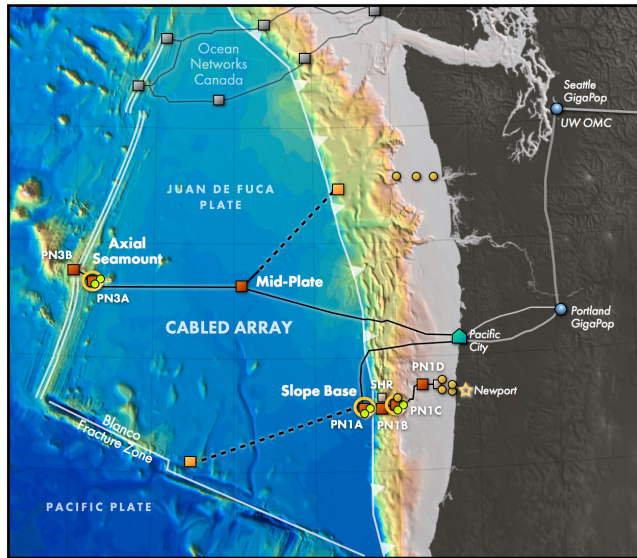
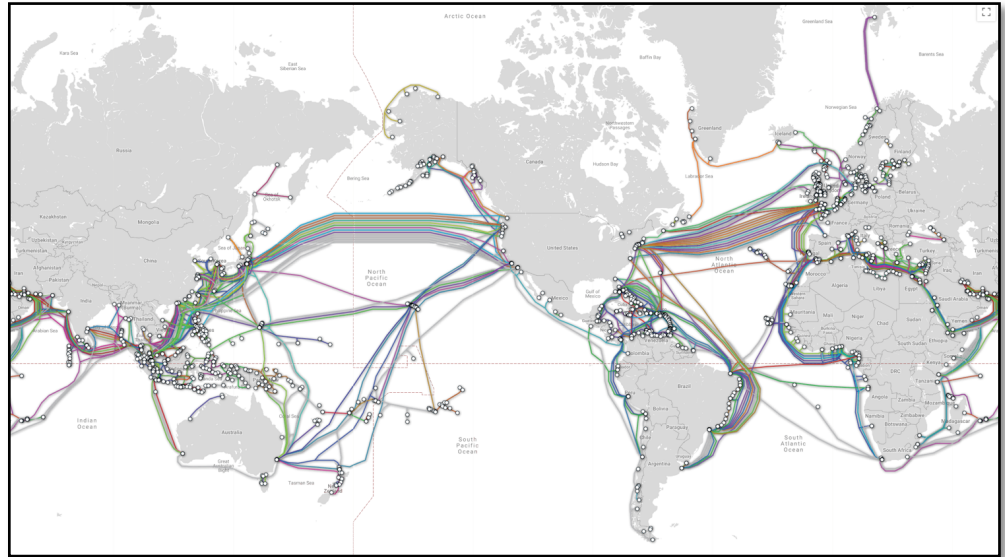


Submarine Environmental Sensing Over Telecommunication Fiber Optic Cables

Zhongwen Zhan (Caltech)



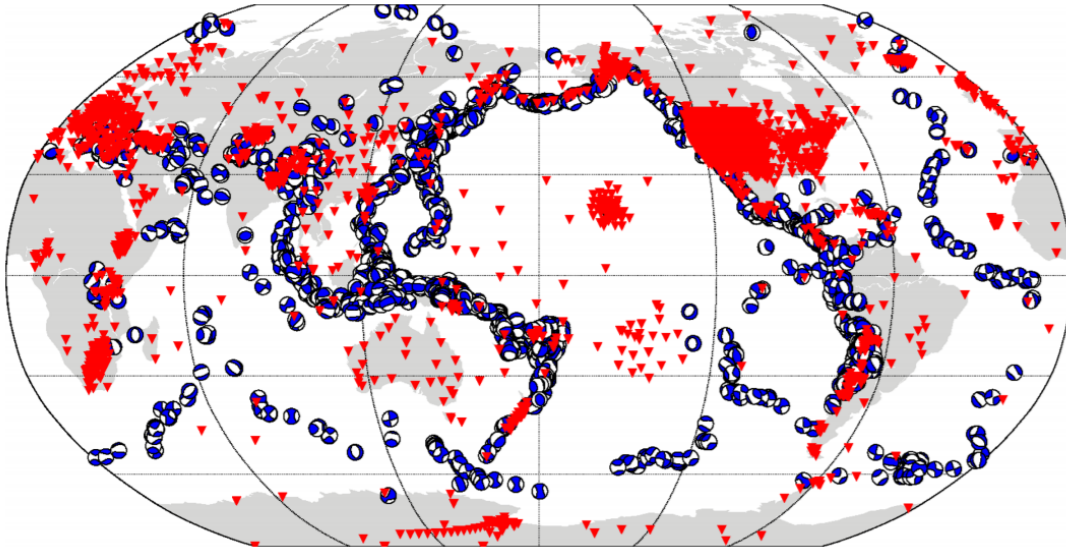
Cabled Observatories



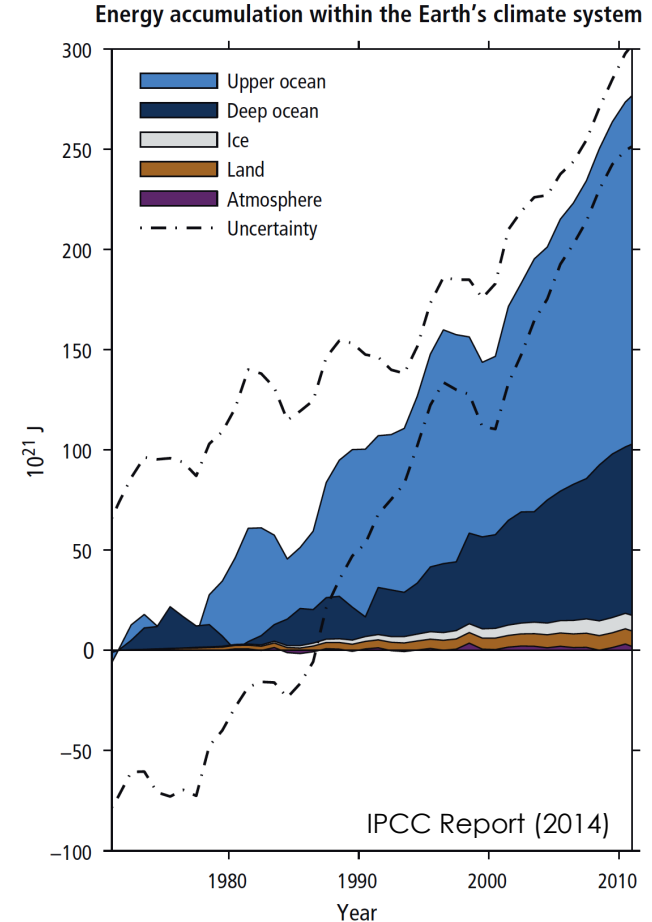
Transoceanic Cables

The needs from two communities

- Seismology: globally uniform coverage
- Oceanography: surface waves, internal waves, tides, currents, and temperature

