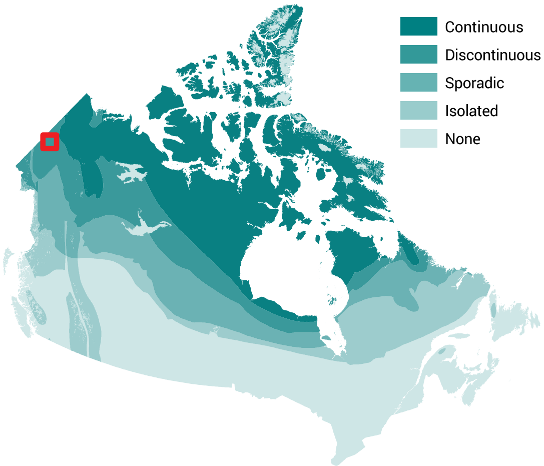
Modelling subarctic air temperature inversions for better simulations of permafrost



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Study locations: Dawson City, Yukon.

Keywords: Temperature inversion, lapse rate, atmospheric reanalysis data, permafrost simulation.

Our model allows the dynamic representation of inversion events in subarctic valleys. This improves the simulation of permafrost changes in places where inversions of air temperature occur. With our method, we can use reanalysis data (globally available from 1948 until today) for driving simulations of permafrost change at different elevations and in high spatial resolution. This approach is versatile and future-proof because it extends the use of reanalysis data to areas with strong inversions but few long-term meteorological observations.

Figure 1. Dawson City and the Yukon River. During winter inversions, the air near the valley bottom here is much colder than higher up. Our model now allows to process reanalysis data so that this effect is more accurately captured. With this, permafrost change can be simulated in the valley bottom as well as in the surrounding slopes. Photo credit Mehdi Pouragha.

Research summary

Once the model is calibrated with local weather observations, it only relies on global reanalysis data and hence can be applied in the vicinity of the calibration site, even where no observational data is available. It can be applied for all years with reanalysis data, not just those with local observations. This enables us to better represent air temperature in subarctic valleys subject to strong and frequent temperature inversions. Producing reliable time series for air temperature in such complex terrain is essential in modelling permafrost and understanding its future evolution. This research is currently tested against observations in other valleys so that it can be further refined for application in other areas. Our research in Dawson demonstrated that a dynamic representation of inversion events in subarctic valleys is possible with reanalysis data.

Taking action

This model paves the way for improved and more accurate results of permafrost simulations in subarctic valleys. Valleys subject to temperature inversions are generally colder than expected at the bottom. However, climate change not only produces increasing air temperatures but also weakens inversions, thereby affecting differing places unequally. The next steps in this research would be to simulate permafrost spatially, and to extend simulations with future climate scenarios.

Connections to other projects

2 3 This project is part of Theme 3 — *Prediction of permafrost change* and can be linked to project *Simulation-based climate services for permafrost environments* by Galina Jonat when simulating future climatic scenarios.

Partners, team members and support

We thank Nick Brown for his support with data science, and Derek Cronmiller and Panya Lipovsky for shared field work and for their support in finding existing field data.

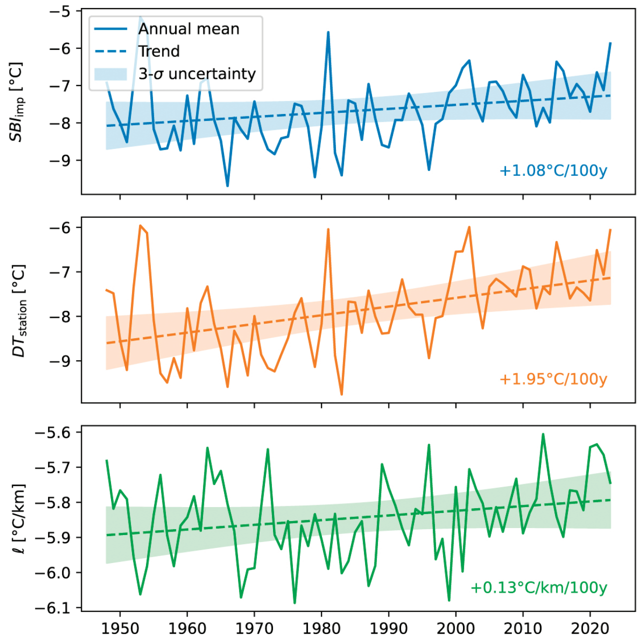

Figure 2. Mean annual values and trends of surface-based inversion impact (SBI_imp), inversion strength (DT_station), and the upper atmosphere lapse rate (l). The first two rows confirm a weakening of inversion strength. The temperature profile of the troposphere above Dawson City is also subject to a gentler lapse rate. This shows that atmospheric warming differs between elevations and seasons, even in one valley. Note that due to the inversion metrics definitions, strong inversions correspond to strongly negative values and hence positive trends correspond to a weakening of the inversions.

Acknowledgment, thanks and funding

This work was performed on the traditional territory of the Tr'ondëk Hwëch'in First Nation and supported by the governments of Yukon and British Columbia, the Digital Research Alliance of Canada, as well as NSERC PermafrostNet, and an NSERC Discovery Grant.

References

Pozsgay, V., and Gruber, S (2025) 'Modelling the temporal dynamics of subarctic surface temperature inversions from atmospheric reanalysis for producing point-scale multi-decade meteorological time series in mountains', *Arctic Science*, 11, pp. 1-16. Available at: https://doi.org/10.1139/as-2025-0027