



EVENT DETECTION THRESHOLD ON SUBMARINE FIBER OPTIC IN THE ARCTIC

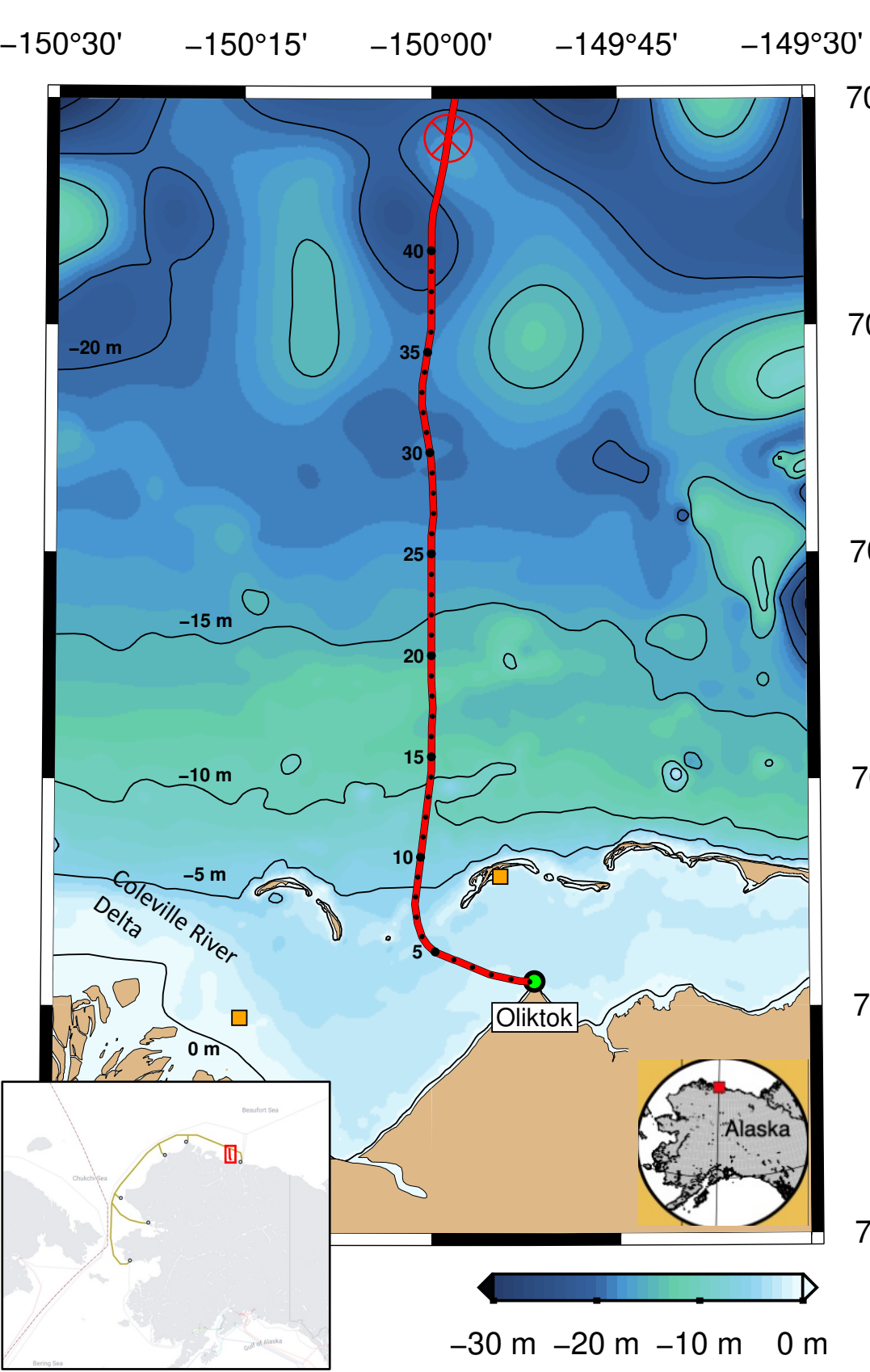
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Abstract

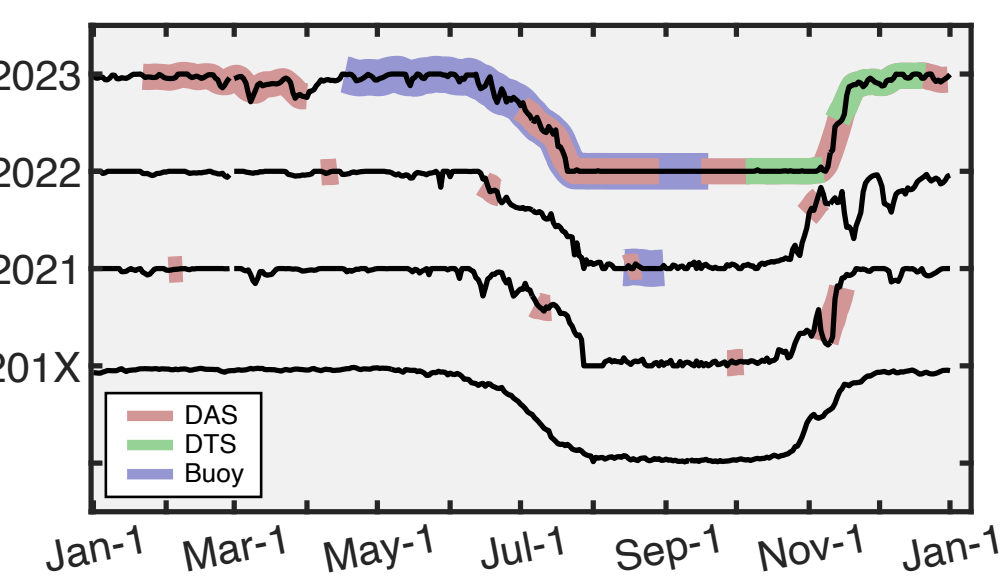
Distributed Acoustic Sensing (DAS) is increasingly leveraged for event detection at local, regional, and teleseismic scales for both earthquakes and anthropogenic sources. Despite the abundance of telecom submarine fiber optic, a very limited number are accessible to the event monitoring research community. In Alaska, we interrogate a segment of submarine dark fiber optic cable approximately 42 km long extending northward into the Beaufort Sea from Oliktok Point. Since 2023, this cable has enabled us to continuously monitor seismic events, capturing hundreds of events ranging from local to teleseismic epicentral distances. Preliminary analyses indicate that this system can reliably detect teleseismic events of magnitude 4 and higher and local events down to magnitude 1 across a variety of back azimuths. Variations in cable depth beneath the seafloor and the presence of ocean surface ice do not have a significant impact on signal recovery. However, the cable's geometry affects the signal amplitude for specific back-azimuths, distances, and hypocenters, particularly across the change in fiber orientation from N-S to NNW to SSE approximately 5 km offshore. We observe significant signal attenuation beyond 35 km distance along fiber, likely due to scattering and other non-linear effects. Additionally, a one-way repeater at 42 km will not allow signal recovery from the backscattered light and acts as a hard limit for detection along the fiber. This research demonstrates that DAS data recorded on submarine fiber optic can be used to monitor both natural and anthropogenic signals from local to teleseismic distances, demonstrating the potential to bridge data gaps in regions currently lacking coverage from conventional arrays. SNL is managed and operated by NTESS under DOE NNSA contract DE-NA0003525.

Where?



