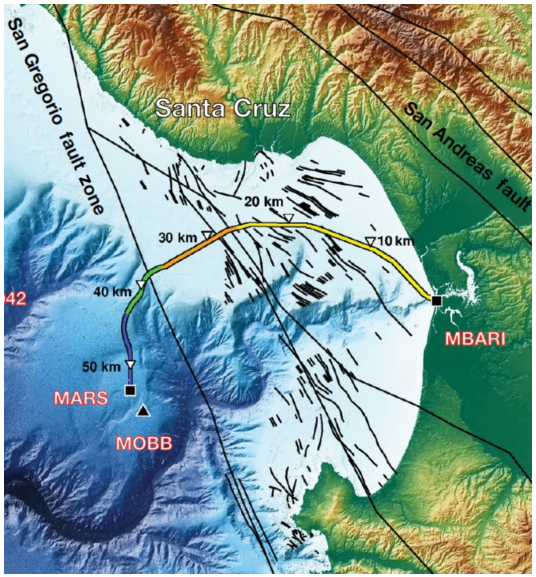


SeaFOAM:

A permanent DAS deployment in Monterey Bay, California

for monitoring and earthquake early warning

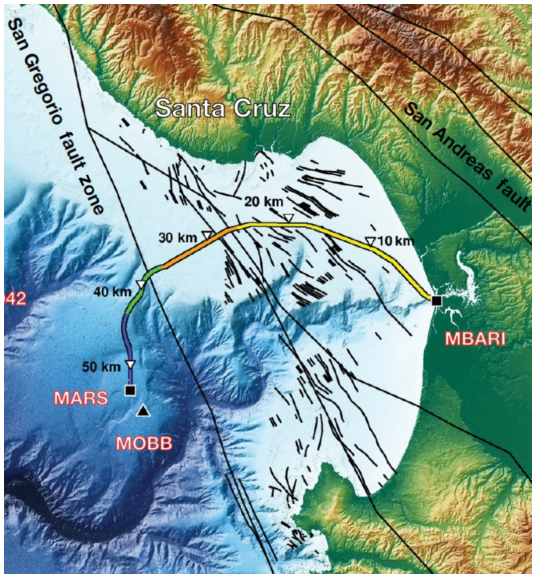
Li-Wei Chen, Yuancong Gou, Barbara Romanowicz,
Ivan Henson, Julien Marty, Doug Neuhauser, Brian Pardini, Taka'aki Taira, Stephen Thompson, Junli Zhang, Stephane Zuzlewski
and **Richard Allen**

NSF

MBARI

Berkeley Sound science, serving society
Seismology Lab

Cal OES
GOVERNOR'S OFFICE OF EMERGENCY SERVICES



SeaFOAM:

A permanent DAS deployment in Monterey Bay, California

for monitoring and earthquake early warning

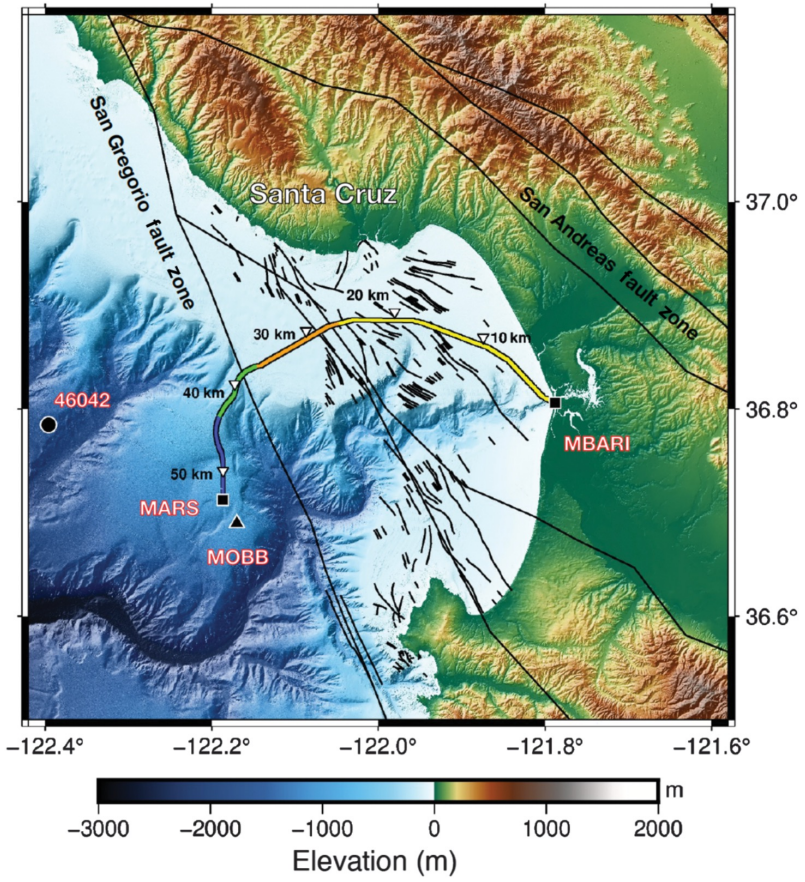
Preface…

SeaFOAM will be a **permanent seafloor DAS observatory** with **open data at NCEDC.org** (Northern California Earthquake Data Center)

Open question:
What sample rate and channel spacing should we record at?

SeaFOAM

Location and motivation



MARS Cable

- 52 km across Monterey Bay
- Operated by MBARI for research
- Previously operated MOBB broadband OBS (2009-2014)

Targets

- ***Extends earthquake monitoring capability offshore***
- Crosses the poorly understood San Gregorio Fault (M7+ after AD 1270) and many other smaller faults
- Microseismic processes
- Physical oceanography
- Marine mammals
- …others?

