FEBUS OPTICS
Distributed Optical Fiber Sensing

UCA JEDI
INITIATIVE D'EXCELLENCE

Agence Nationale de la Recherche
ANR

CENTRE DE PHYSIQUE DES PARTICULES DE MARSEILLE
CPPM

National Centre for Scientific Research
DEMOKRITOS

Distributed sensing of earthquakes and ocean-solid Earth interactions analysis using fiber optic telecom seafloor cables

GeoAzur
TERRE - OCÉAN - ESPACE

UNIVERSITÉ CÔTE D'AZUR

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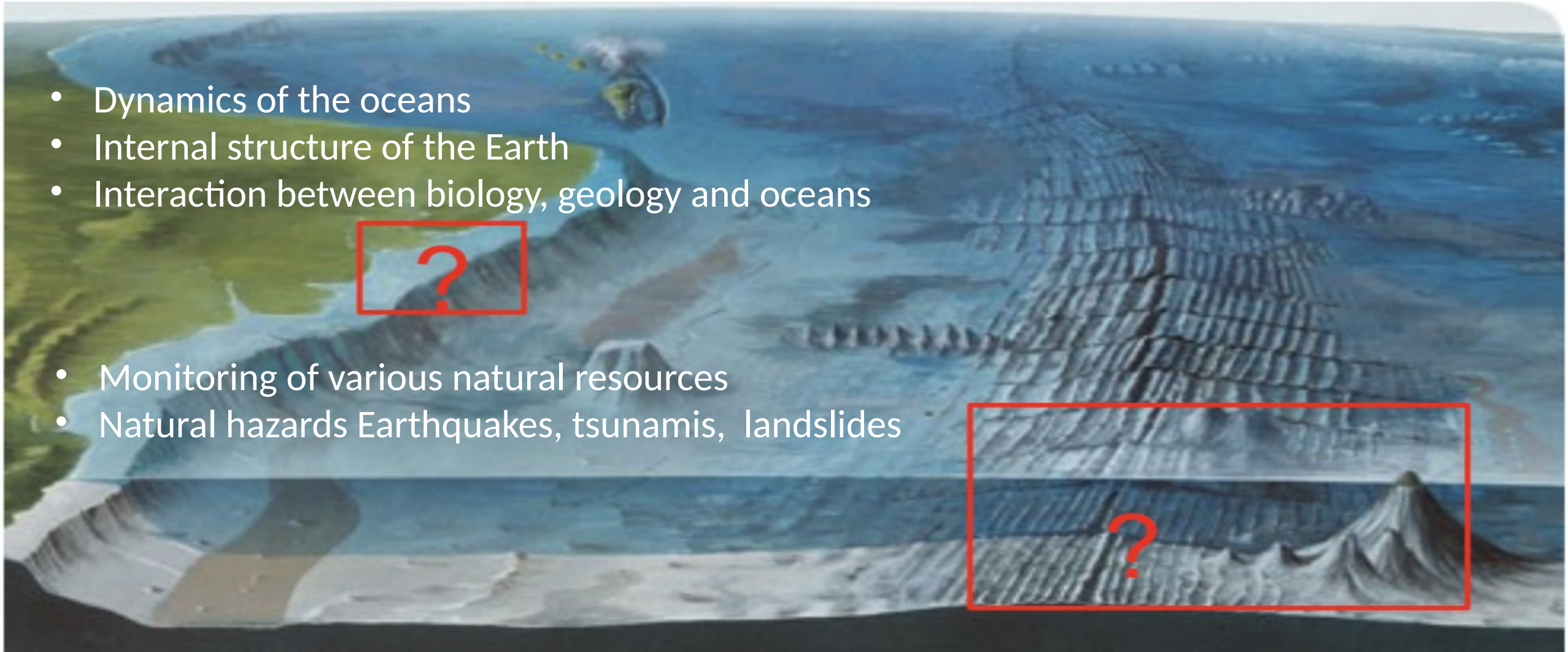
October 2019, DS meetup

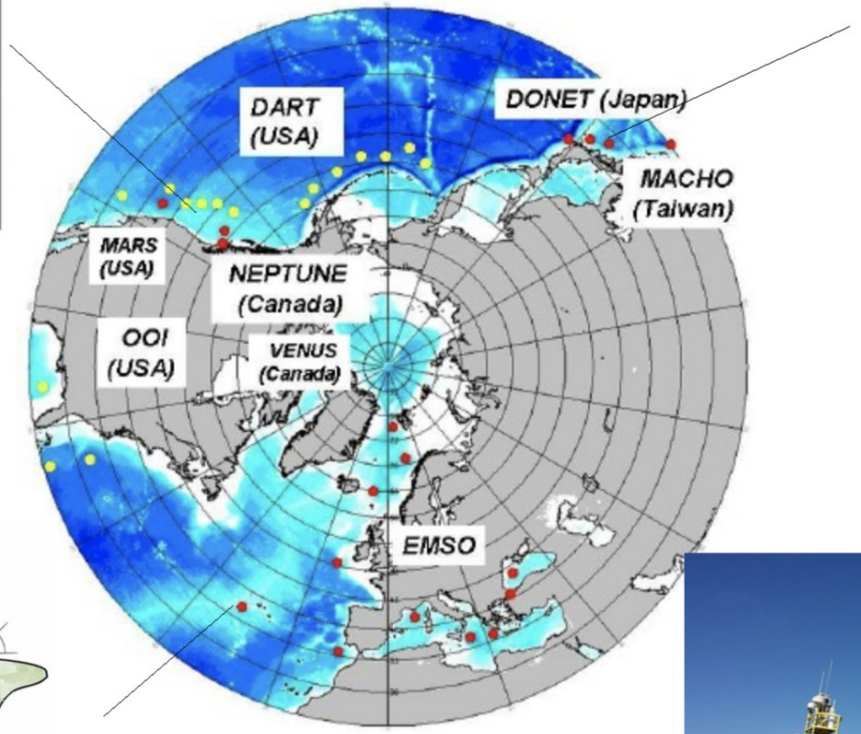
Ocean floor instrumentation holds the answers to numerous key scientific questions

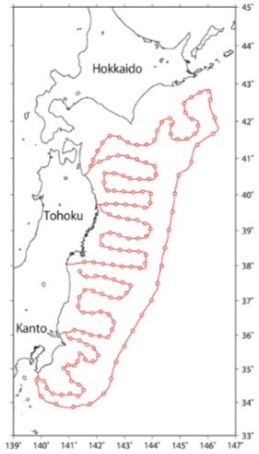


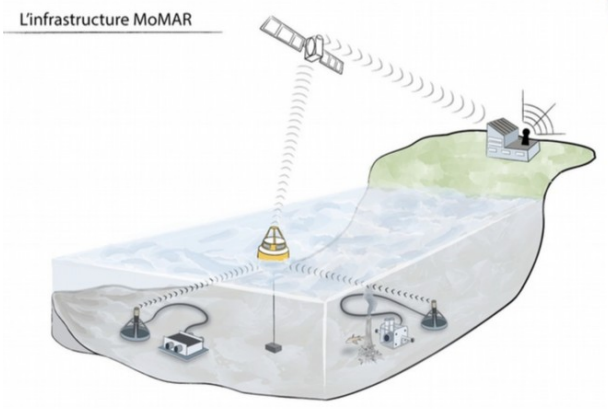
- Dynamics of the oceans
- Internal structure of the Earth
- Interaction between biology, geology and oceans

