Enabling the deployed fiber communication infrastructure for future sensing services

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Outline

- About Sikt
- Optical Sensing techniques
- Sikt’s activities on Optical Fiber sensing
  - Distributed Acoustic Sensing field test
  - State of polarization field test
  - Coexistence between DWDM and DAS (lab-*test*)

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Sikt- Norwegian Agency for Shared Services in Education and Research

- Was established on 1 January 2022 through a merger between NSD (Norwegian Centre for Research Data AS), Uninett AS and Unit – the Directorate for ICT and Joint Services in Higher Education & Research.
- The organization is a public administrative body under the Ministry of Education and Research.

Our mission is to help Education and Research achieve its goals by providing shared, value-adding services you can trust.

Sikt has approximately 400 employees across its head office in Trondheim and additional offices in Bergen and Oslo.

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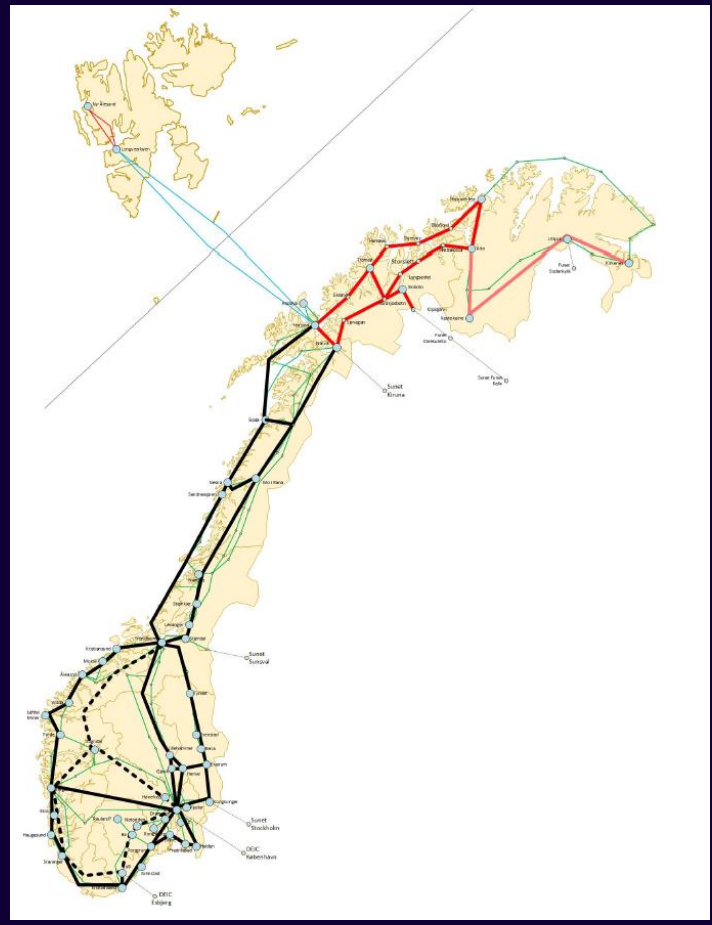
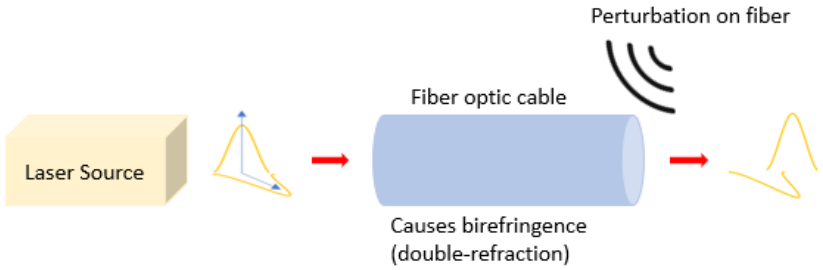
Uninett, Sikt

The Infrastructure department of Sikt has the responsibility to build, develop and operate the Norwegian National research and education network (Uninett)



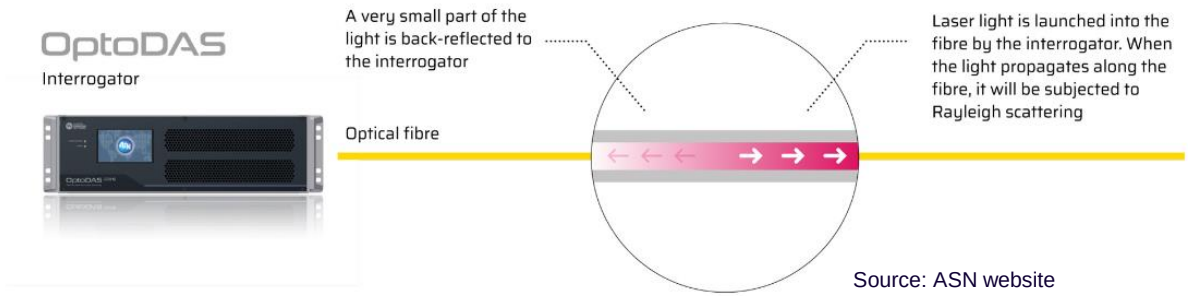
Optical sensing techniques



Source: Kristina Shizuka Yamase Skarvang

Technology	DAS	Phase / Interferometry	SOP
Equipment requirements	DAS interrogator	Ultra-stable laser	Regular coherent linecards
Spectrum requirements	No impact on existing channel plan (can operate outside of telecom spectrum)	Spectrum required	No impact on existing channel plan
Sensitivity	High	High	Medium
Range	< 150 km	> 10 000 km	> 10 000 km
Spatial resolution	meter-scale	60-120 km-scale	60-120 km-scale

