# Snow Coupled Distributed Acoustic Sensing for Intrusion Detection of Polar Bears in Arctic Camps

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**Abstract**

Everchanging arctic climate conditions continue to negatively impact the habitat of the polar bear. The changes cause them to search for food outside of their traditional hunting grounds and potentially encounter humans in locations where interactions weren't previously documented. One such occurrence in 2018 found a female polar bear at Summit Science Station near the center of the Greenland Ice Sheet (GIS) which is over 300 km from the closest traditional food source. In an attempt to mitigate the safety concern posed by potential interactions, the U. S. National Science Foundation-Office of Polar Programs-Arctic Sciences-Research Support and Logistics Program (NSF-OPP-ARC-RSL) has sponsored an effort to evaluate new technologies for use as a perimeter monitoring tool around remote arctic research camps. Distributed acoustic sensing (DAS), a technology often used for perimeter detection in high security areas, uses fiber optic technology to sense mechanical vibrations due to seismic or acoustic sources, including foot-steps. The systems are typically very sensitive and can not only be used to detect an intrusion, but often characterize the type of intrusion. Sensor ground coupling in soil is well understood for these systems; however, use in arctic conditions with direct snow coupling is not. A range of human foot pressures was used to simulate foot pressures of various sized polar bears. The very large surface area of the polar bear foot when considered over three points of contact for a walking quadruped, results in a similar foot pressure when compared to the single point of contact of a walking human. Using polar bear analogues, we demonstrate DAS performance in direct snow coupling, evaluate the loss in system sensitivity due to increasing snow pack and assess the effects of extreme cold on fiber optic sensors down to -70 degrees Celsius.

# NS11B-0634: Snow Coupled Distributed Acoustic Sensing for Intrusion Detection of Polar Bears in Arctic Camps

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## 1. INTRODUCTION

Polar bear encounters with humans have increased in arctic regions where their habitat is changing rapidly (Pope, 2019; Sterling & Derocher, 2012). Specifically, an encounter on June 24, 2018 at the NSF Greenland Summit Station, spurred an investigation into early warning systems in order to mitigate these encounters. Distributed acoustic sensors DAS, were evaluated as an intrusion detection system in a controlled laboratory setting where system temperatures were dropped to -70 degrees Celsius. Typically, DAS systems are installed in the ground making it necessary to confirm system performance in snow. Humans were used to replicate polar bears walking near the sensor. Functionality with snow depth and extreme cold was evaluated.


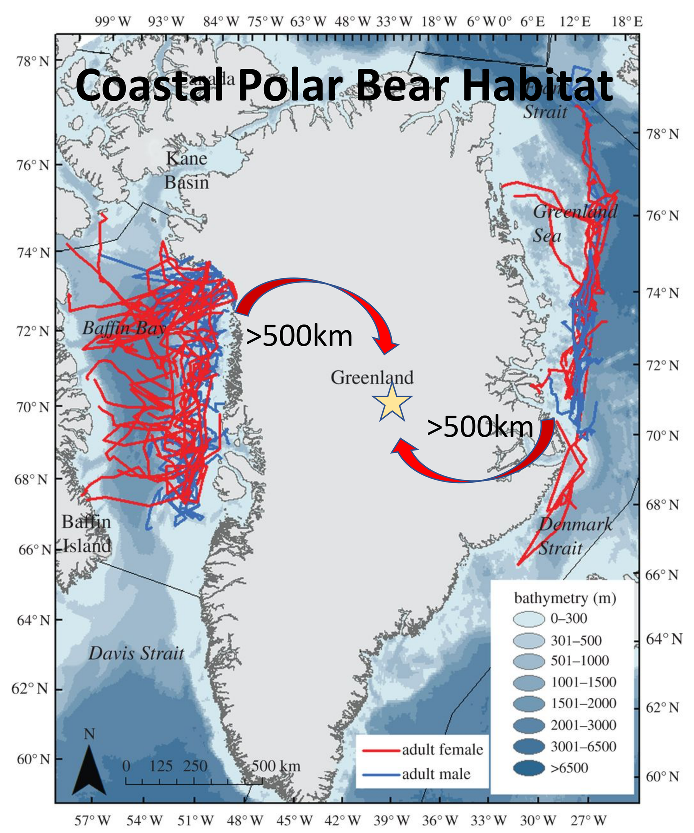


Figure 1. A) Photograph of a polar bear at Greenland Summit Station, June 24, 2018 (Katz, 2018); B) Breeding season movements of pack ice polar bears, relative to Greenland Summit Station (after Laidre et al., 2012).

