PermafrostNet
NSERC | CRSNG

Annual General Meeting Report

2024

NSERC PermafrostNet

Location: Mud gully slump, Stewart River, First Nation of Nacho Nyak Dun.
Photo credit: Frederic Brieger.

Introduction

NSERC PermafrostNet was pleased to invite the permafrost community to our sixth network Annual General Meeting (AGM) in Ottawa, ON, on Monday December 9th, 2024. The in-person meeting focused on synthesizing the research findings the network has made over the last 5 years. Combining the AGM with ArcticNet's 5th International Arctic Change Conference (AC2024) allowed our investigators, students, post-doctoral fellows, partners, and collaborators to share their work with a much larger community.

AC2024 is a special 20th edition of the Annual Scientific Meeting (ASM). The conference is a hub for Arctic and northern research in Canada and featured many plenary, technical, training and poster sessions by network members. The international conference took place from December 9th to 12th. With many events in the days and weeks before and after, the event maximized the interactions between people who had travelled from all over Canada and the world. AC2024 brings together researchers from the natural, health, and social sciences to meet the challenges and opportunities of a rapidly changing Arctic region. The conference pushes the boundaries of our collective understanding of the Arctic and strengthens our ability to address the issues of today and tomorrow.

Interdisciplinary cooperation and knowledge sharing across the Arctic and the North, as well as innovative and evidence-based research, are key in achieving climate change adaptation and proposing sound mitigation strategies. As a hub for Arctic research in Canada, the Arctic Change conference brings together a broad range of research in and about the Arctic and northern regions of Canada and the world. The AC2024 advances our collective understanding with an inclusive view of the North spanning from Inuit Nunangat, across the Canadian territories and provinces, circumpolar Arctic regions, and beyond.

The conference was held on the traditional, never-ceded Algonquin Anishinaabe territory, and we acknowledge our responsibilities to the Algonquin people. We also acknowledge that the national capital region of Ottawa-Gatineau profits from Algonquin stewardship over millennia of the broader landscape of the Kitchissippi watershed. We acknowledge our privilege as academics collaborating on research taking place on Inuit, First Nation and Métis lands, and our commitment to inclusion, meaningful collaborations and promoting Indigenous-led research.

The Rogers Centre is a strong advocate for environmental respect, conservation, and sustainable living and was awarded LEED Gold certified status in LEED (Leadership in Energy and Environmental Design) is a green building rating system administered by the non-profit Canada Green Building Council. It was voted the "World's Best Convention Centre" in 2021 by the International Association of Conference Centres.

The NSERC PermafrostNet AGM was co-chaired by Professor Melissa Lafreniere (Queen's University) and Jackie Ziegler (University of Victoria). The AGM featured updates on theme progress, progress synthesising research projects and focused presentations on transversal topics. This was followed by an afternoon breakout session on future permafrost research.

The AC2024 conference included a keynote plenary by Theme 4 co-lead Pascale Roy-Léveillée, five sessions chaired by network members and partners, nine oral presentations, and 14 posters by NSERC PermafrostNet and CREATE LEAP students.

In addition to the sharing of research findings, the network held an evening reception on Sunday December 8th at the Royal Canadian Geographical Society, hosted a booth in the exhibitor hall, and organized a career training session. PhD student Galina Jonat co-organized the ArcticNet Student Association's Early Career Northern Researcher (ECNR) day on the 9th of December.

AC2024 was a record-breaking success; ArcticNet hosted over 1700 members of the Canadian and international Arctic research community for a week of discussion, networking and knowledge sharing. With approximately 570 Northern participants (33%), 2024 was the most representative conference to date. Northern participation is critical to the conference and NSERC PermafrostNet supported this through the Northern Travel Fund enabling attendance of ten Indigenous guests. This ensures Northerners participate in the conversation around current results emerging from Arctic research and the future of research in Canada.

Figure 1: NSERC PermafrostNet members at the Annual General Meeting 2024, Ottawa, ON.

Report contributors: Tristan MacLean, Nick Brown, Frederic Brieger, Erika Hille, Ramona Pearson, Galina Jonat, Emma Street, Jackie Ziegler, Melissa Lafreniere, and Stephan Gruber.

Contents

NSERC PermafrostNet AGM

(Synthesis, Theme updates, breakout session on future permafrost research)

The 2024 AGM took place over one day, featuring updates on theme progress, progress synthesising research projects and focused presentations on transversal topics. An afternoon breakout session on future permafrost research followed this. The presentations are available on the network website (www.permafrostnet.ca).

AGM Program

9:00 – 10:30 am

- *Introduction to the 6th NSERC PermafrostNet AGM* – Melissa Lafrenière (Queen's University) and Jackie Ziegler (University of Victoria), AGM co-chairs.
- *Have you developed a ground ice addiction? Theme 1 can help you fix your cravings* – Daniel Fortier (Université de Montreal)
- *CPERS database* – Toni Lewkowicz (University of Ottawa)
- *Developing an Overview of Permafrost Monitoring Methods. Update from the Theme 2 working group* – Trevor Lantz (University of Victoria)
- *Progress on simulating transient permafrost change* – Stephan Gruber (Carleton University)
- *Theme 3 (Modelling) update* – Oliver Sonnentag (Université de Montreal)
- *Theme 4 Project Update: Permafrost Hazard Interviews across Canada* – Jackie Ziegler (University of Victoria)
- *Community needs* – Ramona Pearson (Dehcho First Nations)
- Q+A

10:30 – 11:00 am *Break*

11:00 – 12:00 pm

- *Early detection and high-resolution monitoring of terrain disturbance* – Brian Moorman (University of Calgary)
- *Impacts of thawing permafrost on water systems* – Melissa Lafrenière (Queen's University)
- *A brief overview of theme 4 and some thoughts on permafrost geohazard research* – Pascale Roy-Léveillée (Laval Université)
- *Impacts of Permafrost Thaw on Linear Infrastructure* – Jocelyn Hayley (University of Calgary)
- *Permafrost thaw adaptation and mitigation* – Chris Burn (Carleton University)
- Q+A

12:00-1:00 pm *Lunch*

1:00 – 2:00 pm

- Breakout session on future research and the connections and collaborations required.

