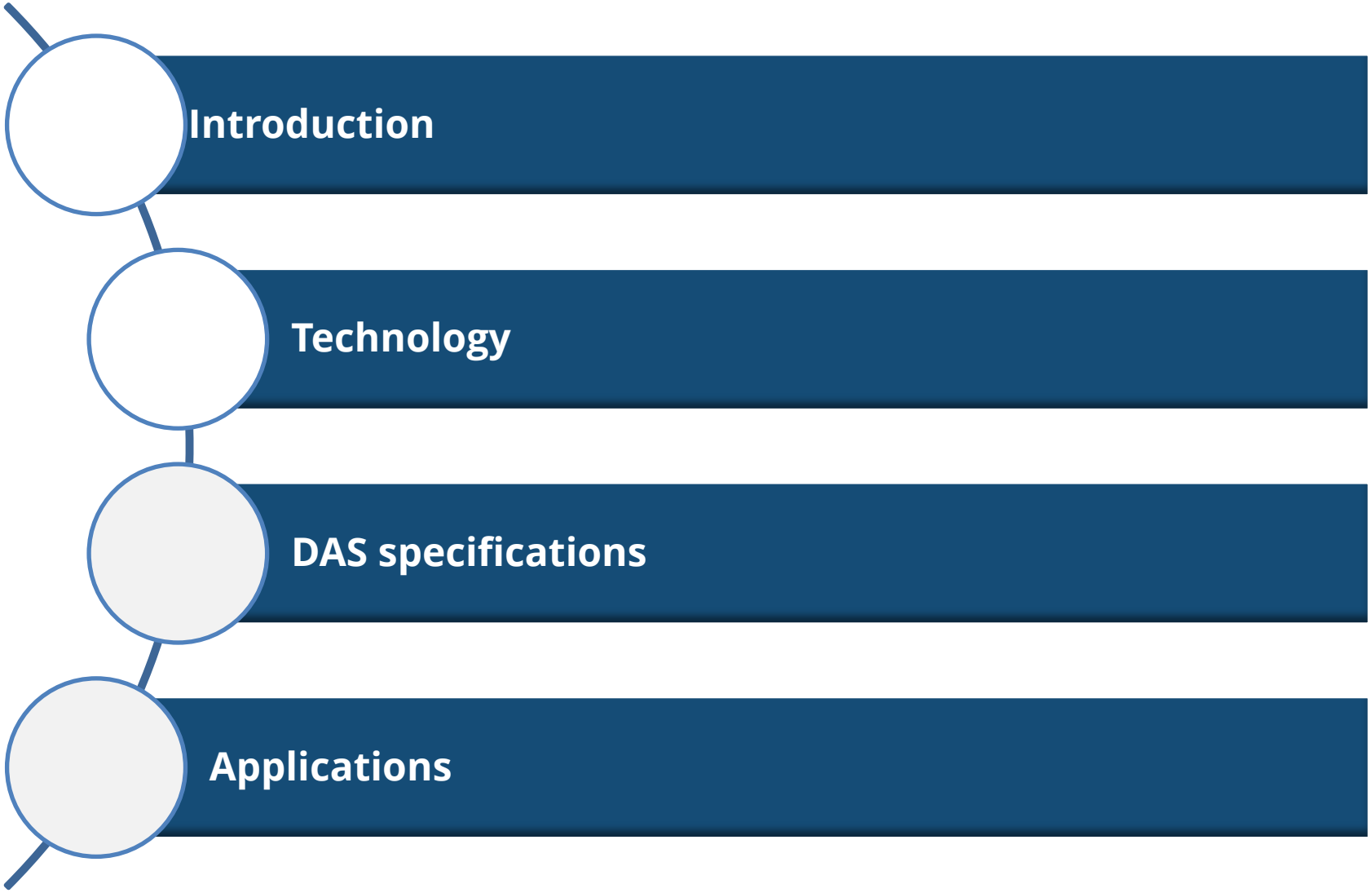
SPIN ITN - Workshop

22/11/20201
Athena Chalari

SPIN
MONITORING A RESTLESS EARTH

SILIXA
actionable insight

Outline



Who are we

We are the global leading independent provider of fibre optic-powered data solutions.

Our suite of integrated distributed fibre optic technologies (DAS, DSS & DTS), provides ultra-high-definition data sets that solve mission critical measurement challenges in the Alternative Energy, Mining, Environmental & Earth Sciences, Infrastructure and Oil & Gas sectors.

Our dedicated domain specific teams use their expertise to deliver world class real-time data solutions. These enable our clients to gain actionable insight into their assets and systems to increase efficiency, prevent loss, reduce operational costs and extend lifespans.

Alternative Energy	Mining	Environmental and Earth Sciences	Infrastructure	Oil and Gas

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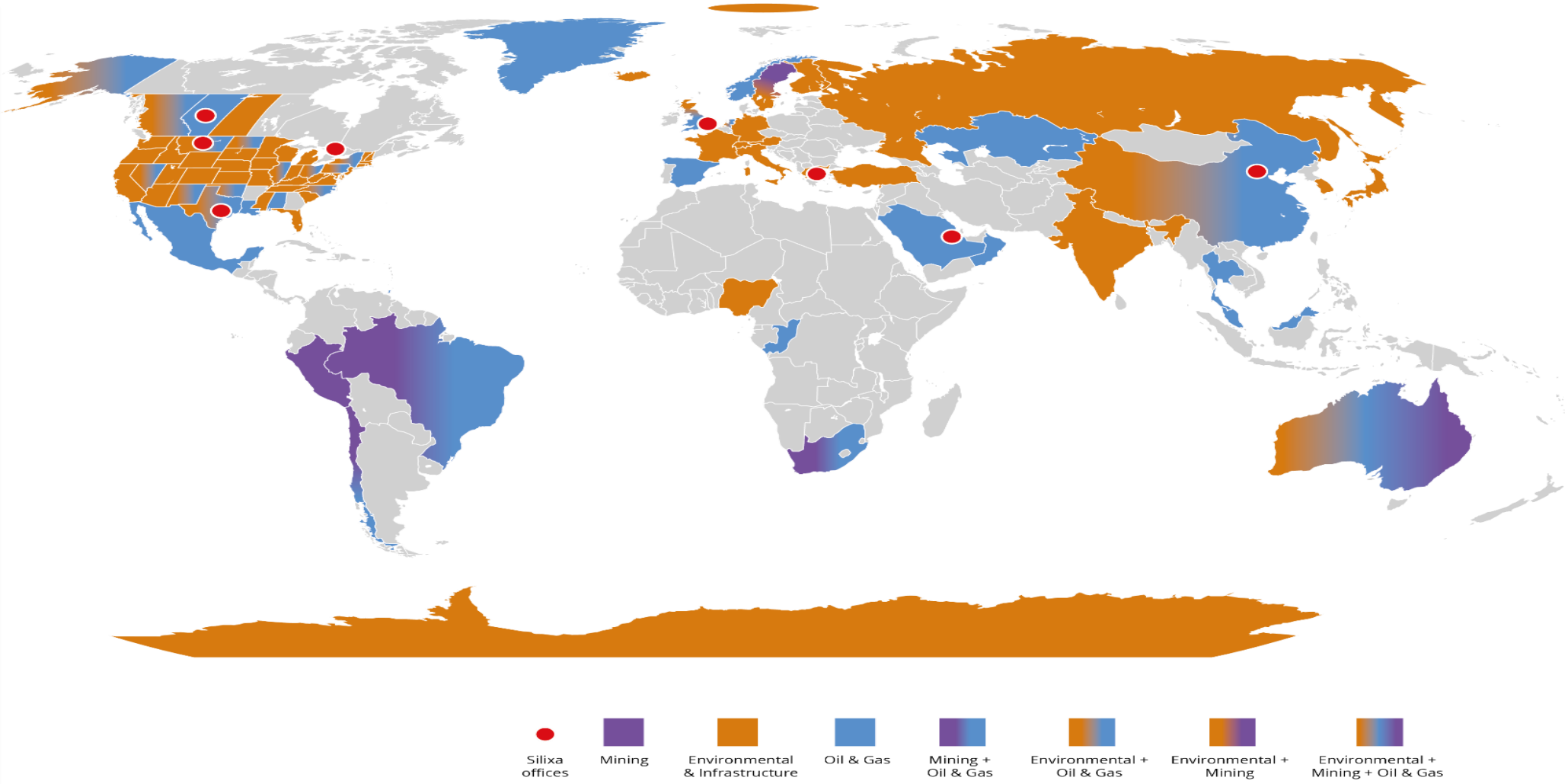
Silixa at a Glance

