PermafrostNet
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NSERC PermafrostNet projects

THEME 1 – Characterization of permafrost

Data handling sub-theme


Formerly Michel Paquette and Samuel Gagnon

Title: PINGO: Permafrost Information Network of Ground Observations

Supervisors: Daniel Fortier with Duane Froese, Trevor Lantz and Peter Pulsifer

Michel's work led to: 1) the development of a detailed plan for import of existing data into the Permafrost Information Network of Ground Observations (PINGO) database; 2) develop standard and database structure, which was completed and has resulted in the development of a guide to data publication, the "NSERC PermafrostNet Data Publication Handbook"; 3) integration of permafrost data from partners; and 4) implementation and refinement of integration and mediation layer to allow joint querying of several databases. Samuel's work led to 1) the refinement of the data publication process on the PINGO database; 2) in collaboration with Theme 1, the publication of two historic reports containing profile data from more than 250 boreholes in polar desert environments; and 3) the coordination with partners for the next phases of data publication from other historic reports in PINGO. This project also worked on the expert evaluation of the Ground Ice Map of Canada (GIMC).

Mahya Roustaei

Title: Standardization of permafrost characteristics.

Supervisors: Duane Froese with Fabrice Calmels, Daniel Fortier and Jocelyn Hayley.

Mahya's project will assess the use of CT scanning for characterizing detailed physical properties of permafrost samples. CT scanning allows non-destructive imaging of ice, gas and sediment properties of permafrost cores and cuttings. This project will also build on the PINGO database by using CT scan standardization to improve interpretation of existing data in the database.

Teddi Herring

Title: Canadian permafrost electrical resistivity survey next practices and database (CPERS).

Supervisors: Antoni Lewkowicz with Fabrice Calmels and Anne-Marie LeBlanc.

The goal of Teddi's project is to integrate existing and future Electrical Resistivity Tomography (ERT) surveys in a Canadian Permafrost Electrical Resistivity Survey database (CPERS). The data in CPERS is being used to infer the presence, continuity, and depth of permafrost over a range of spatial scales and detect changes over time. Teddi is also working with network partners Dr. Calmels (YukonU) and Dr. LeBlanc (Geological Survey of Canada) on the manuscript of best practices for ERT surveys of permafrost.

Innovation for quantifying thaw sub-theme

Hosein Fereydooni

Title: Characterizing the ice and water content of permafrost with dielectric methods.

Supervisors: Stephan Gruber with David Stillman, Jocelyn Hayley and Daniel Fortier.

Hosein's project utilizes laboratory and field-deployed dielectric spectroscopy to estimate ice and water content of soils under changing temperature conditions. Laboratory spectra will yield freezing characteristic curves for simulating permafrost change, supporting several projects in Themes 3 and 5, and help to reduce limitations of single-frequency methods such as time-domain reflectometry. Results will be compared with differential scanning calorimetry on small samples (U. Montreal) and the work by Theme 1 PhD project 1 (CT-scanning) obtained from cores, where solute contents and macroscopic ice content will provide further evidence to support the interpretation of dielectric spectra.

The improved detection of ground ice beneath natural surfaces and engineered structures resulting from this project is important because ground-ice loss drives the impacts of permafrost change. Field work will be planned to maximise the benefits from co-location with other projects and partner activities.

Zakieh Mohammadi

Title: Strength and consolidation behaviour of permafrost sediments.

Supervisors: Jocelyn Hayley with Brian Moorman, Pascale Roy-Léveillée and Stephan Gruber.

Zakieh's project is working on a number of interrelated conditions that govern the overall settlement of degrading permafrost such as strength, consolidation behaviour and excess pore pressure dissipation. Zakieh is developing a systematic approach that could be used for a qualitative evaluation of thaw-settlement potential at the feasibility phase of construction projects. She will also be developing a quantitative version of the framework, which could be used at the site scale for estimating the anticipated thaw-settlement. This includes working on thaw-consolidation test results to develop predictive correlations as the next step.

Khatereh Roghangar

Title: Geomechanical properties of thawing permafrost.

Supervisors: Jocelyn Hayley with Brian Moorman, Shawn Kenny and Duane Froese.

Khatereh's project is focused on Geomechanical properties of thawing permafrost including a geotechnical database in PINGO and a geotechnical layer for GRIP with indicators of sediment strength and sensitivity to thaw. Khatereh has determined the distributions of the input variables to run Monte Carlo simulations on Python using Probabilistic Modeling. She is also working on the TEMP/W analysis process.

Ground-ice characteristics sub-theme

Tabatha Rahman

Title: Permafrost and ground ice conditions in the Hudson Bay Lowlands.

Supervisors: Pascale Roy-Léveillée with Maara Packalen, Stephen Wolfe and Bernhard Rabus.

