Nordunet Workshop 7 October 2024

Environmental and geophysical scientific opportunities related to Polar Connect

by Martin Landrø

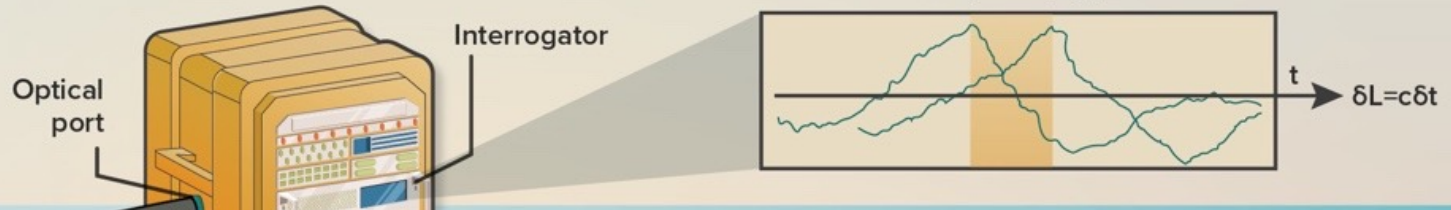
SFI Centre for Geophysical Forecasting

NTNU

Centre for Research-based Innovation

The Research Council of Norway

How Distributed Acoustic Sensing works with light pulses in a Fibre Optic cable



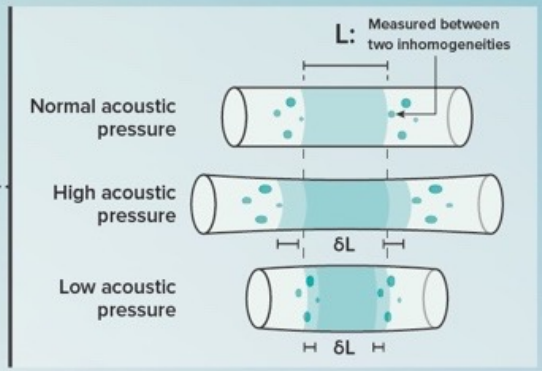
1 Light pulses are injected into a fibre cable at regular intervals

2 Acoustic sources, such as whales, ships and earthquakes, radiate oscillating pressure fields

3 These oscillating pressures stretch and compress the fibre

4 Inhomogeneities in the fibre scatter the light pulses back to the interrogator

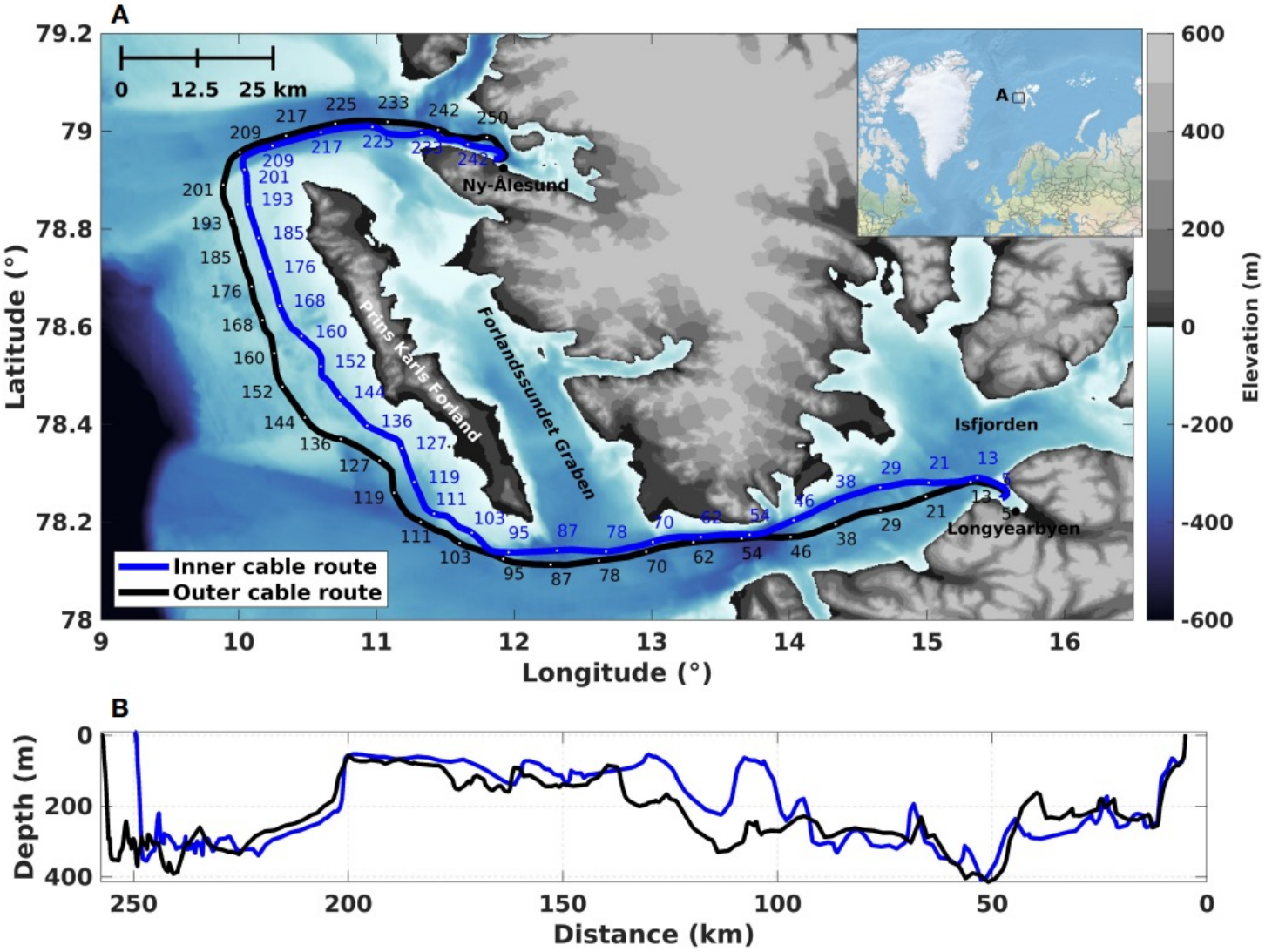
5 Variations in backscattered light due to the stretching of the fibre can be tracked at the interrogator to tell us about the acoustic pressure field at points along the fibre