Daniel Fortier – *Have you developed a ground ice addiction? Theme 1 can help you fix your cravings*.

- Theme 1 aims 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.
- Specific objectives
    - 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
    - Evaluate and apply methods to predict and measure thermal, hydrologic geochemical and geomechanical behaviour of frozen soil during thaw to support improved simulation
    - Develop a framework for the spatial and stratigraphic syntheses of geotechnical and geological data to *support ground ice map products*
- Projects are progressing well. Projects include:
    - PINGO Database structure - Michel Paquette, Samuel Gagnon, Nick Brown.
    - Ground Ice Potential Database
    - Databases– Yukon, Mackenzie Valley PIN, Nunavik
        - Presently ~50,000 ice measurements from ~ 13,000 boreholes primarily Mackenzie Valley
    - Regional studies
        - Hudson Bay Lowlands– Tabitha Rahman
        - Mackenzie valley corridor- Alexandre Chiasson
        - Mackenzie Mountains and subarctic hillslopes and landslides- Joe Young
    - 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*
        - Electrical resistivity – *Teddi Herring*
- Partnerships
    - Many local community connections with field programs (Sahtu, ISR, HBL, Nunavut)
    - NWT Geological Survey– Thermokarst Collective Mapping Synthesis papers
        - Kokelj and Rudy led forthcoming papers that 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

Toni Lewkowicz – *CPERS database*.

- The project created and populated a database of electrical resistivity tomography (ERT) data to study permafrost.
    - Data collected between 2008-2022.
    - 209 profiles, 280 surveys, 15 profiles with time-lapse data.
    - 16 landform types.
- An interactive web map has built to filter the data.
- Best practices for using ERT to study permafrost were established and published as an open-access article.

- 302 literature sources were compiled in a searchable interactive table.
- Initial large-scale interpretations of the data were made.
- There are aspirations to add more data, improve large-scale interpretations potentially using machine learning, and enhance data sharing and usage in the permafrost research community.

Trevor Lantz – *Developing an Overview of Permafrost Monitoring Methods. Update from the Theme 2 working group*.

- Theme 2 aims to use monitoring to reveal and quantify permafrost change in Canada and understand its varying rates and expressions at the land surface.
- The theme has two sub-objectives;
    - To measure or infer permafrost change using a variety of new methods.
    - To synthesise new and existing monitoring data and findings.
- Researchers presented several project updates spanning remote sensing, field measurements, simulations, incorporation of traditional knowledge and synthesis concepts.

Examples highlighted include:

    - Using Interferometric Synthetic Aperture Radar (InSAR) and field measurements to measure surface displacement (surface heave) and it's relation to snow accumulation.
    - Mapping and interview-based documentation of permafrost changes noticed by Indigenous communities.
    - Modeling to analyze factors affecting formation of polygonal terrain and ice wedge ponds.
    - Evaluating thermal metrics using simulations for monitoring capability.
    - Leveraging borehole temperature data to quantify permafrost temperature changes.
    - Using Airborne SAR and Optical Data to monitor permafrost.
    - Developing a conceptual model for permafrost terrain types.
- In summary, Theme 2 comprises a diversity of monitoring-focused research that mirrors the diversity of methods for monitoring. Synthesis activities in Theme 2 are in development.

Stephan Gruber – *Progress on simulating transient permafrost change*. Site-specific, transient, quality-tested with ground observations

- This update covered progress on six projects.
- Understanding ice wedges better - Gabriel Karam and Mehdi Pouragha
- New insight from thermal monitoring - Nick Brown, Niccolo Tubini, Olivia Meier-Legault
- Contextualizing permafrost hazards - Victor Pozsgay, D. Cronmiller, M. Geertsema, E. Stewart-Jones, P. Blake
- Driving transient simulations anywhere - Nick Brown, Bin Cao, Victor Pozsgay, Hannah Macdonell
- Testing simulations with ground observations - Hannah Macdonell, Luis Padilla-Ramirez
- Connecting ground, weather, and climate - Galina Jonat, Alex Cannon
    - Enabling factors– How has the network made this possible? Expertise: Consistent support of students by partners.
    - Momentum: Multiple students working on related topics.
    - Capacity: A network data scientist with domain expertise.
    - Infrastructure: Compute infrastructure, supported software, emerging data conventions, databases.

- Friendliness: Working together across domains, taking students who work on simulations into the field and exposing field scientists to modelling approaches, investing time into conversations.

Oliver Sonnentag – *Theme 3 (Modelling) update*.

- Theme 3 aims to improve the accuracy and delivery of transient permafrost simulation so that its results can support stakeholder needs at local and national scales.
- Theme 3's researchers are using the tools; GEOtop, FreezeThaw1DExIce and CLASSIC.
- There are three completed student projects:
  - Temporal Deep Learning Approach to Bedfast and Floating Thermokarst Lake Ice Mapping using SAR imagery: Old Crow Flats, Yukon, Canada - Maria Shaposhnikova.
  - Fate of carbon in Canadian permafrost-affected soils - Charles Gauthier.
  - Development and demonstration of a statistical ranking framework for ground temperature simulations, tailored towards permafrost environments - Hannah Macdonell.
- Ongoing projects are:
  - Influence of feather mosses on soil physical characteristics and biogeochemistry - Rose Lefebvre.
  - Implementation of plant hydraulics in CLASSIC - Muhammad Umair.
  - Simulation-based climate services for permafrost environments - Galina Jonat.
- Benefit to the research project of being part of a network:
  - Access to expertise: e.g., CLASSIC in a permafrost context
  - Opportunities for Collaboration: e.g., Melton & Sonnentag
  - Resources: e.g., AGMs, Director of Operations..
  - Increased Visibility: e.g., AGU, EGU, CGU
  - Funding Opportunities: e.g., student and postdoc stipends
  - Networking and Career Development: e.g., Ouranos
  - Broader Impact: e.g., sharing results beyond the scientific literature, e.g., Nordforsk/NFRF.

