Seismology, oceanography, and bioacoustics with DAS on the OOI RCA

Ethan F. Williams

Brad Lipovsky, William Wilcock, Shima Abadi, Marine Denolle, and Qibin Shi

with thanks to…

Deborah Kelley, Chuck McGuire, Kellen Rosburg, Mike Harrington, Nataliya Vorobyeva, Ken Feldman, Dennis Manning, and Dan Reeves

OCEAN OBSERVATORIES INITIATIVE

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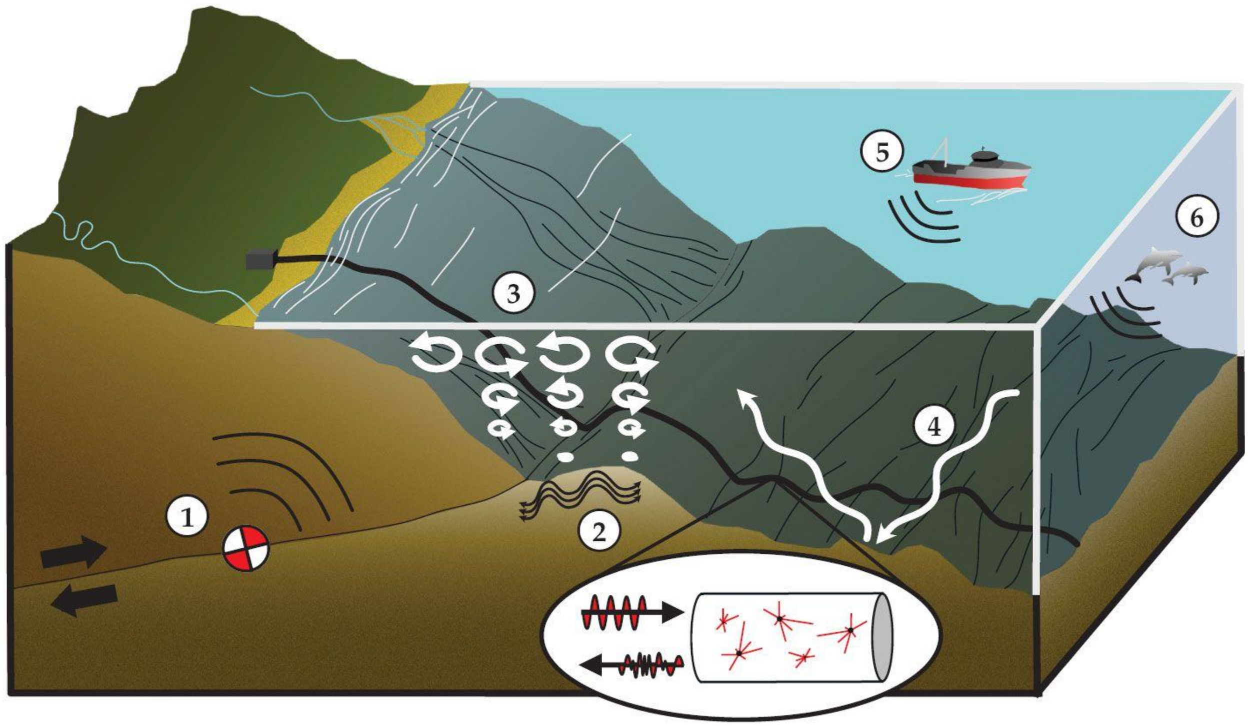
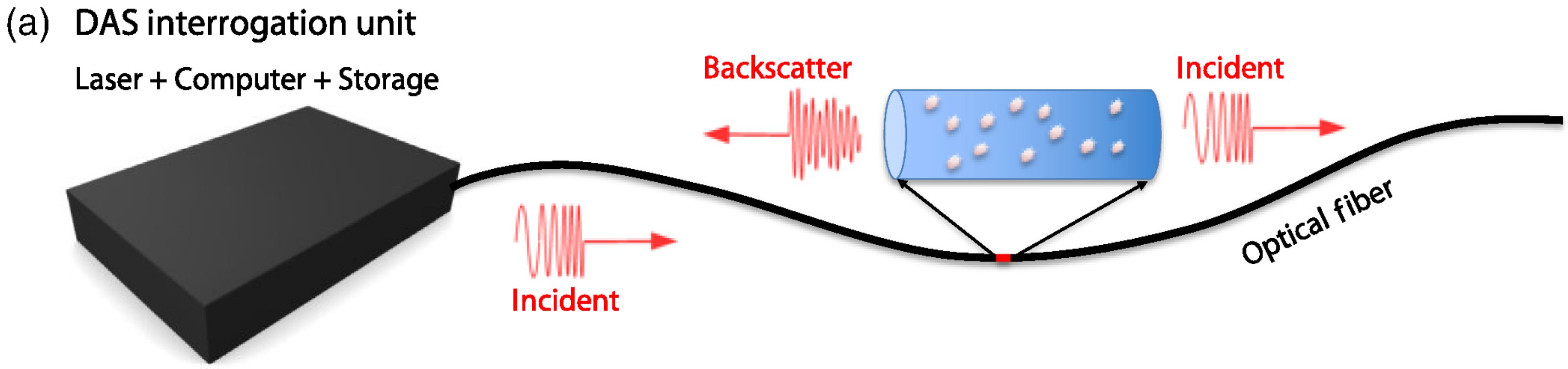
Distributed acoustic sensing (DAS)

- Converts ordinary optical fibers into dense linear arrays of sensors
- Can record strain from seismic/acoustic waves as well as temperature perturbations

