IEAGHG Monitoring Network
Updates from Edinburgh meeting 2016

Tim Dixon

US DOE Carbon Storage R&D Project Review Meeting

16th August 2016

Pittsburgh

Panel

- Tom Daley, LBNL
- Katherine Romanak, BEG University of Texas at Austin
- Simon O'Brien, Shell, Canada

11th Monitoring Network Meeting

Hosts: BGS, SCCS

Sponsors: UKCCSRC, US DOE, MSG GSL

6th - 8th July 2016

Edinburgh, UK

Technical Sessions

- Monitoring Seismicity
- Novel and Distributed Techniques
- Reducing Monitoring Costs
- Near-surface Monitoring – Long-term Natural Variability
- EOR - Monitoring, Reporting and Verification Plan
- Ongoing Injection Projects
- Closed and Post-injection Projects
- Use and Application of Pressure Measurements
- Conformance in the Monitoring and Modelling Loop
- Conclusions and Recommendations


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GHGT-13
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Some Overall Key Messages & Conclusions

- Monitoring optimization to reduce costs
- Benefits being demonstrated by permanent installation of fibre-optic distributed acoustic sensors (DAS), and some limitations, and developments such as helical fibres.
- Temporal and spatial complexity of near-surface baselines and implications for monitoring.
- Lost-cost leakage detection with laser technique at Quest
- The need to close the monitoring-modelling loop
- What does conformance look like in practice?
- Overall – good progress with learning from pilot and demonstration projects
- Overall – good progress in reducing costs for large-scale projects

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Energy Geosciences
EARTH & ENVIRONMENTAL SCIENCES AREA

BERKELEY LAB

Deep Subsurface Monitoring Summary

Tom Daley

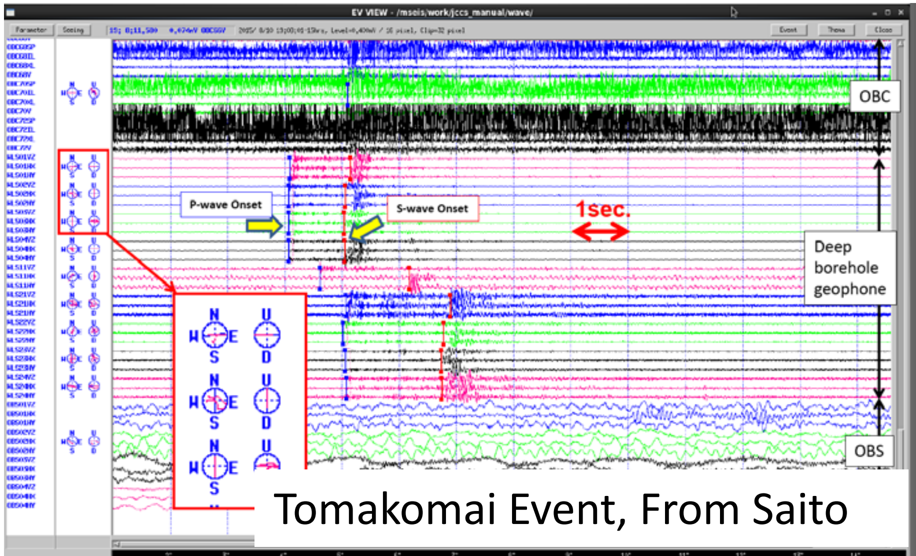
Lawrence Berkeley National Laboratory

Session Topics Relating to Deep Monitoring

- Induced Seismicity
- Novel/Distributed Monitoring Techniques
- Wellbores – Legacy and Future
- Use and Application of Pressure Measurement
- Monitoring Storage Reservoir to Overburden

Induced Seismicity

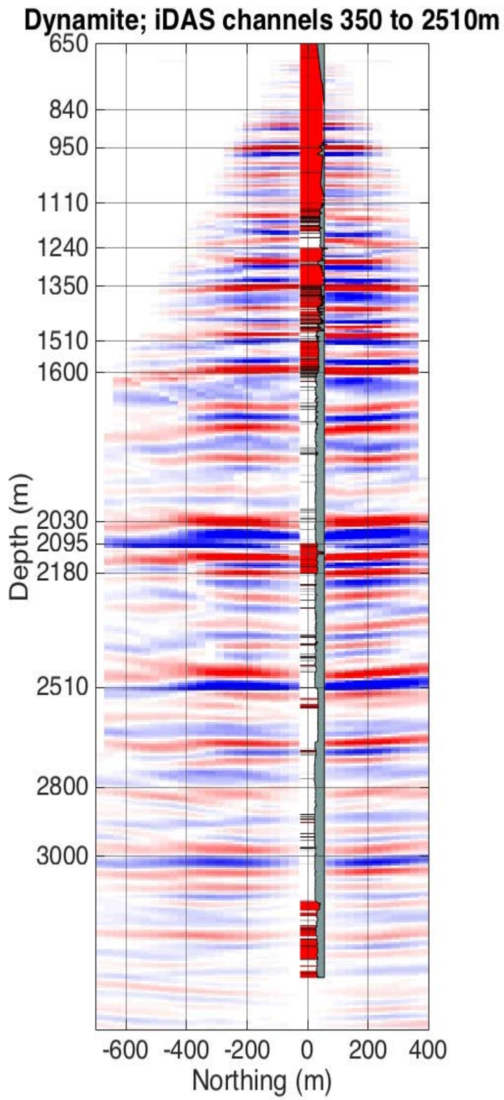
- The risk of Induced Seismicity at large scale storage sites needs to be anticipated.
- Microseismic monitoring examples included data comparisons between induced and natural events from two projects
  - Rousse – 2009-2015 with three years of post-injection monitoring (Thibeau)
  - Tomakomai 14 months preinjection and continuing (Saito)
- Microseismic monitoring can incorporate the use of earth tide modulation to identify changes in geomechanical conditions (Delorey, et al).



Tomakomai Event, From Saito

Novel/Distributed Monitoring

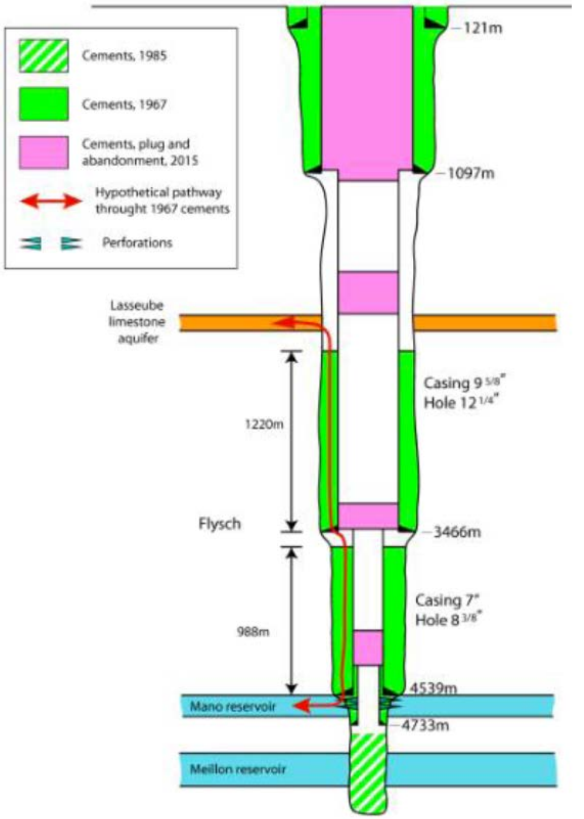
- Focus on Distributed Acoustic Sensing (DAS)
  - DAS has potential of a new seismic paradigm with permanent installation and continuous monitoring with reduced costs
  - Technology is advancing: Testing of well deployments and improved cables (e.g. helical wound cable)
  - DAS Examples:
    - Quest, Canada; modelling of Goldeneye for VSP and microseismic (Dean, Shell)
    - Otway, Australia and Aquistore, Canada (Daley and Freifeld, LBNL/DOE)
- Optimizing pulsed neutron logging (Conner/Gupta, Battelle)