The goal of Tabatha's study is to improve understanding of ground-ice dynamics in the Manitoba portion of the Hudson Bay Lowlands. The research focuses on assessing the volume and tri-dimensional distribution of ground ice, elucidating the environmental conditions that favored ice-wedge aggradation, and predicting terrain evolution pathways as climate warms and permafrost degrades in the region. Fieldwork is carried out in collaboration with Arctic Gateway Group/Hudson Bay Railway. Tabatha is also working in collaboration with the Geological Survey of Canada to help compile borehole data related to previous work in Northern Manitoba for integration into Permafrost Information Network.

Alexandre Chiasson

Title: Past environmental change and permafrost characterization along the proposed Mackenzie valley Highway corridor, Northwest Territories, Canada.

Supervisors: Duane Froese with Sharon Smith, Steve Kokelj and Stephen Wolfe.

Alexandre's project is developing better understanding of the ground-ice conditions along the proposed Mackenzie Valley Highway (MVH) right-of-way in the Northwest Territories. The project is integrating borehole data into the Permafrost Information Network of Ground Observations (PINGO), analysing physical properties of cores and classifying thermokarst types. Preliminary work on peat plateaus in the Mackenzie Valley led to a collaboration with Steve Kokelj, GNWT, on Thermokarst collective mapping.

Joe Young

Title: Characterizing the setting and mechanisms of recent permafrost mass-wasting in the central Mackenzie Valley, NWT.

Supervisors: Duane Froese and Fabrice Calmels.

Joe's project is providing field-based characterization of ground ice distribution and the assessment of mass-wasting thaw potential in sloped discontinuous permafrost terrains.

THEME 2 – Monitoring of permafrost change

Measure or infer sub-theme

Emma Street

Title: Inuvialuit and Gwich'in knowledge of permafrost systems.

Supervisors: Trevor Lantz with Erika Hille, Amy Amos and Vernon Amos.

In this project Emma works with land users from Inuvialuit and Gwich'in communities in the western Arctic to document traditional knowledge of permafrost and permafrost-related change. To characterize the historical range of variation in permafrost conditions and document local observations of change or anomalous conditions. Emma will conduct semi-structured interviews with experts in communities in the Beaufort Delta region. This research will be pursued in collaboration with Inuvialuit Game Council and Gwich'in Renewable Resources Board. Emma will also work with partner organizations to access and analyze previously recorded interviews that may contain permafrost related observations. Working closely with local organizations in partner communities Emma will also develop a high-resolution mapping protocol which utilizes the best available information (Sentinel, WorldView-3, LiDAR DEMs, UAV ortho-mosaics and DEMS) to inventory permafrost hazards (lake drainage, ice-wedge ponding, slumps, landslides etc.). This work will support Bingqian Zhang's research on terrain type delineation by providing data to train and validate that work. This work is conducted in partnership with three communities across the western transect (Dawson City, Aklavik and Sachs Harbour). Co-developing a mapping protocol with partner communities will create lasting capacity to monitor change and result in technique of relevance across the circumpolar. Emma will also explore other methods of data collection (focus groups, participatory photography) that can be used to triangulate the perspectives that emerge from mapping and analysis interview data.

Lingcao Huang starting in 2023 (formerly Grant Francis)

Title: Spatial monitoring permafrost change using Landsat.

Supervisors: Trevor Lantz with Antoni Lewkowicz, Steve Kokelj and the Canada Centre for Mapping and Earth Observation (Robert Fraser).

In many permafrost regions, the frequency of thaw-related disturbances is increasing so rapidly that maintaining accurate inventories presents a significant challenge. To overcome this challenge we will conduct investigations using indicators derived from the Landsat archive for mapping terrain disturbances associated with permafrost thaw and for interpreting their underlying processes in a geomorphic and climatic context. Semi-automated and manual mapping procedures will be developed for established indicators of permafrost thaw phenomena. 1) Ice wedge degradation: Lingcao will explore the potential of the Planet/Cubesat archive to detect recent ice wedge melt pond development over decadal scales. 2) Active layer detachments: Lingcao to lead the development of using Sentinel InSAR to identify active layer detachments. 3) Synthesis of the links between thaw processes and spatial patterns: Lingcao will continue his work to develop a circumpolar-scale map of thaw-slumps (and other mass wasting features).

Allison Plourde

Title: Measuring surface displacement using winter SAR.

Supervisors: Bernhard Rabus with Stephan Gruber and Peter Morse.

SAR and InSAR are two methods of radar remote sensing that can be used to detect displacements of the ground surface. These displacements result from seasonal and long-term freezing and thawing and other processes such as fluctuating groundwater levels. Although SAR data is of higher quality in winter (due to absence of liquid water) than in summer, existing InSAR methods to measure long-term surface displacement can only make use of summer SAR data. To overcome this limitation, research exploring the impact of snow cover on the InSAR signal is required. This is important because it will improve the ability to track surface subsidence, one of the most ubiquitous impacts of permafrost thaw, more accurately over long durations. Allison will use measurement and experimental manipulation of snowpack at sites adjacent to the Inuvik-Tuktoyaktuk Highway to answer two questions: (1) Are existing physical models of the InSAR dry snow signal correct? (2) Can the snow signature in winter InSAR data be removed to enable the accurate measurement of heave from the winter refreezing of the active layer? Allison will establish field instruments to simultaneously measure snow depth change (accumulation and wind re-deposition) and active layer freezeback and assess their contributions to InSAR displacement measurements in the immediate vicinity of the instruments. Instrumentation is expected to include two ground-based sensors: one tilt logger permafrost motion sensor, one snow height sonic ranger; as well as two corner reflector (CR) targets for InSAR based displacement measurements, one CR deeply anchored as a stable reference, one CR floating on a soil surface raft and elevated to measure only displacement and not snow depth change.

