The Expected Temperature Change in the Year 2100 Due to Permafrost Thawing

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http://ccdatacenter.org/documents/FeedbackFromPermafrost.pdf

Abstract

Carbon released from permafrost soils will likely have a very significant impact on future temperatures (perhaps 0.13 to 0.3 degrees C by 2100, and certainly more by 2200):

> It [(permafrost melt)] was first proposed in 2005. And the first estimates came out in 2011. Indeed, the problem is so new that it has not yet made its way into major climate projections, Schaefer says." …"None of the climate projections in the last IPCC report account for permafrost," says Schaefer. "So all of them underestimate, or are biased low." … "It's certainly not much of a stretch of the imagination to think that over the coming decades, we could lose a couple of gigatons per year from thawing permafrost," says Holmes…. But by 2100, the "mean" estimate for total emissions from permafrost right now is 120 gigatons, say Schaefer. http://www.washingtonpost.com/news/energy-environment/wp/2015/04/01/the-arctic-climate-threat-that-nobodys-even-talking-about-yet

Time Period	Change in Radiative Forcing (W/m^2)	Equivalent Emissions (GTCO2e)	Atmospheric CO2e Change (PPM)	Temperature Increase for a Climate Sensitivity of 3.0
1870-2100	.33	440	25.5	0.19
2011-2100	.33	440	25.5	0.19
2015-2100	.33	440	25.5	0.19
1870-3000	0.69	6100	54.6	0.41

(Although there are current greenhouse gas emissions from permafrost thawing, no source could be found which estimated the current annual or historical amounts.)

Permafrost Facts

Permafrost is permanently frozen soil, and occurs mostly in high latitudes. Permafrost comprises 24% of the land in the Northern Hemisphere [(98.47 million mi^2)], and stores massive amounts of carbon. As a result of climate change, permafrost is at risk of [thawing], releasing the stored carbon in the form of carbon dioxide and methane, which are powerful heat-trapping gases. In addition, permafrost is structurally important, and its melting has been known to cause erosion, disappearance of lakes, landslides, and ground subsidence. It will also cause changes in plant species composition at high latitudes.

https://www.wunderground.com/climate/permafrost.asp

15	Billion acres of permafrost in the Northern Hemisphere (.24 * 640 acres/square mile * 98.47 million mi square miles)
6,126	GTC Carbon stored in permafrost converted to GTCO2 (=1672*3.664) (http://www.globalcarbonproject.org/global/pdf/Tarnocai_2009.Soil%20Organic%20Pools%20in%20Permafrost.GBC.pdf)
400	Maximum amount of CO2 that could be emitted per acre of permafrost (TCO2)
1.5	Rise in global temperature (°C) enough to start permafrost thaw in Siberia (https://www.theguardian.com/environment/2013/feb/21/temperature-rise-permafrost-melt)
5.2	Estimated annual emissions for 120 GTC emitted by 2100 (GTCO2)
.08	Percent of carbon stored in permafrost that needs to be emitted per year to reach 120 GTC by 2100

Recent Articles on Permafrost Thawing

Ancient low–molecular-weight organic acids in permafrost fuel rapid carbon dioxide production upon thaw
A new study for the first time quantify the process by which dissolved organic carbon released from thawing permafrost and released into streams and rivers is rapidly broken down by microbes into carbon dioxide and released to the air. The scientists estimate by 2100, between 5 to 10 Tg of organic carbon will be released from northern permafrost soils every year. Proceedings of the National Academy of Sciences September 28, 2015

Note: this is about twice the rate shown above and would lead to temperature increase closer to .3°C by 2100

Guest post: What the latest science says about thawing permafrost (13 April 2015)

Because of momentum in the climate system and continued warming and thawing of permafrost, emissions are expected to affect the climate for many centuries to come. We estimate that 59% of total emissions from permafrost will occur after this century.

