

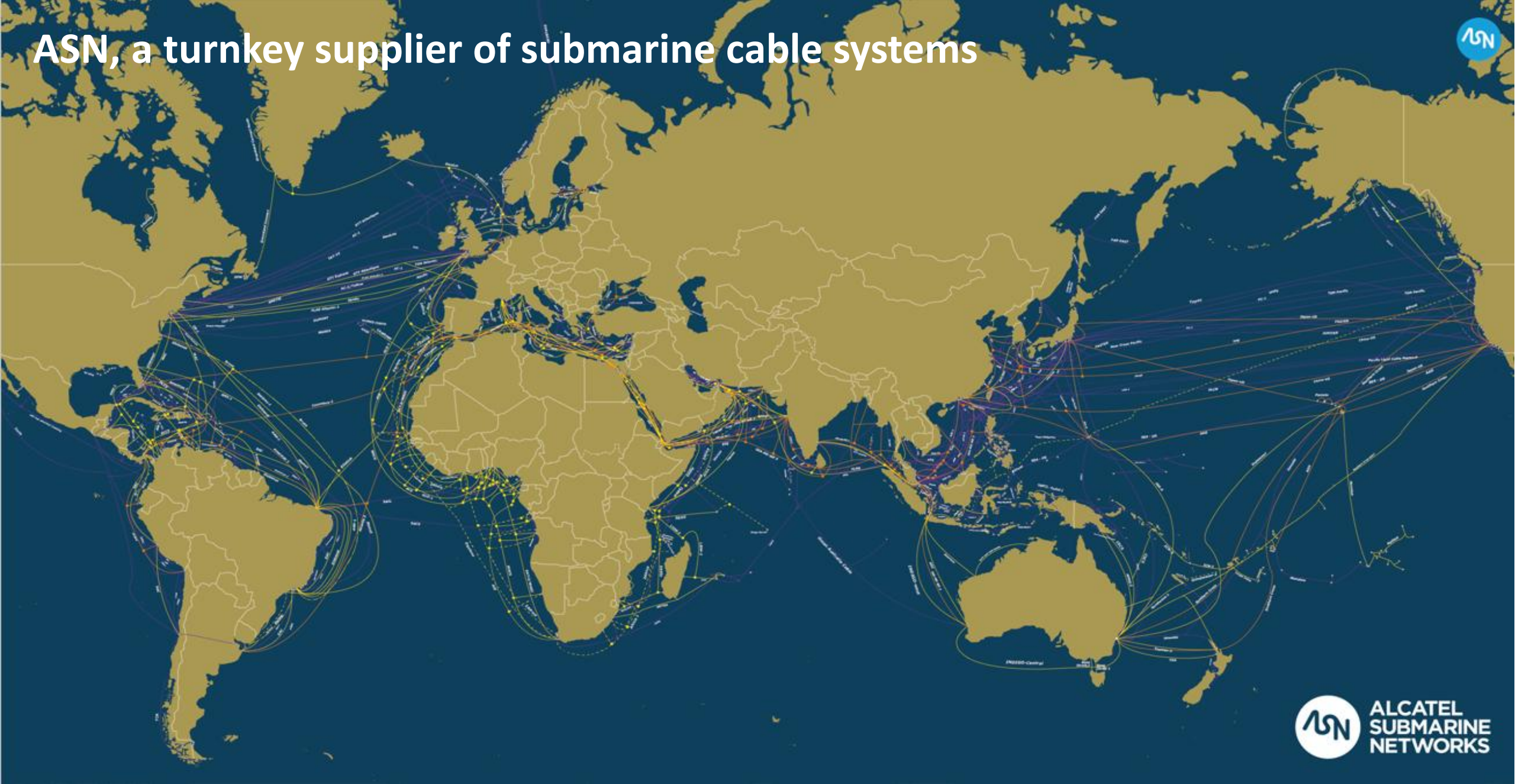
GEANT infoshare



GEANT infoshare



ASN, a turnkey supplier of submarine cable systems



ASN, a turnkey supplier of submarine cable systems



+850,000 km

of submarine optical cables
deployed around the world

+20 times

the circumference
of the earth

+300,000 km

of submarine cables
under marine maintenance

7 vessels

owned & operated for
installation & maintenance

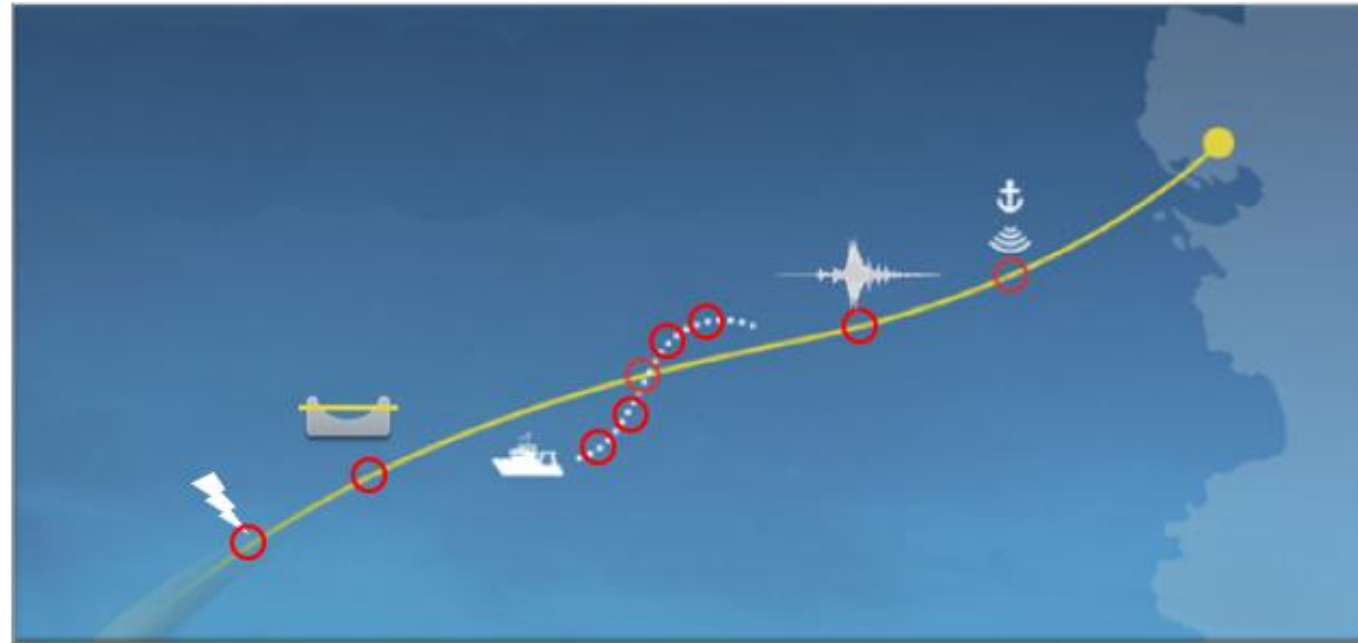
+160 years

of experience with
end-to-end expertise

+2,000

people working
worldwide





Cable condition monitoring

- Abrasion
- Cable movement
- Burial condition
- Thermal changes
- Electrical fault

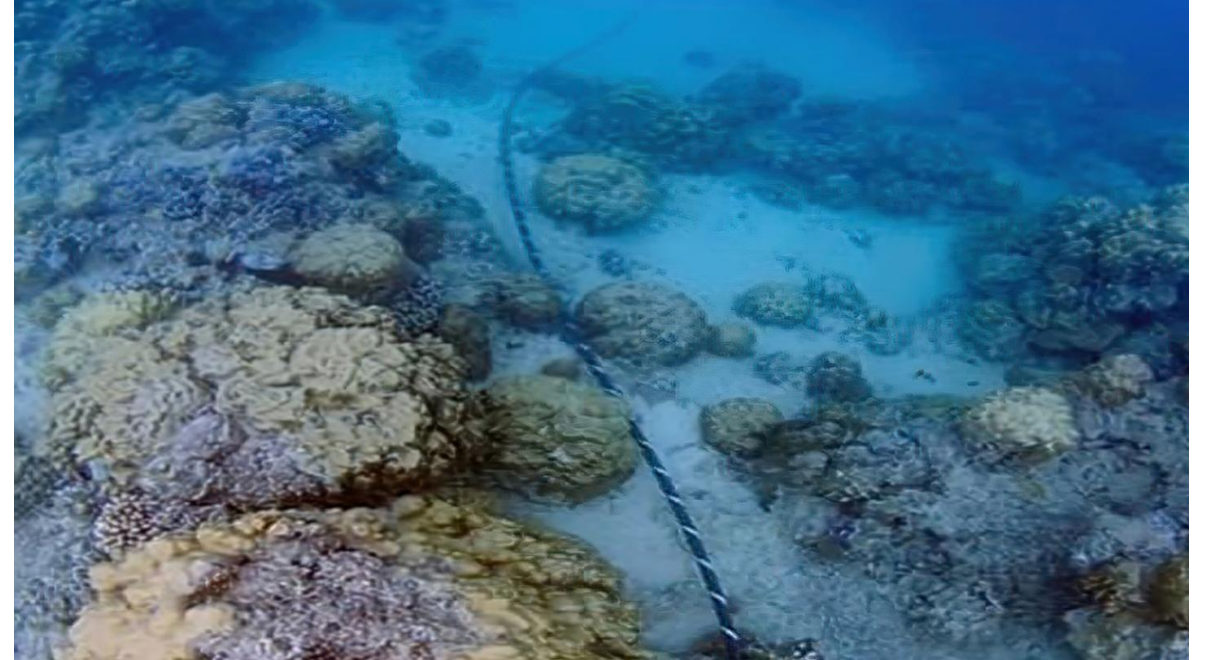
Cable threat monitoring

- Seabed fishing
- Anchoring
- Marine operations
(cable lay, trenching, boulder relocation, dredging, ...)
- Sabotage, physical contact

Surveillance in ocean space


- Seismic imaging
- Surface vessels
- Explosions
- Seismology, earthquakes
- Tsunami
- Marine life, oceanography

1. OptoDAS product line and capabilities
2. ASN DAS applications – *turnkey* ++
3. Scale-up for DAS in NRENs

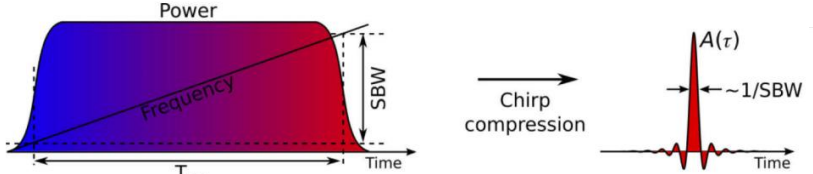


The OptoDAS – For monitoring of dynamic strain along an optical fiber

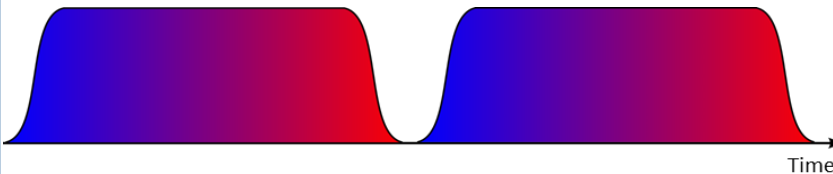
OptoDAS Interrogator



Frequency swept interrogation, FSI



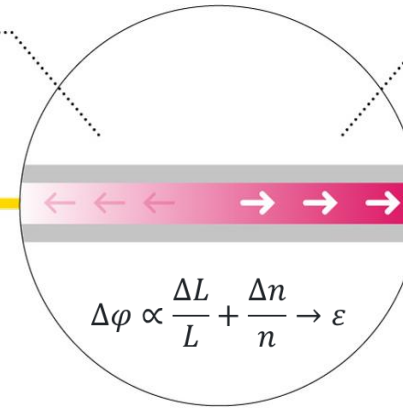
A coded probing technique



- ✓ + 30 dB optical power budget
- ✓ Spatial resolution not dependent on range
- ✓ **171 km range, with 2 m resolution**
- ✓ Time resolution of μHz to kHz

