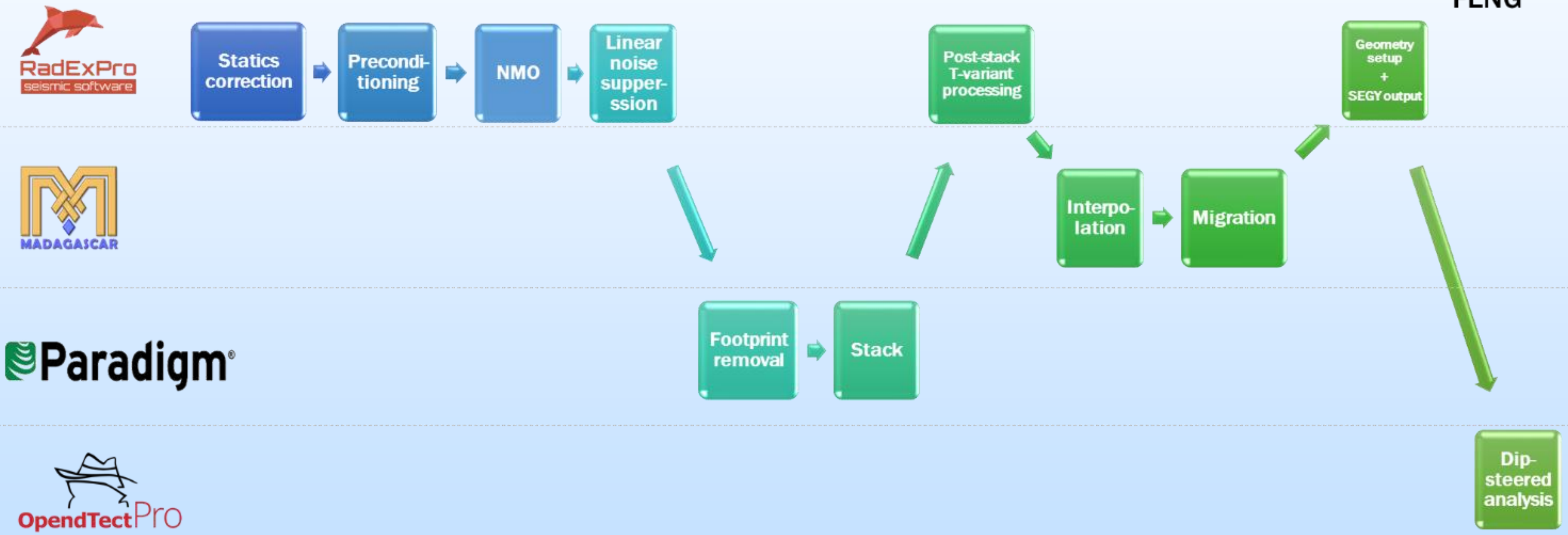
~5 day acquisition
Daylight hours



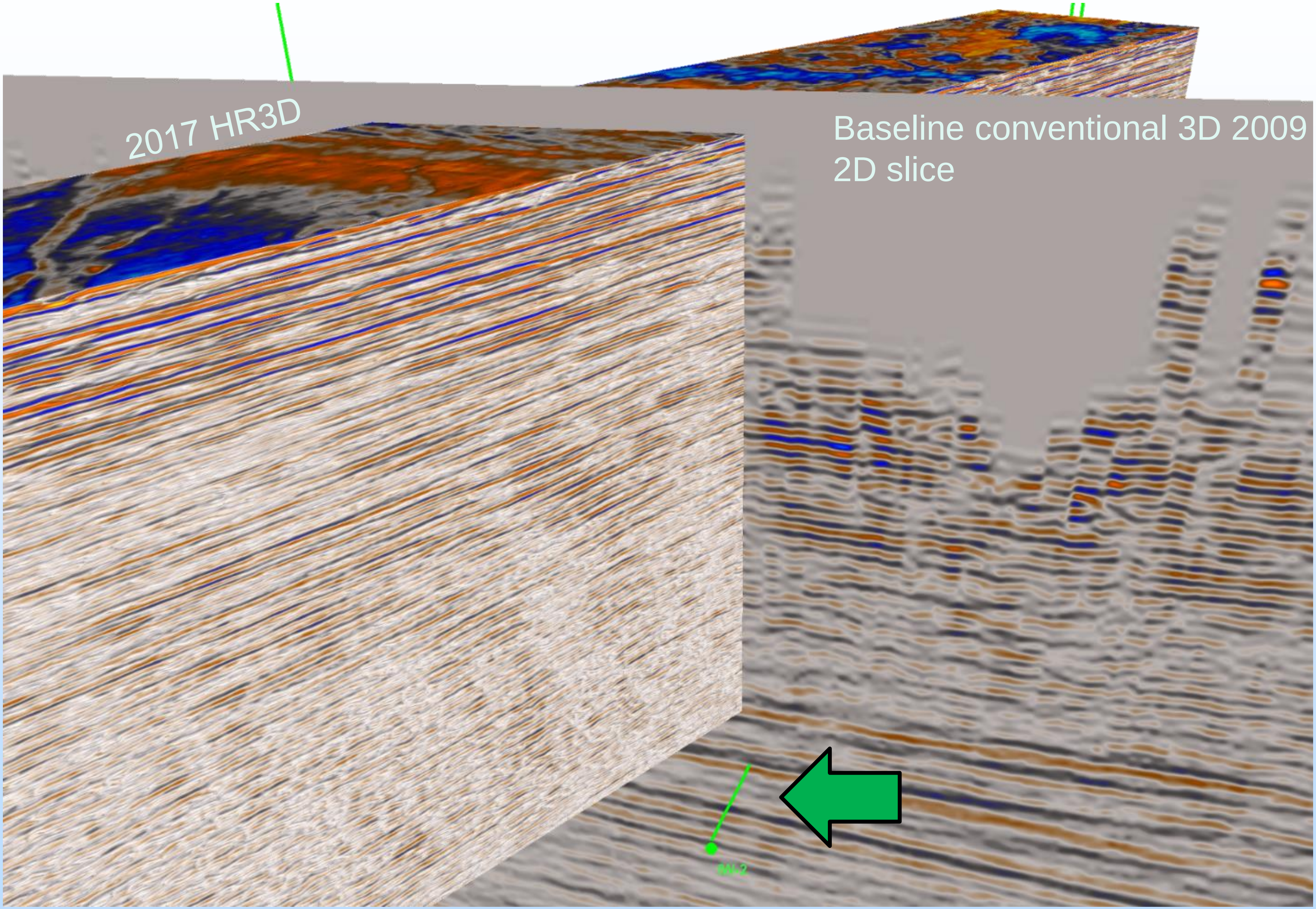
Array Design: four streamers of 25m length with 10m inline separation. Each solid-core Geometrics GeoEel™ streamer has 8 channels (32 total array channels) with a 3.125m group interval spacing, resulting in a remarkably small final processing bin size of 3×3 m.

HR3D data processing workflow

FENG



HR3D vs Conventional 3D



International Journal of Greenhouse Gas Control 88 (2019) 124–133

Contents lists available at ScienceDirect

International Journal of Greenhouse Gas Control

journal homepage: www.elsevier.com/locate/ijggc

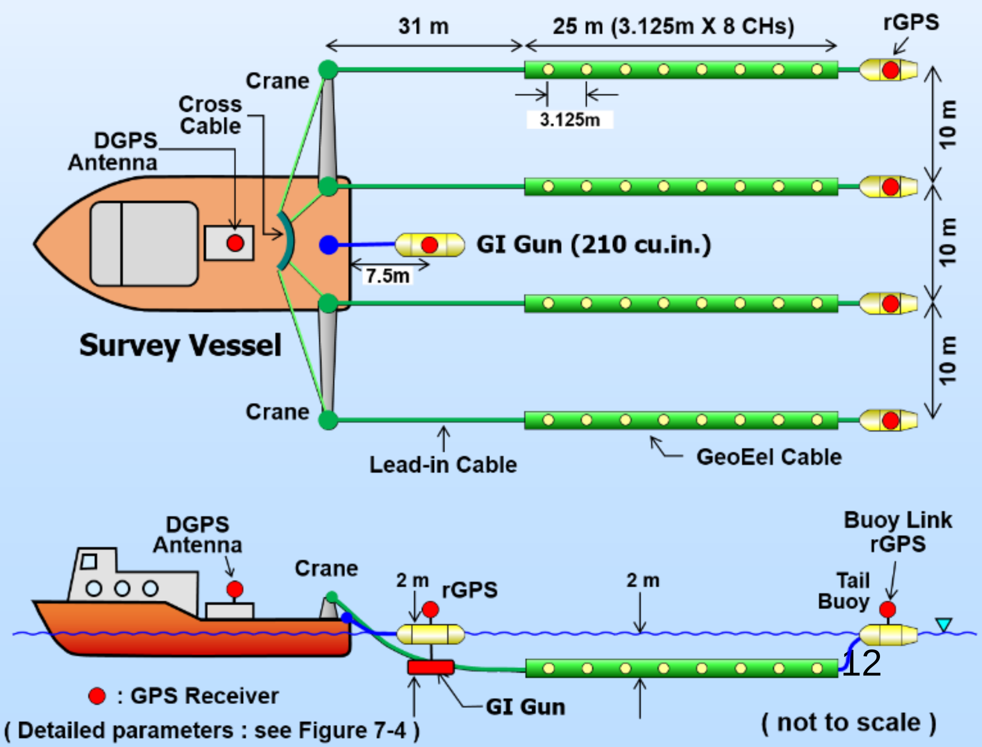
High-resolution 3D marine seismic acquisition in the overburden at the Tomakomai CO_2 storage project, offshore Hokkaido, Japan

T.A. Meckel*, Y.E. Feng, R.H. Treviño, D. Sava

Gulf Coast Carbon Center, Bureau of Economic Geology, Jackson School of Geosciences, The University of Texas at Austin, Austin, TX, USA

