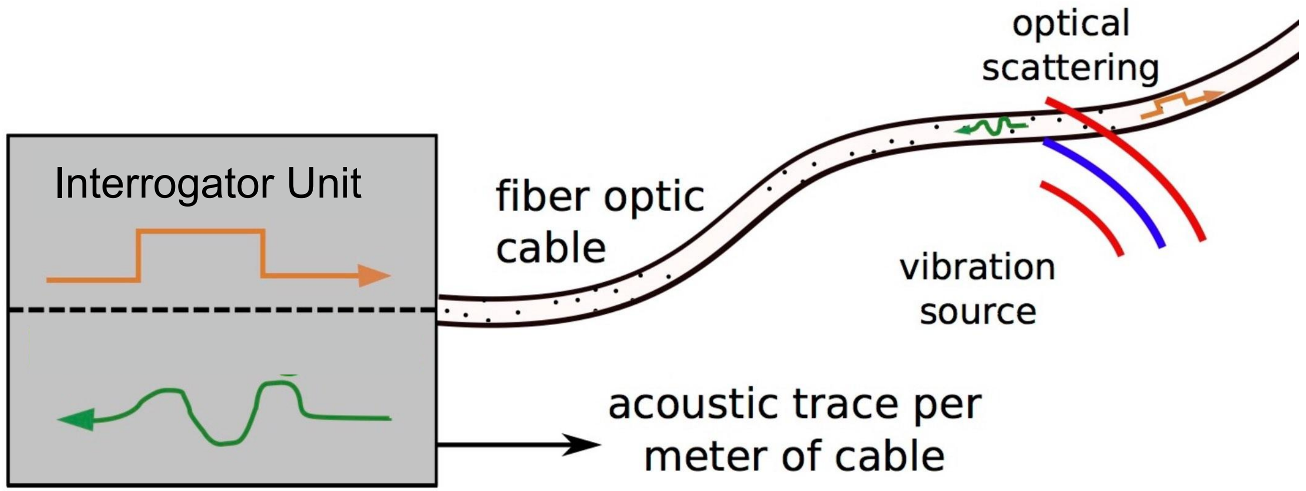
Session 2: Distributed Acoustic Sensing for Earthquake Science

What is distributed acoustic sensing (DAS)?

Distributed acoustic sensing uses laser light pulses that are Rayleigh backscattered from small variations in the refractive index of the fiber. An interrogator unit (IU) rapidly and repeatedly sends laser pulses into the cable and monitors the return time of the back-scattered light.

When a seismic wave passes by the fiber-optic cable, the cable is deformed, the scatterers move, and the IU detects the changes in the return time of the scattered light. This yields broadband measurements of strain (or strain rate) along the fiber with a spatial resolution on the order of meters over distances of multiple kilometers.



Session 2: Distributed Acoustic Sensing for Earthquake Science

Eileen Martin, Virginia Tech

Advances in passive seismic algorithms for large-scale DAS data

Martijn van den Ende, University Côte d’Azur

The challenges (and solutions) of using fibre-optic cables as seismological antennas

Bin Luo, Stanford University

Distributed acoustic sensing using long range submarine fiber-optic cables

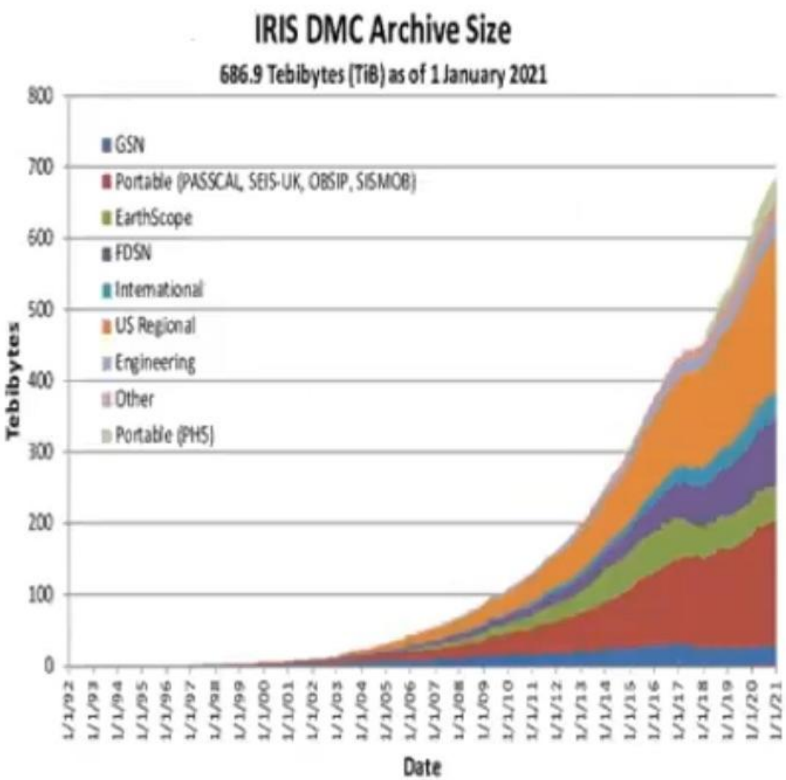
Jonathan Ajo-Franklin, Rice University

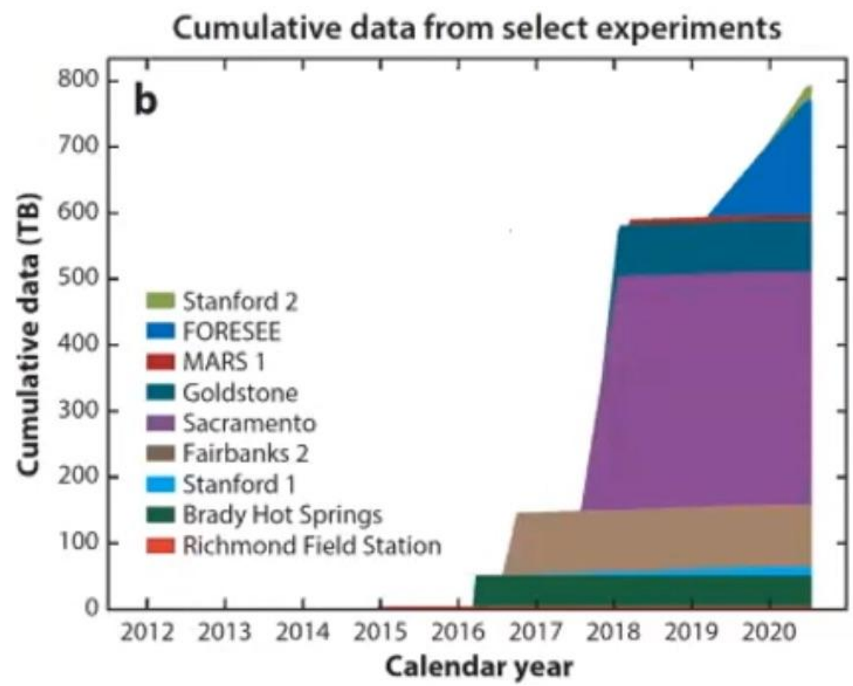
Exploring The Subsurface with Regional DAS Networks: Results from the Imperial Valley Dark Fiber Project

Eileen Martin, Virginia Tech

Advances in passive seismic algorithms for large-scale DAS data

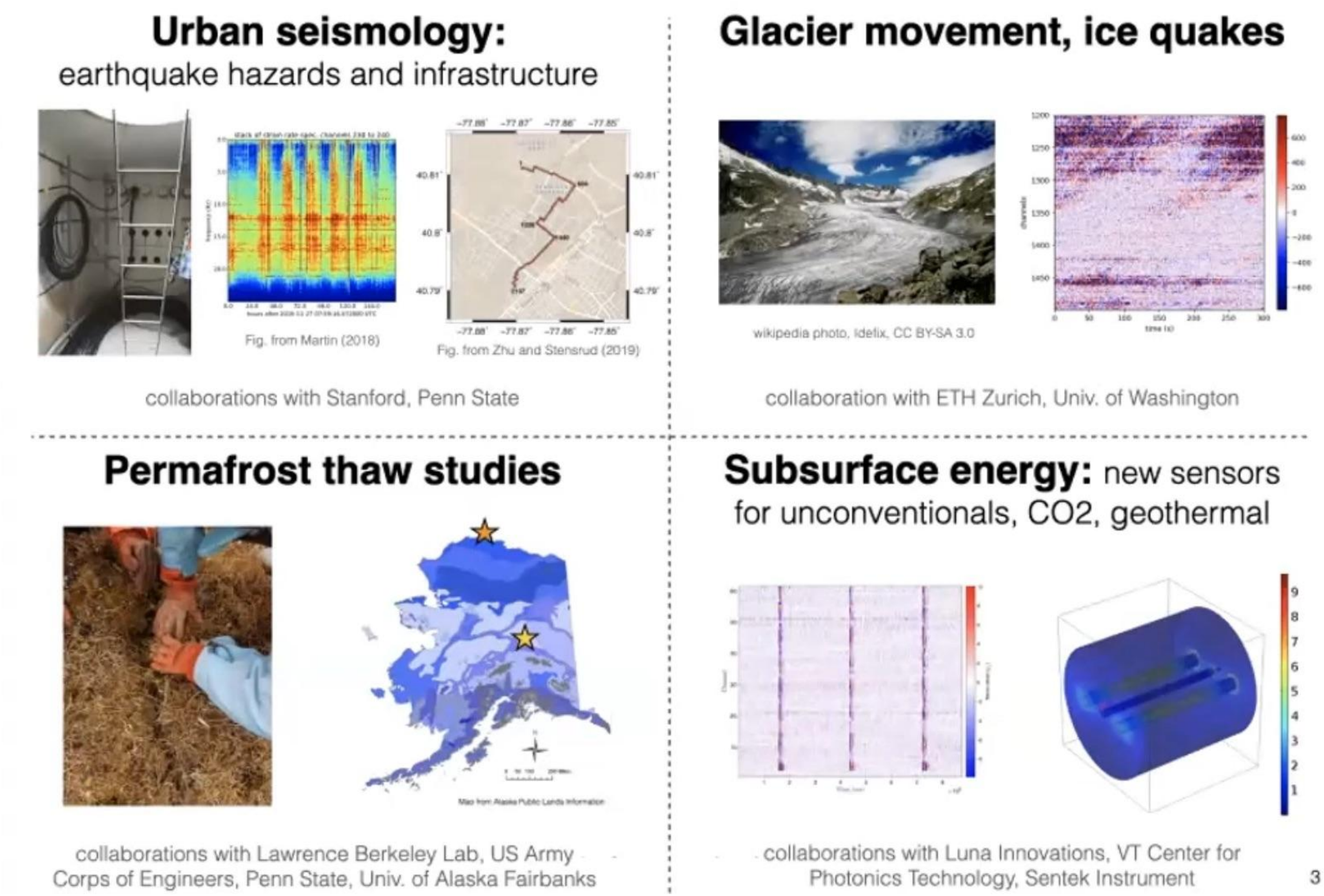
Why are faster, more efficient algorithms needed for working with DAS data?