Aquistore DAS VSP: Miller et al, 2016

Wellbores – Legacy and Future

- More confidence is needed to understand and characterize wellbore integrity.
- The timing and frequency of integrity logging needs to be resolved.
- Improvements needed to understand cement flow pathways, example scenario modeling for Rousse (Thibeau)
- The use of more advanced downhole instrumentation has great potential, but installation could add risks (Duguid)
- Modelling flow in an open wellbore requires a specific approach. Analog with gas storage well blowout - Aliso Canyon (Oldenburg, LBNL/DOE).
- The coupling of reservoir to wellbore is important. Depressurization and associated effects can lead to phase changes during upward flow



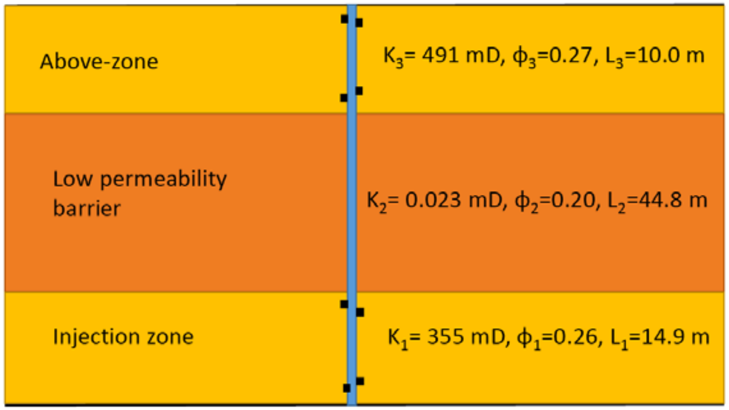
Thibeau, Total

Use and Application of Pressure Measurement

- Focus on Above Zone Monitoring Interval (AZMI) for leakage signals in pressure data
- There is increasing technological maturity in understanding pressure gauge data in above zone intervals, including physical mechanisms for pressure transfer.

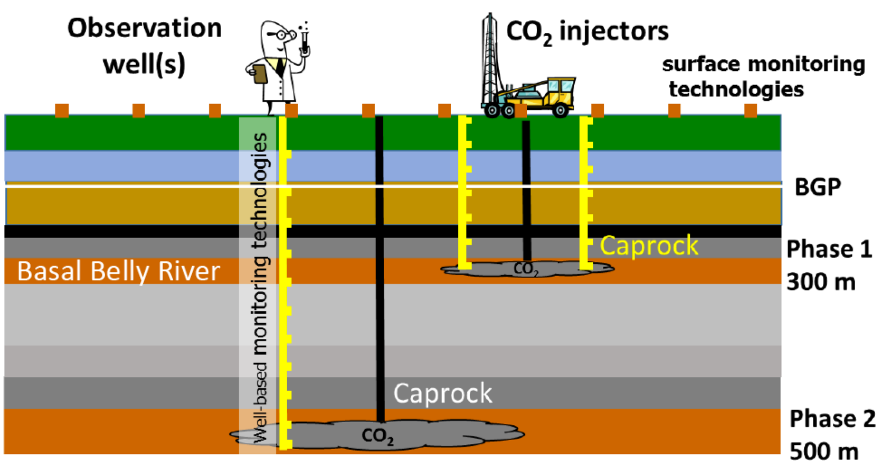
- Pressure-based down-hole measurements are likely more effective (detection and cost) than geochemical analyses from wellbore samples for leakage detection.

Mult-Level Pressure at Otway (Innis-King)



Monitoring Storage Reservoir to Overburden

- Studies of deep storage monitoring and shallow release monitoring miss the intermediate depth of potential secondary accumulations, i.e. ‘thief zones’: potential targets for AZMI
- The advent of projects that are now looking at CO_2 migration and detection in shallow overburden (e.g. CaMI) is a significant advance.



CaMI: Controlled release at 300 m and 500 m with variable seal (Lawton)

THE UNIVERSITY OF TEXAS AT AUSTIN

WHAT STARTS HERE CHANGES THE WORLD

Shallow Monitoring Summary
IEAGHG 11th Monitoring Network Meeting

Katherine Romanak
Gulf Coast Carbon Center
Bureau of Economic Geology
The University of Texas at Austin

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Session 5: Near-Surface Monitoring – Long-term Natural Variability.

Chair: Katherine Romanak, BEG

14.20 – 14.40 Long-term sea water monitoring in coastal Japanese waters. *Jun Kita, RITE*

14.40 – 15.00 Continuous monitoring of weak natural CO_2 leakage near Rome. *Dave Jones, BGS*

15.00 – 15.20 Development and proof for monitoring technique of subseabed CCS. *Kiminori Shitashima, Tokyo University of Marine Science and Technology.*

15.20 – 15.40 Discussion:

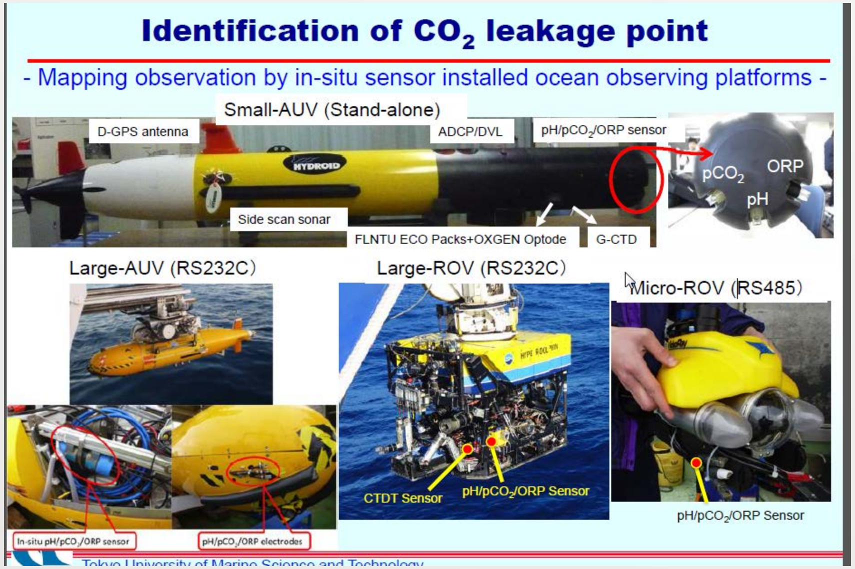
- Detecting changes in natural variability over longer time periods.
- Attribution of a signal and differentiation from background noise.
- Preparation and response to claims of leakage ahead of project implementation.
- Managing the public's reaction to these issues.