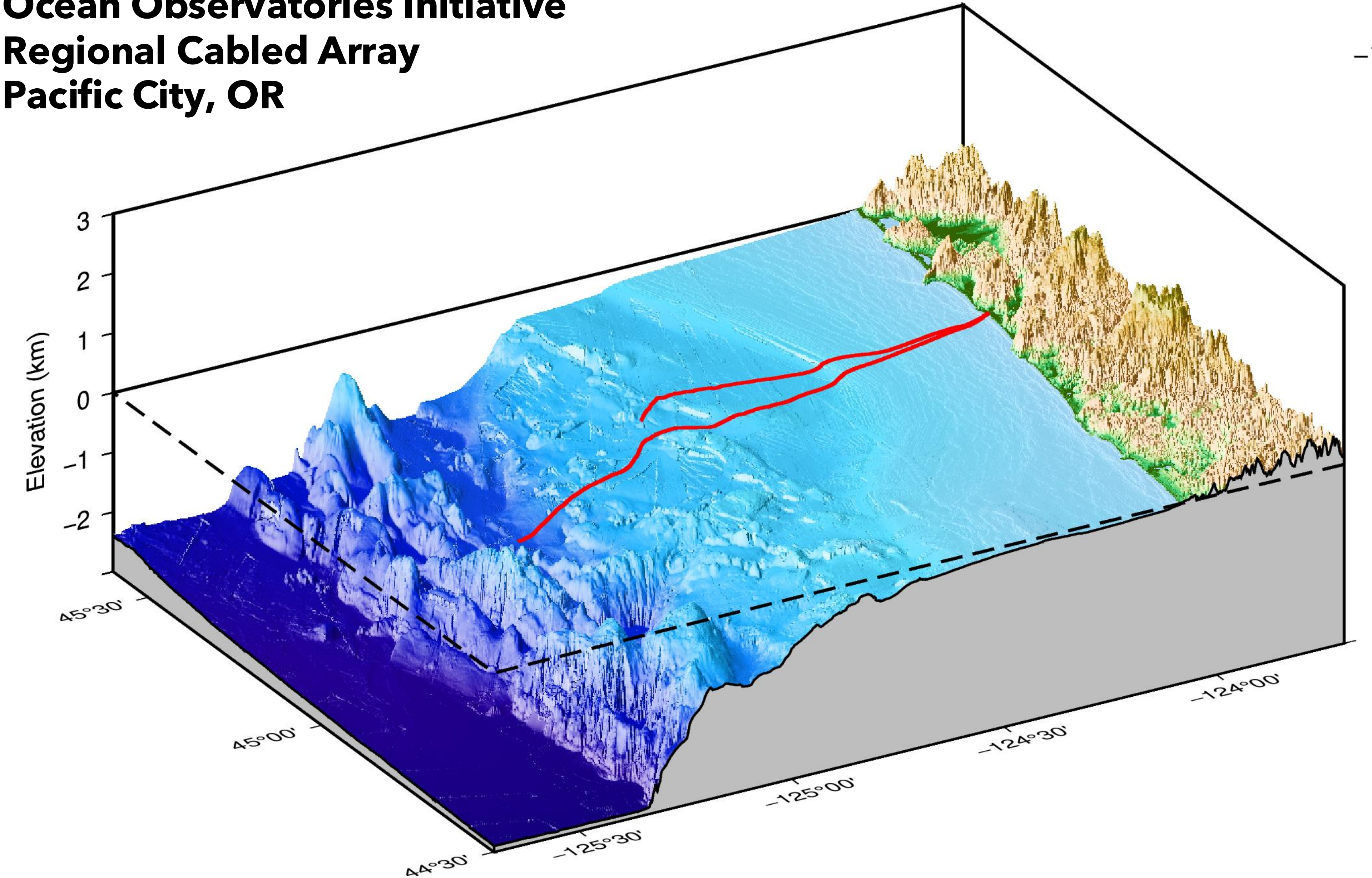


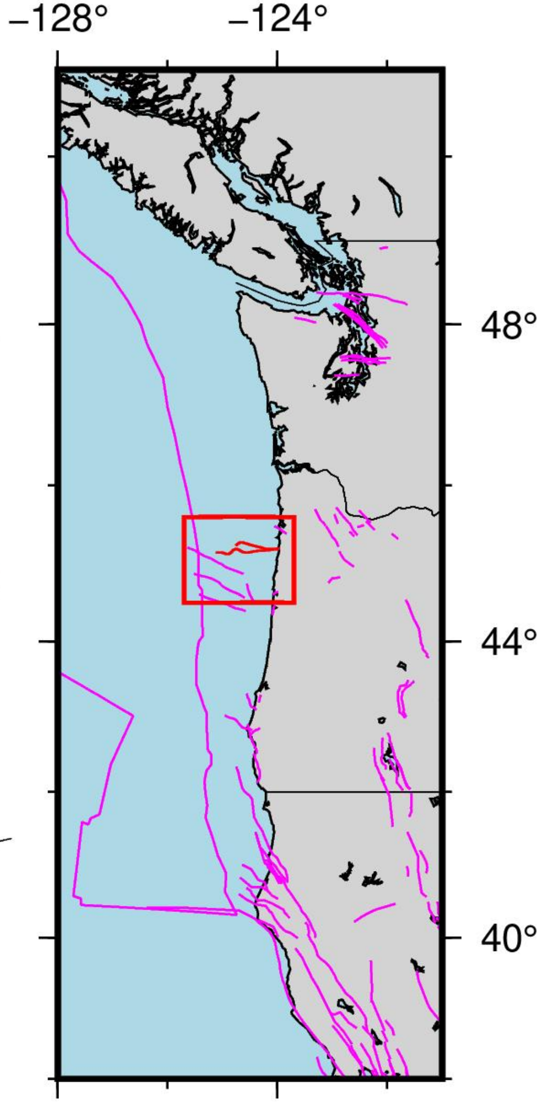


Zhan (2020)

Williams (2022)

Ocean Observatories Initiative
Regional Cabled Array
Pacific City, OR





Multiplexed DAS with lit fiber on the OOI RCA

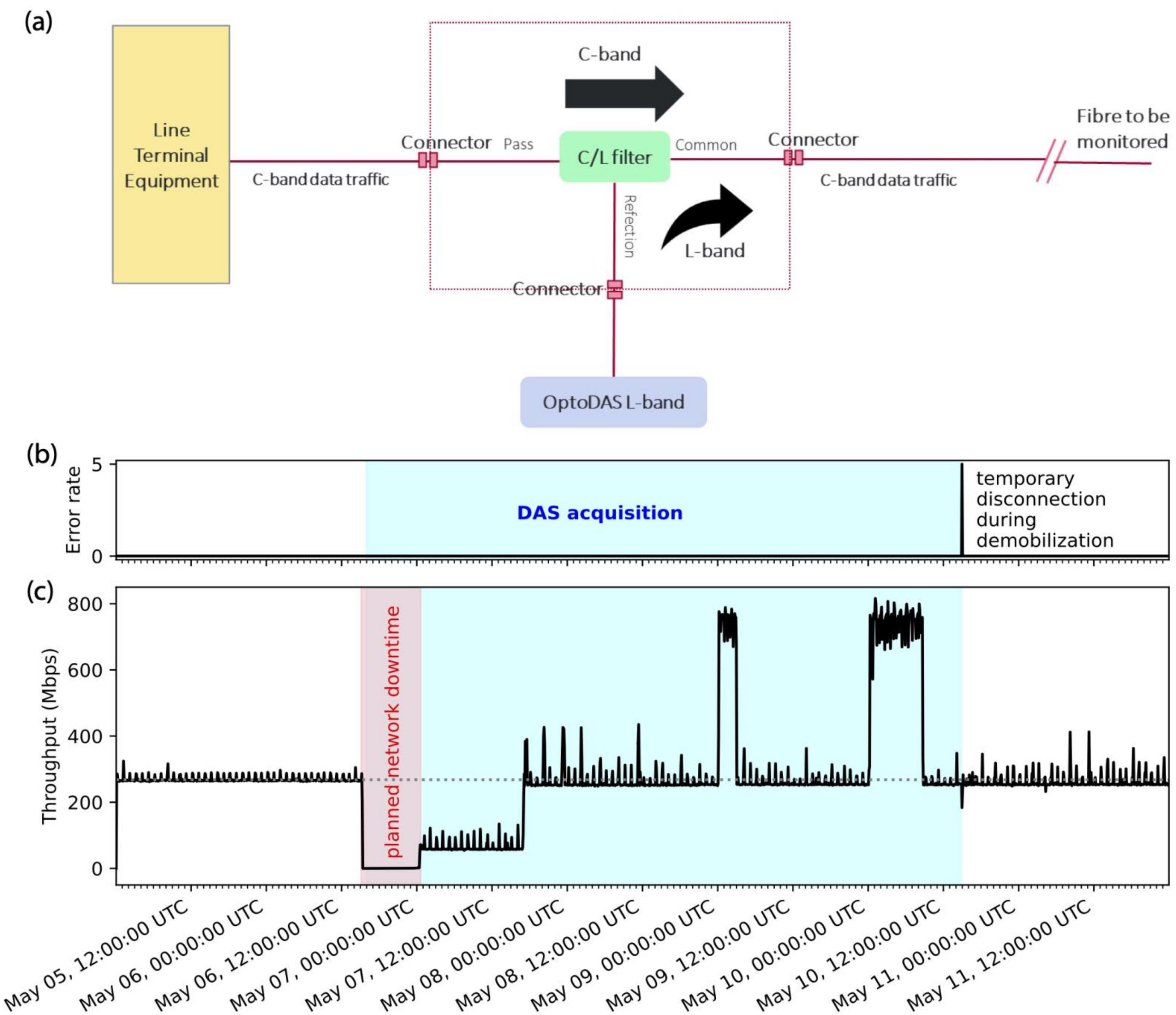
4-day experiment in May 2024

DAS data acquired on both lit and dark fiber

Network error rate and throughput archived during the lit-fiber part of the experiment

