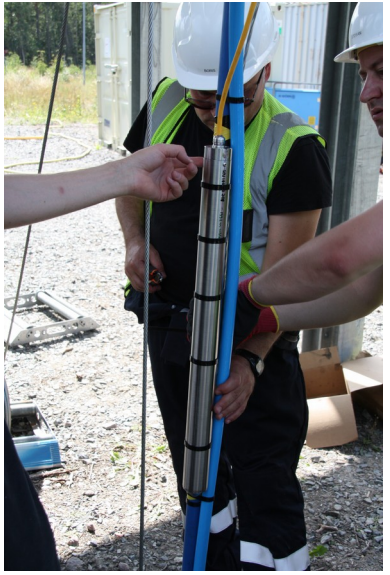
UPPSALA UNIVERSITET

Comparing high-sensitivity geophones to fiber-optic DAS technologies in a hard-rock VSP survey



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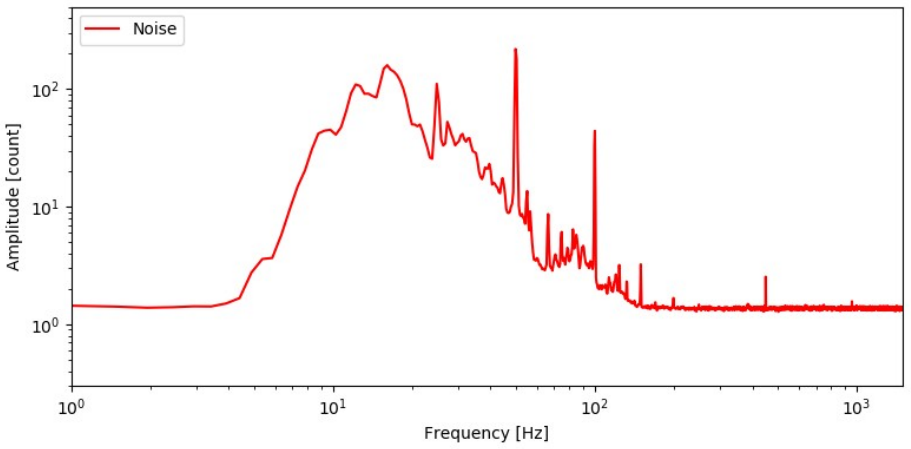
[3]HydroResearch

SILIXA sense the difference

HydroResearch

Preparing for a local seismic network at the proposed nuclear waste repository in Forsmark, Sweden

The nuclear waste repository will be located next to the three nuclear power plants in Forsmark.



Noise spectrum, 14 Hz vertical near-surface geophone.

The repository area is significantly affected by

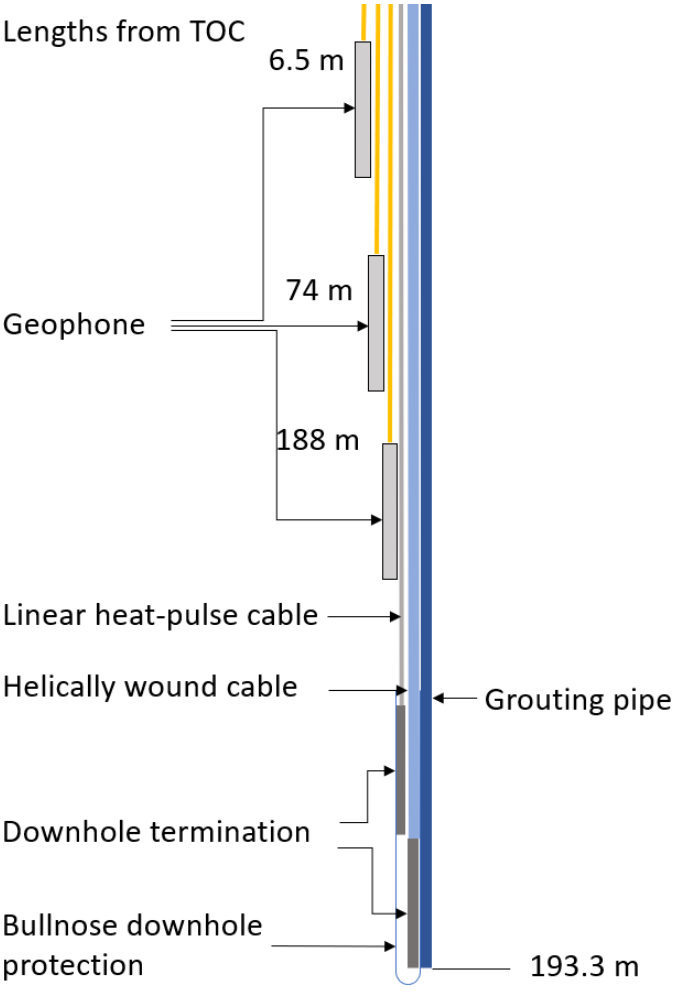
- Mechanical noise induced by the power plants
- Electromagnetic noise from the power distribution, and the power cable to Finland.

(Lund et al., 2012,2016,2017)

Tests of instrumentation for the seismic network

The Swedish National Seismic Network (SNSN), Silixa, Hydroresearch and the Swedish Nuclear Fuel and Waste Management Co. (SKB) performed instrument tests in Forsmark:

- 200 m deep borehole
- 1.2 km walk-away VSP
- Silixa cables and interrogators:
  - Linear single-mode and iDASv2
  - Helical single-mode and iDASv2
  - Helical Constellation and Carina iDASv3
- Institute of Mine Seismology (IMS) 5-element 240 V/m/s geophones at 6.5 m, 74.5 m and 188.5 m depth.
- IMS and Guralp Affinity digitizers.