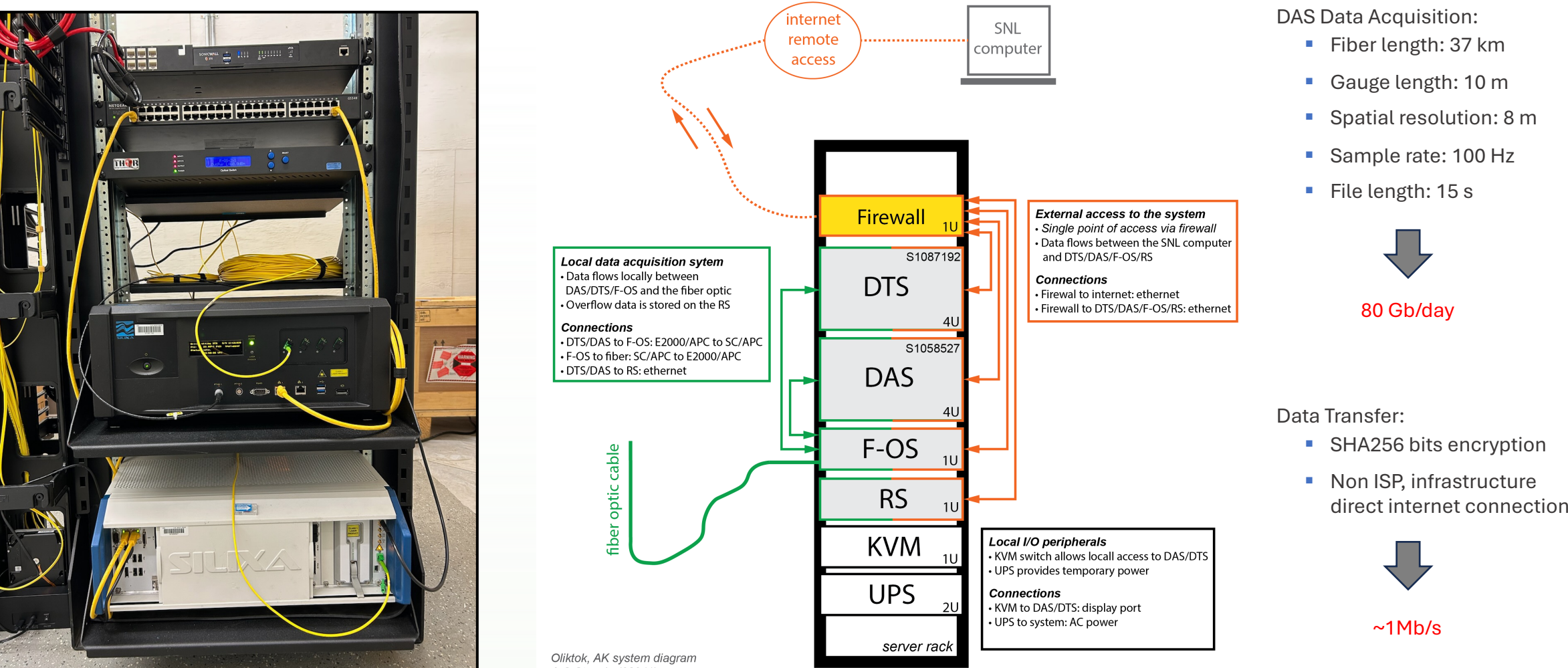
Why?

1. Investigate the submarine permafrost seismic structure
2. Find unconventional signals to characterize the nearshore subsurface seismic structure
3. Characterize temperature variations along the fiber optic cable
4. Identify and characterize other natural and anthropogenic signals



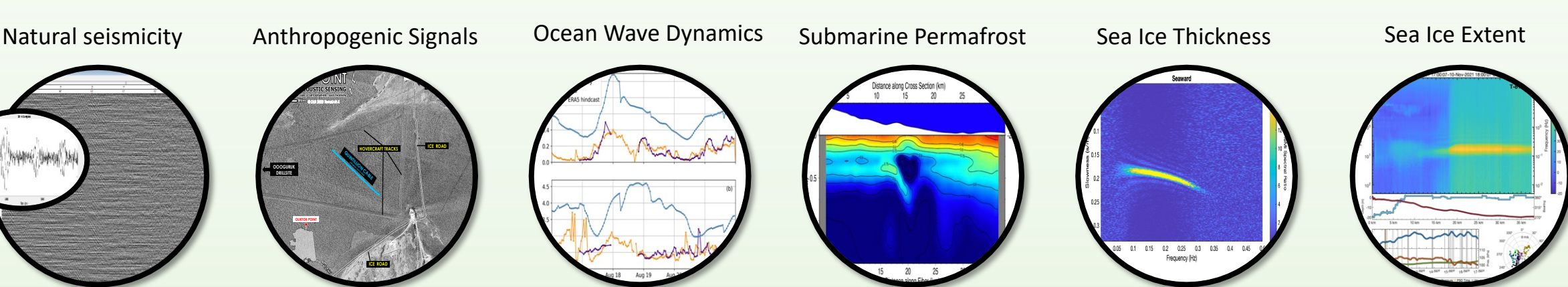
DAS and DTS data coverage (2021-2023). Black line indicates percent ice coverage

How?

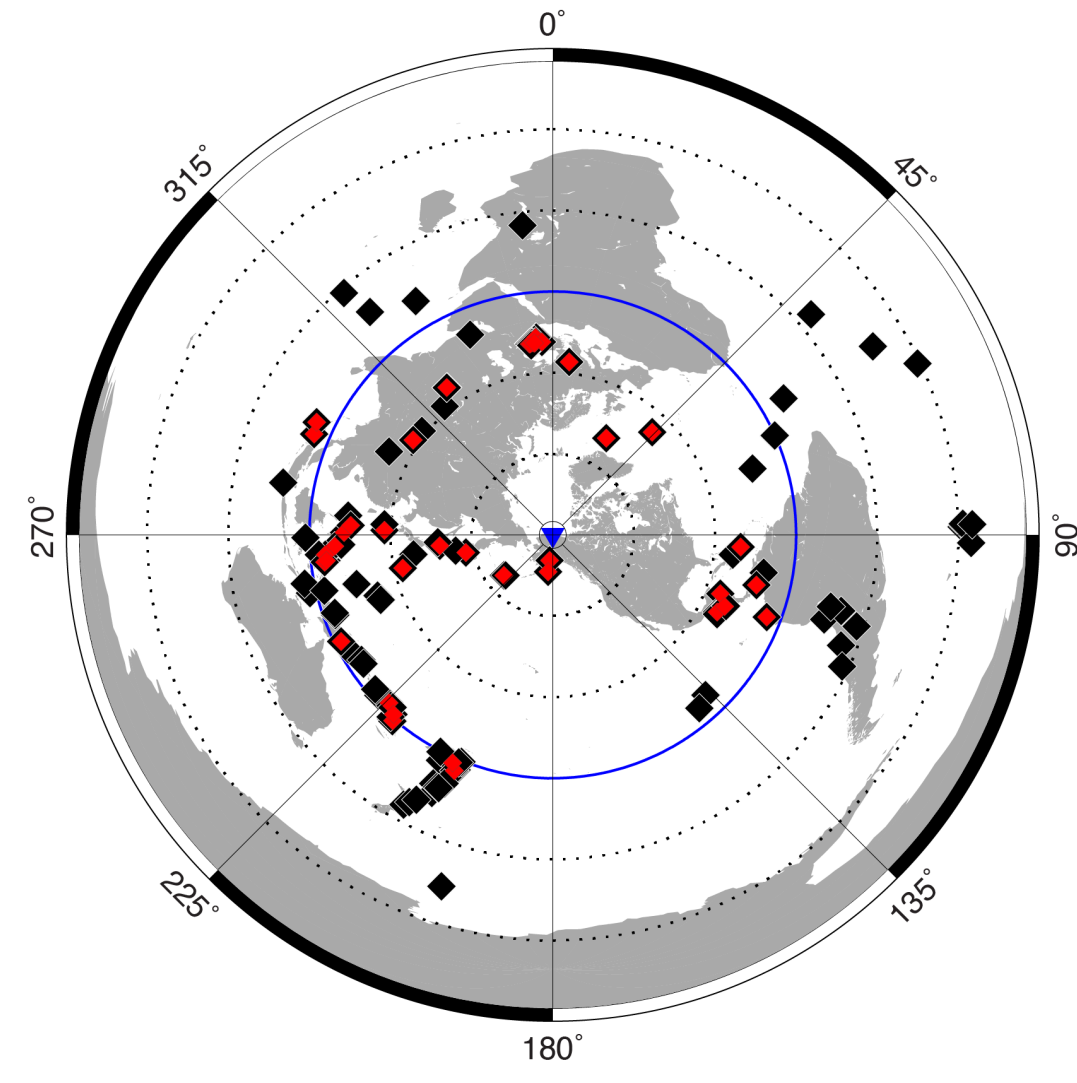


Remote data acquisition system capable of recording both DAS and DTS data on a single dark fiber

What?

