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

Project Number DE-FE0028193

Tip Meckel, Ramon Trevino, & Katherine Romanak

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Gulf Coast Carbon Center

U.S. Department of Energy
National Energy Technology Laboratory
Addressing the Nation's Energy Needs Through Technology Innovation – 2019 Carbon Capture, Utilization, Storage, and Oil and Gas Technologies Integrated Review Meeting
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Acknowledgements

U.S. DEPARTMENT OF ENERGY
NETL

Thank you to our Japanese colleagues!

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Ministry of Economy, Trade and Industry

Japan CCS Co., Ltd.

JGI, Inc.

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RITE
Research Institute of Innovative Technology for the Earth

Presentation Outline

- Project Overview: Goals and Objectives
- Technical Status
  - UHR3D Seismic Processing & Publication
- Specific accomplishments most recent FY
- Lessons Learned
- Summary

Goals & Objectives

Goal: Validate technologies to enhance MVA

Objectives:

1) Acquire UHR3D seismic dataset and validate MVA technology at operational CCS field demonstration project - FOAK

2) Validate untested dynamic acoustic positioning techniques (SBL)

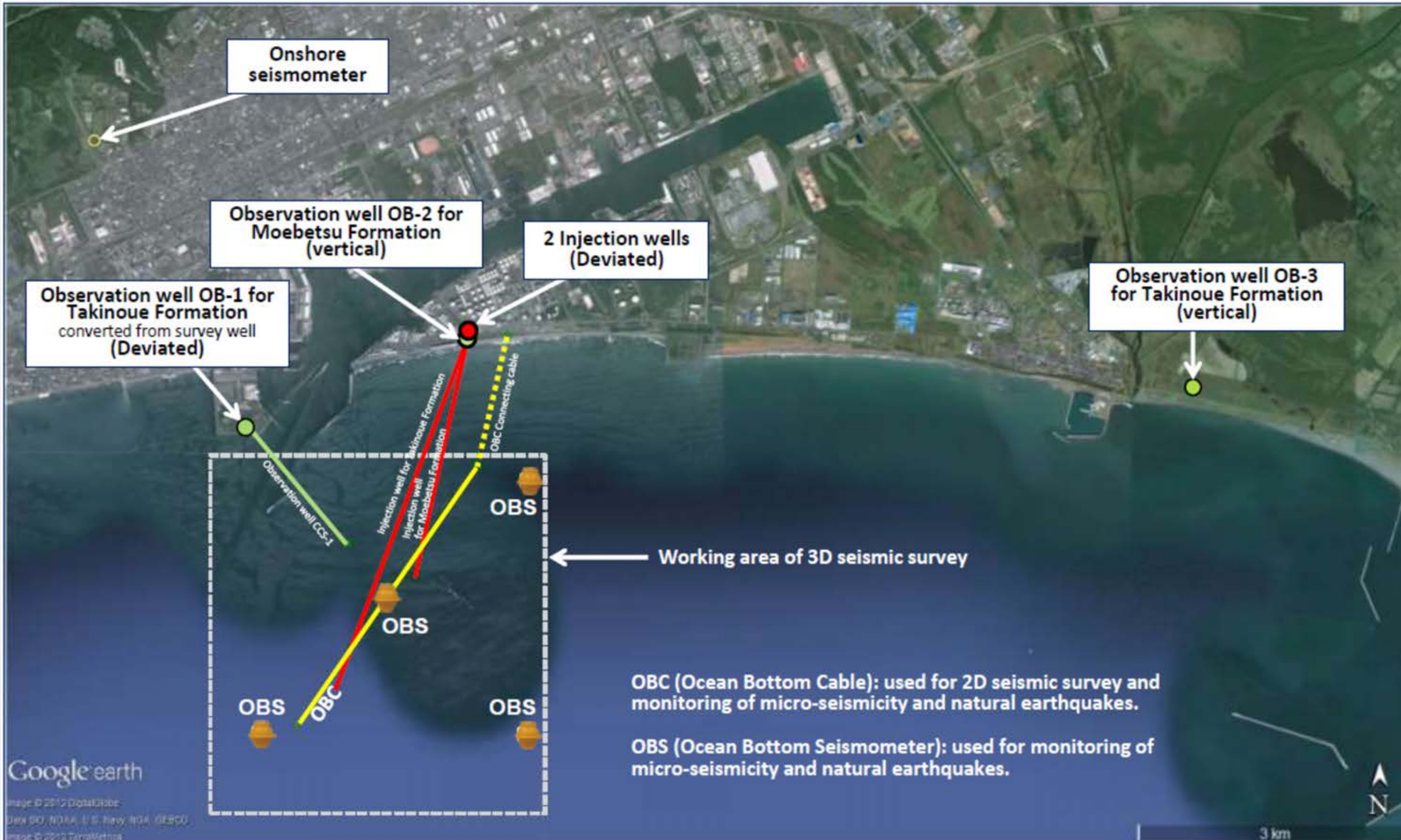
3) Define CO_2 plume boundaries
   – Environmental monitoring task

Tomakomai Port, Hokkaido Japan

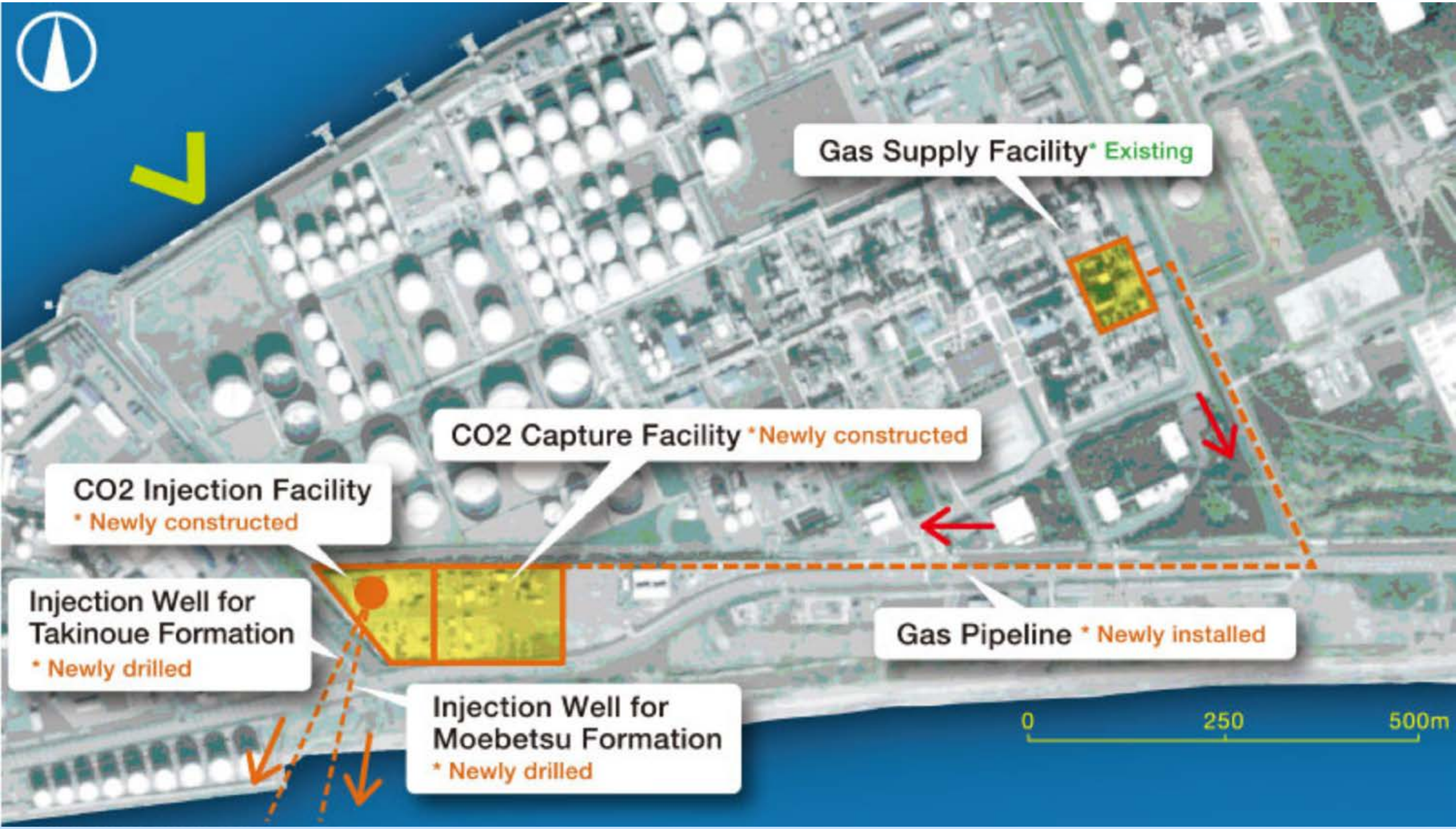
CO_2 Project Basics

- Ministry of Economy, Trade and Industry (METI)
- Japan CCS Co., Ltd. (JCCS)
- 2012-2020
- Demonstrate and verify integrated CCS system
  - CO_2 gas separation, compression, transport, geologic storage
- 100,000 tonnes/year rate, 3 year injection
  - CO_2 is captured from offgas generated at a hydrogen production unit in refinery
  - ~70,000 tons by HR3D survey date in August 2017
- 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.

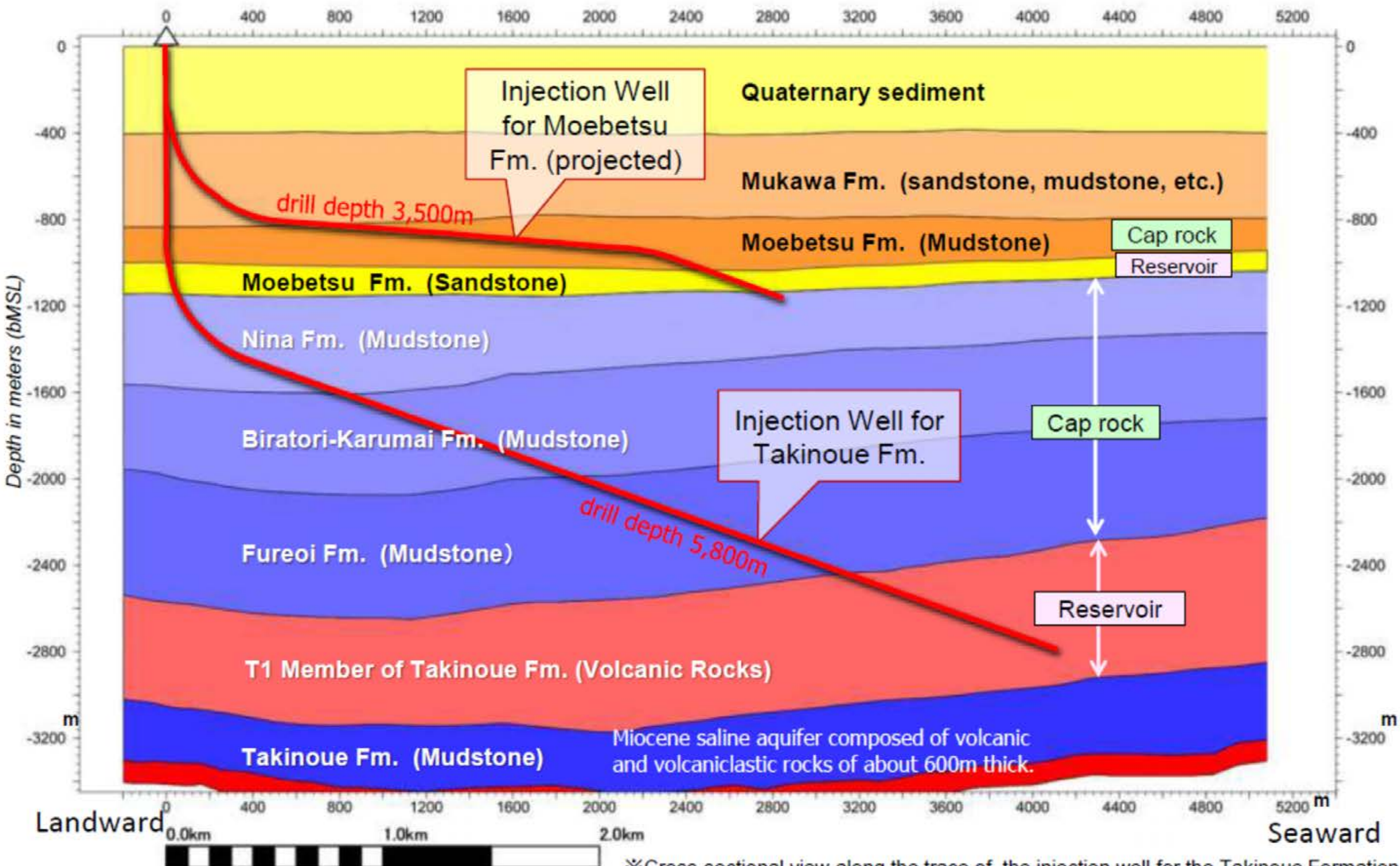
Layout of Monitoring Facilities



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


Gas Supply Facility* Existing
CO2 Capture Facility *Newly constructed
CO2 Injection Facility
* Newly constructed
Injection Well for
Takinoue Formation
* Newly drilled
Gas Pipeline * Newly installed
Injection Well for
Moebetsu Formation
* Newly drilled
0
250
500m

