NSERC PermafrostNet

Canada’s strategic partnership for permafrost knowledge

2019-2025

www.permafrostnet.ca

Front cover:
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Ekati region, Lac de Gras, NT
September 2022

NSERC CRSNG

MacLean, T., Stockton, E.J., and Stephan, G. (eds.) 2024. *NSERC PermafrostNet: Canada’s strategic partnership for permafrost knowledge (2019-2025)*. In: Frozen Ground 47 (2023). E.J., Stockton, and C.R., Burn (eds.) International Permafrost Association (IPA). DOI: 10.52381/IPA.FG472023.1.

NSERC PermafrostNet

By Janet King (Chair of the Board) and Stephan Gruber (Scientific Director)

Canada is a permafrost country and already today, permafrost thaw affects all Canadians directly or indirectly. For example, through effects on community infrastructure, ecosystems that support traditional livelihoods and cultural practices, national and regional infrastructure, and through thawing carbon that further amplifies global climate change. Currently, our permafrost knowledge is not sufficient to address and prepare for thaw-related issues.

Canadians concerned about permafrost have joined forces to provide leadership on understanding, predicting, and adapting to permafrost thaw. This is important because connecting and advancing permafrost knowledge for action requires new types of research, new expertise, new modes of collaboration, new services, and greater capacity. As part of our strategic mandate, we also work to broaden and sustain the conversation about a forward-looking vision and strategy about permafrost knowledge in Canada.

The collaborative focus of projects in NSERC PermafrostNet has nurtured stronger, more sustainable, and strategic partnerships across Canada, bringing together northern communities, government, industry, and academia. NSERC PermafrostNet has also enhanced the training of graduate students, northern research assistants and post-doctoral fellows, who will bring new knowledge and practice into their professional lives, along with the experience of considering multiple perspectives.

As funding for NSERC PermafrostNet concludes in 2025, it will leave a legacy of a knowledge community better connected and better equipped to support adaptation to permafrost change across the North.

This compendium of 11 completed projects serves as a snapshot of the 42 projects that the network is undertaking.

On behalf of all network participants, we extend our sincere gratitude to the organizations and individuals that support NSERC PermafrostNet. We hope the collaborations and connections made through this network will continue to grow.

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Theme 1: Characterization of permafrost, led by Dr. Daniel Fortier and Dr. Duane Froese, is advancing the quantitative understanding of ground-ice in the field and laboratory.

Theme 2: Monitoring permafrost change, led by Dr. Trevor Lantz and Dr. Antoni Lewkowicz, develops and integrates diverse methods to detect and quantify permafrost change.

Theme 3: Prediction of permafrost characteristics and change, led by Dr. Claude Duguay and Dr. Joe Melton, works to improve the accuracy and delivery of permafrost simulation to support partner needs across scales.

Theme 4: Hazards and impacts of permafrost thaw, led by Dr. Jocelyn Hayley and Dr. Pascale Roy-Léveillée, works to understand the relevance and controls of impacts and hazards driven by permafrost thaw and improve their prediction.

Theme 5: Adaptation to permafrost thaw, led by Dr. Ryley Beddoe and Dr. Christopher Burn, supports northerners in adapting to permafrost in transition, e.g., sump failure, embankment stabilization, and infrastructure maintenance costs.

The network

NSERC PermafrostNet is a strategic partnership network connecting over 40 partner organizations, 50 students and postdocs, and 12 universities with the common goal of boosting Canada's ability to adapt to permafrost thaw. Partners include Federal, Indigenous, Provincial, and Territorial government as well industry, not-for-profit, and other research networks in Canada and internationally.

The network operates from 2019 to 2025, with core funding from the Natural Sciences and Engineering Research Council of Canada (NSERC) and major contributions from partner organizations. NSERC PermafrostNet is hosted by Carleton University and follows a shared governance model with partner organizations and northerners making decisions at the highest level.

The network is structured in five themes. The network investigators include the theme leads as well as Dr. Stephan Gruber, Dr. Shawn Kenny, Dr. Melissa Lafrenière, Dr. Brian Moorman, Dr. Bernhard Rabus, and Dr. Oliver Sonnentag.

Research and training

The network's research has the goal of boosting Canada's ability to monitor, predict, and adapt to large-scale permafrost thaw and its consequences. It takes a collaborative approach, integrating expertise across disciplines, sectors, and regions. Training in NSERC PermafrostNet connects students and post-doctoral fellows through theme and network meetings as well as joint supervision and field campaigns with northern research assistants and collaborators in partner organizations. The network investigators, students, and post-doctoral fellows are also building capacity, sharing knowledge, and learning about permafrost through their collaborative activities with Northern communities. Data is an important element in NSERC PermafrostNet research. The network has developed protoypes of reliable and useful data and knowledge products for stakeholders, some of which integrate field data with simulation.

Building and sustaining a permafrost knowledge partnership

Nearly 60 people with an interest in permafrost and from diverse backgrounds – government, researchers, industry, northerners – gathered for a workshop "Toward a Canadian Permafrost Network" at Carleton University in 2017. Results identified focus areas for research, community needs such as a secretariat and increased capacity, and important principles for collaboration: shared governance and inclusion of northerners, open data, and communication that makes knowledge available for action. The workshop led to the formation of NSERC PermafrostNet and the Canadian Permafrost Association (CPA).

Subsequent meetings have shaped the network application and informed its evolution. Since 2019, NSERC PermafrostNet has been fostering new relationships and collaboration across Canada's diverse permafrost community and internationally via coordinated research, open data, and meetings. In the second half of the funded network duration, the importance of strategically building permafrost knowledge in Canada has been acknowledged as vital. As an Arctic nation, Canada has a responsibility and opportunity to be a global leader in understanding, predicting, and adapting to permafrost thaw. To catalyze this vision, the network is engaging with other initiatives such as ArcticNet, the Canadian Permafrost Association, Permafrost Pathways, and raising the agenda in the policy world, e.g., through micro-engagements, publications (Gruber et al., 2023), and sessions at the Canadian Science Policy Conference.

