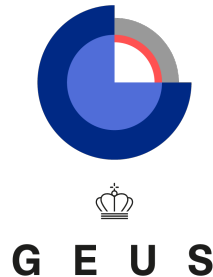
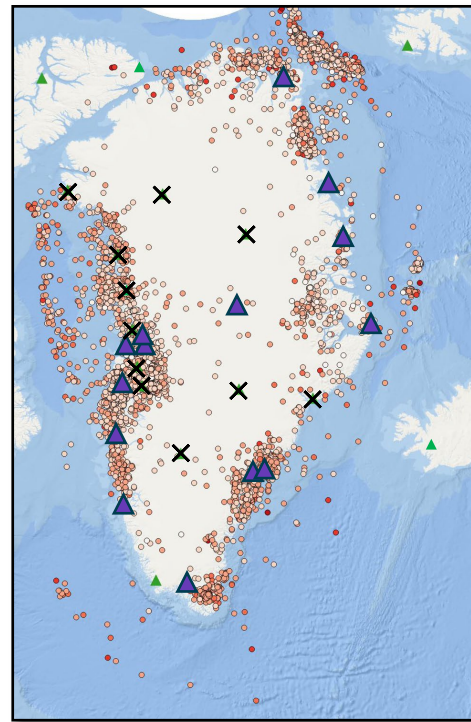
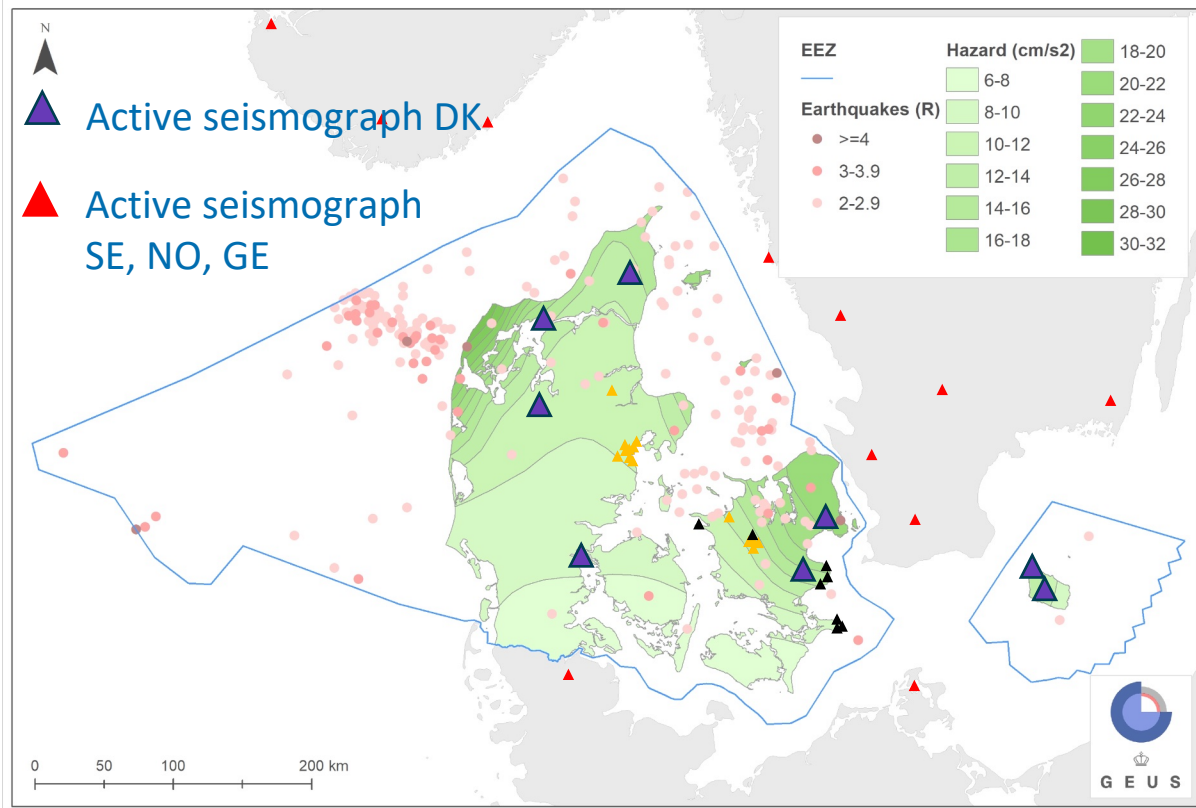


Two years of NORDUnet, DeiC, and GEUS collaboration on fiber sensing for seismology in the Baltic Sea