Eileen Martin, Virginia Tech

Advances in passive seismic algorithms for large-scale DAS data



Eileen Martin, Virginia Tech

Advances in passive seismic algorithms for large-scale DAS data

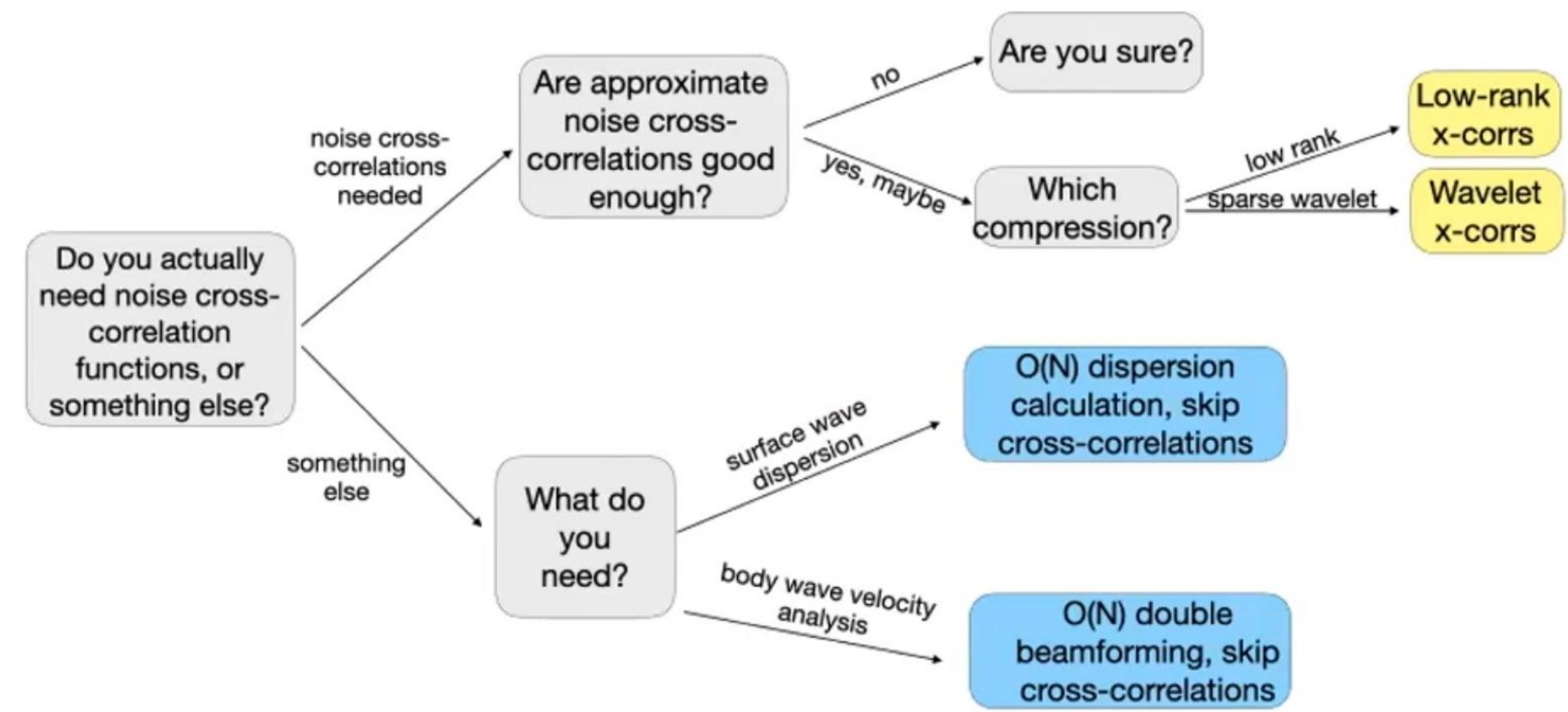
Some targets for improved algorithms:

- Noise removal
- Noise as signal - ambient noise processing
- Real-time data products (SOH, low-f data)

Eileen Martin, Virginia Tech

Advances in passive seismic algorithms for large-scale DAS data

Map to more efficient ambient noise analysis

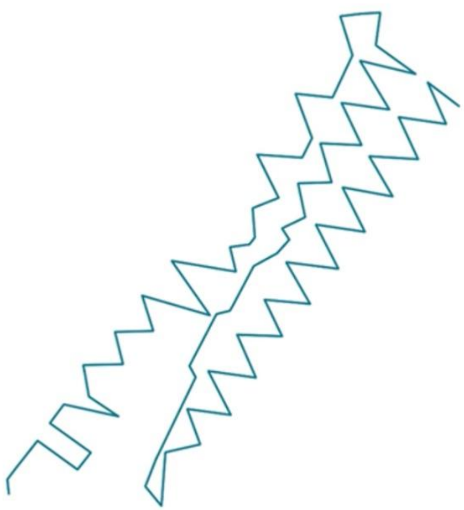


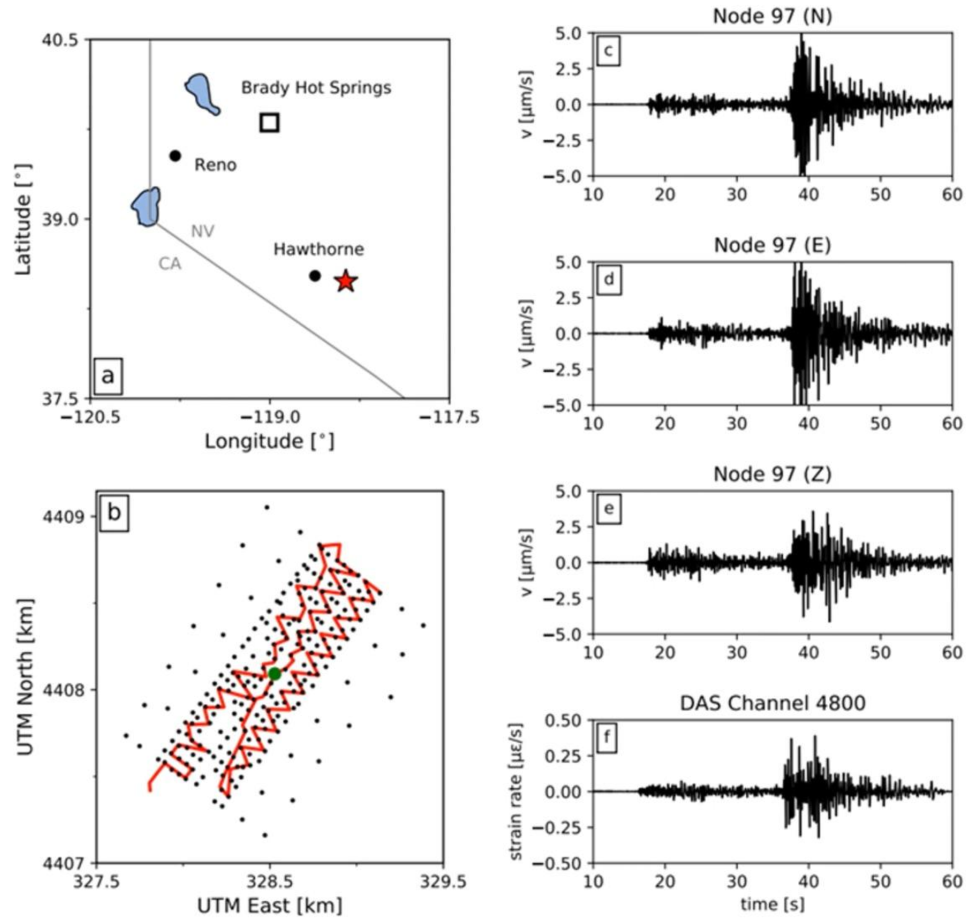
Martijn van den Ende, University Côte d'Azur

The challenges (and solutions) of using fibre-optic cables as seismological antennas

