The Arctic Carbon Time-Bomb is Triggered

Thawing Far North and Arctic Permafrost

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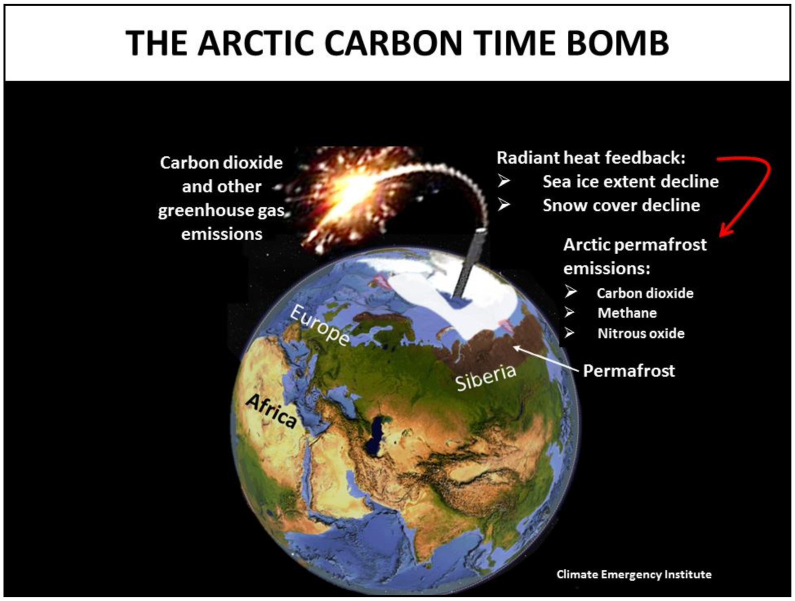
Permafrost Distribution (NASA)

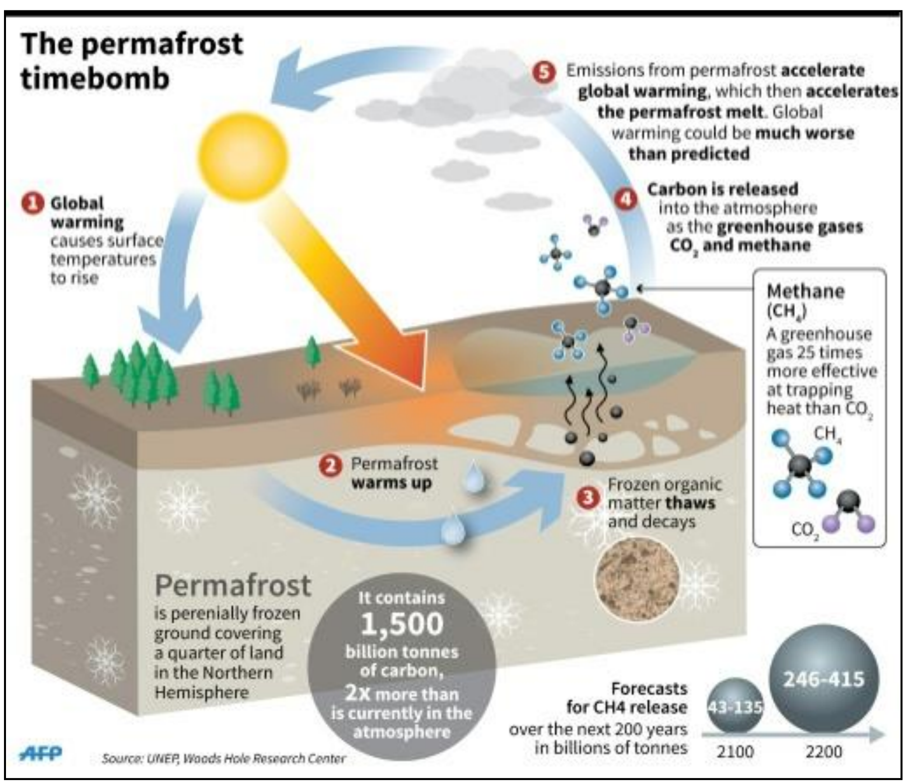
Permafrost Distribution Arctic Polar View

Thawing permafrost due to global warming with Arctic amplification is a literal planet time-bomb, and a prime component cause of runaway global change.



Permafrost greenhouse gas feedback emissions

Due to amplified arctic warming thawing permafrost is emitting all three major greenhouse gases methane carbon dioxide and nitrous oxide. Recent research shows that the amounts of each of these emissions are greater than had been assumed.