Institute of Physics Innovation Award 2015

World Oil Award for The Best Deepwater Technology 2020

World Oil Award for New Horizons Idea 2020

Queen's Award for Innovation: Enterprise 2021



14 Years with No Loss Time Injury

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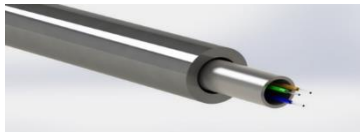
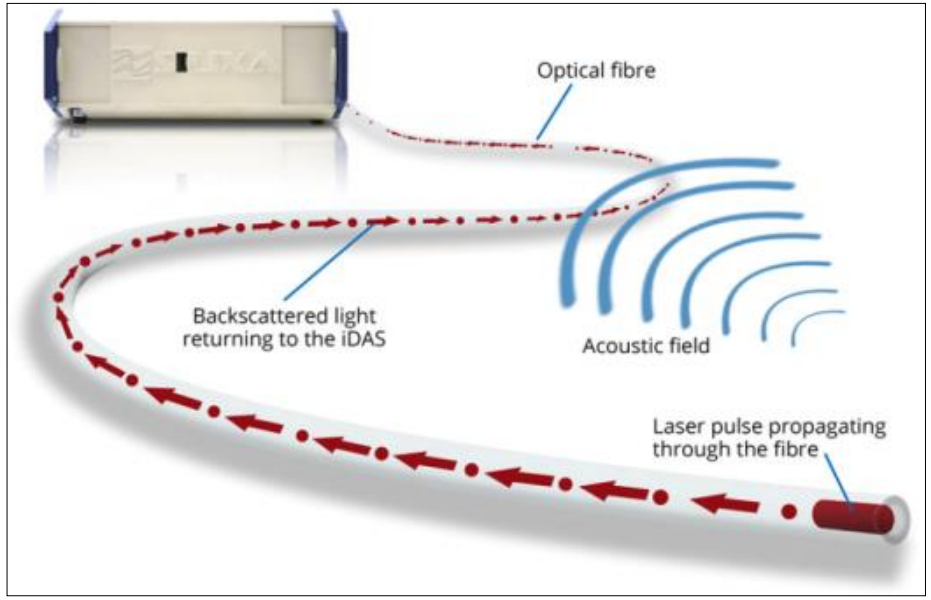
The Fibre Optic Advantage

Conventional borehole geophones and fibre optic Distributed Acoustic Sensing (DAS)

- Bulky, not well suited to permanent deployment
- Limited number of channels
- Multicomponent
- Single acoustic parameter system

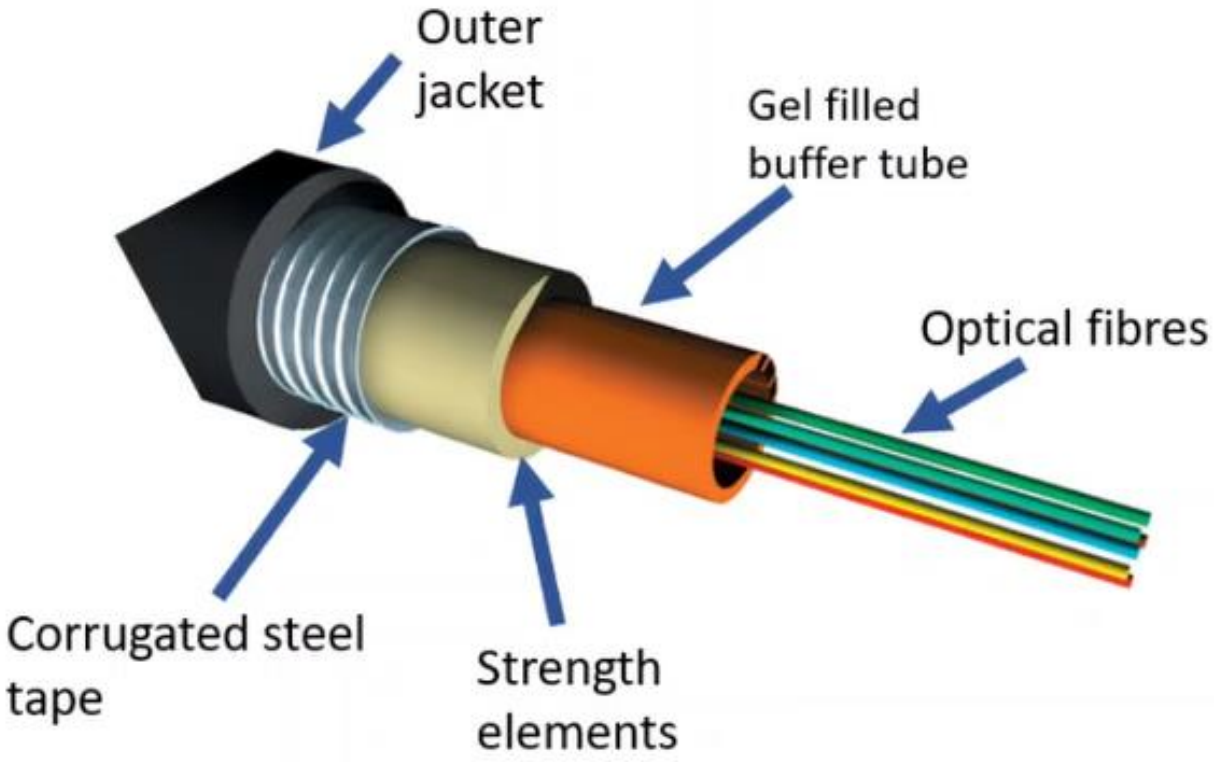


Cable with multiple optical fibres



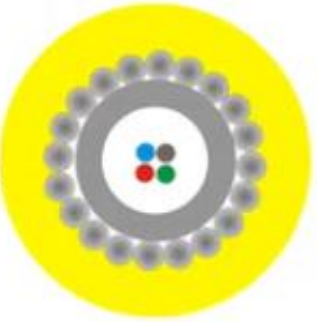
- Slim package for permanent deployment
- Deployed in downhole and surface Cables
- Dense array giving fine spatial sampling
- Single seismic component only
- Cost effective permanent monitoring system
- Multiple Parameter system, DAS, DTS & DSS

Cable types



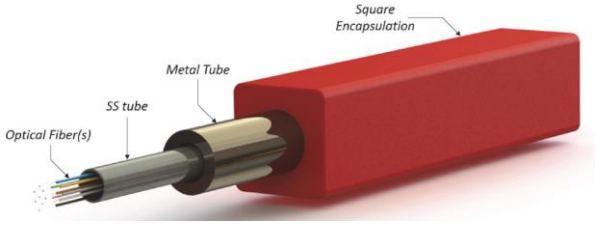
Double Steel Tube Deep Borehole

Single Steel Tube Shallow borehole



All Polymer Surface

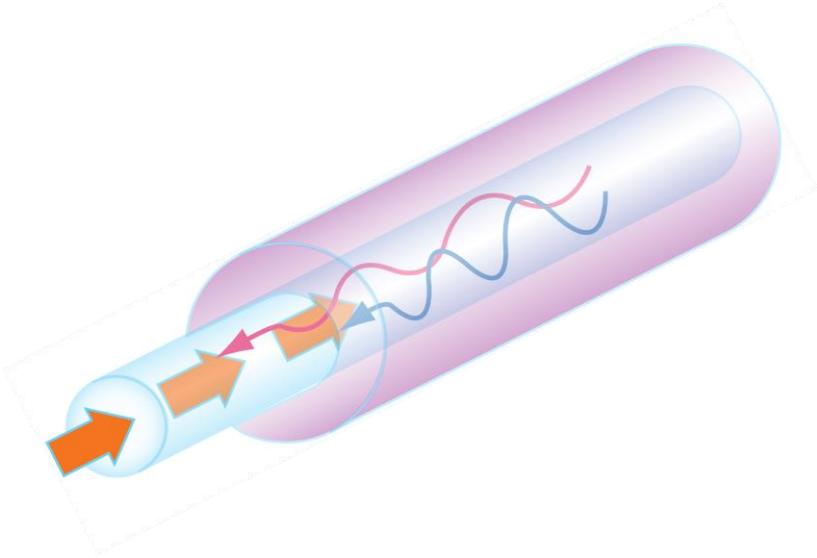
….Or just use Dark fibres in telecom networks



Basic optical principles – light loss in optical fibre

Optical fibre attenuation

- **Diffuse Reflection or Scattering**
- Absorption at specific wavelengths
- Bending
- Optical fibre joints, splice connectors



Scattering

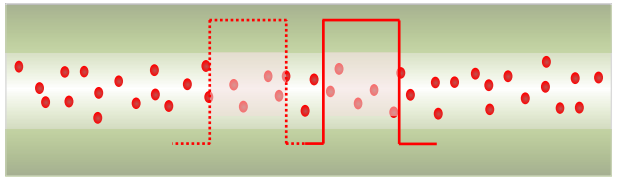
- **Rayleigh**, elastically scattered photons (same wavelength)
- **Raman**, scattered photons having a different wavelength caused by the effect of vibrational and rotational molecular transitions related to the energy states
- **Brillouin** scattered photons having a different wavelength caused by large scale low frequency vibrational motion of a lattice of atoms

