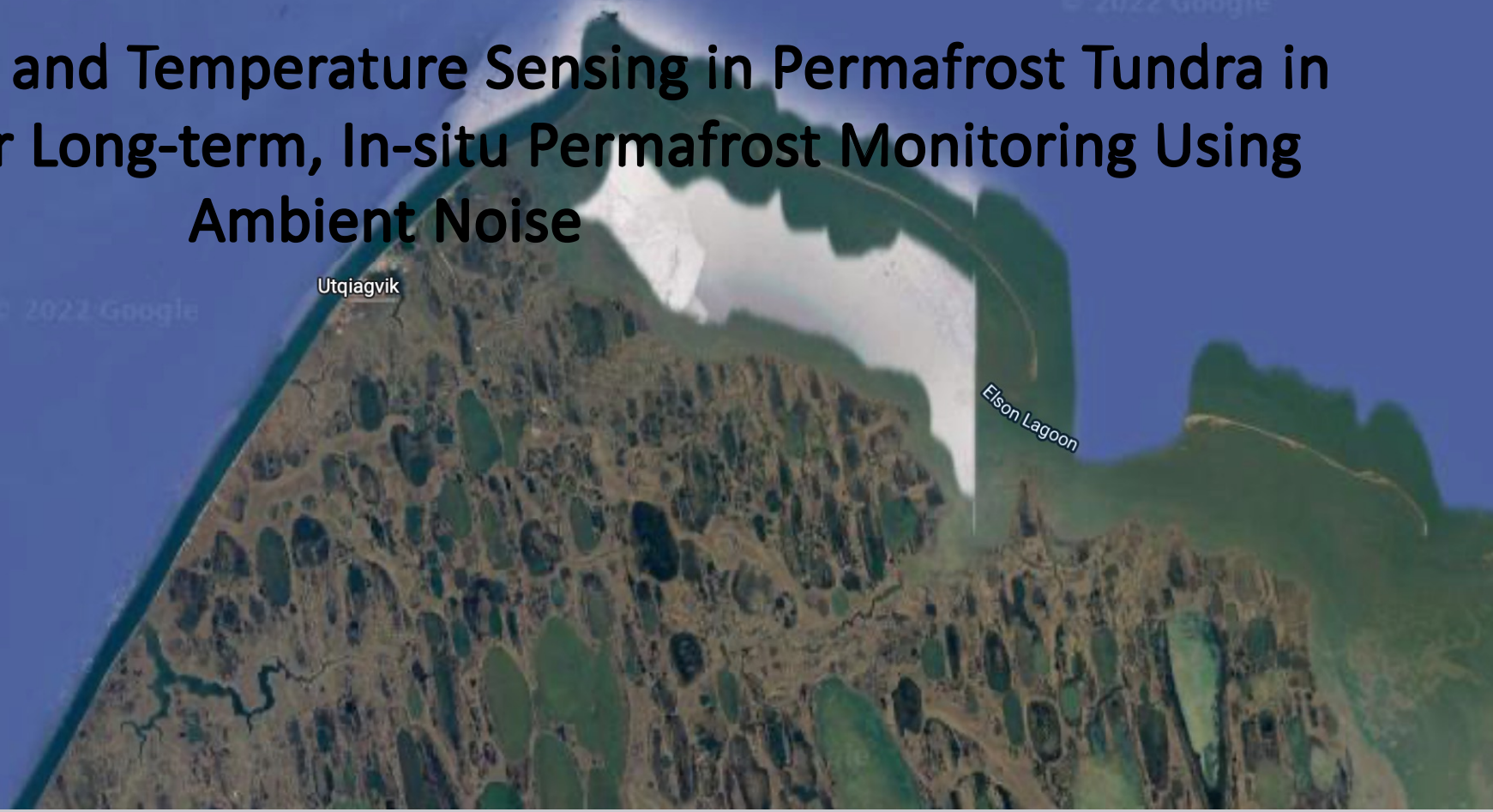
Signals in the Soil (CMMI-2034363)

Distributed Acoustic and Temperature Sensing in Permafrost Tundra in Utqiaġvik, Alaska for Long-term, In-situ Permafrost Monitoring Using Ambient Noise