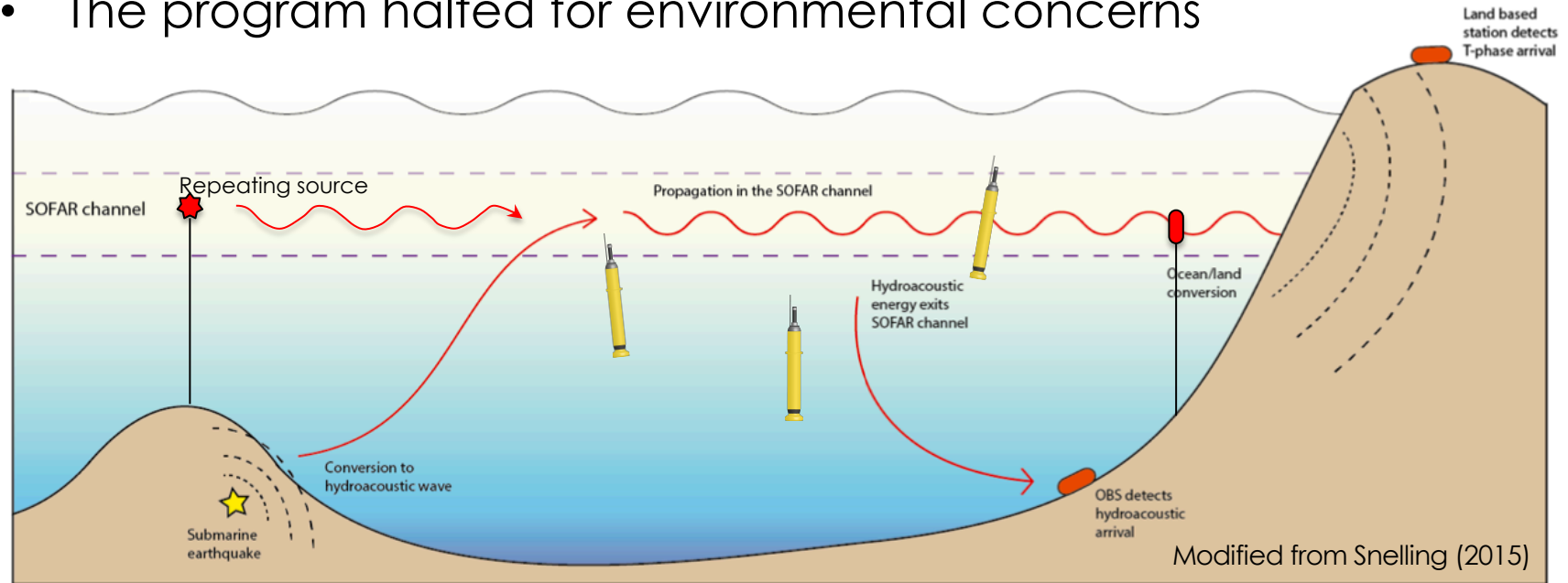
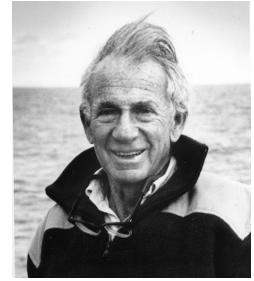


Hosseini and Sigloch, 2015



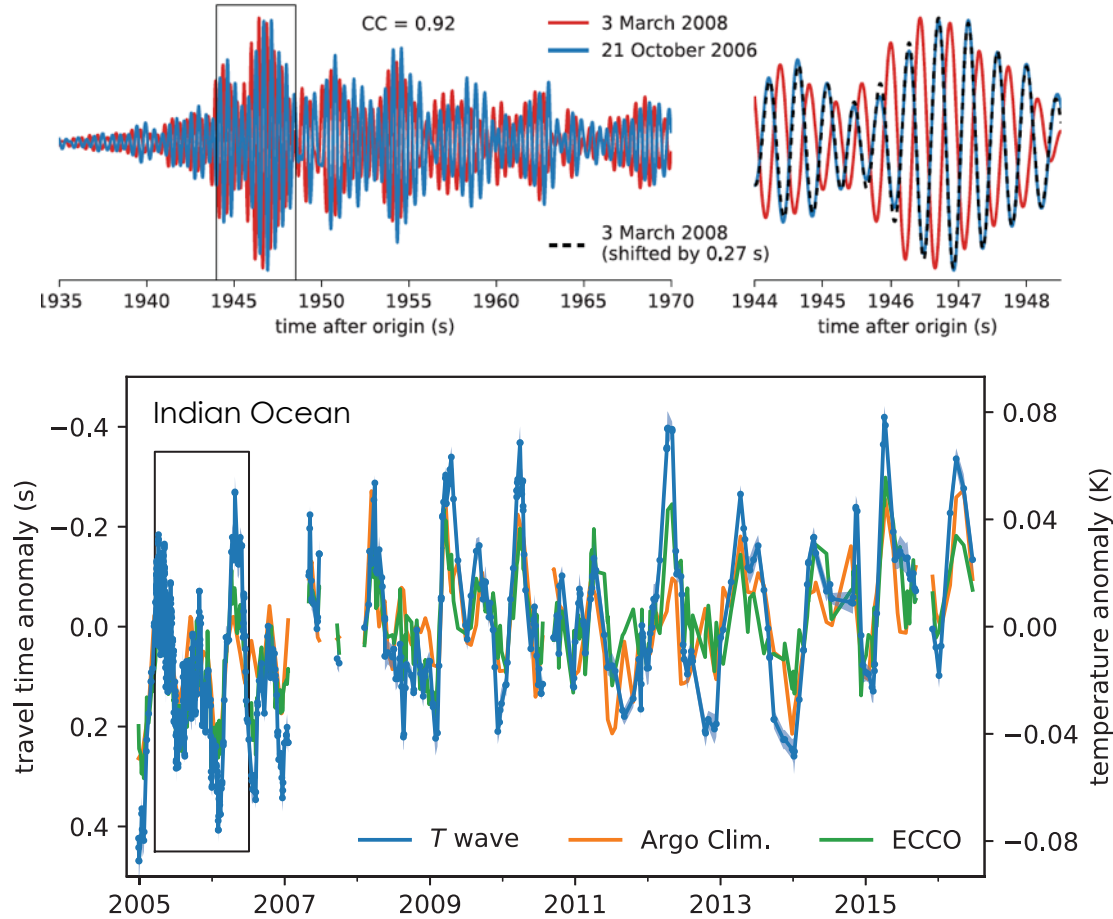
Ocean acoustic thermometry

- Use long-range observations of repeating acoustic sources to monitor ocean temperature
- The program halted for environmental concerns