MBARI

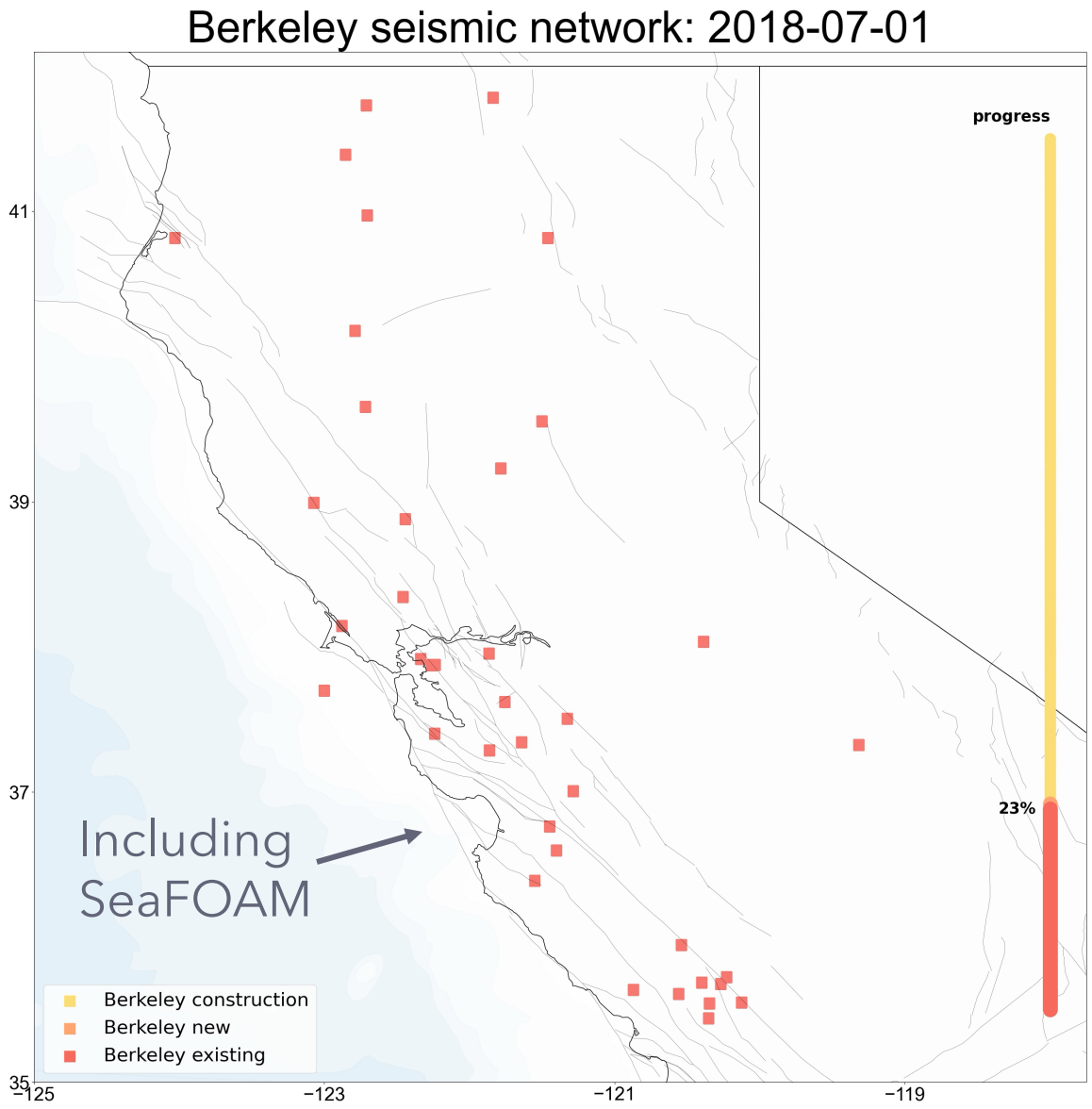
Growth of

Dual-use geophysical networks

Real-time hazard information

and

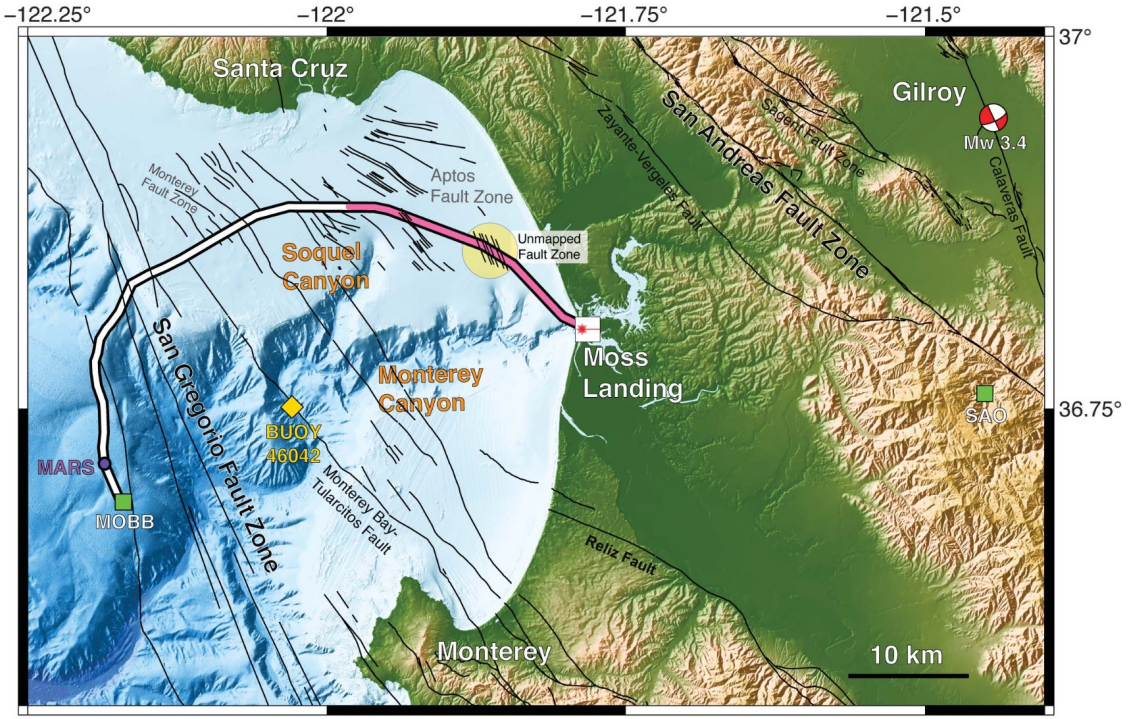
scientific discovery

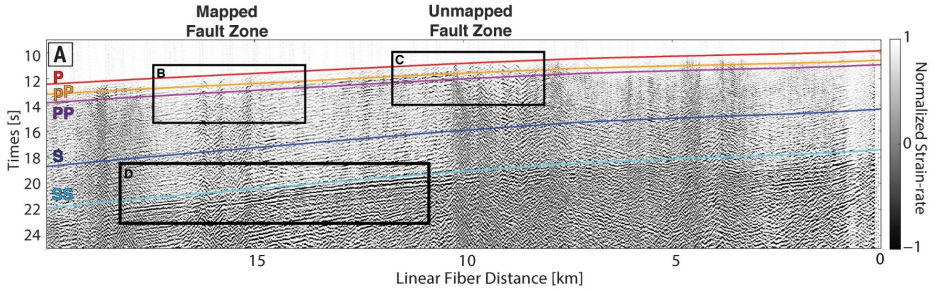


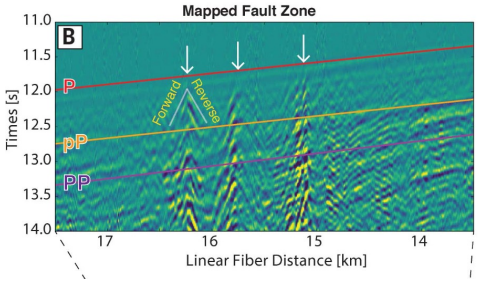
MARS cable

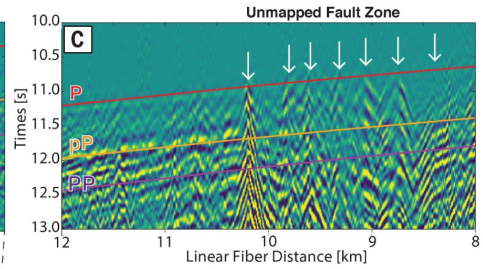
Lindsey et. al, 2019

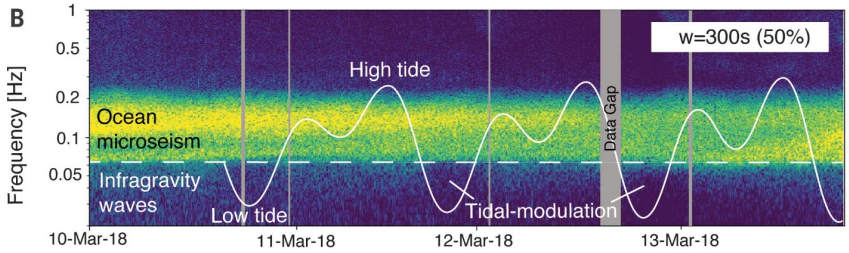
- First 20 km (pink)
- 4 days of data
- Identified faults and hydrodynamic signals

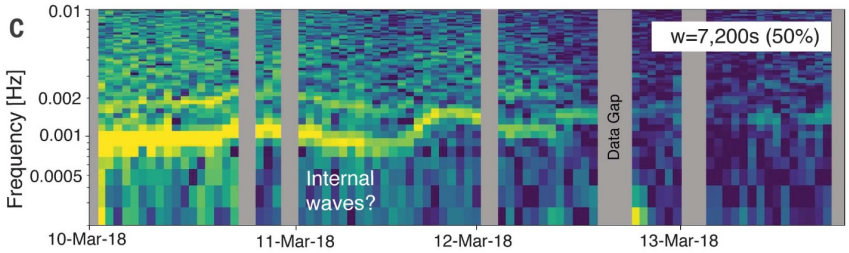






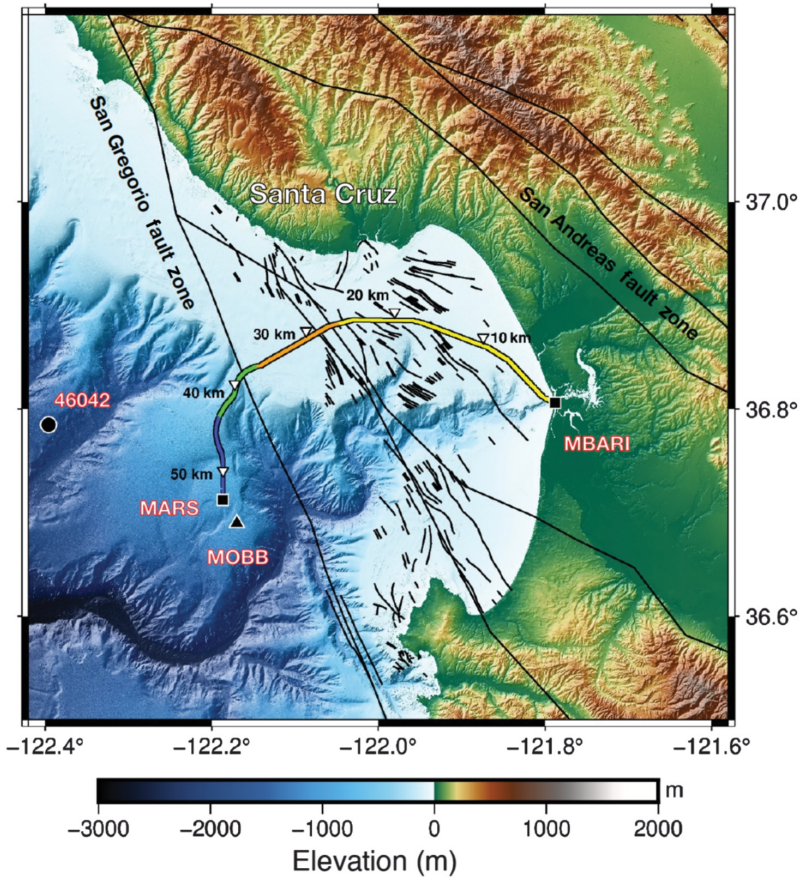






SeaFOAM

Motivation



Initially, 1-year continuous deployment funded by NSF

- Microseismicity
- Regional and teleseismic earthquakes
- Ocean currents and waves
- Ambient seismic noise
- Marine mammals
- ***Plus, real-time monitoring***

Now, *permanent* deployment funded by CalOES

- Enhance California's earthquake early warning capability
- *While continuing to study all of the above*

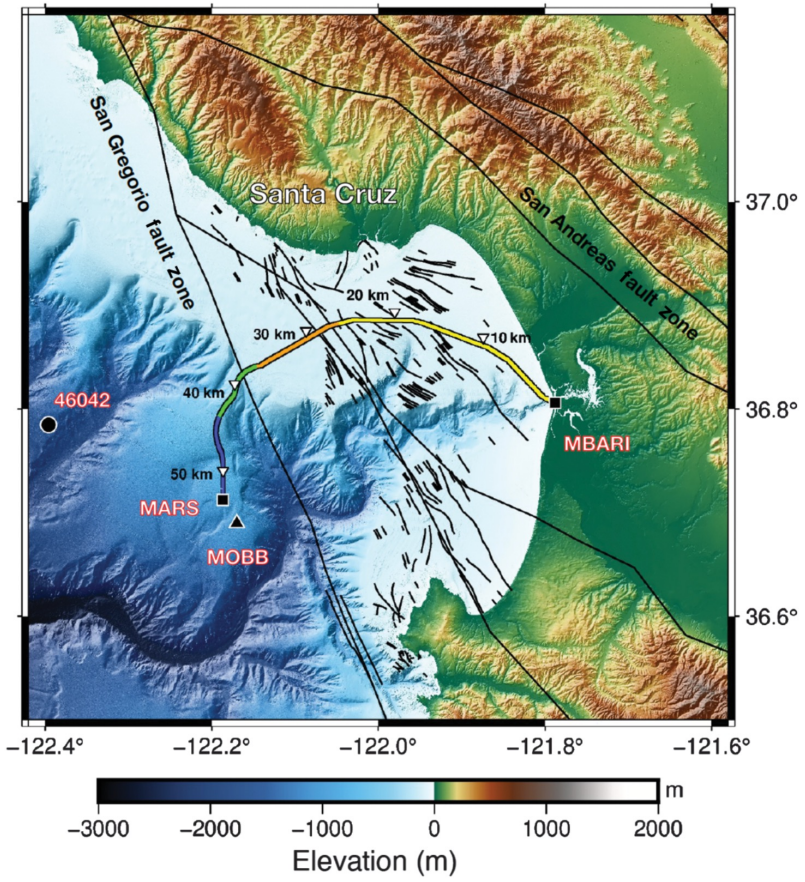
NSF

Cal OES
GOVERNOR'S OFFICE
OF EMERGENCY SERVICES

MBARI

SeaFOAM

Spec sheet



Recording parameters

- DAS: Optasense QuantX
- 52 km cable, mostly buried
- 200 samples per sec
- 5.1 m channel spacing
- 20.4 m gauge length
- 10,245 channels
- 360 GB per day, 130Tb per year
- Start date: July 21, 2022

