House Committee on Science, Space, and Technology
“Amplifying the Arctic: Strengthening Science to Respond to a Rapidly Changing Arctic”
Tuesday, September 20, 2022, 10 a.m. ET

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Chairwoman Johnson, Ranking Member Lucas, and distinguished Members of the Committee, thank you for inviting me to testify at today’s hearing. My name is Dr. Susan M. Natali and I am the Arctic Program Director and a Senior Scientist at Woodwell Climate Research Center (“Woodwell”). My work focuses on the local to global effects of permafrost thaw in Arctic and boreal regions. The following testimony elaborates on this work and explains the current knowledge of permafrost emissions within the greater context of climate change and the extent to which current climate models account for such emissions. The testimony also sheds light on how available evidence and existing gaps are informing adaptation and mitigation policies. Finally, the testimony features recommendations that will empower this Committee to advance evidence-based policy solutions to permafrost thaw for the ultimate benefit of those living within the circumpolar Arctic and beyond.

Woodwell’s commitment to advancing Arctic research and understanding of permafrost thaw.

Woodwell is a non-profit organization based in Falmouth, Massachusetts that comprises research scientists and policy experts who work with partners worldwide to understand the impacts of and to address climate change on a global scale. Woodwell scientists helped to launch the United Nations Framework Convention on Climate Change in 1992 and shared the Nobel Prize awarded to the Intergovernmental Panel on Climate Change (IPCC) in 2007. The organization continues to have global impact, bringing together cutting-edge science and translating scientific advances into climate policy solutions.

Woodwell’s Arctic program examines the impacts of climate change in this region, and like the Arctic itself, our impact transcends geopolitical borders. Our research, conducted through on-the-ground observations, satellite remote sensing, and computational modeling, is enabling us to measure and monitor changes across tundra and boreal landscapes. The cascading effects of these changes pose immediate threats to Alaskan communities, ecosystems, and infrastructure, but they also present severe risks to the long-term health, stability, and safety of our planet. In fact, in November of last year, I testified before your colleagues in the Foreign Affairs Committee on the national security implications of climate change in the Arctic. In that testimony, I addressed the particular threat to security emanating from permafrost thaw and presented unequivocal evidence to support urgent policy action.

Less than one year later, we have discovered that the negative consequences of inaction are much higher than previously understood. The latest data confirm that the Arctic has warmed three to four times greater than the global average temperature increase of 1.1°C above pre-industrial levels (Rantanen et al., 2022). In the coming years, Arctic temperatures are projected to continue rising. And with these rising temperatures, we can expect to exacerbate a host of climate hazards, including wildfires across Arctic tundra and boreal forests, sea ice melt, coastal erosion, altered abundance and distributions of key Arctic species, and permafrost thaw (Armstrong McKay, et al., 2022).

Arctic residents and scientists have been observing permafrost thaw for decades. However, the scale and coordination of the research in this space have not been sufficient to meet the urgency of the threat and drive meaningful policy change. That is why, in April of this year, Woodwell launched Permafrost Pathways, a new initiative funded through the Audacious Project. With partners at the Arctic Initiative at Harvard Kennedy School and Alaska Institute for Justice, Permafrost Pathways will amplify our efforts to collect the best data on Arctic carbon emissions, contextualize this information within global emissions budgets, and transform this science into actionable policy recommendations.

Current knowledge of permafrost thaw processes, local impacts, and global carbon budget.

As part of this process, we need to ensure that decision makers have a fundamental understanding of permafrost and its relevance to climate change. Permafrost is ground that has been continually frozen for at least two consecutive years and often for thousands of years. Permafrost extends across the boreal and tundra biomes and in mountain regions across the globe, underlying roughly 15% of the exposed land surface area in the Northern Hemisphere (Obu, 2021) and 38% of Alaska's land area (Pastick et al., 2015). As global temperatures rise, this once-frozen ground is beginning to thaw, creating an increasingly unstable and dangerous environment. Among the most observable impacts is thaw-induced ground collapse, which can contribute to the destruction of infrastructure, homes, schools, medical facilities, roads, and public utilities that ensure access to electricity, clean water, and other necessities. Permafrost thaw is also impacting critical military infrastructure, including at the Northern Warfare Training Center at Fort Wainwright, Alaska (Guy et al., 2021), where military leaders must increasingly focus not only on threats from foreign actors but also on the changing conditions of their own local environments.