<u>Conclusions:</u>

- No measurable impact of C-band RCA observatory communications on DAS data quality, and vice versa
- DAS on the OOI RCA can now be collected at any time, without interrupting observatory telemetry



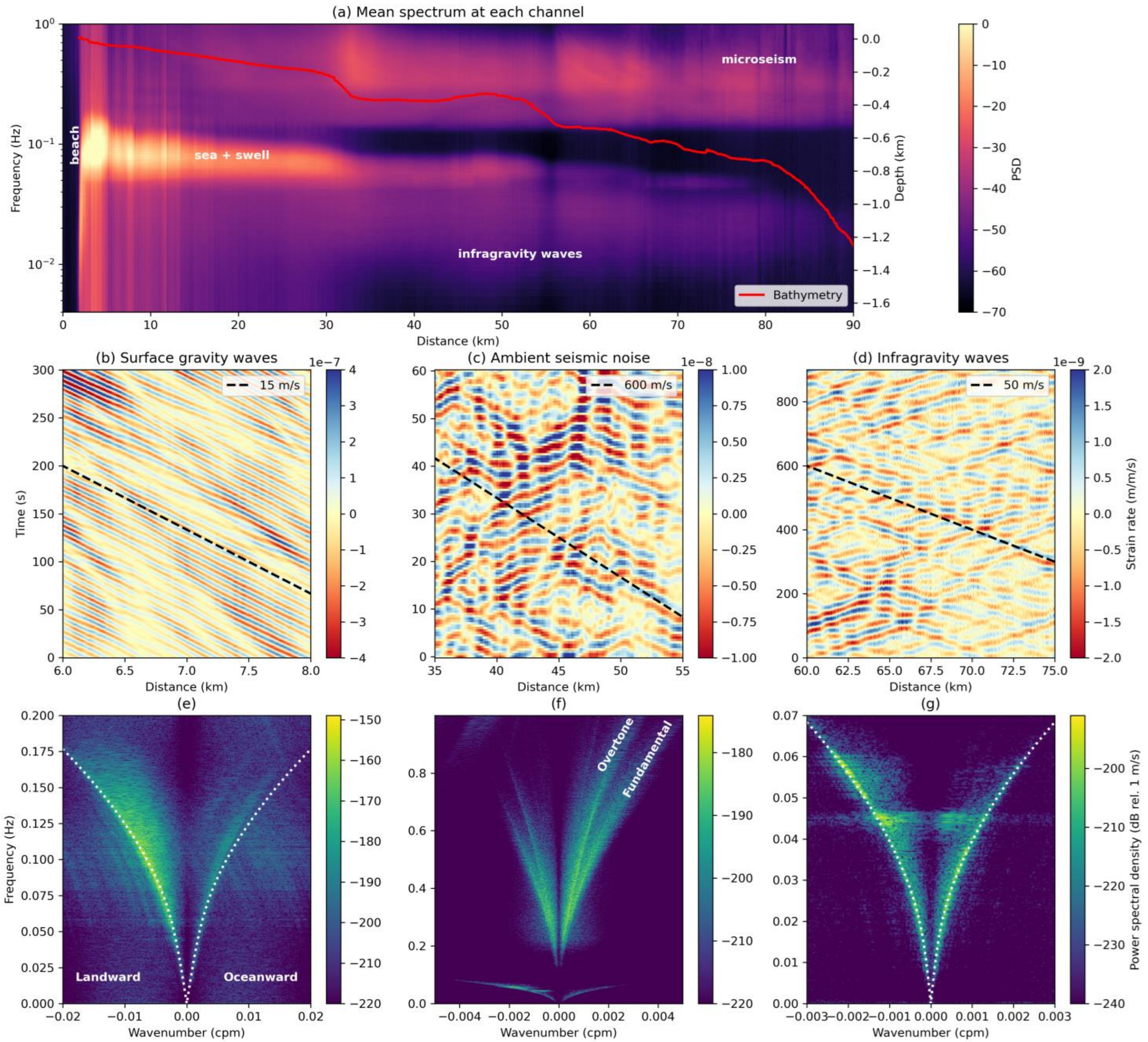
Ocean and solid-earth signals at low frequencies (< 1 Hz)

<u>Ocean surface gravity waves:</u>

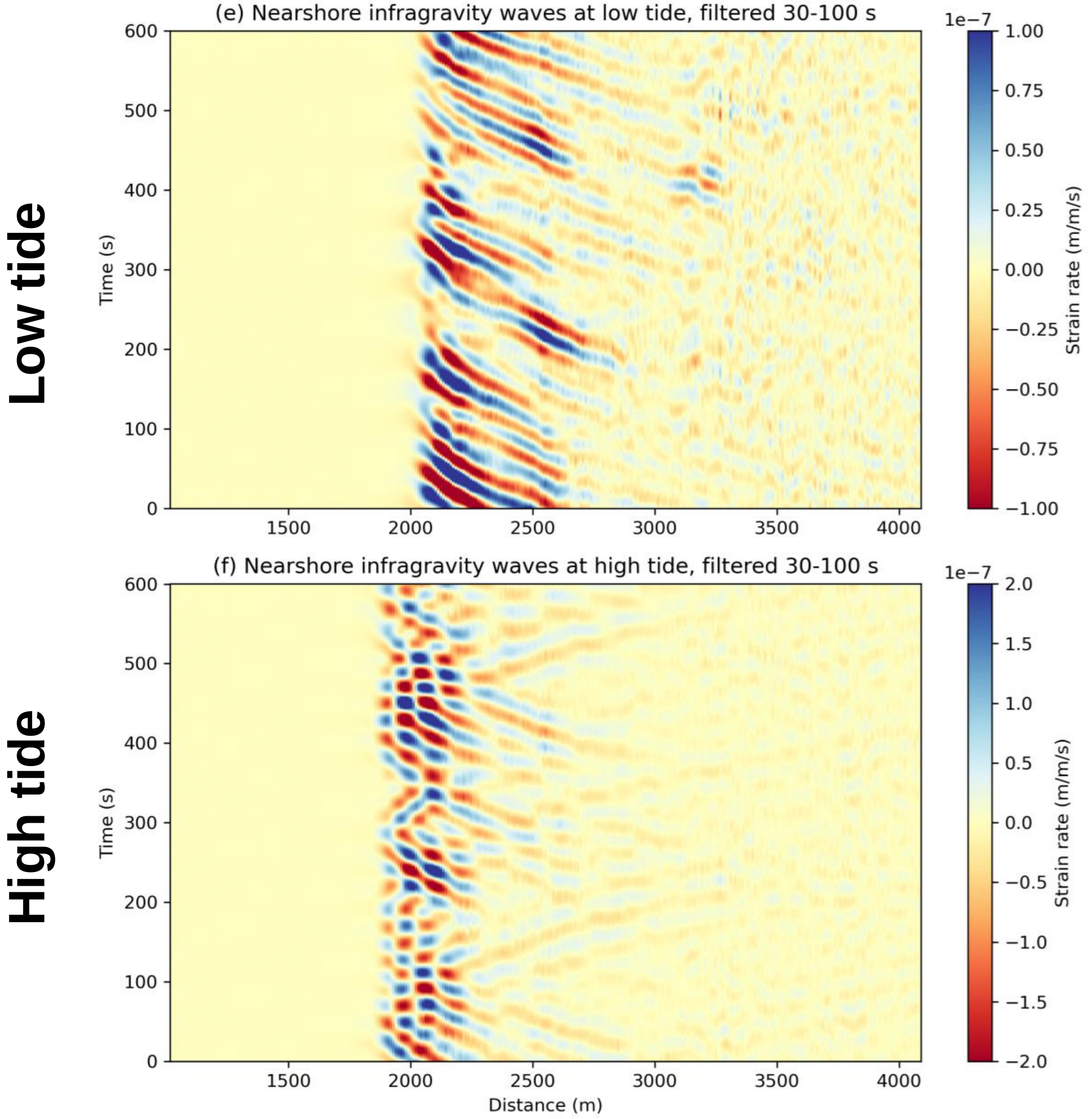
- Apply pressure at the seafloor, which induces strain the the buried cable
- Shorter period (2-20 s) wind waves and swell are visible across the shallow shelf in water <200 m depth
- Longer period (30-300 s) infragravity waves are visible across the full cable