Currently archived on RAID disk

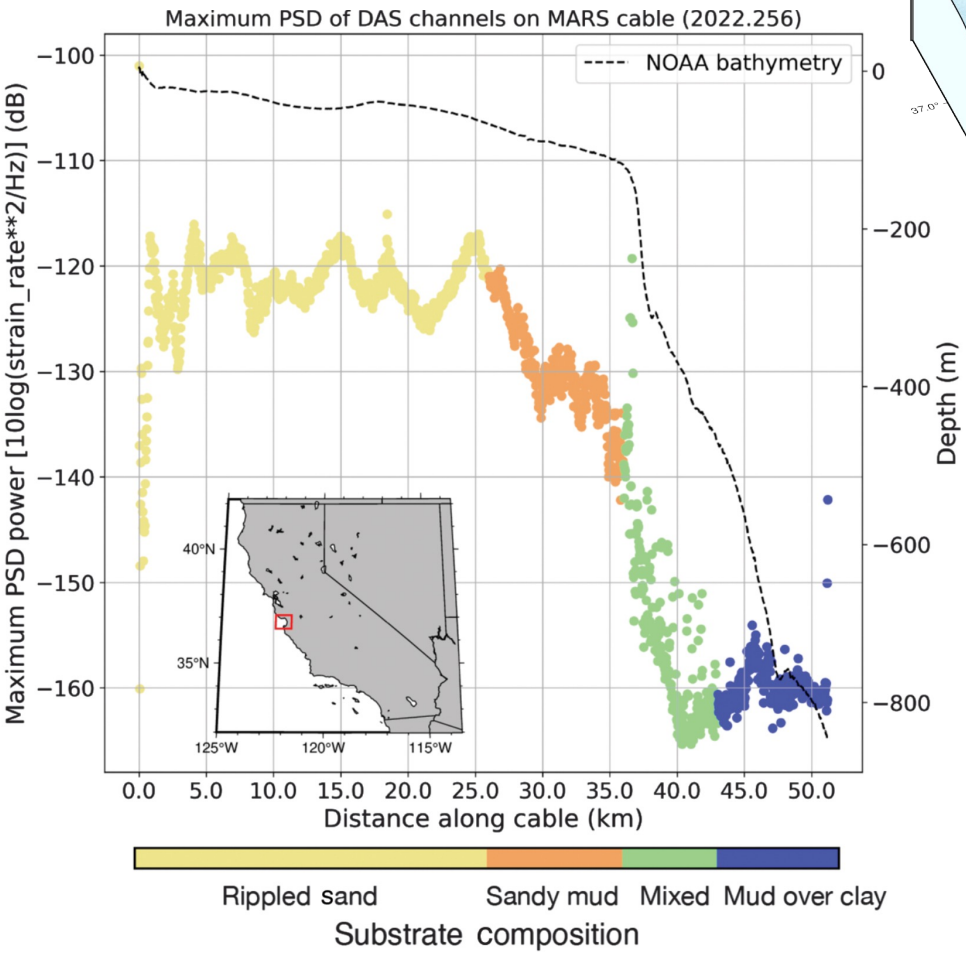
Decimated streaming parameters

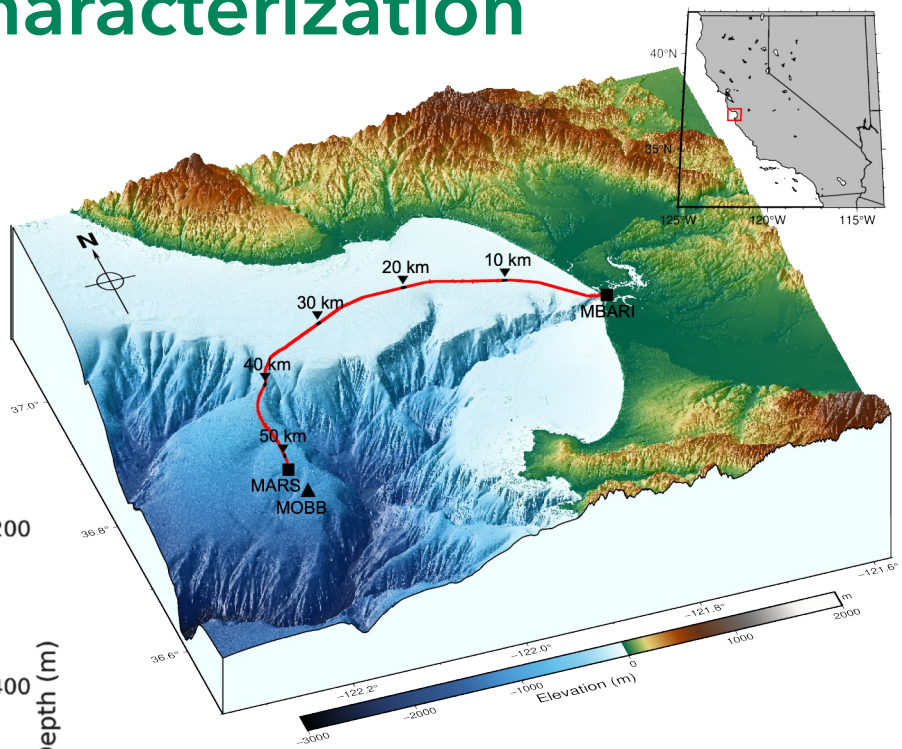
- 100 samples per sec
- 200 m channel spacing
- 20.4 m gauge length
- 256 channels