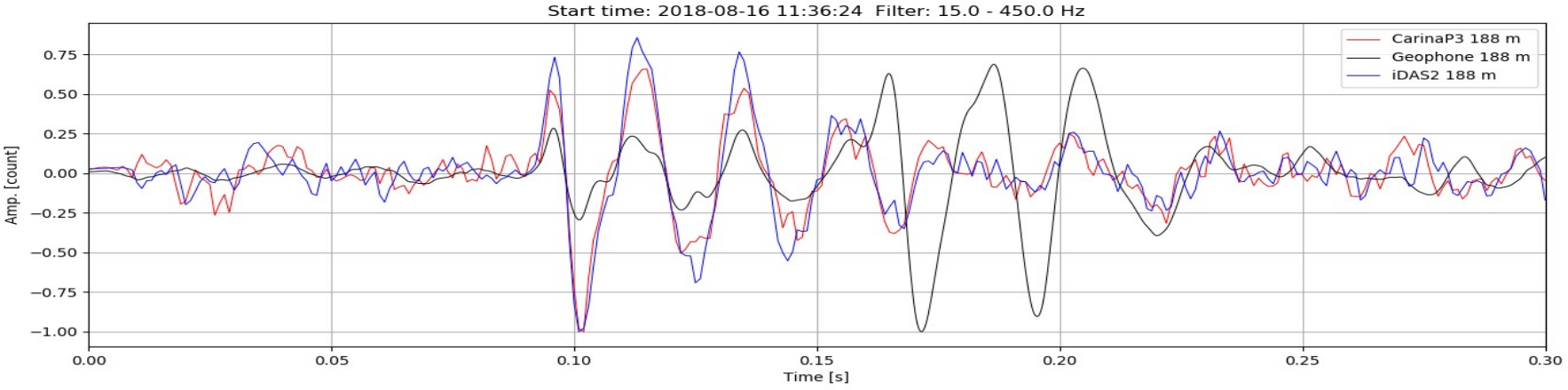
VSP Survey

- Approximately 10 m spacing
- 120 shot points
- 10 weight drops/shot point

Bobcat with weight drop of 400 kg

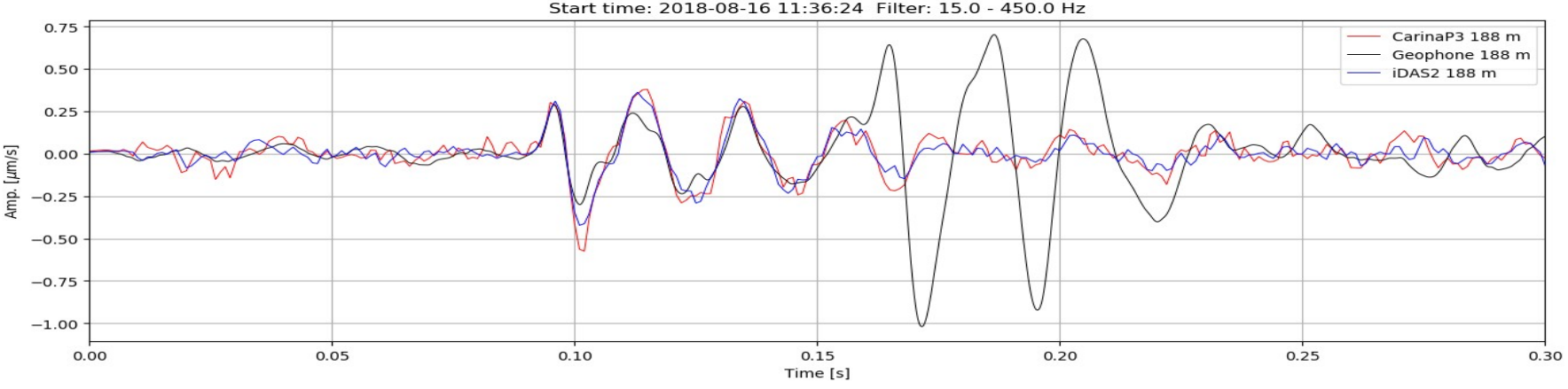
Comparison at 188 m depth, 470 m distance, stack of 10 shots, helical cables and vertical geophone

Amplitudes normalized to one.