## 2. SNOW COUPLED DISTRIBUTED ACOUSTIC SENSING: Theory & Approach

Typical system components:
1. A sensing fiber optic cable (20-40 km in length).
2. A class 4 laser/computer central processing unit (DAS).

Measurement: Mechanical waves (sounds /vibrations) cause fiber impingement, resulting in laser backscatter and subsequently, measured signal (figure 2).

Classification: Signal can be classified into different target types based on amplitude, spectral response, spatial foot print, and duration.

Approach:
- Phase 1- Confirm very low temperature functionality of fiber (-70C). MTS environmental chamber.
- Phase 2- Confirm snow coupling is appropriate for this target. Assess effects of burial in snow / signal reduction. Cold box test cell.
- Phase 3- Perform proof of concept at Summit Station (Summer 2020).

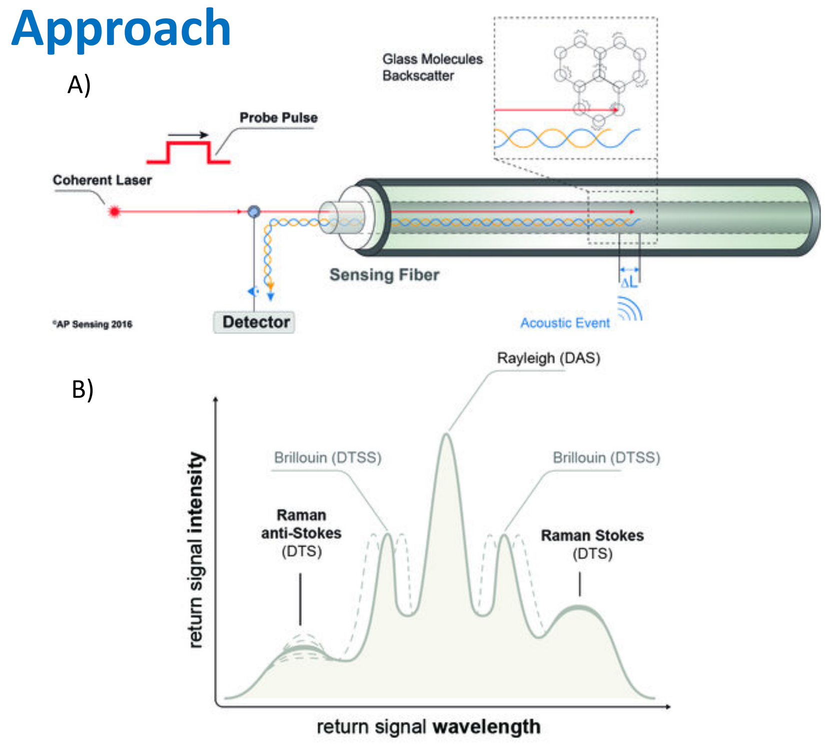


Figure 2. A) Schematic describing fiber optic sensor processes; B) backscatter signal intensity and uses including DAS and distributed temperature sensing (apsensing.com).

