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Published October 5, 2020

How thawing permafrost could fuel climate warming

The Arctic is warming more than twice as fast as the rest of the world, and some scientists believe that thawing permafrost — ground frozen since the last Ice Age — is about to release enormous amounts of climate-warming emissions.

❒ Permafrost can contain the remains of plants and animals, including woolly mammoths and woolly rhinos from the last Ice Age that ended more than 11,000 years ago. As permafrost thaws, that organic material begins to decompose.

❒ What is permafrost?

In the coldest regions of planet Earth, ice binds together soil, rock, sand and organic matter. This layer of permafrost can begin just centimeters below the Earth's surface.

- ➠ The "active layer" is topsoil that freezes and thaws seasonally.
- ➠ Permafrost is frozen ground, and often contains the remains of dead plants and animals.
- ➠ Unfrozen ground is also found in permafrost regions

❒ Where is permafrost?

Anywhere cold enough to keep the ground frozen year-round for at least two years counts as permafrost. About a quarter of the Northern Hemisphere contains permafrost.

- ➠ Beneath boreal and alpine forests permafrost can be patchy and sporadic.
- ➠ The Arctic tundra is where much of the world's permafrost is found.
- ➠ Underneath the Arctic Ocean, permafrost can be found in the seabed.

❒ How deep is permafrost?

Permafrost depth depends on several factors: the air temperature, precipitation patterns, and plant and tree cover. Permafrost can be as deep as 1,500 metres (4,900 feet).

- ➠ Discontinuous permafrost is found in patches.
- ➠ Continuous permafrost is where almost all of the ground is frozen.

❒ Permafrost deterioration begins with the active layer

➠ Thin active layers are found mostly in the High Arctic, with its short, cool, summers. As temperatures rise, active layers deepen.

➠ Thicker active layers are found further south, sometimes beneath boreal forests. These layers also can have more dry bedrock, sand or gravel.

❒ Protection on the surface is being destroyed

➠ Forests and plants insulate and cool the ground below but more frequent and hotter fires are wiping out this protective layer

➠ Peat is organic matter. It is a powerful insulator and slows permafrost thaw. Peat also stores a huge amount of carbon, so when it burns, it emits large amounts of greenhouse gases.

❒ Changes above can offer clues to deterioration below

➠ Ice wedges form when the frozen ground cracks. When they melt, ponds can form.

➠ Taliks are thawed areas surrounded by permafrost. They are often found at the bottom of a lake or river.

➠ Thermokarst is the pitted relief that forms on the surface of the ground where permafrost has degraded.

➠ Pingos form when water below the surface of the ground freezes and expands, pushing permafrost into conical, hill-like formations.

❒ Climate change is throwing permafrost regions out of balance

➠ Heavy summer rains are increasing, soaking the landscape, warming the ground and speeding up permafrost thaw.

➠ Human activity can also destabalise permafrost and anything built on top of it. Everything from underground pipes to tree cutting generates heat.

➠ A changing climate is also melting sea ice, exposing permafrost along the coast to warmer waters, storms and waves

Just centimeters below the Earth’s surface is a ticking time bomb that could detonate as global temperatures rise. It's called permafrost.

Permafrost is found at high altitudes in mountains such as the Himalayas, the Andes and the Southern Alps of New Zealand, as well as at the poles in Antarctica and, especially, in the Arctic.
Permafrost is a lot like concrete. In permafrost, ice binds together soil, rocks, sand and organic matter. Some of that organic matter includes the remains of plants and animals that have been frozen since the last Ice Age, more than 11,000 years ago.

Now, human-induced climate change – caused by the buildup in the atmosphere of greenhouse gas emissions from industrial activity, mainly the burning of coal, oil and natural gas - is raising global temperatures and driving heat waves that can cause permafrost to thaw. And as permafrost thaws, the organic matter locked within it is starting to decompose, a process that releases even more climate-warming carbon dioxide and methane into the atmosphere.

Scientists estimate that permafrost in the Northern Hemisphere alone holds about 1.5 trillion tonnes of carbon. That's twice what is in the atmosphere now, and three times more than what humans have emitted since the Industrial Revolution began.

For now, the permafrost emissions are being absorbed by plants and trees and fueling their growth. But soon, scientists say, the emissions will be so high that the trees won't be able to keep up.

How bad will it get?