The Arctic warming is more than double global warming

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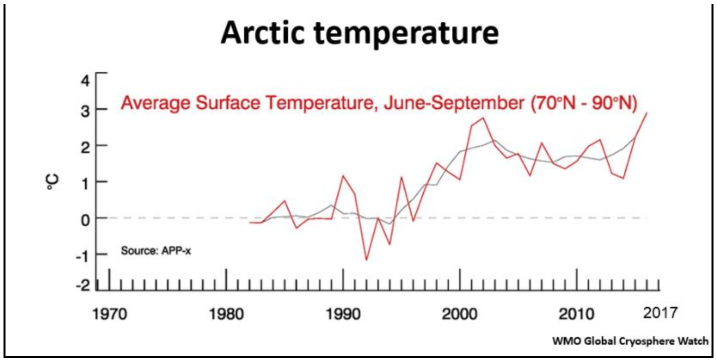
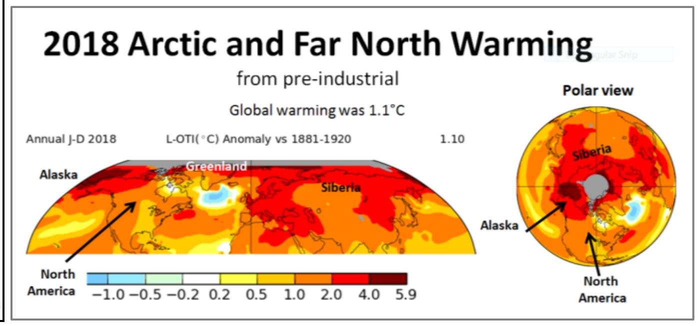




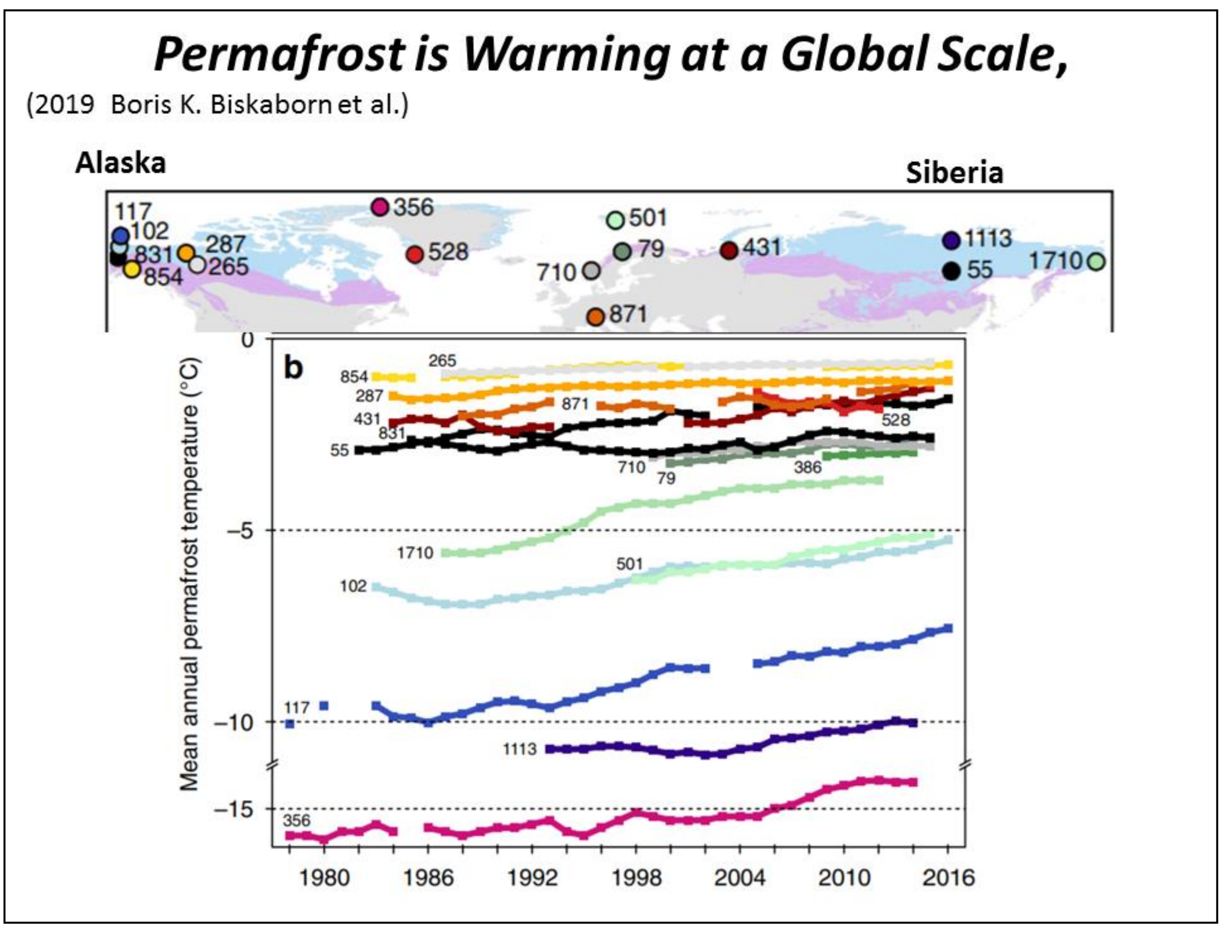
Permafrost warming

Direct measurements show that permafrost is warming globally.

