Advances in Distributed Acoustic Sensing (DAS) monitoring for CCS projects

Dr Anna Stork, Senior Geophysicist

CO_2 storage - and opportunities for geoscientists, 18 May 2022

SILIXA
actionable insight

Distributed Fibre Optic Sensing Technology & Advantages

CCS Monitoring Challenges

Case Studies

Carina® CarbonSecure™ CO_2 Monitoring Solution

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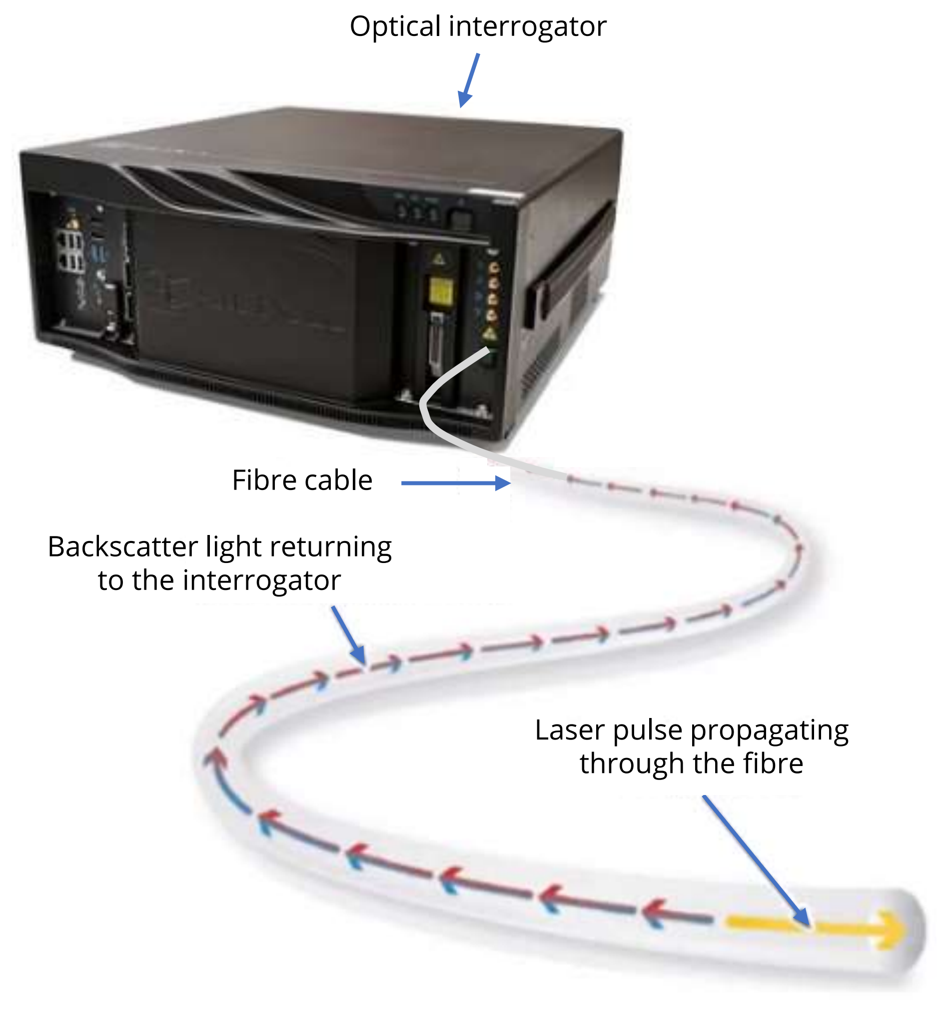
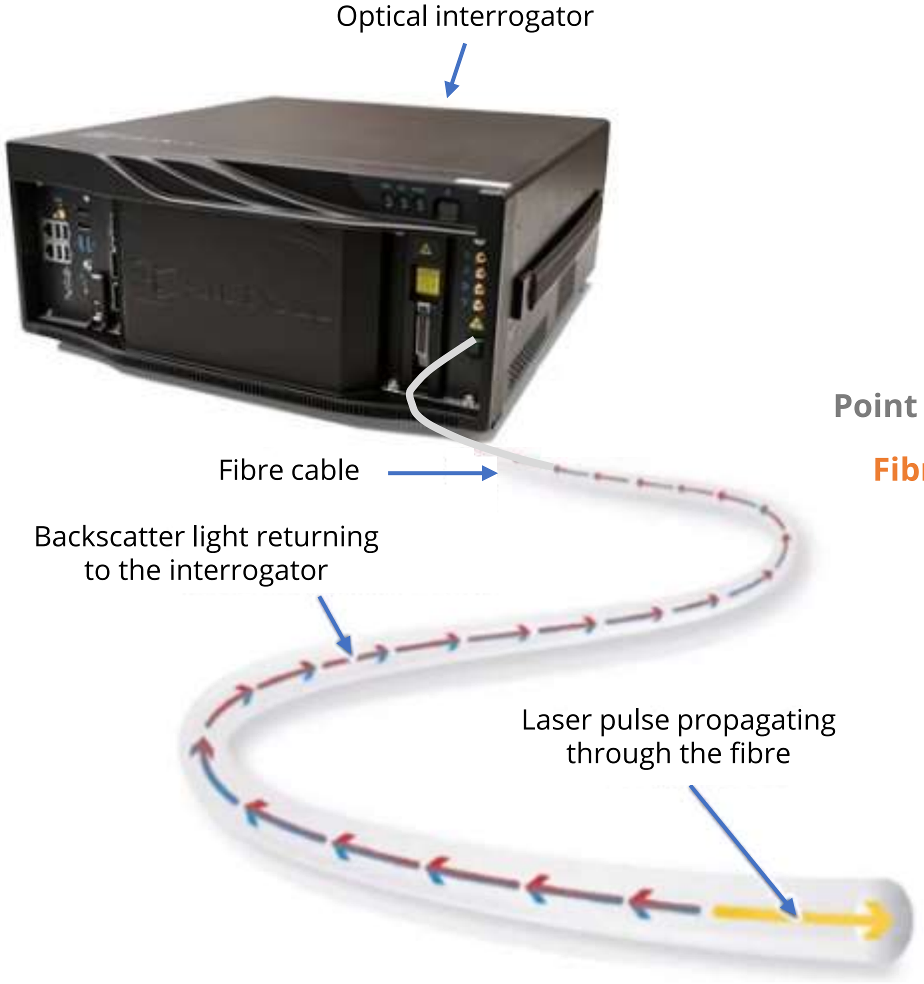
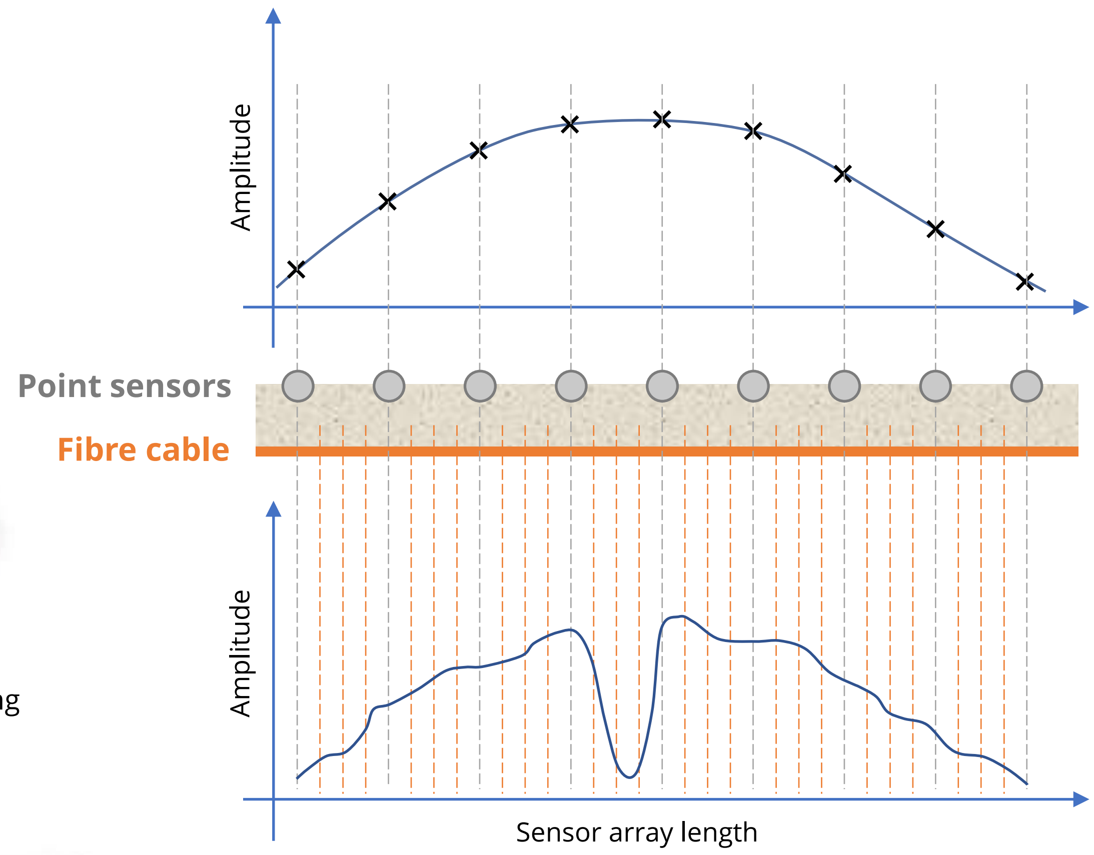
What is Distributed Fibre Optic Sensing?



- Light-based measurement technique using a laser “interrogator” and a fibre optic cable.
- The sensor is the fibre optic cable.
- Used to measure temperature, strain-rate or strain.
- Used in borehole & surface measurements.
- Wide aperture coverage compared to standard sensing systems.
- Specifications:
  - <1m spatial sampling capability.
  - Measurement range 10s of kilometres.
  - Simultaneous measurements at all points along optical fibre cable.