Hawthorne M4.3 earthquake

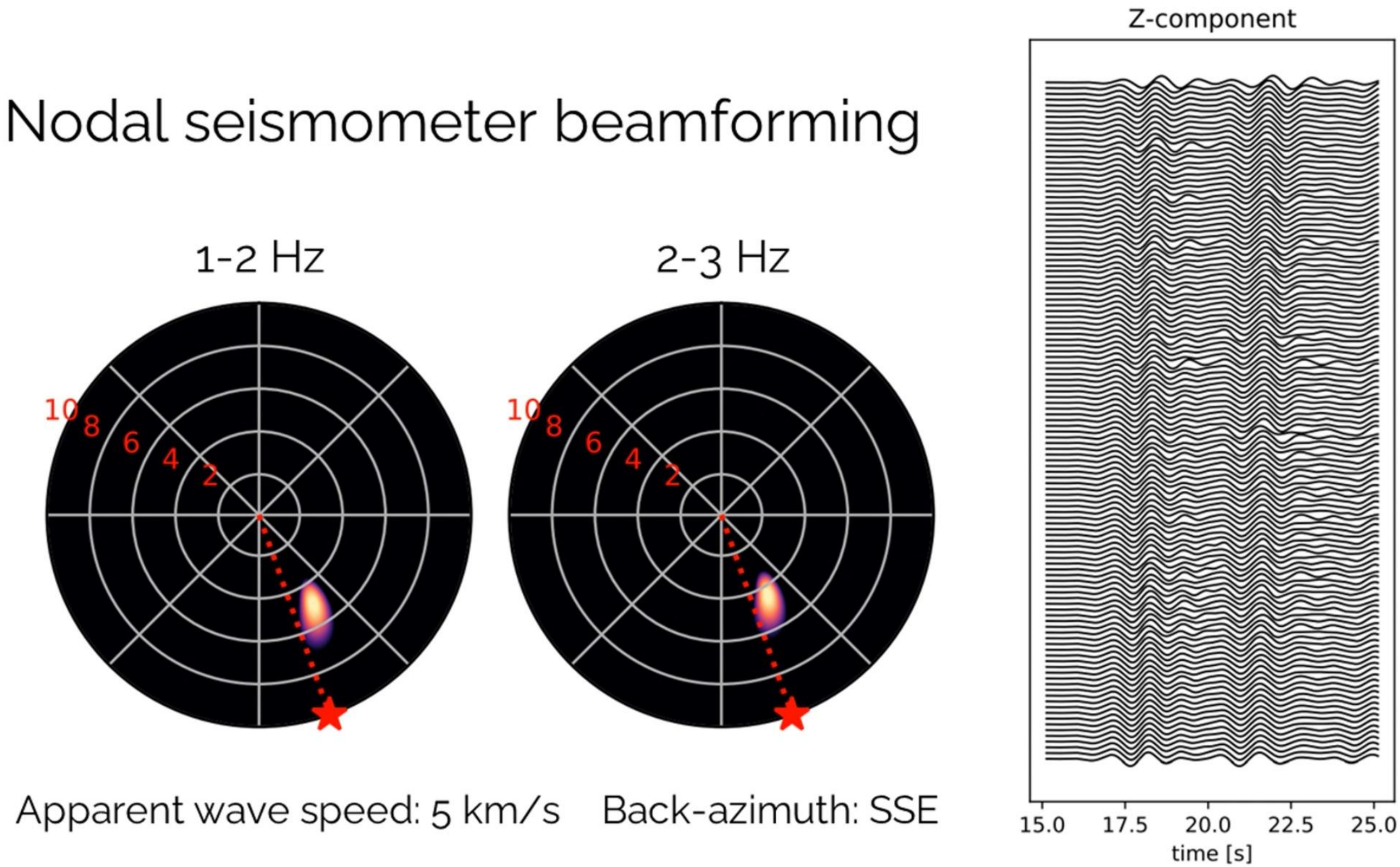
See: Feigle & the PoroTomo team (2018)
Wang et al. (2018)





Martijn van den Ende, University Côte d’Azur

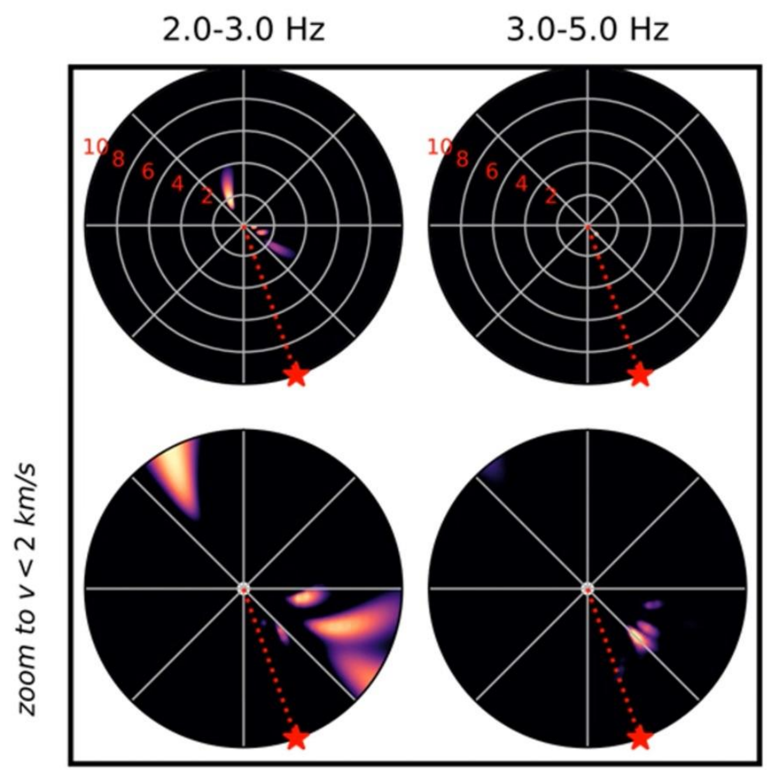
The challenges (and solutions) of using fibre-optic cables as seismological antennas

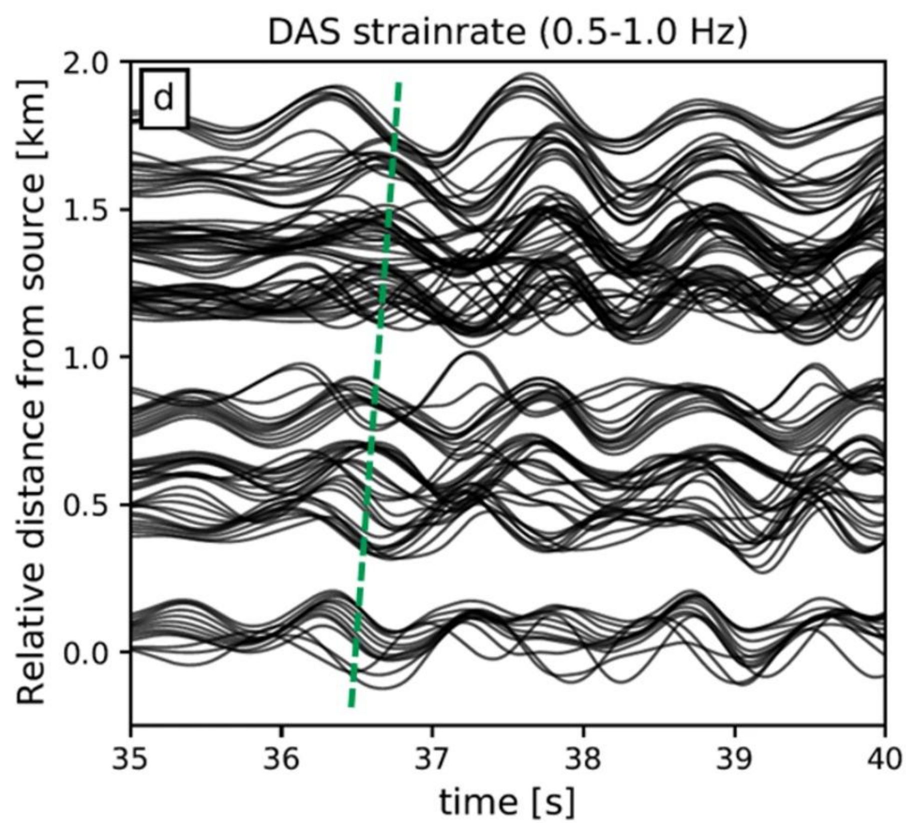


Martijn van den Ende, University Côte d'Azur

The challenges (and solutions) of using fibre-optic cables as seismological antennas

DAS beamforming - poor due to lack of coherence

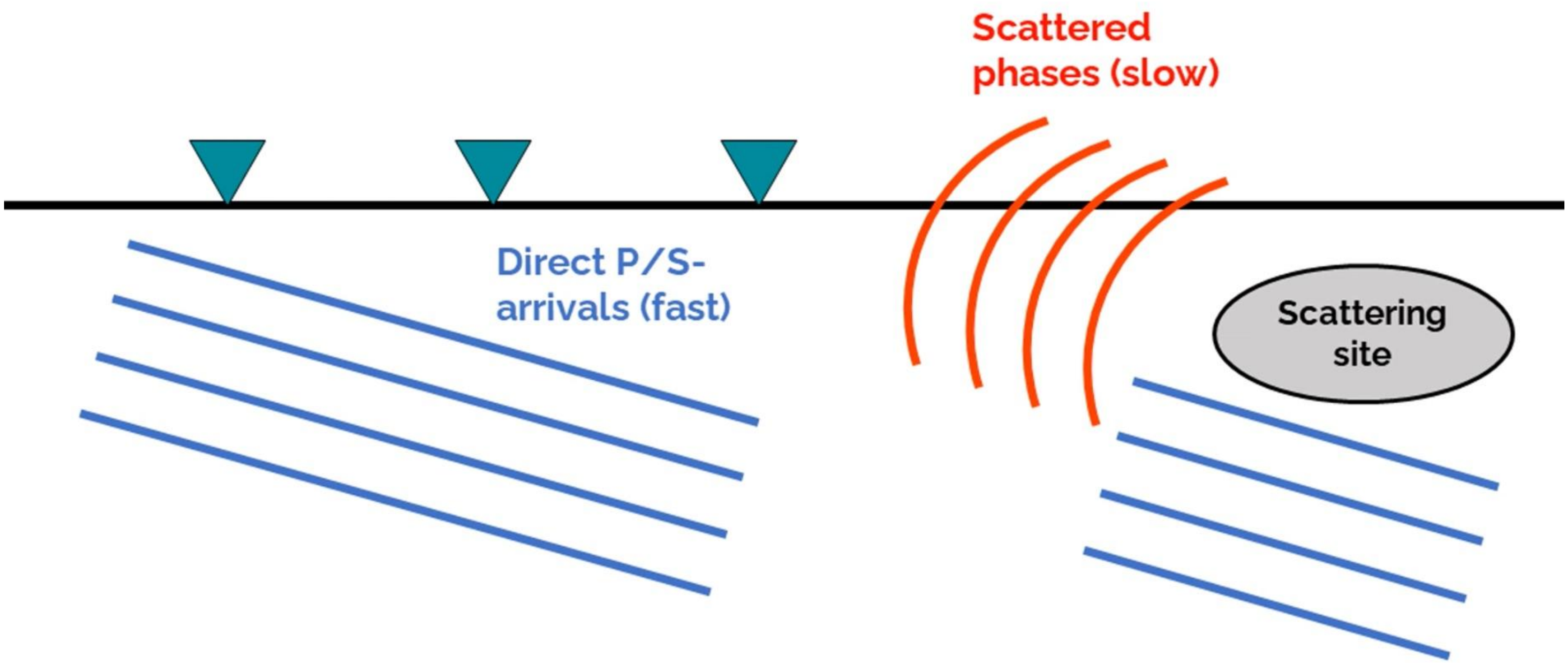




Martijn van den Ende, University Côte d’Azur

The challenges (and solutions) of using fibre-optic cables as seismological antennas