- Monitoring of various natural resources
- Natural hazards Earthquakes, tsunamis, landslides

...yet seafloor instrumentation is very limited

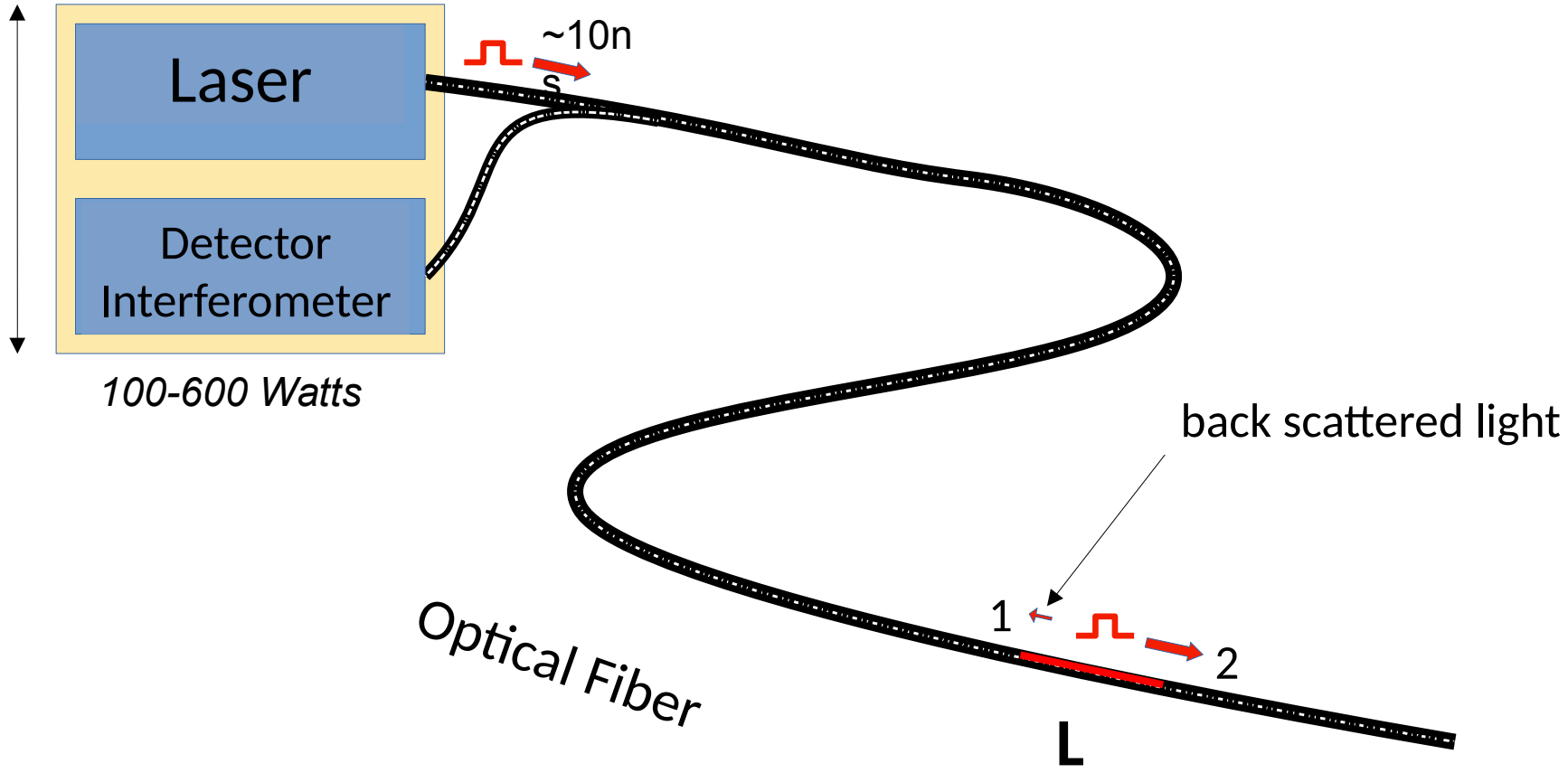




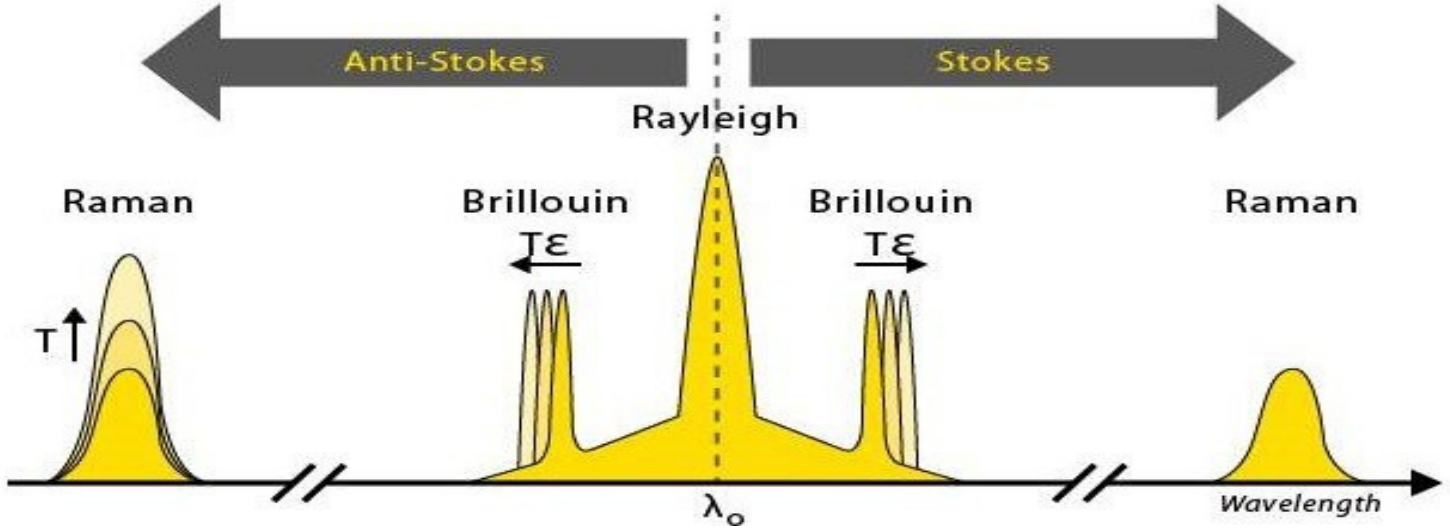


Reflectometry

The principle behind *Distributed Fiber Optic Sensing (DFOS)*

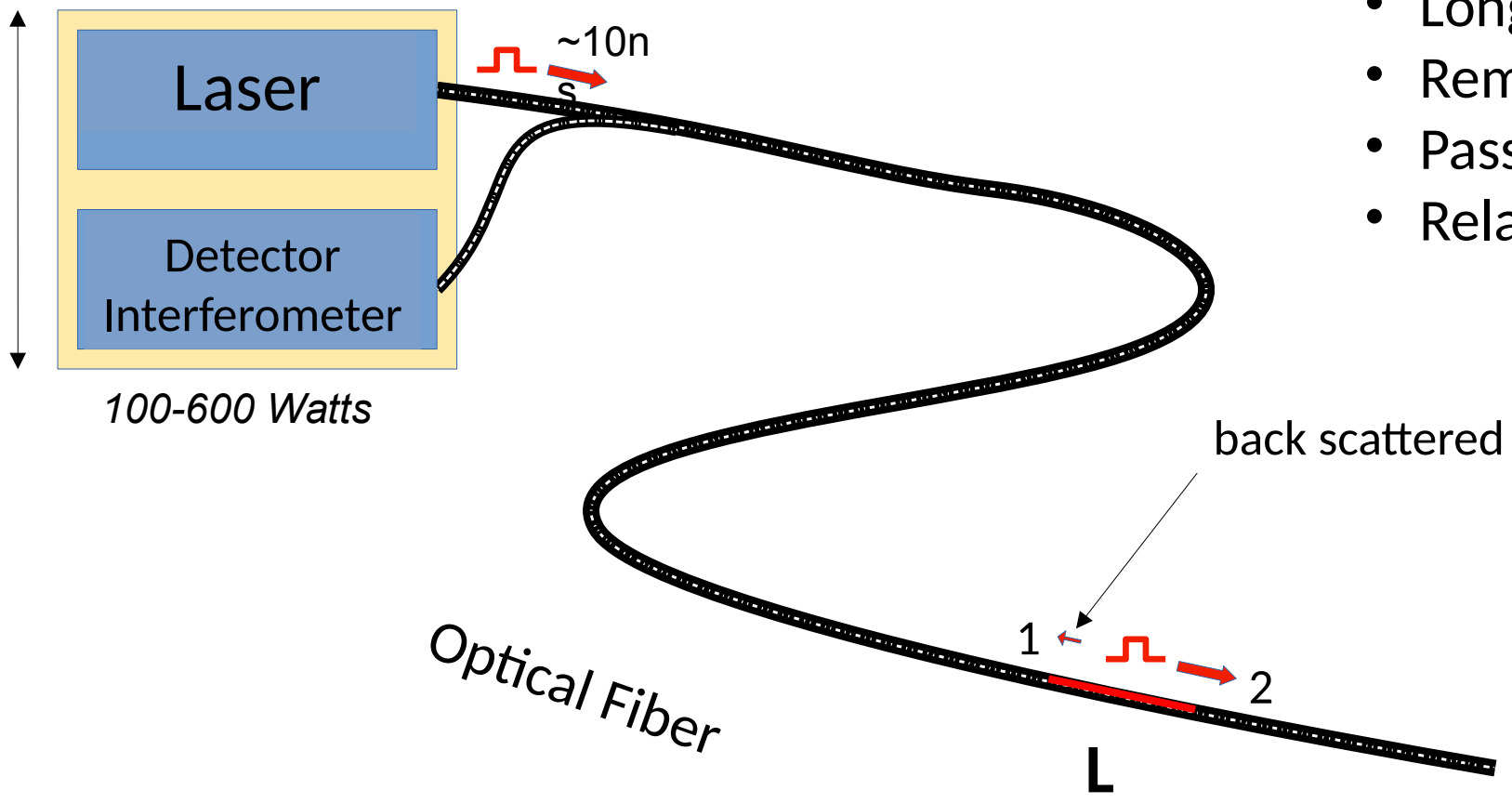


Flavors of backscattering



- **Rayleigh**: elastic and related to heterogeneities in the fiber. Analyze phase delays to measure vibro-acoustic perturbations → Distributed Acoustic Sensing (DAS)
- **Raman**: inelastic and related to excitation of vibrational energy of fiber molecules → DTS