Usman Iqbal

Title: Airborne InSAR to monitor permafrost thaw near linear infrastructure.

Supervisors: Bernhard Rabus and Fabrice Calmels; Government of the Northwest Territories Department of Infrastructure (GNWT-DOI).

Terrain deformation associated with permafrost thaw will increase the cost of managing linear infrastructure in the north. Repeat pass InSAR can monitor terrain displacement in permafrost environments, but at present, the coarse resolution of most InSAR is insufficient to detect changes relevant to infrastructure managers. This is because at extents appropriate for linear infrastructure, often 100–250 km, common spaceborne image swaths produce displacement gradients with a spatial resolution significantly coarser than 10 m. Furthermore, existing SAR satellites operate in orbits that pose operational challenges to monitoring of East-West trending infrastructure. Here, airborne repeat pass InSAR presents a cost-effective alternative for monitoring linear infrastructure such as roads, pipelines, and coastlines. Airborne InSAR can also resolve both vertical and horizontal displacements separately and can generate spatial strain and stress fields at scales fine enough (0.5–1 m) for infrastructure analysis. Usman will develop the processing techniques required to use airborne repeat pass InSAR for creating maps relevant to monitoring stresses on linear infrastructure caused by permafrost thaw. The most obvious products are maps of permafrost change (coherence-based and amplitude-based) and subsidence (input: InSAR phase), and maps of standing water (input: InSAR coherence and/or SAR backscatter); more elaborate products are high quality cost-effective displacement gradient (strain) maps to assess infrastructure integrity. All products can contribute to assessing the risk of damage for linear infrastructure in remote permafrost terrain related to frost heaving or thaw subsidence with linkages to projects from Theme 5.

Maps of standing water produced by this project will also be used by Theme 3 (together with other field and remote sensing datasets) to work toward the modeling of lowland thermokarst development. To quantify the quality of infrastructure integrity maps achievable with the airborne system Usman will compare the accuracy of displacement measured by: 1) medium resolution spaceborne InSAR, 2) high resolution spaceborne InSAR, and 3) repeat pass airborne InSAR data. Usman will also test and optimize different motion compensation algorithms. The work is being conducted in partnership with Yukon Government Transportation Engineering Branch along the Alcan Highway and in collaboration with other potential end-users such as GNWT-DOI. Test segments will be selected in collaboration with network partners to create synergy with preexisting test sites and with documented permafrost-related infrastructure problems. Usman will be involved in planning and executing two spring and fall airborne campaigns of airborne sensor SlimSAR based out of Kluane-Silvercity. Campaigns will result in acquisition of suitable (two-directional) InSAR data sets acquired along the Alcan Highway. Synergies with Theme 5 project - Risk management of linear infrastructure in remote permafrost terrain may open up as the projects develop.

Synthesis sub-theme

Fereshteh Ghiami Shomami

Title: Interpreting ground temperature and subsidence for better quantifying permafrost change.

Supervisors: Stephan Gruber with Kumari Karunaratne and Derek Mueller.

Permafrost temperature is a key metric of permafrost change, but existing methods for its quantitative interpretation mostly report on sensors at single depths. Furthermore, latent heat consumption when thawing permafrost perturbs the ground temperature signal. Given that, it can be difficult to detect changes in permafrost based on trends in ground temperature time series of a single depth. Moreover, strong lateral landscape-scale variation of temperature is often invisible in analyses that only use a small subset of Canada's data.

Using PINGO (Theme 1), this project aims to develop and automate new methods for characterizing spatio-temporal variation in ground temperature and detect trends. In doing so, Fereshteh will analyse all thermal data available in Canada as well as co-located time series of surface movement to investigate where and when is permafrost thaw occurring and what spatial patterns exist in Canada. Any sign in the profile which can be attributed to the loss of ground ice will be complemented with trends of annual temperature ranges at different depths, providing insight on the thermal effects of ground-ice loss. Further, to assess the performance of the developed method, detected thaw induced changes in the profile will be tested using simulated data based on GEOtop and FreeThaw1D.

Multisite analysis will employ statistical models for separating pattern related to site characteristics and climate in order to better understand the drivers of observed changes. In a final step, Fereshteh will develop and improve products that are suitable for communicating results on permafrost change to non-expert audiences and will provide key methods and insight towards prototype climate services and synthesis reporting based on the monitoring of permafrost temperature and surface subsidence that may result in recommendations for future monitoring strategies.

THEME 3 – Prediction of permafrost change

Representation of key phenomena sub-theme

Rose Lefebvre

Title: Simulating land cover change and its influence on permafrost with CLASS-CTEM.