## 3. PHASE 1 – Extreme Cold Fiber Testing

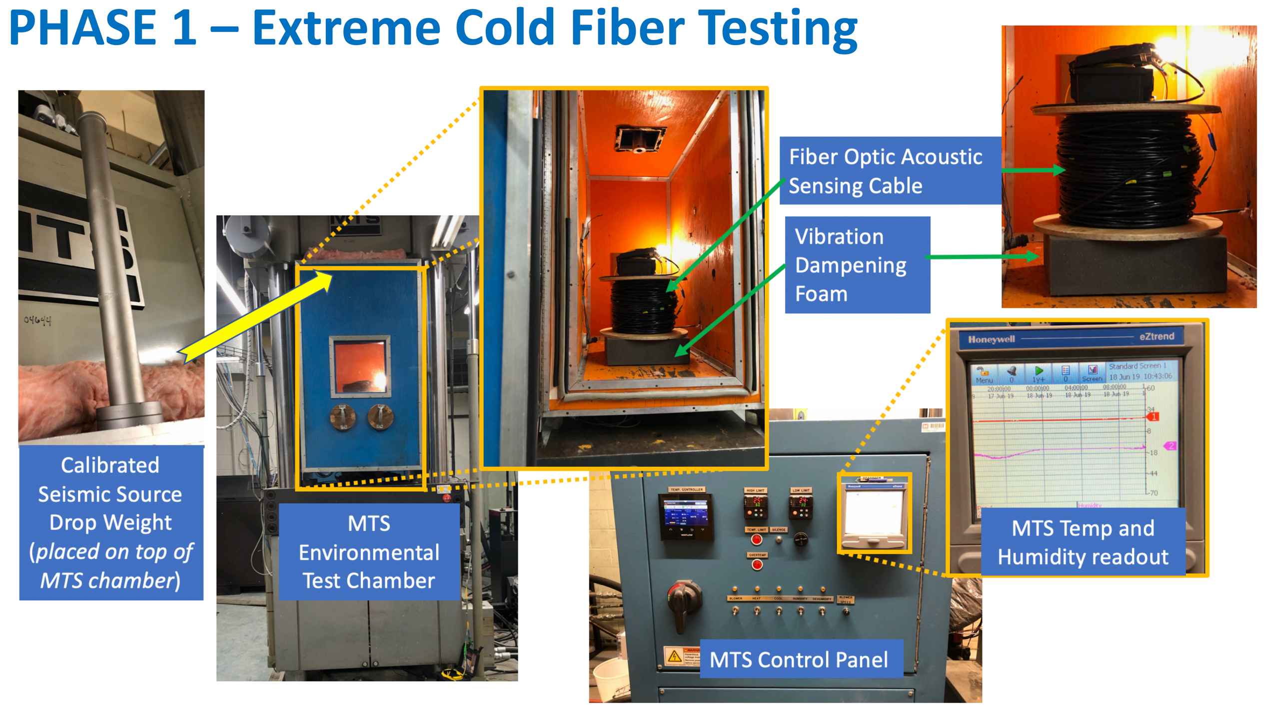


Figure 3. Phase 1 test using MTS control chamber. From left to right: drop hammer seismic acoustic source, MTS chamber, inside of chamber with 150m of fiber optic spool and one of the launch boxes placed on foam for vibration dampening, MTS control panel, and control panel readout.