A very small part of the light is back-reflected to the interrogator

Optical fibre



Laser light is launched into the fibre by the interrogator. When the light propagates along the fibre, it will be subjected to Rayleigh scattering

Sensing resolution

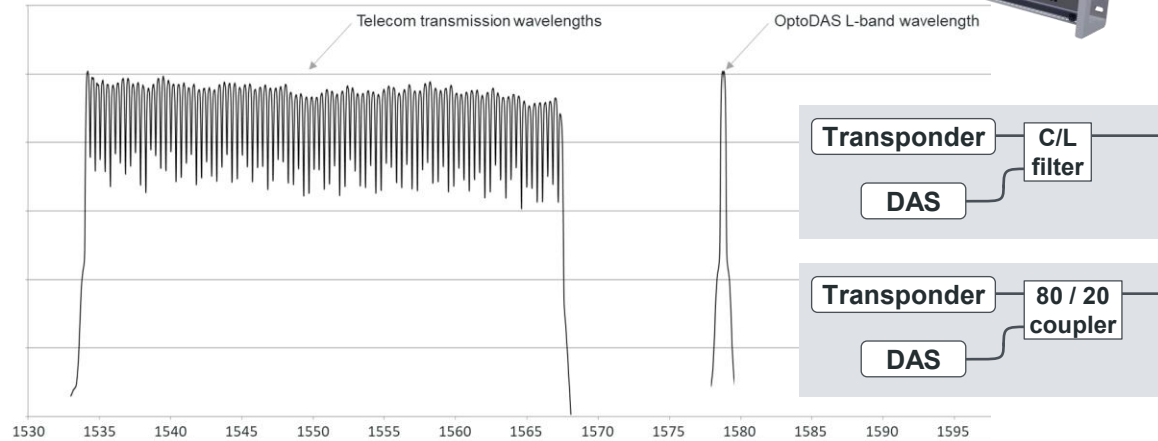
- ✓ Space dx – meter
- ✓ Time dt – millisecond
- ✓ Strain $\epsilon - \frac{pm}{m\sqrt{Hz}}$

Constraints in fiber

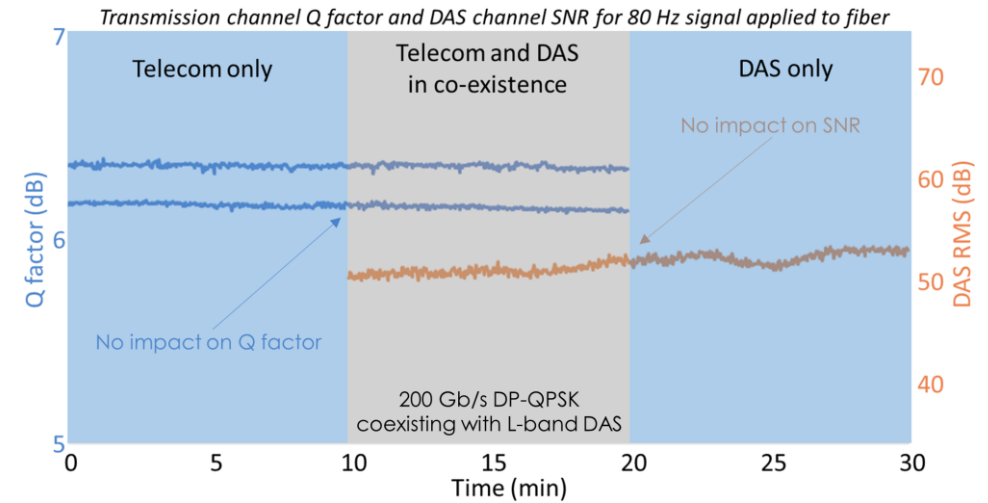
- Rayleigh: -75 dB/m
- Loss: 0.16-0.20 dB/km



DAS in L-band



- DAS outside of telecom bandwidth
- DAS connected through standard C/L filter or coupler

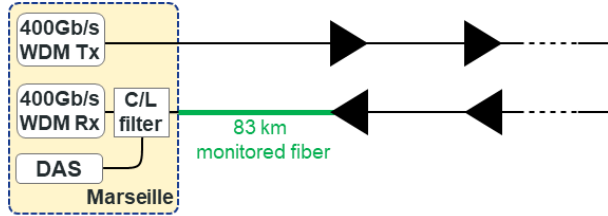


Results:

- Non-intrusive co-existence of DAS and telecom
- **No impact to Q factor of running telecom channels**
- No impact to DAS signal-to-noise ratio
- **DAS performance and range as in a dark fiber**

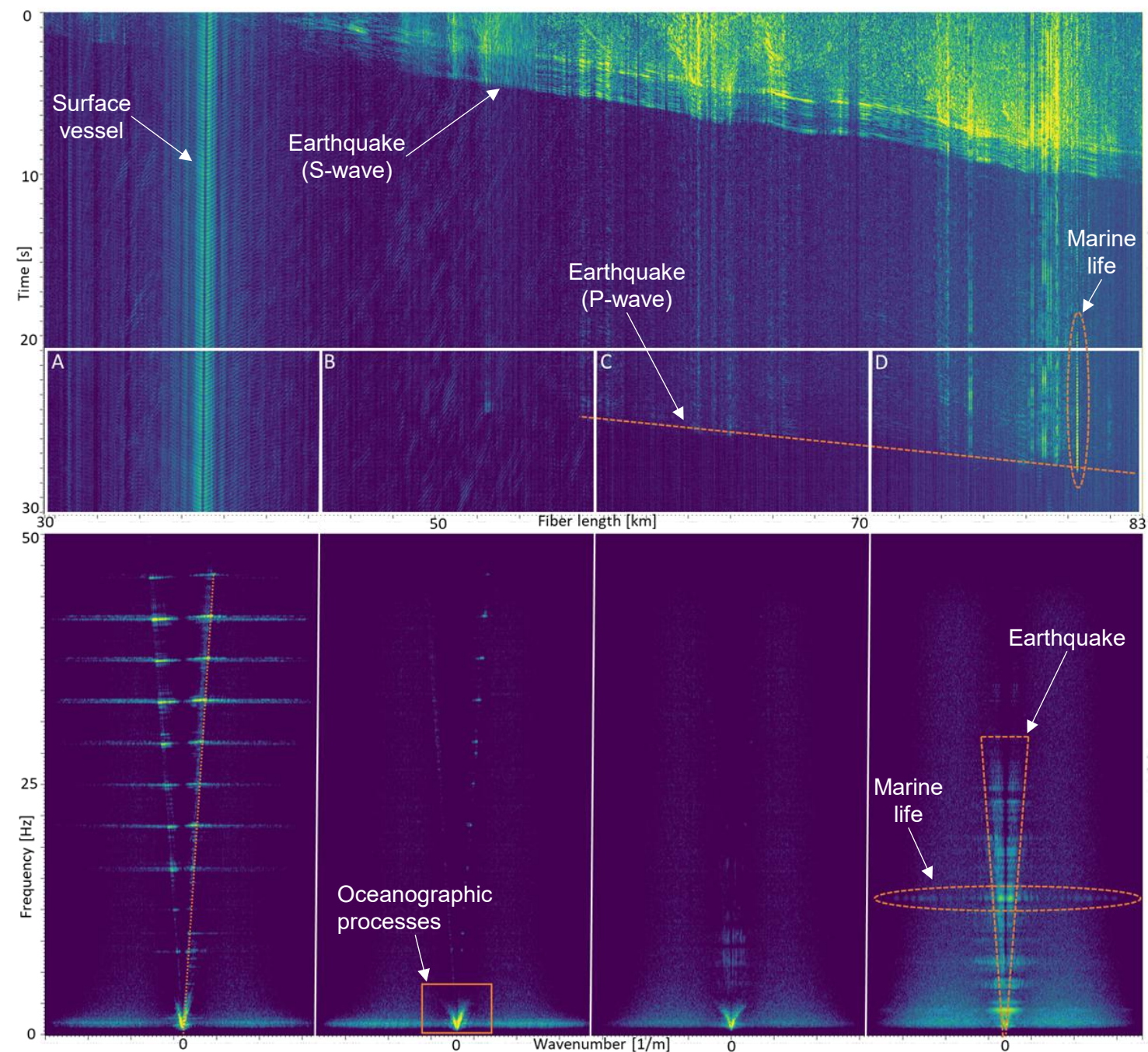
Brenne et. al., "Distributed Acoustic Sensing Solution for Repeated Networks", SubOptic 2023 Conference, Bangkok, Thailand, March 2023.

L-band OptoDAS on 2Africa



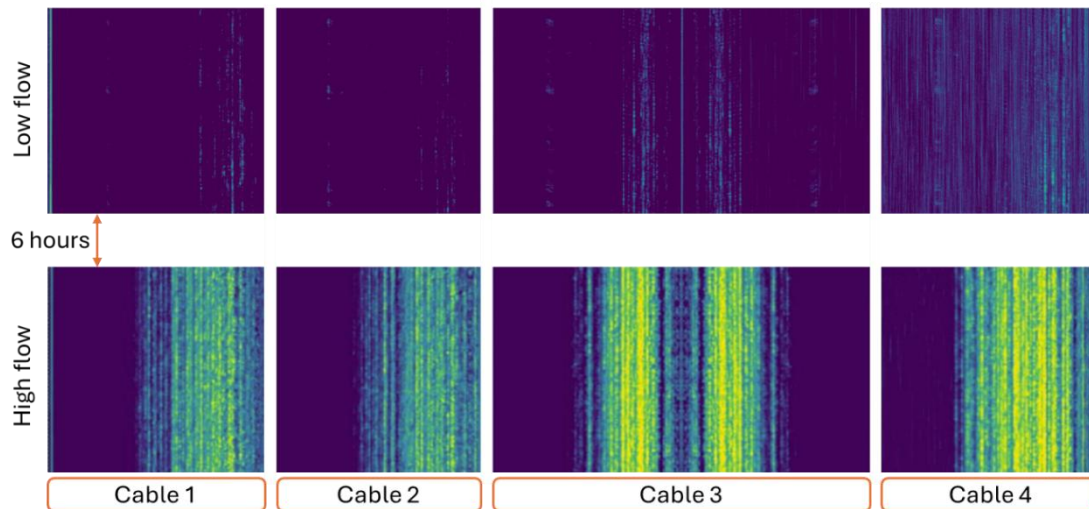
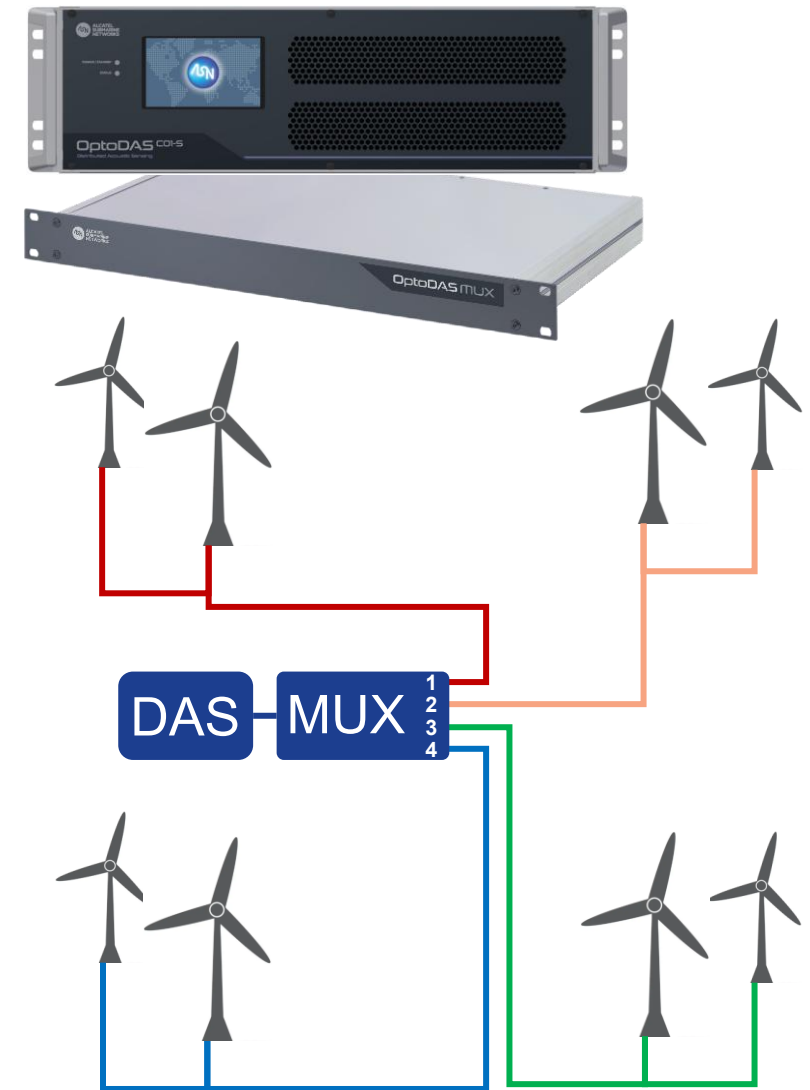
- Data example with 4 concurrent signals:
 - Surface vessel
 - Earthquake
 - Marine life
 - Oceanographic processes
- A high-fidelity reconstruction of the wavefields propagating in the seabed
 - Dense spatial sampling, 1 m, with 8 m spatial resolution
 - Sampling frequency ~ 1 kHz
 - *The full wavefield is sampled*
- Enables processing techniques that significantly enhance data utility
 - Frequency-wavenumber (fk) domain analysis
 - *Well-suited for event-specific filters*

