Groundwater and tundra fires may work together to thaw permafrost

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Permafrost peatbog border. Storflaket, Abisko, Sweden. Credit: Dentren/Wikipedia

Groundwater may play an unrecognized role in thawing Arctic permafrost following wildfires, according to new research.

The new study reveals that, after wildfire burns off a portion of organic rich soil that normally insulates permafrost, summer warmth penetrates deeper into the frozen soils, allowing groundwater to flow downgradient and potentially contributing to greater release of greenhouse gases.

The study's lead author, ecohydrologist Samuel Zipper from McGill University and the University of Victoria (Canada), will share his findings on 22 October at the Geological Society of America Annual Meeting in Seattle, Washington.

Conventionally, Zipper says, researchers tend to estimate permafrost thaw by vertically measuring thawed soil depth at single locations, offering a one-dimensional perspective of the aftereffects of fire on the Arctic landscape.

Instead, he suspected that groundwater might play an unrecognized role in the process, where it thaws permafrost in other areas after flowing through once-frozen soils. Once wildfire burns through the organic-rich soil that usually insulates permafrost, summertime temperatures can reach deeper into the frozen ground, contributing to even greater thaw.

"What's interesting to me," says Zipper, "is if you burn one location, how do other parts of the landscape respond to that fire? Can groundwater flow transmit the impacts of burning from one spot to another by moving water and heat through the subsurface?"

To explore the question, Zipper and his colleagues ran over 20,000 simulations of the largest Tundra fire in recorded history: Alaska's Anaktuvuk River Fire, which scorched over 400 square miles. They ran simulations both with and without groundwater flow to tease out its contribution to permafrost thaw following fires. Zipper suspected that, after summertime temperatures penetrate the permafrost, groundwater would flow more rapidly, delivering a greater amount of water into

nearby streams.

They found that, indeed, wildfire does lead to deeper permafrost thaw, which is enhanced by groundwater flow. But, surprisingly, more water evaporated following fire, so there was less overall groundwater flow reaching the stream.

"Even though the water was able to flow more rapidly," says Zipper, "there was actually less water being supplied to the subsurface because of this change in evaporation. We found this kind of interesting dynamic where there was more room for water to flow, but less water available to flow."

Additionally, the results suggest that wildfire may trigger a positive feedback loop of permafrost thaw. When permafrost thaws simply from the Sun's warmth, groundwater flows from the thawed soil into more permafrost, melting it, which releases more groundwater to thaw more permafrost. Zipper suspects that fire could prematurely set this loop into motion and intensify its effects.

To follow up on the results of the study, Zipper plans to work with data from more Alaskan field sites, which will help him determine the pervasiveness of the phenomenon. "We want to know, how real and widespread is this process?"

Permafrost contains many organic compounds left by long-dead but not degraded frozen plants. Thawing permafrost releases greenhouse gases from those compounds into the atmosphere, which further intensifies warming. The Arctic is among the most rapidly warming regions on Earth, and hotter summers tend to bring more fire-prone vegetation, according to Zipper.

To properly manage and protect these landscapes, Zipper says it's

important to form a complete picture of their response to fire, and incorporating groundwater into that picture is essential.

"Our findings show that you can't really understand how permafrost is going to respond to disturbances like fire without understanding what's happening in the groundwater system," says Zipper. "Groundwater is a component of the Arctic's water cycle that's been under appreciated just for lack of data. It's kind of the next frontier for figuring out what's going to happen in the Arctic's future."

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