Improving active faults monitoring leveraging submarine telecom fiber optic cables : first results from central Chile

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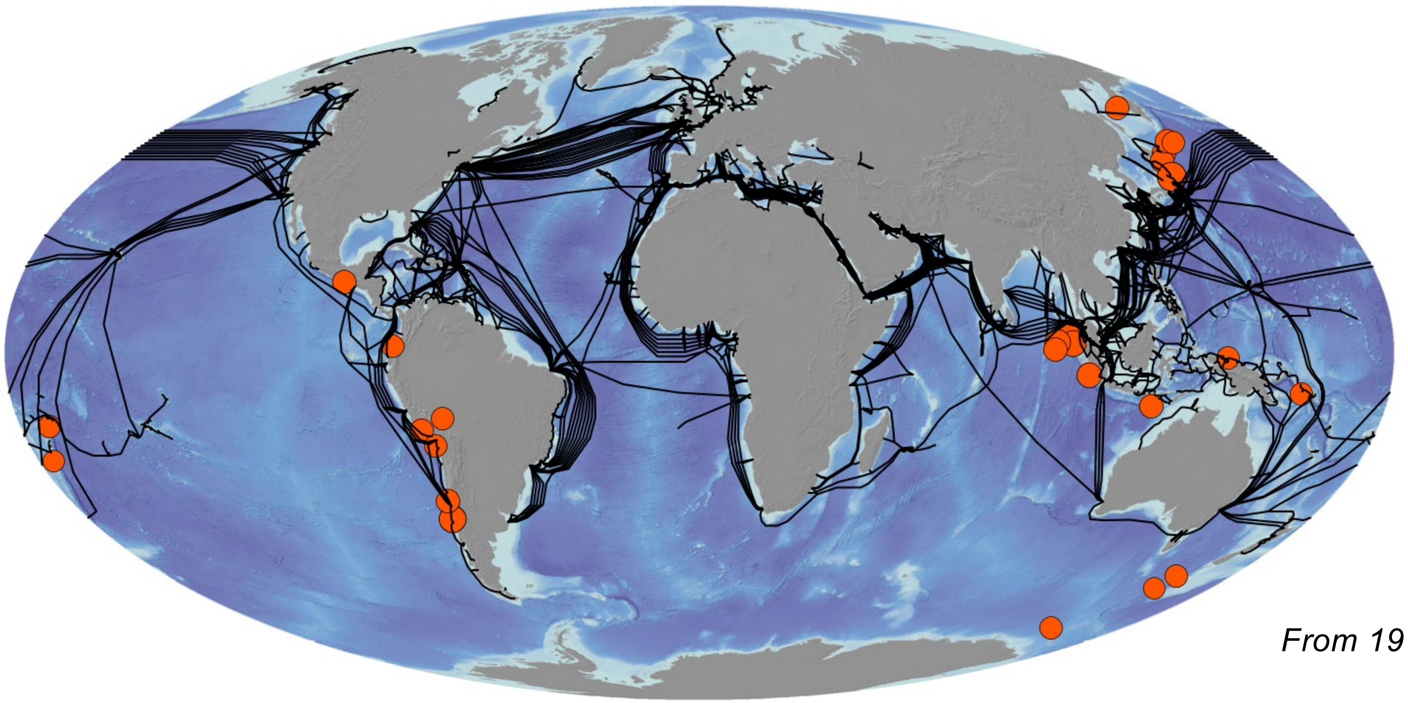
Earthquake with Magnitude > 8 and Fiber optic telecom cables

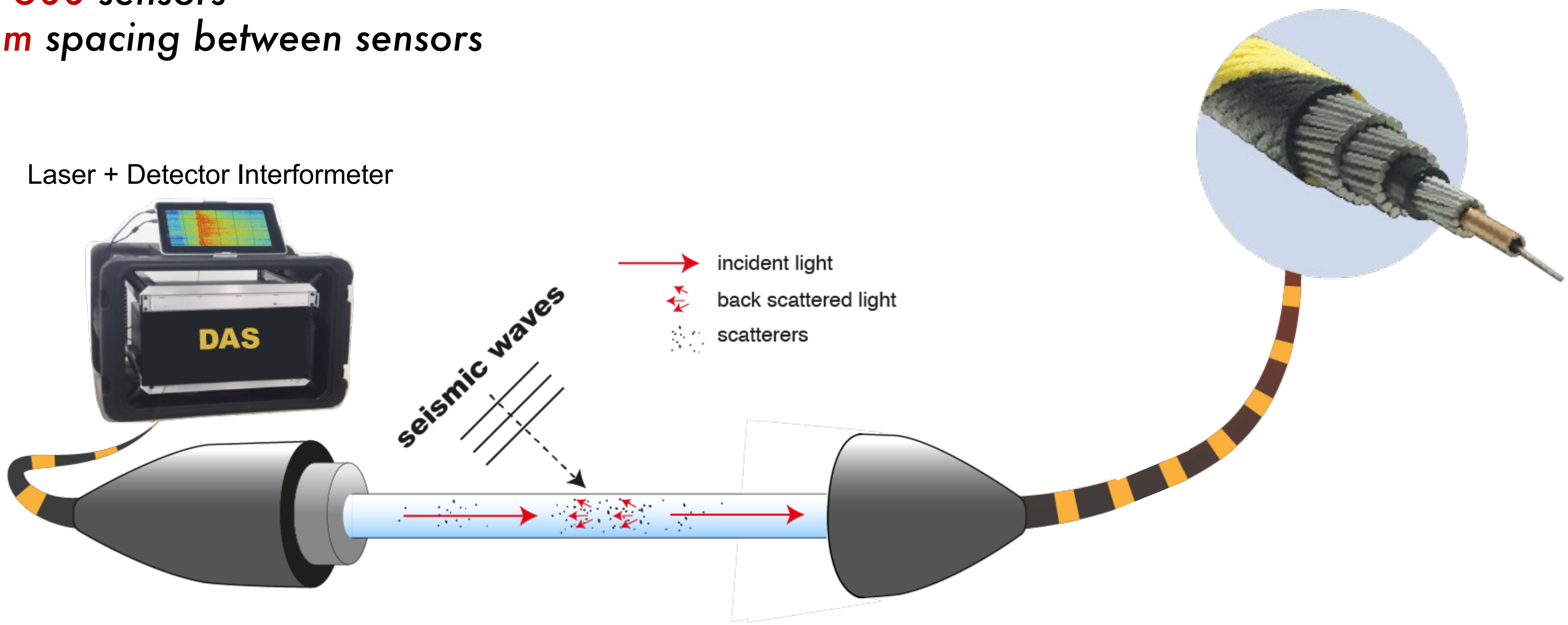


From 1976 to 2016

Provide continuous real-time data close to the faults for
active fault monitoring and **early warning**

