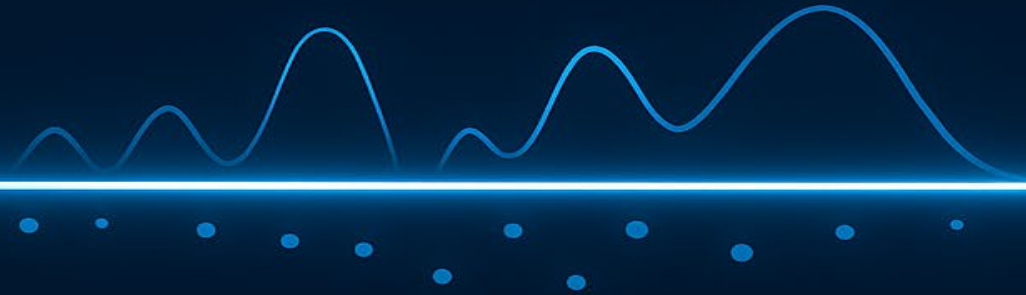


Distributed Acoustic Sensing for Ocean Acoustics

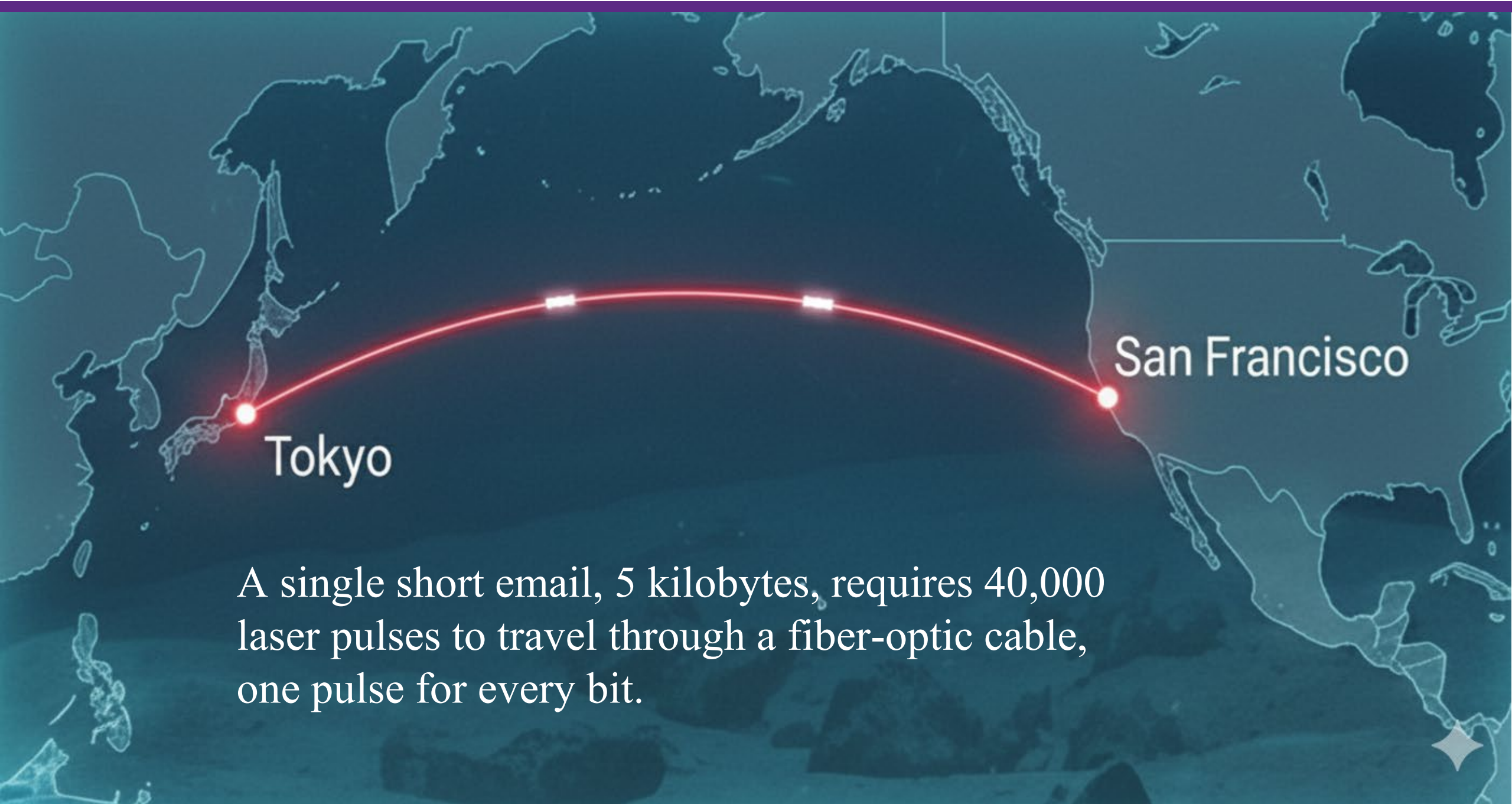
Shima Abadi

Professor, University of Washington
Director, Ocean Data Lab



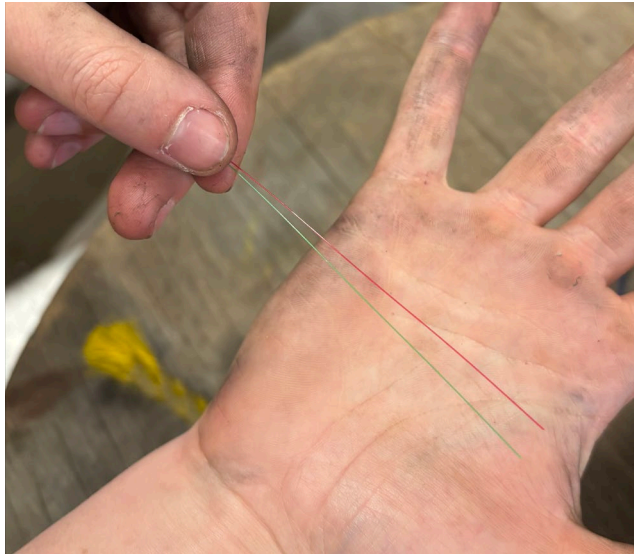
OCEAN DATA LAB

DOSIT Webinar, Sept. 2026

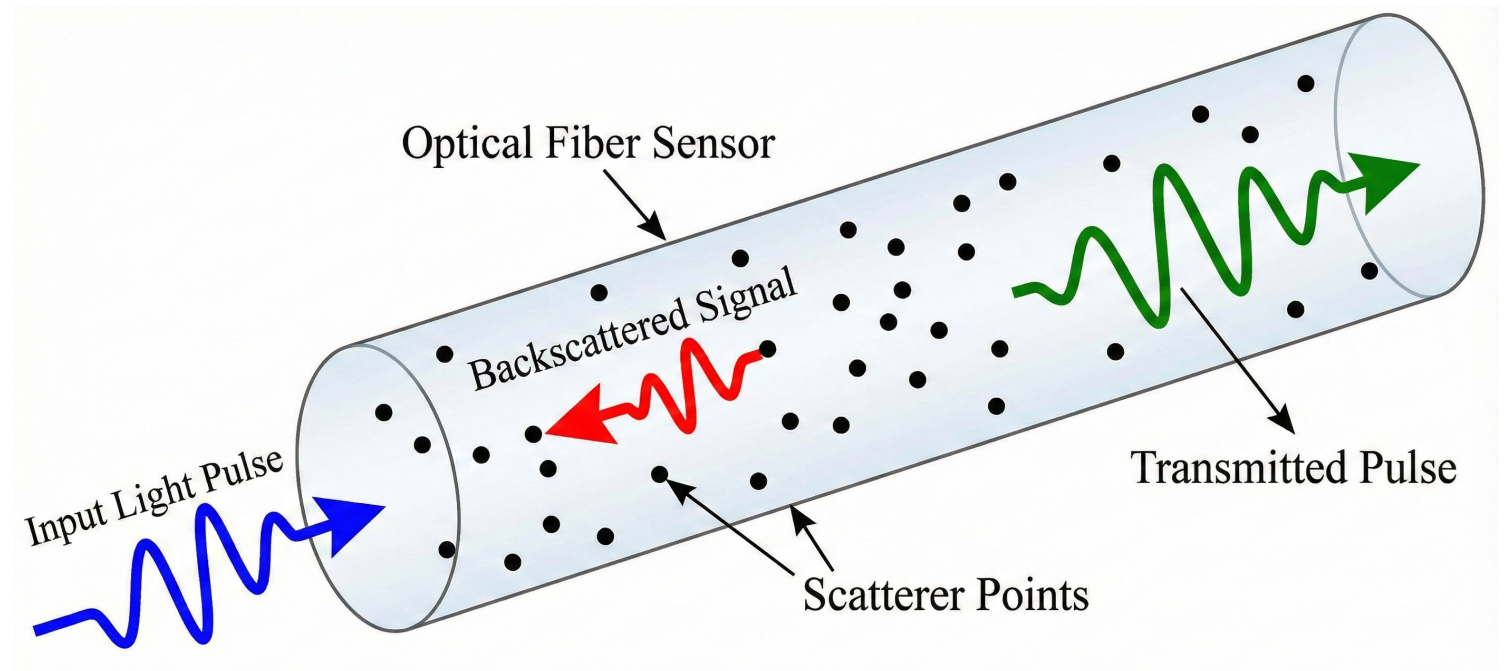


A single short email, 5 kilobytes, requires 40,000 laser pulses to travel through a fiber-optic cable, one pulse for every bit.

Distributed Acoustic Sensing (DAS)



- Changing the length of the fiber changes the pattern of Rayleigh scattered energy
- Comparing the pattern between successive pulses provides a measurement of strain rate along a section of the fiber (gauge length)



**OFFSHORE
ENERGY**

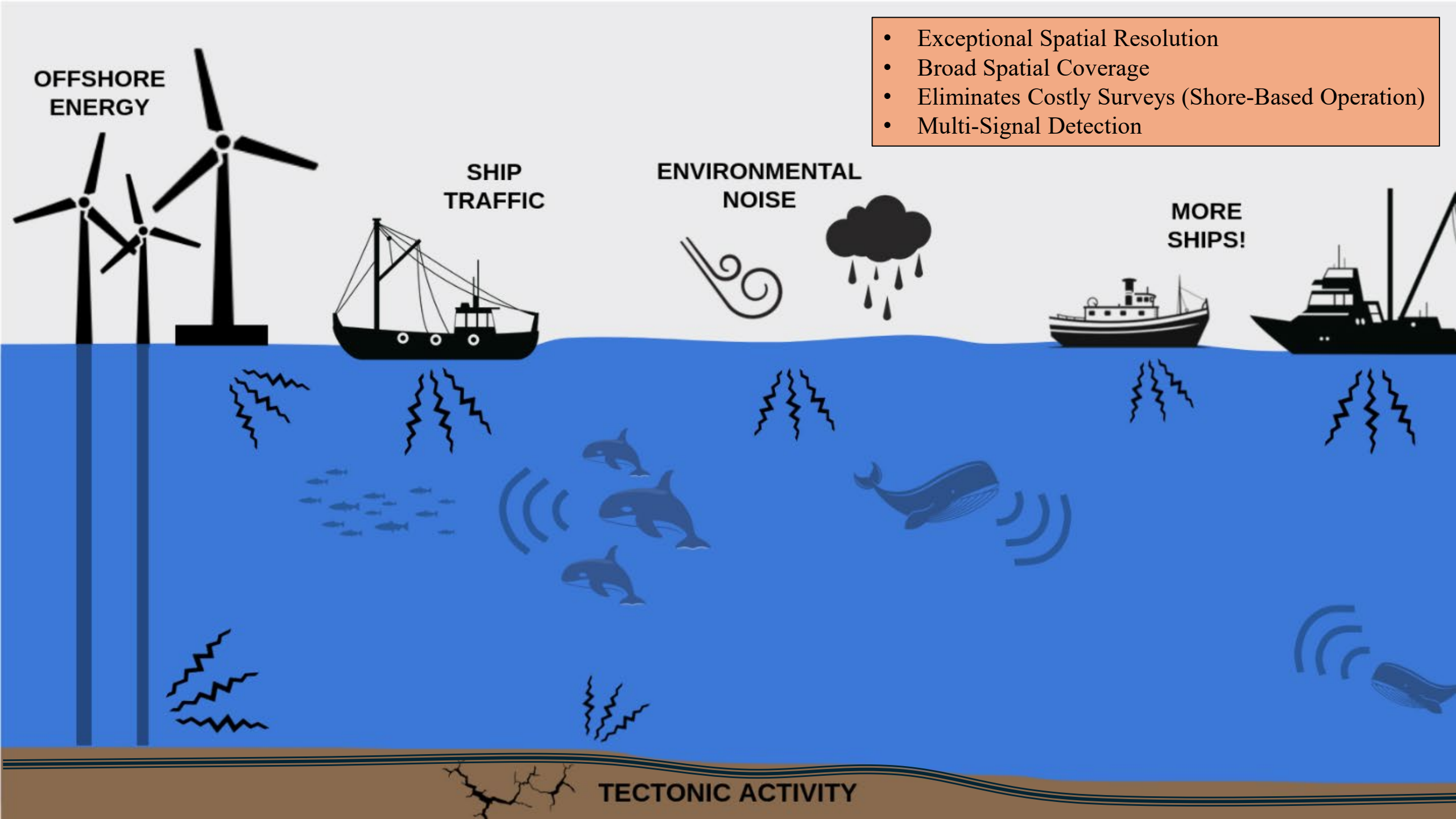
**SHIP
TRAFFIC**

**ENVIRONMENTAL
NOISE**

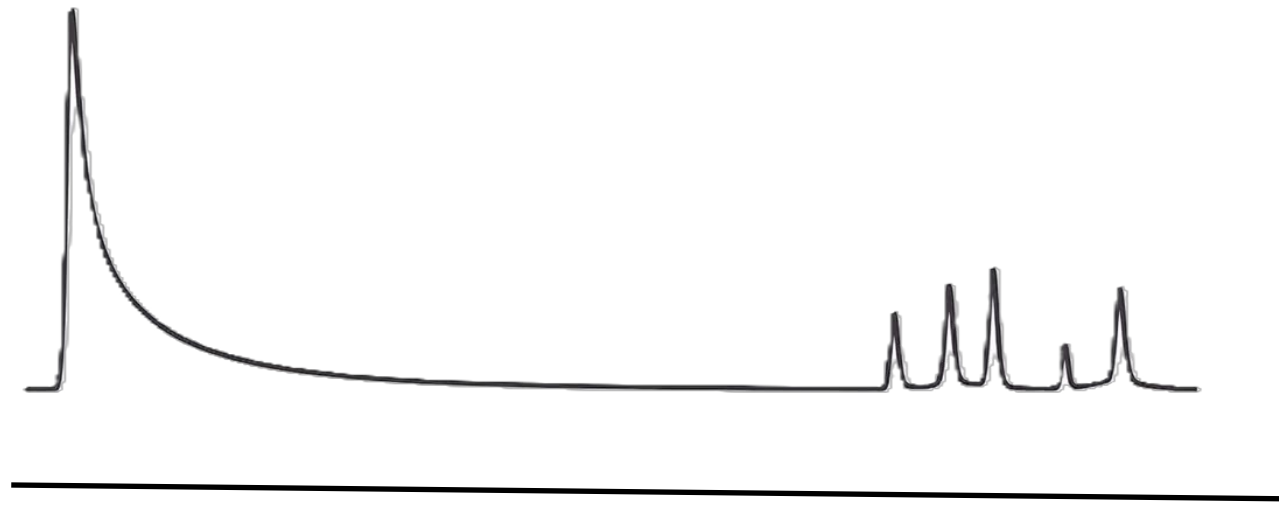
**MORE
SHIPS!**

TECTONIC ACTIVITY

- Exceptional Spatial Resolution
- Broad Spatial Coverage
- Eliminates Costly Surveys (Shore-Based Operation)
- Multi-Signal Detection

