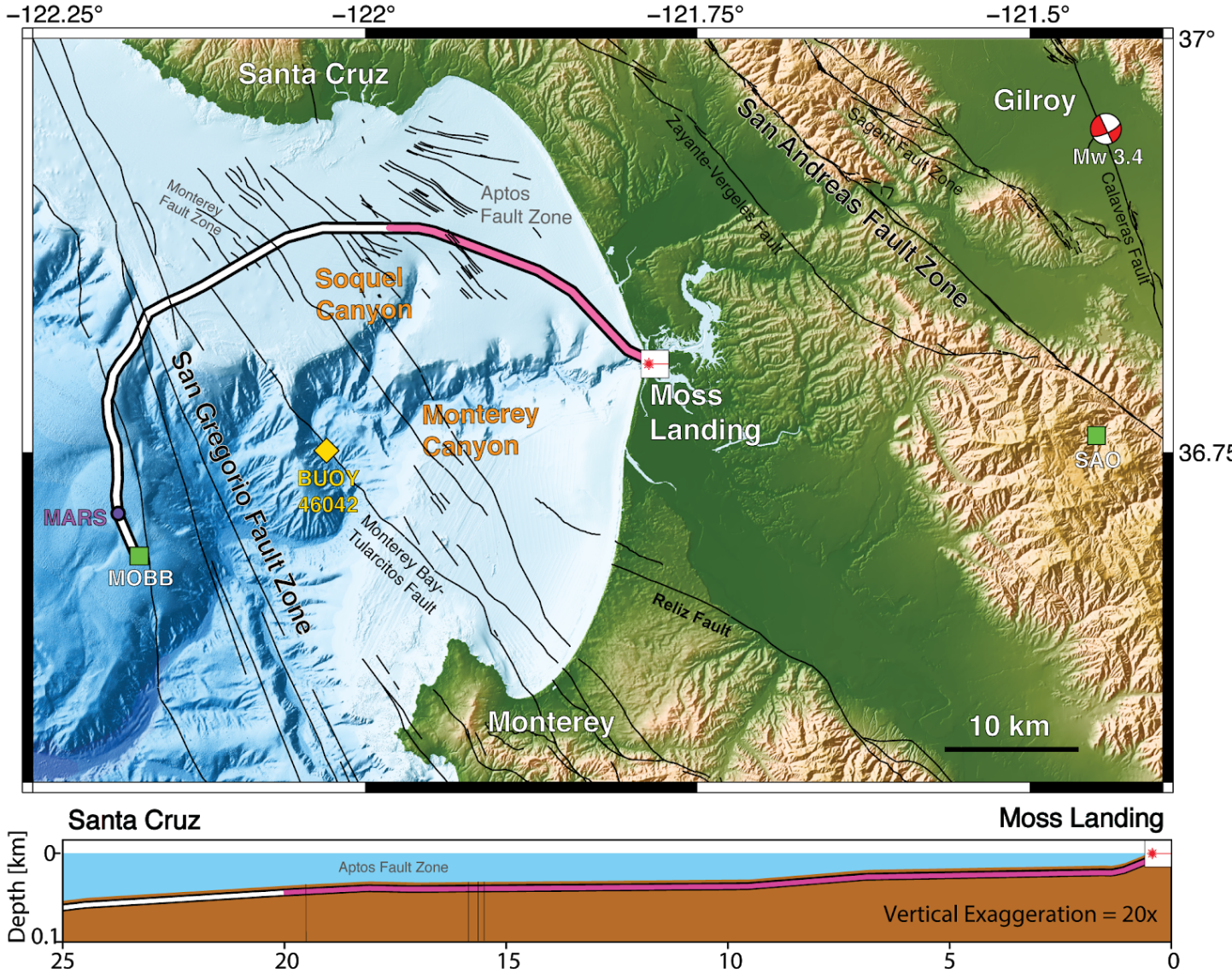
DAS offers marine geophysicists access to broadband, meter-scale data spanning multi-kilometer apertures from shore to shelf.