Distributed Acoustic Sensing:
Dense network of acoustic and seismic sensors

150 km long arrays
37500 sensors
4 m spacing between sensors



Building a seafloor observatory submarine telecom fiber optic cables

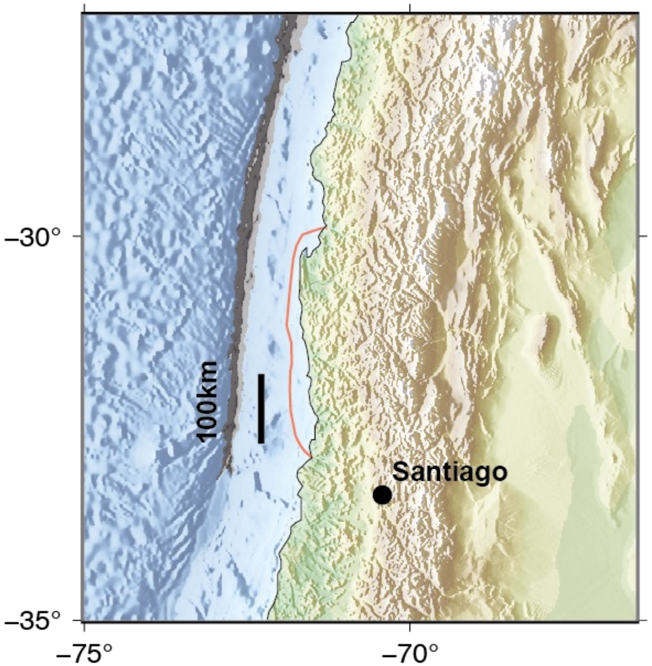
Past and on going offshore experiments:

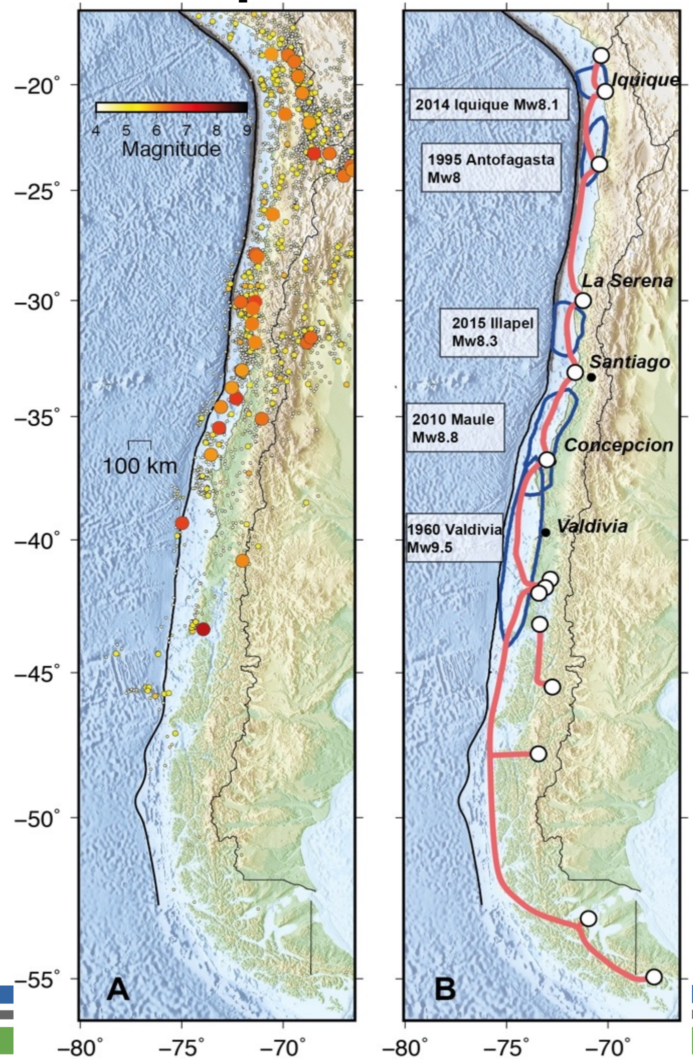
Central Chile POST (~150km)

Region of **high seismicity**

Installation: October 27 2021
Duration: 37 days
Amount of data: 74 TO

~150km, 125Hz, 4m, GL=8m

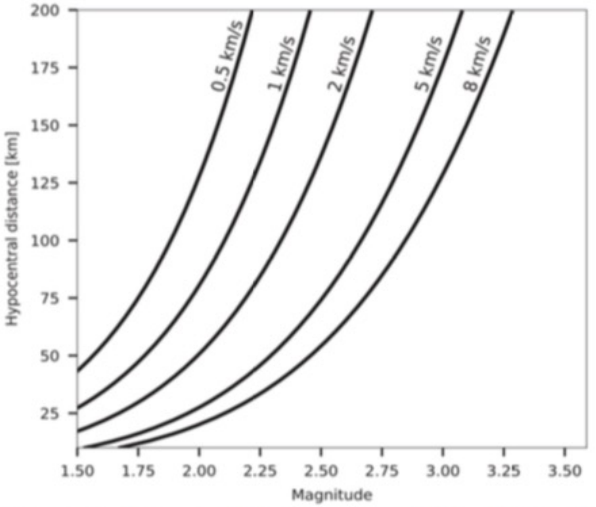




Monitoring megathrust faults with abyssal fiber optic cables

Detect weak seismic signals from more than 30000 DAS sensing points

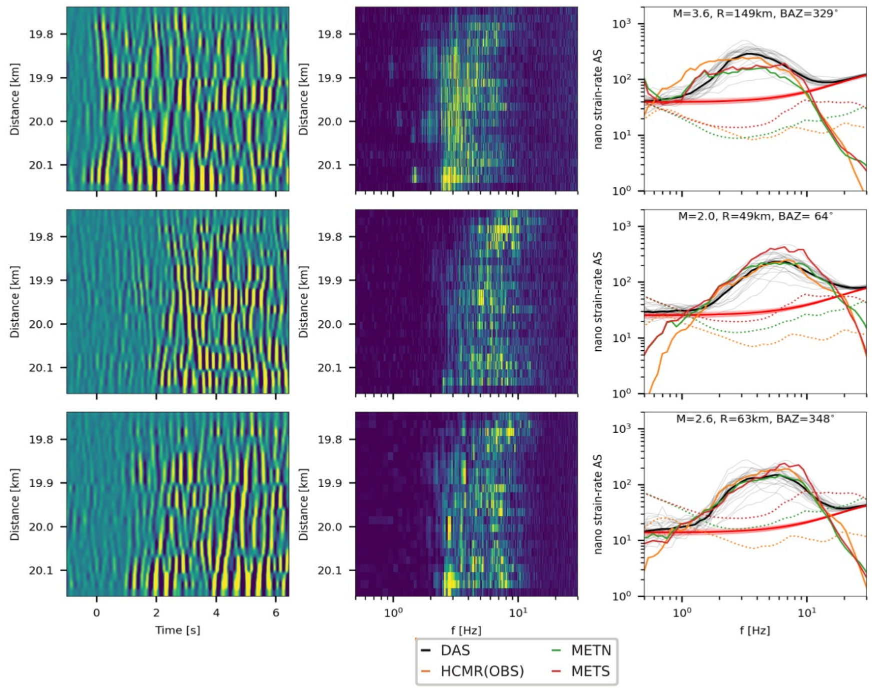
- Earthquake **detection capabilities using DAS are similar to those of broadband** instruments.



S-wave detection thresholds (SNR=1) between 1 and 15 Hz, for ground accelerations at different apparent velocities.

