
# Theme 1: Permafrost characterization and ground ice potential

PermafrostNet 2024 AGM

Ottawa, ON

December 9, 2024

# Theme 1: Characterization of permafrost.

## Objective:

*To improve the understanding of ground-ice loss and its consequences though better* ***characterization of permafrost*** *in the* ***field*** *and in* ***laboratories*** *so that* ***prediction*** *can better represent* ***processes during thaw*** *and have relevant subsurface input such as* ***ground-ice content****.*


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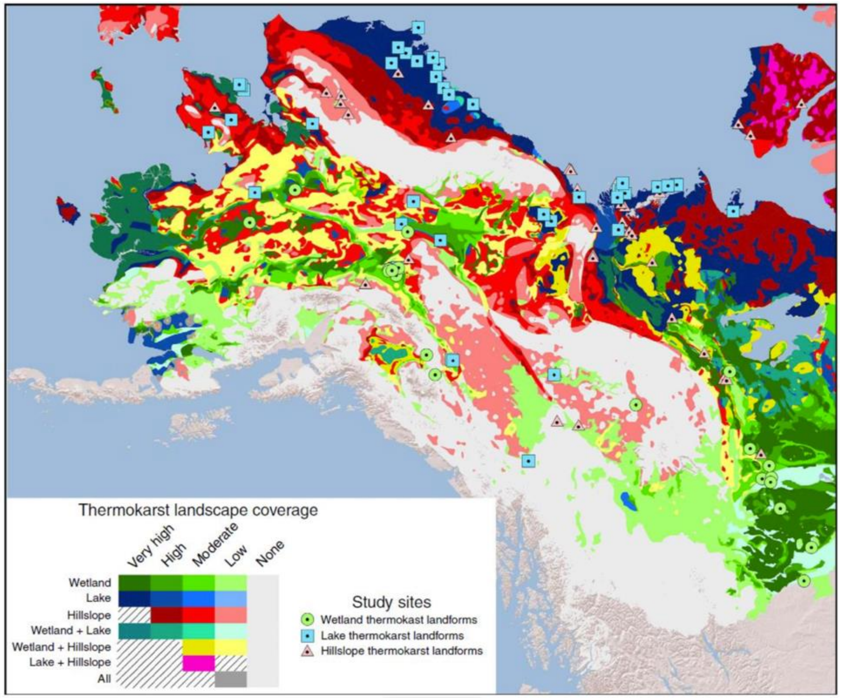
# Specific objectives:

1. Develop and implement a system for handling permafrost data *that can support prediction, evaluation of prediction and analysis of permafrost change* (PINGO)– the database and field data
2. Evaluate and apply methods to predict and measure thermal, hydrologic geochemical and geomechanical behaviour of frozen soil during thaw to support improved simulation
3. Develop a framework for the spatial and stratigraphic syntheses of geotechnical and geological data to *support ground ice map products*




Olefeldt et al. 2017

# Co-investigators

Daniel Fortier (Montreal)
co-lead Theme 1
**PDF1, PhD6**


Duane Froese (Alberta)
co-lead Theme 1
**PDF2, PhD1, PhD5, MSc2**

Jocelyn Hayley (Calgary)
co-lead Theme 1
**PhD3, MSc1**

Pascale Roy-Léveillée
(Laval)
**PhD4**

Toni Lewkowicz
(Ottawa)
**PDF3**

Stephan Gruber
**PhD2**

**3 PDF/RA**

**4 PhD**

**2MSc→ Both converted to PhD**

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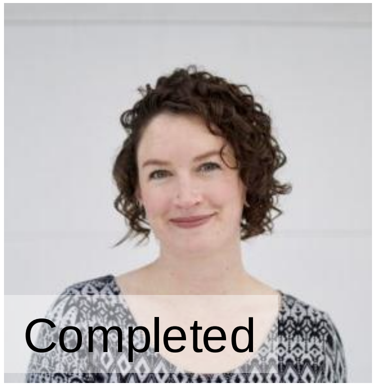
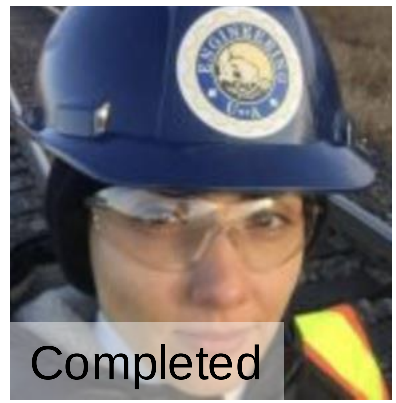

Completed


Completed


Completed

# Partners

Steve Kokelj
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Yellowknife

Stephen Wolfe,
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Fabrice Calmels
Yukon University

