

Hi Reddit, I'm Sue Natali, Scientist at Woods Hole Research Center, here to talk about arctic ecosystems and how thawing permafrost can impact global climate. Ask Me Anything!

AmGeophysicalU-AMA <sup>1</sup> and r/Science AMAs<sup>1</sup>

<sup>1</sup>Affiliation not available

April 17, 2023

### **Abstract**

I am Sue Natali, Associate Scientist at Woods Hole Research Center (<http://whrc.org/staff/susan-natali/>). I've been working in the Arctic since 2008, and my research has involved fieldwork across Alaska and in northeast Siberia. I study the effects of climate change on arctic ecosystems and the consequences of these changes for carbon cycling. My research addresses these questions: How do climate change and fire affect permafrost thaw? How do plant communities respond to warmer temperatures and ground thaw? How does permafrost impact soil moisture? What are the impacts of these changes on carbon cycling? What are the implications of permafrost thaw for global climate? I'll be back at 1 EDT to answer all your permafrost and climate change questions. Ask Me Anything! The AGU AMA series is conducted by the Sharing Science (<http://sharingscience.org>) program. Sharing Science: By scientists, for everyone. More at [sharingscience.agu.org](http://sharingscience.agu.org).

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AMGEOPHYSICALU-AMA [R/SCIENCE](#)

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I moved to Alaska nearly three years ago, and most of the locals acknowledge global climate change as a huge catalyst of change for all life in the arctic. There are still many who roll their eyes and insist that it isn't a huge deal.

What resources would you recommend to steer conversations towards what is demonstrably happening and why thawing permafrost matters to everyone in the climate change discussion?

[AustinMtG](#)

Great question! I think the best resource in some ways depends on the audience. For some, stories from people experiencing the effects of climate change first-hand are the most powerful and for others, the numbers documenting these changes are more convincing. Here are some suggestions:

I think this recent NY Times article about our research in Alaska is a really clear story and has great graphics: <https://www.nytimes.com/interactive/2017/08/23/climate/alaska-permafrost-thawing.html>

This article provides a more local perspective: <https://www.adn.com/alaska-news/rural-alaska/2017/07/07/the-permafrost-is-dying-bethel-sees-increased-shifting-of-roads-and-buildings/>

Here's a link to a policy brief we prepared at Woods Hole Research Center, which gives a concise overview of the relevance of permafrost for global climate change discussions: [http://whrc.org/wp-content/uploads/2015/06/PB\\_Permafrost.pdf](http://whrc.org/wp-content/uploads/2015/06/PB_Permafrost.pdf)

For a current overview of the range of changes occurring in the Arctic, I recommend this report on

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Snow, Water, Ice and Permafrost in the Arctic (SWIPA): <http://www.amap.no/swipa2017>

This report, "Thresholds and Closing Windows: Risks of Irreversible Climate Change," focuses on changes in the high latitudes in the context of current emissions and committed future (was prepared before the Paris Climate Agreement) but still relevant: [http://iccinet.org/wp-content/uploads/2015/11/ICCI\\_thresholds\\_v6b\\_151203\\_high\\_res.pdf](http://iccinet.org/wp-content/uploads/2015/11/ICCI_thresholds_v6b_151203_high_res.pdf)

Can you tell us some things about the permafrost microbiome? What sort of organisms predominate? Is there a pattern of transition as the permafrost melts, such as specific organisms coming to the fore, size of organisms increasing in general, or some such?

[aquarain](#)

Thanks for your question. I'm not a microbiologist, but I'll offer some general thoughts. There are organisms that are active in permafrost soil at sub-zero temperatures. And yes, the microbial community does change as permafrost thaws, as a result of changes in temperature but also due to accompanying changes in moisture, and in substrate and nutrient availability. In a study I was involved with, led by Kai Xue, we found that warming temperatures are altering the microbial functional community of the thawed soils, and these changes were related to increased greenhouse gas emissions. This is an important research area--particularly linking the microbial communities to functional responses (e.g., greenhouse gas emissions)--and a great question.