Lior et al. 2021a

Strain rate at 3km depth *DAS amplitude spectra* *Strain rate spectra*



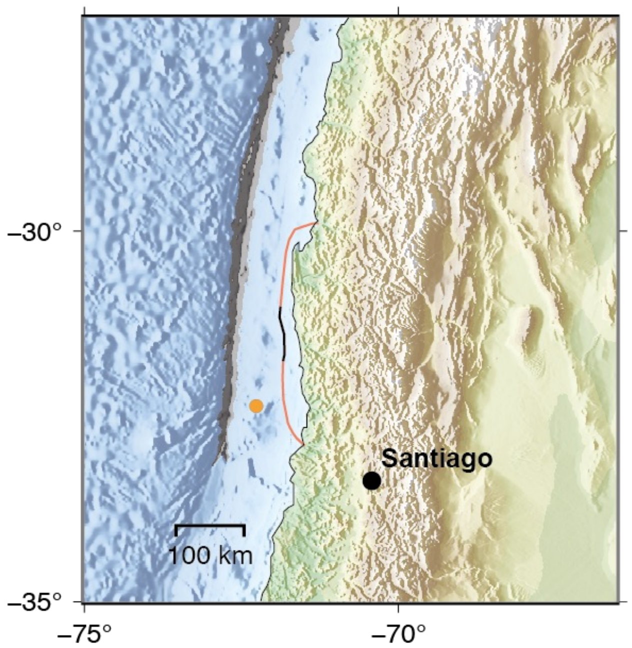
- Detection capabilities are a function of the recorded noise, **cable response and apparent velocity.**

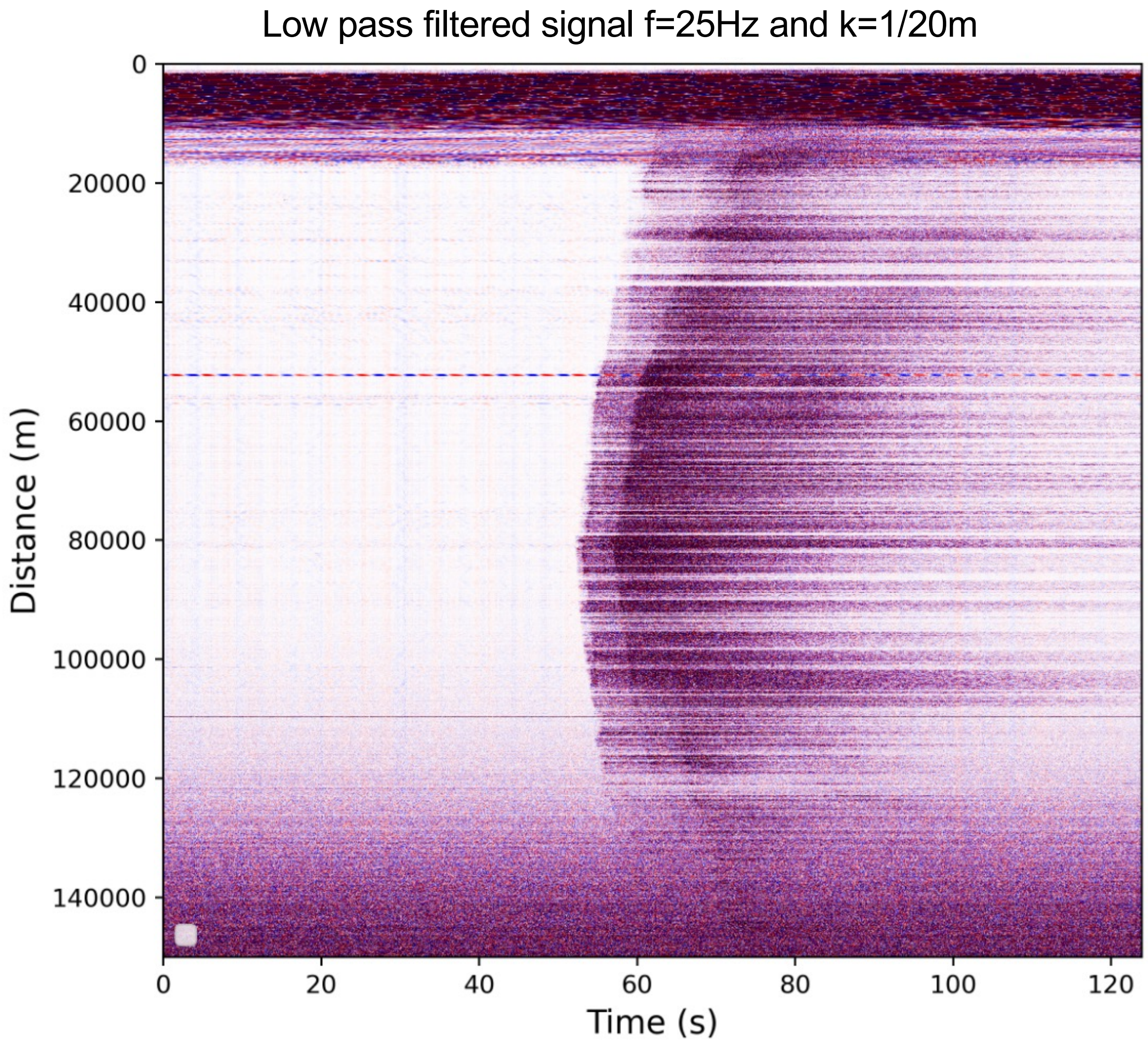
Building earthquake catalog

Automatic detection

Objective : real time, reliable on raw data

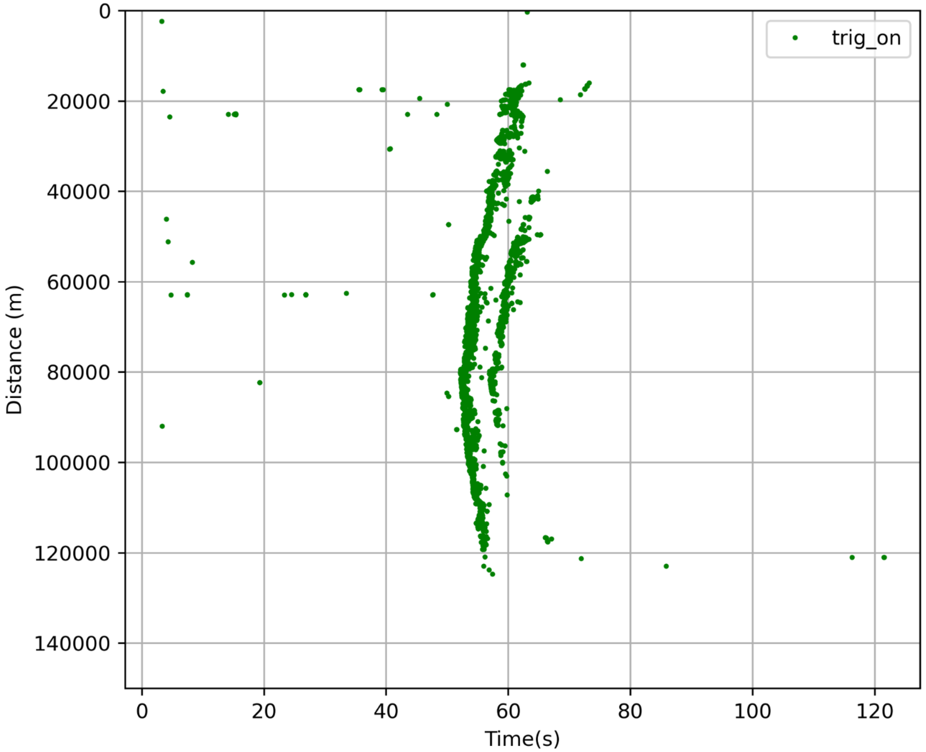
Magnitude = 2.8 Ml
Latitude: -32.397
Longitude: -72.267
Depth = 14.9 km