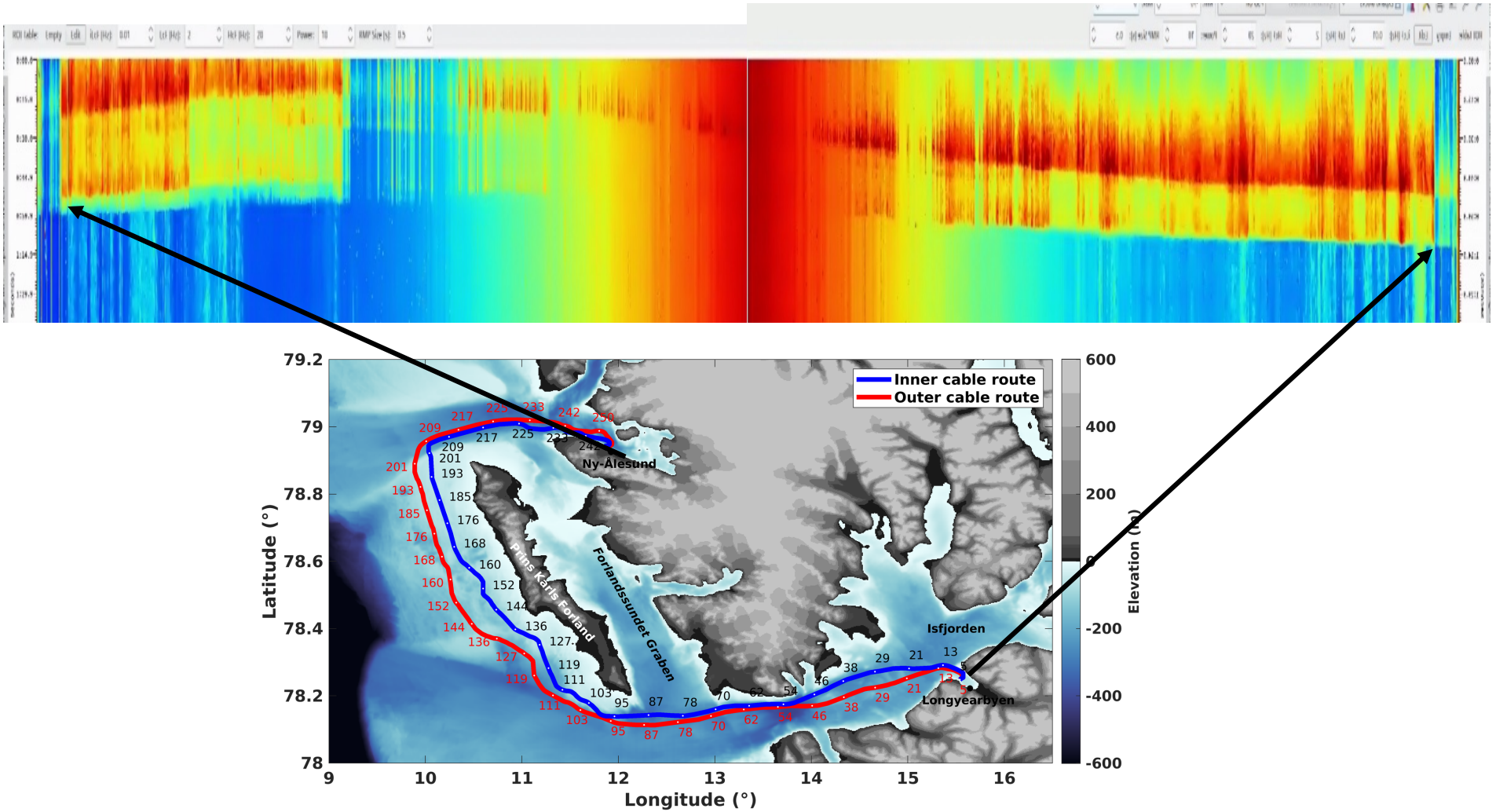
Fibre optic cable

CGF SFI Centre for Geophysical Forecasting

The two fibre optic cables offshore Svalbard

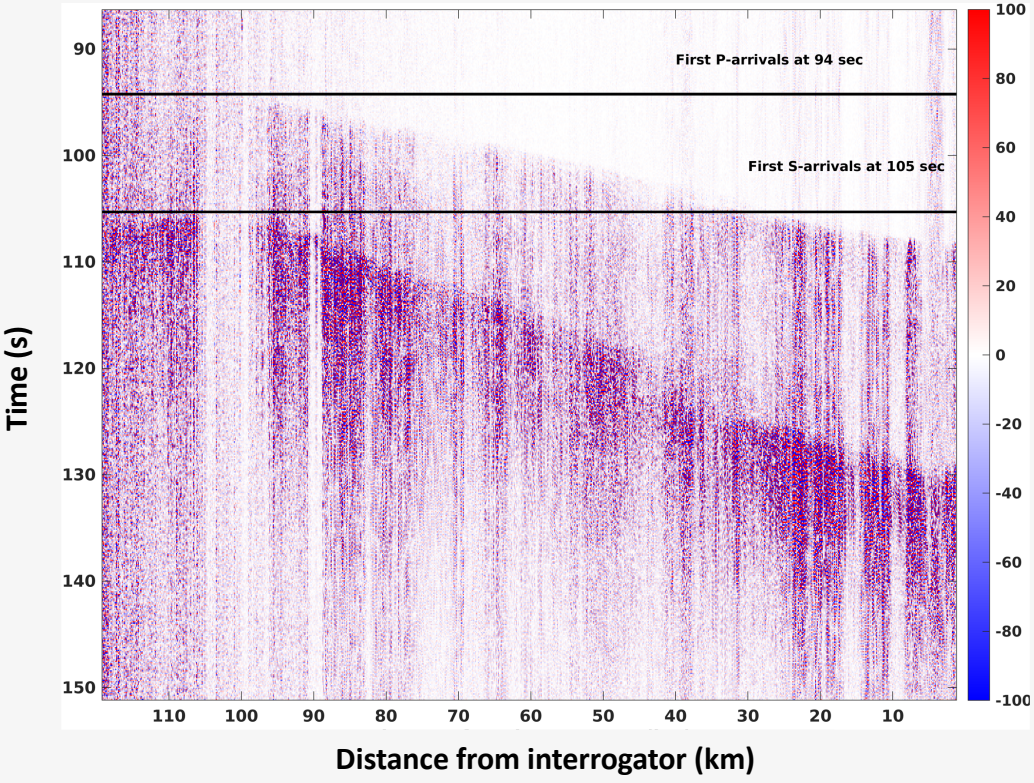