Tine B. Larsen

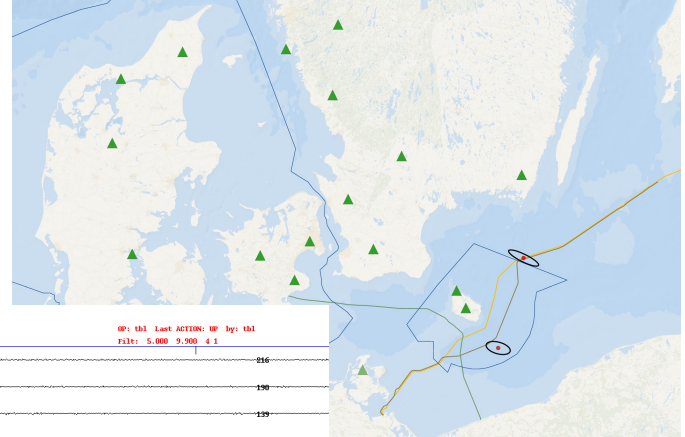
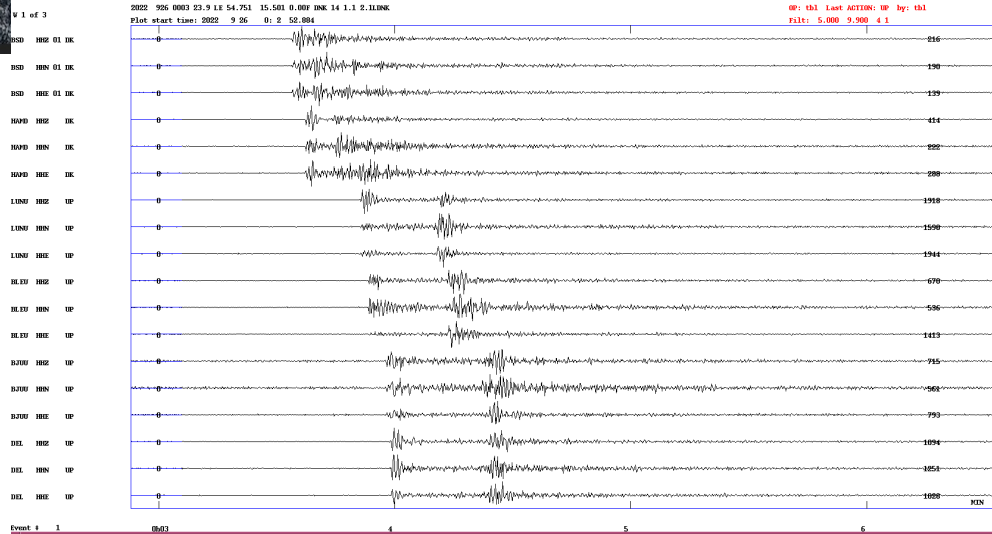
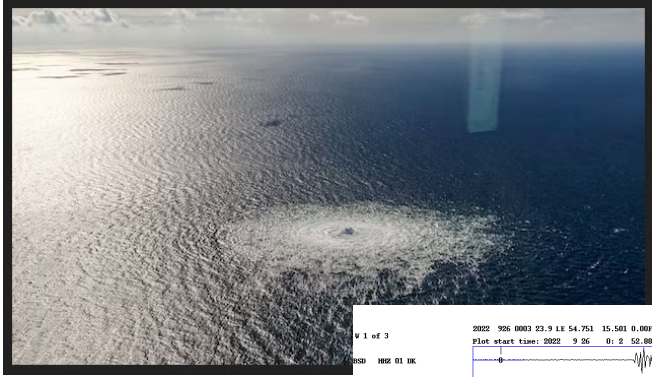


GEUS operates the seismic service for Denmark and Greenland



Started in 1926, measure 24/7, permanent and temporary seismographs, primarily earthquakes

Detect mainly earthquakes ... then came Nord Stream



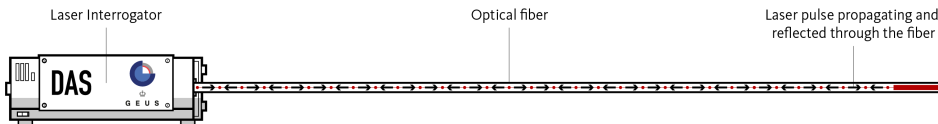
2022-09-27, detected on seismographs, clearly blasts

Looked for new technology to get closer to offshore source

- Fiber sensing on subsea cables is attractive
- We needed equipment and knowledge

