Fibre sensing

An overview

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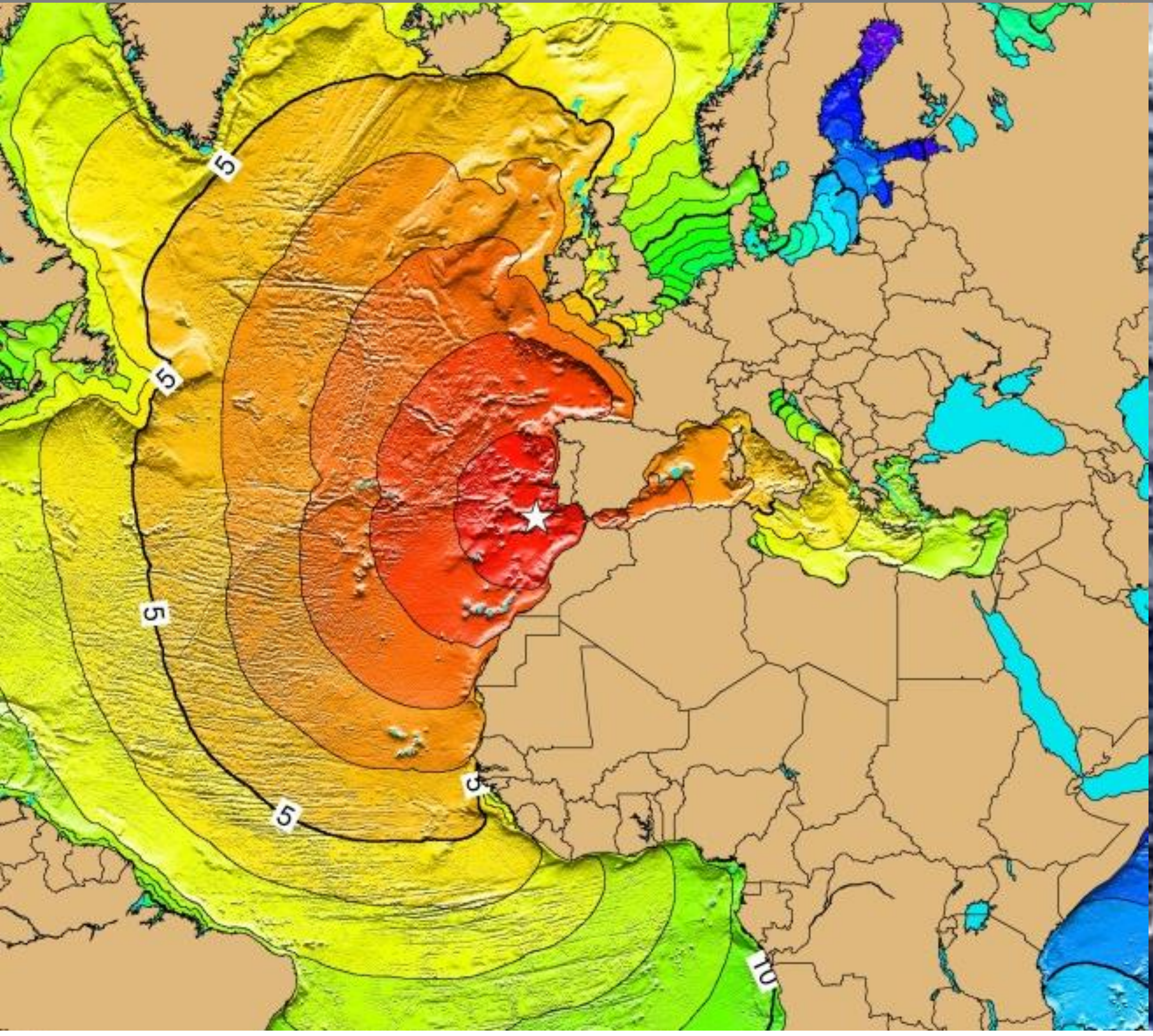
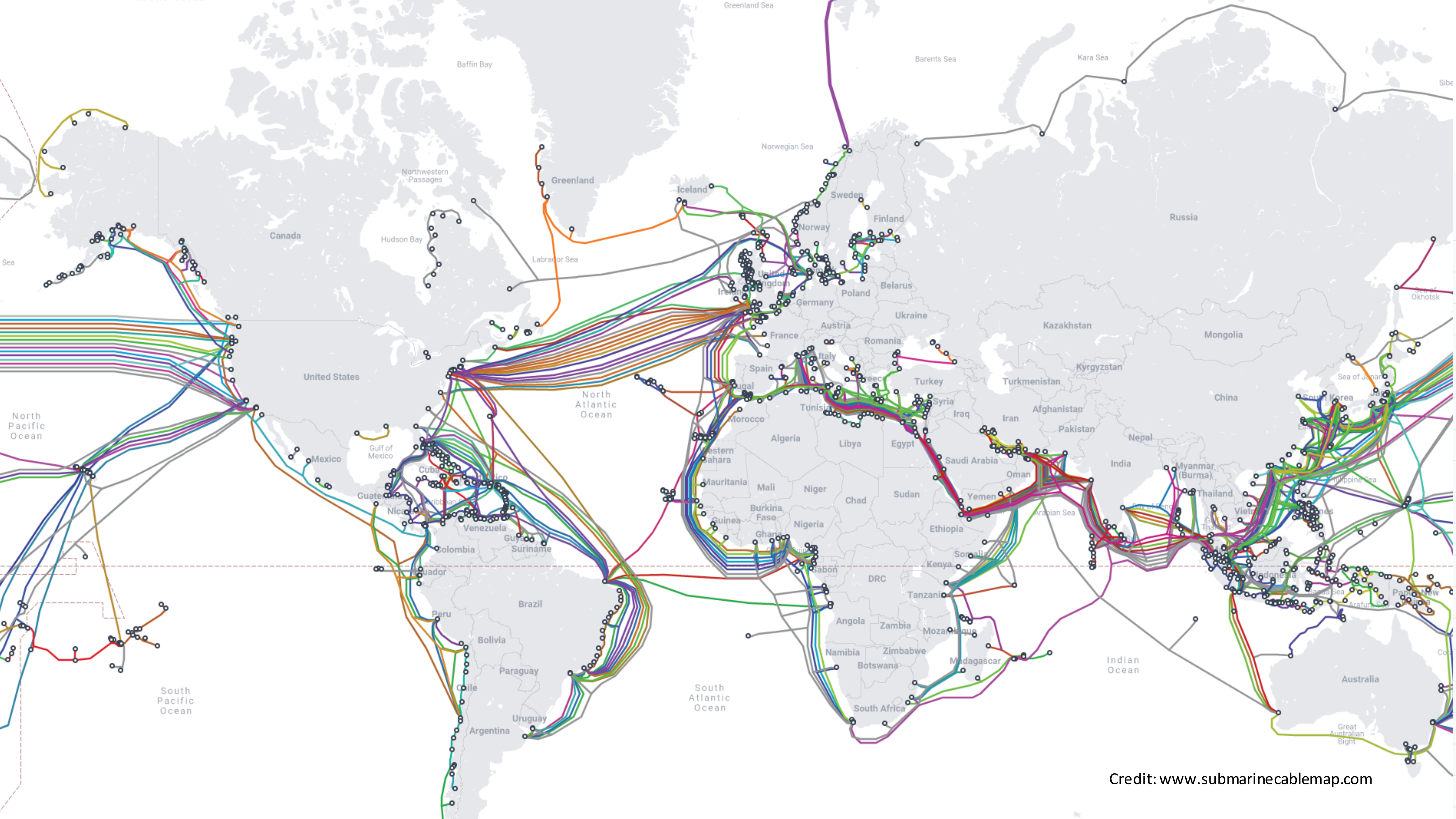
SingaREN visit
29th April 2024