Permafrost is warming at a global scale, (2019 Boris K. Biskaborn et al.)

During the decade between 2007 and 2016, … globally, permafrost temperature increased by 0.29 ± 0.12 °C. The observed trend follows the Arctic amplification of air temperature increase in the Northern Hemisphere.

Carbon release resulting from permafrost degradation will potentially impact the Earth's climate system because large amounts of carbon previously locked in frozen organic matter will decompose into carbon dioxide and methane. This process is expected to augment global warming by 0.13–0.27 °C by 2100 and by up to 0.42 °C by 2300

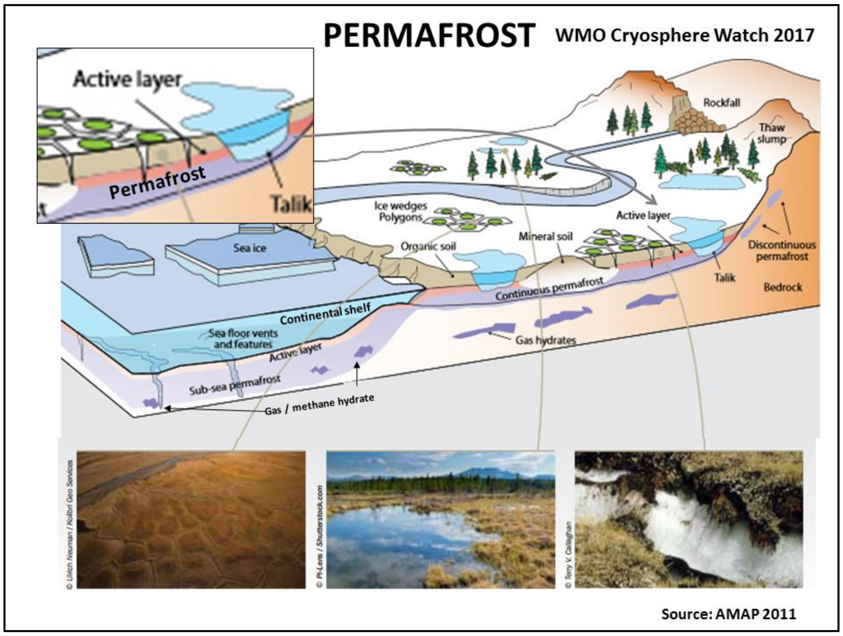


Thawing of permafrost is shown by the increase in the active layer depth.

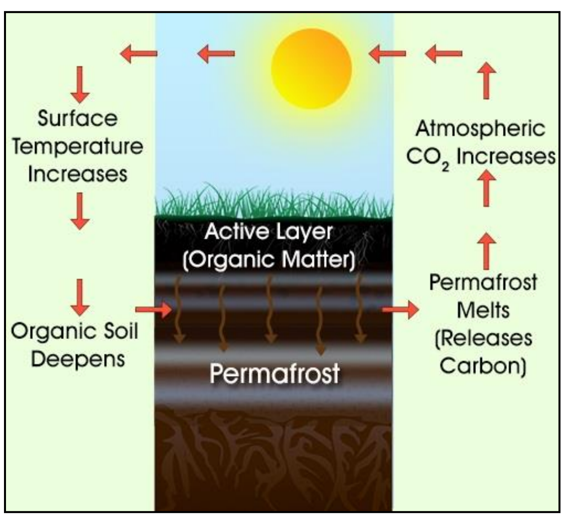
Recent observations in a Siberia region suggest that thawing is extending right through the permafrost (article further below)

The Permafrost Active Layer

The active layer of permafrost, the topmost layer of soil, thaws in the summer and freezes in the winter. During the summer, the active layer warms up enough for plants to grow. Because the Arctic is warming, many permafrost regions now have shorter winters. In these areas, scientists have observed an increase in the depth of the active layer and a decrease in the depth of the permafrost.

