Winters in Siberian permafrost regions have warmed since millenia

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Aerial photo of the Lena delta, taken during a summer expedition in July 2012. Credit: Volkmar Kochan/rbb

For the first time, researchers at the Alfred Wegener Institute have successfully decoded climate data from old permafrost ground ice and reconstructed the development of winter temperatures in Russia's Lena River Delta. Their conclusions: over the past 7,000 years, winter temperatures in the Siberian permafrost regions have gradually risen. The study will be published today on *Nature Geoscience*'s website.

You won't find any glaciers in Russia's Lena River Delta. Unlike in Antarctica or Greenland, in the Siberian tundra ice doesn't form above ground on hillsides or elevated plains. Rather, it forms directly underground as ice wedges.

"Ice wedges are a typical feature of permafrost regions. They are formed when the permanently frozen soil contracts in response to intensively cold winter temperatures, causing it to crack. When the snow melts in spring, the melt water fills these cracks. Since the ground temperature is roughly minus ten degrees Celsius, the water refreezes immediately. If this process repeats itself winter after winter, over the decades and centuries an ice body shaped like a giant wedge is formed," explains Dr Hanno Meyer, a permafrost researcher at the AWI Potsdam and first author of the study.

With a depth of up to 40 metres and a width of up to six metres, the ice wedges of the Siberian Arctic may not be as physically impressive as Antarctic glaciers. However the ice wedges, some of which are more than 100,000 years old, store climate information in much the same way, allowing scientists to investigate them using glacier research methods. "The melt water always comes from the snowfall of a single winter. Therefore, when it freezes in these frost cracks, information on the winter temperatures in that specific year is also preserved. We have now succeeded for the first time in using oxygen isotope analysis to access the temperature information stored in the ice and compile it into a climate curve for the past 7,000 years," states AWI researcher and co-author Dr Thomas Opel.

Exposed ice wedges at the coast of the Siberian island Muostakh. With this picture in mind, one can understand, why early researchers thought ice wedges could be nothing else than buried glaciers. Credit: Thomas Opel, Alfred-Wegener-Institut

The new information represents the first well dated winter-temperature data from the Siberian permafrost regions and indicates a clear trend: "Over the past 7,000 years, the winters in the Lena River Delta have steadily warmed - a trend we haven't seen in almost any other Arctic climate archive," says Hanno Meyer. As the permafrost expert explains, the likely reason is: "To date, primarily fossilised pollen, diatoms and tree rings from the Arctic have been used to reconstruct the climate of the past. But they mostly record temperature information from the summer, when the plants grow and bloom. Ice wedges are among the few archives that can exclusively record winter data."

Further, the new data will allow the researchers to fill an important gap: "Most climate models indicate a long-term cooling in the summer and long-term warming in the winter for the Arctic over the past 7,000 years.

But until now, there has been no temperature data to support the second claim, essentially because the majority of climate archives record information from the summer. Now we can finally demonstrate that ice wedges contain similar winter-temperature information as predicted by climate models," says AWI modeller and co-author Dr Thomas Laepple.

At this point, the researchers can't exactly determine yet how many degrees the Arctic winters have warmed. As Thomas Opel explains, "The results of the oxygen isotope analysis can only tell us whether and how the isotopic composition has changed. If it rises, it indicates a warming. But the exact extent of warming is something we can't yet make a statement on."

Nevertheless, the researchers found clear indications for the causes of this warming.

According to Hanno Meyer: "The curve shows a clear partitioning. Up to the dawn of industrialisation around 1850, we can attribute the development to changes in the Earth's position relative to the sun. In other words, the duration and intensity of the solar radiation increased from winter to winter, causing temperatures to rise. But with industrialisation and the strong increase in the emissions of greenhouse gases like carbon dioxide, this was supplemented by the anthropogenic greenhouse effect. Starting at that point, our data curve shows a major increase that clearly differs from the gradual warming in the previous phase."

In a next step, the researchers will investigate whether the same indicators for a gradual rise in winter temperatures in the Arctic can also be found in other permafrost regions around the globe. As Thomas Opel elaborates: "We already have data from an area 500 kilometres east of the Lena River Delta that supports our findings. But we don't know how it looks for example in the Canadian Arctic. We suppose the development was similar there, but don't yet have evidence to back up that assumption."

The data for the new Lena River Delta temperature curve comes from 42 ice samples, which AWI researchers collected over the course of several expeditions from 13 ice wedges that the river had uncovered during flooding. "For the purposes of the study, we only included samples for which we could clearly determine the age. Fortunately, for ice wedges this is relatively simple as a large number of plant remains and other organic material enters the ground ice during snow melt- and we can use the radiocarbon method to precisely determine the age of this material," says Hanno Meyer.

More information: Long-term winter warming trend in the Siberian Arctic during the mid- to late Holocene, *Nature Geoscience*, Vol 8, DOI: 10.1038/ngeo2349

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