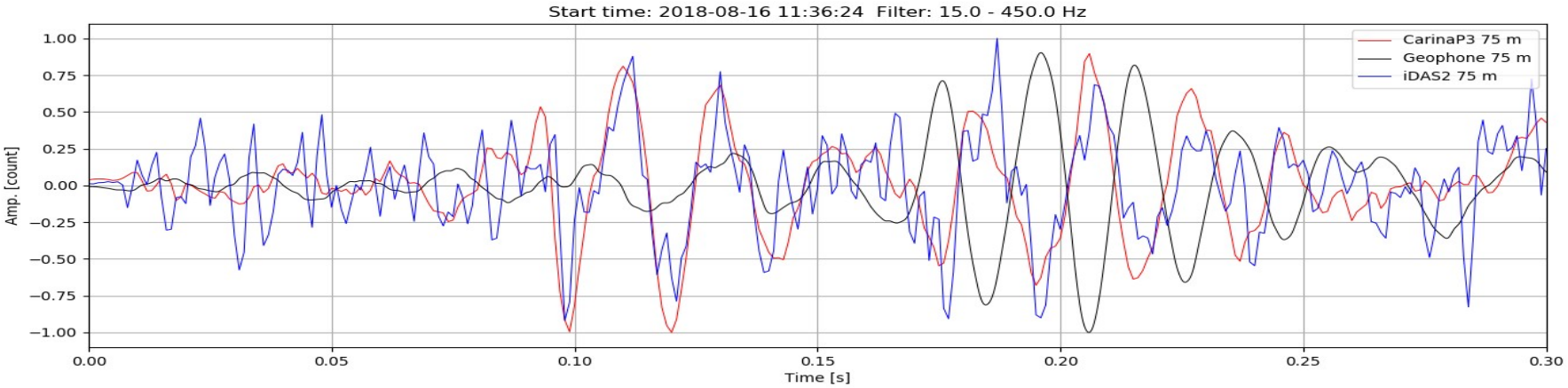
Velocity amplitudes.

Fiber amp scaled with velocity as distance over travel time



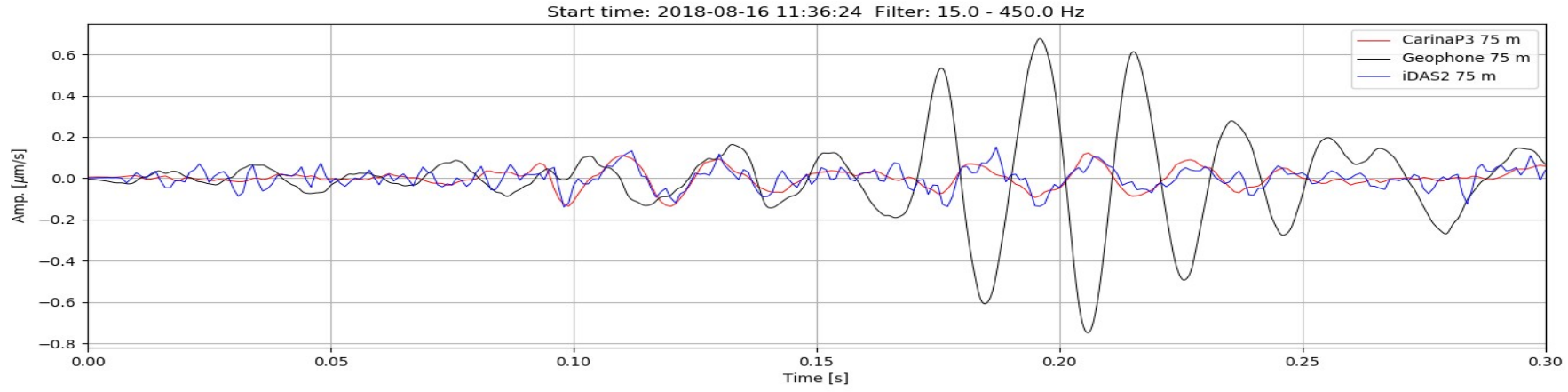
Comparison at 75 m depth, 470 m distance, stack of 10 shots, helical cables and vertical geophone

Amplitudes normalized to one.



Velocity amplitudes.

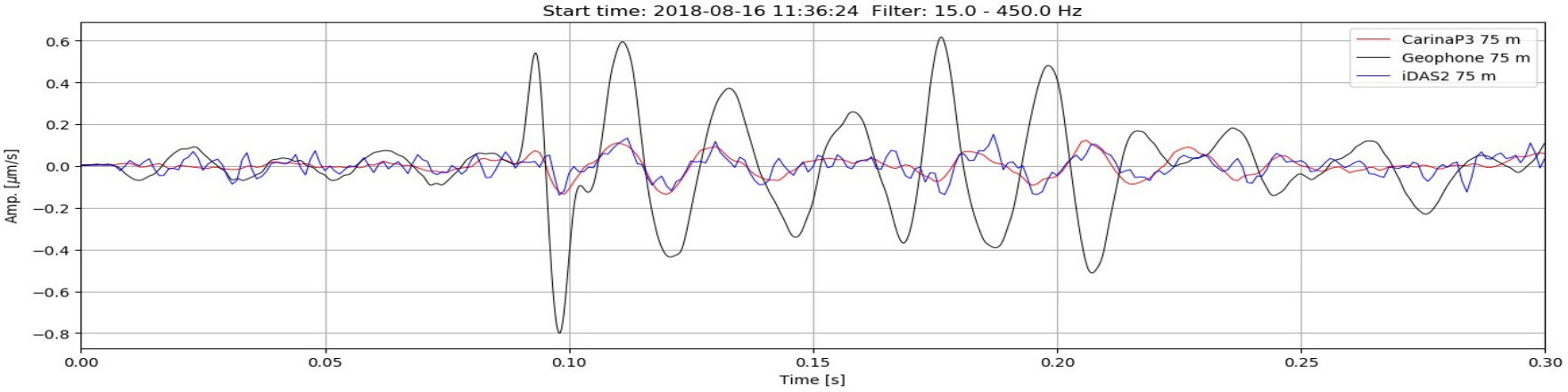
Fiber amp scaled with velocity as distance over travel time