The value created

A survey to NSERC PermafrostNet members in January 2024 asked what value they get from participating in the network. The responses have been summarized in a word cloud. Reading the responses in detail, data sharing and strengthened community ranked highest. These were supported by strong relationships and trust, as well as new and complementary people, connections, and capabilities. This enabled exposure to and integration of diverse perspectives, shared field opportunities, relevant research questions, and new standardized methods. Making the network research valuable for others is a strong desire of the participants. Translating, mobilizing, and applying the research results over time leads to new practice for a sustainable future. The connections formed will continue to build and strengthen the depth and impact of permafrost knowledge in Canada.

Establishing a Canadian database of geoelectrical surveys of permafrost

By Teddi Herring and Antoni G. Lewkowicz (University of Ottawa)

This project addresses the need for a comprehensive database of electrical resistivity tomography (ERT) surveys of permafrost in Canada. The Canadian Permafrost Electrical Resistivity (CPERS) database was created to facilitate data sharing to enable researchers, practitioners, and communities to collaboratively enhance their understanding of permafrost conditions and dynamics.

Methodology and key findings

Teddi Herring developed the CPERS database to archive ERT surveys in a standardized manner, promoting easy data sharing and access. The database currently includes data from 280 ERT surveys conducted between 2008 and 2022 across Canada and Alaska. Teddi used this data to make large-scale interpretations of permafrost conditions in relation to climate, landform type, surface cover, and surface disturbance, which would not have been possible without the amalgamation of a large, standardized dataset. Best practices for ERT surveying of permafrost have also been published as a part of the CPERS project, offering guidance to optimize data acquisition, processing, and interpretation (Herring *et al.*, 2023).

Taking action

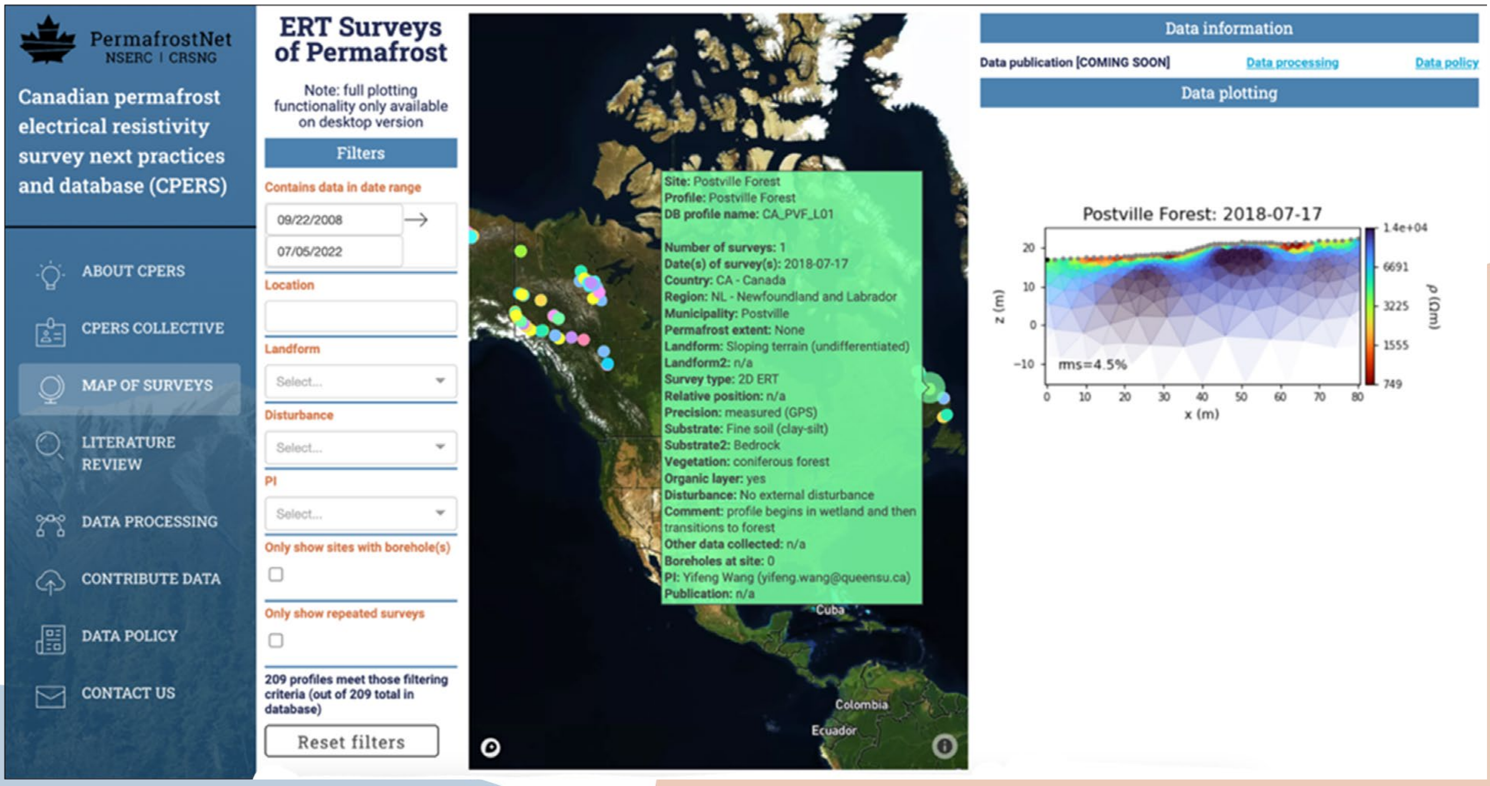
Recognizing the importance of data in characterizing permafrost environments and making informed decisions, the project encourages contributions to the CPERS database.

Partnerships and support

The project was based at the University of Ottawa and had numerous contributors, including data providers (Antoni Lewkowicz, Alexandre Chiasson, Yifeng Wang, Robert Way, Joseph Young, and Duane Froese), technical support personnel (Nick Brown and Etienne Godin), and field assistants. This project ran in parallel with the IPA Action Group "Towards an International Database of Geoelectrical Surveys on Permafrost (IDGSP)", enabling collaboration on several aspects. Metadata fields and database structure were developed with IDGSP, and Teddi wrote the data processing and website code used by CPERS and IDGSP.

Acknowledgments

Thanks to the Inuit of Nunatsiavut, Labrador, the Sahtu Dene and Métis of the Central Mackenzie valley, Teslin Tlingit Council, Kluane First Nation, White River First Nation, Nacho Nyak Dun First Nation, Kaska Dena First Nation, Tr'ondek Hwëch'in First Nation, Vuntut Gwitchin First Nation, the Nunatsiavut Government, Nunatsiavut Research Centre, NunatuKavut Community Council, and communities of Fort Good Hope, Norman Wells, and Tulita. Digital resources were provided by the Digital Research Alliance of Canada.