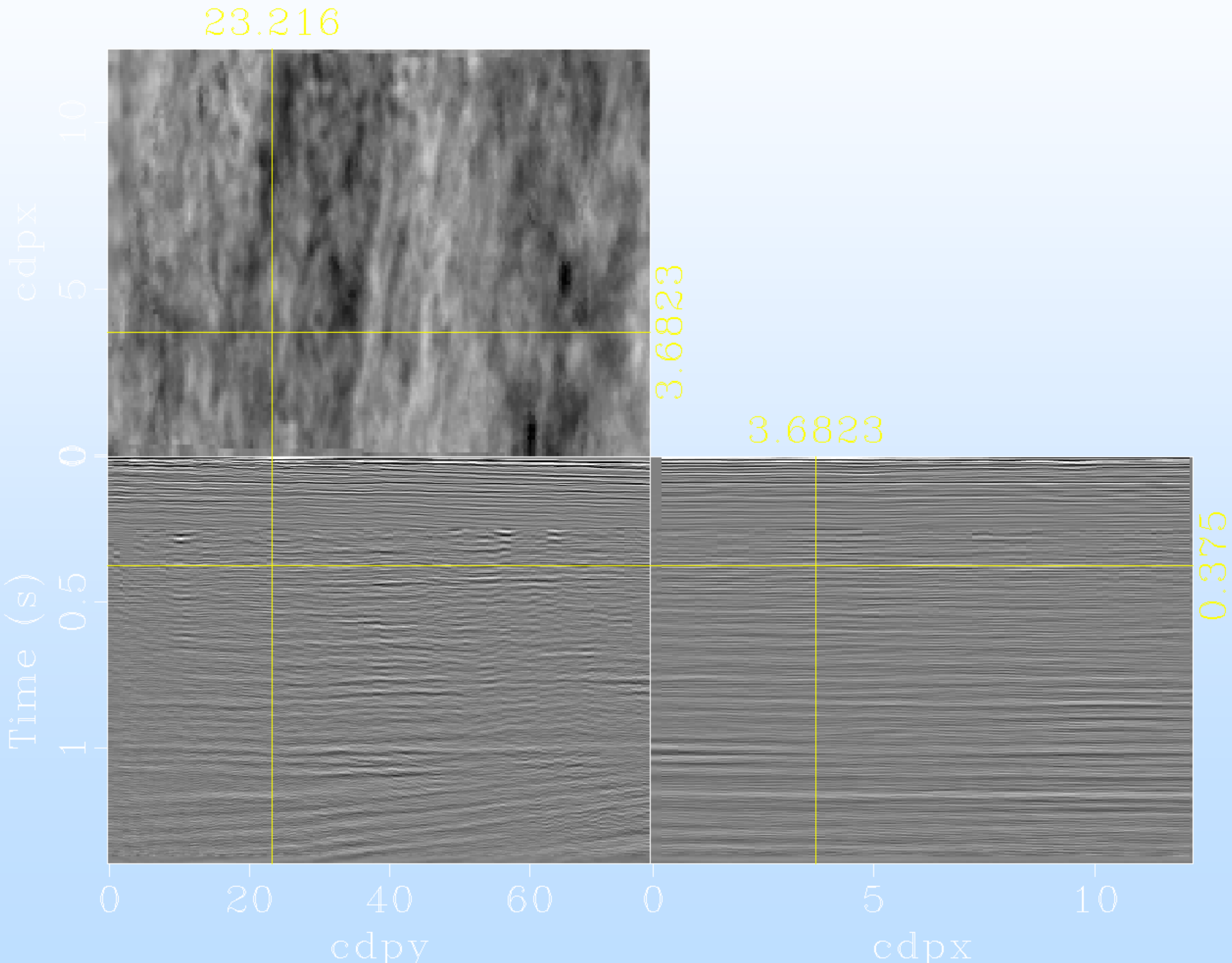
SSRN's Top Ten download list for the [Earth Science Research Network](): Seismology topic.

The SSRN is a research repository and an international journal. The ranking demonstrates the study's value to the broader scientific community. [View the full article here.]()



Merging HR3D and Conventional

Matching and merging high-resolution and legacy seismic images.
S Greer, S Fomel. Geophysics 83 (2), V115-V122, 2018.



Accomplishments FY17-19

- HR3D survey successfully collected.
  - Sensitivity and repeatability studies successful.
- Novel processing techniques developed.
- Merging of conventional and HR3D data.
- Successful demonstration of MVA technology
  - No indication of CO_2 migration into overburden above injection interval.
- GCCC invited into the Asian CCS network.

Tomakomai SOPO Task remaining: Second HR3D Survey

November 22, 2019, cumulative CO_2 injection reached the target of 300,110 tonnes, and accordingly, injection has been suspended.

- **Subtask 2.2: P-Cable acquisition survey**
  - **Subtask 2.2.1: Vessel Subcontracting** –
  - This subtask includes all activities need to subcontract a vessel for UHR3D seismic data acquisition. Demonstration of completion will be a signed contract.

  - **Subtask 2.2.2:Novel Positioning Technology <u>Selection</u>** –
  - This subtask includes all work elements for researching, pricing and selecting in-water dynamic positioning technology previously untested for P-Cable systems. All necessary development work and performance attributes for validating methods will be summarized in a quick look report (**Deliverable 5**).
-
  - **Subtask 2.2.3: Novel Positioning Technology <u>Deployment</u>** –
  - The technology identified in Subtask 2.2.2 will be deployed during one UHR3D data acquisition survey.

Previous investigations of Short Baseline (SBL) wer legitimate four years ago, but the technology is not currently viable as a positioning option for high-resolution 3D (HR3D) seismic survey acquisition. SBL technology is best for downward directed positioning, not horizontal. Vessel prop wash creates too much turbulence for accurate positioning of towed arrays.

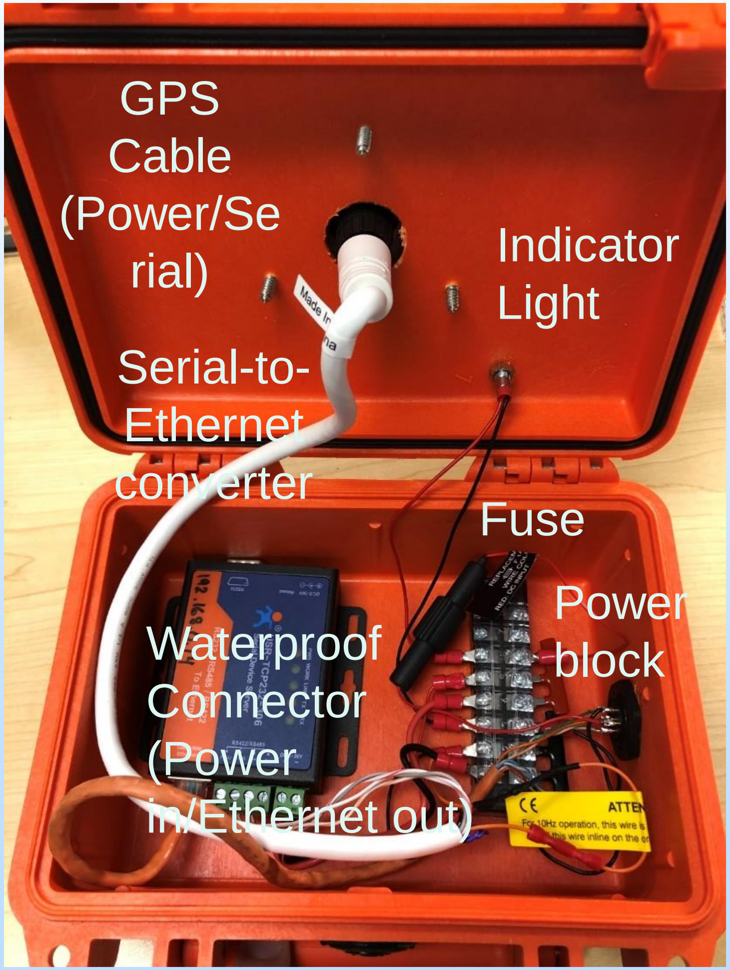
Japanese tail buoy design used at Tomakomai