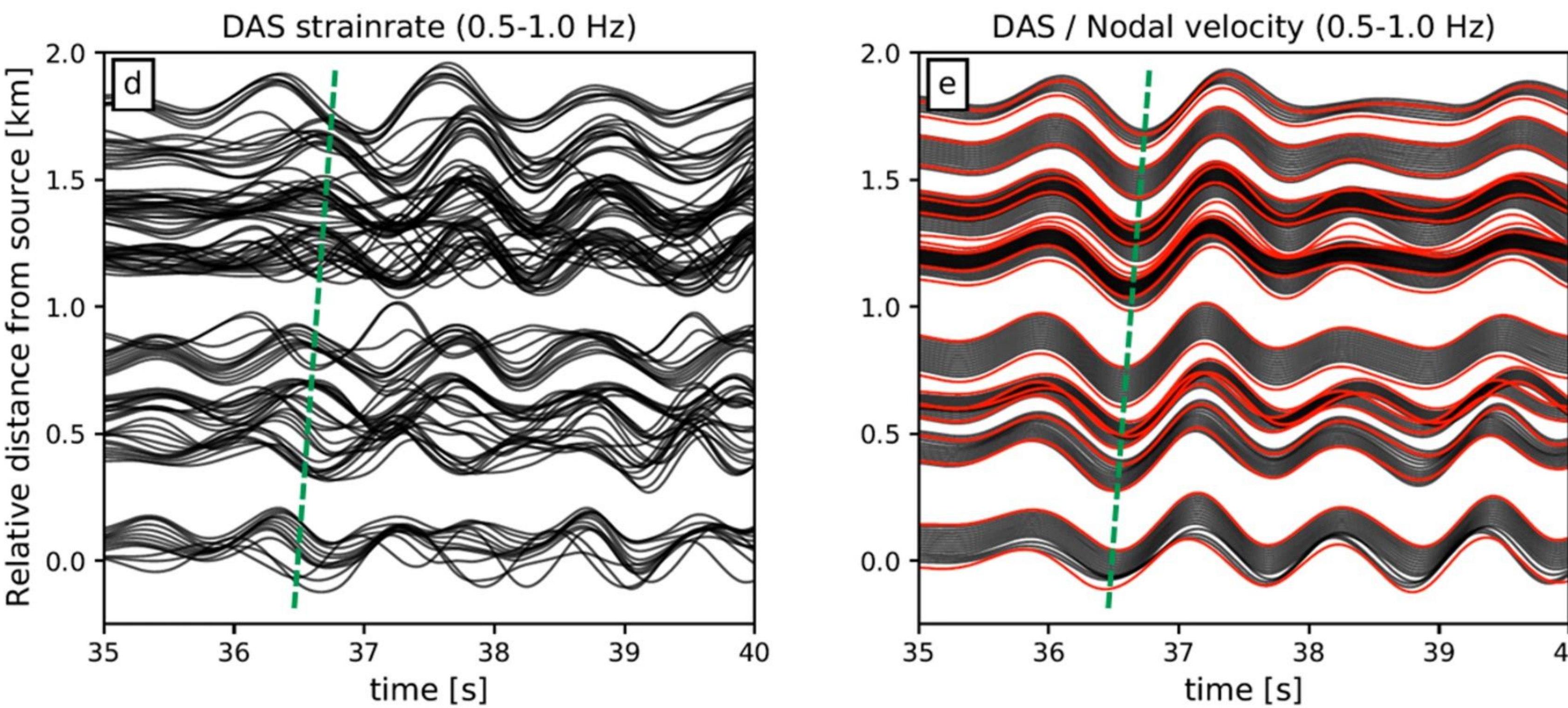
Interpretation - DAS directional sensitivity



Martijn van den Ende, University Côte d’Azur

The challenges (and solutions) of using fibre-optic cables as seismological antennas

Solution - use seismometer as reference, integrate DAS data

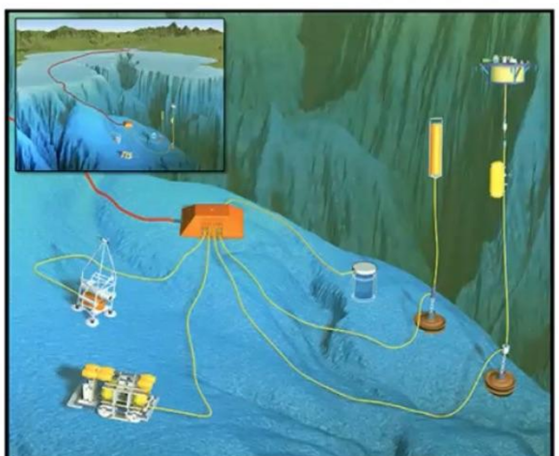


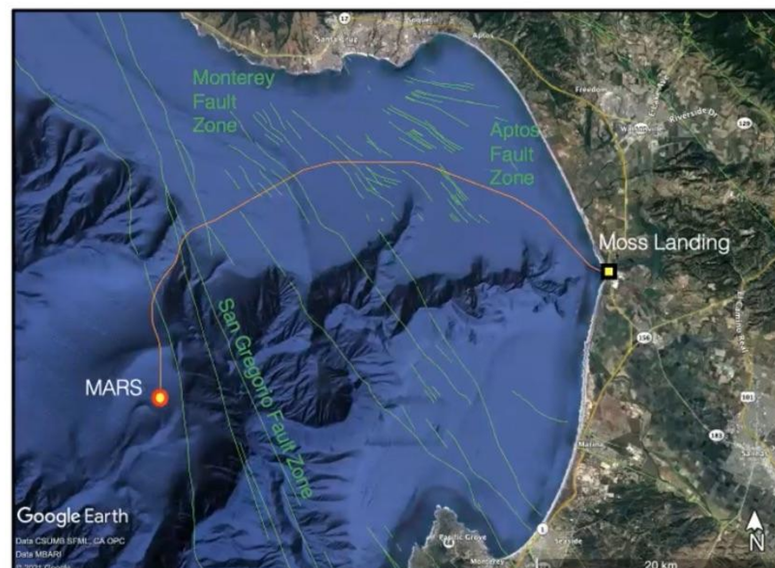
Bin Luo, Stanford University

Distributed acoustic sensing using long range submarine fiber-optic cables

Submarine fiber-optic cable at Monterey Bay

- A 52-km-long submarine fiber-optic cable connecting to the MARS observatory
- The cable trajectory intersects with multiple fault zones