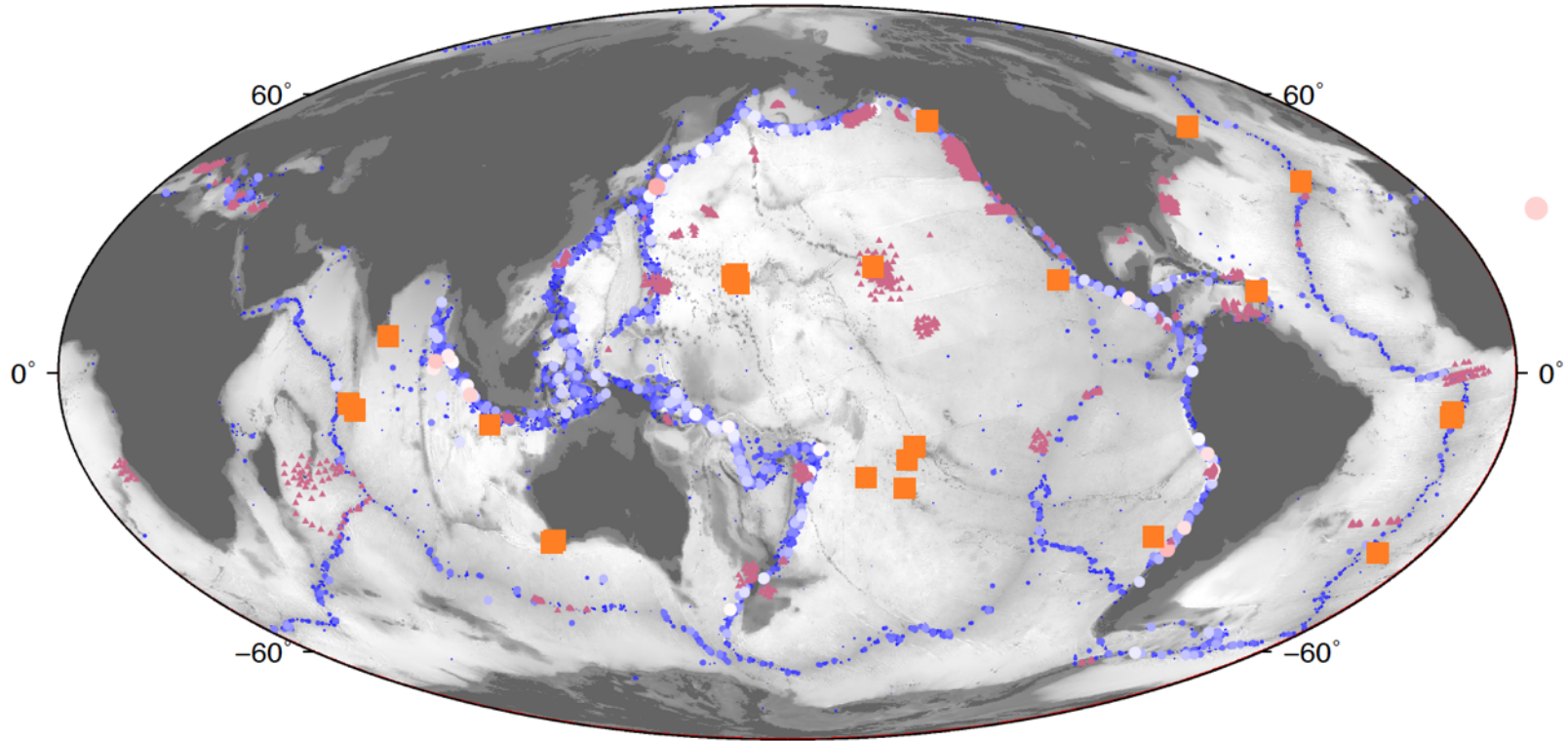
Modified from Snelling (2015)

Seismic Ocean Thermometry

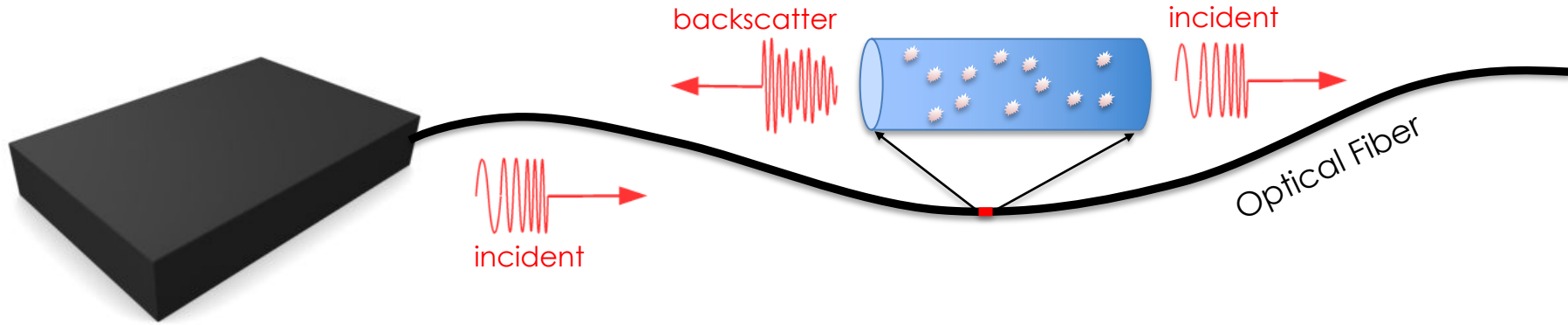


Wenbo Wu (Caltech)