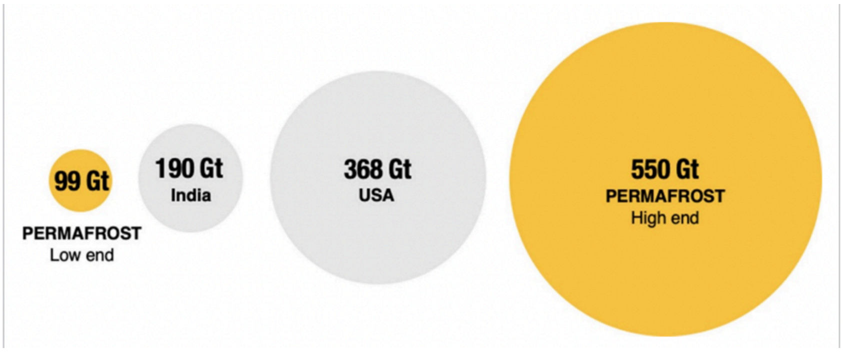
Left: Researcher in front of exposed permafrost cliff - photo by Becky Tachihara.
Right: Field site in Canada's Northwest territories - photo by Scott Zolko.

For Alaskan residents living on the front lines of the climate crisis, permafrost thaw is compounding the hazardous, and at times life-changing and life-threatening conditions, created by rapid climate change. For coastal communities, the risk and severity of climate impacts are particularly high, as the loss of sea ice along the coastlines is increasing storm impacts, and permafrost thaw is exacerbating coastal and riverine erosion and flooding (Lantuit et al., 2012; GAO, 2009). Recognizing the compounding effects of multiple environmental hazards, the State of Alaska Hazard Mitigation Plan and the Denali's Commission's recent statewide environmental threat assessment now include a new hazard, usteq (Yup'ik word meaning "surface caves in"), which is a catastrophic form of ground collapse that occurs from the combined effects of thawing permafrost, flooding, and erosion (Denali Commission, 2019; State of Alaska, 2018). Indigenous communities that have contributed the least to climate change, are also experiencing less-quantifiable losses of cultural resources, traditional food procurement, storage, and ways of living. (Brubaker et al., 2011; Brinkman et al., 2016; Bronen, 2015; Hong, Perkins, and Trainor, 2014). As discussed below, these communities are facing adaptation challenges as they attempt to navigate a policy landscape that does not account for permafrost thaw.

Beyond these localized impacts of permafrost thaw, which present risks to communities across the Arctic, the global significance of permafrost lies with the sheer volume of the carbon it stores: 1.4 trillion tons of carbon—or four times the amount of carbon that humans have released since the Industrial Revolution and roughly twice as much carbon as is currently in the Earth's atmosphere (Hugelius et al., 2014; Schuur et al., 2015). Cold and frozen conditions have prevented carbon-rich organic material, which is derived from dead plants and animals, from decomposing, creating a massive "carbon store" in permafrost soil where captured carbon is locked away beneath the earth's surface.

Much of this carbon has been locked in the soil for decades, centuries, or even millenia. However, as permafrost thaws, ancient carbon stored in the soil is breaking down, releasing carbon dioxide and methane into the atmosphere, which can further exacerbate climate change. We are at the precipice of a potentially transformational and devastating shift—one in which the massive store of carbon is slowly becoming a source of greenhouse gasses (GHG). This shift is already occurring at individual sites throughout the Arctic and boreal regions where carbon emissions are surpassing carbon uptake. (Natali et al., 2019).

As global temperatures continue to rise, an increasing proportion of permafrost across the Arctic will be lost, contributing to GHG emissions. Permafrost warmed an average of 0.29°C between 2007 and 2016 (IPCC, 2019) and an estimated 7% of near-surface permafrost has already been lost across the Arctic (Li et al., 2021). Experts predict a loss of up to 69% (likely range) of near-surface (top 3m) permafrost over the next century (McGuire et al., 2018). Even with low levels of additional warming and a high mitigation effort, the loss of nearly a quarter of near-surface permafrost is likely. Without aggressive, near-term climate mitigation, the resulting carbon emissions could be as high as 550 Gt CO2 by 2100, on par with or even exceeding continued emissions from the United States based on current rates (Natali et al., 2021).



Range of projected cumulative permafrost carbon emissions from 2022 through 2100 (Gt CO2; 1 Pg C = 3.67 Gt CO2) for low Gasser et al., 2018) to high emissions scenarios (Schuur et al., 2015) compared to cumulative emissions from major fossil fuel emitting nations, (Friedlingstein et al 2022) if their current (2020) emissions rates continue through the end of the century. Note that the rates of permafrost emissions are not consistent over this time period; they will increase through 2100 and will likely continue for decades or centuries beyond this timeframe (Natali et al., 2022).

Uncertainty due to gaps in monitoring and modeling.

