Evaluating Permafrost Thaw and Ground Temperature Change from Borehole Data in Canada

Olivia Meier-Legault, Stephan Gruber

Carleton University

Motivation

With nearly half of Canada sitting atop permafrost[1] and climate change intensifying in the North, the permafrost thermal regime is changing. Given the severe consequences created by permafrost thaw, identifying vulnerable regions is critical.

Analysing borehole temperature measurements as a quantitative method to evaluate climate-driven permafrost change is a standard practice in global and national climate assessments (e.g. Canada's Changing Climate Report, IPCC). However, these assessments often use a limited number of sites and monitoring metrics when reporting on change at the national or regional level. In response to this, three key areas emerge for improving the reporting on permafrost change:

1. Using a denser and wider spatial coverage of ground temperature data
2. Analysing change across the entire thermal profile
3. Explicitly evaluating permafrost thaw

Objective and methods

The goal of this project is to provide a more complete understanding of climate-driven permafrost thaw and temperature change in Canada by addressing the three key areas listed above as follows:

1. Using borehole temperature data from permafrost regions across Canada spanning greater than 5 years.
2. Calculating monitoring metrics to capture change across all sensors in the borehole.

Example metrics

- Mean annual/monthly ground temperature per sensor
- Active layer thickness (ALT)
- Thaw depth duration[2]
- Date of maximum/minimum temperature per sensor
- Zero curtain length
- Depth of zero annual amplitude

3. Applying thaw metrics currently in development.
4. Summarizing metrics that best describe change per borehole and comparing metrics across all boreholes.

Summaries of permafrost thaw and temperature change produced from the relevant metrics will support climate and resiliency action in Canada's North.

Challenges

- Accessing borehole temperature data
- Determining which metrics best characterize permafrost conditions per borehole
- Aggregating metrics between boreholes with sensors of varying depths