Source:Jan kristoffer Brenne, Alcatel Submarine Networks Norway



Source: ASN website

DAS is a technique for dynamic monitoring of strain distribution along an optical fibre

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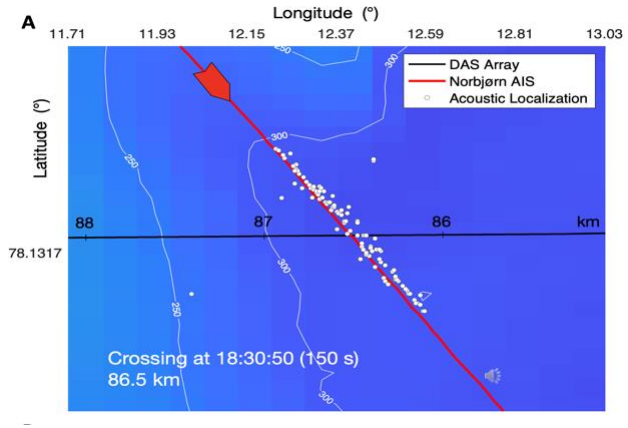
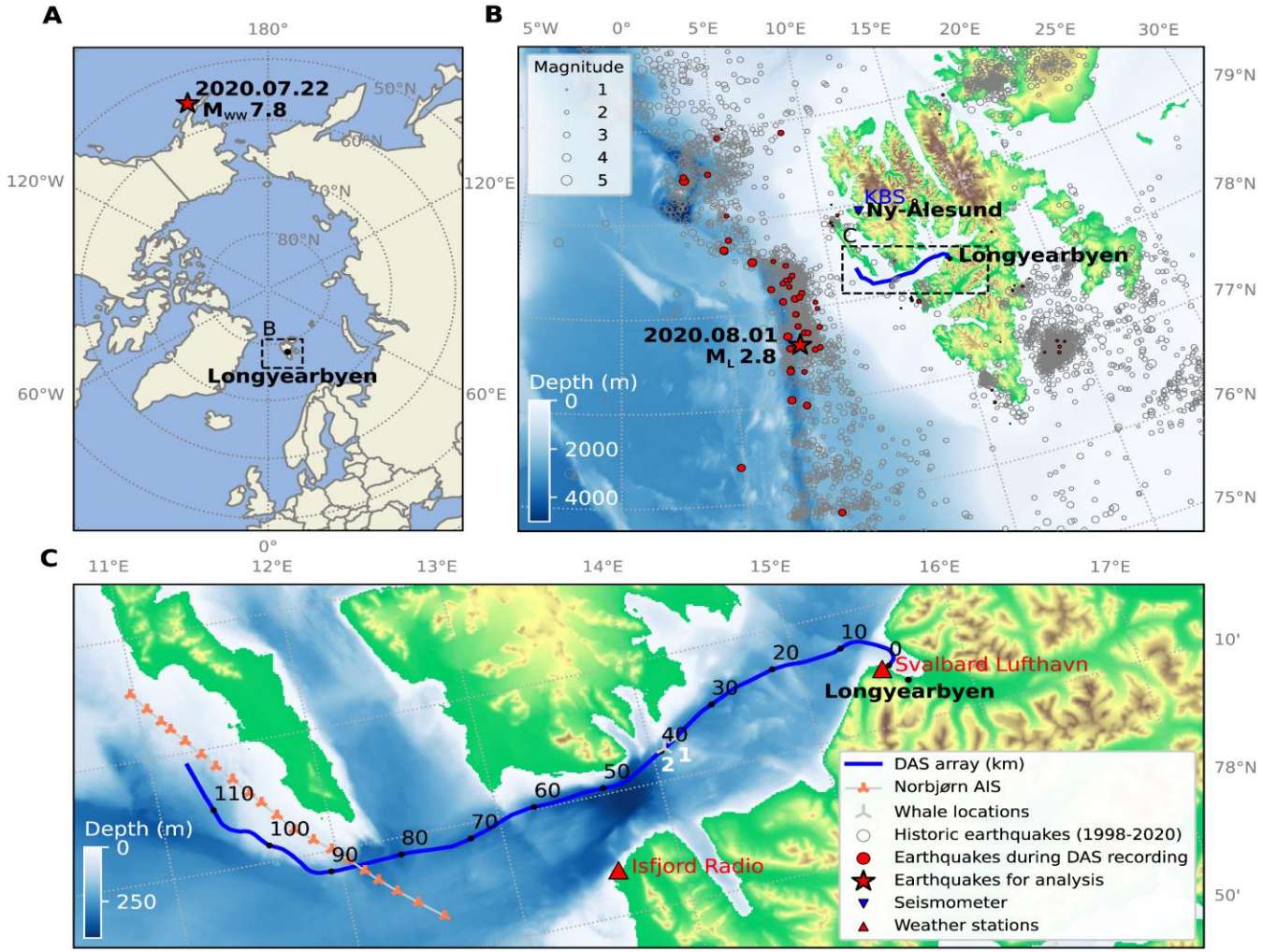
Field test 2020: Svalbard