Fibre Optic Sensing Advantages





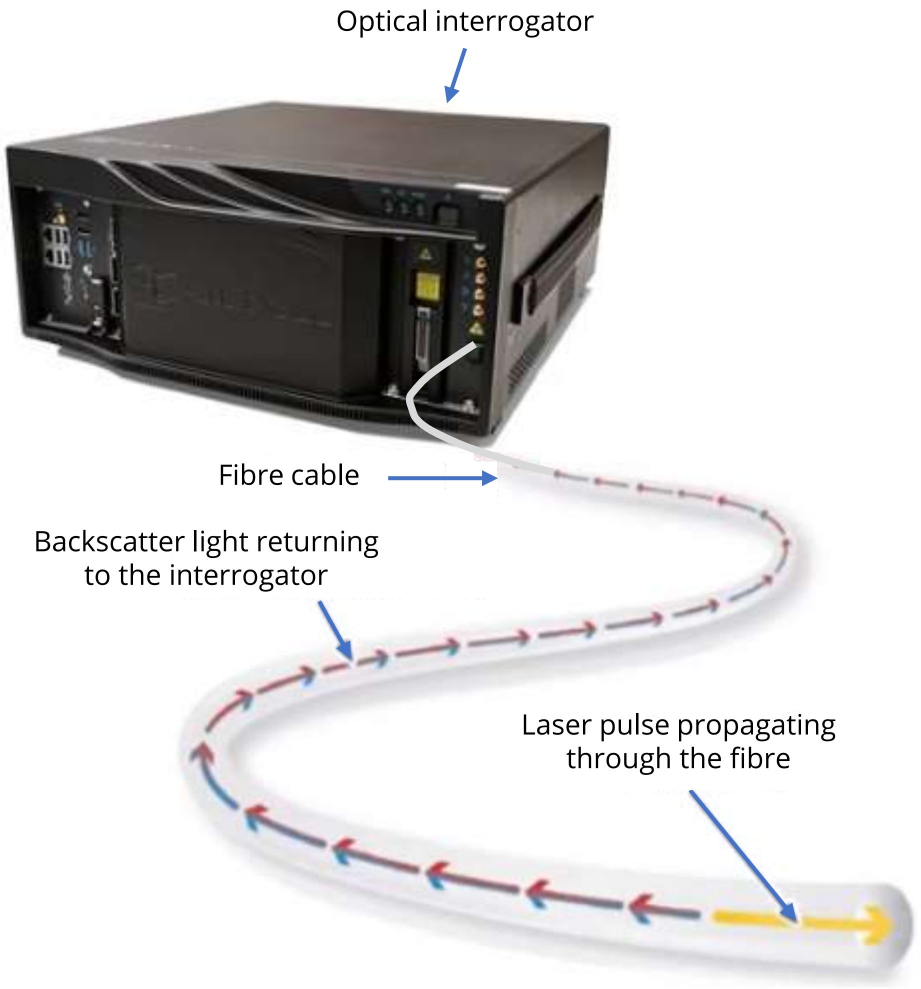
Point Sensors

- Large numbers required to provide detailed monitoring.
- Information may not be representative of the actual conditions.

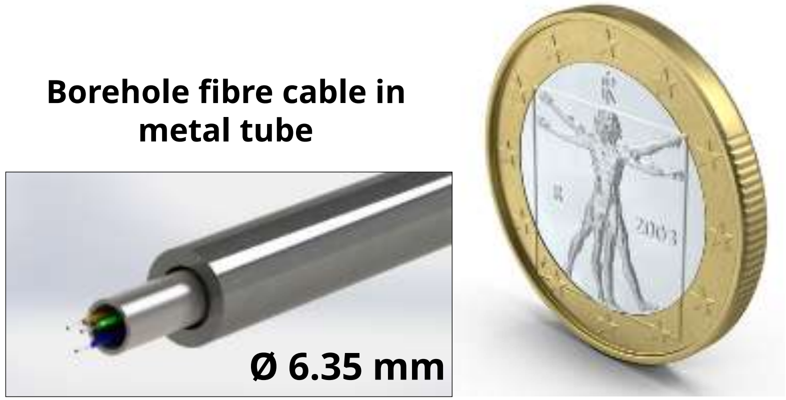
Distributed Fibre Optic Sensing

- Help recover detailed and complex signals.

Fibre Optic Sensing Advantages



Borehole fibre cable in metal tube



Array of borehole sensors

<u>Fibre-optic cables</u>

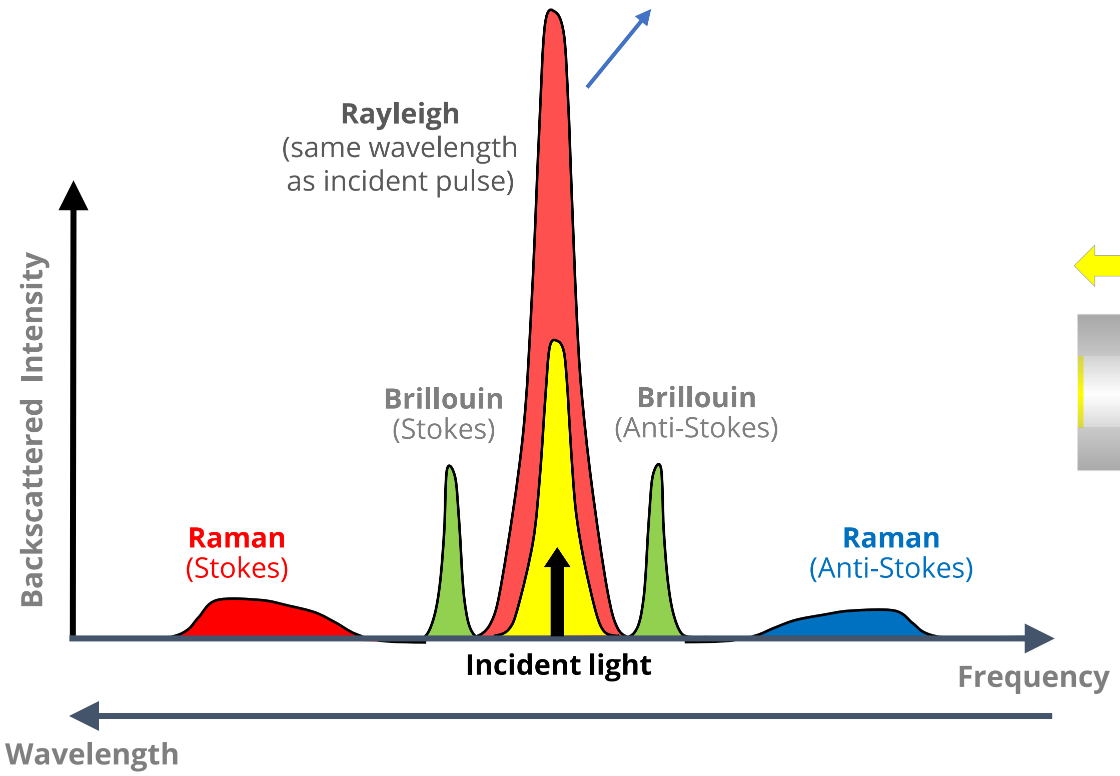
- Continuous sensor.
- Slim package for permanent deployment.
- Large aperture, dense array.
- No electronics.
- ***Single cable with multiple optical fibres for acoustic, temperature, and strain sensing.***

<u>Geophones</u>

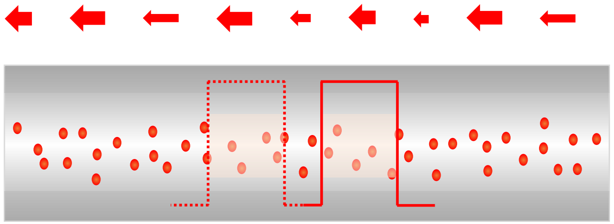
- Discrete sensors.
- Bulky, not well suited to permanent deployment.
- Limited number of channels.
- Electronic components and connections required.

Distributed Fibre Optical Sensing Technology

iDAS™	Carina®
Acoustics **(DAS)** >120dB Dynamic range	

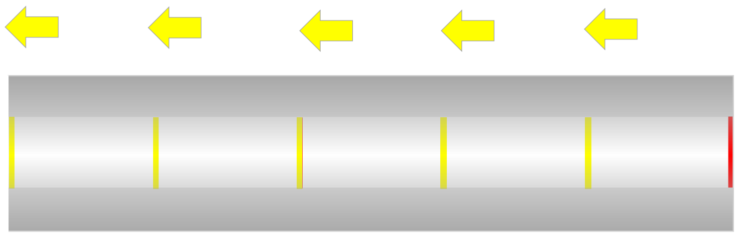


Backscatter



Standard Fibre

Enhanced backscatter



Engineered Fibre

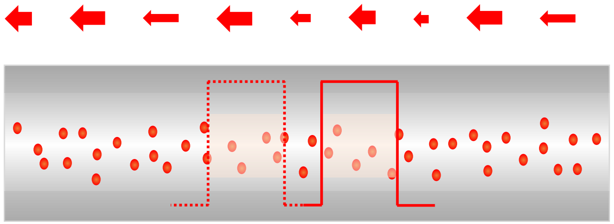
US Patent No. US 10,883,861 B2
EP Patent No. 3265757