Public

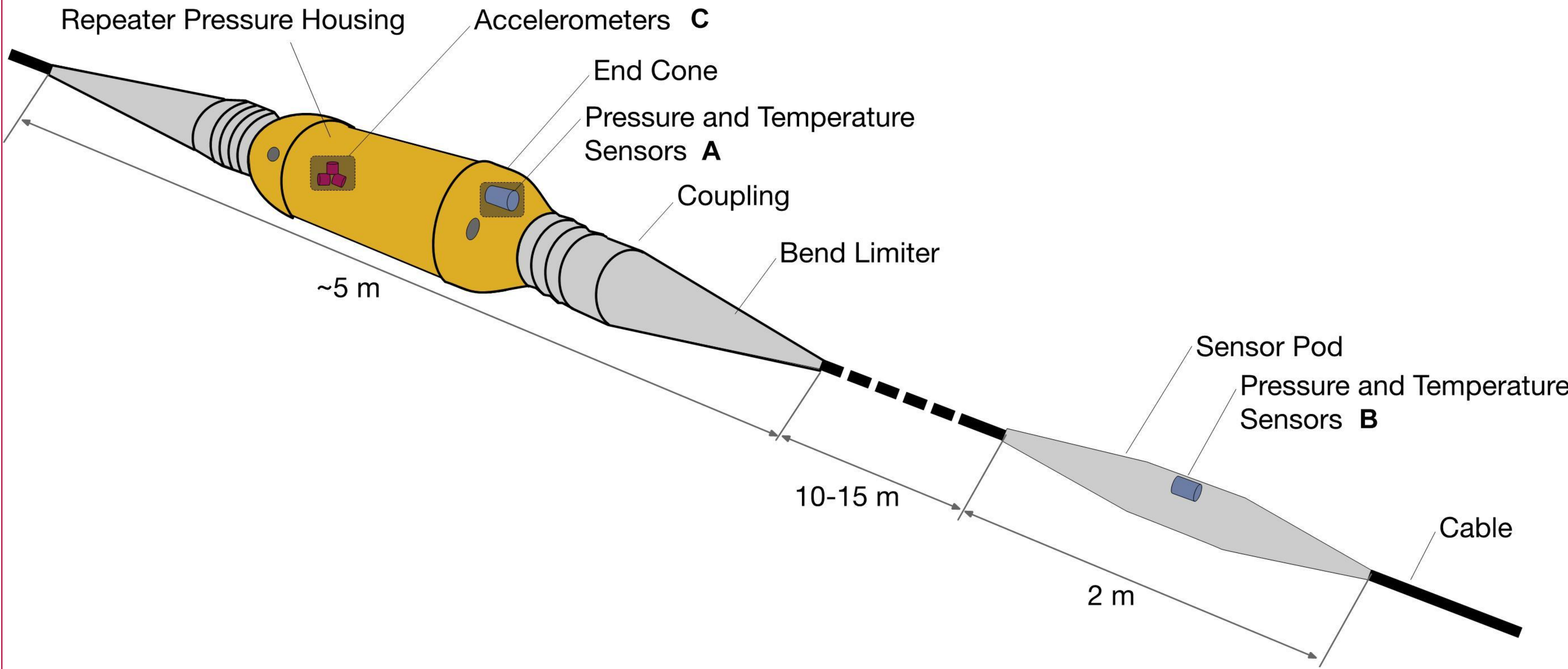
Some of the many global challenges





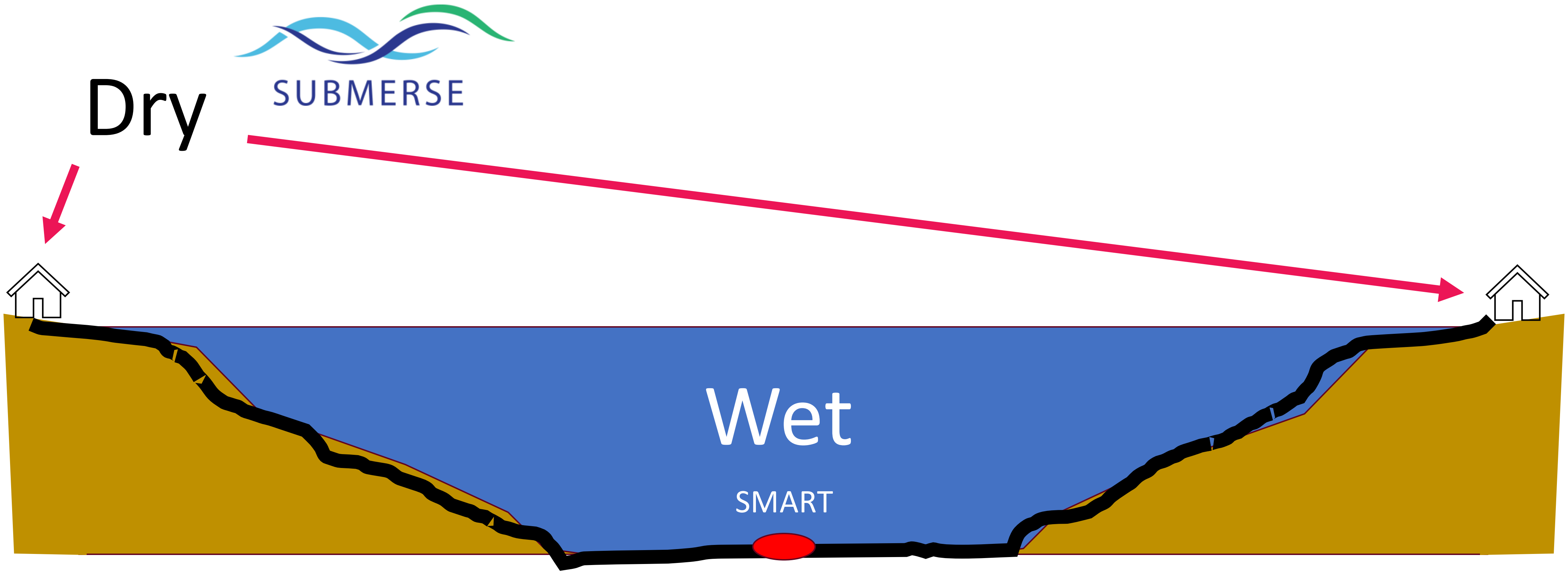
Credit: www.submarinecablemap.com

SMART Cable concept



Howe et al., (2019, August 2). *Smart cables for observing the Global Ocean: Science and implementation*. SMART Cables for Observing the Global Ocean: Science and Implementation. Retrieved June 10, 2022, from https://www.frontiersin.org/articles/10.3389/fmars.2019.00424/full

Wet vs Dry Sensing



SUBMERSE

Aim

Investigate utilising existing telecommunication systems, rather than dedicated submarine fibre, for monitoring the earth and oceans, without disrupting telecoms traffic.

Objectives

- Define a standardised concept architecture to integrate sensing technologies (DAS, SOP, SOP OTDR, SOP OFDR) into a single telecoms submarine cable system.
- Complement existing infrastructures, datasets, and SMART cable concepts by developing a scalable data dissemination system from the new instruments to existing research infrastructures and communities.
- Deploy a standardised prototype research instrument in at least 3 geographically diverse locations.
- Scientifically validate and calibrate the instruments deployed
- Produce open, machine readable, long-term datasets.
- Develop the concept in collaboration with research communities, research infrastructures, Government institutions and industry.
- Defining training and capacity building which allows for enhancing the collection, interpretation, processing and reuse of the data generated by the research instruments
- Developing a roadmap and strategy to implement a sustainable research instrument and datasets from more countries

Consortium Members

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NTNU Norwegian University of Science and Technology