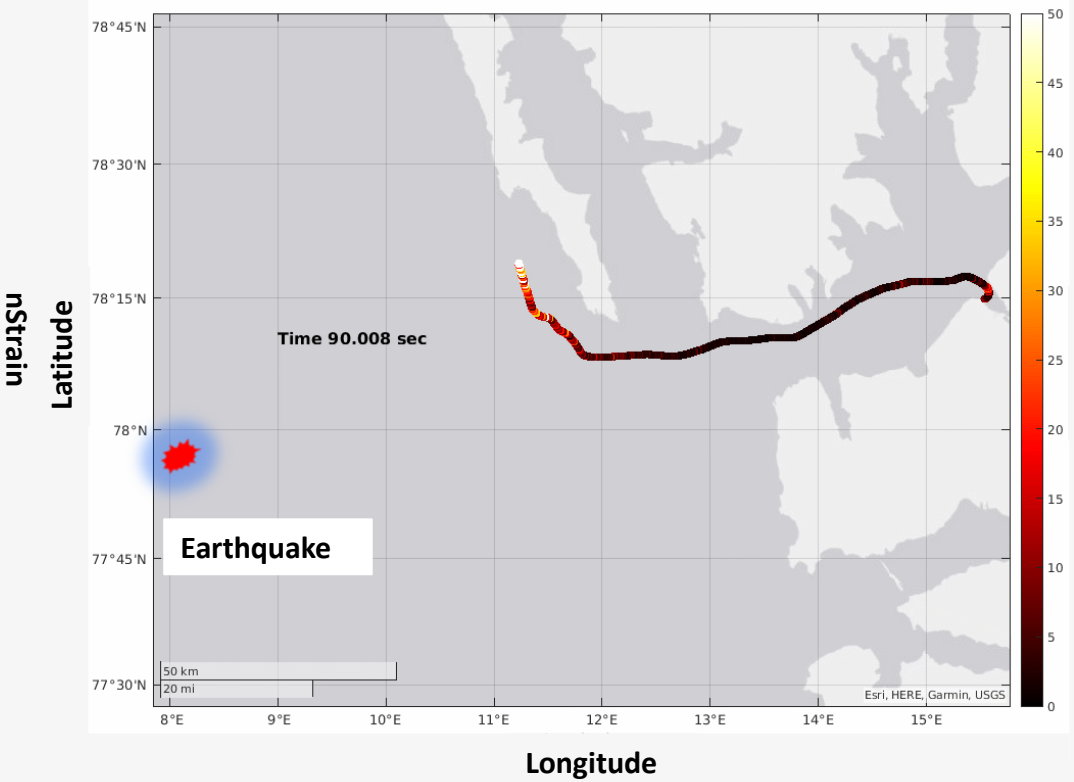
The 2022 CGF Svalbard field campaign: Using 4 interrogators



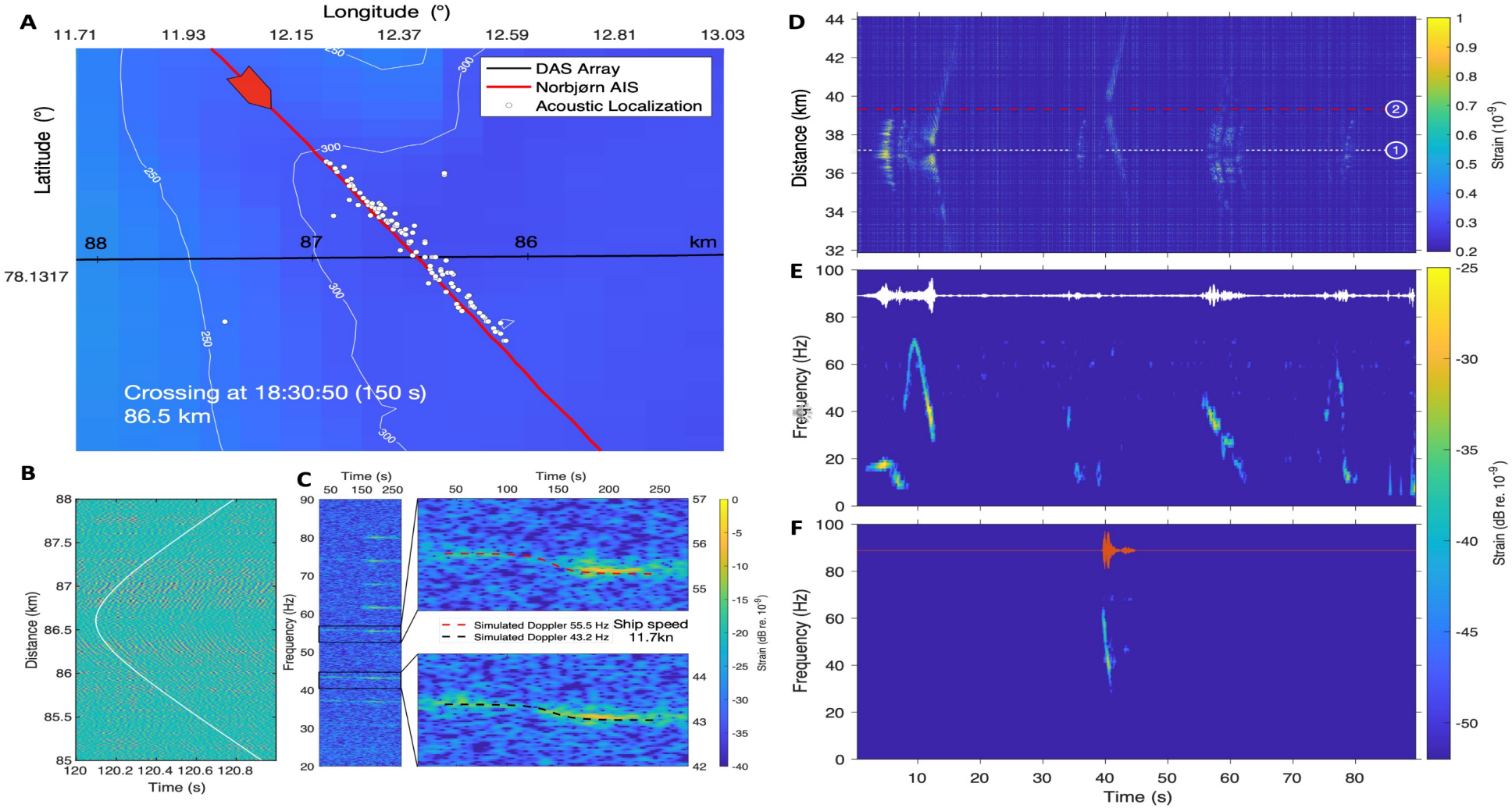
Analysis of a Local Earthquake in the Arctic using a 120 km long Fibre-optic cable