Future of Seismic Ocean Thermometry relies on sensor coverage, like Seismology



DAS: optical fiber as Distributed Acoustic Sensors

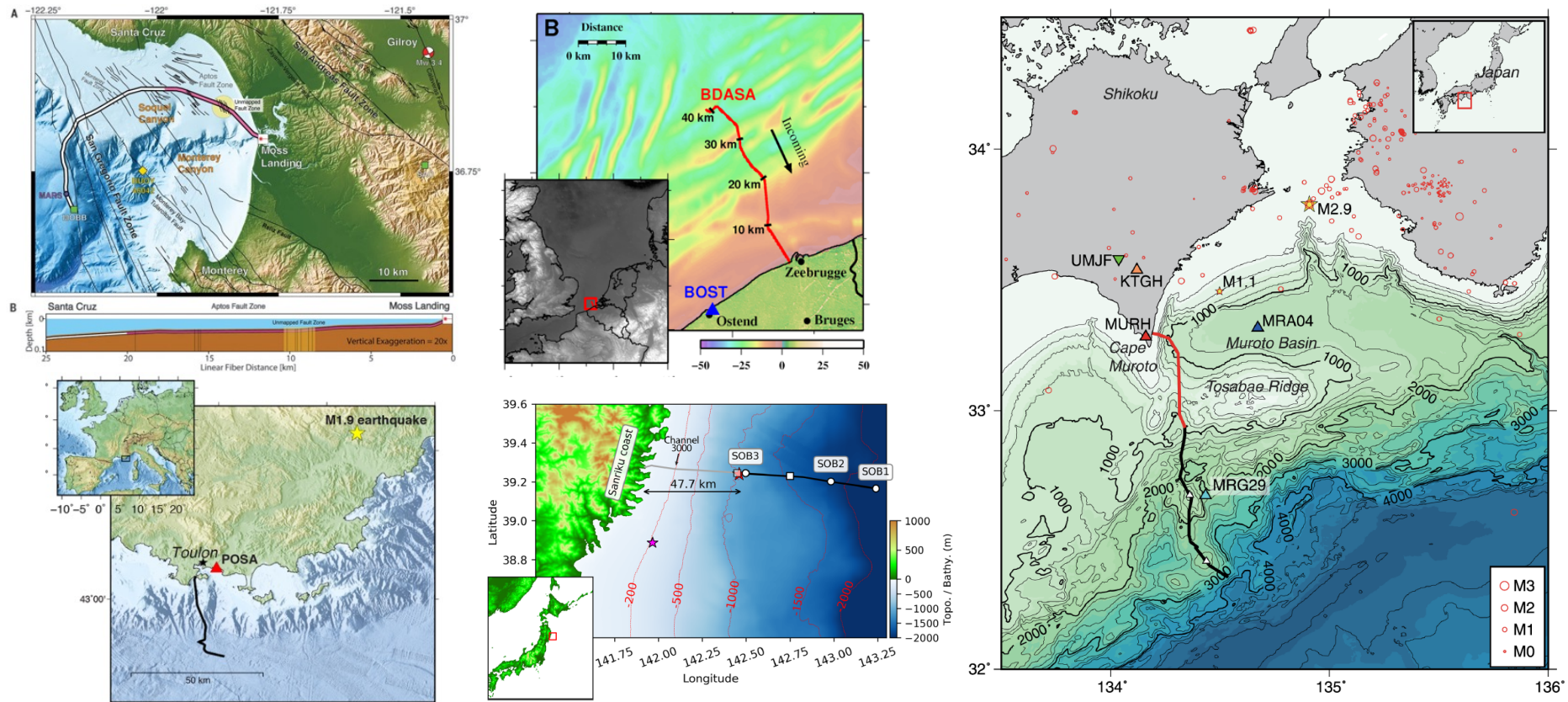


1 m of fiber = 1 strainmeters

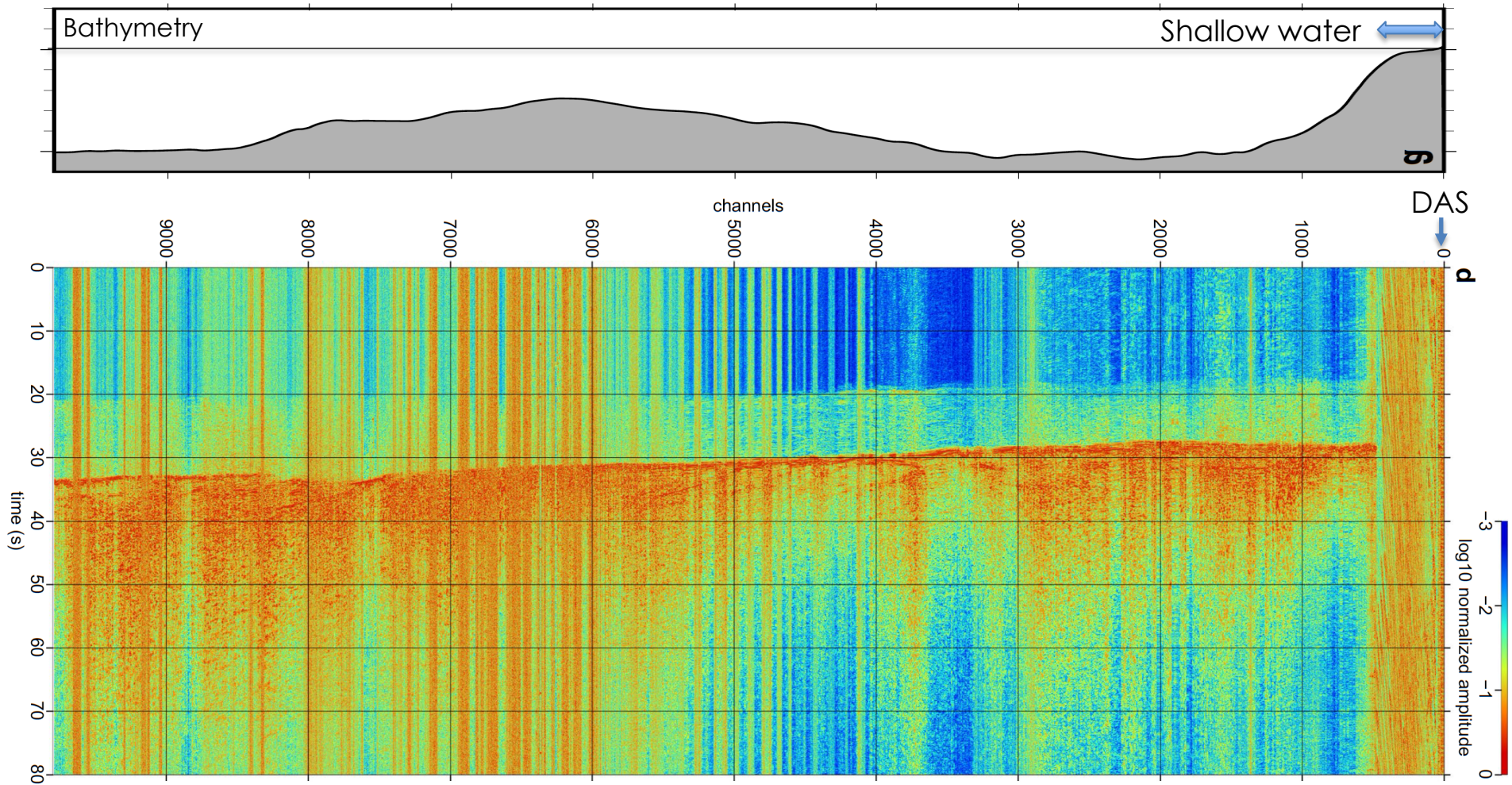
10 km of fiber = 10,000 sensors

Equipment only required at one end