Interactive Canadian permafrost electrical resistivity survey (CPERS) web map.

Non-destructive characterization of permafrost cores using industrial computed tomography and multi-sensor core logging

By Mahya Roustaei, Joel Pumple, Jordan Harvey, and Duane Froese (University of Alberta)

This study develops the non-destructive methods of Industrial Computed Tomography (CT) and Multi-Sensor Core Logging (MSCL), to characterize permafrost materials. The focus is on visualizing cryostructures, measuring bulk frozen density, and estimating excess ice and volumetric ice content. These approaches address limitations of traditional methods, and in the case of MSCL, provide a rapid and standardized tool for permafrost characterization.

Methodology

The study uses a recently installed Nikon XTH 225 ST Industrial CT scanner and Geotek Multi-Sensor Core Logger in the Permafrost Archives (PACS) Lab at the University of Alberta. We developed a new approach to maintain frozen samples for several hours through scans, allowing high resolution micro-CT data to be collected at high spatial resolution. MSCL benefited from a new calibration approach to frozen bulk density using a 137Cs gamma source, high resolution imaging and magnetic susceptibility. Dragonfly (ORS 2021) was used to process the 3D scans of the frozen cores. Segmentation was completed through multiple image processing steps using an automatic image segmentation algorithm called "Otsu".

Key findings and taking action

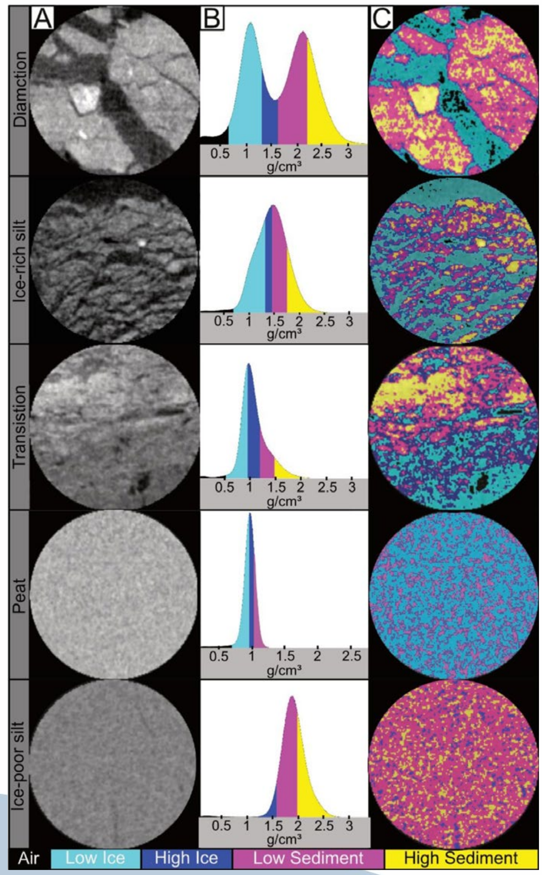
Results demonstrate strong agreement with destructive analyses at similar spatial scales, highlighting the accuracy of these non-destructive methods. These techniques can be integrated into standard core processing, but also provide legacy digital archives of permafrost physical properties to support future studies, along with preservation of sampled materials for future investigations.

Partnerships and support

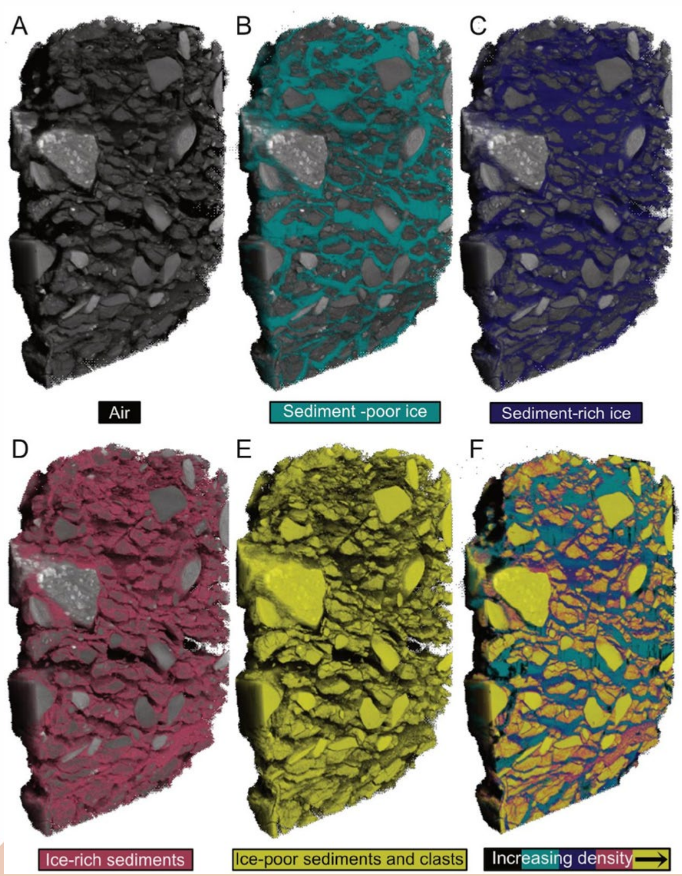
The project involved collaboration with researchers from the University of Alberta, PACS Lab, Northwest territories Geological Survey, Sahtu Communities, and research assistants.

Acknowledgments

Laboratory infrastructure for the PACS Lab was funded by Canadian Foundation for Innovation, Government of Alberta, and University of Alberta. We also thank Geotek and Nikon Metrology for their support and constructive feedback.



(A) Slices of the cores before image processing, (B) histograms, and (C) image segmentation results.