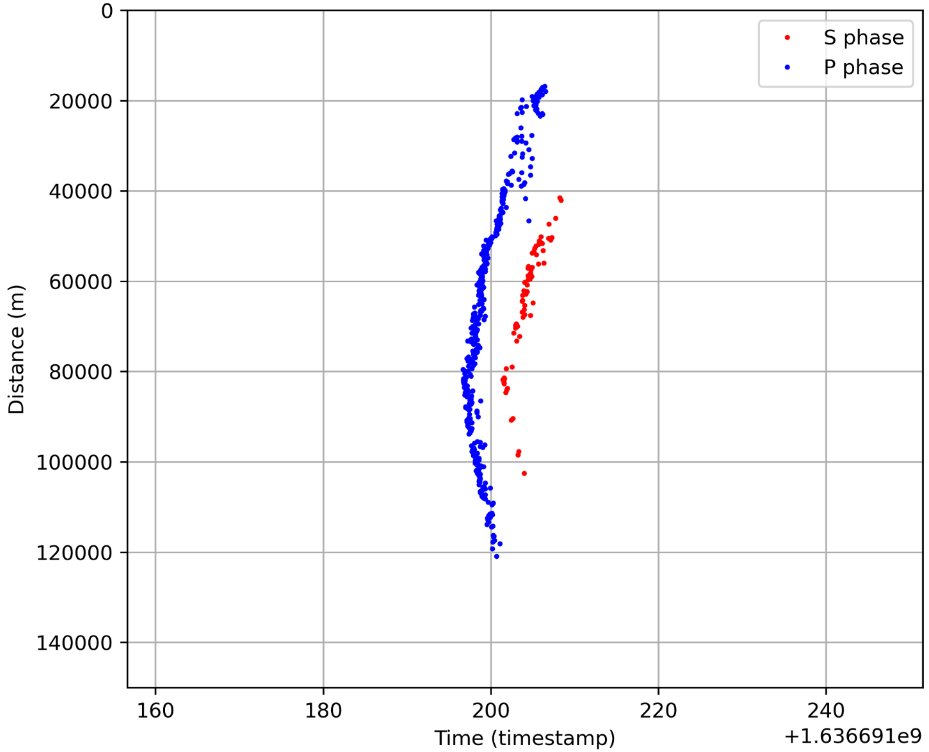


Building earthquake catalog

1st step: STA/LTA detections



2nd step: clustering *HDBSCAN*

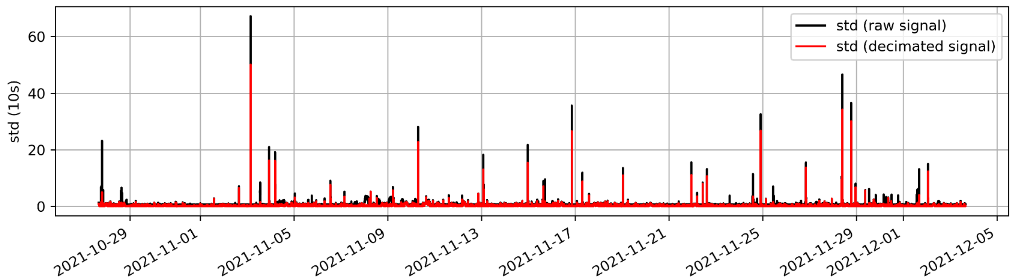


Baillet et al. in prep

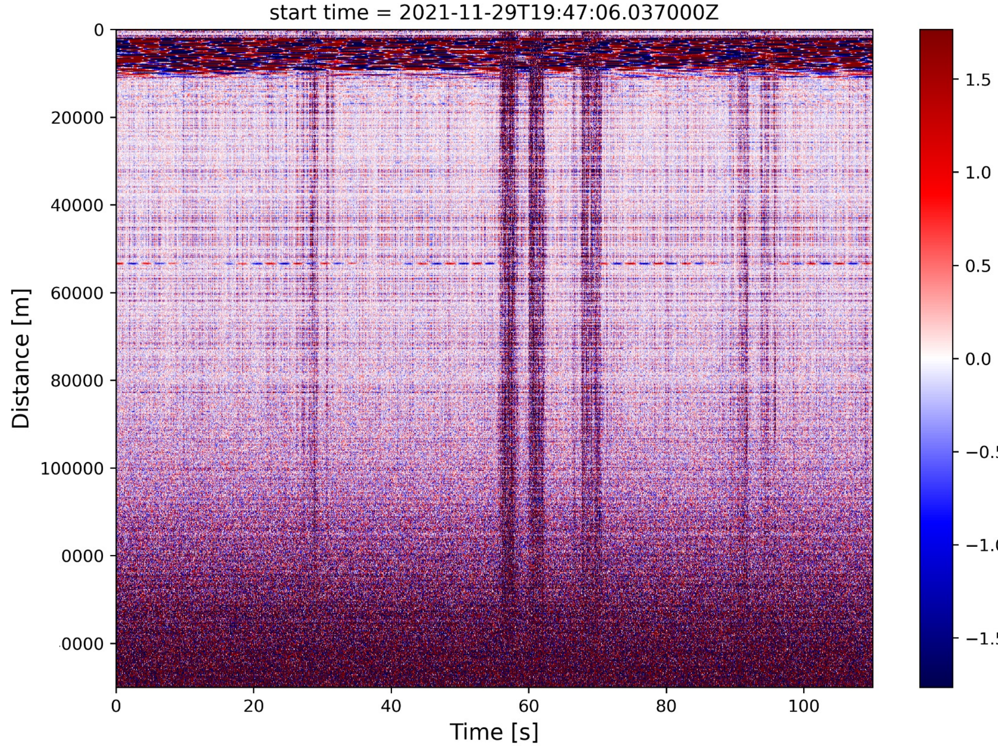
Building earthquake catalog

On 36 days of data
- 25661 clusters
- 2778 clusters after removing outliers
- **1091 earthquakes so far** vs 209 in the CSN

Simpler metrics to detect all M>2 events
std over 10s long files – stored in the header files



