Examining the impact of climate change on Siberia's stores of permafrost

March 1 2021

Dr Sebastian Breitenbach exploring possible passages in an ice-filled cave in Siberia. Credit: Northumbria University, Newcastle

Northumbria University is to play a leading role in a major study to assess the long-term impact of global warming on Siberia's thawing permafrost.

Permafrost is frozen ground that stores vast amounts of fossil carbon. Given that permafrost holds twice as much carbon as the atmosphere, and that almost a quarter of the Northern Hemisphere is covered in permafrost, this frozen land plays an essential role in stabilizing climate change.

Thawing permafrost is considered one of the key climate tipping elements that would lead to long-term irreversible changes to global climate. However, today's warming global temperatures mean permafrost is beginning to thaw and release greenhouse gases into the atmosphere.

Northumbria University is home to a team of world-leading academics specializing in reconstructing climate and environmental changes through the millennia. They have been awarded a Leverhulme Trust Research Project Grant of £489,000 to reconstruct Siberia's climate over the past 500 to 800 thousand years and estimate the long-term fate of Siberia's permafrost under today's rising temperatures.

The researchers will work in partnership with experts from Germany's Alfred Wegener Institute Helmholtz Center for Polar and Marine Research (AWI) in Potsdam.

A record high of 38 degrees was reported in Eastern Siberia in June 2020. This led to an unprecedented number of wildfires in the region, releasing further carbon into the atmosphere. The links between wildfire and permafrost stability are complex, but evidence suggests that permafrost thaw and degradation has tripled in recent years in response to more and hotter fires.

The four-year study will assess how Siberia's permafrost expanded and contracted in response to the changing climates of the past, and the role of the cold glacial and warmer interglacial periods.

The study will be the first to collectively combine the archives of permafrost ice, cave deposits and crustacean fossils to reconstruct past temperatures and regional climate histories. Previous studies have only examined these archives individually.

Permafrost ice originates from, and preserves, atmospheric precipitation, meaning it holds records of winter and summer temperatures. The composition of the ancient permafrost ice samples will allow the researchers to decipher the climate conditions at the time the ice formed. In a similar vein, cave deposits can inform on the long-term mean temperature changes, and crustacean fossils tell the story of the summer temperature, each containing an important climate archive.

The researchers hope the holistic view obtained by combining findings from each of these archives will give new insights into how temperatures changed, which can help to reveal seasonality changes in the past.

The team have found several sites which they describe as having great promise to provide them with the important samples and data they need from caves, ice and lake deposits.

They will use tiny shallow lakes and permafrost ice from the Arctic seaboard, from the Batagay Megaslump and the Mamontova Gora site in Central Yakutia; the Botovskaya Cave in southern Siberia; and the so far unstudied Kirensk Karst region, more than 500 miles northeast of Lake Baikal.

Caves hold crucial evidence of past environmental conditions. Carbonate formations known as speleothems can only grow when water flows into the cave from the soil above. As in permafrost all water is frozen, this means speleothems could only have grown at a time when the climate was warmer and the land above the cave was not frozen.

The fossils of tiny shrimp-like creatures, known as ostracods, also hold much promise for the research team. At just 0.5 to 2 mm in size, ostracods only live for a few months in summer and build a carbonate shell similar to mussels. The fossilized carbonate shells from shallow ponds in the permafrost region will provide researchers with an archive of data on the temperatures at the time they were formed.

Thanks to a recent investment in a mass spectrometry lab in the Department of Geography and Environmental Sciences at Northumbria, the researchers will use a method known as clumped isotope geothermometry to extract details on the isotopic composition of the fossilized carbonate shells and reconstruct northern Siberia's summer temperatures across the millennia. Similarly, the team will use speleothems to explore the long-term temperature development during interglacial periods.

Dr. Sebastian Breitenbach, Vice-Chancellor's Senior Fellow in Northumbria University's Department of Geography and Environmental Sciences said: "The Siberian permafrost formed mainly, but not exclusively, during cold periods, known as ice ages or glacials, in the last two million years, while at least some of the permafrost thawed during warm stages, known as interglacials.

"If we look at temperatures in Siberia today, we see that they vary by up to 90 degrees across the year, from -60 in winter up to approximately 30 degrees in summer. However, we need to see this seasonal amplitude in proxy. Was the change in temperature always the same as we know it today, or was it different in the past? How much warmer were past summers, how different the winters?

"We know that the way permafrost responds to climate change and long-term climate controls appears to be more complex than simply reacting to warmer or colder temperatures. We therefore believe that if we can provide evidence on the interplay of temperature and precipitation on a seasonal scale, we can answer the crucial question of whether past permafrost formation and degradation can be attributed to specific climate conditions or seasonality patterns.

"This study will enable us to reconstruct climate conditions and hopefully create a new understanding of whether the past formation, and especially degradation, of permafrost can be attributed to specific temperatures or seasonality patterns."

Dr. Hanno Meyer, Head of the Stable Isotope Facility at AWI Potsdam and expert for isotope-based permafrost palaeoclimatology said: "The combination of multiple isotope signals from several climate archives across East Siberia offers an exciting possibility to unravel past climate dynamics on different temporal and spatial scales for both glacials and interglacials.

"Combining this palaeoclimate information with geological evidence of permafrost formation, stability or degradation will help us to identify potential thresholds in different climate parameters that were responsible for the response of the permafrost system to past climate changes. This knowledge will help us to estimate the future effects of Global Warming on the permafrost in East Siberia and the consequences for local communities as well as the feedback mechanism to the global climate system."

Dr. Breitenbach added: "With the installation of our new mass spectrometry lab, Northumbria becomes one of just four universities in England to be able to undertake the detailed clumped isotopic tests required to reconstruct these temperature conditions. We are very excited to begin to use our new equipment and establish Northumbria as a leading center for geothermometry and carbonate research."

Provided by Northumbria University