Schematic Geological Section



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

Moebetsu Formation

Temperature=44.8 C
Pore Pressure=10.67 MPa

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

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

RESIDUAL GAS
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)

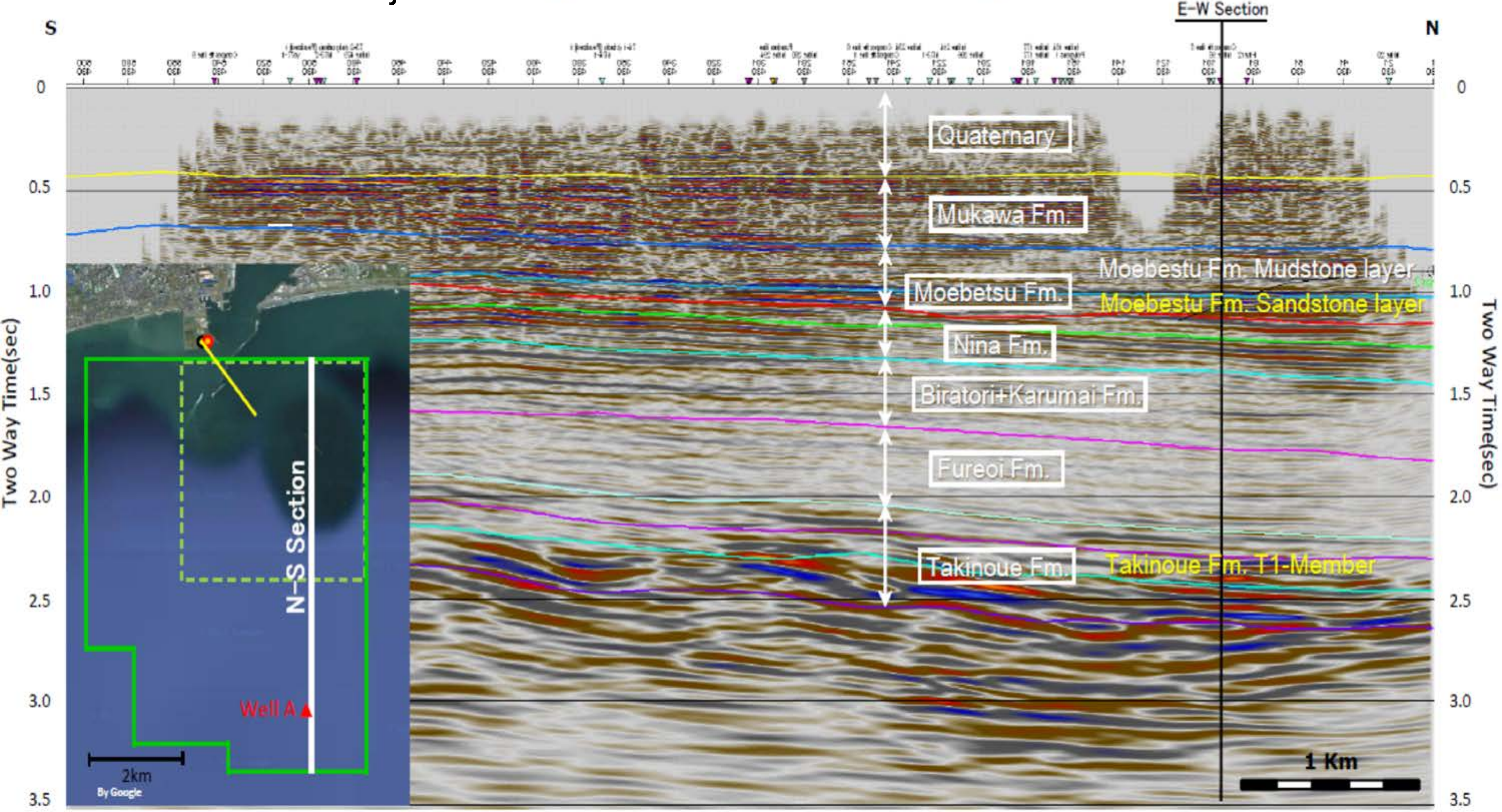
Plagioclase: 36% , Bulk modulus = 75.6 GPa
Clay minerals: 34.5%, Bulk modulus = 25 GPa
Quartz: 23%, Bulk modulus = 37 GPa
K feldspar 6.5%, Bulk modulus = 37.5 GPa

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



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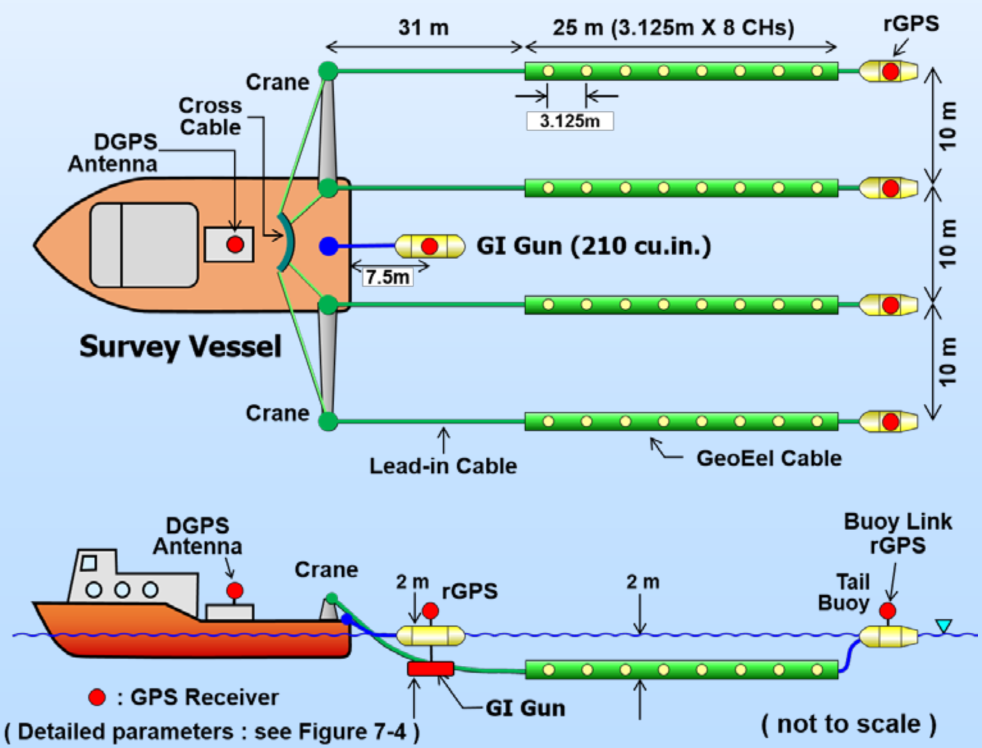
journal homepage: www.elsevier.com/locate/ijggc

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

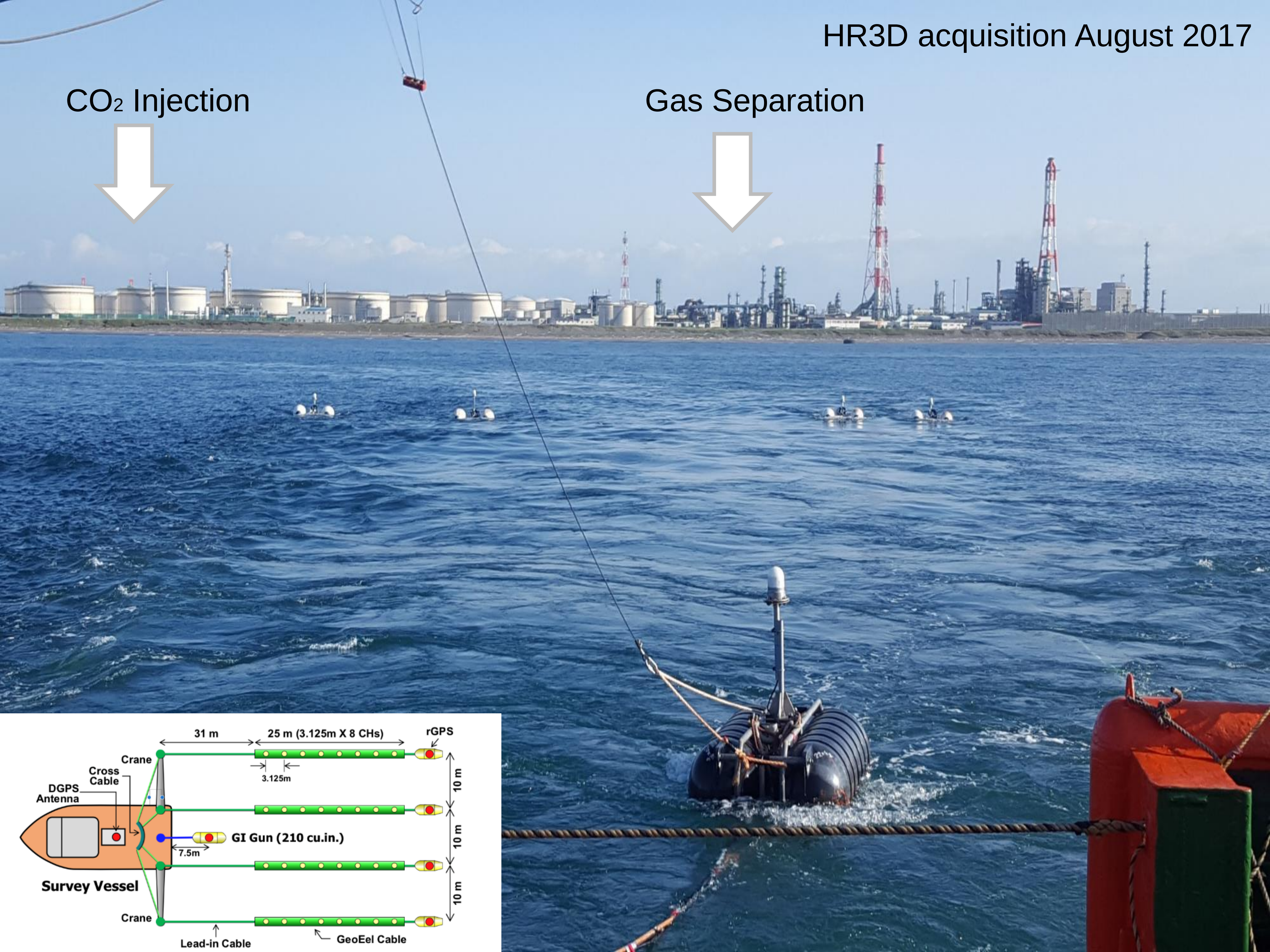
T.A. Meckel*, Y.E. Feng, R.H. Treviño, D. Sava