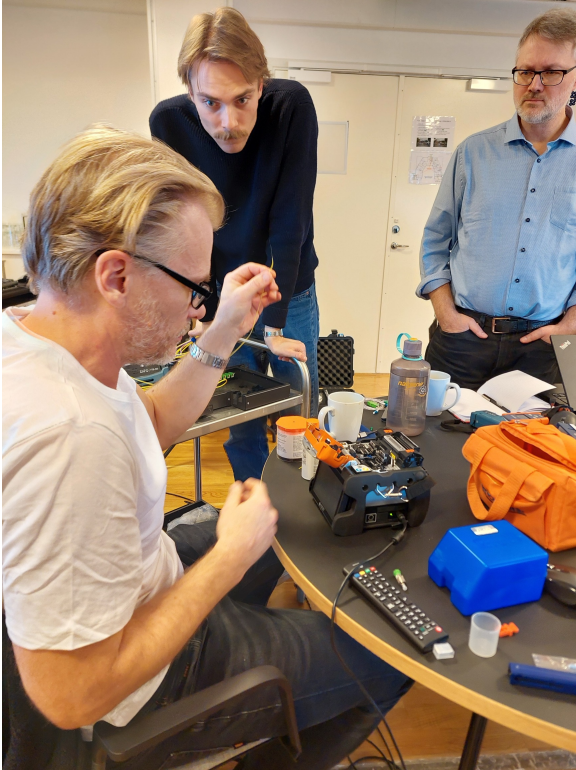


- GEUS had worked with an earthquake on DAS in 2018, thanks to Energinet
- We committed funds to buy an Interrogator
- Got our first ASN OptoDAS interrogator early 2024
- We now own two