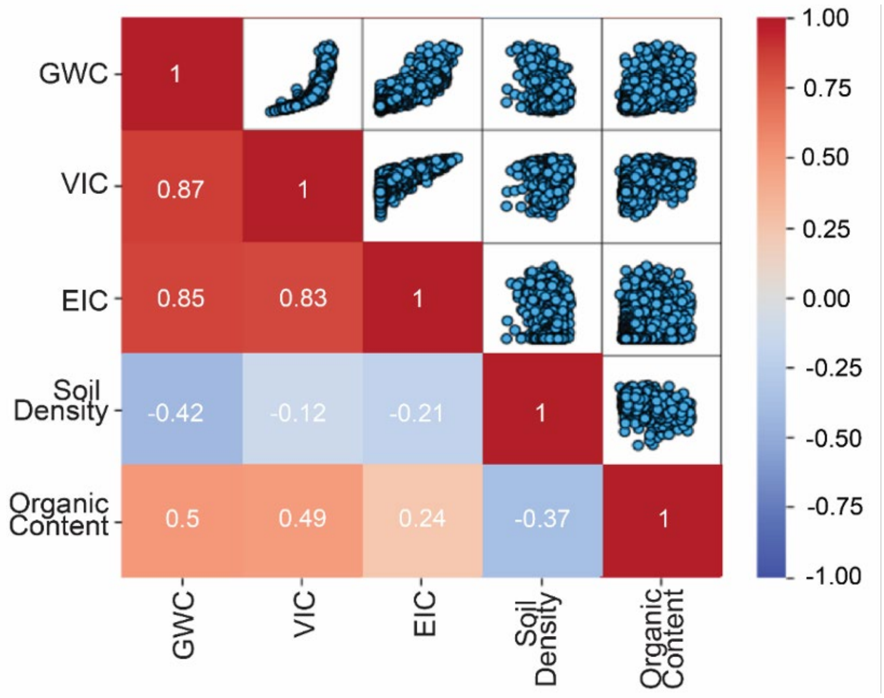


Segmentation of an ice-rich diamict with with the distribution of sediment and ice from industrial CT scanning.

Permafrost index properties database

By Omid Asghari, Mahya Roustaei, Joel Pumple, Alexandre Chiasson, Duane Froese (University of Alberta), and Steve Kokelj (Northwest Territories Geological Survey)

Index properties of soils are commonly used in site investigations and to estimate geotechnical behaviour. In this study we develop a Permafrost Index Properties database of over 2,500 permafrost samples from northern Canada covering a range of depositional environments. The goal of the research is to establish relations between gravimetric water content (GWC) and excess-ice content in permafrost to ultimately build ground ice models from geotechnical databases (>100,000 measurements). This aligns with the goals of Theme 1 to develop a Ground Ice Potential database and contribute to the Ground Ice Map of Canada Network Data Product.



Correlation coefficients of cuboid permafrost index properties. The blue dots represent ~2000 samples from various depositional environments.

Methodology

We sampled over 150 permafrost cores from diverse depositional environments (till, lacustrine, eolian, peat, glaciofluvial and colluvial), primarily from northwestern Canada. These cores were cut into 3 cm³ at two-centimeter intervals. For each cuboid we directly measured GWC, volumetric and excess-ice content (VIC, EIC), organic content (OC), and soil density.

Key findings and taking action

We see a high positive linear correlation (~0.85) between EIC, GWC, and VIC. Database cleaning and filtering were crucial for evaluating relations between variables. Peat and samples with high organic content (≥17%) pose a challenge due to water absorption properties of peat which complicated EIC estimates. We use this database and these relations to convert the large geotechnical databases from northern Canada. The principal component indicates (1) GWC is the main predictor of EIC; (2) higher latitudes correlated more positively with EIC than longitude; and (3) EIC decreased with depth. A Beta regression model was developed to estimate EIC from a large database of geotechnical data (~60,000 measurements) based on the Permafrost Archives (PACS) Index Properties data. Subsequently these data have been used to develop vertical ground ice profiles.

Partnerships and support

We worked with the Northwest Territories Geological Survey, Northern Engineering, and Geological Survey of Canada.

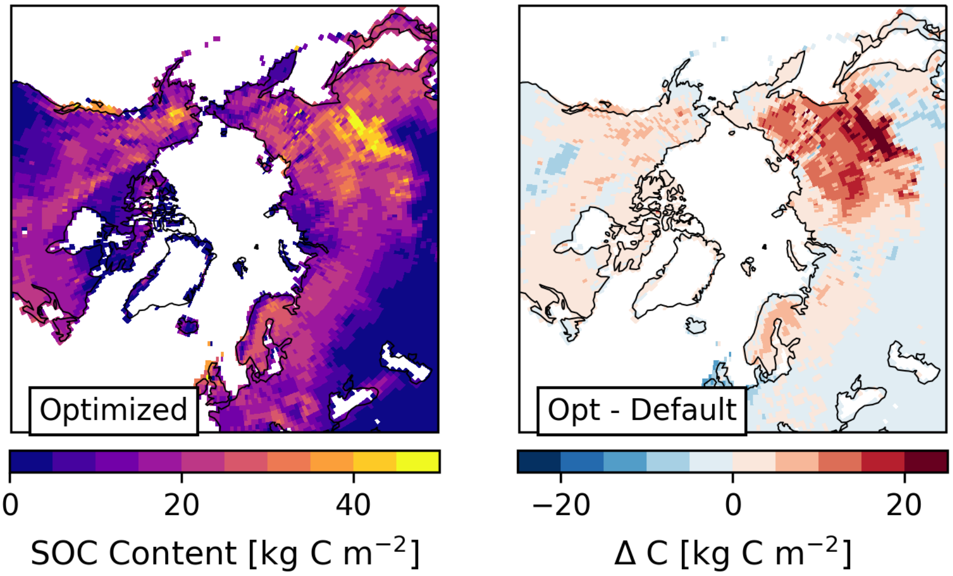
Acknowledgments

Funding was provided by NSERC PermafrostNet, University of Alberta, Canadian Foundation for Innovation, and Government of Alberta.

Fate of carbon in Canadian permafrost-affected soils

By Charles Gauthier, Oliver Sonnentag (Université de Montréal), and Joe Melton (University of Victoria)

This study, conducted at Université de Montréal in collaboration with Environment and Climate Change Canada (ECCC), addresses the critical challenge of understanding the response of soil organic carbon to climate change in permafrost-affected soils. Soil carbon dynamics are simulated in numerical models through simplifications ('parameterizations') of the complex microbially mediated processes that occur in nature. This study improves accuracy of these simulated processes by incorporating observations of both the quantity of carbon and carbon fluxes when determining the form of the parameterization used. Improving the accuracy of simulated soil carbon will enhance the accuracy of climate models and better quantify the amount of carbon that can be emitted while keeping below a certain warming threshold.