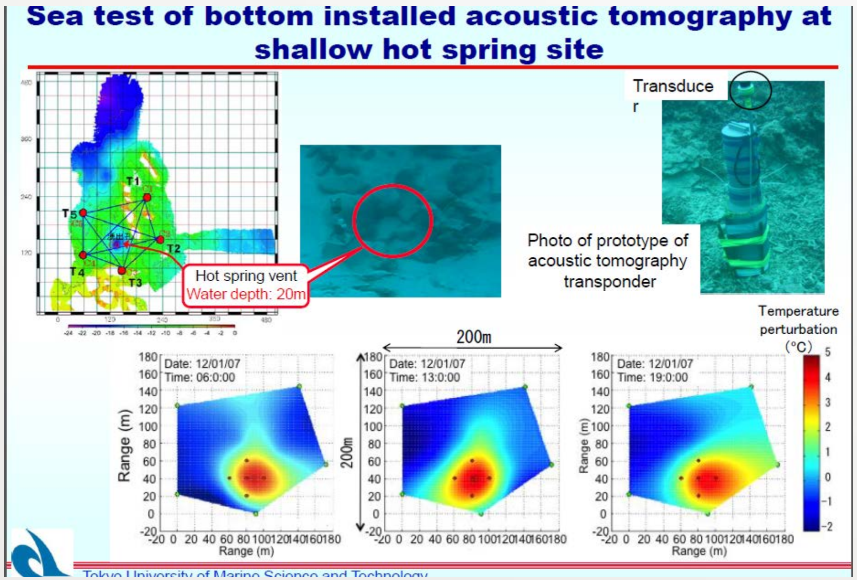
Overarching Themes Shallow Monitoring

- Temporal and spatial complexity of near-surface baselines
- Optimizing Monitoring
  - reduce costs
  - increase accuracy of source attribution of anomalies
  - enhance stakeholder engagement

Optimizing Leakage Location: Offshore

A range of technologies exist offshore for locating leakage

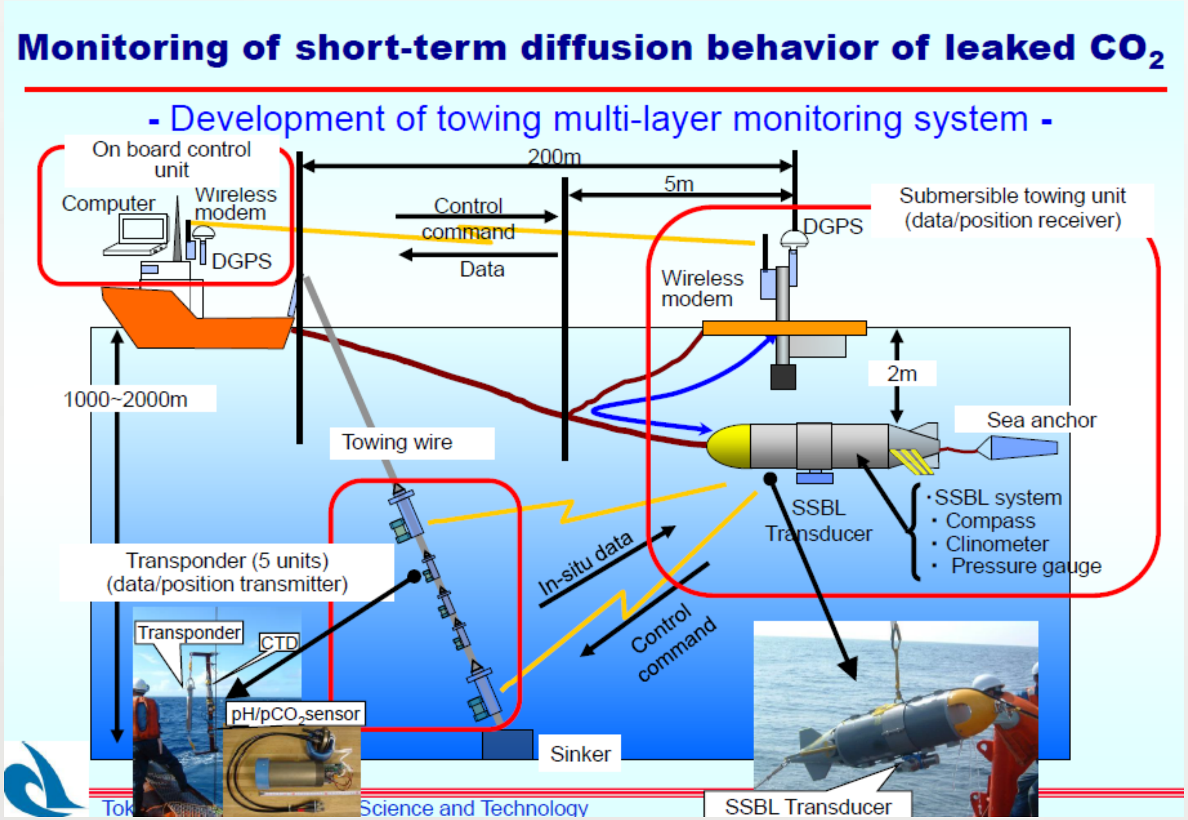




Kiminori Shitashima, Tokyo University, Japan

Optimizing Leakage Location: Offshore

Integrated approaches for locating and monitoring leakage



Kiminori Shitashima, RITE, Japan

Optimizing Leakage Location Onshore

Can continuous monitoring in the deep subsurface inform near-surface monitoring?