These emissions translate into an additional climate warming of 0.13-0.27C by 2100, and up to 0.42C by 2300.

https://www.carbonbrief.org/guest-post-what-the-latest-science-says-about-thawing-permafrost

The Good and Bad Climate News from Permafrost Melt

By John Upton, September 12th, 2014

The worrying news, no matter how you dice the de-icing permafrost findings "There's so much carbon stored in northern permafrost soils that even if, say, 10 percent of that carbon is released through the processes we studied, it would still have a big impact," Cory said. She calculated that "conservative" scenario would raise atmospheric carbon dioxide levels by 75 to 80 parts per million — over and above the effects of continued fossil fuel burning and other causes. And that, she said, would lead to "a lot of warming."

http://www.climatecentral.org/news/good-news-bad-news-on-carbon-from-melting-permafrost-18001

Modeling the permafrost carbon feedback

Posted on 4 October 2012 by Andy Skuce

MacDougall et al predict median permafrost emissions of 174 billion tonnes of carbon by 2100, which are more-or-less independent of the future pathway of our other emissions. Such feedbacks were not factored in to the trillionth tonne analysis, or were assumed to kick in after the "safe" limit of 2°C had been breached. Accordingly, the 440 billion tonnes we can still emit over the next few years and stay under the trillion-tonne limit needs to be reduced from 440 to 270 billion tonnes of fossil fuel, cement and land use emissions, a reduction of some 40%. Avoiding dangerous climate change becomes a lot harder once we face up to the permafrost feedback.

Why even this bleak prospect may be optimistic

Alert readers may have already noticed that this article has not yet used the word “methane”. When organic matter in the permafrost is thawed and decomposes it produces mostly CO_2 but also small amounts of methane, particularly so in the wetlands that are prevalent in areas of thawing permafrost. Schuur and Abbott (2011) polled 41 experts on permafrost decay who estimated that about 3% of the carbon released from the permafrost will be in the form of methane. Methane has a restricted lifetime in the atmosphere, measured in decades, but while present in the air it has

a greenhouse effect some 25 times that of CO_2 over a 100-year period and higher values over shorter periods. According to Schuur and Abbott, the small amount of methane is responsible for approximately half of the warming effect from the permafrost emissions.

The UVic model does not simulate methanogenesis. That is to say that it does not model the generation of methane—all of the permafrost carbon that goes into the atmosphere in the model is in the form of CO_2. This is a significantly conservative simplification over the time period studied.

Also, their model assumes only purely thermal degradation of the permafrost. Physical erosion, for example at coastlines, is not considered. Their model accounts only for permafrost down to a depth of 3.5 metres and there is plenty of carbon stored below those depths that was excluded from their modeling.

Finally, this study does not consider any contribution of methane from methane hydrates, either from under permafrost or under ice sheets, nor from fossil methane currently trapped under an impermeable seal of continuous permafrost.

Summing-up

- Thawing permafrost will release carbon to the atmosphere that will have an appreciable additional effect on climate change, adding at least one quarter of a degree Celsius by the end of the century and perhaps as much as one degree. (In comparison, Swart and Weaver (2012) calculated that combustion of the in-place resources of the Alberta oil sands would increase temperatures by 0.24-0.50°C.)
- The temperature effect of the coming permafrost feedback is not sensitive to the emission pathway that we choose to follow.
- The permafrost feedback response to our historic emissions, even in the absence of future human emissions, is likely to be self-sustaining and will cancel out future natural carbon sinks in the oceans and biosphere over the next two centuries.
- Unfortunately, there are several good reasons to consider the outlook in MacDougall et al. as rosy; as the authors themselves make clear. However, as bad and inevitable as they are, feedbacks from the permafrost are just the (de-)icing on the fossil fuel cake that we are busy baking. It is still up to us to influence how severe climate change is going to be.

http://www.skepticalscience.com/Macdougall.html

The Arctic is leaking methane 200 times faster than usual: Massive release of gas is creating giant holes and 'trembling tundras'

By WILL STEWART FOR MAILONLINE| UPDATED: 14:32 EST, 22 July 2016

Strange bubbles have been discovered in the Arctic permafrost - adding to mysterious behaviour seen in the region, including the sudden appearance of giant holes in northern Siberia.

