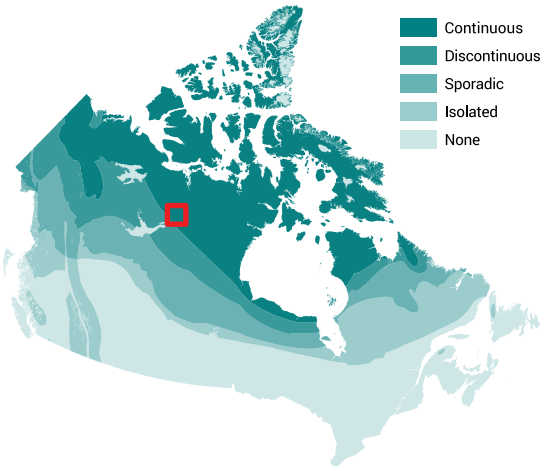
Numerical investigation of environmental controls on ice-wedge cracking



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Keywords: Ground ice, ice-wedge, permafrost modelling, ground surface temperature.

Study locations: Data are from KDI, north-east of Yellowknife, Northwest Territories

This project allows us to study how climate, soil type, and water saturation affect ice-wedge cracking. We evaluated the depth, width, and spacing of cracks, as well as the time of crack initiation and mechanical stress in the permafrost. The numerical model is an advancement over the previous analytical model as it allows us to use realistic climate and soil data as input. This can be particularly useful when studying ice wedges at a particular location. For example, researchers mapping wedge-ice distributions may use this model to estimate the depth of wedges throughout their study area.

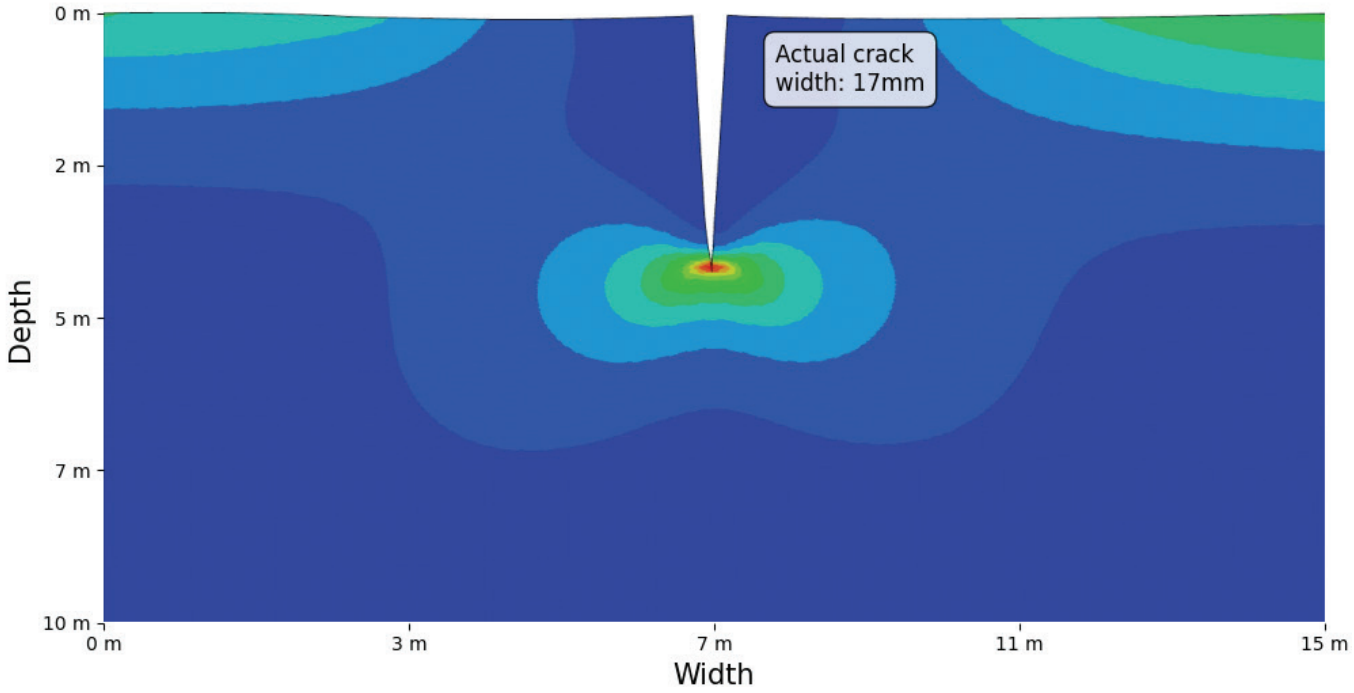

Figure 1. 2-D Simulated crack showing high levels of stress (red) around crack tip and zones of stress relief (blue). The deformation scale is exaggerated to clearly show the crack opening.

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Research summary

To date, the effects of complex environmental controls on the mechanics of ice-wedge cracking have not been quantified. Using the extended finite element method, we developed a 2-D model to explicitly represent the cracking process. Four soil types with different grain sizes and five temperature time series were used to drive the model. The results showed that colder average temperatures led to more cracking and larger cracks (Figure 2). Increased water saturation of the soil was also linked to an increased likelihood of cracking, and certain soil types led to greater cracking, but no specific trend was observed. Our results followed the expected trends from field studies and provided new insights into the driving mechanisms.

Taking action

This project can support ground-ice predictions and the improved modelling of mechanical permafrost behaviour.

Connections to other projects

This project is part of Theme 3 — *Prediction of permafrost* change and is helping to build a more comprehensive understanding of ground ice, complementing Theme 1 and 2 projects related to characterizing and mapping ground ice.

Partners, team members and support

Many colleagues at Carleton University and the wider NSERC Permafrost community provided advice, support, and feedback.

Acknowledgment, thanks and funding

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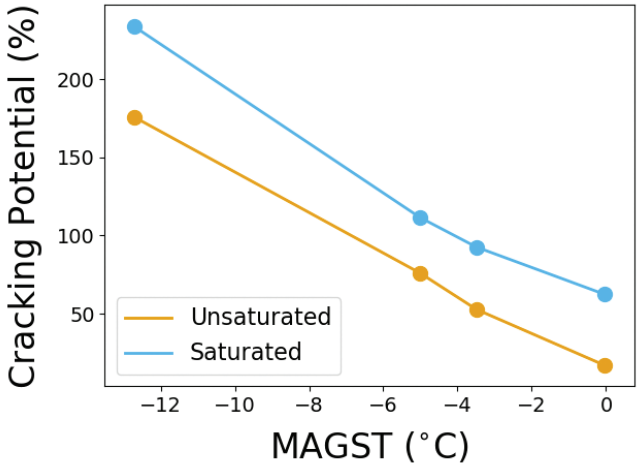

Figure 2. Near-linear trend of mean annual ground surface temperature (MAGST) versus cracking potential. Values greater than 100% indicate a very high likelihood of ice-wedge cracking.

References

Karam, G., Pouragha, M. and Gruber, S., (2024) 'Investigating the controls of ice-wedge initiation and growth using XFEM', *Computers and Geotechnics*, 173, p.106549. Available at: https://doi.org/10.1016/j.compgeo.2024.106549

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