Source: Martin Landrø et al., Sensing whales, storms, ships
and earthquakes using an Arctic fibre optic cable, Nature Published: 10 November 2022, https://www.nature.com/articles/s41598-022-23606-x

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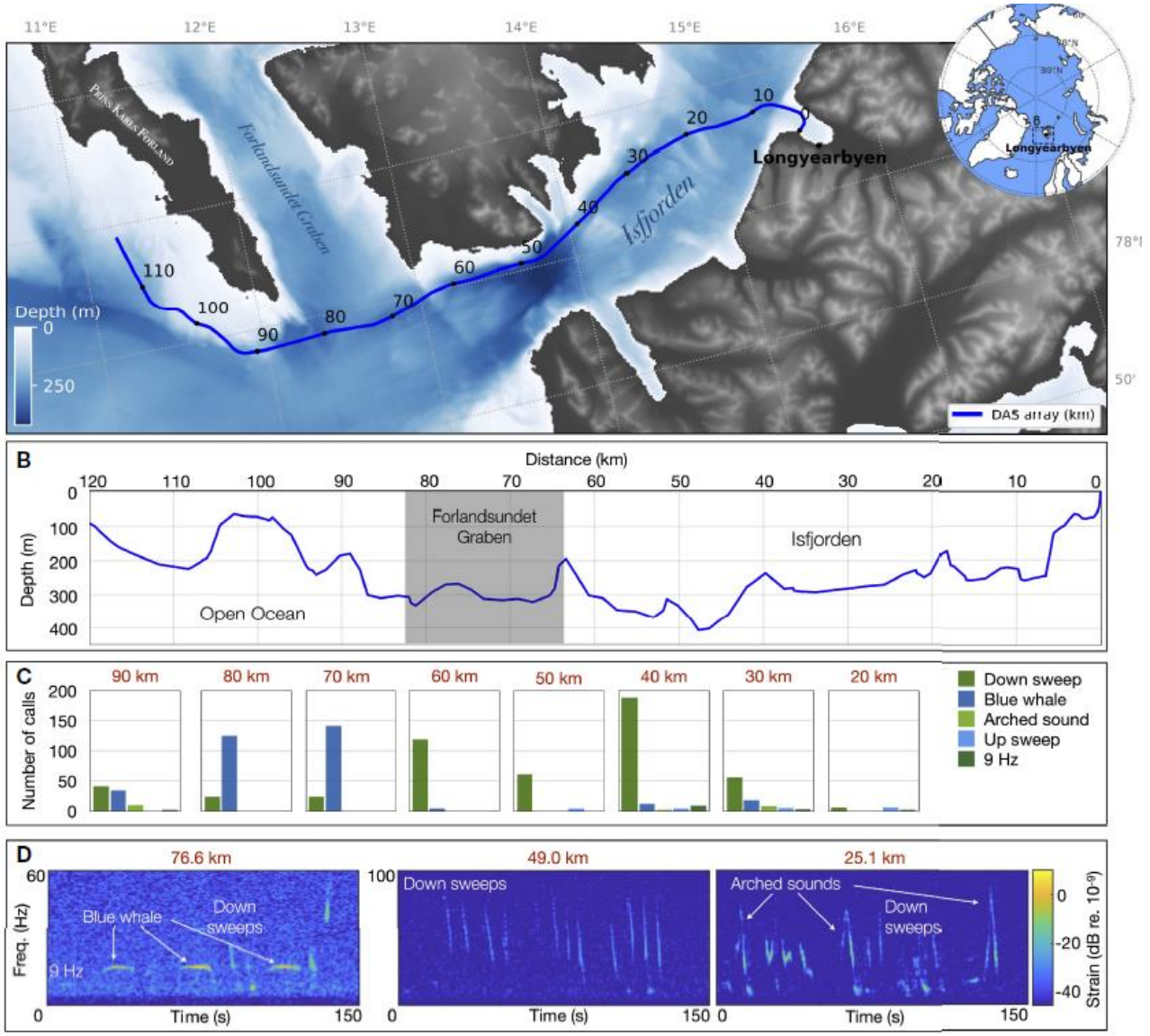
Baleen whale vocalizations detected over the 120 km of the Svalbard underwater distributed acoustic sensing (DAS) array (field test 2020)



Source: Le´ a Bouffaut et al. , Eavesdropping at the Speed of Light: Distributed Acoustic Sensing of Baleen Whales in the Arctic, Frontiers in Marine Science, July 2022

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Data streaming

We live-streamed 250 TB of DAS data from Svalbard to mid-Norway over 40 days of test period (7TB per day)

This technique make it possible for researcher to study whales and their sound production, their calls and their vocalizations from everywhere almost instantly.