Distributed Optical Fiber Sensing Technology

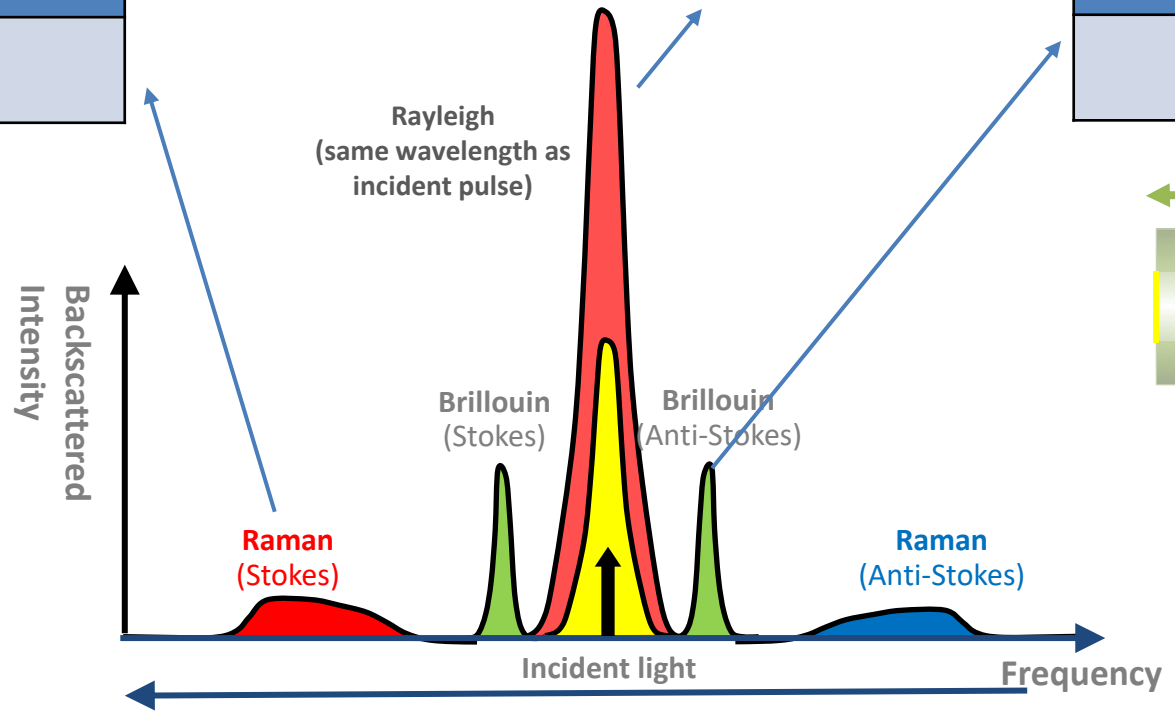
MK2 Ultima	MK2 XT
Temperature (DTS) 0.01ºC Resolution	

IDAS v2	Carina v3
Acoustics (DAS) >120dB Dynamic range	

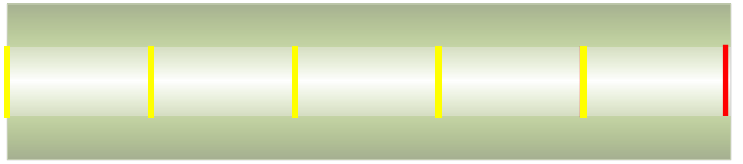
Carina DSS	Fiber Ruler
Strain (DSS) 1 με Resolution	



Standard fibre



Enhanced backscattering



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

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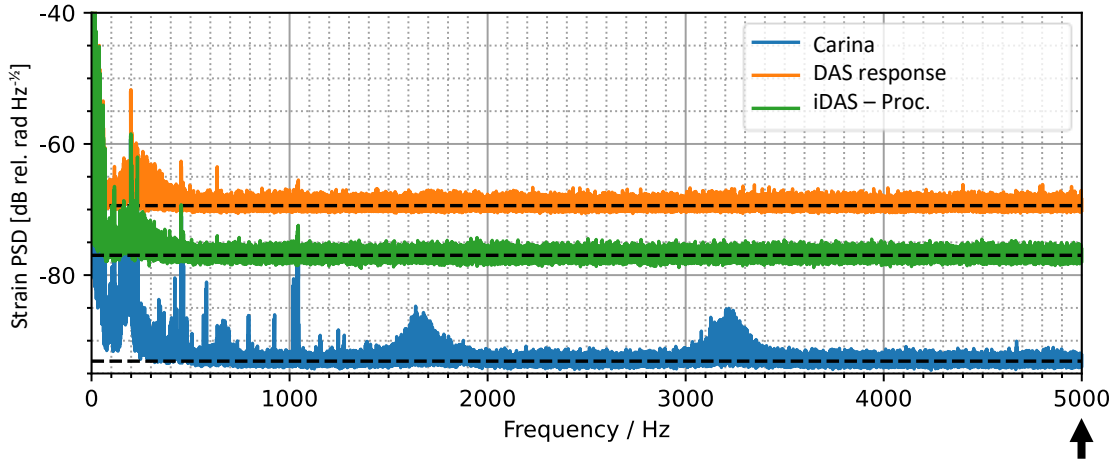
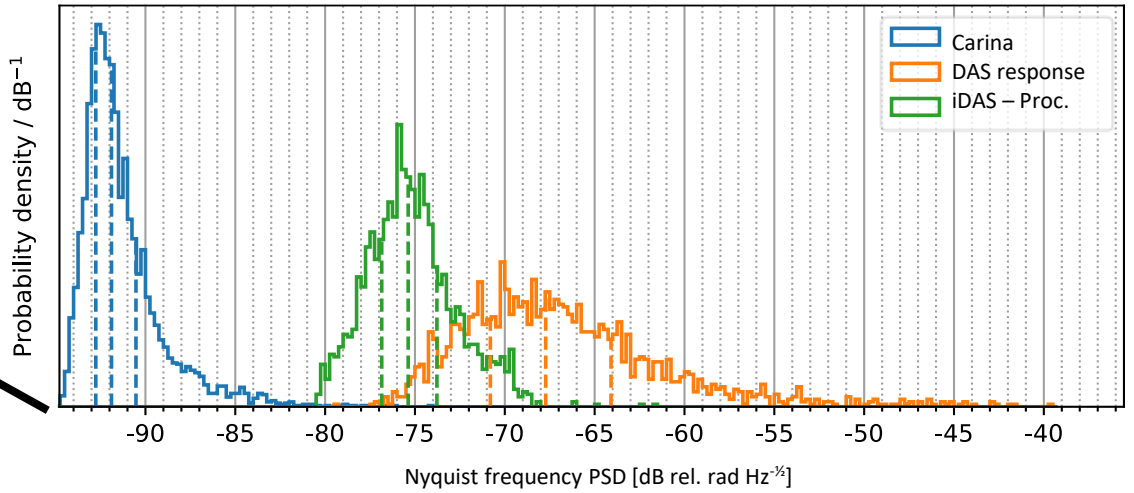
Noise Definition

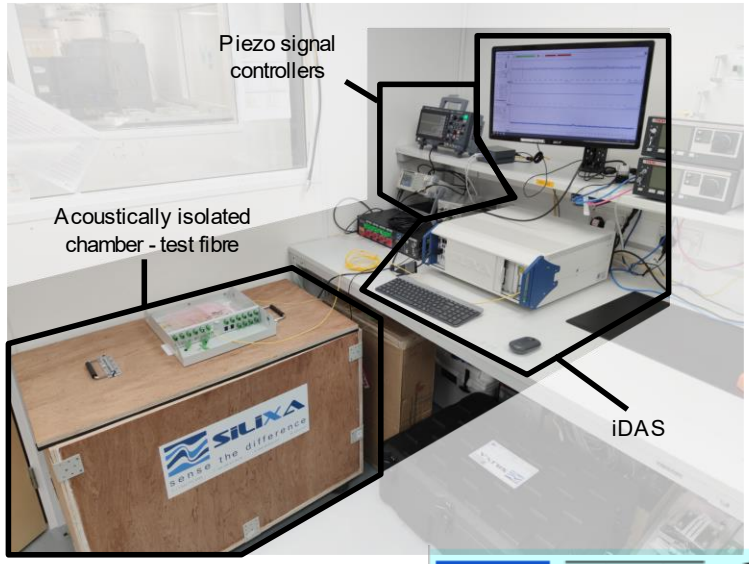
Strain power spectral density (PSD) shows the frequency breakdown of strain noise – median along fibre shown



Nyquist 5 kHz

Spatial consistency of noise is shown by histogram of Nyquist frequency noise along fibre





- Oversampling giving significant noise reduction through weighted spatial averaging without affecting signal.
- No (phase noise) accumulation of noise over distance (iDAS – Proc)

DAS Parameters Summary

Parameter	Units
Gauge length	m
Spatial sampling	cm
Noise performance	pε $Hz^{-½}$
Dynamic Range	dB
Maximum Range	km
Acoustic frequency range (min/max detected)	mHz, Hz, kHz

- **Minimum phase noise [*Interferometric technique*]**
- **Minimum Noise - High Sensitivity – Large dynamic range [*noise floor*]**
- **No crosstalk between channels [*spatial resolution*]**
- **Repeatable measurements for seismic applications [*low frequency*]**