Supervisors: Joe Melton and Oliver Sonnentag with Elyn Humphreys, and Gesa Meyer.

The principal influences on ground heat changes in cold regions are vegetation, hydrology, snow cover and topography. The vegetation in permafrost affected regions varies from boreal to Arctic biomes. To simulate the influence of changing land cover, this project will incorporate new cold-region specific plant functional types (PFTs) into CLASSIC using literature values and remotely-sensed datasets of land cover change. This is an important prerequisite for producing scenario simulations of future permafrost change within the network. Specific cold-region PFTs such as shrubs have been parameterized using site-level observations and literature reviews. Rose will be incorporating the influence of bryophytes (mosses) into CLASSIC to improve model thermal performance and to account for their carbon cycle impacts. Other processes will be included as required to ensure the model is able to adequately capture observed behaviour with the simplest representation possible. Fieldwork was conducted this summer at Scotty Creek, NWT. This site will form one of her suite of sites used to investigate the modelled response to changing land cover.

Maria Shaposhnikova (GRADUATED)

Title: SAR-based water products to support simulation of lowland thermokarst (Completed September 2021).

Supervisors: Claude Duguay and Pascale Roy-Léveillée.

Many shallow arctic lakes and ponds of thermokarst origin freeze to bed in the winter months maintaining the underlying permafrost in its frozen state. Synthetic aperture radar (SAR) offers a unique opportunity to monitor lake ice regimes remotely. Taking advantage of the growing temporal resolution of microwave remote sensing, Maria applied a temporal deep learning approach to lake ice regime mapping. Her project combined imagery for the Old Crow Flats (OCF), Yukon, Canada to create an extensive annotated dataset of SAR time-series labeled as either bedfast ice, floating ice, or land, to train a temporal convolutional neural network (TempCNN). The trained TempCNN, in turn, allowed automatic mapping of lake ice regimes over a 29-year period (1993-2021). The classified maps aligned well with the available field measurements and Canadian Lake Ice Model (CLIMo) simulated ice thickness.

Improved model application sub-theme

Charles Gauthier

Title: Fate of carbon in Canadian permafrost-affected soils.

Supervisors: Oliver Sonnentag and Joe Melton

Permafrost regions are estimated to contain over 1000 Pg carbon (1015g) in the upper three meters, approximately double the carbon contained in either terrestrial vegetation or the atmosphere. At present, it is unclear whether these regions will be a net source of carbon to the atmosphere, due to respiration of the soil carbon, or a net sink of carbon, due to enhanced photosynthetic activity. Understanding carbon emissions better is relevant for risk reduction in the long term. It is important to connect how permafrost environments are modeled (Theme 3 MSc project 1 and Theme 3 PhD project 1) and the input data available (PINGO, Theme 3 PhD project 3) with national and international efforts to understand the carbon dynamics of permafrost regions. This project uses available datasets of soil carbon stocks and respiratory fluxes in a Bayesian optimization framework to produce refined parameter values for CLASSIC's soil carbon scheme. Charles' project will result in more accurate simulations of global carbon stocks and fluxes and their response to future climate changes. CLASSIC enhancements from this work will inform major international bodies such as the IPCC and the Global Carbon Project.

Bingqian Zhang

Title: Mapping and parameterising permafrost terrain types.

Supervisors: Bernhard Rabus with Trevor Lantz, Duane Froese, Joe Melton and Stephan Gruber.

Transient simulation driven by climate data is well suited for understanding the evolution of ground temperature and ground-ice loss over time. At the same time, this requires input data on surface (e.g. vegetation) and subsurface (e.g. ground ice) characteristics in order to produce meaningful results. Subsurface conditions need to be inferred and carefully spatialized based on sparse observations and knowledge about Quaternary history. To produce output data and maps with enough spatial detail to be relevant for local applications and to be tested with ground observations, the data on surface and subsurface characteristics must have significantly higher resolution (~10–100 m) than the typically coarser grids for the climate variables (~10–200 km). These base maps can be delivered in spatially explicit (gridded) form or follow a sub-grid approach where for coarser grids, a list of typical terrain types along with their characteristics and abundance is provided.

The two base maps produced by the network are the GRound Ice Potential and geotechnical permafrost base map of Canada (GRIP) and the PErmafrost Surface Characteristics base map (PESC). GRIP will contain information on variables such as excess ice content, soil type, salinity, or organic content as a function of depth. PESC will be based, and contain information, on surface cover such as vegetation, as well as derivatives of topography relating to the tendencies to accumulate snow and water or to receive solar radiation. The base maps are derivable from primary spatial data capturing generally different moments in time around a chosen "base map datum". These primary data include optical and radar remote sensing layers in their original form or as derived products (e.g., elevation models, land cover), polygon data such as maps of surficial geology and reconstructed Quaternary history and finally point evidence (e.g. boreholes, outcrops). Bingqian's project designs methods of spatial analysis for deriving GRIP and PESC to make these maps available in versions of increasing sophistication. This project provides a key linkage in the flow of information and knowledge between themes and Bingqian is working closely with Theme 1, whose insight is turned into spatial products here, and with the other Themes as potential users of GRIP and PESC.