INESCTEC

U LISBOA UNIVERSIDADE DE LISBOA

GFZ Helmholtz-Zentrum Potsdam

hcmr ΕΛΚΕΘΕ

LifeWatch ERIC

UNIVERSITAS BERGENSIS

Research Organisations

NORDUnet Nordic Gateway for Research & Education

grnet

DeiC DANISH e-INFRASTRUCTURE COOPERATION

CESNET

Sikt

GÉANT Networks • Services • People

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Red CLARA

FCT Fundação para a Ciência e a Tecnologia

FCCN Computação Científica Nacional

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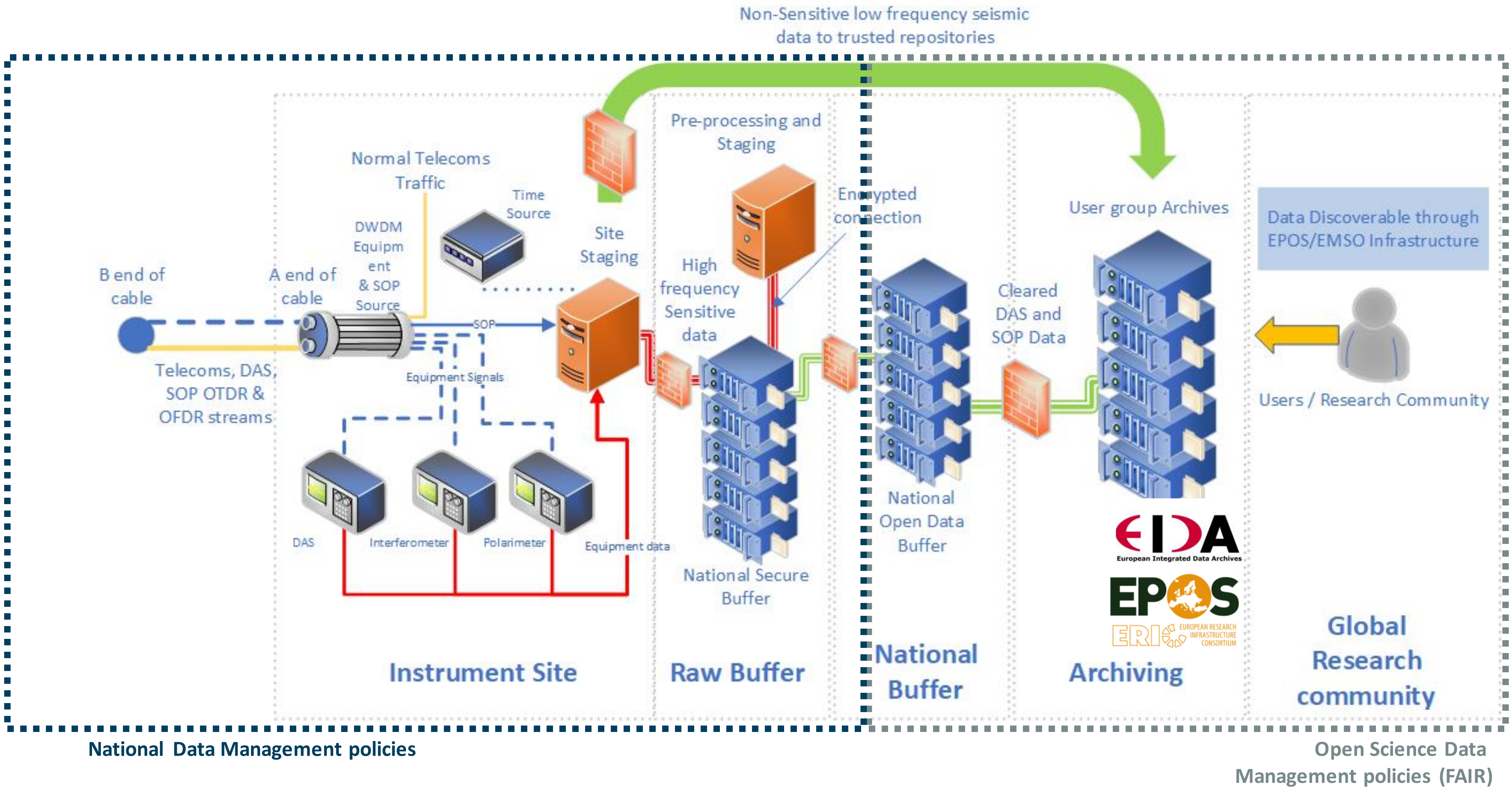
36 Month Project

The high-level instrument architecture – per site



SUBMERSE

Indicative Site Locations

SVALBARD, Norway
(DAS, SOP, SOP OTDR)

Preveza
~~RHODES~~, Greece
(DAS, SOP, SOP OTDR)

SINES, Portugal
(DAS, SOP, SOP OTDR)

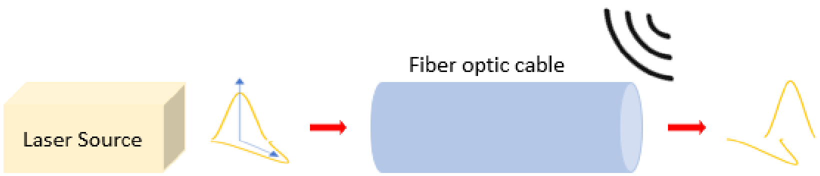
MADEIRA, Portugal
(DAS)

FORTALEZA, Brazil
(SOP, SOP OTDR)

SOP - **State of Polarisation**
DAS - **Digital Acoustic Sensing**
OTDR - **Optical Time Domain Reflectometer**

The technologies

Dry Optical sensing techniques

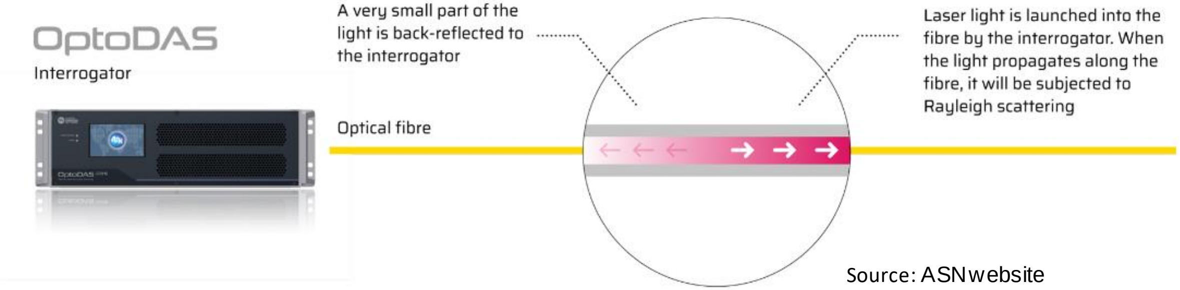


Source: Kristina Shizuka Yamase Skarvang

Tab. 1: Comparison of optical sensing techniques for seismic monitoring with optical fibers

	DAS [2,3]	Phase [4,5]	Polarization [6-8]
Equipment Requirements	DAS interrogator required	Ultra-stable laser source	Regular coherent linecards
Fiber Requirements	L-band or 3 c-band channels	Spectrum required	No impact on existing channel plan
Sensitivity	Medium/High	High	Medium
Localization	Yes	Feasible	Feasible
Reach	< 100 km	> 10,000 km	> 10,000 km
Scalability	Poor	Medium	Good

Adapted from Source: M. Cantono *et al.*, Seismic Sensing in Submarine Fiber Cables,

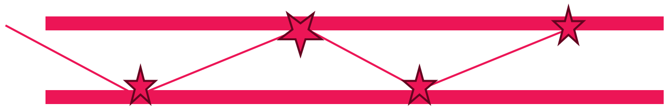


Source: ASN website

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

DAS

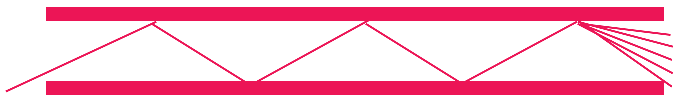
Distributed Accoustic Sensing



Uses reflections from impurities in the fibre when a laser light hits the side, to measure stretch and strain.

SOP

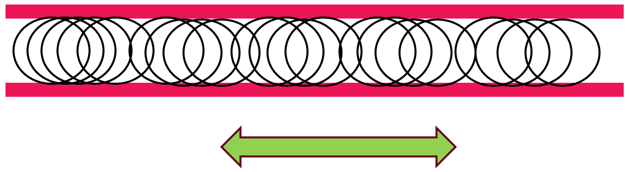
State of Polarisation



Uses the changes in position of the laser light as it exits the fibre to detect changes made to the cable the laser light travels through.

