Sea Ice Seismicity Near Utqiaġvik, Alaska, Using an Inexpensive Triaxial Seismic Sensor

Garrett O'Hara[1]; Rhett Herman[2]
gdohara@iu.edu[1]; rherman@radford.edu[2]

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Background & Methods

This project studied sea ice fracturing near Utqiaġvik, Alaska, using a triaxial seismic sensor built from inexpensive and readily-obtainable components. The objectives of this study were to investigate the orientation, frequency of occurrence, and frequency spectrum of ice seismic signals; to compare the seismic wave occurrences of ice fracturing to earthquakes in the region during data collection; and to see if ice seismic activity might correlate with tides in the area.

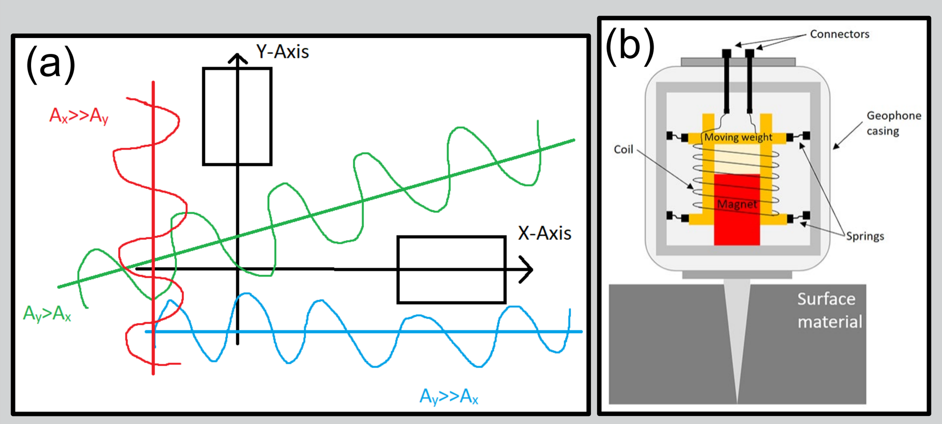
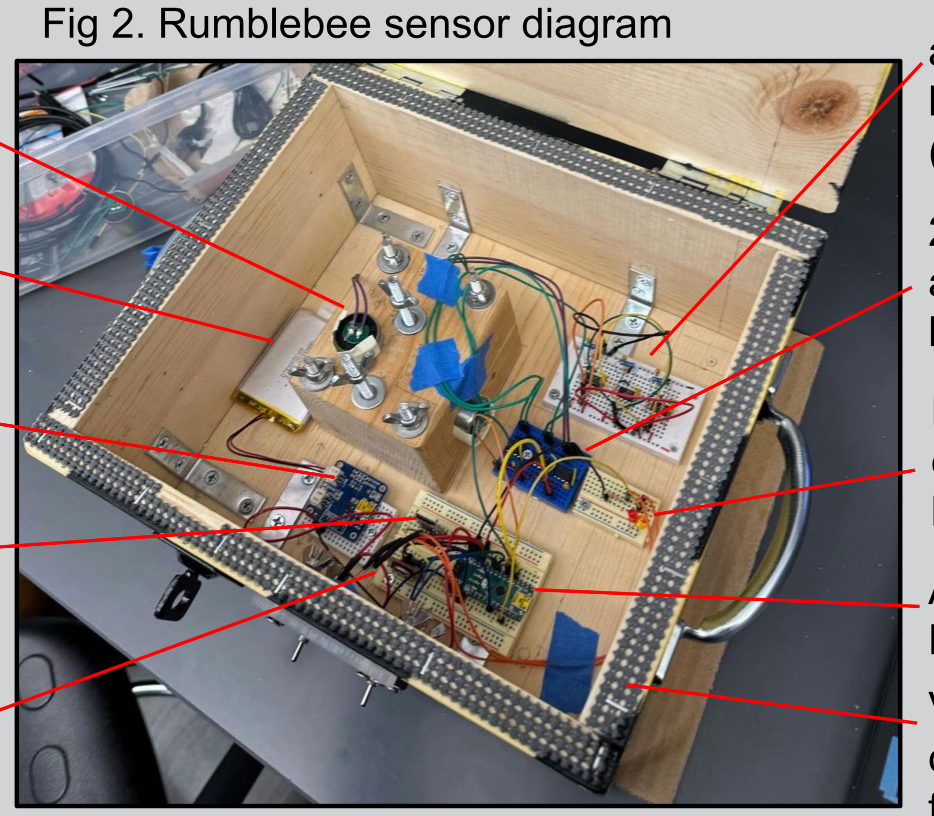