Distributed Fibre Optical Sensing Technology

ULTIMA™ DTS	XT-DTS™
Temperature (**DTS**) 0.01°C Resolution	

iDAS™	Carina®
Acoustics (**DAS**) >120dB Dynamic range	

Backscatter



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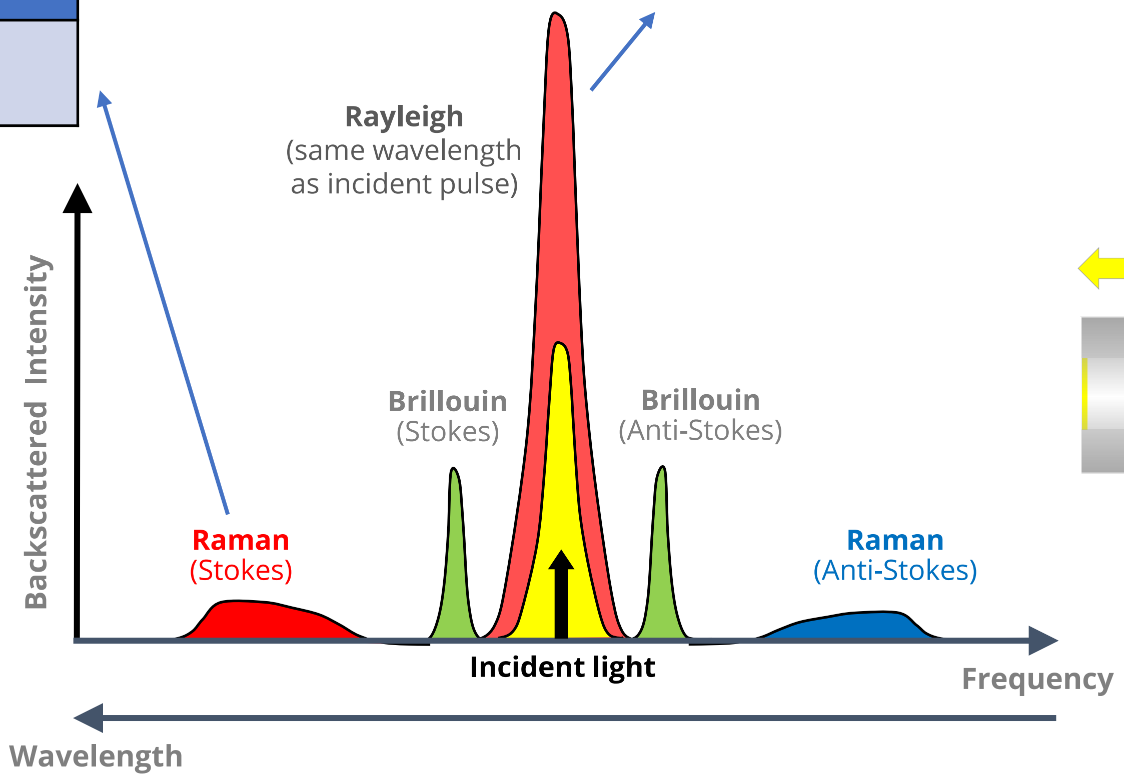

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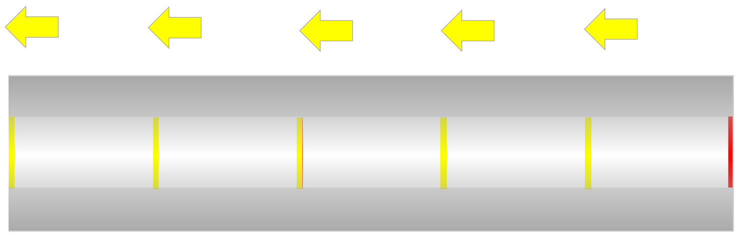

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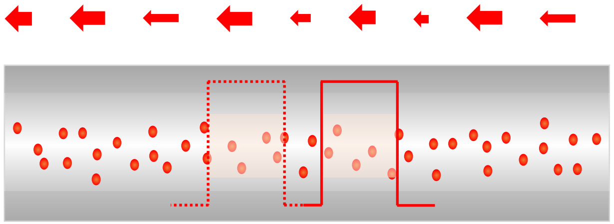
ULTIMA™ DTS	XT-DTS™
Temperature (**DTS**) 0.01ºC Resolution	

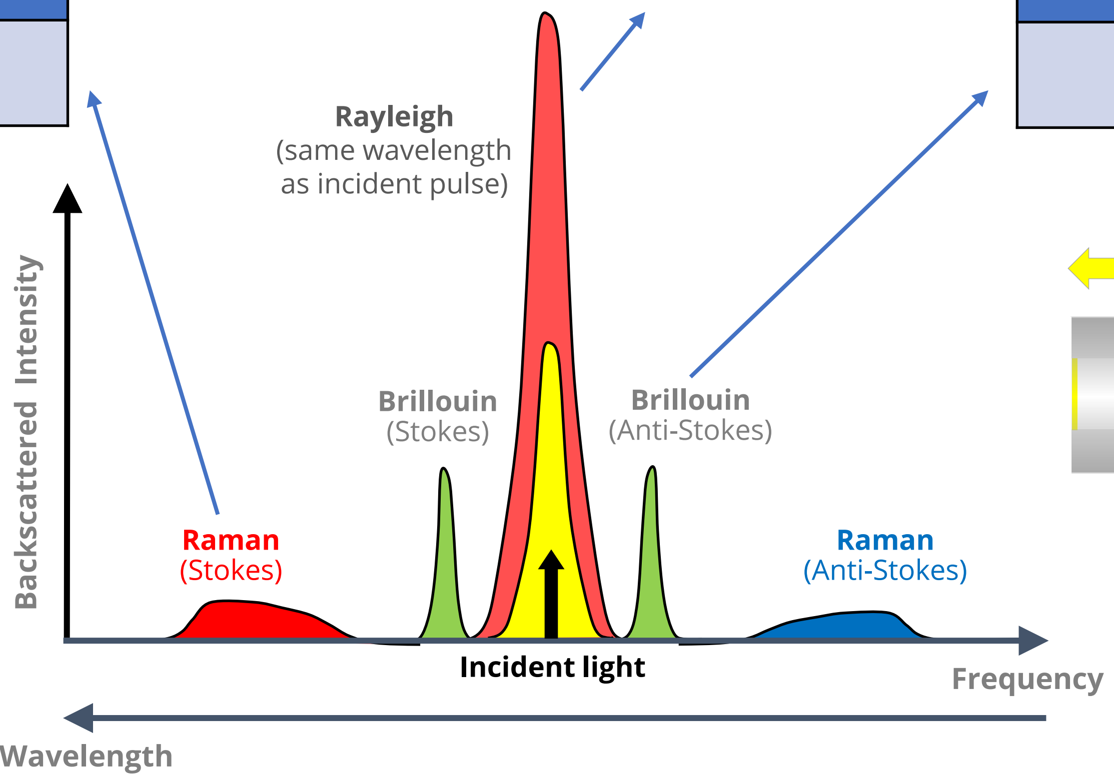
iDAS™	Carina®
Acoustics (**DAS**) >120dB Dynamic range	

iDSS™	Fibre Ruler
Strain (**DSS**) 1 με Resolution	

Backscatter



Standard Fibre



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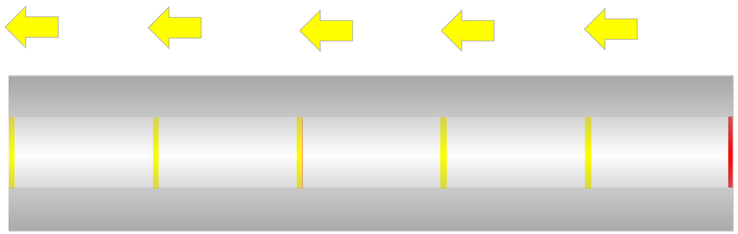

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SILIXA actionable insight

Distributed Fibre Optic Sensing Technology & Advantages

CCS Monitoring Challenges

Case Studies

Carina® CarbonSecure™ CO_2 Monitoring Solution

CCS Monitoring Challenges

Conformance, Containment and Contingency Monitoring

Operators to ensure the safe storage of CO_2

Measurement, monitoring, and verification (MMV) plans to verify

- Is CO_2 injected into the intended storage formations?
- Can the injected CO_2 be tracked over time in the intended storage volume?
- Can leakage be detected?
    - Wellbore monitoring.
    - Subsurface & fault imaging (seismic).
    - CO_2 plume monitoring (seismic, gravity)

CCS monitoring operations present technical challenges

- Harsh environments in-well
- Large storage sites
- Offshore operations

DAS VSP at CO2CRC Otway

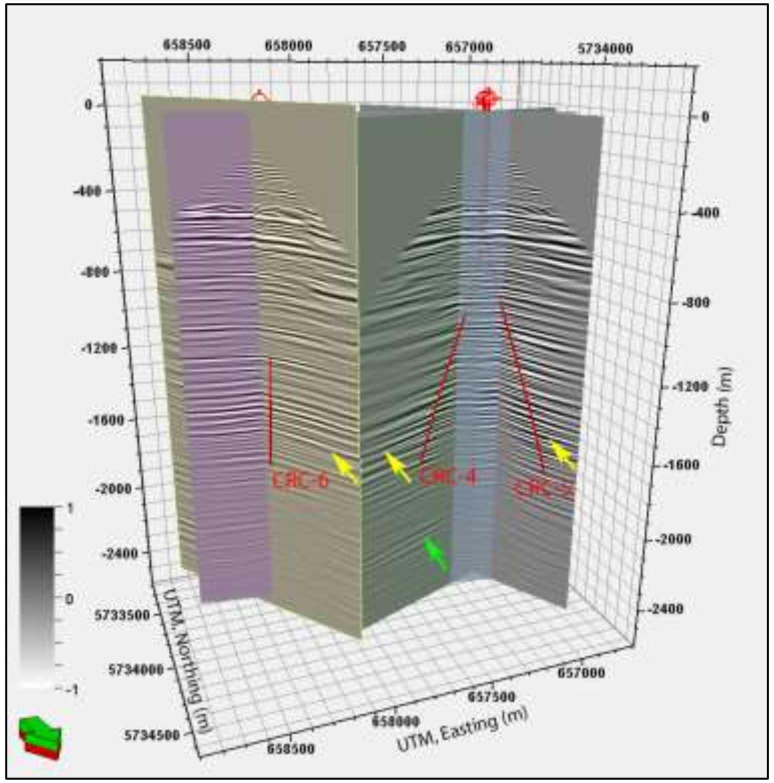
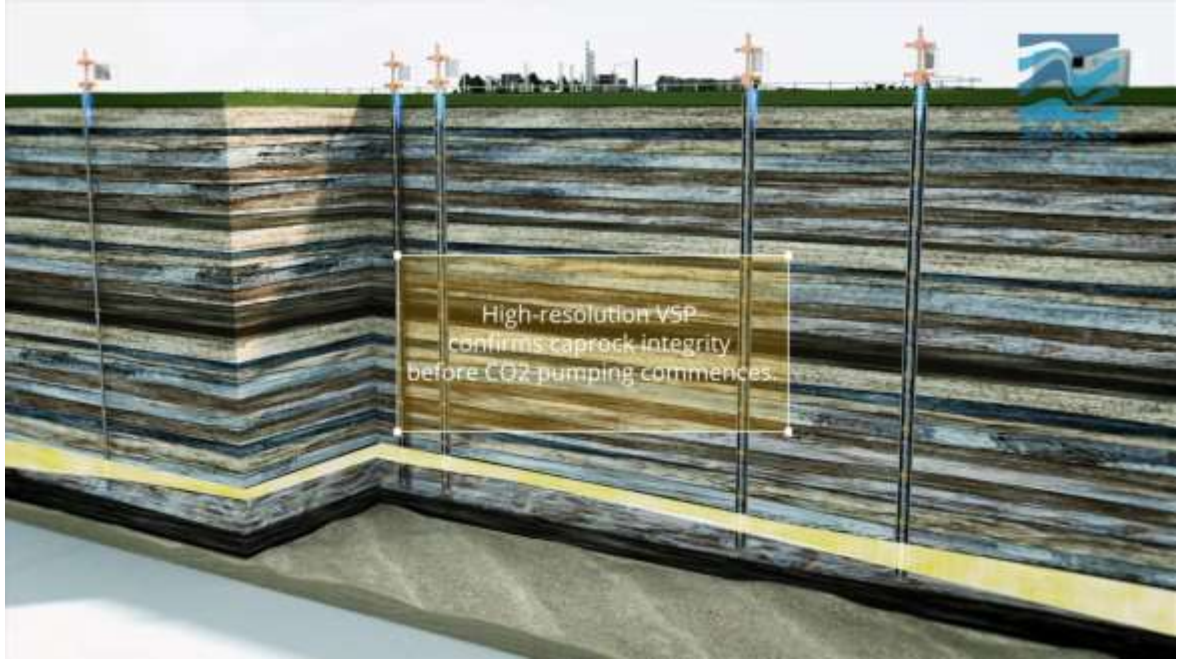