Jackie Ziegler – *Theme 4 Project Update: Permafrost Hazard Interviews across Canada*.

- The project update summarized the progress, with 50 interviews having been conducted across seven provinces and territories.
- *Key findings so far:*
  - Data accessibility and data sharing
    - Between stakeholder groups
    - Between government departments
    - Project level
  - Potential solution:
    - National database with permafrost data and research available
    - Website with a list of completed reports, ongoing projects, names of
    - people and their expertise

Ramona Pearson – *Community needs.*

Ramona provided a summary of the needs of her community.

Brian Moorman – *Early detection and high-resolution monitoring of terrain disturbance*.

Brian provided a summary of the developments in identifying and predicting terrain instability. Brian's presentation focused on permafrost coastlines and covered:

1. Data collection
2. Image analysis
3. Classification and identification of features.

Permafrost coastlines can be very complex environments, making analysis challenging, but providing a great testing ground for developing new techniques.

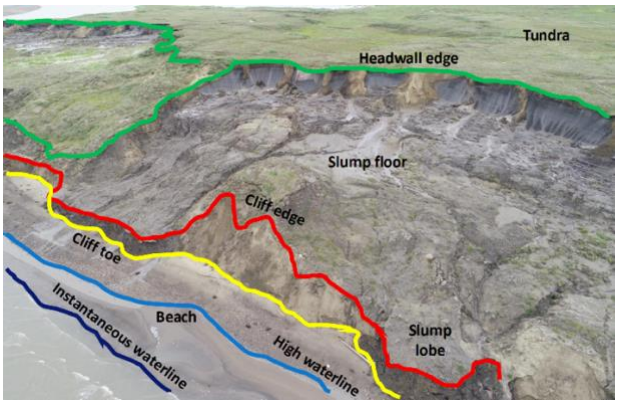

Figure 1: Permafrost coastlines, Brian Moorman.

The presentation synthesised the findings in terms of:

1. Effective ways to collect and process data from Unmanned Aerial Vehicles (UAVs).
2. High resolution object-based image analysis.
    a. Turning pixels into objects, with attributes.
    b. Increasing classification accuracy.
    c. Partially automating the process.
3. Identifying scales of analysis efficiency.
4. Implementing techniques to process on large scales to monitor entire coastlines.
5. Applying the processes and techniques to different environments e.g. Paraglacial and periglacial.
6. Developing machine learning techniques for predicting future landscape instability.

Benefits of being part of a network has been:

- Collaboration
- Cross fertilization
- Providing early career researchers with important experience

Melissa Lafrenière – *Impacts of thawing permafrost on water systems*.

Melissa presented on impacts of permafrost thaw on water systems and the importance of monitoring hydrological changes. The presentation integrated knowledge from multiple studies to assess how climate, terrain, and hydrological factors influence permafrost stability and water quality.

- Permafrost thaw events can be varied and thus influence water levels and chemistry.
- Terrain & Climate Influences:

    - Factors like surficial geology, soil organic content, relief, and hydrologic connectivity play a role in permafrost and hydrological changes.
    - Climate variables include extreme rainfall and the intensity of spring snowmelt.
- Hydrological Changes Due to Permafrost Thaw: Deepening active layers & thawing permafrost lead to increased groundwater flow and altered subsurface pathways that may impact sources of contaminants such as sumps.
- The impact of seasons on Rengleng river water was covered:
    - Winter vs. Spring Melt vs. Summer Thaw
- The impact of thermokarst and slope movements was covered.
    - Changes in surface flow paths and volumes lead to erosion, weathering, and dissolution.
    - This leads to the mobilization of nutrients, salts, metals, and potential contaminants from previously frozen material.
- Results of analysis for levels of nitrogen, total phosphorus, and trace metals were shared.
- Finally, the outputs needed by communities were discussed
    - A resource/guide for communities and decision-makers, on monitoring approaches for early detection of permafrost changes and potential hazards
    - What indicators might best serve as tools for communities to detect permafrost change and to mitigate impacts on communities and infrastructure?

Pascale Roy-Léveillée – *A brief overview of theme 4 and some thoughts on permafrost geohazard research*.

- Theme 4 studies various hazards including mass movements, flooding, changes in water quality, contaminant release, vegetation and terrain changes.
- Highlighted projects address:
    - Coastal and inland slope stability through modeling, classification and feature extraction.
    - Water quality changes and mercury release with thaw.
    - Evolution of thermokarst landforms and impacts on mercury cycling.
- Science can be made more relatable through the use of art to communicate research results.

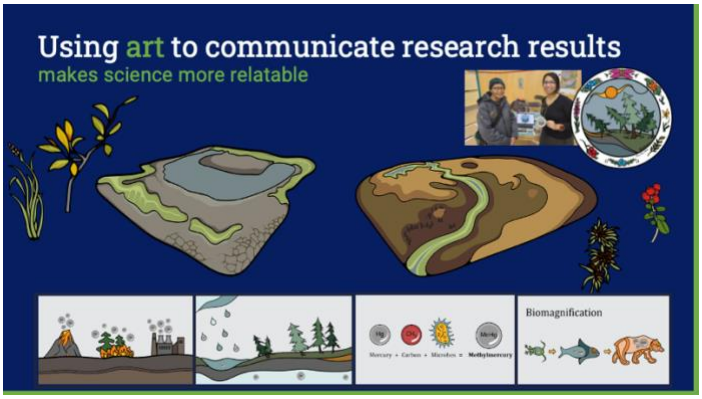

Figure 3: Permafrost research art, Nicole Corbiere.