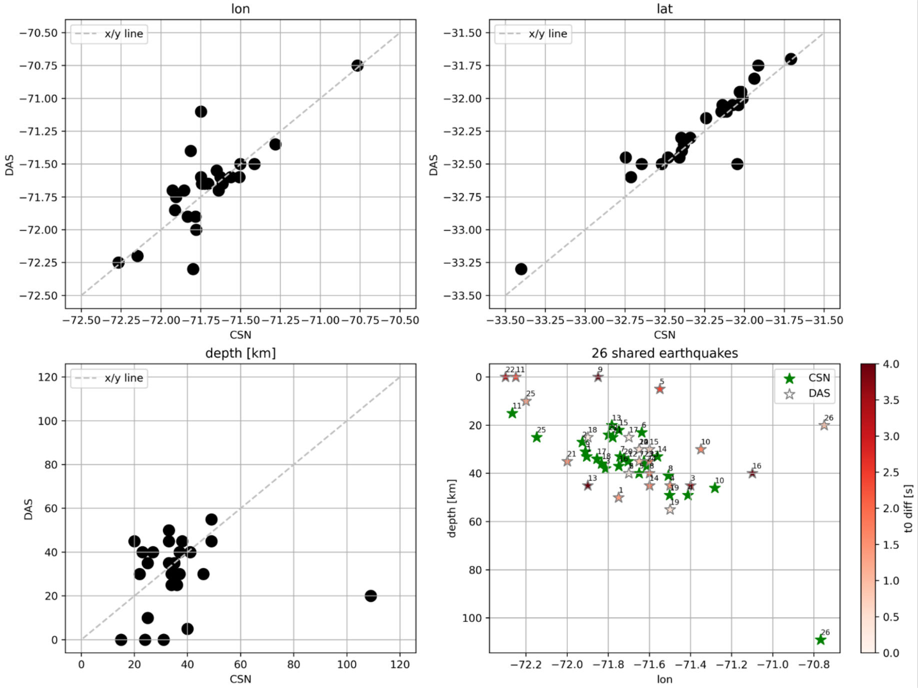
3nd step: cluster sorting

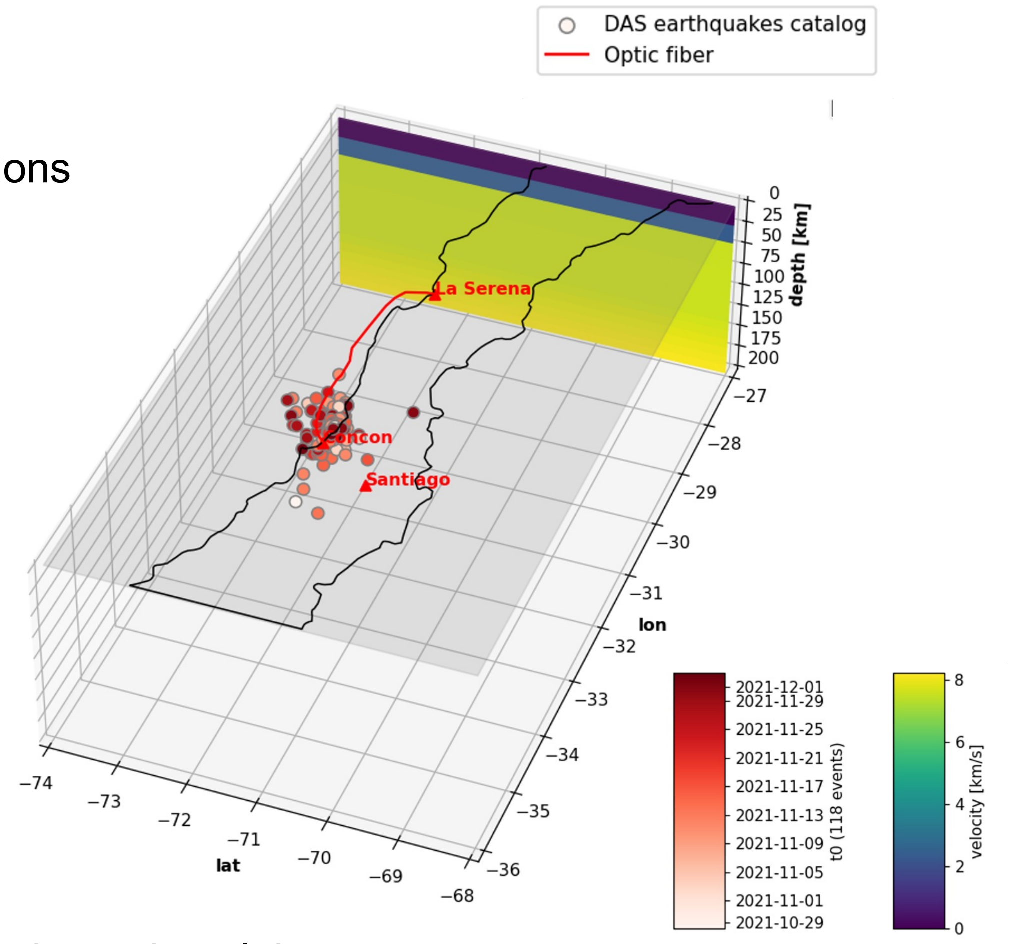


Building earthquake catalog

Assessing Location Capabilities

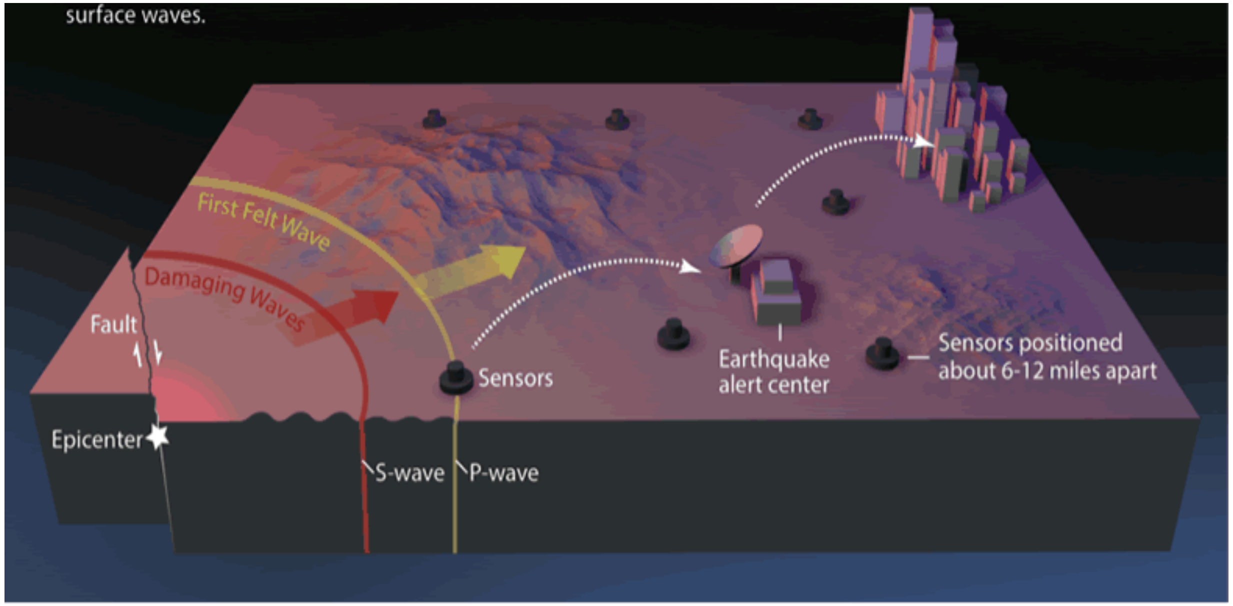
Using automatic STA/LTA phase picks : first localisations