Successive improvements of GRIP are being investigated, and these versions are valuable products for network members and stakeholders and inform the strategy and timeline for production of an improved version for large areas or nationally. Using deep learning methods and higher resolution (primary) remote sensing data, statistical approaches, including neural networks, incremental products are being generated for network participants to use and evaluate in the chosen test areas.

Hannah Macdonell

Title: Quantifying confidence in simulations of permafrost change.

Supervisors: Stephan Gruber with Joe Melton, Trevor Lantz, and Steve Kokelj.

Hannah's project is investigating how well ground temperature models are validated by developing methods and tools for evaluating existing models with existing data. Statistical approaches to error and uncertainty will be used to inform model development (Where and when does the model perform least well? Which model performs better?) and the use of model results (How well do permafrost simulations perform at a particular location?). In a follow-up MSc project, this quantitative evaluation will be complemented by investigating face validity, a concept developed to capture the trust that diverse experts, such as model developers, permafrost field scientists and northerners, place in simulation results based on subjective assessment. Investigating face validity will utilise the diverse expertise in the network to identify and assess unknowns in simulations and to develop ways of communicating these to both model developers and end users. The combination of statistical evaluation with face validity will improve the dialogue between model developers and users of simulation results and thereby reduce barriers to the acceptance and uptake of simulation products. Hannah is closely working with and underpinning the research of Theme 3 and Theme 4 projects.

Galina Jonat

Title: Simulation-based climate services for permafrost environments.

Supervisors: Stephan Gruber with Alex Cannon, Fabrice Calmels and Shawn Kenny.

Galina's project will produce and evaluate simulation-based permafrost data products such as ground temperature or subsidence intended to be useful for a broad range of stakeholders. Simulations will be driven by de-biased/downscaled climate data and use GRIP produced in

Theme 3 PhD project 3 and supported by work in Theme 1. Galina's project differentiates three types of user interest: (1) Detailed information that can be related to individual sites will be provided by simulating permafrost under typical terrain types in an area such as peatlands or low-shrub tundra on till. Users will be able to select terrain types and output variables, such as ground temperature or subsidence, based on their needs and investigate their temporal evolution and uncertainty. One, or several projects, from Themes 4 and 5 will be selected as test cases for site-level simulation and allow interaction with application projects and partner needs. (2) Regional or national maps will show best estimates and confidence intervals for key variables and time slices (e.g., the years 2030–2050) with a resolution of several kilometers, only. This will be based on sub-grid simulation of differing terrain types. (3) Boundary conditions that can be used to impose the combined effects of climate and surface changes onto geotechnical and hydrologic models. The boundary conditions must provide a simple and sufficiently truthful representation of ground-atmosphere interaction. This project produces novel output and insight through constrained model confidence, simulating at a scale fine enough to predict local phenomena and through incorporating an improved data set of ground ice potential and geotechnical characteristics. The products developed here can serve as prototypes for informing future climate services provided in Canada.

THEME 4 – Hazards and impacts associated with permafrost thaw

Prediction sub-theme

Kaitlyn Diederichs

Title: Spatial prediction of thaw slumps.

Supervisors: Trevor Lantz with Peter Morse and Steve Kokelj.

Kaitlyn's project focuses on understanding the spatial distribution of permafrost thaw driven slope failure using a combination of field surveys, GIS inventories and drill core analysis. Kaitlyn hopes to develop a predictive model of terrain susceptibility to slope failure.

Emilie Stewart-Jones and Pia Blake

Title: Understanding and prediction of thaw-induced mass movement in steep mountains.

Supervisors: Stephan Gruber, Geertsema and Krautblatter.

Emilie's project is investigating and predicting thaw-induced mass movements in mountain permafrost terrain. This project provides valuable understanding of permafrost change in the steep mountains of Canada and the effectiveness of climate control on landslides. Emilie's project will generate permafrost simulations specifically for steep mountain areas and based on this, compute a geomechanics-based proxy for distinguishing areas of increased likelihood of permafrost-related rock fall. The project will: (a) collect and harmonize existing and new field evidence of temperature and prominent mass movements such as rock glaciers and rock fall in mountains, (b) optimize and test the simulation tools generated in Theme 3 for application in steep mountains and (c) derive a proxy for the effects of permafrost change on rock instability and test whether it can constrain the location and timing of observed events. This is novel research simulating long-term (many centuries) permafrost change and applying a novel geomechanics-based index. The methods developed in this project will enable forward-looking hazard zonation around infrastructure in steep mountains with permafrost. Emilie has been working with Alice McCulley to prepare a plain language report for Tr'ondëk Hwëch'in Government.

Pia is working on simulating permafrost in heterogeneous steep bedrock slopes in western Canada and creating descriptive analysis of temperature and metrics related to permafrost thaw for important past slope instabilities.

Andrew Clark

Title: Early warning detection of slope failure to enable hazard forecasting.