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

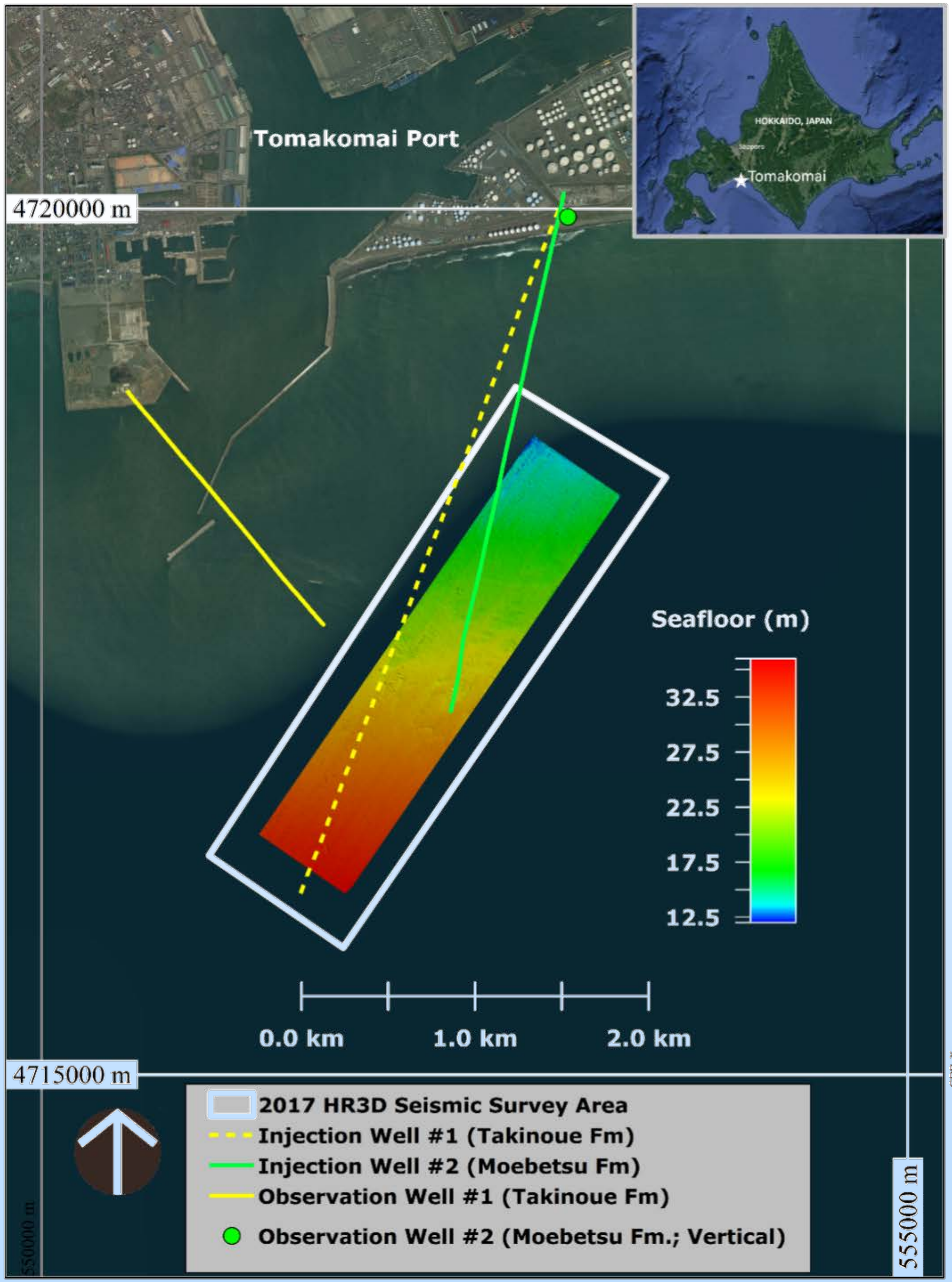
- Sensitivity Study
- Acquisition
- Processing
- Interpretation
- Repeatability Study

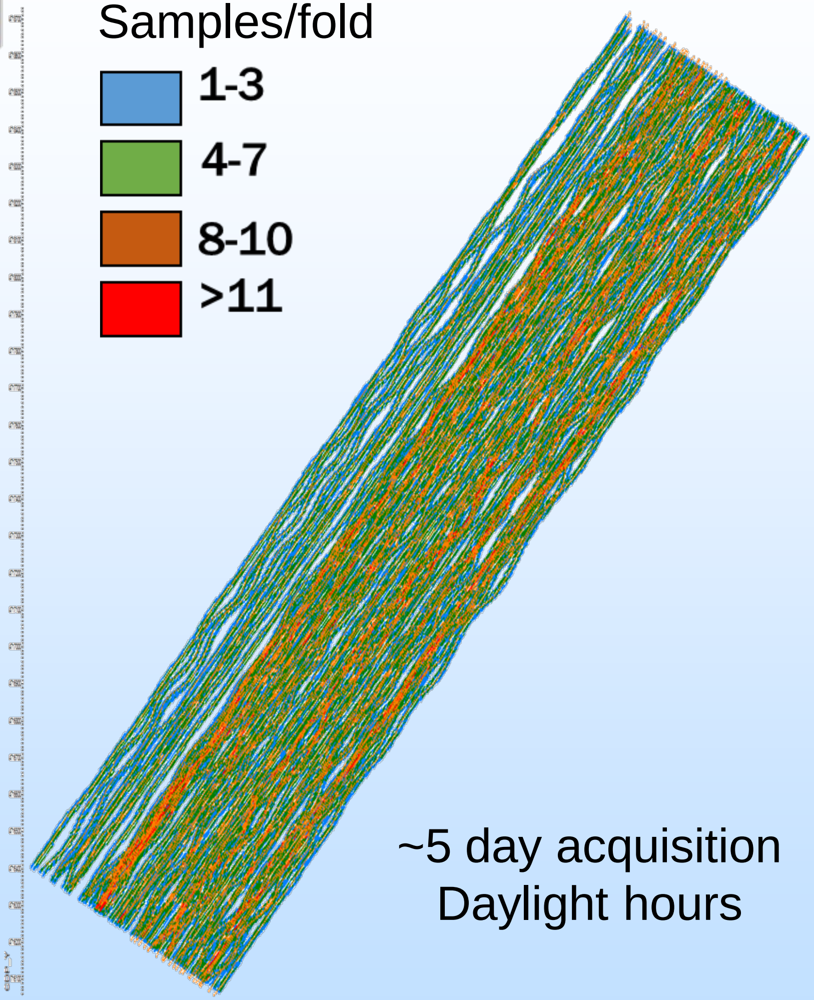


HR3D acquisition August 2017



CDP Binning

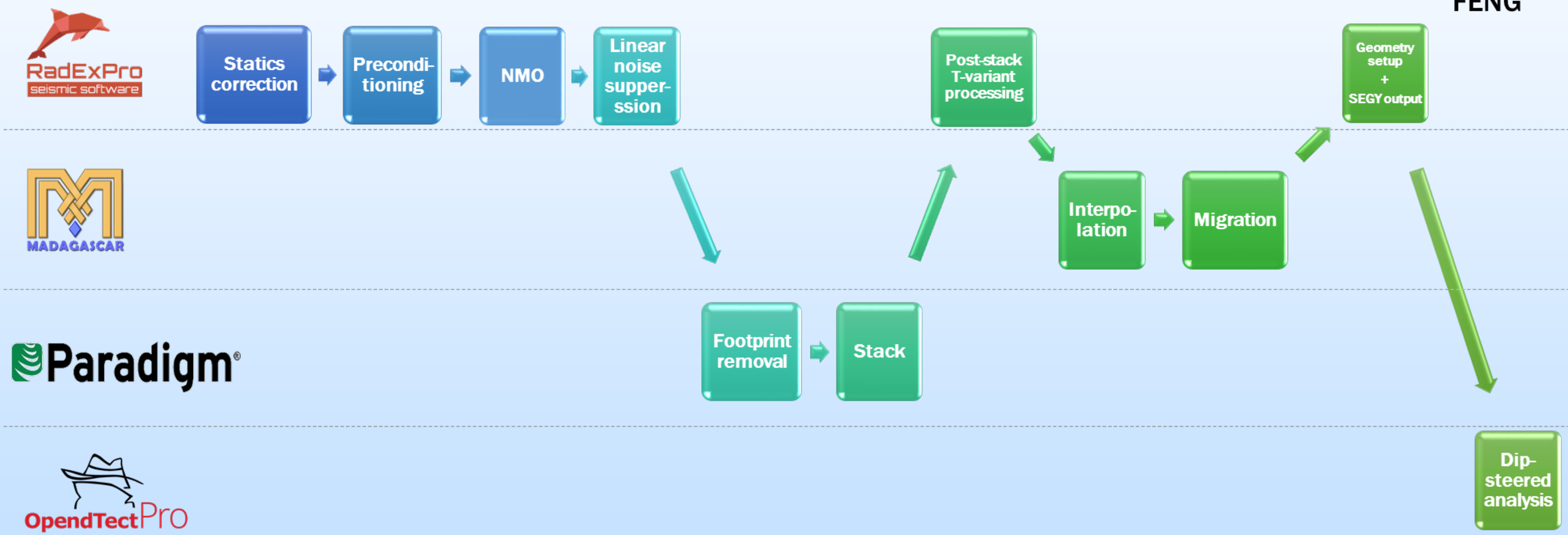




~5 day acquisition
Daylight hours

HR3D data processing workflow

FENG



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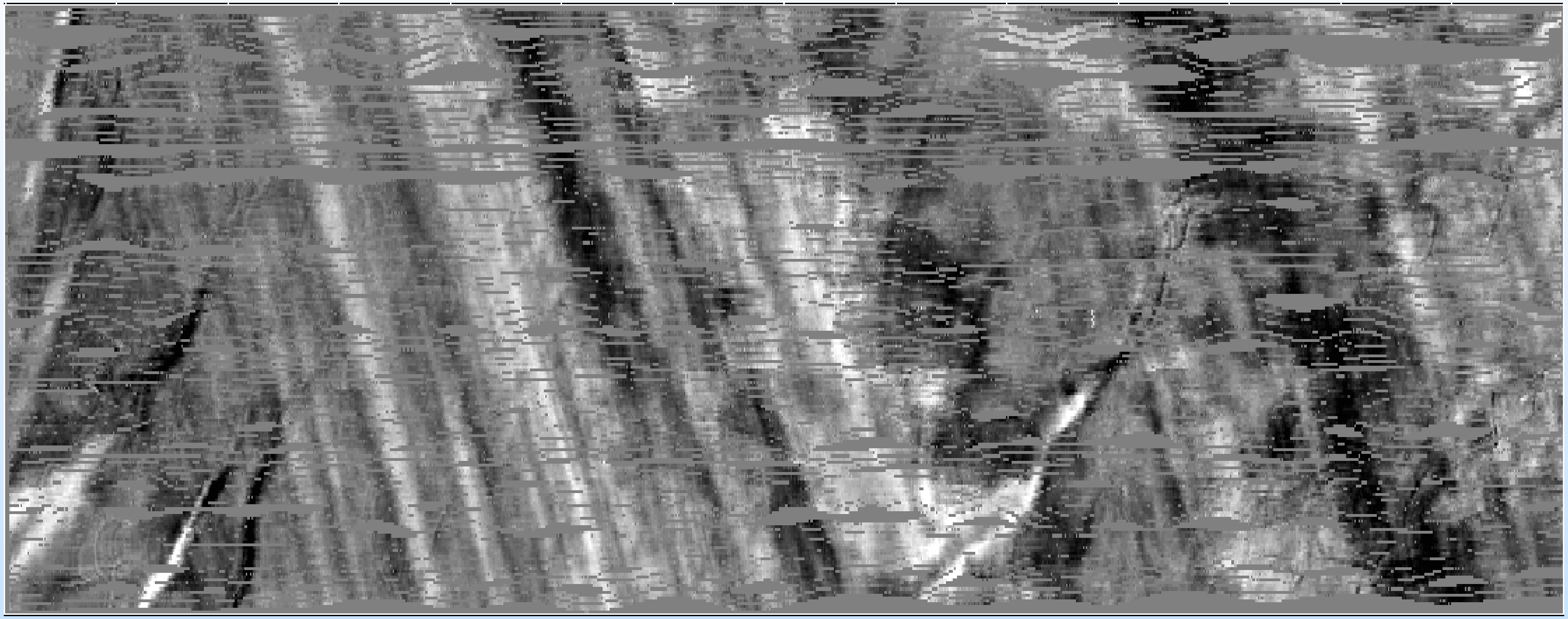
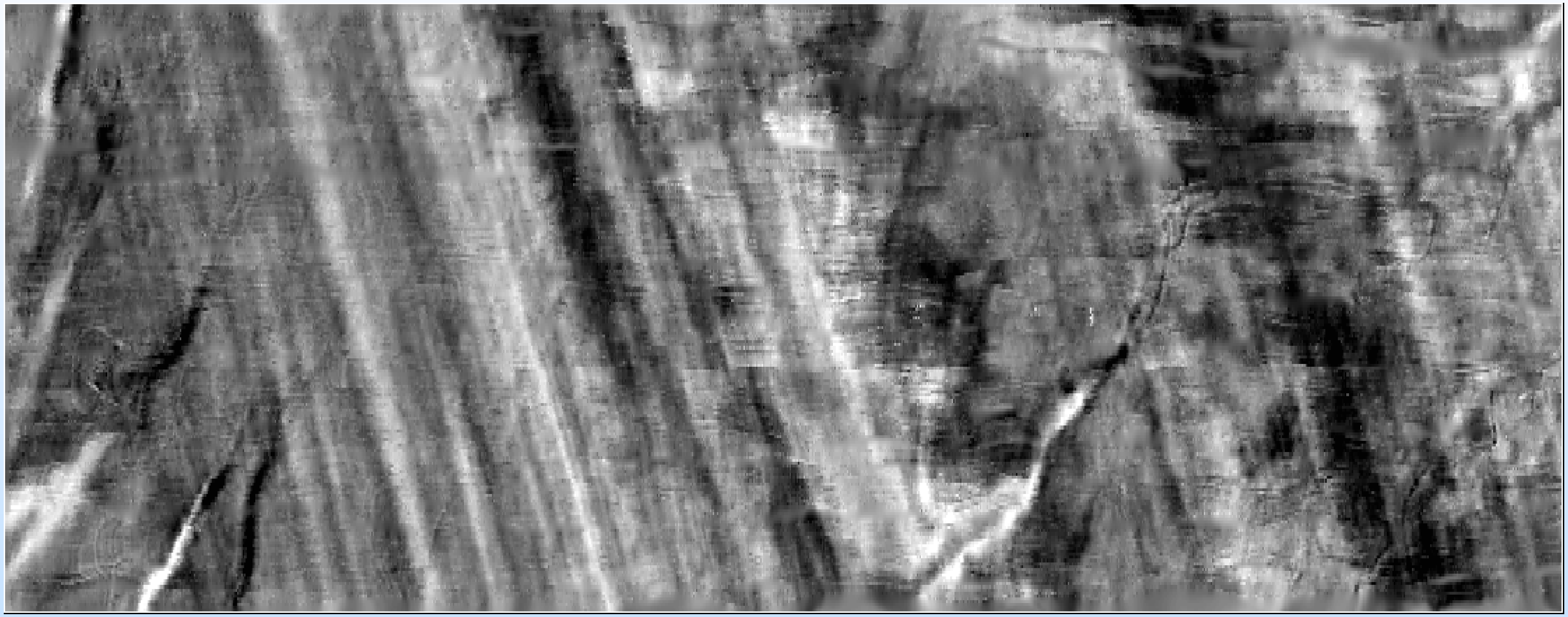
Interpolation