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[1]Stanford University, [2]Lawrence Berkeley National Laboratory, [3]Rice University, [4]Monterey Bay Aquarium Research Institute

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Lindsey, N.J., Dawe, T.C. and Ajo-Franklin, J.B., 2019. Illuminating seafloor faults and ocean dynamics with dark fiber distributed acoustic sensing. *Science*, *366*(6469), pp.1103-1107. https://science.sciencemag.org/content/366/6469/1103.abstract

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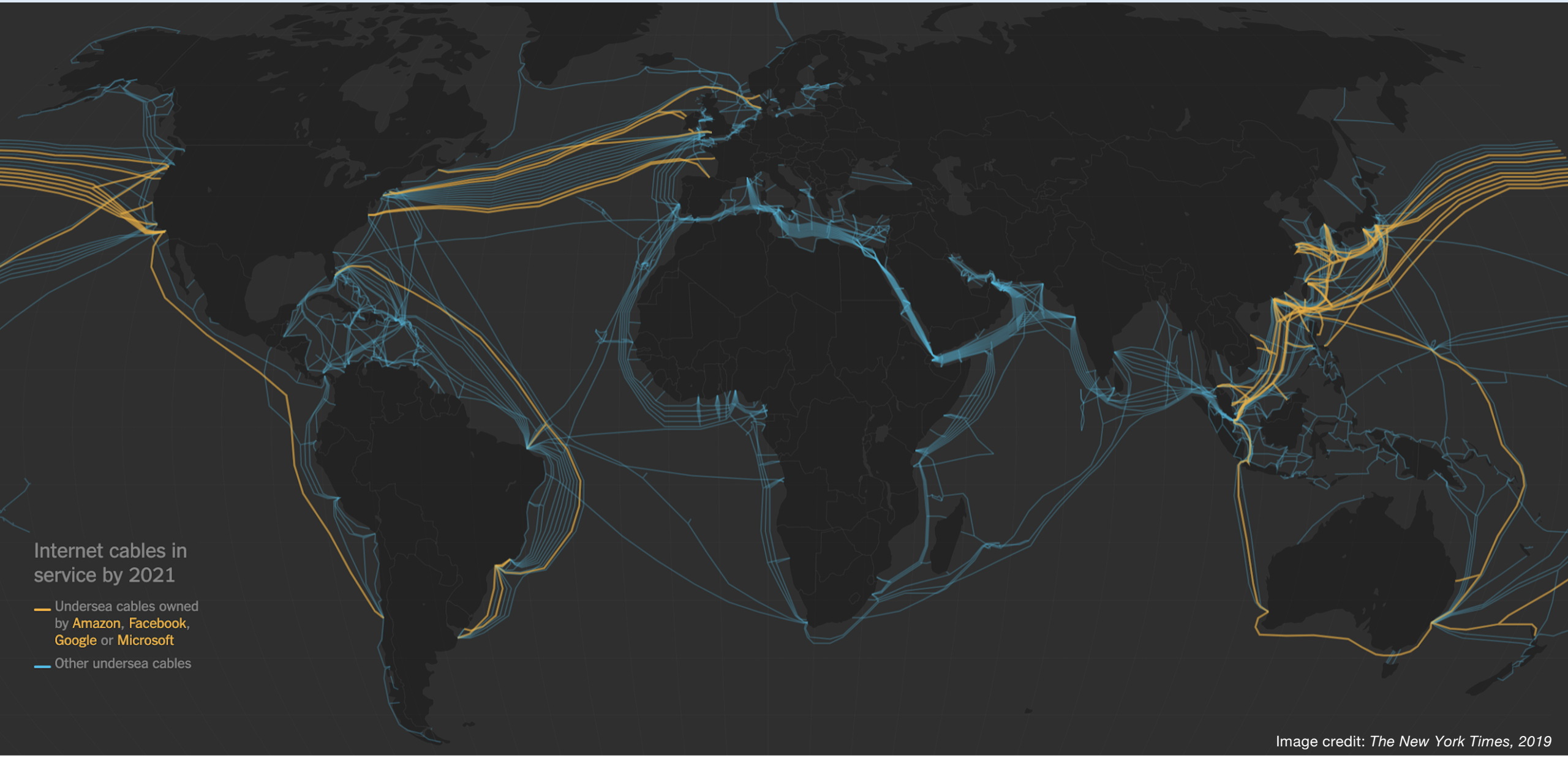
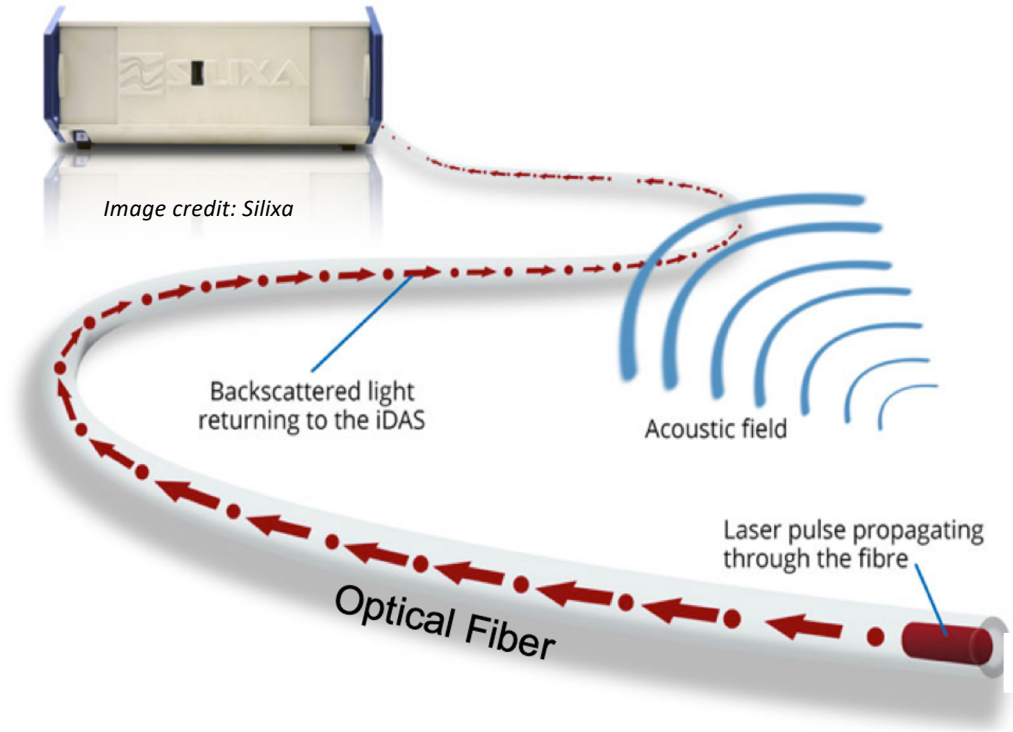