The beauty and power of DAS





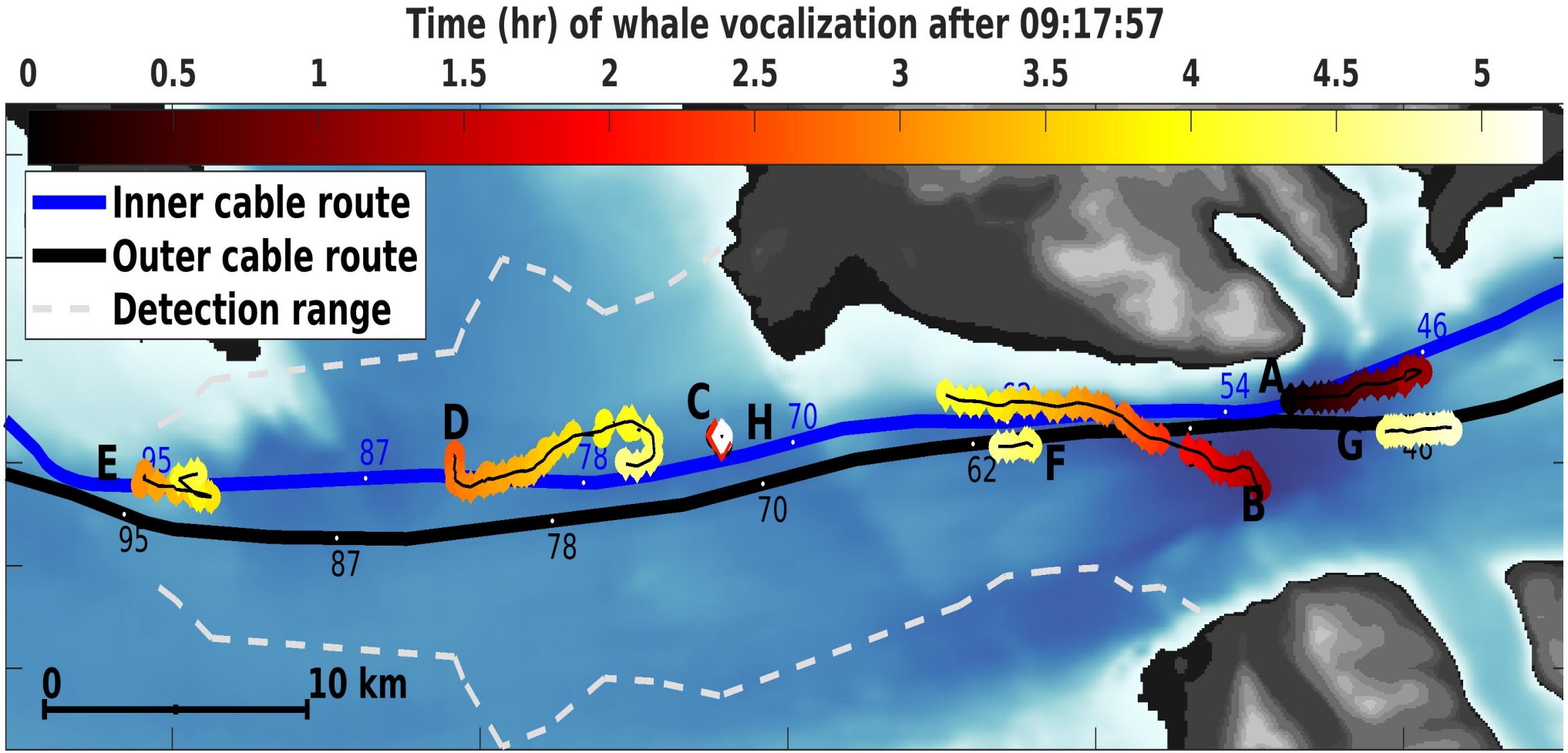
Sensing whales, storms, ships and earthquakes - Arctic fibre-optic cable



Bouffaut, L. et al., 2022, **Eavesdropping at the speed of light: Distributed acoustic sensing of baleen whales in the Arctic**. Front. Mar. Sci. 9, 901348.