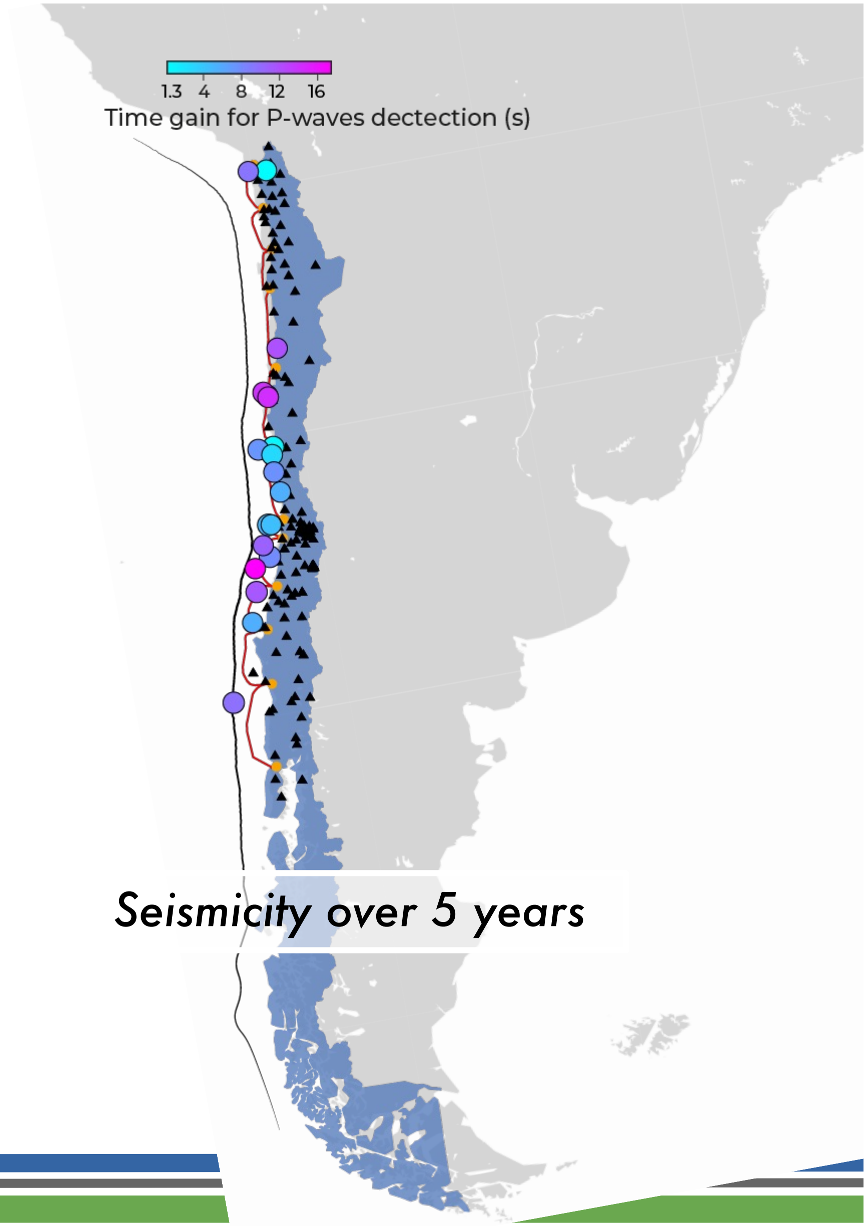




Trabattoni et al. in prep

Develop a prototype of offshore DAS earthquake early warning system





Harnessing Optical Fibers for Earthquake Early Warning: Magnitude Estimation and Ground Motion Prediction

Lior, Rivet et al. 2023 Scientific Report

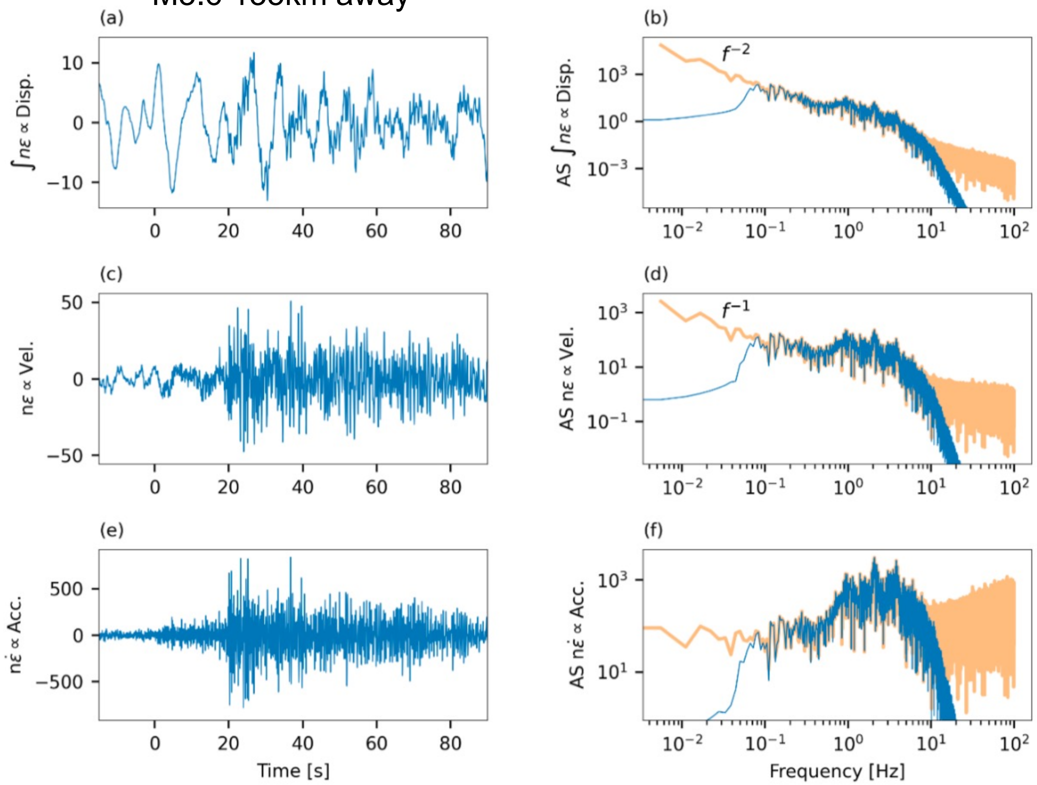
Limitation : DAS low frequency noise

- Target : reduce the low frequency noise to improve magnitude estimation

$D_{rms} \propto M^{5/6}\Delta\tau^{1/6}$

$A_{rms} \propto M^{1/3}\Delta\tau^{2/3}$

M3.6 135km away



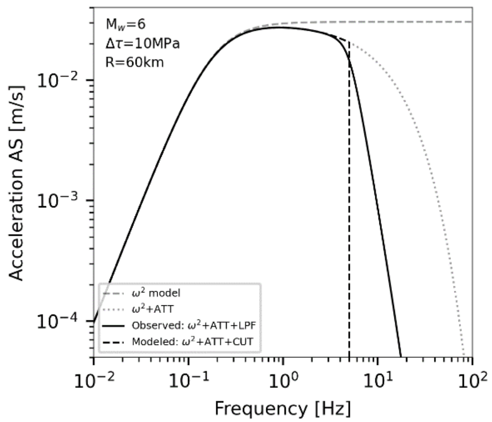
Harnessing Optical Fibers for Earthquake Early Warning: Magnitude Estimation and Ground Motion Prediction