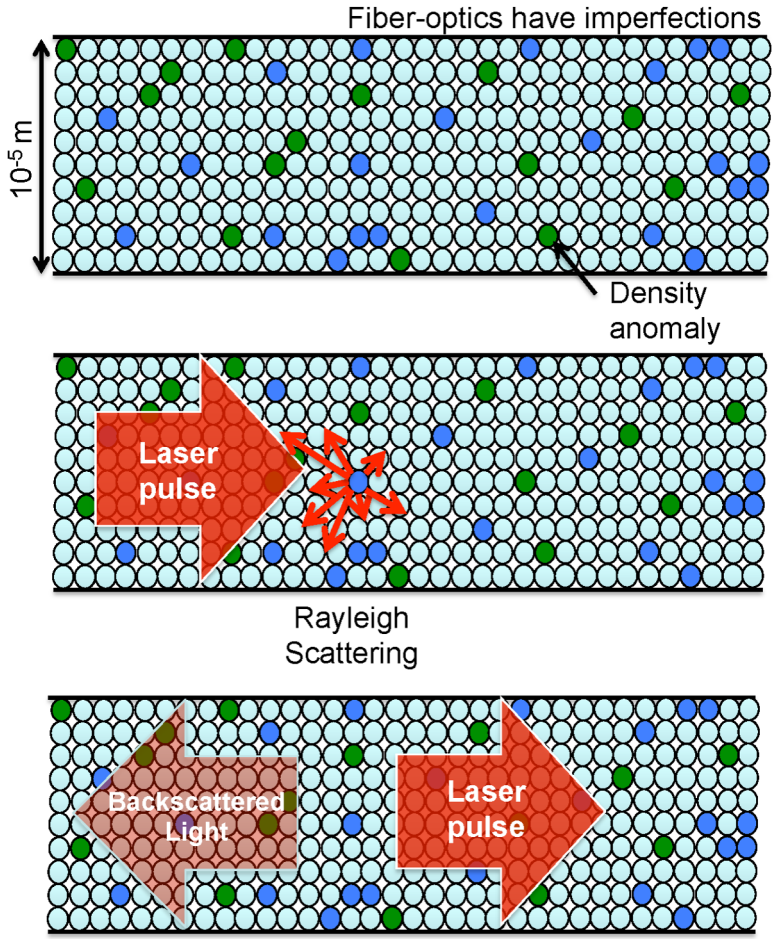
Image credit: *The New York Times, 2019*

Fiber-optic cables are everywhere

Distributed Acoustic Sensing

turns a fiber-optic cable into a massive 1C seismic array (of strain-rate sensors).