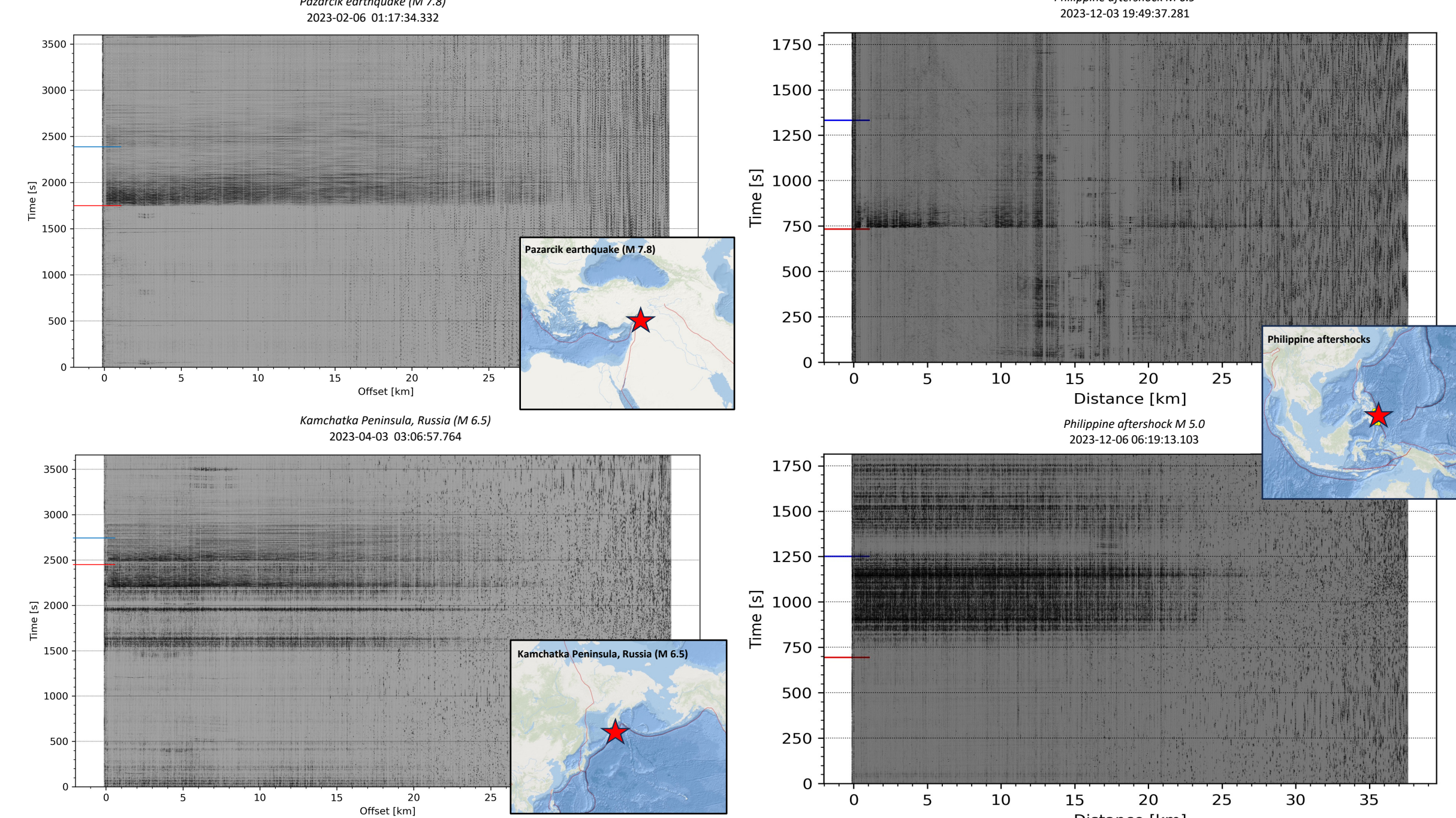


Regional and teleseismic earthquakes



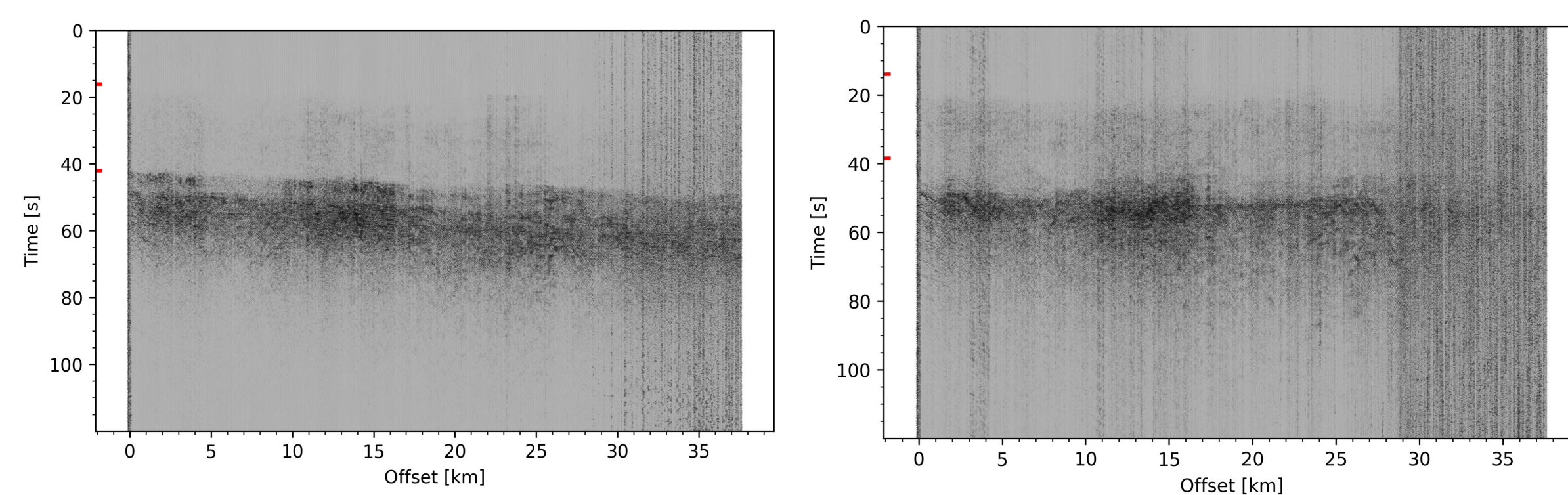
Azimuthal equidistance plot for February 2023 events from M 5 to M 7.8. We identified 41 P and 21 S arrivals (red symbols) for a total of 156 events (black symbols).

- Phases identified for events up to ~90° epicentral distance
- No clear arrivals from back-azimuths 45°-90° & 135°-180°



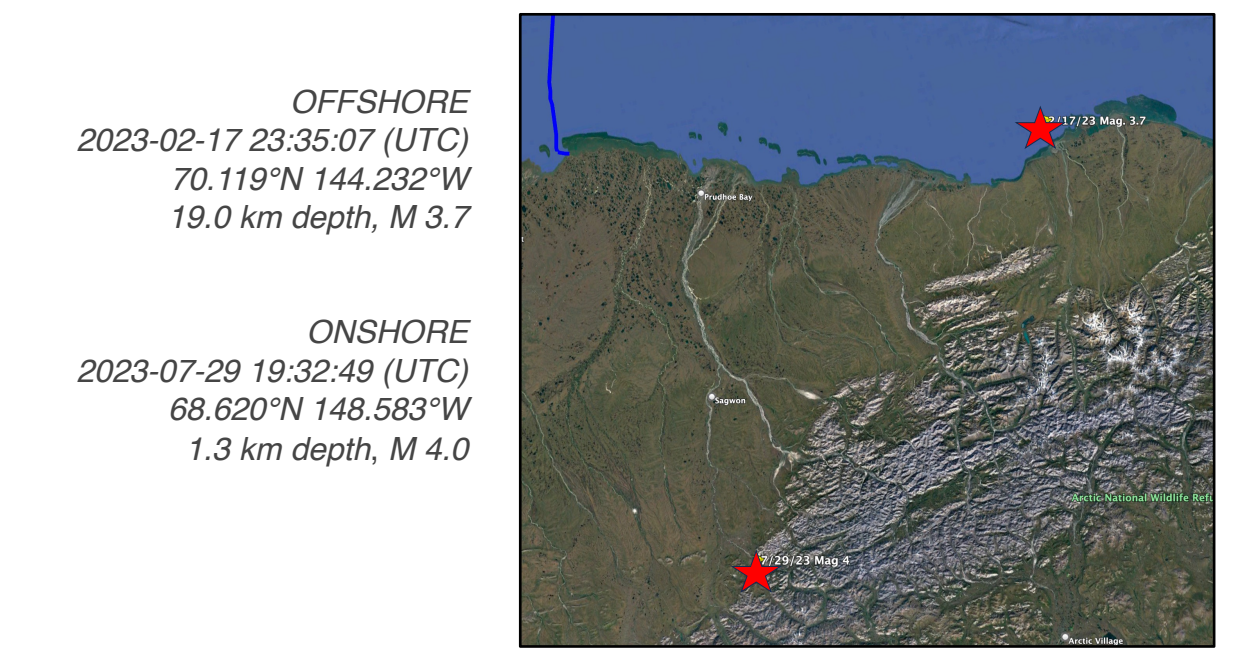
Examples of DAS record sections along distance showing phase arrivals for selected events between M5 and M7.8. SNR decreases significantly beyond 30 km distance along fiber. Amplitude is nm/m/s.