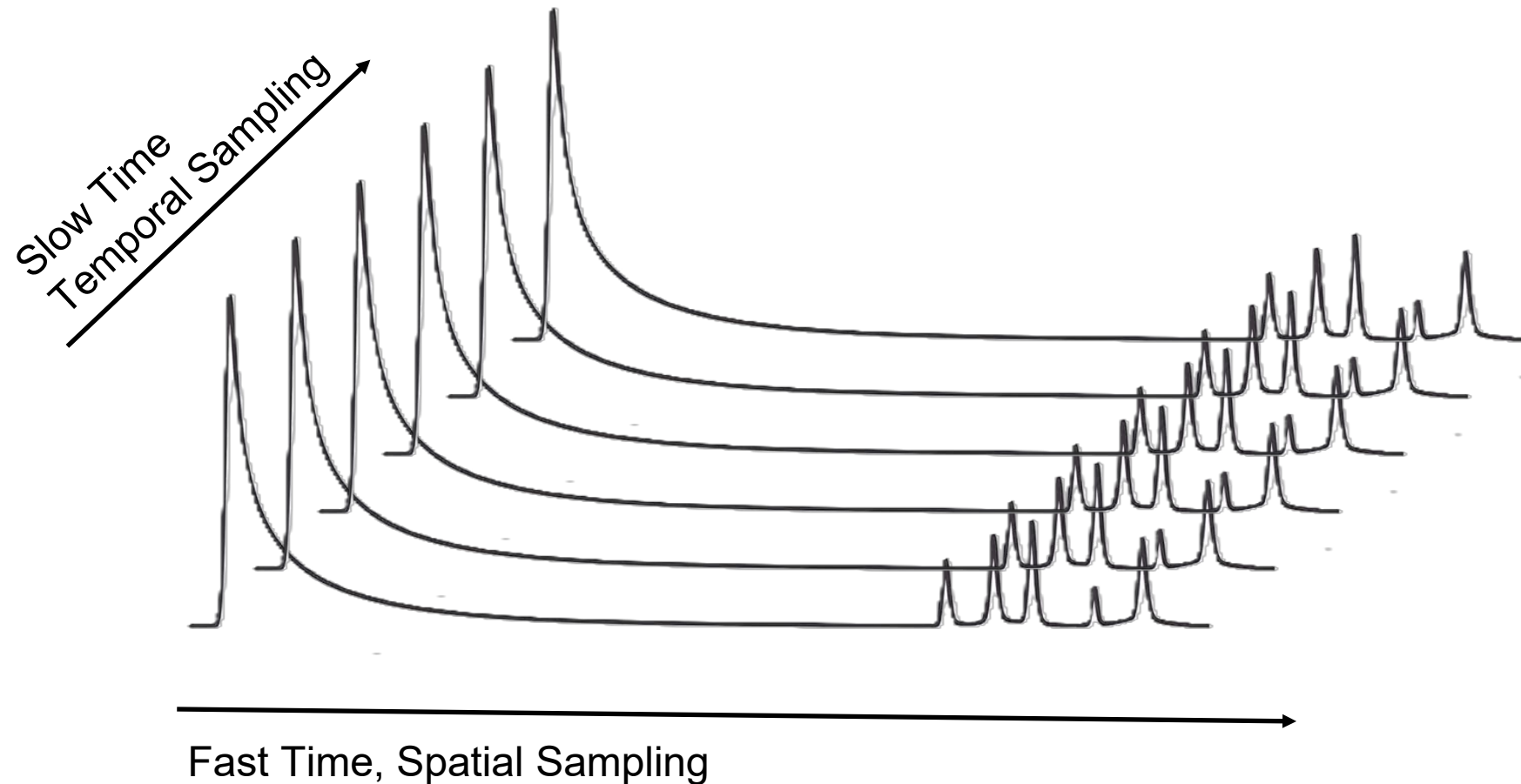


DAS Data Structure - 2D Backscattered Energy



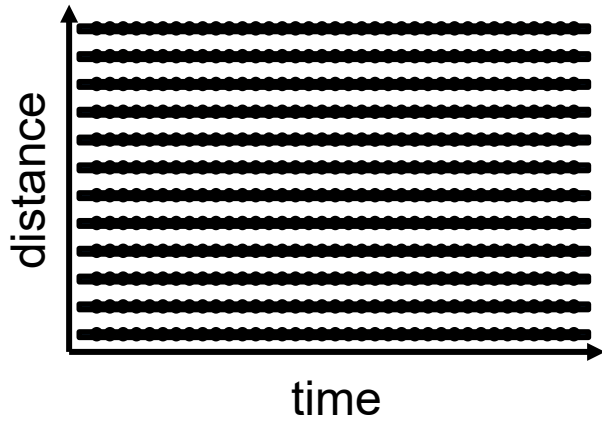
Fast Time, Spatial Sampling

DAS Data Structure - 2D Backscattered Energy

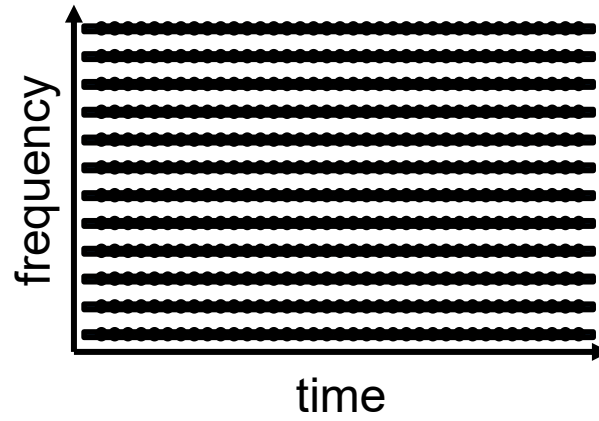


DAS Analysis

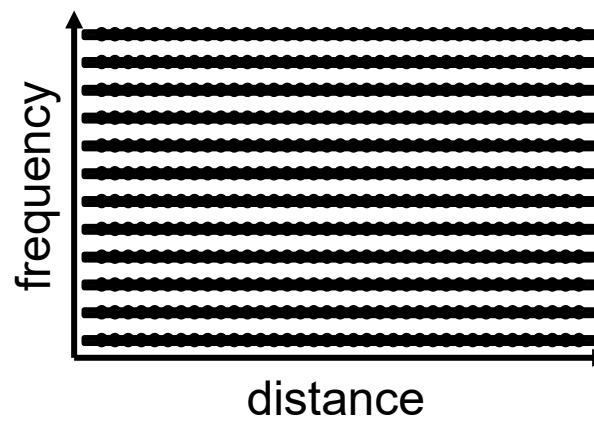
TX Plot



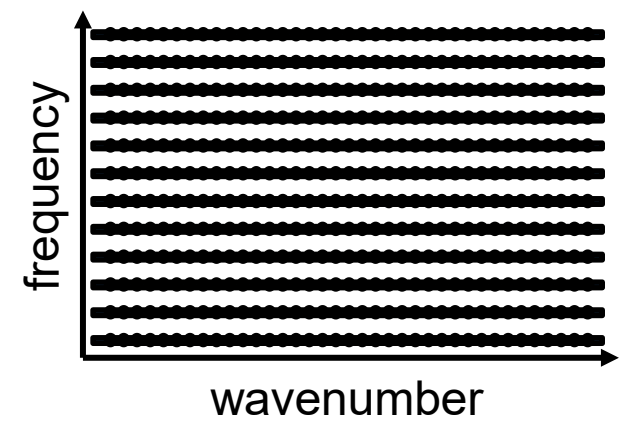
Spectrogram



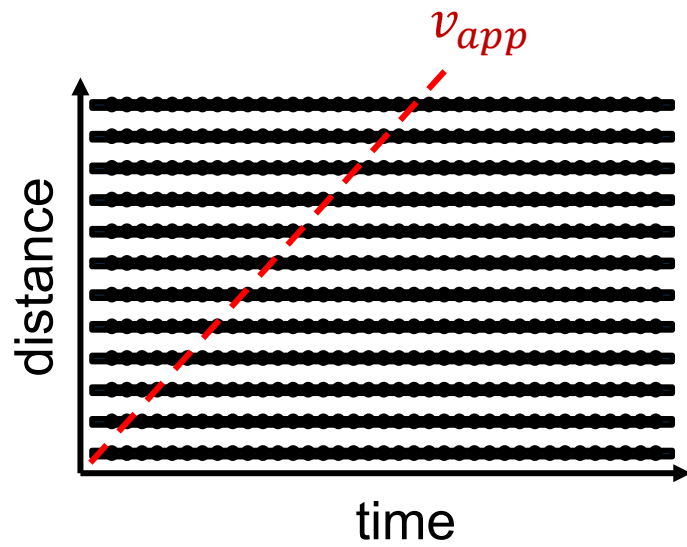
FX Plot



FK Plot

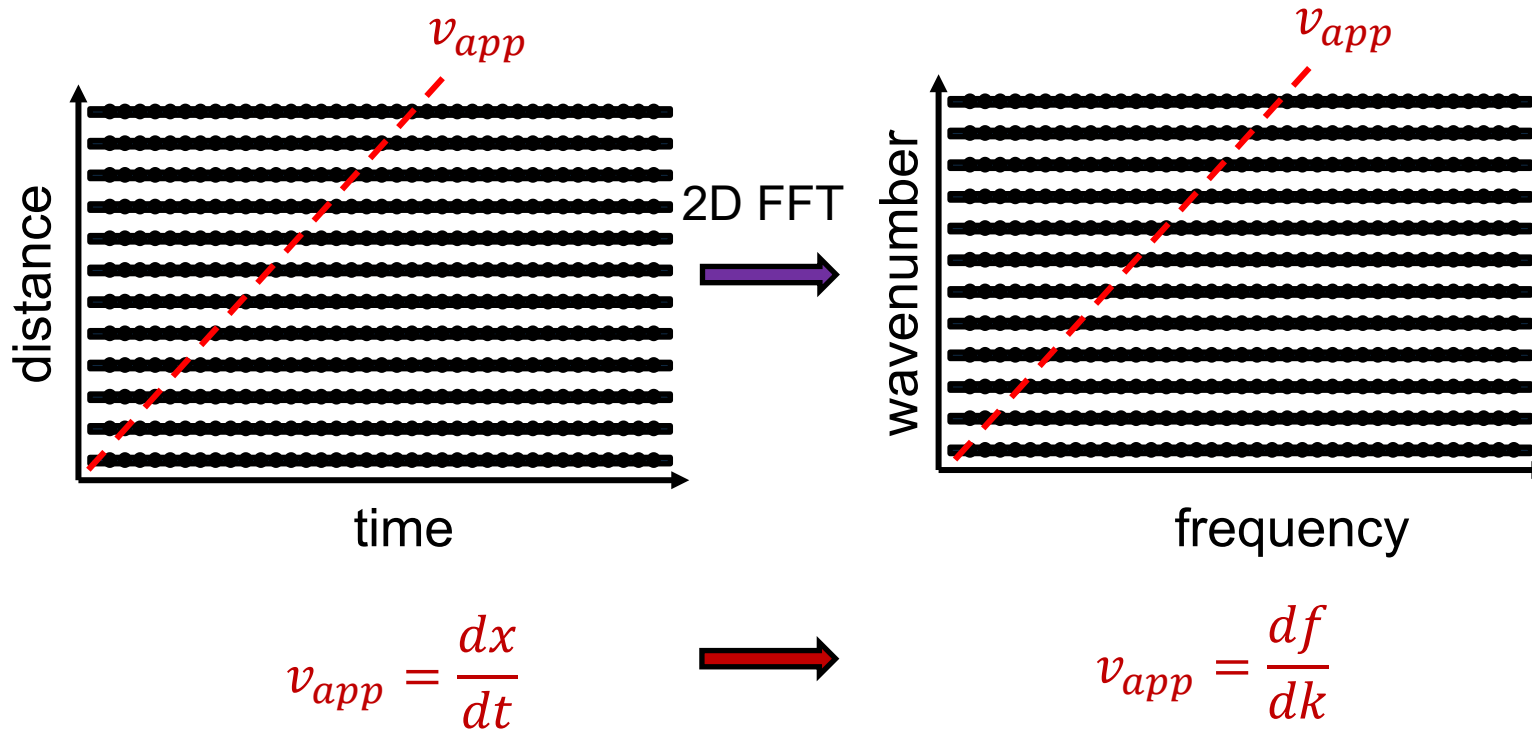


f-k Spectrum

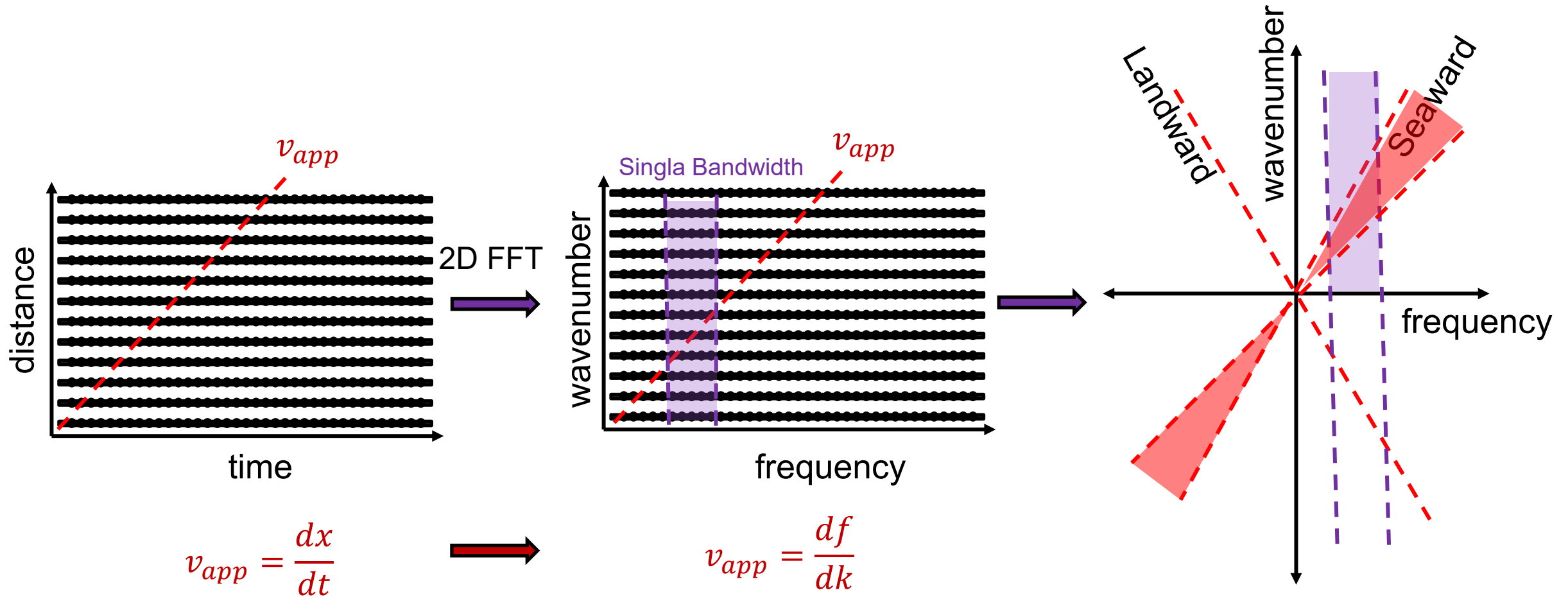


$$v_{app} = \frac{dx}{dt}$$

f-k Spectrum



f-k Spectrum



wavenumber



frequency



wavenumber

< 0.01 Hz
DAS data is
dominated by
temperature
changes caused by
internal waves,
ocean current,
diurnal
heating/cooling of
the environment.

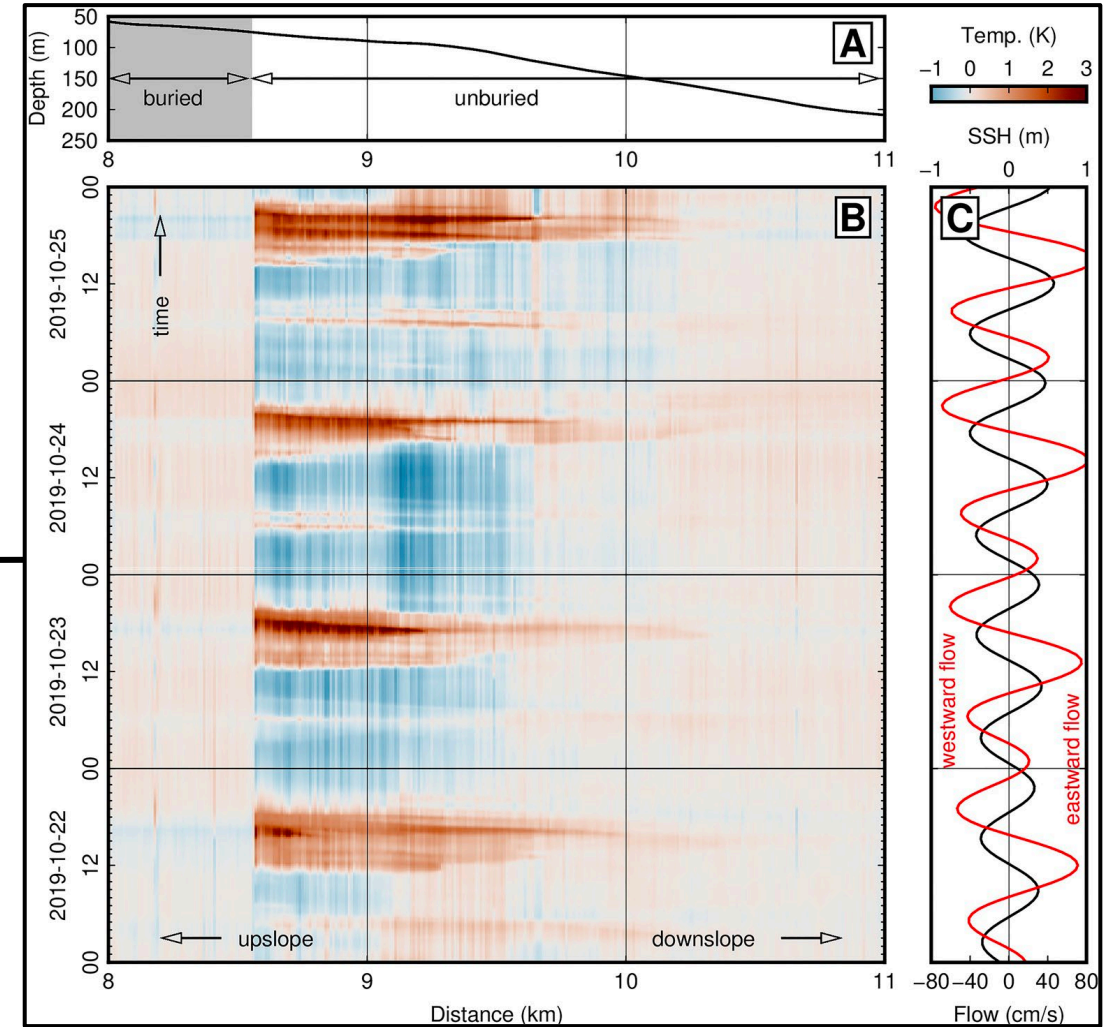


frequency

wavenumber

< 0.01 Hz

DAS data is dominated by **temperature changes** caused by internal waves, ocean current, diurnal heating/cooling of the environment.

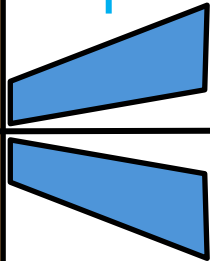


Williams et al. (2023) "Fiber-optic observations of internal waves and tides," JGR.

wavenumber

< 0.01 Hz
DAS data is dominated by temperature changes caused by internal waves, ocean current, diurnal heating/cooling of the environment.

$0.01 \text{ Hz} < f < 0.1 \text{ Hz}$
DAS data is dominated by surface gravity waves moving at a few to a few tens of m/s.

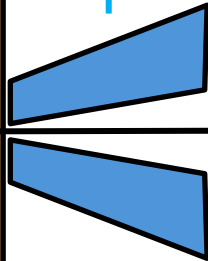


frequency

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frequency

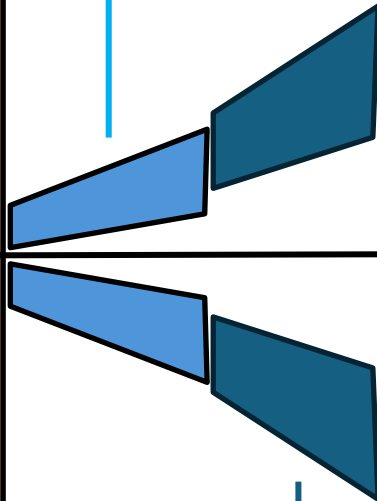
Xenaki, Gerstoft, Williams, Abadi (2025) "Overview of distributed acoustic sensing: Theory and ocean applications," JASA

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$0.1 \text{ Hz} < f < 1 \text{ Hz}$
DAS data is dominated by microseisms traveling at a few thousands of m/s (Scholte waves).

frequency

wavenumber

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frequency

Xenaki, Gerstoft, Williams, Abadi (2025) "Overview of distributed acoustic sensing: Theory and ocean applications," JASA

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DAS data contains seismic activities, i.e., T-waves.

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frequency

wavenumber

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Xenaki, Gerstoft, Williams, Abadi (2025) "Overview of distributed acoustic sensing: Theory and ocean applications," JASA

wavenumber

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DAS data is dominated by surface gravity waves moving at a few to a few tens of m/s.