Left: average 1950-2000 soil organic carbon content of the top 100 cm of soil simulated using the optimized parameter set from the Bayesian optimization. Right: difference in simulated soil organic carbon between the optimized and the CLASSIC default parameter sets.

Methodology

Charles Gauthier optimized the CLASSIC soil carbon parameterization through first determining the most important parameters via a global sensitivity analysis. Secondly, he developed a Bayesian optimization framework that utilized observations of bulk soil carbon from a global compendium of soil cores and soil respiration data from a database of continual chamber measurements to determine optimal parameter values.

Key findings

The optimized parameters demonstrated a difference in simulated soil carbon at the end of the century compared to default parameters. CLASSIC, with the new parameterization, predicted a global increase in soil carbon, particularly in high latitudes, challenging previous predictions based on default parameters.

Implications and taking action

The study underscores the pivotal role of models like CLASSIC in projecting future permafrost thaw and its associated challenges. To address issues arising from thawing permafrost, the findings of this project underscore the importance of appropriate parameterization of soil carbon schemes to ensure the projected response to future change is accurate. Additionally, it demonstrates the importance of a more extensive data collection effort around soil carbon (e.g., radiocarbon) in the many permafrost regions that are under sampled. The refined soil carbon scheme in CLASSIC is a valuable contribution to the broader modeling community, which will facilitate more accurate projections of soil carbon dynamics under future climate change and permafrost thaw.

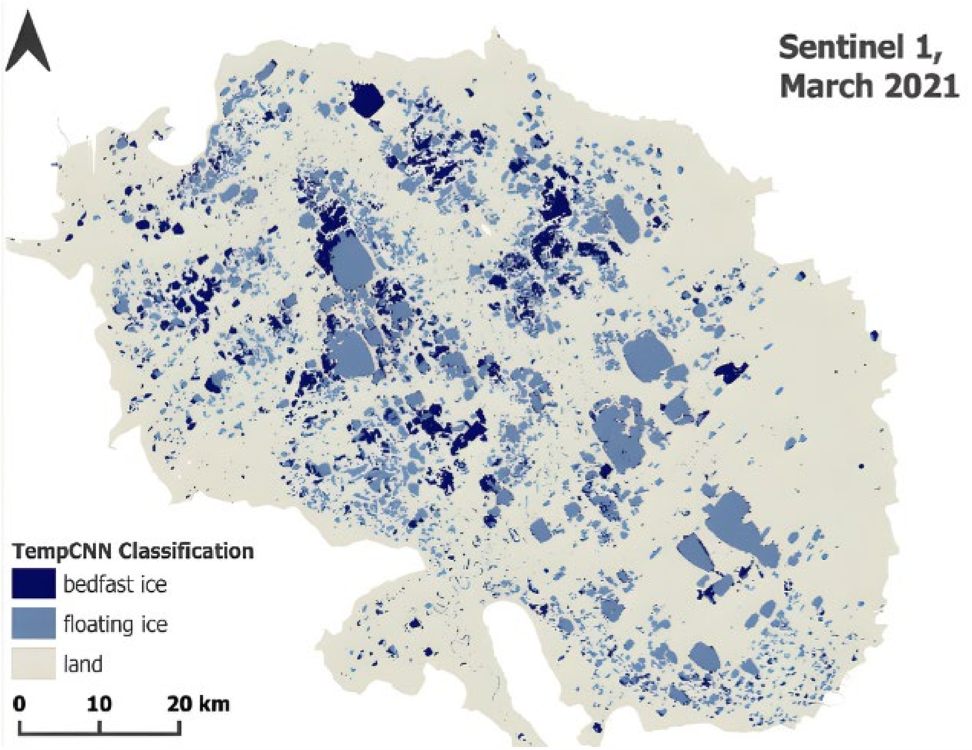
Acknowledgments

The project benefited from advice and feedback from other network members. This interdisciplinary approach enhances the robustness of the research and contributes to a comprehensive understanding of permafrost-related processes. Special thanks to Dr. Gesa Meyer (ECCC) for supporting the simulations with CLASSIC.

Mapping and understanding thermokarst lake ice dynamics over decades

By Maria Shaposhnikova, Claude Duguay (University of Waterloo), and Pascale Roy-Léveillée (Université Laval)

This study focused on mapping and characterizing the changing ice conditions in shallow lakes, particularly in thermokarst lakes. The team produced maps spanning 30 years using machine learning and satellite imagery. Results help understand the critical relation between lake ice conditions and permafrost stability.



TempCNN classification output for Sentinel 1 at Old Crow Flats, YT.

Methodology and key findings

Maria Shaposhnikova employed a temporal convoluted neural network algorithm to generate maps distinguishing bedfast ice (frozen to the lakebed) from floating ice. This distinction is crucial for understanding permafrost stability. Maps over a 29-year period (1993-2021) for Old Crow Flats (OCF) in Yukon revealed an increase in bedfast ice coverage. As permafrost may be sustained or aggrade in a bedfast-ice regime, this transition may affect permafrost sustainability and talik development beneath OCF lakes. This change is tentatively attributed to factors such as catastrophic lake drainage, lower water levels, and reduced snowfall. The accuracy of these maps was tested against field measurements and the Canadian Lake Ice Model.

Implications and taking action

Covering about 20% of northern permafrost regions, thermokarst lowlands are significant reservoirs of soil organic carbon. Documenting transitions between bedfast and floating ice is essential for understanding permafrost dynamics and their impacts on methane ebullition and the regional carbon balance. These maps can aid in tracking lake drainages, identifying catastrophic events, and predicting future changes by simulating lowland thermokarst based on observed bedfast ice and lake extent.