Ashley Rudy
NTGS
Yellowknife

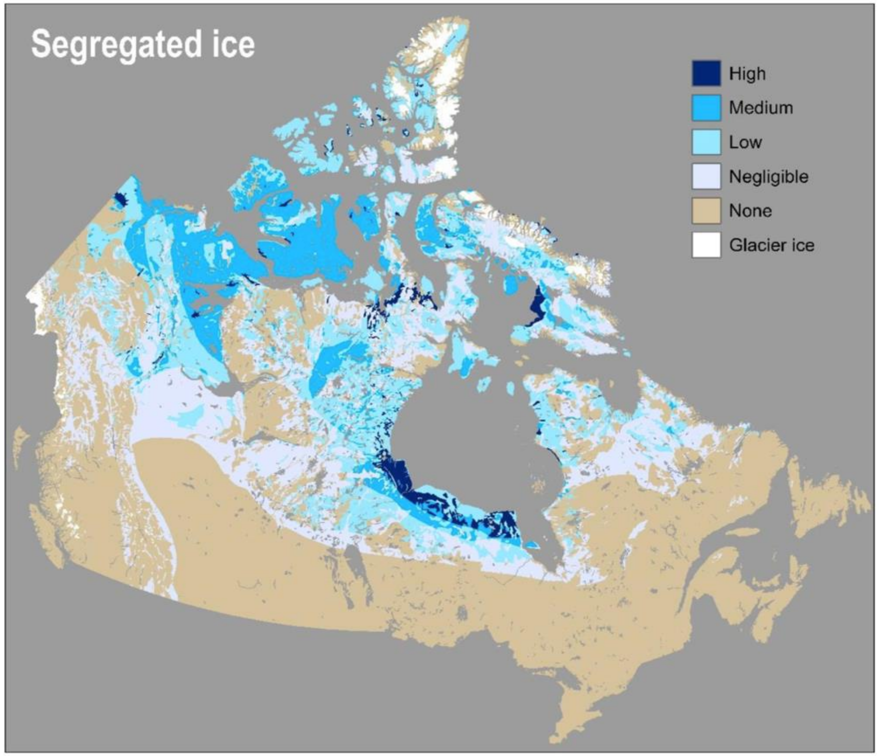
Brendan O'Neill
GSC Ottawa

Peter Morse
GSC Ottawa

Chris
Stevens
SRK/Indepen
dent

# Progress

1. PINGO Database structure, fields draft complete
   - *Michel Paquette, Samuel Gagnon, Nick Brown*
2. Ground Ice Potential Database
   - Databases– Yukon, **Mackenzie Valley PIN,** Nunavik
   - Presently ~50,000 ice measurements from ~ 13,000 boreholes primarily Mackenzie Valley
3. Regional studies
   - Hudson Bay Lowlands– **Tabitha Rahman**
   - Mackenzie valley corridor- **Alexandre Chiasson**
   - Mackenzie Mountains and subarctic hillslopes and landslides- **Joe Young**
   - Polar Desert- ***Withdrew***