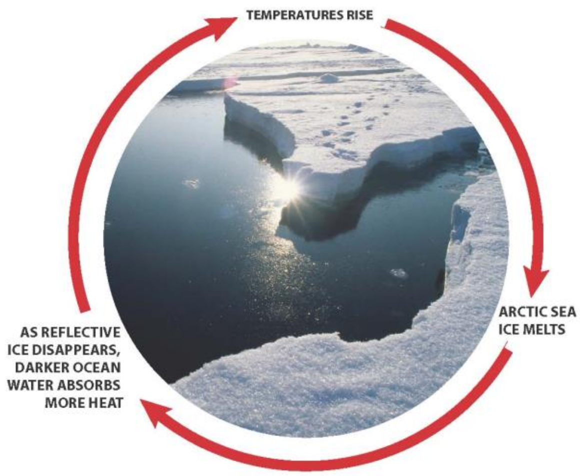


Permafrost thaw global surface warming feedback – emits increasing amounts of Carbon



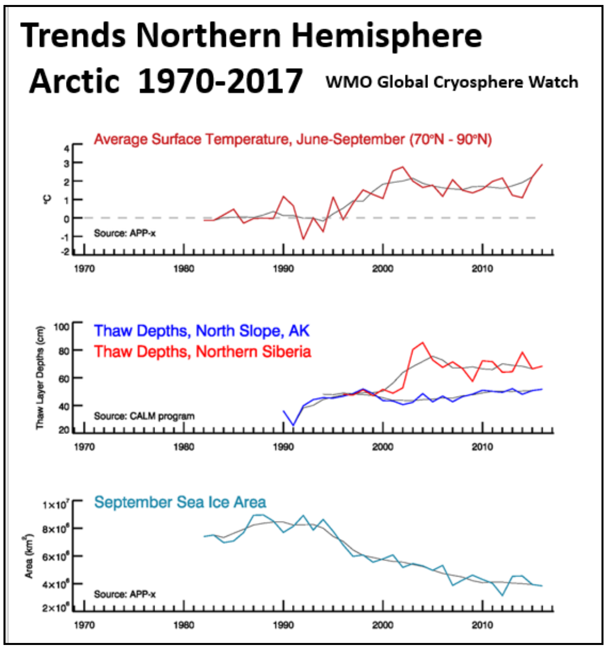
Thawing permafrost is emitting methane, CO2 and nitrous oxide , which will increase with the degree and duration of surface warming. The process is driven by micro-orgasms that come to life and digest the thawed organic material- in doing they release carbon. Because the microbial activity generates heat at some point of Arctic warming permafrost becomes self-sustaining irreversible.

Arctic warming is accelerating at over double the global warming rate. This Arctic amplification is due to summer Arctic sea ice feedback. As summer sea ice extent melts back, less solar radiation is reflected back to space and exposed dark Arctic ocean absorbs heat.



Arctic sea ice feedback

The linkages of Arctic summer sea ice, Arctic amplified warming and permafrost thaw depth are already established clear trends.

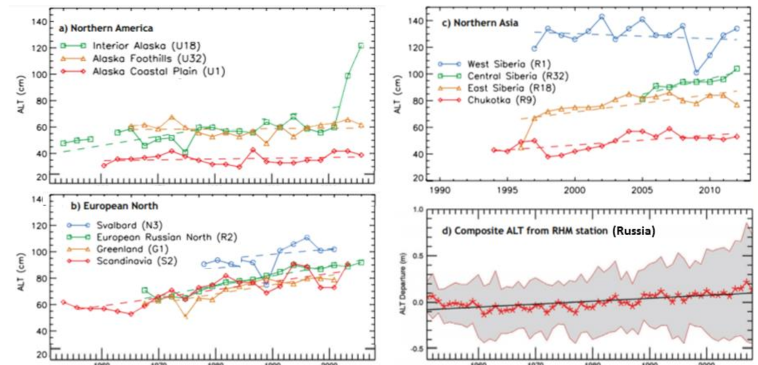


IPCC 2014 5th assessment. 4.7.4.1 Changes in Active-Layer Thickness (ALT)

Many observations have revealed a general positive trend in the thickness of the active layer (see Glossary) for discontinuous permafrost regions at high latitudes. Based on measurements from the International Permafrost Association (IPA) Circumpolar Active Layer Monitoring (CALM) programme, active-layer thickening has been observed since the 1970s and has accelerated since 1995 in northern Europe and on Svalbard and Greenland since the late-1990s. The ALT has increased significantly in the Russian European North, East Siberia, and Chukotka since the mid-1990s. ALT has increased since the mid 1990s in the eastern portion of the Canadian Arctic.

IPCC 2017 ALT to 2012

Global Permafrost Thawing Regions by Increasing Active Layer Thickness (IPCC 2014)



From IPCC 2016 5th assessment Figure 4.23 | Active layer thickness from different locations for slightly different periods between 1990 and 2012

The active layer of permafrost, the topmost layer of soil, thaws in the summer and freezes in the winter. Its depth indicates the summer thawing.