Figure courtesy of Curtin University

CCS Monitoring Requirements – Distributed fibre-optic sensing

- **Pre-injection**:
  - Site characterisation: stratigraphy, caprock continuity, fault zones *(**DAS**)*.
  - Baseline surveys *(**DAS**, **DTS**, **DSS**)*.
- **Injection monitoring**:
  - Flow profiling *(**DTS**)*.
  - Wellbore integrity *(**DAS**, **DTS**)*.
  - CO_2 plume mapping *(**DAS**):*
    - Identify leakage pathways.
    - Possible secondary accumulations.
  - CO_2 plume breakthrough *(**DTS**, **DSS**)*.
  - Microseismic characterisation *(**DAS**)*.
  - Deformation – uplift/subsidence *(**DSS**)*.
- **Post-injection**:
  - Verify continued CO_2 containment and storage *(**DAS**, **DTS**, **DSS**)*.



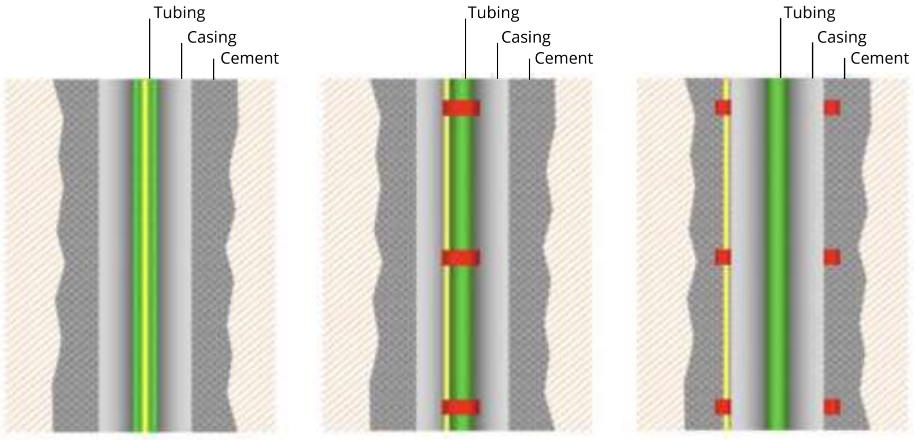
Monitoring costs affect the economic viability of projects: **fast & reliable methods are key**.

DAS for Seismic Applications

- **Phase-coherent DAS systems record full seismic wavefield**:
  - Amplitude, phase & frequency.
  - Enables repeatable measurements.
- **Wide-aperture coverage with long arrays**:
  - Thousands of channels.
- **Flexible installations**:
  1. Surface trenched.
  2. Borehole:
     - Outside casing: Cemented or clamped.
     - Clamped to tubing.
     - Wireline/slickline.
     - Suspended.
- **Standard single-mode and multi-mode fibre acquisitions**:
  - Use of legacy fibre-optic installations.
  - Passive & active seismic.
- **No electronic/mechanical components in sensor**
  - No maintenance
  - Long lifetime

Surface deployment

Borehole deployment options



Inside tubing: Friction **Outside tubing**: Clamped **Outside casing**: Clamped & Cemented

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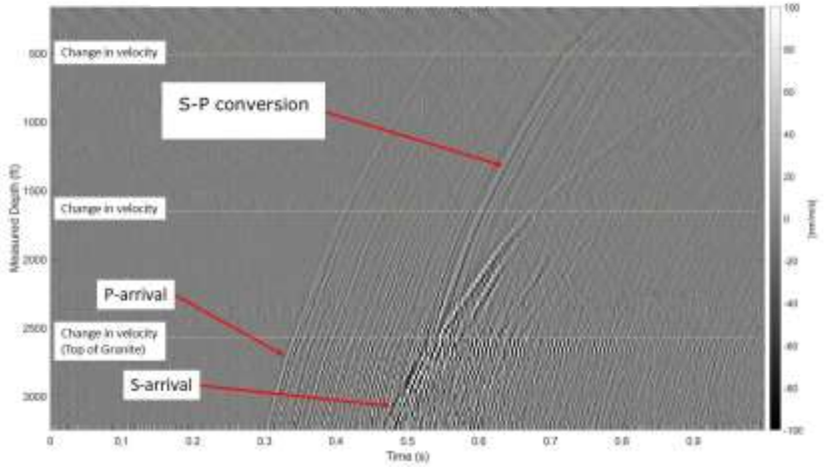
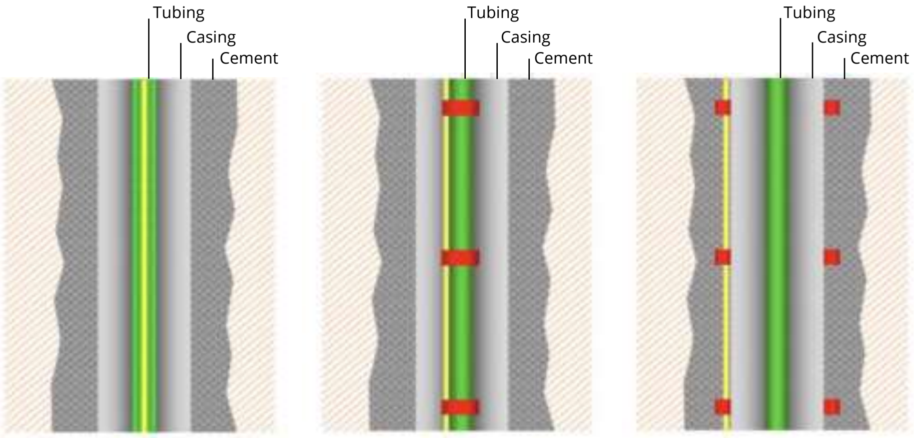
Microseismic event DAS recording



Borehole deployment options



Inside tubing: Friction

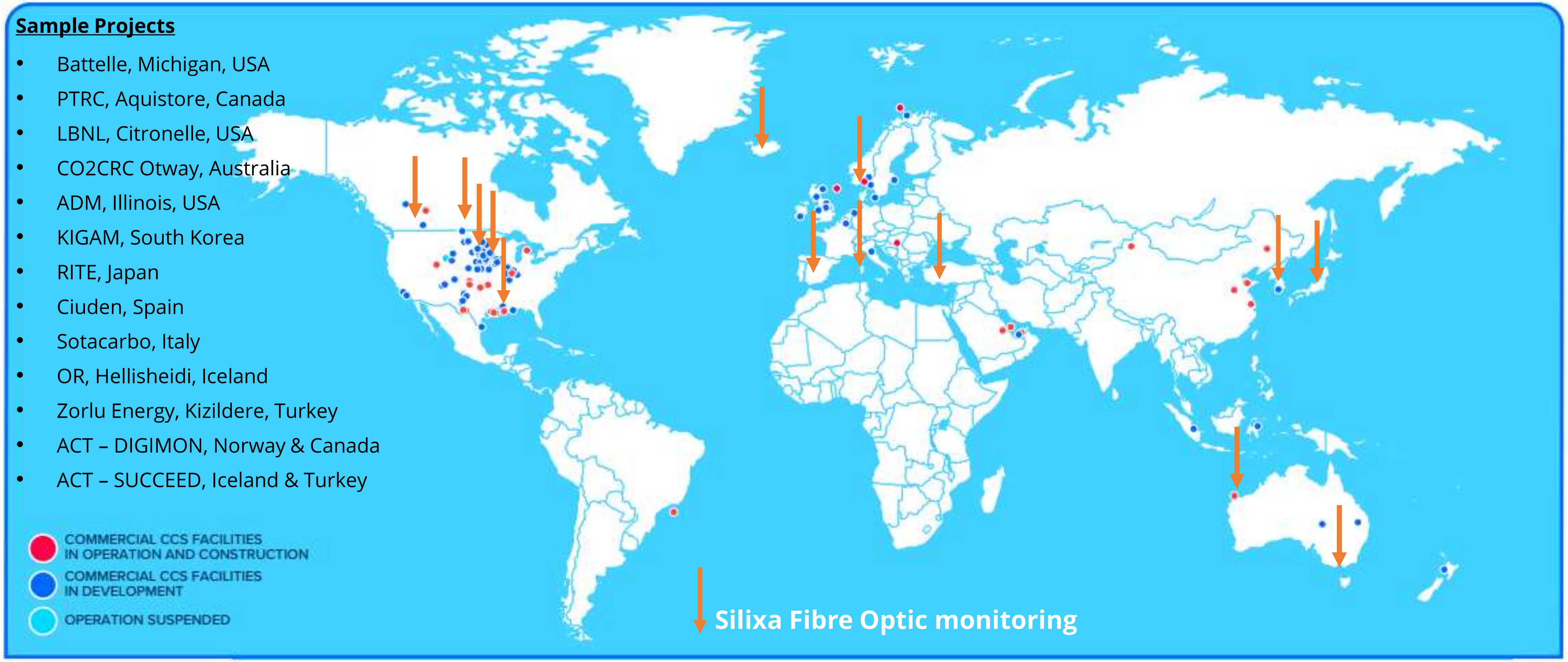
Outside tubing: Clamped

Outside casing: Clamped & Cemented

Silixa CCS Projects

Sample Projects

- Battelle, Michigan, USA
- PTRC, Aquistore, Canada
- LBNL, Citronelle, USA
- CO2CRC Otway, Australia
- ADM, Illinois, USA
- KIGAM, South Korea
- RITE, Japan
- Ciuden, Spain
- Sotacarbo, Italy
- OR, Hellisheidi, Iceland
- Zorlu Energy, Kizildere, Turkey
- ACT – DIGIMON, Norway & Canada
- ACT – SUCCEED, Iceland & Turkey