IPD

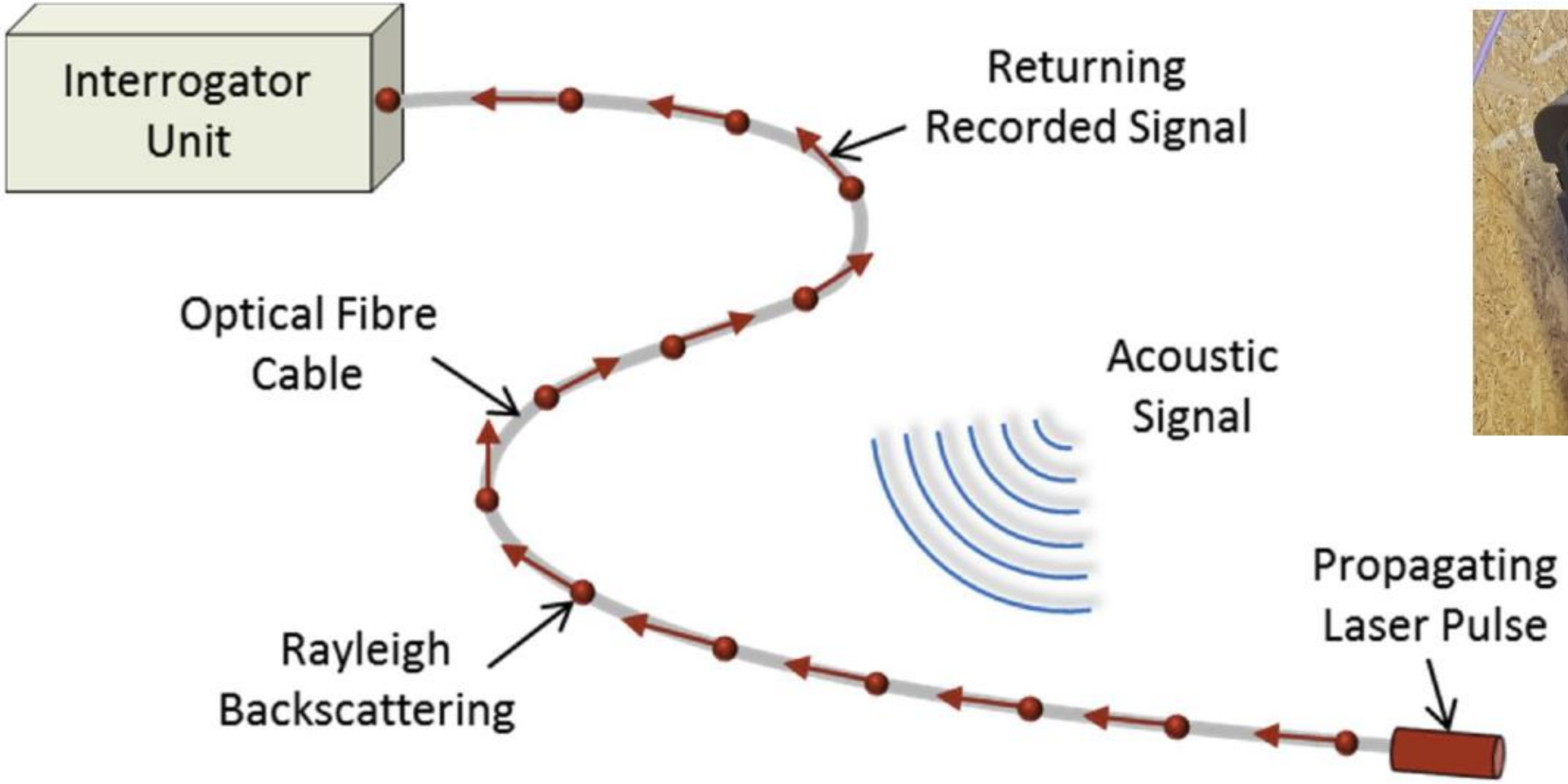
Introformetric Phase Detection



Uses the changes in the time of arrival of the laser light when compared against a reference signal to detect changes to the cable

DAS: Distributed Acoustic Sensing

CGF SFI Centre for Geophysical Forecasting



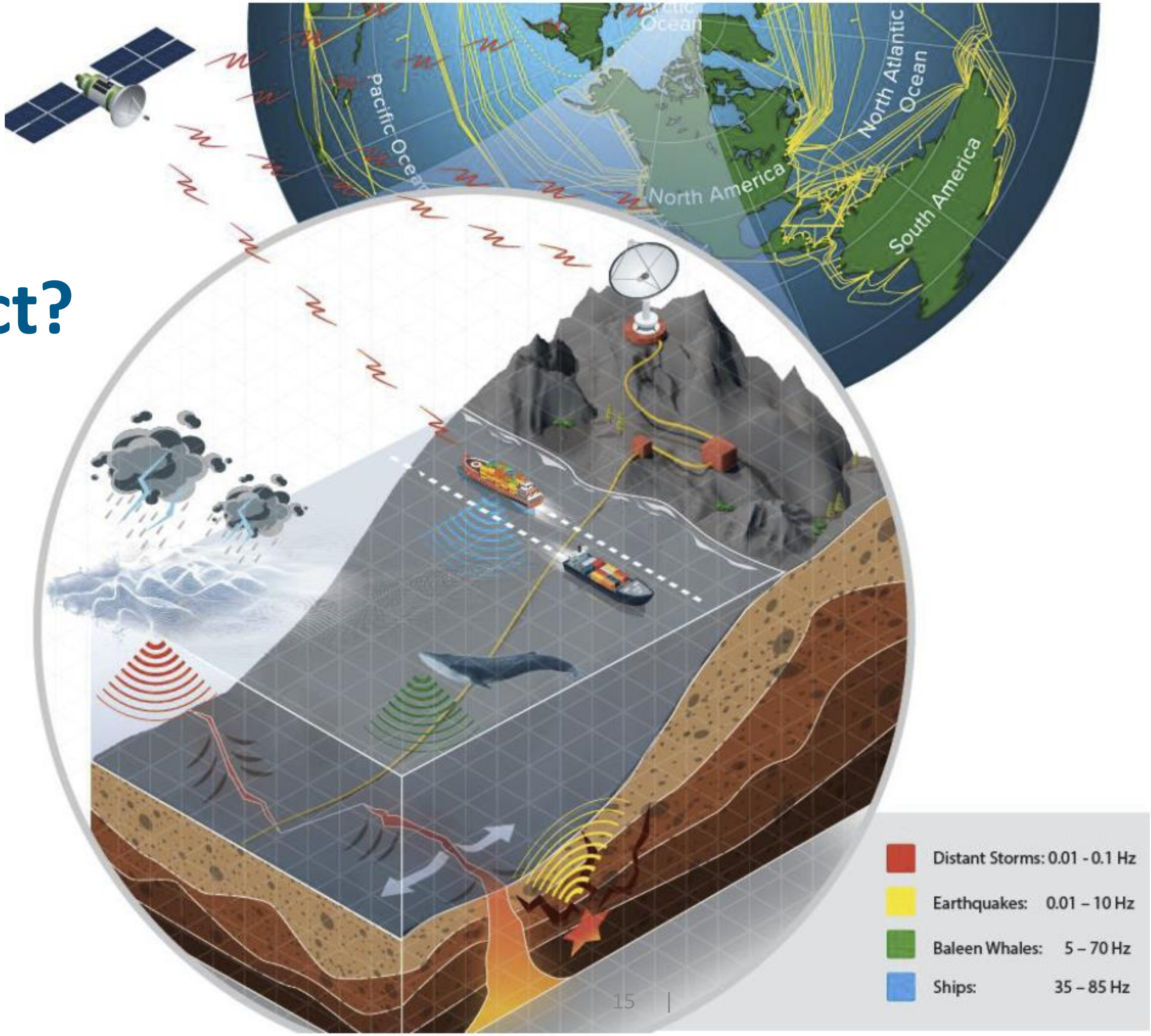
Can also measure transmitted signal or perform polarization analysis at the end of the fibre: SOP

Figure adapted from Wilks et al. , CLIMIT poster 2016

With thanks to Prof Martin Landrø, NTNU

What can DAS detect?