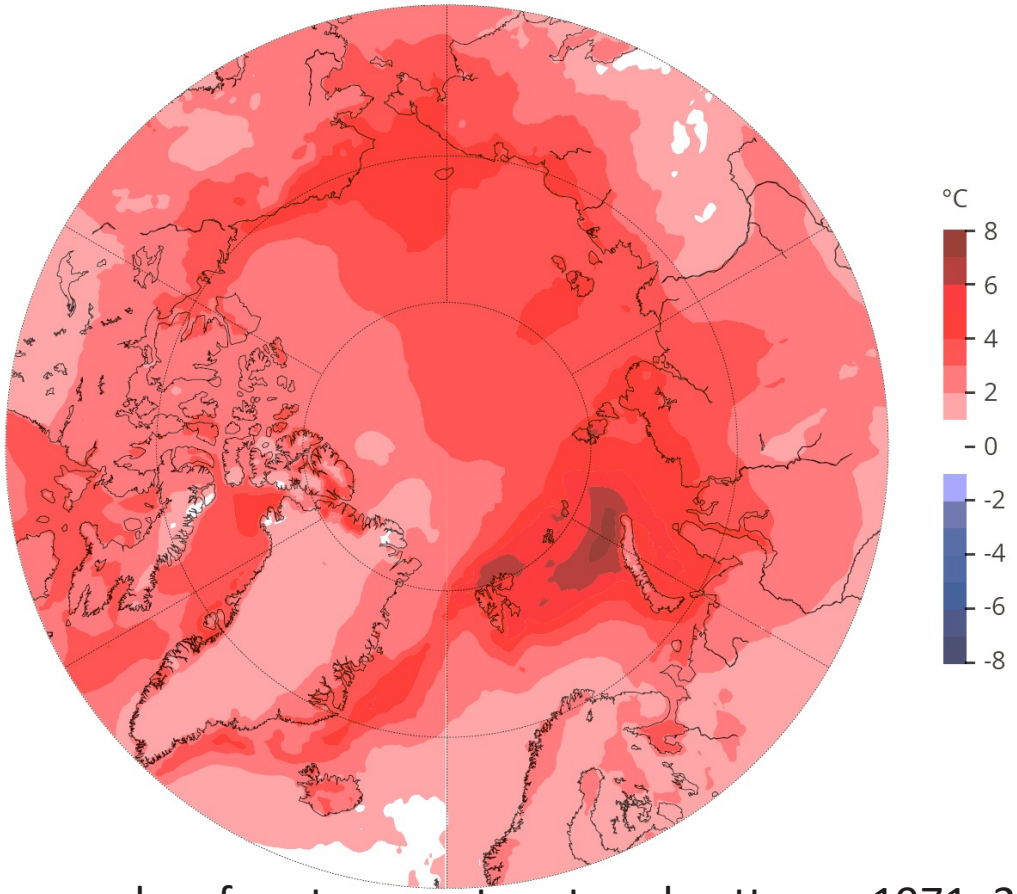
Xiaohang Ji

Ph.D. Candidate
Pennsylvania State University

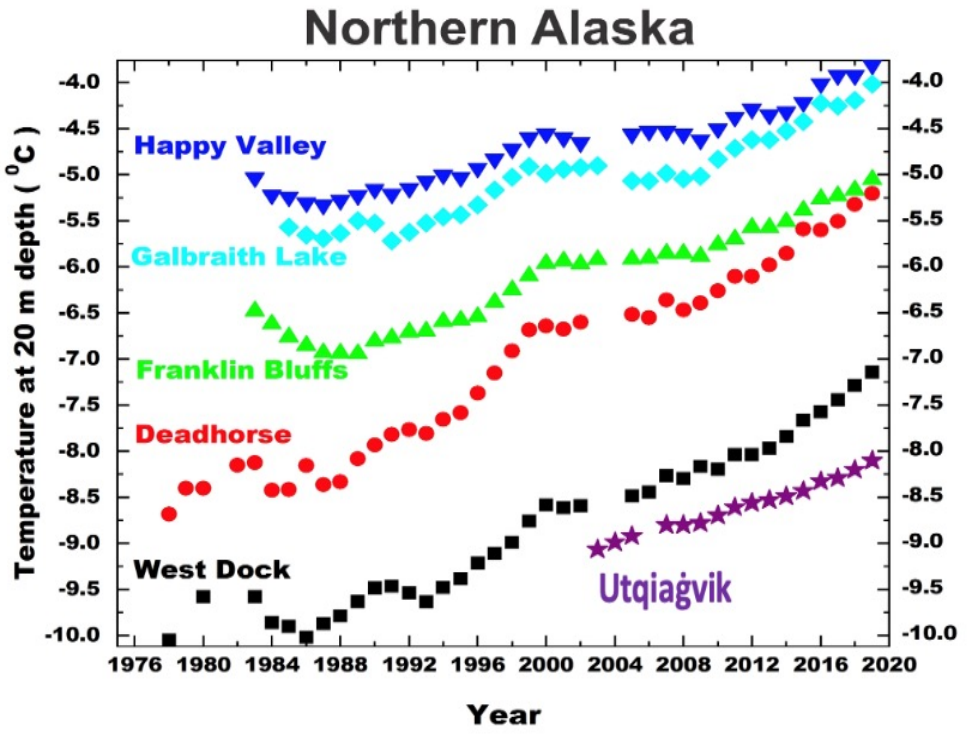
Ph.D. advisor: Dr. Ming Xiao

13th June 2023

Permafrost degradation is happening due to increasing air temperature and ground temperature.

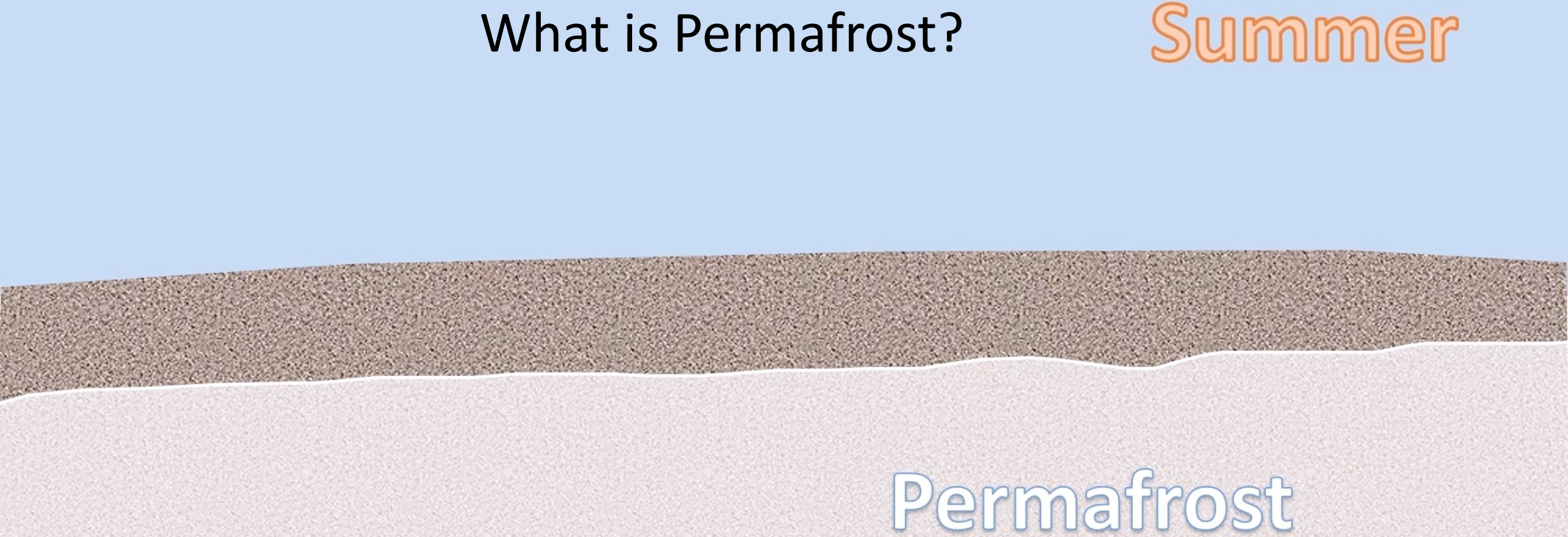


Arctic annual surface temperature trend patterns, 1971–2019, based on combined observed and modeled data (AMAP 2021).



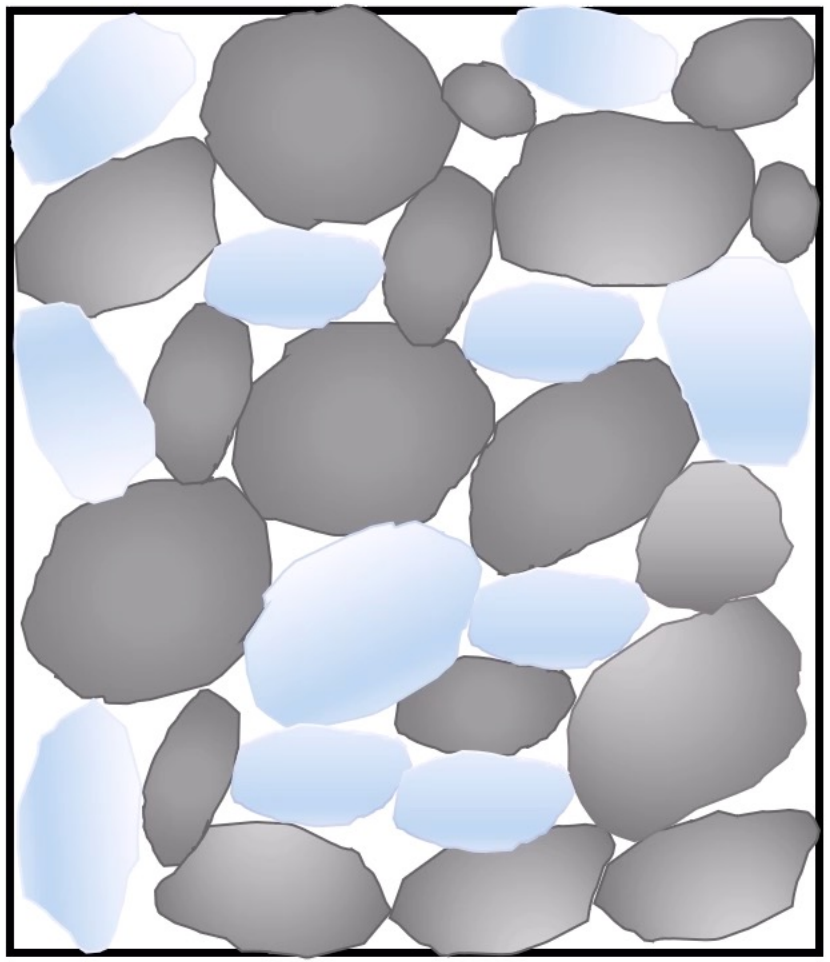
Permafrost temperature variations in northern Alaska (Romanovsky et al., 2019).

What is Permafrost?