Lior, Rivet et al. 2023 Scientific Report

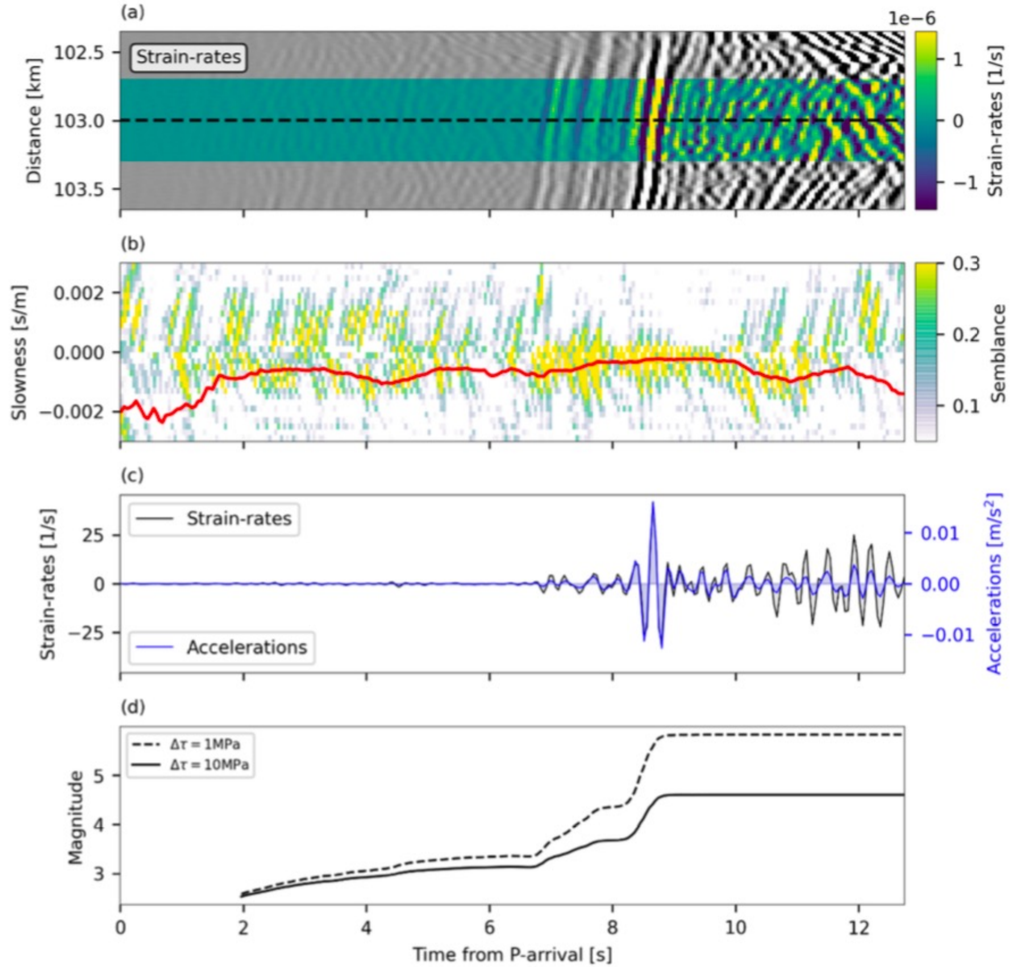
1. Convert strain rate to acceleration in real time

using apparent velocities : $A=\dot{\varepsilon}/p$ estimated from
a slant-stack approach

2. Magnitude estimation from bandlimited ground accelerations



Model derived from (Brune, 1970) from the rms of the ground accelerations (Lior et Ziv, 2020)

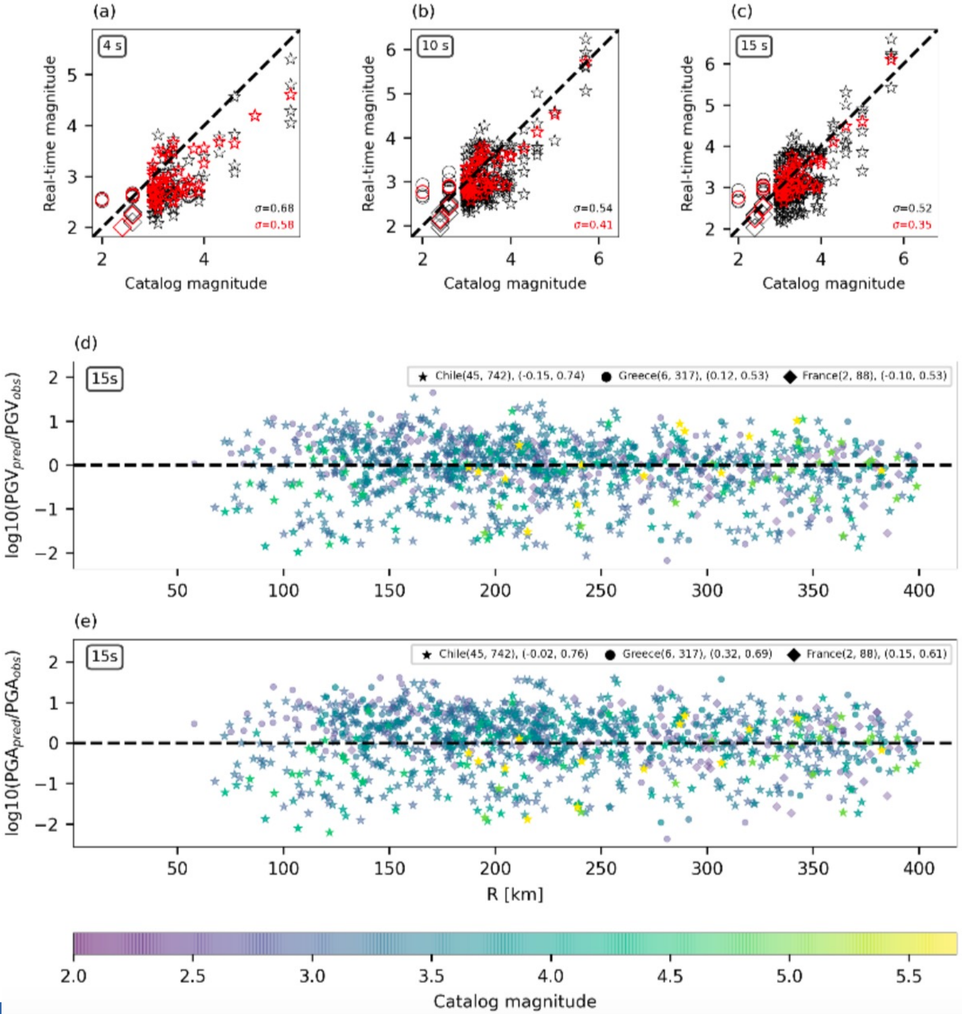


Harnessing Optical Fibers for Earthquake Early Warning: Magnitude Estimation and Ground Motion Prediction

Lior, Rivet et al. 2023 Scientific Report

3. Real time magnitude estimation and PGA and PGV estimations

Physics-based GMPEs (Lior and Ziv, 2018, Lior and Ziv, 2020), derived using the same source model (Brune, 1970)