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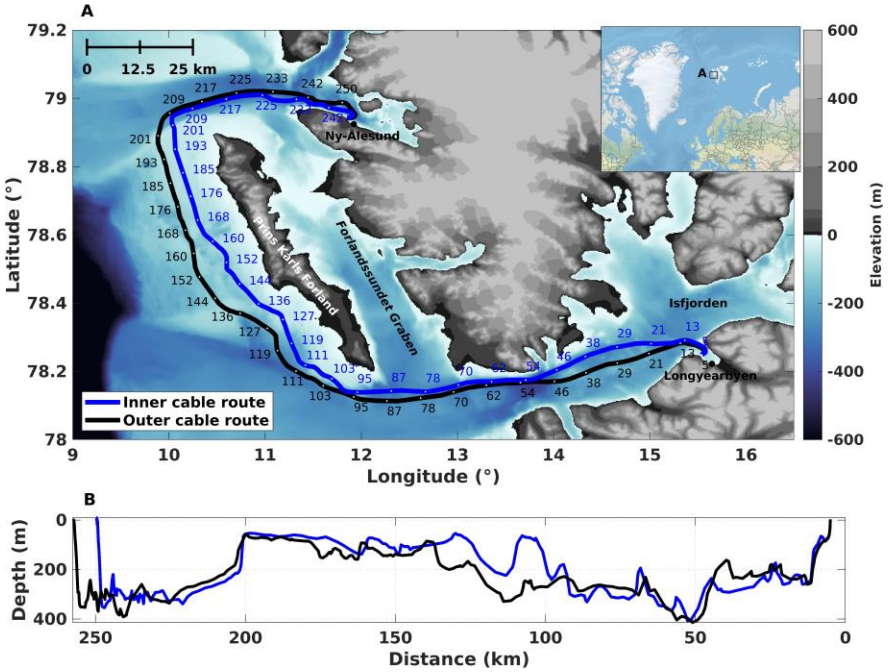
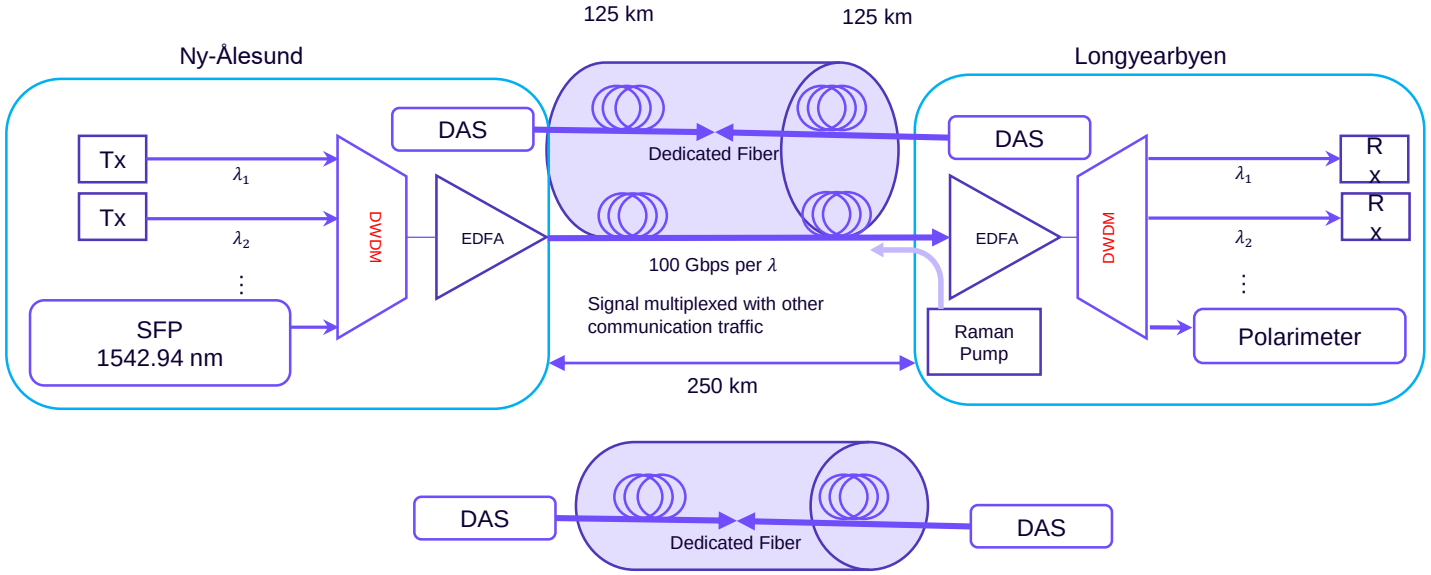
Field test 2022: Svalbard

- Polarimeter (PM1000, Novoptel) connected to a live DWDM link
- DAS (OptoDAS, ASN) interrogators connected to two dedicated fibers in each cable