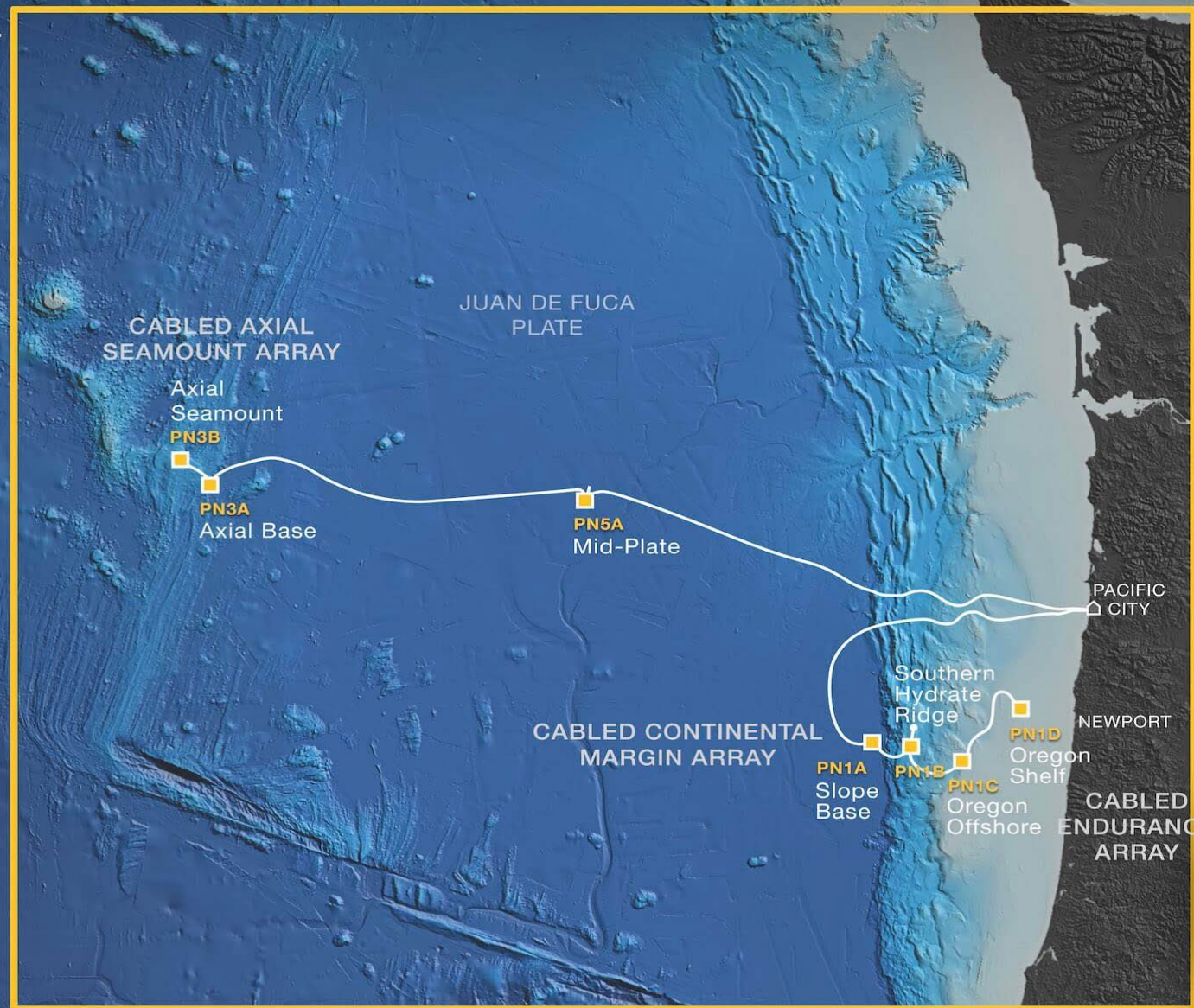
$1 \text{ Hz} < f < 10 \text{ Hz}$
DAS data contains seismic activities, i.e., T-waves.

$f > 10 \text{ Hz}$
DAS data contains biological signals (whales, fish, other marine life) and anthropogenic signals (ships, pile driving, airguns, other human activities).

$0.1 \text{ Hz} < f < 1 \text{ Hz}$
DAS data is dominated by microseisms traveling at a few thousands of m/s (Scholte waves).

frequency

REGIONAL CABLED ARRAY

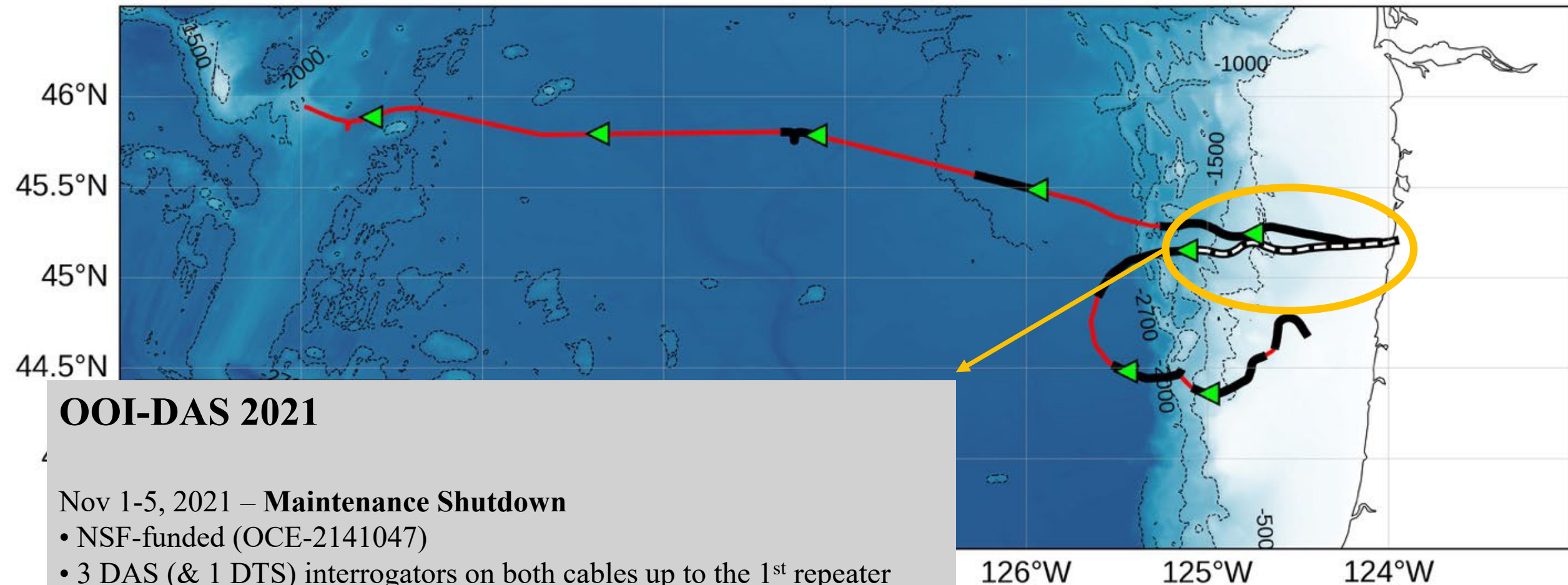


■ Primary Node

— Cable

△ Shore Station



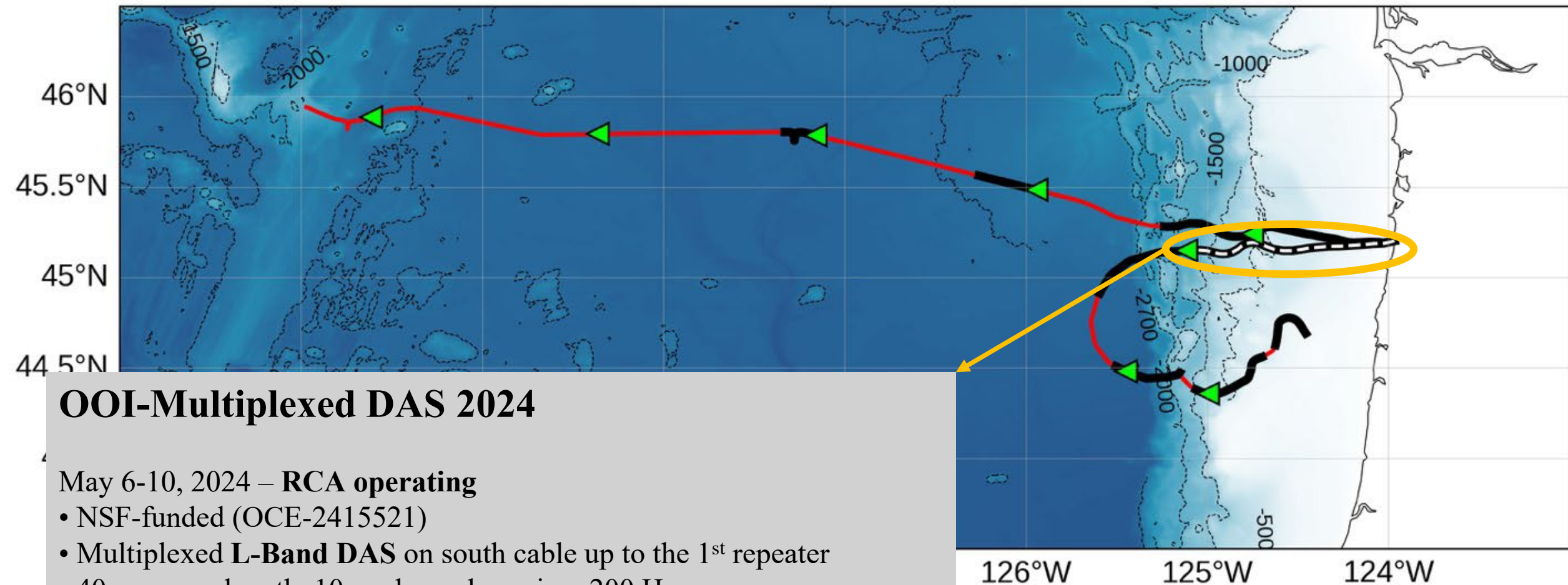


OOI-DAS 2021

Nov 1-5, 2021 – **Maintenance Shutdown**

- NSF-funded (OCE-2141047)
- 3 DAS (& 1 DTS) interrogators on both cables up to the 1st repeater
- 2-50 m gauge length, 2 m channel spacing, 200-1000 Hz sampling rate
- **26 TB** public data set

Wilcock et al. (2025). <https://doi.org/10.1121/10.0017104>

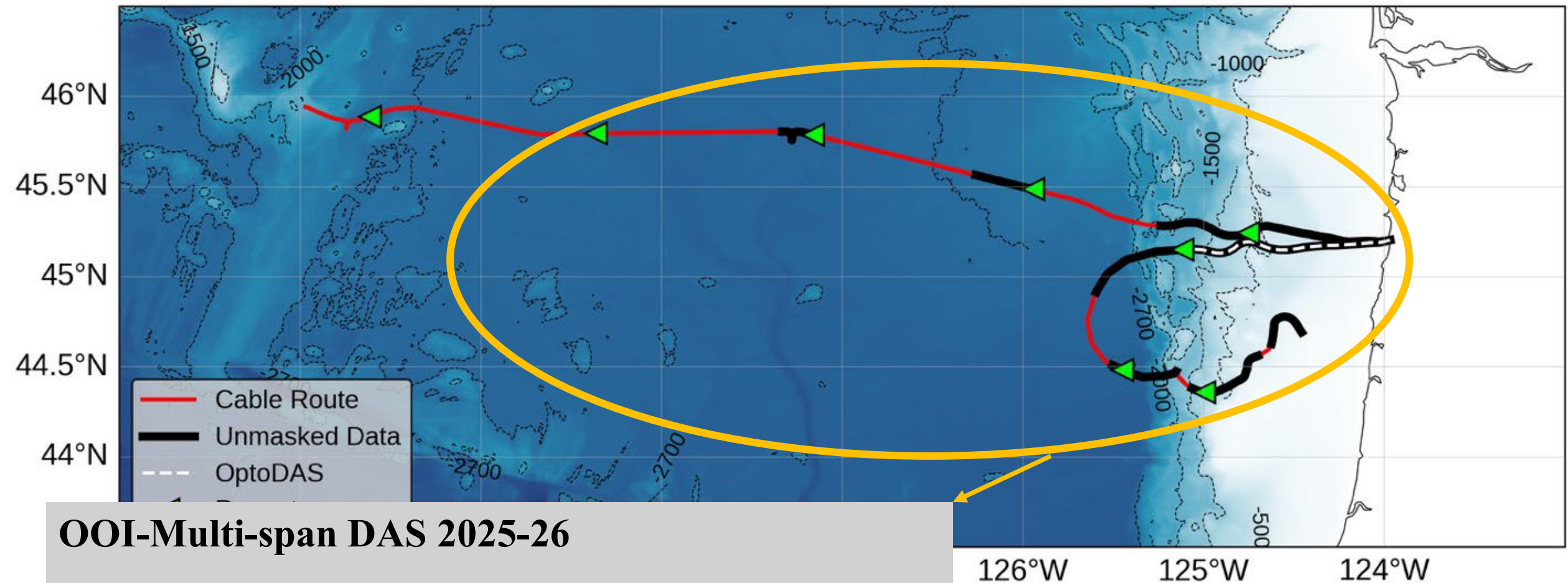


OOI-Multiplexed DAS 2024

May 6-10, 2024 – **RCA operating**

- NSF-funded (OCE-2415521)
- Multiplexed **L-Band DAS** on south cable up to the 1st repeater
- 40 m gauge length, 10 m channel spacing, 200 Hz
- **4 TB** public data set
- No impact on OOI RCA operations
- Demonstrated the feasibility of permanent DAS

Shi et al. (2025). <https://doi.org/10.1785/0220240460>

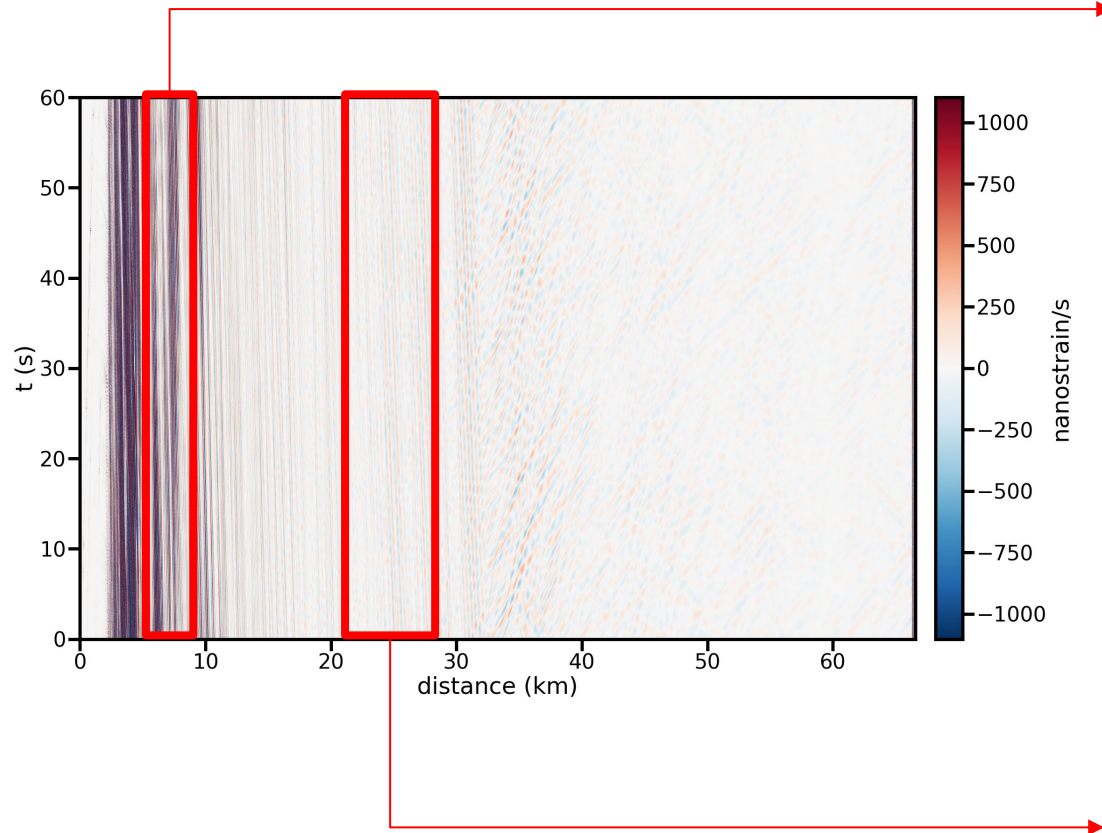


OOI-Multi-span DAS 2025-26

Nov. 2025 – Jan. 2026 – RCA operating

- NSF-funded (OCE-2415521)
- Multiplexed L-Band DAS on south cable up to the 1st repeater
- Multi-span DAS on both cables
- **177 TB** public data set

Raw DAS Data

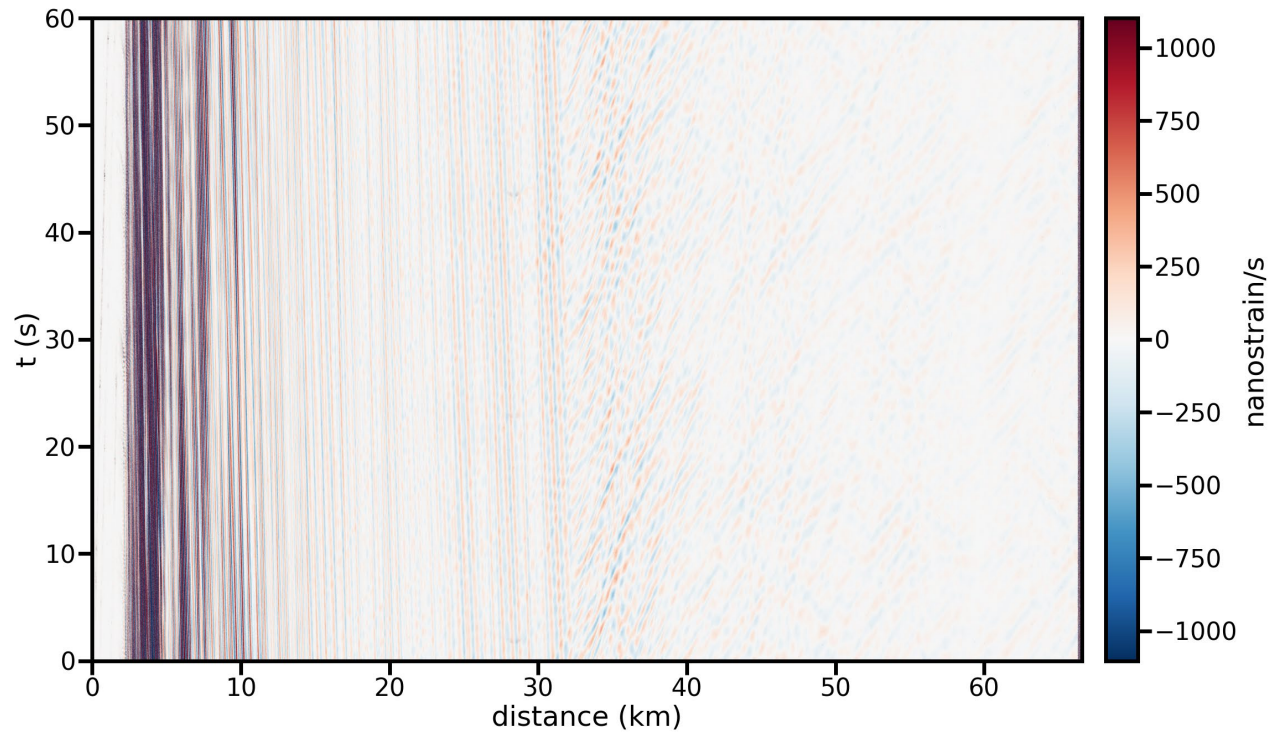


$0.01 \text{ Hz} < f < 0.1 \text{ Hz}$
DAS data is dominated
by **surface gravity**
waves moving at a few
to a few tens of m/s.

$0.1 \text{ Hz} < f < 1 \text{ Hz}$
DAS data is dominated
by **microseisms**
traveling at a few
thousands of m/s
(Scholte waves).