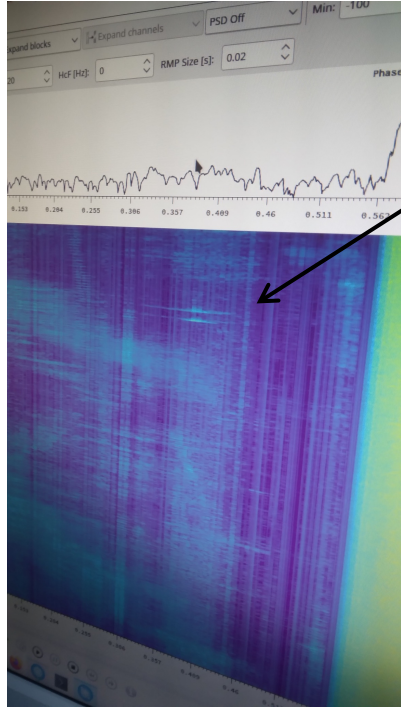


We learned how to handle fibers

- NORDUnet is extremely helpful and Rasmus Lund got us started

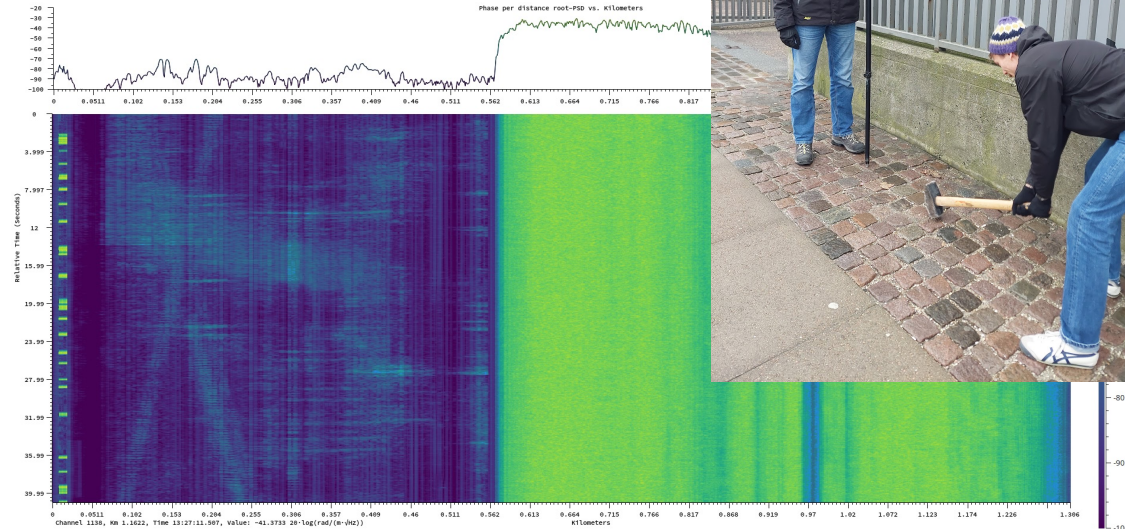


We started with 500 m dark fiber under the sidewalk



Hammer

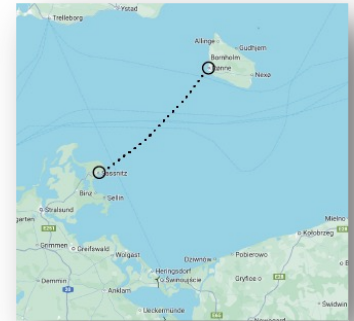
500 m



Going subsea with the help of NORDUnet and DeiC

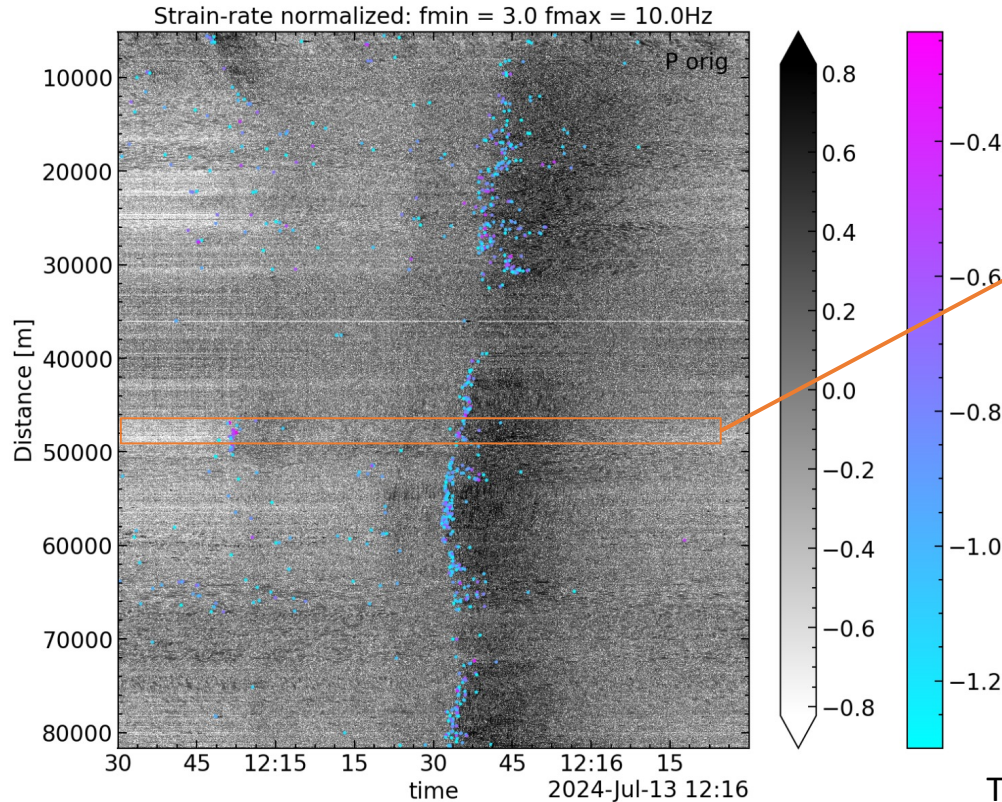


- DAS interrogator was installed in Rønne at the end of June 2024.
- Remote access, slow at first, now in realtime with highspeed DeiC connection
- Recording continuously, currently saving everything
- Data analysed when interesting events happen

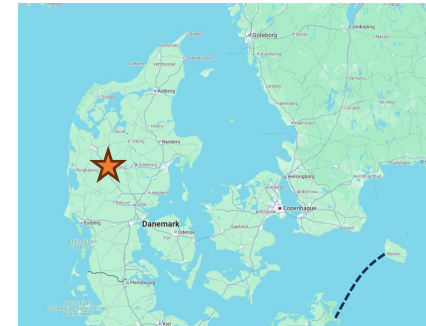
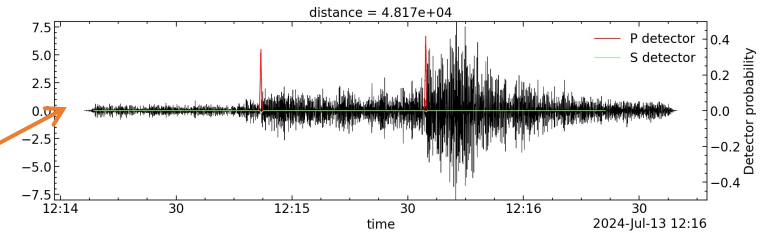


We learned to process data.