Applications

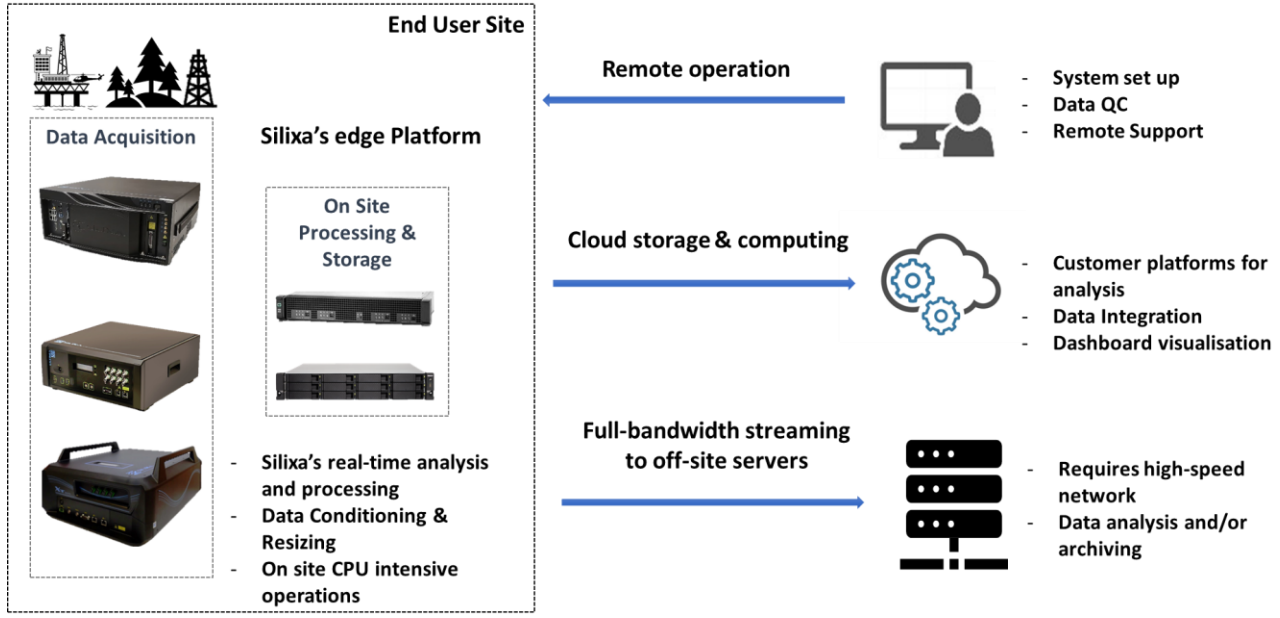
Carina® CarbonSecure™ Summary

Solution

- Distributed Temperature Sensing
- Distributed Acoustic Sensing
- Distributed Strain Sensing
- Structural Faulting
- Induced Seismicity
- Well Integrity
- Plume Migration
- Cap Rock Integrity

Carina® CarbonSecure™

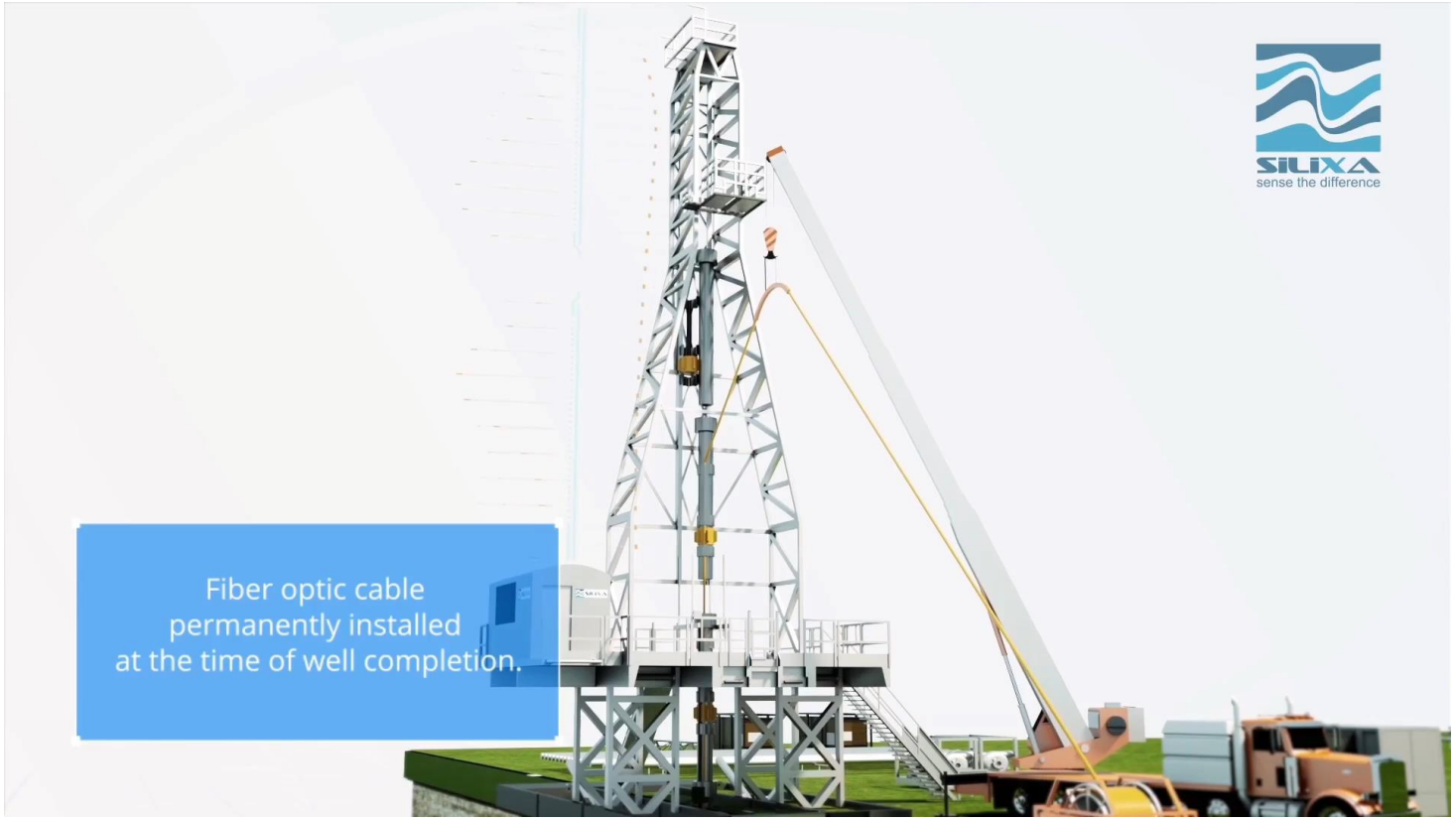
Real time, on line, modular, monitoring platform.



Benefits

- Cost Effective Solution
- Suitable Onshore or Offshore Operations
- Large Spatial Coverage
- Continuous Monitoring or On Demand
- Capable of Remote Operation
- Low Energy Consumption
- Low cost of ownership
- Minimum impact to the Environment
- Long lifetime

Carina® CarbonSecure™ Silixa's Solution for Safe & Economic Storage of Co2

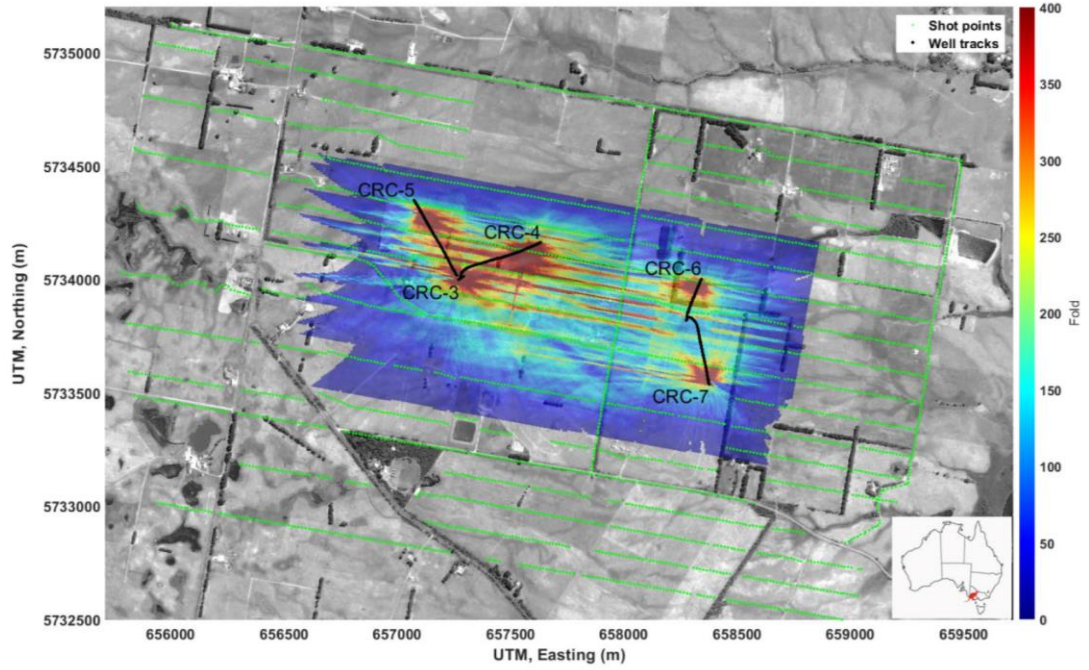


- **Carina ® Sensing System is the core of the most cost effective permanent monitoring solution because of the 100x improvement in SNR.**
- **Complete solution** built on 3 integrated distributed optical measurements in one cable, DAS, DTS & DSS.
- Addresses current **Pain Points**
  - Wellbore and caprock integrity
  - Plume mapping
  - Induced seismicity
  - Long step-out distances up to 150km
  - Cost
- Carina CarbonSecure **delivers**:
  - Verification the amount of CO_2 being stored underground
  - Understanding of CO_2 distribution underground
  - Provides assurance of long–term storage integrity
  - Minimizes environmental impact.
  - Gives lower life-cycle costs.