Streaming into EPIC EEW algorithm

SeaFOAM

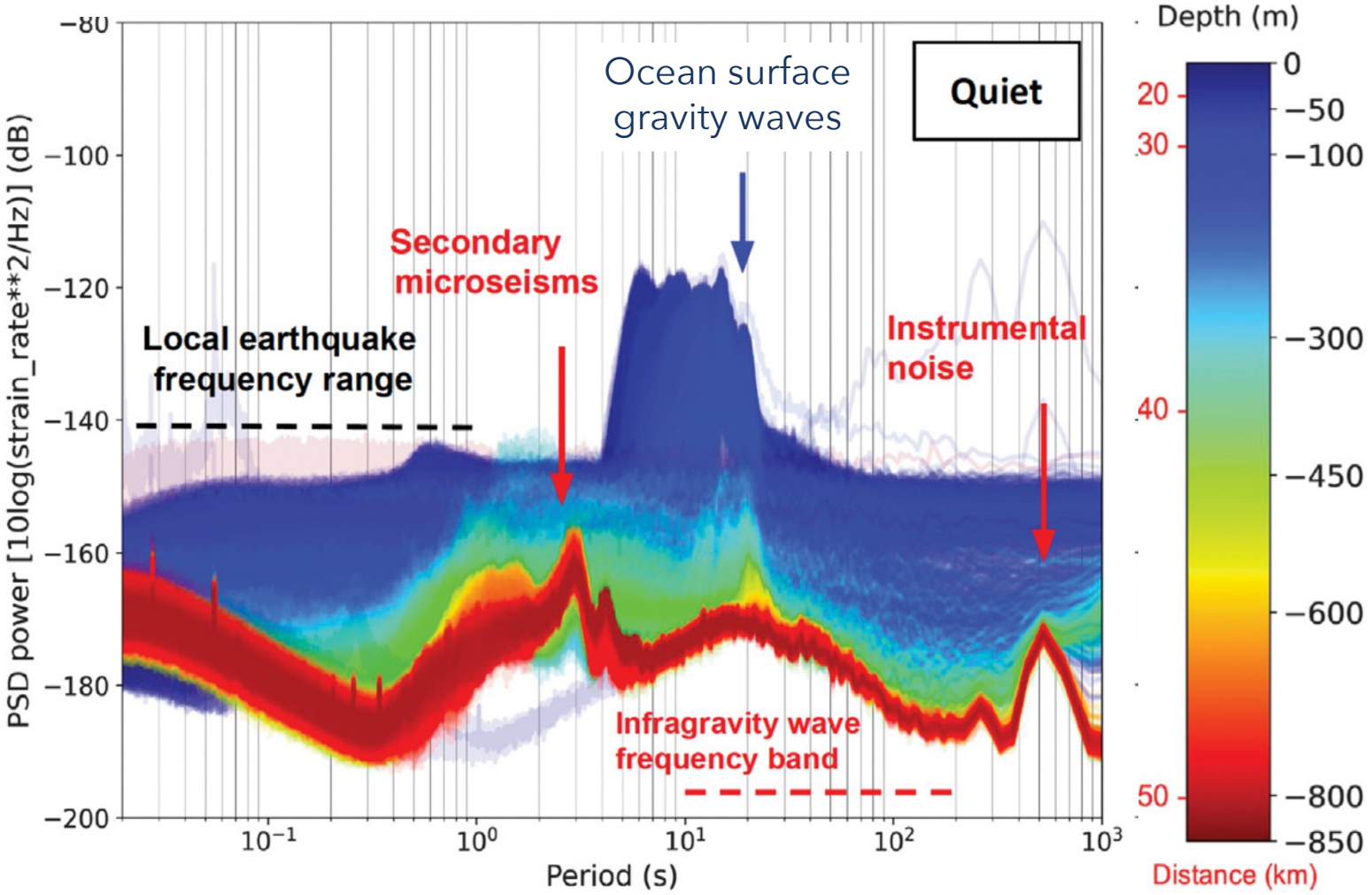
Cable and sea floor characterization





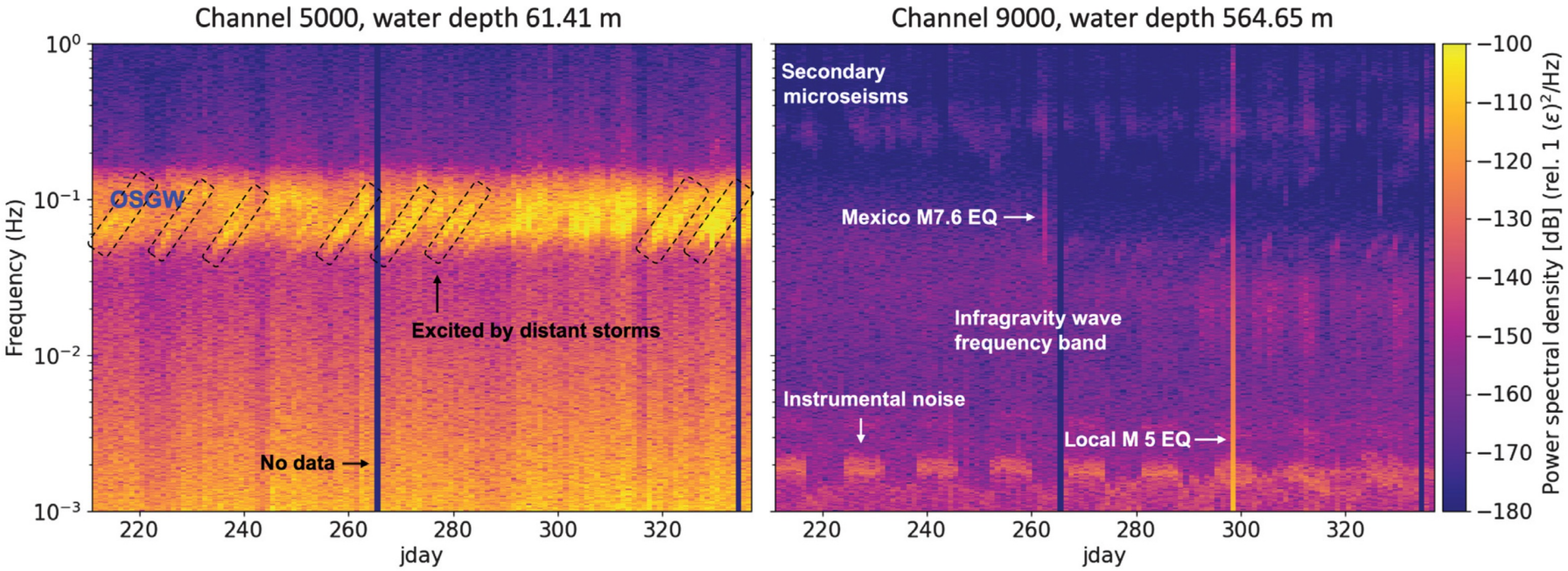
SeaFOAM

Noise *(i.e. signal)* **characteristics**



SeaFOAM

Noise *(i.e. signal)* **characteristics**



Shallow water

- Dominated by ocean surface gravity waves around 10 sec

Deep water - SOFAR channel

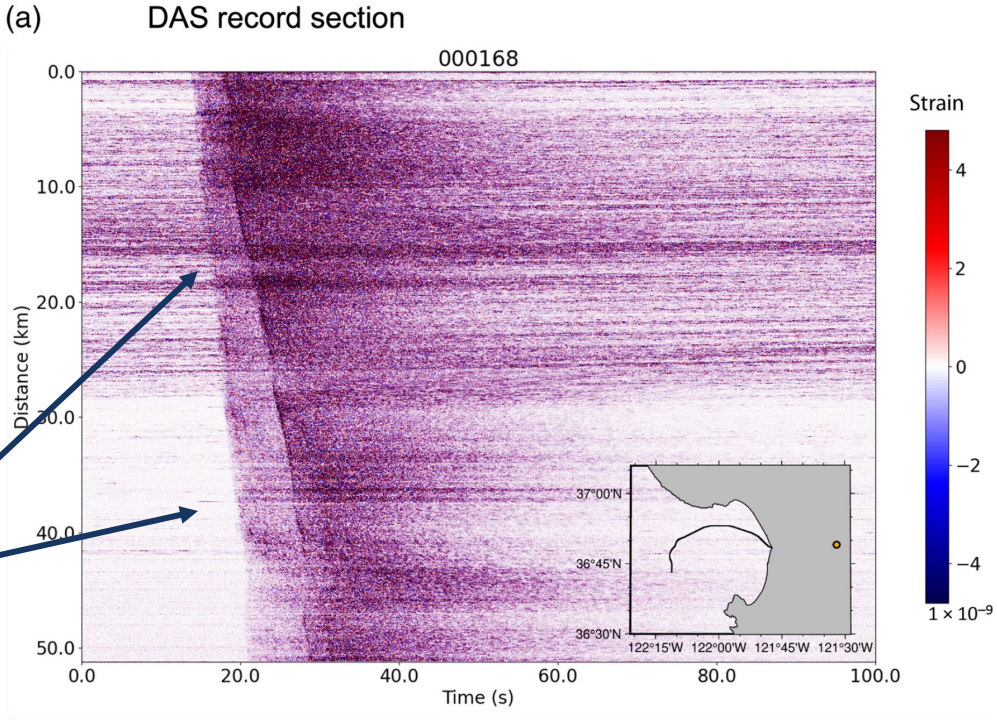
- Secondary microseisms
- Infragravity waves
- Earthquakes near and far