Measuring changes in the permafrost is extremely challenging. Imagery and measurements taken by satellites can only tell us so much. Scientists also drop instruments into boreholes and measure greenhouse gas levels at the ground surface to learn what's happening in the permafrost.

Permafrost really varies: some areas are mostly rock while others are mostly ice. Thaw in each of these cases has vastly different outcomes for carbon emissions.

The Intergovernmental Panel on Climate Change (IPCC) has laid out several possible trajectories for cumulative emissions up to 2100 in order to help guide policymakers. Those trajectories, last updated six years ago, envision a range of scenarios from aggressive attempts to rein in man-made, climate-warming emissions – the scenario recommended by scientists to keep average global temperatures from rising more than 2 °C above pre-industrial levels – to a scenario in which emissions continue unchecked. This 'business as usual' scenario could see temperatures rise by about 5 °C by the end of the century.

For the maps in this graphic, Reuters is using this highest – and perhaps most likely – emissions scenario.

Currently, the world is following the unchecked-emissions trajectory, with the burning of fossil fuels in electricity production, manufacturing and transportation responsible for the bulk of emissions today. Efforts to bring down emissions could be frustrated by the additional greenhouse gas burden from climate change impacts such as thawing permafrost; the IPCC scenarios don't account for this phenomenon.

❒ Permafrost covers almost 20 million square kilometers, or about five times the size of the European Union. With unfettered industrial emissions, nearly half of the world's near-surface permafrost is expected to thaw within 20 to 40 years, according to an analysis published in March 2019 in the Nature journal Scientific Data.

❒ About a quarter of the Northern Hemisphere is covered by permafrost. It's found mostly in the Arctic and high mountains. Further south, permafrost is generally patchy, sporadic and isolated.

Near-surface permafrost – permafrost in cold regions that sits close to the Earth's surface – stretches across northern Russia and Canada and much of Alaska.

In the scenarios where climate change policies stabilize greenhouse gas emissions, nearly half of the near-surface permafrost in the Northern Hemisphere could be lost towards the end of the century.

❒ With unfettered emissions, two-thirds of near-surface permafrost could be gone by 2080.

A global concern

Permafrost plays a key role in balancing the planet's temperature by freezing carbon-rich organic matter - a bit like frozen compost - and preventing its decay. When permafrost thaws, that decay starts up again, emitting carbon dioxide and methane.

Scientists fear that permafrost emissions - whatever the mix of carbon dioxide and methane - will outpace trees' ability to absorb them.

There is more than three times as much carbon frozen in permafrost as in all of the forests on the planet, including the Amazon, scientists say.

Cycle of permafrost thaw

❒ Emissions from thawing permafrost contribute to atmospheric concentrations of greenhouse gases, further fueling global warming.

➠ Greenhouse gases in the atmosphere trap heat and raise temperatures globally.

❒ As temperatures rise, the 'active layer' deepens and permafrost thaws. The remains of plants and animals long frozen also begin to thaw.

➠ Active layer layer deepens, thawing the permafrost with carbon-rich organic matter.

➠ Tree growth occurs with deeper active layers, more nutrients and warmer temperatures.

❒ The organic material decomposes, emitting carbon dioxide, and, when oxygen isn't present, methane.

❒ These greenhouse gases enter the atmosphere, amplifying global warming and spurring plant and tree growth. For now, plants and trees are absorbing most of the carbon emitted by permafrost. But it is unclear how much longer they can do this.

❒ The greenhouse gases are emitted largely by microbes, as they feed on thawing organic material in the permafrost. But plants and trees that die due to heat stress or fire also contribute; not only do the plants and trees stop absorbing carbon, they also release carbon they've accumulated.

❒ The best way to prevent permafrost from thawing is to limit climate change by reducing fossil fuel emissions and protecting forests, scientists say. But once permafrost thaws, there's nothing that can be done to stop the carbon from being released.