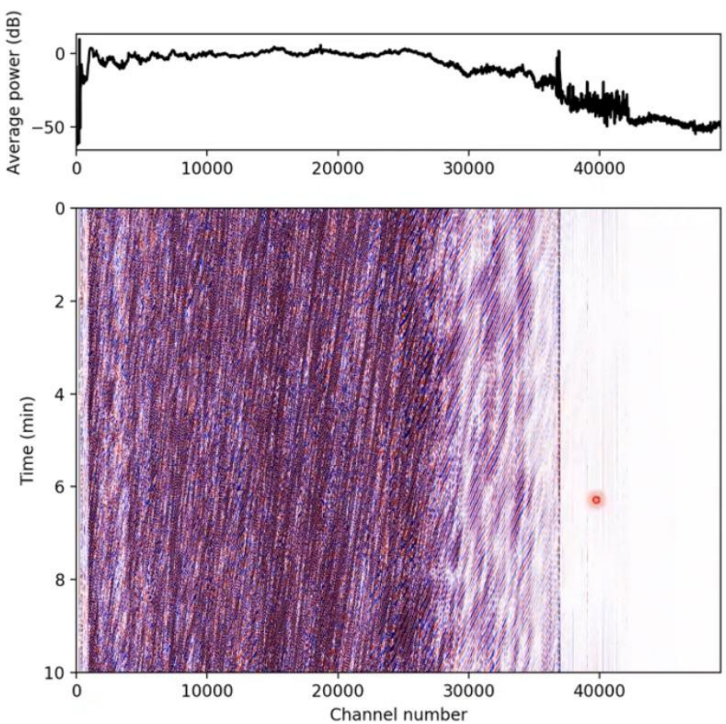


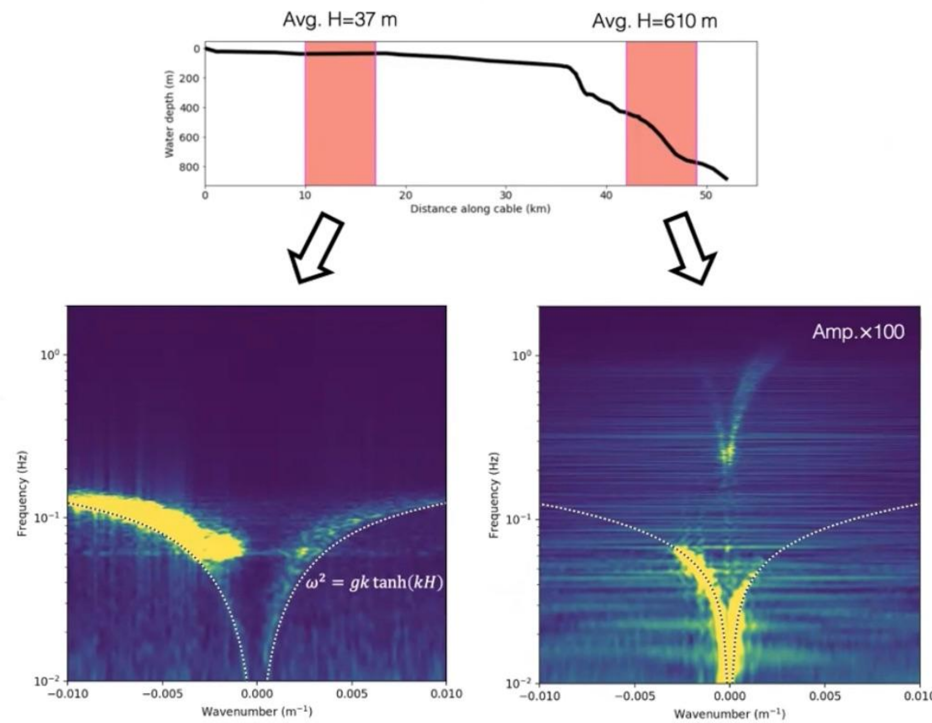


Bin Luo, Stanford University

Distributed acoustic sensing using long range submarine fiber-optic cables

Use DAS data to study signals and noise in the ocean



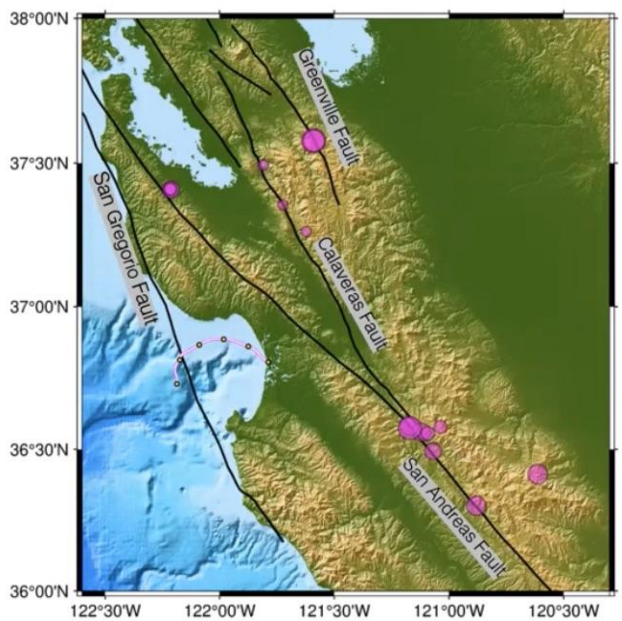


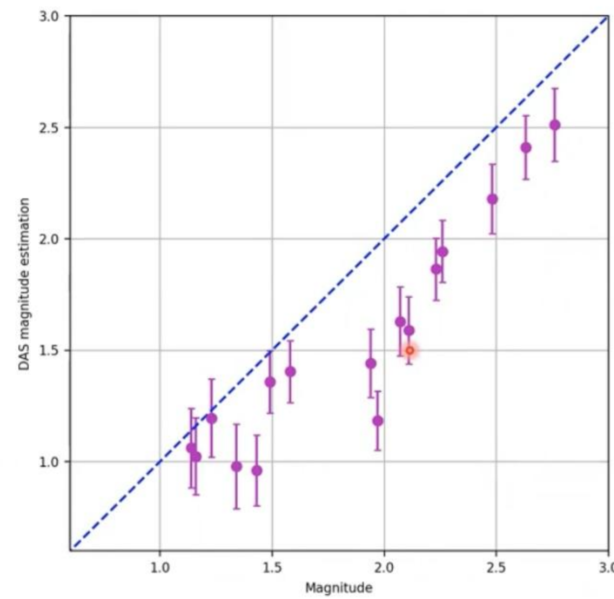
Bin Luo, Stanford University

Distributed acoustic sensing using long range submarine fiber-optic cables

Use DAS data to detect earthquakes and estimate magnitudes

M>1.1 earthquakes are detected





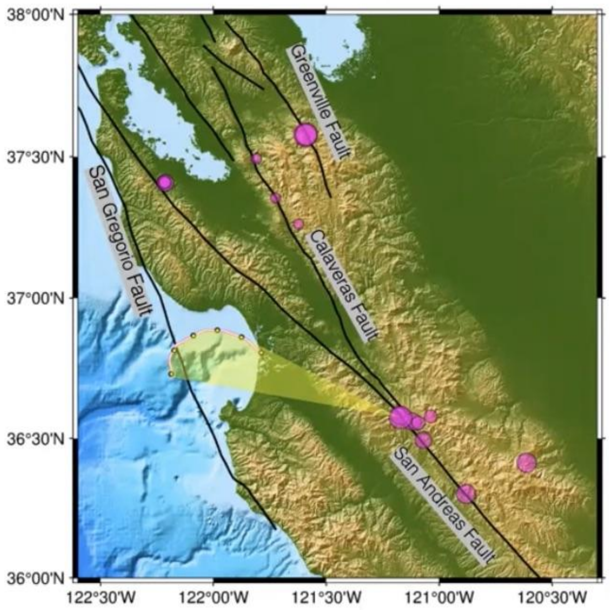
$$M_L = \log_{10}(S_{DAS} \times 10^6 \times GL) + 2.56 \times \log_{10} R - 1.67$$