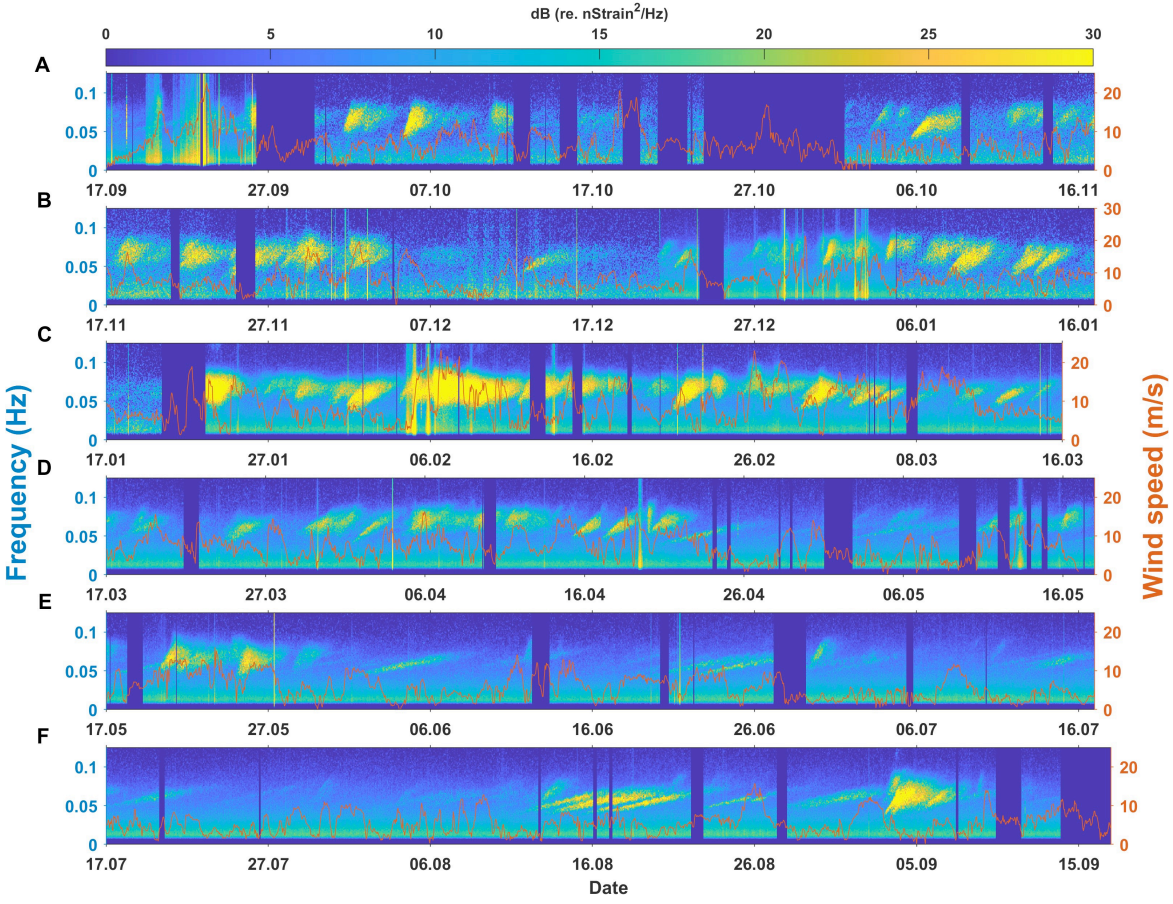
Tracking fin whales

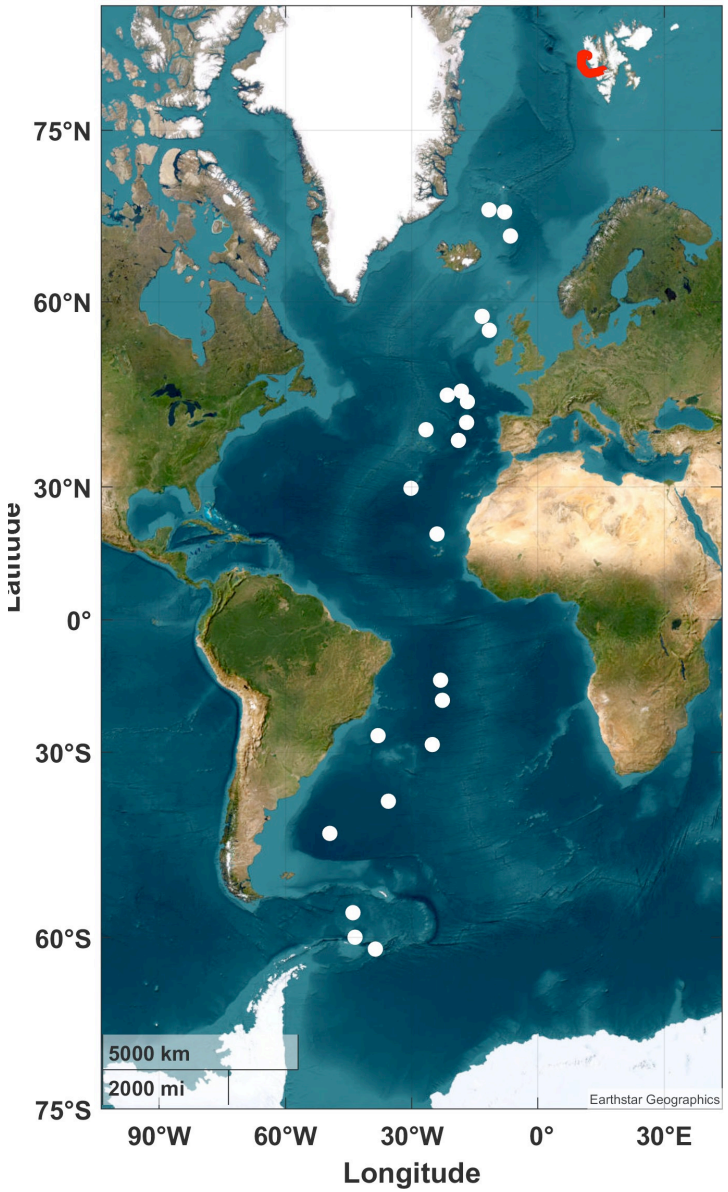
Tracking several fin whales for 5 hours



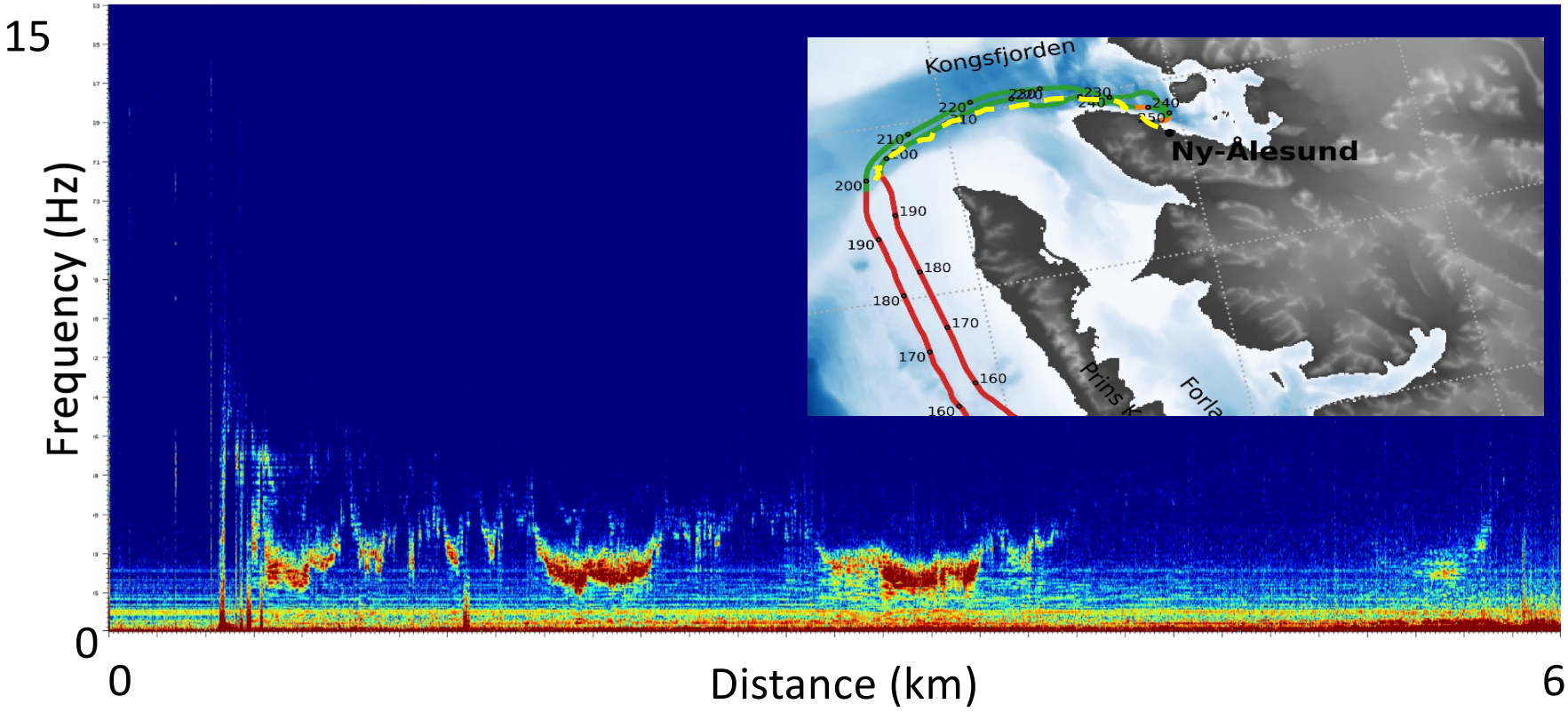
Rørstadbotnen, R. et al., 2023, **Simultaneous tracking of multiple whales using two fibre-optic cables in the Arctic**, Front. Mar. Sci. 10, 3389