Local earthquakes

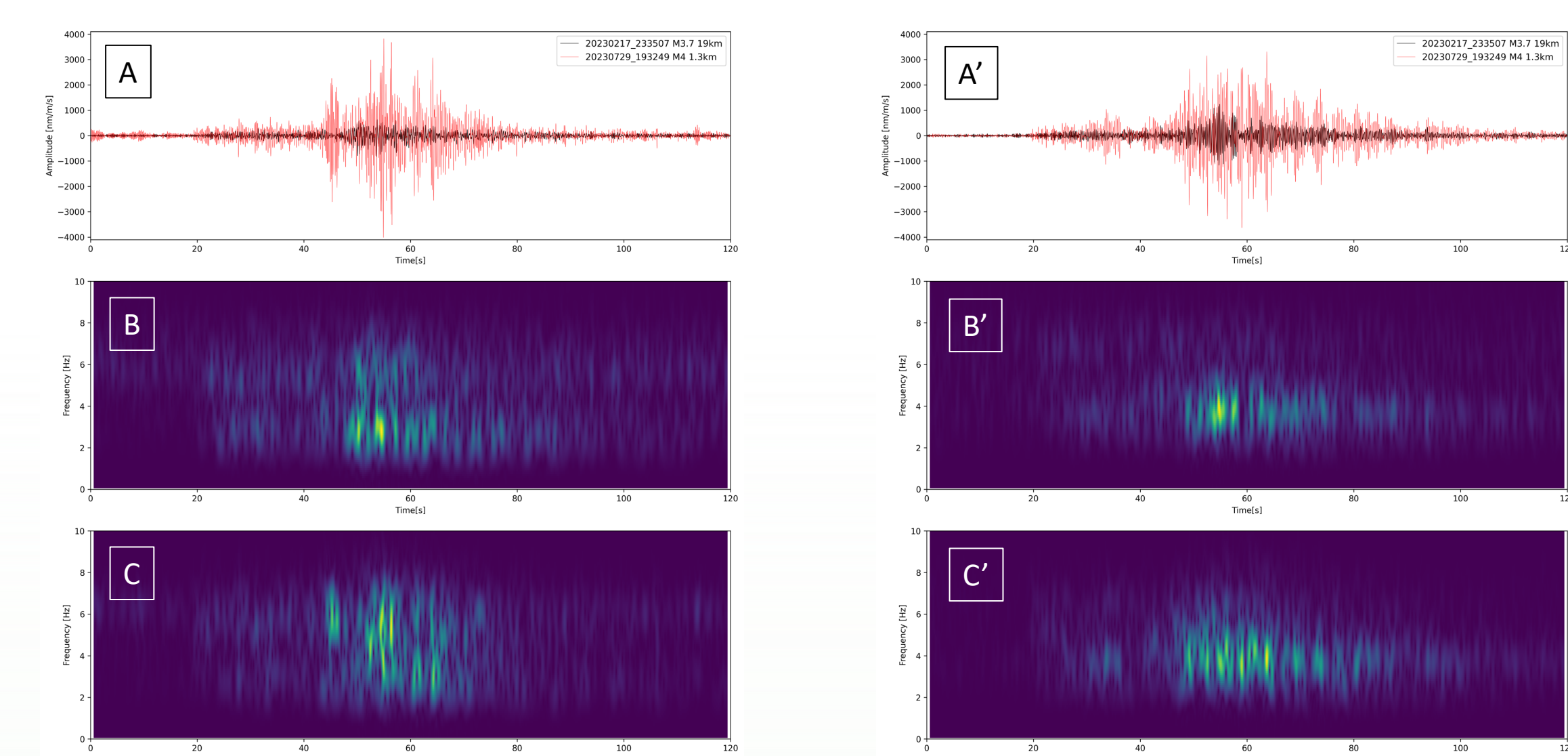


Record section showing signal from the 2023-07-29 onshore event. Amplitudes are nm/m/s.

Record section showing signal from the 2023-02-17 offshore event. Amplitudes are nm/m/s.



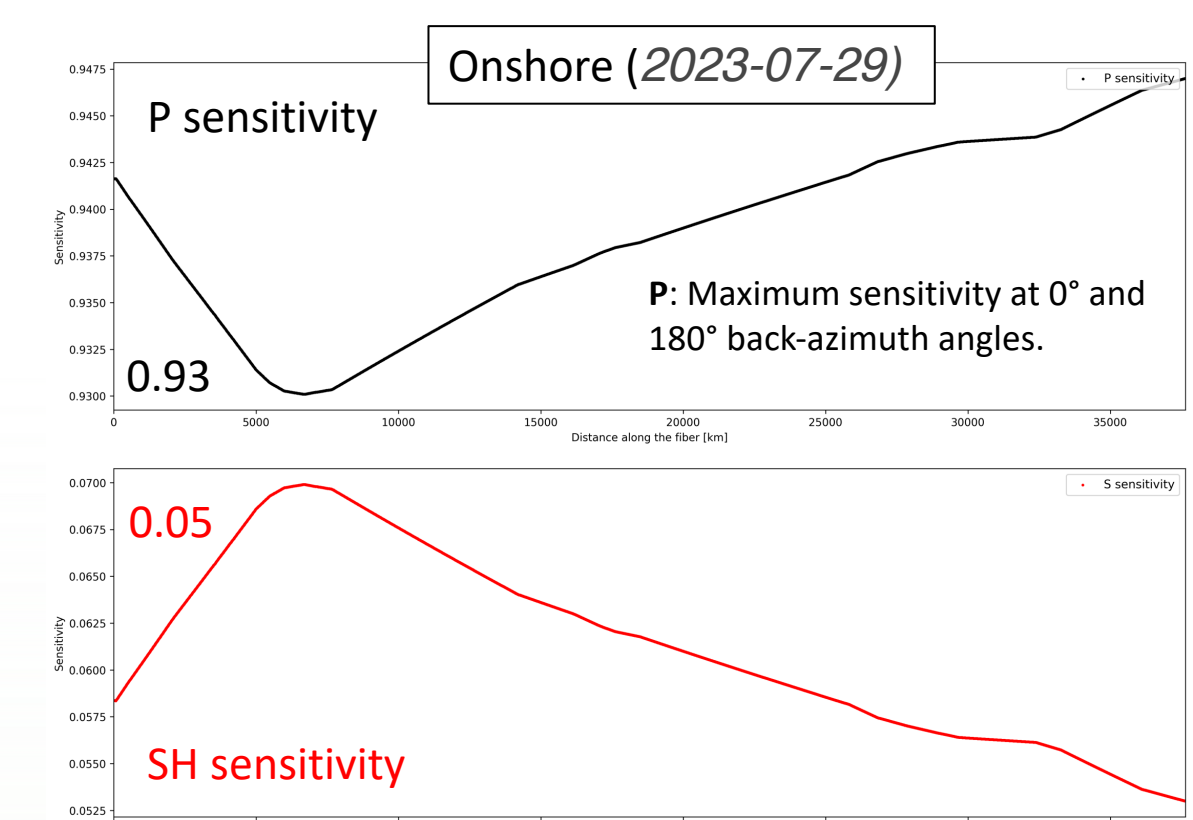
Map showing the location of the two Alaska events relative to the fiber cable (blue, top left)