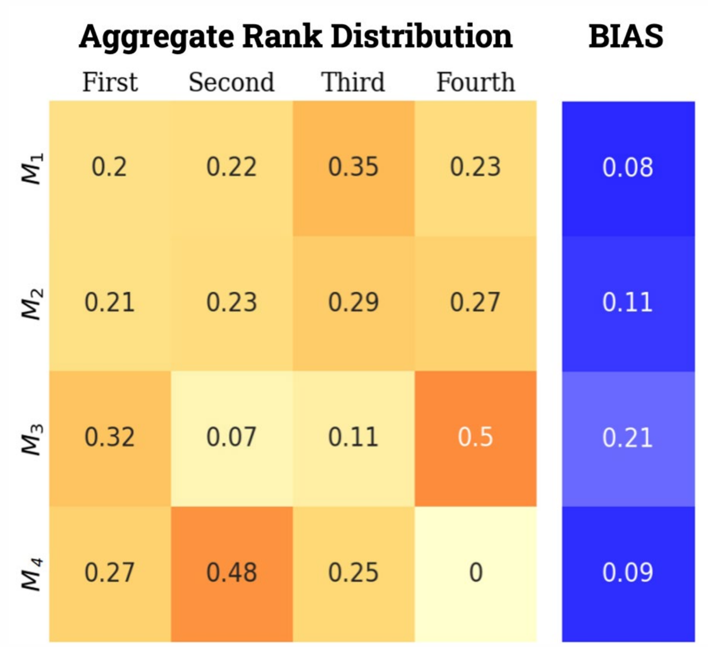
Acknowledgments

The project was conducted at the University of Waterloo, in collaboration with Université Laval. We acknowledge the traditional territory of the Vuntut Gwitchin First Nation. Collaborative efforts with Yukon University and technical support from various contributors enhanced the project's scope and depth. Additional support was available through the NSERC Alexander Graham Bell Canada Graduate Scholarship.

Guiding model selection to support adaptation decision making: a statistical evaluation framework for transient permafrost simulations

By Hannah Macdonell and Stephan Gruber (Carleton University)

This research developed a statistical framework for evaluating and ranking daily ground temperature simulations from different models. This is important because the value of permafrost simulation for informing adaptation depends on our ability to measure and communicate simulation quality. We identified and addressed five key obstacles in evaluating simulations, (1) limited spatial coverage of observations, (2) variables of interest that differ from observed variables, (3) lack of consensus on evaluation statistics, (4) intangible statistical values, and (5) incomplete observational datasets. We frame the testing of permafrost simulations as a ranking problem. Which model or parameter set performs best? Did the new model code result in an improvement, as expected?



Ranking of four models (M_1-M_4). Values represent the proportion bootstrap samples in which a model occupied a specific rank. Values close to 1 denote high confidence in the model's rank. Bias shows the proportion of a model having a warm bias.

Methodology

To address limited spatial coverage, model performance is evaluated separately for different terrain types to mitigate potential observation bias. To address differing variables of interest, we explore in a test case how model performance differs between the surface and deeper observations. Three complementary statistical measures are selected: bias, mean absolute error, and Pearson correlation coefficient. To increase the number of useable observations, a bootstrap procedure works on month-long blocks of the time series. Model ranking with uncertainty is calculated by aggregating model performance using each statistic.

Key findings

Ranking with uncertainty produces summary information that is intuitive to interpret and compare, while reflecting the number and variability of observations available. The 'pyramid of results' produced, allows experts to interrogate simulation performance in more detail as needed. For example, one can view performance by terrain type or by month, and see the distribution of values for the underlying statistical measures.

Taking action

The methods developed are made available in the Python package Accomatic. It will mature with adoption and adaptation, especially in optimising how users can understand results to contextualize their application of permafrost simulations.

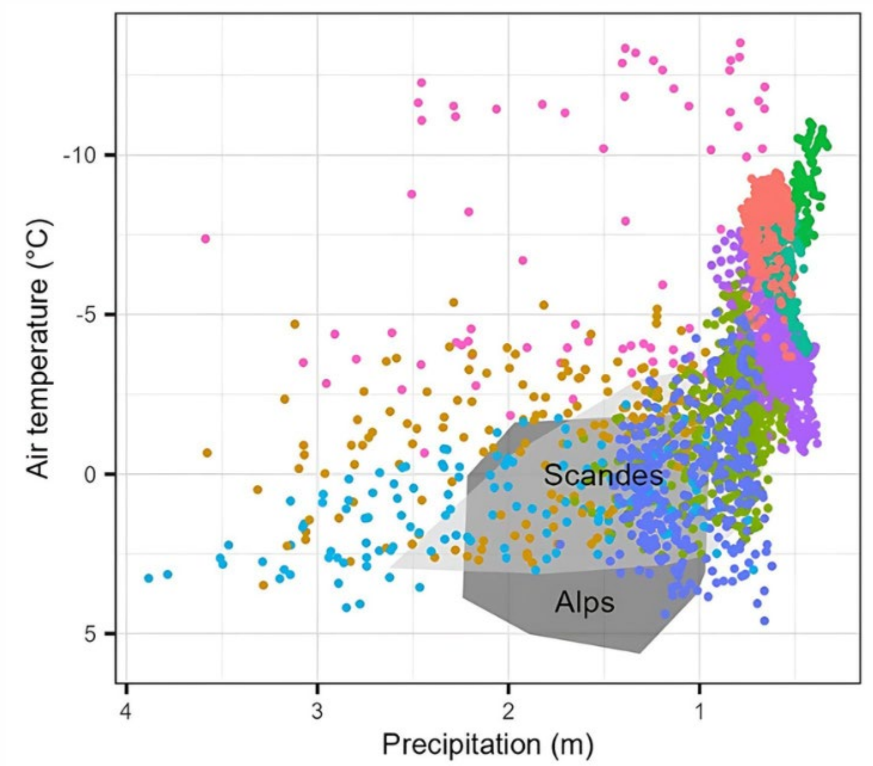
Acknowledgments

The project received support from the Digital Research Alliance of Canada and the Government of the Northwest Territories, with technical support from Nick Brown.

Transferring cryosphere knowledge between mountains: a case study of the western Canadian mountains, the European Alps, and the Scandes

By Emilie Stewart-Jones and Stephan Gruber (Carleton University)

This project originates from a need to quantify permafrost characteristics in western Canadian mountains to better understand permafrost change and related landslides and other hazards. The goal is to determine where knowledge from permafrost research in European mountains can be applied to western Canada directly and where new local research is needed.



Comparison of mountain areas with permafrost in western Canada (coloured) and European areas (grey) for mean annual air temperature and total annual precipitation at a resolution of 30 km x 30 km.