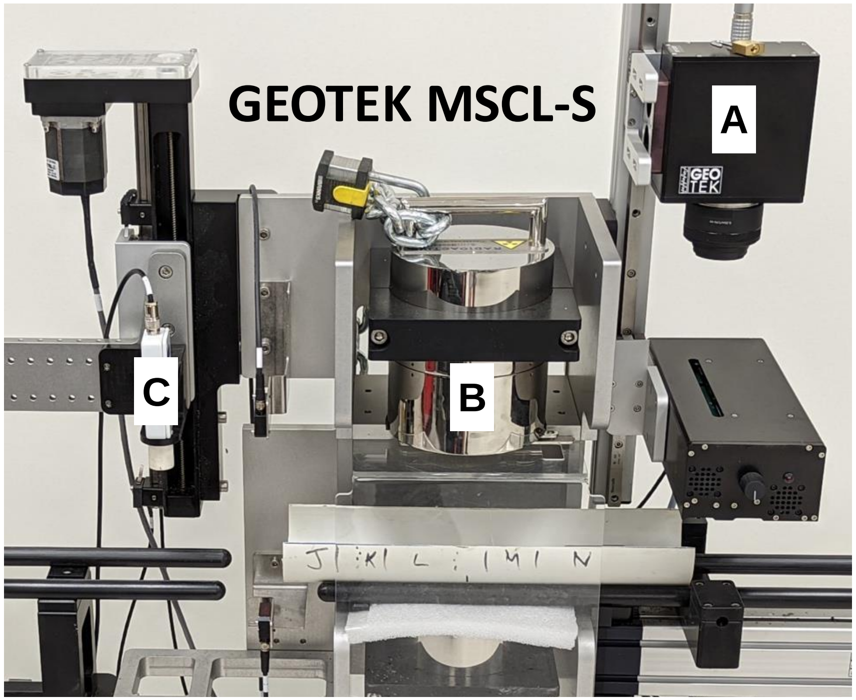

O'Neill et al. 2018

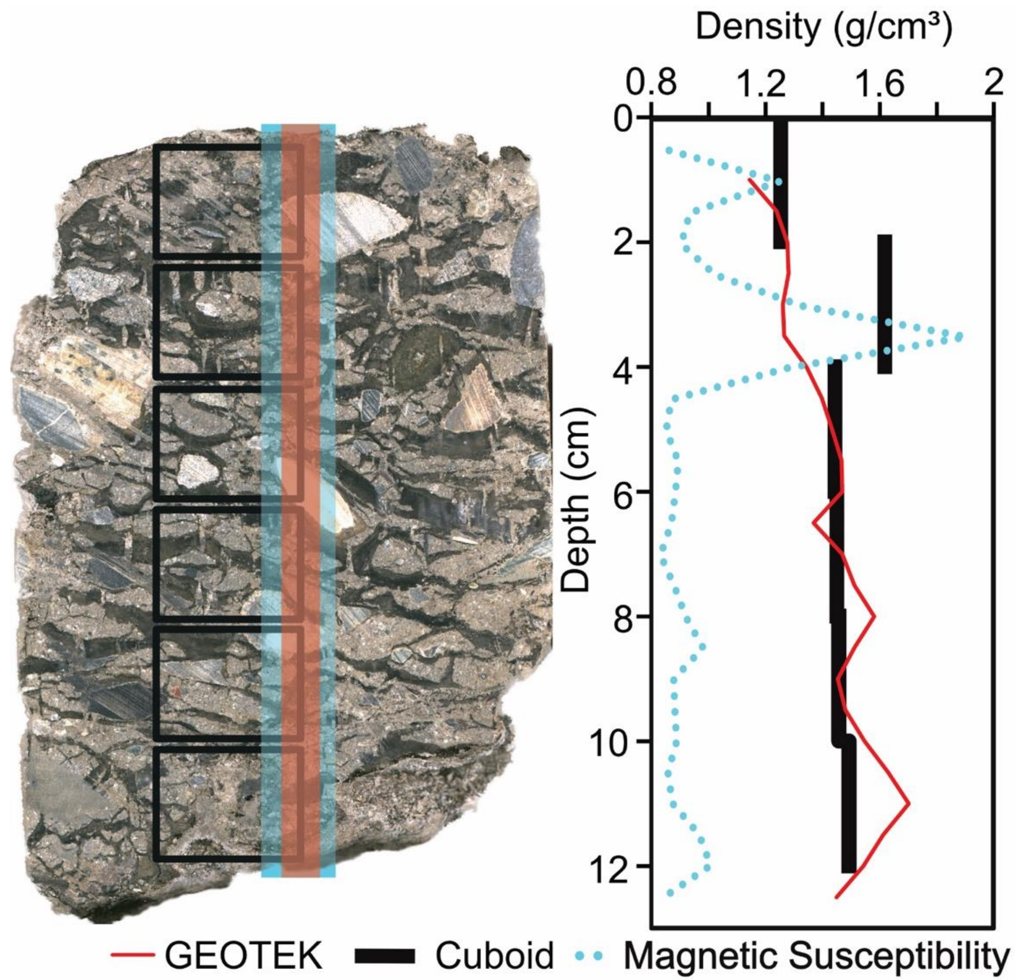
# Progress– Next practices

4. Permafrost characterization
   - Non-destructive and digital archives
     - Computed tomography- *Mahya Roustaei and Joel Pumple*
     - Multi-sensor core logging- *Joel Pumple, Mahya Roustaei PACS Lab*
   - Dielectric methods -- *Hosein Fereydooni Started 2022*
   - Geomechanical properties– *Khatereh Roghangar and Zakieh Mohammadi*
5. Electrical resistivity *Teddi Herring*

# Mahya Roustaei and Joel Pumple Theme 1 CT and MSCL

## Non-destructive methods – GEOTEK (visible ice and ρ)




Multiple rapid non-destructive results

- **A** High resolution core images
- **B** Bulk density (137Cs gamma source)
- **C** Magnetics