Comparison at 75 m depth, 470 m distance, stack of 10 shots, helical cables and horizontal geophones

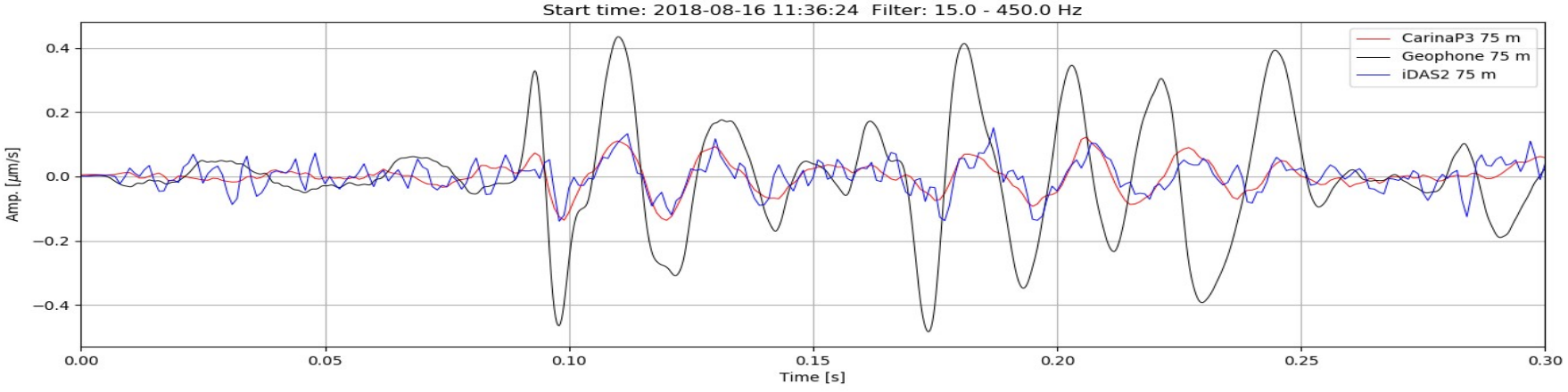
Velocity amplitudes.

Geophone N-comp



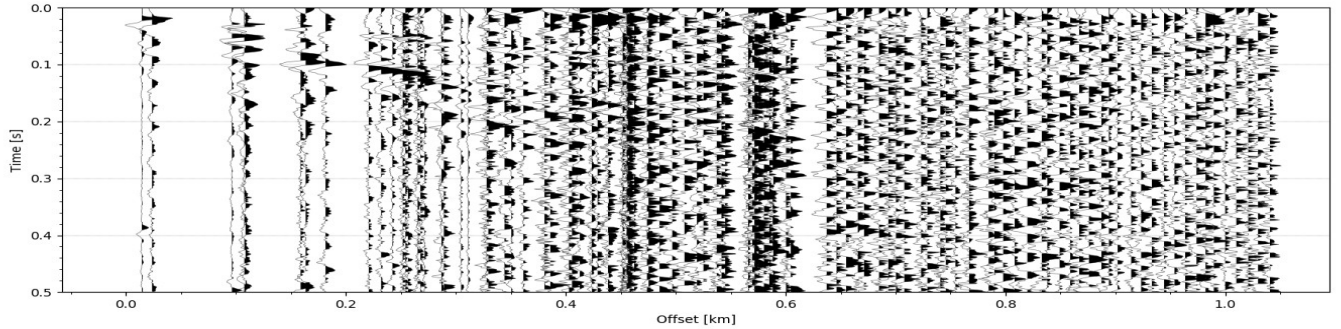
Velocity amplitudes.

Geophone E-comp

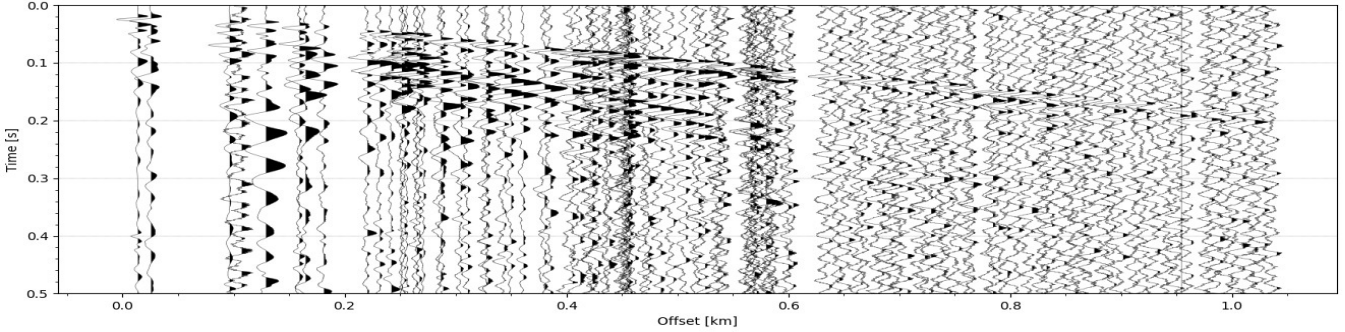


Single trace receiver sections 75 m depth

Carina helical constellation cable.
10 m average.
Poor signal-to-noise beyond 600 m.