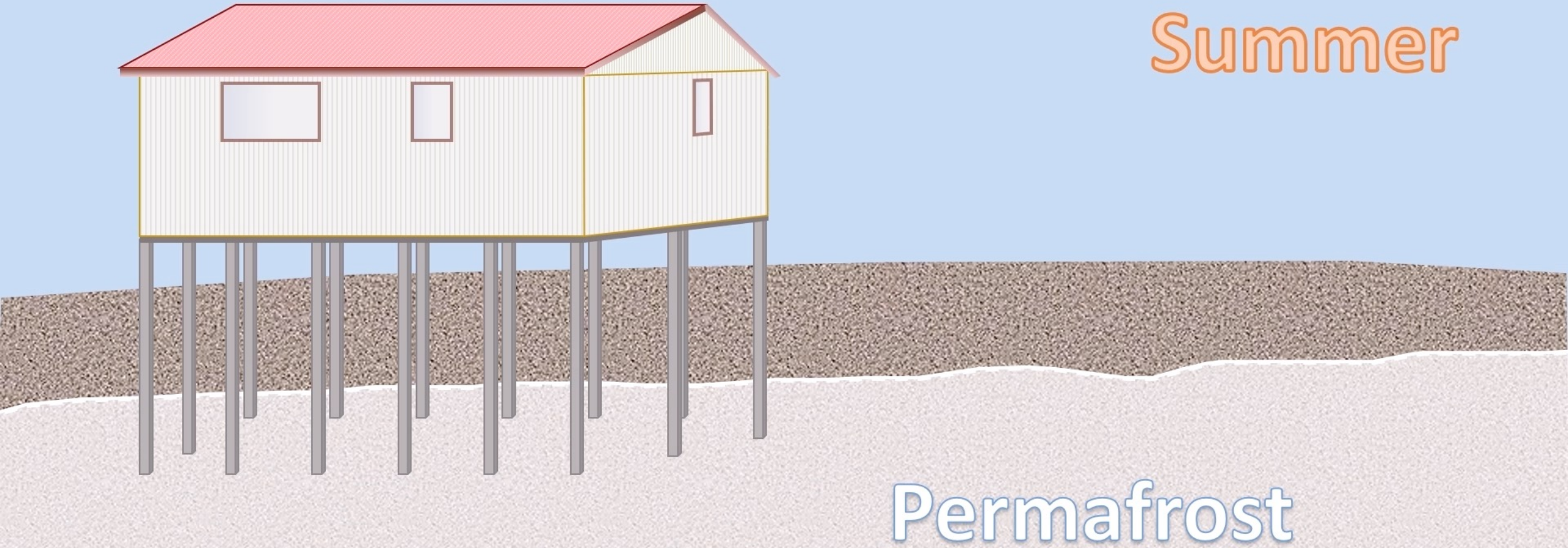


Credit: Min Liew

Frozen



Credit: Min Liew



Credit: Min Liew

Permafrost degradation causes coastal erosion.

Utqiagvik, AK, 12th Aug 2022

Utqiagvik, AK, 12th Aug 2022

A permafrost system can include complex components.

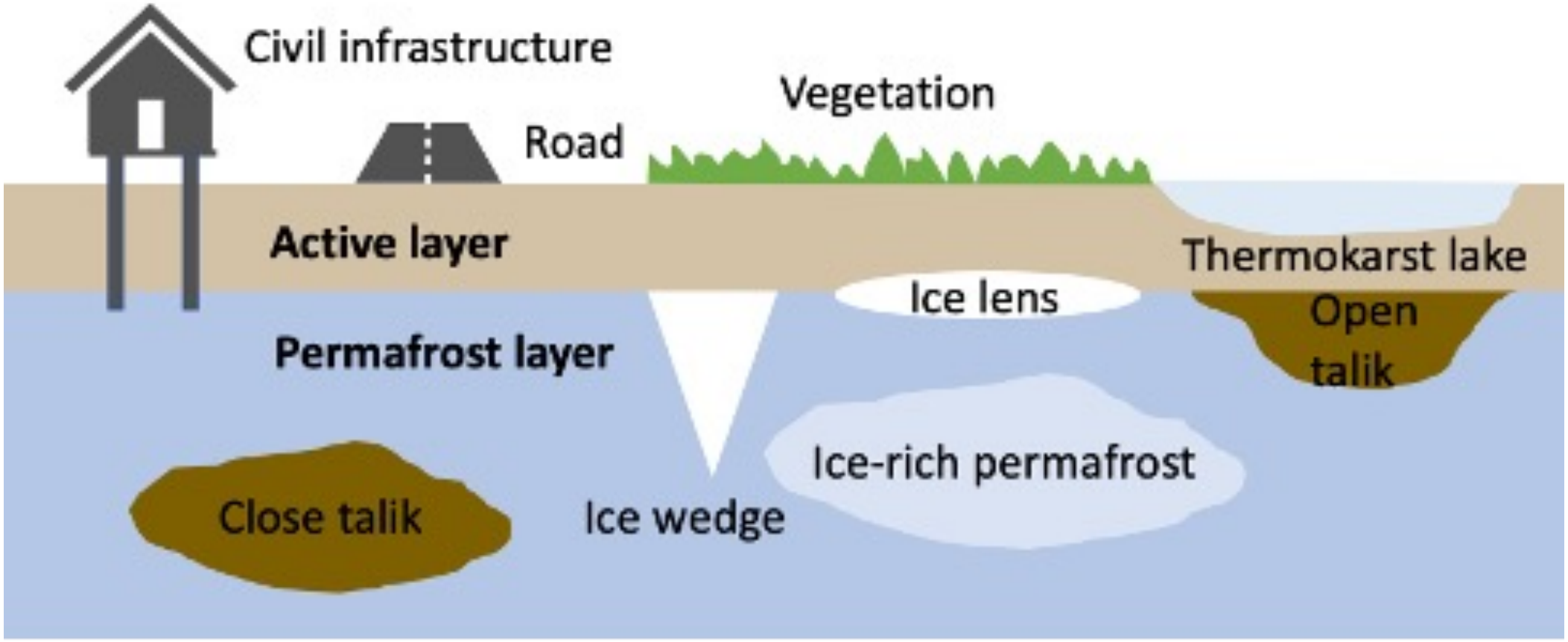


Illustration of permafrost system (not-to-scale)

Permafrost degradation causes engineering problems.

Permafrost degradation increases maintenance costs.

Across Arctic, the lifecycle and replacement costs to maintain infrastructure by 2050-2059 under the RCP8.5 scenario (Suter et al., 2019):

Baseline Lifecycle Replacement Costs *($ Millions)*	Costs with Climate Forcing *($ Millions)*	Difference *($ Millions)*	Percent Increase from Climate Change %
$55,938.34	$71,408.73	$15,470.39	27.7%

In Alaska, the cost of maintaining the public infrastructure affected by permafrost degradation:(Larsen et al., 2008). ($billions)

Projected year	Warm model	Warmer model	Warmest model
2006–2030	$3.6	$6.0	$6.1
2006–2080	$5.6	$7.6	$6.7

RCP: Representative Concentration Pathway

Technologies Used during the Fieldwork

To Understand and forecast the long-term variations of in-situ geophysical and geomechanical characteristics of permafrost in the Arctic Alaska

- **Innovative sensing technology**
  - Combining fiber-optic distributed acoustic sensing (**DAS**), distributed temperature sensing (**DTS**) and ground-truth measurements of geophysical and geomechanical characteristics
- **Ground-truth measurements**
  - Multichannel analysis of surface waves (**MASW**)
  - **Soil Sampling** and **laboratory testing**
- **Data analysis and forecasting model**