Hi Sue, and thank you for doing this AMA! I'm a graduate student in this field (studying boreal and arctic carbon cycle dynamics) and I've lately had a lot of thoughts and worries about the academic career path. Being a tenured professor as a goal appears to be vanishingly unlikely and increasingly painful as a process. I was wondering if you could weigh in on your career path - what do you think of being a researcher in academia, but outside a university? Do you consider it stable and what are some pros and cons that come to mind? Do you eventually aspire for a professorship? Just an aspiring scientist looking for some words of guidance in uncertain times.

PS I cited you in my qualifying exams, so thank you for writing some really excellent stuff!

[bromandawg](#)

Thanks for your question and interest, and congratulations on completing your qualifying exams!

Each career path has its challenges and rewards, and I think the goal is to figure what challenges are worth the rewards. I work at a nonprofit, Woods Hole Research Center, so I'm not actually tenured. The pluses of my career choice: I work at a mission-driven scientific organization that focuses on climate change and solutions, which I find very rewarding. We're a 'soft-money' institution so we are funded from grants--that works out well for me because I really enjoy writing grant proposals (don't so much enjoy the rejections). Challenges for me are that I currently don't have graduate students because we're not affiliated with a university, but I find ways to work around that (great RAs, summer research programs, colleagues' students...), and of course, the grant system is a little unstable....But, my goals are to conduct research that excites me, to be a good colleague, to work with students, to inform the public, and to do policy relevant research. With that in mind, my position is a great fit for me. So my advice is to figure out what components of a work life are really important to you, what components are not, and what challenges you would be willing to accept in order to achieve the goals. In terms of obtaining academic positions--well, papers and grants seem to help a lot. Good luck, and I'm happy to chat more offline!

There have been very alarming articles about methane releases from thawing permafrost vastly accelerating global warming as the arctic region warms faster than the lower latitudes. Yet, I've also seen articles saying the average residence time in the atmosphere for a methane molecule is 5-6 years as compared to a 200-300 residence time for CO<sub>2</sub> molecules. If methane has such a short half-life in the atmosphere, why all the consternation? Will the increase in methane from permafrost overwhelm the natural processes that scrub it from the atmosphere today?

[shiningPate](#)

Thanks for your great question!

On average, methane is indeed removed from the atmosphere faster than CO<sub>2</sub>, primarily through chemical reaction in the atmosphere, which creates water vapor and carbon dioxide. While CH<sub>4</sub> has a shorter residence time than CO<sub>2</sub>, it is a more potent greenhouse, or put another way, it has a shorter lifetime but higher radiative efficiency (i.e., it can absorb more energy). These two components (lifetime and radiative efficiency) combine into the global warming potential (GWP), which is a metric that allows comparisons among different greenhouse gasses. Because of its higher radiative efficiency, over a 100-year timescale, CH<sub>4</sub> has a GWP of ~28, while over a 20 year timescale it's GWP is ~84.

Methane and carbon dioxide from thawing permafrost are a concern, because they are expected to increase as the climate continues to warm and also because the emissions from permafrost thaw aren't accounted for in many climate models, including those that are informing international policy decisions on greenhouse gasses.

Human emissions of fossil fuels are already overwhelming natural processes, leading to build-up of greenhouse gasses in the atmosphere

So with truly ancient permafrost thawing out, how likely are we to encounter ancient bugs that could wipe us out?

[Ozmorty](#)

Thanks for your question. I'll add a little to the other comments that have already posted. The likelihood is low for widespread outbreak--keep in mind that most of these diseases need a vector so the risk of diseases spread world-wide from remote locations in the Arctic are certainly lower than the risk of disease from areas of high human populations and as a result of climate-mediated increases in the transmission of vector-borne diseases.