**Mahya Roustaei, Joel Pumple, Duane Froese, Daniel Fortier : CT and MSCL**

# Non-destructive methods – Industrial Ct Scanner- (VIC, EIC, ρ, $\rho_s$)

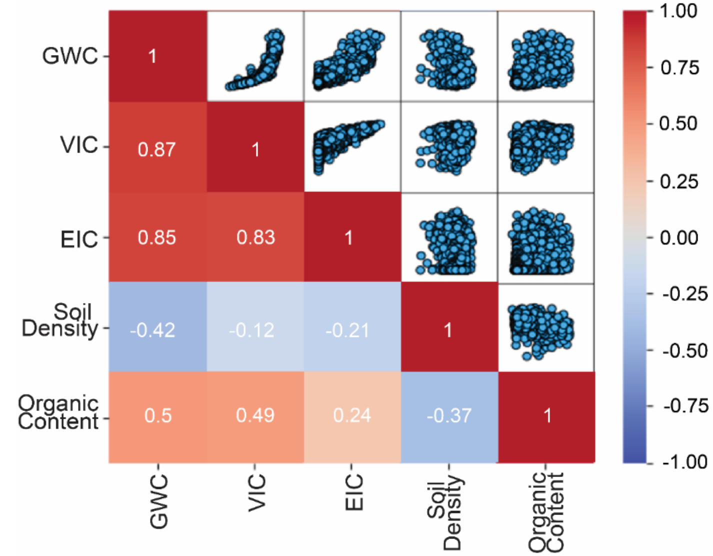


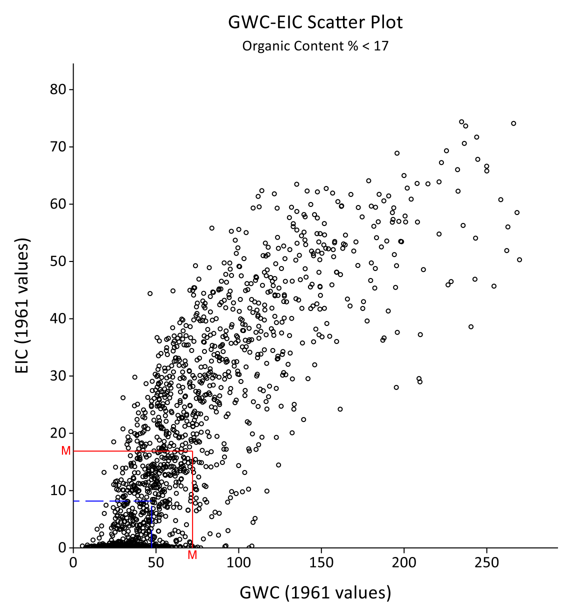
***2 papers 2022 CGS Meetings, 1 paper in The Cryosphere, 2 papers in review, 2 papers to be submitted 01-2025***

# Ground ice potential– progress

***Omid Ansghari, Mahya Roustaei, PACS lab Research Associates***

1. Databases– Yukon, Mackenzie Valley, ITH, Nunavik
   - Abundance of GWC. (75,000+)
2. PACS Lab Permafrost Index Properties – defines relations between gravimetric water content (GWC) and Excess Ice



# Spectral Induced Polarization Field measurements

## Hosein Fereydooni

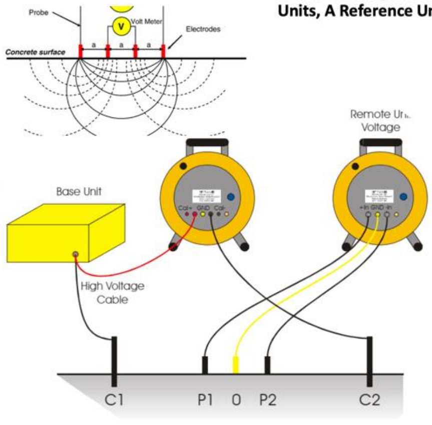
### Measurement Sites

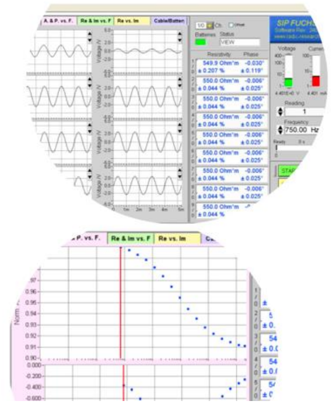
- **Haines Junction – Pingo**
- **Carmacks – Buried ice**
- **Takhini – Retrogressive Thaw Slump**
  - **Two orthogonal 2-metre-profiles**

### Equipment

- **FUCHS III+**

**A Unit Control, A Current Unit, two Potential Units, A Reference Unit**



# A Study of Effective Parameters in Thermal Modeling Impacting Permafrost Response to Climate Warming

30 Pages • Posted: 17 Aug 2023

Khatereh Roghangar
*affiliation not provided to SSRN*

Jocelyn L. Hayley
*affiliation not provided to SSRN*

## Abstract

Abstract : Climate warming is causing significant changes in the Arctic, leading to increased temperatures and permafrost instability. The harmonic active layer has been shown to be affected by climate change, where warmer ground surface temperatures result in progressive permafrost thaw and a deepening active layer. This study assessed the effects of critical parameters on permafrost ground response to climate warming using the fifth phase of the Coupled Model Intercomparison Project (CMIP5) and TEMP/W software. We analyzed variations in depth, climate scenarios, water content, and soil types to predict the depth of the active layer and settlement in the future using the soil characteristics along Hudson Bay Railway corridor. The results indicate

Analyzed the effects of thermal modelling parameters (i.e., water content, soil type, model depth, climate scenario and permafrost coverage) on climate-driven permafrost thaw and settlement using the CMIP5 and TEMP/W software

# A Framework for Predicting Thaw Settlement in Permafrost Regions

Zakieh Mohammadi and Jocelyn Hayley

## Regional Scale Assessment

**Status:**
Completed and published.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Cold Regions Science and Technology
Volume 216, December 2023, 104005

Qualitative evaluation of thaw settlement potential in permafrost regions of Canada

Zakieh Mohammadi, Jocelyn L. Hayley

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## Local Scale Assessment

**Creating predictive tools/methods for thaw settlement** by accounting for the unique characteristics of fine-grained, coarse-grained, and highly organic soils.