Source: Global Status of CCS 2021 report, Global CCS institute (https://www.globalccsinstitute.com/wp-content/uploads/2021/10/2021-Global-Status-of-CCS-Report_Global_CCS_Institute.pdf)

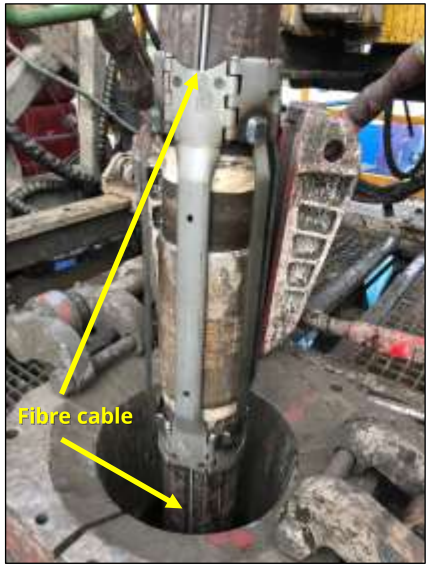
2021
- 27 operational facilities,
- 4 in construction,
- 58 in advanced development.
- North America: >40 new projects since 2020.

- Distributed Fibre Optic Sensing Technology & Advantages
- CCS Monitoring Challenges
- **Case Studies**
- Carina® CarbonSecure™ CO_2 Monitoring Solution

Case Study: Otway project, VA, Australia

Objectives:

- Establish permanent reservoir monitoring for reliable and efficient CCS.
- Reduce the cost of monitoring by tens to hundreds of millions of dollars over the life of a commercial project.
- Provide assurance to Governments and Communities.
- Novel subsurface monitoring technologies & methods:
    1. Appraise,
    2. Implement,
    3. Demonstrate,
    4. Validate.



Project outline:

- CO2CRC with CSIRO & Curtin University.
- Onshore CCS demonstration in rural area.
- 15,000 tons of CO_2 injected by 2022.
- First optical fibre cable installed in 2014.
- >40 km of fibre installed by 2020.
- 5x wells equipped with the Carina® Sensing System.
- Multiple low-impact/low-cost Surface Orbital Vibrator sources (SOV).

Large motor
Max Freq: 80 Hz
Force: 69.6 kN

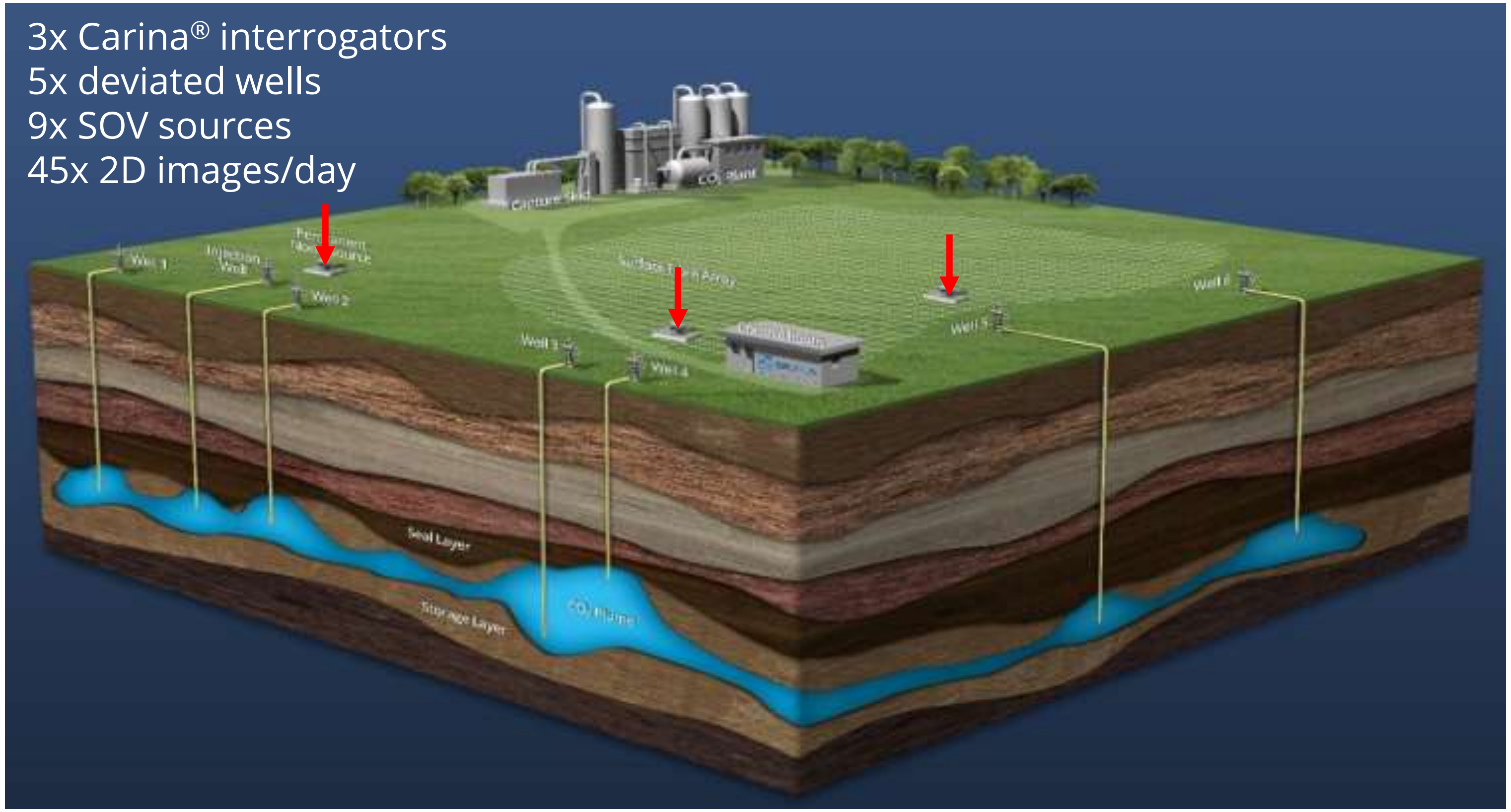
Small motor
Max Freq: 105 Hz
Force: 37.3 kN

Correa et al. 2021 Geophysics

Case Study: Otway project, VA, Australia

Vibroseis trucks

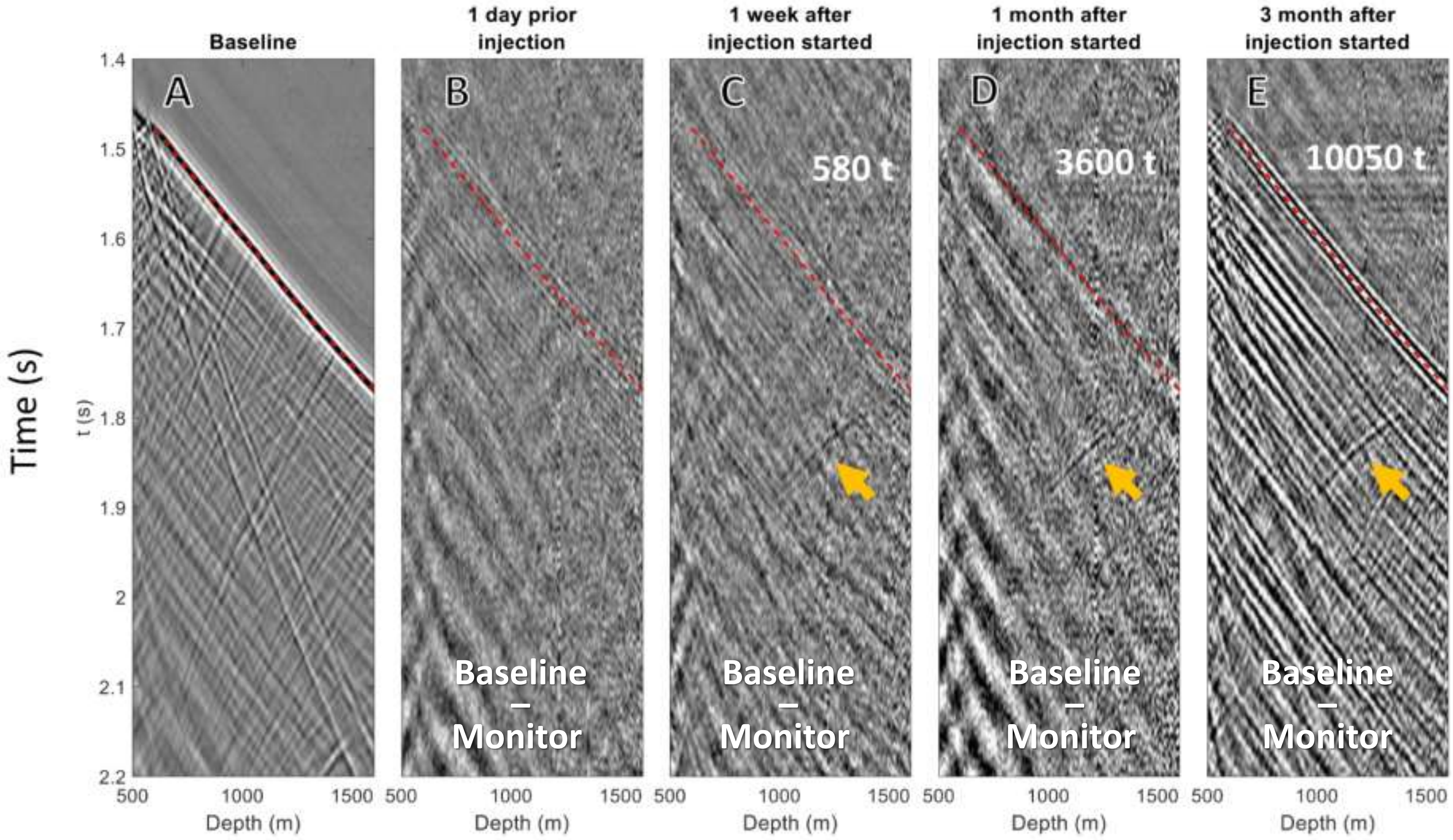
SOV sources



Benefits of using SOVs

- Low operational costs.
- Overcomes issues with access to field sites.
- High temporal resolution.
- High repeatability.
- Results available hours after acquisition.