Atlantic storms – one year

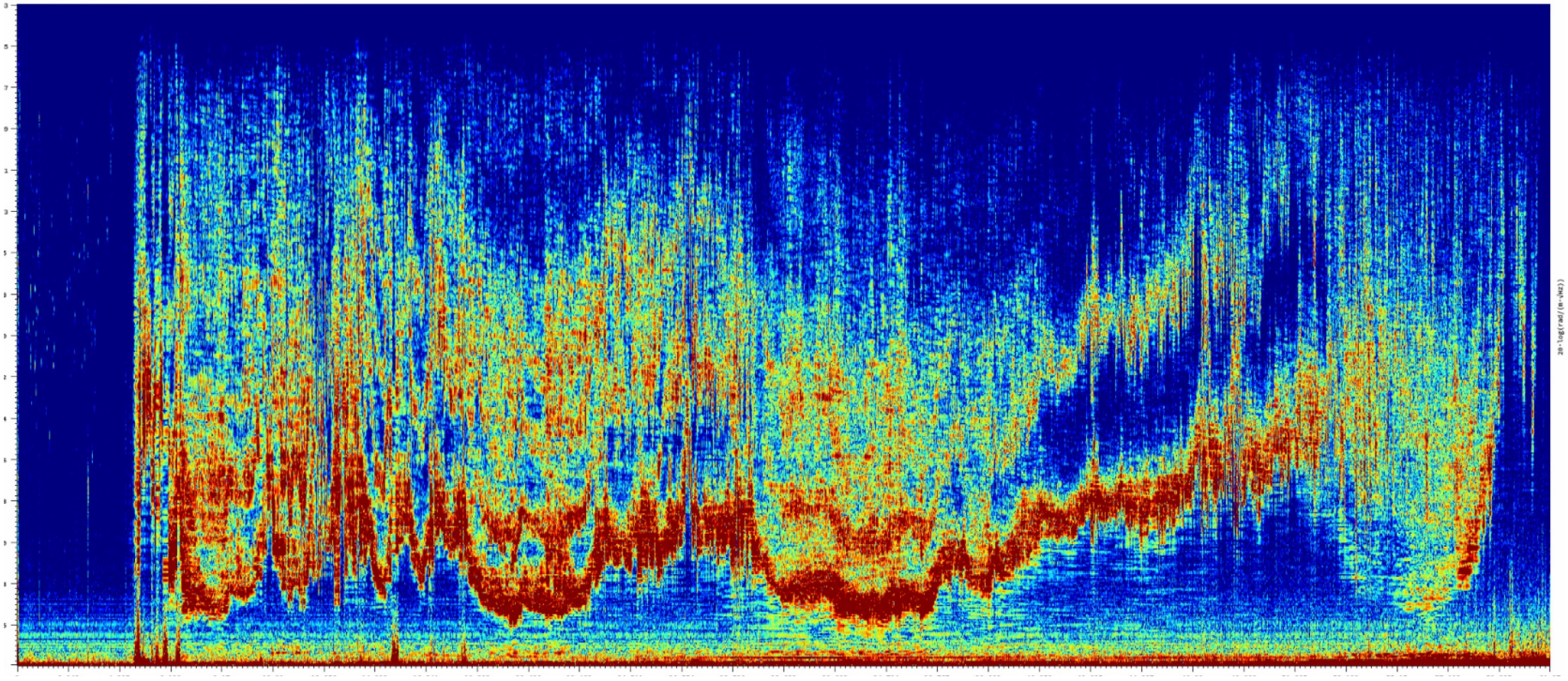




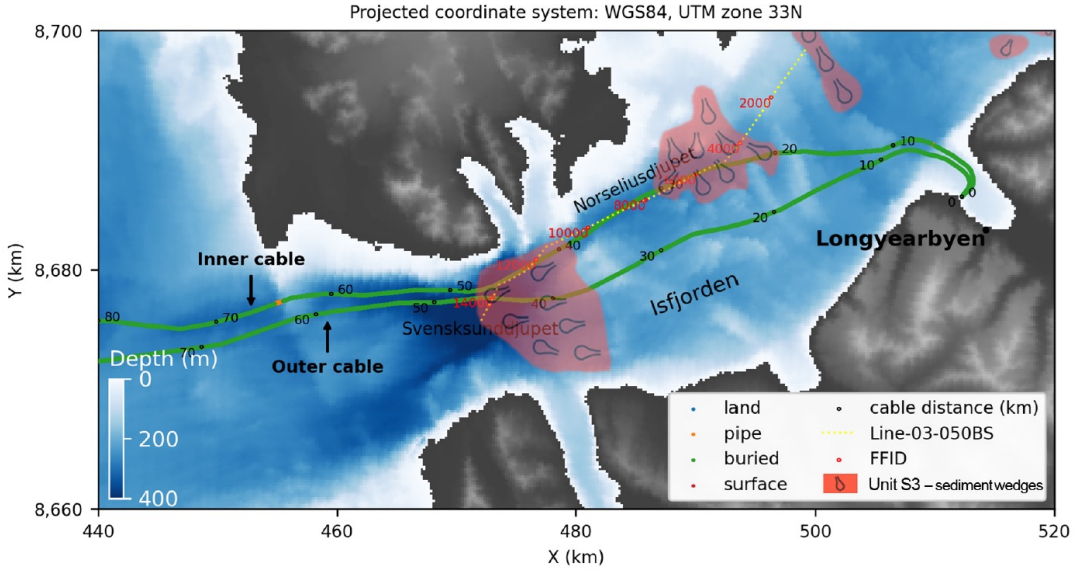
Shear wave resonance effect for sediment thickness – background noise signal