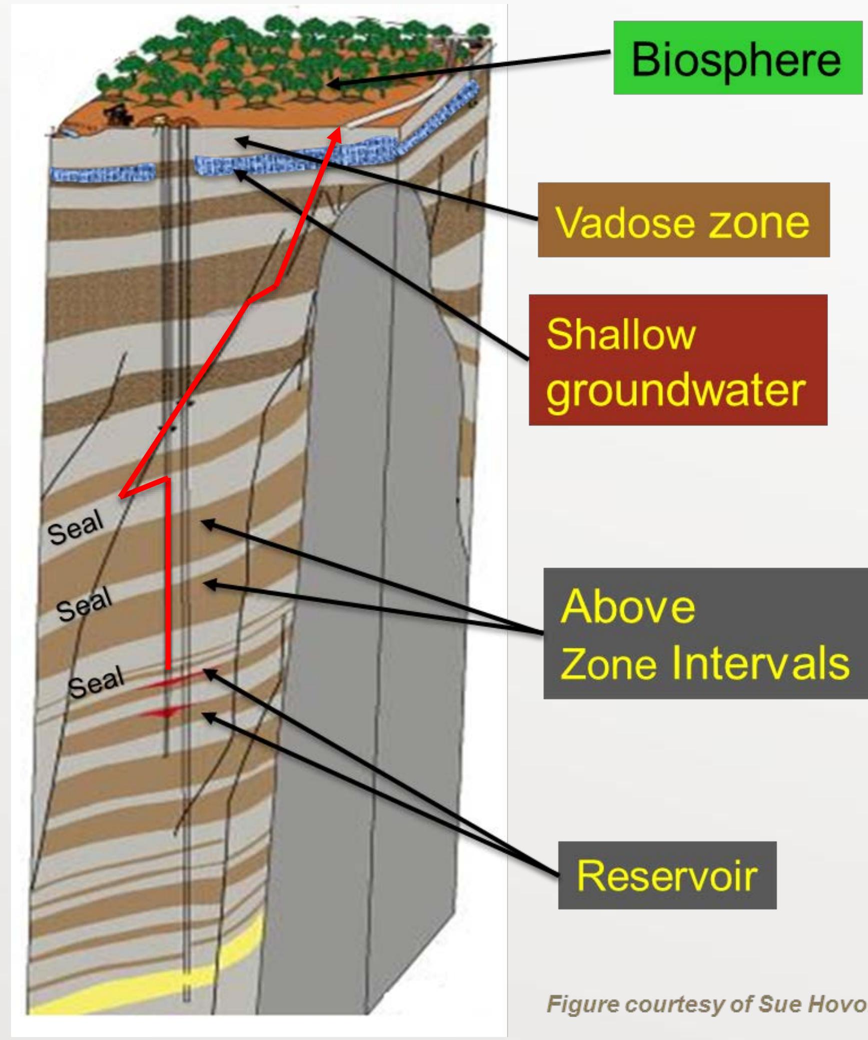


Figure courtesy of Sue Hovorka

International Concern over “Background” and “Baselines”

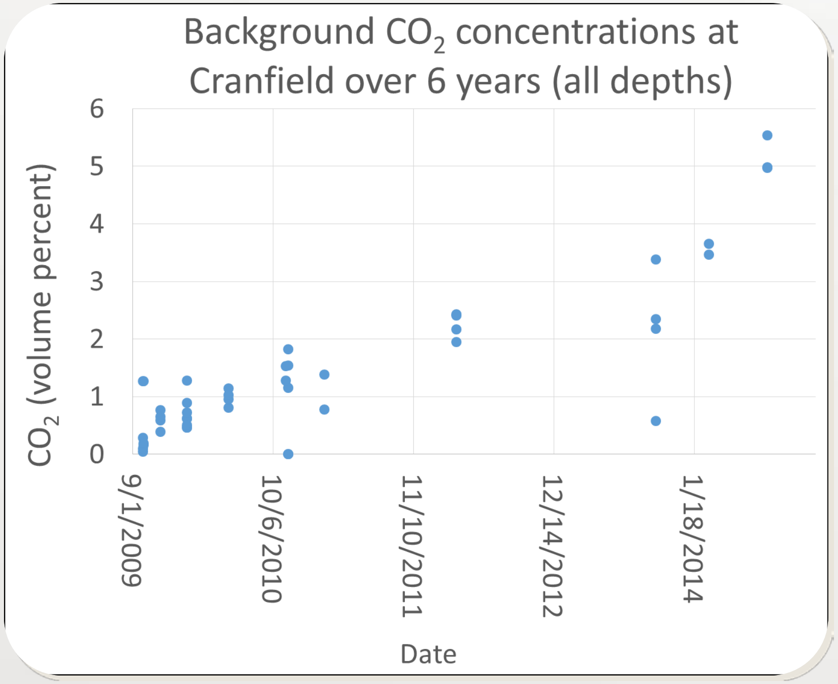
- One year is not sufficient for characterizing natural variation.
- Long-term baselines are changing due to climate change.
- Use of baselines will give inaccurate source attribution leading to false positives.

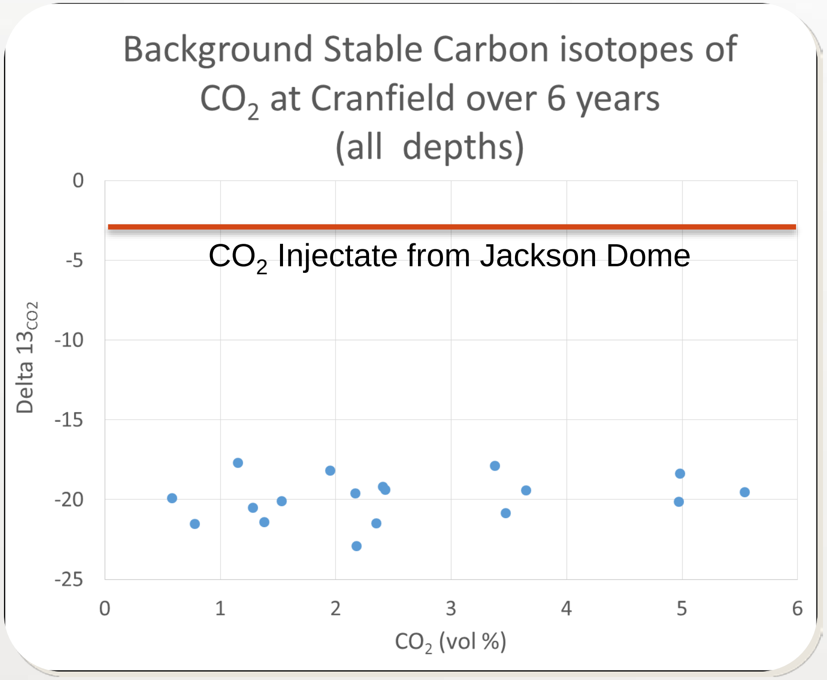
Table 1
Summary of the six main monitoring activities for the CCS regulations discussed in the text.

Regulatory Body / Monitoring Objectives:	IPCC GHG Guidelines	EU		London Convention and Protocol	OSPAR	UNFCCC Clean Development Mechanism	US EPA	
		CCS Directive	ETS Directive				UIC Class VI well regulation	GHG reporting Subpart RR
Overall Objectives	GHG accounting	Protection of the	GHG accounting	Protection of the marine	Protection of the marine	GHG accounting and protection of the	Protection of the environment (underground sources	GHG accounting
Baseline/ Background Measurements	✓	✓				✓	✓	✓
Performance	✓	✓		retention	of retention	✓	pressure and plume extent	
Detection of Leaks or Anomalies	✓	✓		✓	✓	✓	✓	✓
Attribution of Leaks and/or Anomalies	Mentions in the context of baseline isotopic ratios. Not included as a step					Not included as a step but accommodates a range of monitoring techniques		Mentions in the context of baseline CO_2 concentrations. Not included as a step
Environmental Impacts		✓		✓	✓	✓	✓	
Quantification of GHG	✓		✓			✓		✓

Dixon and Romanak 2015

Background at Cranfield





Shift in CO_2 concentration over time with no change in isotopes suggests is “background” CO_2 shift.