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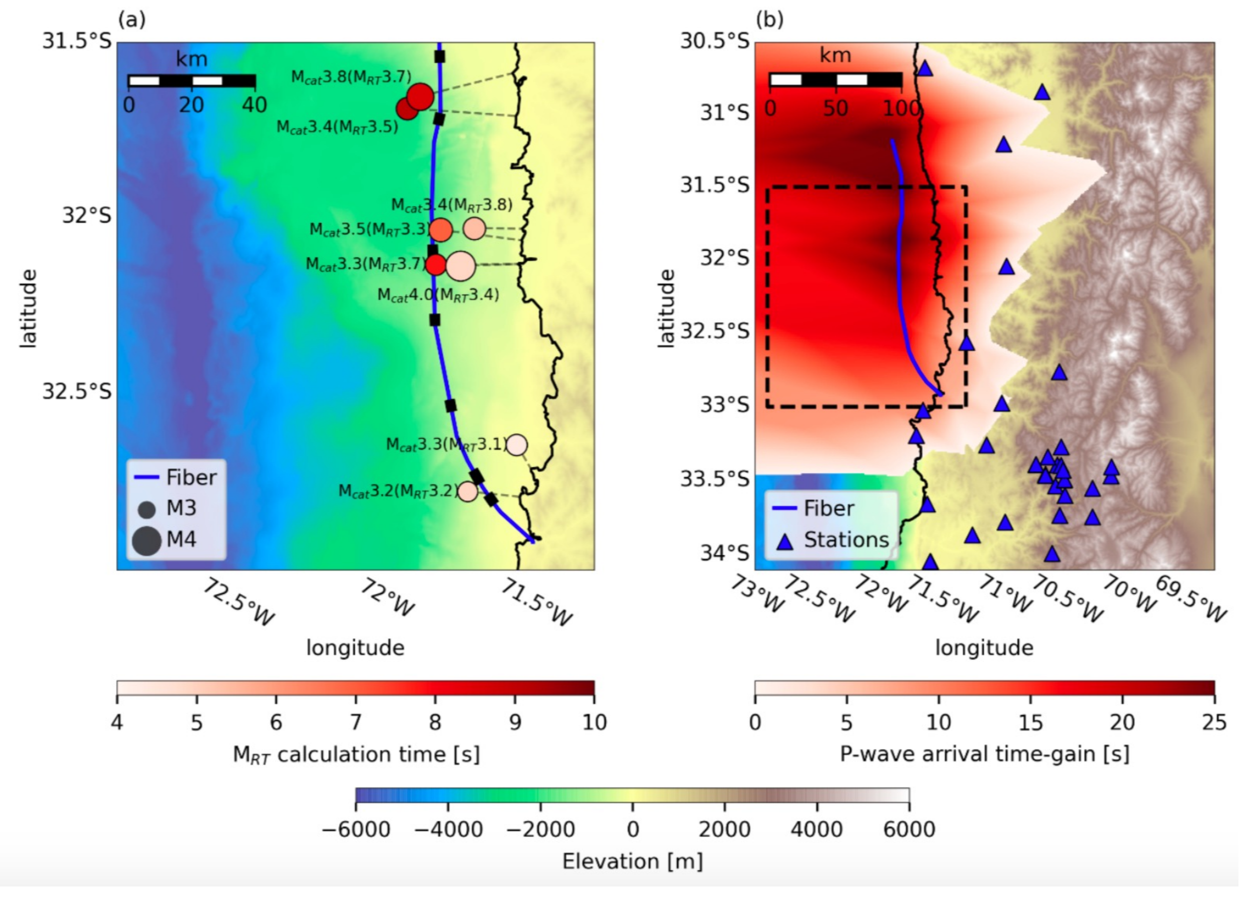
DAS can be used for
real-time magnitude estimation and **ground motion prediction**

- For the offshore earthquakes, **by the time S-waves are expected to reach the coastline**, real-time magnitude estimates are typically **within half a magnitude unit** of catalog values

- **time-gain may be as large as 25 s** for earthquakes that occur near the fiber



Building a seafloor observatory submarine telecom fiber optic cables

150 km long cable

EU-Horizon GeoInquire – LIGURIAN TEST BED

Thank you for your attention!

Geo-INQUIRE is a joint effort of 51 institutions

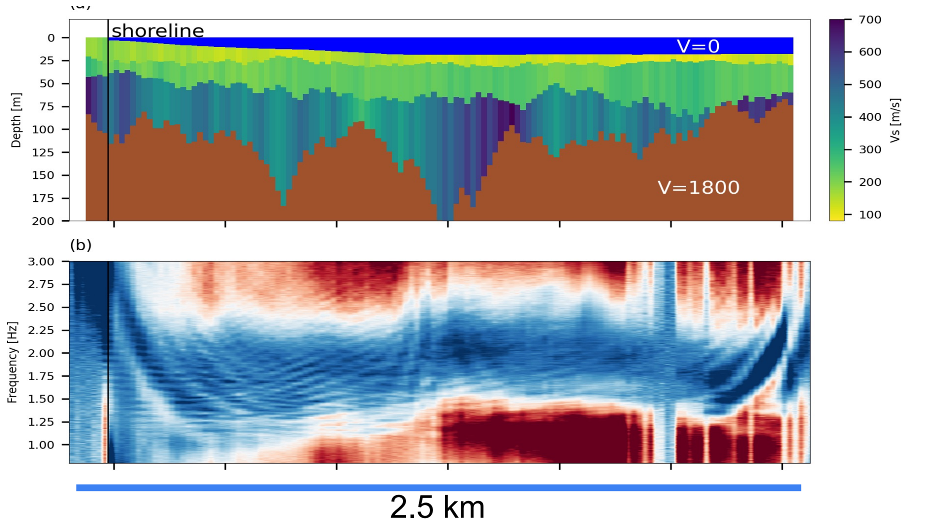
Geo-INQUIRE is funded by the European Commission under project number 101058518 within the HORIZON-INFRA-2021-SERV-01 call.

Image and monitor the crustal properties

High-resolution image of the upper crust

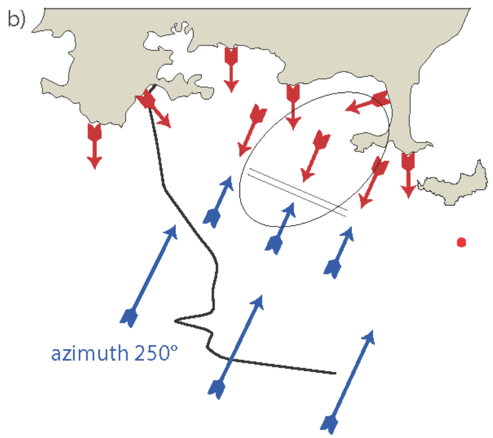
- **Shear-wave velocity** is resolved via Scholte-wave dispersion
- High-resolution **seismic response and basin effects**

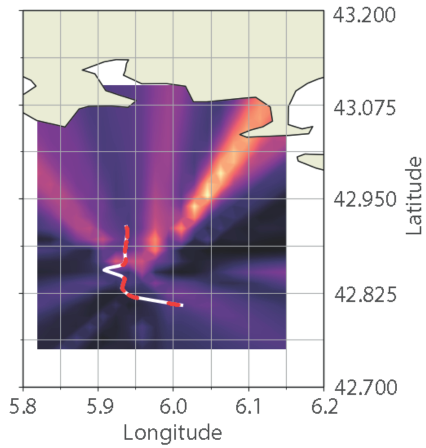
Lior et al. 2022, SRL



Local microseismic noise sources

- To perform **reliable ambient noise surface wave tomography and monitoring**
- Better understand **the mechanism of ambiant noise generation**





Guerin et al. 2022, GJI