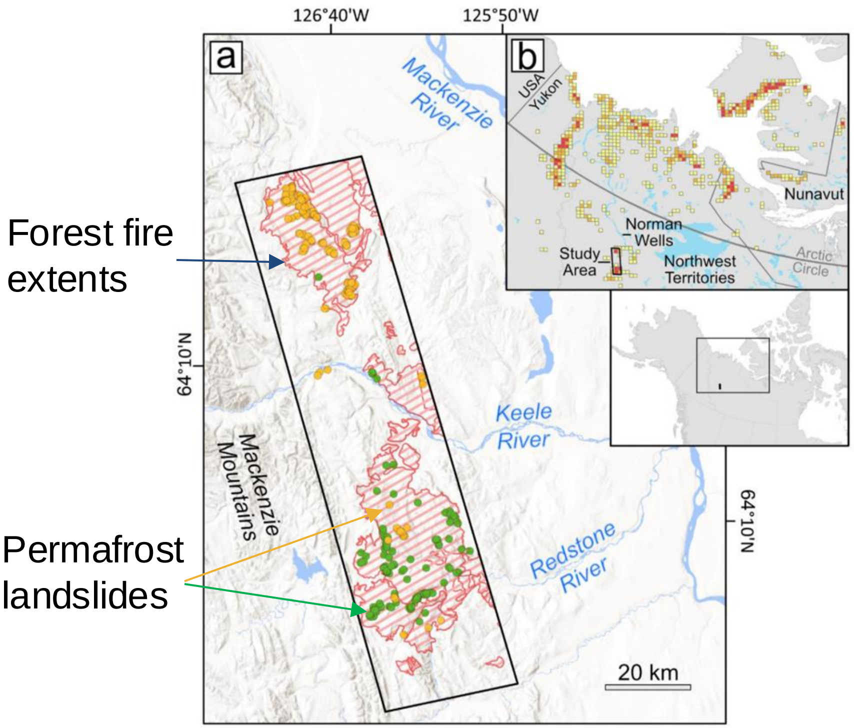
**Status:**

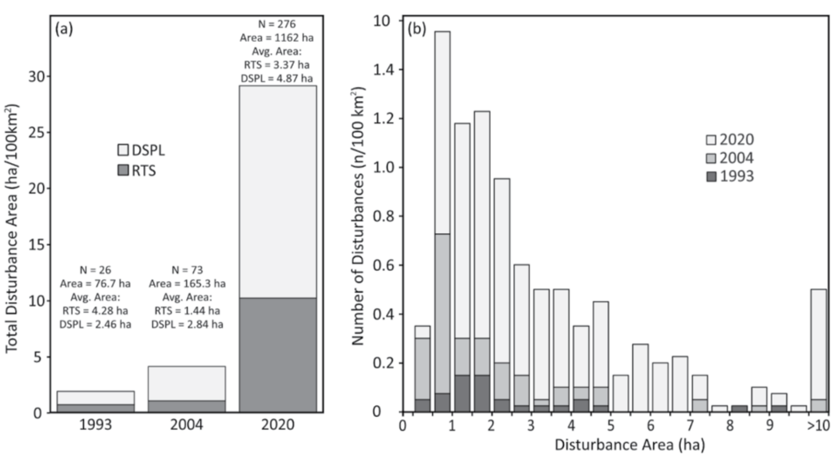
- Integrated thaw consolidation data into a unified database (data is ready to be published).
- Work on coarse-grained and organic soils completed (Papers submitted)
- **Work on fine-grained sediments in progress**.

## Creating the Framework

Integrating diverse components to establish a framework for assessing thaw settlement across various scales (Next step)