Northern exposure

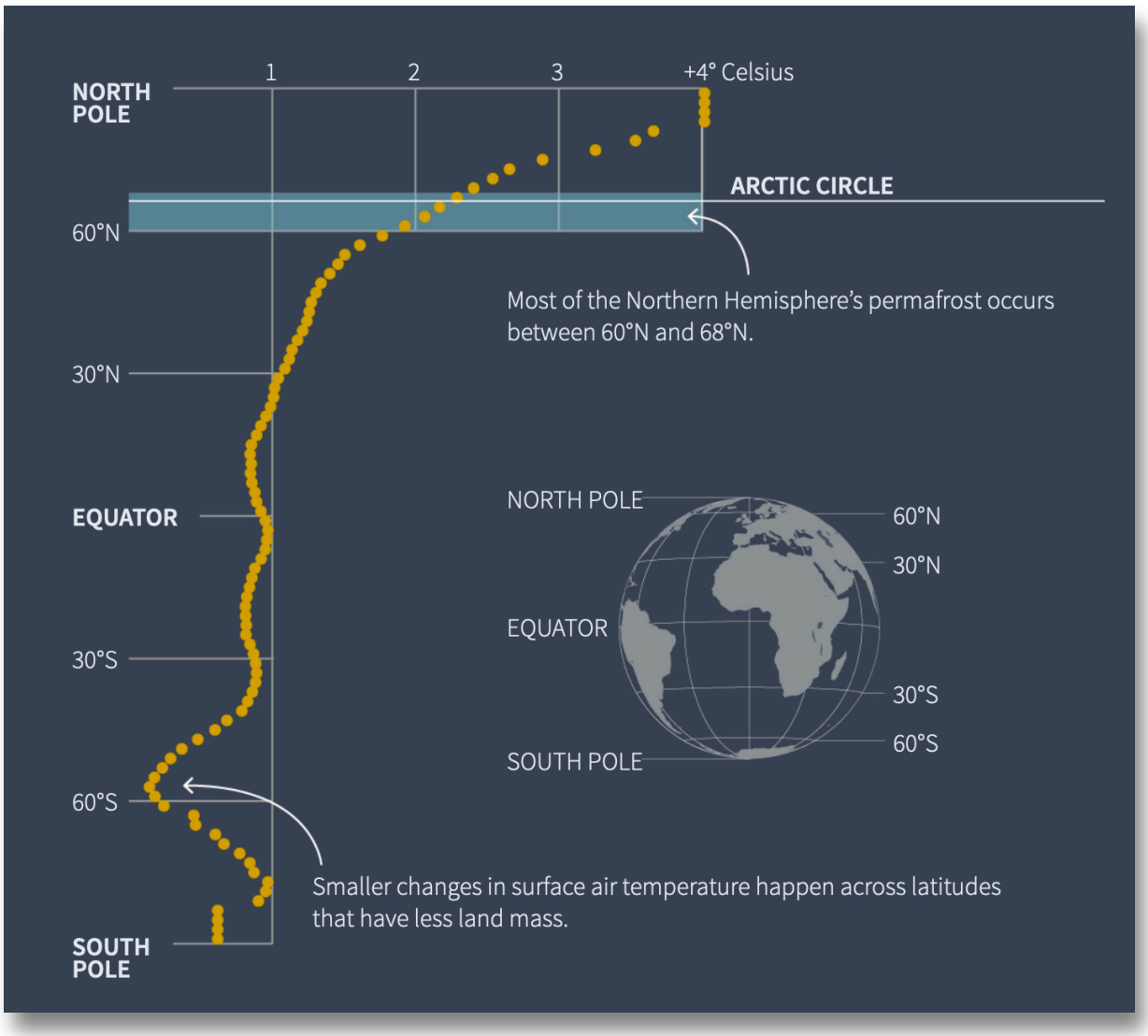
❒ Warmer temperatures in the Arctic are causing snow and ice to disappear.

❒ As ice covering the sea shrinks back, it exposes darker waters that absorb solar radiation rather than reflecting it back out of the atmosphere. This is called the albedo effect, and helps explain why the Arctic region is warming so much faster than the rest of the world. This chart shows how much average surface air temperatures have changed at different latitudes since 1960.

The Siberian Arctic town of Verkhoyansk in June registered a record high temperature of 38 degrees Celsius (100.4 Fahrenheit) during a prolonged heat wave.

Record fires have also engulfed vast swathes of Siberian Russia, emitting more carbon dioxide than Switzerland or Norway do in a year.

The boreal forests of the Arctic have evolved to survive and thrive from occasional fires that would



naturally occur every few decades or centuries in the region. But the more recent fires are different, scientists say. They are starting months earlier than they ever have before, and are smoldering through the winter as underground 'zombie fires.'

The more intense fires are also burning up peat bogs. A forest might grow back in a few decades and reabsorb the carbon it released when it burned; a peat bog is the accumulation of thousands of years of partial decomposition.

