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Scientists say deepening Arctic snowpack drives greenhouse gas emissions

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The ITEX snow fence experiment at Toolik Field Station in Alaska. During the pandemic, UCI's Claudia Czimczik and colleagues still found a way to collect data at the station using a UCI-built emissions detector. Amanda Young / Toolik Field Station

Human-caused climate change is shortening the snow cover period in the

Arctic. But according to new research led by Earth system scientists at the University of California, Irvine, some parts of the Arctic are getting deeper snowpack than normal, and that deep snow is driving the thawing of long-frozen permafrost carbon reserves and leading to increased emissions of greenhouse gases like carbon dioxide and methane.

"It is the first long-term experiment where we directly measure the mobilization of ancient carbon year-round to show that deeper snow has the possibility to rather quickly mobilize carbon deep in the soil," said Claudia Czimczik, a professor of Earth system science and the lead author of the study, which appears in *AGU Advances*. "Unfortunately, it supports the notion that permafrost carbon emissions will be contributing to already-rising atmospheric CO_2 levels."

Fieldwork for the study took place at the International Tundra Experiment (ITEX) at Toolik Lake in Alaska, an experiment started in 1994 by study co-lead author Jeff Welker of the University of Alaska. The original goal of the experiment, Welker explained, was to understand how deeper snow would affect Arctic tundra ecosystems.

Over the last several years, the joint UCI and Alaska team carried out fieldwork at the ITEX site and found that a common Arctic ecosystem—tussock tundra—had turned into a year-round source of ancient carbon dioxide. This was a result of thawing permafrost buried under snow where the snow has been three to four times deeper than the average long-term snow depth since 1994.

When the research started, neither Welker's team nor climate scientists thought that the deeper snow experimental treatment would lead to such a rapid thawing of the permafrost.

"These findings suggest that the stability of permafrost in Arctic Alaska, and possibly globally, can respond rather rapidly to changes in Arctic winter snow conditions, where winter can be up to eight months long," said Welker. "Winter climate feedbacks like this are a tundra characteristic not previously recognized and fully appreciated."

The team's findings, Czimczik explained, suggest that even if humanity stopped emitting planet-warming gases like carbon dioxide immediately, emissions from Arctic sources would still continue.

"The implications are that if the climate models are right and the observations continue to show an increase in snow, then in addition to the strong warming, the snow will greatly accelerate emissions from permafrost," said Czimczik. "I was very concerned when I saw the data."

Until now, climate change models that help groups like the Intergovernmental Panel on Climate Change forecast different climate change scenarios do not take emissions from permafrost into account in part because those emissions are hard to quantify. But Czimczik and her team built sensors at UCI and were able to directly measure permafrost carbon emissions at their Arctic field site.

"We weren't sure if we would be able to see permafrost carbon emissions in the field," said Czimczik. "However, we can even see the ancient carbon emissions during the summer," when carbon emissions from plants should be dominant.

Former UCI Earth System Science Ph.D. student Shawn Pedron and University of Alaska postdoctoral researcher Gus Jespersen visited the site in 2019 to install the sensors.

"Collecting the data in the remote Arctic was quite difficult but also very memorable," said Pedron. "The result that ancient carbon is mobilized in soil insulated by snow is what we had expected to find from our earlier work, but we were also surprised to find how much more carbon overall was in the area of enhanced snow."

"Having an experiment in place for nearly 30 years, especially one that focuses on winter conditions, is such a rarity in the Arctic," said Jespersen. "That timeframe has given us a unique window into one possibility for the future Arctic, and it's been sobering to witness and document the cascade of ecosystem changes that have all resulted from simply having more snow on the ground."

Current climate change is causing snow and ice to retreat across much of the Arctic. But the same warming driving the retreat is also driving increased evaporation, and therefore, precipitation in certain regions. Deeper snow acts like a blanket, insulating the ground that warmed up in the summer from cold air temperatures. This causes the permafrost to thaw, which allows microorganisms to consume the previously frozen organic matter and, in the process, release planet-warming gases.

"Permafrost emissions are likely going to start earlier than we expected," said Czimczik.

Czimczik added that she hopes a growing awareness of the threat of emissions from natural sources will further encourage people to curb emissions from other sources that are under human control. "It's an opportunity for individuals, but also CEOs and governments, to decrease emissions and invest in carbon capture solutions, and we need to do an even better job than we thought since permafrost emissions will make us miss our greenhouse gas and temperature target."

More information: S. A. Pedron et al, More Snow Accelerates Legacy Carbon Emissions From Arctic Permafrost, *AGU Advances* (2023).
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