Some Common Recording Parameters:

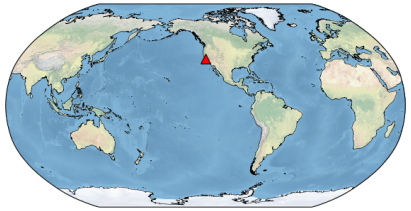
Laser pulse width ~ 10 – 40 ns
Spatial sampling (L_G) ~ 10 m
Maximum aperture ~ 30 km (standard fiber)
Laser pulse rate (t^{-1}) ~ 10 - 100 kHz
Digital sampling ~ 100 – 1000 Hz
Data flowrate ~ 0.01 – 10 TB/day

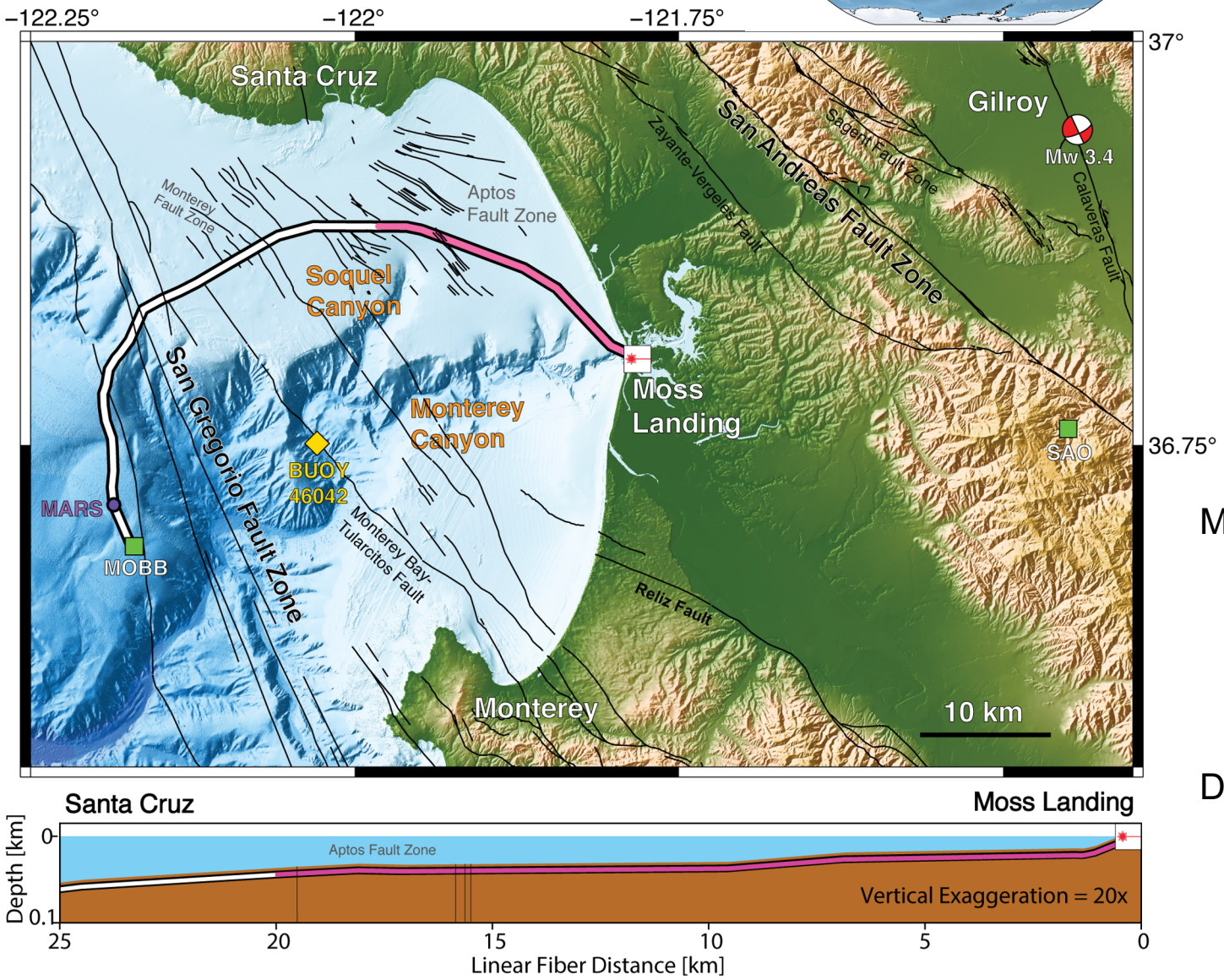
$$\epsilon_{xx}(t, x_j) = \frac{\lambda}{4\pi n L_G \zeta}\Delta\Phi = \frac{1550 \cdot 10^{-9}\ (\mathrm{m})}{4\pi \cdot 1.445 \cdot 10\ (\mathrm{m}) \cdot 0.735}\Delta\Phi = 11.6 \cdot 10^{-9} \cdot \Delta\Phi\ (\mathrm{rad})$$