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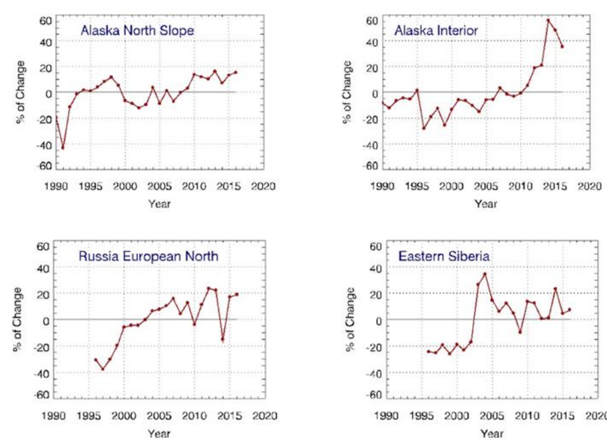
Cryosphere Watch (WMO) ALT to 2016

Thawing permafrost as evidenced from increasing active layer

Cryosphere Watch Figure 3: *Percent change in active layer thicknesses (ALT) relative to the 1991-2015 average*



NOAA permafrost ALT to 2016

Permafrost Active Layer Thickness Increase Trends

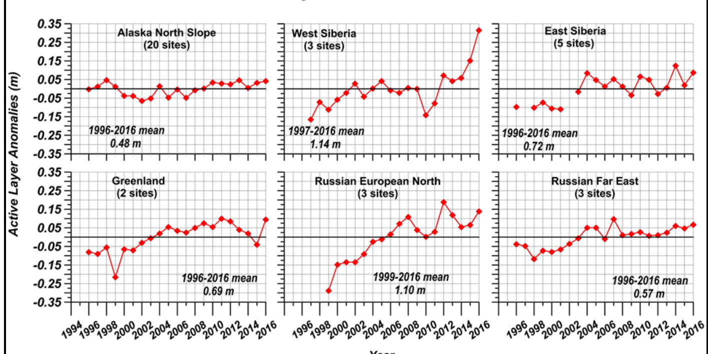
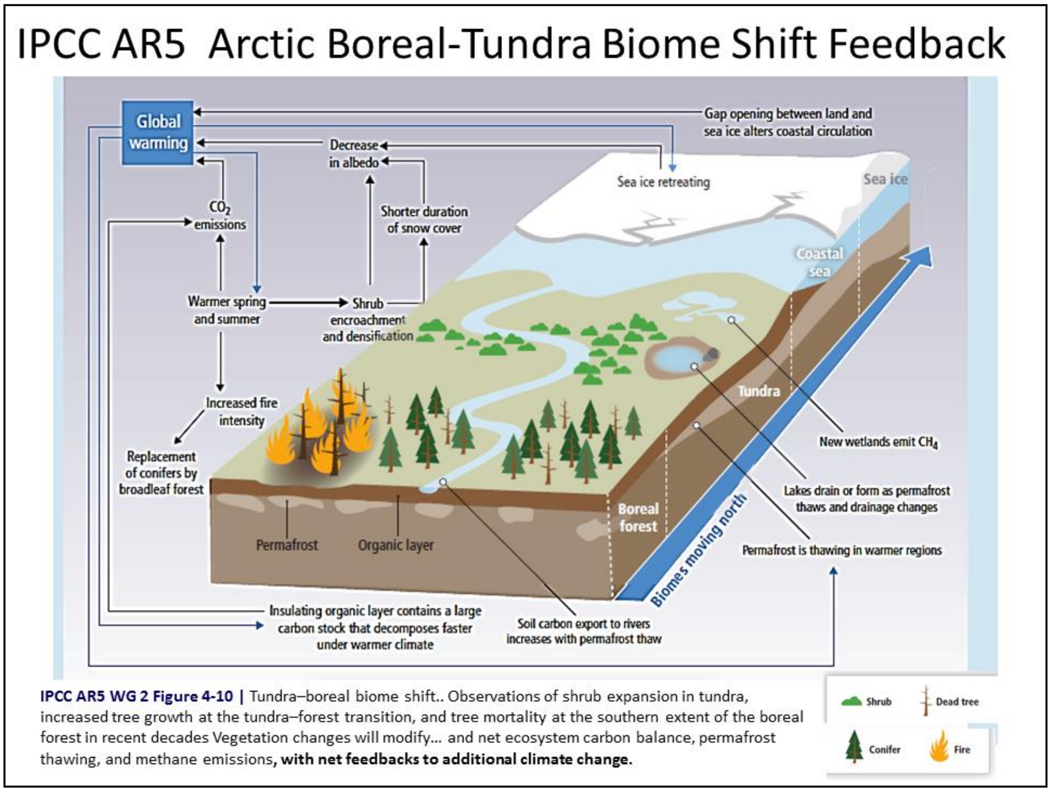