Jocelyn Hayley – *Impacts of Permafrost Thaw on Linear Infrastructure*.

Jocelyn synthesized the risks and challenges that permafrost thaw poses to linear infrastructure (roads and railways). It covered 11 research projects focused on predicting thaw settlement, monitoring infrastructure changes, and developing mitigation strategies.

1. Predicting & Assessing Permafrost Thaw impacts

- Framework for Evaluating Thaw Settlement.
    - Developed new empirical methods for large-scale thaw settlement assessment.
    - Integrated tools to support infrastructure design and reduce maintenance costs.
- Serviceability Analysis of Infrastructure on Permafrost.
    - Used probabilistic models to predict thaw settlement under climate change scenarios.
    - Helps design more resilient infrastructure.
- Geocryologically-Driven Landscape Changes (Hudson Bay Railway).
    - Collected permafrost cores and ground temperature data.
    - Developed models to predict future geomorphological evolution.
- Flood Susceptibility Mapping (Hudson Bay Railway).
    - Created models to predict flood risks under extreme weather.
    - Helps develop adaptation strategies to prevent infrastructure washouts.

2. Monitoring Permafrost & Infrastructure Stability

- Airborne InSAR & Optical Photogrammetry for Monitoring:.
    - Used satellite data to monitor permafrost changes along highways and railways.
    - Helps detect ground deformation where physical access is limited.
- Tracking Thaw Settlement Vulnerability (Hudson Bay Railway):
    - Developed thermo-mechanical models to assess permafrost degradation risks.
    - Mapped vulnerability under different climate conditions.
- Tracking Highway Maintenance Costs in Yukon (1994–2022):
    - Assessed how climate change has increased infrastructure repair costs.
    - Supports financial planning for future road maintenance.

3. Mitigation and adaptation Strategies for Infrastructure Protection

- Snowbank Compaction to Lower Ground Temperatures.
    - Field tests along Yukon highways showed that compacting snow reduced thawing.
    - Offers a simple technique to protect road embankments.
- Geocell-Supported Railway Embankments:
    - Tested geocell placement in embankments to enhance stability.
    - Reduced settlement and improved long-term performance.
- Frost Jacking Effects on Railway Bridges:
    - Investigated how frost jacking affects bridges in cold climates.
    - Aims to improve the resilience of railway infrastructure.

Integrated Approach for Long-Term Solutions

1. Understanding Permafrost Behavior
2. Risk & Vulnerability Assessment
3. Technological Solutions
4. Adaptation Strategies
5. Economic & Practical Implications

Proactive, data-driven strategies are essential to maintaining and adapting linear infrastructure in permafrost regions as the climate warms. By leveraging predictive models, advanced monitoring technologies, and innovative adaptation techniques, we can mitigate risks, reduce

costs, and ensure the long-term resilience and functionality of critical infrastructure like highways and railways.

Chris Burn – *Permafrost thaw adaptation and mitigation*.

- Theme 5 aims to support northerners in adaptation to permafrost in transition.
- The theme comprises projects initiated to address specific permafrost thaw challenges.
- Highlighted projects span topics like landscape change impacts on mercury release, stability of waste sumps, highway embankment stabilization methods, geotechnical modeling of railway infrastructure, cost analysis of infrastructure maintenance, wind impacts, and railway bridge frost jacking monitoring.
- The network enables education and cross-pollination between students working on adaptation-related studies.
- Over 20 students are currently collaborating on research with Theme 5.
- The ultimate objective is to develop skilled people who can support adaptation needs in the face of ongoing permafrost transitions.
- In summary, Theme 5 promotes student-conducted research targeting practical problems associated with permafrost thaw across infrastructure, contaminant release, landscape evolution, and other themes. Through this experiential learning, the next generation of adaption specialists is being cultivated.

Breakout session on future permafrost research

Figure 4: Co-chair Jackie Ziegler opens the breakout discussion.

The afternoon of the AGM was dedicated to a structured discussion session for attendees to discuss four key questions concerning network outputs and future permafrost research in Canada. These questions were:

- What end products are needed from permafrost research?
- What do you need to help produce these end products?
- Who do you need to collaborate with?
- What new connections do you need to make?

Figure 5: Breakout discussion topics.

At the end of the table-based discussions, note-takers from each group reported back to the room. The note-takers were Emma Street, Kumari Karunaratne, and Erika Hille, with Jackie Ziegler and NSERC PermafrostNet Scientific Director Stephan Gruber summarizing the discussions, feedback and overall proceedings of the AGM. Following this session, attendees continued their discussions informally for the rest of the afternoon while members of the Board of Directors held their bi-annual meeting across the hallway.

Figure 6: Breakout discussions.

Emma Street

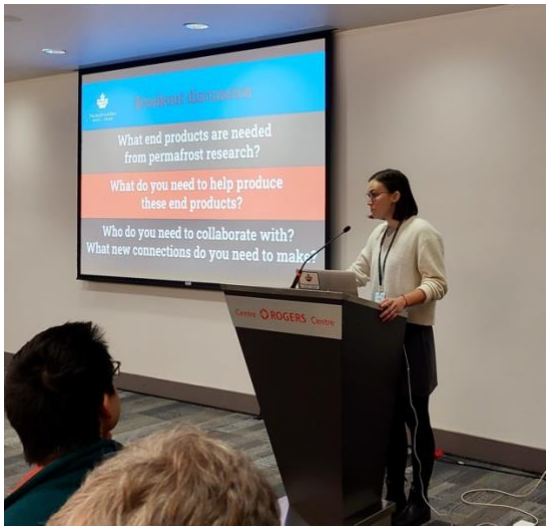

Figure 7: Emma Street group report.