- **Brillouin**: inelastic and related to interaction between light and internal acoustic waves → DDS

Distributed FO Sensing



Advantages for seafloor

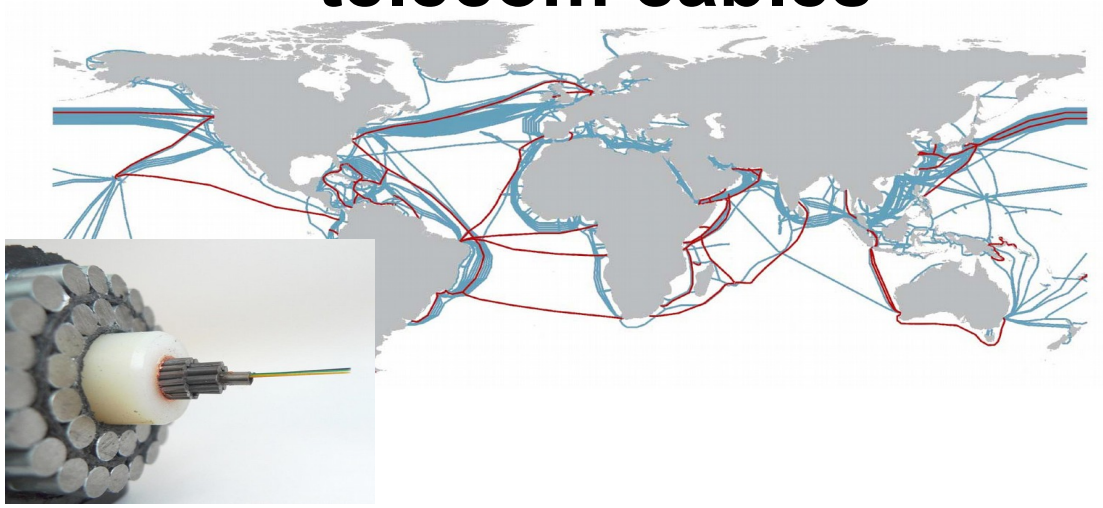
- Multi-physics : T, strain, acoustics
- Distributed : meter scale
- Long distance (40km+)
- Remote measurement
- Passive sensors
- Relatively low cost

Cable matters, not the fiber

Option 1: dedicated cables

Cheap and can decide
on the scientific target.
But cable needs to be
protected and anchored

Option 2: seafloor telecom cables



Already covering a significant fraction
of oceans and coastal areas.
But special design and not everywhere