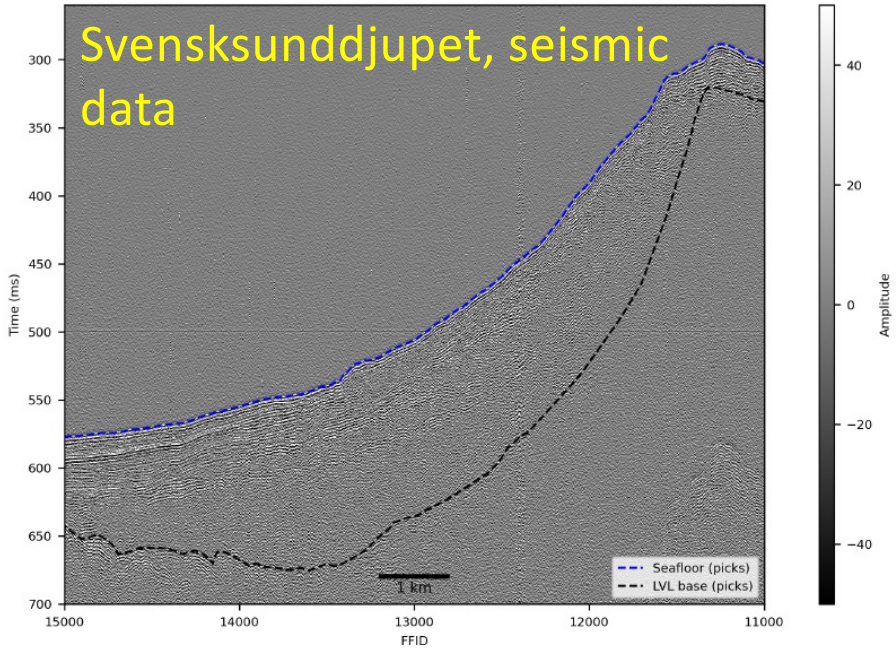


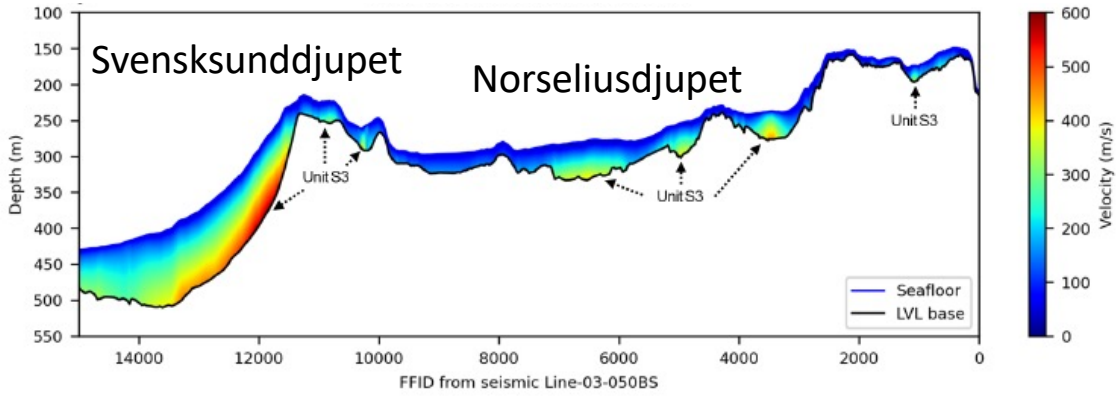
Earthquake signal enhances the resonance effect => higher order modes