Trouble in the Arctic

Permafrost has long been a solid base for construction, but a thawing Arctic is changing that. When the frozen ground thaws, it shifts and subsides unpredictably.

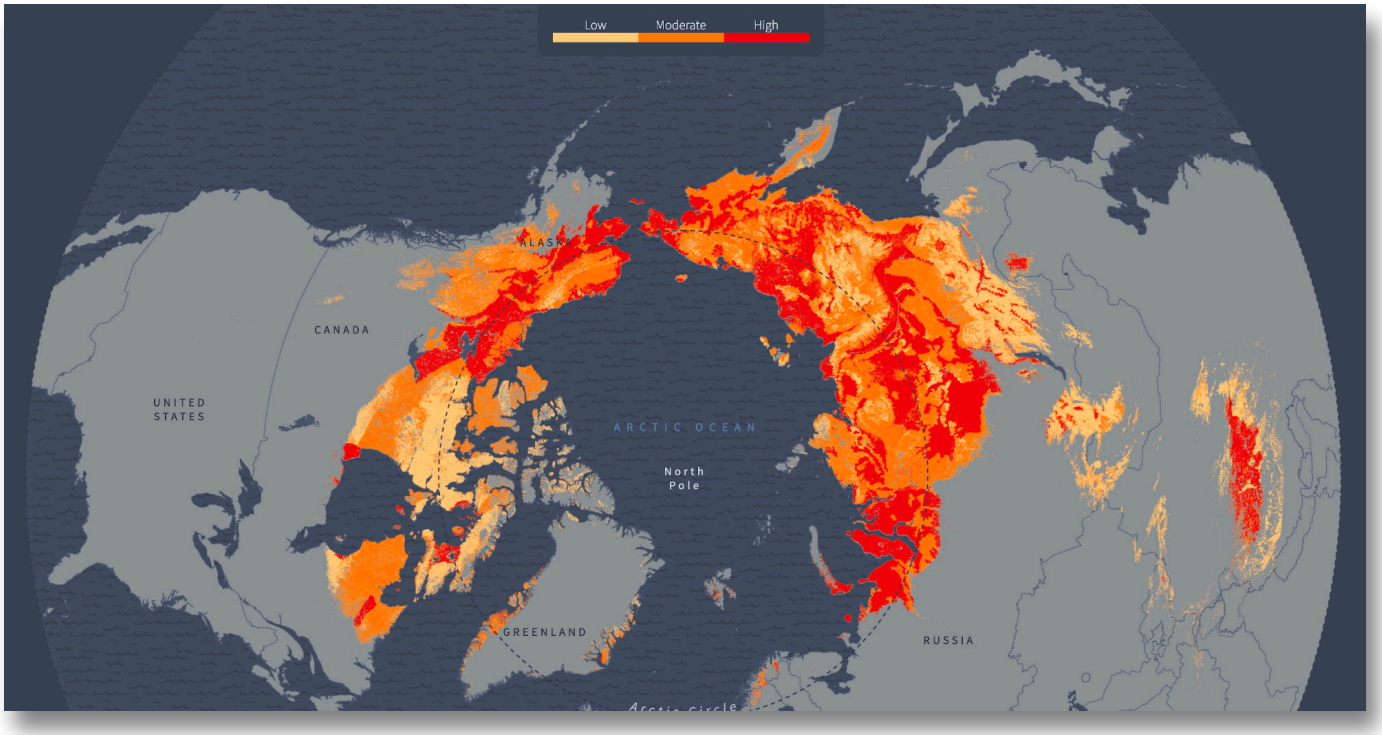
A fuel tank at a power station run by a nickel mining company in the remote Russian city of Norilsk lost pressure on May 29 and leaked 15,000 tonnes of diesel into the local river system and an additional 6,000 tonnes into the surrounding subsoil.

The company's billionaire co-owner, Vladimir Potanin, blamed thawing permafrost driven by climate change as one reason for the spill, saying it eroded the tank's foundation.

In a 2018 study published in Nature, scientists found 69% of all Arctic infrastructure could be at risk of damage by mid-century due to thawing permafrost. More than 3.6 million people live in the areas that will be affected.

Potential risk of infrastructure damage

Severity of risk for near-surface permafrost areas as measured under the 'business as usual' scenario where no additional climate change measures are in place by 2080



Scientists already have found dramatic signs of permafrost thaw: in Siberia, giant craters are forming as gases from decomposing matter build up underground and then explode.

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