Supervisors: Brian Moorman and Bernhard Rabus.

Andrew's project is focused on remote sensing of Arctic coasts in the Western Canadian Arctic. Specifically, his PhD research investigates the volumetric change along Arctic coasts by leveraging the availability of 3D data from ArcticDEM and UAV-SfM datasets. This work will be used to better understand the role of Arctic coastal erosion on the climate system and in carbon cycling. Further, Andrew's research introduces techniques for automating coastal feature extraction by using object-based image analysis, which creates boundary features for characterizing the coastal zone but also makes contributions to large scale monitoring of Arctic coastal erosion.

Erika Hille

Title: Understanding and prediction of thaw-driven flash flooding and water quality change.

Supervisors: Melissa Lafrenière with Steve Kokelj.

Erika's research looks at how and why the response of aquatic systems to permafrost thaw varies between contrasting permafrost landscapes across the Canadian Arctic.

The overarching goal of Erika's project is to develop a conceptual framework for characterizing the sensitivity and response of Arctic streams and rivers to permafrost thaw. Erika is addressing key gaps in our understanding of how landscape factors influence the hydrology and water quality of streams and rivers in the western Canadian Arctic. Erika's project is identifying the environmental catchment-level factors that control spatial variability in the biogeochemical responses of peatland stream catchments to ice wedge degradation. She is also examining how carbon-rich peatland tributary streams influence the biogeochemical response of river networks to retrogressive thaw slumping and investigating how permafrost thaw is modifying groundwater flow pathways to Arctic rivers in winter. Erika is carrying out community consultations with the Inuvik Hunters and Trappers Committee and the Tuktoyaktuk Community Corporation and collaborating with them on the project. Several rainfall events during early August 2018 led to an overland flooding event in Resolute. The community was forced to respond by trenching several roads in the community to drain flood waters from the vicinity of buildings. This project is quantifying and analyzing relationships between permafrost characteristics and ground ice across different geomorphic and vegetative settings, and integrating these results with slope and drainage conditions, potential erosion zones, hydrological change and the frequency and magnitude of flooding events. Through this research Erika is determining what type of active layer and permafrost conditions cause hydrologic systems to become flashier and more sensitive to changing precipitation.

Water samples were collected twice weekly from peatland streams along the Inuvik-to-Tuktoyaktuk Highway. In late-August 2022, a detailed water quality survey was conducted at Miner River, to determine the cumulative effects of retrogressive thaw slumping and peatland stream tributaries on fluvial chemistry. In collaboration with Northwest Territories Geological Survey (NTGS), spatial variability in the water chemistry of the peatland streams and the Miner River will be explained by regional variability in terrain features and permafrost conditions.

Danielle Chiasson

Title: Permafrost recovery in drained lakes and ponds.

Supervisors: Pascale Roy-Léveillée.

Danielle is identifying controls on permafrost recovery rates and limits in drained lake and pond basins. This project is working in Old Crow Flats, along with other network projects and members of the Vuntut Gwitchin First Nation, collecting peat samples and cores for study.

Old Crow Flats is an arctic lowland ecosystem within the continuous permafrost zone of northern Yukon. The region is composed of thousands of lakes, meandering rivers, and permafrost features. Most of the lakes are susceptible to change through erosion, expansion, and eventual drainage, leaving behind large drainage basins. This project is investigating the evolution of drained basins older than 100 years within the forest/tundra ecotone and comparing their evolution with recently drained lakes. There are two objectives 1) Characterize vegetation succession and post-drainage permafrost restoration of ancient lakes and 2) Examine whether the rapid landscape change we see today (last 100 years) is typical or accelerated by climate change.

The study sites are located on drained lake basins in the boreal forest/tundra ecotone in Old Crow Flats, Yukon, within the Traditional Territory of the Vuntut Gwitchin First Nation. Permafrost is 60 m thick in Old Crow Flats, with active layer thicknesses ranging from 25 to 55 cm at the study sites. The terrestrial surface of the tundra sites is dominated by a mixture of vertical shrub tundra and dwarf shrub tundra, as well as sphagnum-dominated peatlands. Remnant ponds in the basins support an abundance of aquatic macrophytes and floating mats. Peat samples have been collected from various basins for carbon dating, along with preliminary geophysics to determine whether permafrost is recovering within the basin since drainage. Further research includes reconstructing vegetation succession within the basins. Peat and sediment cores will be analyzed for macrofossils and pollen.

THEME 5 – Adaptation to permafrost thaw

Sheida Majidi

Title: Risk management of linear infrastructure in remote permafrost terrain: Churchill Railway.

Supervisors: Shawn Kenny with Ryley Beddoe, Pascale Roy-Léveillée and Fabrice Calmels.