“Baselines” are Shifting

Vol 464 | 25 March 2010 | doi:10.1038/nature08930 nature

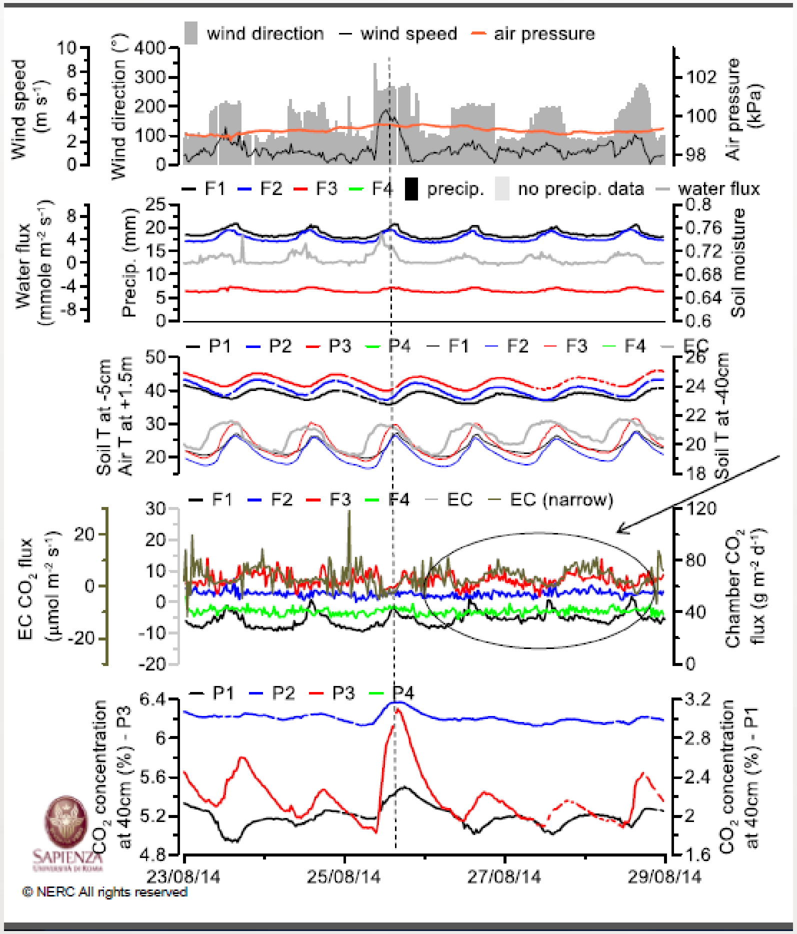
Temperature-associated increases in the global soil respiration record

Ben Bond-Lamberty[1] & Allison Thomson[1]

RS = the flux of microbially and plant-respired CO_2 from the soil surface to the atmosphere,

Complexity of CO_2 Concentration Variations

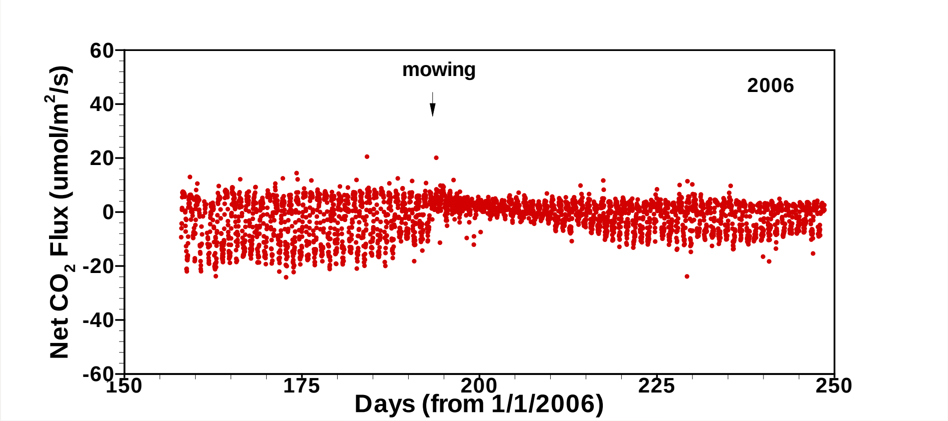
- Pinpointing variations in CO_2 from respiration is complex.
- Massive data collection and complex analysis
- How to communicate this complexity to stakeholders?

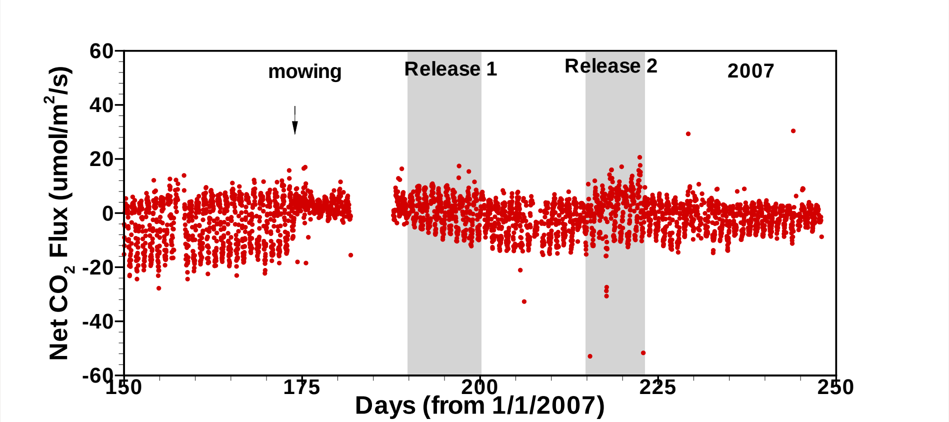


Dave Jones, British Geological Survey

Modelling the Complexity

- Can we detect the leakage signal from the measured CO_2 flux data (as a time series)?
  - Are there distinct temporal features (leakage vs. biological)?
  - Any structure to the biological signal?
  - How bring out the different components?





The (EC) measured CO_2 flux at MTU station in 2006 summer (no releases) and 2007 summer (with releases)

Curtis M. Oldenburg, LBNL, USA

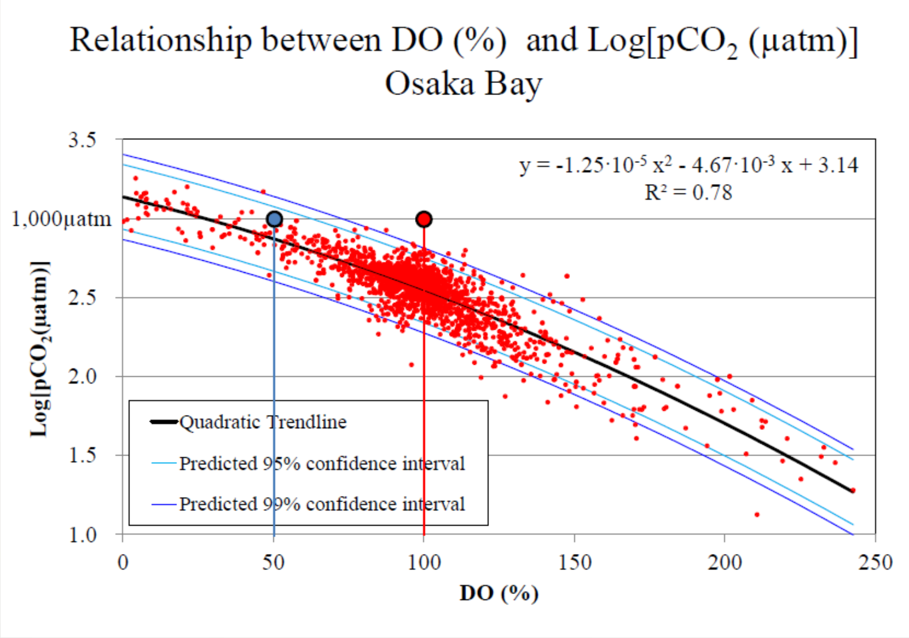
Osaka Bay- Long Term Natural Variability