Before interpolation



Interpolation

After Madagascar plane wave destruction interpolation, 1500 iterations

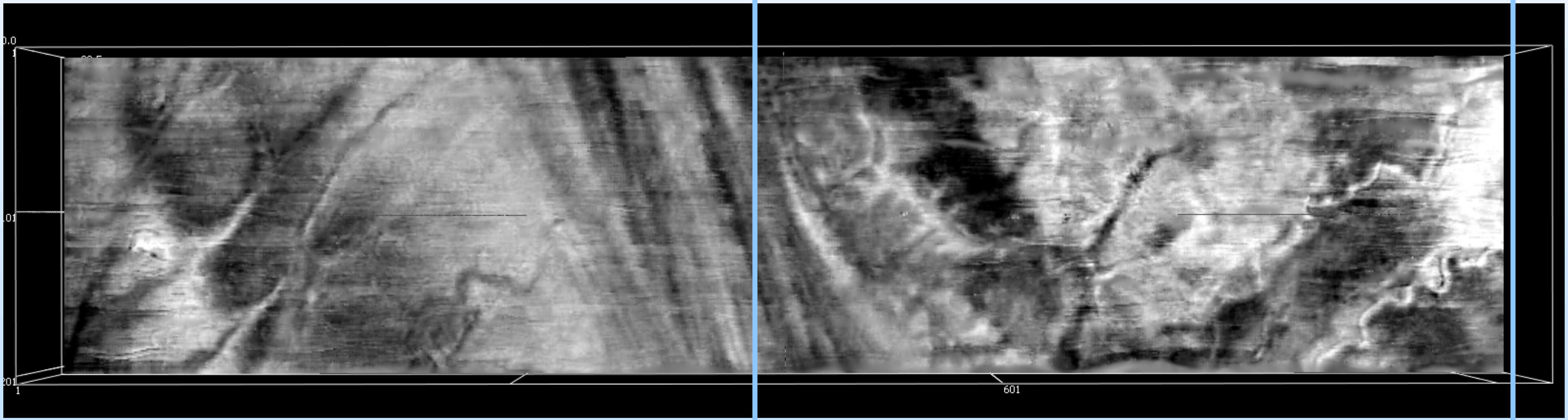


Migration

Post-stack phase-shift migration using Madagascar

Z=53.5

Before migration

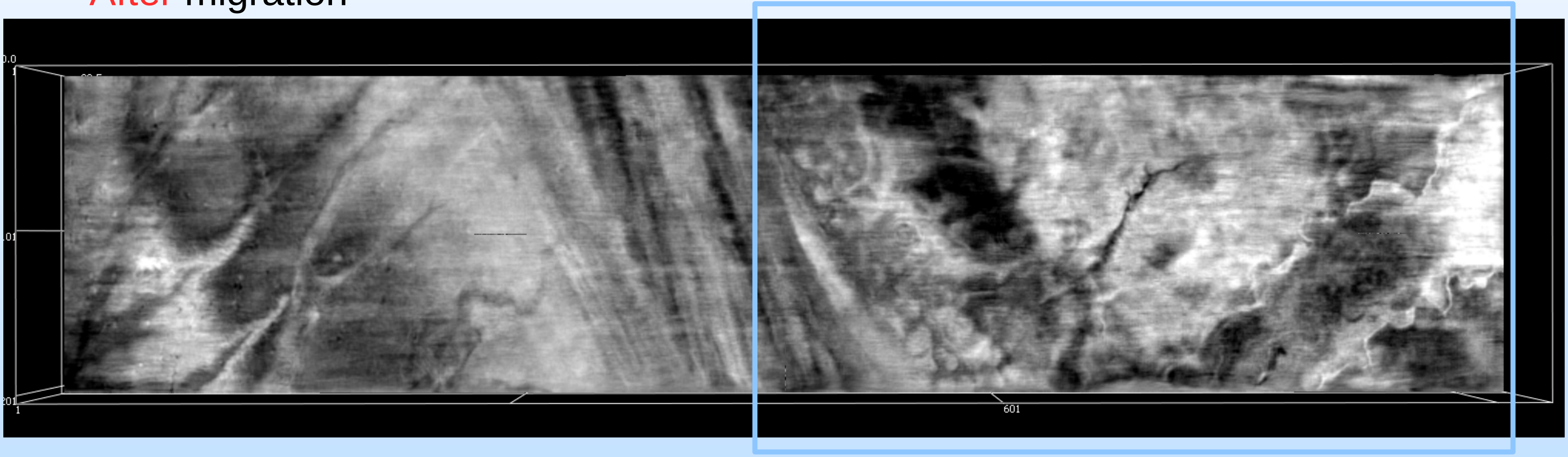


Migration

Post-stack phase-shift migration using Madagascar

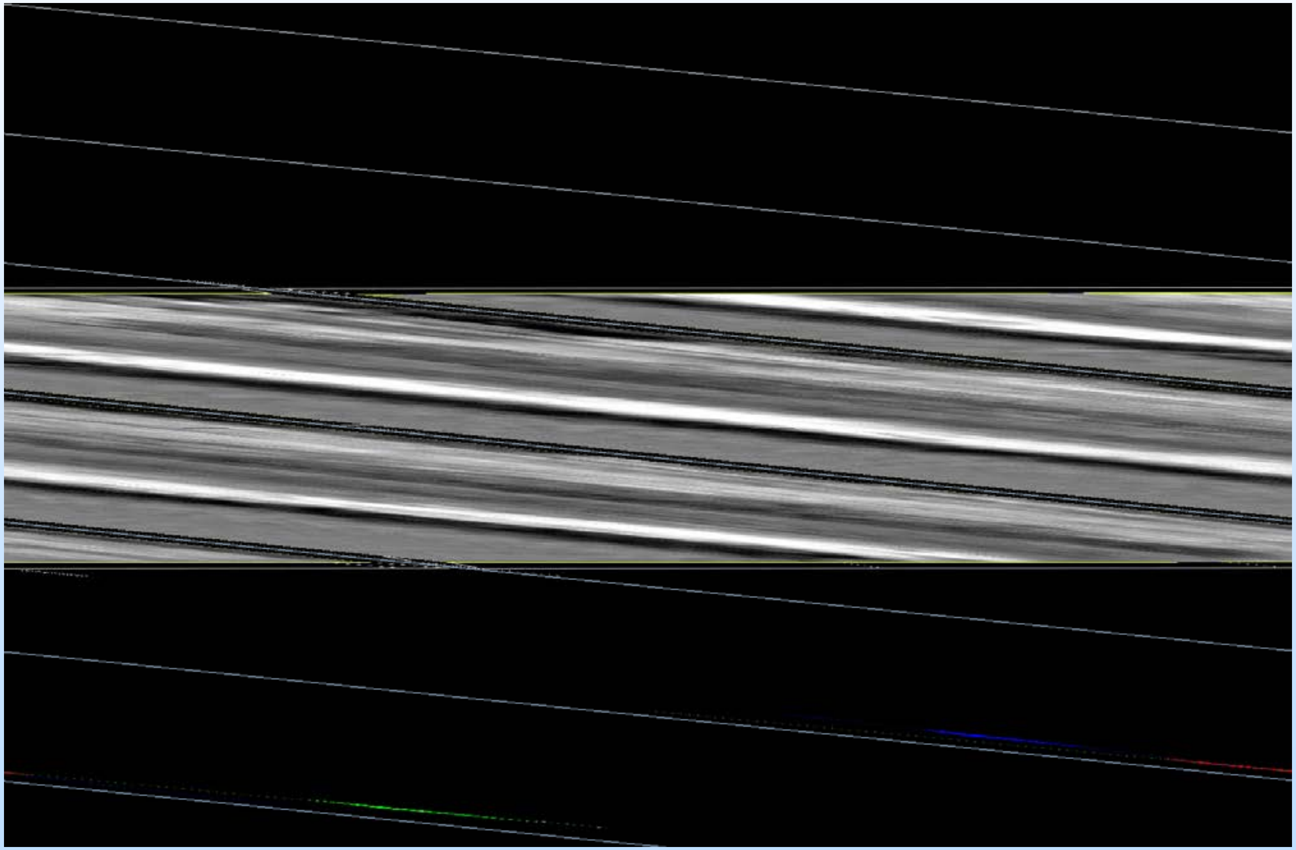
Z=53.5
After migration

Sharper image + suppressed footprint

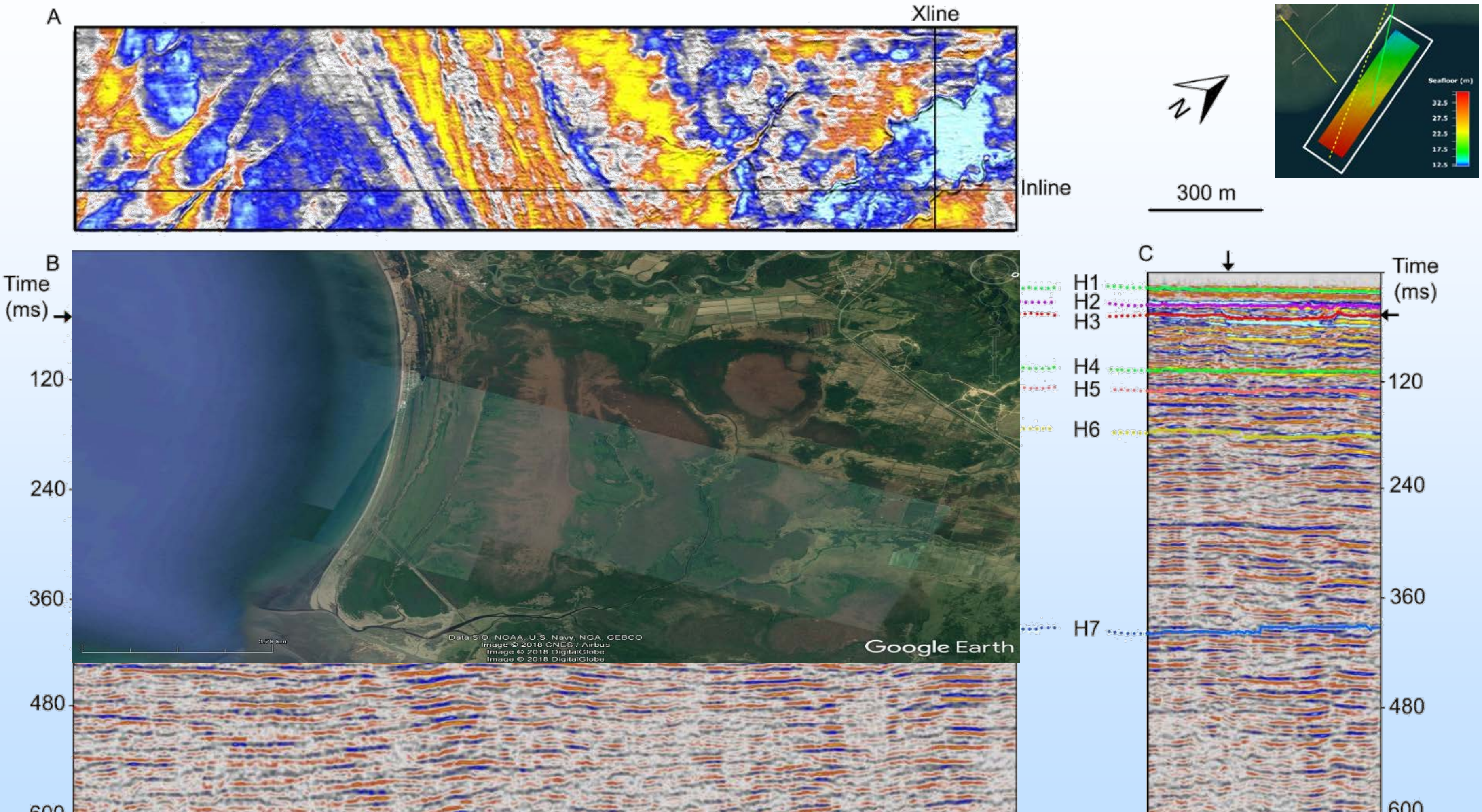


Using velocity from conventional seafloor cable dataset