Methodology

The project quantified the similarity in regional climates between well-studied European mountain areas (the Alps and Scandes) and western Canadian mountain regions with permafrost. Using the ERA5 climate reanalysis, the study calculates and compares relevant permafrost-related variables at a grid resolution of about 30 km x 30 km, including mean annual air temperature, incoming solar radiation, precipitation, continentality, latitude, and elevation.

Key findings

The project found that direct transfer of knowledge about ground temperature regimes and their spatial patterns from the Scandes and Alps to western Canada is inappropriate. Overlap in climatic variables that drive ground temperature is concentrated in small areas only. The areas in western Canada receive more radiation than those in the Scandes, and less than in the Alps. The areas in western Canada are more continental than the European areas and extend into much colder conditions.

Implications and taking action

Further localized research is needed in western Canada to understand its mountain permafrost. The comparison method developed here can equally help inform the transfer of knowledge to other understudied permafrost areas globally by highlighting climatic similarities and differences with well-studied regions. Although imperfect, reanalysis climate data enables such analysis in remote cryosphere areas with sparse in situ data.

Acknowledgments

Thanks to Marten Geertsema (BC Ministry of Forests) for his continuing support and advice.

Compacting snowbanks along highway embankments to lower ground temperatures and preserve permafrost

By Patrick Jardine and Christopher Burn (Carleton University)

Snow accumulation beside highway embankments insulates the ground from cold winter conditions, traps heat below the surface, and causes permafrost to thaw. Permafrost degradation may lead to infrastructure damage, such as cracking and subsidence of the driving surface. Compacting the snow increases its thermal conductivity, allows heat to escape from the ground more easily, and prevents permafrost beside the road from thawing. The technique is relatively inexpensive and easy to implement compared to traditional engineering solutions such as installing cooling systems beneath the road.

Using skidoos to compact snowbanks along the South McQuesten Road; an offshoot road of the Silver Trail used to access Eagle Gold Mine north of Mayo, YT.

Methodology

Patrick Jardine conducted field experiments along the Dempster Highway and Silver Trail in Yukon to investigate the effectiveness of snow compaction using skidoos. The snowbanks were compacted over 50 m sections. Patrick measured the difference in ground surface temperature between compacted sites and locations nearby that were undisturbed.

Key findings

Compaction was effective at reducing mean daily ground surface temperatures by about 2-3 °C. The greatest temperature differences were observed in February, with a maximum difference of 12.1 °C. Increases in snow density were limited to the basal depth-hoar layer of the snowpack at tundra sites but were recorded throughout the snowpack at sites in the boreal forest.

Implications and taking action

The results suggest that compaction may be a viable method for preserving permafrost and protecting infrastructure in cold regions. The effectiveness of compaction depends on the snow conditions and the timing of compaction. Further testing is needed to optimize compaction techniques and scheduling, and to determine the feasibility of using the technique on a large scale. Further study should examine the potential environmental impacts of compaction and forecast the long-term effects of compaction on permafrost.

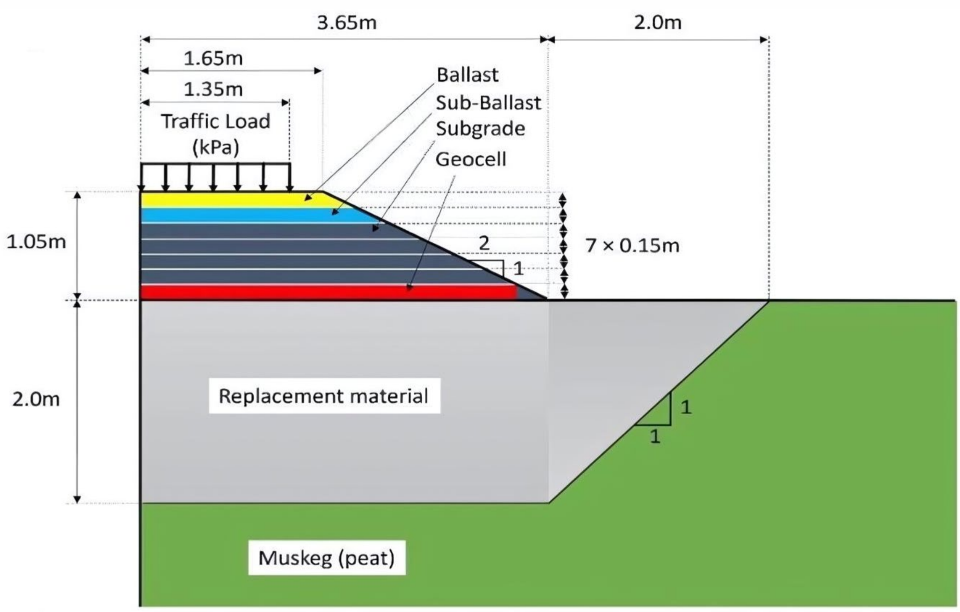
Acknowledgments

The project was based at Carleton University with support from the First Nation of Na-Cho Nyäk Dun and collaboration with the Government of Yukon.

Geocells as effective supports for permafrost thaw under railway embankments

By Payam Sharifi and Ryley Beddoe (Royal Military College)

The Hudson Bay Railway (HBR) in northern Manitoba faces significant deformations and instabilities annually due to permafrost degradation. To address this, geocells, commonly used in non-permafrost soils, have been employed to enhance railway support. This project assessed the effectiveness of geocells in reducing thaw-induced deformations and settlements, employing numerical scenario analyses and field monitoring.



Schematic view of a Hudson Bay Railway geocell embankment with details of the embankment layer.

Methodology
Modeling experiments focused on rail deformation and embankment stability under degrading permafrost conditions. A series of numerical models were conducted to simulate and quantify the performance of a typical geocell reinforced embankment founded on peat with underlying permafrost. Thermo, hydro, and mechanical processes were considered using the finite element software package, GeoStudio (including TEMP/W, SEEP/W, and SIGMA/W). In the field, digital image correlation monitored track displacement and deformations at geocell-reinforced locations. The project evaluates geocell effectiveness under varying permafrost conditions and analyzes long-term stability.

Key findings
The study reveals that geocell reinforcement strongly reduces lateral deformation, especially when the active layer is between 1-2 m below the rail. Optimal geocell height improves embankment stability by up to 50%. However, the study notes a gradual performance decline over the long term due to the increasing effect of permafrost degradation. Overall, geocells can offer substantial improvements to embankment design life when applied judiciously.