CO2CRC Otway project, VA, Australia

Reducing the *cost* of CO_2 *monitoring* by tens to hundreds of millions of dollars over the life of a commercial project and *further development* of CCUS programs

- Onshore CUS in rural area
- 15,000 tonnes CO_2 injection by 2022 at 2.1 km
- Need to reduce environmental footprint
- 2014 first optical fibre cable installed
- 5 wells now equipped with the Carina Sensing System
- Additional helically wound surface fibre optic cables
- Over 40 km of optical fibre installed (2020)
- Multiple low impact/low cost SOV's
- Capable of remote passive or continuous monitoring



Optimal solution for surveillance of CO_2 Sequestration

(EAGE Workshop on Fibre Optics Sensing for Energy Applications)

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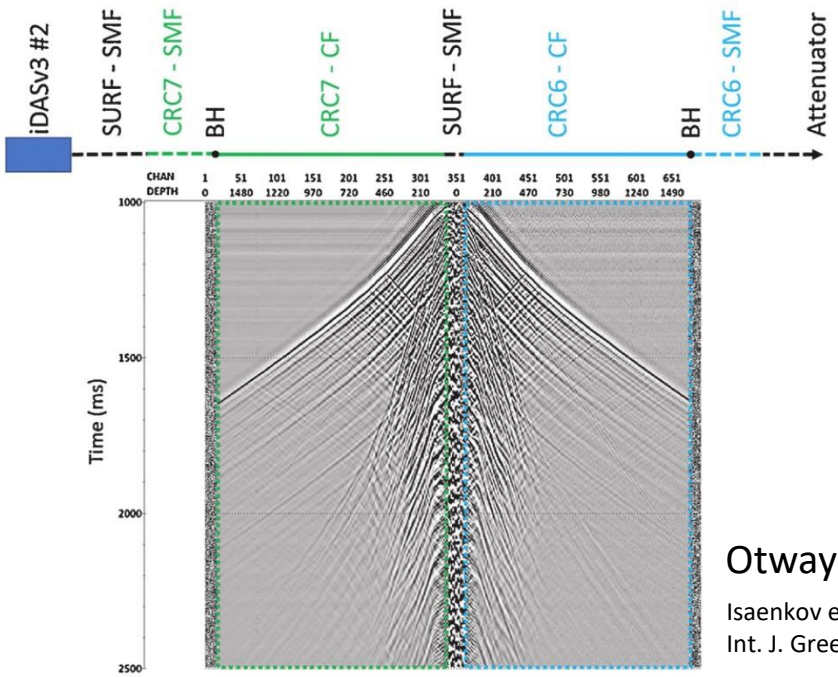
Flexible installation methods – Otway & Geolab sites

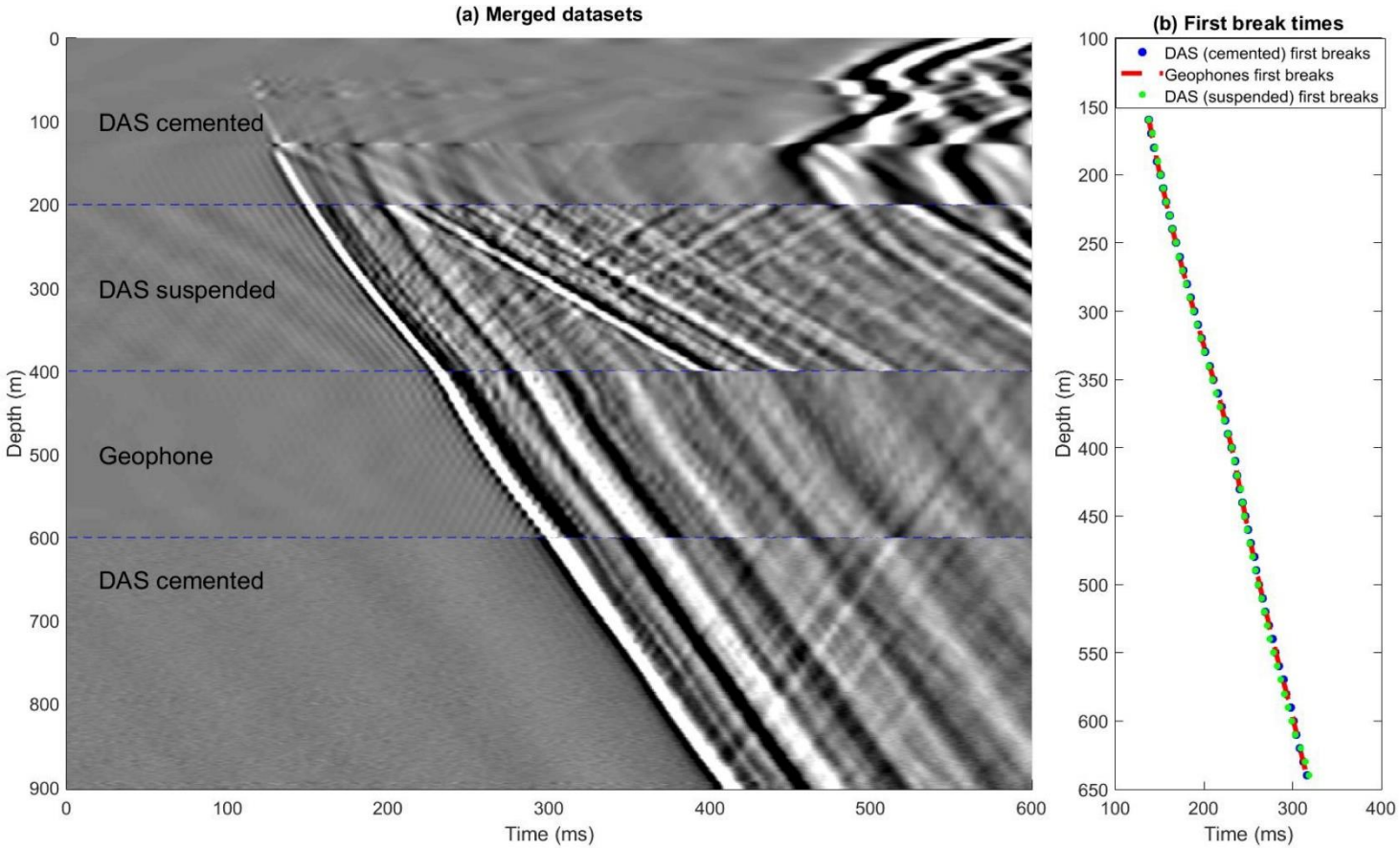
- Cable can be
  - ✓ cemented behind casing,
  - ✓ deployed on tubing,
  - ✓ suspended,
  - ✓ or via wireline.
- Multiwell acquisition



Otway CO2CRC site

Isaenkov et al. 2021.
Int. J. Greenhouse Gas Control

Data recorded at Curtin University Geolab site

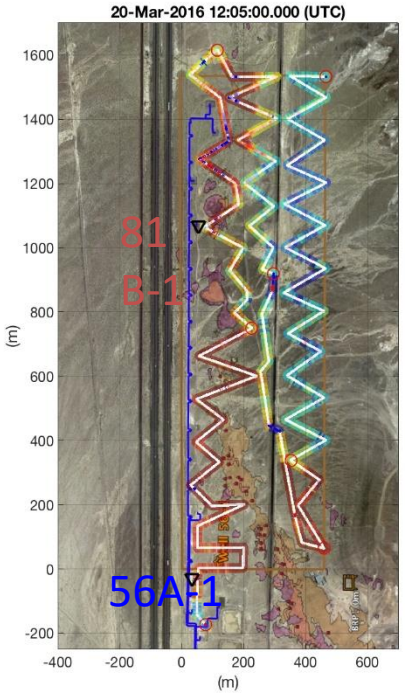


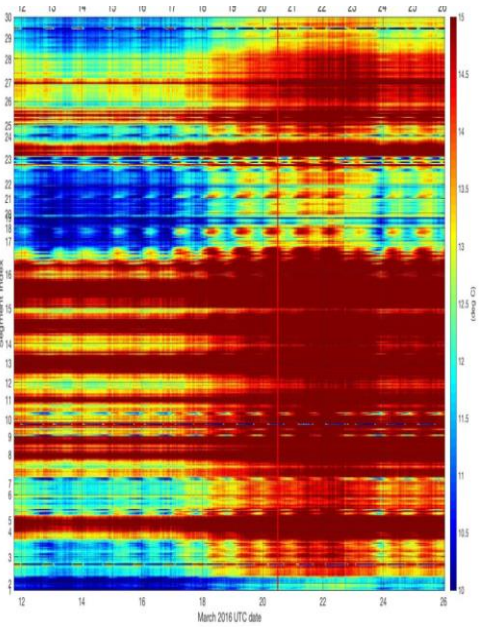
Correa et al. 2017. Fourth EAGE Borehole Geophysics Workshop

POROTOMO -Brady Hot Springs

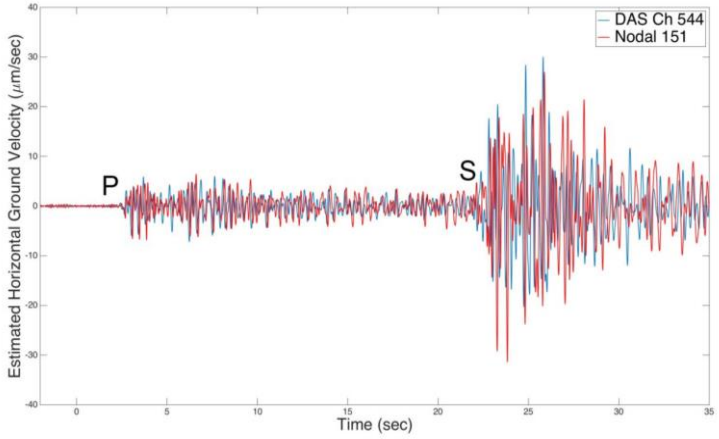
DAS and DTS were recorded continuously over 15 days while a series of changes to pumping and injection were made.