SeaFOAM

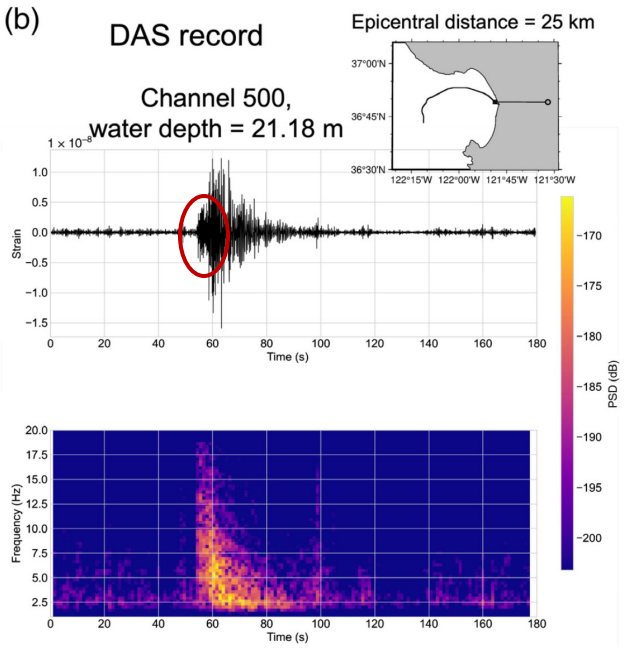
Local earthquake

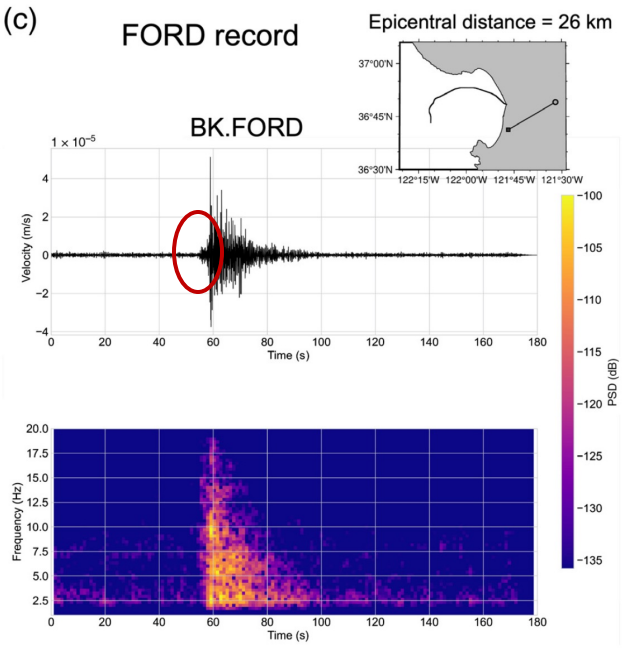
M2.7 on
San Andreas Fault

Visible in
both shallow
and deep



Seismic arrivals are
more complex on
DAS



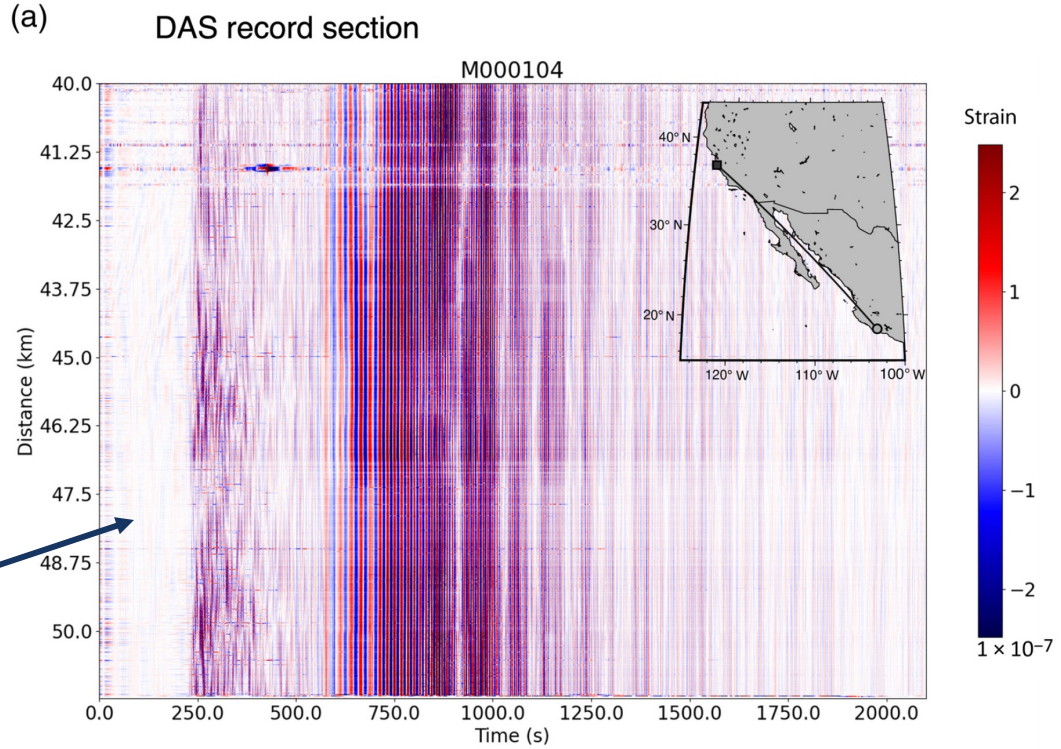


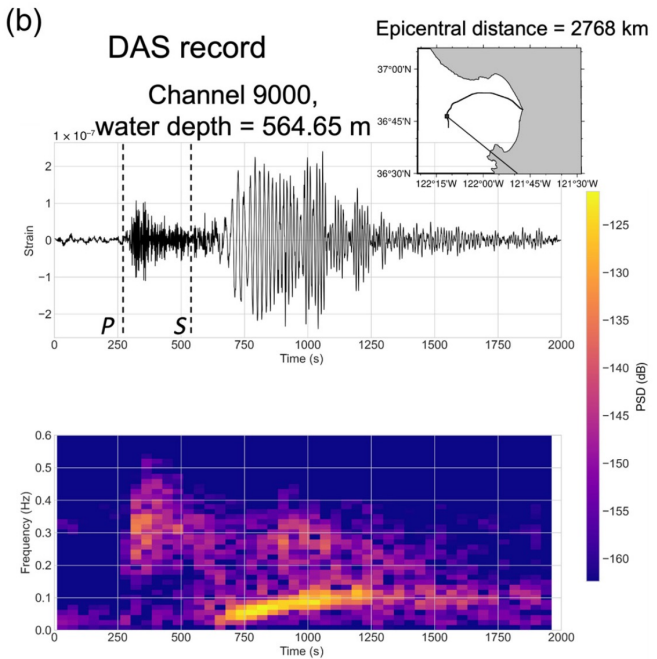
SeaFOAM

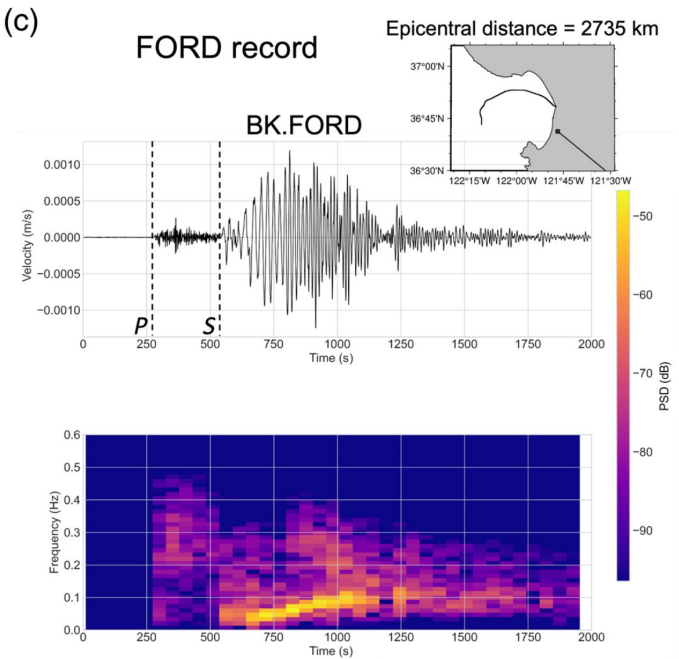
Teleseismic earthquakes

M7.6 Mexico
Sep 19, 2022

Visible in deep only



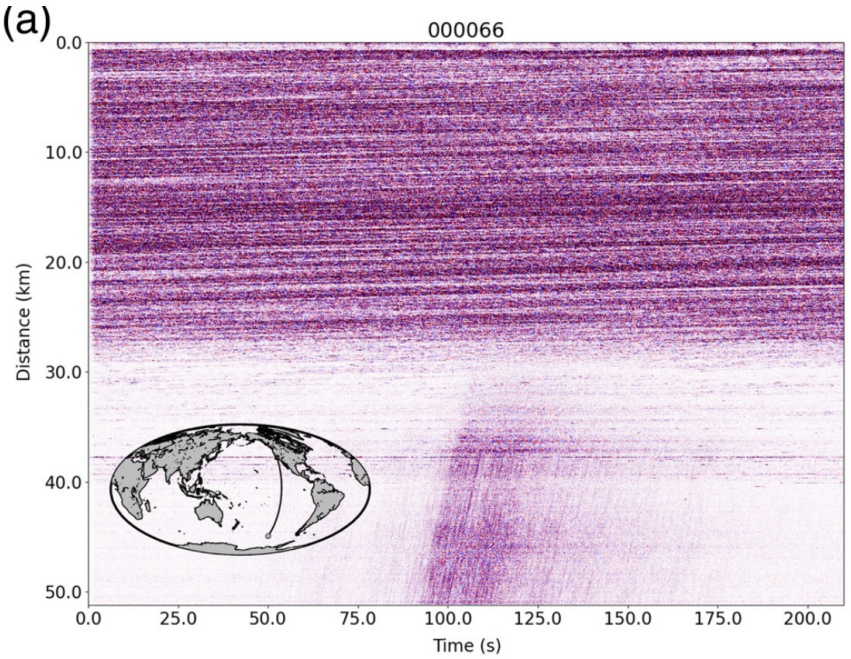


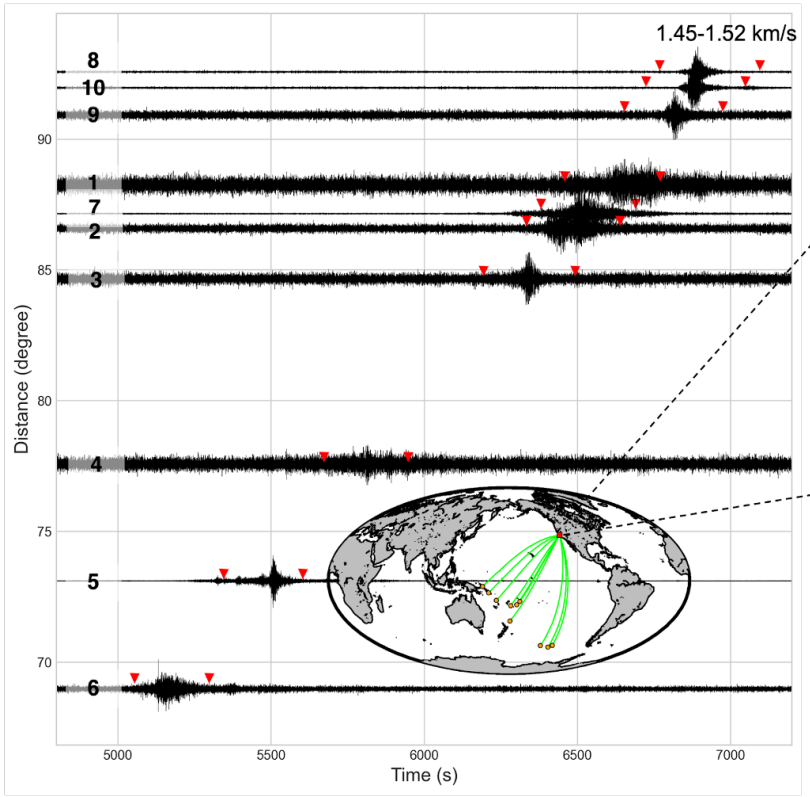


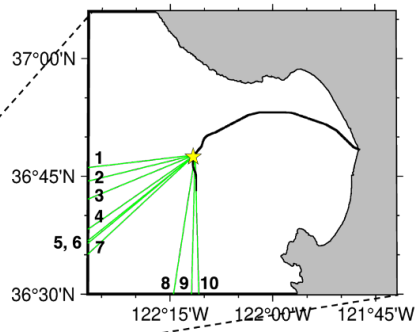
SeaFOAM

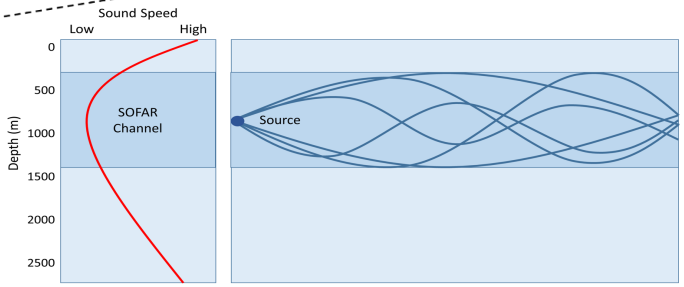
T-wave from teleseismic

Cable extends into SOFAR channel



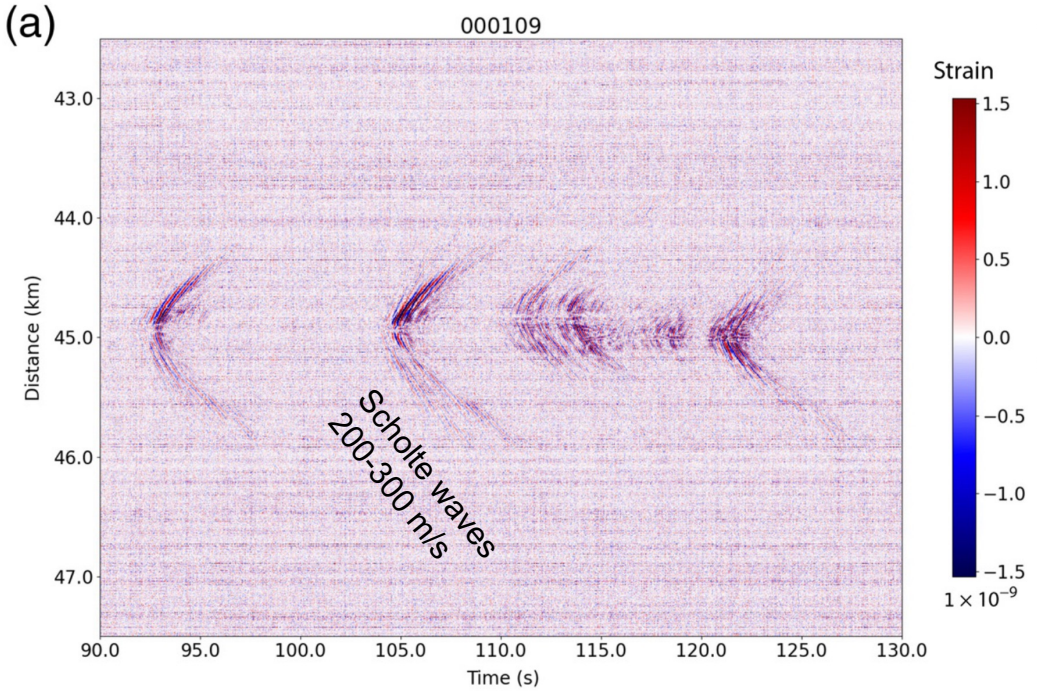


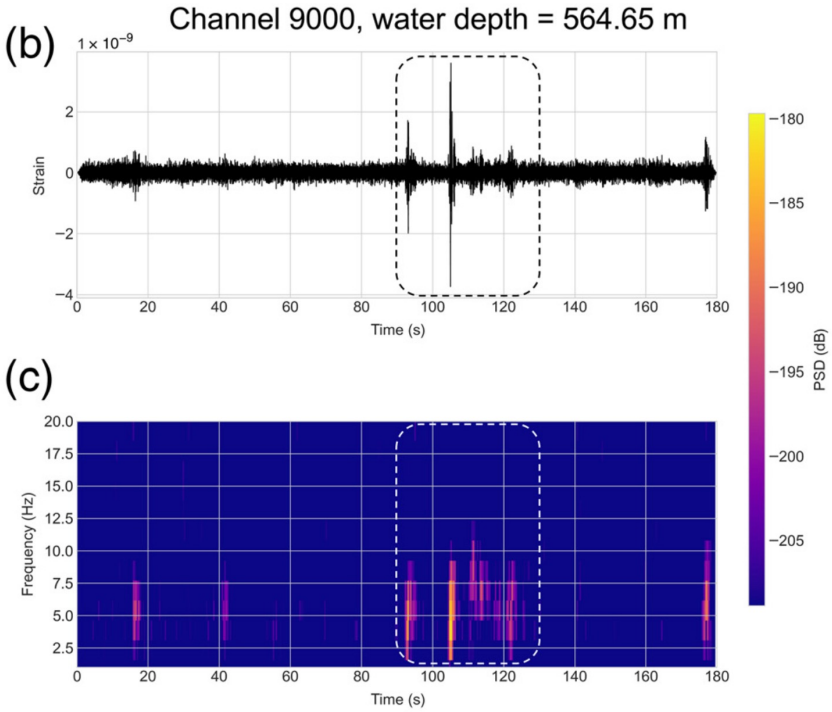


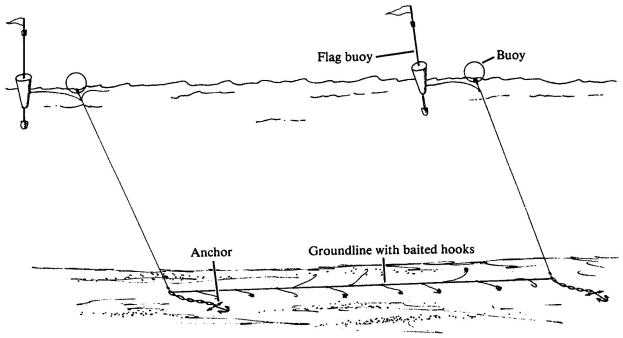


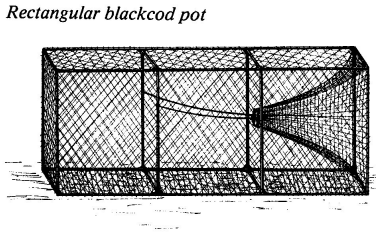
SeaFOAM

Seafloor impacts?









Traps?
Pots?
Longlines?
Trawling?