Fig 1. (a) Seismic wave measurement on three axes gives us the rough orientation of the wave If the wave's amplitude is greater on the sensor lying along the y-axis, it is traveling more in the x-direction, and vice versa.
(b) Geophone diagram.

Key components:

- 1x SM-24 vertical & 2x RTC horizontal geophones
- Arduino Nano w/10-bit ADC, f_{data}~400Hz
- 386 audio amps for 200x signal amplification

Fig 2. Rumblebee sensor diagram



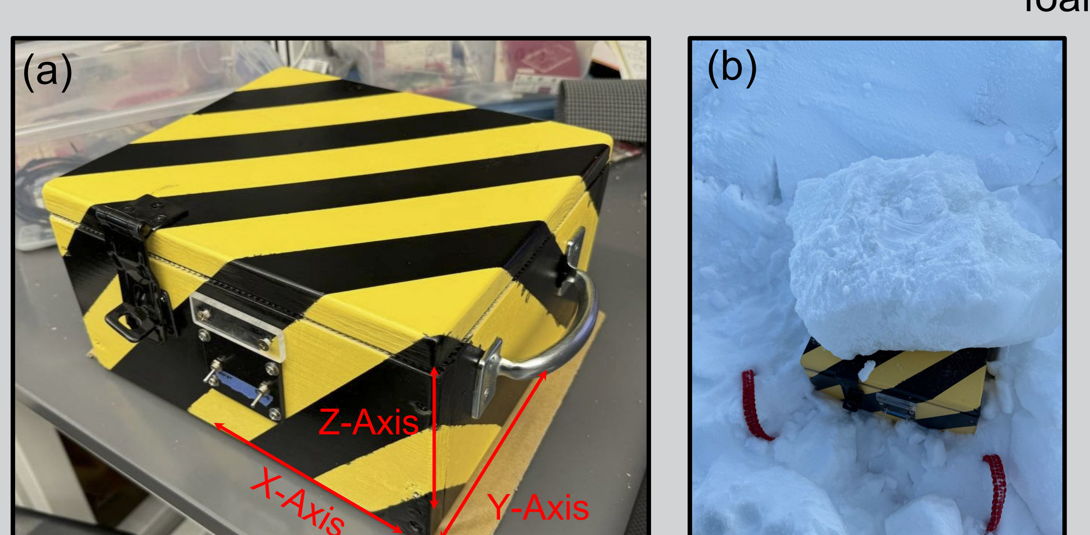


Fig 3. (a) Rumblebee device relative axes. (b) Sensor deployment, ice block placed on top to provide better contact with the ice surface.

Results

We compared the ice seismic data (e.g. timing) to published seismic events using the USGS Earthquake Hazards site. We also sought to compare our ice seismic data to tidal patterns.

We used Python (within Anaconda) to process the raw data and make the graphs. The relative amplitudes of the two horizontal sensors give the wave direction - we had marked the orientation of the 3 axes of our seismometer.