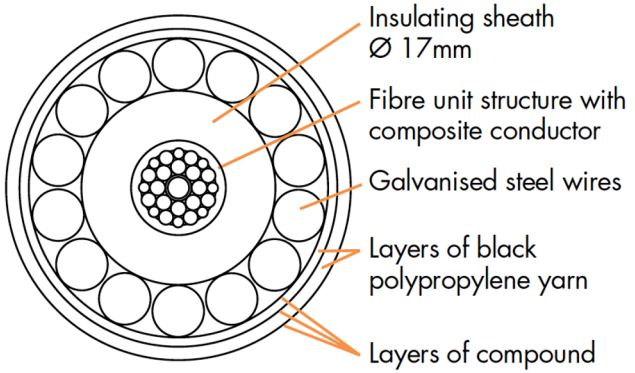
Lindsey, N.J., Rademacher, H. and Ajo-Franklin, J.B., 2020. On the broadband instrument response of fiber-optic DAS arrays. *Journal of Geophysical Research: Solid Earth*, *125*(2), p.e2019JB018145. https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2019JB018145

Crossing the shoreline

The DAS-MARS Cable Experiment







Outer diameter: 31mm

OALC4 Single Armoured Cable (SA)

MARS cable laid in 2006 (UC Berkeley/MBARI)

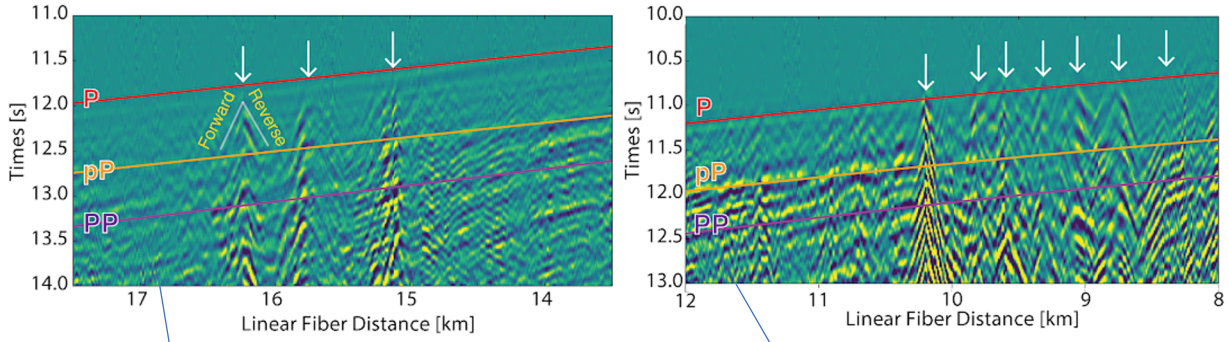
- 52 km long, 0.5-1 m deep
- Provides power/comm to seafloor node
- Continuous operation 2006 - 2019
- No unused fiber
- Routine node maintenance 3 - 4 days / year