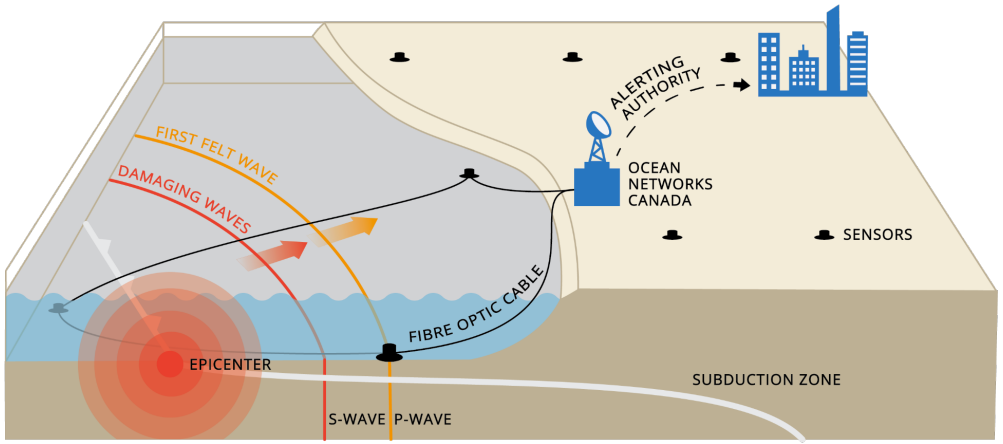
SeaFOAM

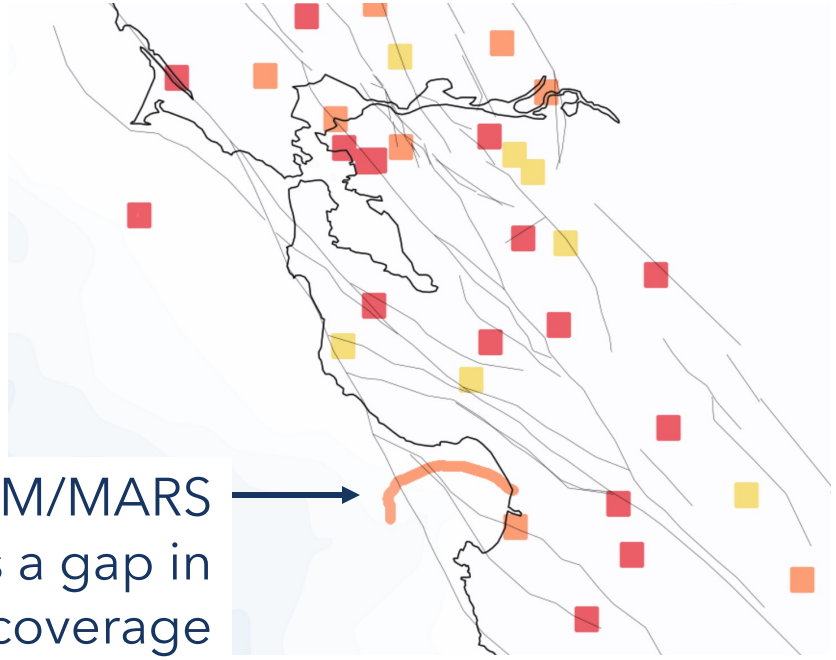
Enhancing earthquake early warning

1. Triggering on seismic arrivals

2. Locating the earthquake

3. Magnitude estimation





SeaFOAM/MARS fills a gap in coverage

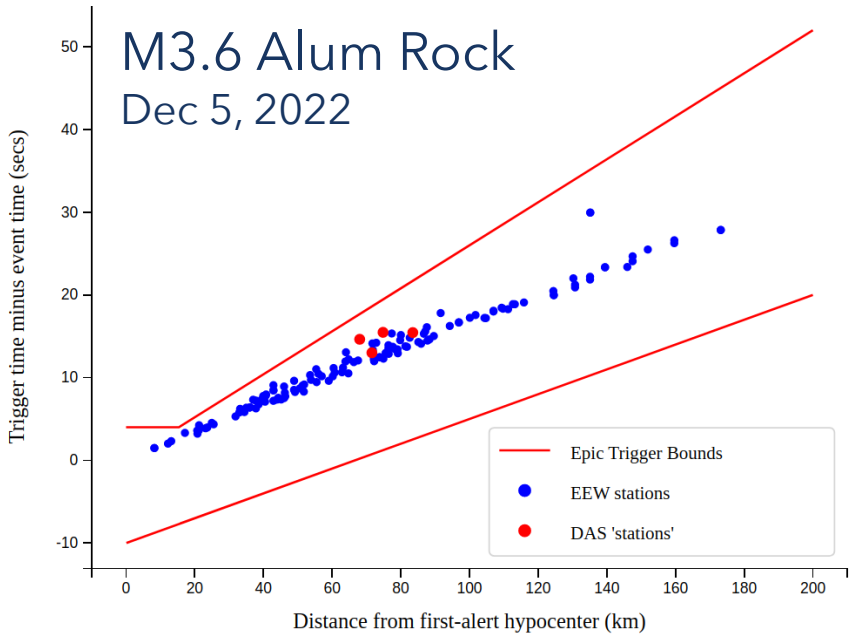
SeaFOAM

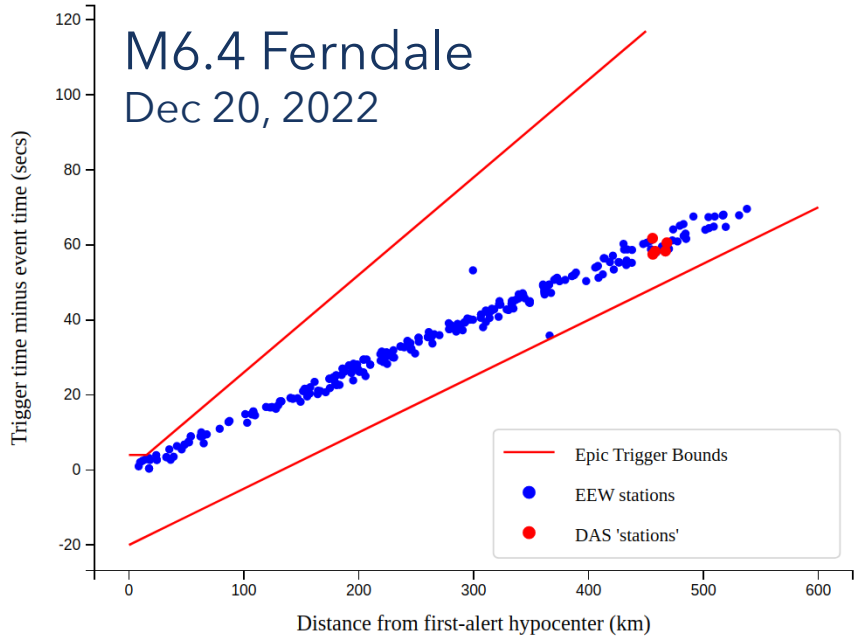
Enhancing earthquake early warning

DAS channels can stream directly into existing algorithms like EPIC

1. Triggering on seismic arrivals

2. Locating the earthquake





Ivan Henson, Berkeley

SeaFOAM

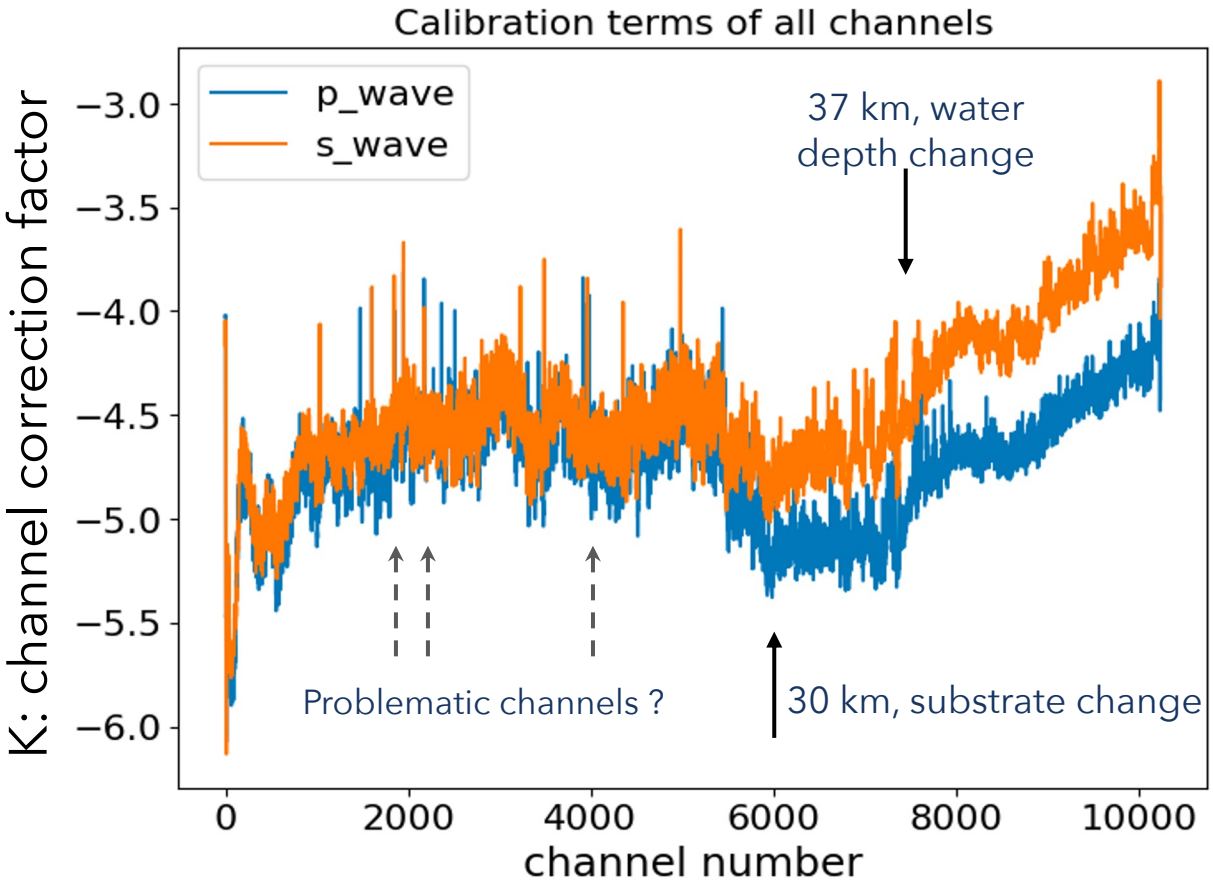
Enhancing earthquake early warning

DAS channels can stream directly into existing algorithms like EPIC

3. Magnitude estimation

$$\log_{10} E_i^P = 0.437M - 1.269 \log_{10} D_i + K_{i\ (array)}^P,$$
$$\log_{10} E_i^S = 0.690M - 1.588 \log_{10} D_i + K_{i\ (array)}^S.$$