Installation of DAS and DTS

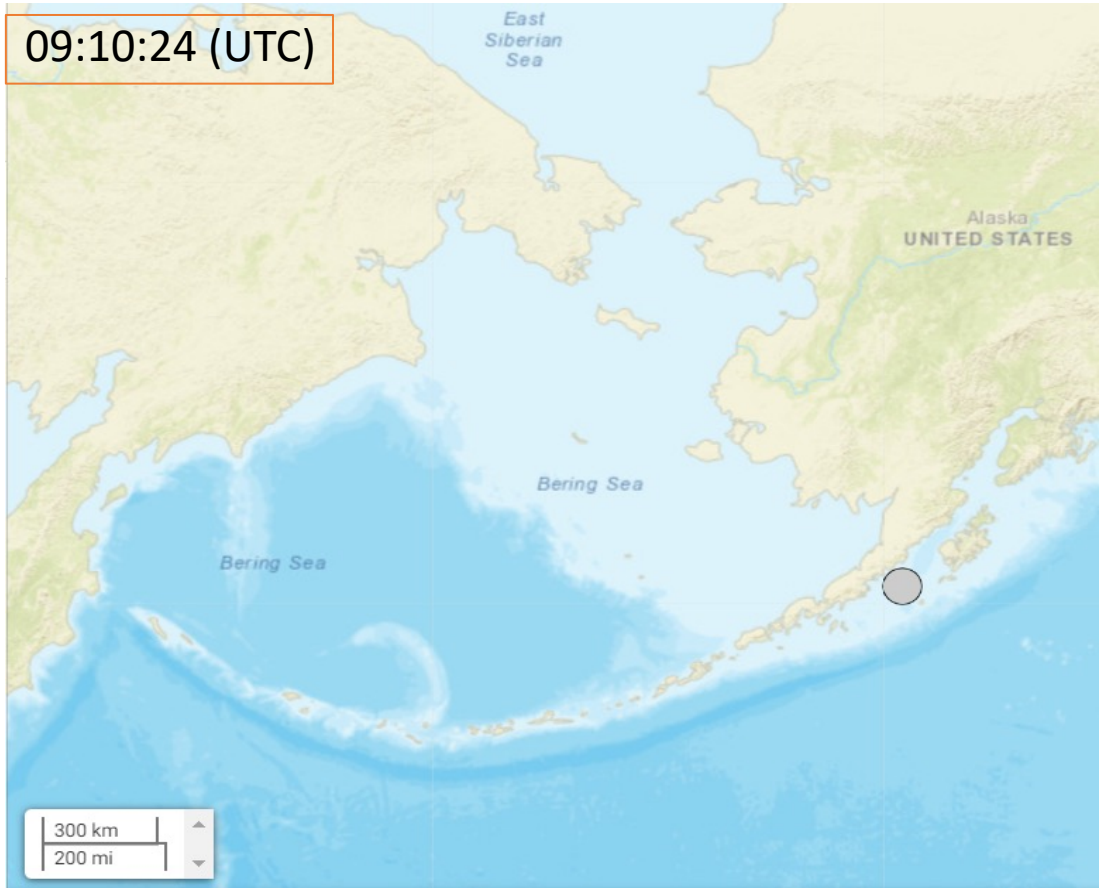
Fieldwork August 29 to September 10, 2021