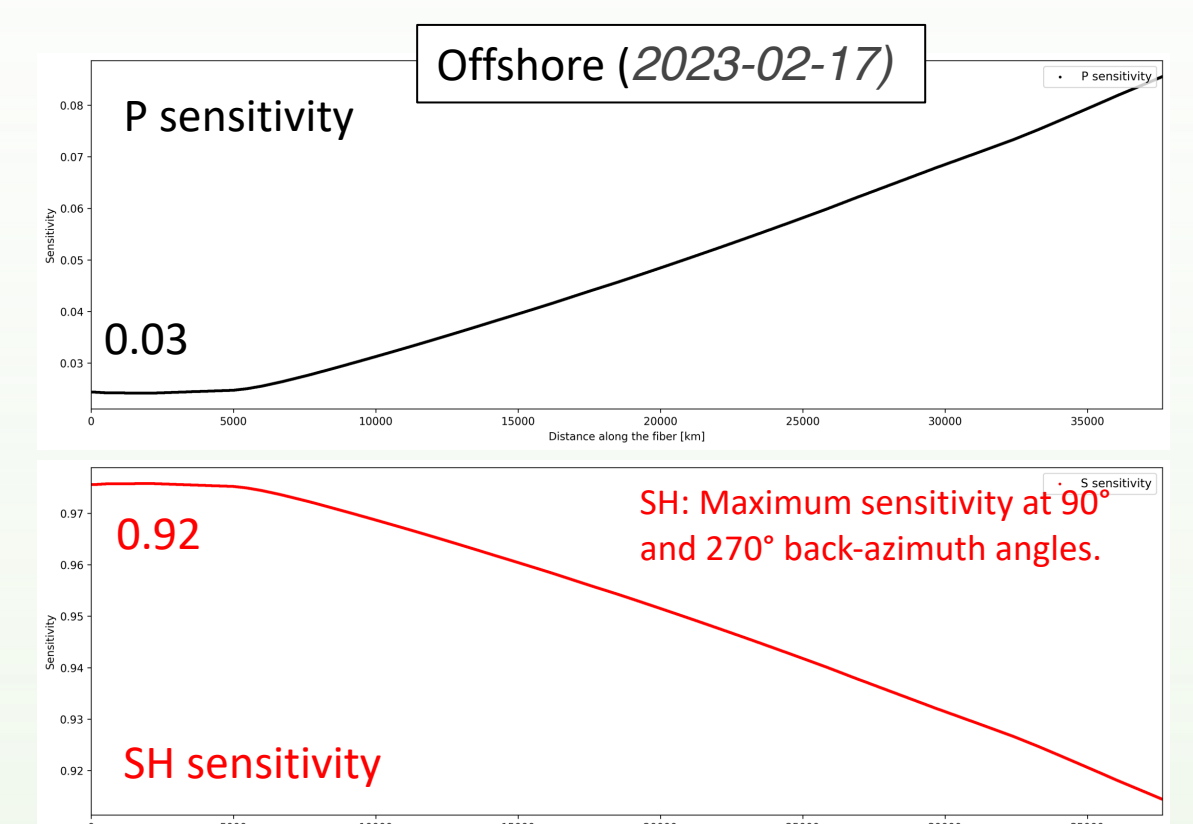
[A] Waveforms recorded on channel 200; [B] and [C] corresponding spectrograms. Distance along fiber is 1522 m.

[A] Waveforms recorded on channel 3000; [B] and [C] corresponding spectrograms. Distance along fiber is 24466 m.

Integral of signal envelope for each channel along the fiber. Note the difference in amplitude for the two events.

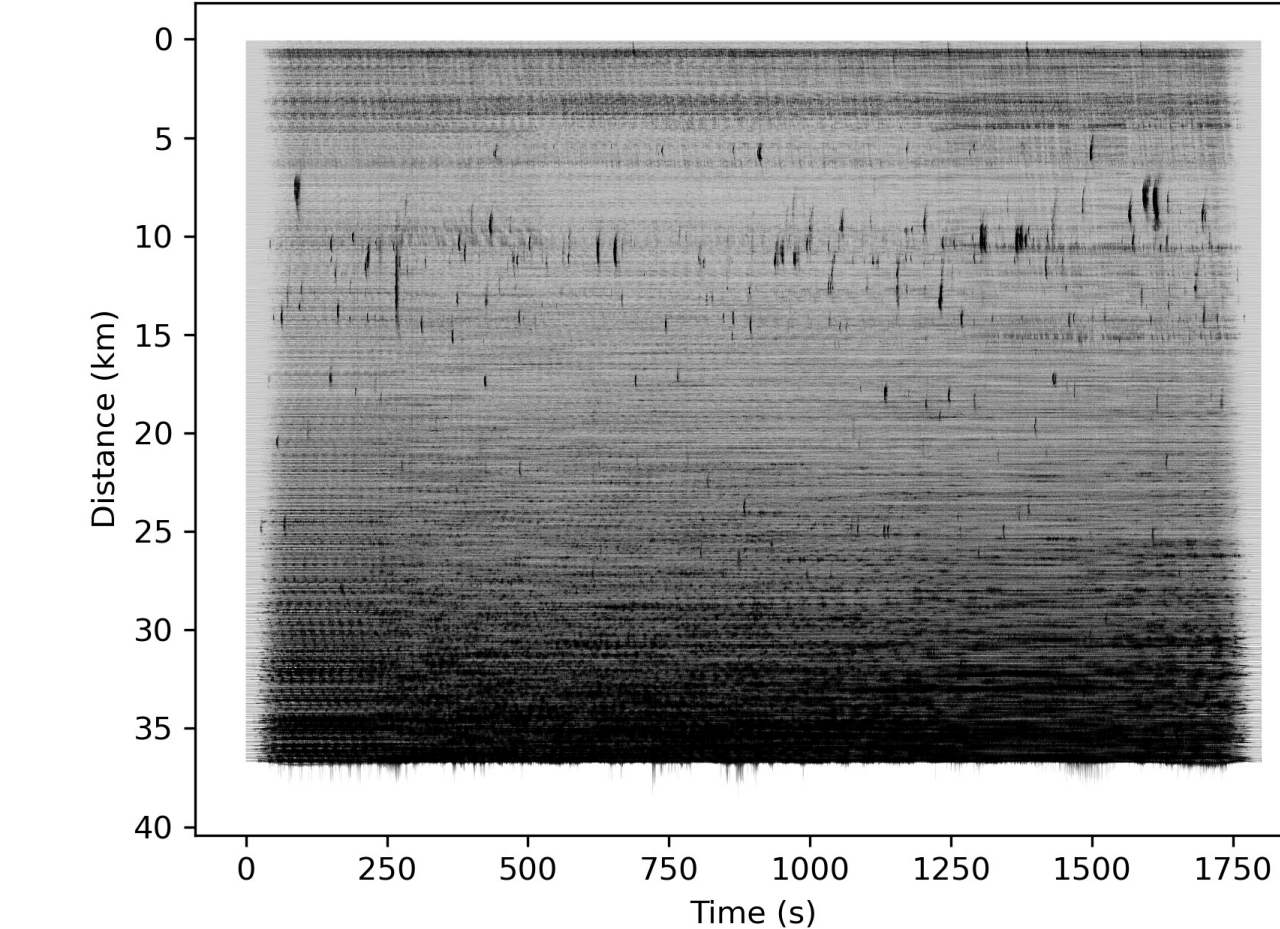


Theoretical sensitivity to back-azimuth for each DAS channel-event pair (2023-07-29).