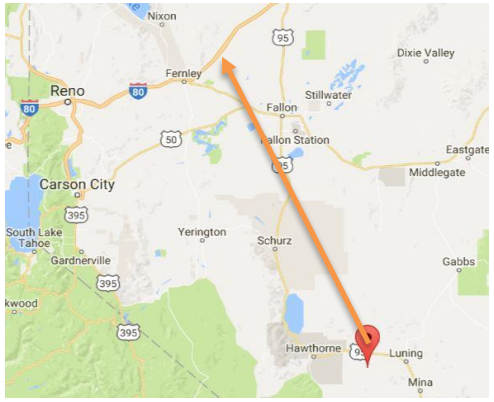
- DAS and DTS data were collected using a single cable with multiple optical fibers
- Horizontal/Trenched
  - ~8,500 m buried cable length
  - Buried 1 m
  - Sample spacing 1 m (DAS and DTS)





(modified from Miller et al., 2018)



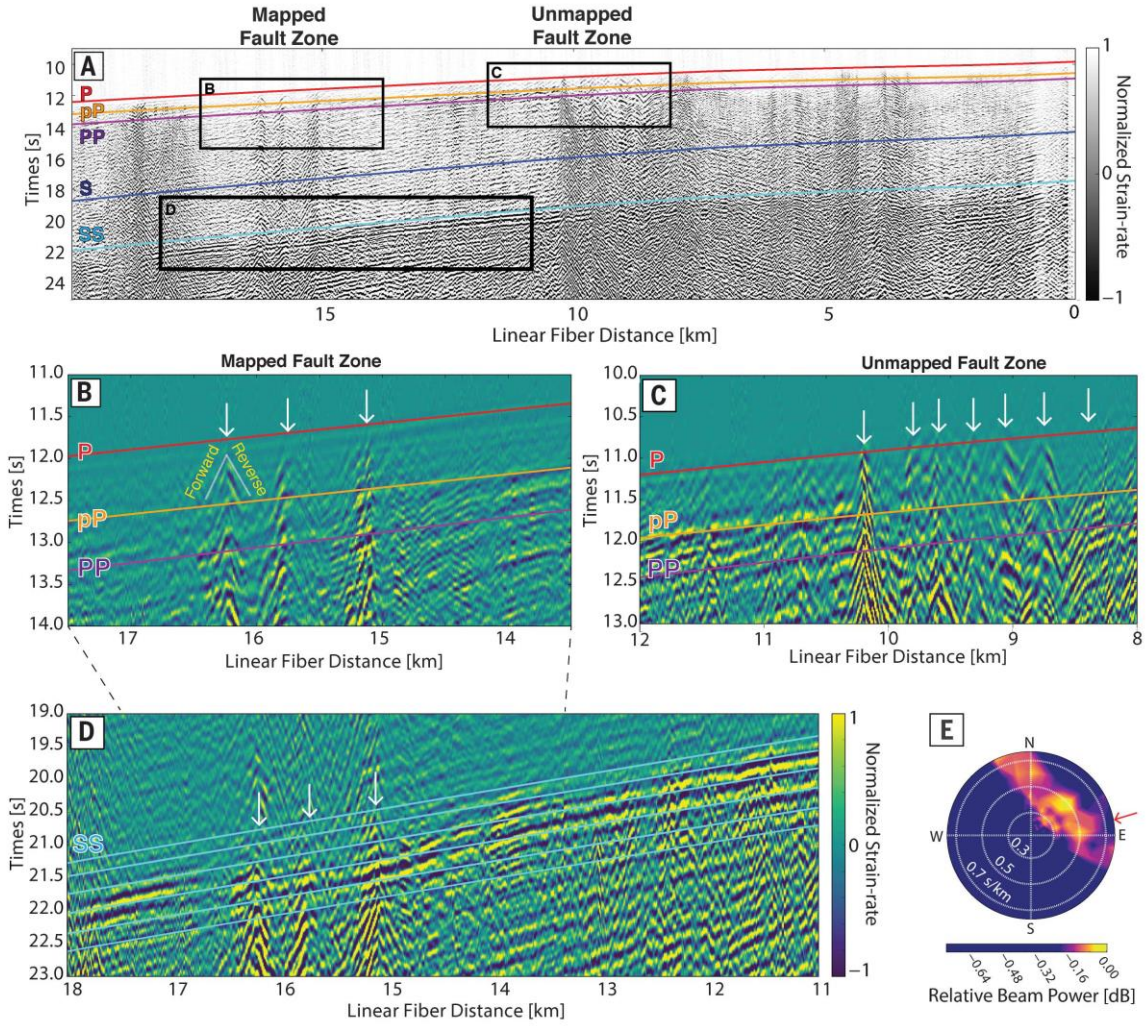


4.3 earthquake that occurred near Hawthorne, Nevada.

Time series of ground motion as recorded by DAS and a co-located Nodal seismometer.
(modified from Feigl et al., 2017).