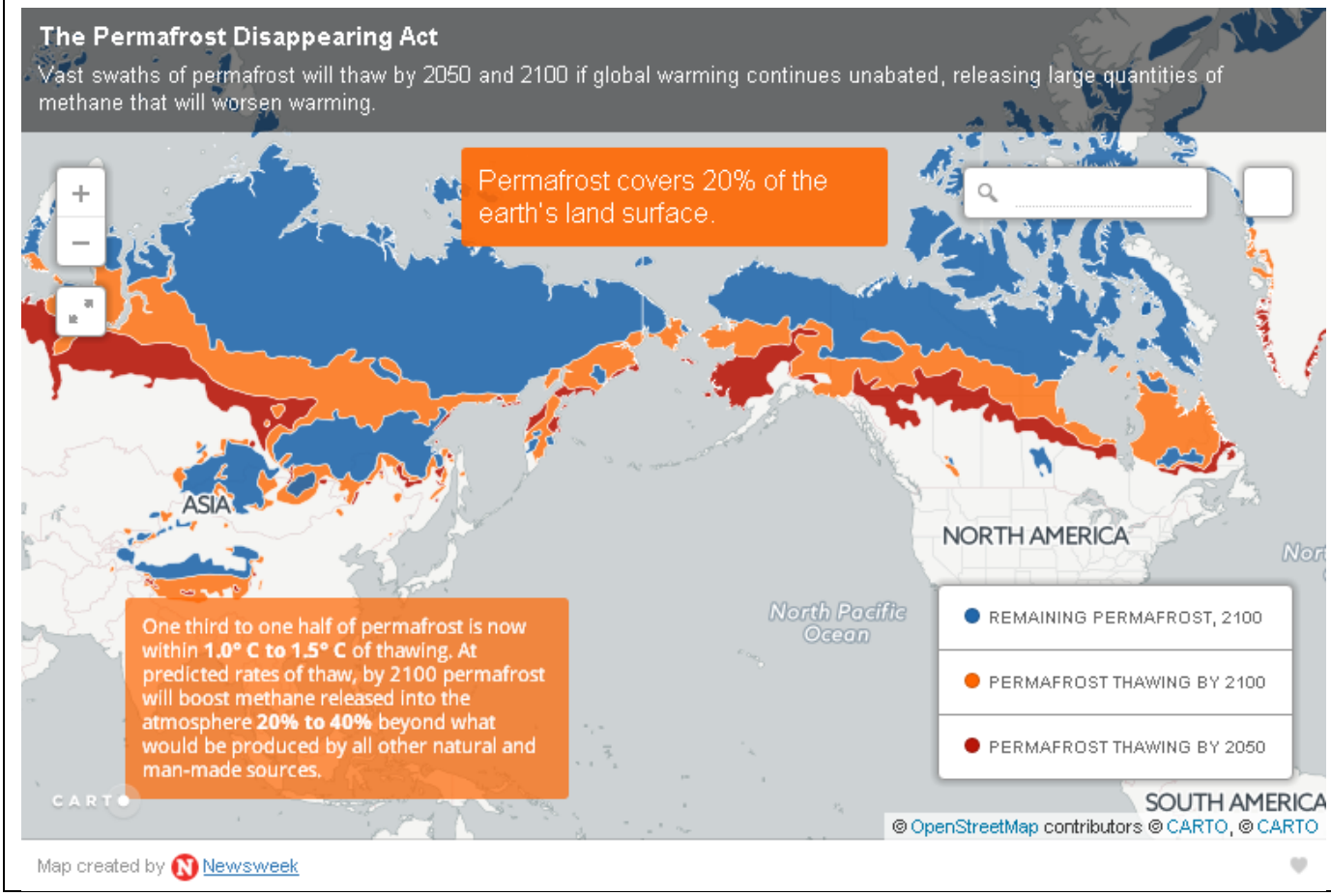
Now Russian scientists have revealed the bubbles in the wobbly Earth are are leaking methane gas some 200 times above the norm in the atmosphere.

The 'trembling tundra' also contains concentrations of carbon dioxide 20 times higher than usual levels.

The extent of the harmful greenhouse gases buried in this new phenomenon of jelly-like bubbles poses 'very serious alarm' concerning the impact of global warming, expert Alexander Sokolov warned.
http://www.dailymail.co.uk/sciencetech/article-3703458/The-Arctic-leaking-methane-200-times-faster-usual-Bizarre-gas-bubbles-create-trembling-tundras-speeding-global-warming.html

Melting Permafrost Is Turbocharging Climate Change

Without a lot more data, there's no way to know for sure how much methane is escaping from lakes like these globally. But according to the latest estimates, published last year in *Biogeosciences*, thawing beneath lakes in yedoma permafrost—the oldest, most carbon-rich type of permafrost found in Alaska and Siberia—could, by 2100, increase the amount of methane accumulated in the Earth's atmosphere by as much as 2.6 billion metric tons. By 2300, that could spike to 10 billion metric tons. Before 2000, yedoma permafrost hadn't thawed enough to begin forming these methane lakes. Now there's no looking back. "It's like the food for microbes has been locked away in the freezer for 30,000 years," Walter Anthony says, "and now the freezer door is open." The degree of warming that implies is catastrophic. "The methane causes climate warming, which causes more permafrost to thaw, which causes more gas to be produced, which causes more warming, so you get a positive feedback loop."