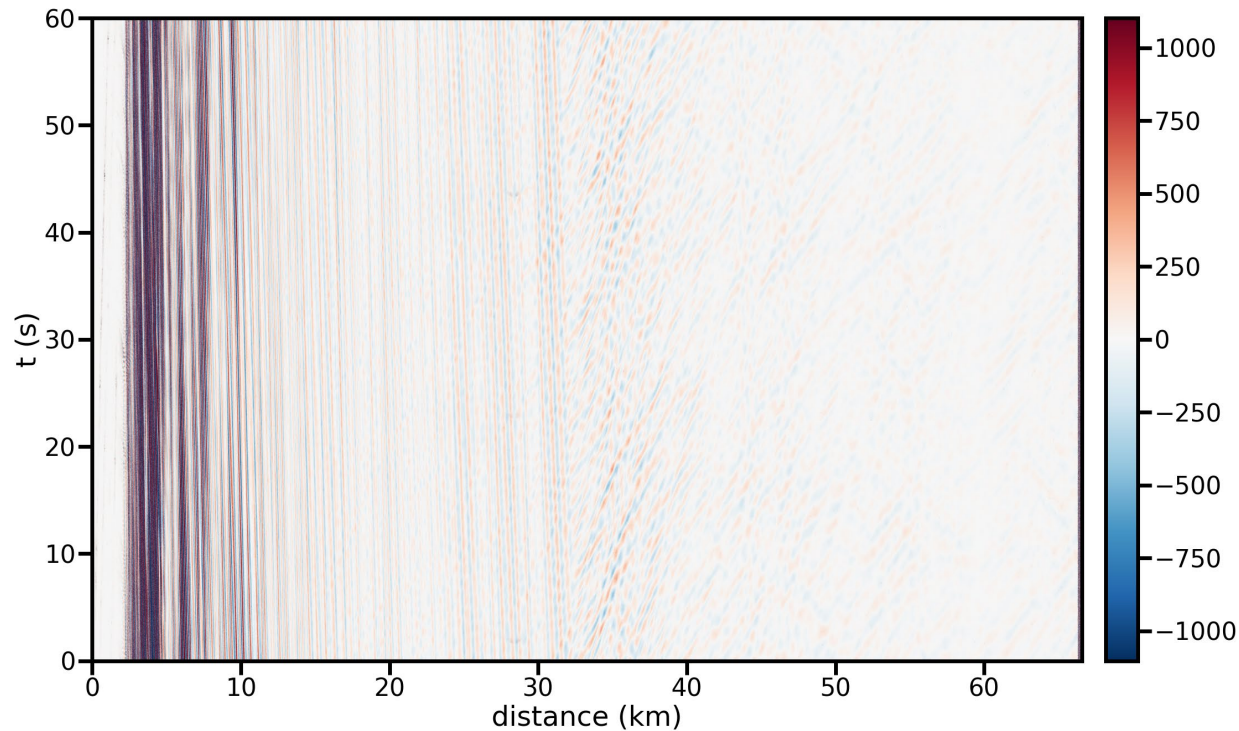
Marine Bio-acoustics with DAS

Raw Data

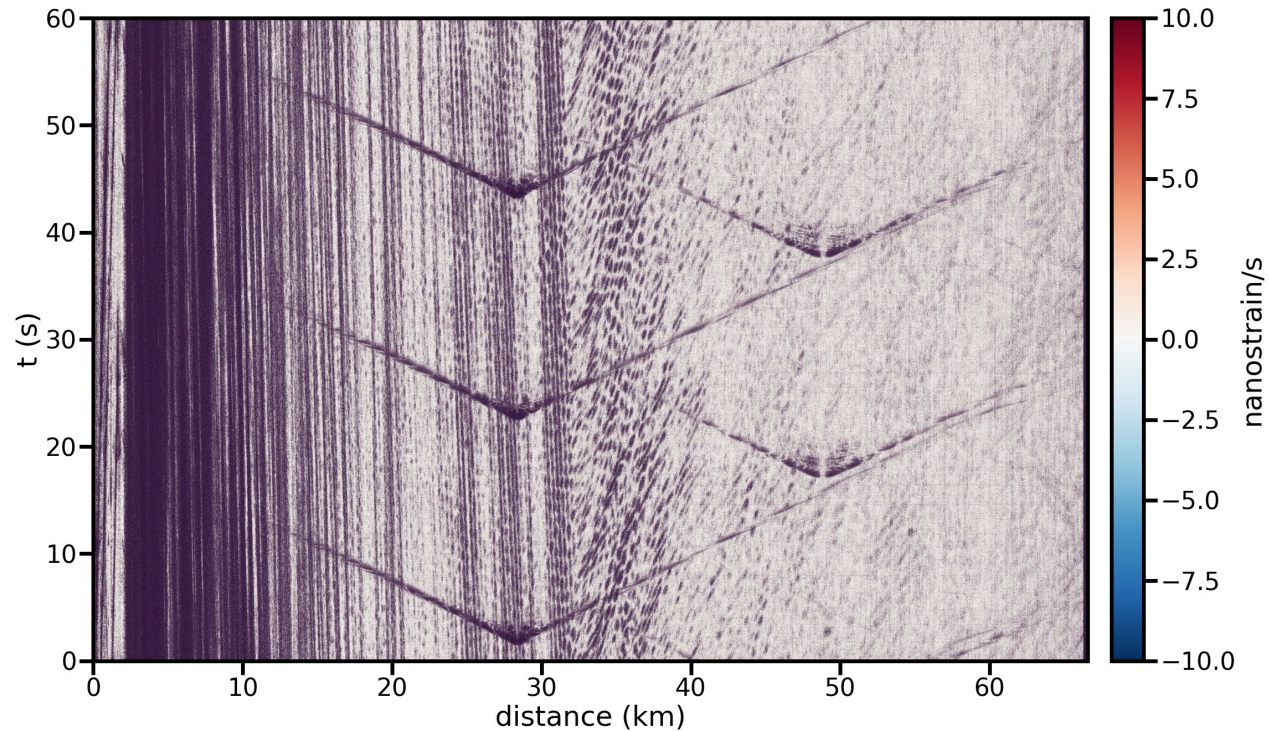


Marine Bio-acoustics with DAS

Raw Data

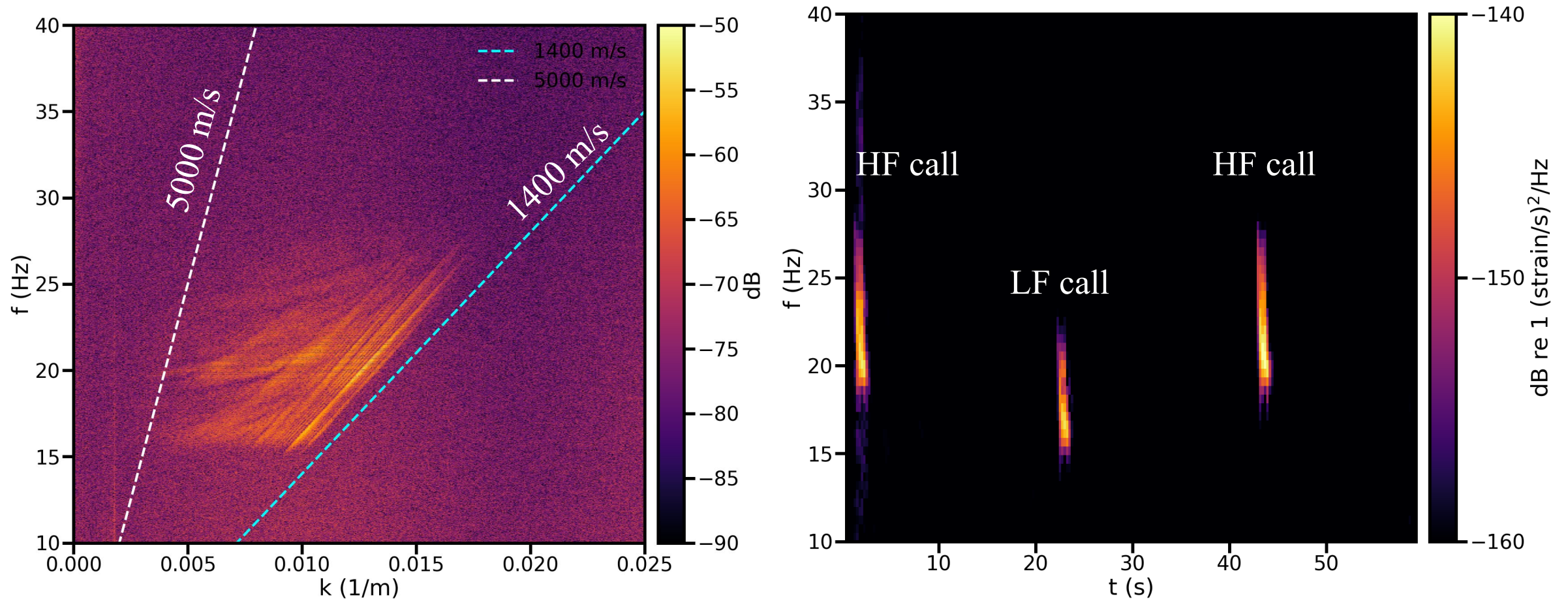


BP Filtered (14-30 Hz) Data

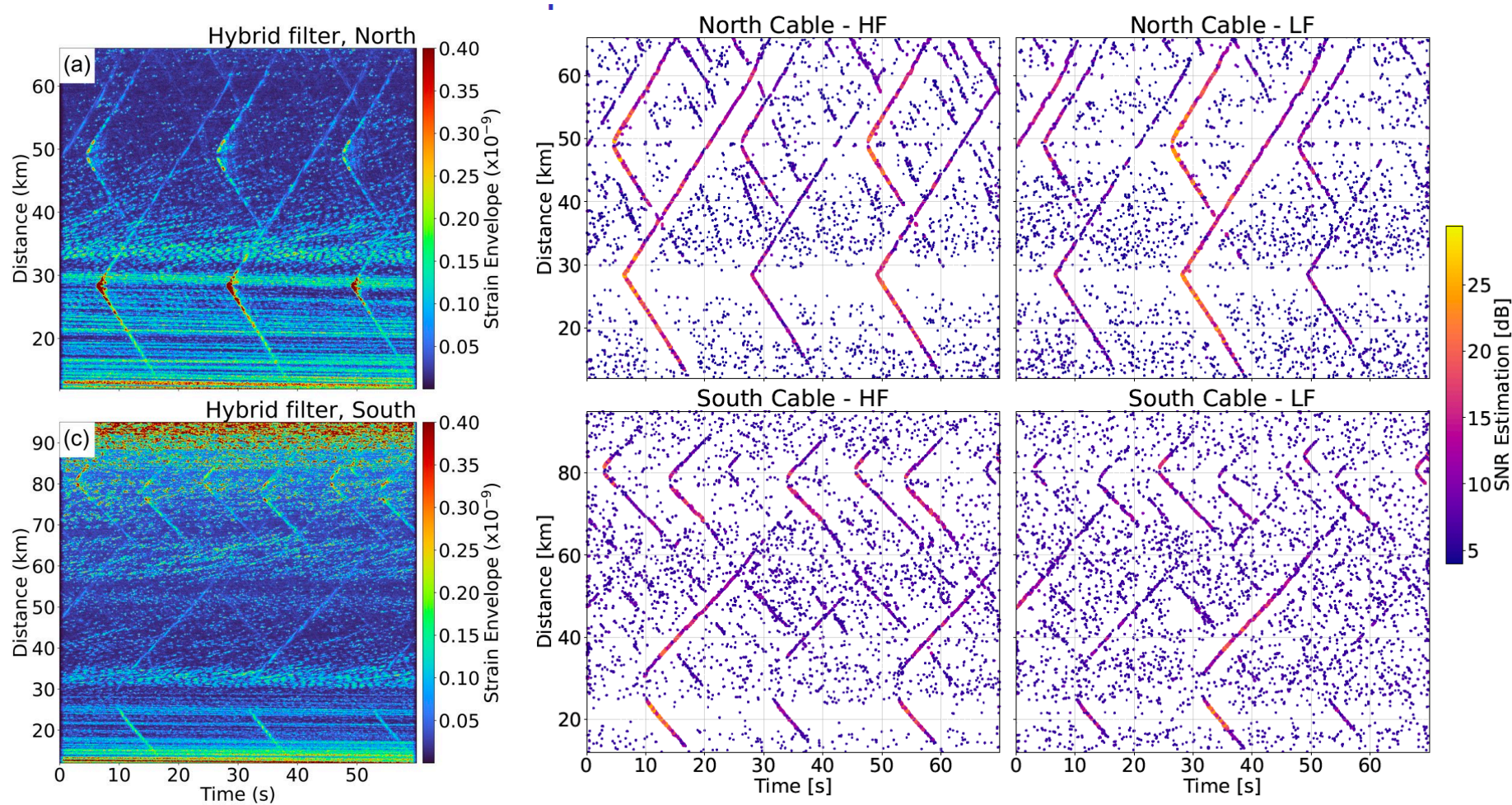


Wilcock, Abadi, Lipovsky (2023). Distributed Acoustic Sensing recordings of low-frequency whale calls and ship noises offshore central Oregon. JASA EL; 3(2): 026002.

Marine Bio-acoustics with DAS

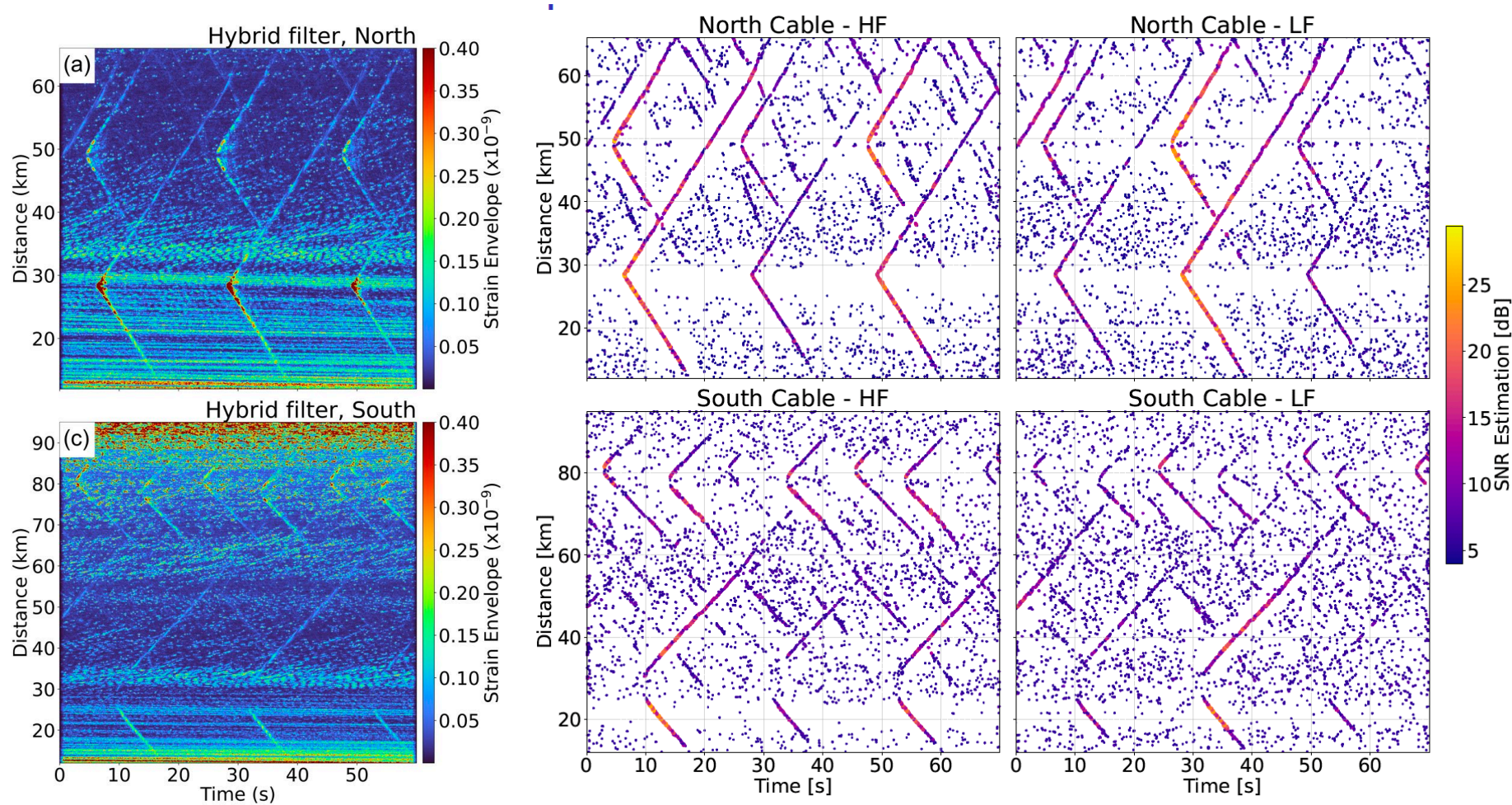


Call Denoising and Association



Goestchel, Wilcock, Abadi (2025) “Enhancing fin whale vocalizations in distributed acoustic sensing data,” JASA <https://doi.org/10.1121/10.0036696>

Call Denoising and Association

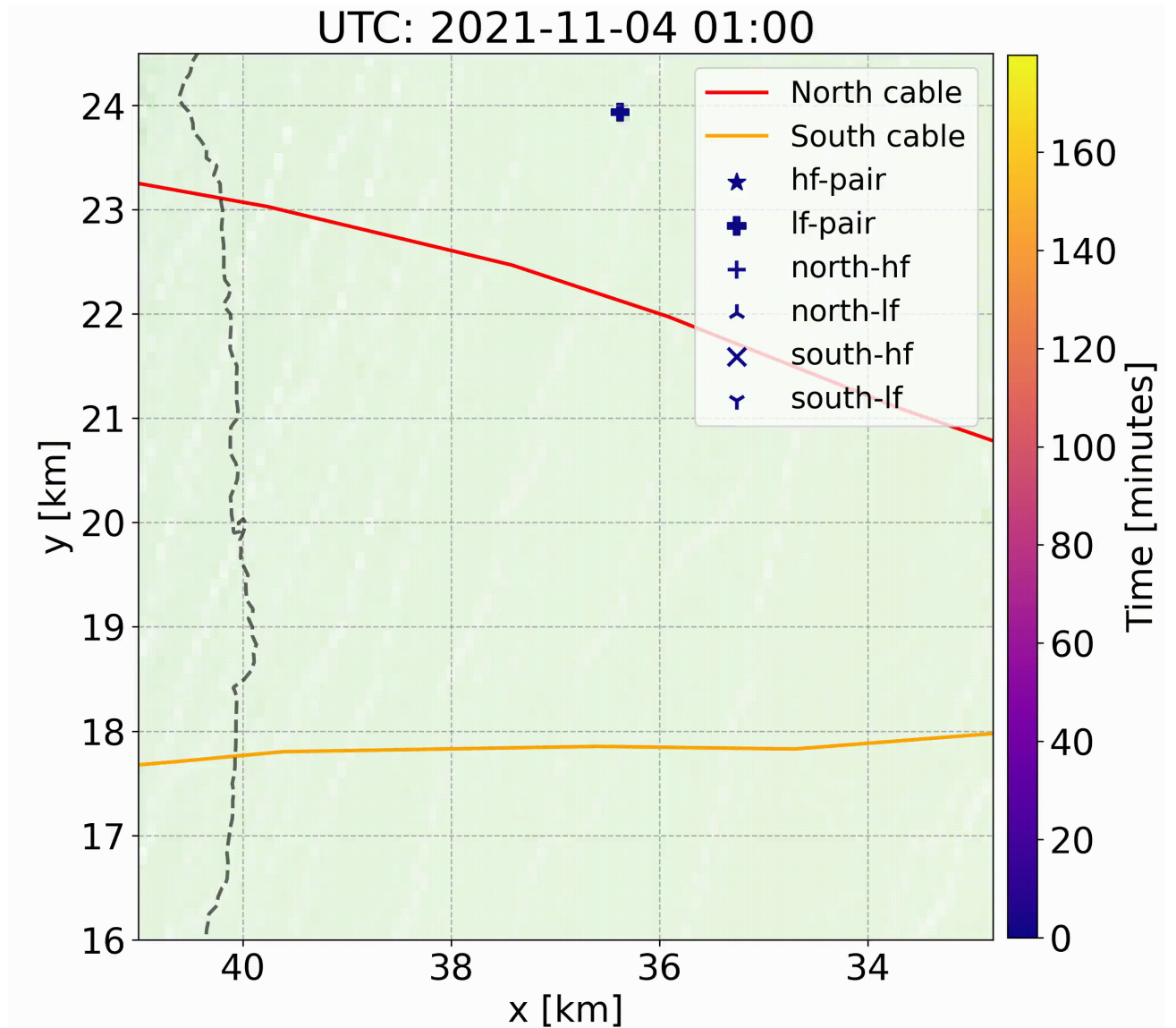


Goestchel, Wilcock, Abadi (2025) “Enhancing fin whale vocalizations in distributed acoustic sensing data,” JASA <https://doi.org/10.1121/10.0036696>

Localization & Tracking

There are multiple tracks in the 4-day dataset revealing a wealth of information about **fin whale calling behavior**.