These troubling projections of future carbon release due to permafrost thaw are very likely an underestimate of actual future emissions because they do not include critical disturbance processes that may double the magnitude of the permafrost carbon feedback (Turetsky et al. 2020, Natali et al. 2021). Models of permafrost carbon emissions typically depict permafrost thaw as a slow top-down process in which elevated air temperatures gradually increase heat transfer into the soil and thaw permafrost (e.g., at a rate of <centimeter per year). However, the rate of permafrost thaw can be exacerbated by abrupt, nonlinear thawing that causes extensive ground collapse in areas with high ground ice. Abrupt thaw events, while often taking place on comparatively small spatial scales, can rapidly expose deeper permafrost layers, and therefore a larger volume of stored carbon, over rapid timescales (e.g., meters per year or quicker) (Natali et al., 2021). Abrupt thaw events can be triggered by extreme weather, such as the recent heat waves in Siberia and Alaska. More frequent and severe Arctic and boreal wildfires further catalyze the emissions feedback loop from the permafrost region by directly releasing large amounts of carbon during combustion, and by expediting permafrost thaw (Natali et al., 2021). All of these processes are accelerating due to climate change, and the scientific community is increasingly recognizing the amplifying effect that these under-represented mechanisms of carbon loss from the permafrost region have on the magnitude and timescale of resulting emissions (Turetsky et al. 2020).

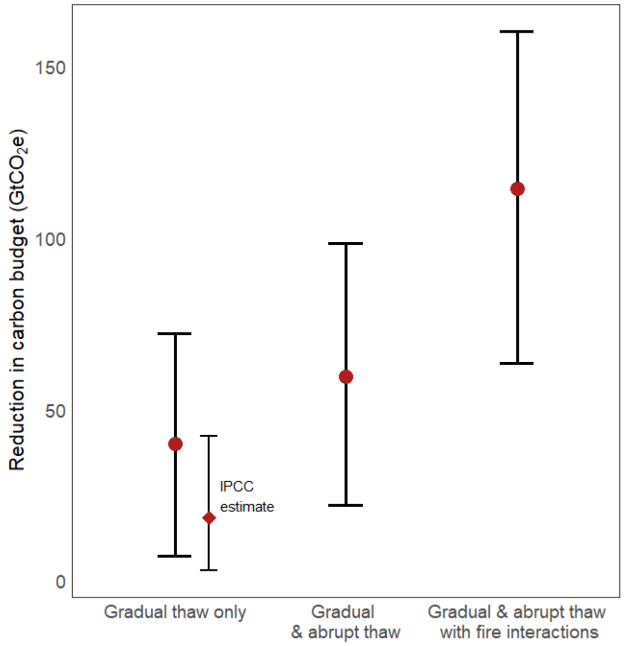
Unfortunately, only a small minority of global-scale climate models incorporate permafrost thaw, and none of these represent processes other than gradual thaw. Models used to inform nationally determined contributions under the Paris Agreement, for example, failed to account for key processes that can greatly accelerate permafrost thaw rates and carbon emissions, notably abrupt thaw and wildfires in Arctic regions (Baillargeon et al., 2021). For almost a decade, the IPCC has reported with high confidence the likelihood of a permafrost carbon feedback on global climate. Yet, the IPCC reports low confidence when it comes to assessing the timing, magnitude, and form (carbon dioxide or methane) of this feedback. The latest Sixth Assessment Report (AR6) made a significant step forward as it was the first time that permafrost carbon was included in the Earth System Models that informed the IPCC report (Coupled Model Intercomparison Project Phase 6, CMIP6) (Ciais et al., 2013; IPCC 2018; Canadell et al., 2021) (IPCC, 2021). However, just two of 11 ESMs in CMIP6 included permafrost and neither of these models represented abrupt thaw, wildfire-mediated thaw, or the release of carbon from below-ground combustion during wildfire (Canadell et al 2021, Natali et al., 2022).

Left. As featured in Woodwell's joint submission to the first Global Stocktake of the Paris Agreement (2022). Estimates of the reduction in the remaining carbon budget for 2°C (IPCC, 2021) associated with emissions from permafrost thaw, as a more comprehensive range of permafrost thaw processes are included (from left to right). These estimates are derived from a compact Earth System Model, whose permafrost processes are based on a range of published studies (*e.g.,* Gasser et al., 2018; Turetsky et al., 2020; Holloway et al., 2020). Equivalent IPCC estimate (IPCC, 2021) is included for comparison.

Improving certainty of permafrost thaw for more effective mitigation and adaptation policies.

While rapid progress is being made by the scientific community in this area, the sparse nature of on-the-ground measurements combined with the scale and complexity of Arctic regions and limitations on funding relative to the need for improving permafrost representation in models remain a considerable challenge to progress (Natali et al., 2022). This ongoing scientific challenge highlights the need to more effectively and expeditiously communicate the science of permafrost thaw to key decision-makers and for decision-makers to then integrate this science into ambitious climate policy.