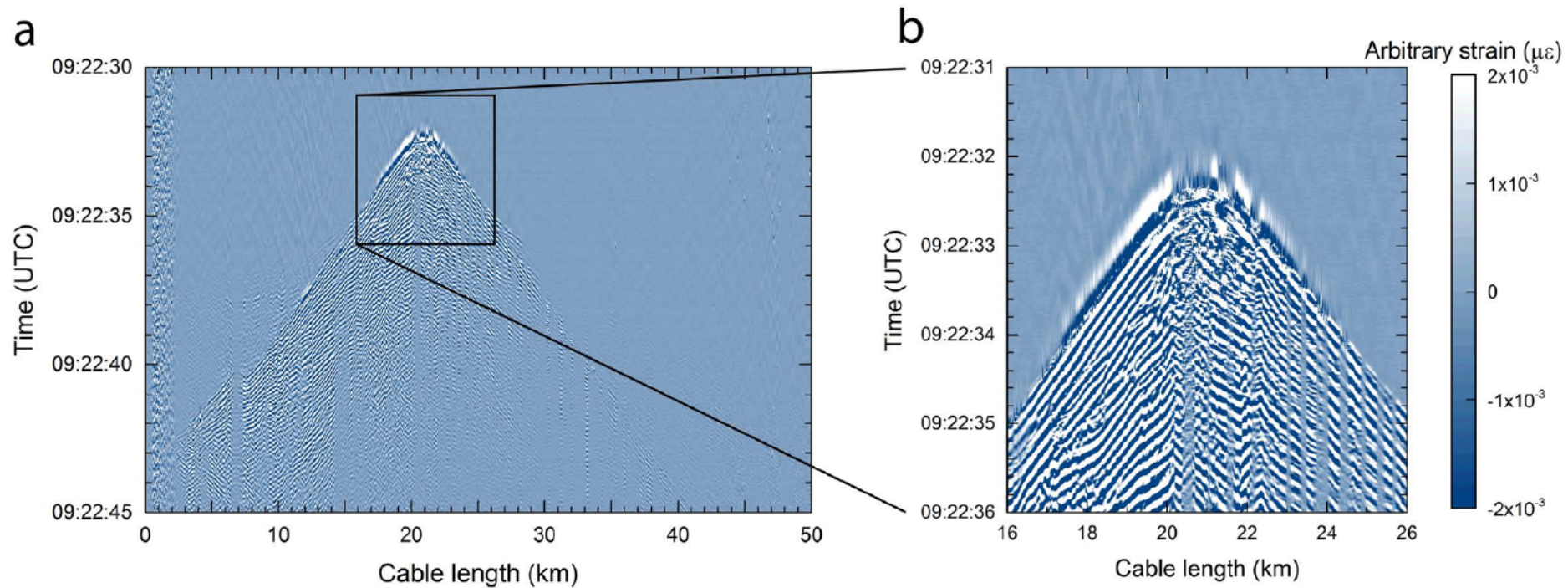
Submarine DAS expands fast



Lindsey et al., 2019; Williams et al., 2019; Sladen et al., 2019; Spica et al., 2020; Matsumoto et al., 2021; Ide et al., 2021

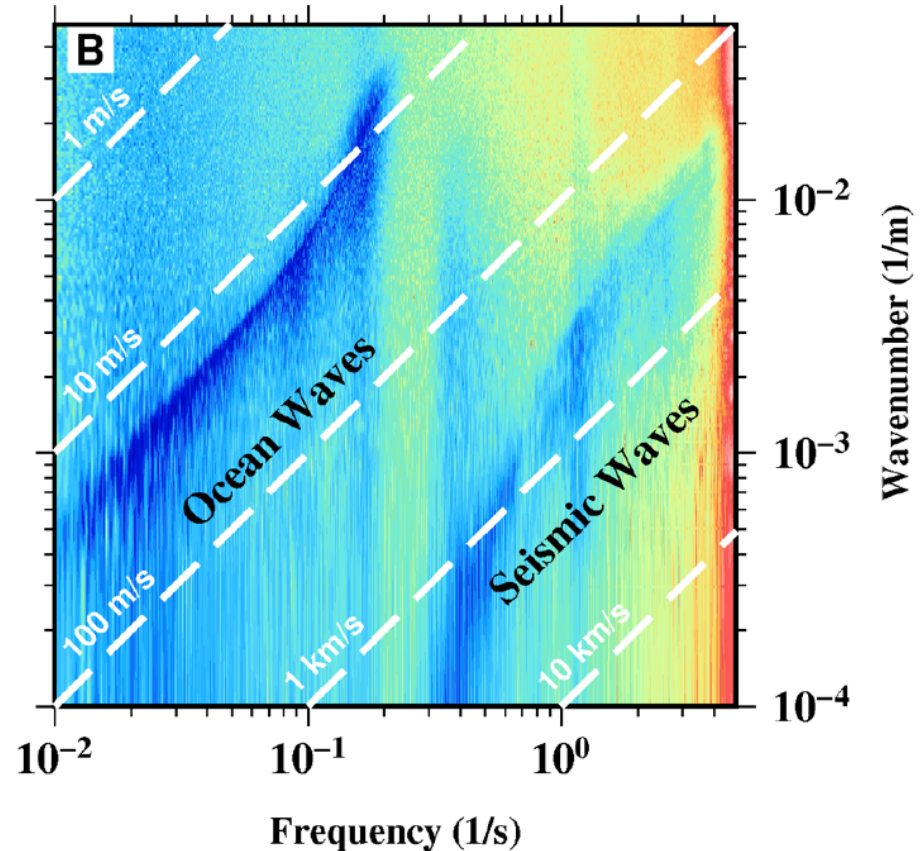
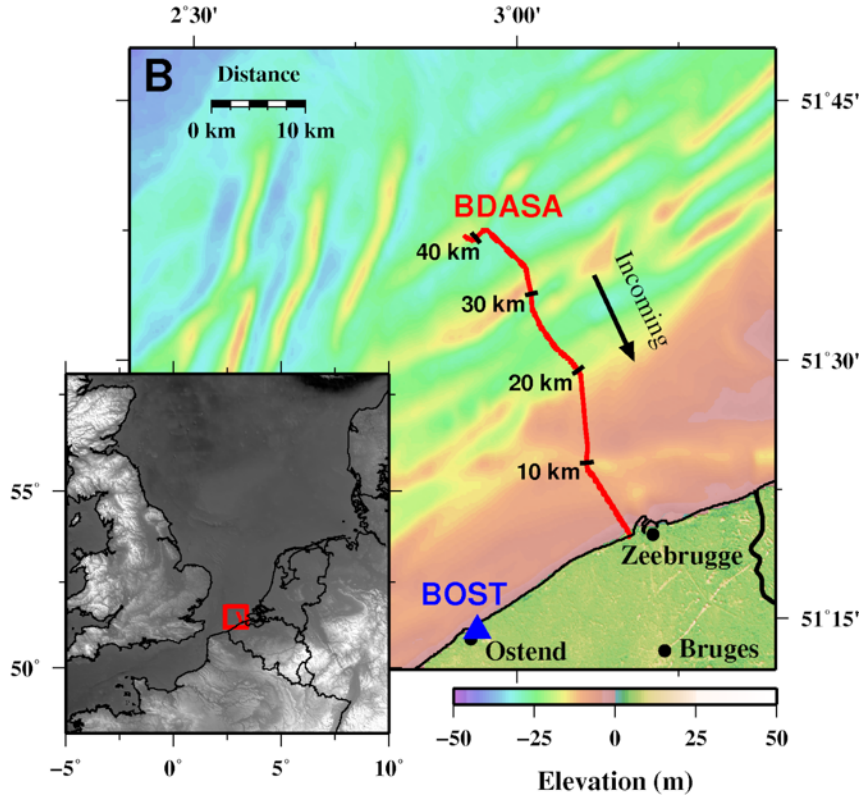