# Past forest fires condition permafrost slopes for failure in the central Mackenzie Valley, NWT



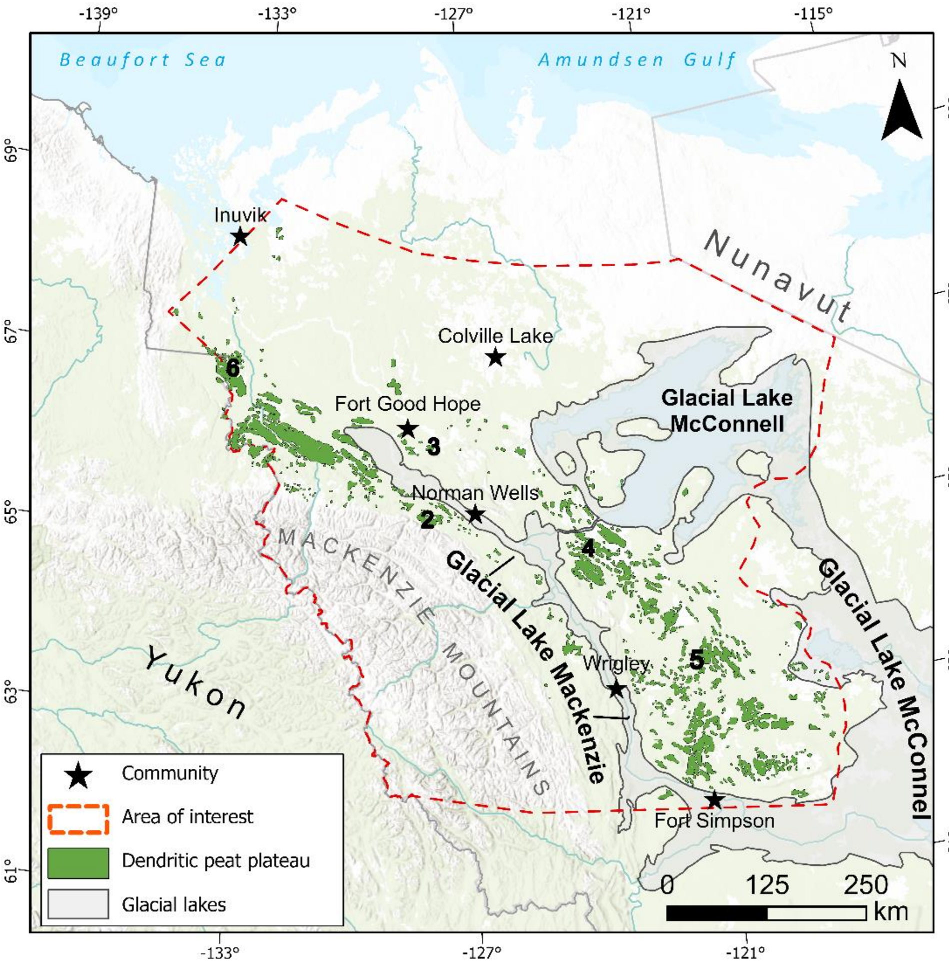

Recent increases in permafrost landslide frequency (278%) and magnitude (602%) between 2004 and 2020 reveal a permafrost landscape in geomorphic transition

More than 80% of permafrost landslides occur in areas burned in the 1990s, indicating the long-term effect of fire on permafrost slope stability

Compounding effects of legacy thermal disturbance from fires and climate drivers of thaw (increasing air temperature and precipitation) are likely to increase slope instability of warm permafrost


Young, J. M., Alvarez, A., van der Sluijs, J., Kokelj, S. V., Rudy, A., McPhee, A., et al. (2022). Recent intensification (2004–2020) of permafrost mass-wasting in the central Mackenzie Valley foothills is a legacy of past forest fire disturbances. Geophysical Research Letters, 49, e2022GL100559.

# Variability in Permafrost Environment in the Central Mackenzie Valley



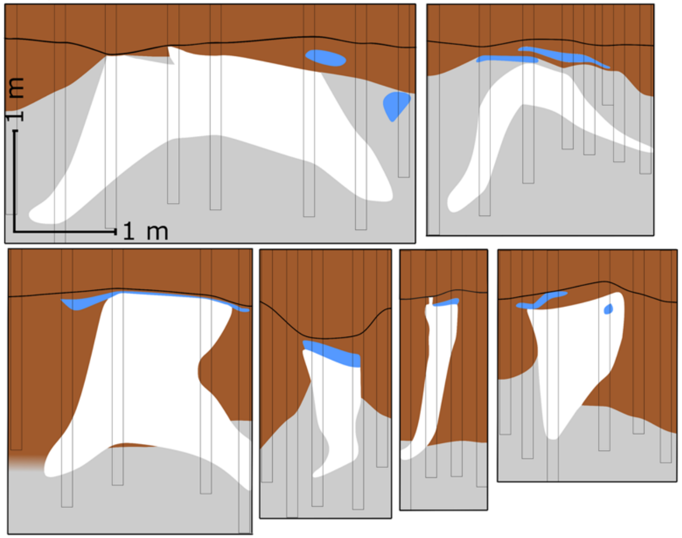

**Two papers are currently in preparation.**

- 1) Chiasson, A., Alvarez, A., van der Sluijs, J., Andersen, B., Kokelj, S., Rudy, A., La Farge-England, C. & Froese, D.G. **Morphology, dynamics and setting of dendritically-drained peat plateaus of the central Mackenzie Valley, Northwest Territories.**
- 2) Chiasson, A., Alvarez, A., van der Sluijs, J., Kokelj, S., Rudy, A., & Froese, D.G. **Investigation of Dendritically-Drained Peat Plateaus: An Analysis of Permafrost Peatland Degradation Over the Past 70 Years in the central Mackenzie Valley, Northwest Territories**.