Brenne et. al., "Non-Intrusive DAS Coexisting in Telecom Networks", OFC 2024, paper M4E.3



OptoDAS MUX – For real-time monitoring of multiple cables

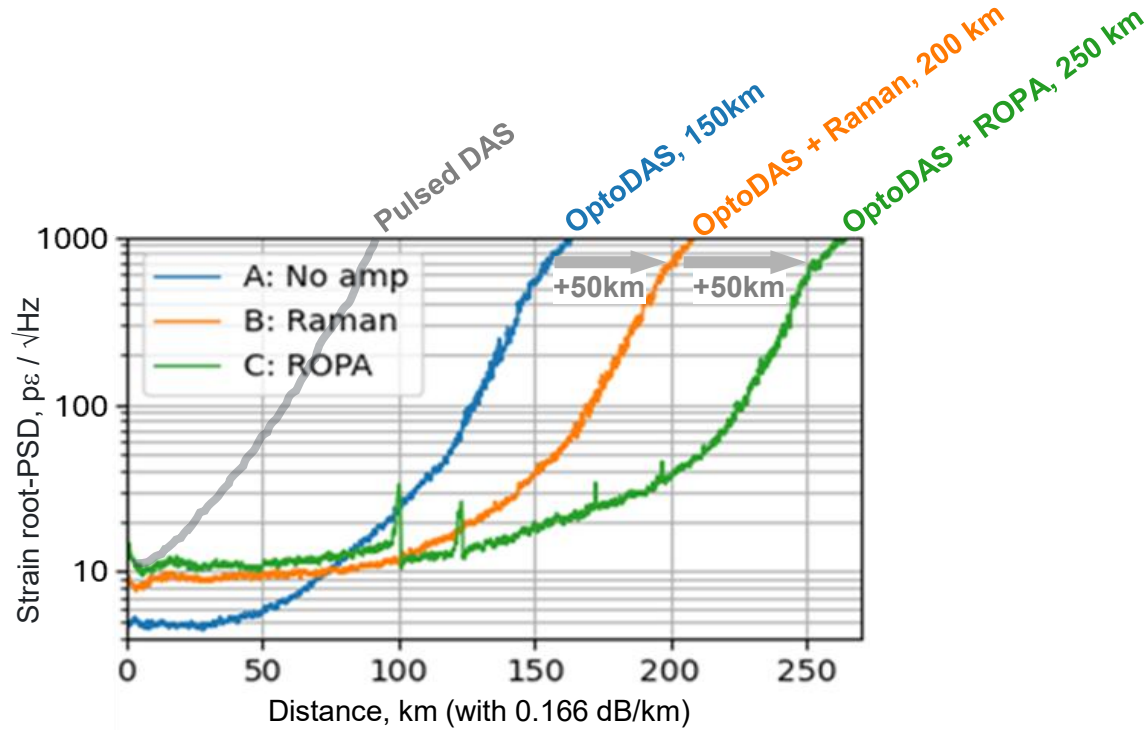
- Real-time DAS coverage of 4 cables with 1 OptoDAS facilitated by the OptoDAS MUX
- Cost-effective and flexible retrofit for star shaped topographies, e.g. windfarms
- Sensitivity, fidelity and spatial resolution is preserved as if 4 OptoDAS interrogators were used
- Sampling rate is divided between the four fibres



Four power export cables monitored with one OptoDAS + MUX

Brenne et. al., "DAS for ultra-long submarine interconnectors and cables", Paper 1370, CIGRE Symposium 2025.

OptoDAS PUMP – For range extension



DAS

Pump

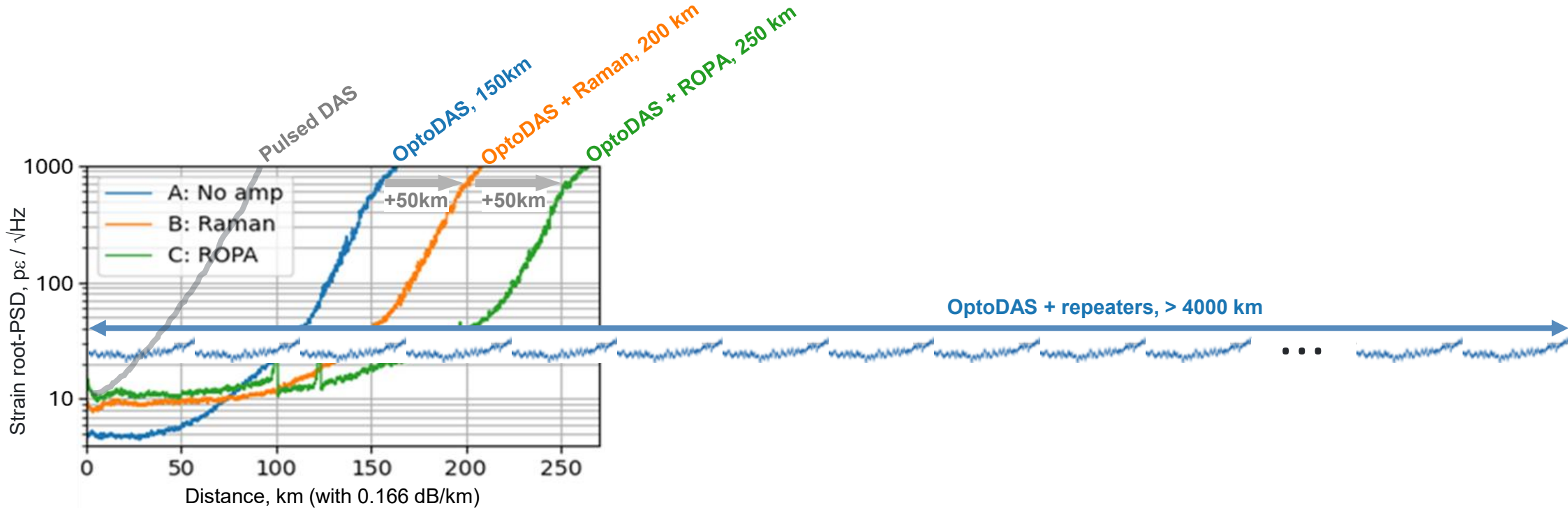
Unreamplified DAS

- 200 km with Raman amplification
- 250 km with remotely pumped amplifier (ROPA)



Rønnekleiv, et. al., "DAS with 302 km sensing range using remote amplification and engineered fiber", OFS29, paper Tu3.6 (2025)

Repeated DAS – For trans-oceanic reach



Repeated DAS

- Scalable system topology for 1000's of km long links
- Constant sensitivity along the cable

Rønnekleiv, et. al., "Range-scalable distributed acoustic sensing with EDFA repeaters demonstrated over 2227 km," Opt. Lett. 50, 25-28 (2025).