Horizontal time slice animation

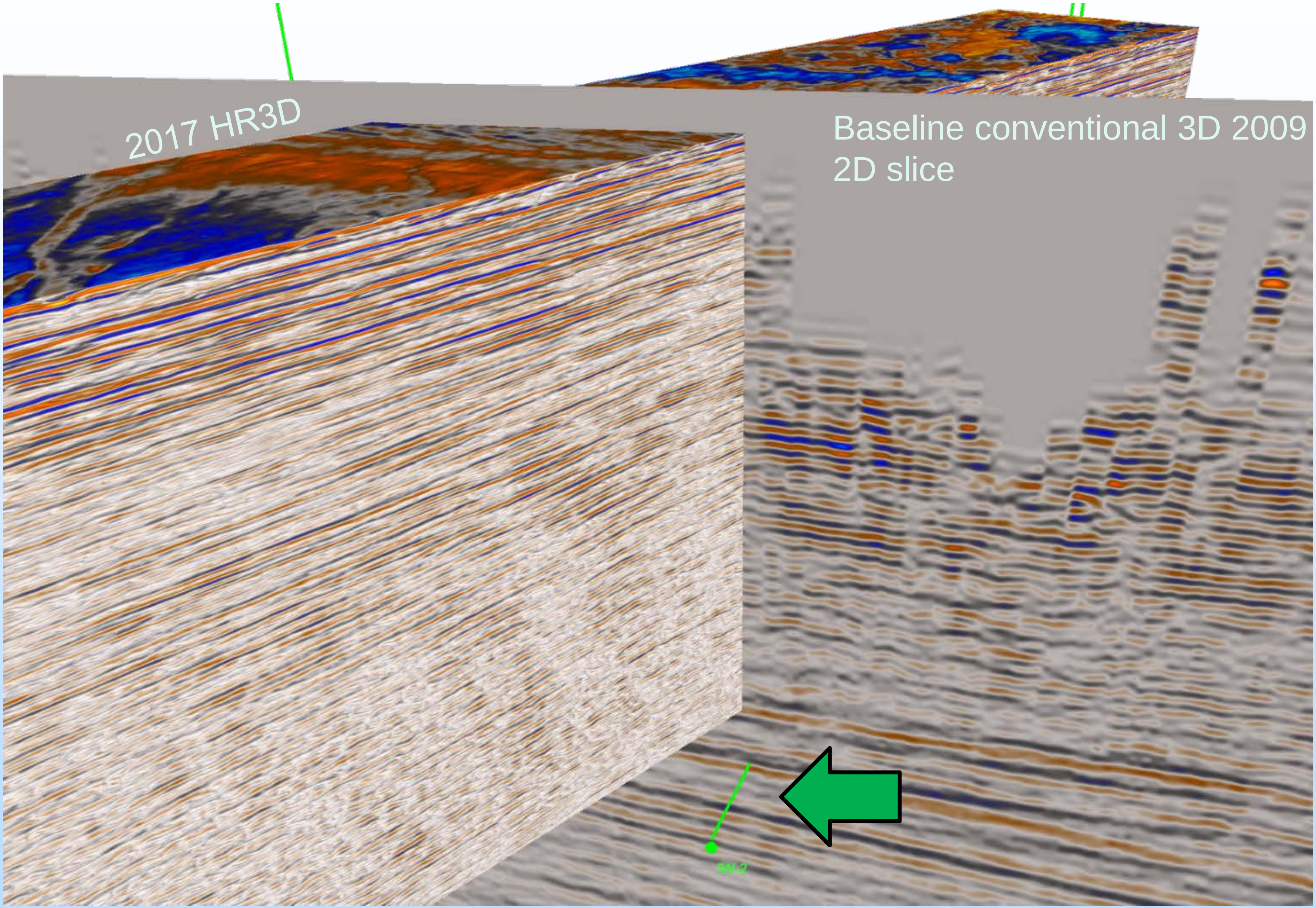


35 ms – 60 ms

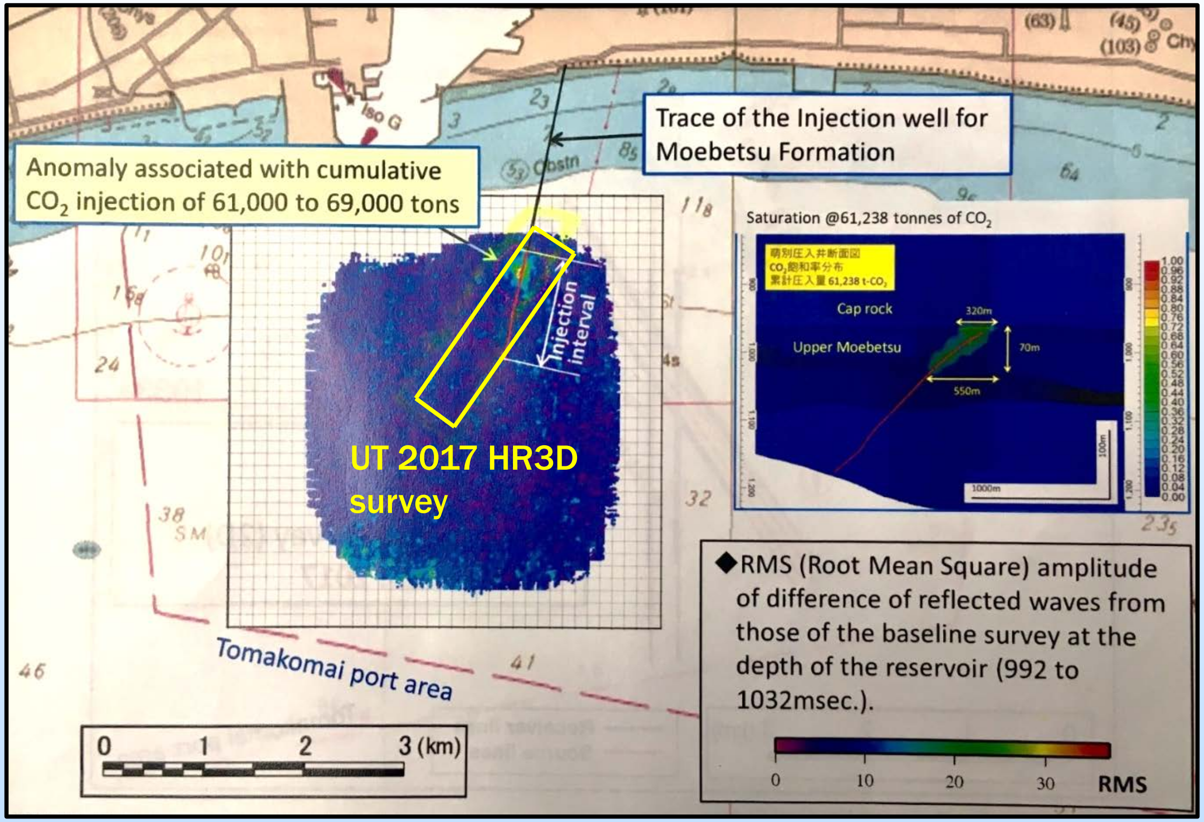


A
Xline
Inline
300 m
Seafloor (m)
32.5
27.5
22.5
17.5
12.5
B
Time
(ms)
120
240
360
480
600
Google Earth
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2018 CNES / Airbus
Image © 2018 DigitalGlobe
Image © 2018 DigitalGlobe
H1
H2
H3
H4
H5
H6
H7
C
Time
(ms)
120
240
360
480
600

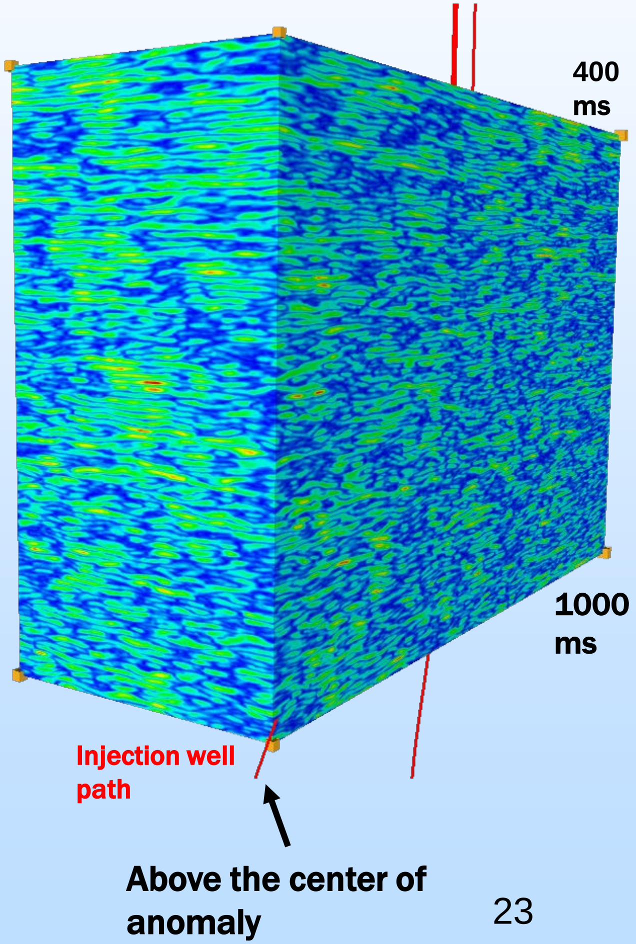
HR3D vs Conventional 3D



CO_2 anomaly in Tomakomai 2017 monitor survey – conventional seafloor cable array