This group discussed the strengths of Indigenous science, local science, and western science working together. The group discussed how this collaboration can help identify priority needs and provide context to permafrost landscapes. The importance of accessible communications was highlighted.

Kumari Karunaratne

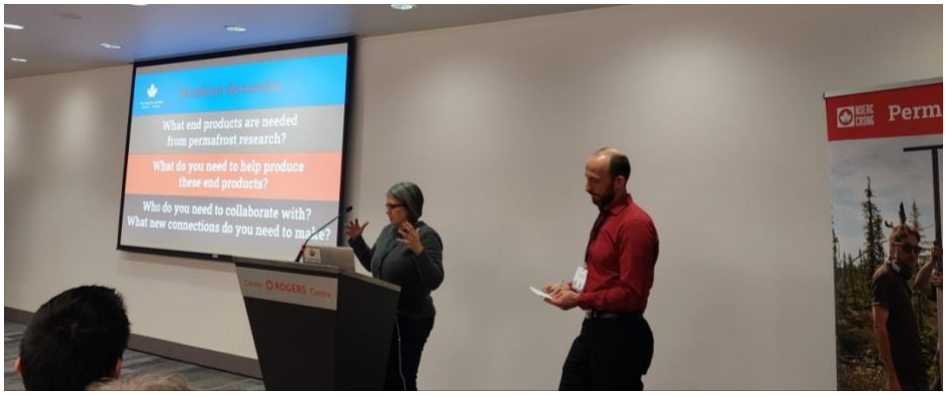

Figure 8: Kumari Karunaratne group report.

Erika Hille

Figure 9: Erika Hille group report.

Jackie Ziegler and Stephan Gruber

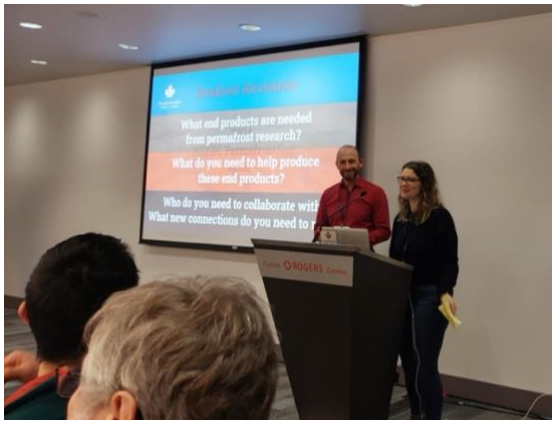

Figure 10: Jackie Ziegler and Stephan Gruber summary.

Arctic Change 2024

Between Tuesday 10, and Thursday, 12 December, AC2024 convened the northern research community for more than 300 oral presentations, 300 poster presentations, and over 80 topical sessions, nine of which were live-streamed and five of which were live interpreted in Inuktitut. There were many presentations by network members, collaborators, and the wider permafrost community at the Arctic Change conference.

AC2024 had a special focus on international collaboration to address the challenges and opportunities brought forth by climate and socio-economic change in not only the Canadian Arctic, but the global Arctic, ahead of the upcoming International Polar Year in 2032. Nine countries were represented at the conference, including six Arctic states. This international focus allowed attendees to engage with international stakeholders and researchers.

The ArcticNet Student Association (ASA) kicked off AC2024 by hosting students and early career researchers during the Early Career Northern Researchers (ECNR) Annual Meeting on the first day of the conference. The 2024 edition of the ECNR Meeting featured over 12 workshops and training sessions for ECNRs, a community pitch contest, networking events, and a special tour of the Arctic Gallery at the Canadian Museum of Nature. NSERC PermafrostNet student Galina Jonat played an important role by serving on the organizing committee for this event.

Keynote plenary

Cryosphere Connections: Dynamics of Change in Our Frozen World, featured:

- Luke Copland, University of Ottawa, presenting *Glacier changes across the Canadian Arctic and beyond in a warming climate* and;
- Pascale Roy-Léveillée, Université Laval, presenting *Local expressions of global change: community-level impacts of permafrost thaw in the Canadian North.*

Permafrost degradation raises international concern for its global impacts on the carbon and mercury cycles, yet it is at the local and regional scales that effects of thaw are observed and experienced first and most directly. There are more than 150 communities located in the continuous and discontinuous permafrost zones of Canada, of which many face permafrost hazards such as ground subsidence, slope failure, contaminant mobilisation, or icing expansion that can threaten infrastructure stability, reduce water quality, or impede access to traditional foods. The surface expression of permafrost thaw varies widely in nature and magnitude across space, reflecting important differences in permafrost conditions, ecosystem resilience, and physiographic context. This presentation reviews impacts of permafrost thaw using contrasting examples from Canadian communities and discusses how collaborative field-based efforts centered on community priorities can produce datasets and models that support northern resilience to permafrost thaw in a warming climate.

The plenary was livestreamed and live interpreted to Inuktitut. Recordings of all the plenaries are available here.

Figure 11: AC2024 Plenary.

Technical sessions

Impacts of climate change on water quality and quantity, and implications for water security
Co-Chairs: Erika Hille, Mike Palmer, Aurora Research Institute, Melissa Lafrenière, Queens University

Arctic Coastal Dynamics in a Changing Climate
Co-Chairs: Hughes Lantuit, Alfred Wegener Institute, Dustin Whalen, Geological Survey of Canada, Pia Petzold, Alfred Wegener Institute, Justus Gimsa, Alfred Wegener Institute

New insights into ground ice in permafrost: Fundamental and applied research at local to regional scales
Co-Chairs: Brendan O'Neill, Natural Resources Canada, Alexandre Chiasson, University of Alberta, Yifeng Wang, Queen's University, Tabatha Rahman, Université Laval, Kethra Campbell-Heaton, University of Ottawa

Permafrost research in support of northern resilience
Co-Chairs: Pascale Roy-Léveillé, Fabrice Calmels, and Adam Kirkwood

Geoscience in support of climate change adaptation and northern development
Co-Chairs: Nicole Couture, Natural Resources Canada, Hugh Brendan O'Neill, Natural Resources Canada

Figure 12: New insights into ground ice in permafrost: Fundamental and applied research at local to regional scales. Chairs: Kethra Campbell-Heaton, Yifeng Wang, Alexandre Chiasson, Brendan O'Neill, and Tabatha Rahman.