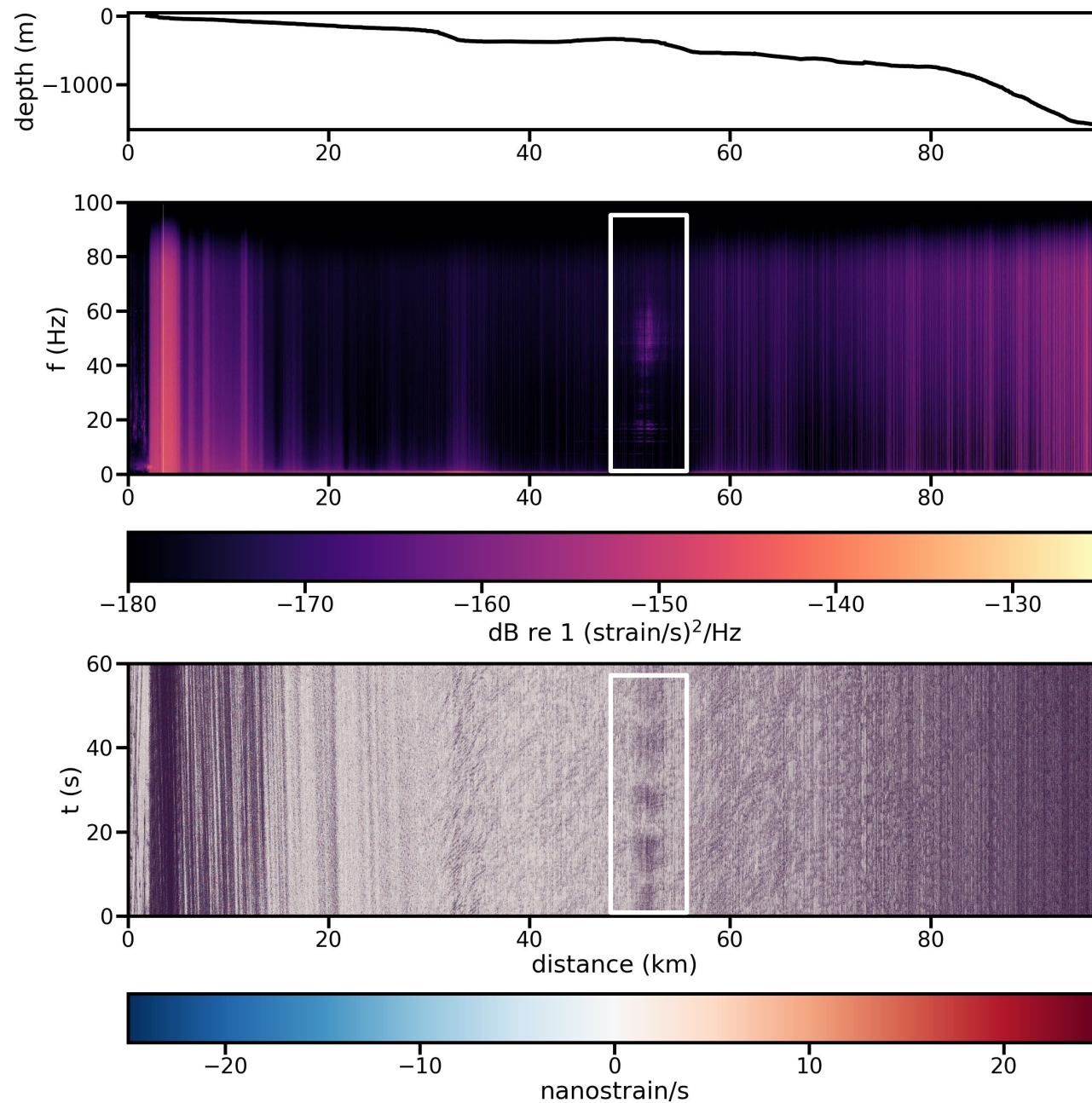
This data processing pipeline can be applied in a future **permanent DAS** system to study their **long-term behavior**.



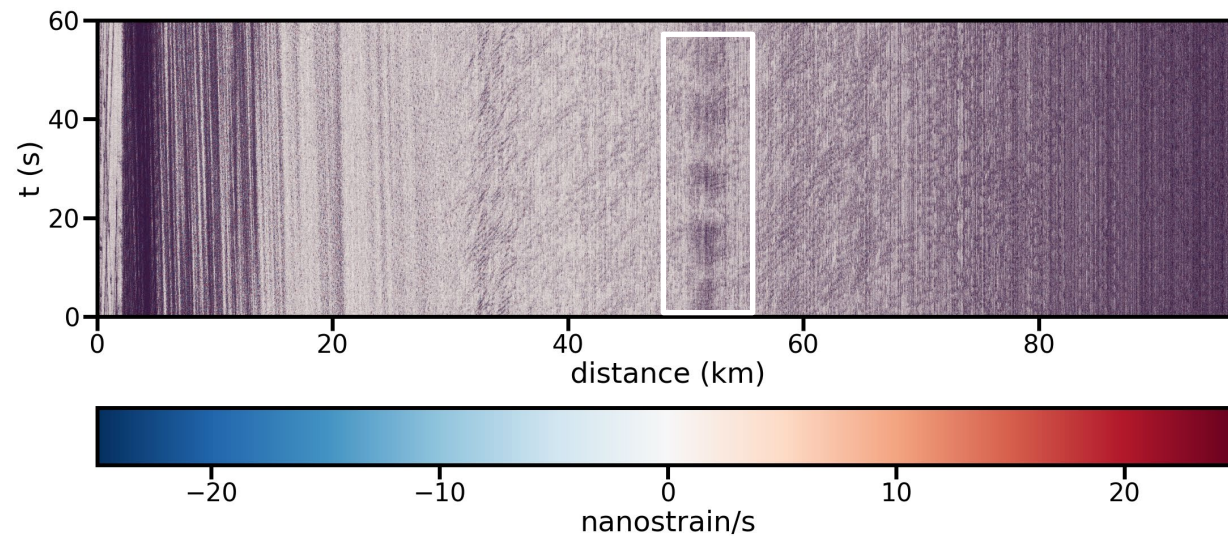
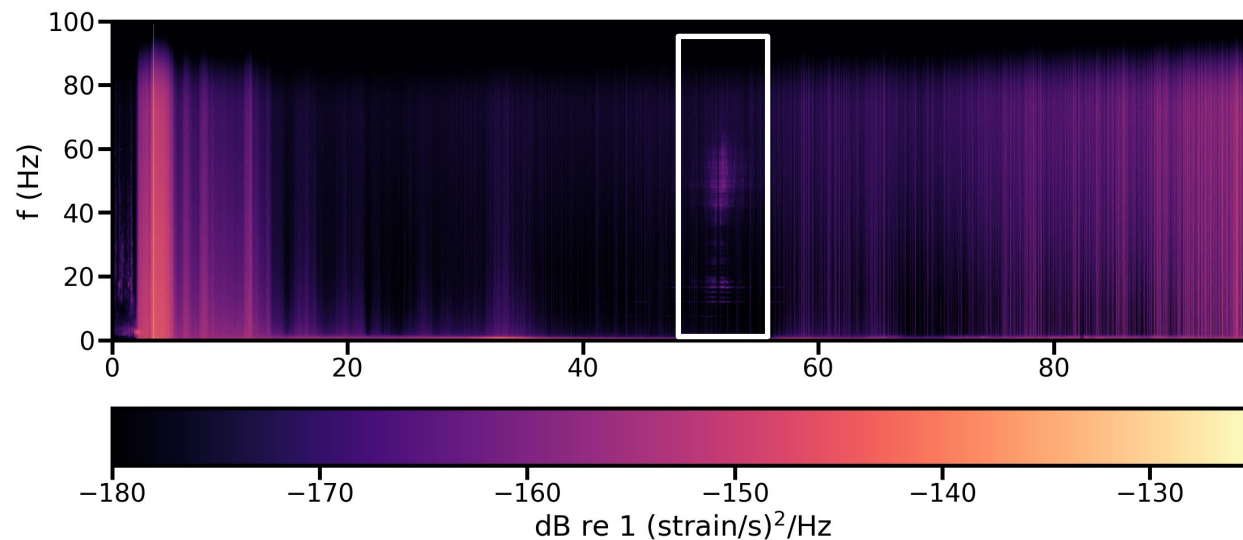
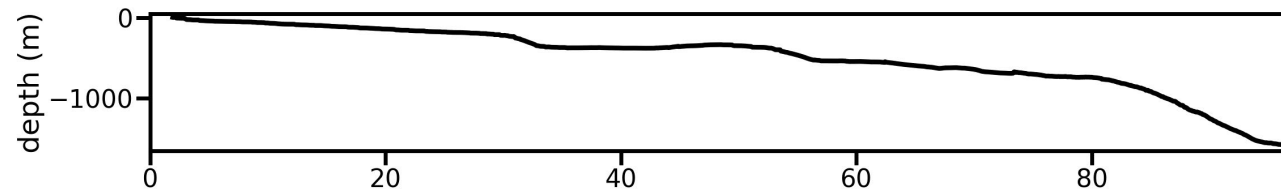
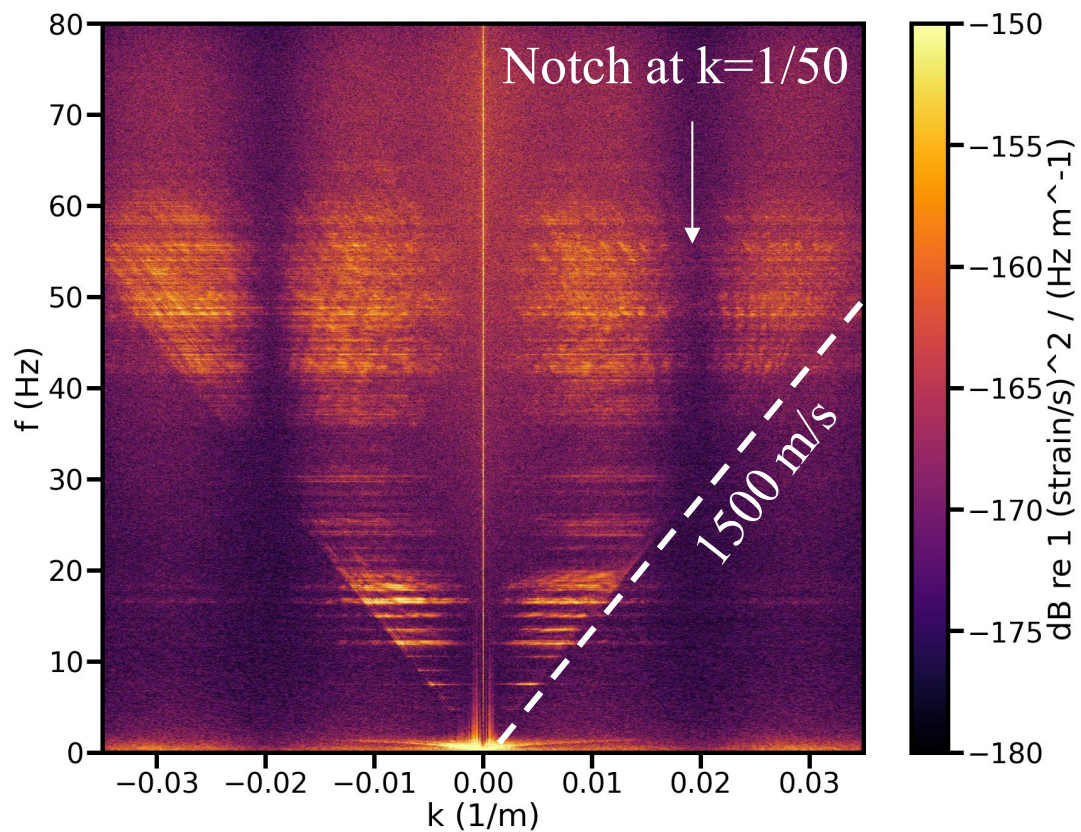
Goestchel, Wilcock, Abadi (2025) “Enhancing Fin Whale Vocalizations in Distributed Acoustic Sensing Data,” J. Acoust. Soc. Am. 157: 3655–3666.

Goestchel, Wilcock, Abadi (2026). Automated Association of Fin Whale Calls for Localization Using Distributed Acoustic Sensing. J. Acoust. Soc. Am. 160 (1): 135–146.

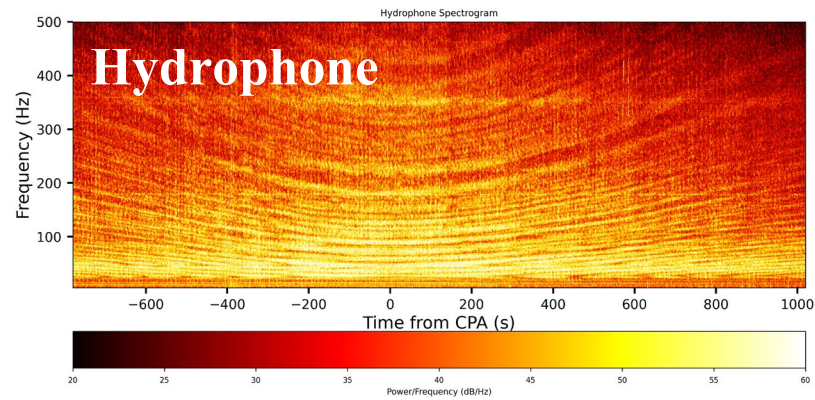
Cargo Ship



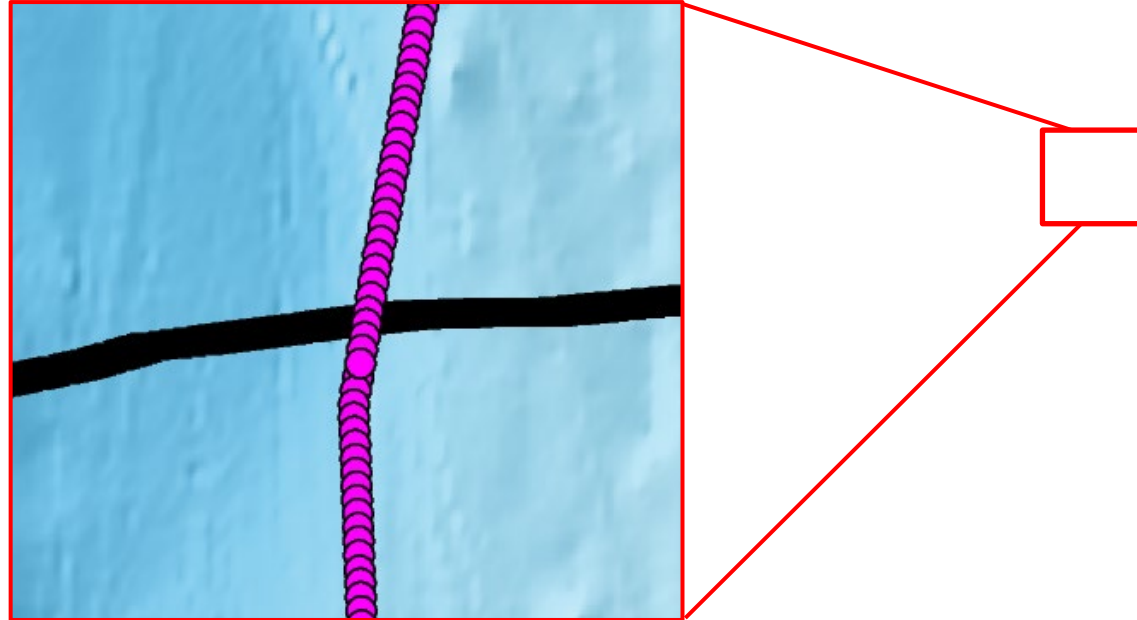
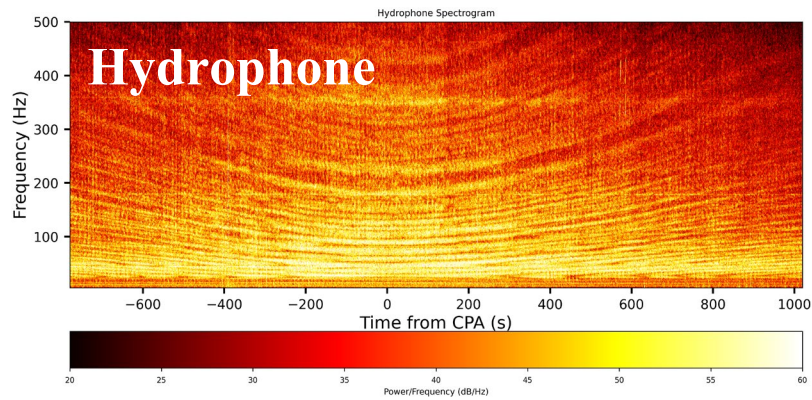
Cargo Ship