OptoDAS components



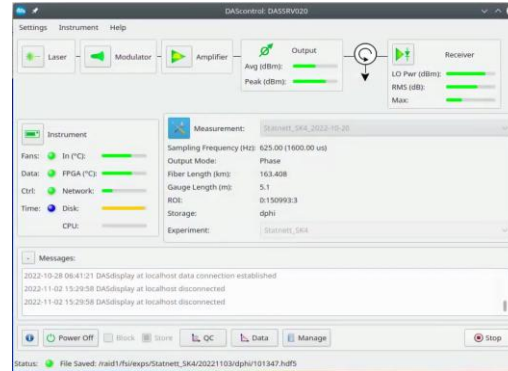
Field rack



DAS instrument

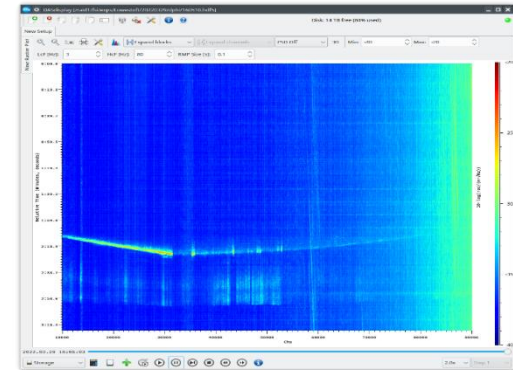
Instrument server

DAScontrol



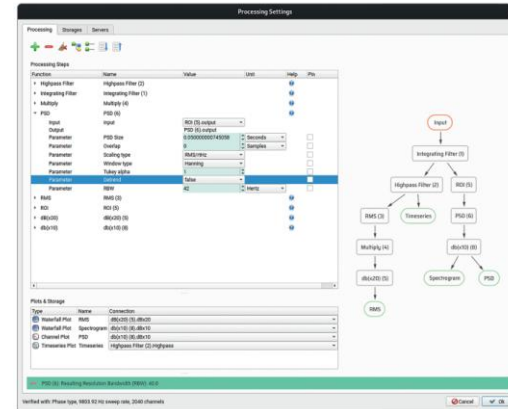
Acquisition control and data management

DASdisplay



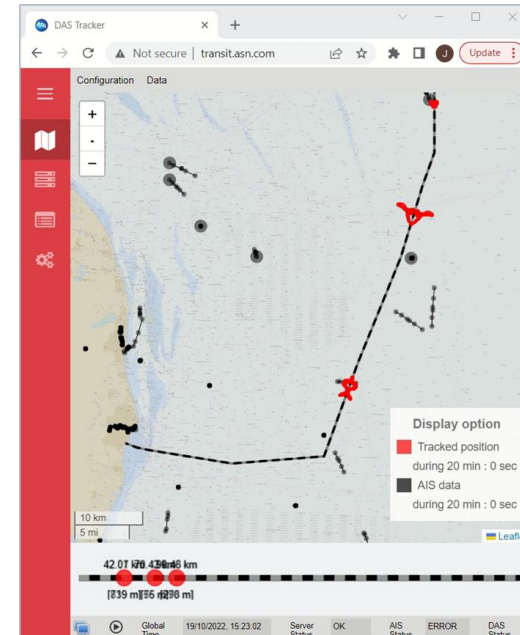
Data processing engine and display

DAScontrol & DASdisplay



Data processing flow

DASweb

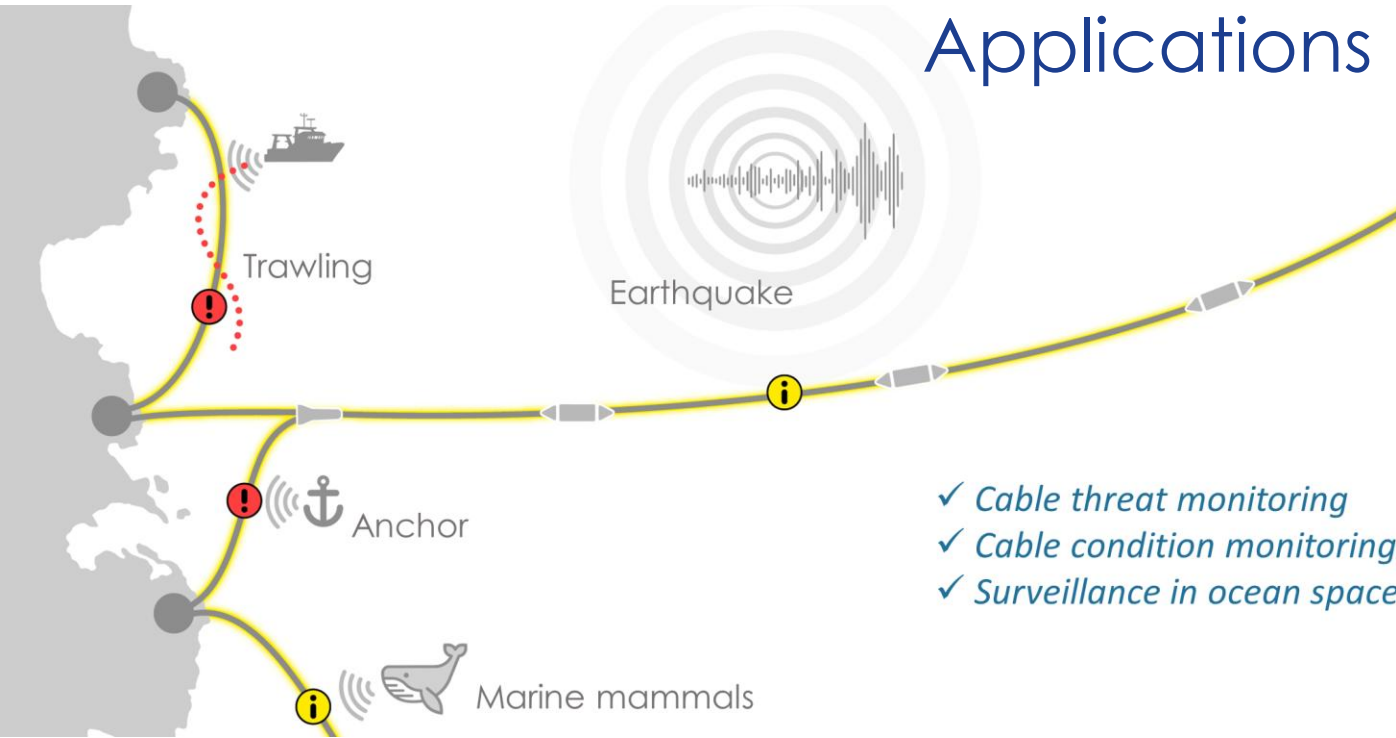


Application specific user interface

Instrument server = Powerful computer:

- Edge computing for alarm generation, event reports, etc.
- Scalable raw data storage capacity in RAID or external NAS RAID
- Data transfer by streaming (*Avro Kafka, ZeroMQ*) or file transfer (HDF5)

Applications of DAS on submarine cables



Added value for asset owners and telecom operators:

- *Real-time alarms for preventive actions*
- *Records of seabed activity – linking the damage to the aggressor – acting as a deterrent*

- ✓ *Cable threat monitoring*
- ✓ *Cable condition monitoring*
- ✓ *Surveillance in ocean space*

Cable condition monitoring

- Abrasion
- Cable movement
- Burial condition
- Thermal changes
- Electrical fault

Cable threat monitoring

- Seabed fishing
- Anchoring
- Marine operations (cable lay, trenching, boulder relocation, dredging, ...)
- Sabotage, physical contact

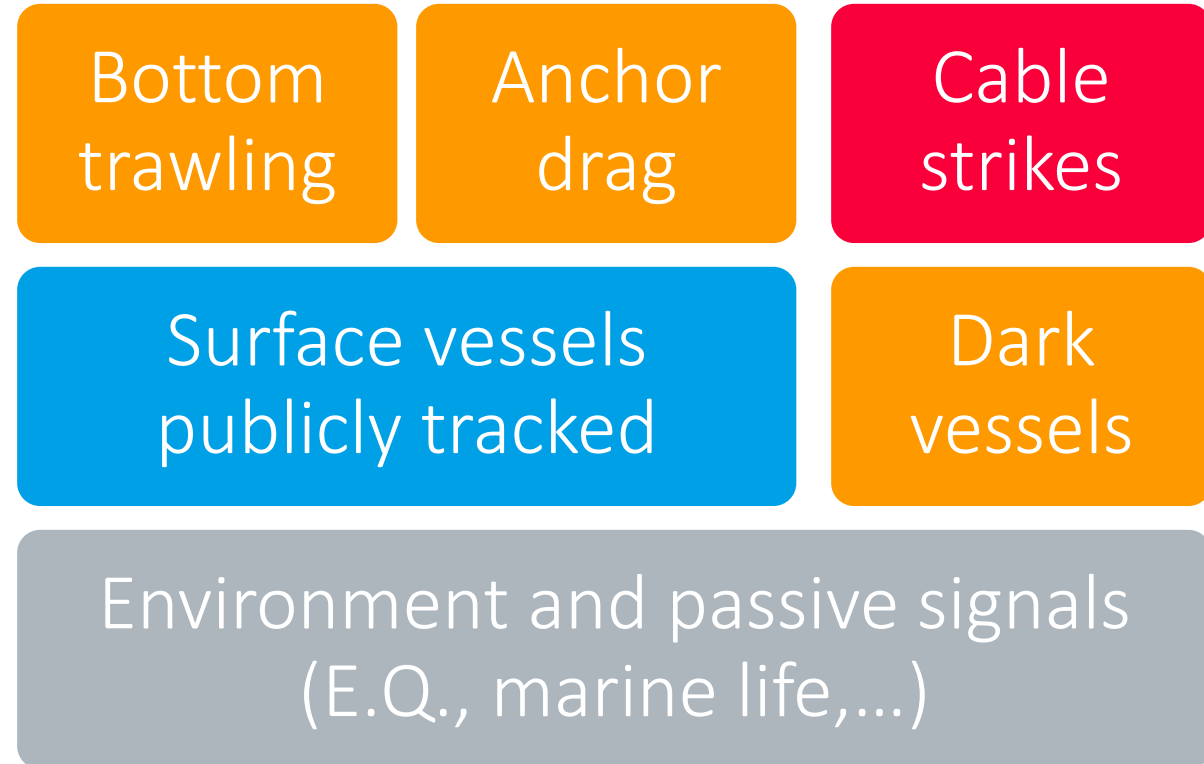
Surveillance in ocean space

- Seismic imaging
- Surface vessels
- Explosions
- Seismology, earthquakes
- Tsunami
- Marine life, oceanography

Cable threat monitoring – Mode of operation



- Real-time
- Location and tracking
- Data archive (events & raw)
- Pinpoint activity hotspots
- Parallel data uses
- Above-surface data integration



Cable threat monitoring

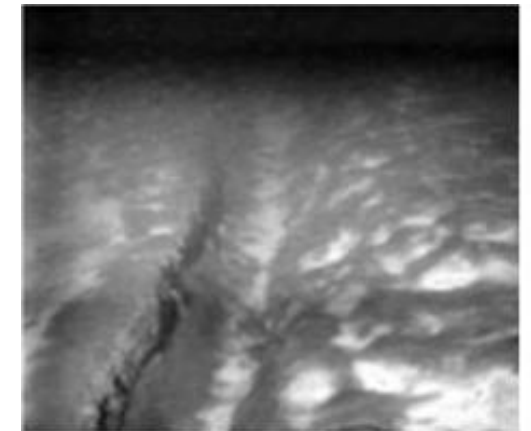
DAS monitoring

- Tracking seabed objects
- Location and alert for trawl and anchor drag within a cable corridor of 3 km
- Early warning for proactive mitigation
- Details for situational awareness and documentation

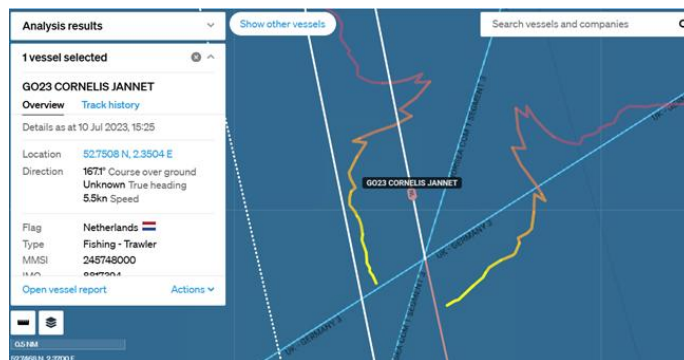
Trawl gear



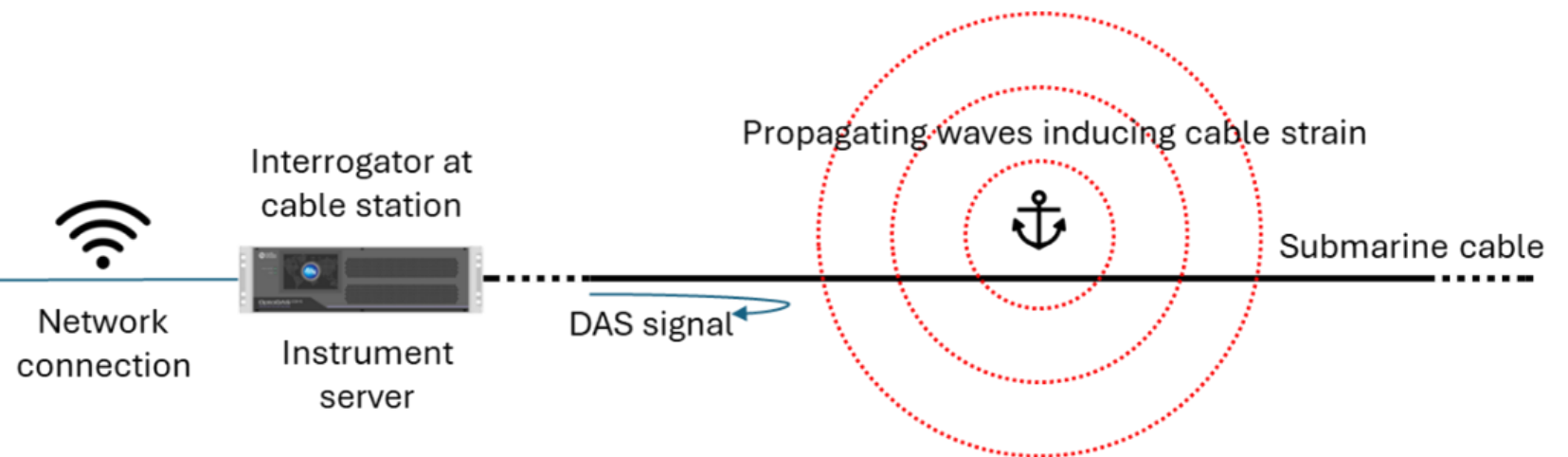
Trawl marks



Oberle et. al., "Submarine Geomorphology: Bottom Trawling and other Fishing Activities" (2017)