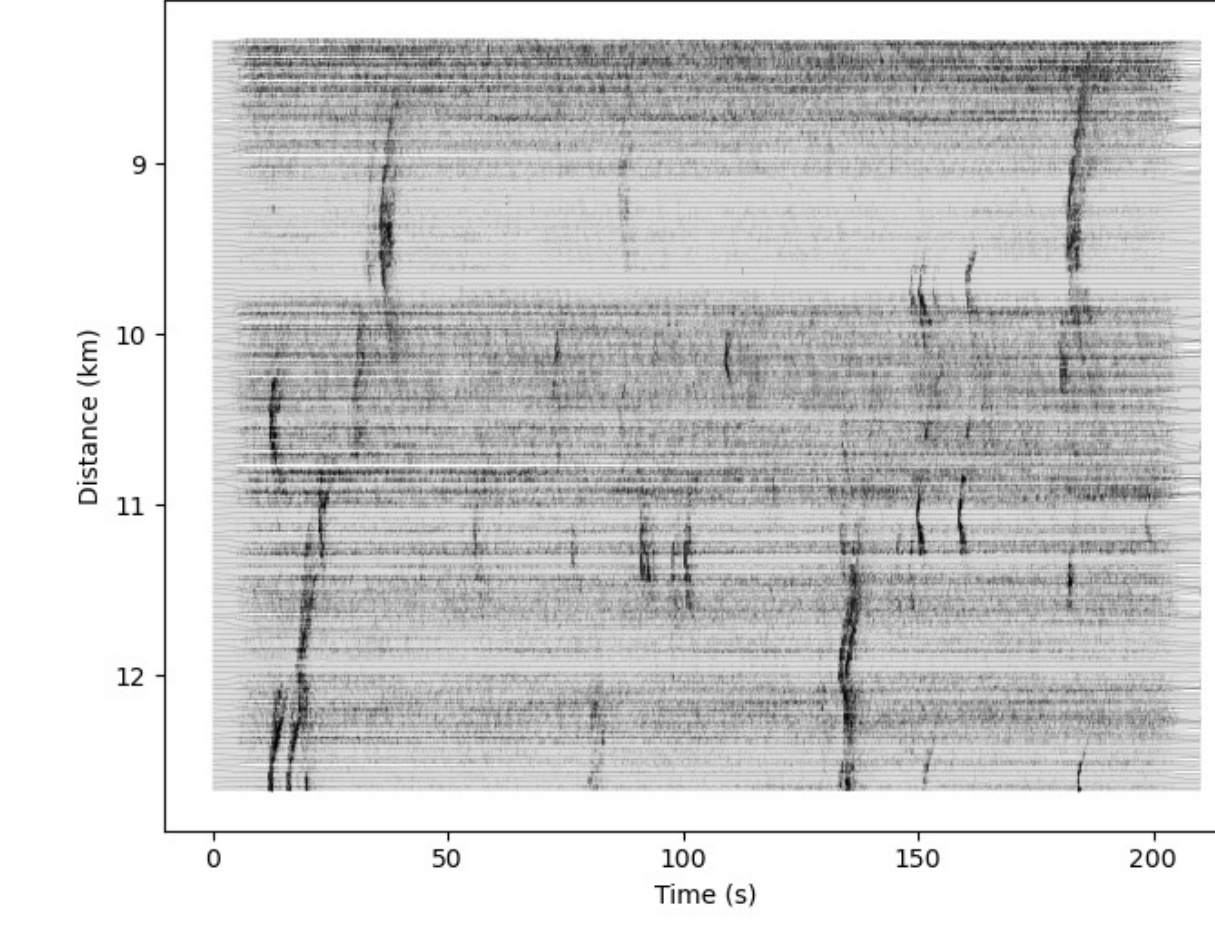


Theoretical sensitivity to back-azimuth for each DAS channel-event pair (2023-02-17).

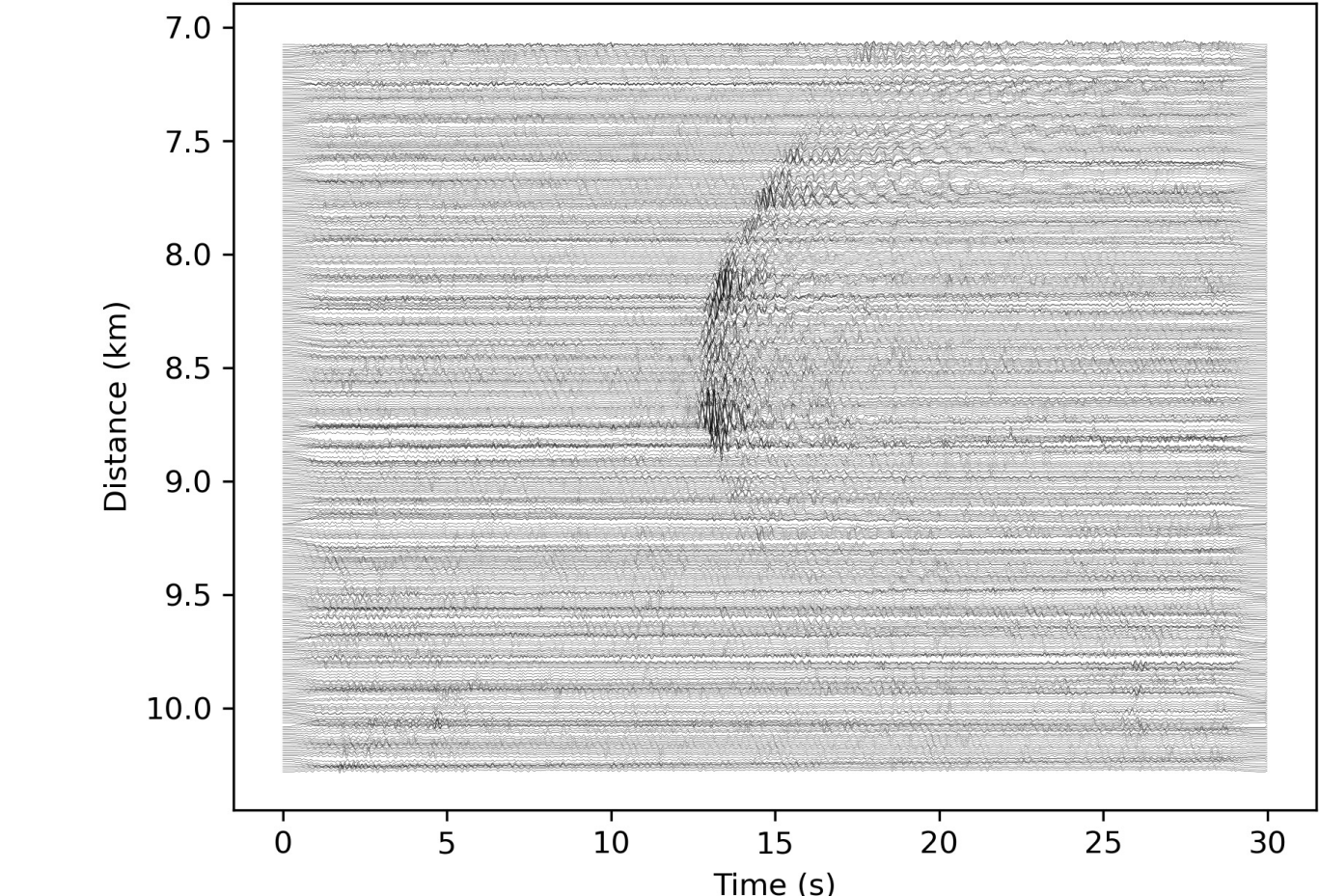
Icequakes



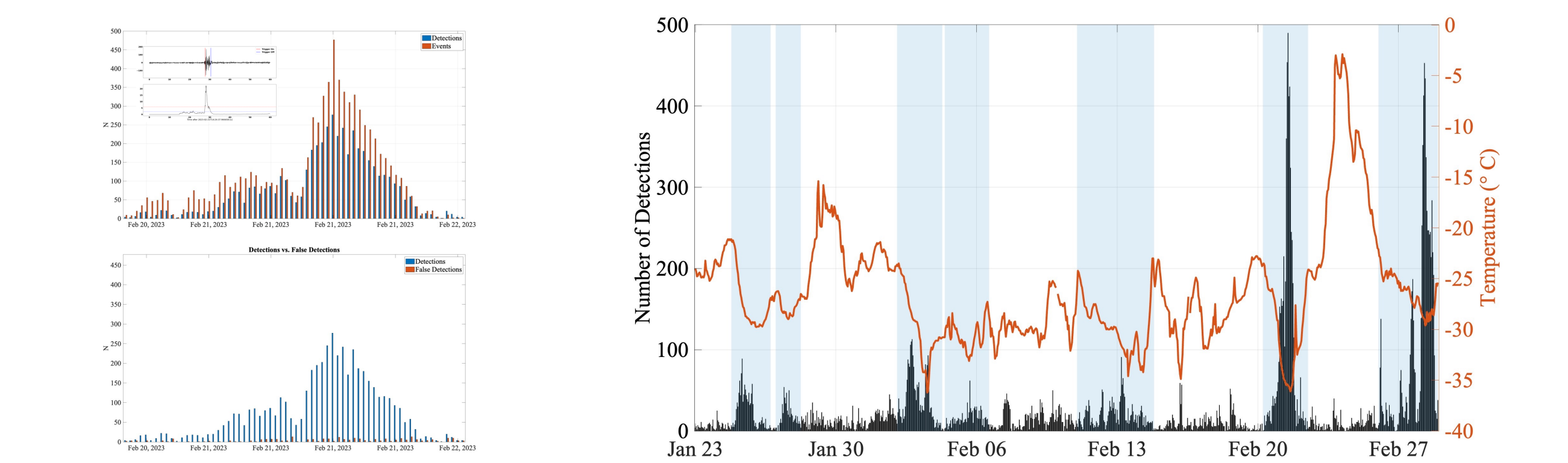
Icequakes observed on 2023-02-21 (14:00-14:30) in the 0.001-10 Hz frequency band. Most events occur along the first 30km of fiber.



