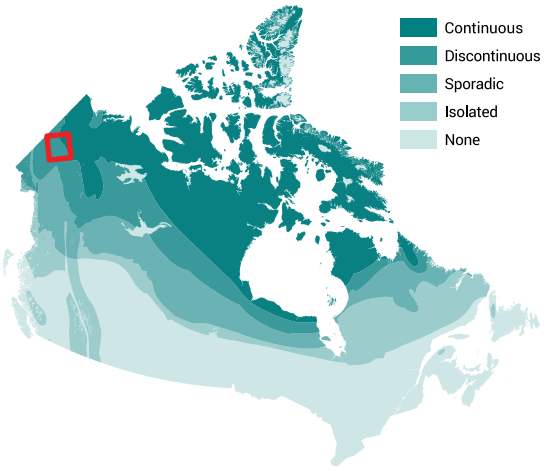
Reduction of ground surface temperatures beside road embankments by snow compaction in central Yukon



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Keywords: Snow, ground temperature, linear infrastructure, highway maintenance, Dempster Highway, climate adaptation.

Study locations: South Dempster Highway near km 96, and The Silver Trail and South McQuesten Road near Mayo, Yukon.

This project investigated snow compaction as a method for improving the thermal stability of linear infrastructure built in permafrost terrain. By increasing our understanding of the snowpack's response to compaction, the technique may be combined with other methods of snow manipulation, such as removal or snow fences, to maximize heat loss under site-specific field conditions. Ground temperatures are typically highest beside northern roads and underneath the shoulder due to snow accumulation, while the driving surface is cleared. Snow management aims to reduce this temperature differential and preserve permafrost to maintain embankment stability.

Figure 1. Left: Study site at Dempster Highway km 96; Right: Compaction of snow beside the South McQuesten Road.

Research summary

Deep snowbanks trap heat in the ground due to their low thermal conductivity, increasing the risk of permafrost degradation alongside northern highway embankments. Thermal modelling has shown that snow compaction may mitigate this risk. Field experiments were conducted in tundra and taiga environments to measure how compaction influenced the physical properties of the snowpack and reduced ground surface temperatures. Snow was compacted in winter 2020–21 with snowmobiles at forested plots near Mayo and above the tree line on the Dempster

Highway. Snow depths were reduced overall by 29 cm near Mayo and 9 cm along the Dempster, where the snow was hard and wind-packed. Despite the difference in snow conditions, mean temperatures at the compacted plots were 2–3°C lower than at undisturbed plots at both sites. The results suggest that snow management may be a viable method of lowering ground surface temperatures.

Taking action

This shows that snow compaction may be effective at lowering ground temperatures when snow cover is relatively deep (>50 cm). Further work is required to assess its efficacy under snow conditions of varying depth, hardness, structure, temperature, and replenishment rate; as well as to optimize the method and frequency of compaction. Research aimed at better understanding how the thermal conductivity of depth hoar changes at varying stages of metamorphism, as well as the force required to crush a depth hoar layer under different snow conditions would help identify areas where compaction may be effective in tundra.

Connections to other projects

This project is part of Theme 5 – Adaptation to permafrost thaw and is connected to Emma Stockton's research investigating the ground thermal regime of highway embankments in permafrost. The project is also related to other network studies on linear infrastructure that include modelling the impact of surface materials e.g. gravel vs vegetation, on the thawing of frozen ground and subsequent settlement of infrastructure by Khatereh Roghangar (Theme 1), exploring ways of monitoring permafrost thaw near linear infrastructure in the Yukon using Synthetic Aperture Radar and optical data by Usman Iqbal (Theme 2).

Partners, team members and support

This project was conducted in collaboration with the First Nation of Na-Cho Nyäk Dun (NND) and Yukon Highways and Public Works. Field assistance from Jennifer Humphries, Emilie Stewart-Jones (Carleton University), Fabrice Calmels and Louis-Phillipe Roy (Yukon University) is acknowledged with gratitude.

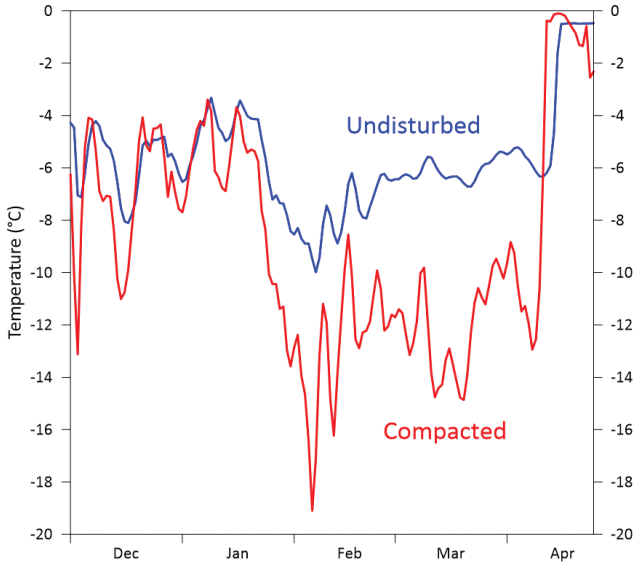

Figure 2. Winter ground surface temperatures at two plots along the South Dempster Highway. At one plot the snowpack was compacted by snowmobile at approximate monthly intervals between December 4, 2020 – April 28, 2021. The other was left undisturbed.

Acknowledgment, thanks, and funding

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References

Jardine, P.A., Burn, C.R., Humphries, J.K., Peter, B., Hope, G., Phillips, J. and McLaren, L.D., (2024). 'Snow management to reduce ground temperatures beside a road in the boreal forest near Mayo, Yukon', in Beddoe, R. and Karunaratne, K. (eds.) 12th International Conference on Permafrost Proceedings. 12th International Conference on Permafrost, 16-20 June 2024, Whitehorse, Yukon, Canada. Available at: http://dx.doi.org/10.52381/ICOP2024.75.1

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