Linear infrastructure is particularly at risk of damage related to frost heaving or thaw subsidence due to the extent and variety of permafrost conditions it may cross. Sheida's project is developing an integrated approach to monitor remote northern linear infrastructure to support operational decisions. The Churchill Railway, recently reopened after railbed failure, will make a strategic case study, allowing Sheida collaborate with others in Theme 5. Current rail inspection practices utilize visual techniques supplemented by NDT for the evaluation of rail track flaws and monitoring of changes in geometric characteristics, as well as light detection and ranging (LIDAR) and ground-penetrating radar (GPR) for the evaluation of the ballast profile and subsurface quality. However, new data (e.g. thermistors, UAV digital images) and tools (e.g. DIC, structure from motion) are needed to monitor and assess the railbed (ballast and foundation) conditions in permafrost regions, so that preventative maintenance activities (e.g. drainage, track geometry corrections) can be planned and sustainable adaptation strategies developed. Sheida is using geotechnical data obtained by drilling and geophysical surveys by GPR or electrical resistivity tomography (ERT) to define permafrost state. Remote sensing observations (optical, LiDAR, RADAR) from unmanned aerial vehicle (UAV) and satellite-based sensors are being used to estimate permafrost change and ground motion. Empirical and screening level computational tools will be developed to estimate risk for defined route segments under continuing climate warming. This knowledge base and tools will help to identify problem areas where more intensive work may be required, with consideration of hydrologic changes in peatlands.

Rae Landriau

Title: Timing of sump stability, western Arctic coast.

Supervisors: Chris Burn with Stephan Gruber, Trevor Lantz and Steve Kokelj.

During the 1960s and 1970s over 50 waste disposal sumps were constructed in the western Arctic during oil and gas exploration. These sumps were open pits during waste disposal, subsequently covered at closure. Permafrost, then at a mean annual temperature below -7 °C in most of the region was assumed to provide an impermeable containment medium in perpetuity. Warming of permafrost now denies this possibility. Management of these contaminated sites requires estimation of the time remaining before permafrost ceases to be an effective containment.

Rae is conducting a study of the ground thermal regime near two sumps in contrasting terrain, one in the outer Mackenzie delta and the other in the adjacent uplands, to establish the thermal regime around these structures. The project is sampling the sump materials to determine their freezing characteristics. Expertise from Theme 3 is assisting thermal modelling of the field conditions around the sumps and their projected future trajectory. The timescale associated with the thermal evolution of sumps and adjacent terrain is required for prediction of contaminant egress from these sumps. When calibrated with records collected in the region, these models will estimate if these structures are likely to be secure for decades or centuries. This is critical data for land managers in the region and for the national response to an undesirable consequence of permafrost warming. The main partner for this project is Steve Kokelj (Northwest Territories Geological Survey). In summer 2022 she carried out fieldwork with Tim Ensom, making field measurements at sites that are of direct significance to GNWT Lands. She is also working with the Inuvialuit Land Administration's sump monitoring round table.

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Adam Kirkwood

Title: Land use planning and mass-wasting hazards near Fort Severn and water quality change.

Supervisors: Pascale Roy-Léveillée.

Adam's project has 4 objectives.

1 – Identification of controls and triggering factors for mass-wasting along rivers of the Hudson Bay Lowlands (HBL).

2 – Production of maps indicating areas potentially vulnerable to slumping and currently affected by thermokarst.

3 – Production of a map of mercury (Hg) stores in the Ontario portion of the Hudson Bay Lowlands.

4 – Assessment of methylation and mobilisation (DOM and Hg) potential to adjacent water bodies in a range of thermokarst contexts.

Fort Severn is located on the Severn River, near the Hudson Bay Coast. Recent mass-wasting activity along the river has triggered local concern that the stability of the town site may be threatened by thaw induced landslides. In partnership with Fort Severn First Nation, Adam is characterizing and comparing surficial deposits and permafrost conditions at the town site and at the sites affected by mass-wasting and use remotely sensed imagery and local knowledge to investigate past mass-wasting events, their timing, and the factors that may trigger them. Potential early warning signs are being identified in collaboration with Theme 4. Conditions and slope failure characteristics will be compared to the controls on thaw slumps as identified by Theme 4 MSc project 3. Maps of ground conditions and associated mass-wasting risk are being produced to facilitate planning and risk mitigation measures. These findings are then being integrated into hazard mapping in Theme 4. The main partner for this part of Adam's project is Chief Paul Burke of Fort Severn First Nation.

Adam is also improving understanding of permafrost change contributing to water quality change via solute loading of surface waters, beginning with a review and compilation of available water quality data across a range of different environmental settings across the Canadian permafrost region to identify metrics of thaw-induced hydrochemical change. He is collaborating with network partners and investigators to deliver the first analysis of permafrost-water quality change as a benchmark for future studies. Field investigations focus on Churchill MB where permafrost coring in 2010-11 indicated the presence of high solute content in the uppermost ice-rich permafrost. This location, along with similar permafrost cores from nearby Arviat NU, indicate the potential for permafrost thaw to mobilize salts to surface waters in this region of the Hudson Bay Lowlands. This project is expanding permafrost sampling to detail near-surface ice and solute conditions, and to establish a network of hydrological monitoring and sampling to determine patterns of hydrochemical variations. Further, winter sampling of lakes across the area for water chemistry is being facilitated with support of the Churchill Northern Research Centre (CNRC) and the involvement of LeeAnn Fishback.