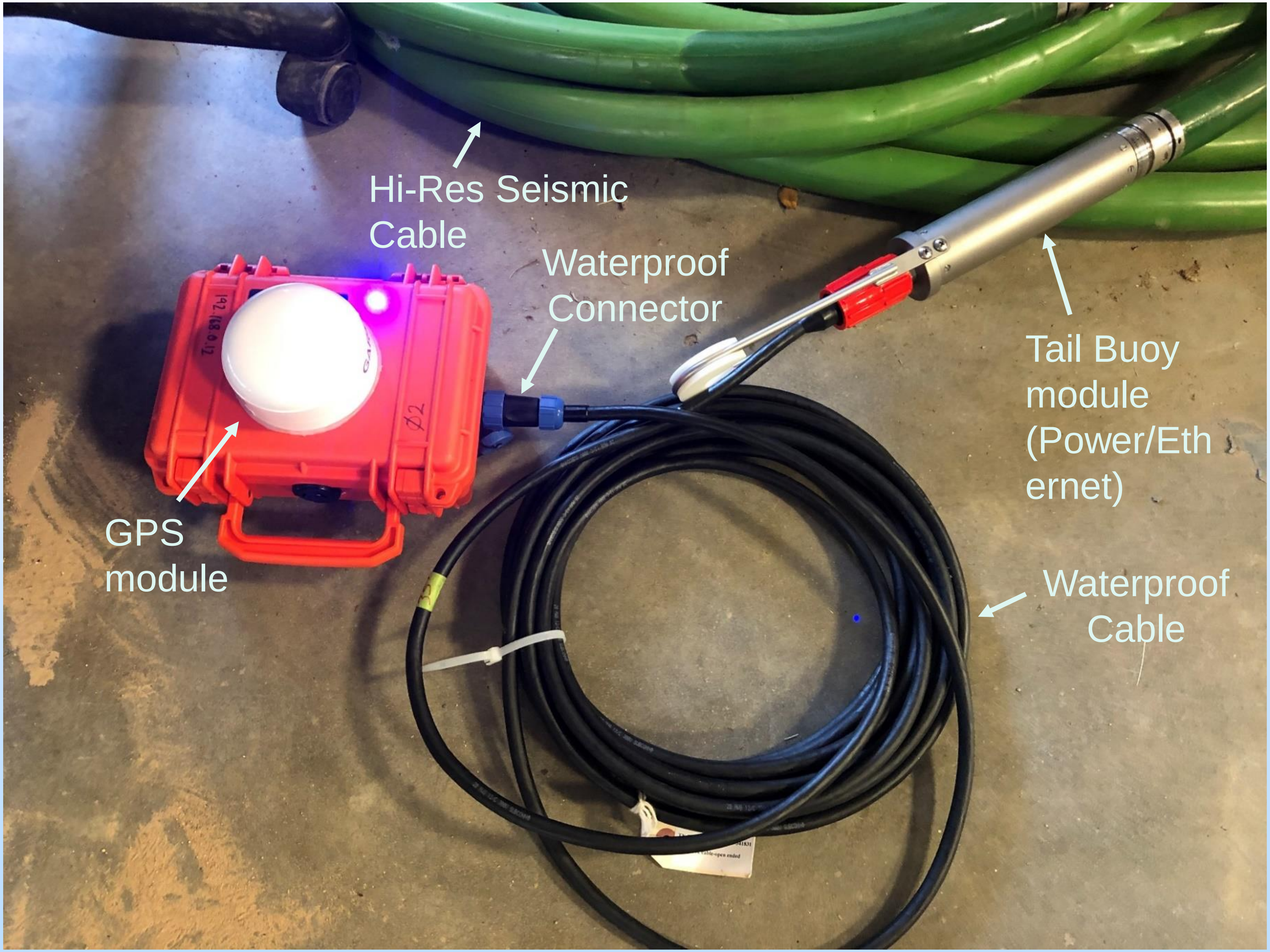
Depends on data telemetry to vessel

Heavy battery packs create some tow ‘surging’ in water.

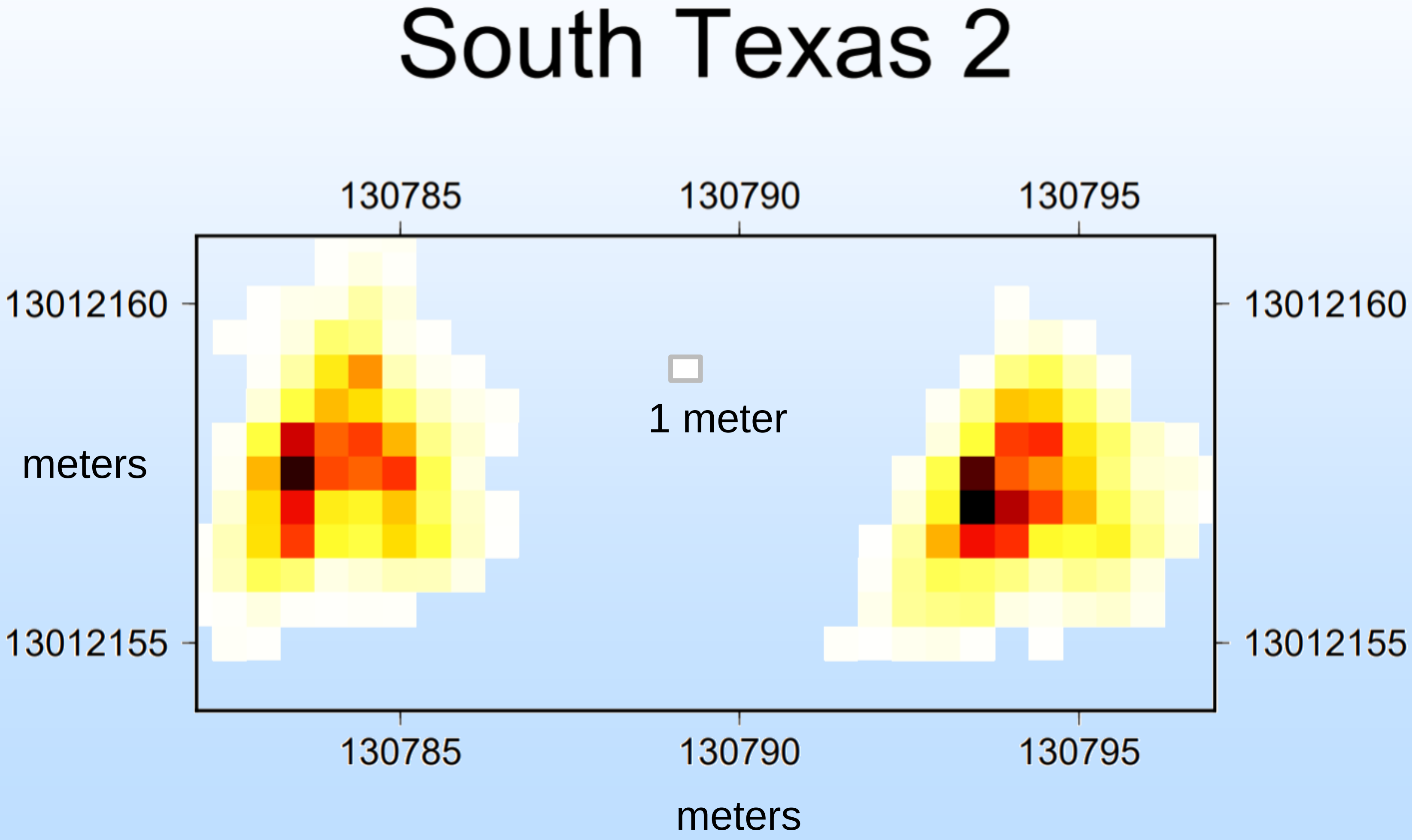
UT-BEG GCCC tail buoy development

- Power through streamer (no battery pack, weight)
- Data transfer through streamer (no telemetry)




Hi-Res Seismic Cable
Waterproof Connector
Tail Buoy module (Power/Ethernet)
GPS module
Waterproof Cable

Land test of accuracy and precision



Accomplishments FY 2020 – Task 2

- Learning tail buoy positioning from Japanese collaboration.
- Design and fabrication of UT tail buoys.
  - Integration into streamer electronics.
- Land test complete: meter-scale resolution demonstrated for these units.
- Sea test pending: Likely Q1 2022 at San Luis Pass, offshore Galveston Island.

Task 3- Environmental Monitoring Objectives

- Provide insight into subsurface field conditions informed by high resolution 3D seismic survey.
- <u>D8- Summary Report</u>: Interpretation of core sediment geochemistry Katherine Romanak

Marine Pollution Bulletin 159 (2020) 111520

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

What natural and social scientists need from each other for effective marine environmental assessment: Insights from collaborative research on the Tomakomai CCS Demonstration Project

Leslie Mabon[a,*], Jun Kita[b], Hiromitsu Onchi[b], Midori Kawabe[c], Toshiya Katano[c], Hiroshi Kohno[c], Yi-Chen Huang[d]

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

Accomplishments FY 2020 – Task 3

- Successful geochemistry sampling and interpretation of marine water column and shallow sediments.
- Draft Manuscript: *Source attribution of gases in marine sediments at offshore CO2 storage sites: case study at the Tomakomai CCS project*
  - To be submitted to applied geochemistry

				O_2	N_2	C_1	CO2	C1 /(C_2+C_3)	C2 /C_3	δ^{13}C1 (‰)	δ^{13}CO2 (‰)
517	1	St.10	1-1	4.56	93.69	346	1.7179	116	0.84	-59.9	-26.2
517	2	St.10	1-2	9.38	90.44	33	0.1671				-24.3
517	3	St.03	2-1	1.39	92	3,993	6.2083			-55.4	-25.7
517	4	St.03	2-2	7.69	91.76	227	0.5244			-58.5	-25.4
517	5	St.02	3-1-1	6.08	93.17	573	0.6931	426	1.51	-63.9	-26.2
517	6	St.02	3-1-2	9.78	90.18	27	0.0356	26			-24.3
517	7	St.02	3-2-1	7.50	91.6	298	0.8661			-49.5	-25.2
517	8	St.02	3-2-2	11.24	88.73	11	0.0306				-19.9
817	1	St.2	0-7	1.20	96.07	2,643	2.4687	1013	1.32	-56.9	-28.0
817	2	St.2	7-14	2.93	95.39	594	1.6154			-60.6	-28.0
817	3	St.2	14-21	1.35	97.43	554	1.1635			-63.9	-28.8
817	4	St.03	0-7	1.16	93.26	11,565	4.4296				-28.2
817	5	St.03	7-14	4.34	94.42	267	1.2038			-44.0	-28.1
817	6	St.03	14-21	4.73	94.65	79	0.6076			-48.7	-27.8
817	7	St.10	0-7	1.10	92.81	4,141	5.6751	1144	1.84	-49.3	-27.7
817	8	St.10	7-14	1.25	94.83	1,265	3.7939	267	3.60	-54.5	-28.2
817	9	St.10	14-21	1.29	93.55	1,351	5.0263	390	0.72	-57.5	-28.4

Lessons Learned

- International deployment demonstrated
  - Overseas shipping transport, contracts, costs, production rates
  - Vessel modifications
  - International communications
- Tail buoy positioning techniques
  - SBL acoustics unable to perform positioning as needed, never deployed.
- Processing techniques – hybrid commercial + other
- Local fisheries consultation and negotiation very important; National group, strong locally.
  - Geochemistry task crucial to facilitating dialog

SUMMARY

1. **Successful demonstration of HR3D as CCS characterization and monitoring tool in overburden.**
2. A successful first high-resolution 3D survey was collected Aug. 2017.
   - Imaging depth ~600 ms = source energy; very noisy port environment.
   - Lack of any apparent faults or fluid/gas anomalies in overburden.
3. Repeatability Study – results look promising for 4D in shallow interval.
   - A second survey cannot be hosted at Tomakomai

4. Second HR3D survey Q1 2022 offshore Galveston Island.

THANK YOU – QUESTIONS?