Third-party maritime surveillance platform:
<https://www.starboardintelligence.com/>



Cable threat monitoring – Seabed fishing



Web application capture: Monitoring with AIS and DAS

Live
Replay
Interrogators status
Database query
Comm. log

ASN

Settings
Track AIS by MMSI
Zoom in
Center map on cable A
Center map on cable B
Zoom out

Date: 13 . 07 . 2023
Time: 12 : 16
Speed: < 120x >
STOP

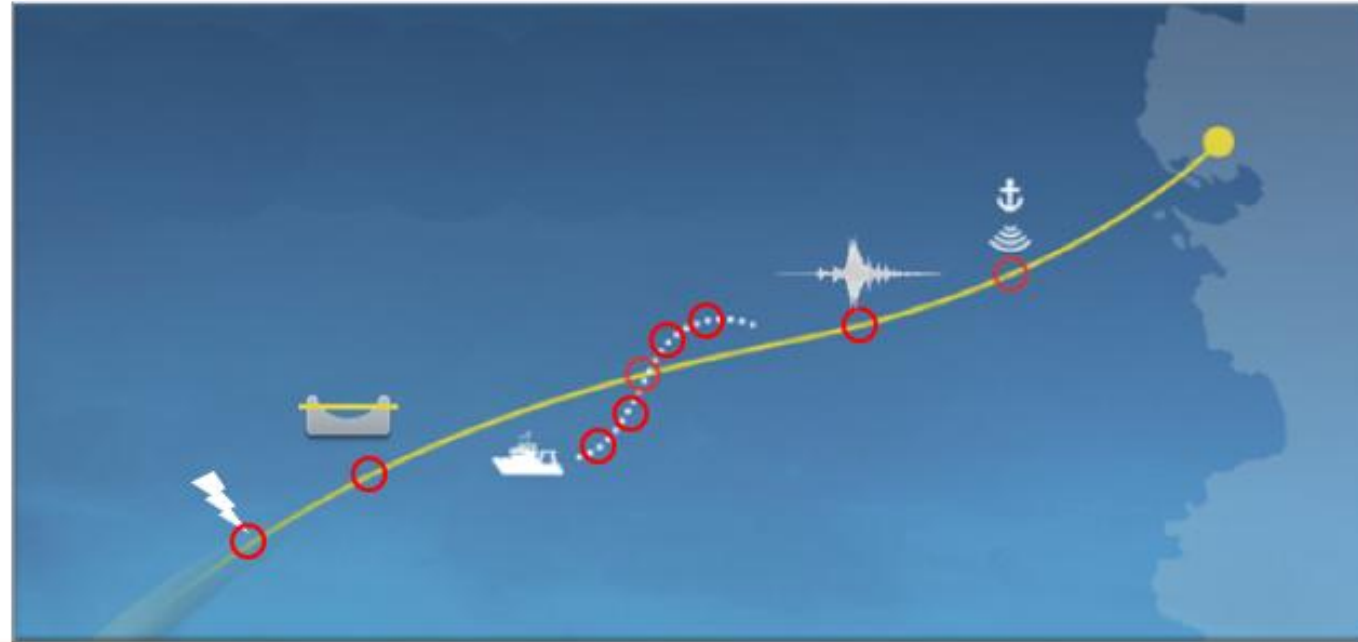
- Surface vessel position (AIS)
- Surface vessel position (DAS)
- Subsurface object position (DAS)
- AIS-linked sub/surface object position (DAS)
- Mirror sub/surface object position (DAS)
- ◆ Physical contact (DAS)

Visualization settings (symbols, expiry)
Track AIS by MMSI
Zoom in
Center map on cable A
Center map on cable B
Zoom out

3 km
2 mi

Leaflet | ©undefined

Tampnet cable, UK, North Sea



Cable condition monitoring

- Abrasion
- Cable movement
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- Thermal changes
- Electrical fault

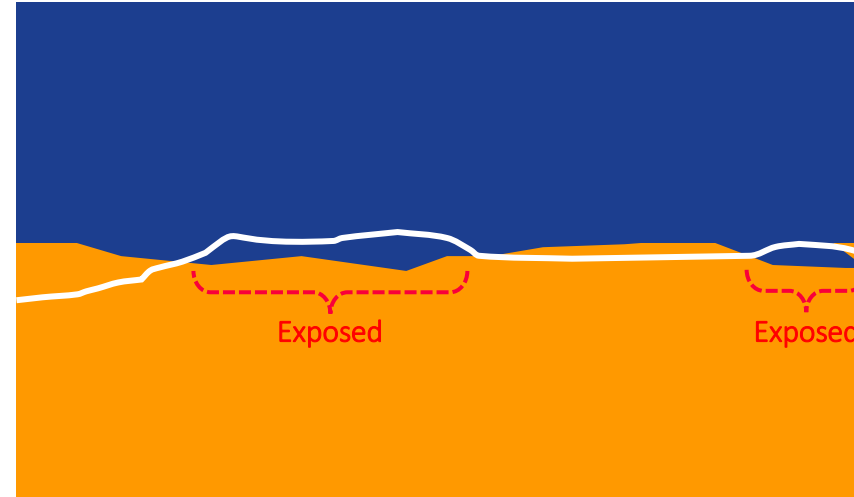
Cable threat monitoring

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(cable lay, trenching, boulder relocation, dredging, ...)
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Surveillance in ocean space

- Seismic imaging
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State of burial – Qualitative status



- ✓ Highlight sections exposed in water
- ✓ Highlight sections with strong water flow interaction

Value generation:

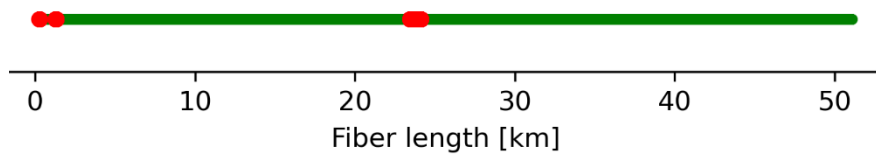
- Continuous monitoring: To capture anomalous noise and useful information over time
- Periodic reporting: Analysis of changes to the cable burial state

Cable condition monitoring – State of burial

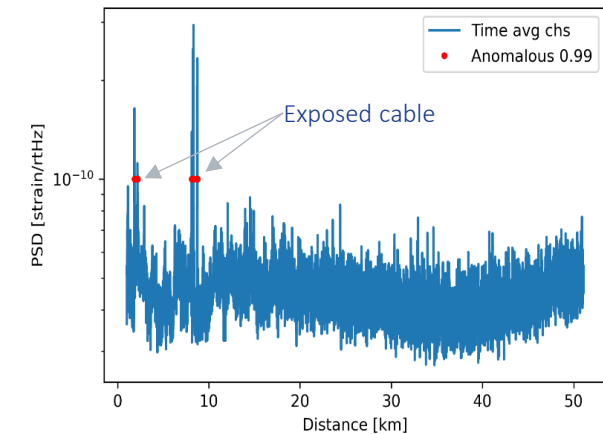
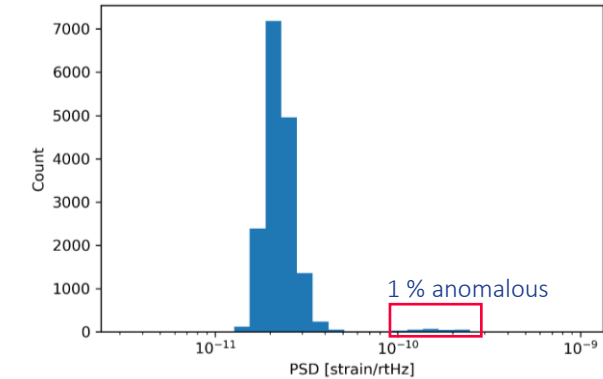
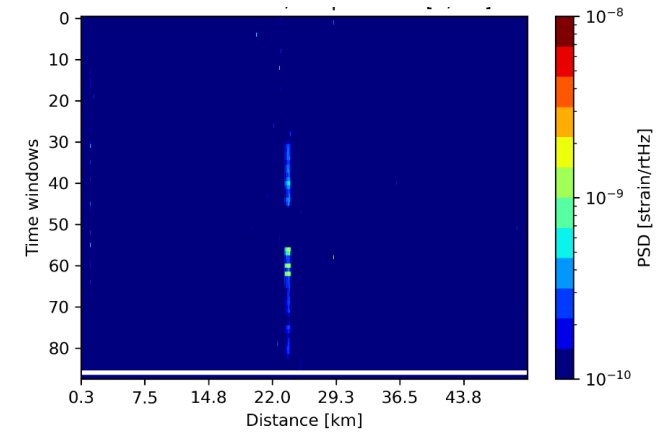
Objective: Detect cable segments that are exposed in water

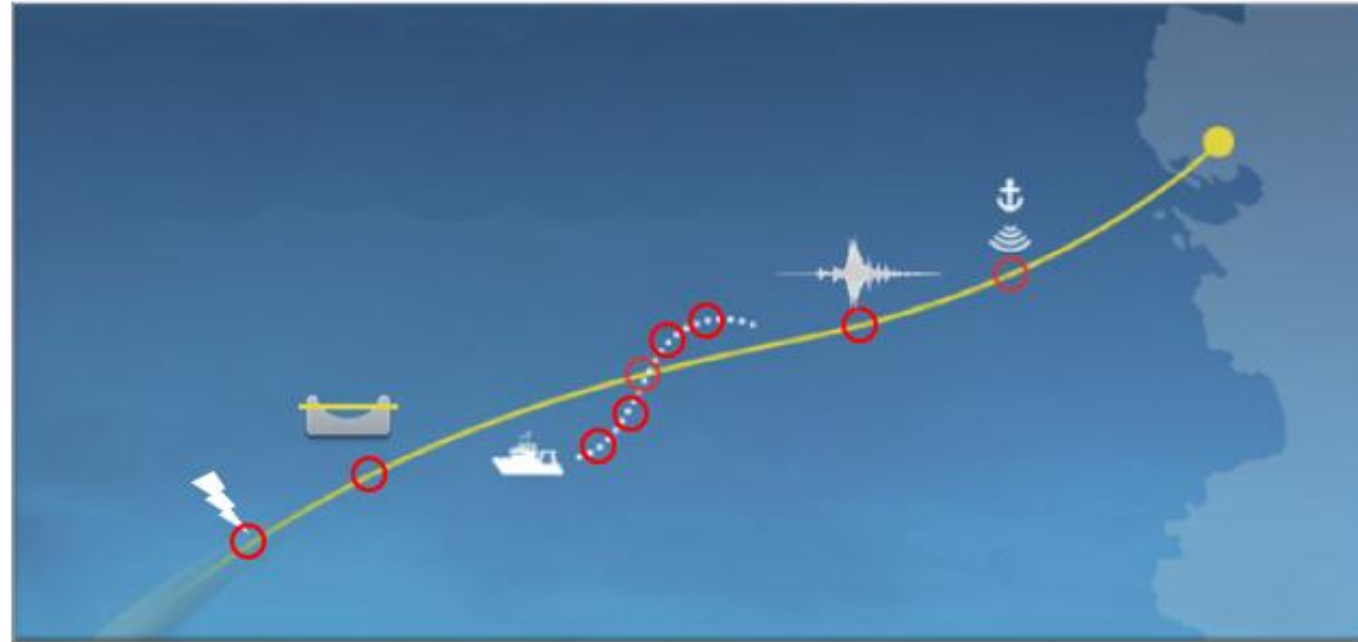
Rationale: Low-frequency noise from water flow (VIV, external forces)

