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Climate change · Permafrost

PERMAFROST IS WARMING AT AN ALARMING RATE

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Teaser

Worldwide permafrost temperatures rose on average by 0.30°C over a ten year period from 2007 to 2016 most notably in the Russia North. Permafrost warming has drastic consequences for global climate but also for infrastructure in arctic communities and for the livelihood of the four million people that live there.

Keywords

Permafrost, warming, climate change, Arctic, Russia, infrastructure, temperature, ice

7% of the Earths land surface area is underlain by permafrost. Permafrost regions cover ¼ of the land area within the Northern Hemisphere including large parts of Russia, Canada, Alaska, as well adfs the high mountain regions such as the European Alps and Tibet. Permafrost areas, particularly those within the Arctic, are symbiotic with the people that live there with an estimated four million people currently living on top of Arctic permafrost. Indigenous nomadic tribes have historically exploited permafrost as a cold storage unit for the long term preservation of food and drink. Infrastructural developments often take place on top and within permafrost exploiting its rigidity. These include streets, oil-, water- and sewage pipelines, airports, but also vast swathes of housing and industry. Permafrost thawing would result in irreversible damage to infrastructure and facilities constructed upon it.

Besides its local and certainly costly impacts on arctic communities, permafrost thawing could potentially have a disastrous impact on the global climate since permafrost reacts quickly to changes in air temperature. Even what most people consider small increases in

air temperature over a longer period of time can warm up and eventually lead to thawing and loss of permafrost. The potential impacts on the global climate system are that alarming because of the so-called “permafrost carbon feedback”.

Release of greenhouse gases

Permafrost soils are a vast source of organic carbon containing an estimated 1400 gigatons of frozen carbon in the form of buried plant and animal remains. What would happen if this frozen carbon begins to warm? When the permafrost soil warms above 0°C and begins to thaw, bacteria start to break down organic material such as plant and animal remains locked in permafrost. This leads to the release of carbon dioxide and methane gases which subsequently enter the atmosphere, drastically increasing the greenhouse effect for the entire global climate system. Some studies estimate that this process could lead to a 0.13 to 0.27°C temperature increase by 2100 (Schuur et al., 2015).

In order to deepen our knowledge about permafrost thawing and its global impact, we and an international team of scientists have carried out a long-term permafrost research worldwide. Our study used permafrost temperatures measured in boreholes included within the Global Terrestrial Network for Permafrost (GTN-P) (Biskaborn et al., 2019).

The scientists involved in the project continuously measured permafrost temperatures in 154 permafrost boreholes distributed globally over a long time period (2007 to 2016). In order to remove the effect of seasons on permafrost temperature, borehole temperatures were measured at 10m depths below the ground surface. Boreholes are key to track fluctuations in permafrost temperatures. Boreholes are vertical holes drilled in the Earth´s surface that can be used to study a whole variety of Earth processes. For example boreholes can be lined and used for permafrost temperature measurement or other observations of rock and sediment physics.

Fig. 1: Typical permafrost landscape of central Siberia. Permafrost warming will lead to dramatic changes in these already variable landscapes. (Photo: Stuart Vyse)

Our results are alarming. Because it turned out that permafrost, which is ground at or below 0°C for at least a two year period, is warming rapidly at a global scale. Of all of the boreholes measured and included within the study, 71 recorded dramatic permafrost warming, with 5 already showing permafrost thawing with measured temperatures above 0°C. Twelve boreholes were seen to cool, whilst the rest remained unchanged. Two

boreholes at sites in northern Siberia (Samoylov Island and Marre Sale) showed an exceptional rise in permafrost temperature. In both of them a 1°C temperature increase was observed since 2008.

Permafrost warming was the greatest in the high arctic

The largest rise in permafrost temperature was seen in the region of almost complete permafrost cover (90-100%), the so-named "Arctic continuous permafrost zone". We found out that temperatures there increased by an average of 0.39°C from 2007 to 2016. In comparison, the more southerly discontinuous permafrost zone consisting of less than 90% permafrost coverage, suffered a smaller but none-the-less significant 0.20°C temperature rise over the same time frame.

But why is permafrost warming between these two zones different? Several effects are responsible for this.

The most important signal came from comparing air temperature and snow thickness data with the temperature changes observed within permafrost. Air temperature increase could explain the strong warming of the northern continuous permafrost. In the more southerly zone of discontinuous permafrost increases in snow depth as well as the shift of the onset of snow to earlier months of the year could play a large role in controlling permafrost temperature.

However, the so-termed "latent heat effect" is also contributing to the fact that simply cold permafrost is warming more rapidly than permafrost that has already warmed. When the permafrost temperature gets close to zero and parts of the ice are melting, the energy is firstly absorbed by the phase change from ice to water. This process is causing a zero curtain effect best visible in seasonal time series data. Studies using satellite images of widely distributed thermokarst lakes within arctic permafrost areas have shown that these water bodies are also expanding rapidly, a sure sign of increasing permafrost thaw on a large scale. Thermokarst lakes are lakes created by melting permafrost.

Permafrost in high mountain areas also warmed up

Permafrost warming was however by no means limited solely to the arctic. Permafrost in boreholes in the global high mountain regions of Europe, Nordic and Central Asia warmed up by 0.19°C. One borehole in the Aldan mountains of Yakutia, Siberia witnessed an astonishing 1.15°C temperature rise at 25m depth. High mountain regions containing permafrost such as in Asia or Europe play a huge role in supplying water to some of the world's biggest economies". China for example depends strongly on rivers that receive the majority of their water from high altitude permafrost regions in Tibet. But it is hard to know exactly how rising permafrost temperatures and thaw would affect the water balance and hence water supply to these countries in the future.

Subsidence and damage to communities

Fig. 2: Poor Infrastructure in regions such as Yakutia will suffer further due to increasing permafrost thaw. (Photo: Stuart Vyse)

The direct impact that permafrost thawing will have on the livelihood of the 4 million people that live within the Arctic cannot be overstated. Over wide areas of Russia the increase in summer active layer thickness resulting from warming is already leading to building subsidence and economic damage on a large scale. Buildings within industrial cities can be seen in places to be slowly consumed by expanding wetland areas. Two Russian students who took part on the "Chukotka 2018" expedition of the Alfred Wegener Institute highlighted the need for better understanding of permafrost thawing: “Our towns and villages are living with the ever increasing threat of at any time sinking into the ground. The future of our communities looks bleak if we do not address permafrost warming and thaw”.

If permafrost continues to warm and thaw, many communities across the arctic will be threatened and may be eventually forced to migrate due to uninhabitable conditions. This will put pressure on other regions that will already be feeling the effect of increased carbon input to the atmosphere from permafrost release through global warming.

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