TEXAS Geosciences
Bureau of Economic Geology
Jackson School of Geosciences
The University of Texas at Austin

METI
Ministry of Economy, Trade and Industry

Japan CCS Co., Ltd.

MARINE ECOLOGY RESEARCH INSTITUTE

JGI, Inc.

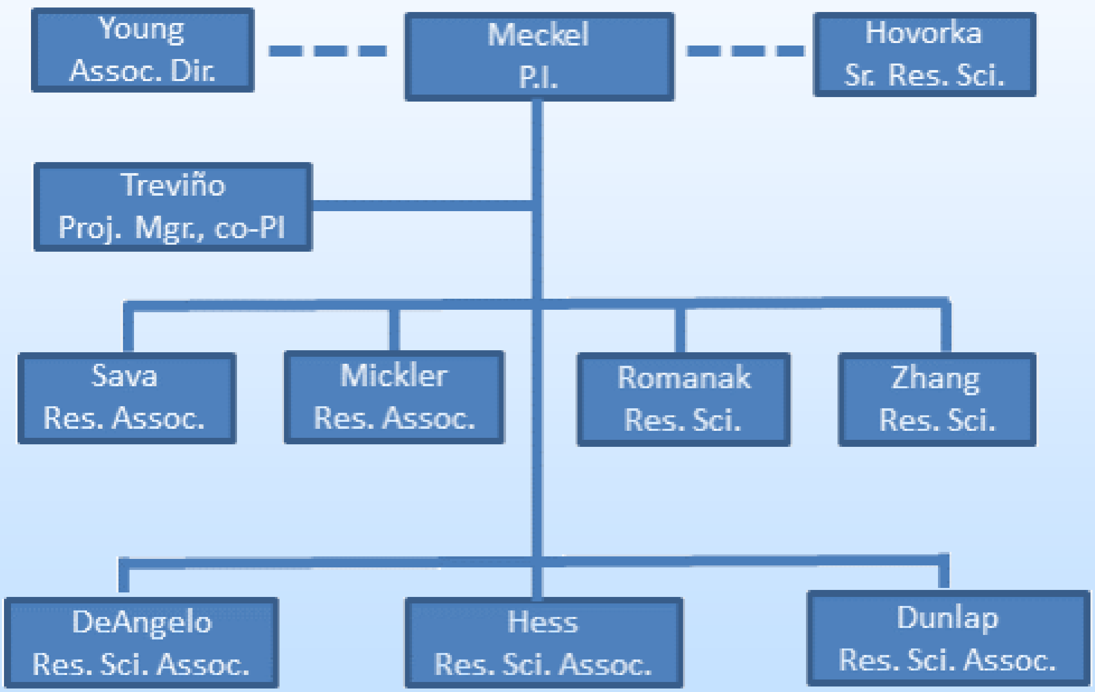
RITE
Research Institute of Innovative Technology for the Earth

Gulf Coast Carbon Center

Appendix

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

Organization Chart



Gantt Chart

		BUDGET PERIOD 1			BUDGET PERIOD 2			BUDGET PERIOD 3									
		YEAR 1				YEAR 2				YEAR 3				YEAR 4			
Task	Tasks	qtr 1	qtr2	qtr3	qtr4	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	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q F
1,4	Project Management																
2) UHR3D SEISMIC IMAGING																	
2.1	CO2 SENSITIVITY STUDY			D4 M1 DP1													
2.2	P-Cable ACQUISITION				M2 M3									M5	M6		
2.3	P-Cable PROCESSING					D5	M4 D6 DP2										M8 D9
2.4	P-Cable INTERPRETATION									D7							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					

Q = Quarterly Report; A = Annual Report; F = Final Report
M = Milestone; DP = Decision Point; D = Deliverable;

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.

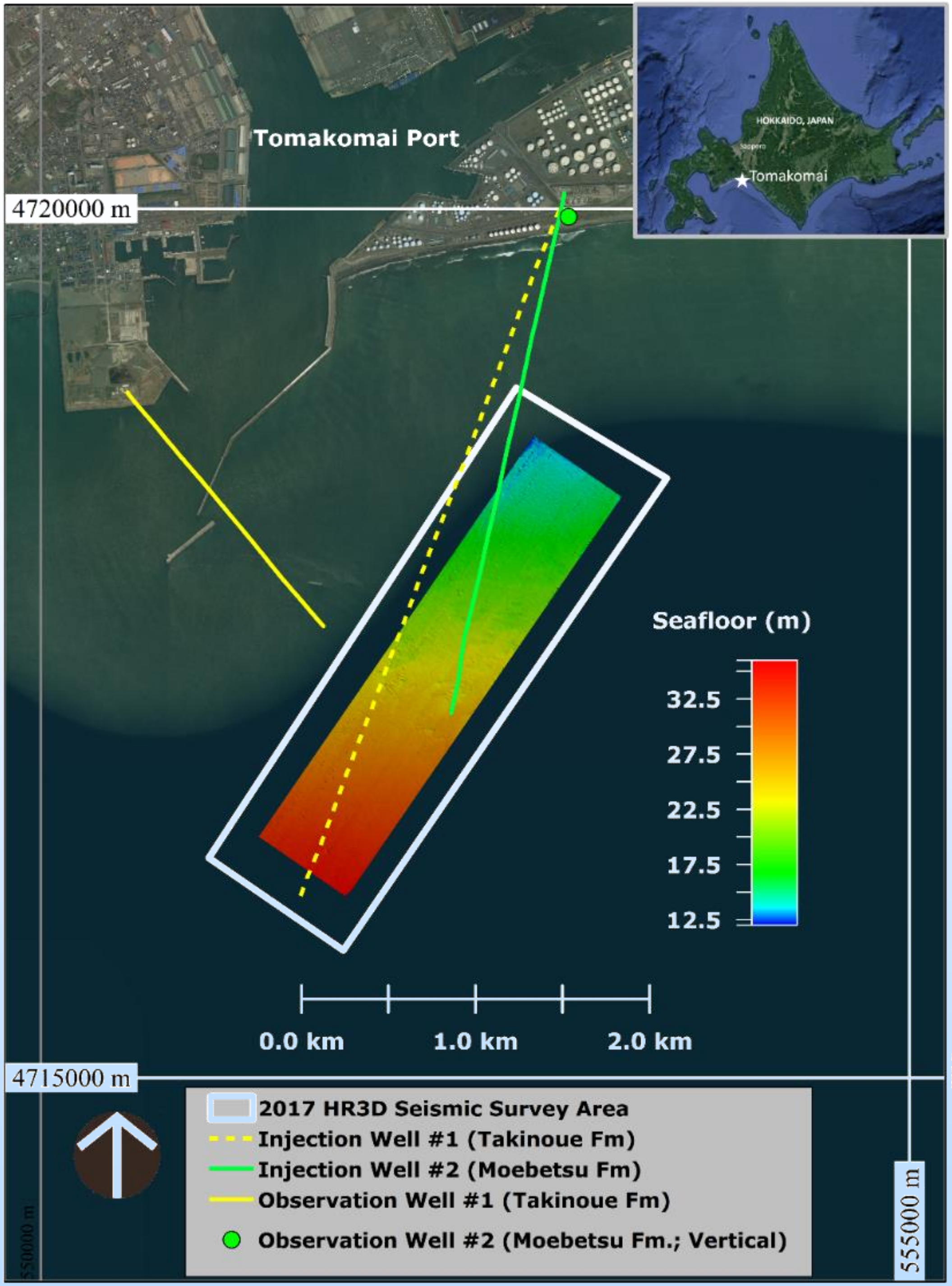
Bibliography

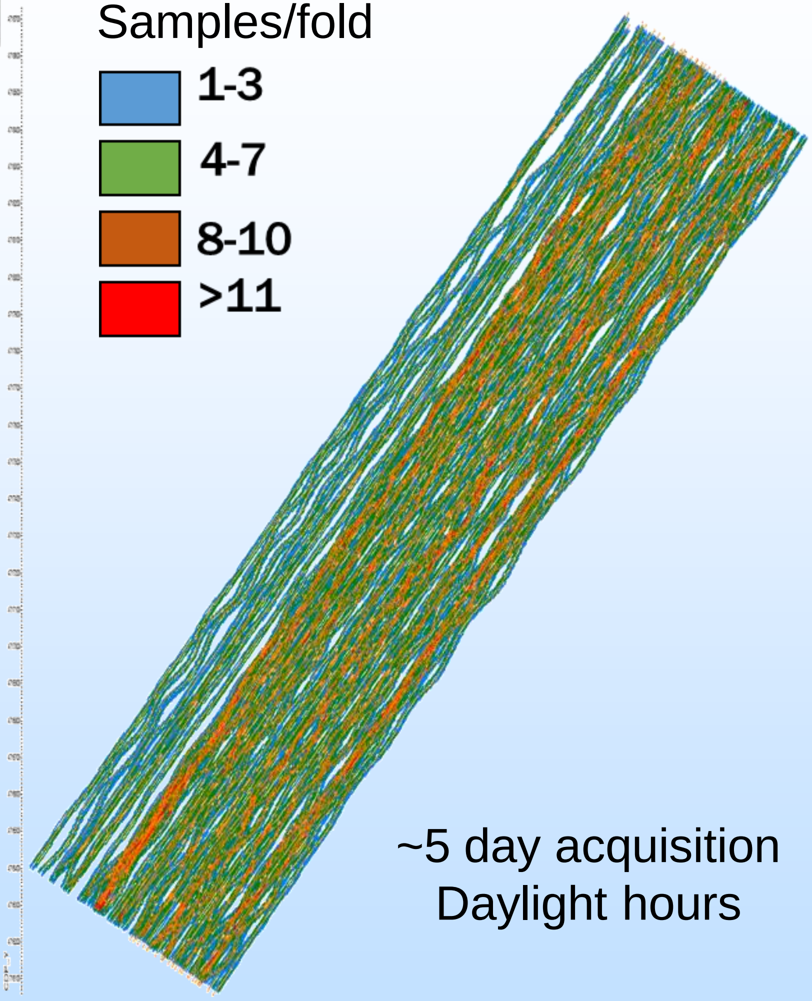
– List peer reviewed publications generated from the project per the format of the examples below.