- Water flow over cable causes low-frequency oscillations
 - Known frequency interval
 - Flow velocity vary with tides
- Mapping oscillations to pinpoint cable sections at risk
- Determine anomalies by variation over time (months)
- Automated statistical analysis
- Periodic reporting (e.g. monthly)



Start [m]	End [m]	Length [m]
260	279	19
1 272	1 321	49
23 436	23 479	43
23 488	23 491	3
23 546	24 134	588





Cable condition monitoring

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- Cable movement
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Cable threat monitoring

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Surveillance in ocean space

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Surveillance in ocean space – Tracking surface vessels



Objects with risk potential

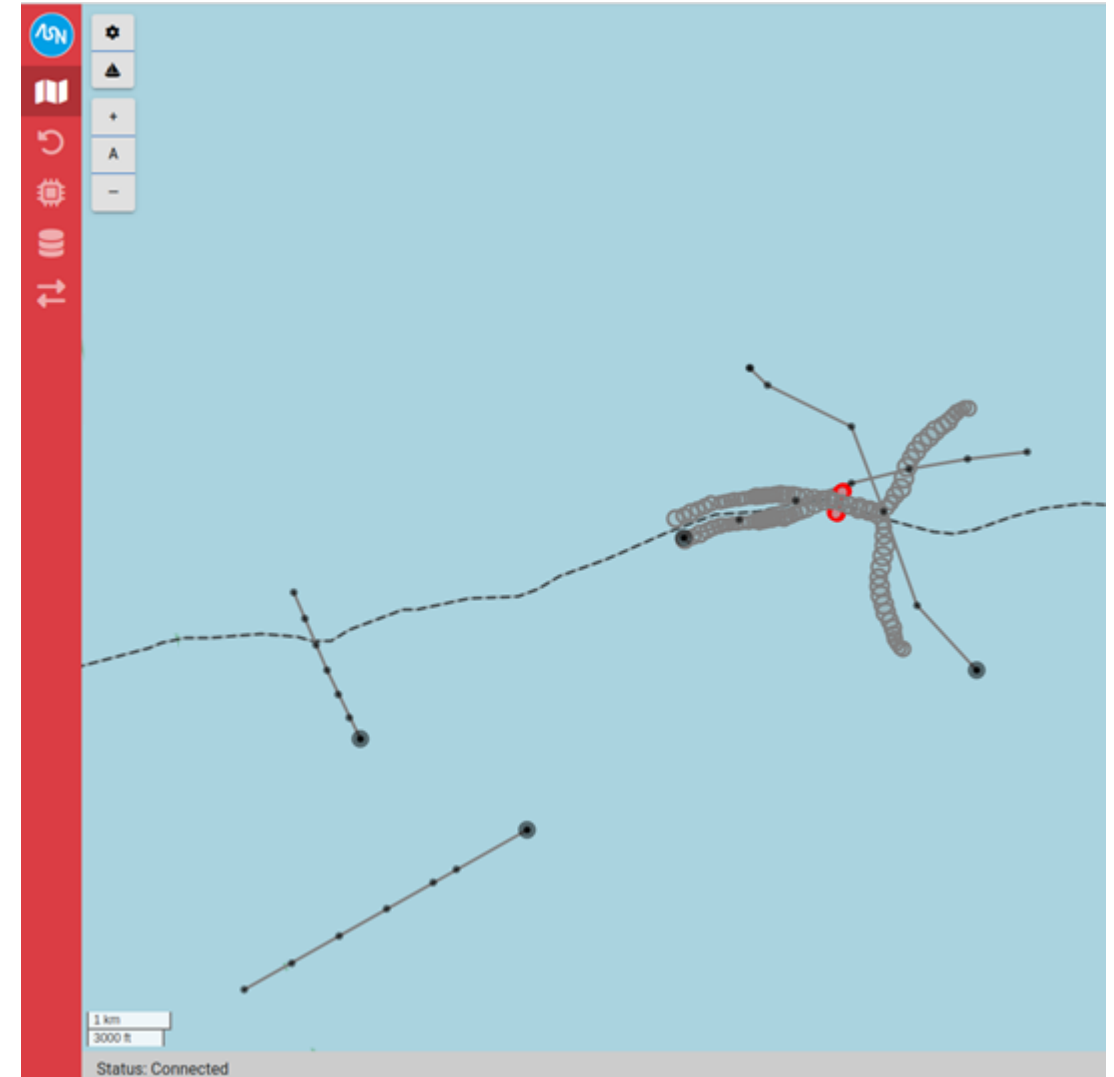
- Seabed interference achieved from low-frequency vibrations ~ 10 Hz
- Tracking anchor drag, trawling...

Vessel surveillance

- Ship noise related to engine, mechanical systems and hull-water interaction measured by DAS
- Signal propagating at speed-of-sound in water, frequency range $\sim 20 - 150$ Hz
- Tracking surface vessels, range strongly depends on ship noise amplitude 1–10 km

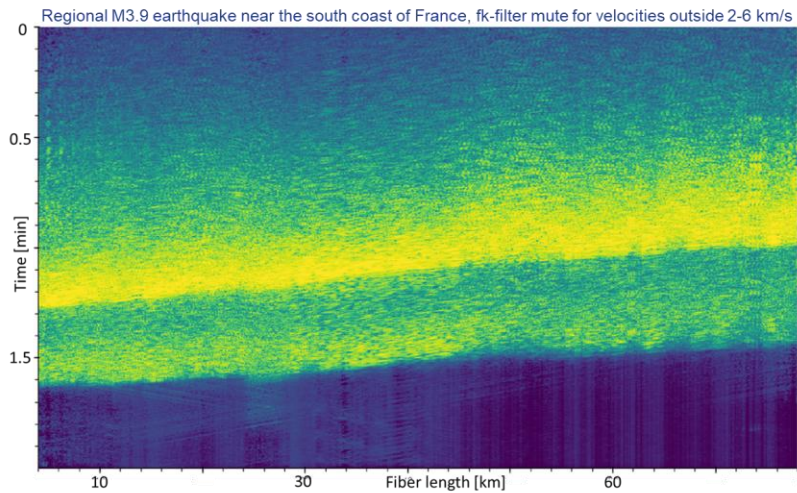
Surface vessel tracking example

- Surface vessel position (AIS)
- Surface vessel position (DAS)

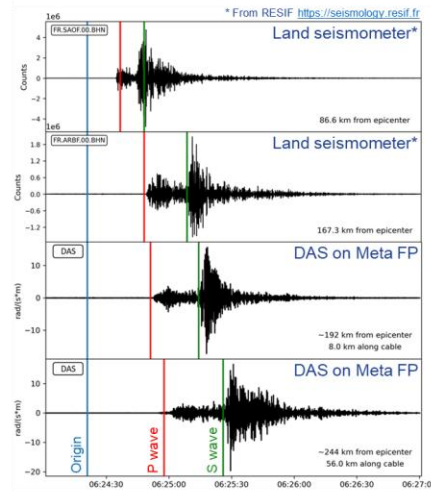


Surveillance in ocean space – Seismology / earthquakes

- Real-time earthquake monitoring with DAS
- Recent field data studies establish capability for detection, location and magnitude estimation
- Integration of OptoDAS with existing seismic networks
- Pre-processed live streaming virtual seismic station array

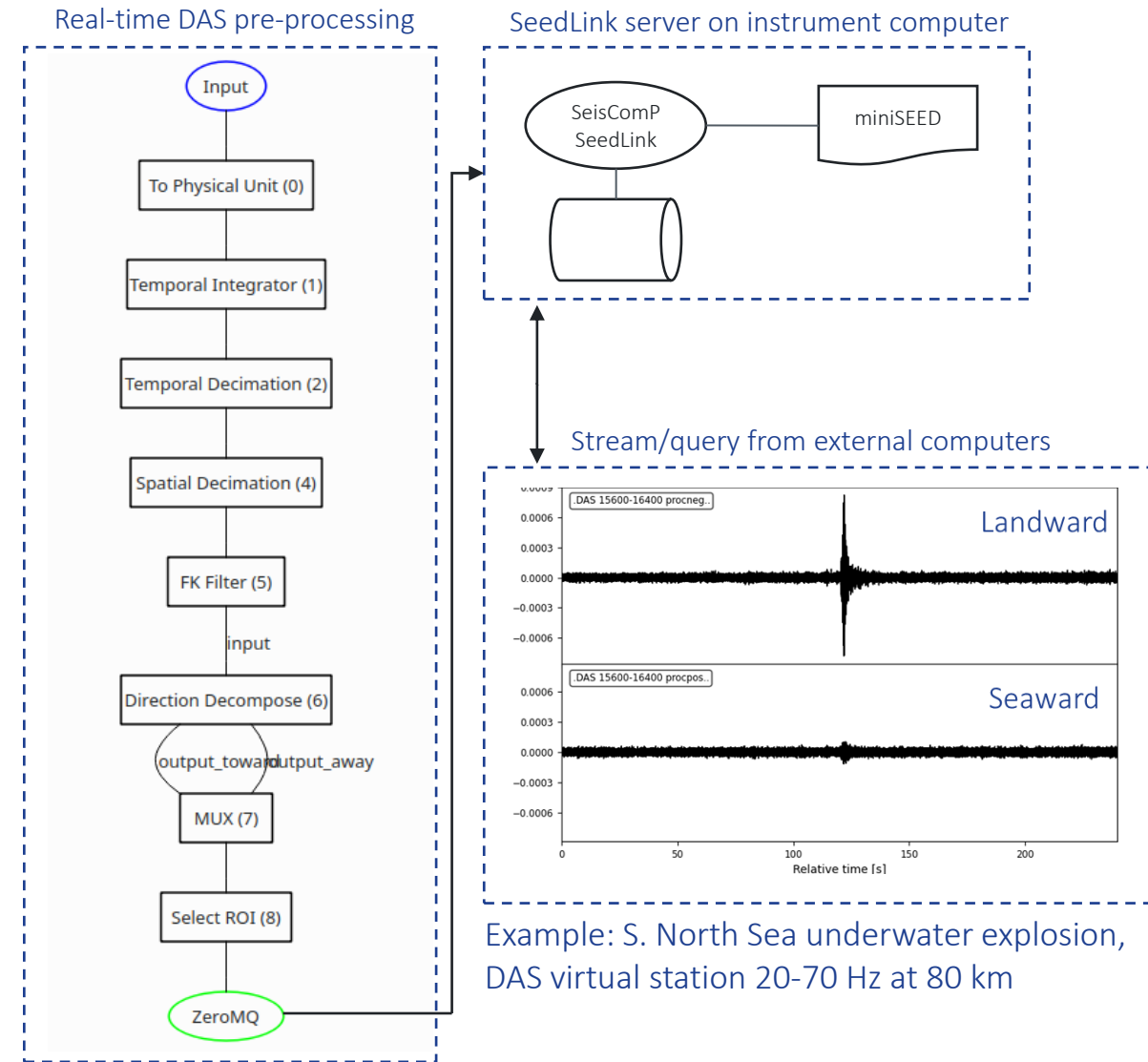


Example: South France regional earthquake



Seedlink – Real-time streaming

<https://www.seiscomp.de/doc/apps/seedlink.html#optodas>



Example: S. North Sea underwater explosion, DAS virtual station 20-70 Hz at 80 km