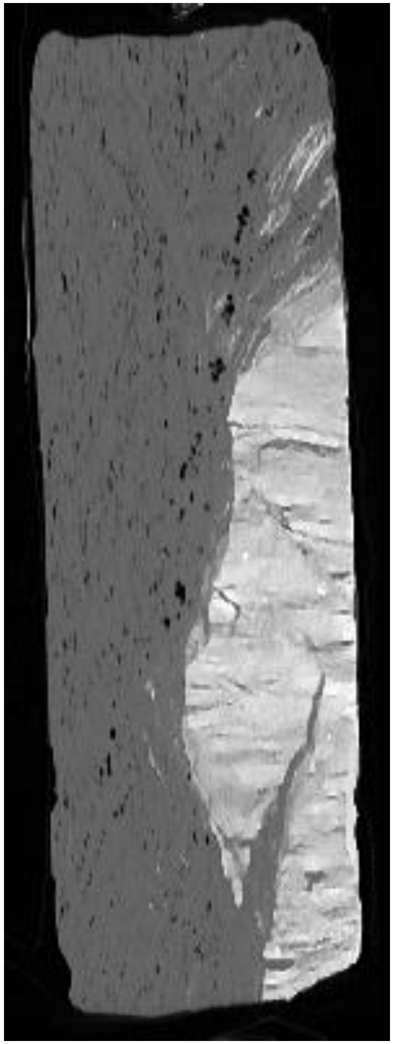
1. The research has provided new insights into the formation and evolution of peatlands in the central Mackenzie valley, allowing us to better understand the factor that contribute to the variability of peatlands morphology.
2. Peatlands are one of the largest carbon sinks on Earth, and understanding the dynamics of dendritic peat plateaus can help us better predict and mitigate the effects of climate change.
3. The preservation and restoration of dendritic peat plateaus, which are covered in Reindeer Lichens, could not only have a positive impact on carbon sequestration and climate change mitigation efforts, but also provide an important source of nutrition for Caribou and other wildlife.

# Ice-wedge volume, morphology, and distribution in northern Manitoba – T. Rahman

Photo by Emmanuel L'Hérault




Ice-wedge morphology



CT-scan

Northern Manitoba hosts a 13,500 $km^2$ polygonal peatland.

To estimate ice-wedge volume and morphology:

- 66 boreholes in 18 ice wedges were collected.
- Cores were CT-scanned and analysed for cryostructures.

***Ice wedges represent 0.88% of the upper 2.5 m of ground.***

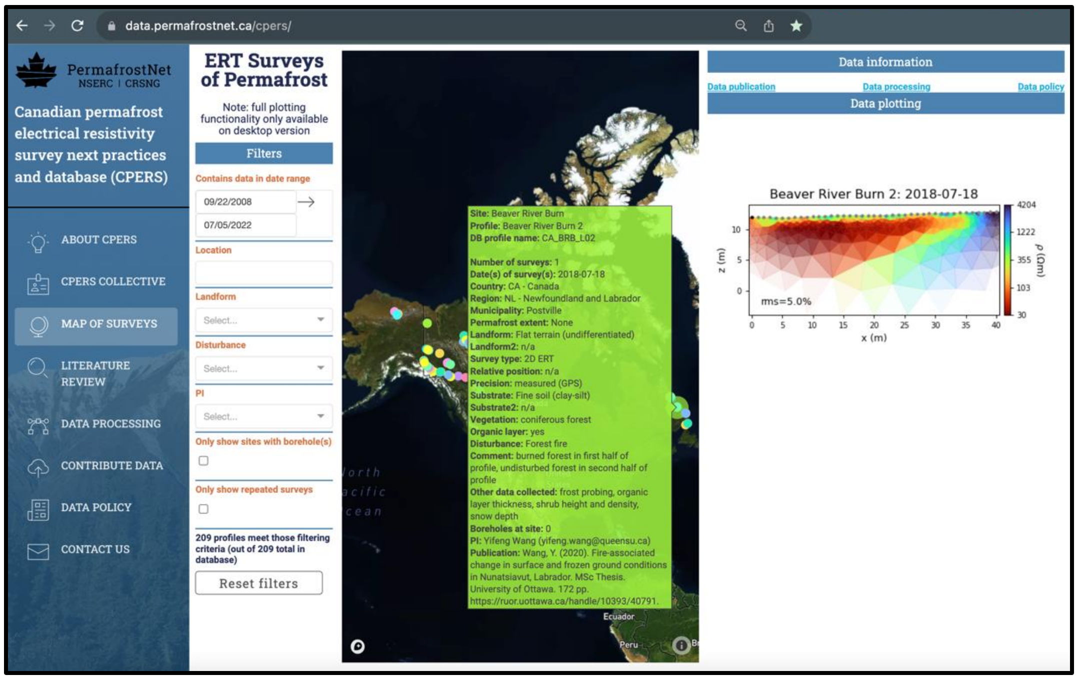
To assess ice-wedge distribution, ice-wedge troughs were mapped on:

- 67.5 $km^2$ of satellite imagery.
- 9.31 $km^2$ of drone imagery.