- 2002-2012 monitoring Osaka Bay
- Long term variability pCO2 versus DO shows inverse relationship

Jun Kita, RITE, Japan

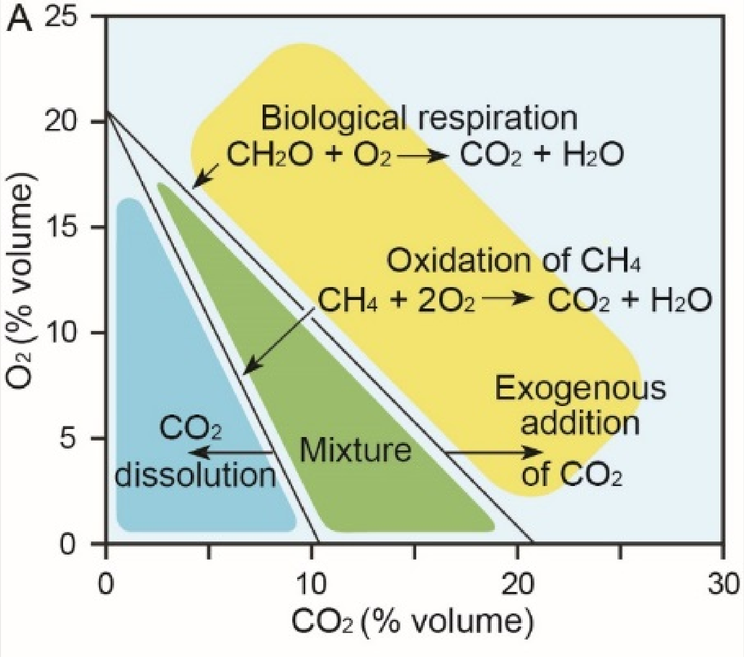
Geochemical Relationships Representing Respiration

Offshore: Bio-Oceanographic Method



Jun Kita, Rite, Japan

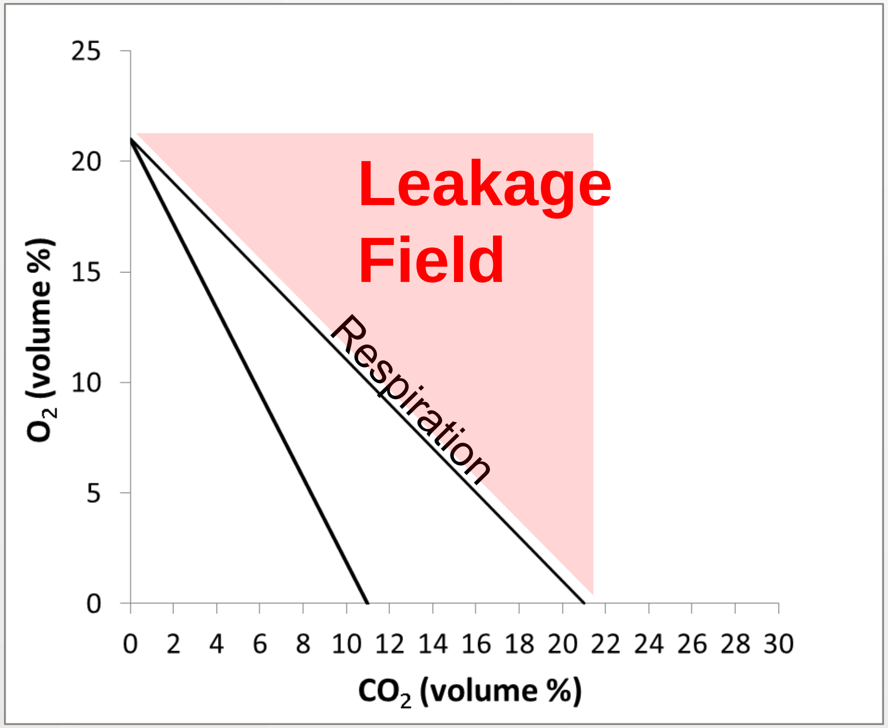
Onshore: Process-Based Method



Katherine Romanak, BEG, USA

Ratios Providing "User-Friendly" Monitoring

- Does not rely on baseline values
- Respiration line as a universal trigger point
- Easy to explain and engage stakeholders
- Instant data reduction and graphical analysis