Topical sessions

Brian Moorman

Title: *Inland impact of arctic coastal erosion: ice wedges and hydrology.*

The direct impacts of arctic coastal erosion in ice-rich permafrost areas are obvious and dramatic. Rapid coastal alteration, dumping of massive amounts of sediment into the ocean, and retrogressive thaw slumps are all obvious signs of coastal retreat in ice-rich permafrost areas. However, less obvious impacts are experienced in the terrestrial environment many hundreds of metres inland from the coast. Small changes to the coastline can result in large changes to the local hydrological baselevel and the impact that has on the hydrological system and geomorphic features such as ice wedge polygons.

For this study, we used very high-resolution drone-derived digital elevation models and orthophotos to examine the impacts of coastal retreat on the hydrological and geomorphological systems near Revneset, Svalbard. This area features a series of beach ridges with mature ice wedge polygons between them extending right up to the coastline. The overall slope of the terrain causes all the surficial runoff to flow through the ice wedge troughs to the sea. In areas where the local baselevel, controlled by coastal erosion, has been lowered, faster flowing water is resulting in the ice wedges eroding out and the nearby landscape drying out. This appears to have impacted both the flora and fauna of the region.

The results of this study demonstrate how local coastal dynamics can have a broader and more significant impact on inland regions surrounding the coast.

Daniel Fortier

Title: *Early Pleistocene glacier ice preserved in permafrost in the eastern Canadian Arctic: the oldest remnant of glacier ice in the northern hemisphere?*

Buried glacier ice is widespread near the margin of formerly glaciated landscapes. It can be preserved in permafrost environments for thousands to millions of years, and thus represents a unique source of paleogeographical, paleoenvironmental, and paleoclimatological information. On Bylot Island, remnants of glacier ice were exposed in headwalls of thaw slumps located on the edge of an upland plateau. This deposit sits on top of a 2.8-2.4 Ma fossil forest deposit. We used sedimentological, cryostratigraphic, and geochemical techniques together with radiocarbon, and paleomagnetic dating to determine the origin and age of the buried ice and surrounding sediments. The ice presented striking similarities with cryofacies, deformation features, and $\delta^{18}O$ values of englacial ice and debris-rich basal-ice layers observed at the base of contemporary glaciers. The cryostratigraphic and isotopic properties of the pure ice with large, interlocked ice crystals and few sediment inclusions are suggestive of an englacial origin (firnification), whereas those of the alternating layers of debris-rich and debris-poor ice are more consistent with a basal glacier ice origin. Paleomagnetic records of the glacio-fluvial sediments overlying the buried glacier ice recorded a normal-reversed-normal magnetic polarity, suggesting that the ice was in place since at least 0.773 Ma. As such, it represents the oldest glacier ice preserved in ice-free Arctic landscapes, and the earliest evidence of a Pleistocene glaciation in the eastern Canadian Arctic Archipelago. The presence of this buried ice near the surface also demonstrates the very strong resilience of cold Arctic permafrost to past climate warming.

Emma Street, Ernie Francis and Irma Cardinal

Title: *Exploring Traditional Knowledge of Permafrost Change in the Gwich'in Settlement Area and Inuvialuit Settlement Region.*

Temperature increases four times faster than the global average are transforming Arctic landscapes at unprecedented rates. These changes drastically impact permafrost, ground that remains at or below 0°C for two or more years, and threaten the infrastructure, ecosystems, and socio-cultural elements of Arctic communities reliant upon it. This project explores the extent and significance of permafrost degradation in the Gwich'in Settlement Area and the Inuvialuit Settlement Region in the western Canadian Arctic. By way of Two Eyed Seeing and community-driven participatory research methodologies, this project in collaboration with the Inuvialuit Game Council, Inuvialuit Joint Secretariat, Gwich'in Renewable Resources Board, Gwich'in Department of Culture and Heritage, and community members, documents Gwich'in and Inuvialuit Traditional Knowledge pertaining to permafrost and observed changes in community. This presentation presents the methodologies behind this research and the results of 110 interviews completed among the eight communities of Paulatuk, Sachs Harbour, Tuktoyaktuk, Ulukhaktok, Fort McPherson, Tsiigehtchic, Aklavik, and Inuvik. Findings from this work highlight community relationship and engagement with permafrost and community concerns including those related to traditional travel route access, subsistence activities, and infrastructure. It is anticipated that these findings will contribute to permafrost knowledge and help amplify mitigation and adaptation needs and potential solutions for Gwich'in and Inuvialuit communities – and those beyond – facing permafrost thaw.

Frederic Brieger

Title: *Permafrost terrain disturbance mapping and susceptibility modeling in the Nacho Nyäk Tagé (Stewart River) watershed, Yukon.*

The Nacho Nyäk Tagé (Stewart River) watershed in the traditional territory of the First Nation of Na-Cho Nyäk Dun (central Yukon) is underlain by extensive discontinuous permafrost and locally highly sensitive to thaw. In addition to impacts from climate change to its ecology, geomorphology, and hydrology, this culturally important area is pressured by mining activities and their environmentally harmful practices. Timely community-led land-use planning is necessary to develop effective management, conservation, and adaptation strategies. This project aims to contribute assessments on the distribution and susceptibility towards permafrost terrain disturbances (PTDs) in the watershed to the undergoing land-use planning process.