Fig. 3. Long-term active-layer change in six different Arctic regions

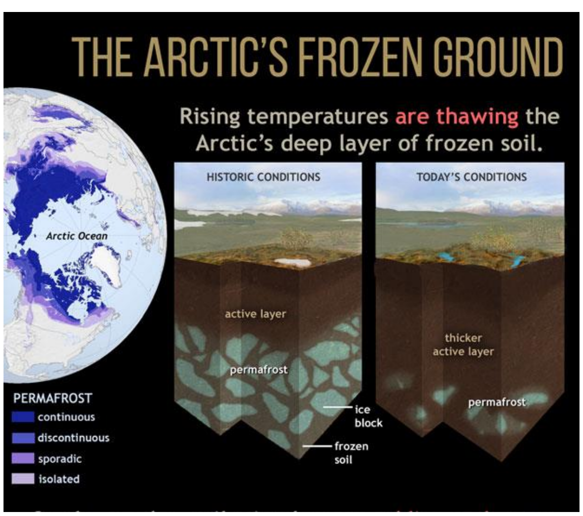
NOAA Arctic Report Card December 2017

IPCC 2014 AR5 predicts Arctic net feed-backs to additional climate change

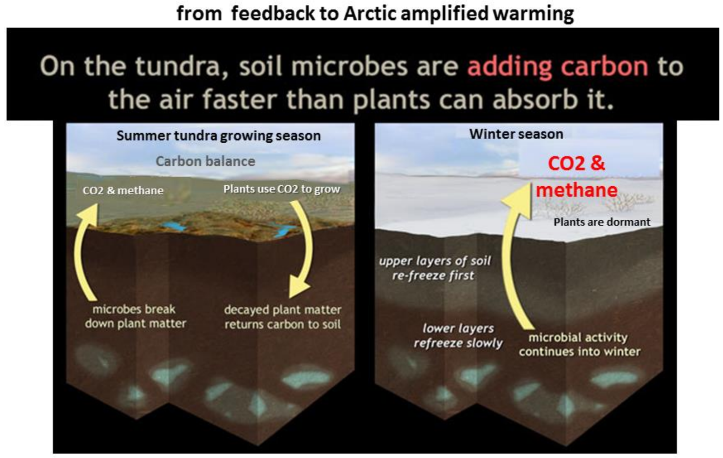


IPCC AR5 WG 2 Figure 4-10 | Tundra–boreal biome shift.. Observations of shrub expansion in tundra, increased tree growth at the tundra–forest transition, and tree mortality at the southern extent of the boreal forest in recent decades Vegetation changes will modify... and net ecosystem carbon balance, permafrost thawing, and methane emissions, **with net feedbacks to additional climate change.**

The Arctic has switched from a carbon sink to a net carbon source due to feed-back emissions of methane and unexpected large CO2 emissions.
NOAA Arctic Report Card 2016 *Thawing permafrost releases carbon into the atmosphere whereas greening tundra absorbs atmospheric carbon dioxide.* ***Over- all tundra is presently releasing net carbon into the atmosphere.***



Runaway Is Triggered
The Arctic is now a net source of carbon emissions from feedback to Arctic amplified warming

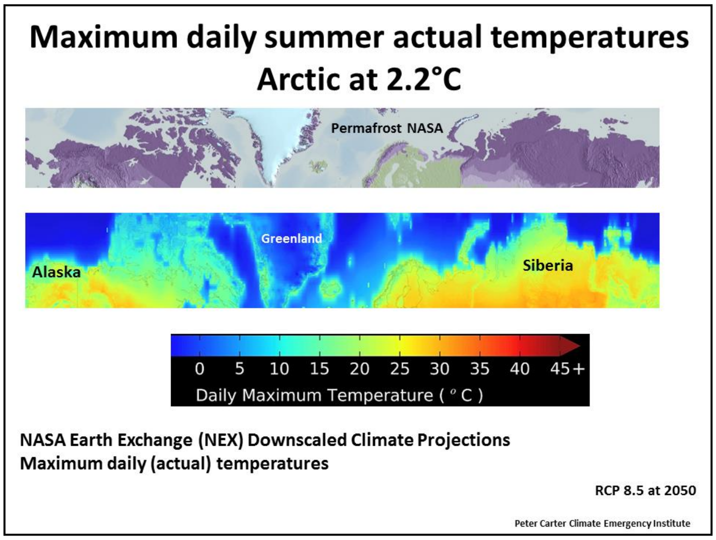


NOAA Arctic Report Card 2016

Future Arctic warming projections

The permafrost models do not include extreme heat, and there are already Arctic winter heat-waves. With Arctic heat waves in winter and summer permafrost is going to thaw much faster.