First earthquake recorded by GEUS interrogator

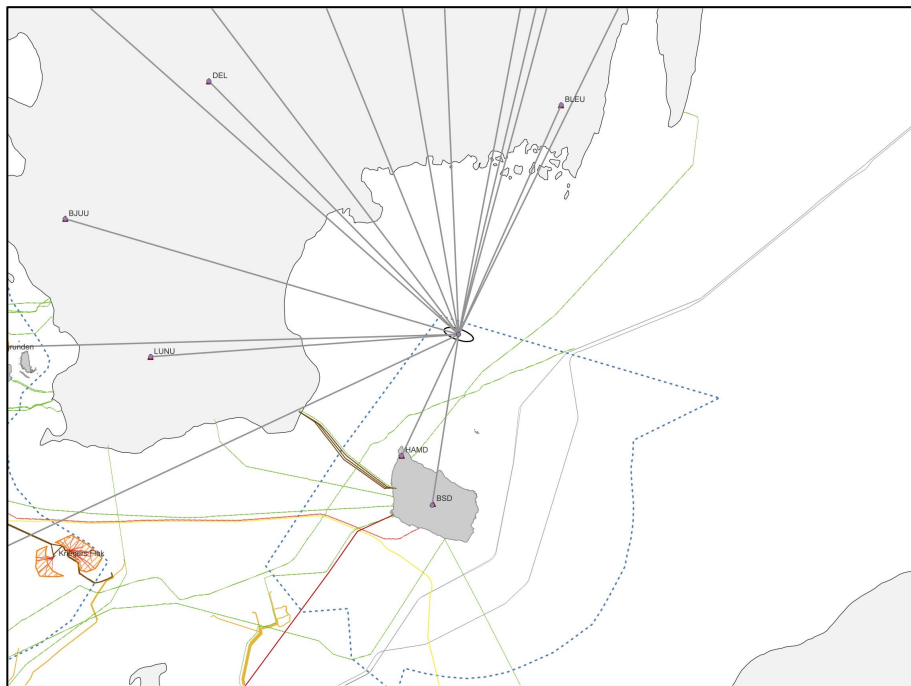


M3 earthquake near Herning in Jutland recorded on the first 80 km of the fiber cable between Rønne on Bornholm and Sassnitz in Germany

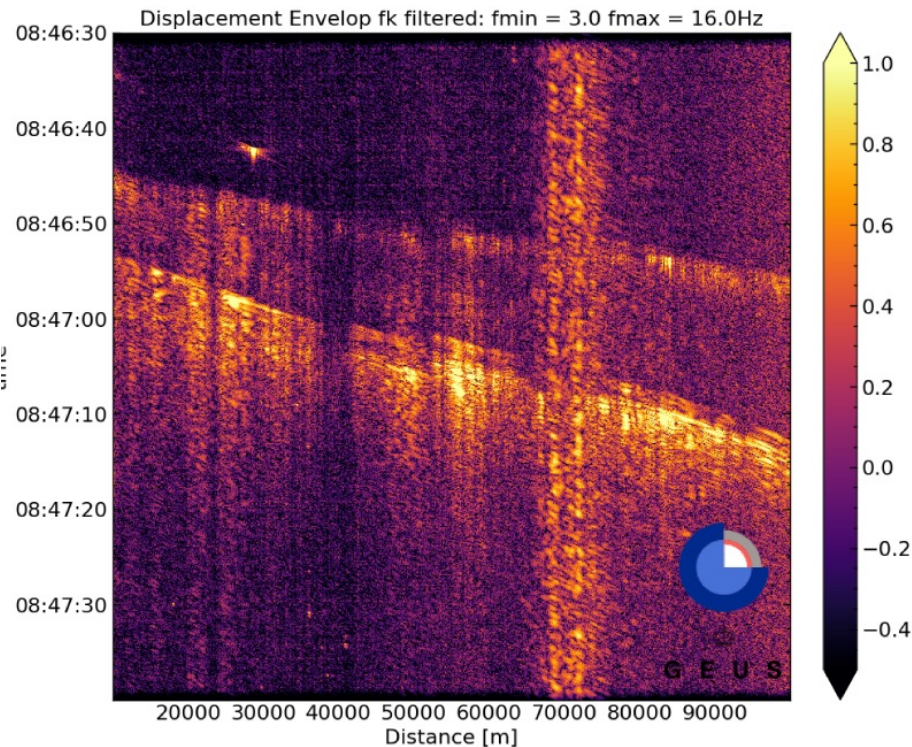


Thanks to NORDUnet and DeIC for use of cable!