- Meckel, T.A., Y. Feng, R.H. Trevino, and D. Sava, 2019, *High-resolution 3D marine seismic acquisition in the overburden at the Tomakomai CO2 storage project, offshore Hokkaido, Japan*, IJGGC, 88:124-133. https://doi.org/10.1016/j.ijggc.2019.05.034

Extra Slides

CDP Binning

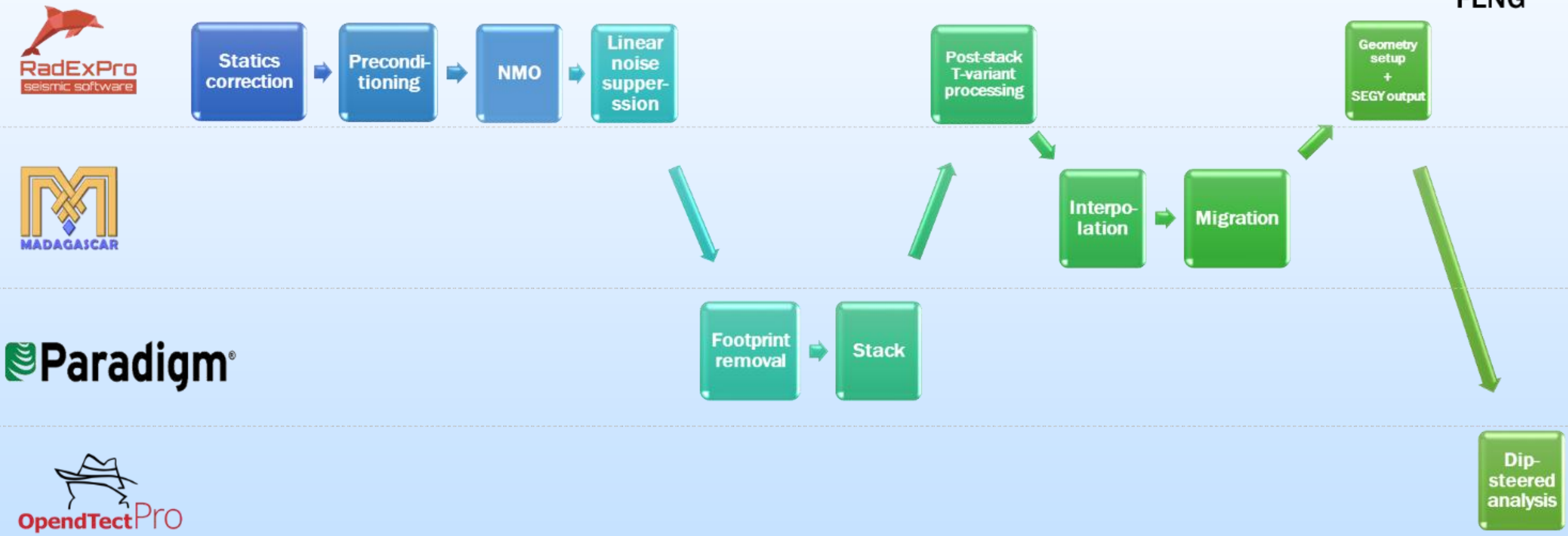




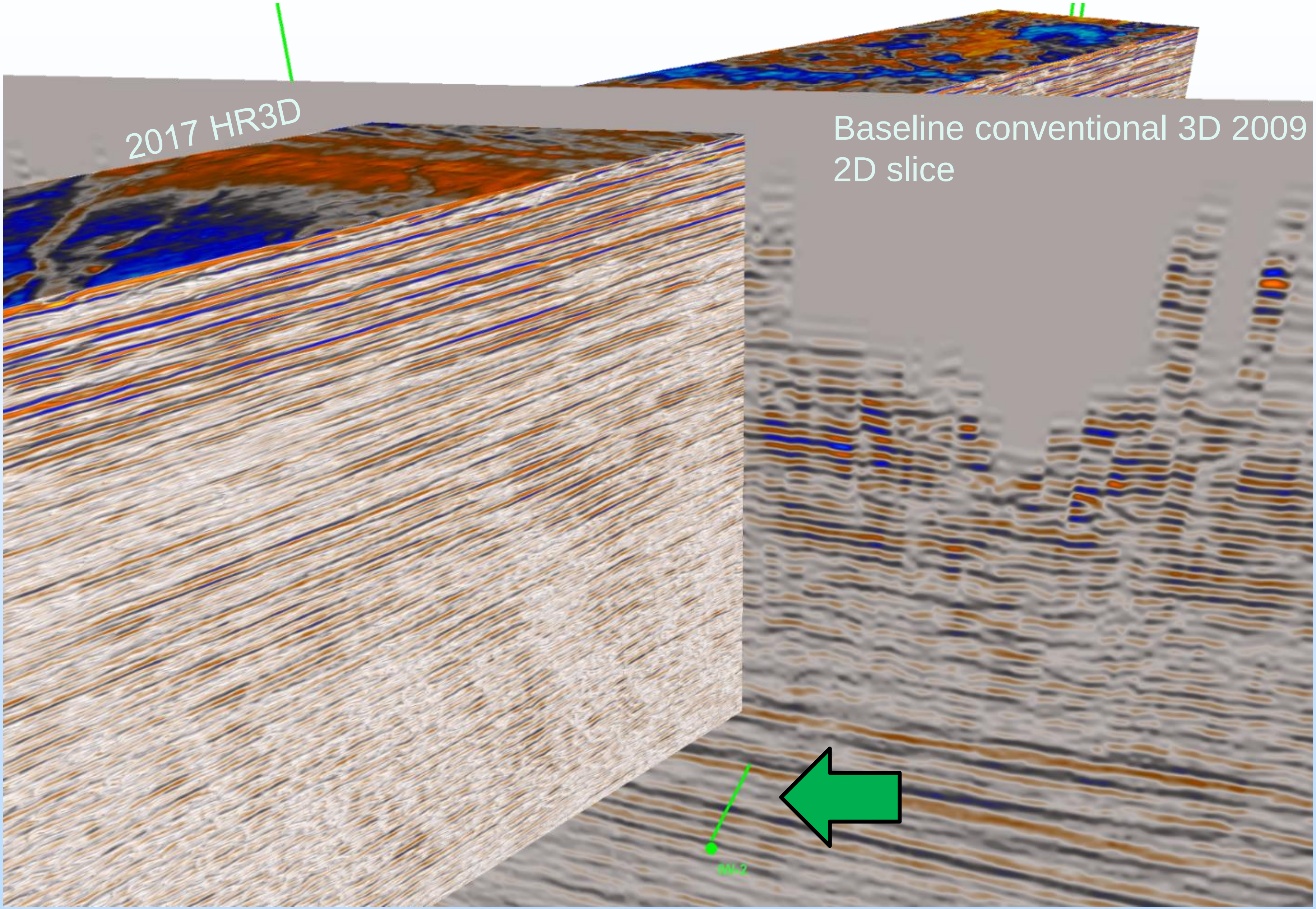
~5 day acquisition
Daylight hours

HR3D data processing workflow

FENG



HR3D vs Conventional 3D



Moebetsu Formation

Temperature=44.8 C
Pore Pressure=10.67 MPa

<u>BRINE</u>
2.49 Bulk modulus (Gpa)
1007 Density (kg/m^3)

<u>CO_2</u>
0.0038 Bulk modulus (Gpa)
265 Density (kg/m^3)

<u>RESIDUAL GAS</u>
0.02 Bulk modulus (Gpa)
137 Density (kg/m^3)

Mineral Composition of Moebetsu
(average values from cores over the interval 968 - 1079.35 m)

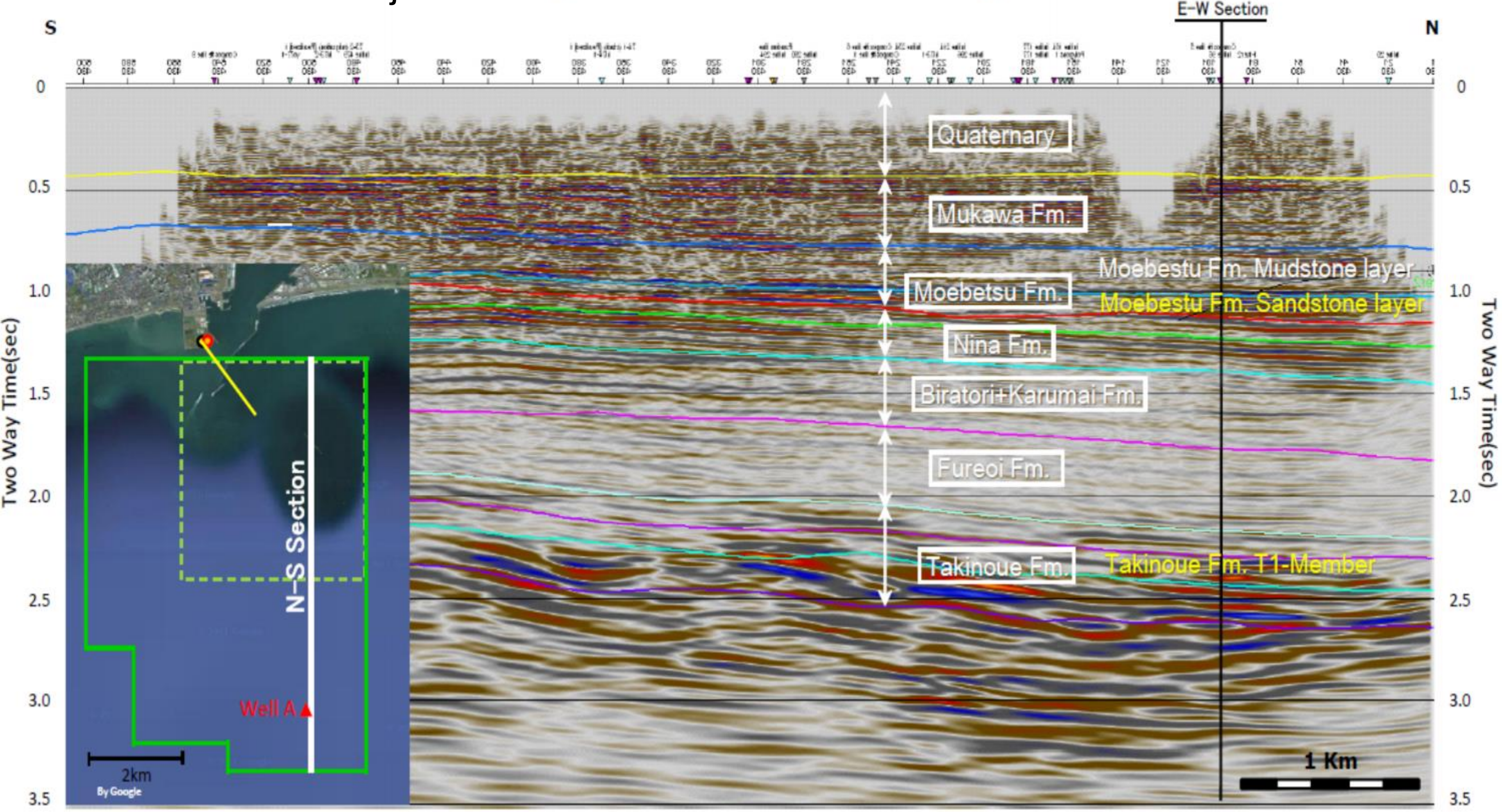
Plagioclase: 36% , Bulk modulus = 75.6 GPa
Clay minerals: 34.5%, Bulk modulus = 25 GPa
Quartz: 23%, Bulk modulus = 37 GPa
K feldspar 6.5%, Bulk modulus = 37.5 GPa