Given the following:

1.8	Atmospheric Methane ppm
1.78E+20	moles of air in the atmosphere
3.20E+14	moles of methane in the atmosphere
16	Molecular mass - grams/mole
5.12E+15	Grams in the atmosphere
5.1	Gigatons of Methane in the atmosphere
.425	Current radiative forcing for Methane
.25	Temperature increase due to current methane (if climate sensitivity is 3.1)

Then the methane from the thawing of the permafrost would add .12 °C of temperature in 2100 and .5 °C in 2300.

Spike in Alaska wildfires is worsening global warming, US says

The devastating rise in Alaska's wildfires is making global warming even worse than scientists expected, according to US government researchers. The sharp spike in Alaska's wildfires, where more than 5m acres burned last year, are destroying a main buffer against climate change: the carbon-rich boreal forests, tundra and permafrost that have served as an enormous carbon sink. Northern wildfires must now be recognised as a significant driver of climate change – and not just a side-effect, according to the report from the US Geological Survey. Suzanne Goldenberg, The Guardian

https://www.theguardian.com/environment/2016/jun/01/alaska-wildfires-climate-change

Significant implications of permafrost thawing for climate change control

Fossil fuel and industrial CO2 emissions need to peak 5–10 years earlier than expected and the carbon budget for 2C needs to be reduced by 6–17% to offset the extra warming that is likely to come from thawing permafrost, according to new research. The pool of carbon buried in Arctic and sub-Arctic permafrost that is susceptible to thaw is higher than previously thought and even a low emissions pathway is likely to see some of it released by 2100, the authors warn. Climatic Change

http://link.springer.com/article/10.1007%2Fs10584-016-1666-5

Arctic melting will cost the global economy £33 trillion by end of next century, scientists calculate

Greenhouse gases released from melting Arctic permafrost will add £33tn to the cost of climate change between now and 2200, according to scientists' calculations reported by The Independent. The figure is equivalent to more than half of current annual global GDP. The results show the need for urgent action to slow warming, the scientists say. The Washington Post, Climate Central and RTCC also have the story. Steve Connor, The Independent

Economic impacts of carbon dioxide and methane released from thawing permafrost

Emissions of carbon dioxide and methane from thawing permafrost could result in an additional $43tn in economic impacts by 2200, according to a new study. Under a moderate emissions scenario, the additional greenhouse gases from permafrost could raise the economic costs of climate change by 13% to $369tn, the study finds. These impacts are sufficiently high to justify urgent action to minimise the scale of the release, the researchers conclude. Nature Climate Change

Metabolic and trophic interactions modulate methane production by Arctic peat microbiota in response to warming

Microbes in Arctic permafrost can adapt rapidly to warming temperatures to produce methane at consistently high rates, a new study finds. Researchers collected peat samples from soils in Svalbard and incubated them at different temperatures. Their results showed that methane production rates rose rapidly with temperature, and that microbes could adapt to warmer conditions within 30 days. Proceedings of the National Academy of Sciences

National Climate Assessment

Permafrost temperatures are increasing over Alaska and much of the Arctic. Regions of discontinuous permafrost in interior Alaska (where annual average soil temperatures are already close to 32°F) are highly vulnerable to thaw. Thawing permafrost releases carbon dioxide and methane – heat-trapping gases that contribute to even more warming. Recent estimates suggest that the potential release of carbon from permafrost soils could add as much as 0.4ºF to 0.6ºF of warming by 2100.[46] Methane emissions have been detected from Alaskan lakes underlain by permafrost, [47] and measurements suggest potentially even greater releases from thawing methane hydrates in the Arctic continental shelf of the East Siberian Sea.[48] However, the response times of Arctic methane hydrates to climate change are quite long relative to methane's lifetime in the atmosphere (about a decade).[49] More generally, the importance of Arctic methane sources relative to other methane sources, such as wetlands in warmer climates, is largely unknown. The potential for a self-reinforcing feedback between permafrost thawing and additional warming contributes additional uncertainty to the high end of the range of future warming. The projections of future climate shown throughout this report do not include the additional increase in temperature associated with this thawing.
http://nca2014.globalchange.gov/report/our-changing-climate/melting-ice)