Subsea blasts north of Bornholm, unknown source, seen over 100+ km

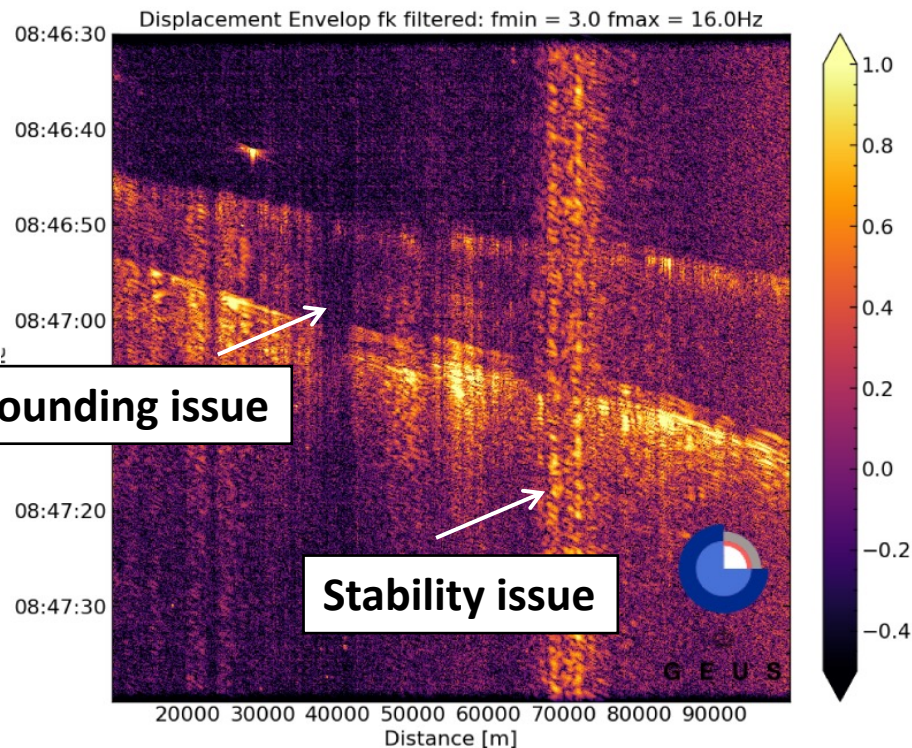


Identified by our regular monitoring



Also seen clearly on DAS

Tests with Danish Navy to understand better what we are seeing

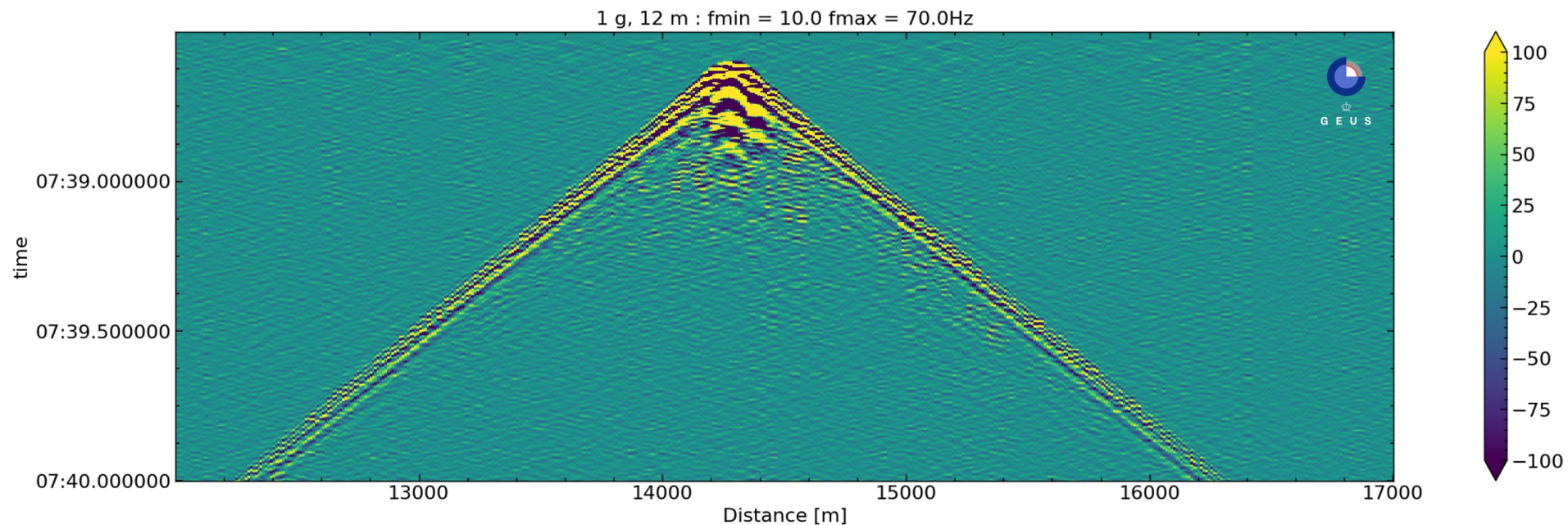


- We detect all kinds of events
- Earthquakes, blasts, ships
- Signals also provide status on cable grounding
- ...and on cable stability