Hydro-acoustic wave on DAS

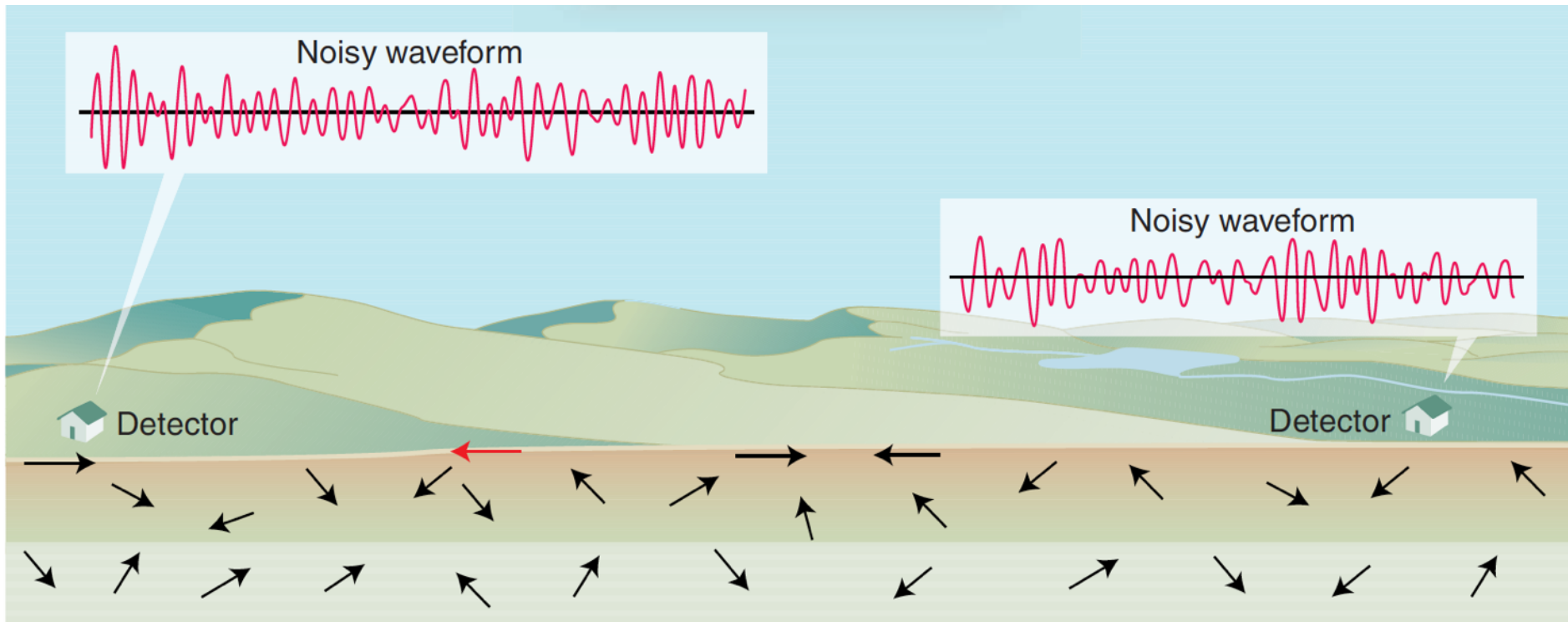


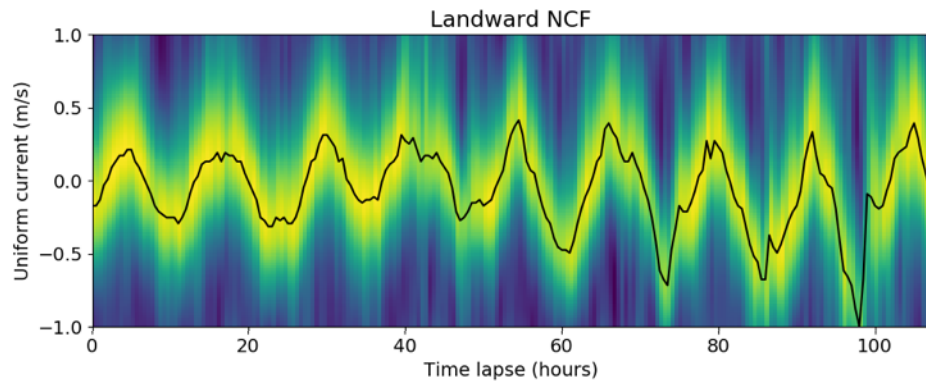
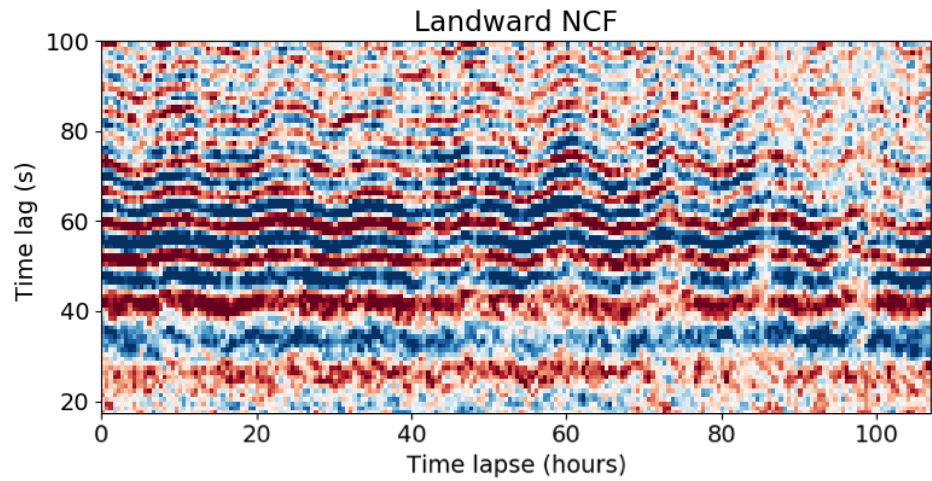
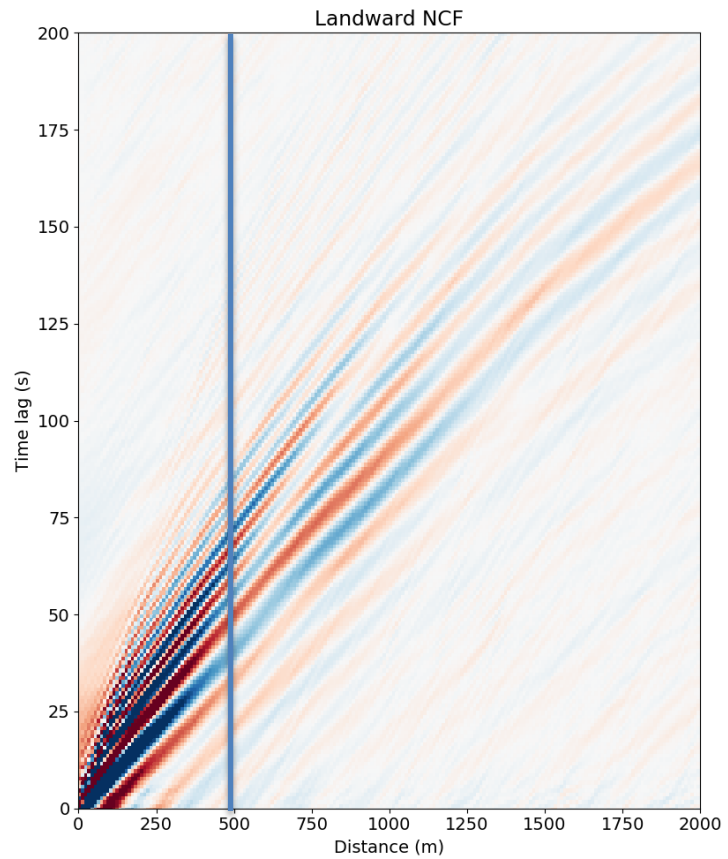
Earthquake T waves on DAS soon?