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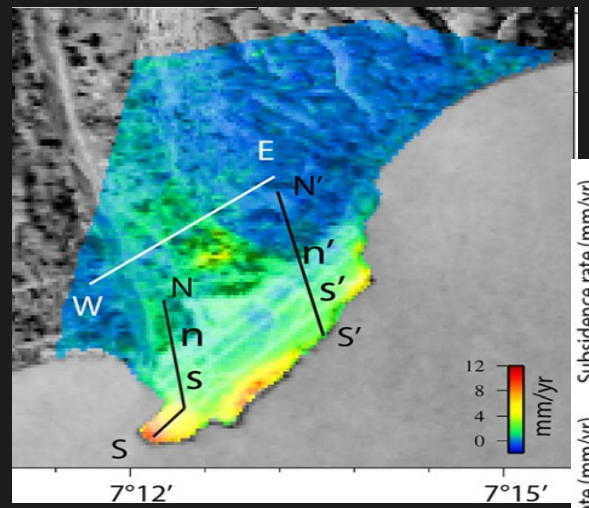
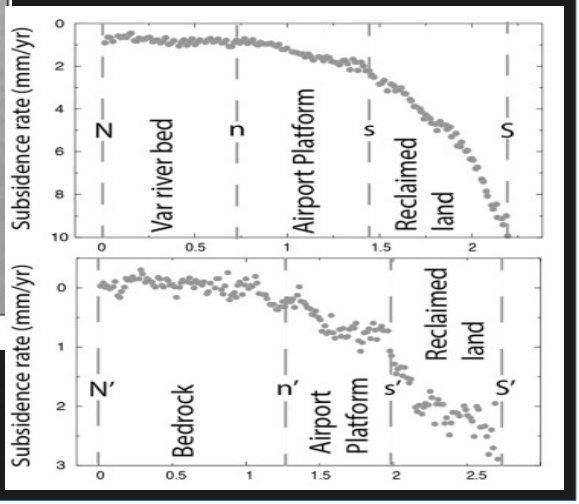
Nice airport: a local site with high scientific, economic and social stakes

Submarine landslide& tsunami, 1979



Subsidence up to 1cm/year



Cavalié, Sladen & Kelner, 2015

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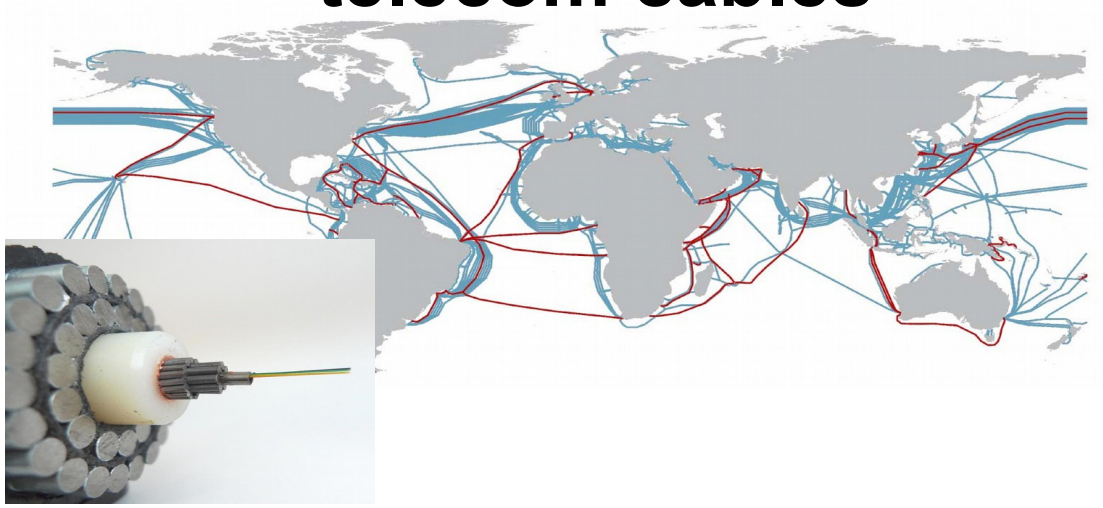

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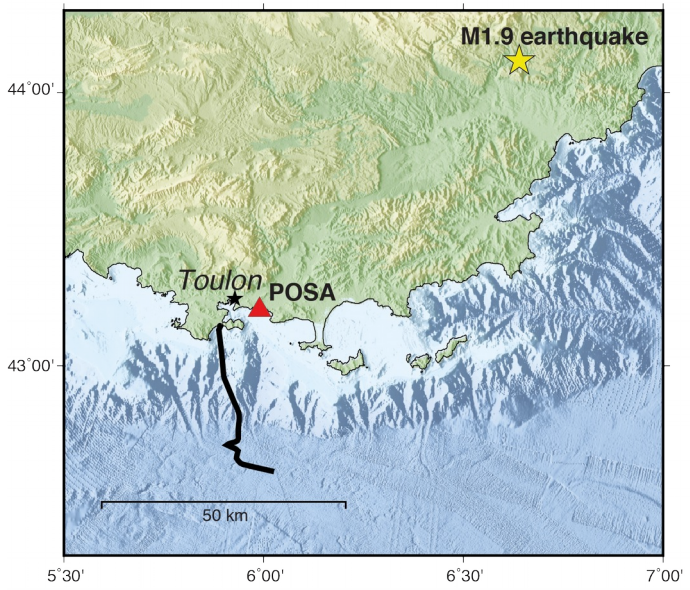
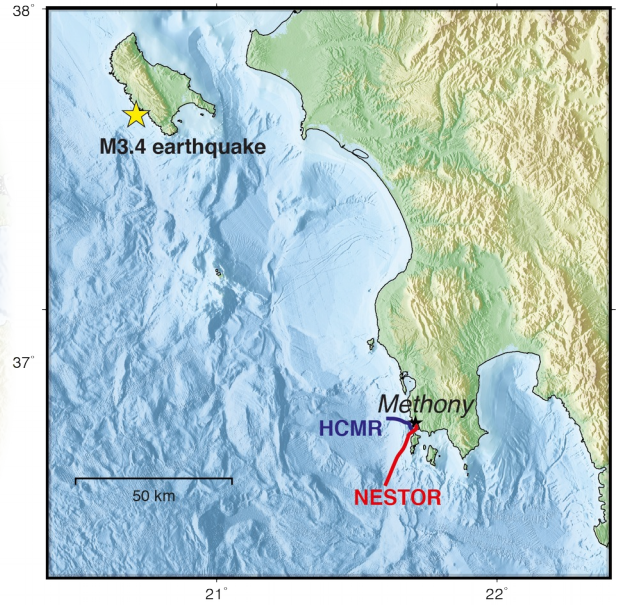
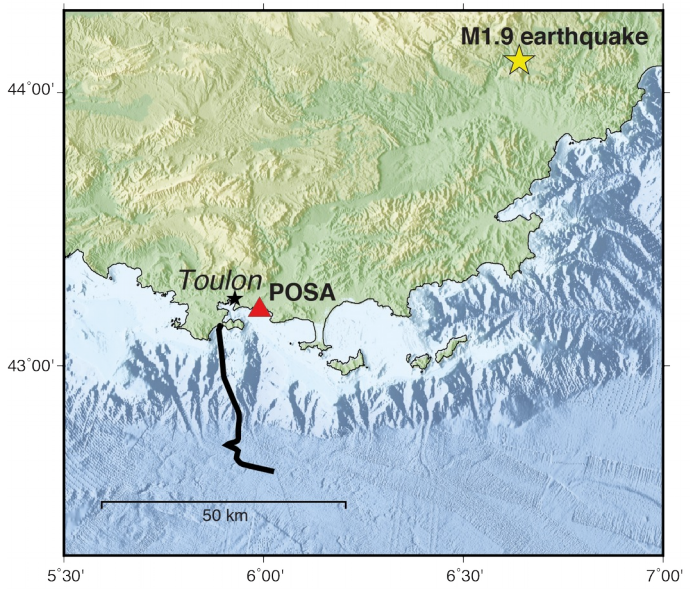
DAS experiments on 3 telecom-like cables in Toulon and SW Greece