There was a recent anthrax outbreak in Siberia last year that impacted humans and reindeer. In this case, the bacteria that caused anthrax had infected reindeer during several outbreaks in the early 20th century. The infected reindeer were buried in shallow graves (it's hard to dig deep in frozen ground), were frozen in permafrost but when that permafrost thawed, the bacteria was still viable and subsequently infected wildlife and humans that came in contact with the bacteria. There are also human bodies buried in the Arctic that were diseased, and those diseases may still be viable. But again, it's a lot less of a concern than disease spread elsewhere or than the risk of amplification of climate change as a result of permafrost thaw.

Hi and thanks for joining us today!

With warming at the poles do you think we'll see a higher incidence of botulism among the indigenous circumpolar populations?

[PHealthy](#)

Thanks for your question!

Climate-mediated disease spread is a really important topic, and one that I'm not an expert on, but I'll offer some thoughts. Botulism is related to temperature because the germination of the spores and toxin production occurs at temperatures above ~4°C. So as temperatures increase, there certainly is possibility for increased risk. There are also many other climate-related issues that Arctic communities are also having to address--loss of sea ice, erosion, and permafrost thaw, persistent organic pollutants. Managing these risks in the Arctic, and climate-related risks elsewhere, will certainly alter how communities function globally.

Does your research cover geologic issues such as landslides, subsidences, and other processes due to loss of permafrost and climate change that make existing areas risky for human settlements? Has there been an increase in surface geologic activity in the Arctic regions you are working?

[kbouser](#)

Great question! It's hard to work on research related to permafrost thaw and not think about changes in the ground structure because it's a fundamental component of ground thaw, and it's also really important for carbon cycling. For example, when the ground collapses, it can result in saturated conditions in the slumped area, which is a great environment for CH<sub>4</sub> production. My research to date has mostly focused on carbon and ecosystem consequences of thaw and subsidence, rather than impacts on human communities. But these impacts are something that Arctic communities have been dealing with now for many years. Communities across the Arctic are faced with many climate-induced changes, including erosion, permafrost thaw and ground subsidence. In a location in Interior Alaska where I have worked since 2008, I can clearly see changes in the amount of ground subsidence. These changes have also been detected over larger areas using remote sensing methods, and by many communities who are dealing with impacts on infrastructure (e.g.: <https://www.adn.com/alaska-news/rural-alaska/2017/07/07/the-permafrost-is-dying-bethel-sees-increased-shifting-of-roads-and-buildings/>).

Hi Sue, and welcome to [r/science](#)!

How much, do you think, the greening of the Arctic and the northward advance of the tree line might offset the GhG esmissions from thawing permafrost?

[IceBean](#)

Great question! I expect that greening will offset some but not all of the greenhouse gas emissions from thawing permafrost.

Here's a couple reasons why: A recent assessment from ~ 100 permafrost-region experts found that while there is greening in the Arctic, biomass is expected to decrease due to water stress and disturbance (fire), factors that are not adequately incorporated into current models. As a result, the study concluded that biomass would offset little or none of the permafrost carbon release.

Keep in mind that currently there's ~1,330–1,580 Petagrams of carbon in soil/permafrost in the permafrost region and only about ~100 Pg of carbon in permafrost-region biomass--hard to imagine a full offset, even if permafrost carbon losses are 'only' 10%.

I also worked on an experiment in Alaska tundra, where we warmed the air and thawed permafrost to monitor the effects on ecosystem carbon cycling. We found that plants did indeed take up more carbon, that they grew larger and they had a longer growing season. However, warming during the winter and increased thaw as the experiment proceeded resulted in microbial activity increases that were greater than the plant response. The tundra switched from a carbon source to a sink.

Here's a link to that article: <http://onlinelibrary.wiley.com/doi/10.1890/13-0602.1/full>

Other observational studies have also reported that arctic tundra are now releasing more carbon than they are taking up. This is really surprising since the region had been taking up carbon for thousands of years.