<u>Seismic waves:</u>

- Rayleigh/Scholte waves, seismic surface waves, are visible along the full cable (1-10 s period)
- The ambient seismic wavefield (called microseism) is partially generated locally by ocean wave interactions, as generated by Jiaqi Feng (Caltech) with the 2021 OOI RCA DAS dataset



Tidal modulation of infragravity waves (IGW) across the Oregon shelf



Observations:

(1) IGWs are strongly tidally modulated when observed at all water depths, up to a factor of 10x in energy, with highest energy at high tide.

(2) Up to 10x higher free IGW energy is propagating away from shore into the Pacific => consistent with expectations for generation at the coast

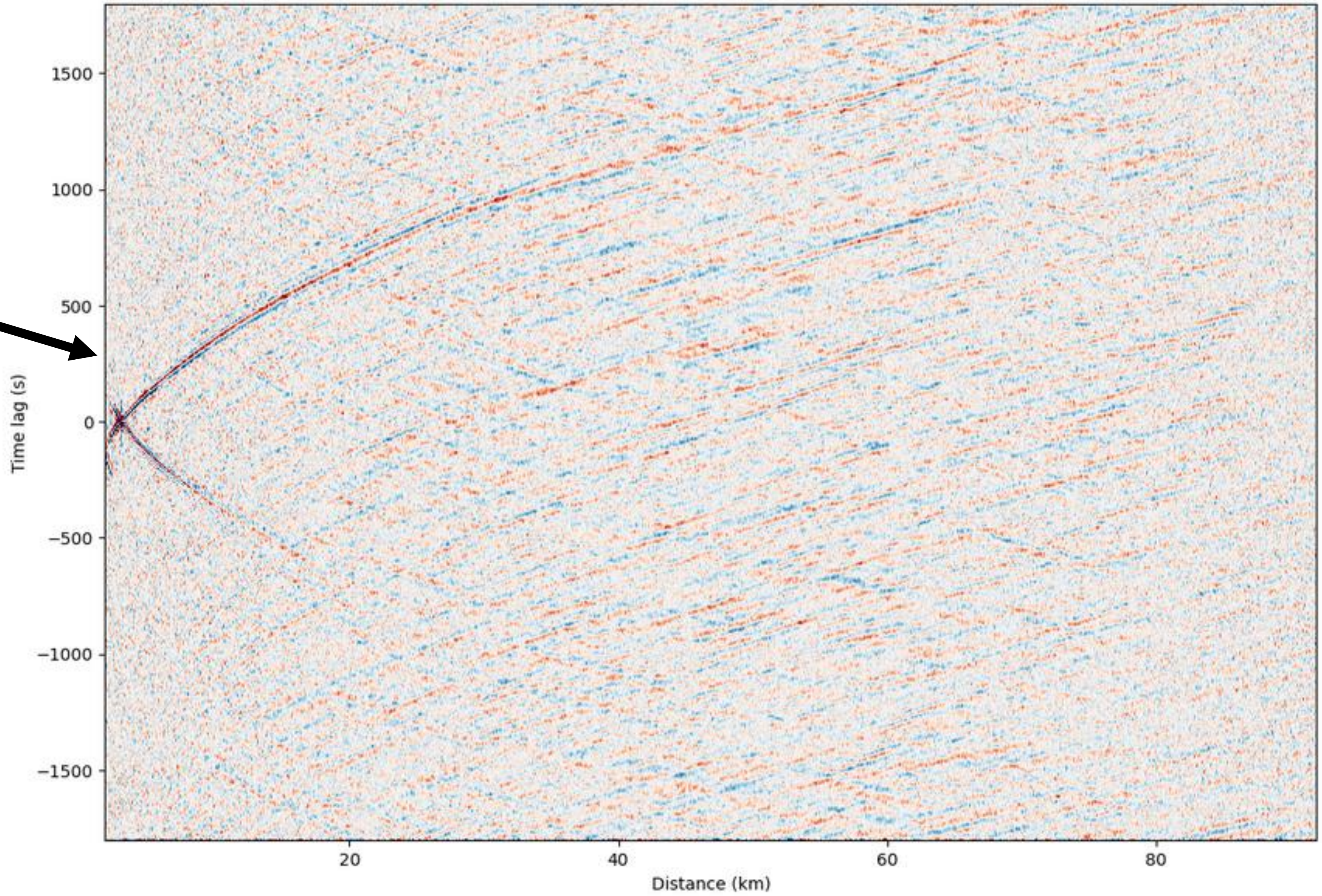
(3) Total IGW energy grows rapidly within 1 km of the coast => nonlinear transfer from ocean swell to low frequencies

(4) At low tide, this coastal energy is all dissipated at the beach; whereas, at high tide, the energy reflects and escapes to deep water.

(5) The apparent reflection coefficient at high tide is greater than 1, meaning that multiple generation mechanisms must be occurring at once.