Yin et al, 2023



Yuancong Gou, Berkeley

SeaFOAM

Enhancing earthquake early warning

DAS channels can stream directly into existing algorithms like EPIC

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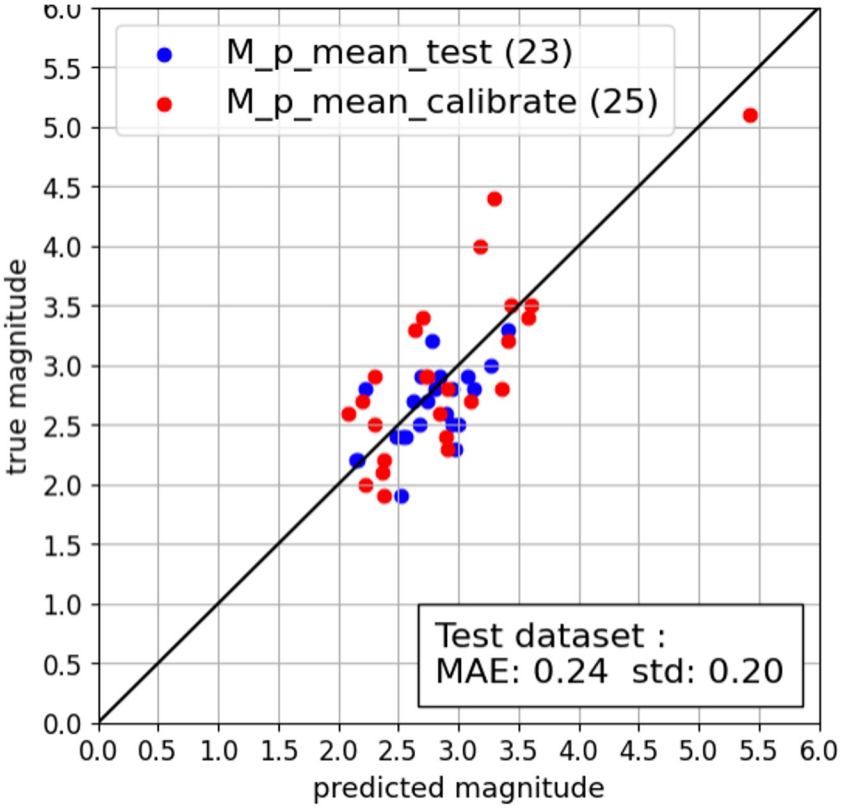
$$\log_{10} E_i^S = 0.690M - 1.588 \log_{10} D_i + K_{i\ (array)}^S.$$

Yin et al, 2023

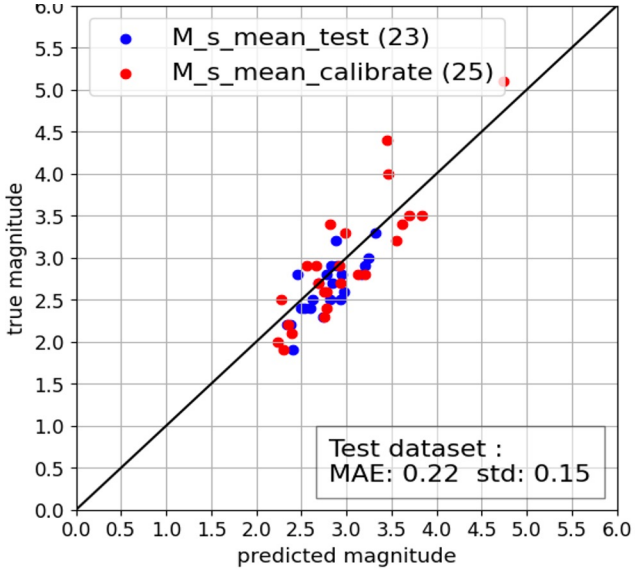
P-wave mag estimation



0.2 mean absolute magnitude error

similar to onshore instrument

S-wave mag estimation



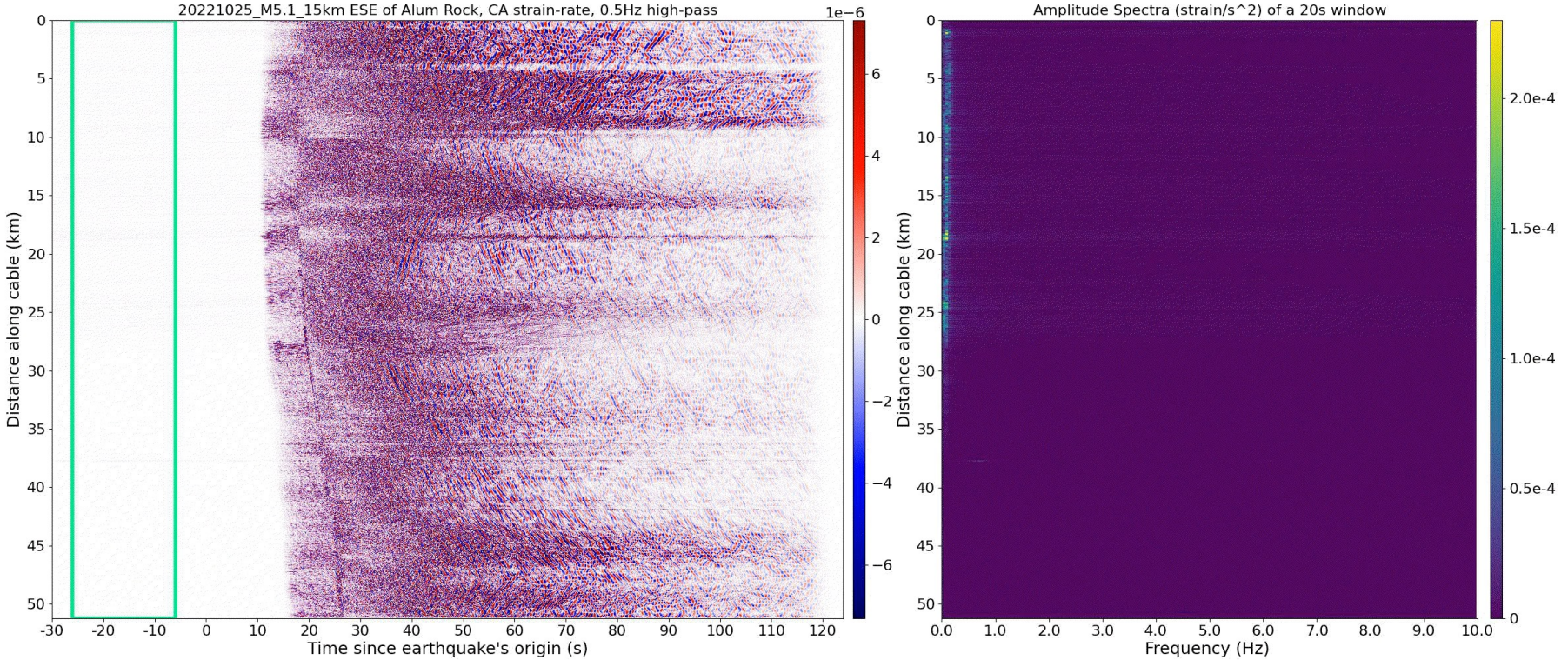
Yuancong Gou, Berkeley

SeaFOAM

Enhancing earthquake early warning

But, we need to utilize the full array capabilities of DAS…

M5.1 Alum Rock earthquake Oct 25, 2022



Optimized detection triggers using short cable sections to maximize warning times

