Climate change affects landscape freeze-thaw but not in the same way everywhere, study shows

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As any resident of northern climates knows, a seasonal thaw is never straightforward. The freeze-thaw process can last over a period of months and historically was mitigated by predictable air temperature and snow cover depth.

Climate change, however, warms the air and thins the snow, and therefore can affect this cycle. According to a new study by Concordia researchers published in the journal *Scientific Reports*, this can have major impacts on greenhouse gas emissions in the north and urban infrastructure in the south.

Using a new statistical framework and by analyzing datasets from the National Snow and Ice Data Center, Princeton University and the Dorval, Quebec-based Canadian Meteorological Centre, the researchers demonstrate how increasing air temperatures and decreasing snow cover work in tandem to increase the effects of climate change in a non-linear fashion, meaning that they work to amplify the overall impact felt on the ground.

Furthermore, they affect Quebec's distinct ecological regions differently, presenting policy makers and residents with unique problems.

"The historical data shows there is a vivid divide between Quebec's northern areas and the southern parts of the province, where the majority of Quebec's population and assets reside," says Ali Nazemi, an associate professor in Concordia's Department of Building, Civil and Environmental Engineering, and the principal investigator of the project and co-author of the paper. The paper's lead author is Concordia graduate Shadi Hatami, Ph.D. 21, currently a postdoctoral fellow at McGill.

Compounding problems

The researchers note that air temperature, snow cover and freeze-thaw cycles are closely linked. A thick layer of snow acts as a blanket for frozen soil in winter. As the snow cover decreases, the warmer air penetrates the ground and thaws begin earlier.

In the far northern regions of the province, such changes result in fewer days of frozen soil, meaning that there is an increased likelihood of a release of thousands of tons of greenhouse gases like carbon and methane into the atmosphere.

These added gases will act to intensify the effects of climate change.

Further south, in the more densely populated areas around the St. Lawrence river valley, there will be more transitional days during the winter season, when the soil experiences a thaw and a freeze, with water repeatedly expanding and contracting as temperatures rise and drop. This will pose an added strain on already fragile road, bridge and water infrastructure.

"By calculating these non-linear responses, we can try to quantify how many fewer frozen days we will see in the north and how many more transitional days we will see in the south under changes in temperature and snow depth conditions," says Nazemi.

"This provides us with a way to approximate how many more tons of gases will be released into the atmosphere and how much more deterioration of our infrastructure we can expect."

A quick reversion is also possible

Just as rising temperatures and thinner snow cover leads to amplified thawing across the province's ecological zones, the authors point out that the reverse is also true, although with less intensity than warming.

In fact, lower air temperatures and more snow cover can also lead to amplified freezing and faster rebound, where the number of frozen days in the north and the number of transitional days in the south would revert closer to the historical average.

Nazemi believes this paper's strength depends on its powerful mathematics and the amount of data made available through various technologies such as satellite remote sensing.

Many previous studies have predicted a rise in greenhouse gas emissions from thawing permafrost, but these were often based on attempts to replicate the physics of the phenomenon in small areas with many assumptions.

The new method relies on the probability theory and statistical function based on data gathered from 25km x 25 km scale pixels of Quebec's territory.

"We brought this newer mathematical analysis to quantify some factors that had not been quantified before," he says. "We are now in the process of upscaling this methodology to cover the entire area of Canada and Alaska."

More information: Shadi Hatami et al, Compound changes in temperature and snow depth lead to asymmetric and nonlinear responses in landscape freeze–thaw, *Scientific Reports* (2022). DOI: 10.1038/s41598-022-06320-6

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