- Wales
- Storms
- Ships
- Earthquakes
- And more



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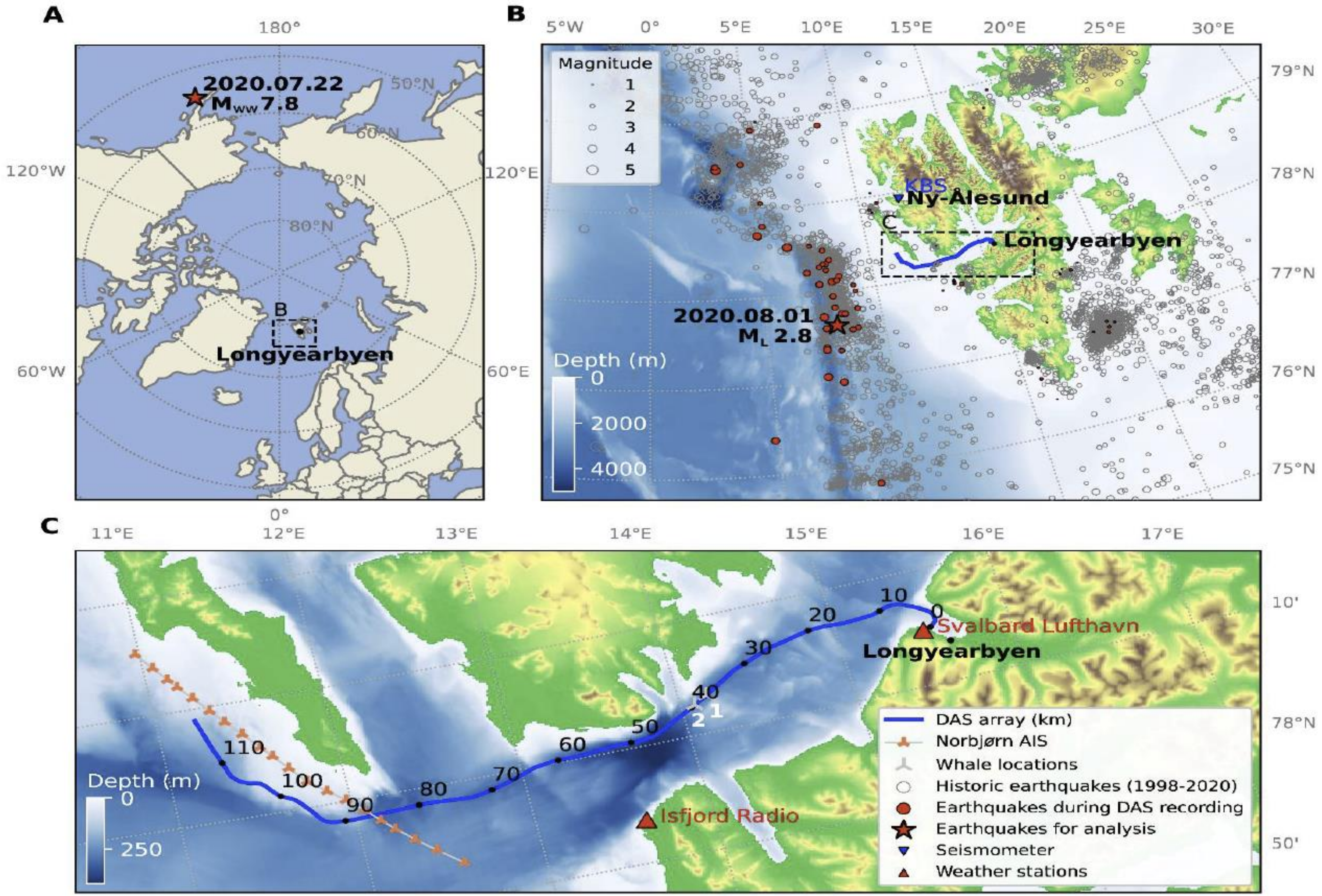
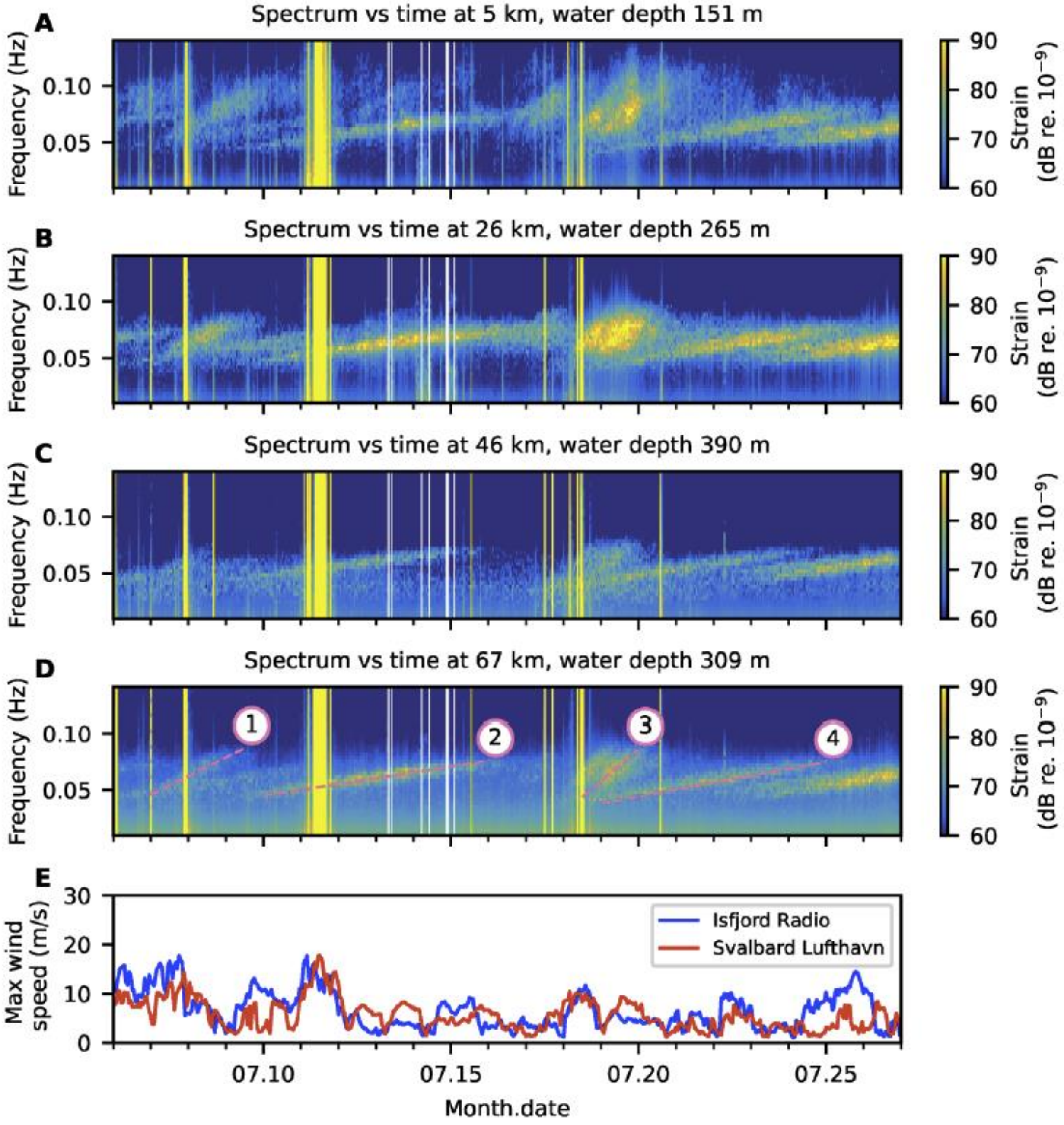
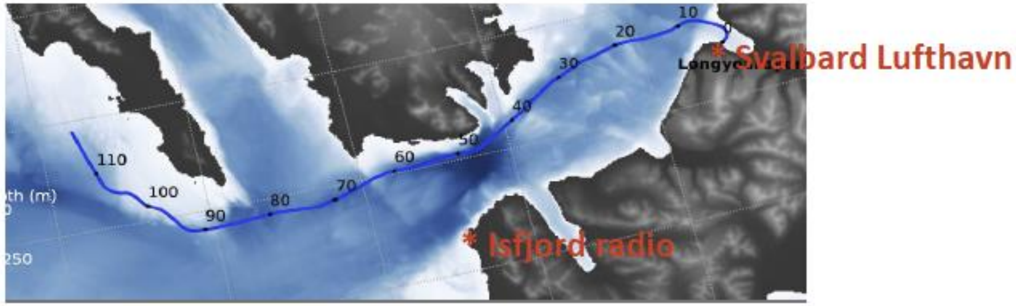