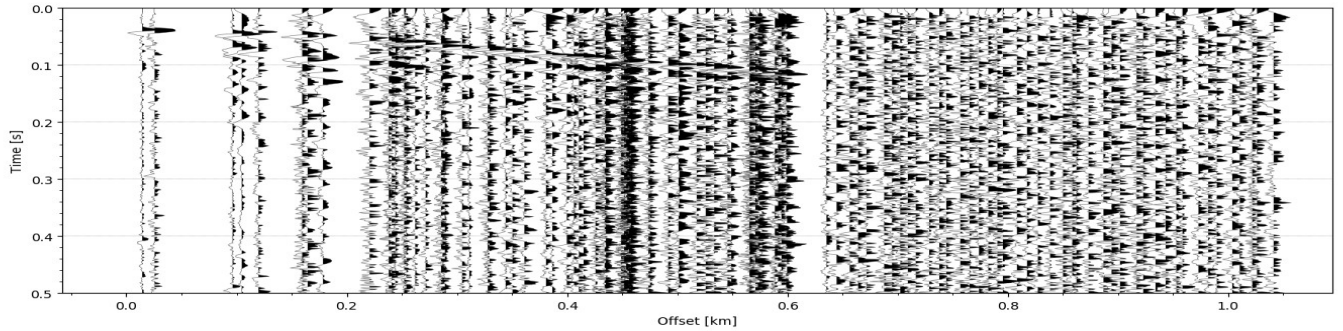


Geophone, horizontal component

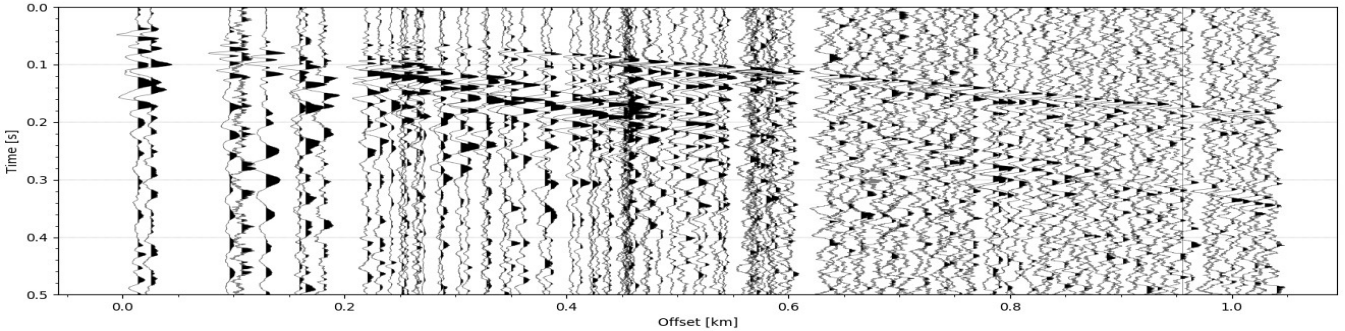


Single trace receiver sections 188 m depth

Carina helical constellation cable.
10 m average.
Poor signal-to-noise beyond 600 m.