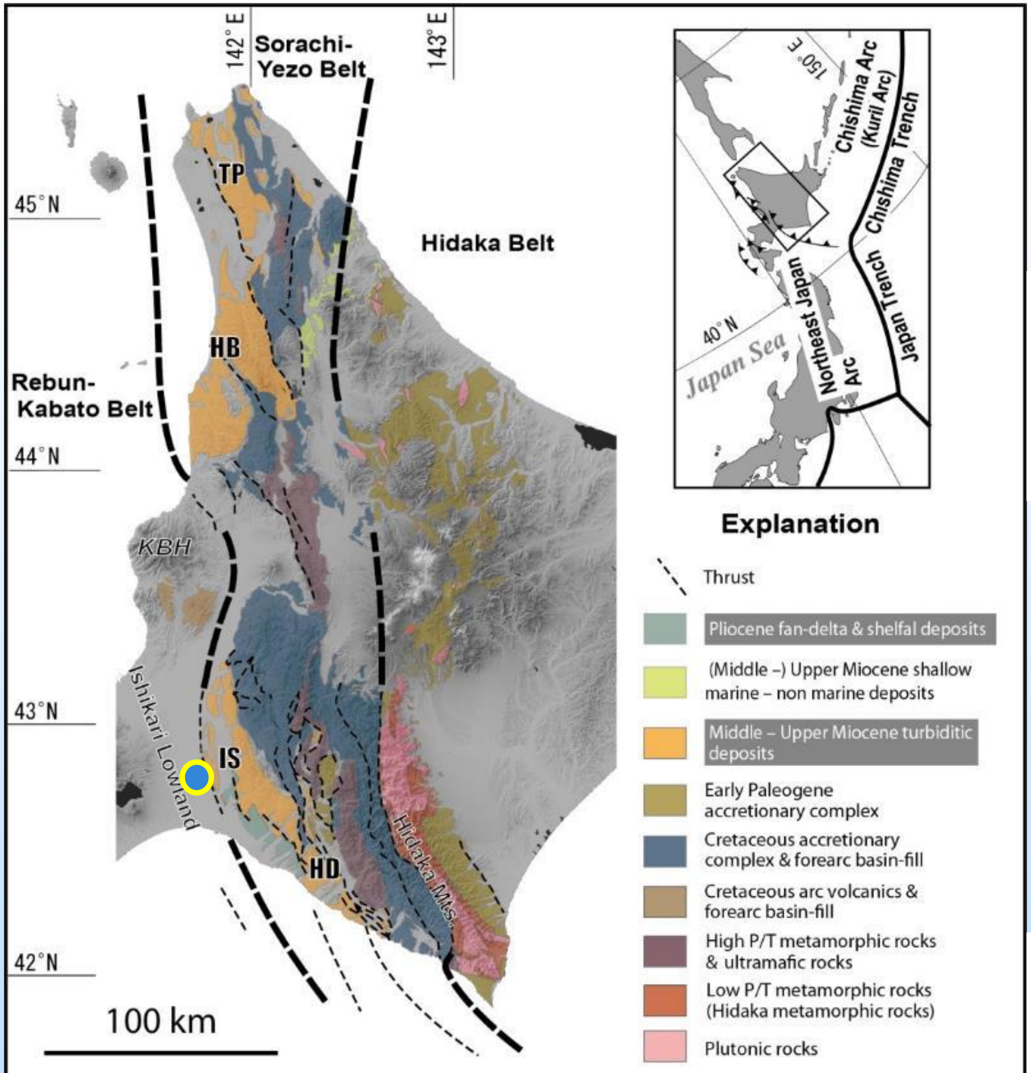
Bulk modulus of the mixture = 40.9 GPa
(Hashin Strikman bounds)

Ito et al., 2013, *Reservoir evaluation for the Moebetsu Formation at Tomakomai candidate site for CCS demonstration project in Japan*, Energy Procedia, No. 37, 4937-4945.

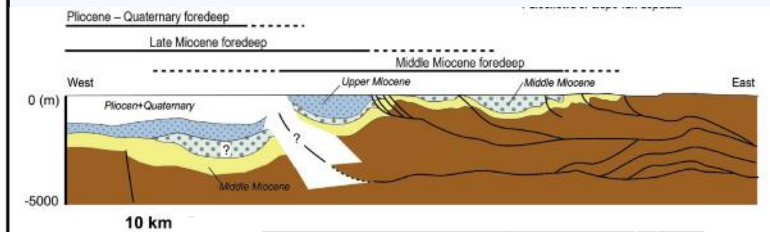
Geological Structure: North-South Section by 3 D Seismic Survey

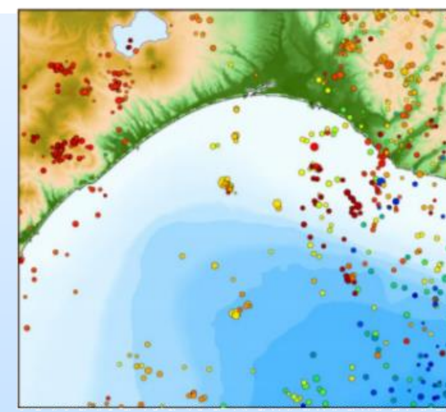
Pre-injection conventional seafloor cable 3D dataset





Yufutsu oil and gas field
JapEx, 1988
Entirely fracture permeability
Up to 40 MMcfd in 2005



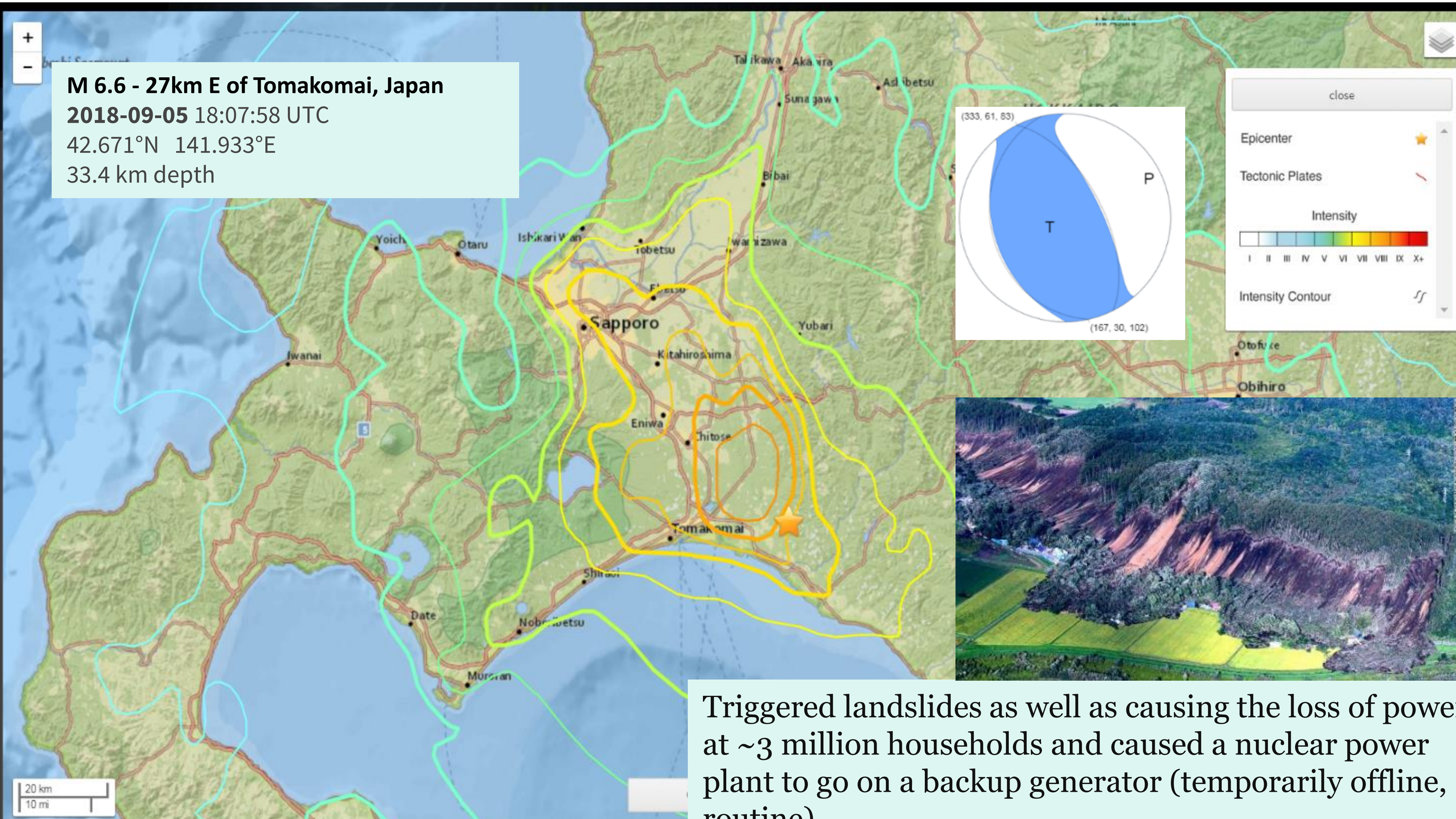


Natural earthquake hypocenter distribution occurred from 2001 to 2010

Fault stability analysis related to CO_2 injection at Tomakomai, Hokkaido, Japan

Y. Kano[a,*], T. Funatsu[a], S. Nakao[a], K. Kusunose[a], T. Ishido[a], X.-L. Lei[a], T. Tosha[a]

M 6.6 - 27km E of Tomakomai, Japan
2018-09-05 18:07:58 UTC
42.671°N 141.933°E
33.4 km depth