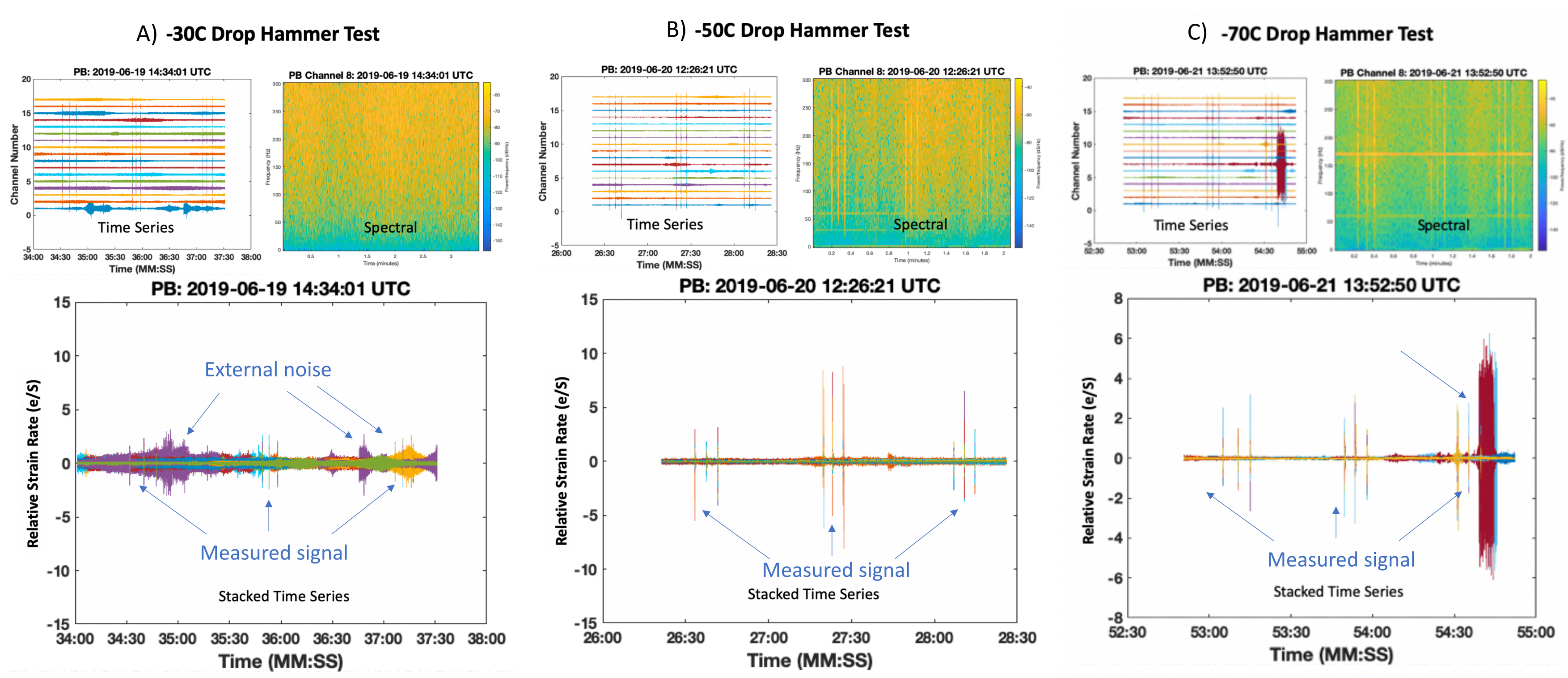


Figure 4. Time series data by channel, spectral data, and stacked time series data for A) -30C drop hammer test; B) -50C drop hammer test, and C) -70C drop hammer test.

A test of fiber functionality down to the lowest expected temperature of -70°C was completed. This test was performed in the MTS environmental control chamber. The approximately 150m of fiber remained on the reel for the test. Launch boxes with 2200m of spooled cable were used on either side of the 150m of sensing cable to replicate a field deployment of 4.5km. Data sets were acquired in 10-degree increments throughout the cooling and warming cycle of the -70° to 0°C range. A drop- hammer, placed on top of the enclosure was used as the seismic/acoustic source for the test. Figure 3 shows a picture of the drop hammer used. The weight was approximately 190g and was dropped from a height of 41.5 cm. Results indicate a reduction in background noise with decreasing temperature, and improved signal to noise ratio. External noise was observed on some of the channels.