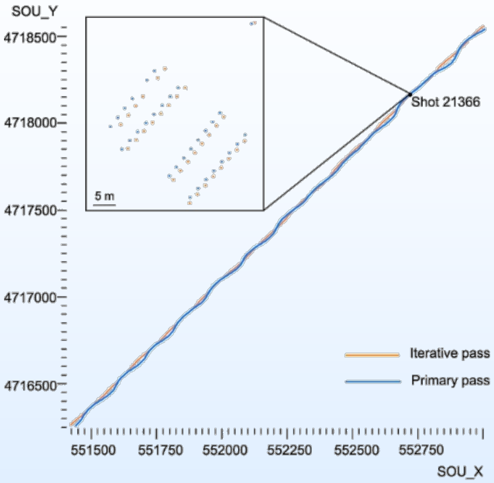


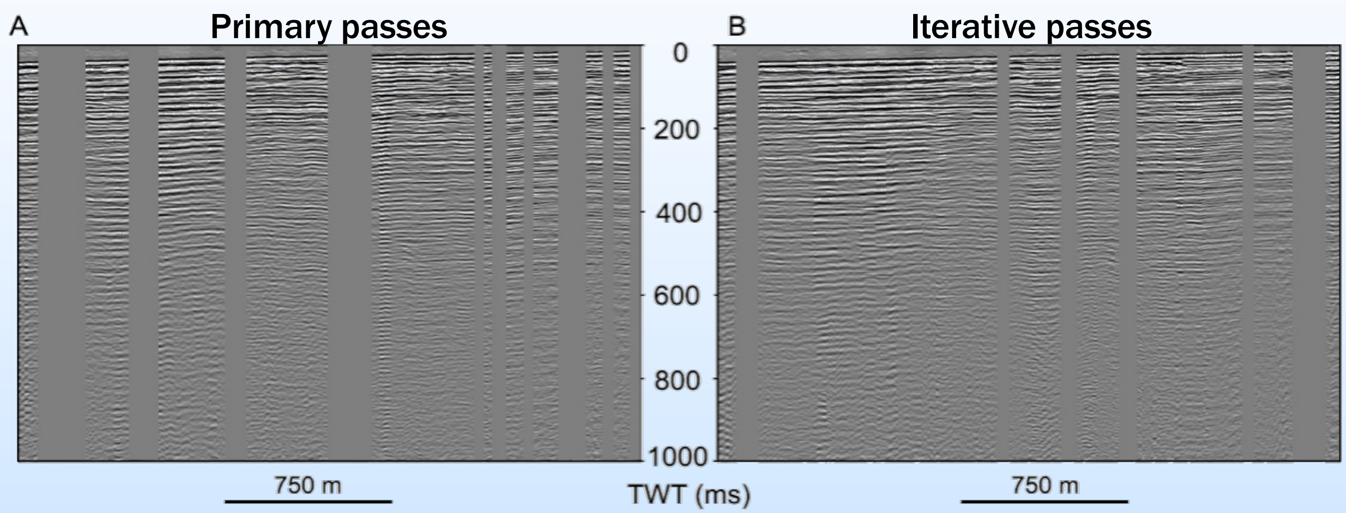
RMS amplitude attribute of HR3D

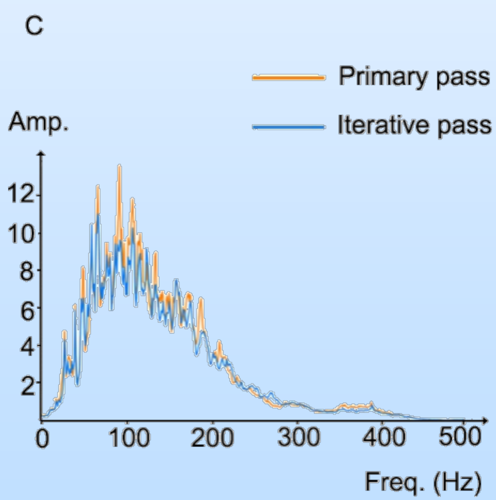


Tanase, D., Tanaka, Y., 2019. Progress of CO2 Injection of the Tomakomai CCS Demonstration Project, GHGT-14.

Repeatability and 4D seismic







- **4D acquisition tentatively planned 2020**

  - CO2 migration in the above-zone?

Accomplishments to Date

- Pre-survey Sensitivity Study complete
- Marine geochemistry methods and data analysis complete
- Successful HR3D seismic acquisition
- Developed advanced processing techniques
- No NRMS anomalies detected in overburden
- Repeatability study complete

Lessons Learned

- International deployment demonstrated
  - Overseas shipping transport, contracts, **costs**, production rates
  - Vessel modifications
  - International communications
- Real-time modifications of survey acquisition
  - Data coverage, density
- Processing techniques – hybrid commercial + other
- Local fisheries consultation and negotiation very important; National group, strong locally.

Synergy Opportunities

- Various presentations (AAPG, AGU, etc.);
- Offshore:
  - Synergy with GoMCARB, STEMM-CCS (UK), Northern Lights Project, Acorn Project.

SUMMARY

1. 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.
2. Repeatability Study – results look promising for 4D in shallow interval.
   - A second survey is planned for 2020; Fisheries negotiations critical.
3. **Successful demonstration of HR3D as CCS characterization and monitoring tool in overburden.**

THANK YOU – QUESTIONS?

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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.

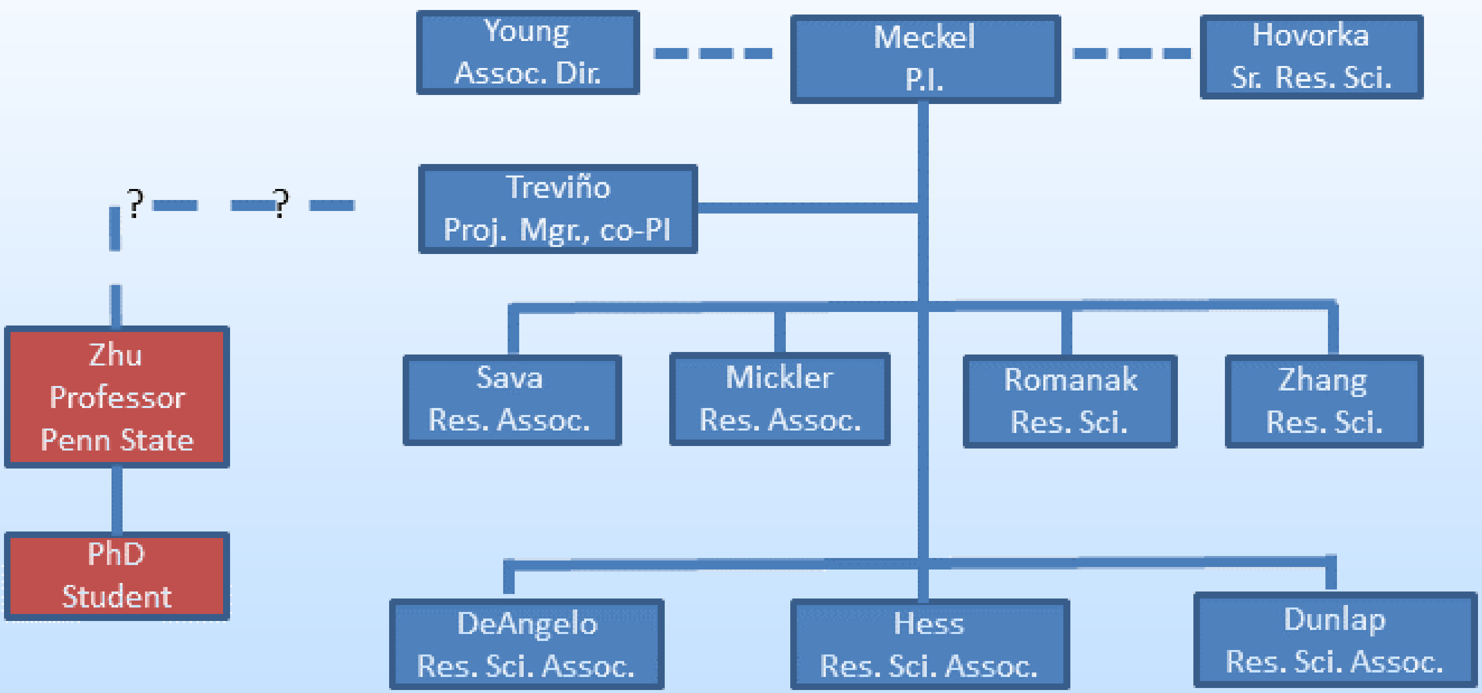
The objectives are to:

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.

- 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

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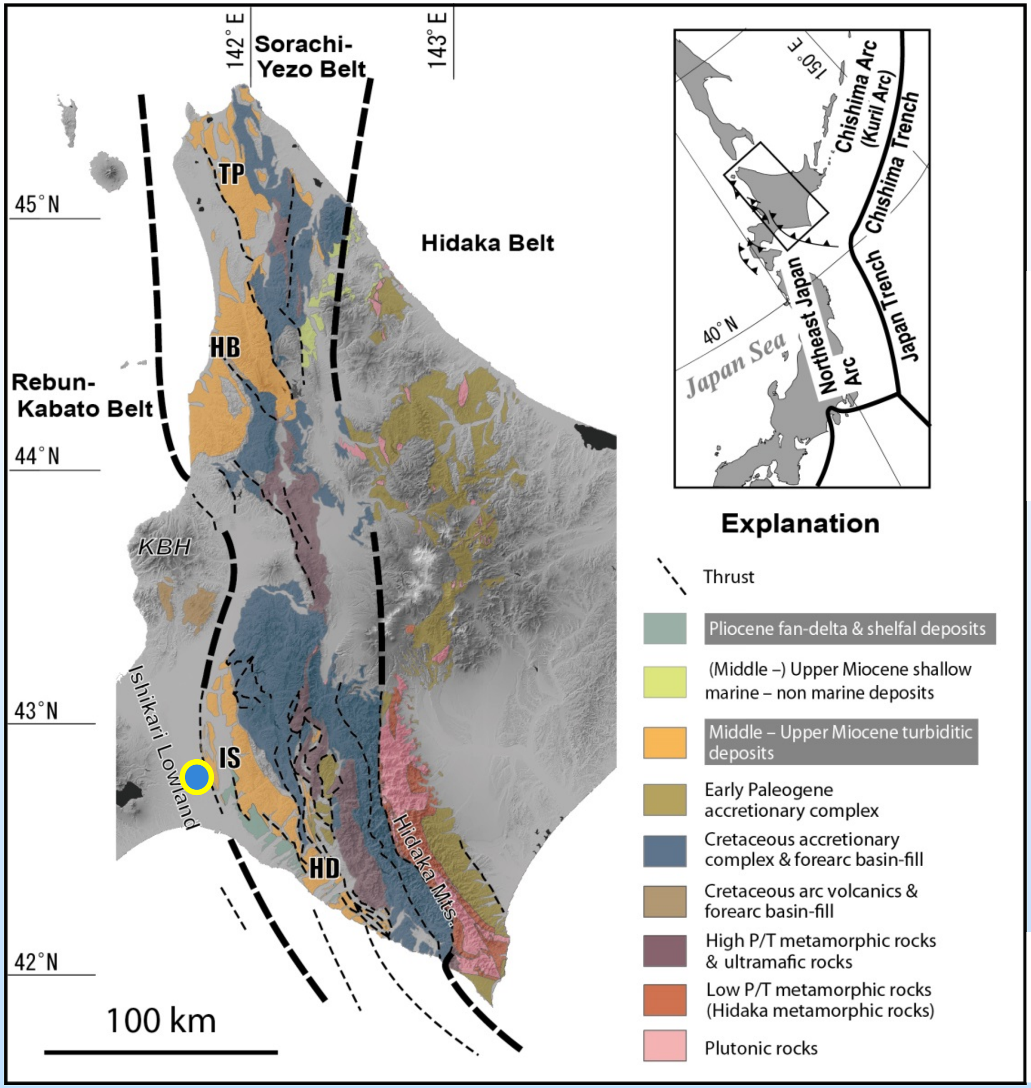
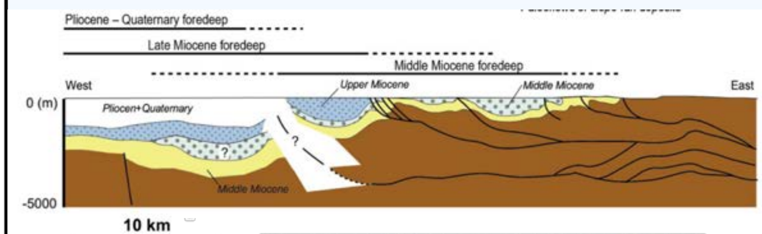
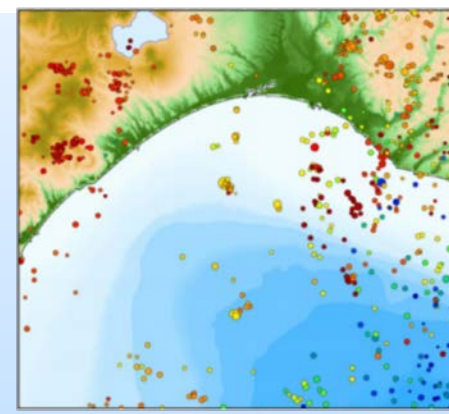