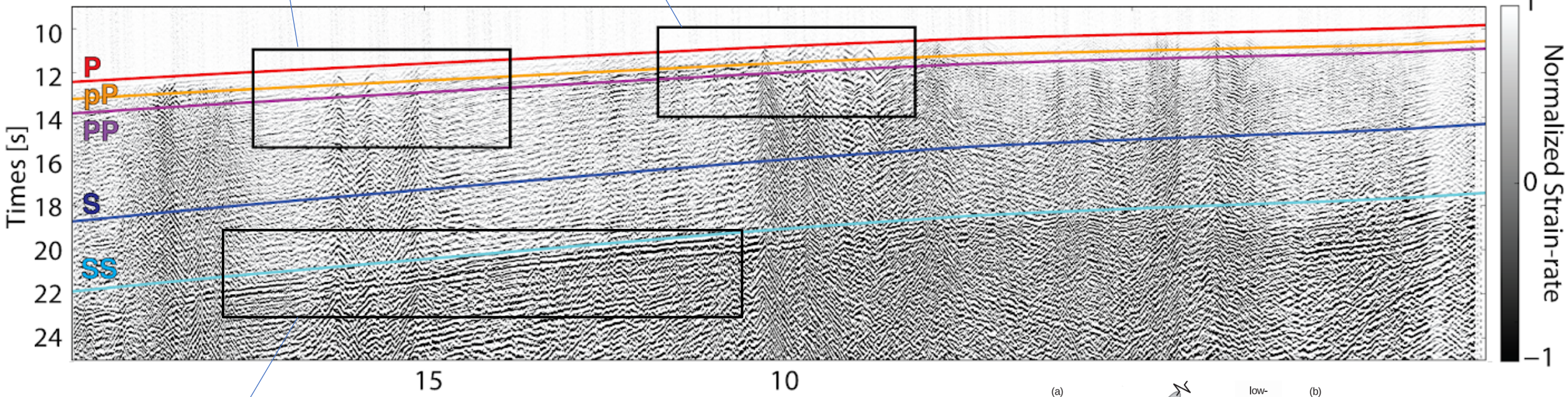
DAS-MARS cable experiment 2018

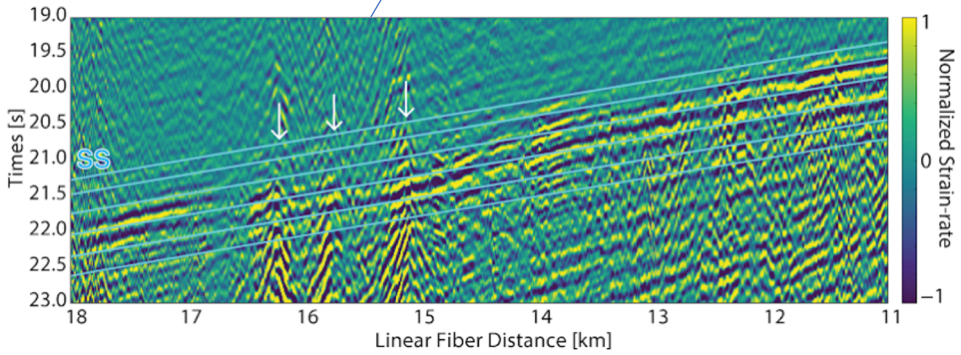
- 3.5 days
- Occupied 1 SMF from shore with Silixa iDAS
- 9,984 DAS @ dt=0.002 s, dx=2 m, L_G=10 m
- Total collected DAS data volume = 3.45 TB

Meterscale AND multi-kilometer

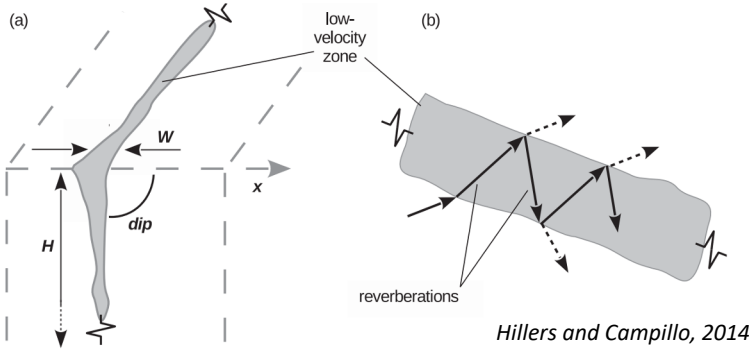
Seafloor DAS in Monterey Bay records M1-3 California earthquake wavefields (at 10 – 50 km offsets) which show **seismic phase conversions** and **0.25-s S-wave delays** at mapped and **unmapped subsea faults**.







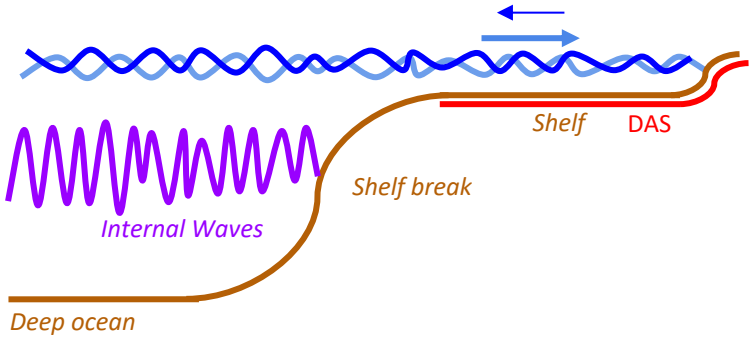
Event: Mw3.4; Z=2.87 km; ~40km offset
Processing: FK-filter removes microseism
Observations: Weak P; Strong S/SS; azimuthal sensitivity; Secondary "point" scattering ~400-800 m/s; SS Wavefront delay = 0.5 s
Hypotheses: (1) Head waves, (2) FZ-trapped waves, (3) Body wave reflections