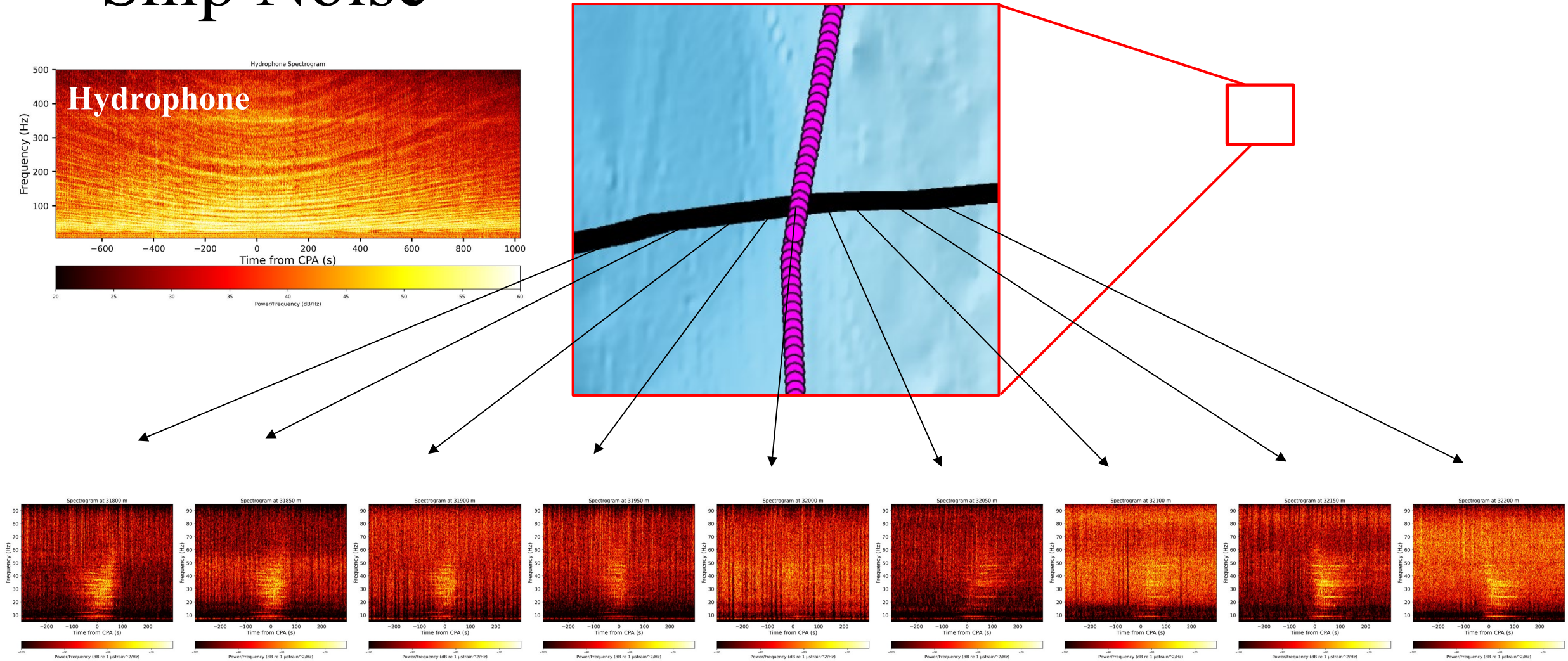
DAS Calibration with Ship Noise



DAS Calibration with Ship Noise



DAS Calibration with Ship Noise



Pressure to Strain Conversion

environment
+ geometry coupling and
strain averaging

$$SL_{das} = RL_{das} + \textcircled{TL_{das}} + \textcircled{H_{das}}$$

environment
+ geometry

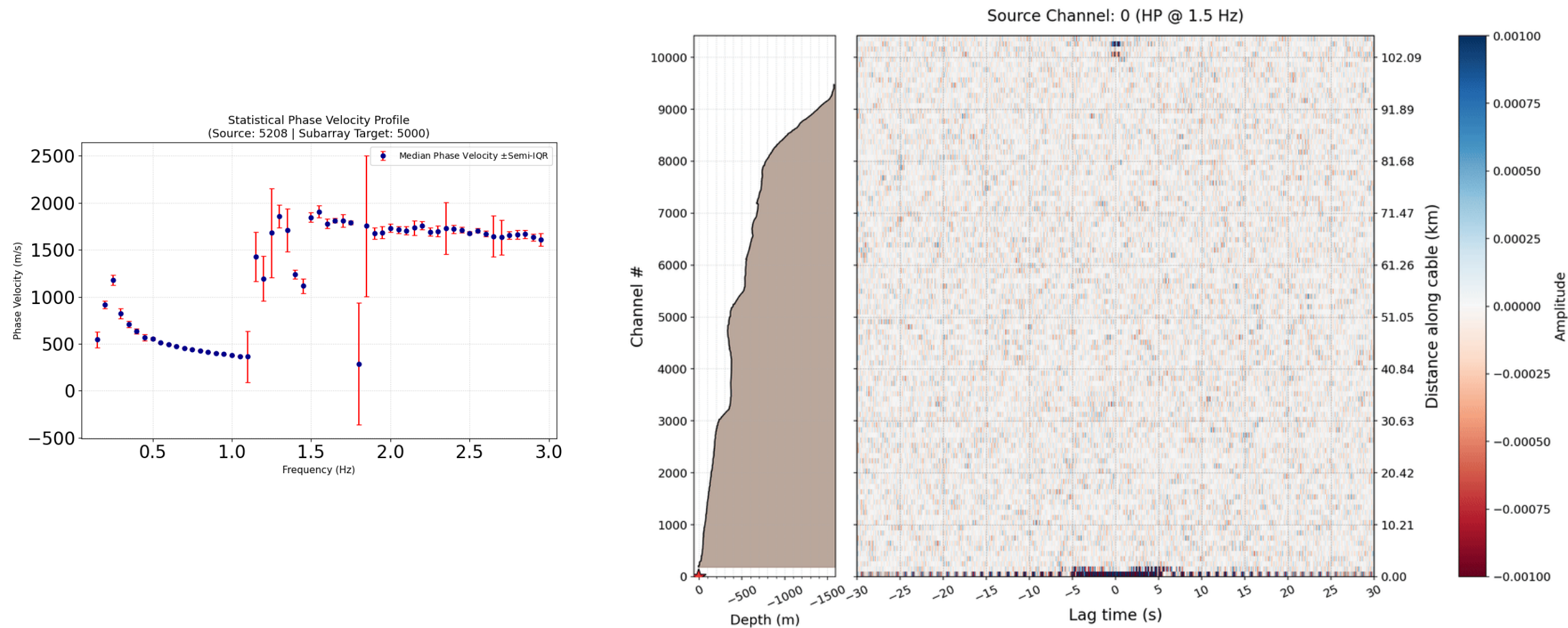
$$SL_{hyd} = RL_{hyd} + \textcircled{TL_{hyd}}$$

Bouffaut et al. (2025): 187.2 dB over the 14–30 Hz band

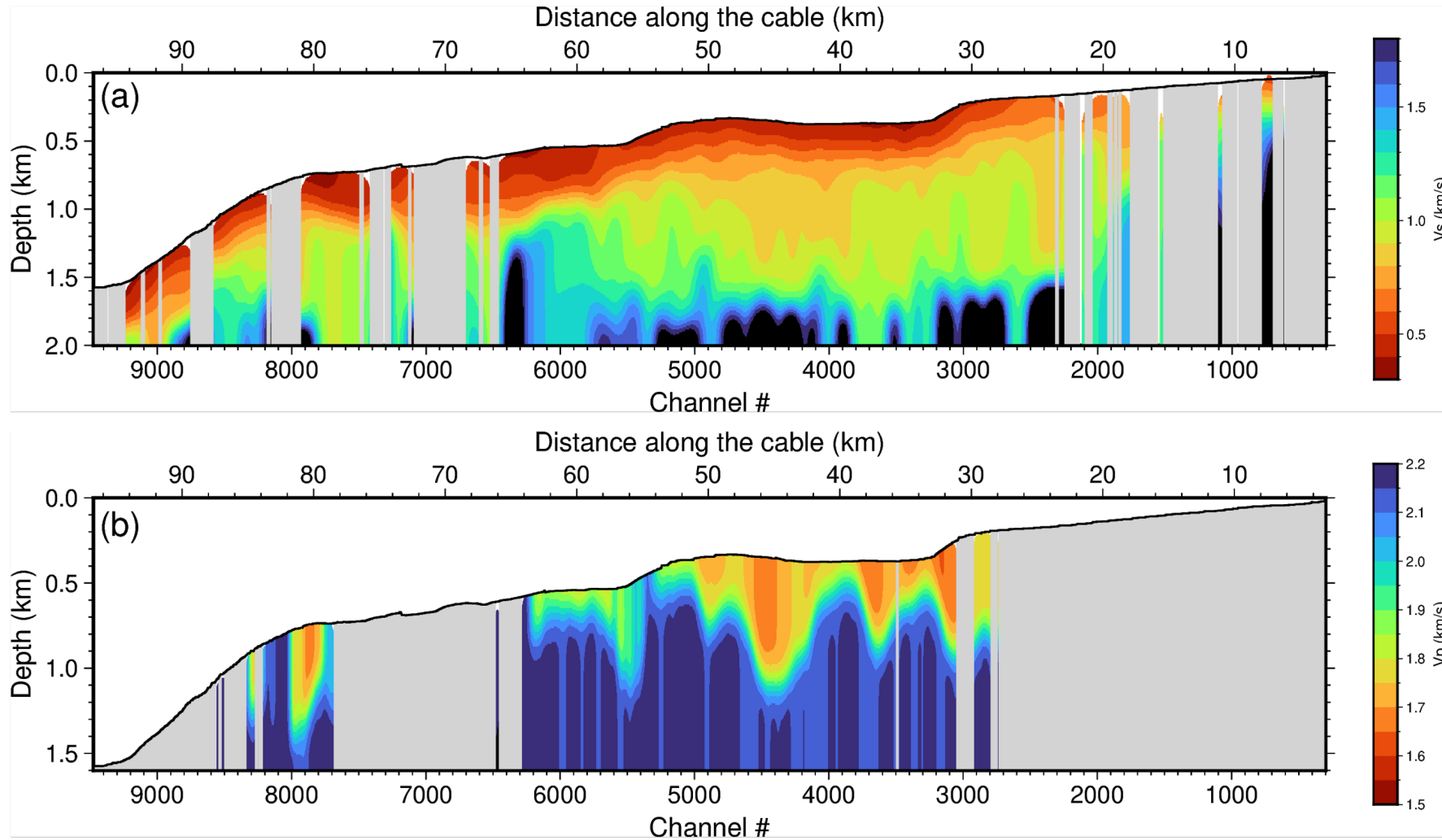
Potter et al. (2024): 130 dB over a much broader frequency range (up to 2.5 kHz)

Glover et al. (2026): conversion factor varied by 10 orders of magnitude for ocean surface gravity waves (0.04–0.4 Hz)

DAS Coherent Noise



Geo-acoustic Inversion



Three Ways to Deploy a DAS Cable

OPTION 1



Repurposed Telecom Cable

Uses “dark” or “lit” fibers inside existing submarine or terrestrial telecom cables. Fast and low-cost, since the cable is already on the seafloor.



Best for: basin-scale coverage using infrastructure that already exists

OPTION 2



Purpose-Built DAS Cable

A new cable is designed and laid specifically for sensing — choice of fiber, coating, and route can be optimized for acoustic sensitivity rather than data bandwidth.



Best for: dedicated monitoring in a chosen area of interest

OPTION 3



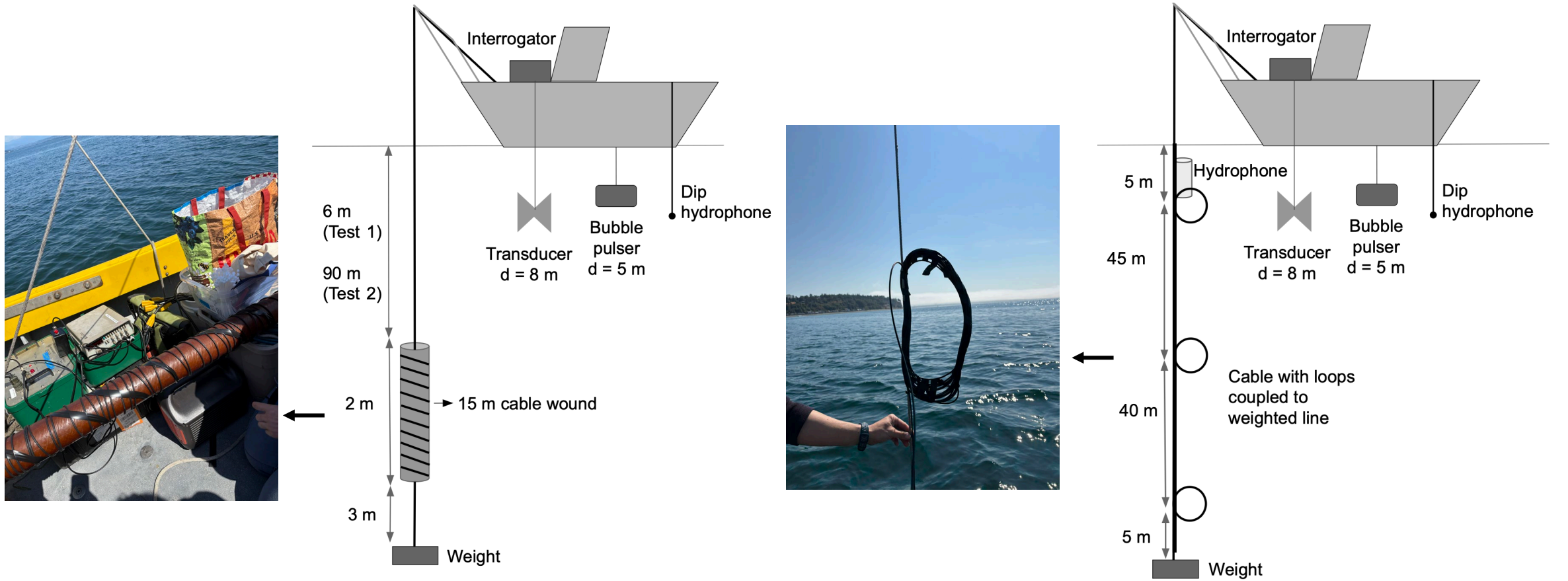
Non-Straight Cable Geometries

The fiber is looped, wrapped, or laid in a spiral / helix rather than a straight run, multiplying the fiber length — and sensitivity — packed into a small area.



Best for: high-resolution sensing at a single fixed point or structure

Loop & Spiral Configurations

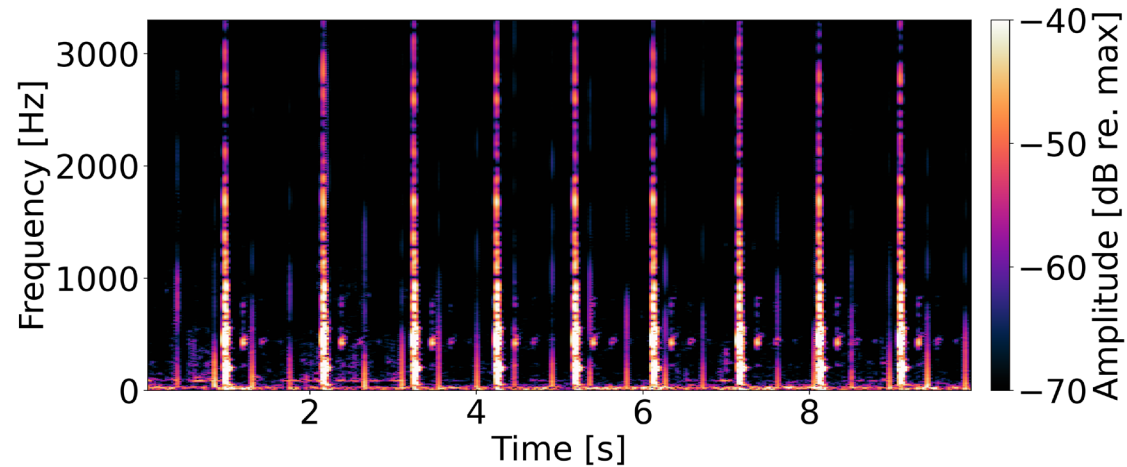


* Juber, Brandicourt, Lipovsky, Goestchel, Wilcock, Abadi. Vertical Array Distributed Acoustic Sensing for waterborne acoustic signals up to 3 kHz. JASA. under review.

** Saw et al (2025). Distributed Acoustic Sensing for Whale Vocalization Monitoring: A Vertical Deployment Field Test, Seismol. Res. Lett. 96, 801–815.

Vertical DAS

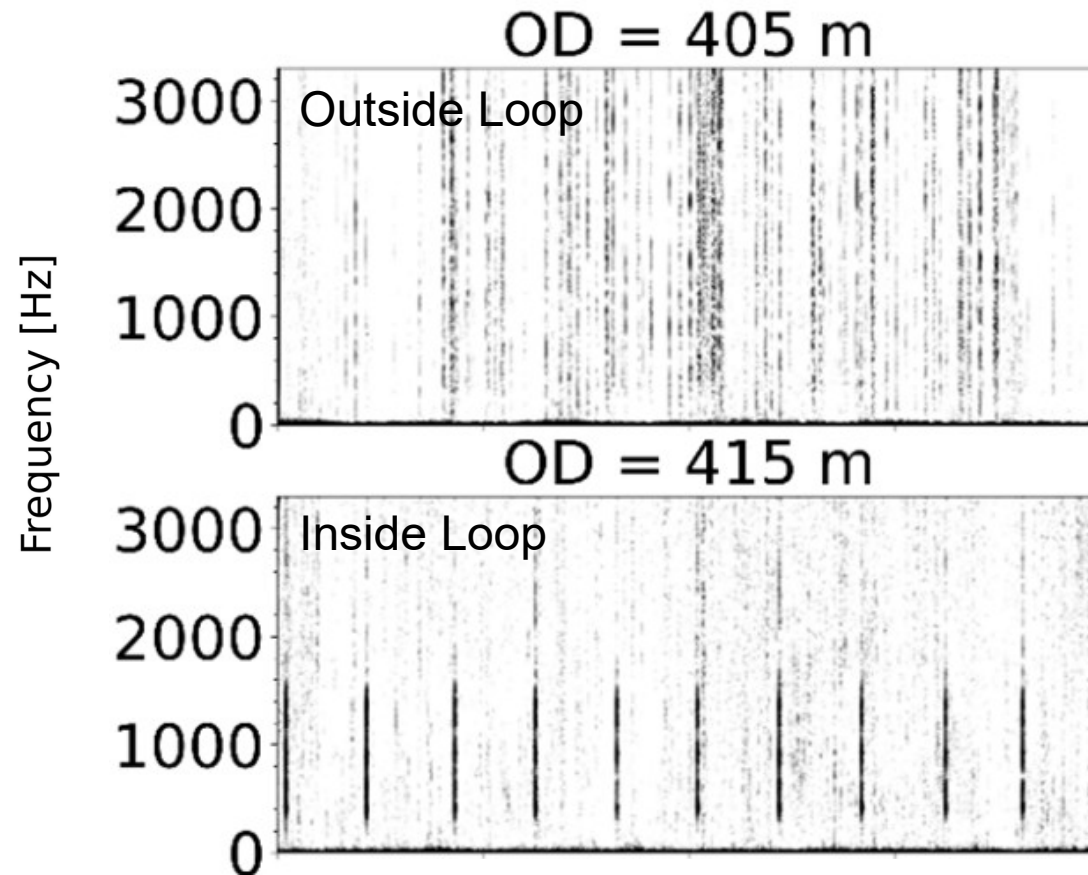
Broadband impulsive signals transmitted at 1-second intervals



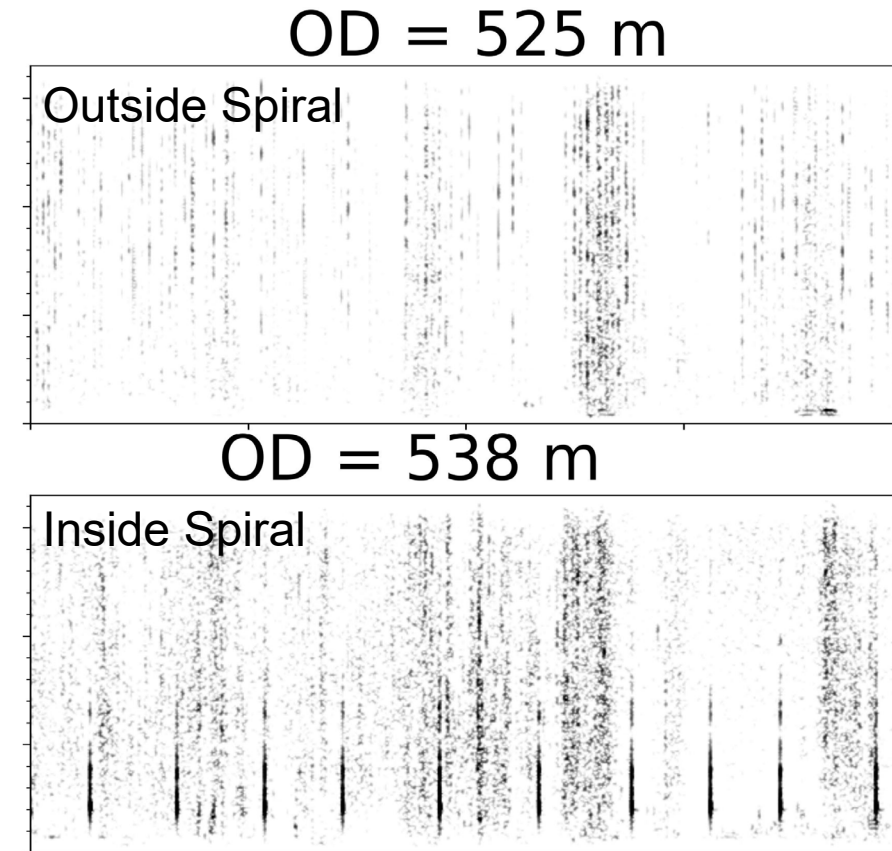
Gauge length: 4.79 m
Channel spacing: 3.19 m
Pulse width: 20 ns