Yufutsu oil and gas field
JapEx, 1988
Entirely fracture permeability
Up to 40 MMcfd in 2005



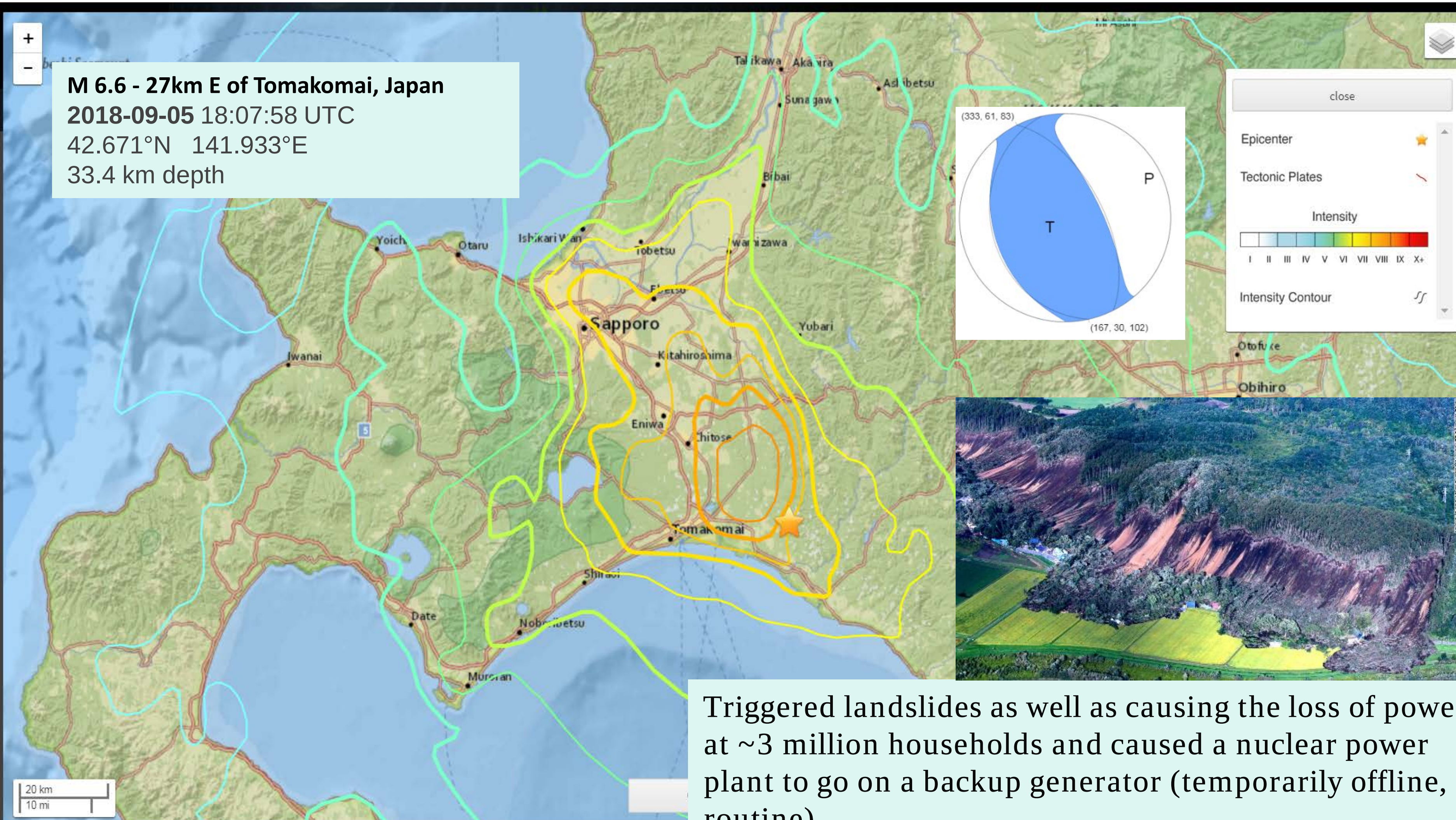


Natural earthquake hypocenter distribution occurred from 2001 to 2010

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]

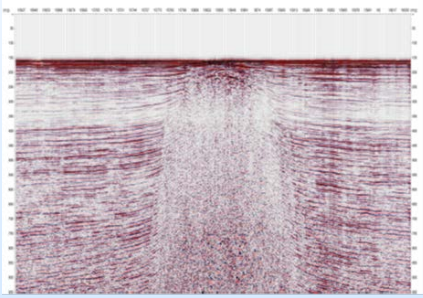
M 6.6 - 27km E of Tomakomai, Japan
2018-09-05 18:07:58 UTC
42.671°N 141.933°E
33.4 km depth



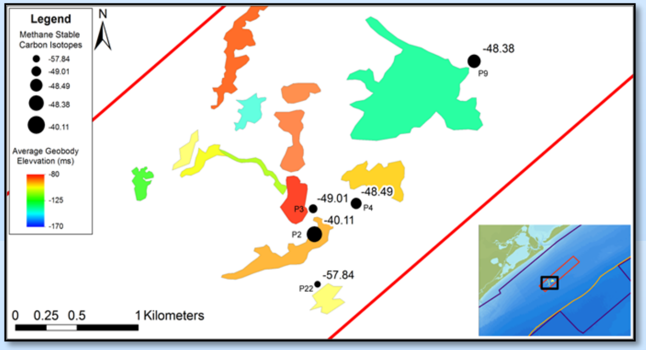
Triggered landslides as well as causing the loss of power at ~3 million households and caused a nuclear power plant to go on a backup generator (temporarily offline, routine).

Task 3- Environmental Monitoring Objectives

- Provide insight into subsurface field conditions informed by high resolution 3D seismic survey (P-Cable) at Tomakomai.
- Augment existing monitoring activities with additional analyses/techniques
- Learn marine monitoring techniques



Tip Meckel, P-Cable seismic image GOM



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

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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

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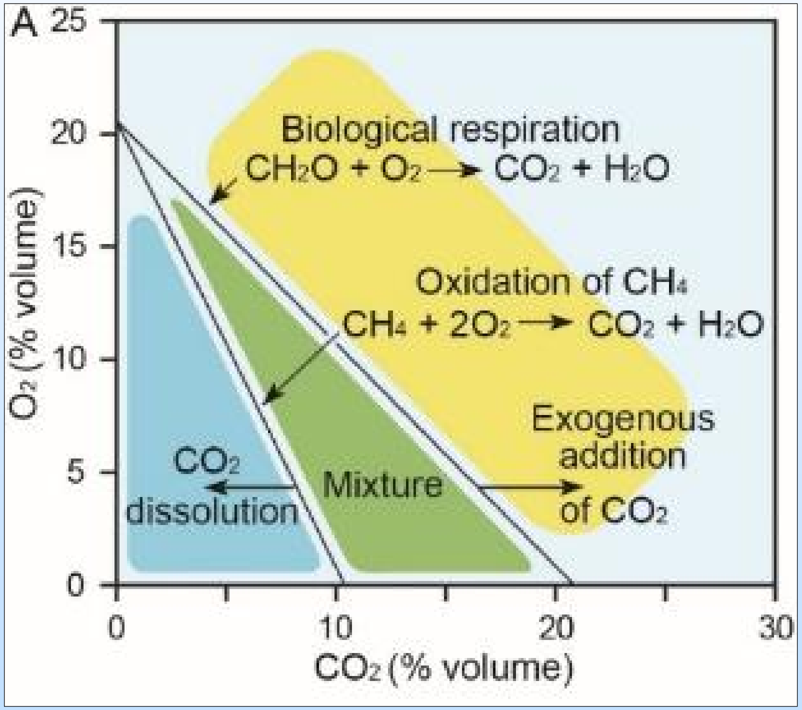
Task 3- Additional Monitoring Objectives

- 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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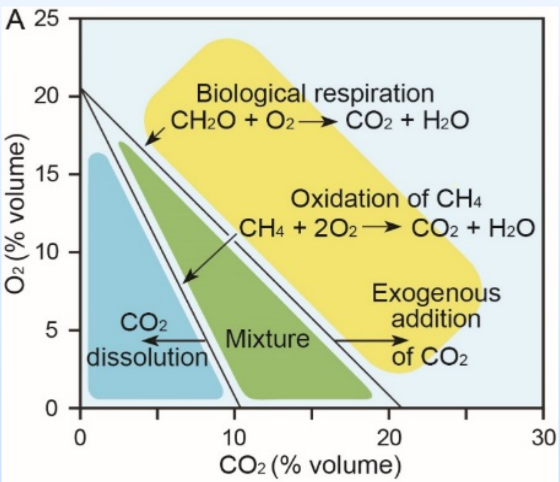
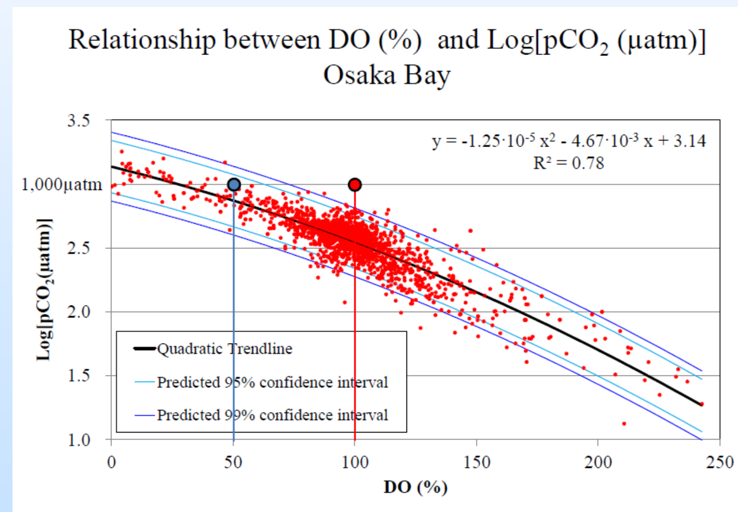
Bio-oceanographic source attribution

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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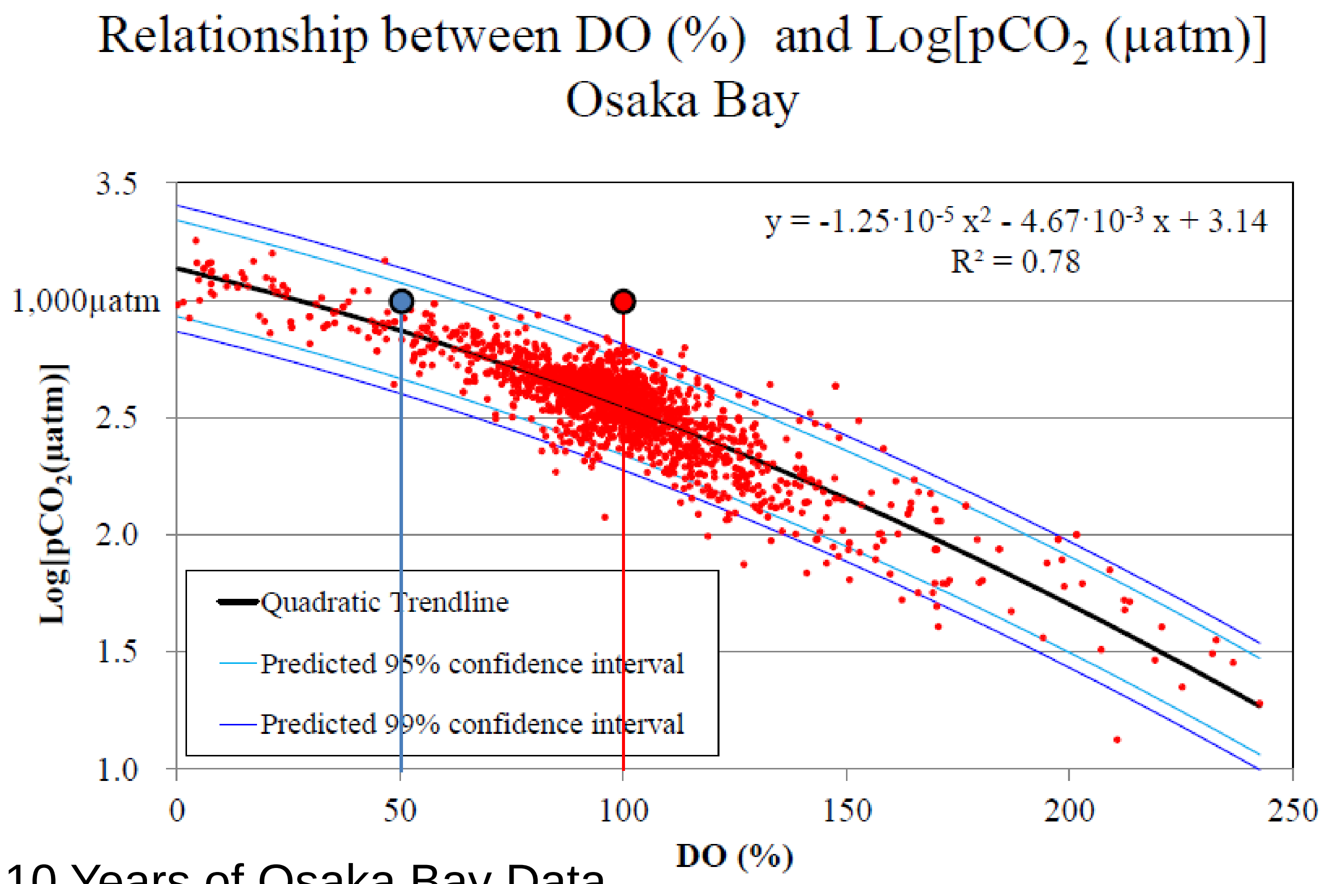
Bio-oceanographic Method