Proposed workflow

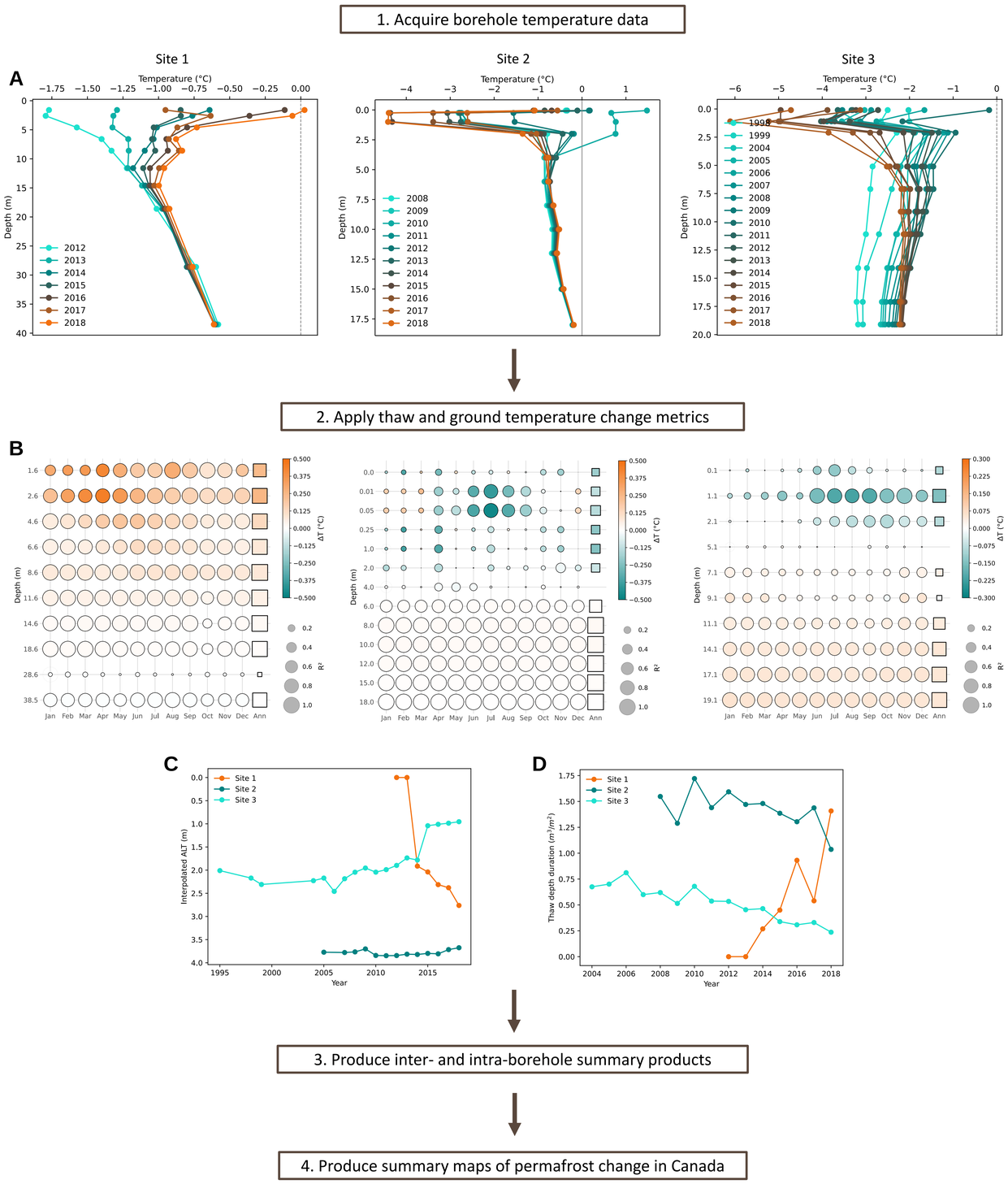

Figure 1. Project workflow demonstrated through sample plots showing borehole temperature data from three sites in Canada. Site 1: CAS_DH11-21B in the Yukon[3], Site 2: Kangiqsualujjuaq creep (KANGCRE) in Nunavik[4], Site 3: Aupaluk HT-299 in Nunavik[4]. **A)** Mean annual temperature profiles, **B)** mean monthly/annual temperature trends for the available period, **C)** change in the interpolated active layer thickness (ALT), and **D)** change in the thaw depth duration.

References/Acknowledgements

[1]Gruber, S.: Derivation and analysis of a high-resolution estimate of global permafrost zonation, The Cryosphere, 6, 221–233, https://doi.org/10.5194/tc-6-221-2012, 2012.

[2]Harp, D. R., Atchley, A. L., Painter, S. L., Coon, E. T., Wilson, C. J., Romanovsky, V. E., and Rowland, J. C.: Effect of soil property uncertainties on permafrost thaw projections: a calibration-constrained analysis, The Cryosphere, 10, 341–358, https://doi.org/10.5194/tc-10-341-2016, 2016.

[3]Lipovsky, P.S., Humphries, J.K., Stewart-Jones, E.T. and Cronmiller, D.C.: Yukon Permafrost Database: A new baseline data resource. In: Yukon Exploration and Geology 2021, K.E. MacFarlane (ed.), Yukon Geological Survey, 37–49, 2022

[4]Allard, M., Sarrazin, D., L'Hérault, E.: Borehole and near-surface ground temperatures in northeastern Canada, v. 1.5 (1988-2019). Nordicana D8, doi: 10.5885/45291SL-34F28A9491014AFD, 2020.

Thank you to Nick Brown for providing the data processing and visualization infrastructure!

Contact Information

Olivia Meier-Legault, 1st year M.Sc. D.S. Student, Department of Geography, Carleton University
Email: OliviaMeierLegault@cmail.carleton.ca

Dr. Stephan Gruber, Professor, Geography Department, Carleton University
Email: StephanGruber@cunet.carleton.ca