2D VSP Monitoring Surveys



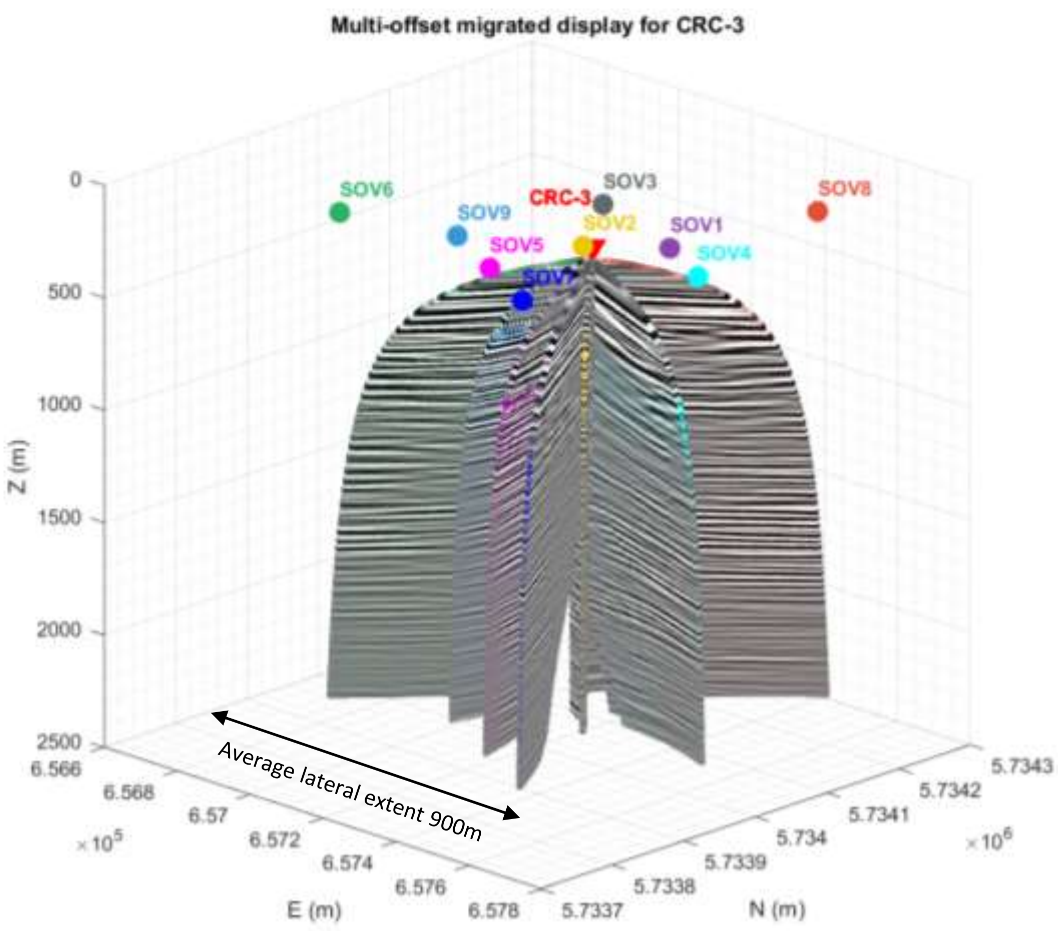
Incremental injected CO_2 in [tons]

Growing seismic signature of the CO_2 plume

Pevzner et al. 2021 Intl Journal of Greenhouse Gas Control

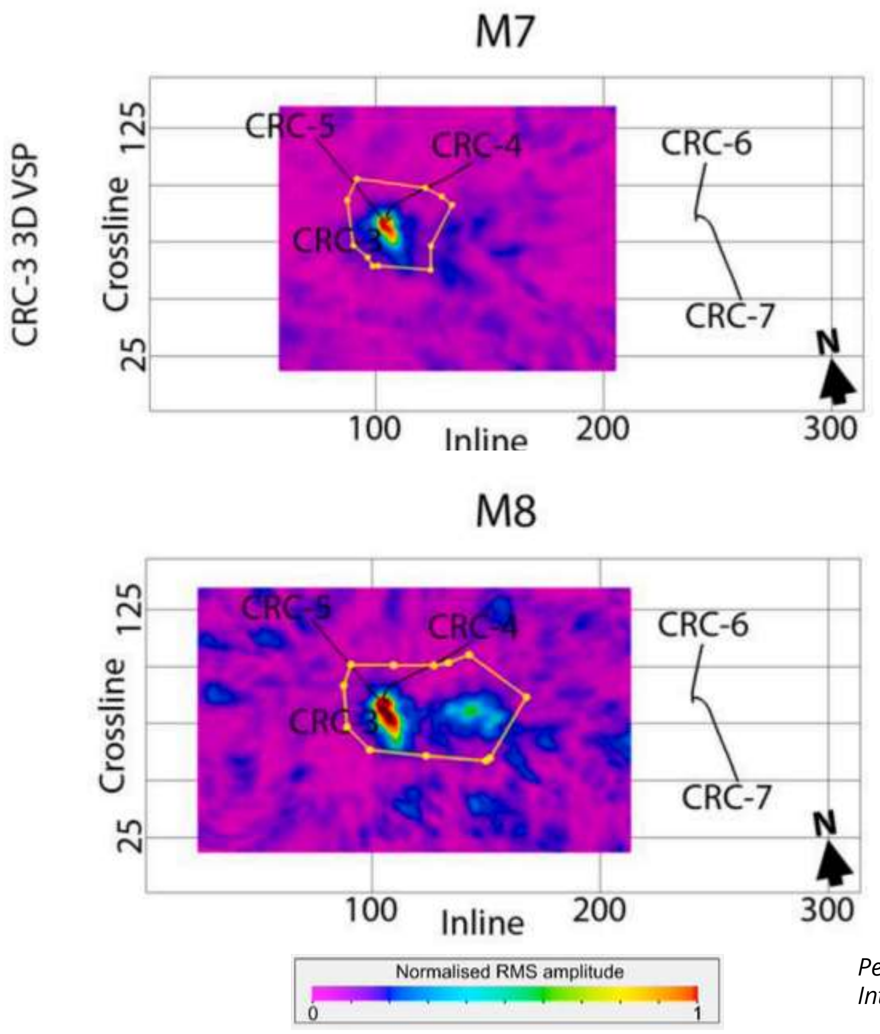
CO_2 Plume Migration

2D Sections for 9 SOV sources and one well (CRC-3)



Yavuz et al. 2021 Geophysical Prospecting

3D Plume migration over time



Jan 2021
4,382 tonnes CO_2

March 2021
8,253 tonnes CO_2

Pevzner et al. 2021
Intl Journal of Greenhouse Gas Control

Case Study: Aquistore project, SK, Canada

Objectives:

- Demonstrate scientific and economic feasibility of *deep saline aquifer* storage for CCS.
- Assess minimum datasets requirements for assuring safe storage.
- Assess possible induced seismicity driven by CO_2 injection.
- Provide the knowhow for jurisdictions and companies with a safe, workable solution to reduce greenhouse gas emissions.

Project outline:

- Managed by Petroleum Technology Research Centre.
- Commercial-scale project with research partners from 15 countries.
- Combined commercial power plant & CCS facility.
- Reservoir at 3,400 m depth.
- Since 2015 >400,000 tonnes of CO_2 stored.
- Most comprehensive full-scale geological field laboratory for CO_2 storage in the world.
- Accelerate understanding and verify the safety of CCS.

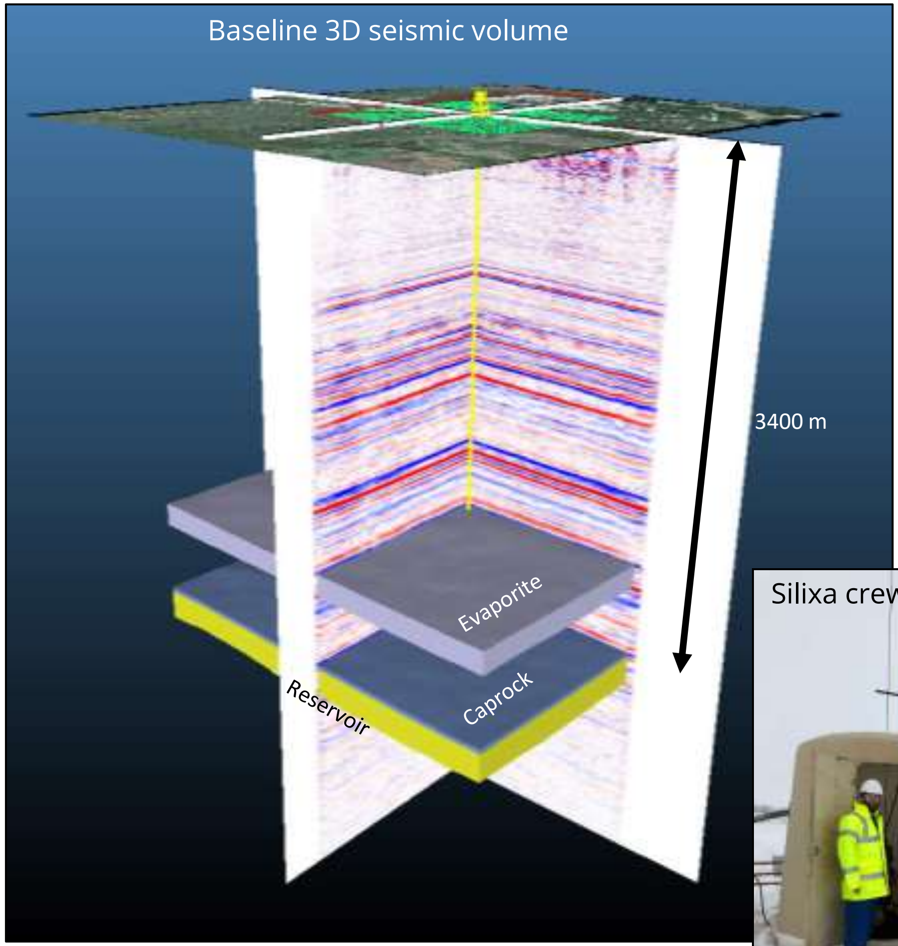
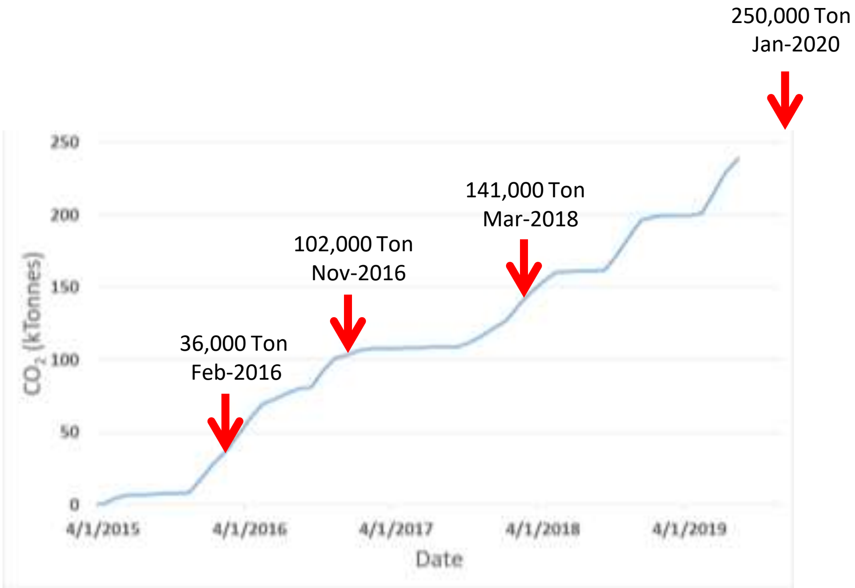