Implications and taking action
Integrating geocell-supported designs into standard practices for future linear infrastructure, particularly in permafrost regions, is promising. This research highlights the potential for extended design life and improved resilience, encouraging further exploration of geocell applications in similar contexts and exploration of geocell applications in other linear infrastructure designs. The project's findings emphasize the use of geocells on the HBR, demonstrating improvements in stability and resilience.

Acknowledgements
The project was conducted at the Royal Military College, with strong support from industry partners, Brett Young and Nathan Gullacher from Arctic Gateway Group.

Increasing climate-related highway maintenance costs in permafrost environments of Yukon

By Astrid Schetselaar and Christopher Burn (Carleton University)

Yukon's highway network spans about 4,800 km across varied terrain divided into seven physiographic regions. Climate-related maintenance costs have risen substantially since 1994 throughout the network. The effects requiring attention from maintenance staff are primarily caused by hydrologic processes above permafrost.

Dempster Highway north of Eagle River bridge (top) and in the Ogilvie River Valley (bottom).

Methodology

Historical Operation and Maintenance (O&M) expenditures were examined for 20 maintenance camps within Yukon's highway network. The data spans over 28 fiscal years from April 1994 to March 2022. Five activities in the record were identified as climate-related: snow management, icing control, culvert activities, and clearing of landslides, and repair after washouts. Expenditure profiles for seven distinct physiographic regions were investigated based on specific landscape characteristics, climate variables, and permafrost conditions.

Key findings

Mean annual climate-related O&M expenditures (constant 2021 dollars) increased from $7.1M in 1994-1999 to $10.9M in 2017-2022 for the network. The costs rose from 25% to 47% of the total maintenance budget. Hazardous events, such as landslides and washouts, increased in frequency and magnitude, particularly for highways within permafrost zones. Expenditure profiles for each region varied depending on landscape characteristics and climate conditions. On a per-kilometer basis, O&M expenditures have been twice as costly for highway sections in terrain with more than half of the area underlain by permafrost than for sections with less permafrost.

Implications and taking action

The variability of costs across the network indicates the range of responses to climate change in terms of required maintenance activities throughout Yukon. Hazard assessment and management may need an approach at the scale of maintenance sections that are 100-150 km long. At this scale, landscape factors that differ between sections may be recognized. This information will help to inform targeted, cost-effective efforts and create a highway network more resilient to the effects of climate change.

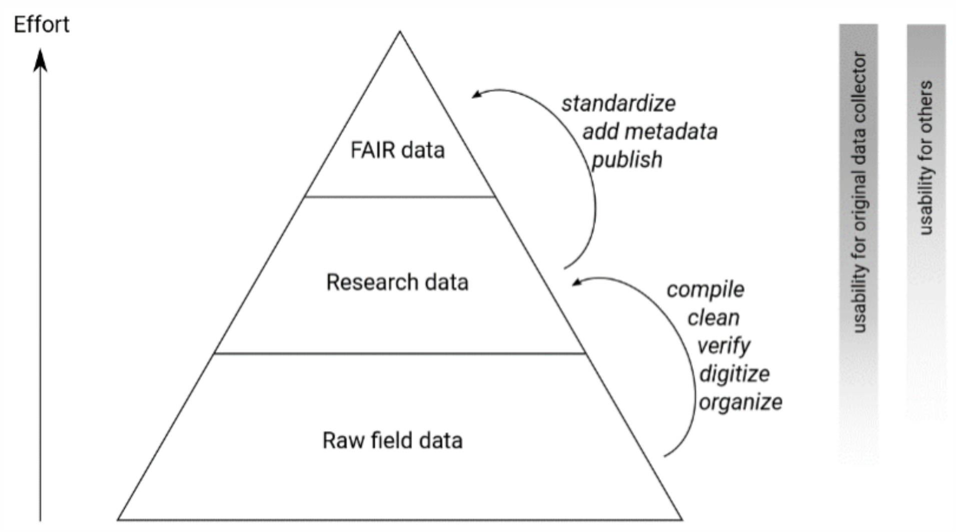
Acknowledgments

The project received support from Highways and Public Works Yukon, Transport Canada's NTAI program, and Polar Knowledge Canada's Northern Scientific Training Program.

Making permafrost data FAIR (Findable, Accessible, Interoperable, and Reuseable)

By Nicholas Brown, Stephan Gruber, Peter Pulsifer, and Amos Hayes (Carleton University)

Data are a unifying element in the network that links themes, stakeholders, and projects. Despite their importance, permafrost data are difficult to obtain due to the expense of measurements and a lack of standardized tools. A number of initiatives and projects demonstrate next practice for managing and distributing interoperable permafrost data and offer a framework for efficient data handling from field to publication.



Only a fraction of collected permafrost data are made available.

Methodology

Five essential challenges were identified in permafrost data management, focusing on ground temperature, site characterization, and borehole profile data. These challenges are framed as a set of requirements and a comprehensive permafrost data system has been designed to meet them. Data publication is conceptualized as a two-phase process, emphasizing the importance of reducing effort at each stage to enhance the overall publication rate for permafrost data. By utilizing established standards for interoperability, the system facilitates the development of visualizations and services to make permafrost data more accessible to diverse stakeholders.

Key outputs

The prototype data system provides a practical solution for researchers collecting permafrost data to streamline, centralize and publish observations. The system, supported by a custom database and existing software (ERDDAP), aligns with international data standards. Additionally, an open-source python library (TSP) was developed to handle ground temperature data heterogeneity by reading from diverse sources and models. The software incorporates functions for common visualizations, analyses, and data output in a variety of widely used formats.

Taking action

The prototype data system can be used to enable researchers and organizations to efficiently manage and distribute their observations. The project encourages further action through the development of visualizations, workflows, and services for-technical stakeholders using the standardized ERDDAP endpoint (data.permafrostnet.ca). The TSP software library can also be collaboratively developed within the permafrost community. Researchers are encouraged to contribute to TSP by adding new modules to support their specific data loggers or model outputs.

Acknowledgments

This project benefited from collaboration with the Canadian Consortium for Arctic Data Interoperability (CCADI) and support from Compute Ontario and the Digital Research Alliance of Canada.

Publications

The following are a selection of network publications. For a full list visit www.permfrostnet.ca/ resources/publications/.

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