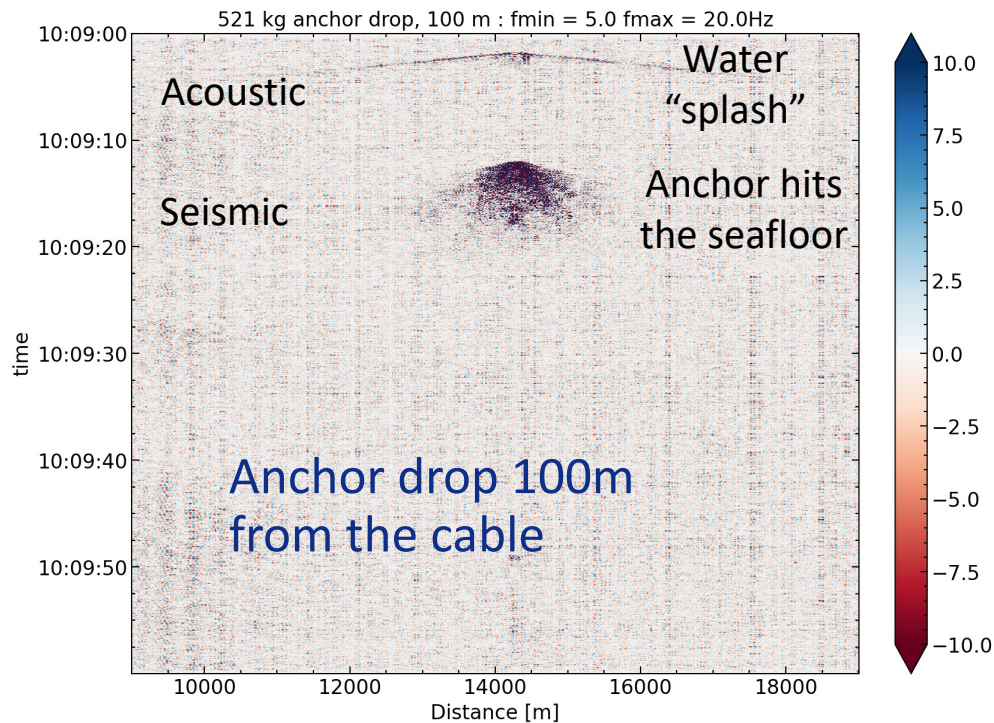
Diver photo from Danish Navy

Tests with Danish Navy to understand better what we are seeing



DK Navy blast, 1 g explosives 12 m above cable, seen over several km

Tests with Danish Navy to understand better what we are seeing

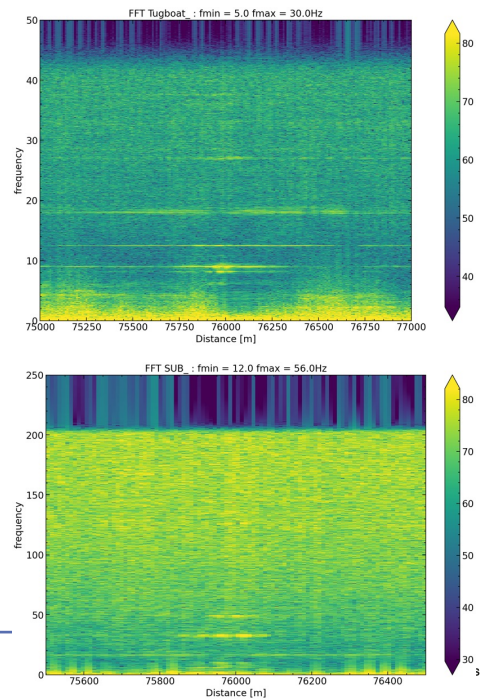
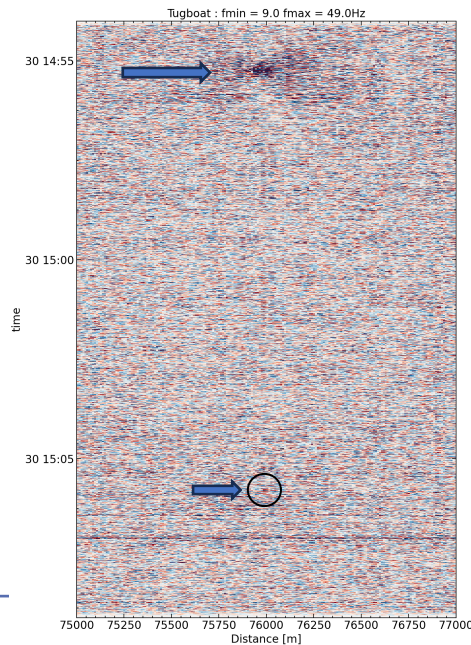
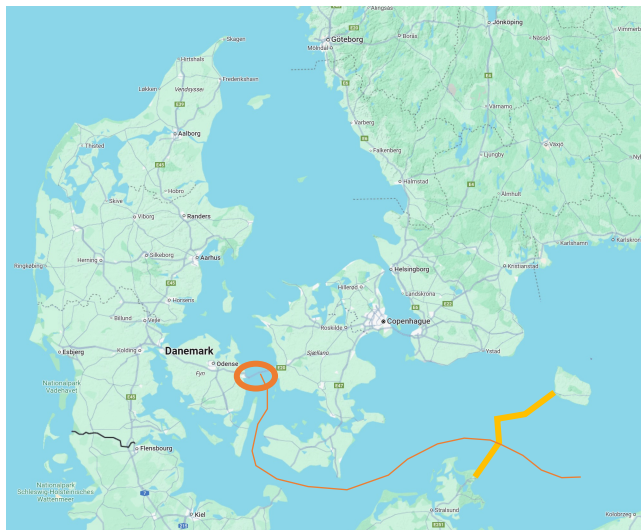
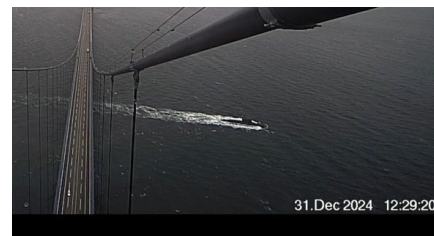
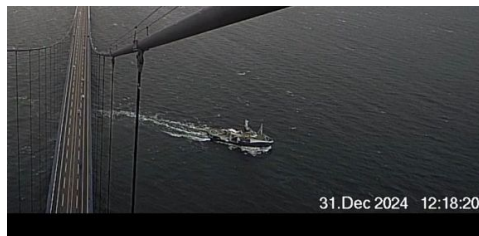