Here's another big issue: The greatest warming in the Arctic is occurring during the 'non-growing season' (NGS; fall, winter, spring). This time period is critical for carbon cycling in the Arctic, because soil microbes that decompose organic matter and produce CO<sub>2</sub> and CH<sub>4</sub> remain active at sub-zero temperatures during this extended period when plant uptake of carbon has ceased. Carbon emissions during the NGS can shift these ecosystems from carbon sinks during the growing season (carbon uptake) to sources (carbon loss to the atmosphere) on an annual basis. Importantly, this is also the time period when we have the least amount of data and knowledge of carbon cycling in the Arctic, partly because it's hard to get equipment to function properly at -40C!

I can go on and on about this one, but I better move on to other questions... thanks!

Hi Sue and thanks for taking the time today!!

Would you share your thoughts on the recent reemergence of the polynya in Antarctica? Is it an indicator of where we are with sea water temps and sort of the final straw in the debate of climate change?

[sraffetto6](#)

Thanks for your question! This one is definitely out of my area of expertise, since I work in the Arctic and on terrestrial systems. But I'll give it a try.

When unusual events occur, it's tricky to know right away whether they are a function of climate change or not. I think we're at a point in our scientific understanding that we can clearly link increased storm intensity or increased fire frequency to climate change, even though any one event may not be climate-change related. In the case of the polynya (which also occurred in the 1970s), I'd say it's a little too early to determine the cause.

What I do know is that scientists, who are experts in this research, are actively studying this polynya, and I think we'll have more definitive answers to the many questions about its causes and behavior in the near future.

How much additional carbon are we going to see enter the atmosphere as tundra melts and decays or burns? How quickly can we expect to see that happen?

[silence7](#)

This is a challenging question, but critically important.

First, I'll start out with just how much carbon is in permafrost region, then how much we can expect to lose. Most of the carbon in northern regions is stored in soil/permafrost. In the northern terrestrial permafrost region there is ~1,330–1,580 petagrams (billion tonnes) of carbon in soil, including in permafrost. There's ~ 100Pg in plant biomass. To give the numbers some context: the carbon stored in soil/permafrost in the northern regions is about twice as much carbon as is in the atmosphere and three times more carbon as is in the world's forests--that's global forest cover!

Now, how much will be lost. A recent synthesis that I was involved with estimated ~ 10% of the carbon in permafrost will be released by the end of this century--that's about 130-160 Pg of carbon, assuming our current rate of fossil fuel emissions. However, this estimate doesn't include carbon emissions from

fire (which burns plants as well as organic soils). Determining the actual rate of release of CO<sub>2</sub> and CH<sub>4</sub> as a result of permafrost thaw across the Arctic is a very active research area, and I wish I could assign confident and specific numbers to every year in this century; but that's not yet possible. However, the estimate I provided (130-160 by 2100) represents a general consensus among studies. To put these emissions in context: If the 130-160 Pg were to be released at a constant rate over the century (which it is not expected to do), that rate is similar in magnitude to the current rate of US fossil fuel emissions (~1.4 billion tons). Importantly, unlike US emissions, carbon emissions from thawing permafrost are not incorporated into many global climate models, including the Earth System Models that informed the last Intergovernmental Panel on Climate Change report, which guided policy makers involved in the Paris Climate Agreement.

Thank you for the great question!

Hello and thank you for doing this AMA!

Do you have some figures about this phenomenon?

What kind of data do you use to study arctic ecosystems? Where do you find it?

How much change can they accept before being unable to adapt any further? Has this tipping point been reached already?

Do we know if this kind of global thawing has happened before, during a "warm" era?

[Hafornin](#)

Thank you for your questions. Yes, there are some figures in some of the links in the other comments I posted. Check these out.