Figure courtesy of Don White, Geological Survey of Canada

Case Study: Aquistore project, SK, Canada

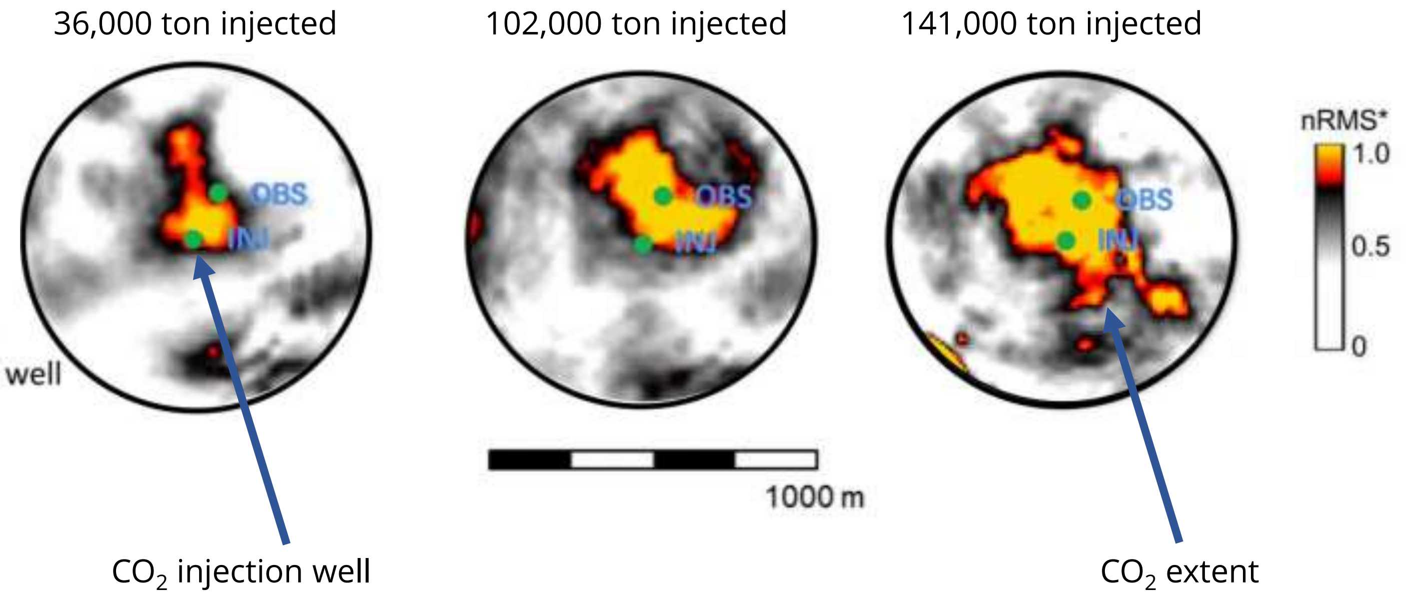


4D DAS VSP
CO_2 Plume Monitoring at >3 km depth

- Repeat dynamite surveys
  - Baseline
  - 4 monitoring surveys

4D DAS Vertical Seismic Profile (VSP)

INJ = Injection well
OBS = Observation well



White et al. 2019 SEG

Distributed Fibre Optic Sensing Technology & Advantages

CCS Monitoring Challenges

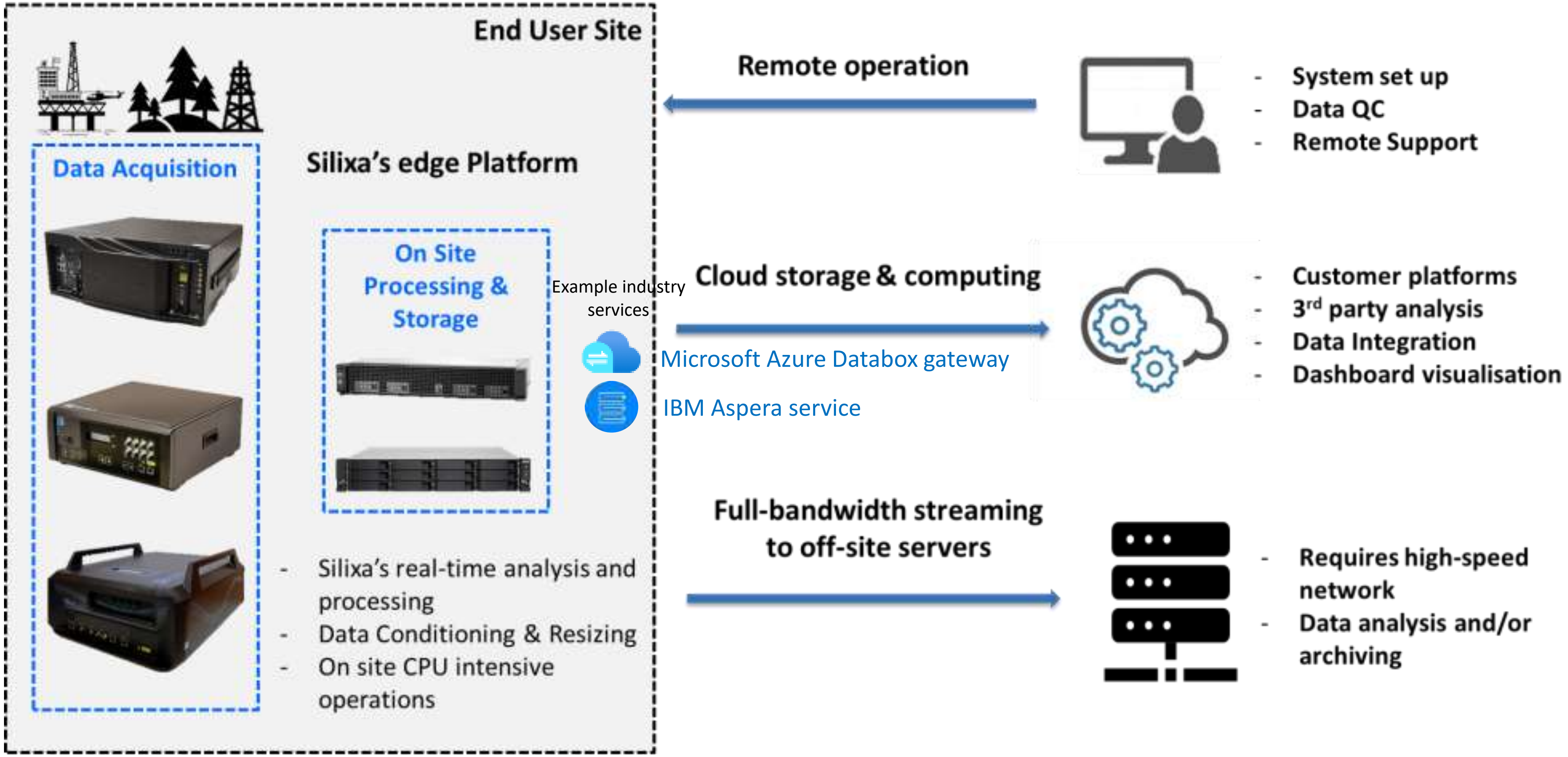
Case Studies

Carina® CarbonSecure™ CO_2 Monitoring Solution

Carina® CarbonSecure™

Solution

- Distributed Temperature Sensing
- Distributed Acoustic Sensing
- Distributed Strain Sensing
- Cementation
- Well Integrity
- Induced Seismicity
- 3D/4D Seismic
- Production/Injection Monitoring
- Flow Metering



Carina® CarbonSecure™: Silixa's Solution for Safe & Economic CCS Monitoring

Complete solution built on 3 integrated distributed optical measurements in one cable, **DAS**, **DTS** & **DSS**:

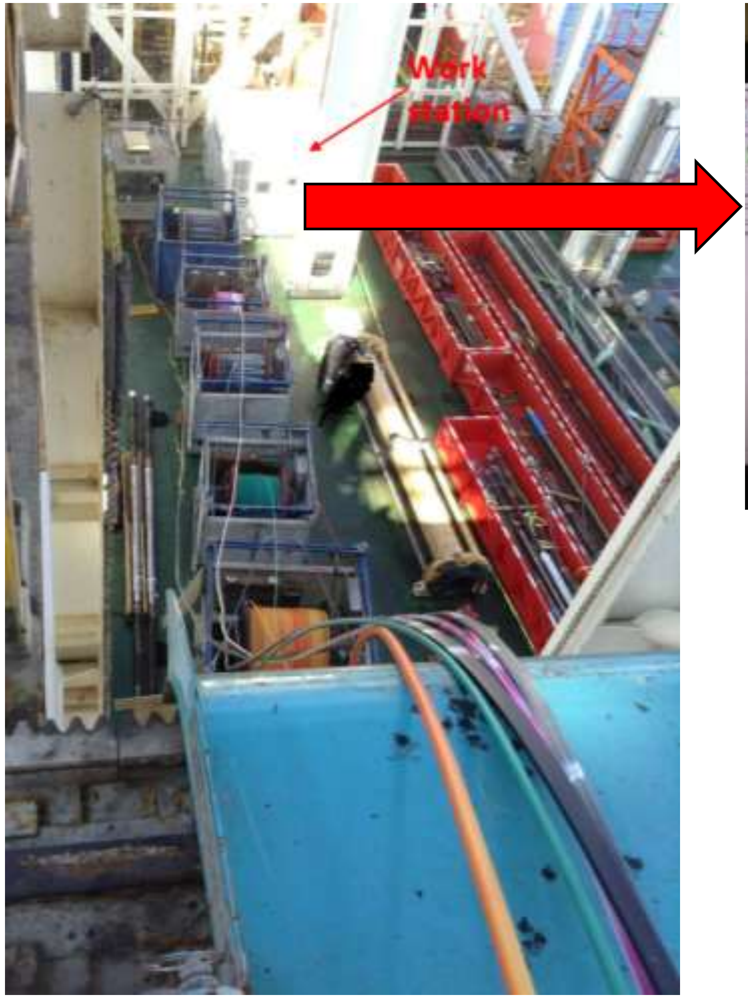
- Assures wellbore and caprock integrity.
- Enables time-lapsed plume mapping.
- Detects induced seismicity.
- When deployed offshore can tolerate long step-out distances up to 150km or more.
- And, reduces cost.

Carina® CarbonSecure™ delivers:

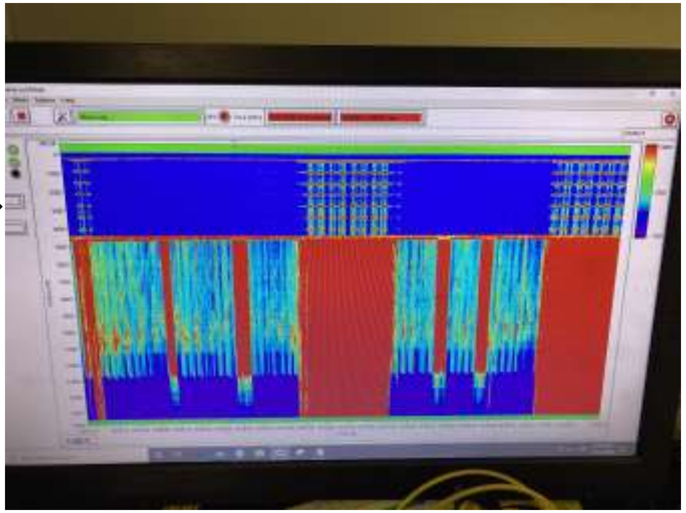
- Verification of the volume of CO_2 stored underground.
- Continuous understanding of CO_2 distribution and movement.
- Assurance of long–term storage integrity.
- Minimal environmental impact.
- Lower life-cycle costs..

SILIXA actionable insight

Offshore Cable Installation



Control lines while RIH



Monitoring DAS while RIH

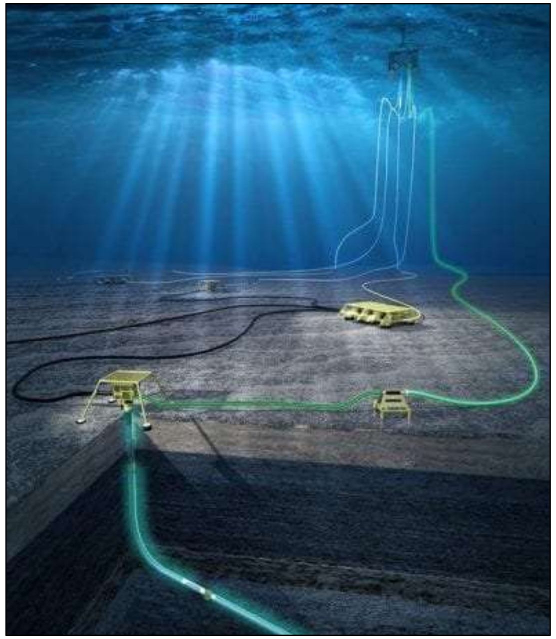
Cost-effective & Proven Subsea Solution

Offshore Conventional VSP Survey

- Light well intervention vessel or jack-up rig,
- Wireline or coil tubing deployment,
- Personnel mobilisation,
- Seismic vessel,
- Duration 8-10 days.

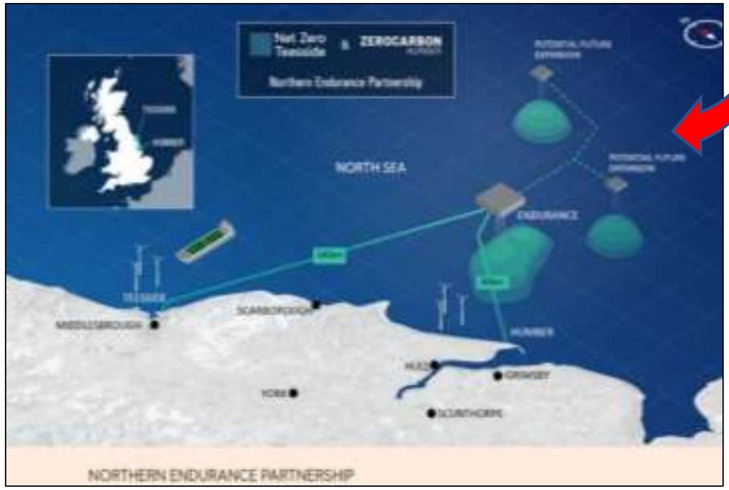
Offshore DAS VSP Survey

- Minimal mobilisation,
- Cable permanently installed,
- Remote operation,
- Seismic vessel,
- Duration 5-10 Days.



World's first subsea DAS system

Planned offshore CSS

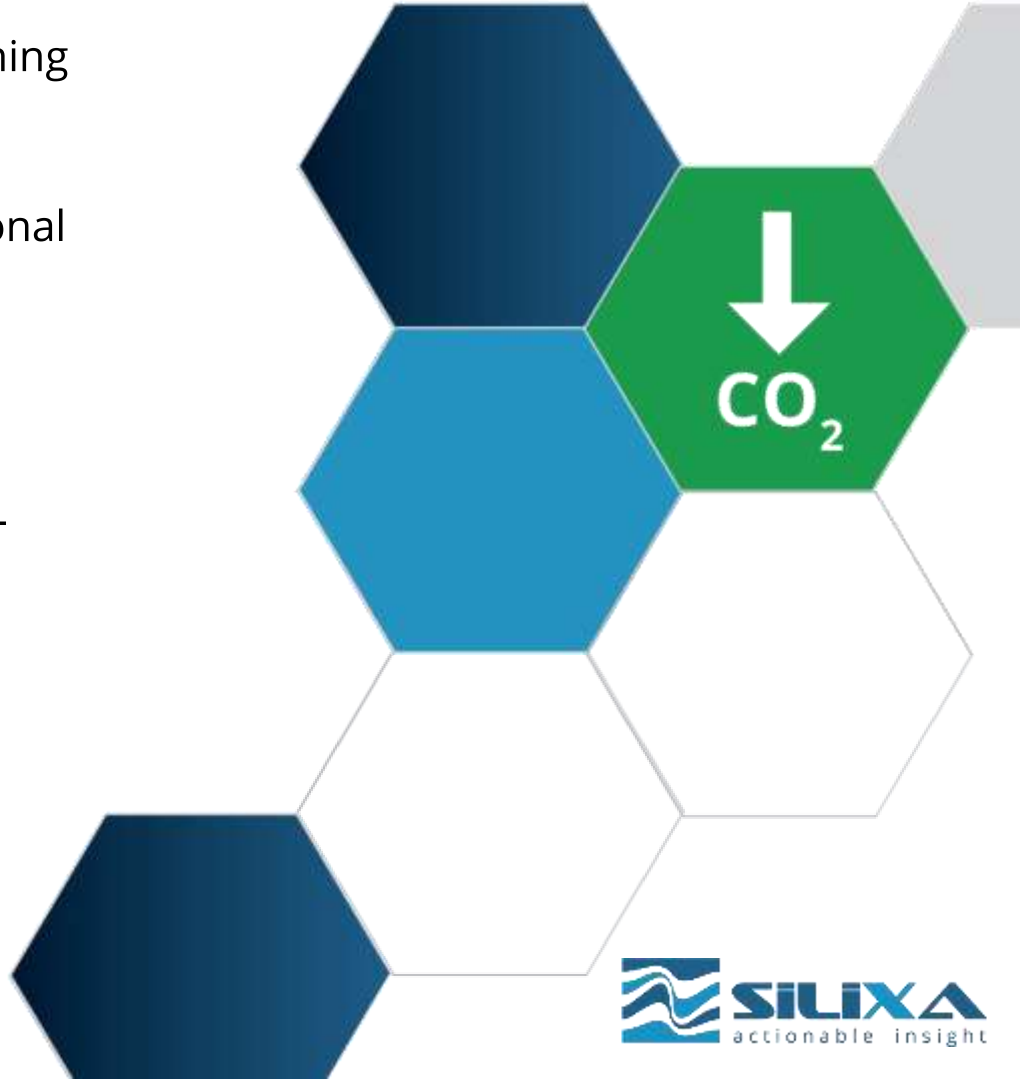


SILIXA actionable insight

Summary

- Safe and secure CCS required during the energy transition phase.
- Comprehensive measuring, monitoring, and verification (MMV) planning is key to ensuring CO_2 safe storage.
- Distributed fibre optic sensing offers a viable alternative to conventional seismic methods by:
  - Reducing monitoring costs,
  - Providing spatially & temporally continuous data.
- Carina® CarbonSecure™ provides a long-term, on-demand, and cost-effective monitoring solution for safe CCS.

Faster CCS adoption worldwide.



Thank you for your attention!

Connect with us at info@silixa.com