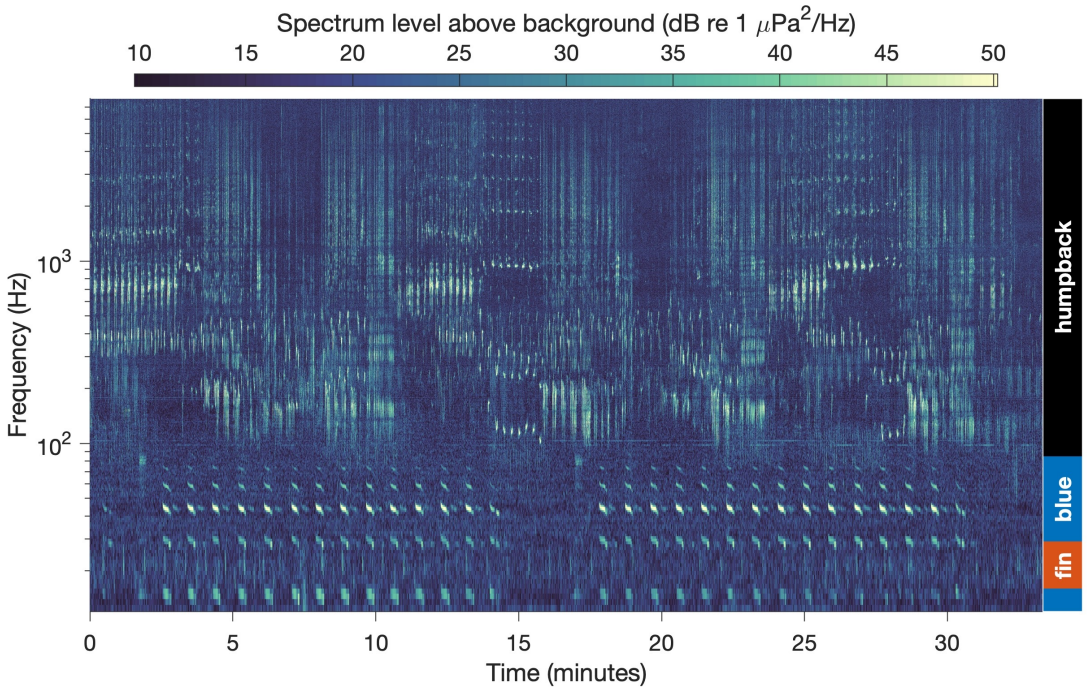
Yuancong Gou, Berkeley

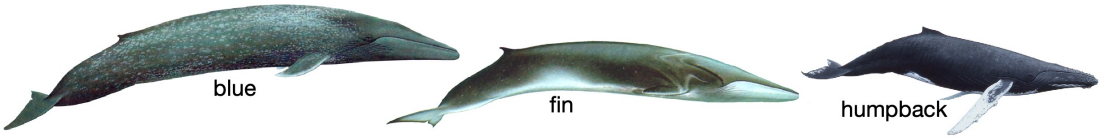
SeaFOAM

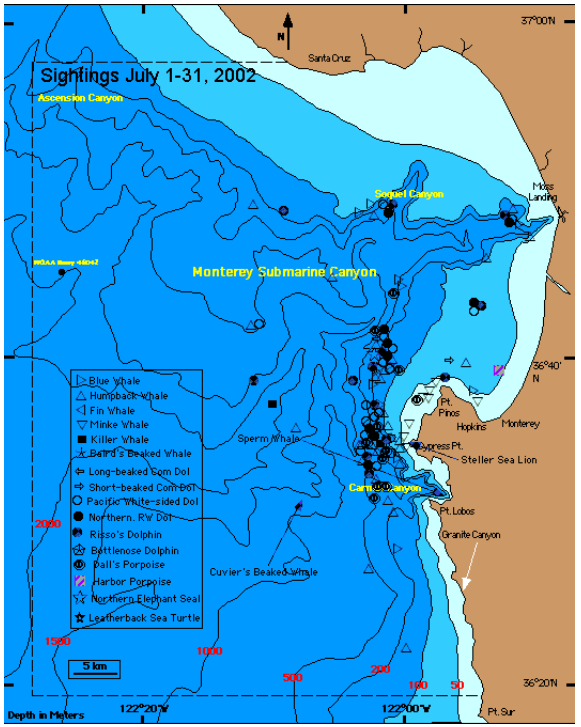
Whale monitoring

Continuous recording at
200 samples per second…

Should be able to monitor
Fin and Blue whales



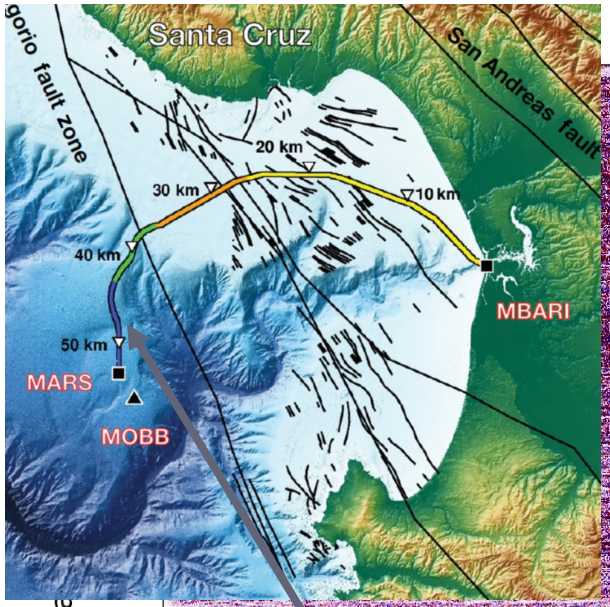


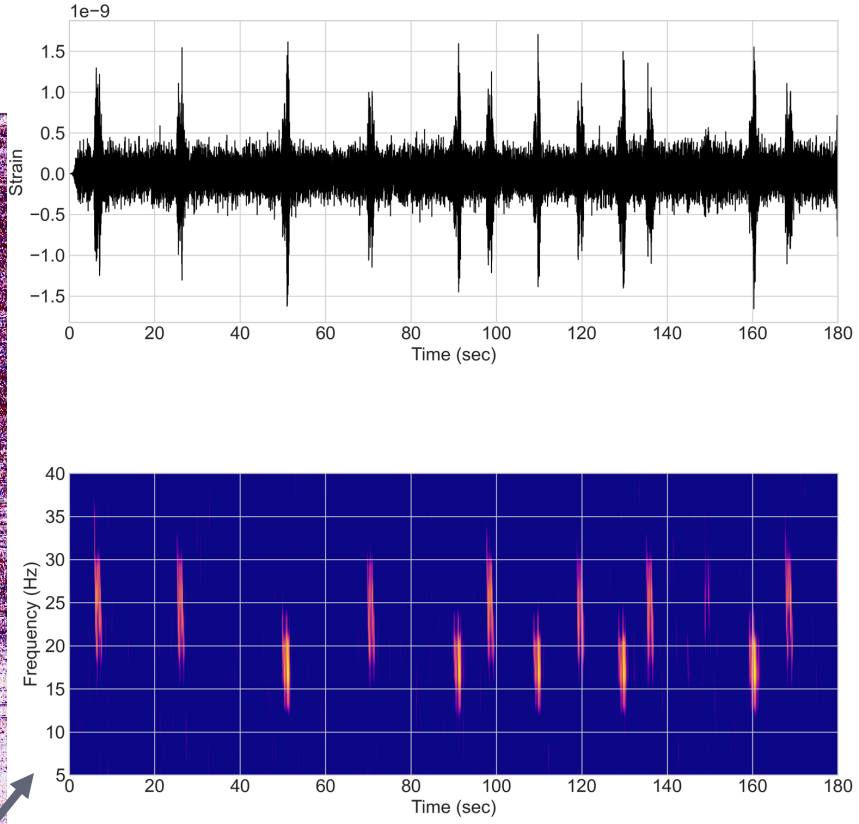


John Ryan, MBARI

SeaFOAM

Fin whale calls



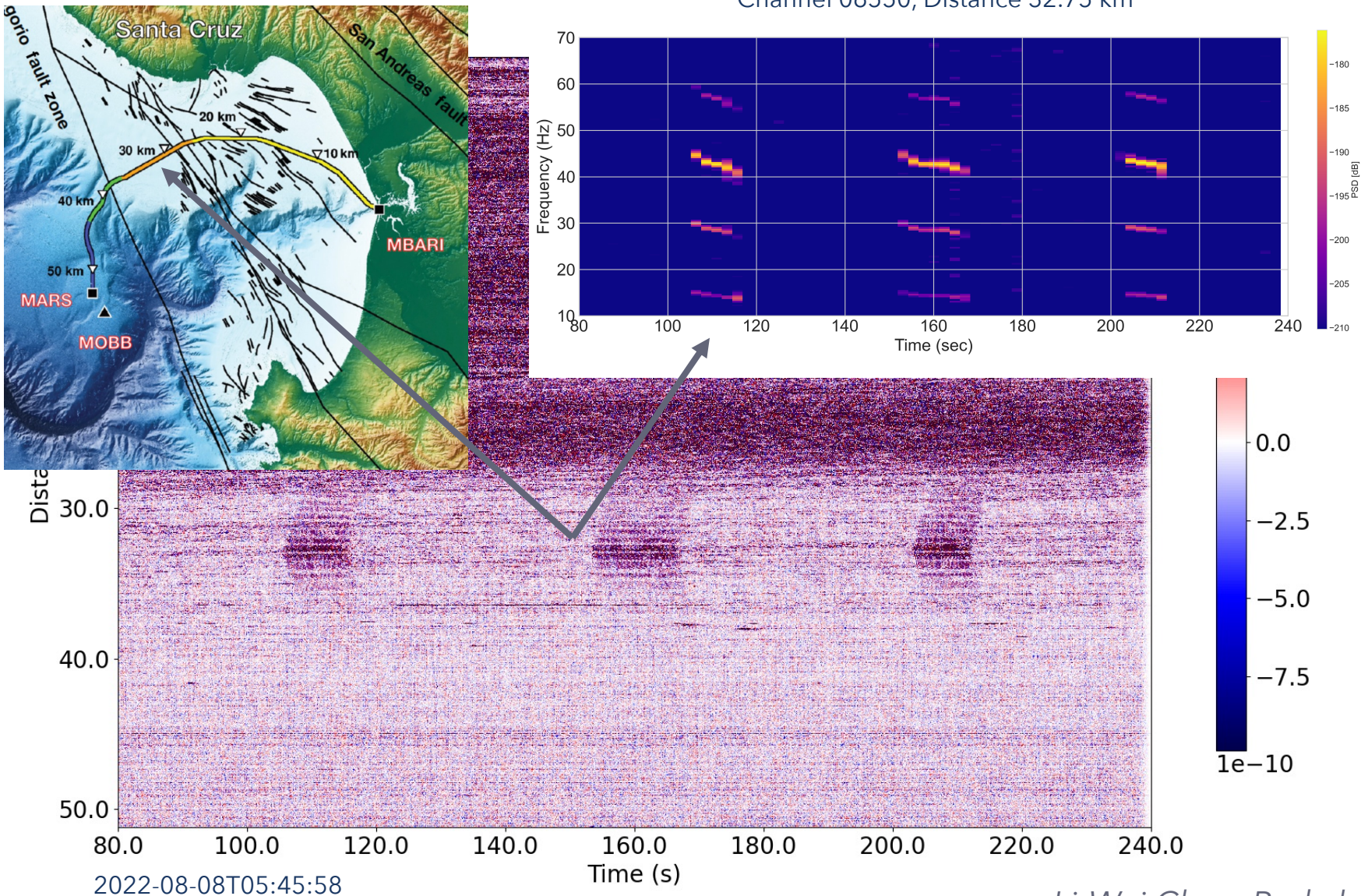


2022-09-18T03:42:16

Li-Wei Chen, Berkeley

SeaFOAM

Blue whale B calls



Li-Wei Chen, Berkeley

More details…

Seismological Research Letters

SeaFOAM: A ~~Year-Long~~ Permanent DAS Deployment in Monterey Bay, California

Barbara Romanowicz[*1], Richard Allen[1], Knute Brekke[2], Li-Wei Chen[1], Yuancong Gou[1], Ivan Henson[1], Julien Marty[1], Doug Neuhauser[1], Brian Pardini[1], Taka'aki Taira[1], Stephen Thompson[1], Junli Zhang[1], and Stephane Zuzlewski[1]

Abstract

Distributed acoustic sensing (DAS) is being explored in a variety of environments as a promising technology for the recording of seismic signals in dense array configurations. There is a particular interest for deploying DAS arrays on the ocean floor, presenting formidable challenges for conventional seismology. Taking advantage of the availability of a dark fiber on the Monterey Bay Accelerated Research System (MARS) 52 km offshore cable at Monterey Bay, California, in July 2022, we installed a DAS interrogator at the shore end of the cable with the intention of acquiring continuous data for a period of one year. Here, we describe the experiment and present examples of observations over the first six months of the deployment.

Is the SeaFOAM data useful to you?

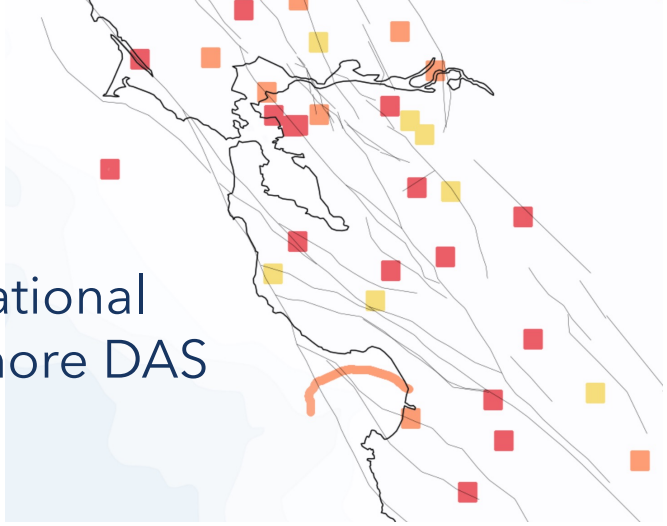
May only collect ***down-sampled data*** starting July 2023

If you see value in collecting and archiving high sample rate data, *please let us know!*

Richard Allen – rallen@berkeley.edu

SeaFOAM

Summary



We are extending Berkeley's observational monitoring networks to include offshore DAS

SeaFOAM is

- collecting data from MBARI's MARS cable across Monterey Bay
- contributing to earthquake early warning in California

- detecting local and teleseismic events: P- S- and T-phases
- detecting ocean surface gravity waves, dispersed swell arrivals, secondary microseisms and infragravity waves
- detecting fin and blue whales, and possible fishing activity

Should we continue to collect high-sample data?

If so, please get in touch:

Richard Allen – rallen@berkeley.edu