## 4. PHASE 2 – Snow & Analogue Polar Bear Testing

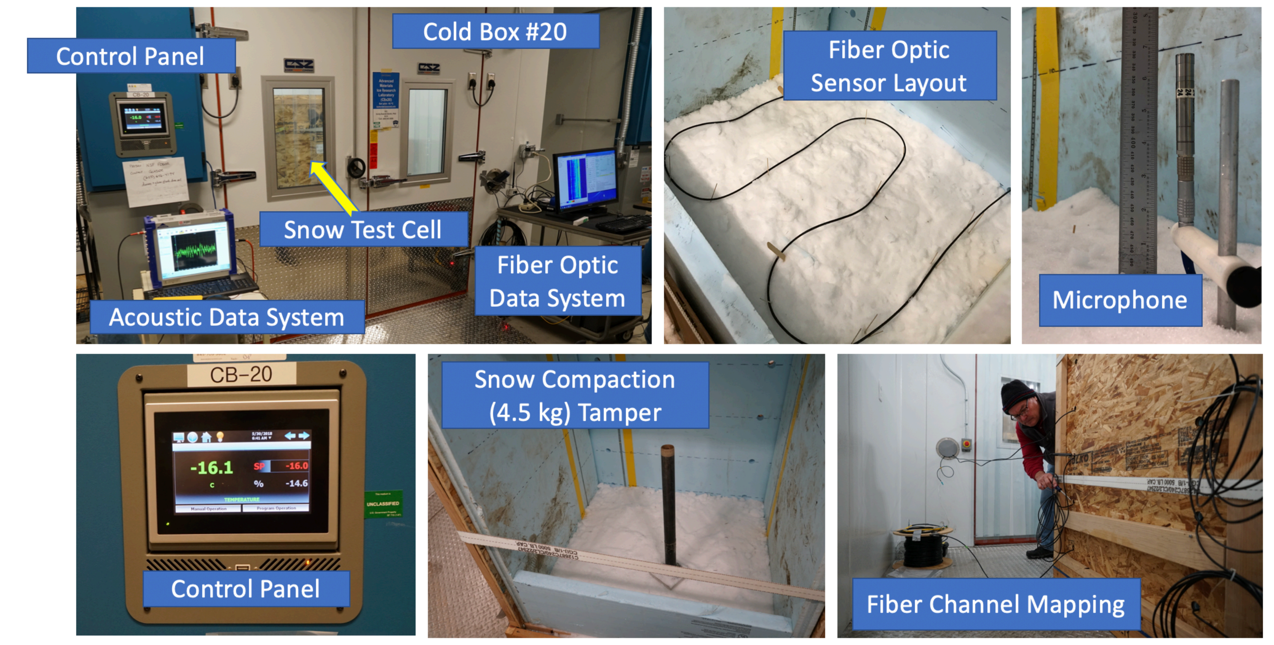


Figure 5. Snow test cell and cold box configuration set up showing control panel, fiber optic sensor layout, data acquisition system locations, snow compaction, and channel mapping.


Figure 6. Data acquisition in the snow test cell showing DAS system setup, analog polar bear step performance, relative sensor position to step locations, and foot surface area recording.