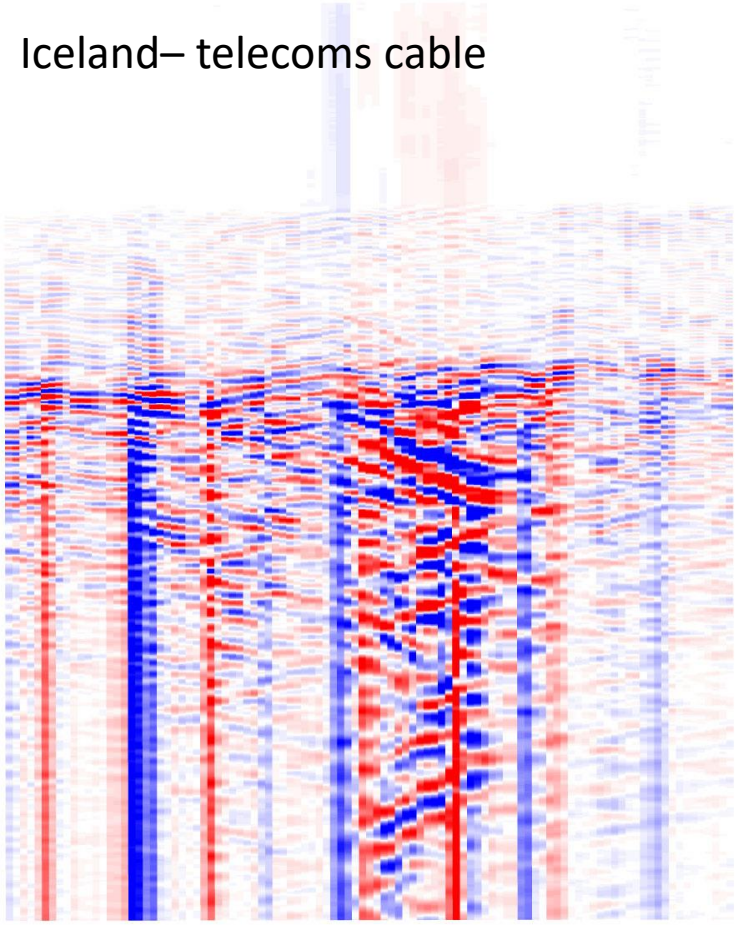
Case Studies– Mapping fault zones

Monterey Bay, California – offshore science cable



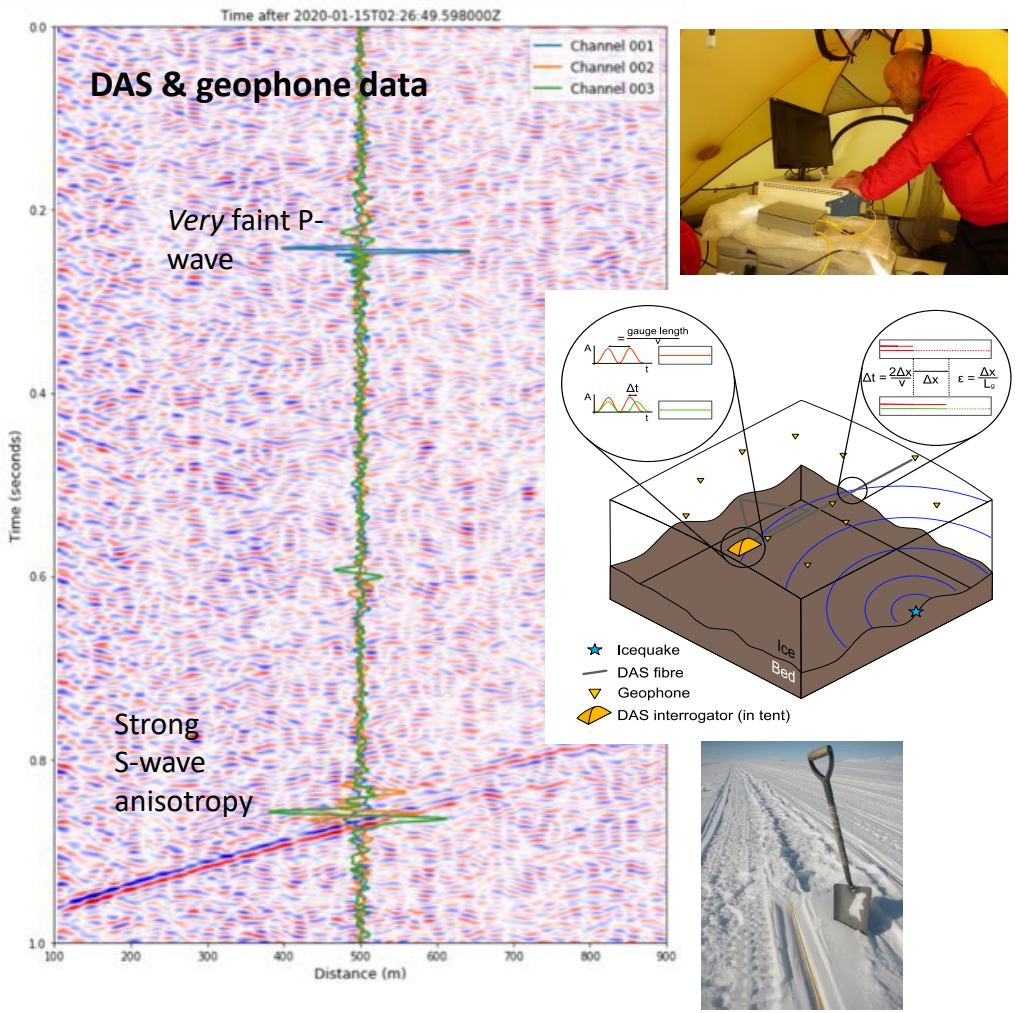
Lindsay et al., 2019

Iceland– telecoms cable



Jousset et al., 2018

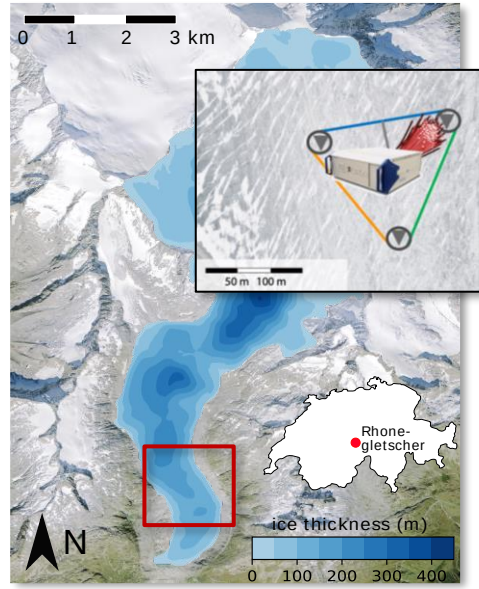
Microseismic, standard SM fibre, surface – Icequakes

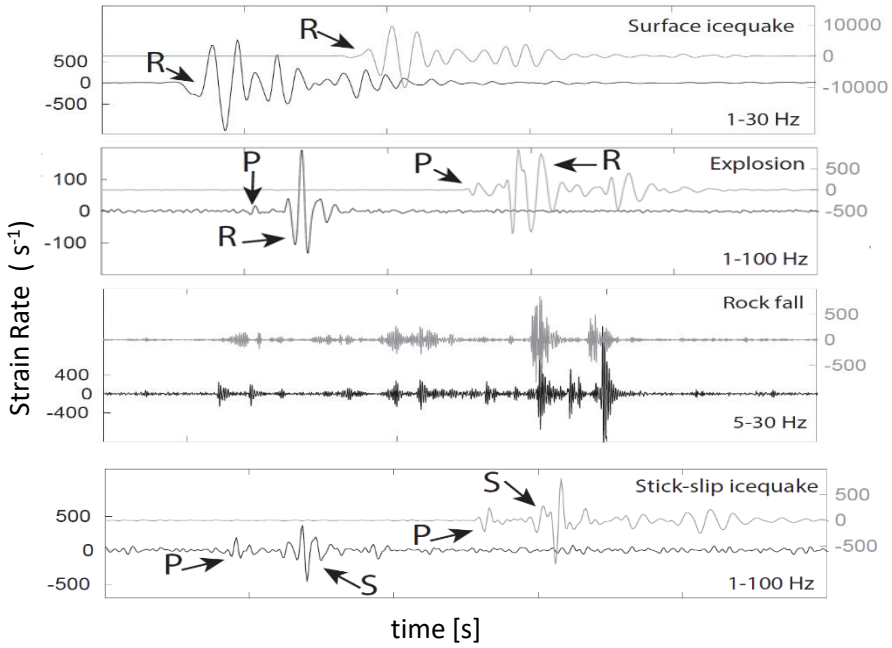


Images courtesy of Mike Kendall & Tom Hudson (University of Oxford); Antony Butcher (University of Bristol)

Rhone Glacier

- 8km surface trenched cable
- Flow velocity 35 m/y
- Ice thickness 200m





co-located channels

- DAS strain rate [10^{-9} s^{-1}]
- seismometers [nm s^{-1}]

Images courtesy of Andreas Fichtner (ETH) and from Walter et al. 2020

Geotechnical Monitoring Solutions

DTS (temperature)

Passive or Active Seepage Detection

- Seepage flow monitoring
- Water level

DSS (strain)

Subsidence and Deformation Monitoring

- Identification of locations with deformation
- Dam/levee breach detection

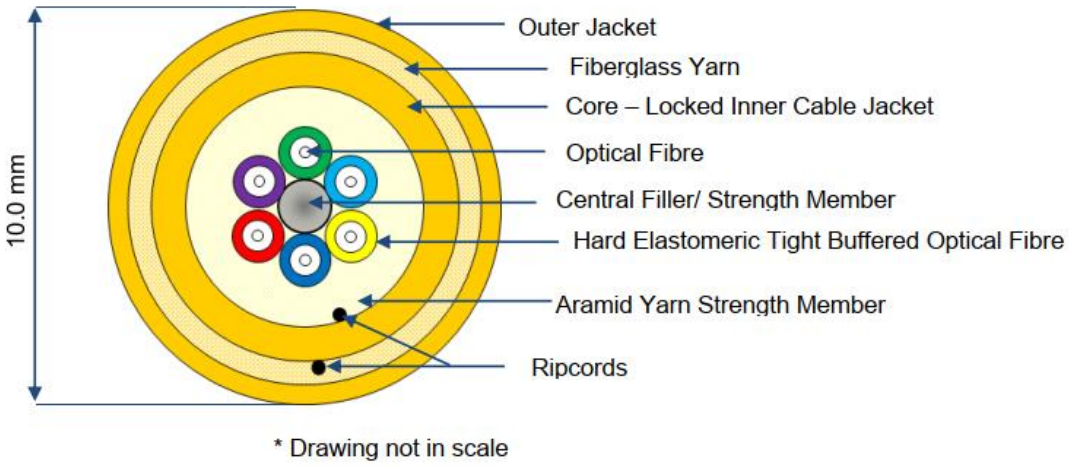
DAS (acoustic)