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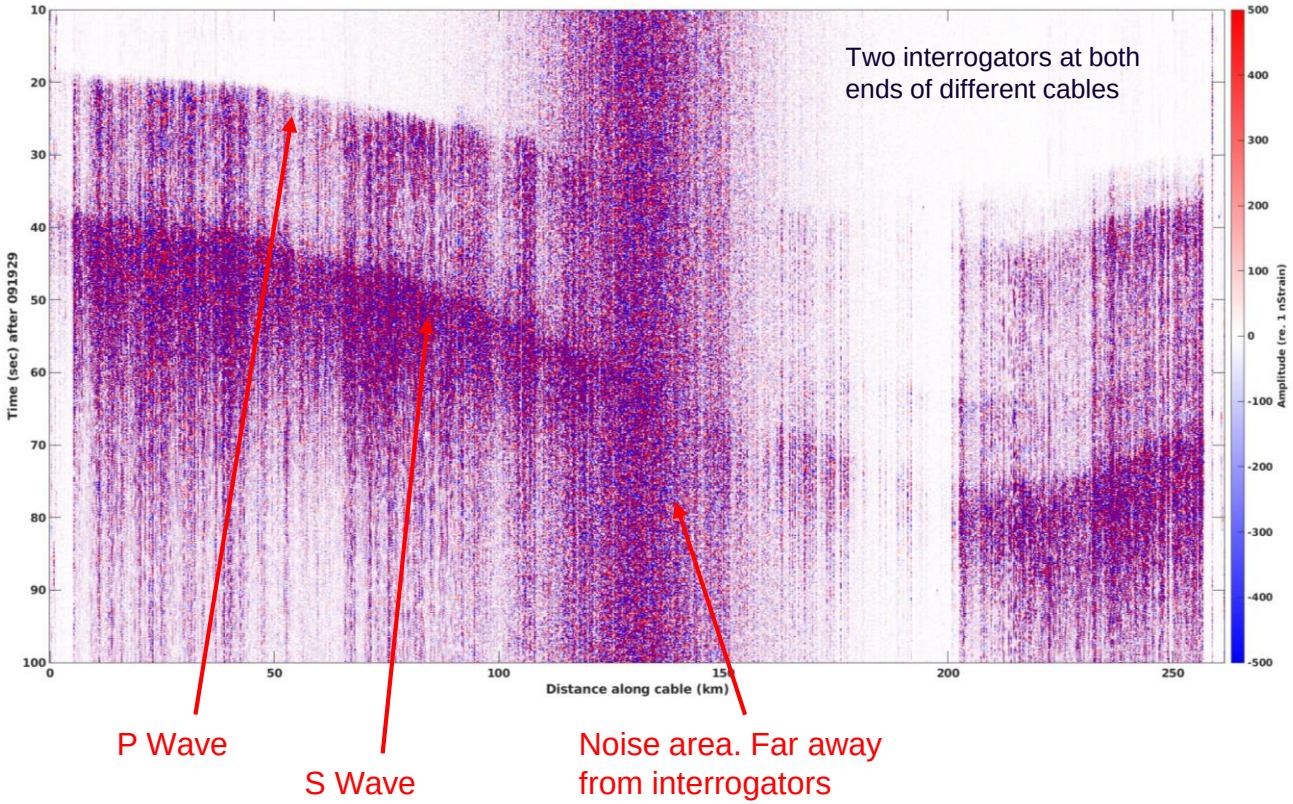
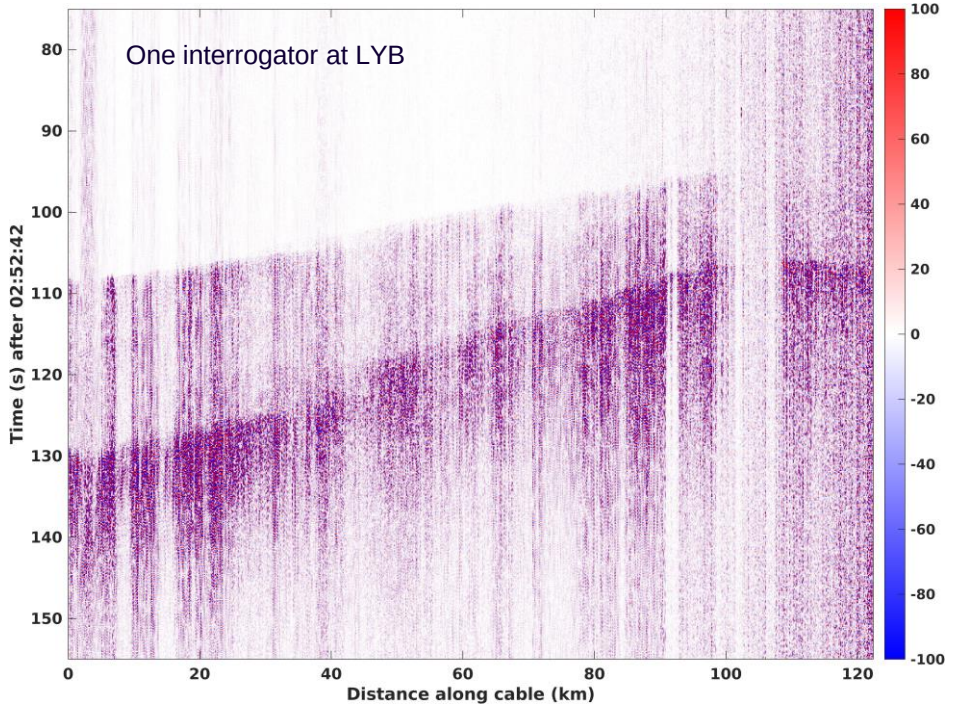
Earthquake analysis with two DAS interrogators



Two interrogators more fiber length and more data to analyse. It will gives a more precis detection of epicenter.(left) Future study will investigate the localization of depth of epicenter.



Source: Rørstadbotnen et al., 2022, Simultaneous Tracking of Multiple Whales using two Fibre-Optic cables in the Arctic, Front. Mar. Sci. Volume 10 – 2023, doi:10.3389/fmars.2023.1130898.