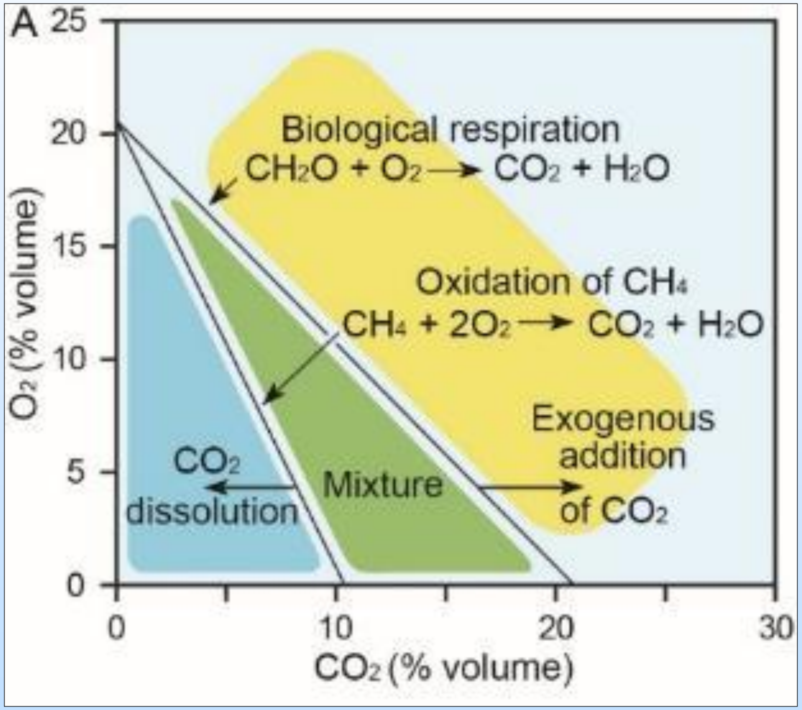
Triggered landslides as well as causing the loss of power at ~3 million households and caused a nuclear power plant to go on a backup generator (temporarily offline, routine).