Subsurface Tomography / Imaging

- Material property changes
  - Density
  - Saturation

Microseismicity monitoring

Example Direct Bury Fiber Optic Cables



* Drawing not in scale

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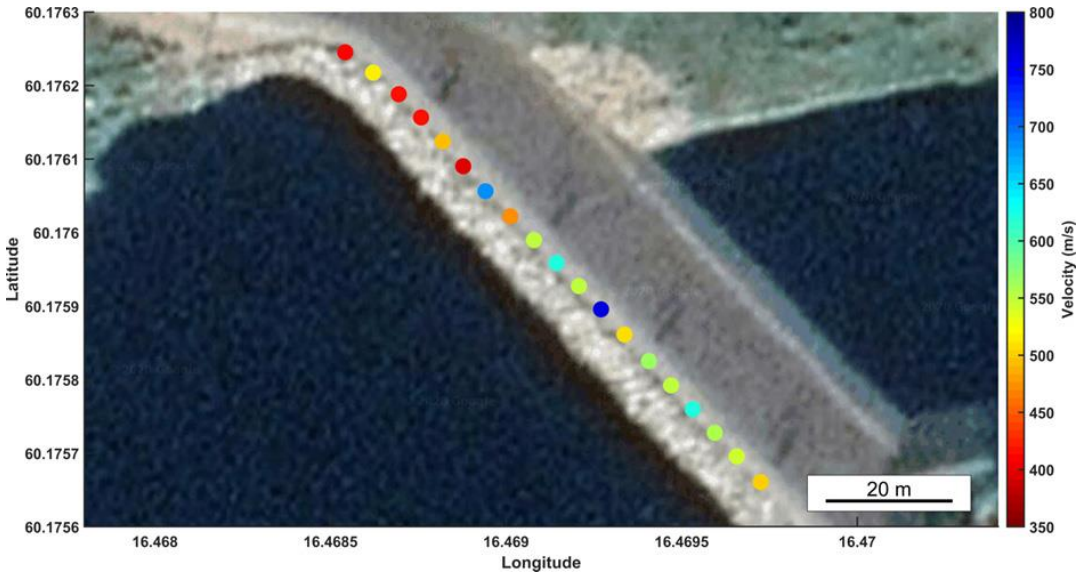
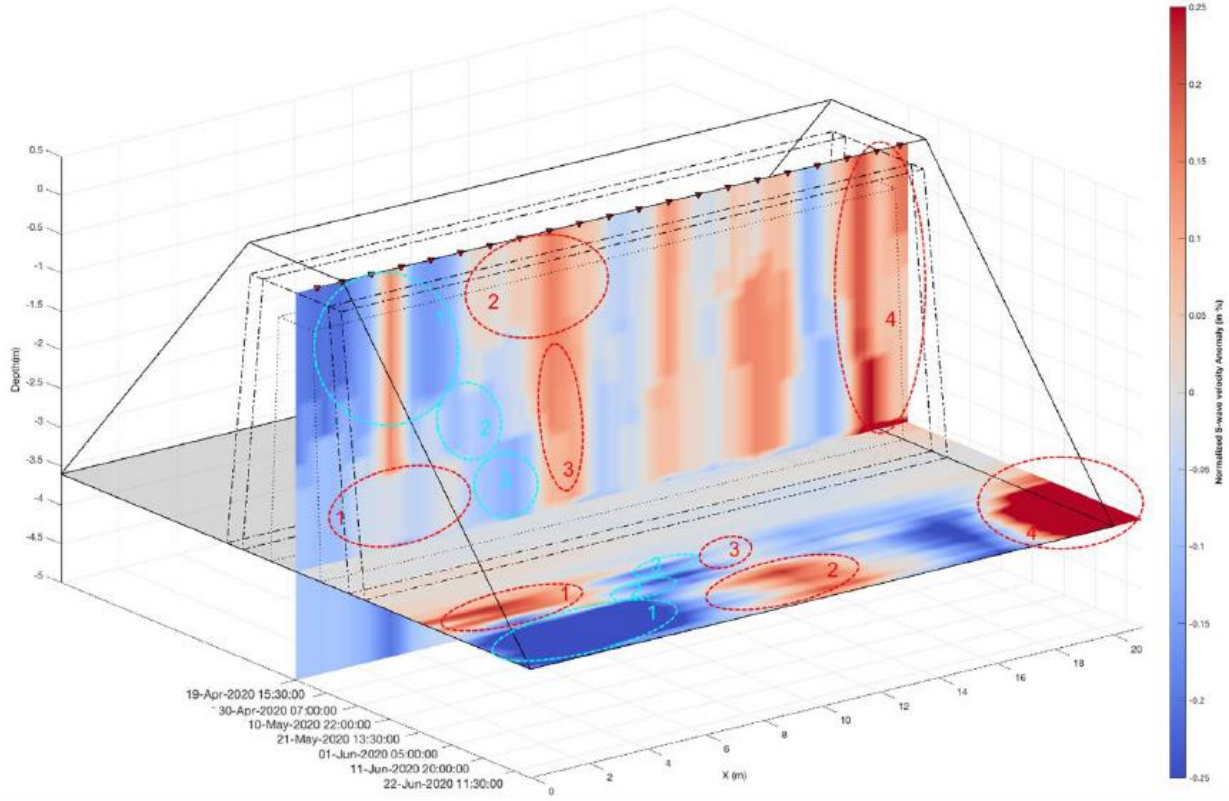
Ambient noise seismic interferometry

- Small scale & large dams
- Imaging & monitoring
- Body-waves, surface waves, coda waves
- Cables buried at crest & in dam – permanent installations
- Gauge length comparison



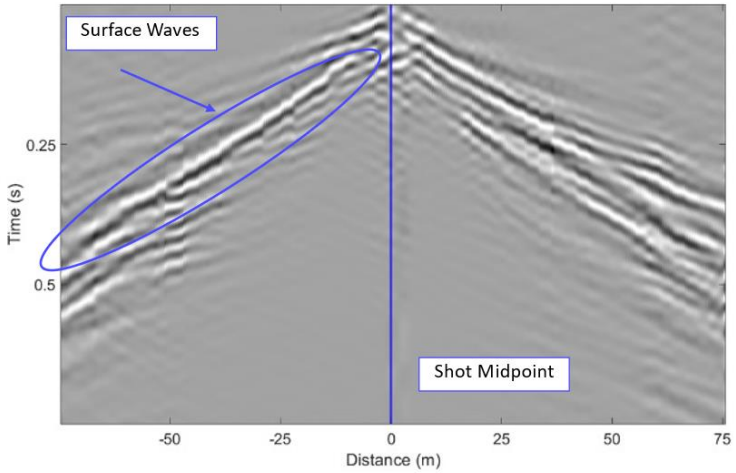
Body wave velocities

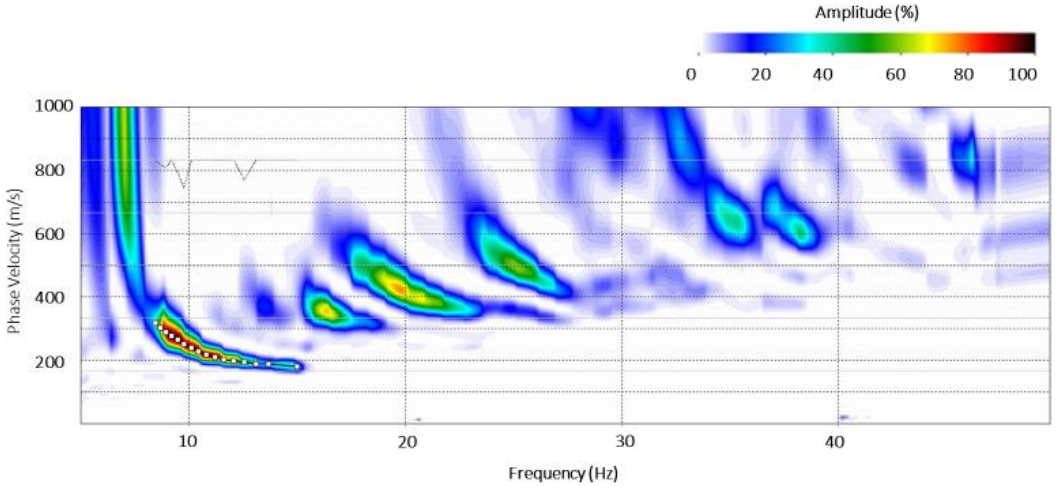


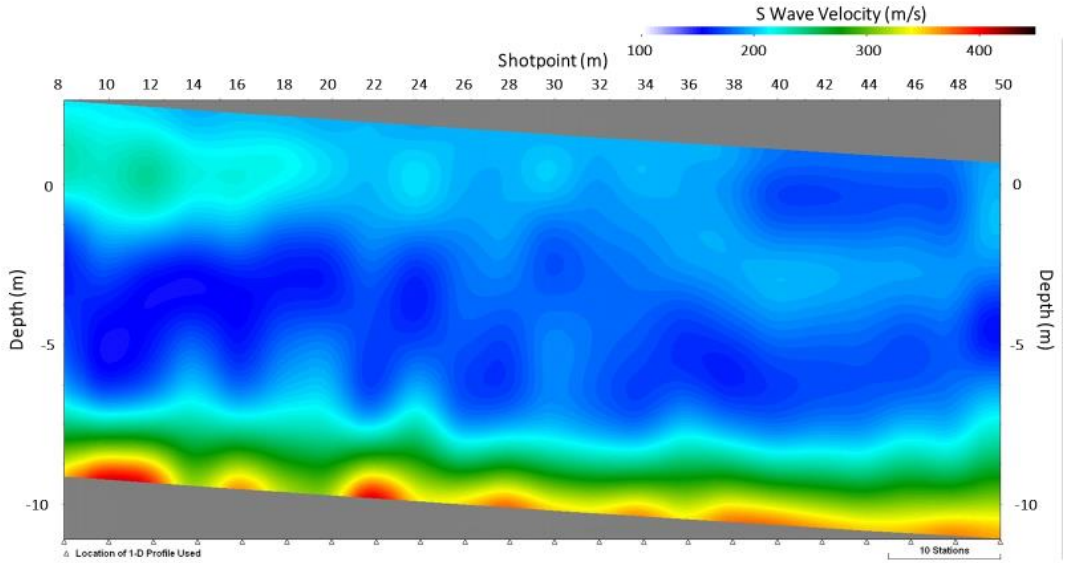
Coda wave imaging & monitoring

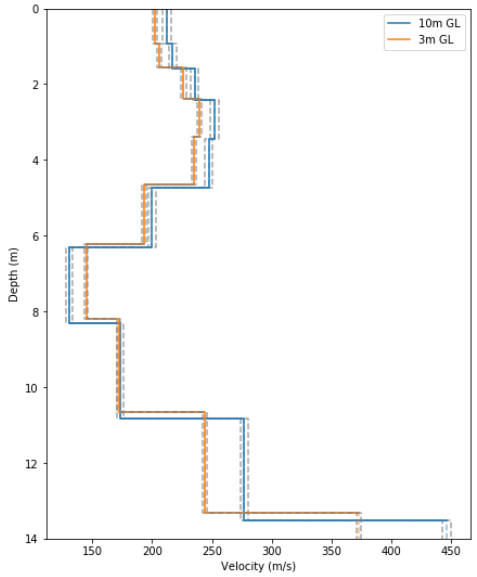
Active MASW

- Gauge length comparison
- 100s m survey length without large field team









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Thank you for listening!
Any questions?