Total length: 2 km

Installation of DAS and DTS

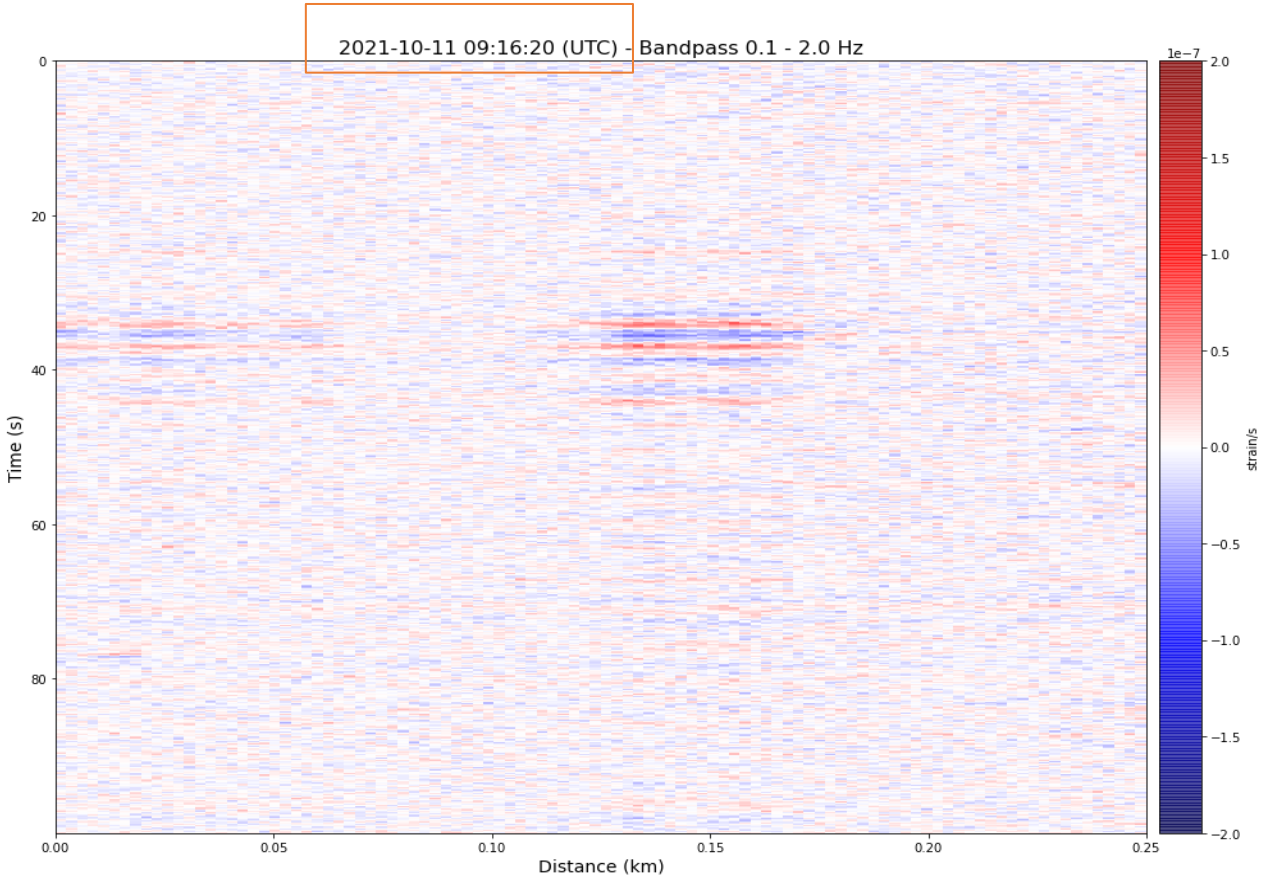
Cable embedment using shovel

DAS Event Type: Earthquakes
Alaska earthquake 2021



Location of *M*6.9 earthquake at Gulf of Alaska

*M*6.9

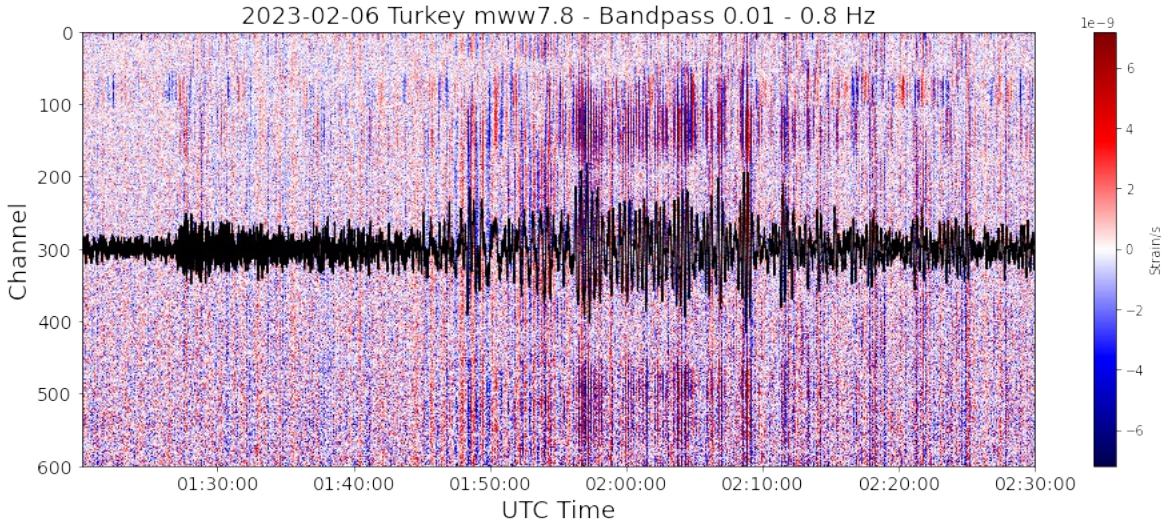


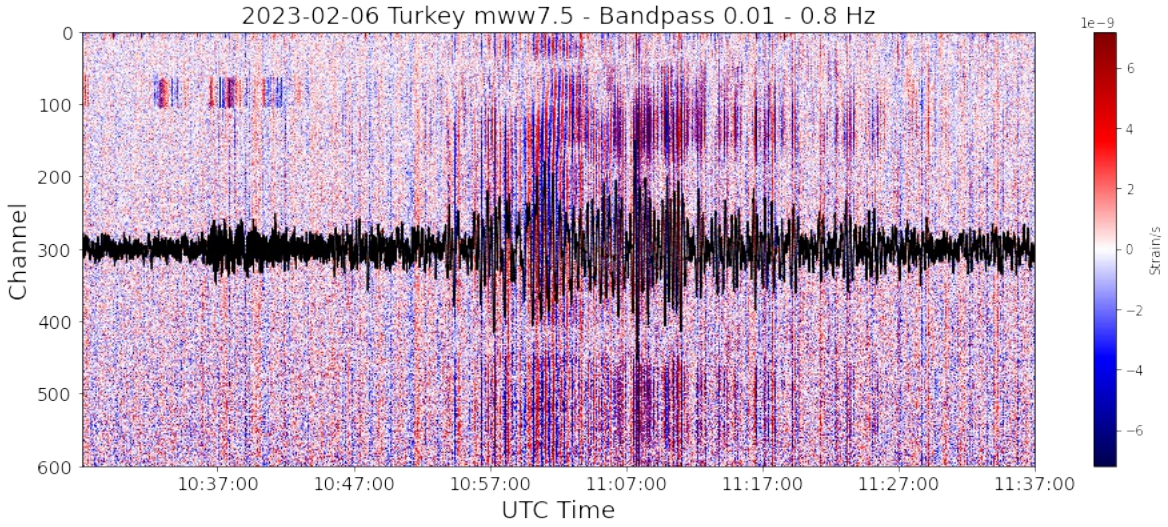
Raw DAS recording of strain rate of *M*6.9 earthquake at Gulf of Alaska