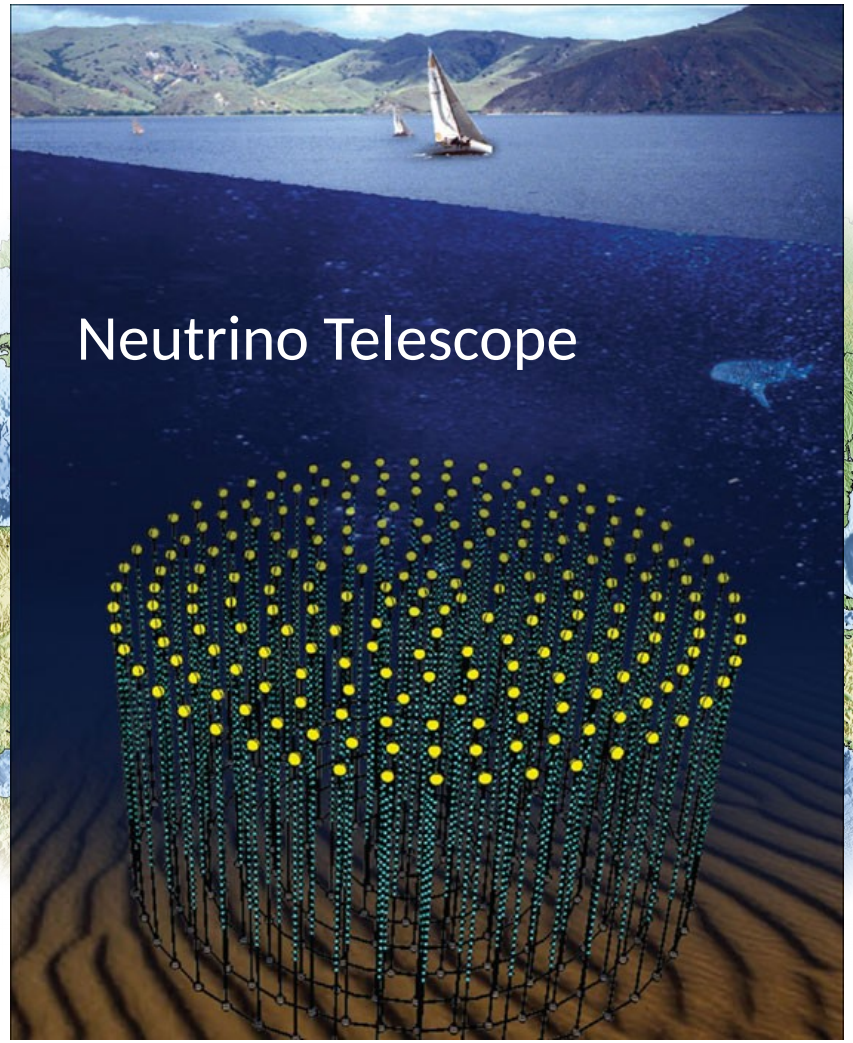


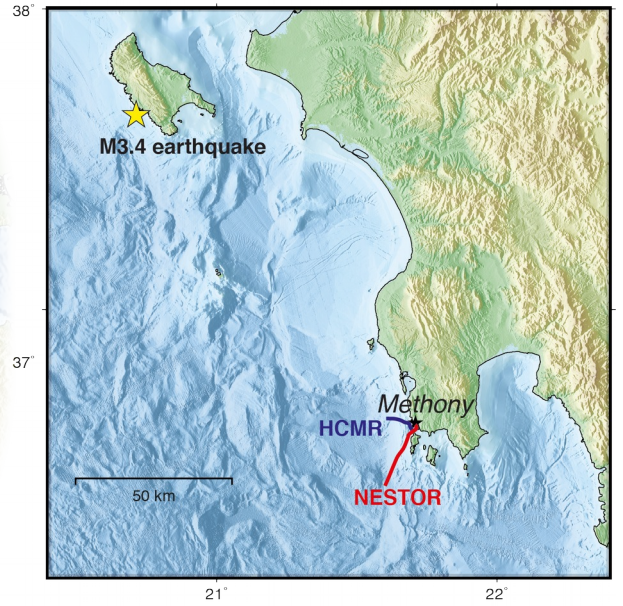
EMSO European Multidisciplinary Seafloor and Water Column Observatory