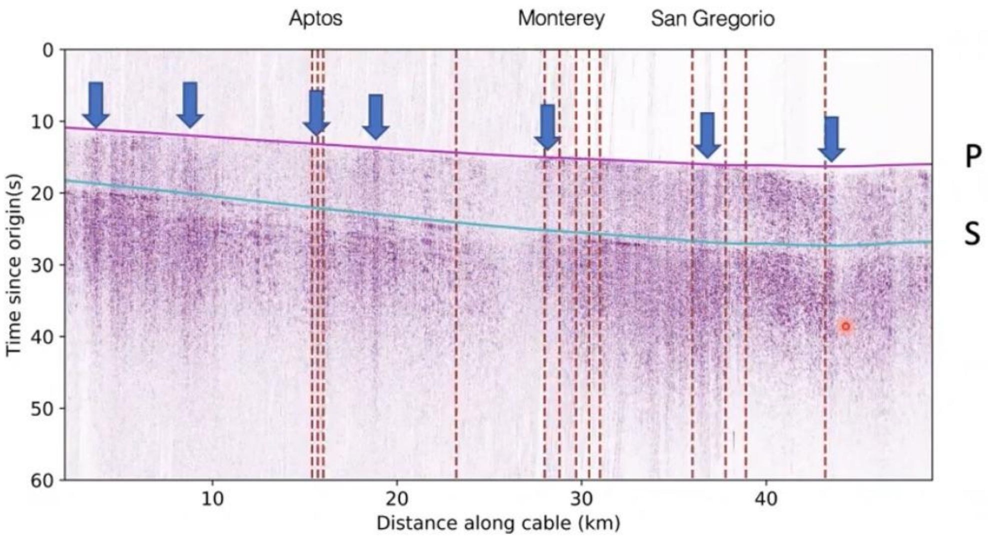
e.g., Lellouch et al., 2021, *SRL*

Bin Luo, Stanford University

Distributed acoustic sensing using long range submarine fiber-optic cables

Use DAS data to detect faults via scattered waves

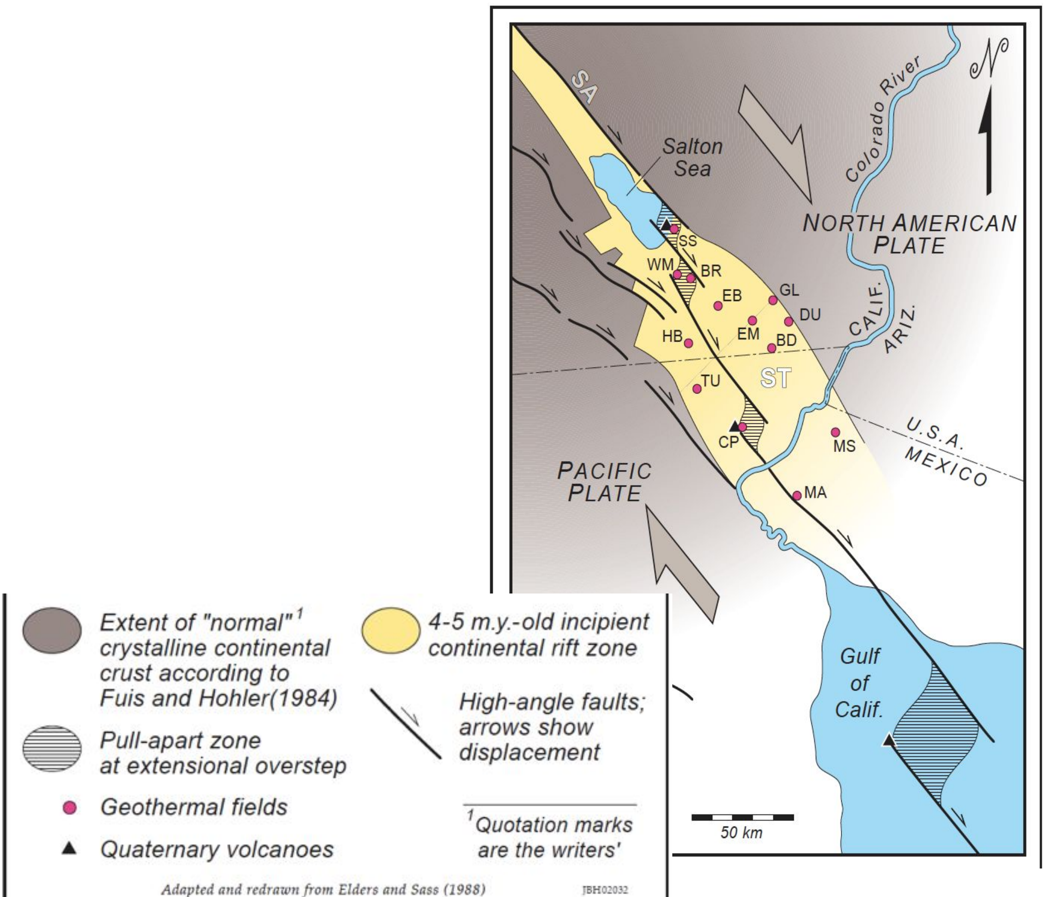


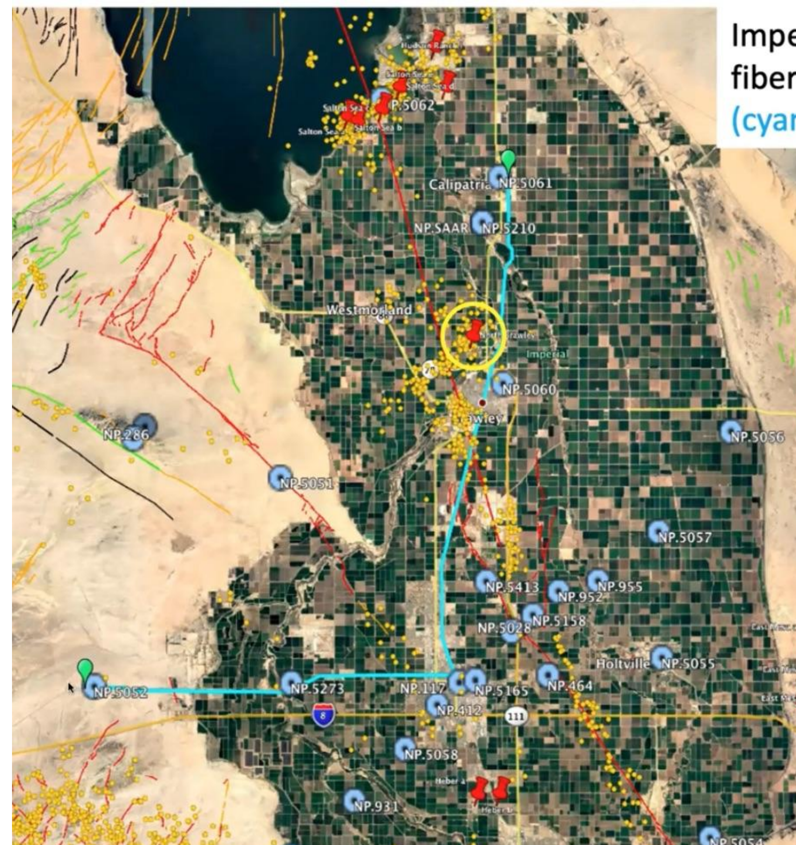


Jonathan Ajo-Franklin, Rice University

Exploring The Subsurface with Regional DAS Networks: Results from the Imperial Valley Dark Fiber Project

Imperial Valley geothermal fields and DAS transect





Jonathan Ajo-Franklin, Rice University

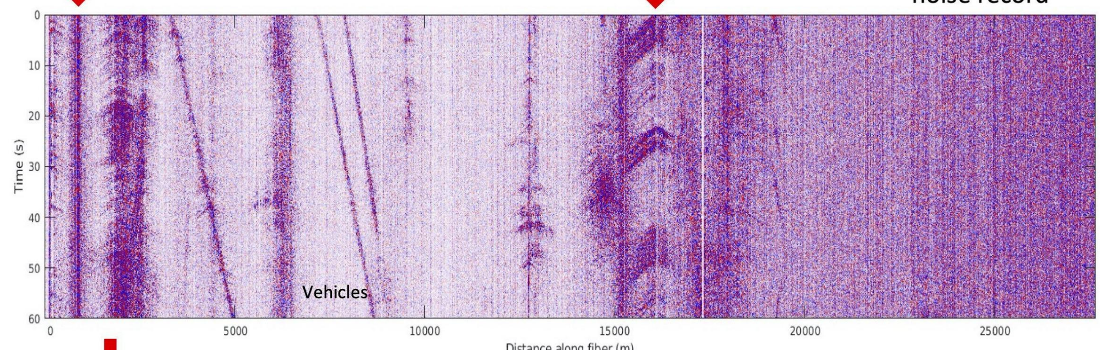
Exploring The Subsurface with Regional DAS Networks: Results from the Imperial Valley Dark Fiber Project

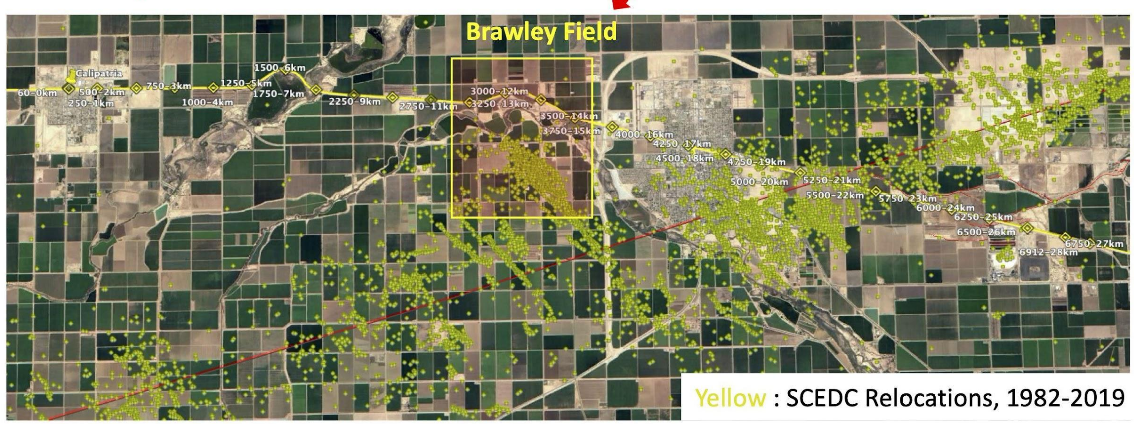
Abundant sources of noise:

Vehicles
Trains
Industry

Sources of persistent surface waves

60 second DAS noise record

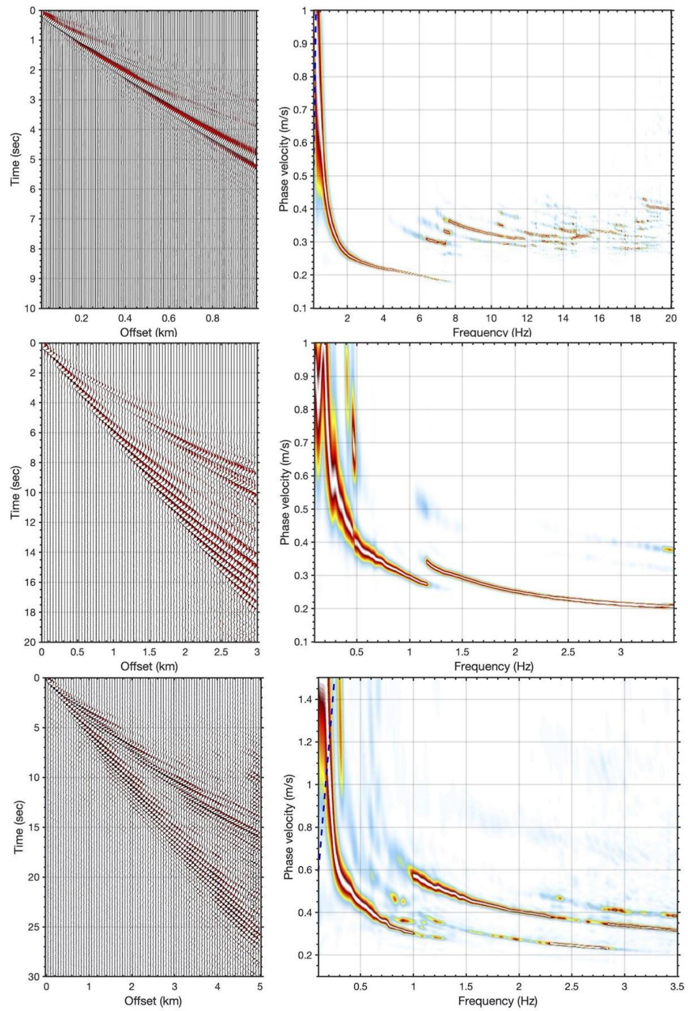


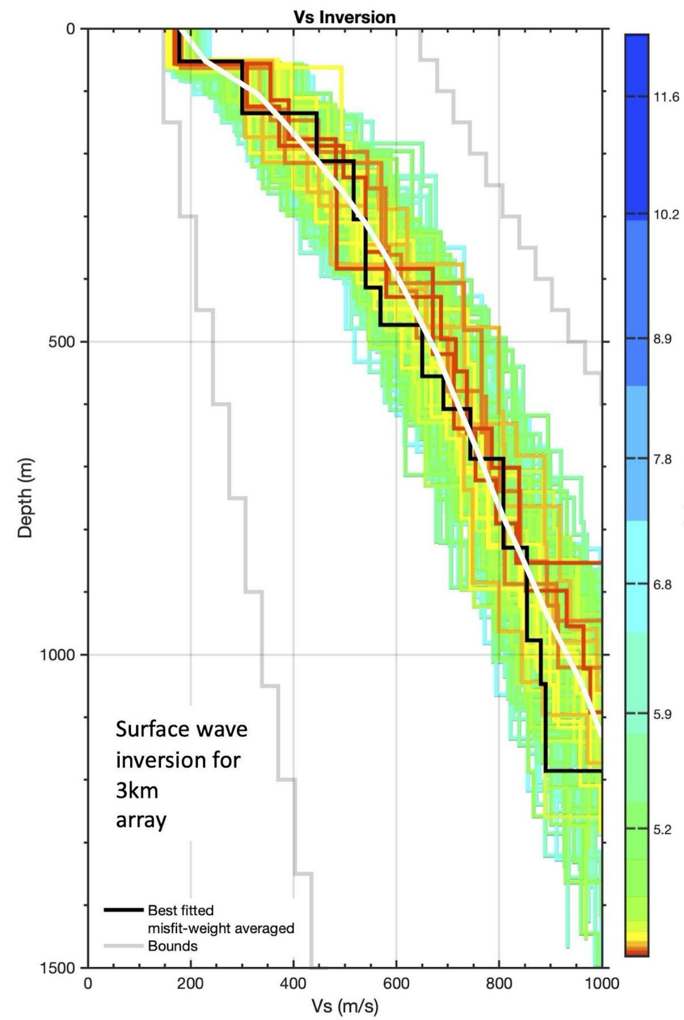


Jonathan Ajo-Franklin, Rice University

Exploring The Subsurface with Regional DAS Networks: Results from the Imperial Valley Dark Fiber Project