Credit: Gabriel Rocha Dos Santos

DAS Event Type: Earthquakes
Turkey earthquake sequence 2023

*M*7.8 and *M*7.5

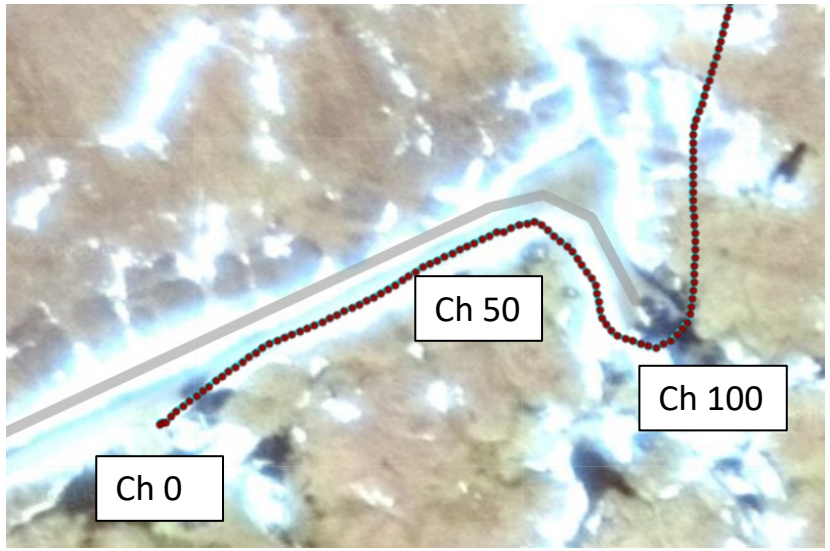




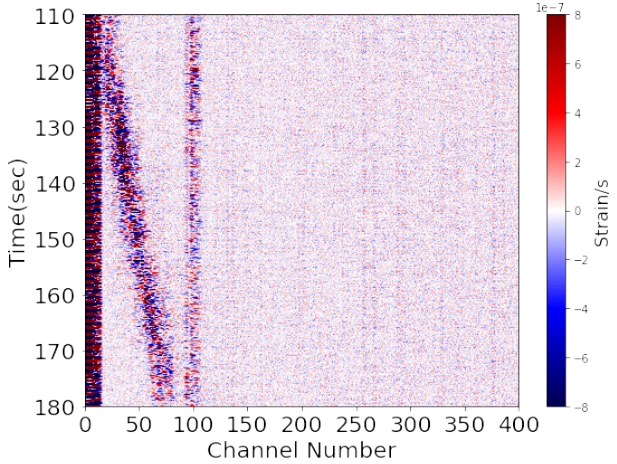
Credit: Gabriel Rocha Dos Santos

DAS Event Type: Car Signals

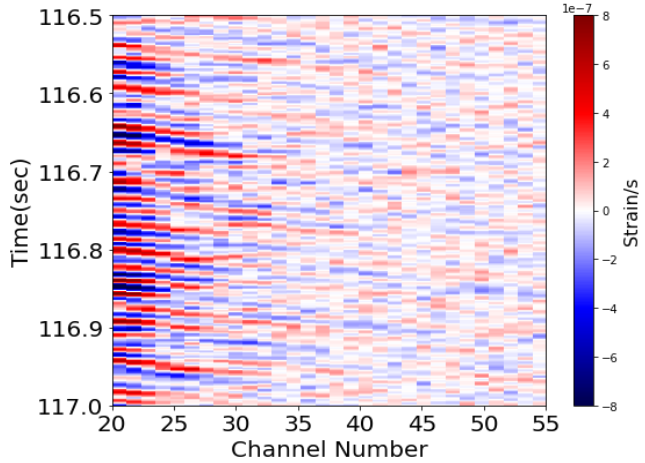
Ambient noise from car signal

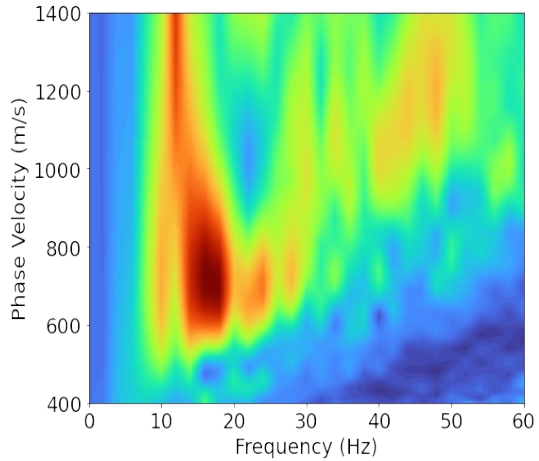


Car signal recorded by the DAS cable

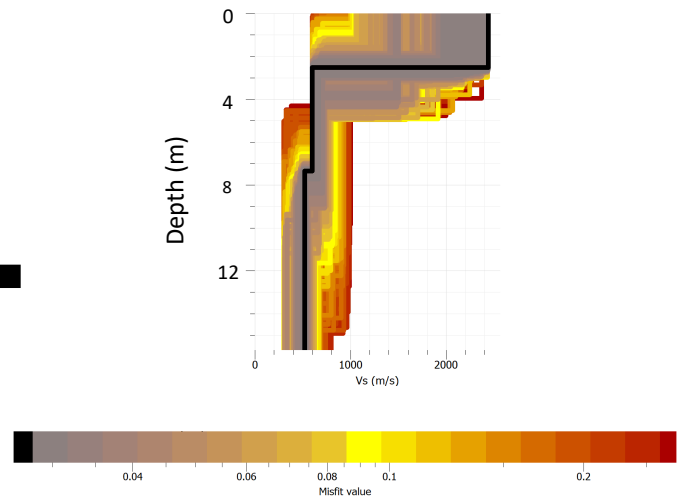


Short time window of straight segment of cable





Dispersion curve of a dozen stacked short time windows



1D Shear wave velocity model created by the dispersion curve

2D Shear wave velocity model

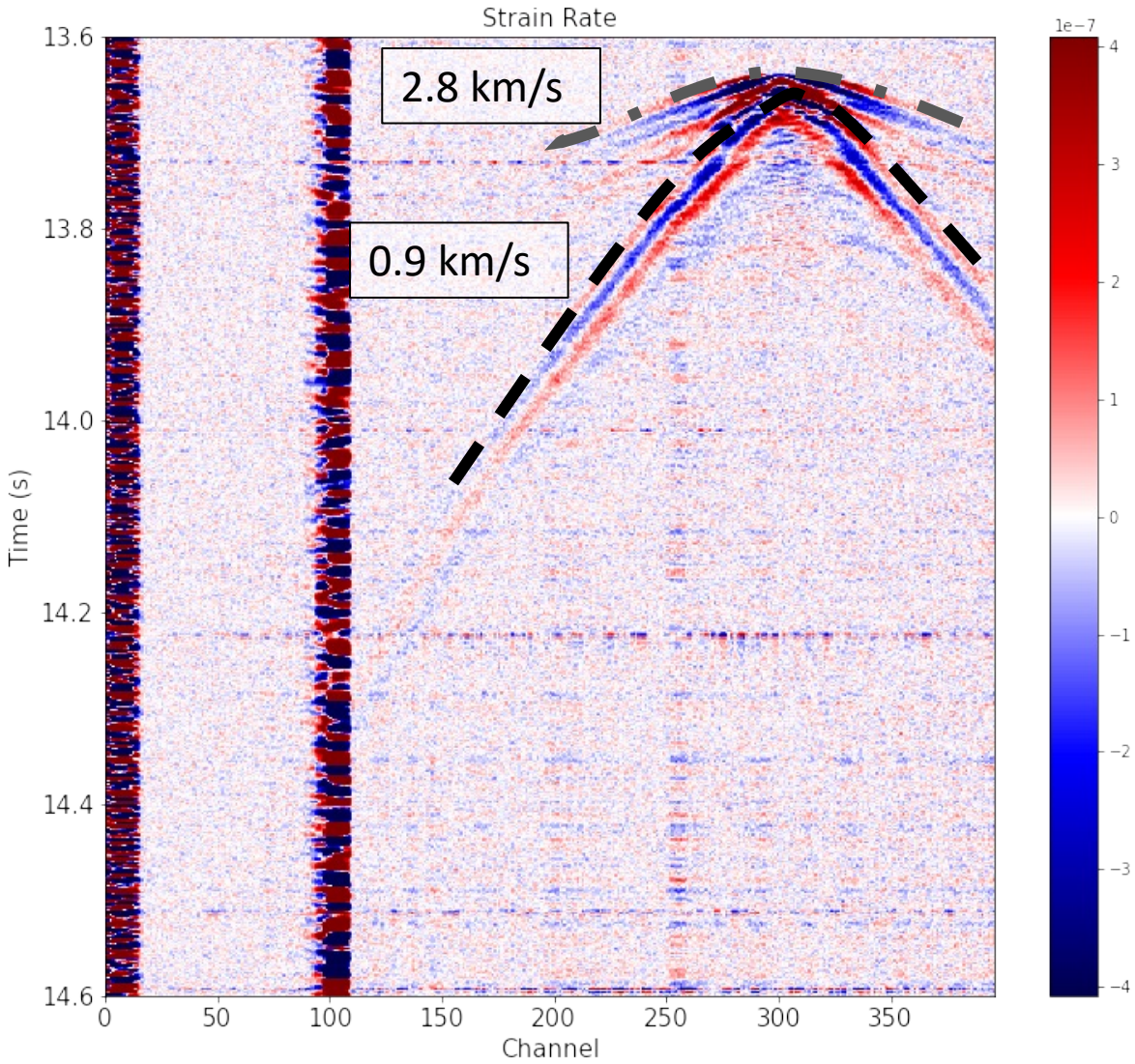
Prediction of shear wave velocity based on temperature model and machine learning models