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

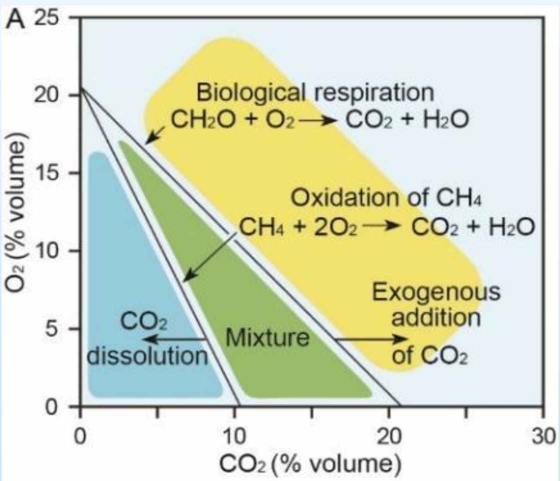
Process-Based Monitoring

- 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



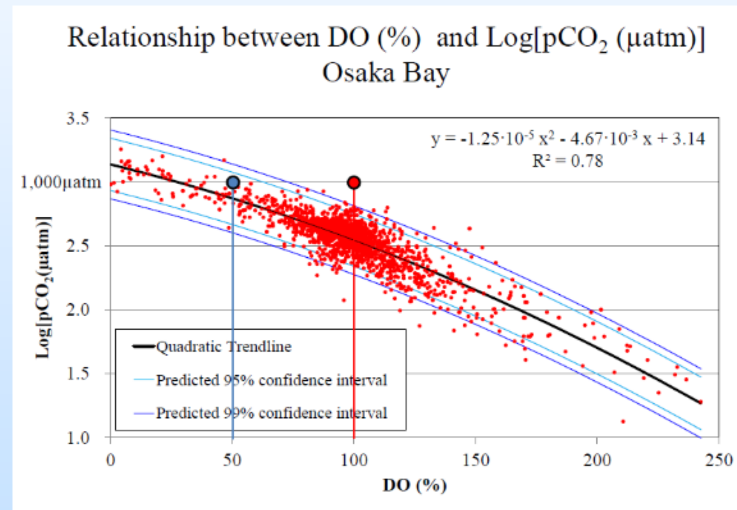
Bio-oceanographic source attribution

Onshore:
Process-Based Method



IEAGHG Meetings

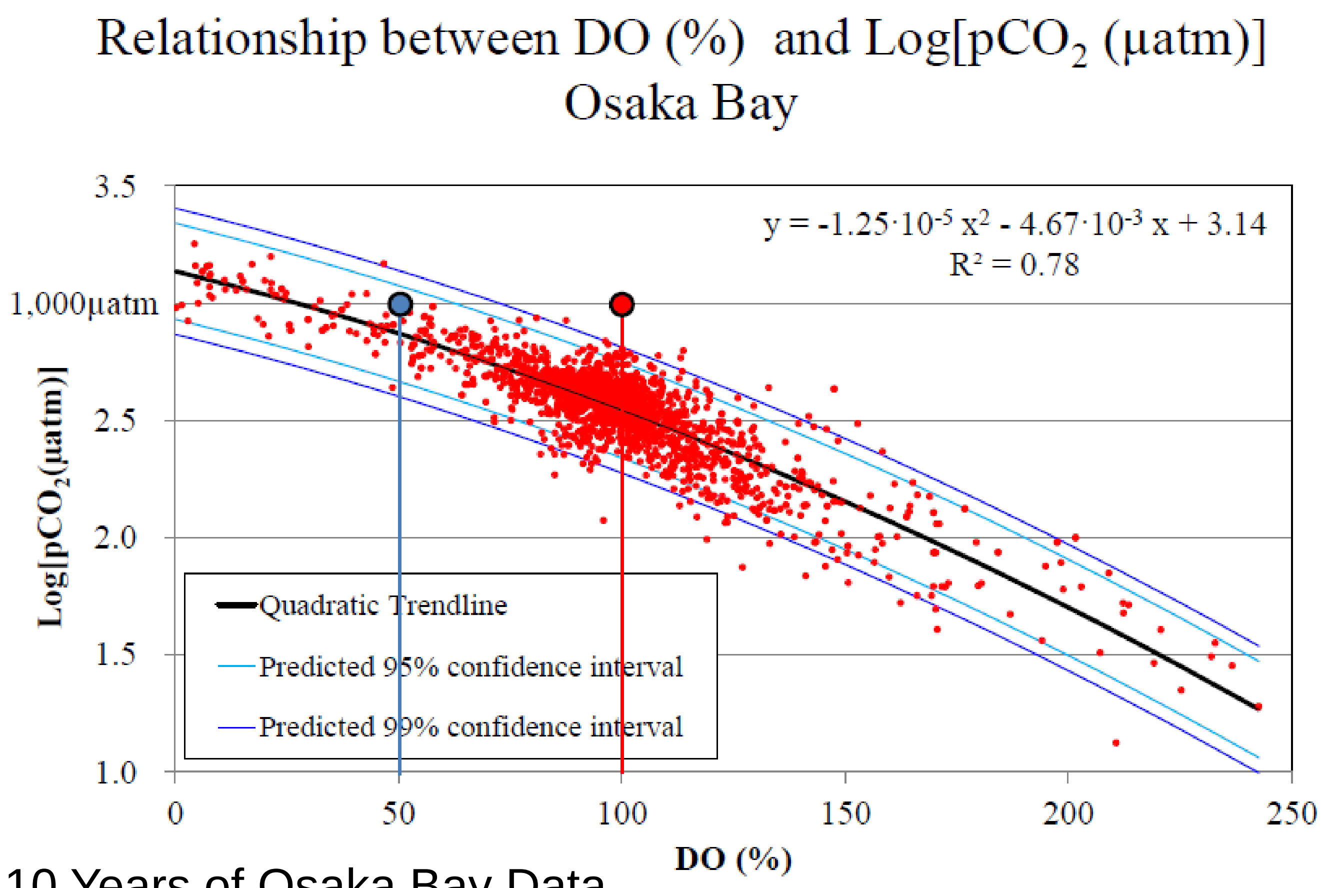
Offshore:
Bio-Oceanographic Method



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

Jun Kita, MERI, Japan

Bio-oceanographic Method



10 Years of Osaka Bay Data

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

Tomakomai Environmental Monitoring

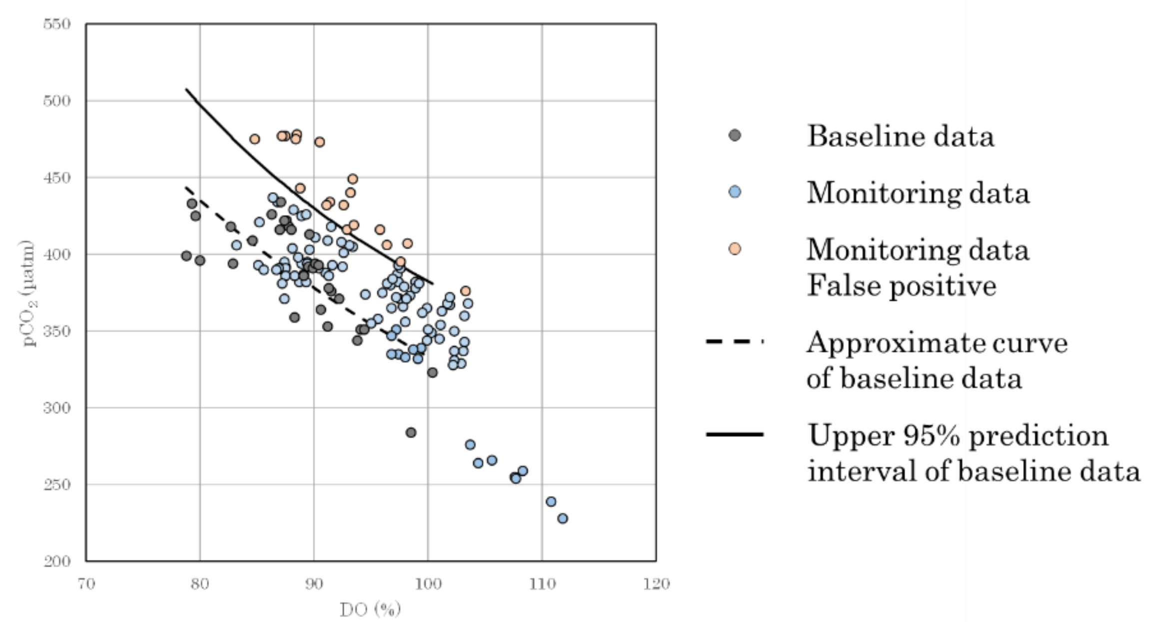
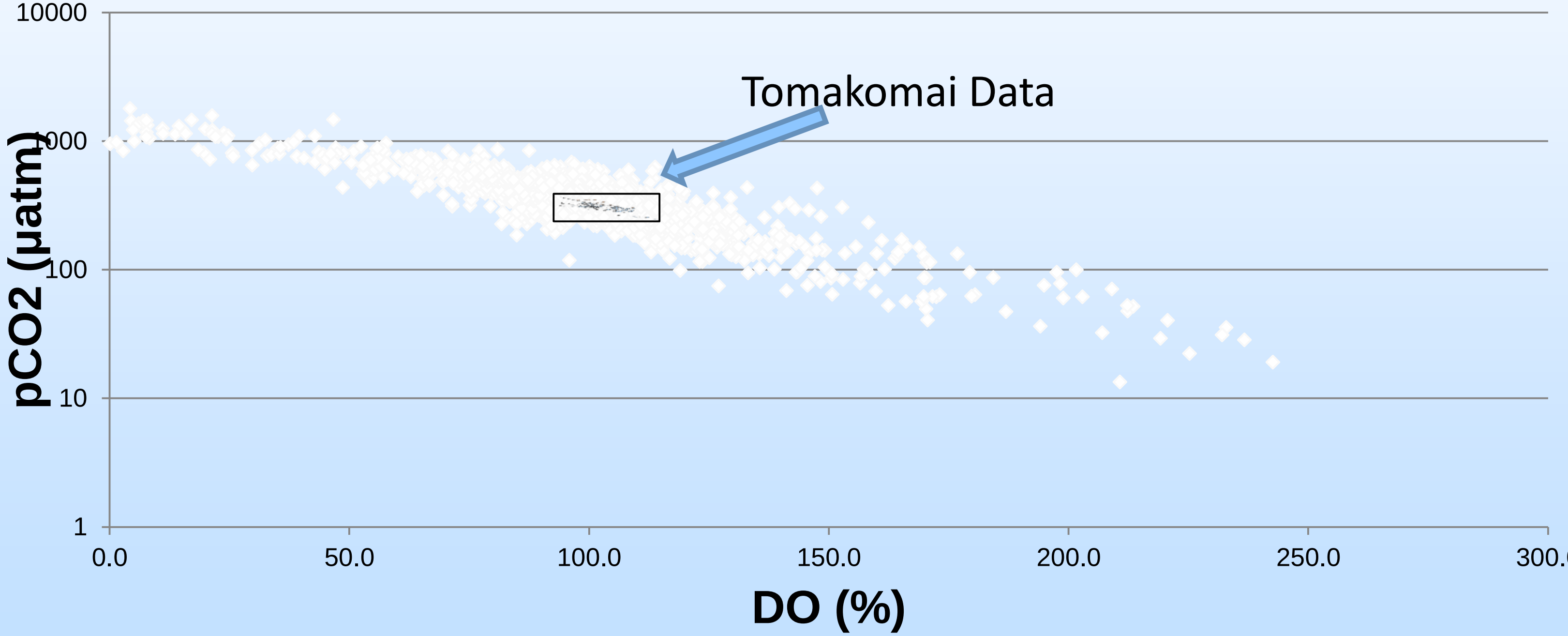


Fig. Relationship between oxygen saturation (DO) and CO_2 partial pressure (pCO_2) of bottom seawater (2 m above the seafloor).

“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”.

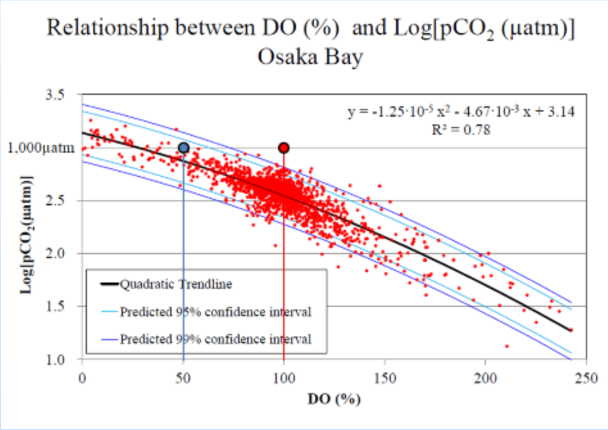
Jun Kita, 2017, 2nd International
Workshop on Offshore Geologic CO2 storage

10 Years of Osaka Bay Data
1 year Tomakomai Data



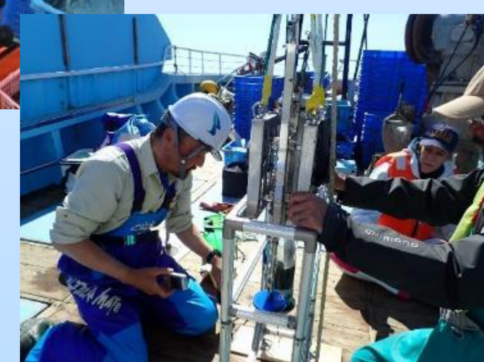
Plans for Method Advancement

- 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

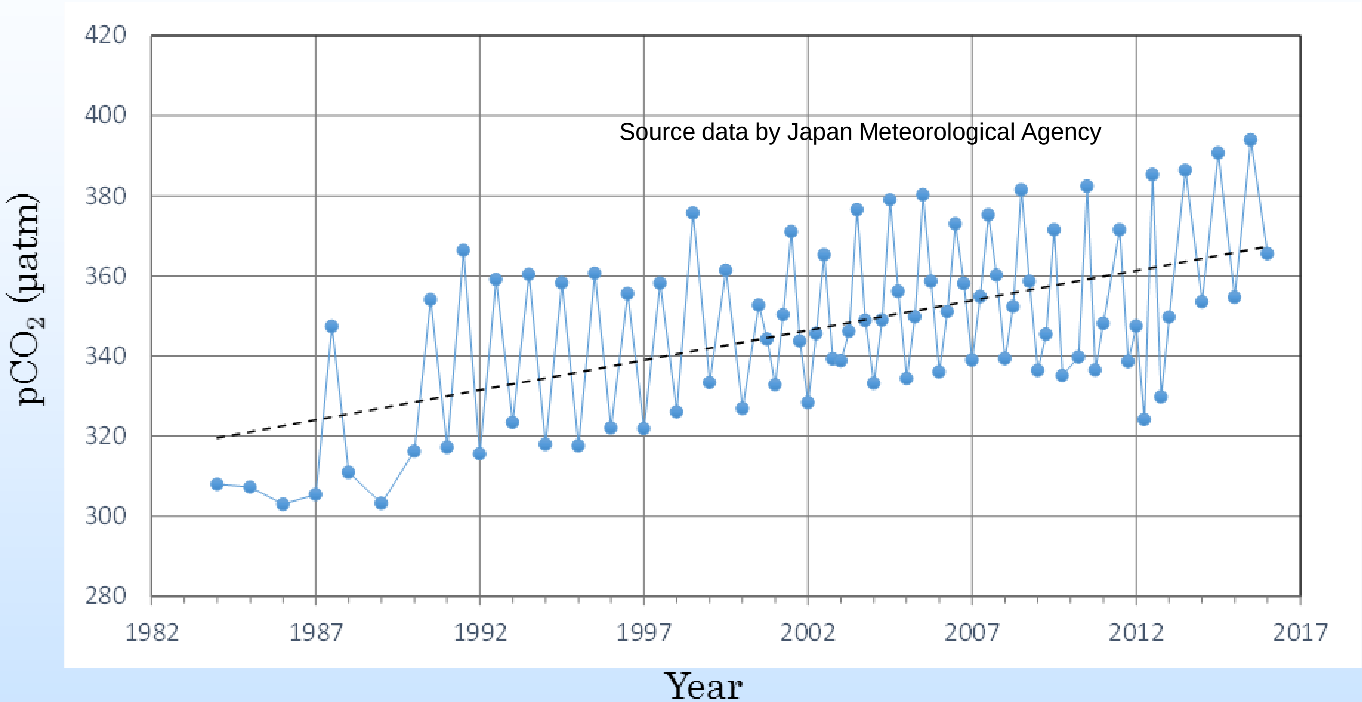


Sediment and Water Sampling

- 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



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