Adam is working on an inventory of peat and permafrost samples from 35 sites across the Hudson Bay Lowlands, installing monitoring equipment and collecting samples that are analysed at Western University for mercury concentrations. His work includes inventory of previous field sites, and the creation of a database of field observations and peat depths/stratigraphic profiles for future analysis of mercury storage in the Hudson Bay Lowlands and the profiling of microbial communities.

To facilitate the creation of a mercury inventory for the HBL, Adam is working with the Ontario Ministry of Natural Resources and Forestry (OMNRF) to develop a data sharing agreement for the procurement of additional chemical data in relation to the peat and permafrost cores provided by the partner.

Patrick Jardine

Title: Highway embankments and snow accumulation/manipulation, Blackstone Uplands.

Supervisors: Chris Burn with Fabrice Calmels and Pascale Roy-Léveillée.

Snow accumulation on the sides of embankments is a primary cause of permafrost degradation beside northern roads. Subsidence below the embankment leads to shoulder rotation and deterioration of infrastructure. These effects have been successfully arrested in numerical simulations where snow cover is cleared or compacted to a higher density.

In collaboration with TEB, Yukon Highways and Public Works, and the Na-Cho Nyak Dun First Nation, Patrick has conducted a field experiment in snow management to validate the projections of the simulations. Snow was compacted by snowmobile or removed from multiple sites in central Yukon; beside the Dempster Highway in the Blackstone Uplands over a 1 km test section, and near Mayo, and the resulting change in ground thermal regime was established in comparison with unaffected sites. Thermal monitoring was designed with assistance from Theme 2; characterization of permafrost at the embankment toe with help from Theme 1. The results will allow maintenance staff to assess if snow management is a cost-effective strategy to arrest permafrost degradation. Simulation, with assistance from Theme 3 and once calibrated for the field site, will be used to estimate minimum maintenance required to achieve thermal stability in the embankment. Sandra MacDougall (TEB) and Steve Kokelj (NWT Geological Survey) are the main partners of this project.

Payam Sharifi (GRADUATED)

Title: Assessing a Geocell-supported railway embankment subjected to permafrost degradation and ponding water conditions using numerical modelling techniques. (Completed project in March 2022).

Supervisors: Ryley Beddoe with Shawn Kenny, Pascale Roy-Léveillée and Jocelyn Hayley.

The Hudson Bay Railway (HBR) is a rail corridor in Northern Manitoba built across a range of permafrost terrain and peat conditions. Every year the Hudson Bay Railway experiences a significant number of differential deformations and embankment instabilities. Recently, HBR has used geocells, a common reinforcement technique in non-permafrost soils, to improve the support of railway on the degrading permafrost and underlying peat layer. Payam's project looked at thermo, hydro and mechanical processes using finite element analyses to examine and predict thaw deformations, settlement, and stability.

Payam's results found that using geocell reinforcement to reduce lateral deformation is most advantageous when the active layer was between 1 – 2 m below grade. Similarly, the stability of the embankment was improved up to 50% when using a geocell at the optimal height. Payam's research did find that the stability performance improvement using geocell will gradually diminish over the long term due to increasing dominance from permafrost degradation. This research has shown that the use of geocells in permafrost embankments can provide significant improvements to the design life of the embankment, and its application and use in future linear infrastructure designs in permafrost regions should be explored further. James Wilson and Brett Young (Arctic Gateway) are the main partners of this project.

Adeleh Moqadam

Title: Sustainable culvert design over degrading permafrost, Hudson Bay railway.

Supervisors: Shawn Kenny with Ryley Beddoe and Claude Duguay.

Recent washouts along the Churchill railway highlight how climate change has lowered the performance standards of linear infrastructure. Significant effort was made to restore the operation of the railway including installation of several culverts. With support from Sheida Majidi, Adeleh will first complete a characterization and investigation of several culverts, both original and recent installations, including characterization of permafrost and local hydrology. Culvert performance will also be assessed. The second stage of this project, conducted with assistance from Theme 3, will use computational simulations to predict culvert performance under continued and accelerated permafrost degradation. James Wilson (Arctic Gateway) and LeeAnn Fishback (CNSC) will be the main partners of this project.

Astrid Schetselaar

Title: Asset management of linear infrastructure in southern and central Yukon.

Supervisors: Chris Burn with Shawn Kenny and Fabrice Calmels.

Linear infrastructure can be subject to significant distress due to permafrost degradation and changes in hydrologic regimes associated with climate change. In collaboration with TEB, Astrid is interrogating existing cost databases for operation and maintenance of linear road infrastructure, extending current research on the north Alaska and Dempster highways to the remainder of the Yukon network. The focus is on costs that are directly related to climate effects. This will improve planning and capacity for rehabilitation and maintenance. Astrid is detailing the financial effects of climate change in permafrost terrain to complement physical effects investigated by other Theme 5 projects. Sandra MacDougall (TEB) is the partner on this project.