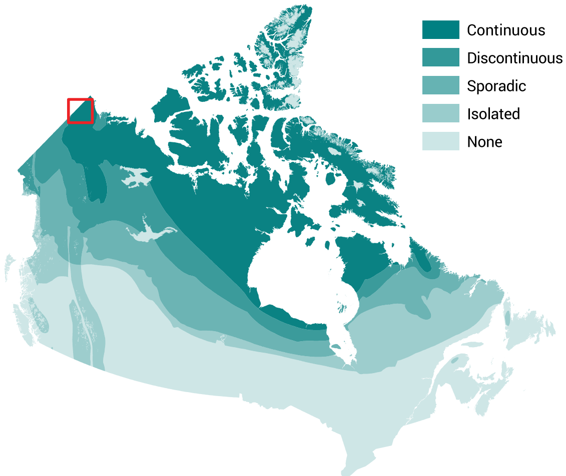
Mapping and understanding how ice conditions change in thermokarst lakes over multiple decades



Maria Shaposhnikova[1], Claude Duguay[1], and Pascale Roy-Léveillée[2]

1. University of Waterloo, Waterloo, Ontario, Canada.

2. Université Laval, Québec City, Québec, Canada.

Study locations: Old Crow Flats, northern Yukon.

Keywords: Lake ice, thermokarst lake, bedfast ice, lake drainage, satellite remote sensing, machine learning, neural network.

This research produces maps from a machine-learning algorithm that establishes where the ice in shallow lakes is frozen to the bed (bedfast ice) and where it is not (floating ice). The differences in ice conditions impact the stability or thaw of permafrost. The maps can be generated going back 30 years and reveal how fast and where changes are happening. Having such maps helps us understand why changes in environments such as the Old Crow Flats occur and predict how they might continue in the future. The maps can inform local knowledge holders and scientists on how observations at differing locations may be related.

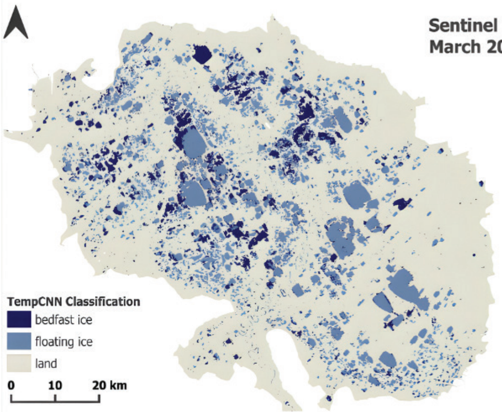


Figure 1. A map produced from a machine learning algorithm using a Synthetic Aperture Radar (SAR) image taken by the Sentinel 1 satellite in March 2021. The algorithm has classified the surface as either land, floating ice or bedfast ice. Maps have been produced from 1993 to 2021 and the machine learning algorithm can be applied in other permafrost regions.

Research summary

Lake ice changes in response to climate change. Many shallow Arctic lakes and ponds freeze to bed in the winter months, maintaining the underlying permafrost. As climate changes, fewer lakes are expected to develop bedfast ice, and this can accelerate permafrost thaw. To understand this, we need to know where the ice is bedfast, where it floats, and how these patterns change over time. This research has developed a method for making such maps based on satellite radar images. It produced maps for the Old Crow Flats from 1993 to 2021 that aligned well with field measurements and the Canadian Lake Ice Model. The maps show that the area covered by bedfast ice has increased over the 29 years, which is tentatively attributed to the catastrophic drainage of some lakes, lowered water levels, and a reduction in snowfall in the region.

Taking action

The next step for researchers following up on these findings would be to simulate the development of lowland thermokarst. Accurate maps of bedfast ice and lake extent allow for the tracking of lake drainages and early identification of catastrophic drainages and thermokarst events and processes, which scientists can use to predict future changes and also for the local community to employ mitigation and adaptation measures.

Connections to other projects

4 This project is part of Theme 3 — *Prediction of permafrost change*, and linked to other projects in Theme 4 — *Hazards and impacts associated with permafrost thaw*, such as those being conducted in Old Crow Flats by Danielle Chiasson, looking at permafrost recovery in drained lakes and ponds, and Nicole Corbiere, looking at mercury and methylmercury concentrations in drained basin complexes.

Regional synthesis

This work provides a strong baseline for future thermokarst lake ice dynamics analysis in the Old Crow Flats and beyond, as thermokarst lowlands cover approximately 20% of the northern permafrost regions and contain significant stores of soil organic carbon. Documenting transitions between bedfast and floating ice is crucial for understanding permafrost dynamics beneath shallow lakes and drained lake basins, with potential impacts on methane ebullition and the regional carbon balance, as well as affecting the livelihoods of the local community (e.g., fishing, trapping, and travelling).

Partners, team members and support

This research benefited from support from Nina Vogt, Louis-Philippe Roy, Caleb Charlie, and Cathy Koot (Yukon University), who collected field data in April 2021, Kevin Turner (Brock University), who provided a vegetation map of Old Crow Flats, and Nastaran Saberi (University of Waterloo), who provided technical support throughout the project.

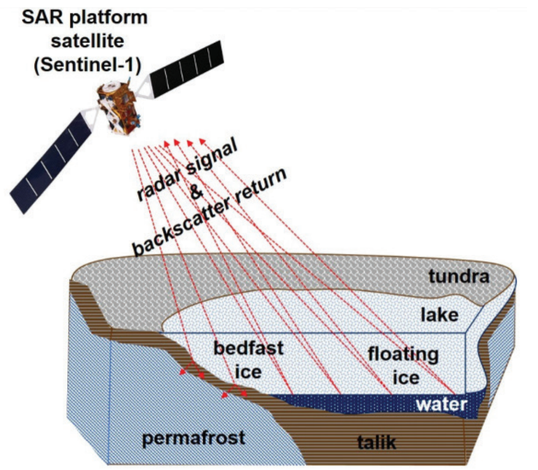


Figure 2. The components of tundra and lake landscapes and how a Synthetic Aperture Radar (SAR) satellite can detect the difference between land, floating ice and bedfast ice.

Acknowledgment, thanks and funding

This project recognizes Old Crow Flats as the traditional territory of the Vuntut Gwitchin First Nation and Aklavik First Nation and the Vuntut Gwitchin First Nation land claim agreement. The Old Crow Flats include Vuntut National Park, the Vuntut Gwitchin Category A Settlement Lands, and Special Management Area lands. Thanks go to the Vuntut Gwitchin First Nation and Yukon Government. This work was supported by the Natural Sciences and Engineering Research Council (NSERC) Alexander Graham Bell Canada Graduate Scholarship and NSERC PermafrostNet.

References

Shaposhnikova, M. (2021). *Temporal Deep Learning Approach to Bedfast and Floating Thermokarst Lake Ice Mapping using SAR imagery: Old Crow Flats, Yukon, Canada*. MSc Thesis, University of Waterloo. Available at: http://hdl.handle.net/10012/17414.

Shaposhnikova, M., Duguay, C., and Roy-Léveillée, P. (2023). 'Bedfast and floating-ice dynamics of thermokarst lakes using a temporal deep-learning mapping approach: case study of the Old Crow Flats, Yukon, Canada', The Cryosphere, 17, 1697–1721. Available at: https://doi.org/10.5194/tc-17-1697-2023.

PermafrostNet
NSERC | CRSNG