Loop Configuration



Spiral Configuration

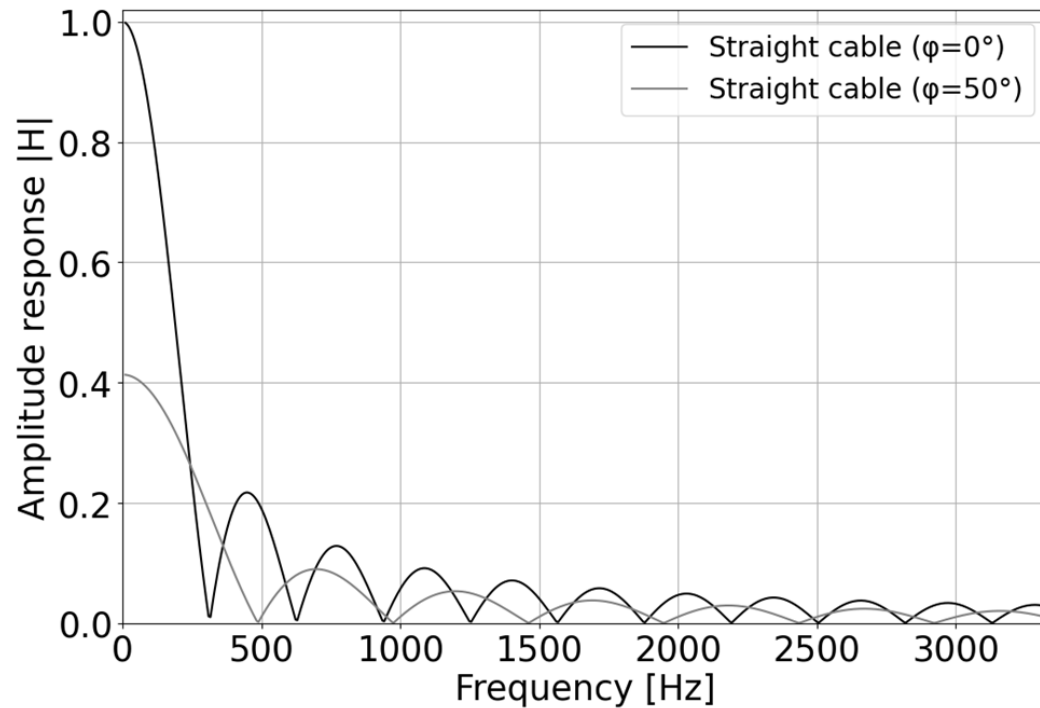


Juber, Brandicourt, Lipovsky, Goestchel, Wilcock, Abadi. Vertical Array Distributed Acoustic Sensing for waterborne acoustic signals up to 3 kHz. JASA. under review.

Why Fiber Loops Enhance High-Frequency Detection?

Straight Fiber

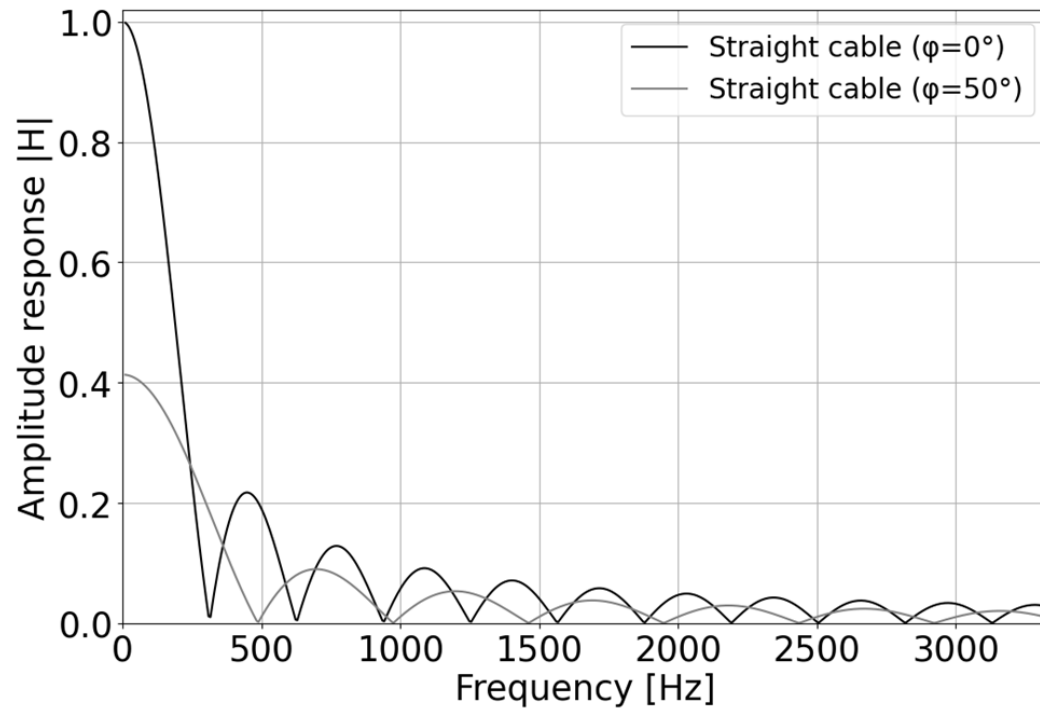
$$\hat{t} = \hat{i}$$



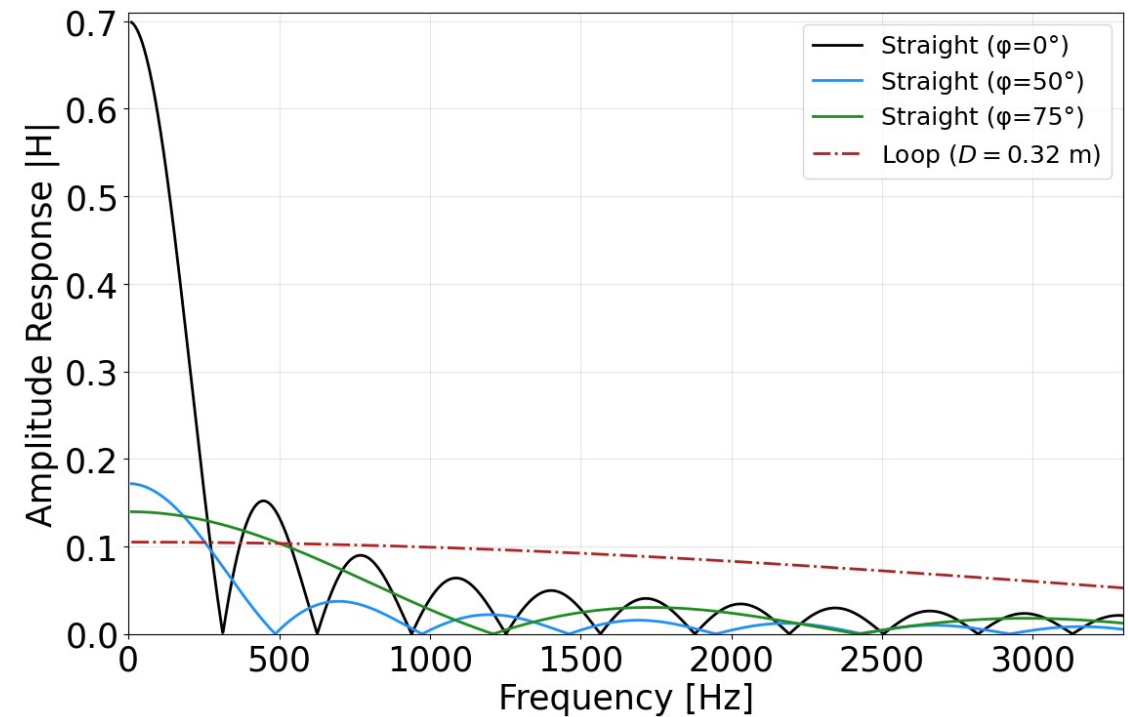
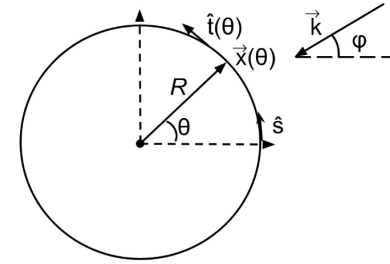
Why Fiber Loops Enhance High-Frequency Detection?

Straight Fiber

$$\hat{t} = \hat{i}$$

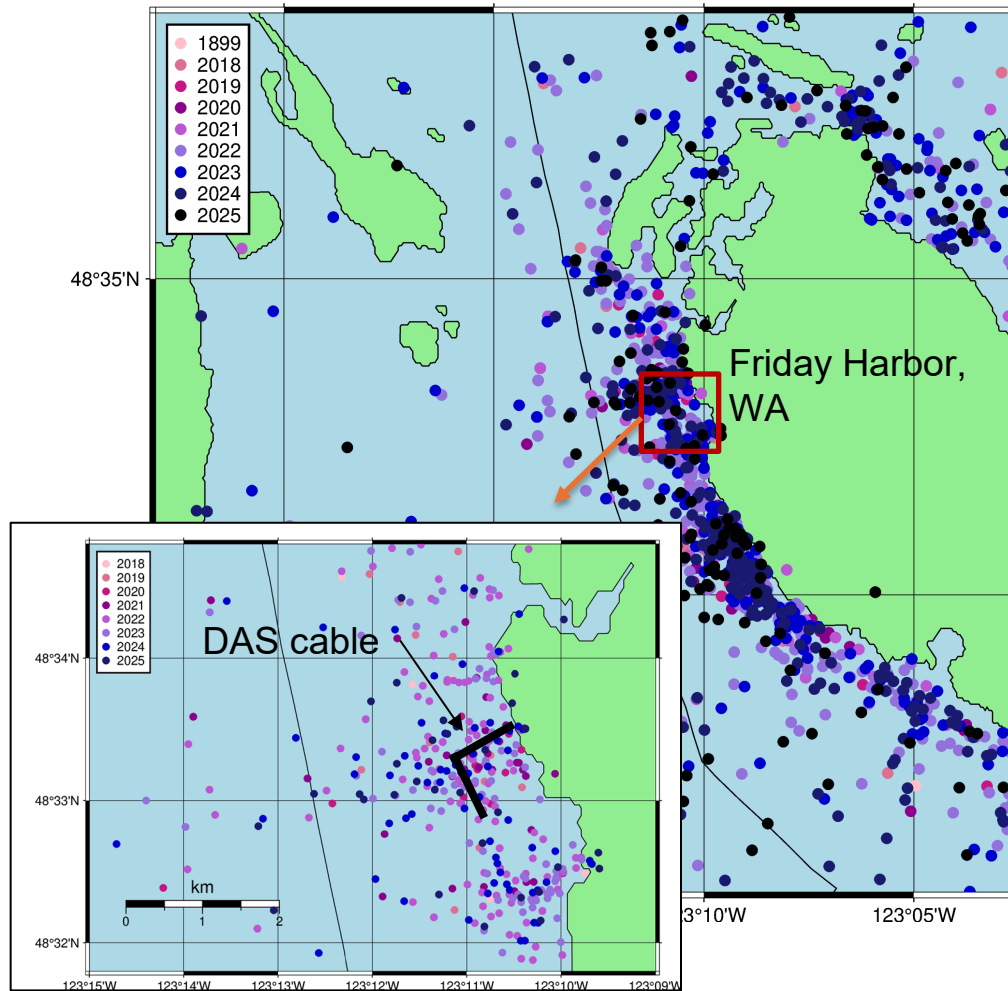


Looped Fiber

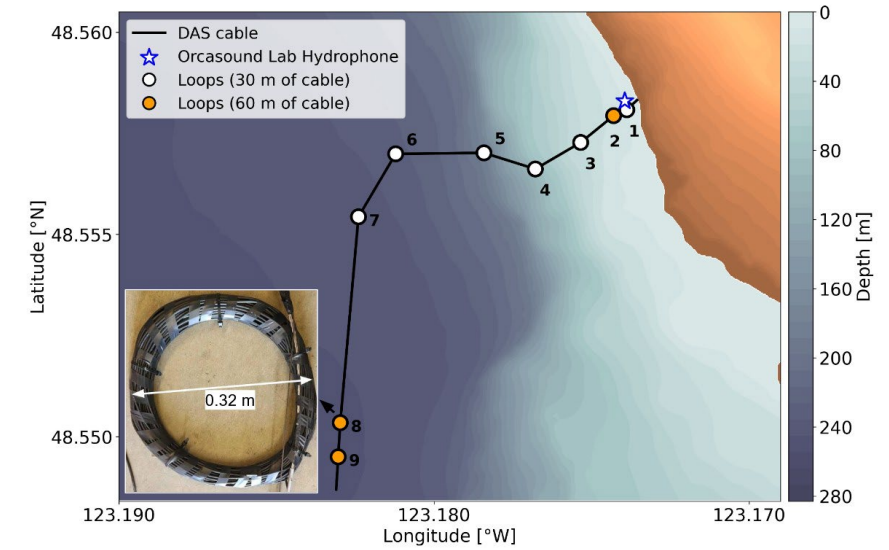


High-Frequency Detection of Whale Vocalizations

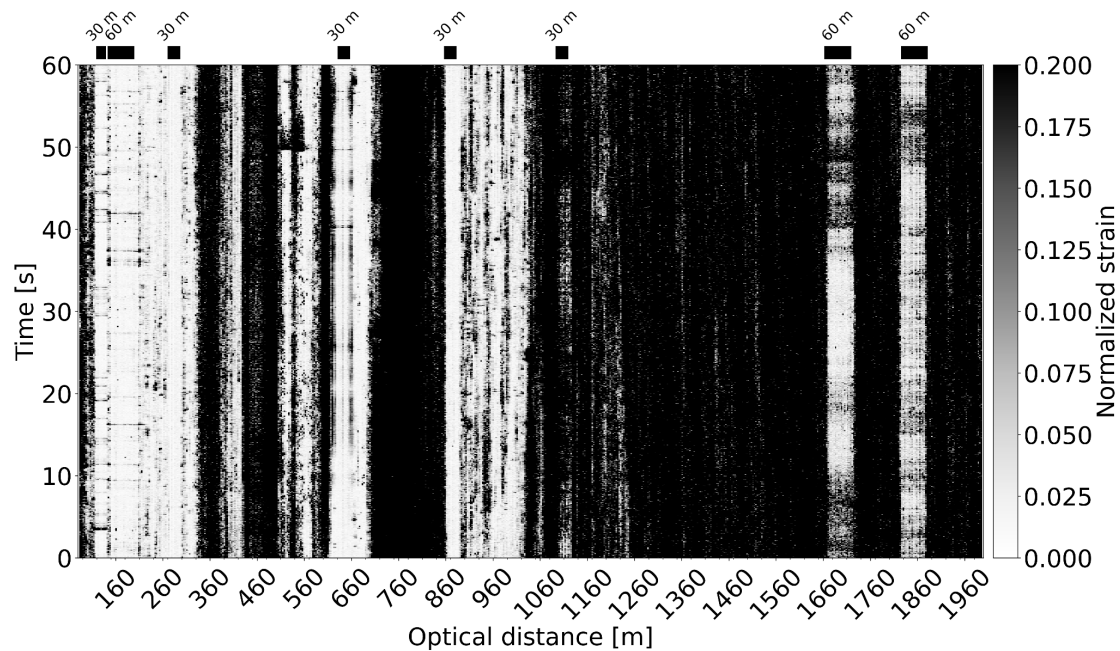
Southern Resident killer whales Sightings



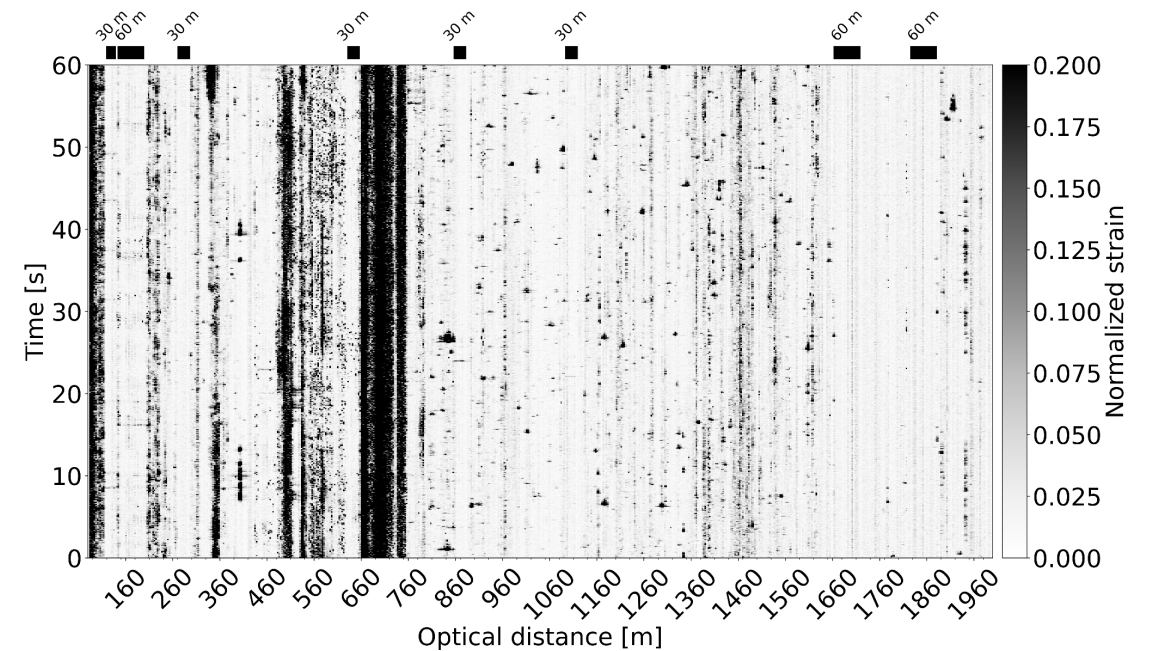
Effect of Fiber Loops



Maximum flood

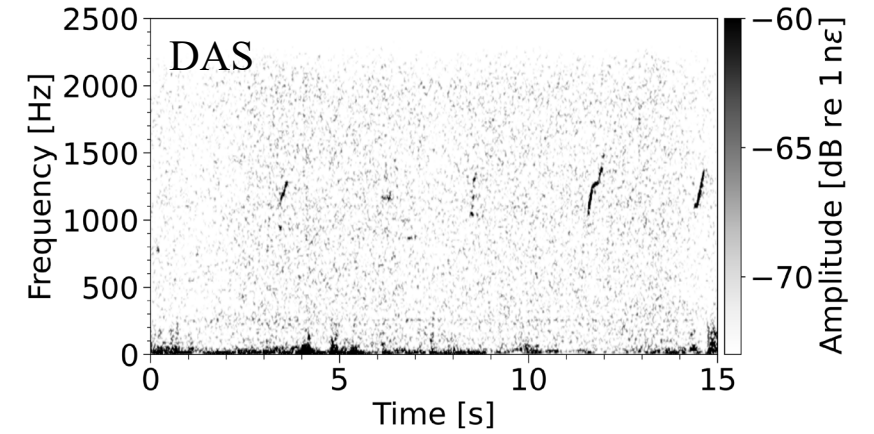
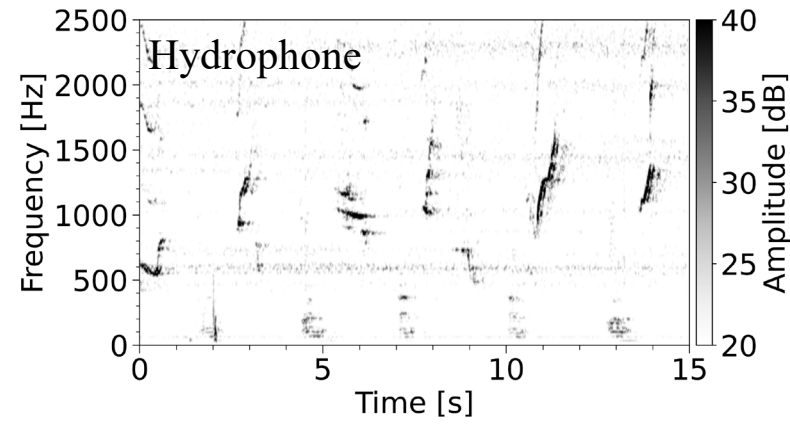