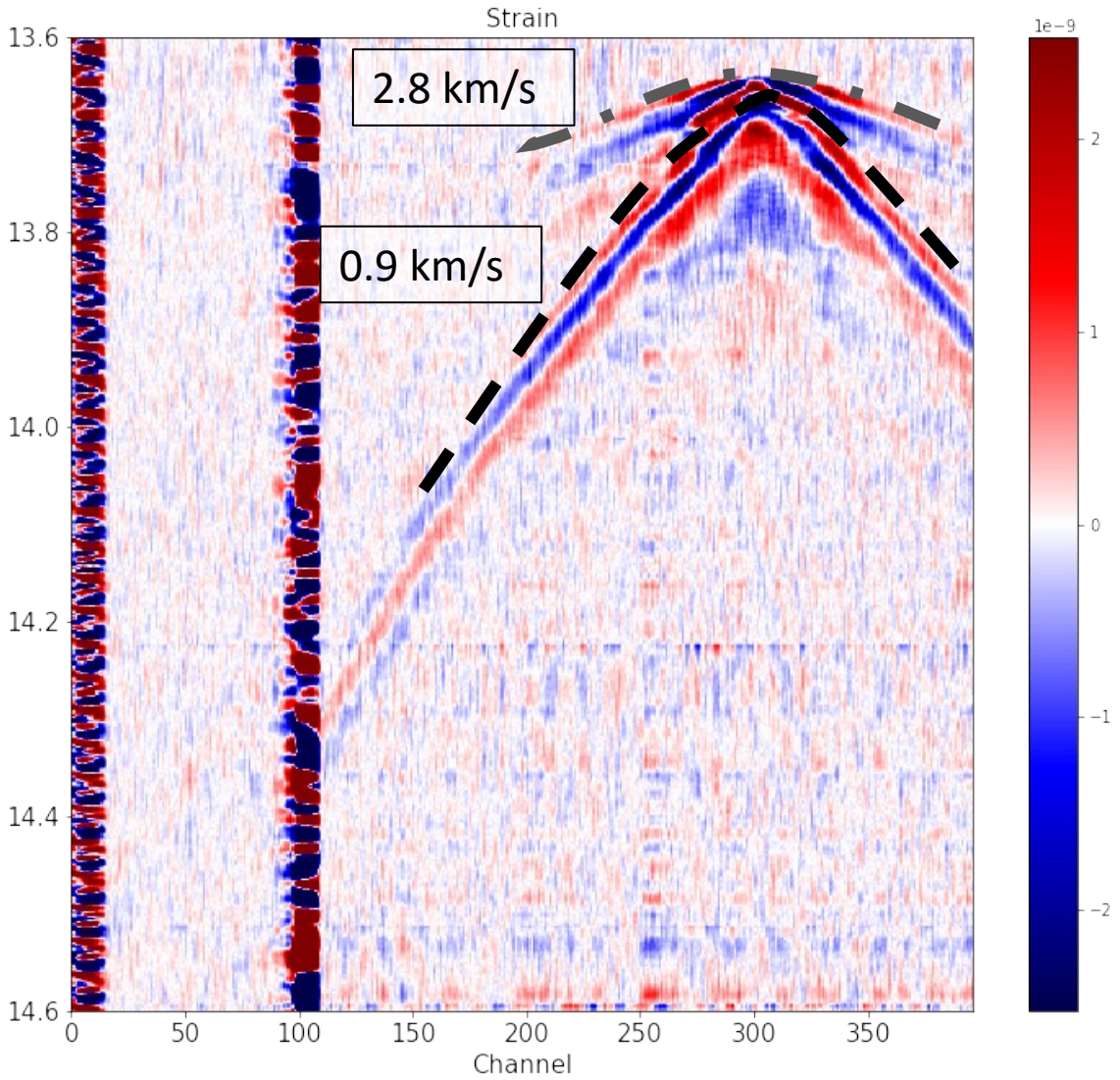
Credit: Gabriel Rocha Dos Santos

DAS Event Type: Ice Wedge/Ice Layer Cracking

Gauge Length: 20m ; Bandpass: 5 – 200Hz

Source Distance: ~ 70m

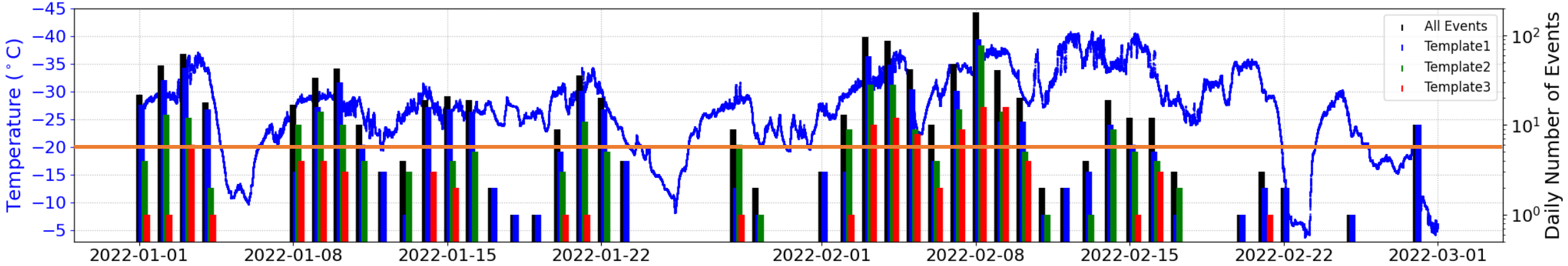




Credit: Gabriel Rocha Dos Santos

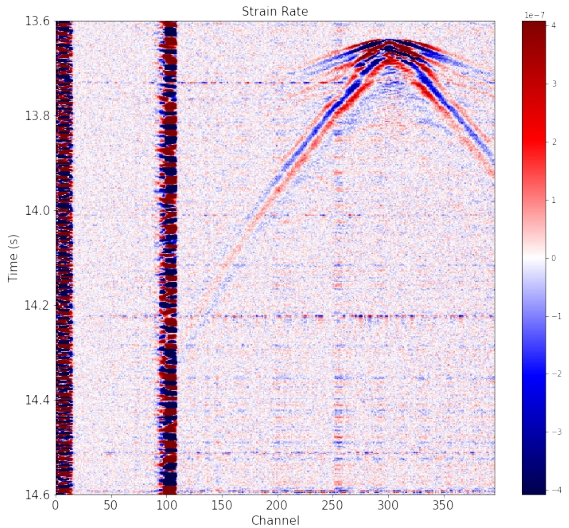
DAS Event Type: Ice Wedge/Ice Layer Cracking

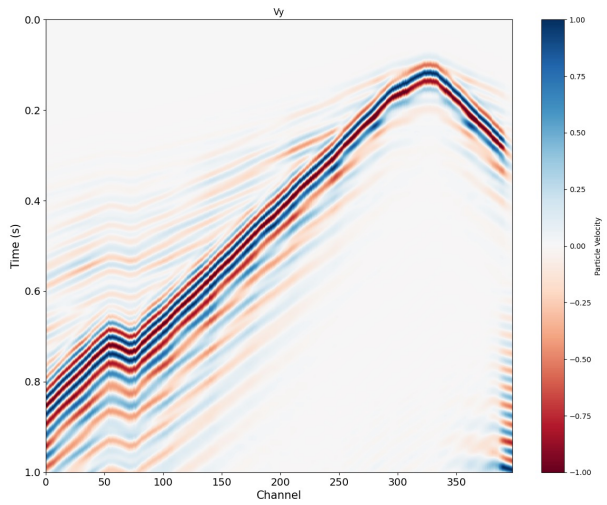
Total : 1017 Events in 2 months

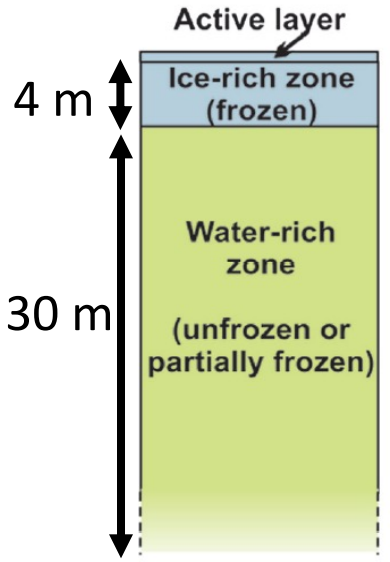


Event Detection: Template Matching

Big winds
Leading larger big NSR







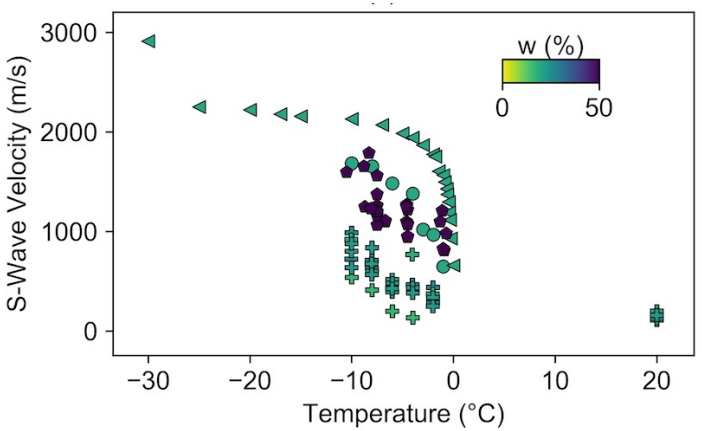
Gauge Length: 20m ; Bandpass: 5 – 200Hz Model simulation

Credit: Gabriel Rocha Dos Santos

Ground-Truth Temperature Measurements: DTS and Thermometer

Fieldwork August 6 to 13, 2022

Vs decreases as temperature increases.



Silt permafrost
Ji et al. (2023)

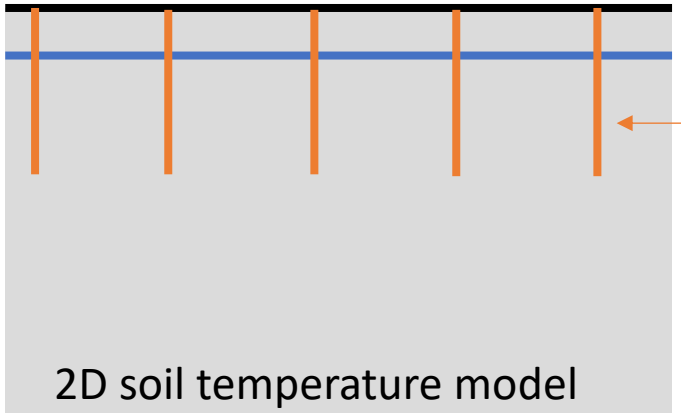
DTS cable

Depth: at 0.2 – 0.3 m

Thermometer installation

Depth: up to ~1.5 m

Temperature sensing diagram
(not to scale)



GIPL model (Geophysical Institute Permafrost Laboratory)