10 Years of Osaka Bay Data

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

Tomakomai Environmental Monitoring

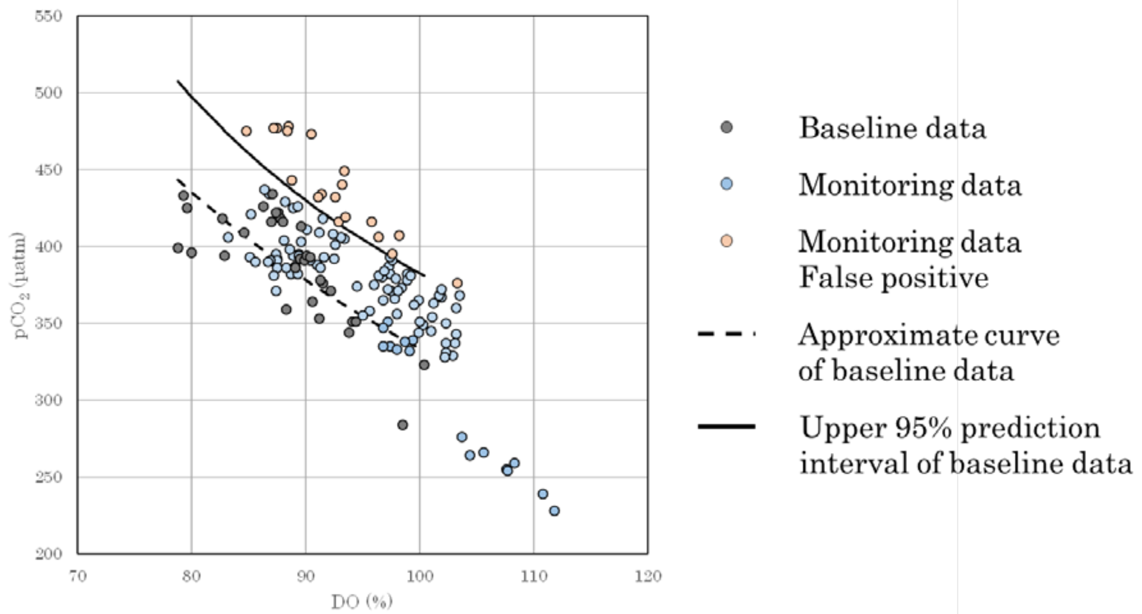
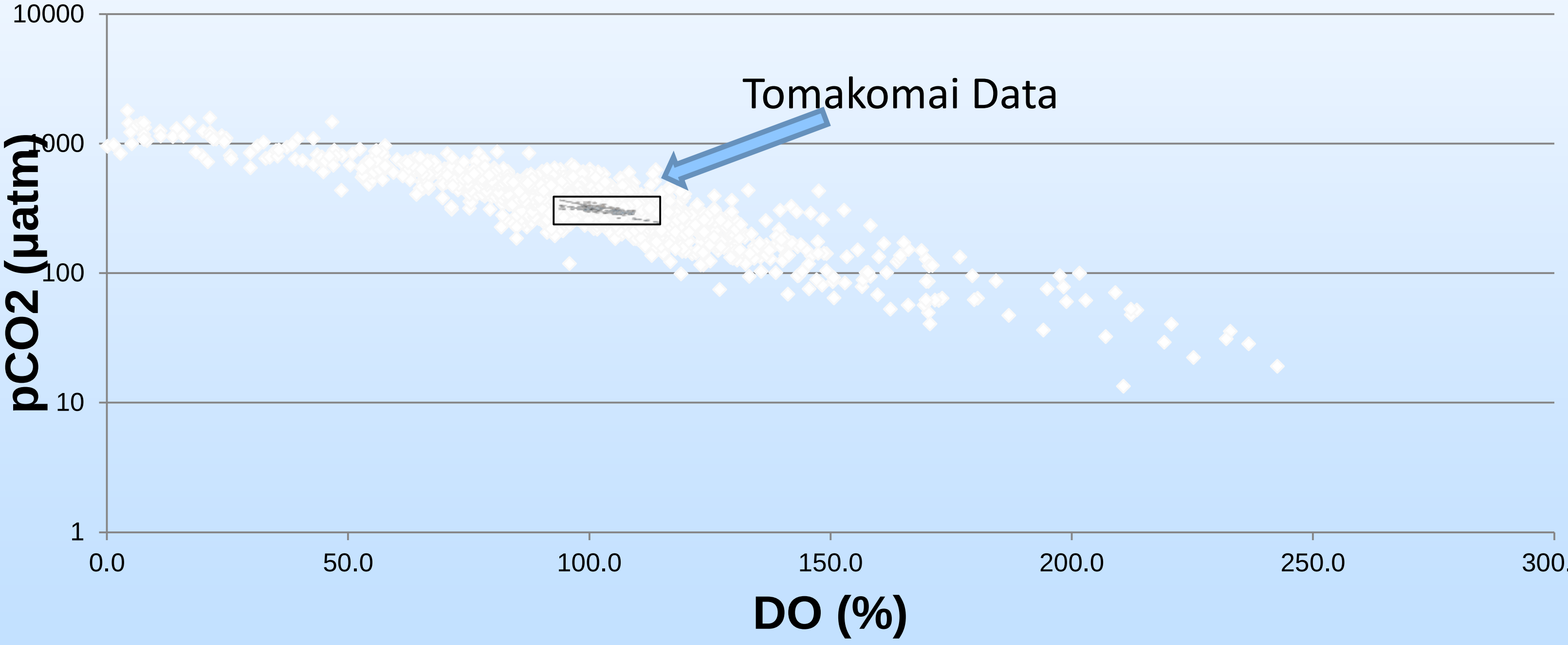


Fig. Relationship between oxygen saturation (DO) and CO_2 partial pressure (pCO_2) of bottom seawater (2 m above the seafloor).

"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



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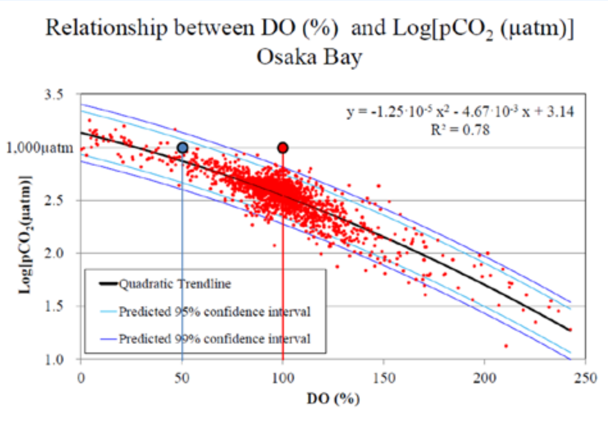
Plans for Method Advancement

- Current bio-oceanographic method is still baseline-dependent
- Instead we will attempt to:
  - Use stoichiometric relationships
  - 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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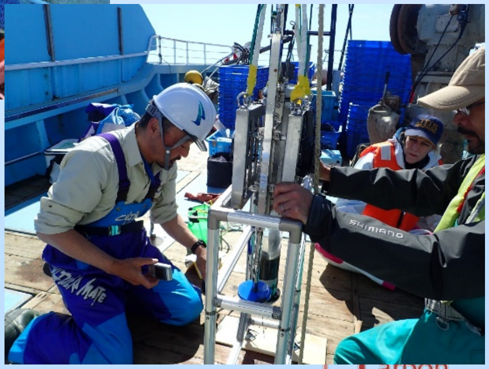
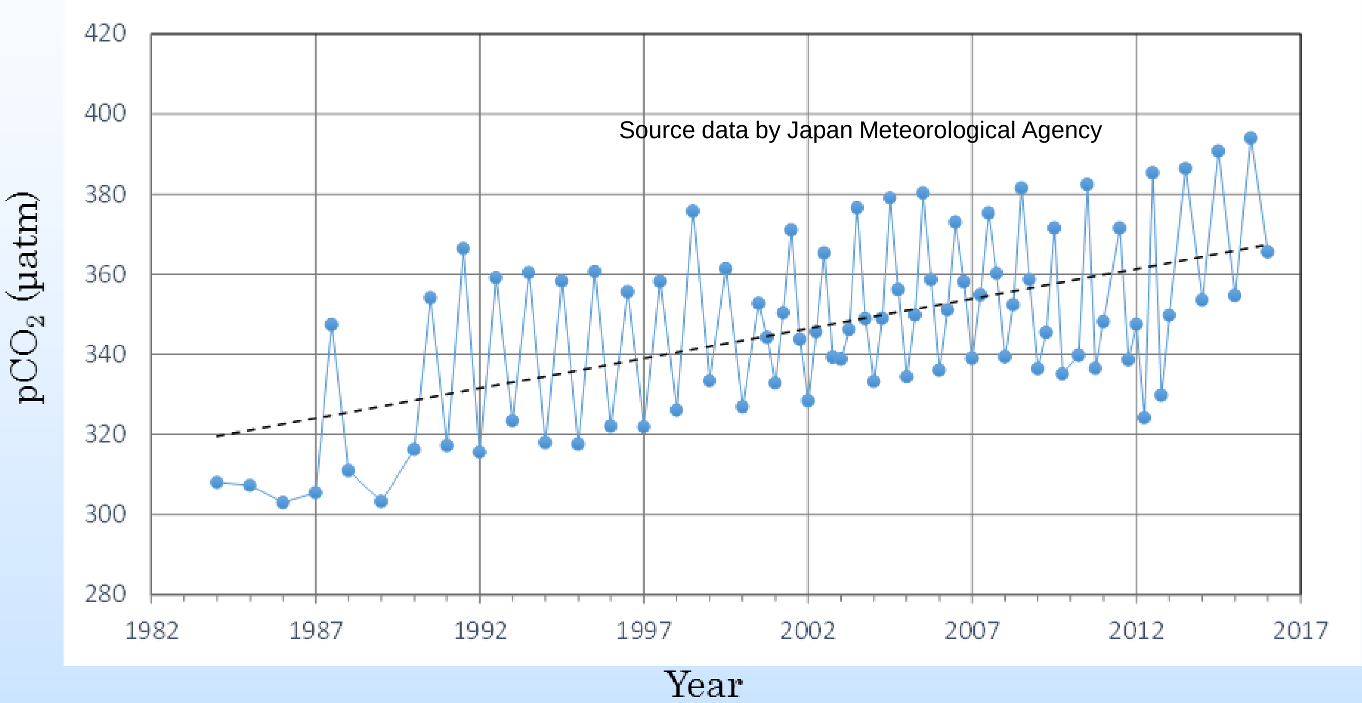
Sediment and Water Sampling

- 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



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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