Extremely high maximum temperatures are projected for the Arctic at 2°C.



It looks like Arctic permafrost is already thawing much faster than estimates, due to insulation by more Arctic snow, predicted by climate models.

From National Geographic (2018)

Some Arctic ground no longer freezing—even in winter

Data from two Arctic sites suggest some surface layers are no longer freezing.

https://www.nationalgeographic.com/environment/2018/08/news-arctic-permafrost-may-thaw-faster-than-expected/

AUGUST 20, 2018

CHERSKIY, RUSSIA Nikita Zimov was teaching students to do ecological fieldwork in northern Siberia when he stumbled on a disturbing clue that the frozen land might be thawing far faster than expected.

In April he sent a team of workers out with heavy drills. They bored into the soil a few feet down and found thick, slushy mud. Zimov said that was impossible. Cherskiy, his community of 3,000 along the Kolyma River, is one of the coldest spots on Earth. Even in late spring, ground below the surface should be frozen solid.

Except this year, it wasn't.

Every winter across the Arctic, the top few inches or feet of soil and rich plant matter freezes up before thawing again in summer. Beneath this active layer of ground extending hundreds of feet deeper sits continuously frozen earth called permafrost, which, in places, has stayed frozen for millennia.

But in a region where temperatures can dip to 40 degrees below zero Fahrenheit, the Zimovs say unusually high snowfall this year worked like a blanket, trapping excess heat in the ground. They found sections 30 inches deep—soils that typically freeze before Christmas—that had stayed damp and mushy all winter. For the first time in memory, ground that insulates deep Arctic permafrost simply did not freeze in winter.

Polygons formed by the annual freezing and thawing of ice wedges just below the earth's surface are visible from above near the Northeast Science Station in Cherskiy, Russia. PHOTOGRAPH BY KATIE ORLINSKY, NATIONAL GEOGRAPHIC

"This really is astounding," says Max Holmes, an Arctic scientist with Woods Hole Research Center in Massachusetts.

The discovery has not been peer-reviewed or published and represents limited data from one spot in one year. But with measurements from another scientist nearby and one an ocean away appearing to support the Zimovs' findings, some Arctic experts are weighing a troubling question: Could a thaw of permafrost begin decades sooner than many people expect in some of the Arctic's coldest, most carbon-rich regions, releasing trapped greenhouse gases that could accelerate human-caused climate change?

Already, three of the last four years have been earth's hottest on record, with 2018 on schedule to be number four. And the poles are actually warming far faster, with areas 300 miles north of the Arctic Circle in Norway reaching 90 degrees Fahrenheit this July. If significant quantities of permafrost start thawing early, that would only make things worse.

"This is a big deal," says Ted Schuur, a permafrost expert at Northern Arizona University. "In the permafrost world, this is a significant milestone in a disturbing trend

Nearly a quarter of the Northern Hemisphere's landmass sits above permafrost. Trapped in this frozen soil and vegetation is more than twice the carbon found in the atmosphere.

As fossil-fuel burning warms the Earth, this ground is thawing, allowing microbes to consume buried organic matter and release carbon dioxide and methane.

Permafrost temperatures across the Arctic have been rising since at least the 1970s—so much that small-scale localized thawing is already underway in many places. But the vast majority of this frozen land is still insulated by an active layer of freezing and thawing ground above it.

Now signs are emerging that the annual freeze-up can quickly change.

Eleven miles downriver from where the Zimovs' started their drilling, Mathias Goeckede with Germany's Max Planck Institute for Biogeochemistry spends weeks each summer traversing crumbling boardwalks over spongy Siberian ground. He tracks carbon exchange between the earth and the atmosphere.

Measurements at his site show that snow depth there has roughly doubled in five years. When excessive snow smothers the ground, warmth below the surface may not dissipate during winter. Data from a drill hole on Goeckede's site appears to capture that phenomenon: In April, temperatures 13 inches below ground there increased roughly 10 degrees Fahrenheit in that same five-year period.

"This is just one site, and it's just five years, so this really should be considered just a case-study," Goeckede says. "But if you assume it's a trend or that it might continue like this, then it's alarming."

Thousands of miles away, Vladimir Romanovsky saw something similar. Romanovsky, a permafrost expert at the University of Alaska, Fairbanks, runs some of the most extensive permafrost monitoring sites in North America, with detailed records going back 25 years, and in some cases longer.

"For all years before 2014, the complete freeze-up of the active layer would happen in mid-January," he says. "Since 2014, the freeze-up date has shifted to late February and even March."