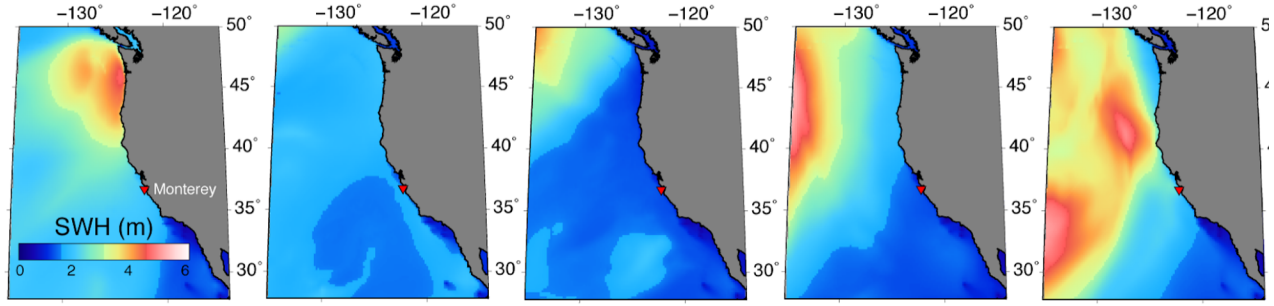
Hillers and Campillo, 2014

Broadband response

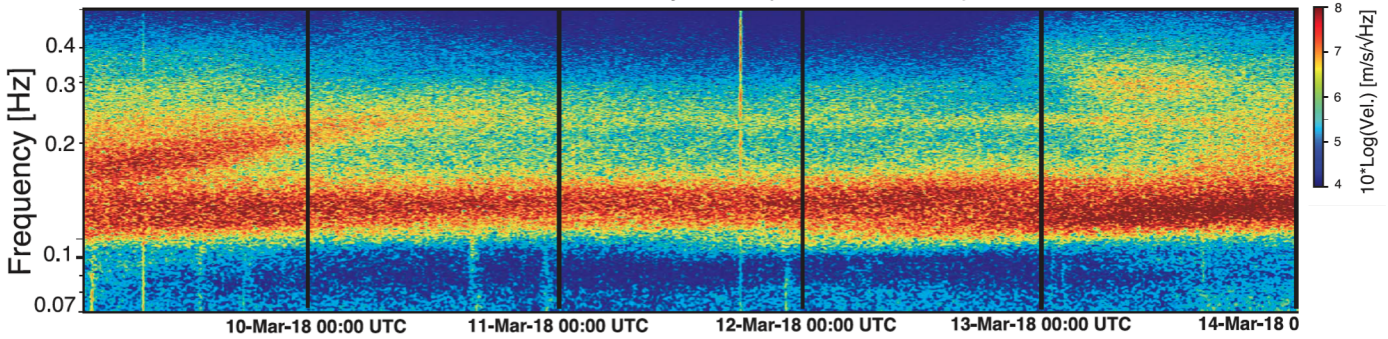
Microseisms around 0.05 – 0.2 Hz dominate 50 m depth DAS records, correlate with onshore seismometers and Pacific wave height.
At **8 – 20 mHz**, DAS channels show **strong tidally-modulated signal.**

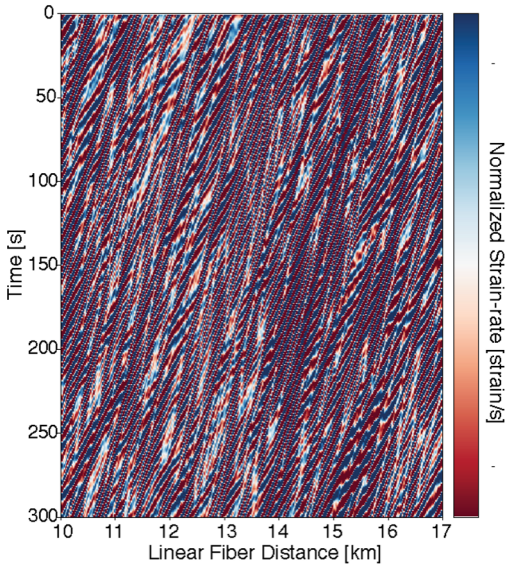


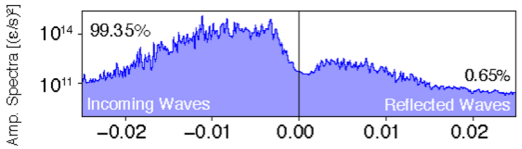
Sea State Satellite Model (Wavewatch III Reanalysis)