Toward empirical tsunami Green's functions

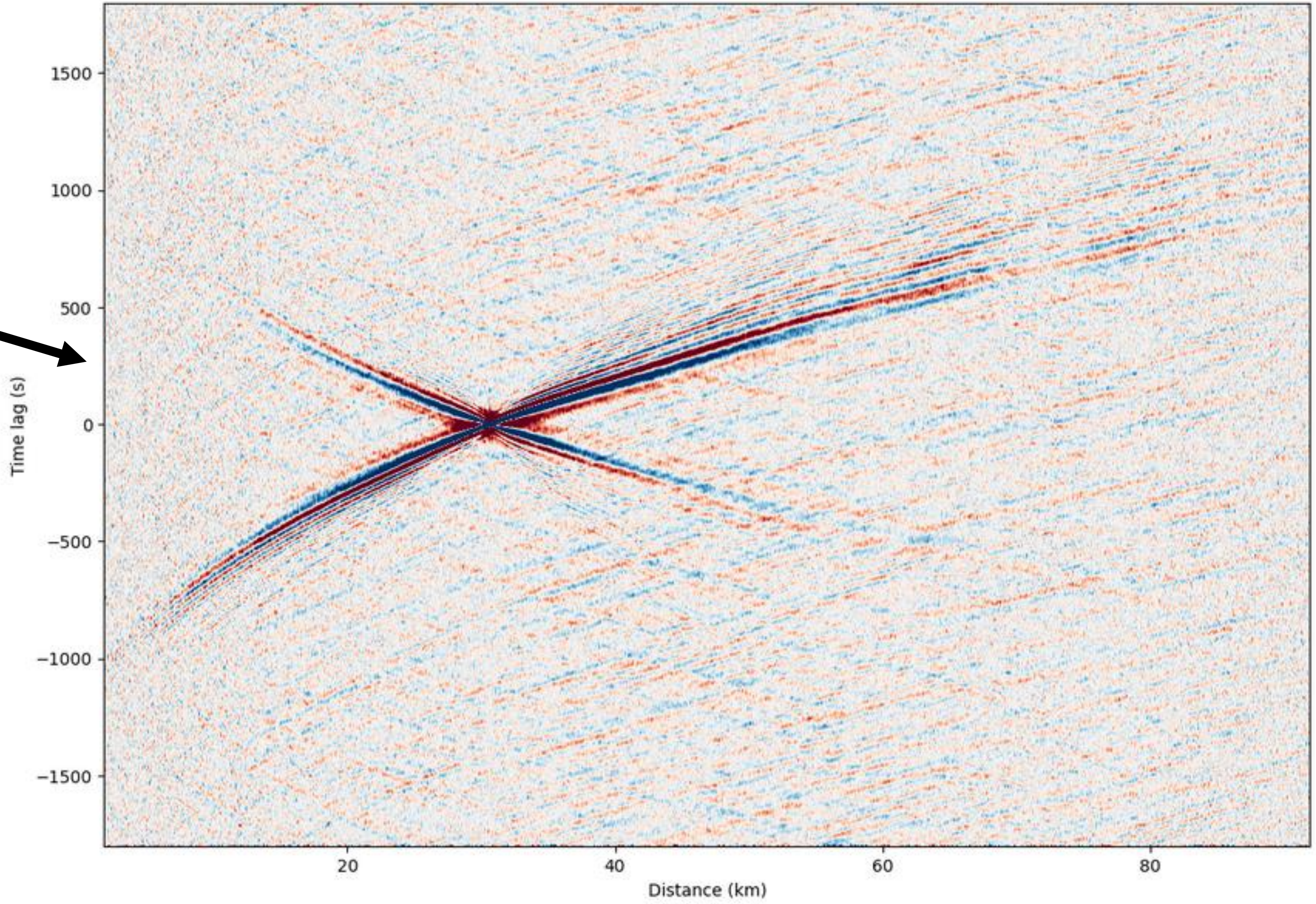
Beach



Cascadia deformation front

Toward empirical tsunami Green's functions

Beach



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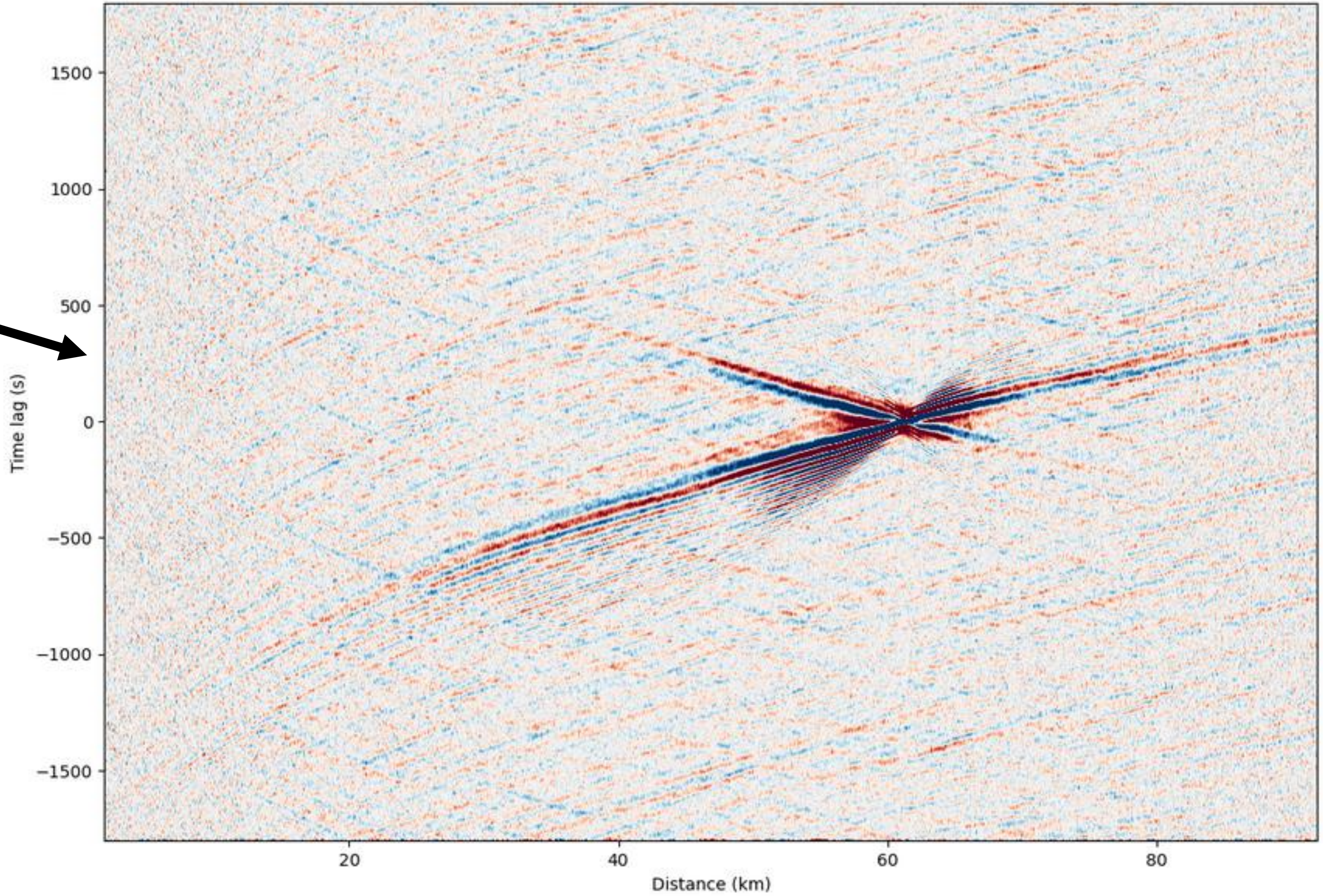