Geophone, horizontal component

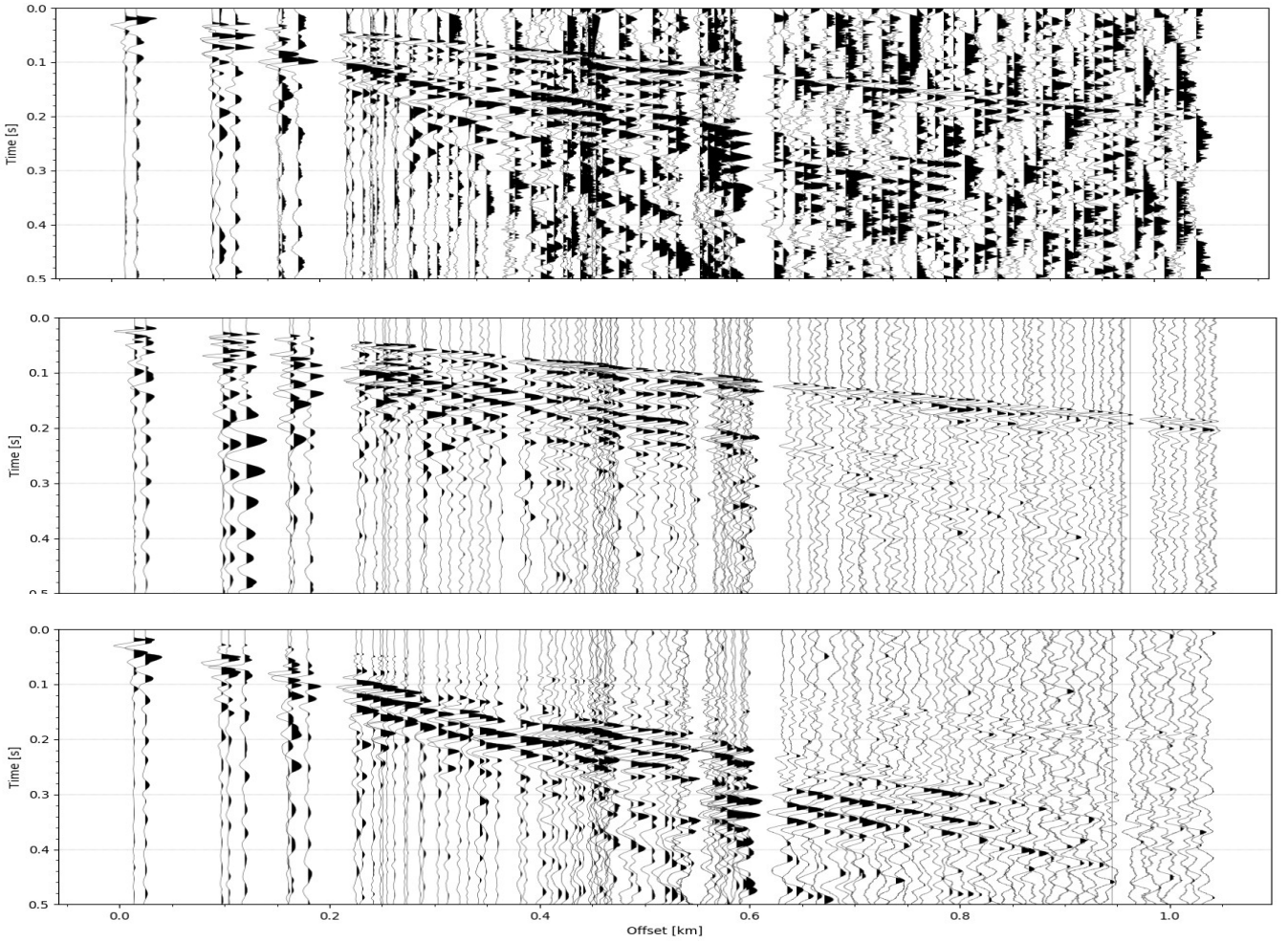


Stacked receiver sections 75 m depth

Carina helical
constellation cable
P-wave visible

Geophone,
horizontal component

Geophone,
vertical component
P-wave barely visible

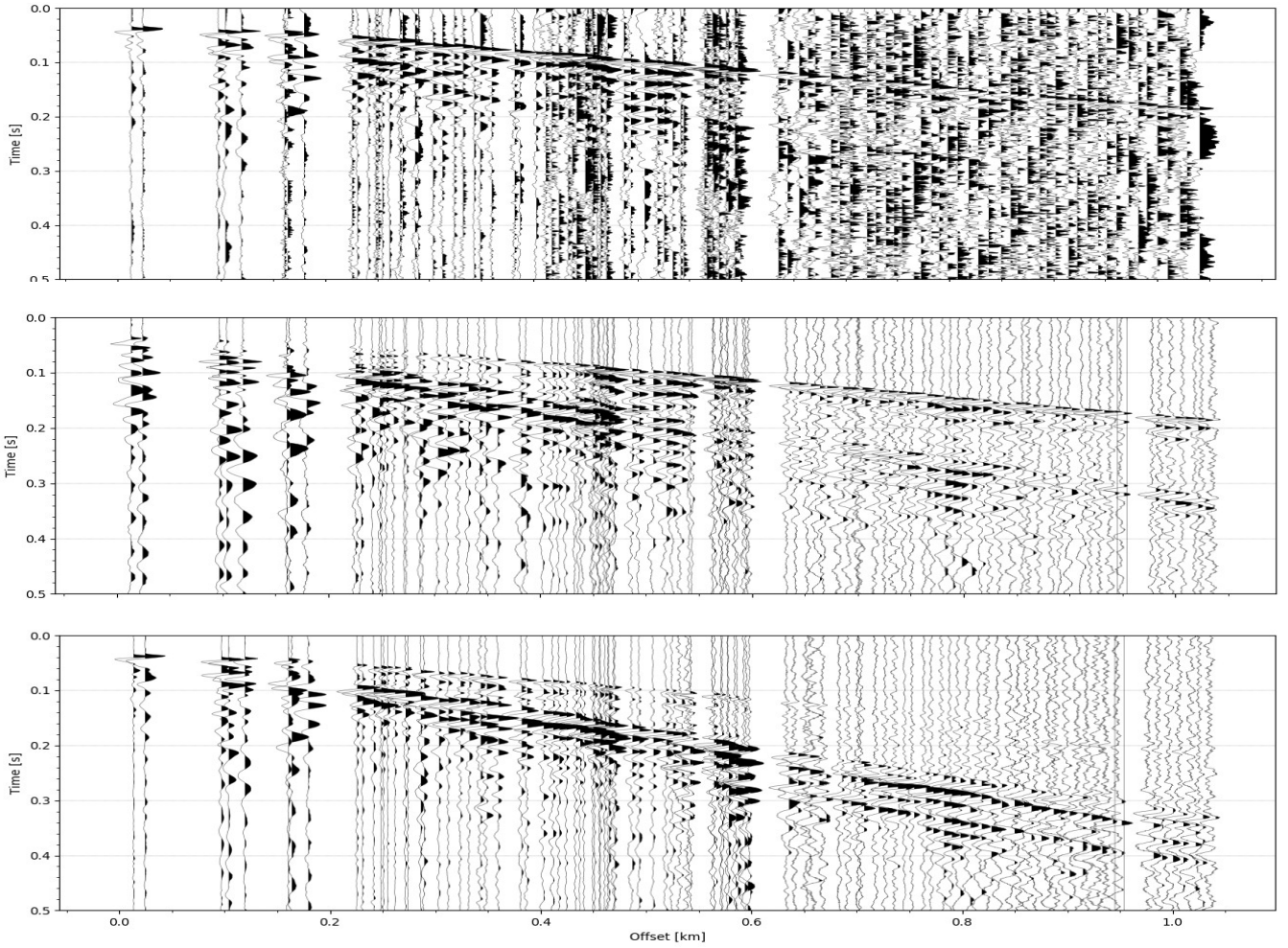


Stacked receiver sections 188 m depth

Carina helical constellation cable
P-wave visible

Geophone, horizontal component

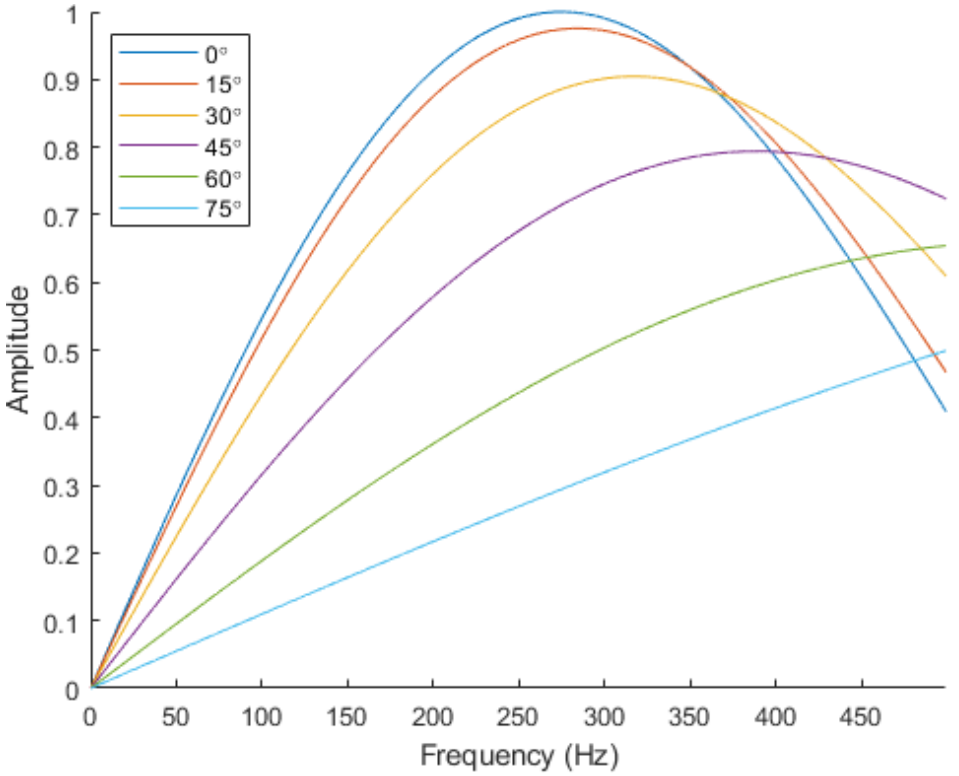