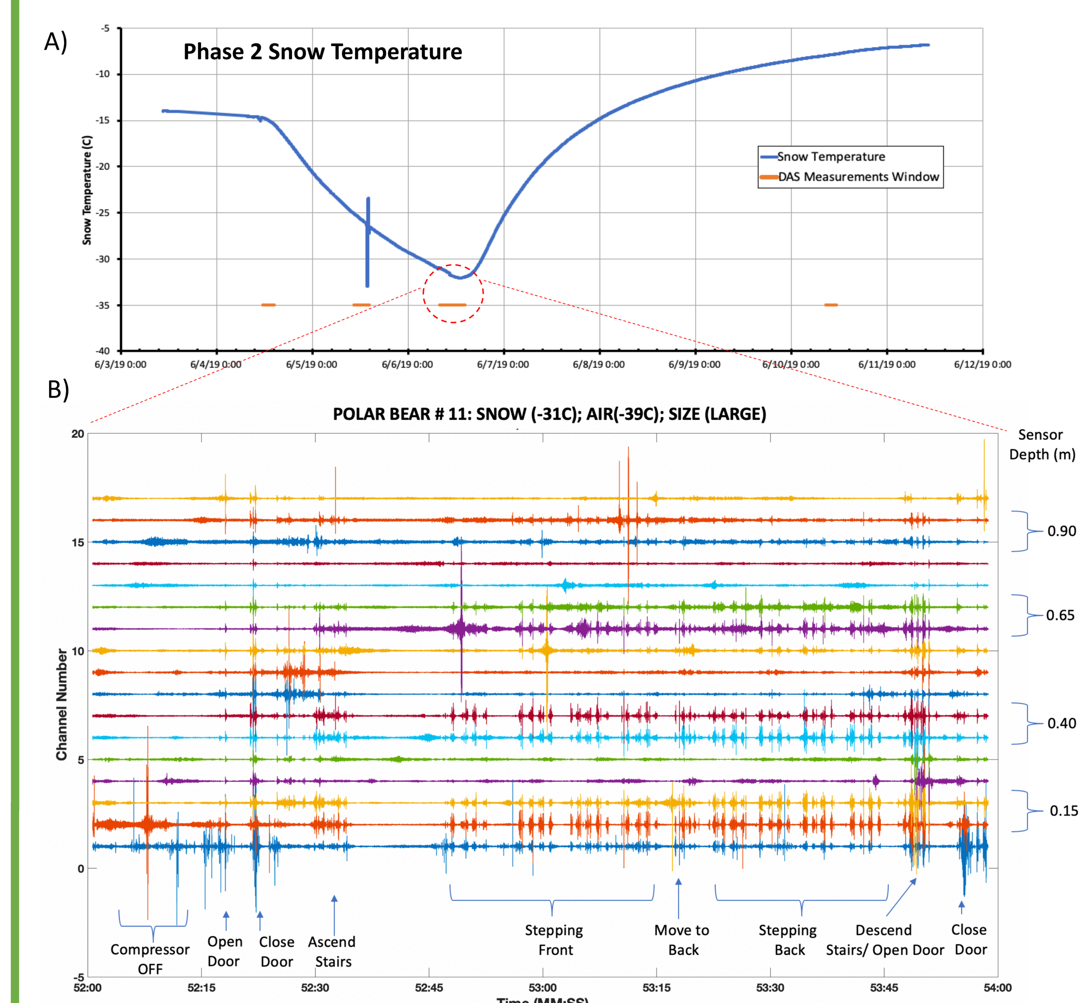


Figure 7. A) Snow temperature at 0.4m depth for the duration of the test; B) DAS results for polar bear #11 at -39C air temperature and -31C snow temperature. Note recognizable step patterns and significant amplitude to depths approaching 1m.

- 4 separate test temperature ranges with as many as 15 individual polar bear analogues per test.
- Shoe soles were photographed relative to a scale, and shoe surface area was calculated.
- Shoe surface area in conjunction with the weight of the participants was used to calculate foot pressure.
- Foot pressure of the participants was then related to polar bear foot pressure to classify small, medium, large, and extra large polar bears.
- Polar bears tend to walk with 3 points of ground contact at any one time. Humans with one point of contact.
- Since polar bears have very large feet, sometimes up 30cm in diameter, when compared to the relatively small surface area of a human foot, a human can easily provide comparable foot pressures.

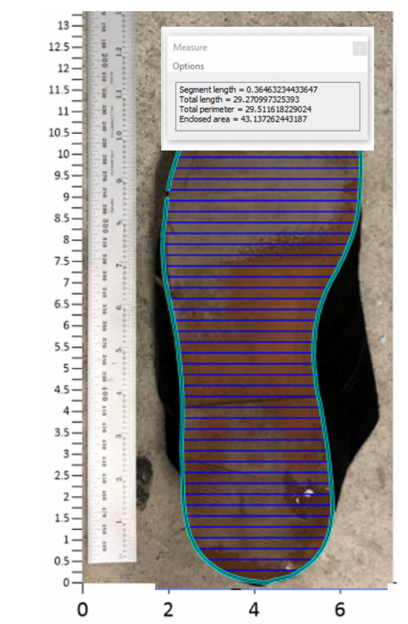

Figure 8. Foot surface area calculation for relation to polar bear size.

## 5. CONCLUSIONS

Phase 1: Extreme cold temperatures should not impede fiber performance, with the experiment exhibiting an increased signal to noise ratio at colder temperatures.

Phase 2: Snow coupled DAS testing using very light polar bear analogue steps, demonstrated detectable signals at depths of at least 0.65m in the unprocessed data.

## 8. AKNOWLEDGEMENTS

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Figure 9. A variety of analogue polar bears for the Phase 2 testing.

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