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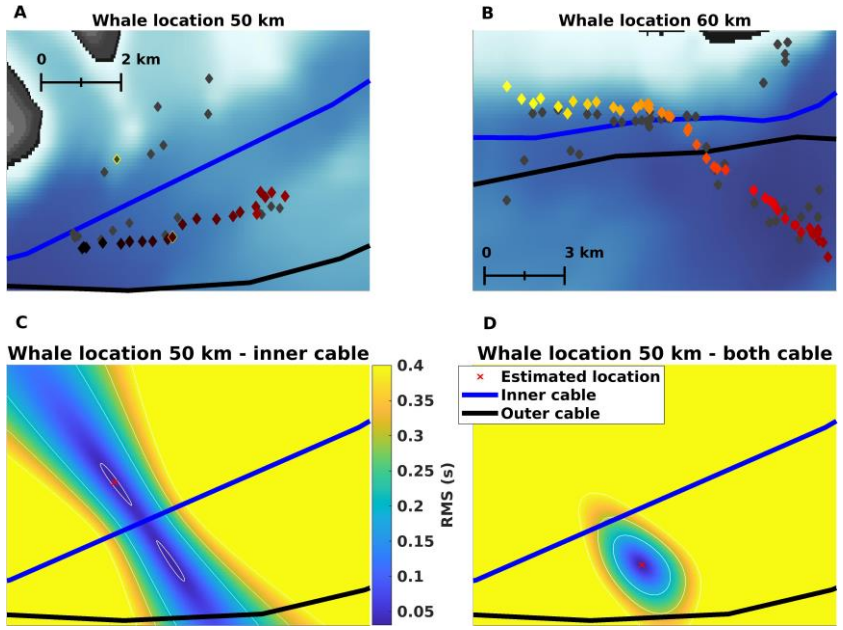
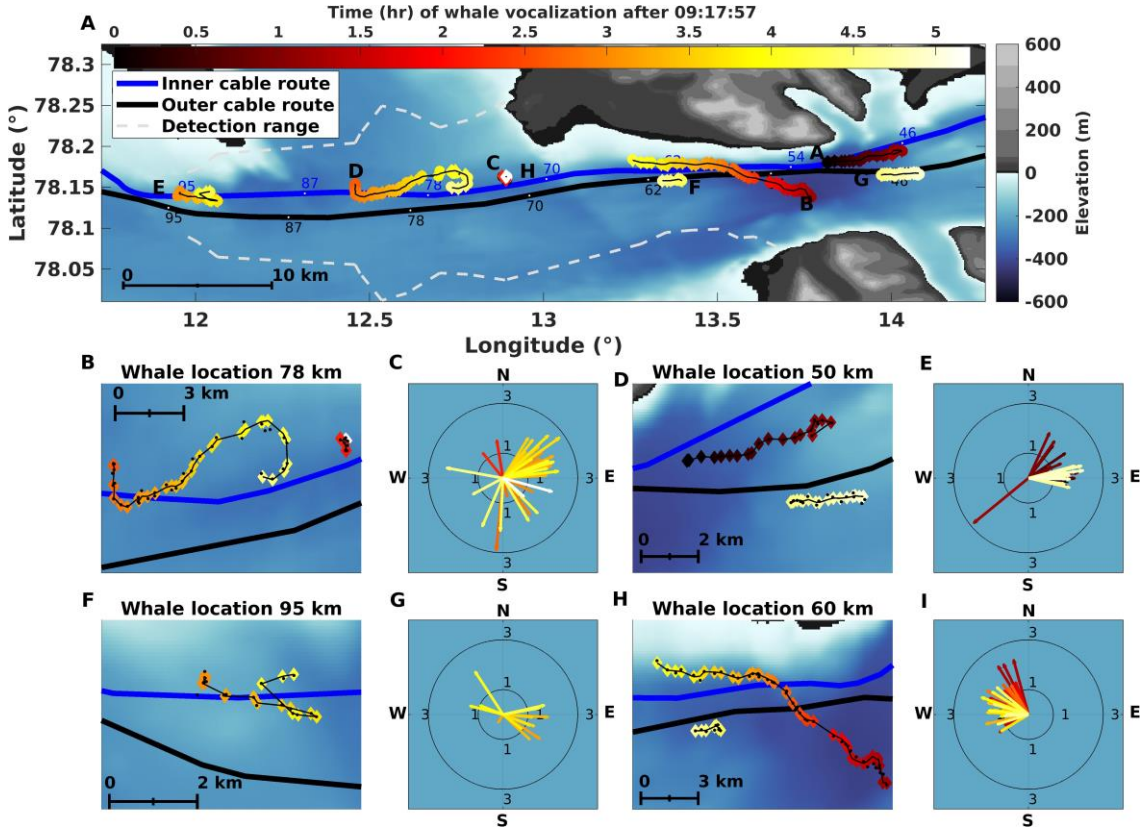
Whale tracking with DAS interrogation on two cables





Introducing DAS interrogation two cables resolved the well-known left-right ambiguity

Source: Rørstadbotnen et al., 2022, Simultaneous Tracking of Multiple Whales using two Fibre-Optic cables in the Arctic, Front. Mar. Sci. Volume 10 – 2023, doi:10.3389/fmars.2023.1130898.