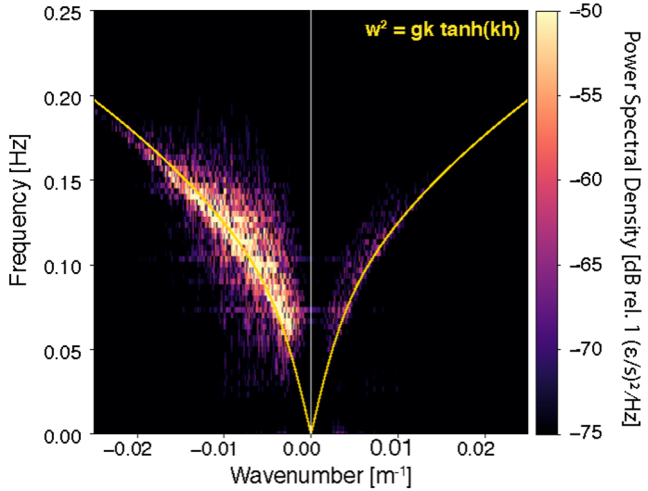


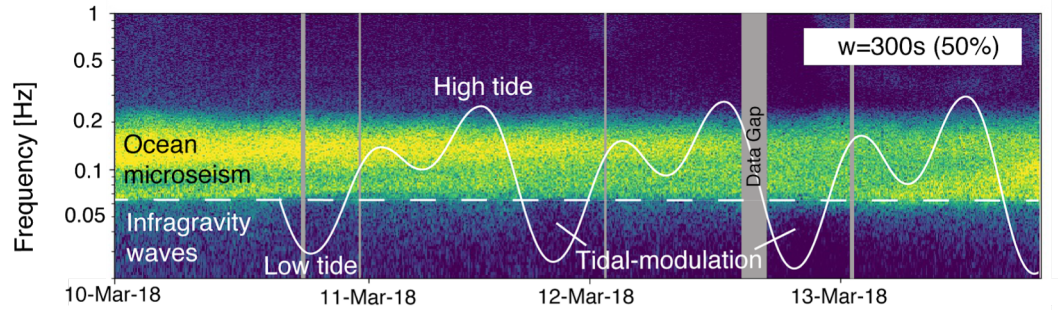
Onshore Broadband Seismometer Microseism Spectra (BK.SAO.BHN)

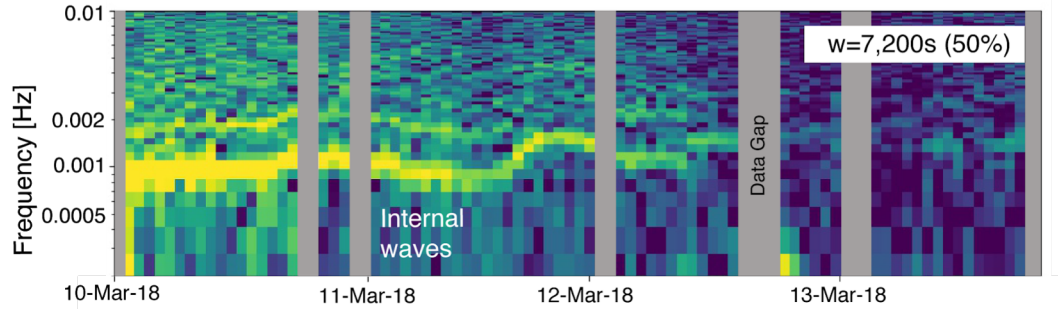












Summary

- Fiber-optic Distributed Acoustic Sensing (DAS) represents a new way to explore ocean/solid earth processes.
- Quality data from single mode fiber inside armoured MARS cable buried at 0.5 m.
- Seismic wavefield from M3.4 earthquake at 40 km located faults in secondary scattering zones.
- Primary microseism energy dominates shallow water fibers.
- FK array analysis confirms Longuet-Higgins-Hasselmann hypothesis for in situ secondary microseism generation produced by bi-directional wind-water waves.
- Longer period hydrodynamic processes also recorded by DAS (T=50 - 1500 s).
- Short-term access to optical fibers during maintenance is likely feasible, inquire with telecom operators.

Learn more about fiber sensing:
https://www.iris.edu/hq/initiatives/das_rcn
https://ctemps.org

Watch a tutorial on DAS:
https://www.njlindsey.com/

Read the papers:

Lindsey, N.J., Dawe, T.C. and Ajo-Franklin, J.B., 2019. Illuminating seafloor faults and ocean dynamics with dark fiber distributed acoustic sensing. *Science*, *366*(6469), pp.1103-1107. https://science.sciencemag.org/content/366/6469/1103.abstract

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Stanford University