But this winter, Fairbanks, too, saw extremely heavy snow. And for the first time on record, the active layer at two of Romanovsky's sites didn't freeze at all.

"This is really a very important threshold," he adds.

Romanovsky says his sites were chosen because they fairly represent central Alaska.

"So, we assume that freeze-up didn't happen this winter within large areas in the Alaskan Interior," he says.

And even scientists uncomfortable with the limited data say the possibility that something so fundamental could change so quickly gives them pause.

"It's worrisome," says Sue Natali, a permafrost expert, also with Woods Hole, who saw an active layer not re-freeze recently during a research trip to Alaska's Yukon region. "When we see things happening that haven't happened in the lifetime of the scientists studying them, that should be a concern."

An Accelerating Cycle

The stakes are high. If a region's active layer stops freezing consistently, consequences can be swift. Once unfrozen, soil microbes in the active layer can decompose organic material and release greenhouse gases year-round—not just in summer. And it exposes permafrost below to more heat so that layer, too, can begin thawing and releasing gases.

And the movement of all this water, above and below ground, can transport large amounts of heat, hastening thawing. Permafrost collapse can begin feeding on itself, releasing more greenhouse gases, which fuel more warming.

No one expects permafrost will ever release all its stored carbon. Most models suggest just 10 to 20 percent at most would escape even at high human emissions scenarios.

But more than a dozen Arctic climate scientists contacted by *National Geographic* agree that this year's active-layer data highlights the limitations of global climate models. The sophisticated computer programs that forecast future climate scenarios often used by government decision-makers simply can't capture major changes in permafrost.

"When we simulate these things there are a number of processes the models don't include—processes that multiply the transfer of heat," says Daniel Fortier, an associate professor of geography with the University of Montreal. "I think it's safe to say that things are happening faster than we were expecting."

For example, scientists have long known that loss of sea ice and rising temperatures will lead to more Arctic snow over time, which models are able to incorporate. But those same simulations are far less reliable when trying to track the cascading shifts in soil types, surface vegetation, melting ice, and the flow of water that will come from rising temperatures and all that snow, all of which could substantially hasten permafrost thaw.

"The models can't handle those landscape-scale changes, all of the processes that could lead to rapid change," says David Lawrence, a permafrost modeler with the National Center for Atmospheric Research in Boulder. "And it's going to be a long time before they can."

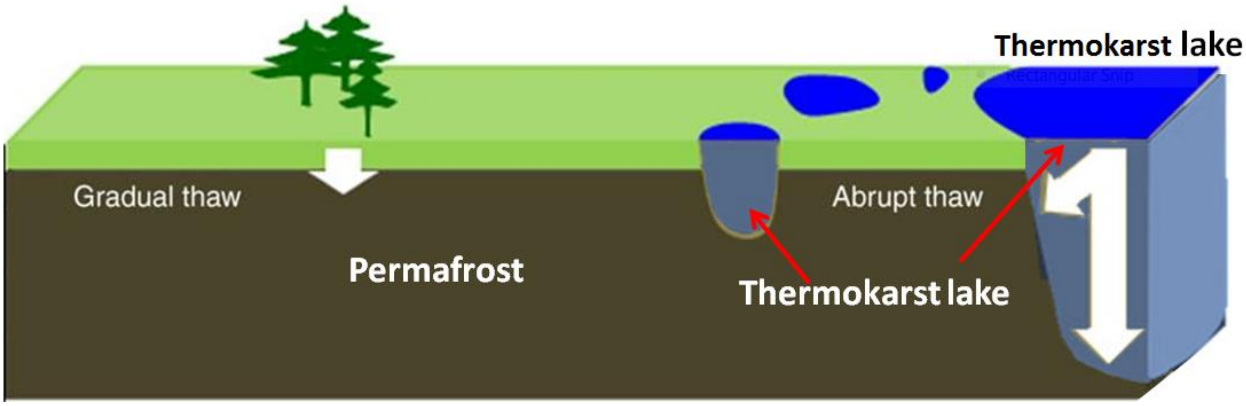
By the time some changes are detected, a significant transition may be underway, he says. That means the public and policymakers may not grasp the real risks.

'Abrupt thaw' of permafrost beneath lakes emit more methane much faster and the thawing is irreversible, a process is not in Arctic models.

(21st-century modeled permafrost carbon emissions accelerated by abrupt thaw beneath lakes, Katey Walter Anthony, 15 August 2018

(NASA 20 Aug 2018 Bubbling Lakes Are Speeding Up Arctic Permafrost Melt, And That's Really Bad News)

Thawing permafrost is forming a multitude of new lakes across the Arctic within the permafrost. The permafrost forming the lateral walls and bottom of the lake is now exposed to lake water, instead the active layer of more permafrost. The lakes are called thermokarst lakes.



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