With thanks to Prof Martin Landrø, NTNU



SFI Centre for Geophysical Forecasting



Munk, 1963: $$x = \frac{g}{4\pi\left(\frac{df}{dt}\right)},$$

1: Edouard 4100 km

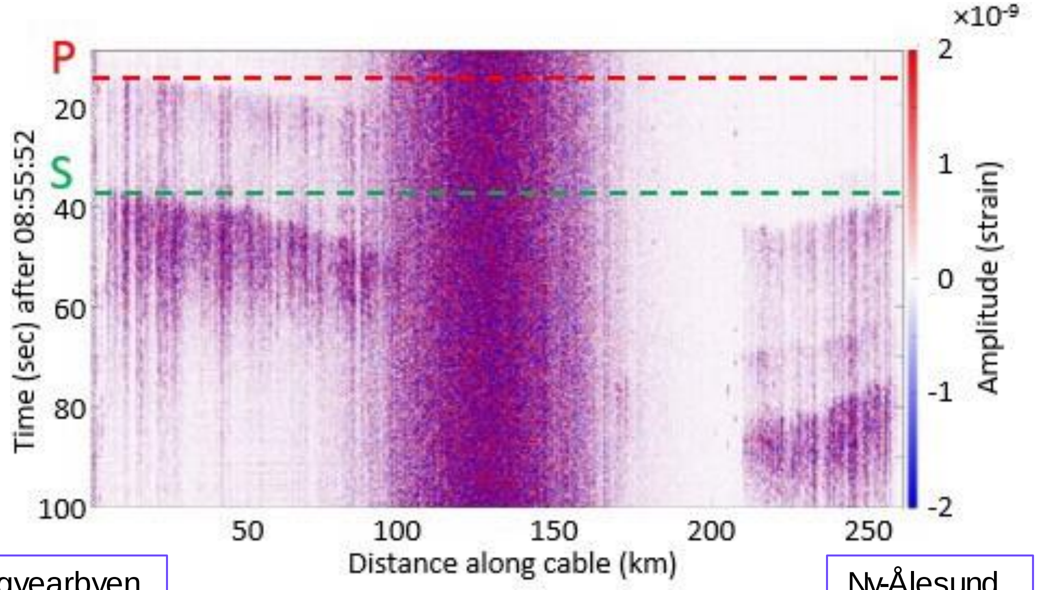
2: Offshore Brazil, 13000 km

3: Storm between Iceland and Greenland 2400 km

4: Offshore Brazil, 11 000 km

With thanks to Prof Martin Landrø, NTNU

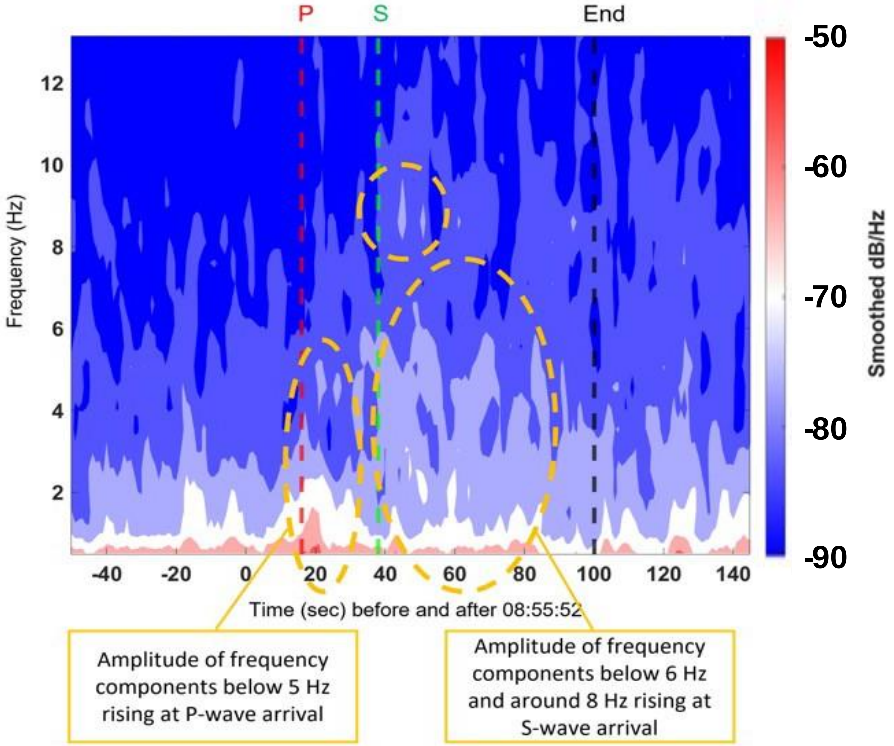
Detection of M2.7 Earthquake with DAS and SOP

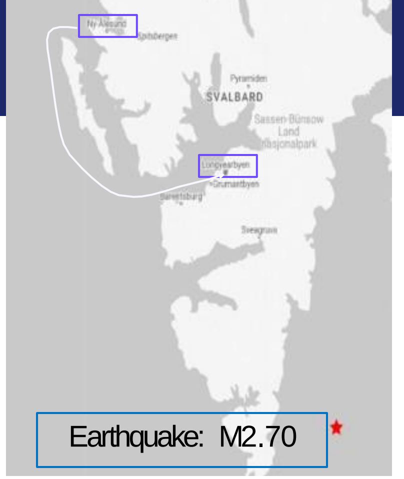


Longyearbyen

Ny-Ålesund

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





Earthquake: M2.70

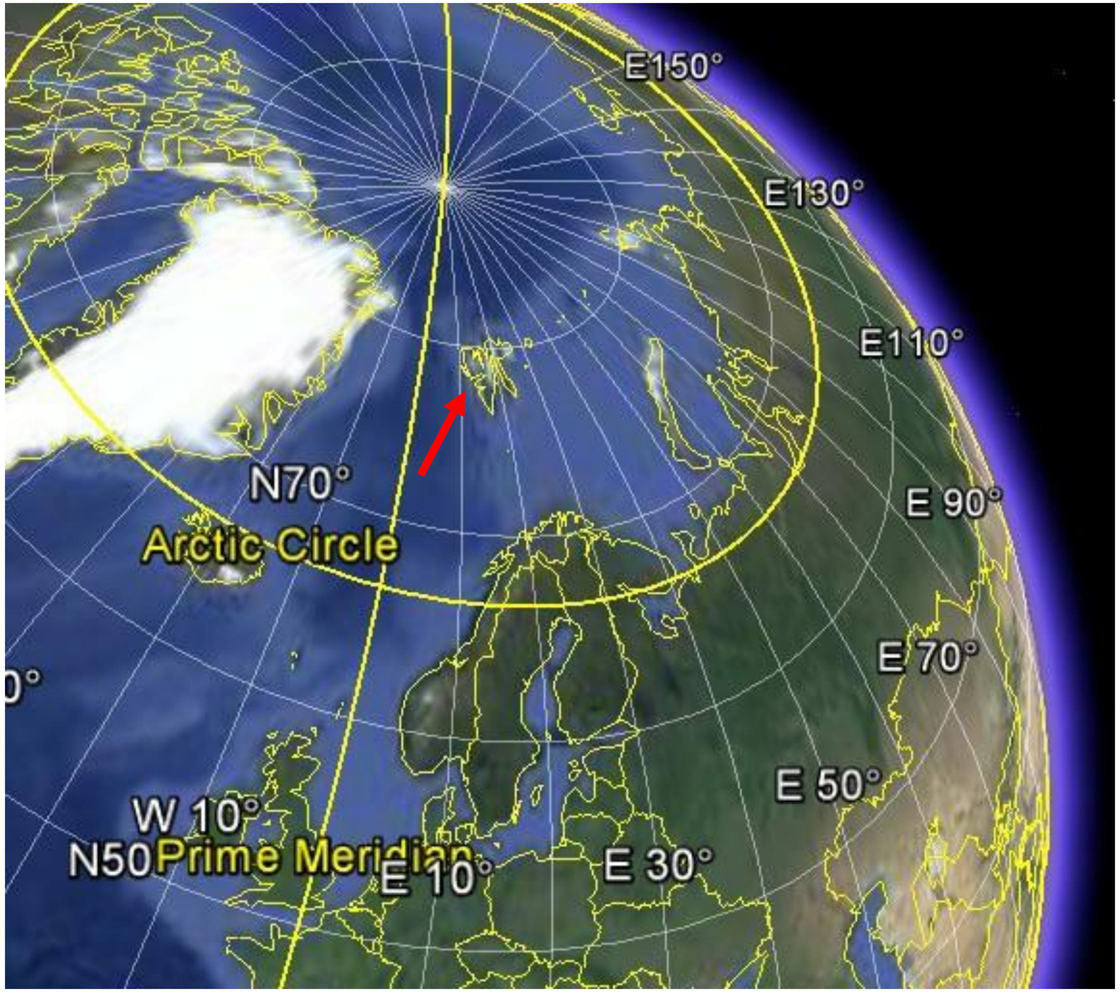
NORSAR seismometer

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

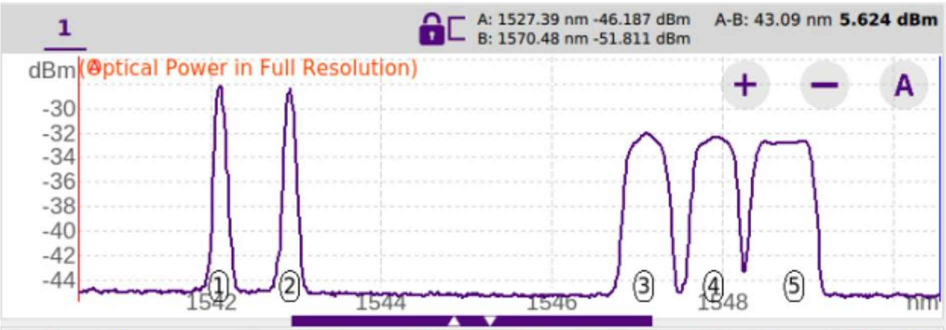
SOP variation corresponds with the timing of the Earthquake hitting the cable