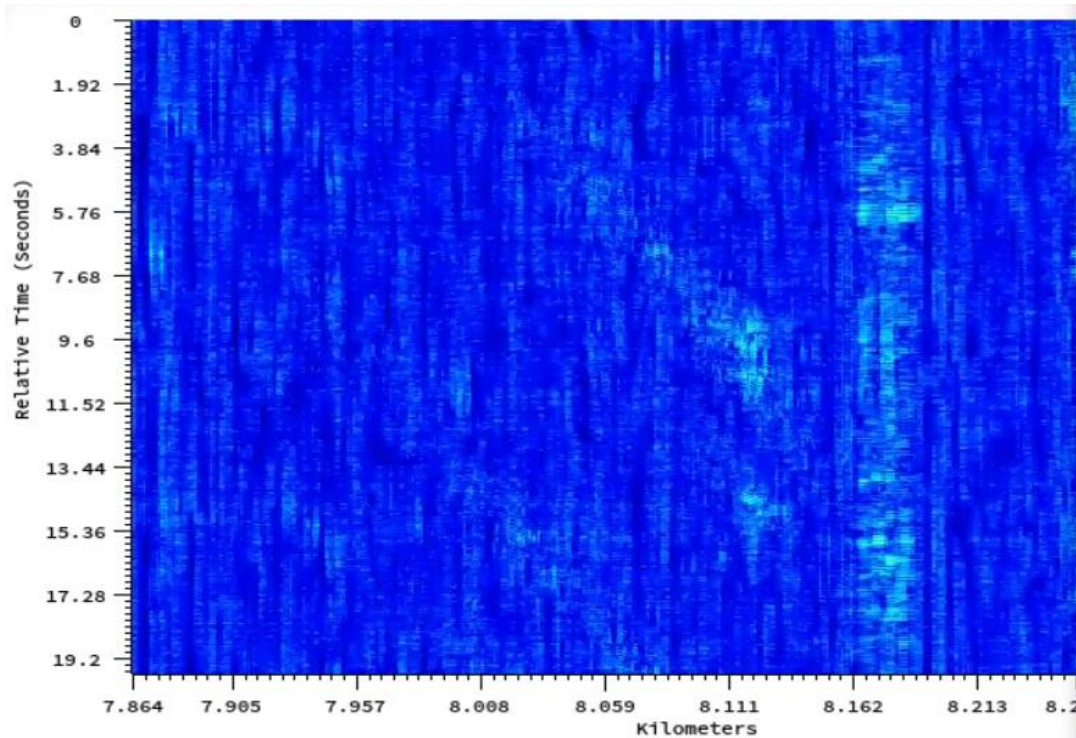
Surveillance in ocean space – Seabed tap-test with mini ROV



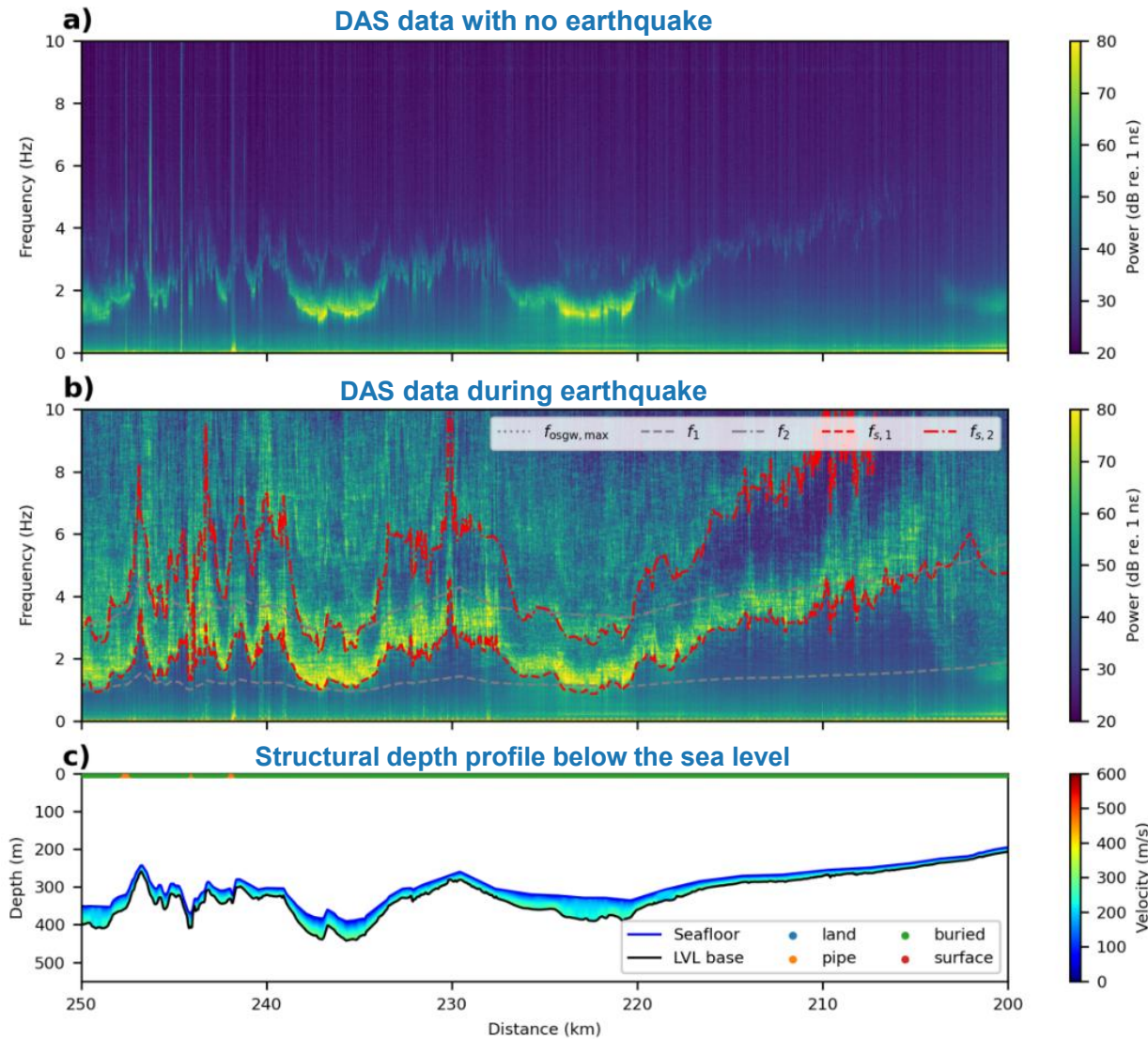
OptoDAS amplitude data view



Drone camera feed



Surveillance in ocean space – Near-surface imaging

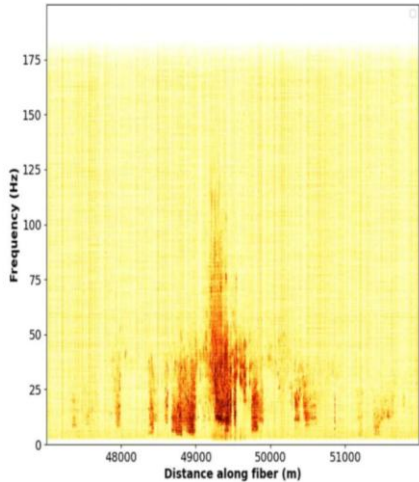
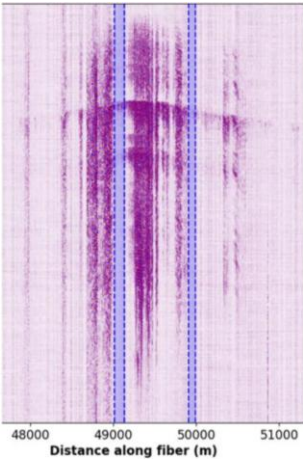
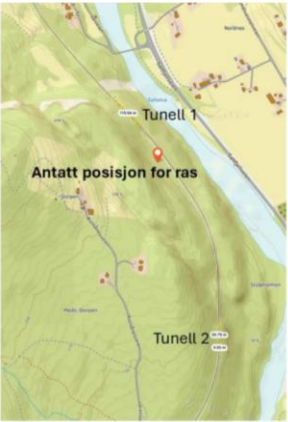


Mapping of sedimentary layer thickness beneath seafloor:

- Input: DAS data with and without earthquakes
- Processing: Shear-wave resonances

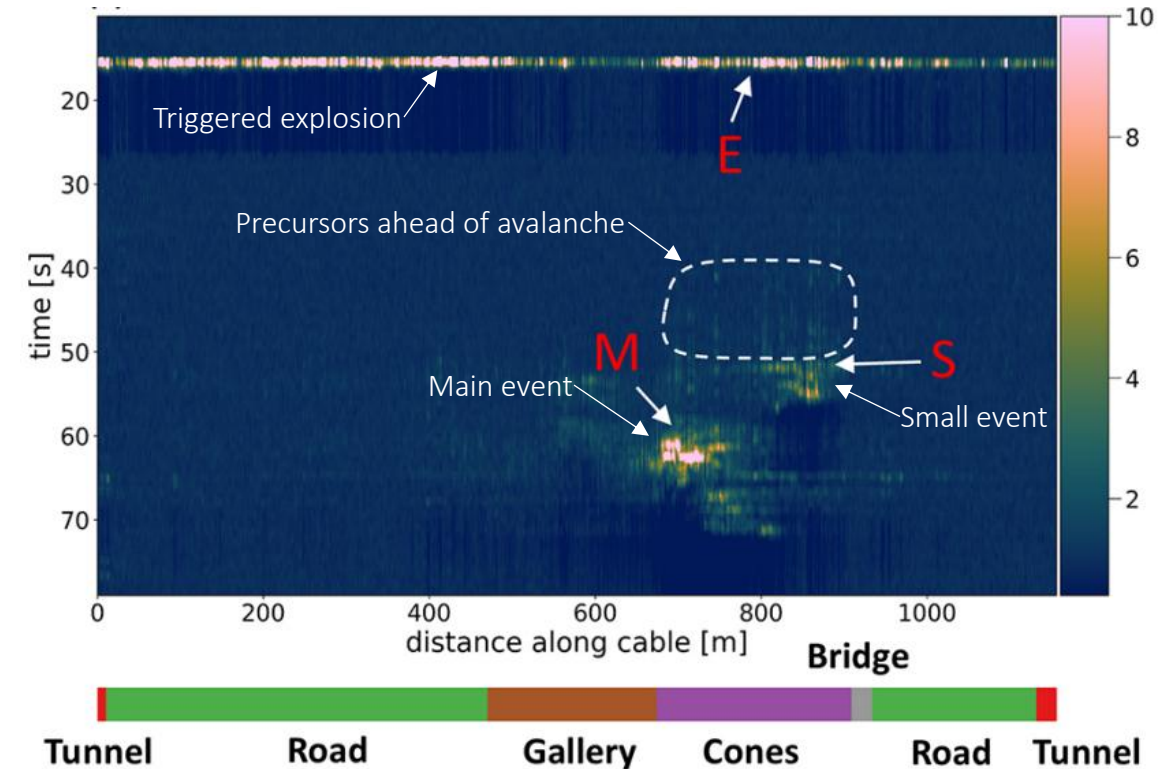
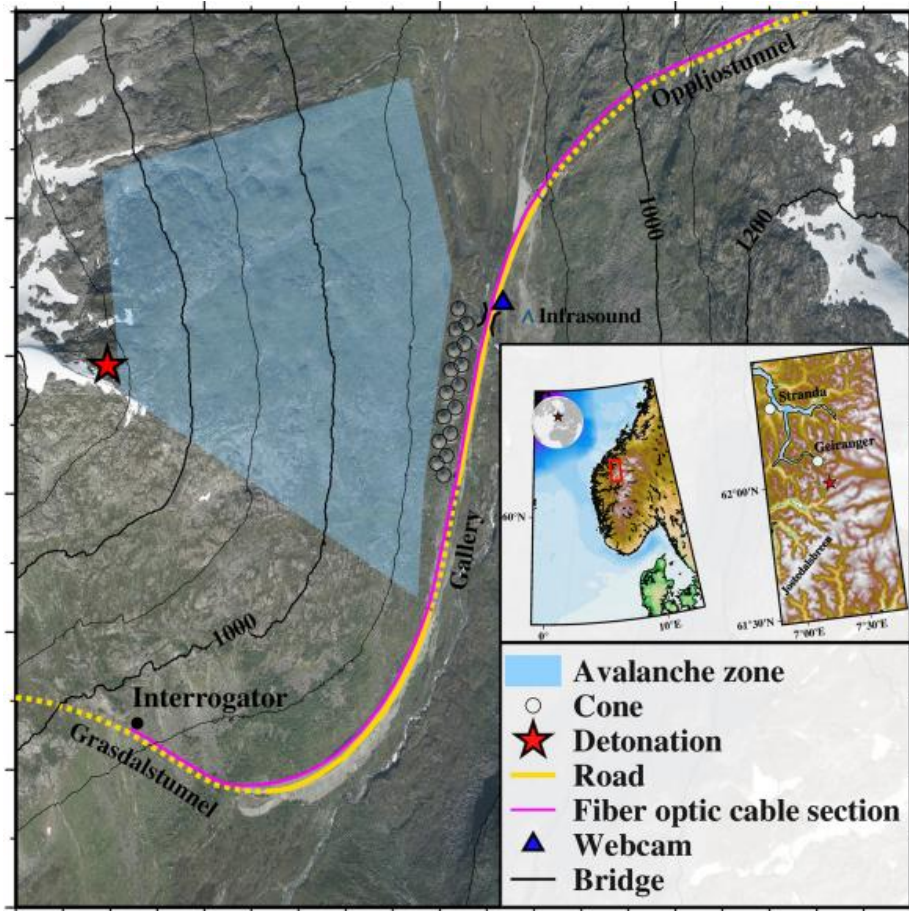
Kittinat Taweasantanon et. al., Near-surface characterization using shear-wave resonances: A case study from offshore Svalbard, Norway, Geophysics (2024) 89 (4): B317–B327. <https://doi.org/10.1190/geo2023-0530.1>