DAS experiments on 3 telecom-like cables in Toulon and SW Greece



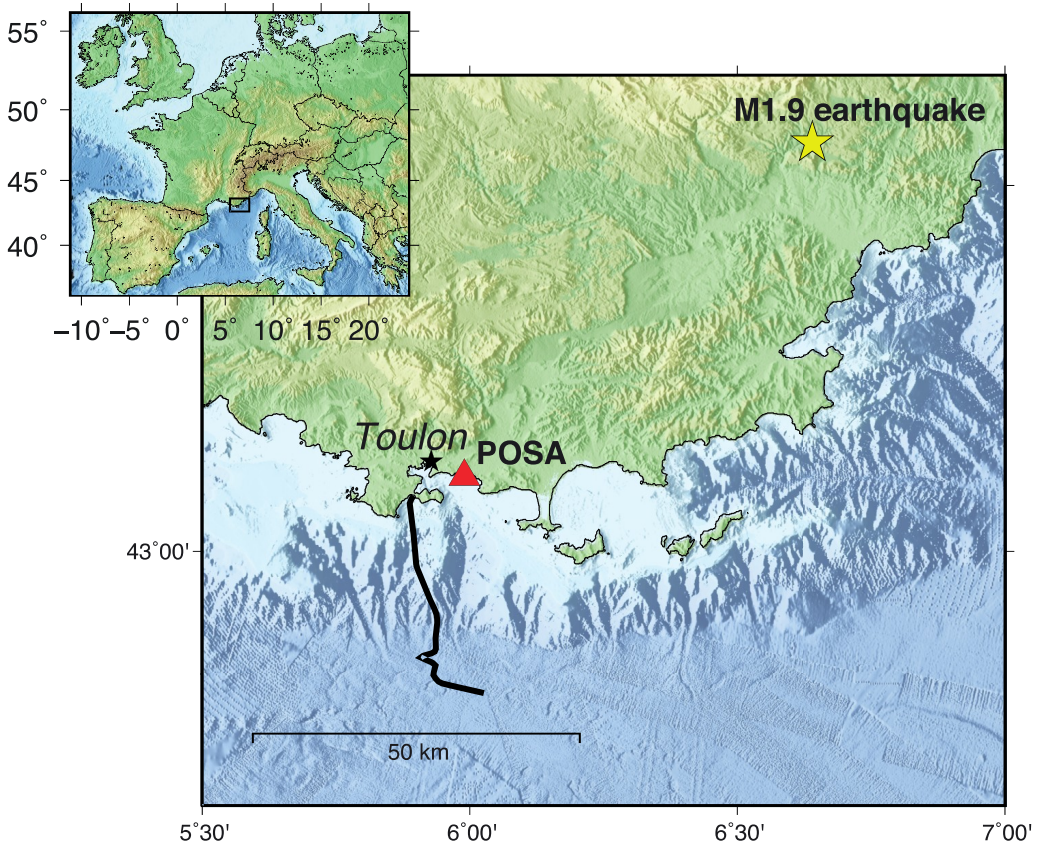
MEUST/KM3NET

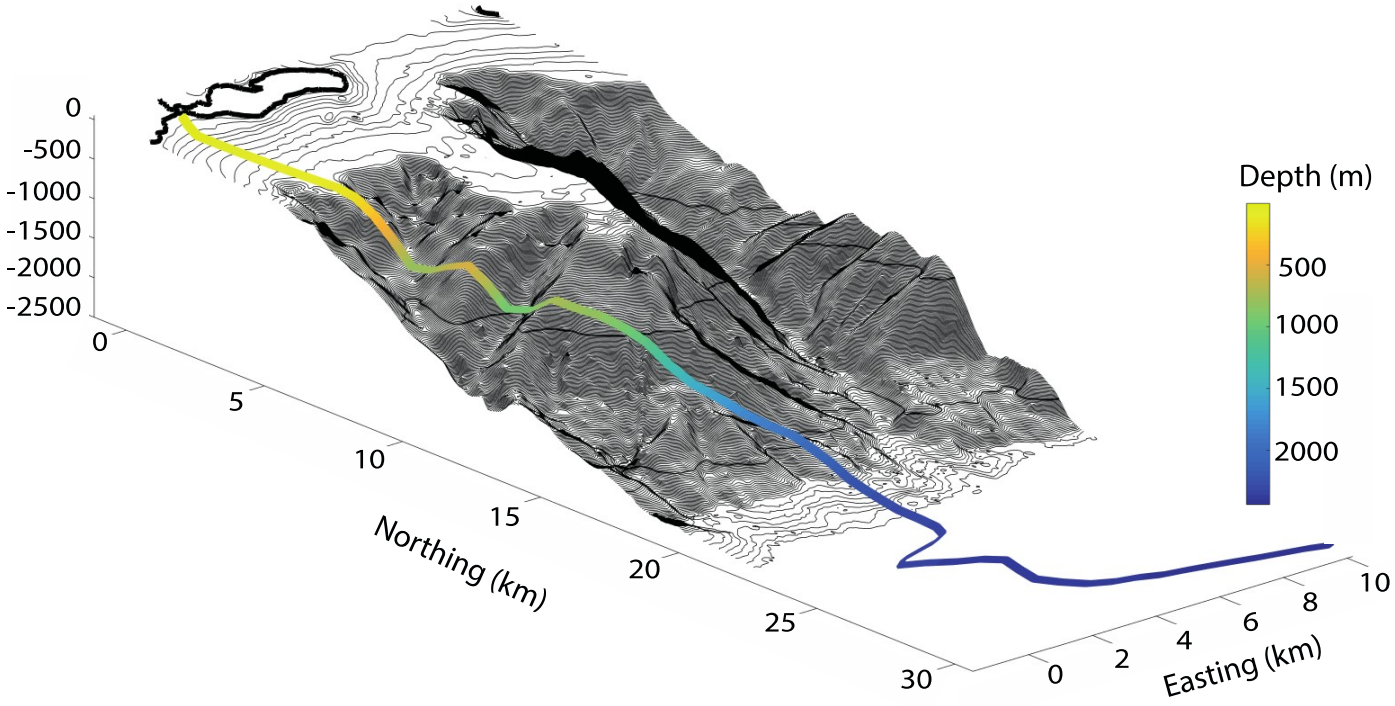


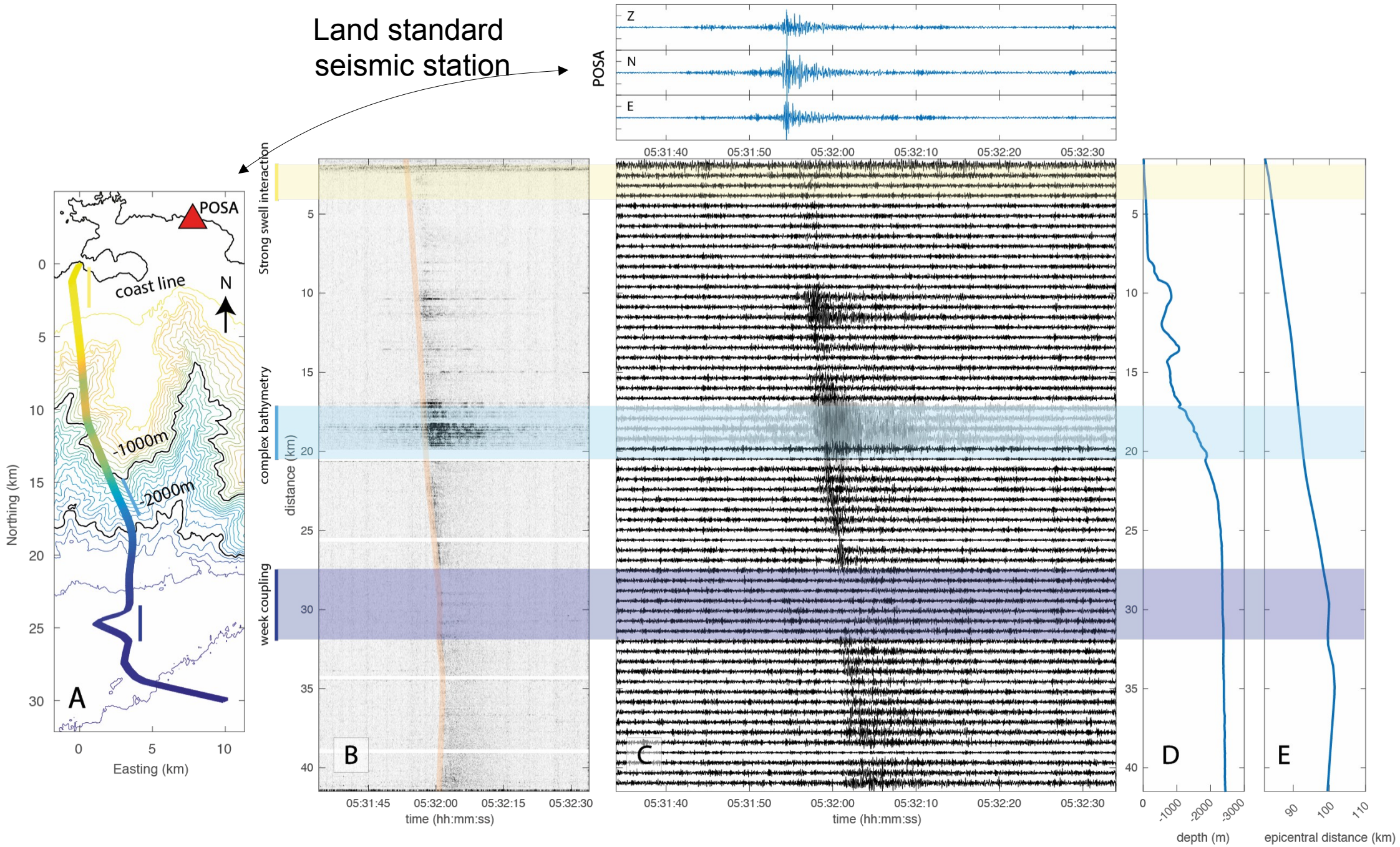


NESTOR project

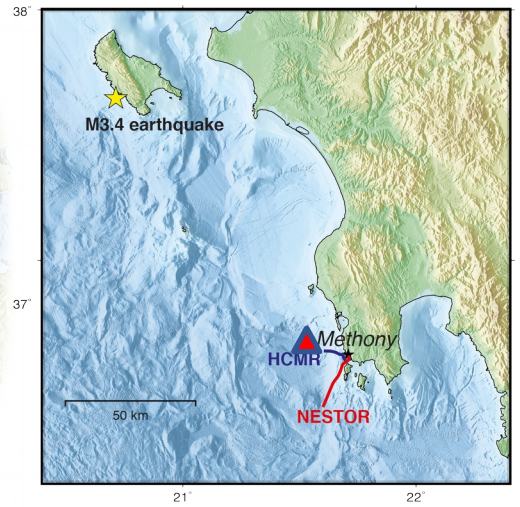
A M1.9 earthquake detected on the Toulon cable