"Water splash" signal propagates further out than the anchor hitting the sea floor

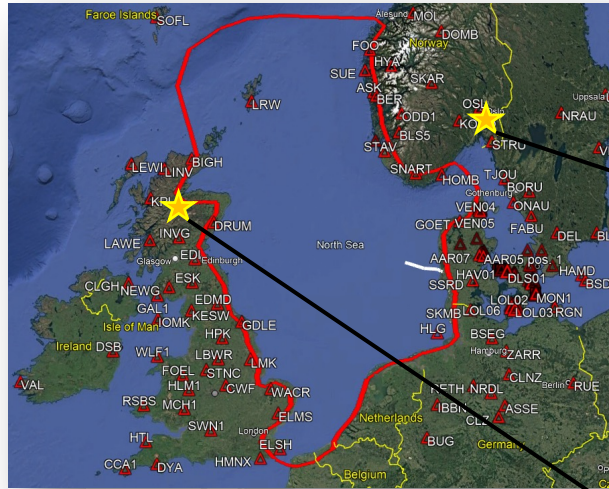
We have to be careful when downsampling the data – we might lose our signal!

Bonus Russian submarine!

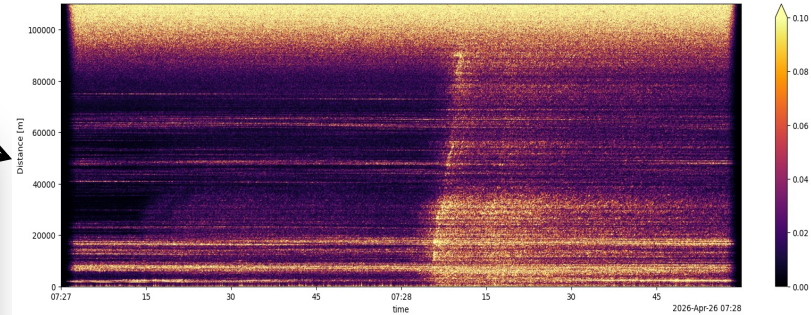
- Tugboat followed by submarine 11min later under the Great Belt Bridge seen on CCTV
- Track tugboat back in time with AIS when crossing the cable
- Signal attributed to the submarine 11min later



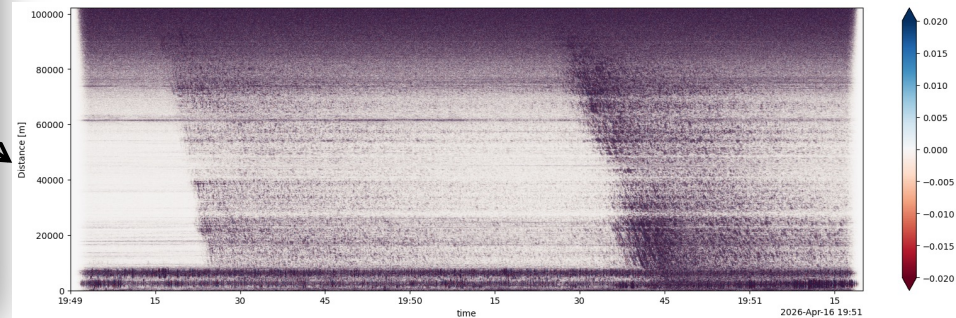
SAFE-C project: integrating DAS data into seismic monitoring of North Sea seismicity



M3.6 Oslo Eq. (~500 km away)



M3.3 Scotland Eq. (~750 km away)



Using CANTAT-3 for North Sea and Aurora for real time data pipeline test

Many future possibilities

- Better earthquake monitoring
- Better subsurface models
- Maintenance monitoring of critical infrastructure – before breakdown
- Monitoring suspicious activities, sabotage, submarines...

Some issues to be resolved...

- Data volumes - edge computing with ML?
- Data management – what to save, what to discard
- Data sharing – confidentiality issues – and data volumes
- Cable coordinates – confidentiality issues
- Access to cables – going L-band?



Current data storage.... 20Tb disks