NTNU Sikt CGF SFI Centre for Geophysical Forecasting ALCATEL SUBMARINE NETWORKS

Svalbard – close to the North Pole



DAS coexistance with DWDM



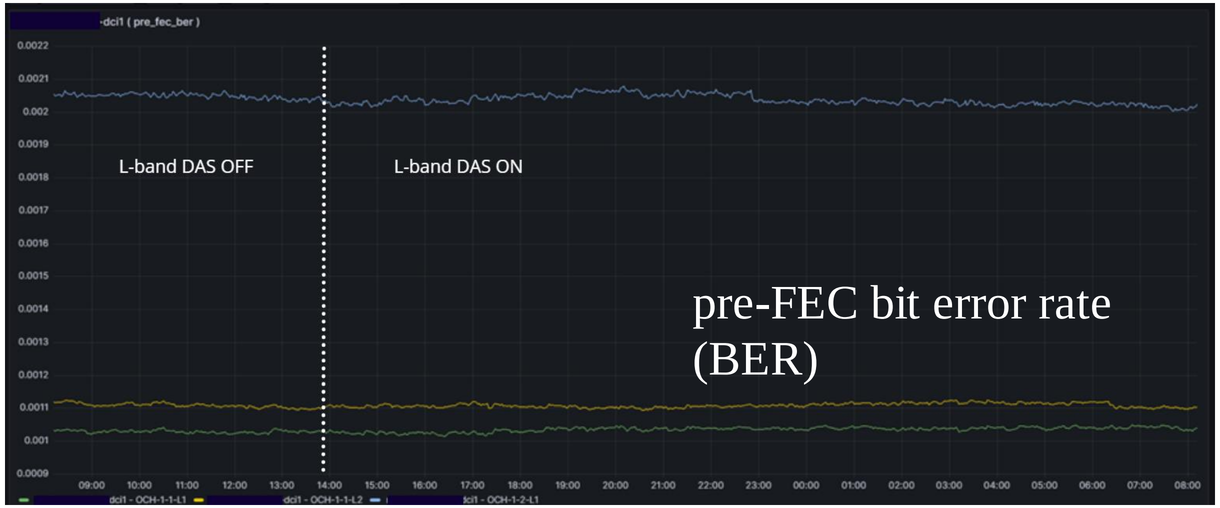
Detekt.: Alle Splitter: Nei Nb: 005/005 Pcomp: -20.52 dBm/ 8.872 uW

Kanal	L snitt(nm)	L Min(nm)	L Maks(nm)	P snitt(dBm)	P Min(dBm)	P Maks(dBm)
001	1542.111	1542.071	1542.157	-27.69	-27.92	-27.44
002	1542.927	1542.887	1542.973	-27.80	-28.01	-27.41
003	1547.076	1547.027	1547.151	-27.62	-28.27	-26.70
004	1547.894	1547.831	1547.974	-27.95	-28.92	-26.99
005	1548.853	1548.819	1548.916	-27.11	-29.93	-25.78

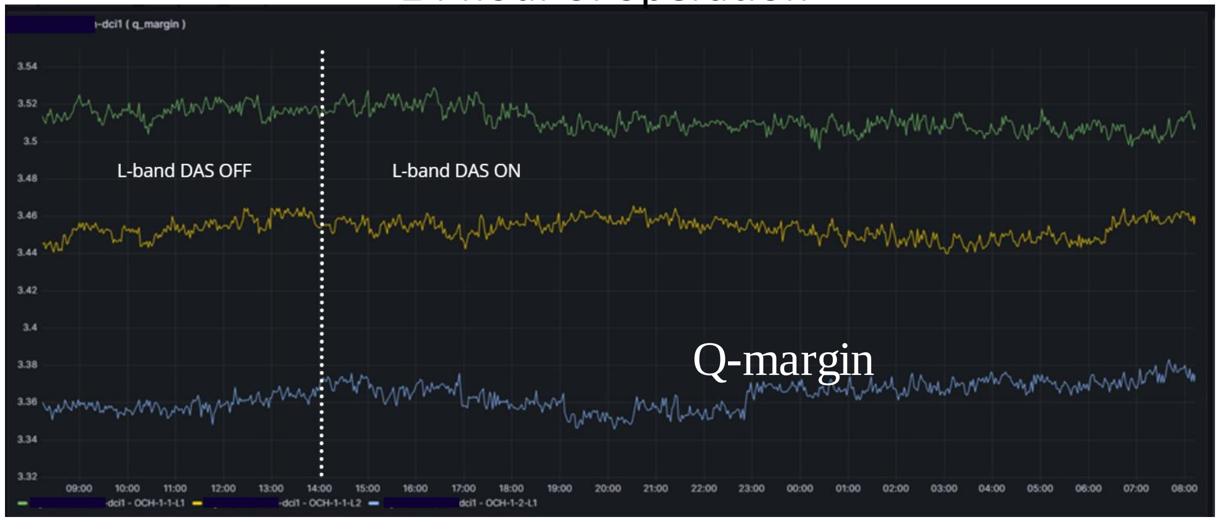
5 Active wavelengths monitored

1. 1G
2. 1G
3. 200 G
4. 200 G
5. 300 Gbps (Production traffic)

200G (62Gbaud QPSK with SDFEC-G2), 300G (84.23Gbaud 16SQAM with SDFEC-V. Monitored for 14 days in total with no degradation in signal