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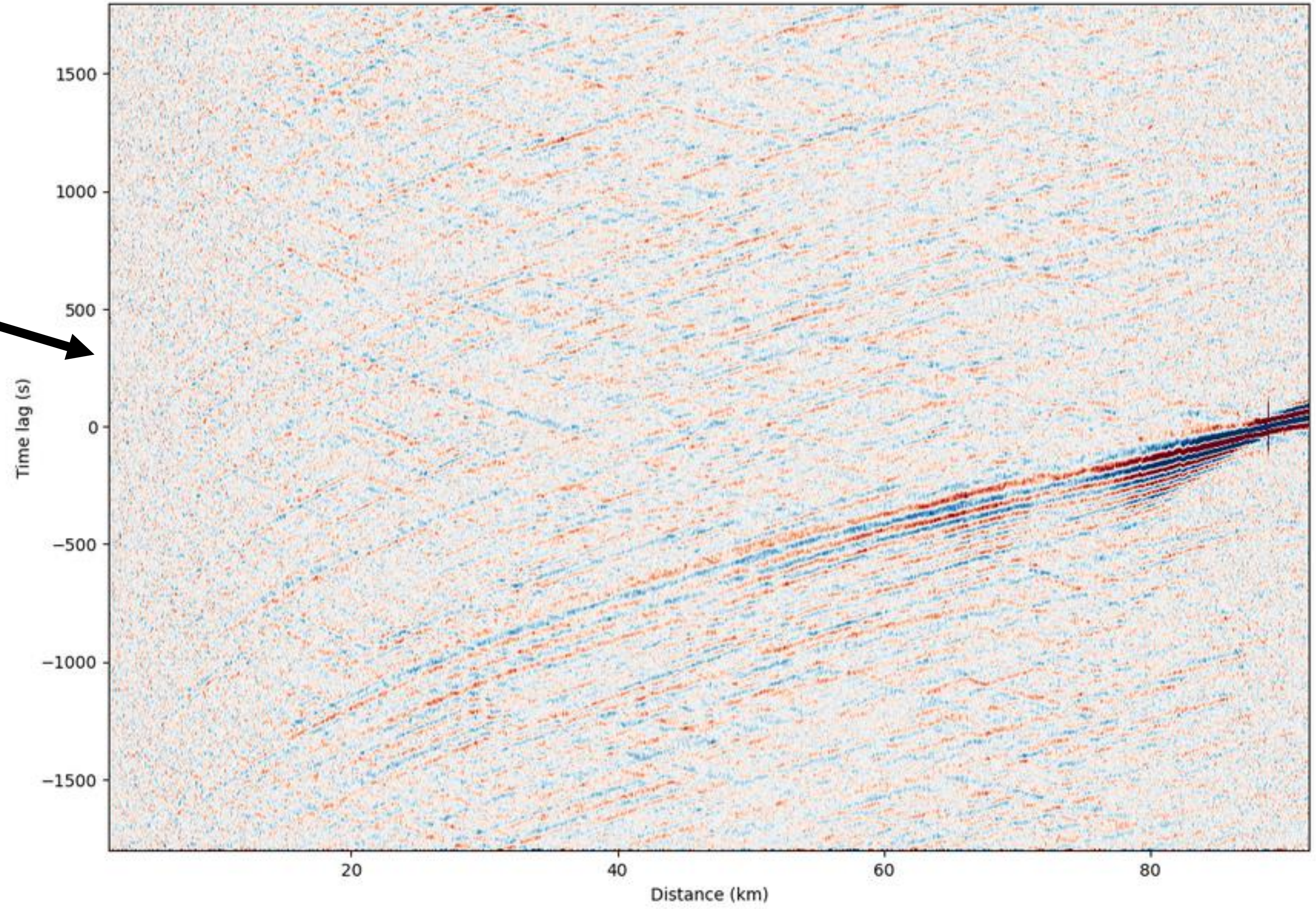
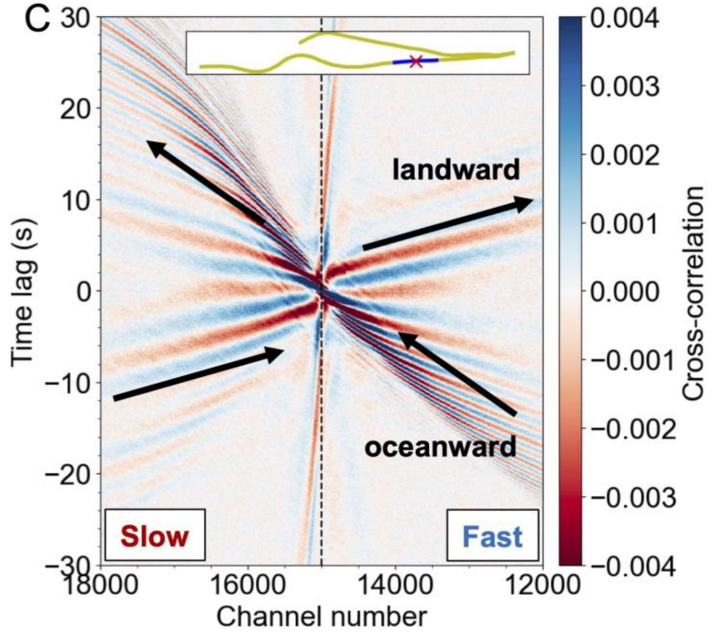
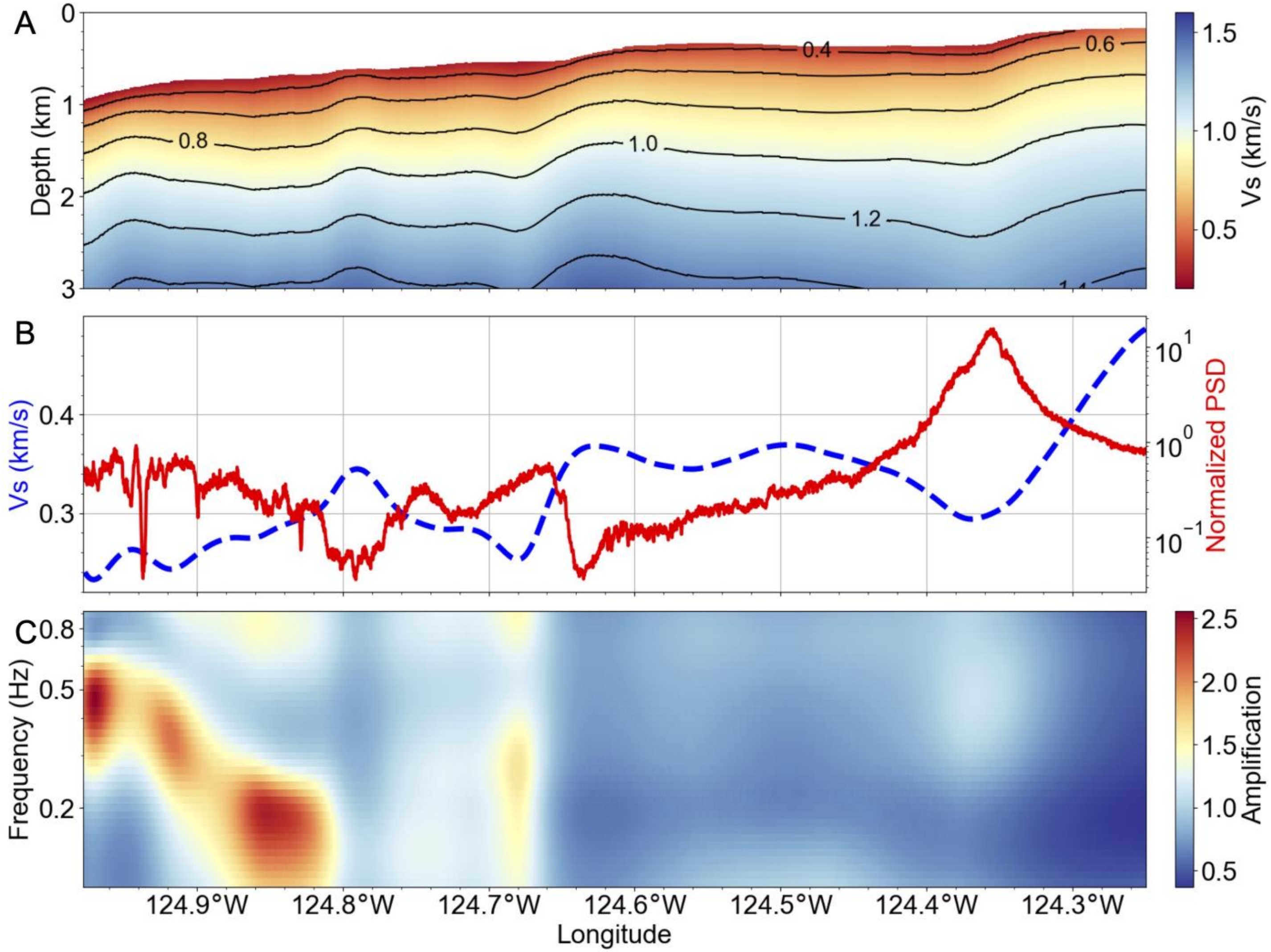