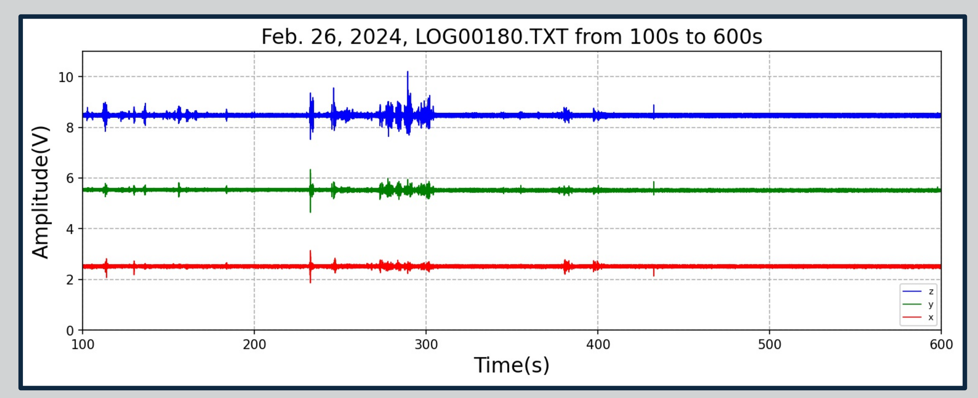


Fig 4. An example of multiple icequakes in a short amount of time. Our group did not notice this, but the equipment picked it up.

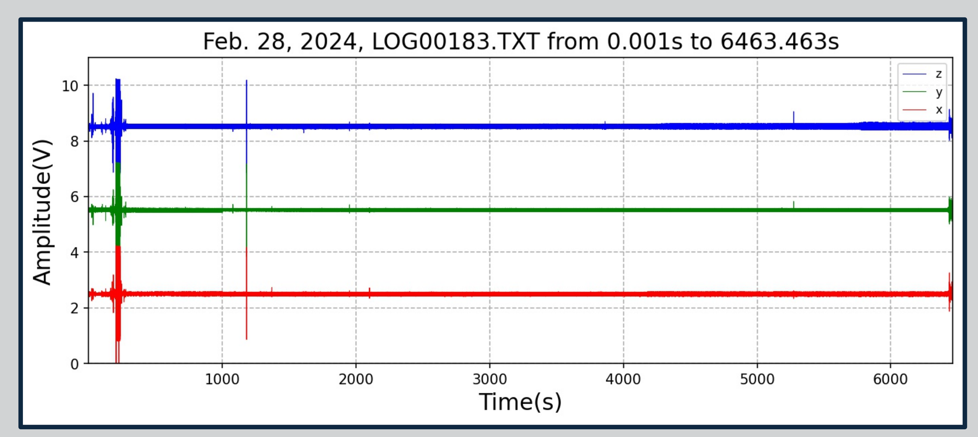


Fig 5. Full data for ~1.8 hours, Feb-28-2024 showing obvious activity in 2 areas.

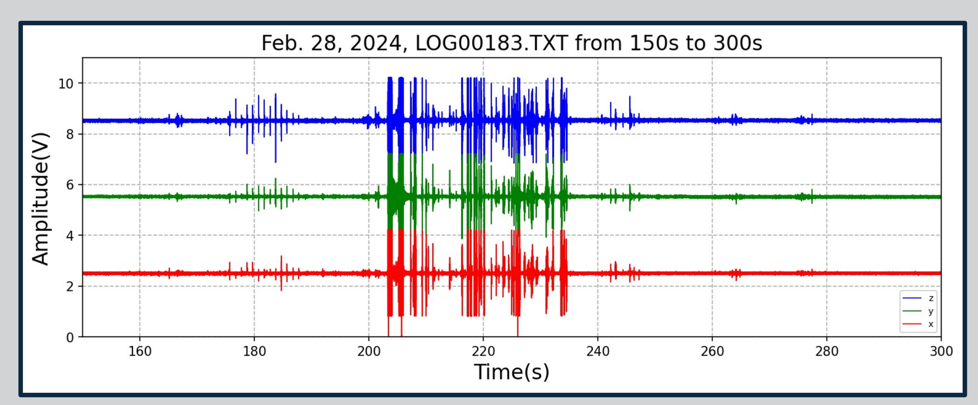


Fig 6. Feb-28-2024 zoomed in to show details of ice quakes. Note the different amplitudes for the (identical) x- and y-axis geophones.