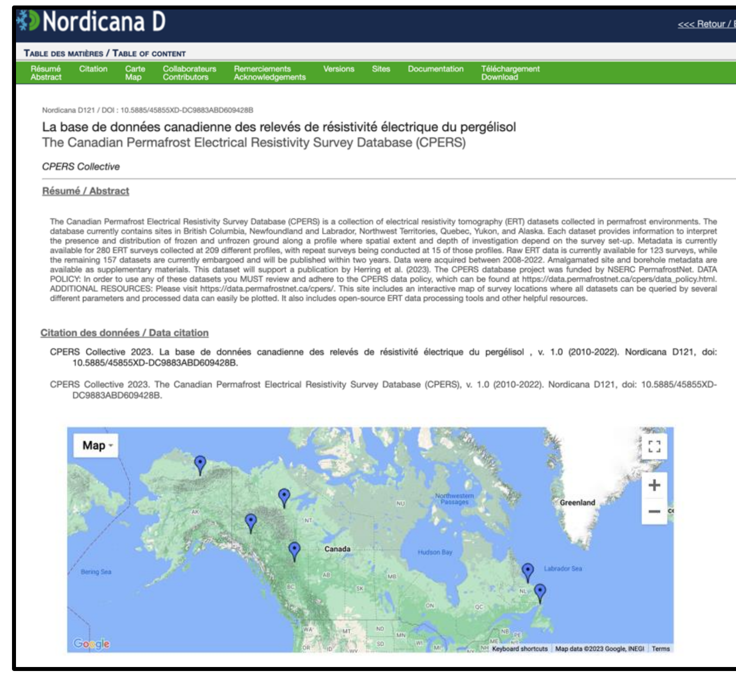
***Ice-wedge density is 0.05 $m/m^2$ in peat plateaus, and peat plateaus represent 39% of the study region.***

# Created a database of ERT surveys of permafrost

## Data can be searched and visualized using the web interface




## Data are archived long-term in Nordicana D

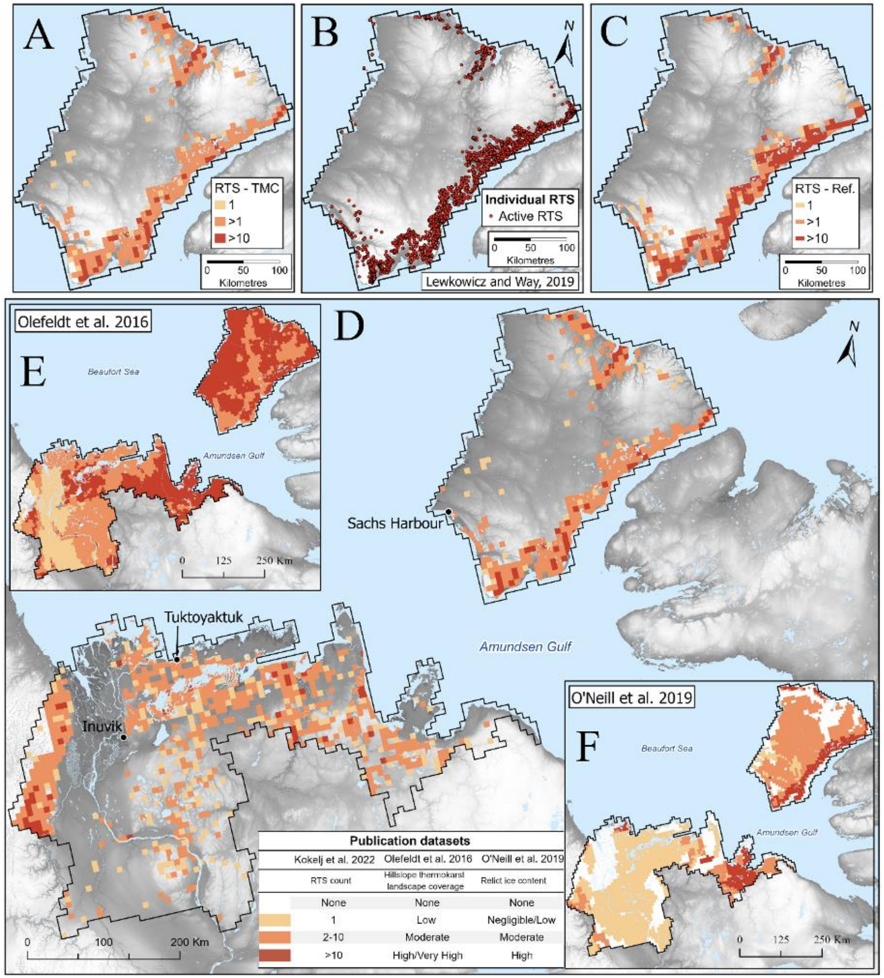



## 280 ERT surveys (2008-2023) in Canada and Alaska + best practice for ERT surveys

Herring et al. Permafrost and Periglacial Processes, 2022, 33(2) + Permafrost and Periglacial Processes, 2023, 34(4).

# Partnerships

- Many local community connections with field programs (Sahtu, ISR, HBL, Nunavut)
- NWT Geological Survey– Thermokarst Collective Mapping Synthesis papers
  - Kokelj and Rudy led papers forthcoming engaged several network investigators and graduate students-
- Geological Survey of Canada
  - Wolfe and O'Neill engaged with network investigators and graduate students– Canadian thermokarst database and MS for the last 16,000 years



# Training and Progress

- Student projects proceeding well and training aspects are being met or exceeded

- Ground Ice Potential database– ~50,000 measurements but should move to 75,000