Rockfall 10 m before railway



Automatic detection of seismic signals from avalanches

- Distinct precursor signals ahead of the avalanche
- Impulsive high-amplitude signals when snow masses abruptly stops, e.g. in the stopping cones in front of the road



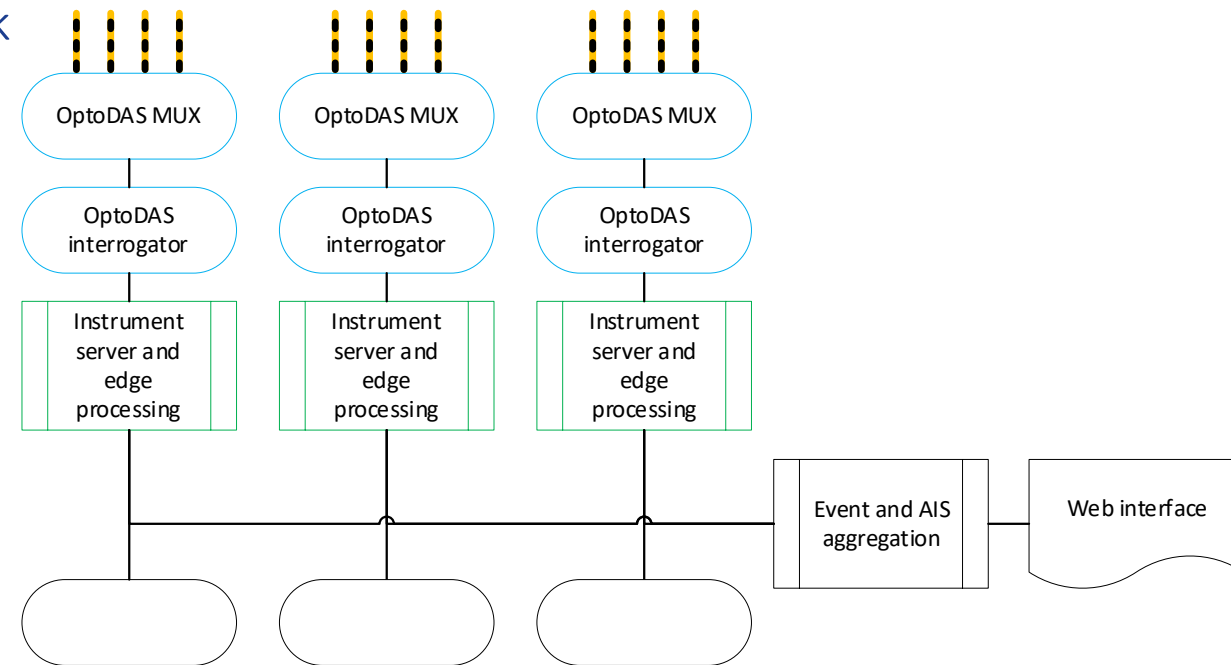
F. Kleine, et. al. “Seismic signal characterization of snow avalanches using distributed acoustic sensing in Grasdalen, western Norway”, Nat. Hazards Earth Syst. Sci., 25, 2771–2782, 2025. <https://doi.org/10.5194/nhess-25-2771-2025>

Scale-up potential for DAS in NRENs



The OptoDAS ecosystem – Versatile and flexible

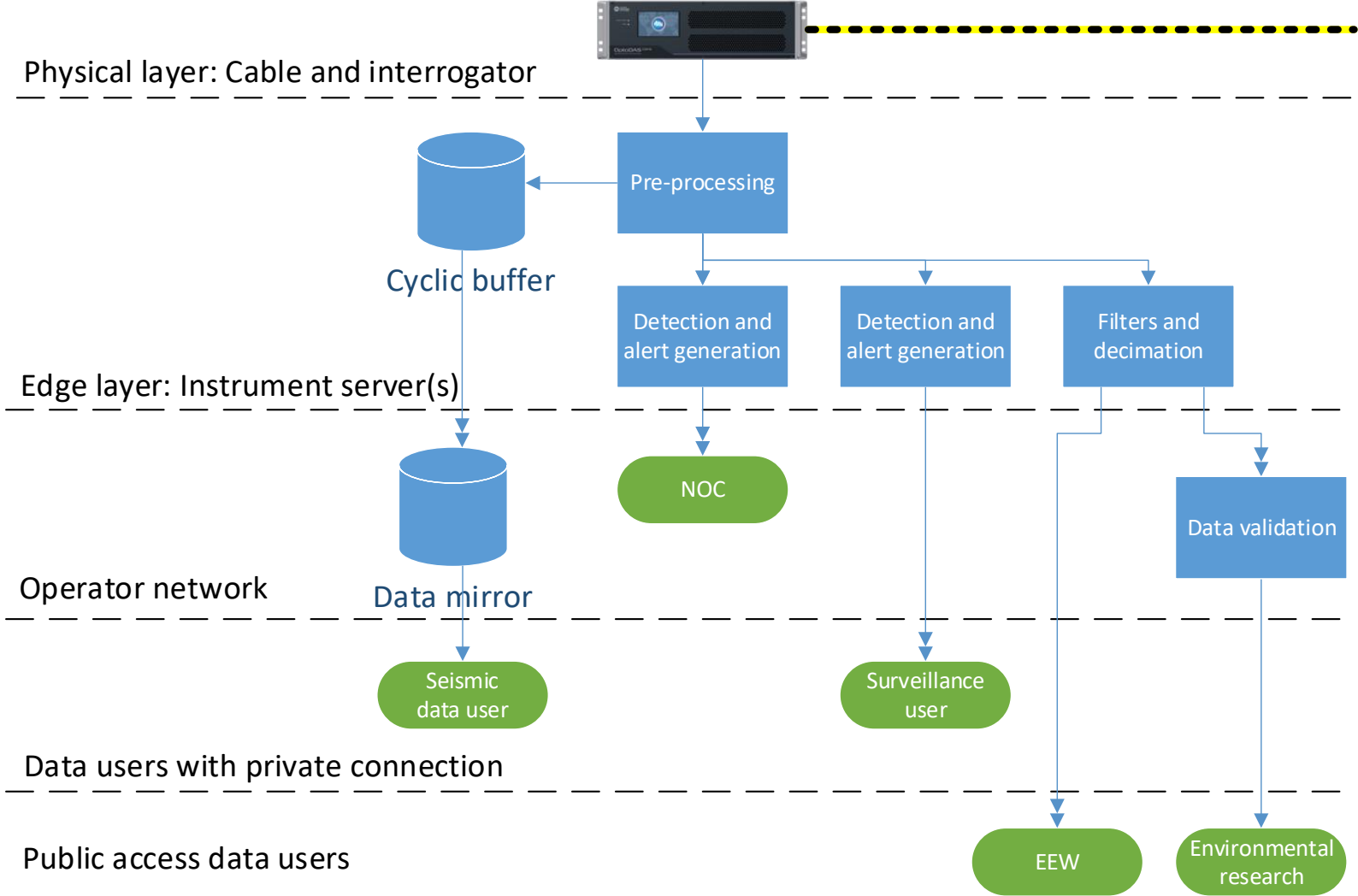
- Flexible framework for DAS data processing flows with a versatile toolbox for advanced signal processing
- Powerful edge computing capability – only alarm messages needs to be transferred though the network
- Months of raw data storage capacity in RAID disks at the edge *OR* directly stream raw data to data center (with no storage of sensitive data at the edge)
- Scalable architecture for multiple fibers (OptoDAS MUX) and multiple locations. Aggregation into a simplistic web interface.
- Cybersecurity compliant Linux server
- Customer root access to Linux server – allowing the customer to run its own data processing and system/security applications



Data sharing



Data flows and network connections to user groups

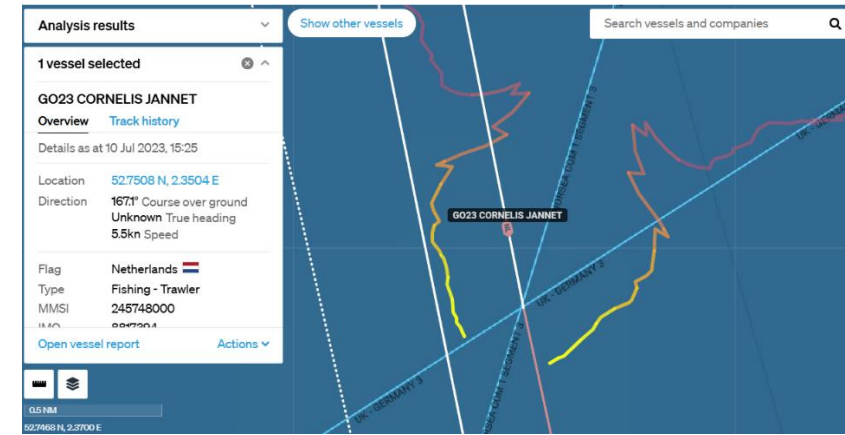


Conclusion

- NRENs serve as important research infrastructure! Not only data transmission links
- Equipping the NRENs with DAS may contribute to societal security, national security, ocean space surveillance, environmental research, smart cities, and many more...
 - Integration in maritime awareness platforms
 - Integration in natural hazards warning systems
 - ++

- ASN pioneered long-range DAS, being the first to:

- Reach beyond 100 km, now 200 km with Raman (250 km with ROPA)
- Co-exist with live DWDM coherent data transmission
- Simultaneous monitor 4 different cables fibers with one interrogator
- Introduce repeatered DAS for > 4000 km trans oceanic reach
- Locate and track seabed activities inside the submarine cable corridor
- Stream real-time 'virtual' seabed seismometer data in Seedlink to seismic networks



- ASN is committed to continue staying at the leading edge of DAS technology ...

... just as NRENs are at the leading edge of optical networks!



Think ahead, trust ASN