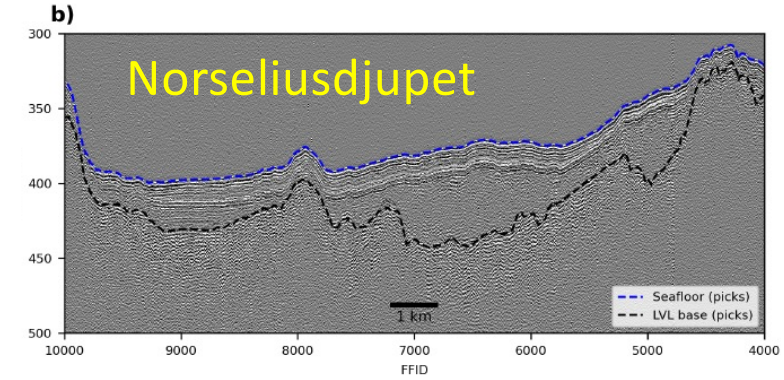


Mapping the sediment column from fibre optic cable data

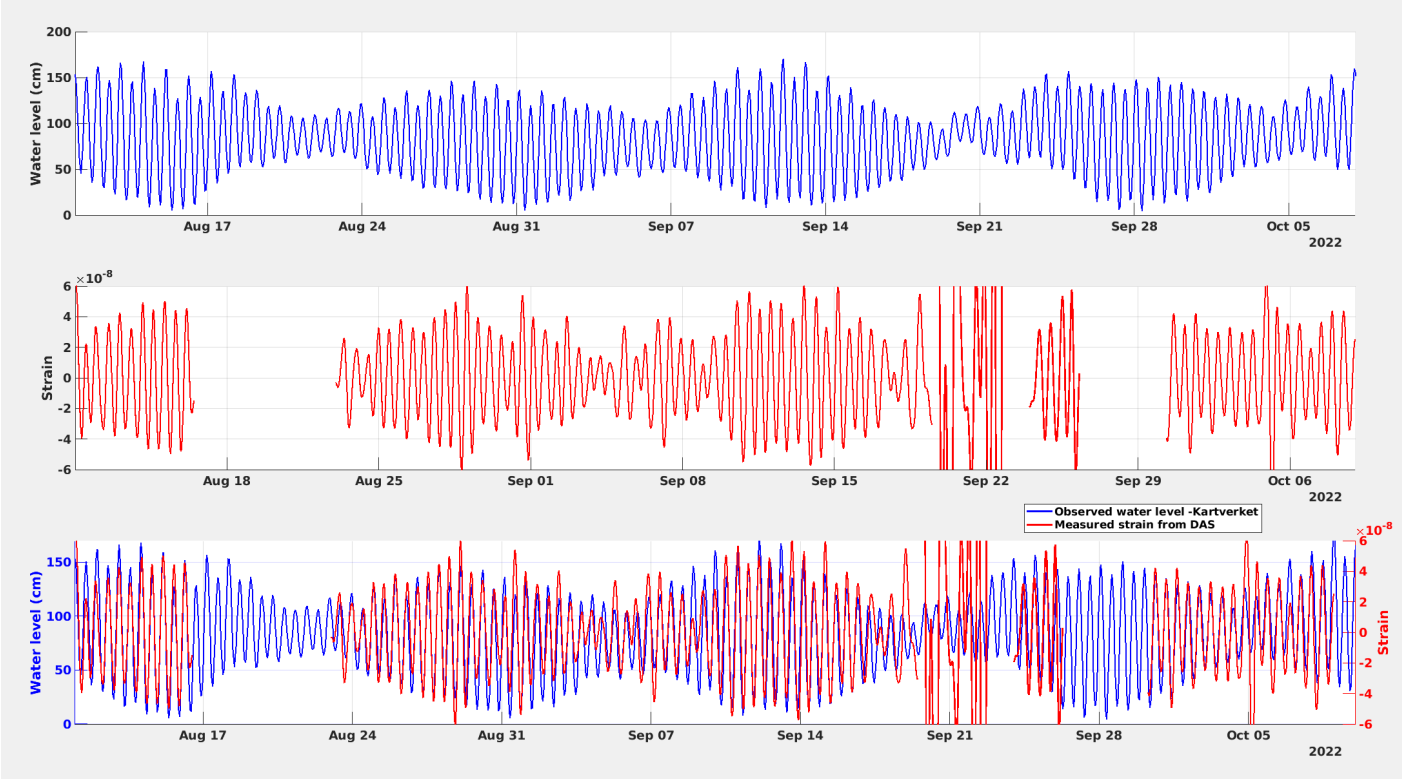








Tides: DAS signals up to 50 nanostrain



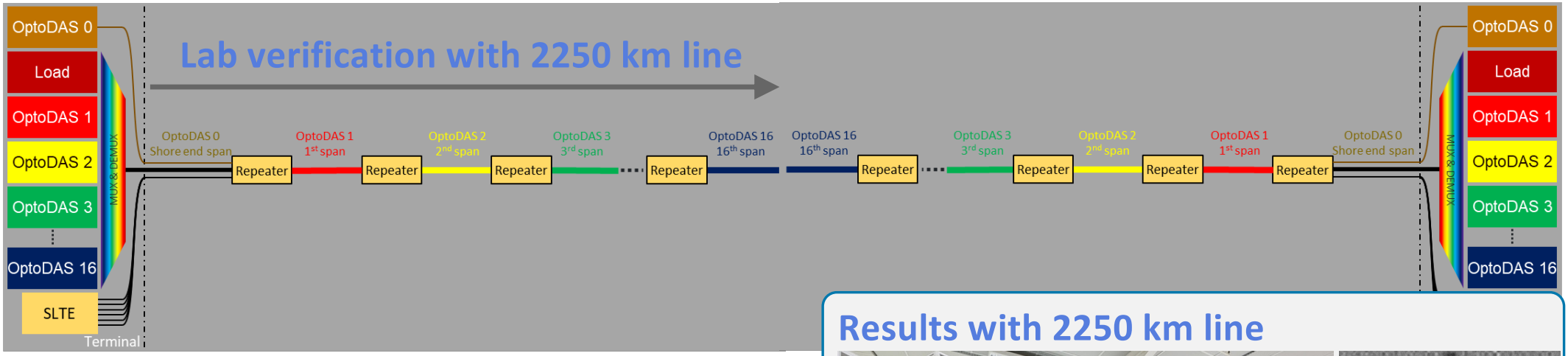
Evelyn Roeloff, 2010; Journal of Geophysical Research: Measure tidal horizontal strains up to 34 nanostrain using strainmeters

Temperature or subsurface strain or both?

Repeatered DAS

J. K. Brenne, "Advancements in Distributed Acoustic Sensing over long-haul submarine links", 32th NORDUnet Conference, Bergen, Norway, 2024

Range-scalable DAS – with sensing performance like DAS on dark fiber (sensitivity, spatial resolution, temporal resolution)

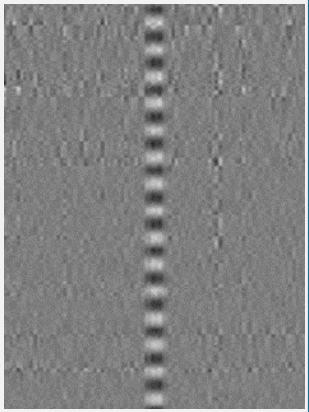


Enables complete coverage from shore-to-shore along the entire length of new repeatered submarine links. Key features:

- Spatial resolution: ≥ **2 m**
- Sampling frequency: **1 kHz**
- High-end DAS **sensitivity** enabling detection of trawls, anchors, sabotage, seismic waves, mammals and for oceanography studies ++
- **Scalable** system topology for 1000's of km long links
- Highest possible **reliability** – unmatched reliability compared to submerged electronics or DAS interrogators
- Consumes **one fiber pair** for DAS

Results with 2250 km line

Audio signal recorded after 2250 km



nano-strain (nε) signal recorded after 2250 km

Summary

- **Ocean floor DAS:**
  - Efficient tool for whale tracking
  - Need to develop efficient and fast algorithms (huge amount of data)
  - Potential tool to avoid/reduce amount of ship strikes
  - Oceanography: Storms, tides, currents, …
  - Mapping of sediment thickness from resonance effects
  - SOP
  - Polar connect: Long range (10’000 km => optical amplifiers needed)

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References

- Bouffaut, L. et al., 2022, **Eavesdropping at the speed of light: Distributed acoustic sensing of baleen whales in the Arctic**. Front. Mar. Sci. 9, 901348.

- Landrø, M. et al., 2022, **Sensing whales, storms, ships and earthquakes using an Arctic fibre optic cable**, *Sci Rep* **12**, 19226.

- Landrø, M., S.E. Johansen, N. Schmitz, H. E. F. Amundsen, 2022, **Using DAS-fibres for Lunar seismic imaging**, paper presented at the European Lunar Symposium 2022 May 24th-26th.

- Rørstadbotnen, R. et al., 2023, **Simultaneous tracking of multiple whales using two fibre-optic cables in the Arctic**, Front. Mar. Sci. 10, 3389