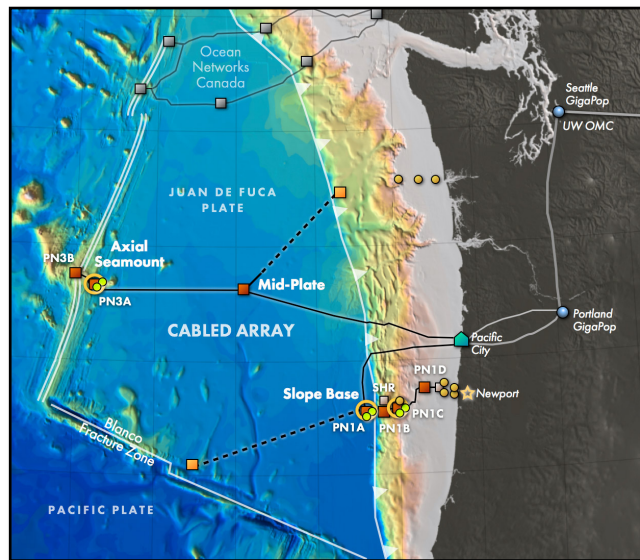
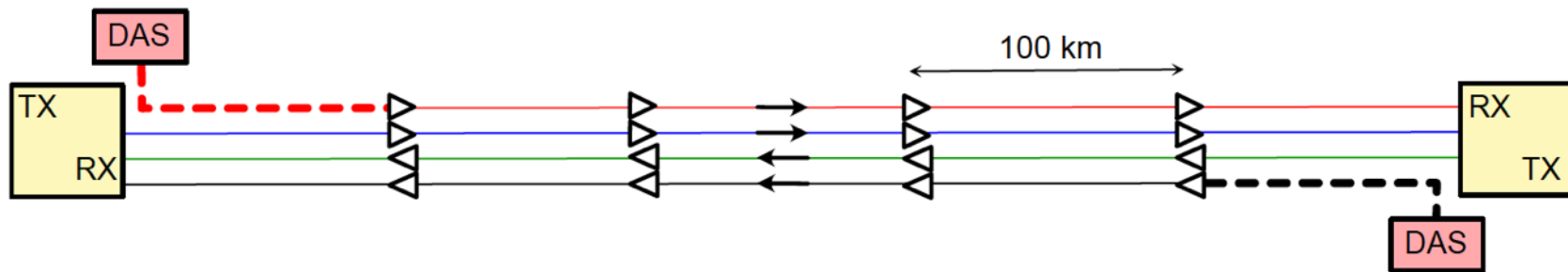
Submarine DAS array detects ocean waves too



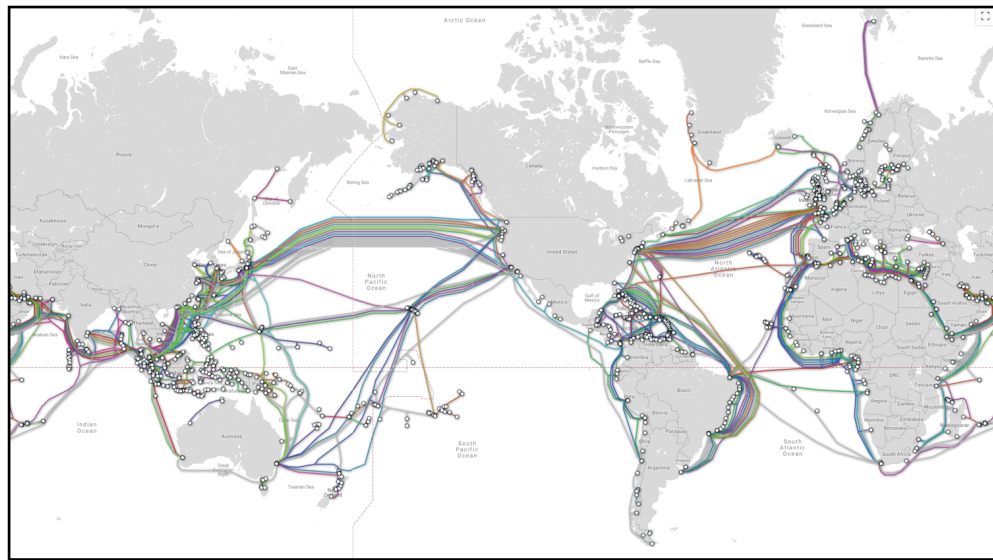
$$C_{AB} = \int_0^T u_A(\tau) u_B^*(t + \tau) dt = G_{AB}(-\tau) + G_{AB}(\tau)$$