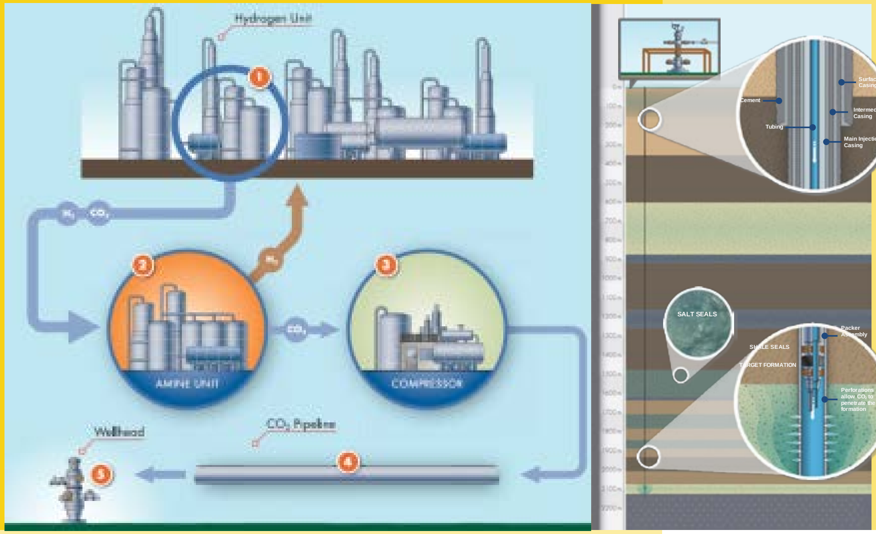


Katherine Romanak BEG

QUEST AT IEAGHG MMV NETWORK MTG

Carbon Storage and Oil and Natural Gas Technologies Review Meeting

Pittsburgh – August, 2016



Simon O'Brien, Luc Rock
Shell Canada Limited

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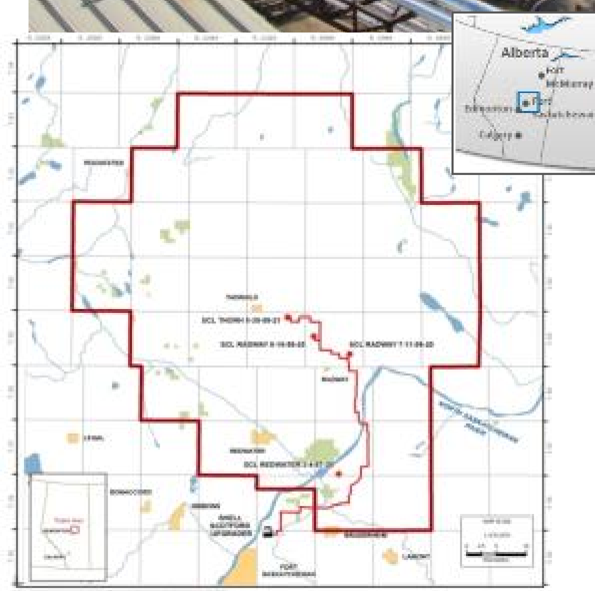
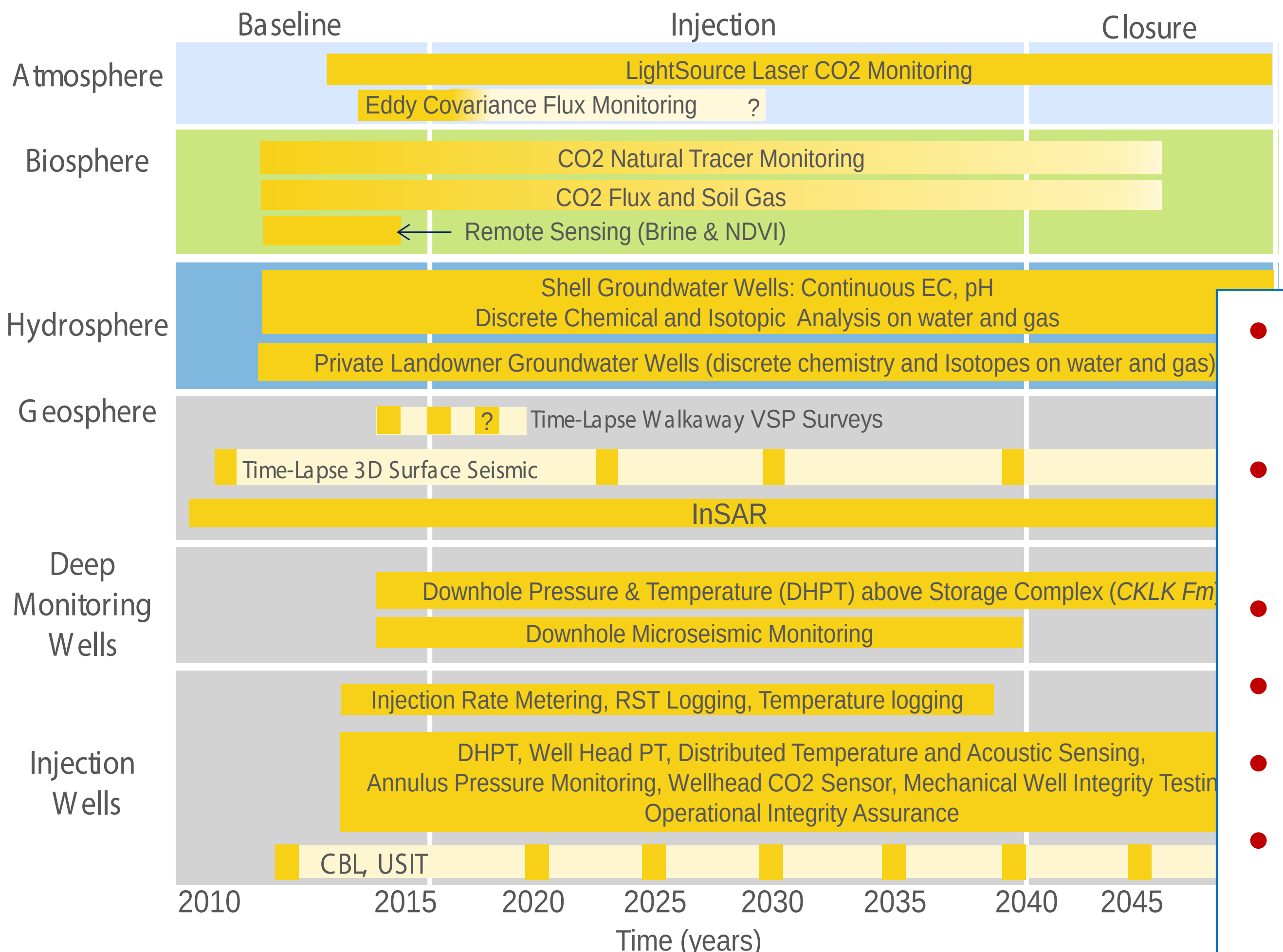
QUEST PROJECT AT A GLANCE

- **World First** – the first full-scale CCS project for oil sands
- **Where** – capture at Scotford Upgrader; storage in saline aquifer: the Basal Cambrian Sands (at a depth of 2000m)
- **Impact** – 25 million tonnes of CO_2 captured over a 25 year period (1/3 of CO_2 from the Upgrader) – equivalent to the emissions of 250,000 cars
- **Technology** – syngas capture using amines