Note the increased frequency of events between 8 km and 13 km distance along fiber for only a few minutes of data (14:17:00)

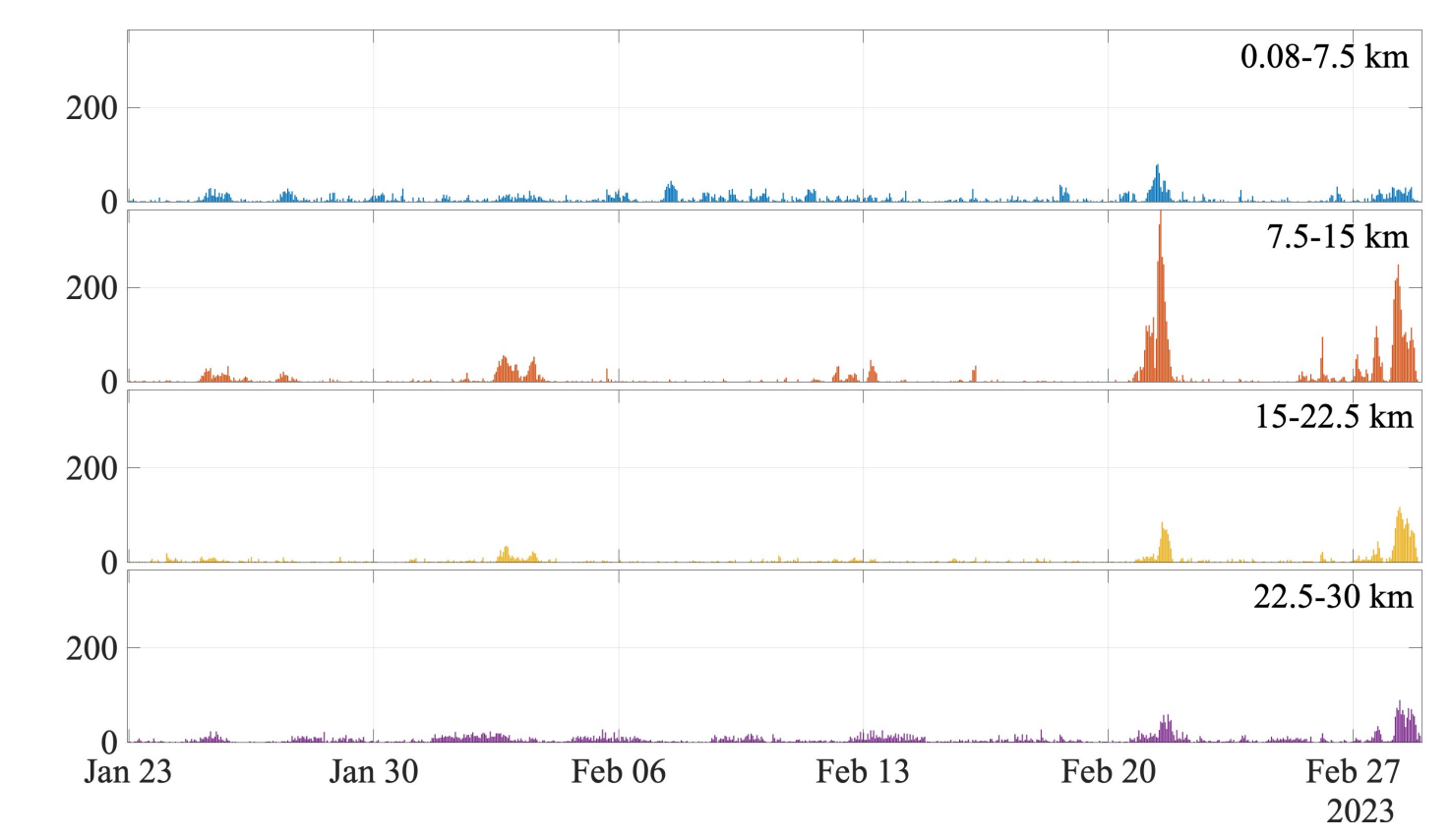


Approximately 3 km lateral extent for a select event on 2023-02-21 (14:24:30). Data filtered between 0.001 and 10 Hz.



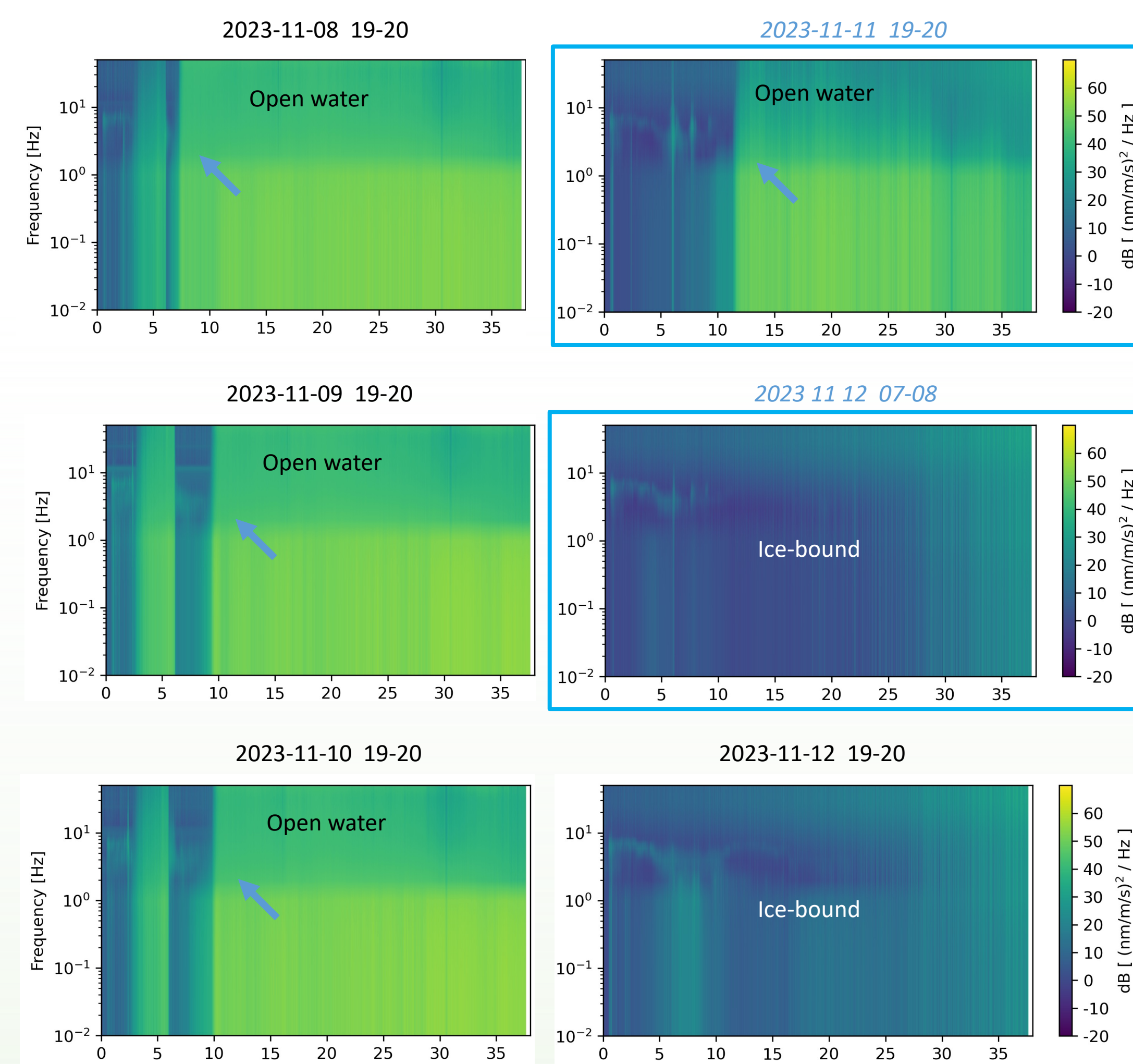
(Top) STALTA detections (blue) compared to manually picked events (red). Inset shows a detection example. (Bottom) STALTA detections (blue) compared to identified false detections (purple).