Cascadia deformation front

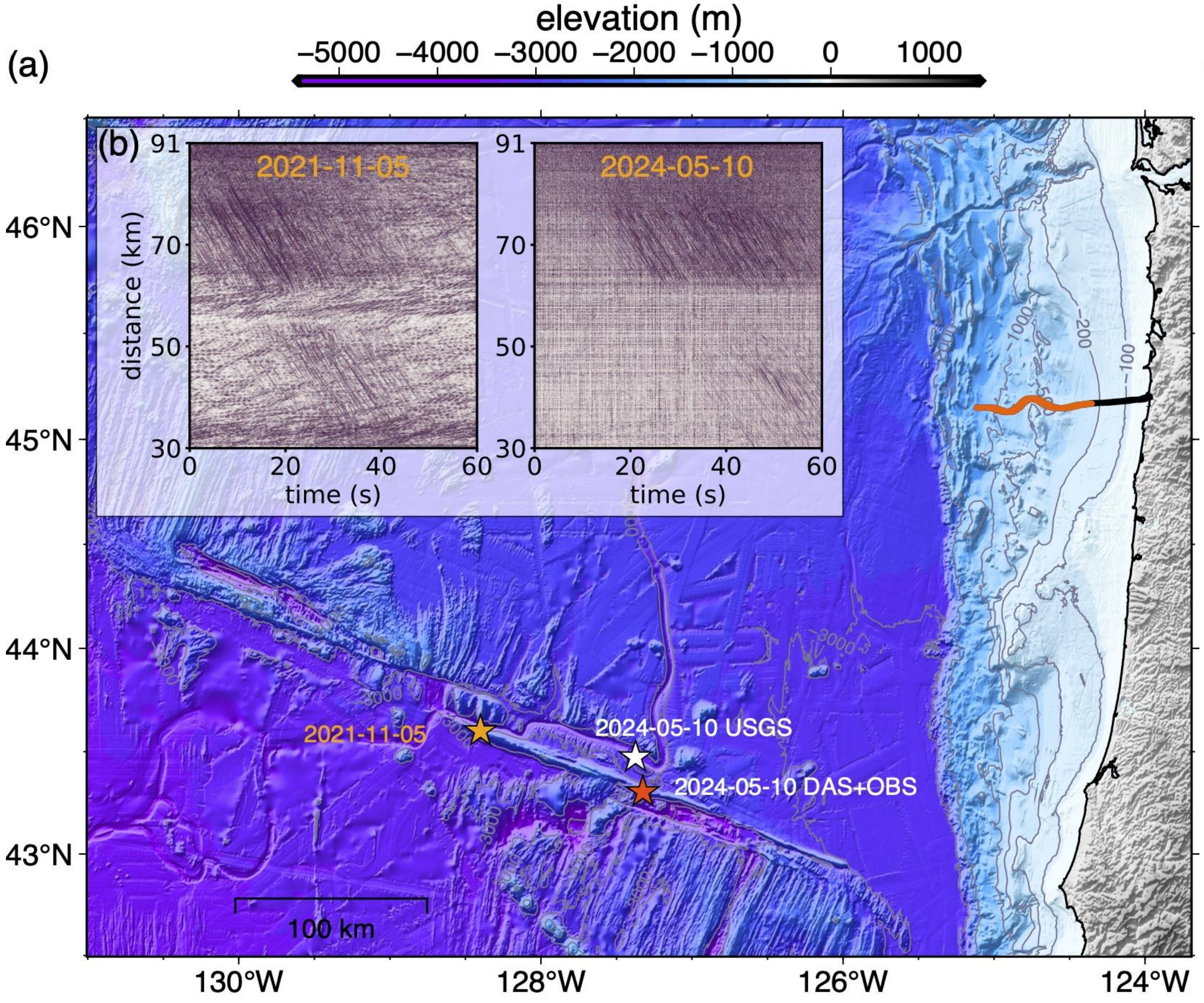
Shear-wave velocity inversion and site amplification (Jiaqi Fang – Caltech, me)

- Utilizing the 2021 dataset, Jiaqi applied the same cross-correlation approach to the 1-10 s period seismic wavefield
- Rayleigh/Scholte wave velocity as a function of frequency is sensitive to shear-wave velocity as a function of depth



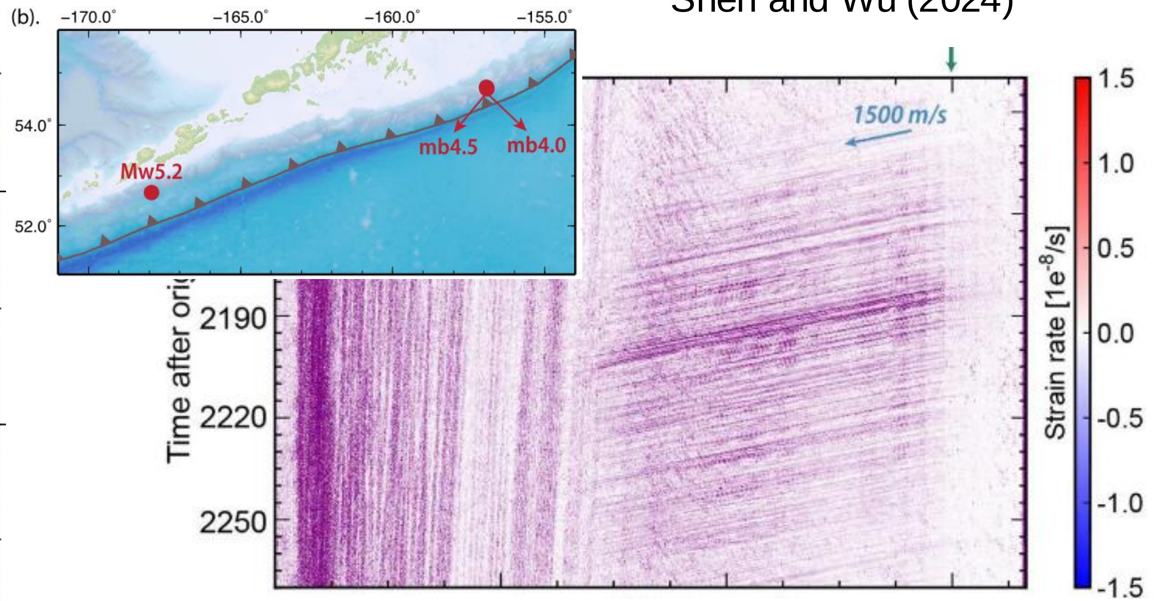


T waves from local to teleseismic earthquakes (Qibin Shi – UW, Zhichao Shen – WHOI)



Shi et al. (submitted)