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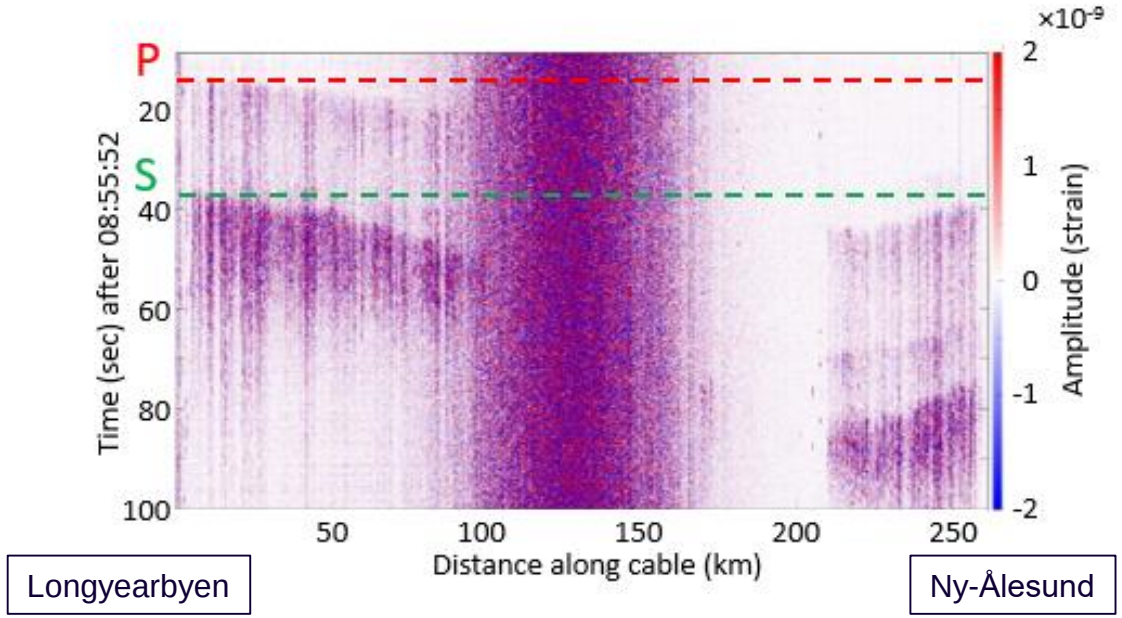
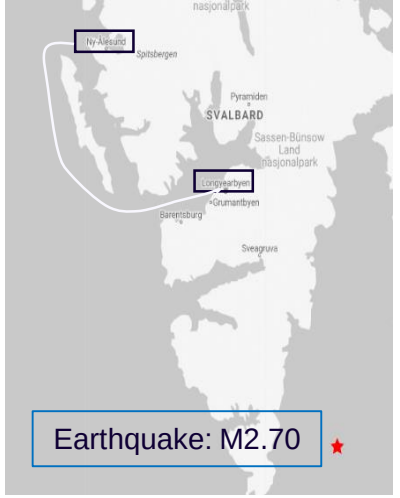
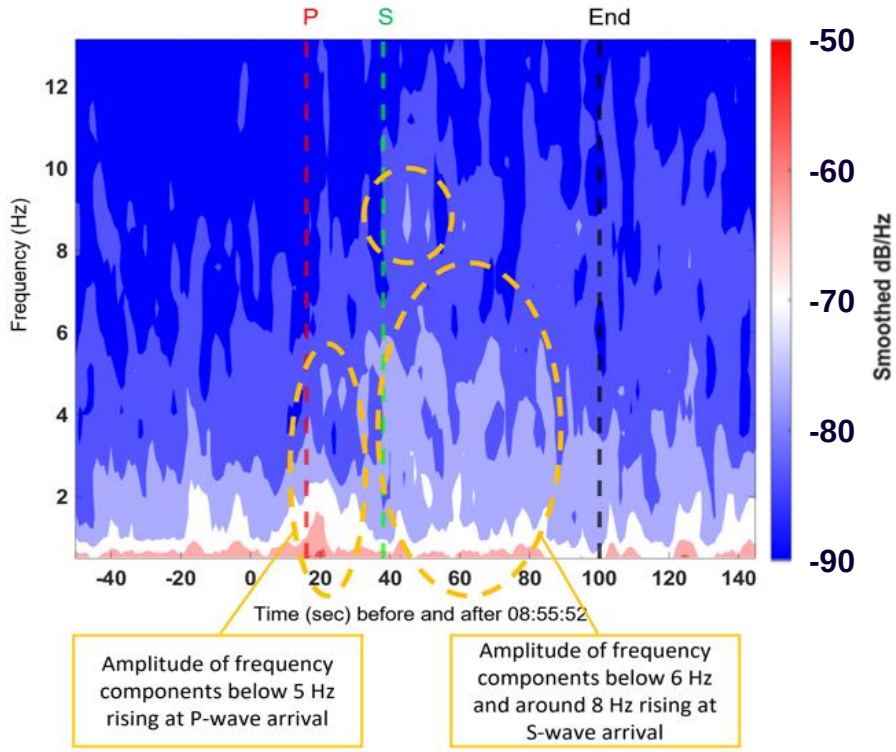
Detection of M2.7 Earthquake with DAS and SOP