A total of 277 PTDs including 80 retrogressive thaw slumps (RTSs) were mapped in satellite imagery to understand the current spatial distribution of thaw-induced geohazards in the watershed. PTDs are indicators of sensitive permafrost terrain that is likely to respond strongly to climate change. RTSs in particular are indicative of thawing ice-rich permafrost and have increased in frequency and activity. Along the banks of Nacho Nyäk Tagé, they are typically associated with ice-rich glaciolacustrine sediments or tills, as validated by field observations.

Terrain susceptibility towards PTDs was modelled using random forest machine learning at a 16 m spatial resolution and revealed distinct spatial patterns related to the physiography and climatic history of the region. Tenfold cross-validation resulted in an average AUROC of 0.89, indicating high accuracy of model predictions. RTSs are predominantly found on gentle, northwest to northeast-facing slopes and riverbanks consisting of fine-grained glaciogenic sediments from the late McConnell glaciation.

Gabriel Karam

Title: *A Simulated Study of Ice-Wedge Behaviour at Illisarvik, NWT, and Salluit, QC, Using XFEM.*

Ice wedges comprise a large portion of the massive ice found in the continuous permafrost zone, impacting the hydrology, subsidence, and ecosystem of the surrounding terrain. Many field studies have investigated the different aspects of ice wedges — namely cracking predictors, geomorphological characteristics, and wedge-ice distribution. However, field data and longitudinal studies on cracking events are scarce due to the low frequency of ice-wedge cracking. Here, numerical methods can complement field studies and provide new insight into the formation process and other important variables such as estimated wedge-ice volume.

We propose a case study using an existing 2-D numerical model to study ice-wedge cracking at two contrasting locations. First, Illisarvik, NWT, is the only studied site of lake drainage and the subsequent creation of incipient wedges. These wedges have a unique shape compared to their more-mature counterparts. Second, Salluit in the north of Quebec is a site of cold temperatures, frequent cracking, and mature wedges with defined morphology.

Our model uses the extended finite-element method (XFEM) to explicitly simulate cracks in soil. Soil properties and climate data are taken as inputs, which can be derived from either observed meteorological data or reanalysis products. This approach is versatile and can be employed at any location with appropriate data. Results from both sites will be compared to existing field studies to evaluate model performance and draw conclusions regarding the formation and growth of ice wedges.

Hosein Fereydooni

Title: *Spectral Induced Polarization can reduce the ambiguity of detecting ground ice in warm permafrost.*

Electrical Resistivity Tomography (ERT) is a widely used technique for identifying ground ice in permafrost regions. While it usually distinguishes ground ice due to its high resistivity compared to unfrozen materials, some subsurface conditions and configurations can cause ambiguity. In contrast, Spectral Induced Polarization (SIP), which leverages the polarization properties of ground ice, potentially offers less ambiguous identification.

In this study, we compare published ERT and new SIP results near a retrogressive thaw slump in Yukon, Canada. The SIP measurements were conducted in the winter of 2023, using frequencies ranging from 1.46 Hz to 40 kHz. The ERT measurements were carried out in 2019, with both surveys employing a dipole-dipole array along the same survey line. While the ERT results showed no clear evidence of ground ice, the SIP real and imaginary results at 40 kHz and the Resistivity Frequency Effect (RFE) indicate the presence of ice within the same locations and depths.

The findings suggest that ground ice may exist in regions with resistivity as low as 100 Ωm (despite ground ice typically having higher resistivity), likely due to fine-grained materials with higher liquid water content. Since ERT relies solely on resistivity, it can lead to misinterpreting warm and ice-rich clay, sand, or silt (low-resistivity materials) as being unfrozen, SIP may offer additional insight. As a new technique, however, procedures and tools for SIP survey design and execution, as well as methods for processing and interpretation, are demanding and less well developed than for ERT.

Nick Brown

Title: *Rapid lowering of the top of permafrost : causes, forecasting, and implications for monitoring*.

Active layer thickness is an important variable in permafrost regions. It affects biogeochemical processes, water transport, and ground stability. It is also one of three products used to track permafrost as part of the essential climate variable framework.

Global observations of active layer thickness show increases at typical rates on the order of centimetres per year. However, in warm permafrost, much higher rates are observed, up to an order of magnitude greater. Several explanations have been provided to explain this discrepancy such as the partitioning of latent vs. sensible heat, an increase in the thermal gradient, and the formation of taliks.

We investigate two additional explanations: First, by approaching isothermal conditions in thawing permafrost, heat transport deeper into the ground is diminished. Consequently, a greater proportion of the downward heat flux at the top of permafrost is available for phase change. Second, that in very dry permafrost, the shape of the thermal profile inherently accelerates deepening in warm permafrost. To test this, we simulate 120 years of warming in different ground conditions and climates using the numerical model FreeThaw1D to recreate this phenomenon. We demonstrate how the acceleration of active layer deepening is connected to the presence and loss of ground ice in permafrost.

A stronger understanding of the processes that lead to rapid active layer deepening will be beneficial for forecasting when it will occur and interpreting changes in ground thermal regime.

Samuel Gagnon

Title: *Formation of thermo-erosional gullies in the ice-rich transition zone of marine sediments.*

Thermo-erosional gullies are one of the most widespread forms of permafrost degradation in the Arctic. Their formation, development, and stabilization have been reported in ice-wedge polygonal terrain where ice-wedge degradation by thermo-mechanical processes catalyses the development of gully networks. However, thermo-erosional gullies forming in the absence of polygonal networks can also develop, though they have yet to be reported. This study aimed to characterize such gullies and provide an explanation for their mechanism of formation in a marine terrace along the coast near Ikaluktutiak (NU,Canada). The stratigraphy of near-surface permafrost is characterized by a layer of ice-poor sandy sediments (30-50 cm) overlying marine clay of varying ice contents. The top (~1m) of the marine clay forms an ice-rich transition zone (volumetric ice content >75%) that overlies marine sediments with much lower ice contents (<20%). Nineteen thermo-erosional gullies forming perpendicular to the coast have been characterized using field measurements, photographs from automated cameras, and drone surveys. The depths and widths of the gullies generally ranged from 2 to 3m, while the lengths of the main channels varied between 4m and 50m. Of the nineteen gullies identified within a 200-m section, sixteen gullies were active and retreating inland, and showed signs of ground subsidence due to groundwater flow (e.g., overhangs, tunnels). We suggest that gullying is initiated in the spring when the active layer reaches the interface between the sand and marine clay layers where groundwater flow causes melting of the ice in the transition layer and subsidence of the surface layers.