Vs models from ambient noise analysis for array subsets of varying length (1, 3, 5 km)

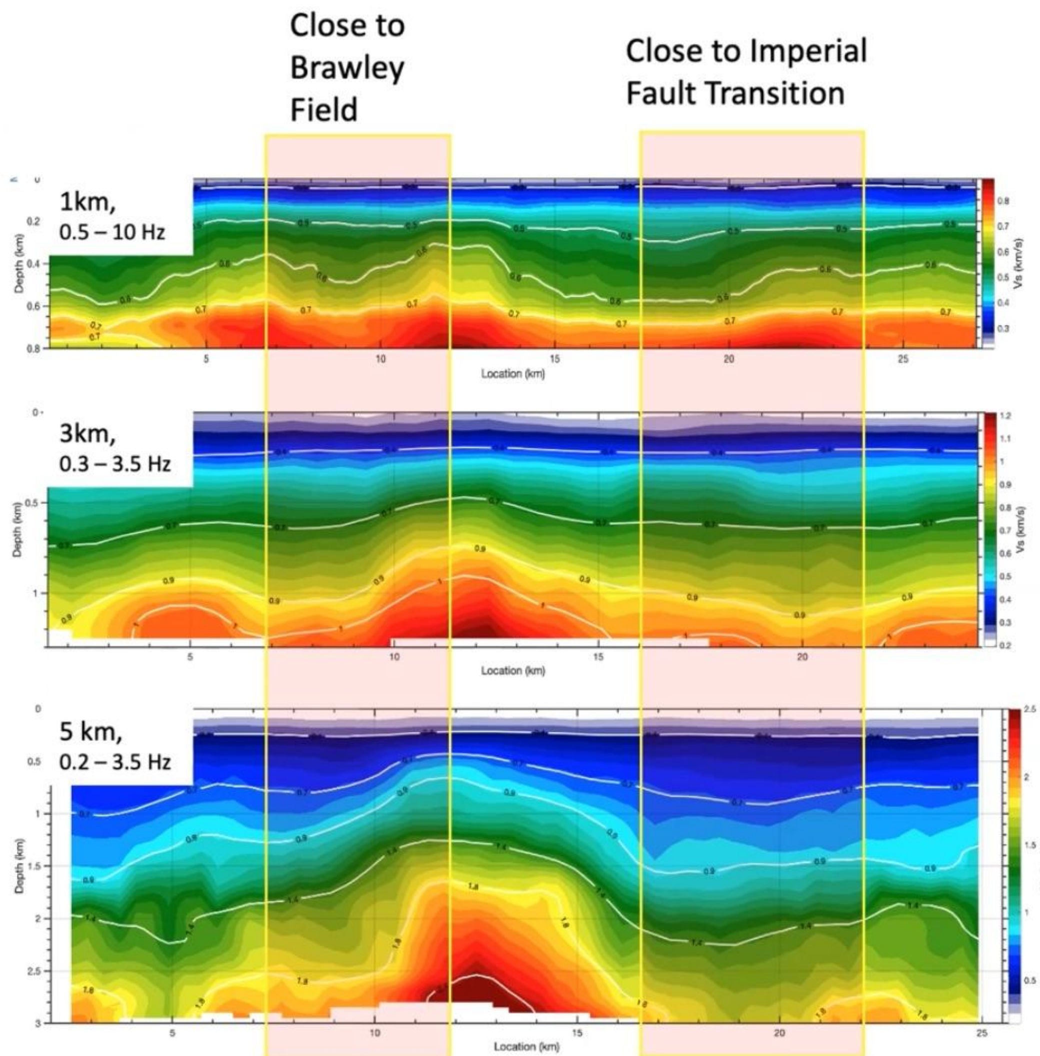




Jonathan Ajo-Franklin, Rice University

Exploring The Subsurface with Regional DAS Networks: Results from the Imperial Valley Dark Fiber Project

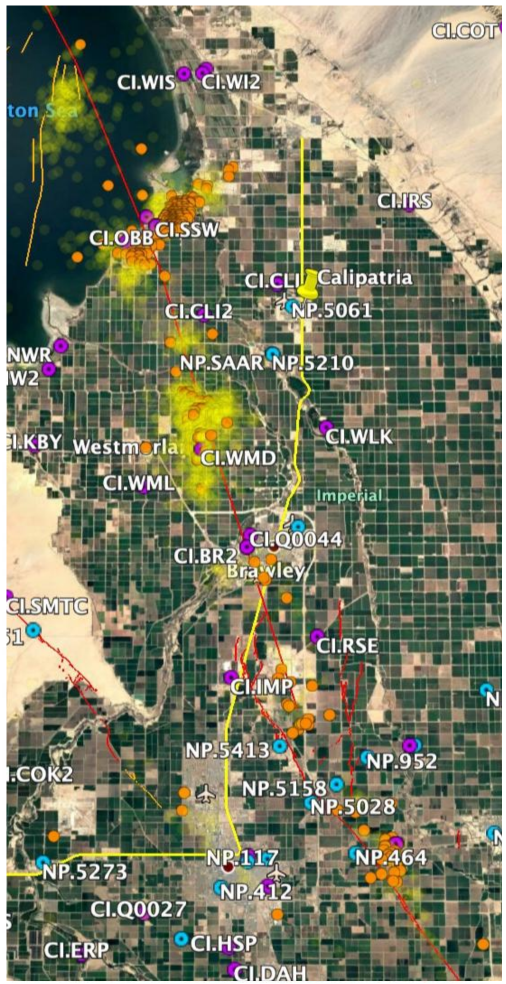
"Stitched" Vs models from the different array subsets (1, 3, 5 km) reaching to different depths (note: blue slow, red fast)

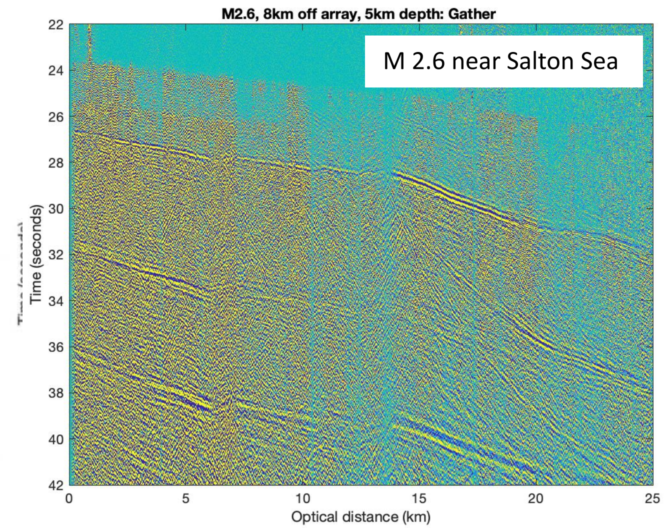


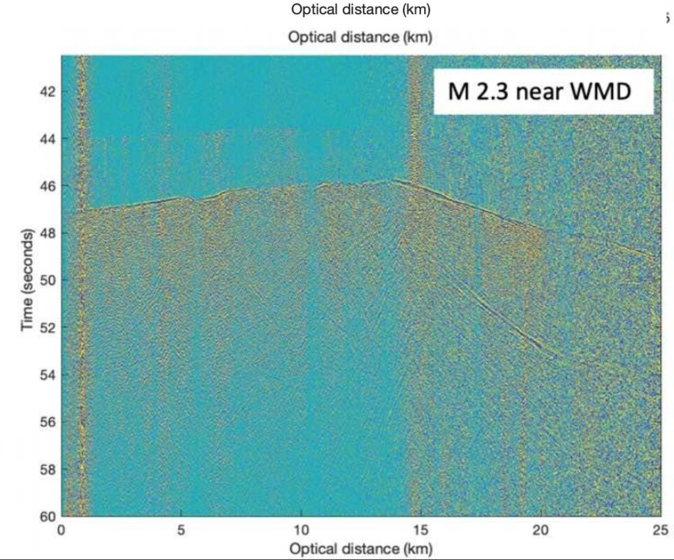
Jonathan Ajo-Franklin, Rice University

Exploring The Subsurface with Regional DAS Networks: Results from the Imperial Valley Dark Fiber Project