Slack water

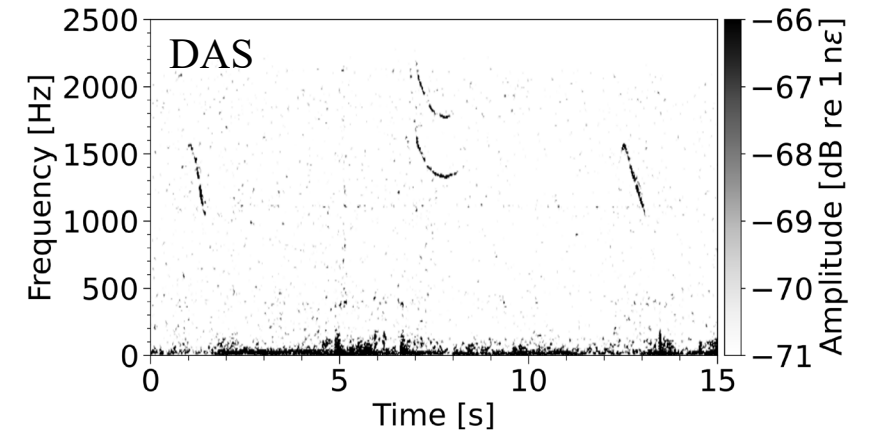
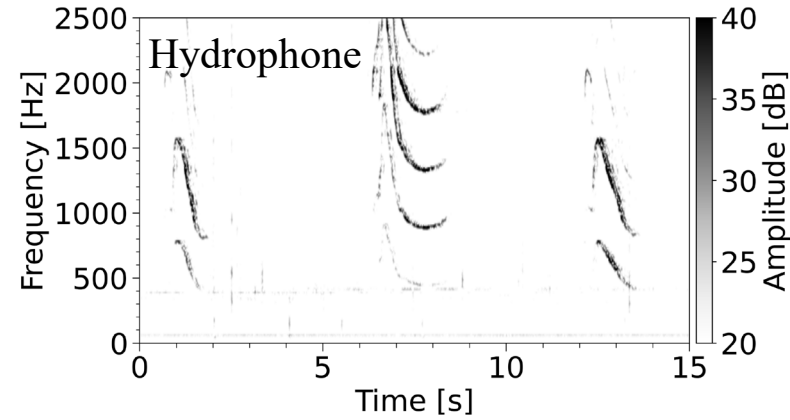




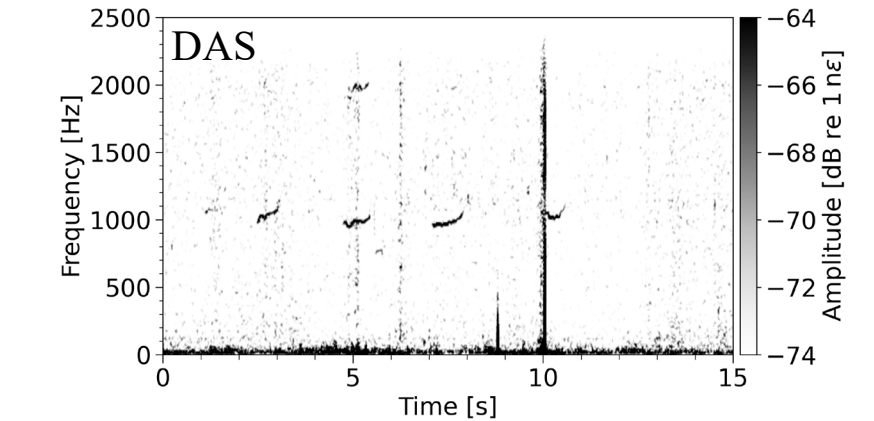
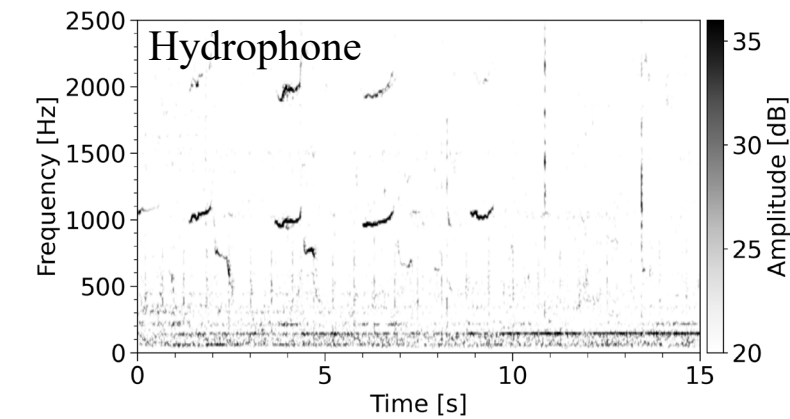
Humpback Whales



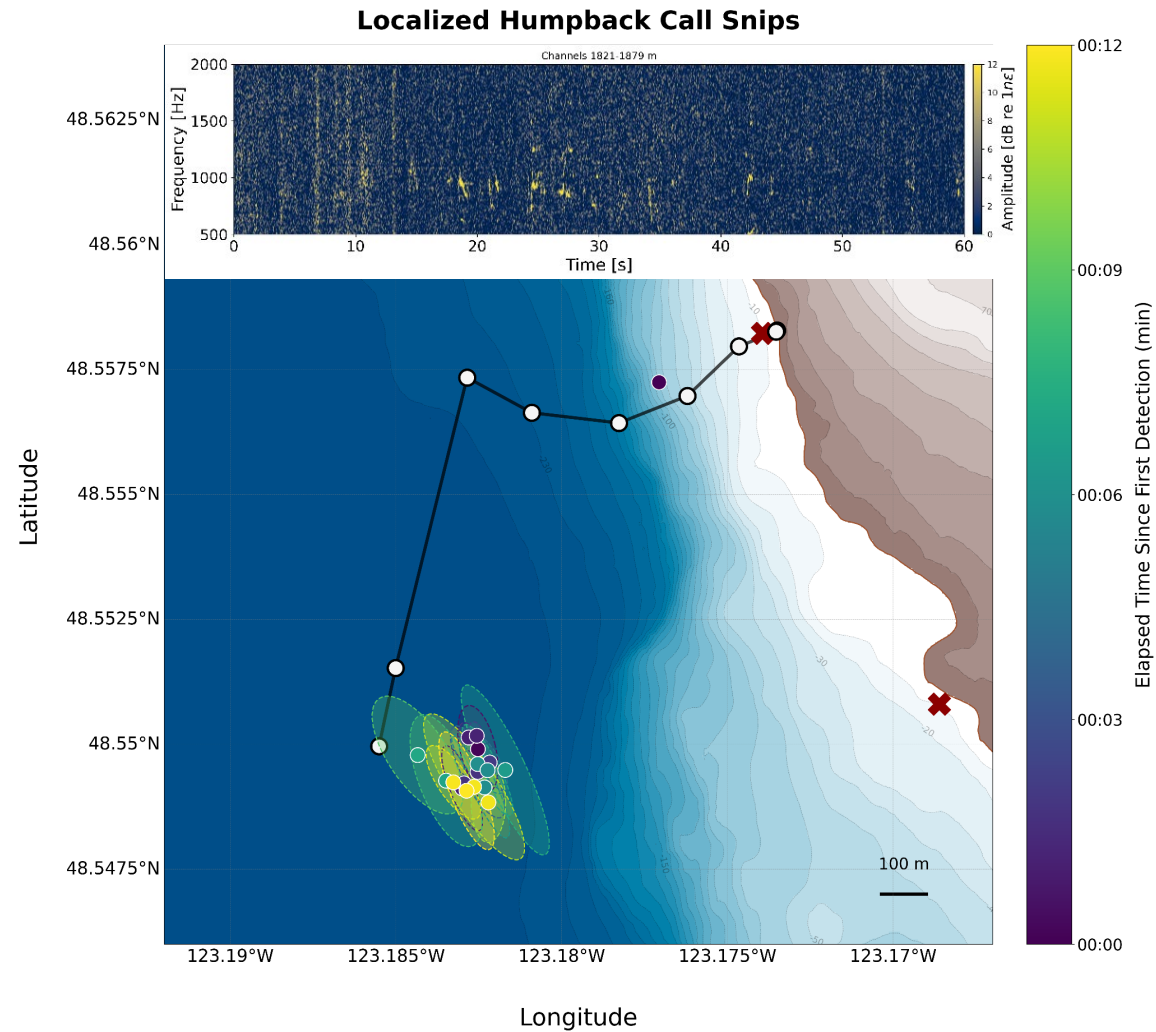
Bigg's Transient Killer Whales



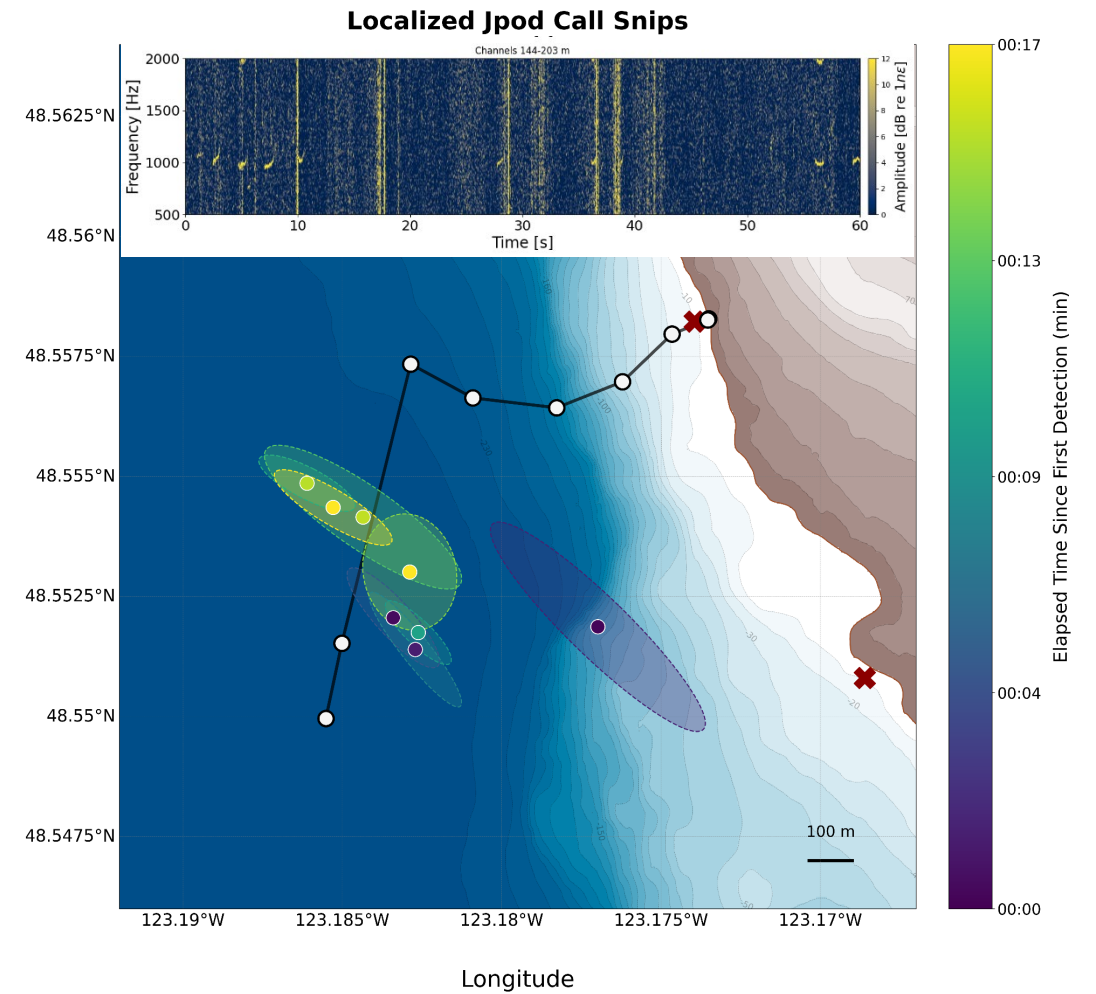
Southern Resident Killer Whales



Humpback Localization



Jpod Localization

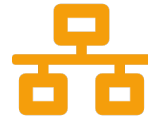


Key Challenges



TBs per day

- Continuous high-frequency sampling along entire fiber length
- Data accumulates 24/7, growing faster than it can be processed
- Near-real-time analysis is constrained by I/O throughput limits



\$\$\$ + Latency

- Shipping TBs over WAN is slow and expensive
- Cloud egress fees can exceed compute costs
- Processing must be co-located with storage to be viable



Key Principle: Compute must go to the data — not the other way around. Remote transfer is impractical at DAS scale.

Where DAS Is Headed



Multi-Span DAS

Chaining interrogation across repeater spans to sense along entire transoceanic cable routes, not just the first 100–150 km from shore.



Permanent DAS

Fixed, always-on interrogators integrated into cable landing stations for continuous, long-term monitoring rather than short survey campaigns.



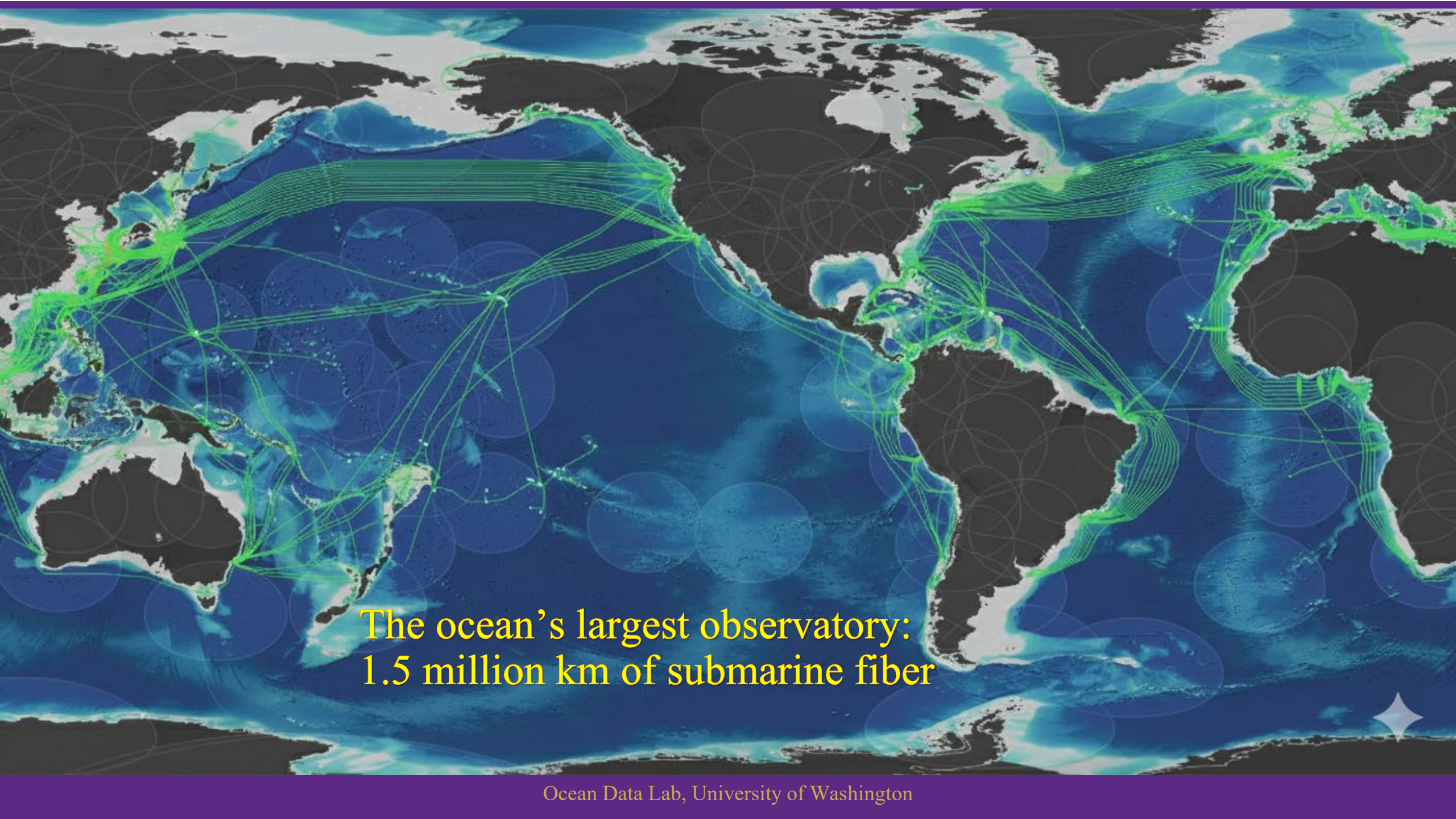
High-Frequency DAS

Faster pulse and sampling rates that push sensing bandwidth beyond seismic bands and into higher-frequency underwater acoustics.



Portable DAS

Compact, field-deployable interrogators that turn any accessible fiber — temporary or permanent — into a rapid-response sensing array.



The ocean's largest observatory:
1.5 million km of submarine fiber

The Big Picture

- A single fiber-optic cable acts as a **multi-physics observatory** — monitoring environmental, geophysical, and structural phenomena simultaneously over long distances.
- DAS leverages **existing infrastructure** — no new sensors, no new deployments, just a cable already on the seafloor.

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The Physics is Remarkable

- DAS detects **nano-scale strain** on a fiber buried under multiple layers of armoring and seafloor sediment.
- Despite that isolation, it still captures **acoustic signals propagating through the water column** above.

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We Are Just Getting Started

- The first subsea DAS demonstration was in **2019** — this is an extremely young field.
- The early years were an **exploration phase**: figuring out what DAS *can* sense and under what conditions.
- We are now crossing a threshold — shifting from capability discovery toward **systematic scientific production**. The most important discoveries with subsea DAS **haven't happened yet**.



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Thank You for Your Attention!

Questions & Discussion Welcome.