Tabatha Rahman

Title: *Permafrost landscape evolution in the Barrens of northern Manitoba.*

The Barrens are a 14,200 km^2 area of polygonal tundra in the continuous permafrost zone of northern Manitoba. Rapid climatic warming in the Barrens is affecting the Hudson Bay Railway, a crucial transportation infrastructure built on permafrost. However, terrain changes expected with continued permafrost warming and thaw are not well defined for the Barrens, where little is known about ground ice conditions, permafrost thermal regimes, or thermokarst dynamics. This research examined ground-ice conditions and controls on thermokarst evolution to better predict future landscape changes in the Barrens. Objectives were to 1) characterize permafrost and ground-ice conditions to assess vulnerability to thaw and thermokarst; 2) inventory recent geomorphological changes to infer future landscape evolution; and 3) develop a conceptual model of the expected geomorphological evolution along the railway. Geomorphological changes across the Barrens were assessed from historical aerial photographs and satellite imagery from 1927 to 2024. In representative areas, 45 permafrost cores were extracted extending up to 5.5 m beneath the surface. Organic layer thickness, sediment texture, and thaw consolidation potential were measured. Snow conditions and ground thermal regimes were assessed. Preliminary results indicated four categories of change: burning, wetting, greening, and drainage. Ice-rich permafrost is insulated from the atmosphere by a peat layer 110 to 240-cm thick, leading to a thermal offset of up to -3.1 °C. Thermokarst was most widespread where peat was thinnest, and near-surface ice content was relatively high. Pool ice above wedge ice indicated post-disturbance permafrost recovery at sites that burned before 1947 and in 2012.

Training session

Exploring Professional Skills for Permafrost Careers in Canada's North by NSERC PermafrostNet and CREATE LEAP.

NSERC PermafrostNet and NSERC CREATE LEAP hosted a professional skills training session for those interested in permafrost and science-based careers in Canada's North. As northern communities witness and experience the accelerating impacts of permafrost thaw on infrastructure and ecosystems, the urgency to grow the workforce of professionals trained to address these challenges grows in tandem. These professionals are called upon to be adaptable to emergent and ongoing issues, able to apply multi-disciplinary solutions, and comfortable engaging and collaborating in a northern context.

This panel session featured experienced researchers who provided guidance and advice on how to secure and sustain rewarding careers that aim to improve climate resiliency while fostering collaboration.

Panelists:

Steve Kokelj – Northwest Territories Geological Survey
Camellia Gray – Inuvialuit Settlement Region
Erika Hille – Aurora Research Institute, Director of the Western Arctic Research Centre
Nick Brown – NSERC PermafrostNet Data scientist

Chair: Tristan MacLean, NSERC PermafrostNet Director of Operations

Figure 13: Panelists - Steve Kokelj, Camellia Gray, Nick Brown and Erika Hille.

Format

The training session was held as a panel discussion facilitated by a moderator, with prepared questions and an open Q+A with the audience. Each panelist provided a brief introduction, followed by six rounds of discussion and closing remarks. The discussion covered; defining moment in the panelists careers, specific skills and competencies are most in demand, professional occupations that are important in permafrost research, educational experiences and qualifications that are beneficial and advice on effective strategies for building and maintaining professional networks and undertaking collaborations, and finally what the future holds for careers in permafrost related fields.

Poster presentations

This year NSERC PermafrostNet members and CREATE LEAP students presented their posters to 1700 members of the Canadian and international Arctic research community. There were over 300 posters in total presented at the 2024 Arctic Change conference.

Adam Kirkwood
Spatial variation of Hg storage in the Hudson Bay Lowlands.

Alexandre Chiasson
A Standardized Mapping Nomenclature for Permafrost and Thermokarst Features.

Danielle Chiasson
Post-drainage evolution of Wolverine Lake, Old Crow Flats, Yukon.

Frederic Brieger
Settling lands: Revealing spatiotemporal patterns of ground movement under community infrastructure in Mayo, Yukon.

Galina Jonat
An impact-centric framework for preparing and selecting climate model data for permafrost studies.

Léa Cornette
Navigating the Arctic Firescape: Biogeochemical Cycles of Soil Nutrients and Indigenous Perspectives in the Inuvialuit Settlement Region.

Muhammad Umair
Characterizing carbon and water fluxes in the arctic boreal forest using plant hydraulics parameterization in the presence and absence of permafrost: a modelling approach.

Nick Brown
Interpreting and quantifying temperature-derived thaw metrics as indicators of permafrost change.

Olivia Meier-Legault
Improving permafrost thaw detection in Canada using multiple boreholes and temperature-derived metrics.

Pia Blake
Effects of Snow and Surface Material on Surface Offset of Canadian Steep Slopes.

Victor Pozsgay
Summarizing Transient Permafrost Ensemble Simulations for Investigating Climatic Influences on Slope Failures.

CREATE LEAP Posters

Bruno Lecavalier
Environmental Sensitivity and Variability of CO2 Fluxes on the Forest-Tundra Ecotone: Insights from 12-Years of Eddy Covariance in the Inuvialuit Settlement Region.

Rachel Lackey
Quantifying near surface lateral groundwater flow in a discontinuous permafrost setting.

Rémi Lord-Quintric
M*apping post-fire vegetation composition and structure changes in the Taiga Plains using unoccupied aerial vehicule.*