PHYS.ORG

How a warming Arctic is accelerating global climate change

July 26 2024

Credit: Northern Arizona University

Three recent papers authored by Ted Schuur, Regents' professor of biological sciences at Northern Arizona University, and other researchers around the world, organized through the Permafrost Carbon

Network, investigate the biological processes taking place in the warming Arctic tundra and provide insight into what we can expect from that region as the climate continues to change.

The world's most northern ecosystems, including the northern circumpolar permafrost region, are an important storage reservoir of organic carbon. Although this region, which includes the tundra and much of the boreal forest, contains only 15% of Earth's soil area, it stores around one-third of the world's soil organic carbon.

Just like water, carbon cycles through Earth's ecosystems, some being pulled out of the atmosphere by plant photosynthesis (a process known as uptake), and some being released into the atmosphere through other biological processes such as decomposition. The natural processes that release carbon into the atmosphere are collectively known as ecosystem respiration.

Currently, permafrost ecosystems are warming three to four times faster than the rest of the planet, which is resulting in increased carbon cycling and increased respiration in the region. Although human activities are still the dominant contributor of greenhouse gas emissions to the atmosphere, researchers expect additional emissions from the Arctic permafrost to accelerate future climate change by 10%–20%, with an anticipated impact comparable to a large, industrialized nation by 2100.

Increased emissions projections from the permafrost region are poorly accounted for in the targets set by the Paris Agreement, an international treaty adopted by 196 countries in December 2015 to limit global warming. These future emissions from permafrost are not accounted for in the targets that 196 countries set as part of the Paris Agreement. That means that global and national carbon emissions cuts will have to be more ambitious in order to account for permafrost thaw and still meet agreed-on temperature targets.

Researching respiration

Schuur and his scientific collaborators have undertaken the critically important task of collecting and analyzing data from the permafrost region to better understand the factors that affect ecosystem respiration at sites across the globe.

In one study, published in *Nature Climate Change*, the researchers analyzed multiple decades of annual carbon dioxide flux data from 70 sites in both permafrost and non-permafrost ecosystems, including summertime data from 181 ecosystems. They found that non-permafrost systems store additional carbon with increases in summer plant growth, but in permafrost ecosystems, carbon losses in the fall and winter were substantial enough to be offset by similar increases in summer uptake.

"This analysis of long-term field measurements helps us to develop a more complete picture of carbon cycling in the North and how it's changing as temperatures rise," said Sue Natali, a co-author of the study and senior scientist at Woodwell Climate Research Center. "We're seeing permafrost areas release more carbon in the fall and early winter than they used to, a consequence of rising temperatures and deeper thaw during the summer."

Natali leads Permafrost Pathways, which heads the ABCflux database project that contributed to this study.

In another article published in *Nature* on April 17, researchers compiled data from 56 experiments at 28 tundra sites that used miniature greenhouses to simulate warming, then synthesized their results to get a better sense of how future warming may impact the region. They found that a mean temperature increase of 1.4°C in the air and 0.4°C in the soil produced a 30% increase in ecosystem respiration.

Both studies also pointed to local environmental factors—such as water and nutrient availability—that caused variations in carbon uptake or respiration at the different sites.

The data from these studies are helping to provide a specific and detailed understanding of carbon cycling in response to warming in the permafrost region and the feedback to climate change—information that can be used to inform global policy creation to reduce human greenhouse gas emissions in order to limit global warming.

"Experiments such as these expose natural ecosystems to environmental conditions that we expect to occur in the Arctic in the future," Schuur said. "These data, collected from experiments across the entire region, give us an insight of how the Arctic region will act to accelerate future climate change as stored permafrost carbon is released to the atmosphere in the form of carbon dioxide and methane greenhouse gases."

Decades of data and counting

Research into permafrost ecosystems is ongoing, and as researchers collect more data, they can draw better informed conclusions about carbon cycling. In the *Nature Climate Change* analysis, researchers addressed the contradictory findings of previous research comparing carbon dioxide uptake with carbon dioxide loss based on measurements taken between 1990 and 2009.

Since that time, the number of sites collecting in fall and winter has increased tremendously, and using the additional data, the Nature Climate Change analysis found that in permafrost ecosystems, non-growing season carbon losses exceed growing season uptake. In other words, the permafrost region is becoming a source of atmospheric carbon—one that the researchers expect to increase over time.

The globally collaborative nature of this research adds complexity to collecting, analyzing and drawing conclusions from permafrost data. In a third paper published in *Nature Climate Change* on April 30, Schuur and his co-authors explained the repercussions of the loss of access to permafrost sites and their data as a result of the Russian invasion of Ukraine.

The full network of Arctic carbon flux monitoring sites accounts for 55% of the landscape variability across the entire permafrost region and provides 50% more information compared to a network with the 27 Russian sites removed. Building 27 new sites in North America to mirror the lost environmental space would help regain up to 80% of the information in the full network, the researchers wrote, but it would not make up for the data gap that exists, because some ecosystems within Russia do not have North American analogs.

More information: Craig R. See et al, Decadal increases in carbon uptake offset by respiratory losses across northern permafrost ecosystems, *Nature Climate Change* (2024). DOI: 10.1038/s41558-024-02057-4

S. L. Maes et al, Environmental drivers of increased ecosystem respiration in a warming tundra, *Nature* (2024). DOI: 10.1038/s41586-024-07274-7

Edward A. G. Schuur et al, Russian collaboration loss risks permafrost carbon emissions network, *Nature Climate Change* (2024). DOI: 10.1038/s41558-024-02001-6

Provided by Northern Arizona University