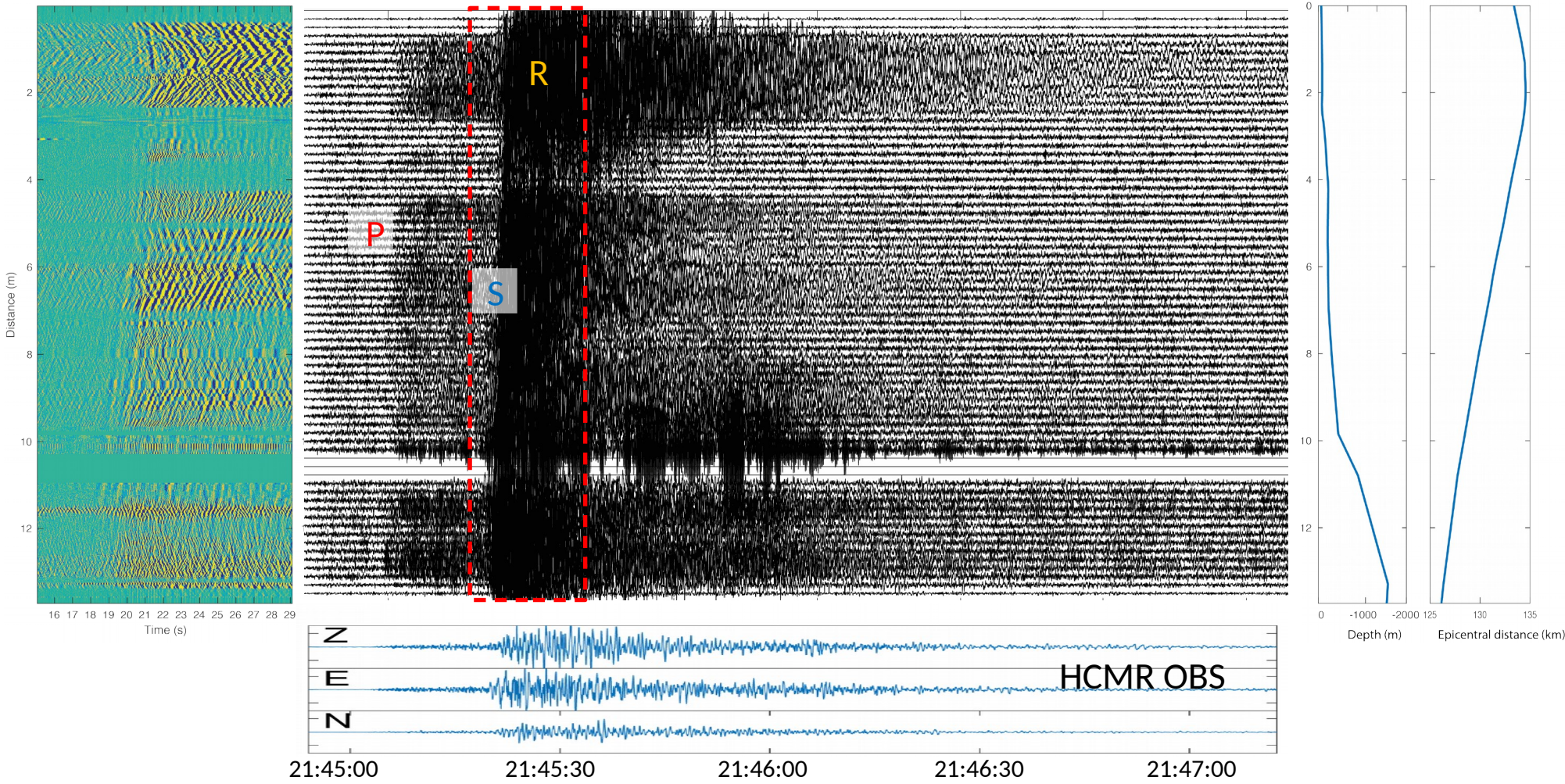





Land standard
seismic station
POSA
Z
N
E
05:31:40
05:31:50
05:32:00
05:32:10
05:32:20
05:32:30
Strong swell interaction
complex bathymetry
week coupling
distance (km)
coast line
N
-1000m
-2000m
Northing (km)
Easting (km)
A
B
C
D
E
time (hh:mm:ss)
depth (m)
epicentral distance (km)

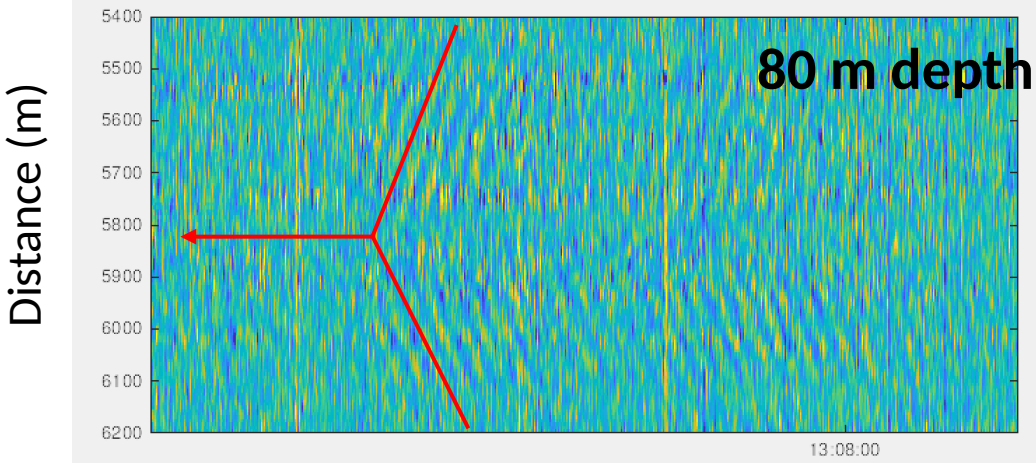
A M3.4 earthquake detected on the Greek cable