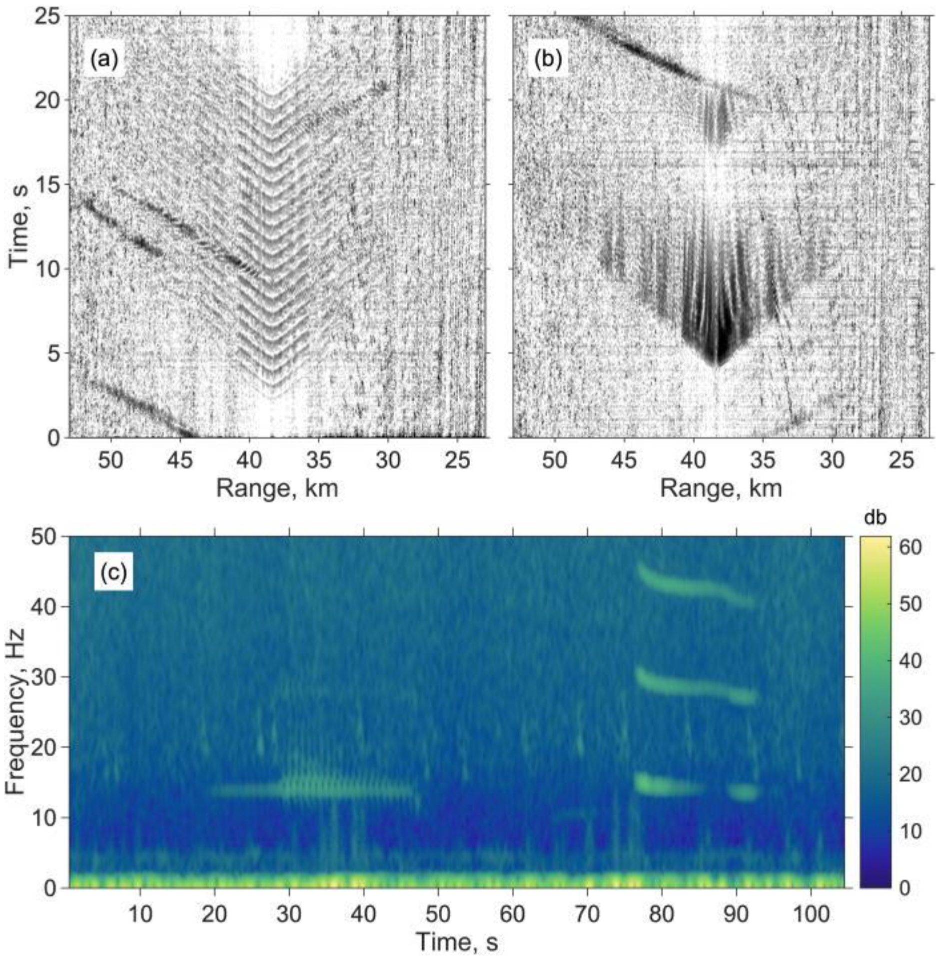
Shen and Wu (2024)



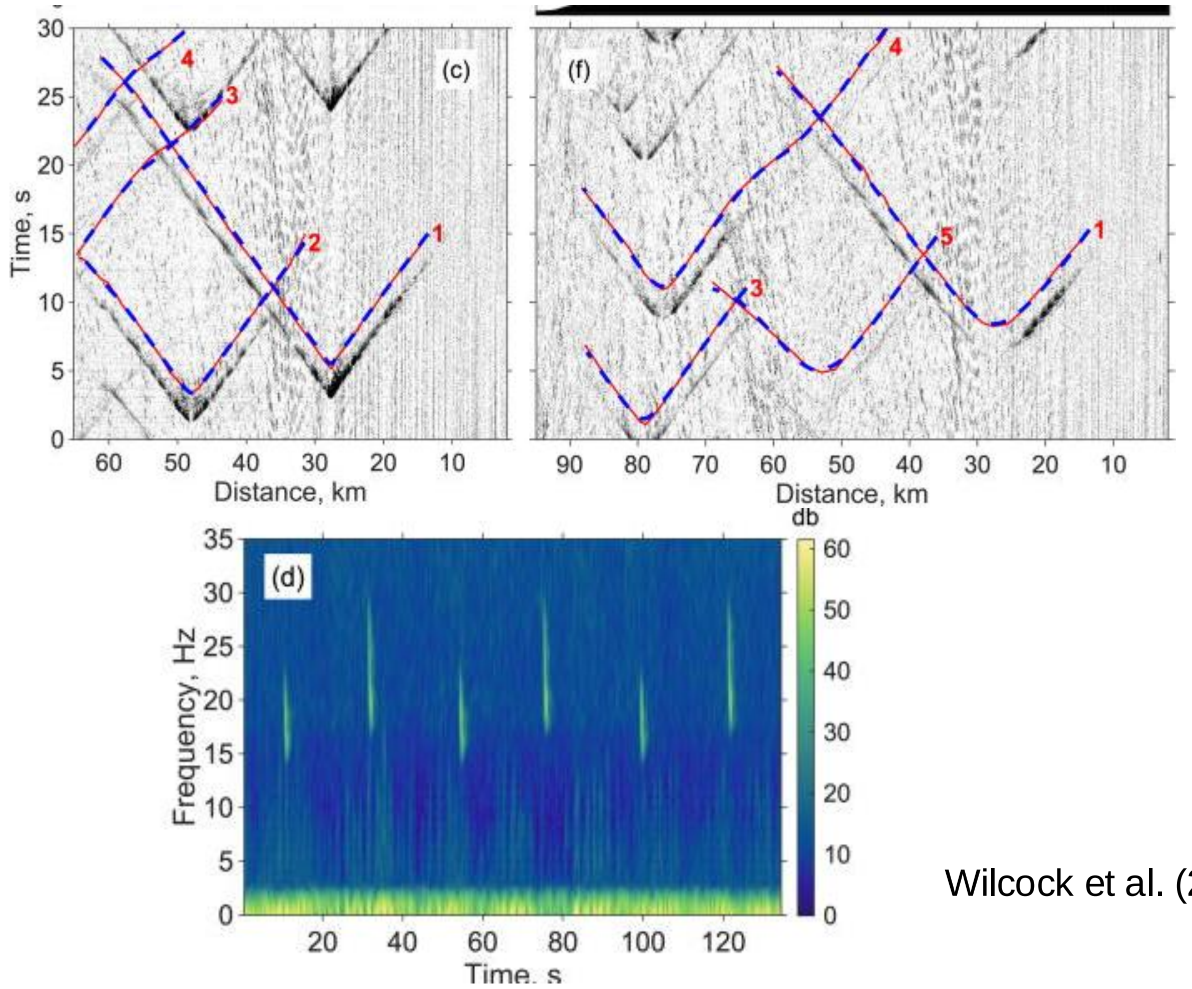
- Acoustic waves generated by offshore earthquakes, which propagate through the SOFAR channel
- Have been used for "seismic ocean thermometry" a passive version of ocean acoustic tomography

Blue and fin whale vocalizations (William Wilcock, Shima Abadi, Brad Lipovsky – UW)

Blue whale A call **B call**



Fin whale 20 Hz calls on the N (left) and S (right) cables



Wilcock et al. (2023)

Conclusions and opportunities

- Multiplexed L-band DAS can operate on the OOI RCA without disrupting observatory telemetry or compromising DAS data quality.
- Infragravity waves observed in deep water offshore Oregon are mostly generated locally at the coast and are strongly tidally modulated by surf-zone processes.
- Seismic ambient noise constrains the shear-wave velocity structure of forearc sediments, revealing micro-basin structures with order-of-magnitude ground motion amplification.
- Even on a buried cable, DAS can easily record T waves from around the Pacific basin, which can be used to detect and locate small seismicity on offshore fault zones and for ocean acoustic tomography.
- DAS can record low-frequency whale calls, such as from blue and fin whales, and the acoustic travel-times observed across an array can be used for localization/tracking. We expect that DAS is also sensitive to humpback, grey, and right whale calls.