NORSAR seismometer

[Extract the timing the seismic waves hits the cable from DAS data]



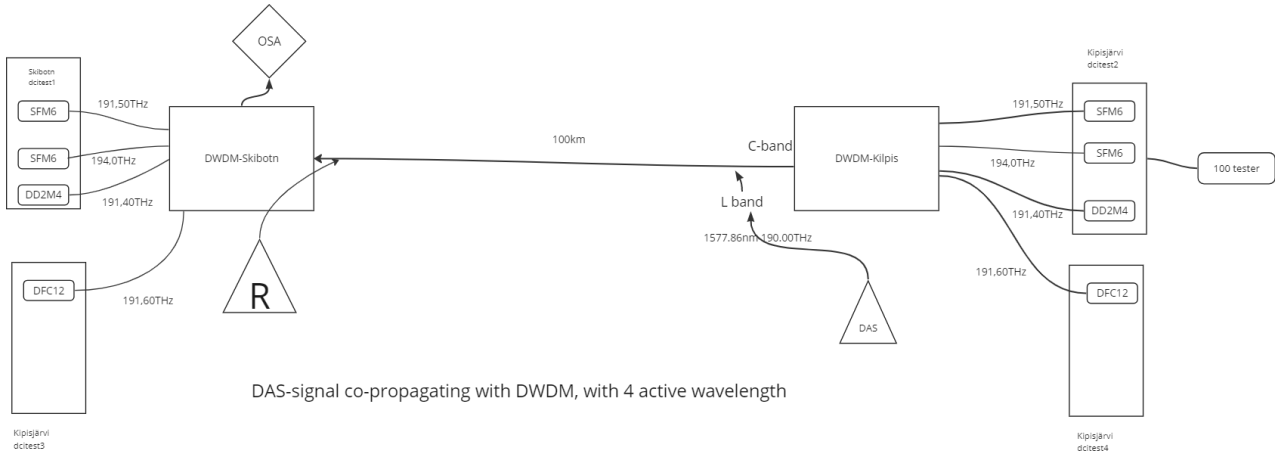
Source: Kristina Shizuka Yamase Skarvang et al., Observation of Local Small Magnitude Earthquakes using State Of Polarization Monitoring in a 250km Passive Arctic Submarine Communication Cable, OFC 2023

[SOP variation corresponds with the timing of the Earthquake hitting the cable]

Coexistence of DWDM and DAS

Coexistence of DWDM and DAS have been tested with four main scenarios

- co-propagating without Raman
- co-propagating with Raman
- counter-propagating without Raman
- counter-propagating with Raman



DAS-signal co-propagating with DWDM, with 4 active wavelength

DAS with different operational power range have been tested with running DWDM channels with a variety of modulation format, Symbol rate and bitrate

The effect of DAS seen from DWDM point of view

	No Raman	Raman
co-propagating	With normal DAS operation power range there will be no issue on running channels. With full DAS power the higher modulation format will be degraded but QPSK channel is less affected. To totally isolate the DAS signal from the channels it could be good to use a C/L-filter at receiver side (1,5dB insertion penalty)	DAS with normal operating power range has no negative impact on performance quality on the running channels. We see a change on noise floor (1-1,5dB)
counter-propagating	We see no signal degradation on running channel. To protect the laser on operation channels it will be beneficial to use C/L-filter at Tx-side of the DWDM-link (inbuilt filter on ROADM due OTDR usage 1575nm-1611nm).	Not possible We can't insert C/L-filter on Rx side of DWDM where we have the Raman pump

DAS/DWDM coexistence seen from DAS point of view

	No Raman	Raman
co-propagating	There is no impact on DAS-performance. This configuration is possible with available C/L-filters.	There is no impact on DAS-performance. This configuration is possible by using C/L-filters with an isolation ratio (leakage from other band than L-band on L-port) greater than 35dB on L-port. (The suppression of Raman at 1425 nm and 1454 nm through typical C/L-filters was not adequate, which causes DAS-noise floor to increase considerably in our test.
counter-propagating	There is no impact on DAS-performance. This configuration is possible with available C/L-filters.	Not possible. We can't insert C/L-filter on Rx side of DWDM where we have the Raman pump No impact on DAS performance, but not possible due to limitations in Raman amplification layout used in these tests.

Conclusion and further work

- Demonstrated the benefit of DAS for geophysics applications and environmental monitoring
- Demonstrated the advantage of DAS on multiple fiber cable for a more exact event localization
- Demonstrated feasibility of low magnitude earthquake detection by SOP in a 250 km passive submarine cable in live communication infrastructure
  - Combined SOP and DAS monitoring enabled identification of record low magnitude earthquakes (M2.7) in SOP data
- Demonstrated the coexisting of DAS and DWDM and its possibilities and limitations

- Next step:
  - Combined phase and SOP testing by coherent transmission transceivers
  - In-field DAS recordings in combination with DWDM in live networks
  - Perform detailed comparison of SOP and DAS recordings of earthquakes
  - Establishing noise reduction methods for SOP by long-term field experiments
  - Time-synchronization between SOP detectors/devices on different cables

Thank you!

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Sources

https://www.nature.com/articles/s41598-022-23606-x

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