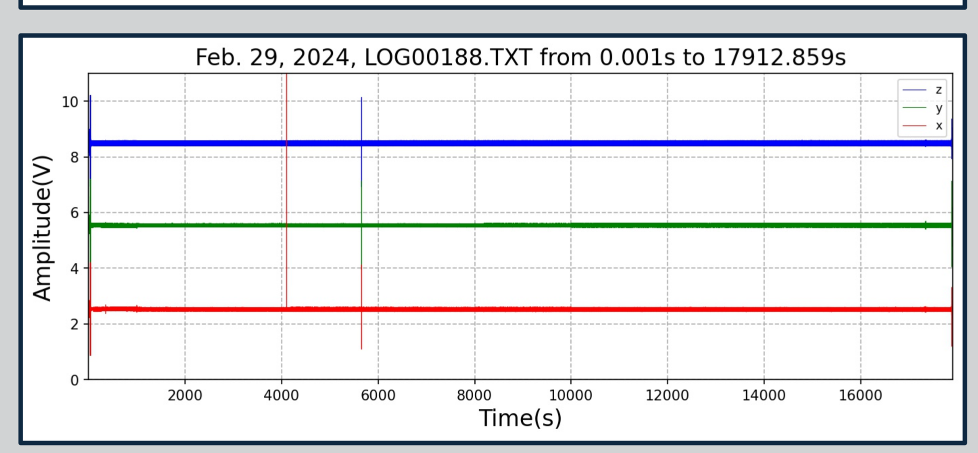
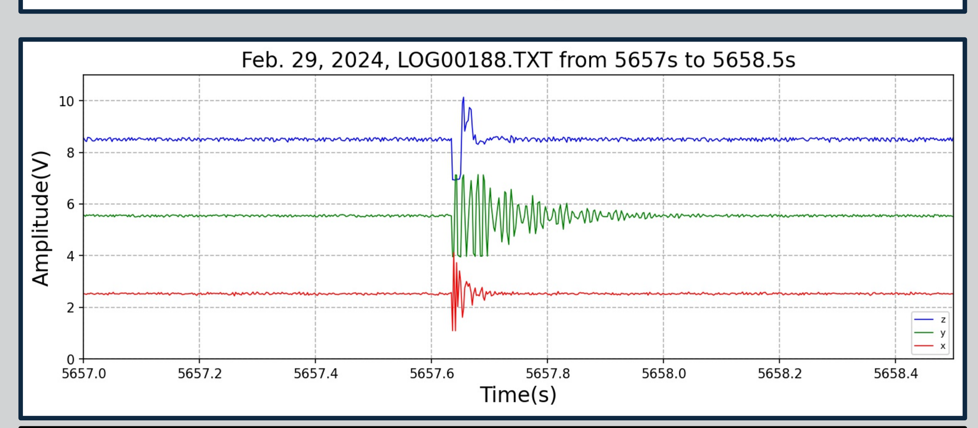


Fig 7. Full data for ~5 hours from Feb-29-2024, with strong activity around 5,600 seconds into the data collection.



Mag	Depth km	Day	Time UTC	Lat	Lon	Dist km
3	10.1	2024-02-29	22:18:41.370Z	63.46	-148.68	181

Fig.8 LOG00188 (Feb-29-2024) had a seismic event that occurred ~1 minute after a reported M3.2 earthquake in central Alaska. The relative x- and y-axis responses are consistent with a quake from that direction.

Interpretations

LOG00188 (Seen in Fig 8) contained a recorded seismic event that occurred within 15 seconds of a reported 3.2 magnitude earthquake in Central Alaska. This is well within the margin of error for the logged times (±59 seconds).

- The peaking z-axis is indicative of seismic waves approaching from the seafloor, supporting the interpretation that this signal was from an earthquake.
- ~1 minute is around the expected time it would take for seismic waves to travel from Central Alaska to the sensor.
- While our clocks were not as carefully synced as we would have liked, we are confident that our times are within one minute - or less - of being synced.