I am primarily a field scientist so I travel to the Arctic--I work mainly in Alaska and Russia--to collect data. The types of data I collect include, vegetation composition and cover, active layer (ground that thaws and refreezes annually) and permafrost carbon composition and ice content, CO<sub>2</sub> and CH<sub>4</sub> fluxes, depth of ground thaw, soil temperature, moisture, etc. I'm interested in quantifying carbon fluxes from permafrost regions and identifying the drivers of those fluxes, so the data I collect focus on addressing those goals. Some data are from experiments that we've set up to examine how the Arctic will change--for example we established experimental fires, permafrost thaw, and soil drying experiments. I also have been involved in studies where we synthesized data from published studies to get a broader perspective. And finally, I collaborate with remote sensors who obtain data from satellites that observe the Earth from space.

In terms of previous warming events (e.g., between about 55.5 and 52 million years ago), these have been linked to permafrost thaw and also to carbon emissions from increased microbial decomposition of organic carbon in permafrost.

As for tipping point, I would say that in terms of permafrost thaw, there's not a single tipping point because there is not a single permafrost temperature. It varies quite a bit across the permafrost zone. In one place where I work in the sub-Arctic the permafrost temperature is ~ -0.3. In that location, the permafrost is expected to thaw in a few more decades. In another region the temperature is -8C, so the effects will vary. Once the permafrost thaws, this is in a way a tipping point, because then there is no action we can take to stop microbes from decomposing the organic matter and releasing CO<sub>2</sub> and CH<sub>4</sub>, until the permafrost refreezes under more stable climatic conditions.

Hi Sue, thanks for answering our questions! I was wondering if there's any sort of analog to the

clathrate gun that comes from permafrost melting? It seems like with reflective ice melting, methane and other GHGs releasing, that we could hit a point where arctic warming becomes an inevitable atmospheric catastrophe. Also, is this a geometric or linear process?

Also, say hi to my good friend Zander for me at WHRC!!

[maxshaferlandau](#)

Thanks for your question! I'd say we're already at the point where Arctic warming is an inevitable problem, but one that can be attenuated by strong reductions in fossil fuel emissions. For example, model projections for loss of near surface permafrost range up to 70% loss by end century--but those projections are for high emissions scenarios and are cut in half under low emissions scenarios. We're already committed but we can reduce the impact substantially.

In terms of the analog to 'clathrate gun': I generally just talk about positive feedbacks, or amplification of climate change resulting from permafrost thaw. Not as catchy, right? The term 'carbon bomb' was used for a while to describe carbon emissions (but not necessarily the feedback) from thawing permafrost, but that term has somewhat gone out of fashion. The reason it's not used so much is because it suggested an immediate release, but in reality the loss of carbon from permafrost will occur gradually and at different rates across the Arctic (not linear). Now that said, gradual is a relative term. Given that the carbon has accumulated in permafrost over tens of thousands of years, loss of 10% of the carbon pool in 100 years is pretty abrupt on a geologic timescale, although more gradual on human-timescale.

I'll send along your message to Zander--he's a great colleague!

Hi Sue...Thanks for joining us today. I've read that shallow, >2meters, thermarest lakes are not staying frozen at depth year round, releasing methane in the process. Also, this was projected not to happen for another 7 decades. Do you see this as a general trend, perhaps affecting deeper lakes in the near future?

[bligh8](#)

Great question! There are areas under shallow lakes and also under soil active layer (ground above the permafrost that thaws and refreezes annually) in permafrost ecosystems where the ground is perennially thawed (i.e., a talik). These perennially thawed areas can accelerate permafrost thaw and also shift the area to a carbon source. In anoxic environments under lakes, this leads to increased CH<sub>4</sub> (and CO<sub>2</sub>) production. There are taliks in places where I work now, and they are expected to expand and continue to form through the century. This paper (<https://www.the-cryosphere-discuss.net/tc-2017-189/>) suggests that talik formation will peak in 2050 in the sub-Arctic, and field measurements suggest that may happen sooner.