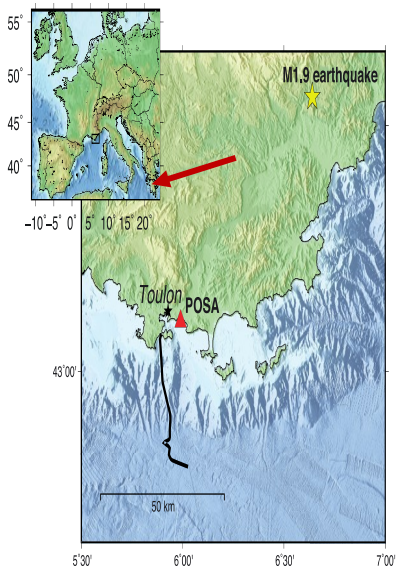


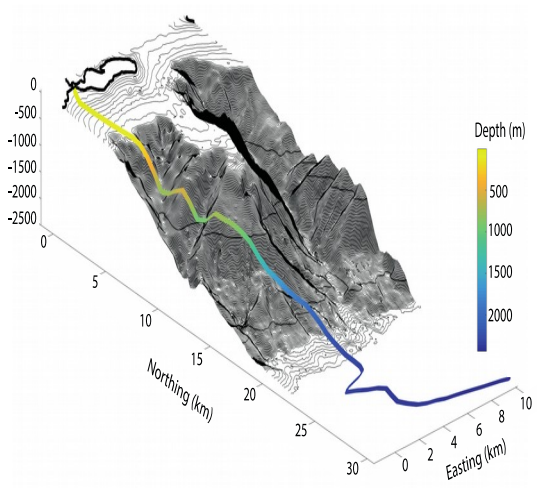


Boats

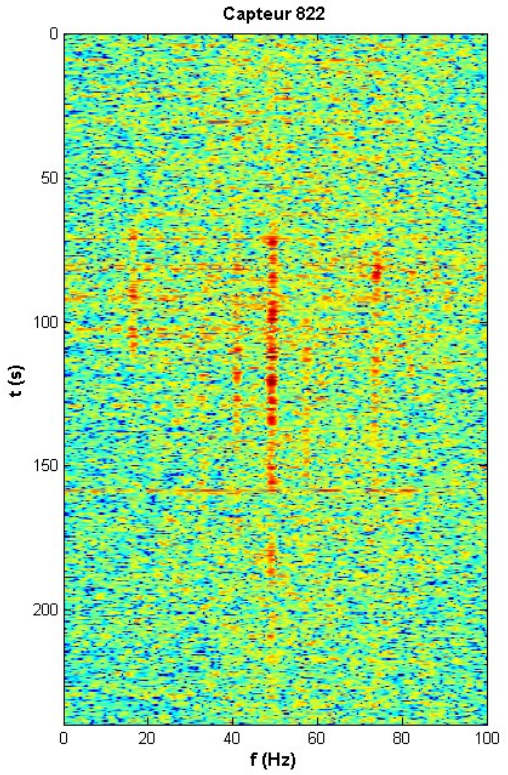
Boat trail pressure





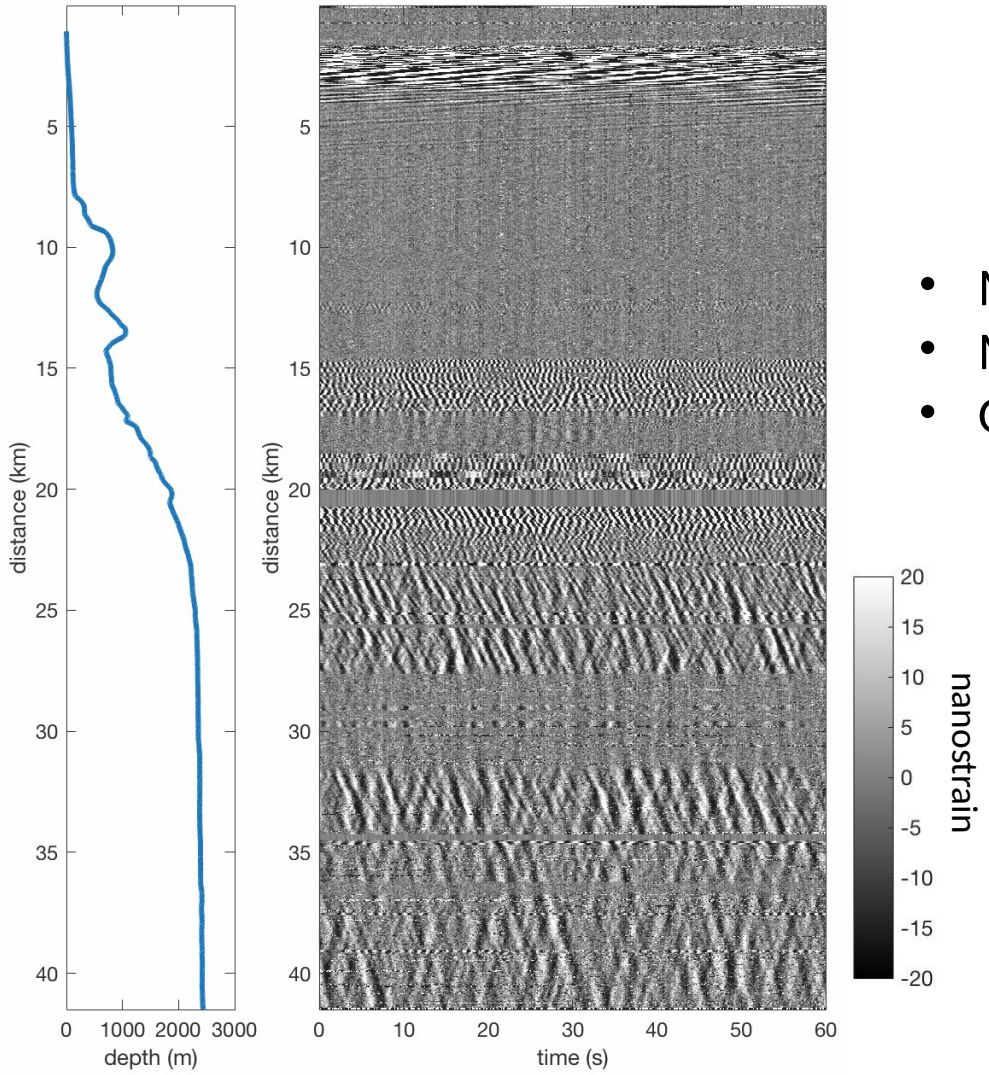


Acoustic signature with harmonics



At greater depth? Detect mammals?

Ocean solid-Earth interactions



- Monitoring the evolution of different types of waves
- Multi-scale observation (m-km) of the wave-bathymmetry interaction
- Generation of microseismic noise

General conclusion

- **Dense spatial and temporal sampling** of seismo-acoustic signals, in the oceans and along their margins
- Sense earthquakes, ocean surface gravity waves, microseismic noise, boats… more ?
- Range is limited to 40-50km on standard installations
- Upcoming: longer acquisitions (months), new seafloor and land cables (Monaco-Italy, Sophia-Valrose…)

Sladen, A., Rivet, D., Ampuero, J., De Barros, L., Hello, Y., Calbris, G., & Lamare, P. (2019, June 7). Distributed sensing of earthquakes and ocean-solid Earth interactions on seafloor telecom cables. https://doi.org/10.31223/osf.io/ekrfy under review at *Nature Communications*