Weather Underground
Permafrost stores an immense amount of carbon and methane (twice as much carbon as contained in the atmosphere). In a warming environment, permafrost is expected to degrade, and these gases which have been in storage will be released. This process has already begun in some parts of the world, including western Siberia, and is expected to increase in earnest by the year 2020. Furthermore, as of 2011, no climate model incorporates the effects of methane released from melting permafrost, suggesting that even the most extreme climate scenarios in the models might not be extreme enough.

A third of the Earth's soil carbon is found in the Arctic tundra soil, stored in frozen organic matter. If the high northern latitudes warm significantly (as they are expected to; see Figure 3), permafrost will thaw, allowing the organic matter within the permafrost to decompose. The decomposition will release carbon into the atmosphere. This already happens within the active layer each summer. As the active layer thaws, some organic matter decomposes. Under normal climate conditions (i.e. a cold arctic region), the ground remains cold enough to keep the decomposition very slow. But as air temperature increases and the ground warms, this process will speed up, and scientists think this could begin very soon. Some suggest the arctic tundra could go from being a carbon sink to a carbon source by the mid-2020s.

Researchers at the National Snow and Ice Data Center estimate that by 2200, 60% of the Northern Hemisphere's permafrost will probably be melted, which could release around 190 billion tons of carbon into the atmosphere. This amount is about half of all the carbon released in the industrial age. The affect this will have on the rate of atmospheric warming could be irreversible. At the very least, these estimates mean fossil fuel emissions will have to be reduced more than currently suggested to account for the amount of carbon expected to discharge from melting permafrost.
http://www.wunderground.com/resources/climate/melting_permafrost.asp)

Degrading permafrost can alter ecosystems, damage infrastructure, and release enough carbon dioxide (CO_2) and methane (CH_4) to influence global climate. The permafrost carbon feedback (PCF) is the amplification of surface warming due to CO_2 and CH_4 emissions from thawing permafrost. An analysis of available estimates PCF strength and timing indicate 120 ± 85 Gt of carbon emissions from thawing permafrost by 2100. This is equivalent to 5.7 ± 4.0% of total anthropogenic emissions for the Intergovernmental Panel on Climate Change (IPCC) representative concentration pathway (RCP) 8.5 scenario and would increase global temperatures by 0.29 ± 0.21 °C or 7.8 ± 5.7%. For RCP4.5, the scenario closest to the 2 °C warming target for the climate change treaty, the range of cumulative emissions in 2100 from thawing permafrost decreases to between 27 and 100 Gt C with temperature increases between 0.05 and 0.15 °C, but the relative fraction of permafrost to total emissions increases to between 3% and 11%. Any substantial warming results in a committed, long-term carbon release from thawing permafrost with 60% of emissions occurring after 2100, indicating that not accounting for permafrost emissions risks overshooting the 2 °C warming target. Climate projections in the IPCC Fifth Assessment Report (AR5), and any emissions targets based on those projections, do not adequately account for emissions from thawing permafrost and the effects of the PCF on global climate. We recommend the IPCC commission a special assessment focusing on the PCF and its impact on global climate to supplement the AR5 in support of treaty negotiation.
http://iopscience.iop.org/1748-9326/9/8/085003/pdf/1748-9326_9_8_085003.pdf

Permafrost 'carbon bomb' may be more of a slow burn, say scientists

What they don't mention is that the carbon added to the atmosphere through current forest loss is about 1.6 GTC/year. So between now and 2100, the "slow burn" could add about 120 GTC to the atmosphere - about one-half of the IPCC's "post 2014 carbon budget".- and increase the Earth's temperature by about one-half a degree C by 2100. And, unfortunately, the "slow burn" would continue well beyond 2100, eventually contributing much more than two degrees C of warming.
http://www.theguardian.com/environment/2015/apr/09/arctic-carbon-bomb-may-never-happen-say-scientists