Geophone, vertical component
P-wave visible up to 600 m distance



DAS response

Theoretical iDAS P-wave frequency response.

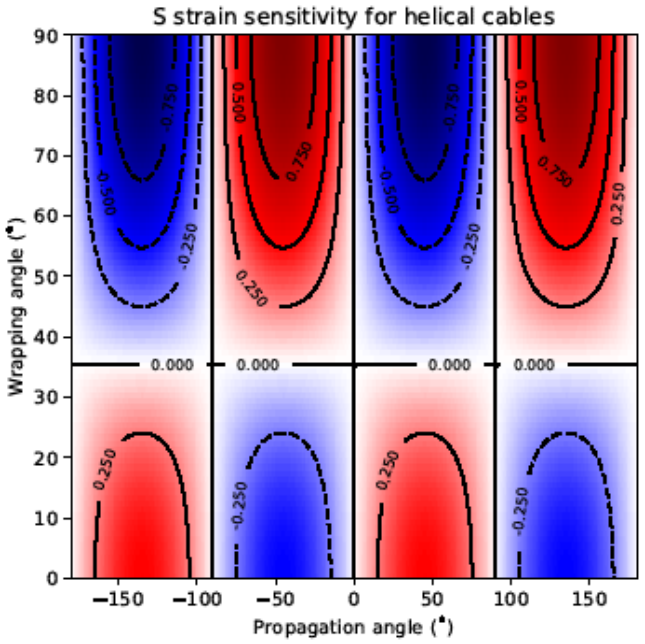
- Frequency response correction.
- Effects of cable coupling, casing string and cement type unknown.
- Helical cable introduces an additional mechanical response.

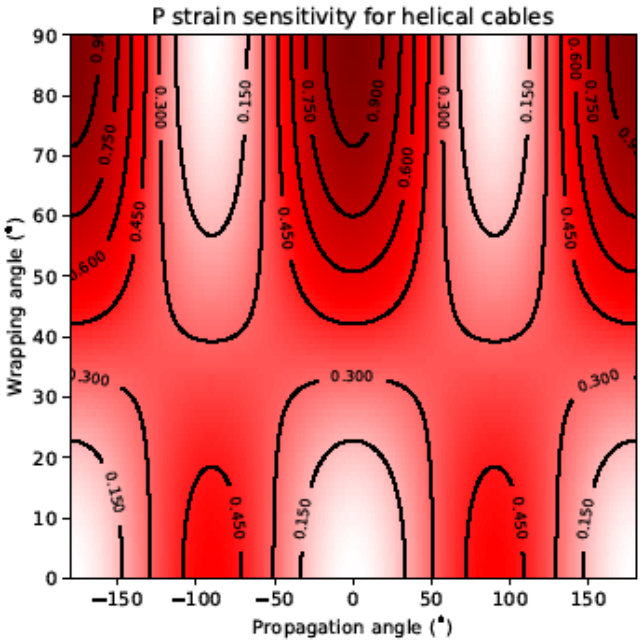


Helical cable response

Helical vs linear fiber Sensitivity to incidence angle.