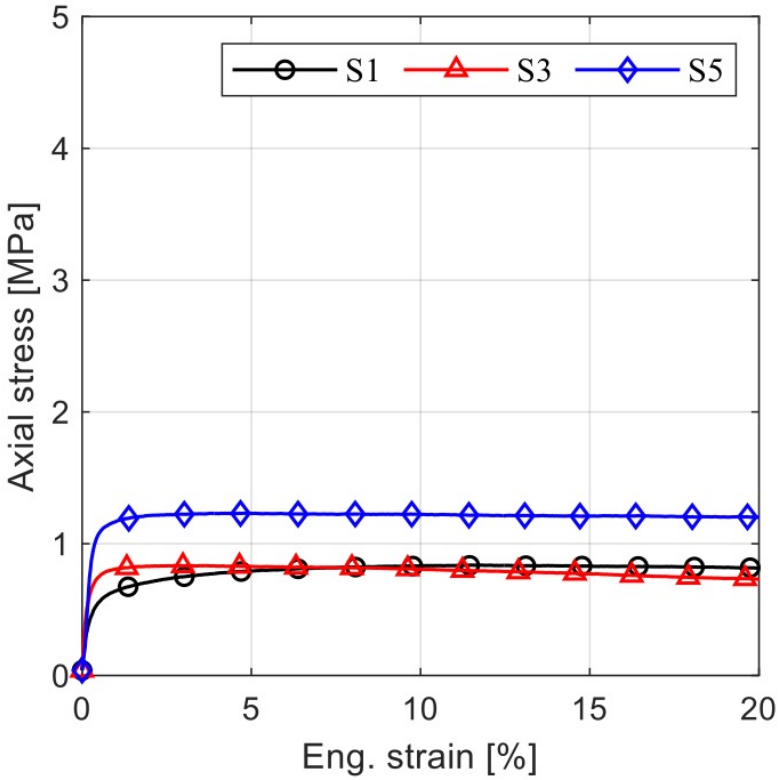
Soil Sampling and Lab Testing

Fieldwork August 6 to 13, 2022

Hand-held driller and boring log

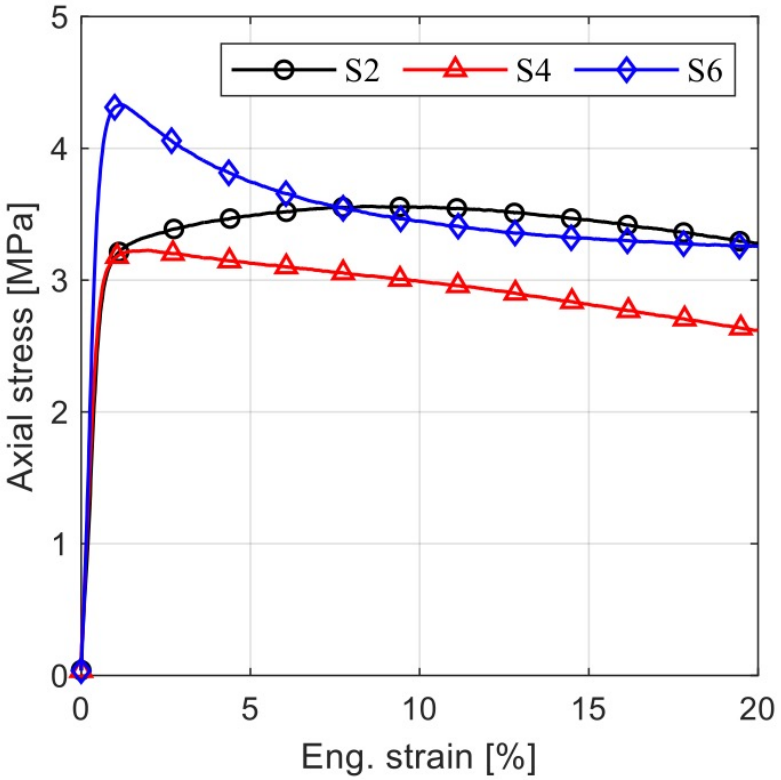
Dr. Ming Xiao

Permafrost Sample



(a) -2 ℃

Example of lab testing results
Unconfined compression test



(b) -10 ℃

Credit: Ziyi Wang

Thank You!

[Signals in the Soil](#)

CMMI-2034363, CMMI-2034366, and

[Navigating the New Arctic](#)

ICER-1927718

YouTube Channel: The Changing Arctic
https://www.youtube.com/channel/UCG_B2Q_Lvjx0xOLPNnBJg9g

Permafrost Research Trip to Utqiagvik, Alaska 2021

The Changing Arctic

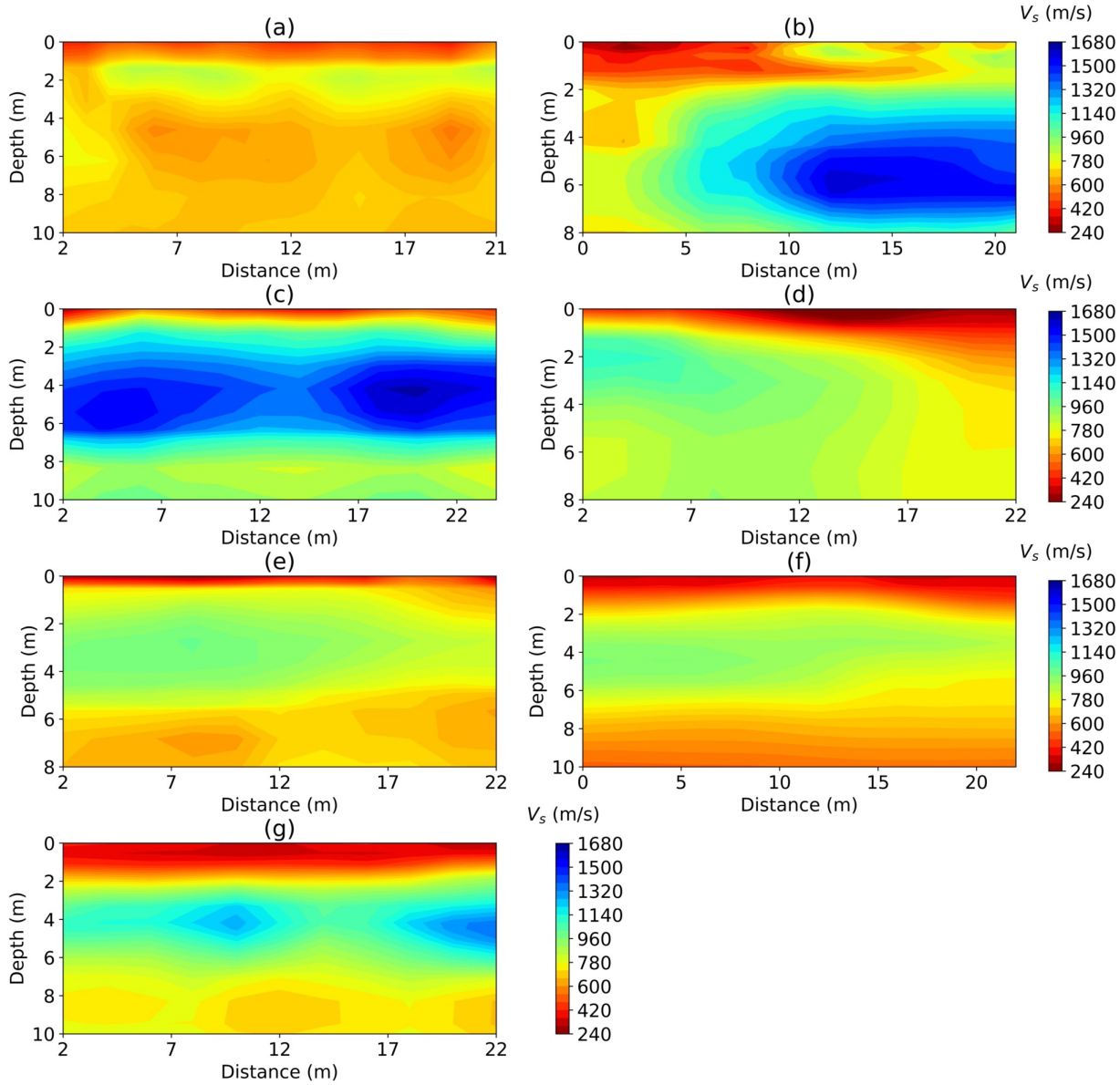
Permafrost Research - Unspooling and Spooling DAS and DTS Cables

The Changing Arctic

DAS and DTS Cable Installation on the tundra of Utqiagvik, Alaska

The Changing Arctic

2D Vs Profiles based on MASW



1D Vs Profiles and Temperature