Detected events per hour between 2023-01-23 through 2023-02-28 (black) compared to air temperature (orange) recorded at the PRDA2 weather station. Durations of the seven identified swarms are highlighted in light blue.



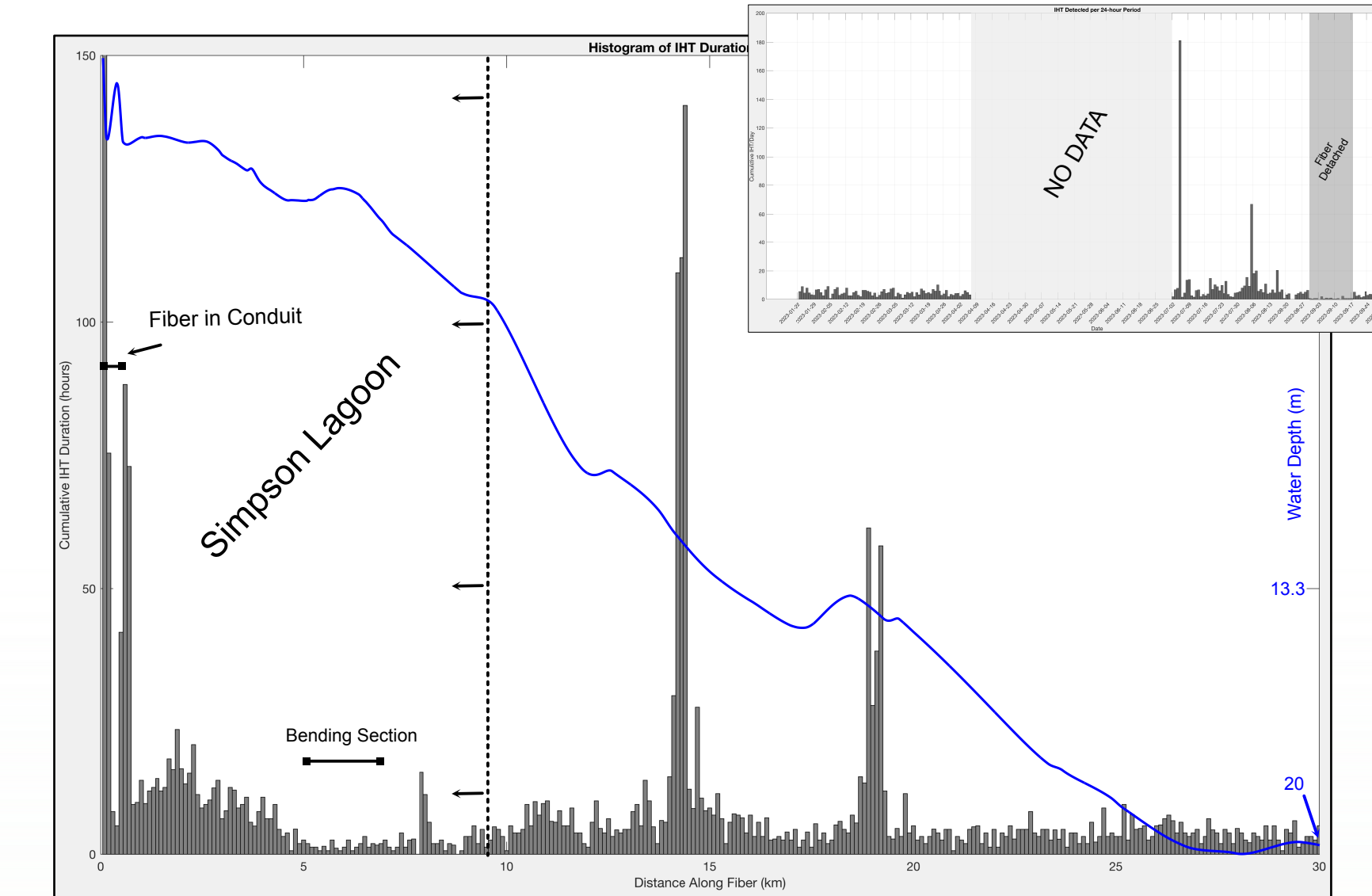
STALTA detections by channel location in the 0.08-7.5 km, 7.5-15 km, 15-22.5 km, and 22.5-30 km range.

Rapid freezing events

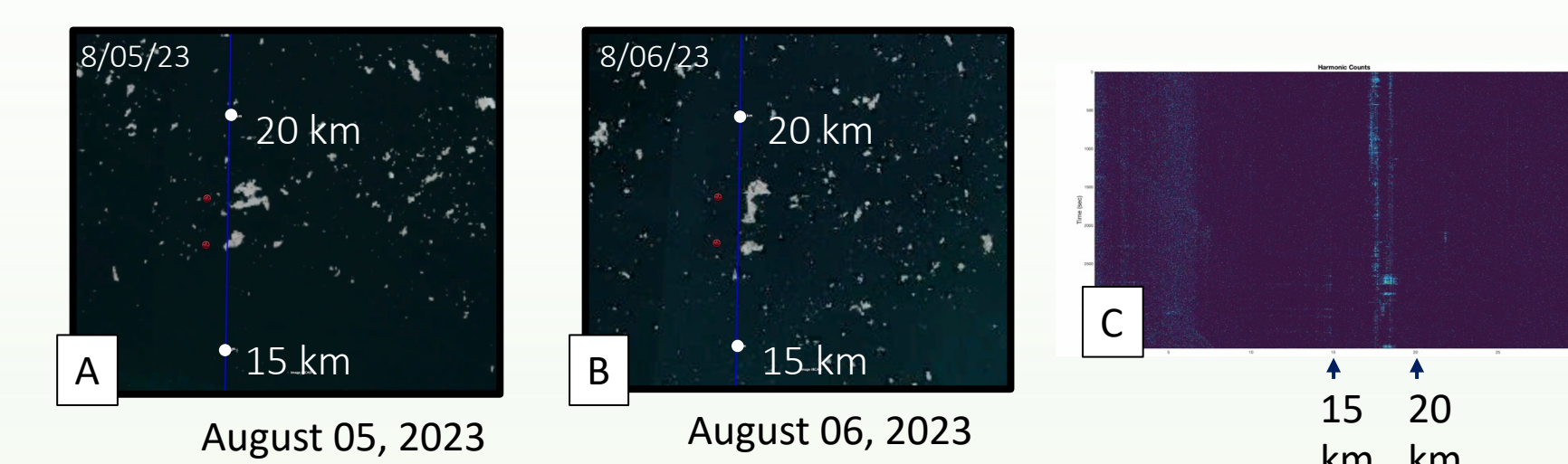


PSD along fiber distance for 1-hour long data. Darker colors are indicative of lower noise levels. Note the change across fiber distance of the boundary location between the 'noisy' environment and the more 'quiet' setting. Lower dB is consistent with decreased levels of ocean wave motion (i.e., presence of ice cap). See Baker and Abbott (2022) for more information on freezing events.

Ice-grounding events



Cumulative IHT is dominant at a few locations. Bathymetry does not appear to be a main driver. Within 5 km of land, artifacts likely dominate, due to the presence of conduit/pipe modes, boats, etc. Inset shows that IHT are concentrated across a few days.



[A] and [B] cloud-free imagery for two consecutive days allows tracking of individual features; [C] heat map of IHT detections; [D] 1-channel seismogram (nm/m/s) and spectrogram showing typical IHT signal