Transfer function required to compute accurate seismic event magnitudes.



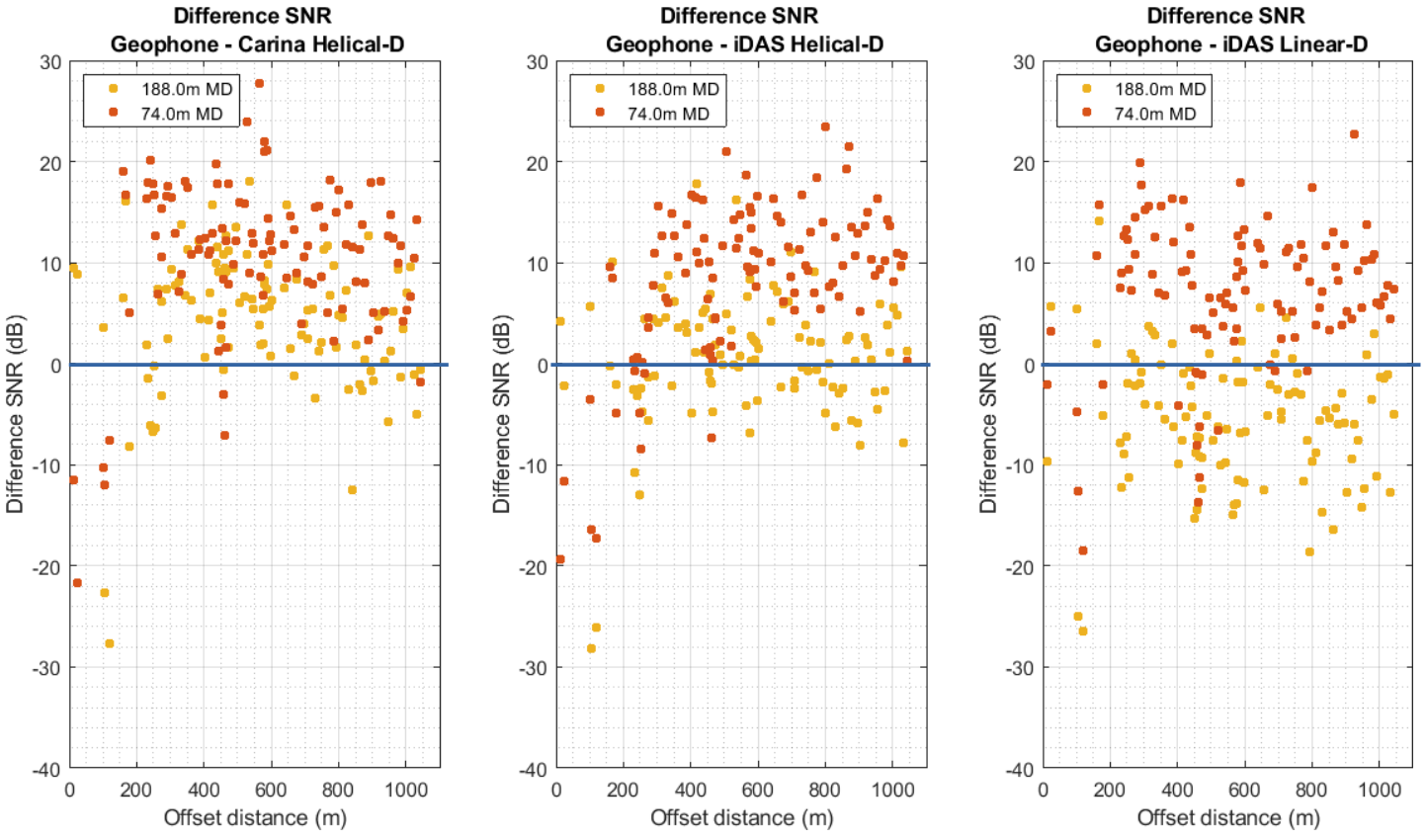


Figures courtesy of Alan Baird, University of Bristol

Signal-to-noise difference for P-wave, geophone minus fiber

- Geophone rotated to ray.
- DAS frequency response correction.
- Bandpass filter.

- Geophone SNR generally higher at 75 m depth.
- Deeper, the geophone SNR is better than the helical cable SNR, but not as good as the linear cable SNR.
- Fiber better at near-offsets
- Results due to incidence angles.



Summary

- Geophones and fiber good performance
  - Both record signal with good SNR
  - Performance dependent on incidence angle, shot distance & frequency.
- P-wave visible along full length of helical fiber.
- S-wave more poorly recorded by the fiber.
- For earthquake magnitude and moment tensor calculations the DAS/cable response needs to be known.

- Future potential
  - Full correction for DAS response.
  - Few geophones for calibration with extensive fiber array.

Acknowledgements

This work was financed by the Swedish Nuclear Fuel and Waste Management Co. (SKB)