Abundant earthquake data



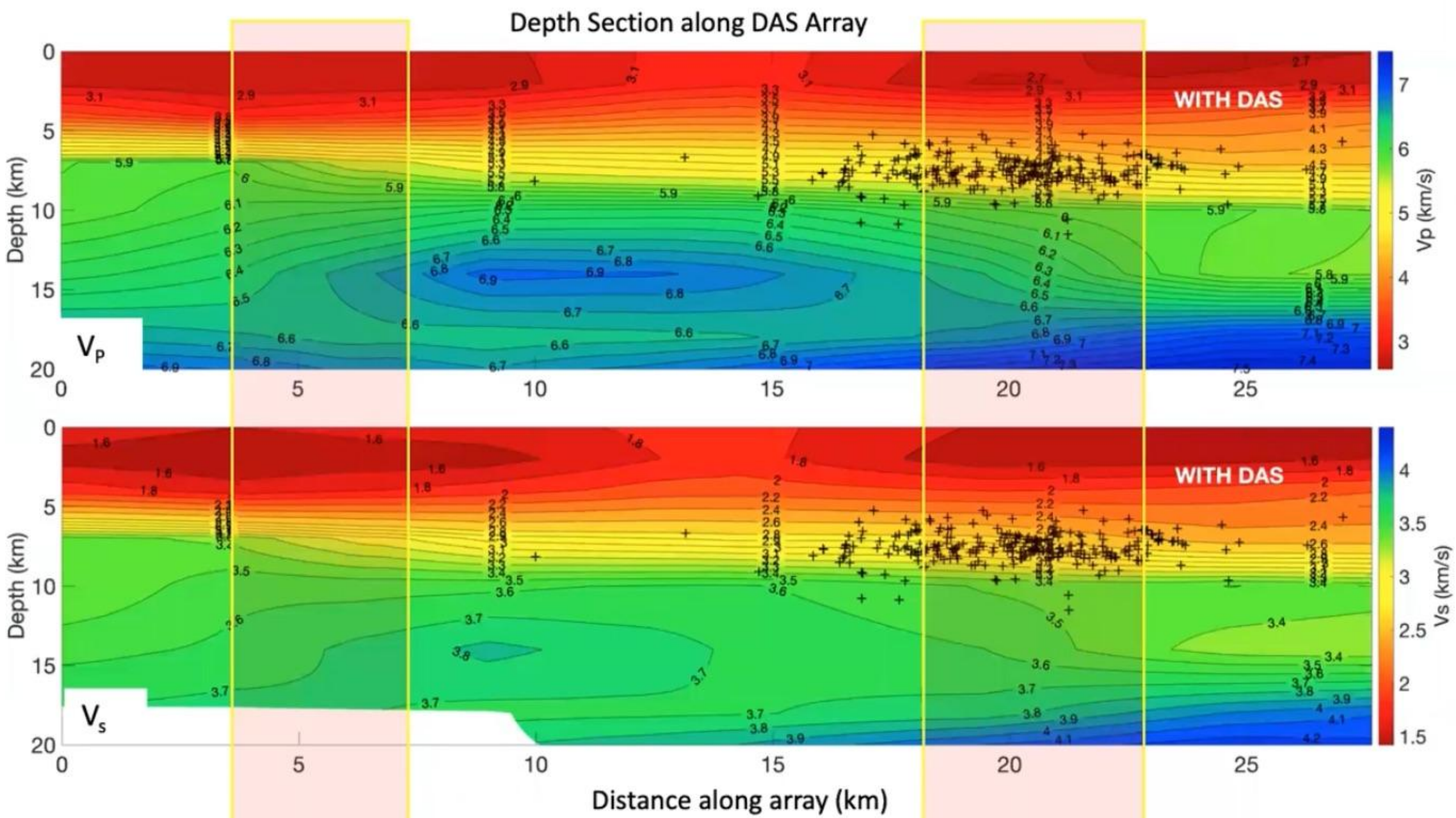




Jonathan Ajo-Franklin, Rice University

Exploring The Subsurface with Regional DAS Networks: Results from the Imperial Valley Dark Fiber Project

Body-wave tomography



Jonathan Ajo-Franklin, Rice University

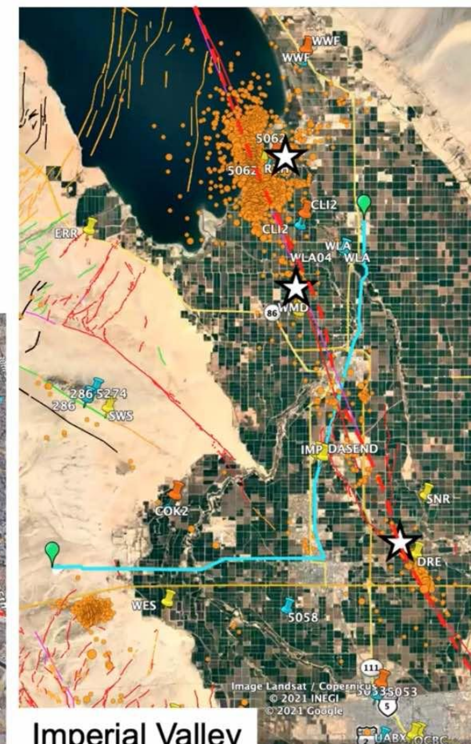
Exploring The Subsurface with Regional DAS Networks: Results from the Imperial Valley Dark Fiber Project

DAS & Dark Fiber for Fault Observatories?

- Recent studies have shown the benefits of large N arrays across faults for both imaging & monitoring seismicity.
- A large number of locations across CA where the San Andreas and associated fault systems cross existing subsurface fiber lines.
- Potential for effectively instrumenting faults in high resolution; value increases with continuous acquisition. Also potential for inter-array imaging.
- Continuing acquisition on this and other transects could provide a powerful resource for exploring the fine scale characteristics of the most relevant active faults. A community opportunity?

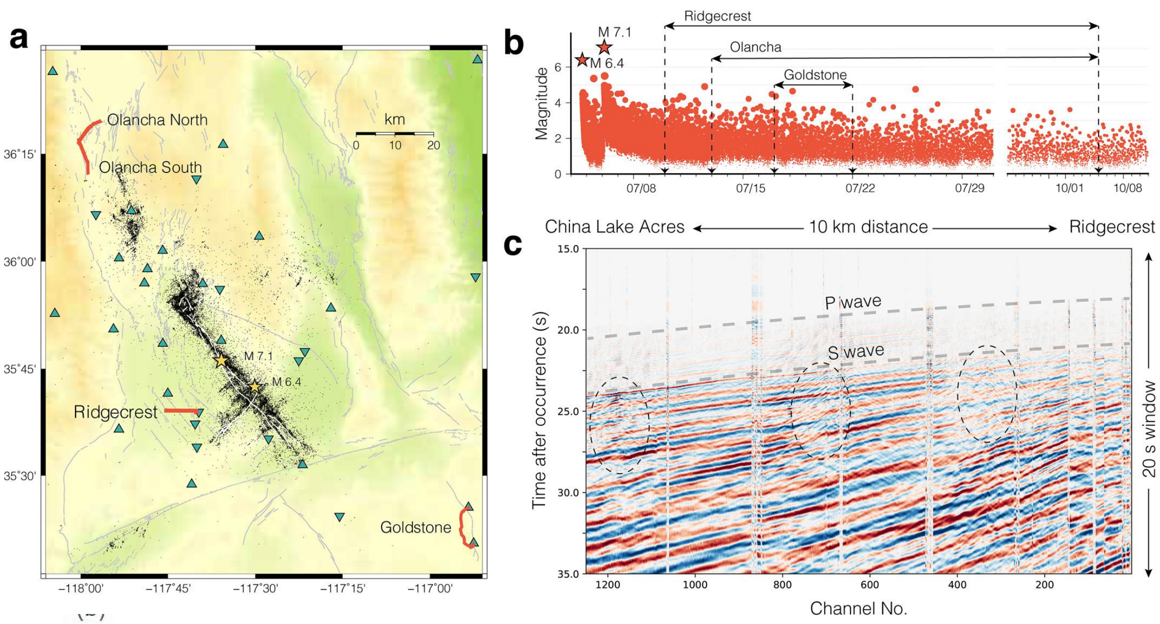
Near Paso Robles?

Near Palmdale?

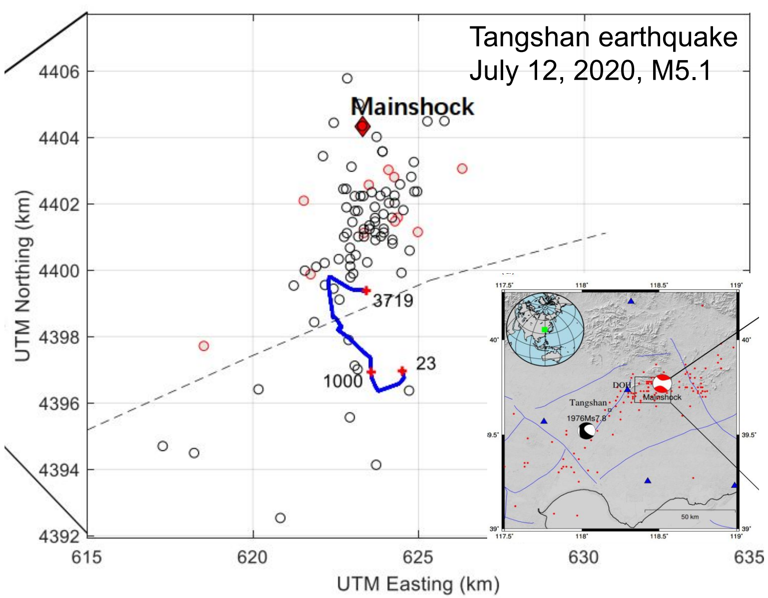


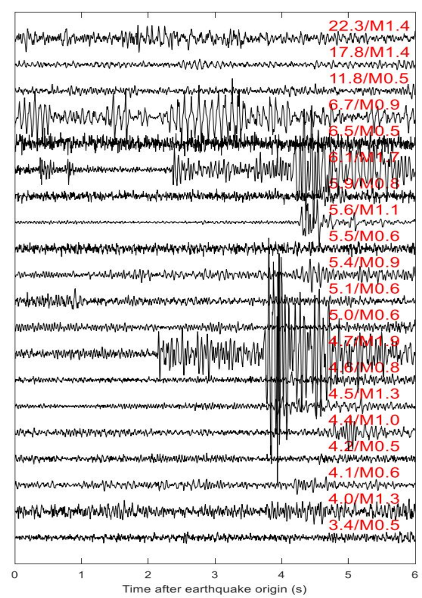
Imperial Valley

DAS for aftershock recording



Rapid Response to the 2019 Ridgecrest Earthquake With Distributed Acoustic Sensing, AGU Advances, Volume: 2, Issue: 2, First published: 25 June 2021, DOI: (10.1029/2021AV000395)





Turning a telecom fiber-optic cable into an ultra-dense seismic array for rapid post-earthquake response in an urban area, Seismological Research Letters, revised and resubmitted, Aug. 2021.