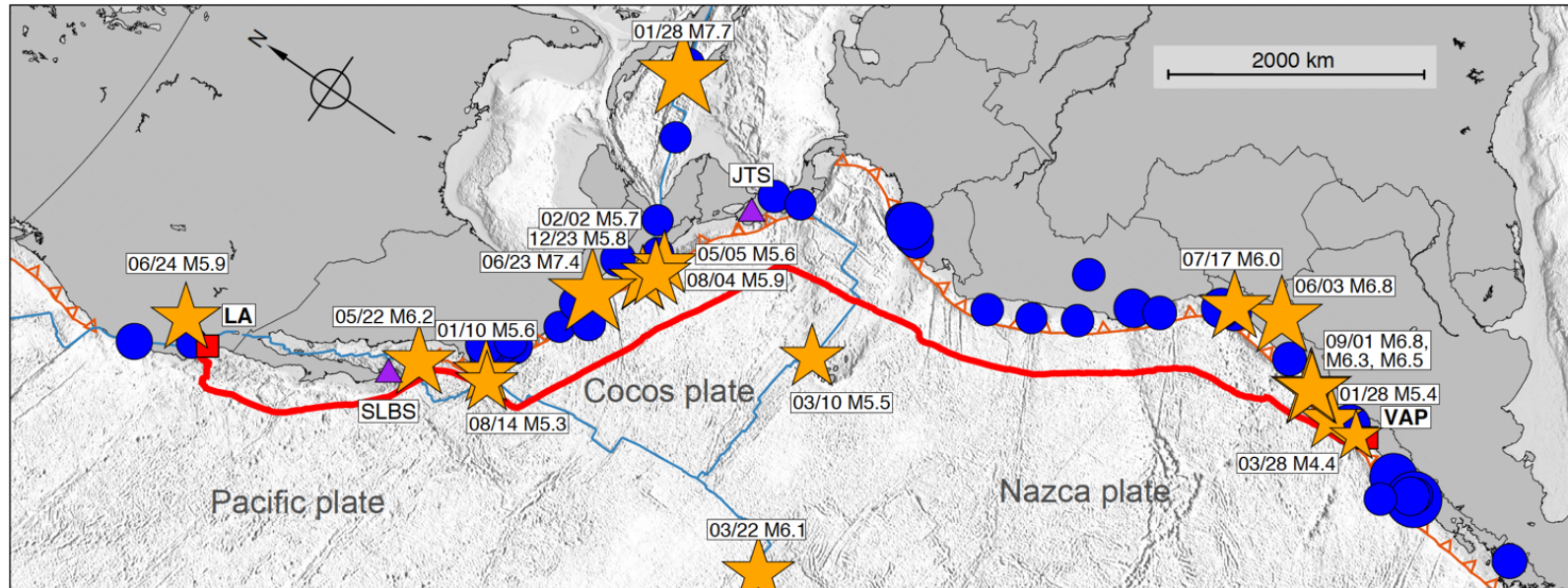
Cabled Observatories



Transoceanic Cables

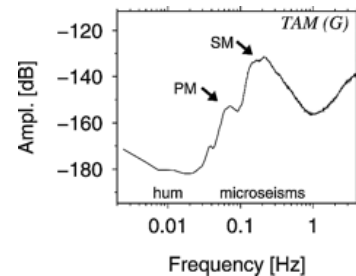
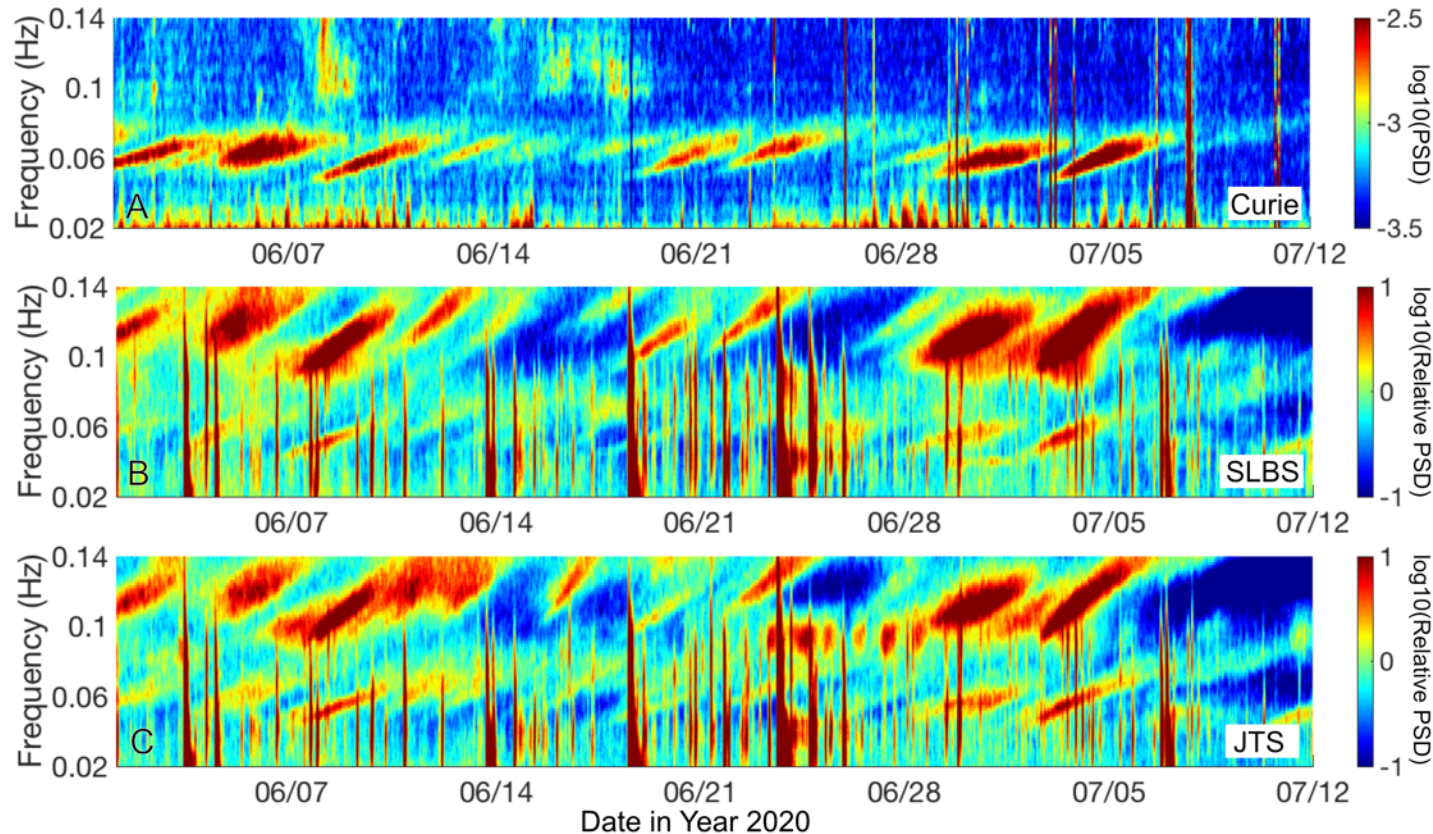
Light polarization-based long range sensing

- Telecom requires measurements of polarization to restore it
- Principle: stress to fiber causes change in light polarization



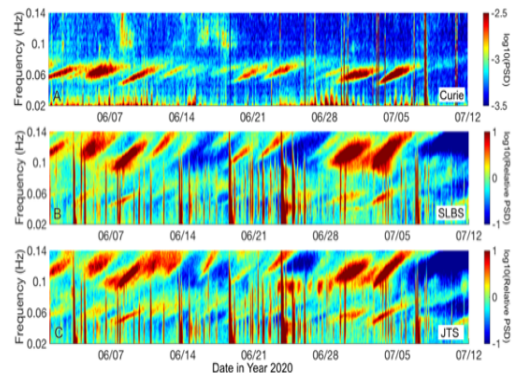
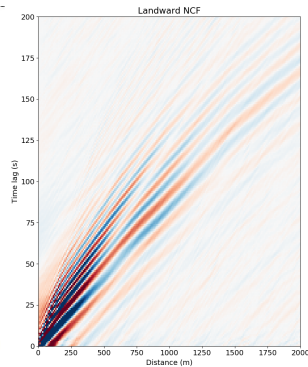
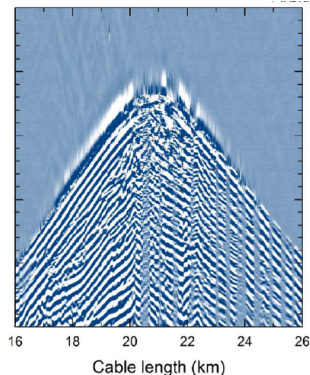
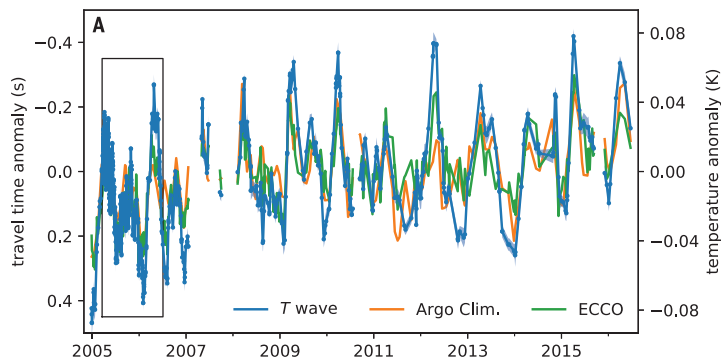
Zhan et al., Science, 2021: A 10,000-km fiber optic cable, Curie, by Google from Los Angeles to Chile

Polarization detection of ocean swells



Promising future of submarine fiber sensing

- Motivated by solid Earth geophysics but applies to ocean environment
- Measures hydroacoustic waves, ocean waves, ocean current, etc.
- Multiple emerging technologies: **DAS**, Phase, **Polarization**, SMART cable
- Need collaborations among seismology, oceanography, fiber optics, telecommunication industry, and regulatory agencies.



Thanks! Questions?