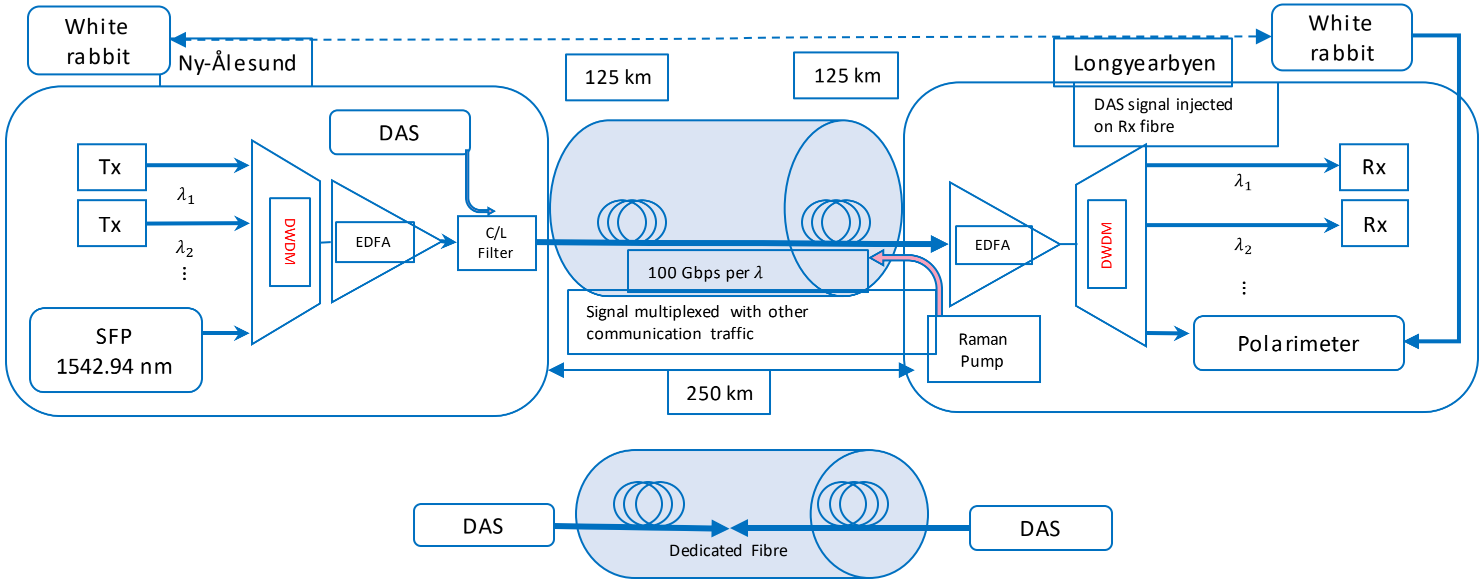
24 hour of operation

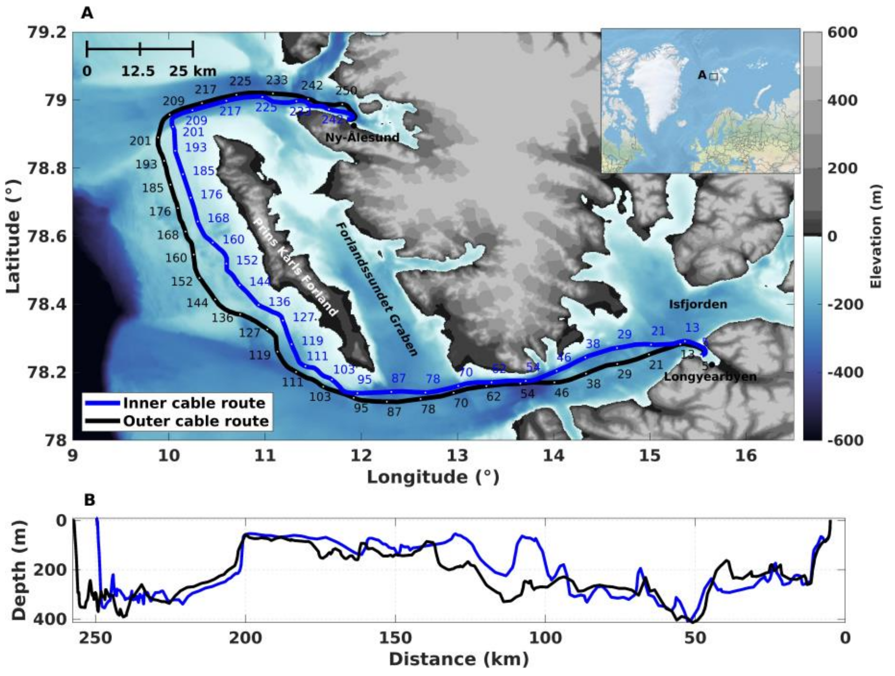


Credit: K. Bozorgebrahimi and R. Veisllari, SIKT

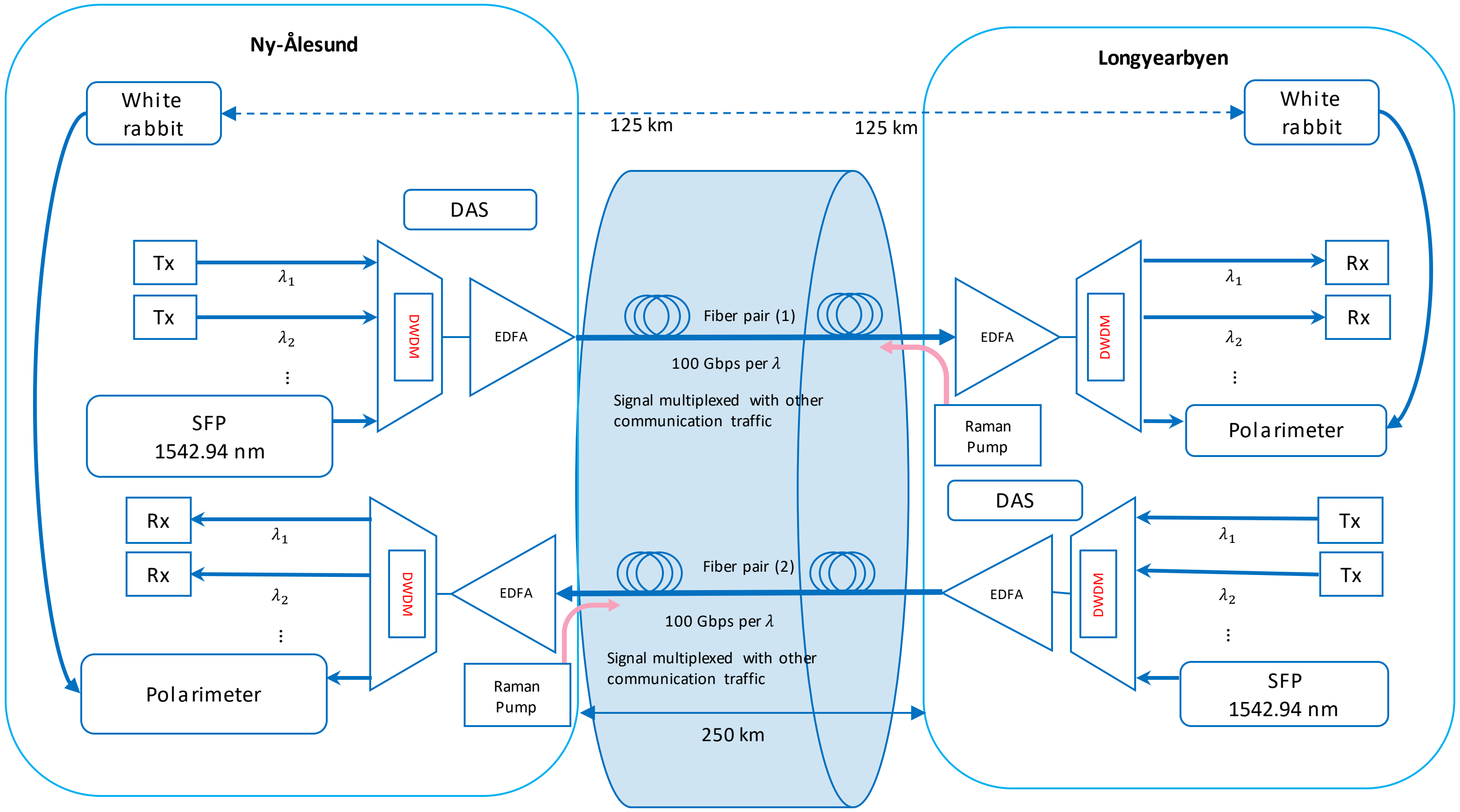
2nd Field Campaign: Svalbard

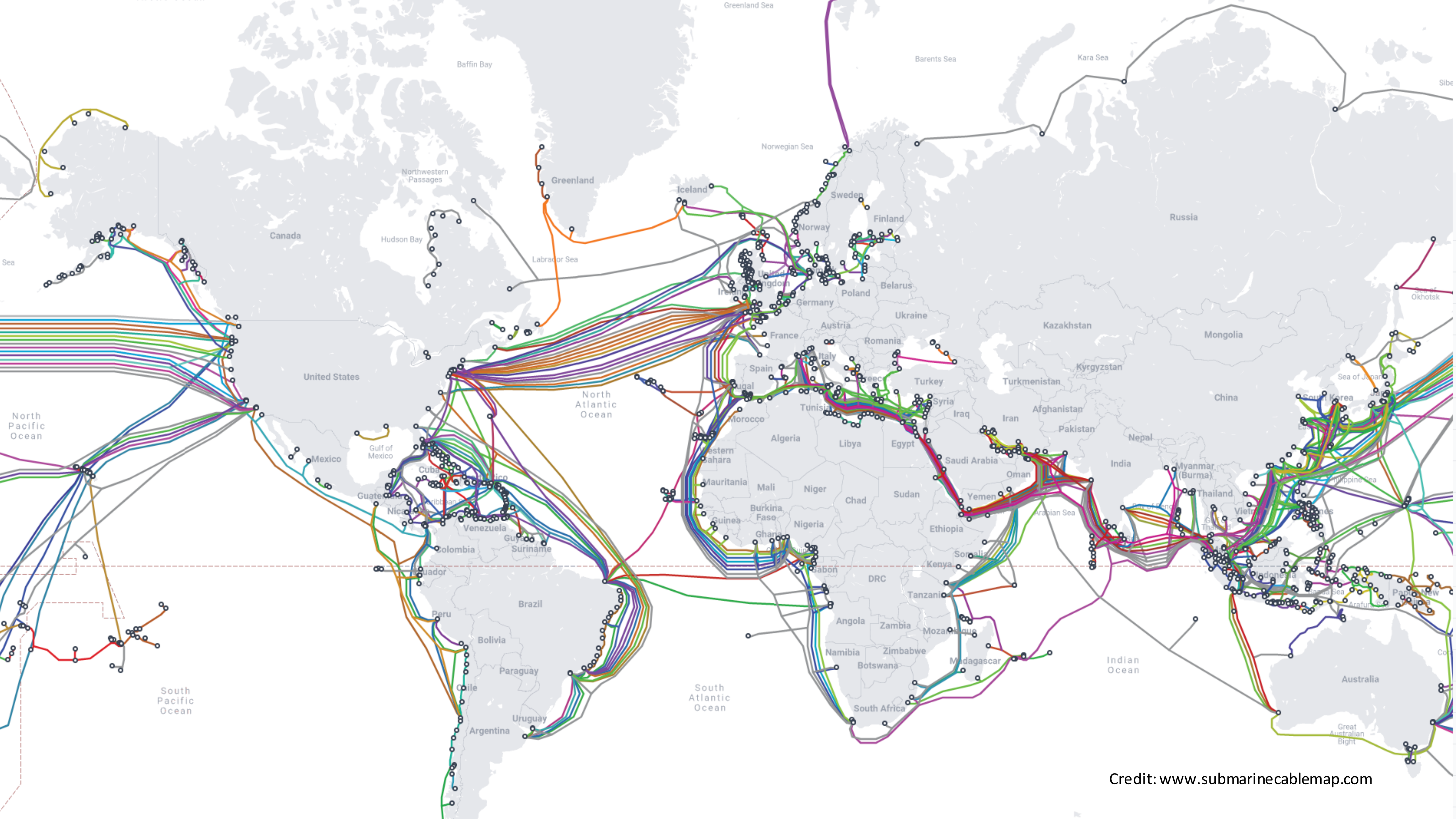
- Polarimeter (PM1000, Novoptel) connected to a live DWDM link
- 2 x CESNET PolBox (Polarimeters) connected to a live DWDM link
- White rabbit protocol running between the two end sites
- 2 x DAS (OptoDAS, ASN) interrogators connected to DWDM system in L band
- DAS (OptoDAS, ASN) interrogators connected to two dedicated fibres in each cable





New SOP experiment – bi directional with white rabbit





Credit: www.submarinecablemap.com

Thank You

Any questions?

www.geant.org

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