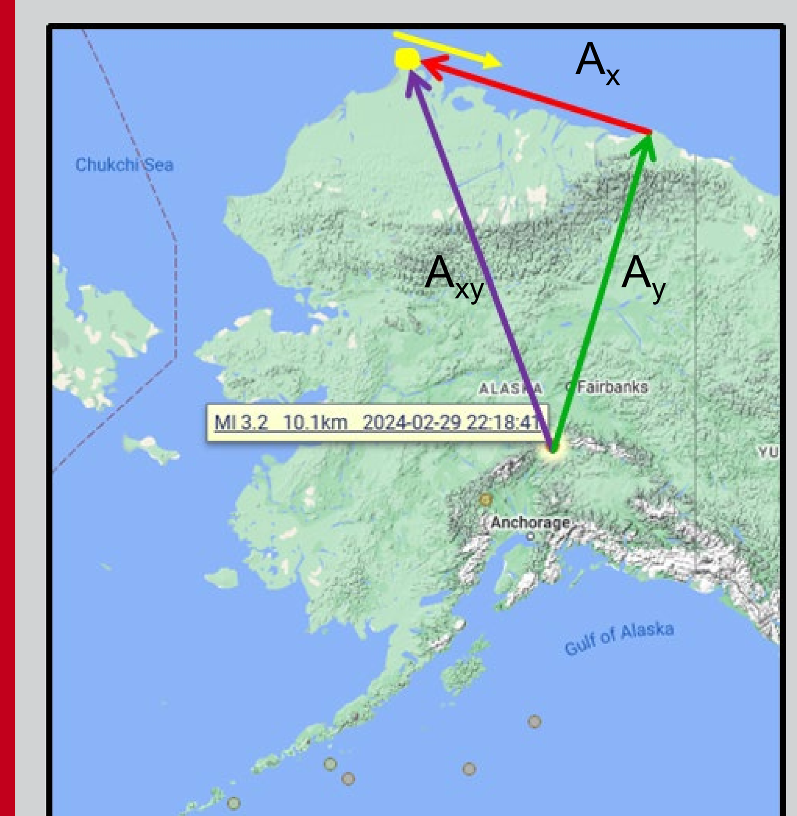
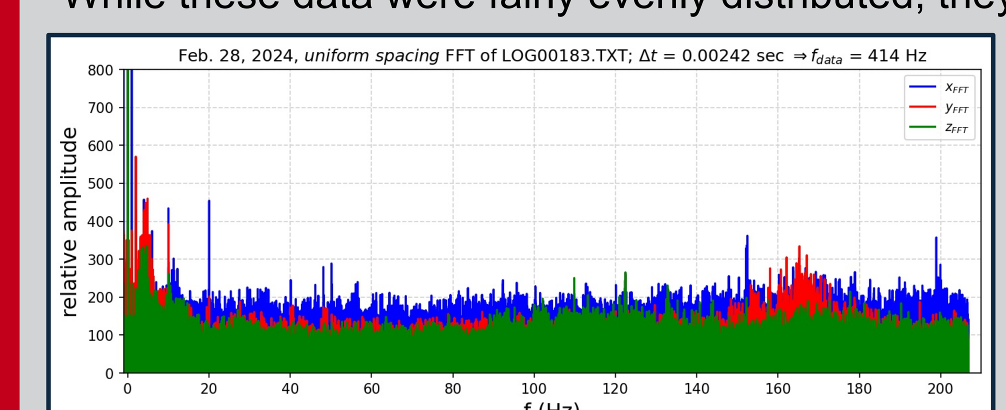


Fig 9. A map of Alaska with representations of the orientation of seismic waves recorded. Since $A_y > A_x$, the wave was traveling more in the x direction than the y direction. See Figure 3(a) for the axes orientation on the sensor. The red arrow represents the the A_x vector, green represents the A_y vector, purple represents the A_{xy} vector. The yellow arrow and point represent the location and relative orientation of the x-axis of the sensor.

Fig 10. Future work will include analyzing the frequency spectrum of the icequakes. This shows the Fourier transform of data from Feb-28-2024. This regular FFT method assumes the data were evenly spaced in time. While these data were fairly evenly distributed, they were not uniformly spaced due to the internal workings of the Arduino. Python packages exist for analysis of such non-uniform data and those will be applied.



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