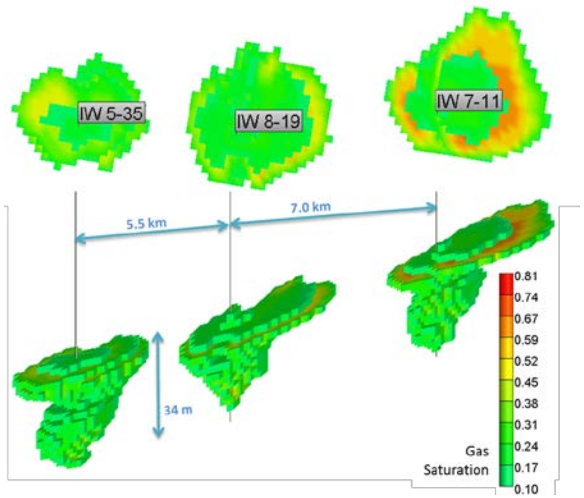
August, 2016

MMV (MEASURE, MONITOR AND VERIFY) PLAN

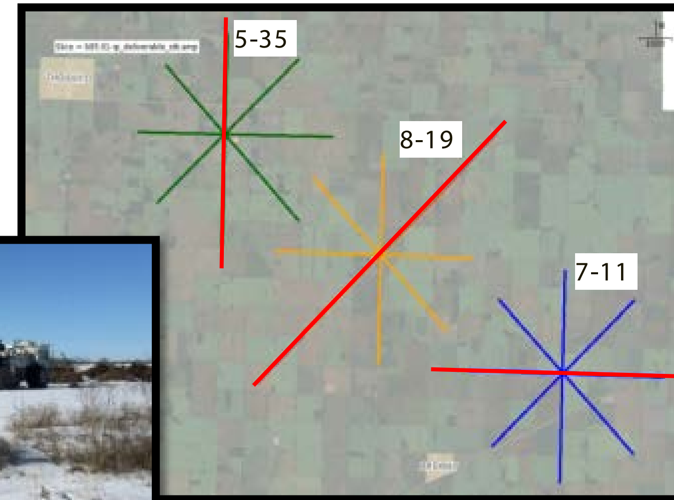


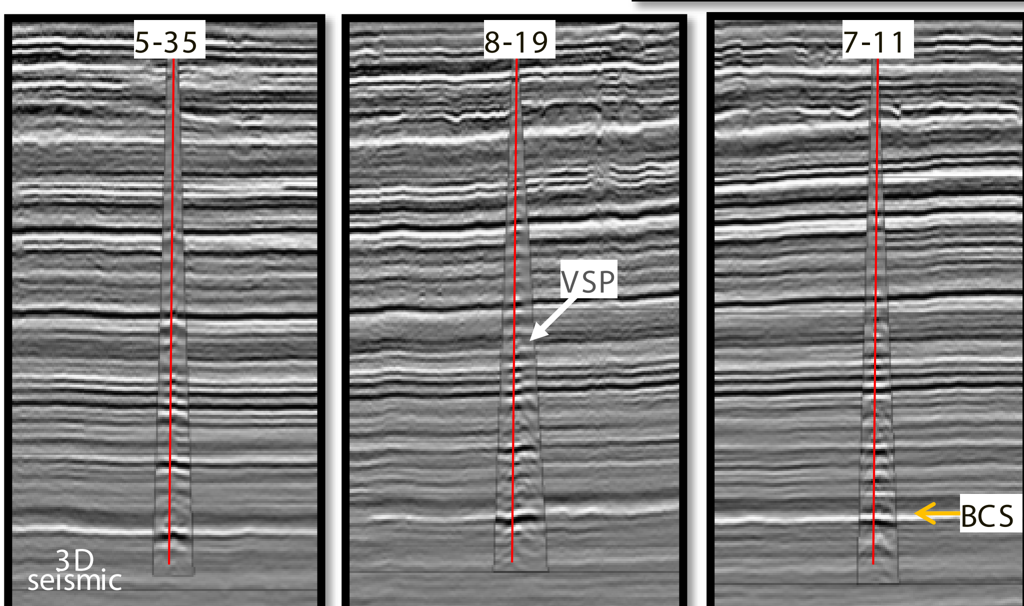
- First of a kind – conservative approach
- Comprehensive: from atmosphere to geosphere
- Risk-based
- Site-specific
- Independently reviewed
- Combination of new and traditional technologies
- Baseline data collected before start-up

SEISMIC MONITORING – VERTICAL SEISMIC PROFILE (VSP)



Model of CO_2 Plume after injecting for 25 years



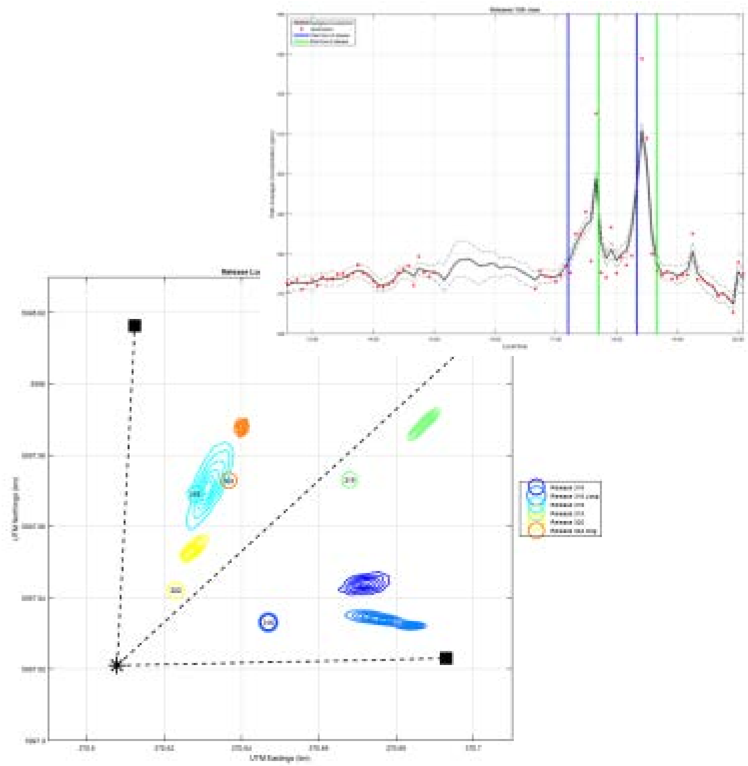


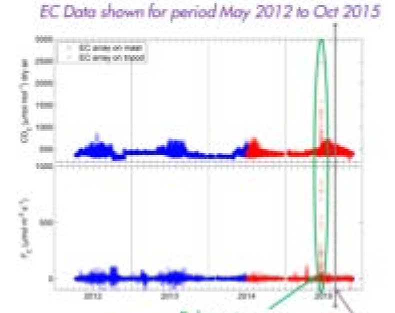
- Design change: from 3D VSP to radial walkaway 2Ds: significant cost savings
- Acquired baseline VSP in Feb, 2015 and the first monitor VSP in Feb, 2016.
- Processing is complete – still evaluating the results, but 4D response is strong

ATMOSPHERIC MONITORING

from Hirst et al. 2015

- LightSource system installed and functional at all injection sites
- Release testing very successful
- **Confirmed as technology for atmospheric monitoring at Quest**





- Eddy Covariance system maintained at 8-19 site until end of 2015
- CO_2 release tests also clearly detected

MMV UPDATE

Key Updates to MMV plan:

- Removed RIA & MIA
- LightSource functionality confirmed
- Revised GW well sampling strategy
- Change in VSP survey design

Domain	Technology	Trigger Event	23 Aug to 31 Dec 2015	Comment
Atmosphere	LightSource	Sustained locatable anomaly above background levels		Impact of inclement weather on system response being investigated
Bio-sphere	Soil Gas	Outside established baseline range		
	Surface CO2 Flux	Outside established baseline range		
Hydro-sphere	Tracer	Outside established baseline range		
	WPH	Sustained decrease in baseline pH values		
	WEC	Sustained increase in baseline WEC values		
	Geochemical Analyses	Outside established baseline range		
Geopshere	DHPT CKLK	Pressure increase 200 Kpa above background levels		
	DHMS	Sustained clustering of events with a spatial pattern indicative of fracturing upwards		
	DTS	Sustained temperature anomaly outside casing		Move to automatic data retrieval
	VSP2D	ID coherent and continuous amplitude anomaly above the storage complex		1st Monitor Q1/2016
	SEIS3D	ID coherent and continuous amplitude anomaly above the storage complex		N/A
	InSAR	Unexpected localized surface heave		assessment after ~ 1 year of injection

Operations:

- Still evaluating InSAR, other technologies
- No microseismic activity
- No valid triggers yet recorded
- **Reservoir quality better than expected – excellent injection performance to date!**

QUEST MMV – KEY POINTS

Now in commercial operation:

- New information used to improve our understanding of risks
- Evaluating all MMV technologies currently in use:
  - Conformance – reservoir better than expected
  - Containment – all systems tested and working
    – technologies connected (deep to shallow)
  - Stakeholders – continue to be a good neighbour
- Focus on driving costs down:
  - Remove technologies if new risk evaluation indicates they are no longer necessary
  - Optimize sampling frequency
  - Maintain adaptability – ready to replace existing technologies with cheaper/ better alternatives

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