Advancing Arctic carbon monitoring and modeling is necessary to truly understand the magnitude and timescale of permafrost thaw emissions—and respond accordingly. Permafrost emissions could take up as much as 40% of the remaining carbon budget to stay below 2°C warming (Gasser et al., 2018). That fraction is even higher if the goal is limiting warming to 1.5°C—the threshold at which we can expect to trigger a critical tipping point for permafrost, ice sheets, and coral reefs (Armstrong McKay, et al., 2022). Resolving scientific uncertainty surrounding permafrost thaw is therefore critical for ensuring the accuracy of the United States' carbon budget and national ambition. The potential harm from neglecting permafrost thaw cannot be overstated. Even the most alarming projections of 3-41 $GtCO_2$ per 1°C of warming by 2100 likely underestimate the potential of permafrost carbon emissions (Baillargeon & Natali, 2021; Natali et al., 2021). While the Administration has committed to [reducing emissions by 50%]() from 2005 levels by 2030, this goal will likely be insufficient if the carbon budget does not account for permafrost thaw.



Resolving scientific uncertainty is also a prerequisite to informing adaptation policies that better respond to the urgent and severe impacts of permafrost thaw on Arctic communities. Federal emergency response and disaster relief programs, including those under the 1988 Robert T. Stafford Disaster Relief and Emergency Assistance Act ("Stafford Act"), often do not consider slow-onset impacts of permafrost thaw, and state, local, and tribal governments are simply not equipped to the hazards of permafrost thaw without federal support (Bronen, 2021). As communities realize the limits of their capacity to adapt to climate change in their current locations, some are considering relocation as the only viable long-term option. The U.S. Government Accountability Office (GAO) recently concluded that more than 70 out of over 200 Alaskan Native villages face significant threats from erosion, flooding, or thawing permafrost (GAO, 2022)–nearly a decade after the GAO identified 31 Alaskan villages in such a position (GAO, 2009). Despite efforts by three Alaska Native communities to fully relocate, to date, no village has successfully completed this process. Instead, communities are facing insurmountable obstacles, citing a lack of governance framework, dedicated federal funding, and government support to facilitate relocation efforts (Bronen and Chapin, 2013; Bronen 2021).

Recommendations for Congressional Action.

Among our top priorities under the Permafrost Pathways project is to develop a rigorous program that will fill in gaps in monitoring of greenhouse gas emissions (i.e., carbon dioxide and methane) across Arctic and boreal lands. The first step to filling these gaps, and thereby reducing scientific uncertainty in the permafrost carbon feedback, is a strategically planned and coordinated carbon flux monitoring network that spans the range of ecological, climatic, and physiographic conditions that occur across the northern permafrost regions. We are also working with Alaska Native villages to monitor permafrost thaw and support climate adaptation planning, including calling for a national climate adaptation and relocation governance framework that respects the human rights of impacted communities.

The success of these efforts largely depends on cooperative actions by this Congress and support from federal agencies whose missions align with the advancement of Arctic research. Recommendations for such actions are as follows:

Develop strategic funding opportunities for permafrost as a larger-scope and long-term research issue. The climate in the Arctic is changing faster than we can perform the science. To keep up with changes and promote a cohesive and continuous research environment, we need lengthened grant periods beyond the traditional three-year cycle of government funded grants. Access to high-resolution satellite imagery through the National Aeronautics and Space Administration (NASA) and National Science Foundation (NSF) should be open-sourced and not fixed to these short grant periods, so that the research community can perform long-term monitoring of hard-to-reach areas of the Arctic.

Allocate focused investment to reduce uncertainty in climate monitoring and modeling. Narrowing the range of potential future emissions from permafrost thaw requires increasing data coverage in space and time and better connecting the measuring and modeling communities. U.S.-funded Earth System Models, which are critical for understanding future changes in the Earth's systems, must reflect the full spectrum of permafrost thaw processes, which will require prioritization, including funding, from the top down to place high value in improving existing climate models. Improved models, increased data coverage in space and time, and novel ways of combining outputs from monitoring towers, atmospheric measurements, and process models will reduce the current uncertainty in Arctic carbon budgets (Natali et al., 2022).

Improve interagency coordination on Arctic research planning and funding. An extensive list of federal agencies with missions that align with our work in the Arctic, including the National Oceanic and Atmospheric Administration (NOAA), NASA, NSF, Department of Defense (DOD), National Park Service (NPS), Fish and Wildlife Service (FWS), Federal Emergency Management Agency (FEMA), Bureau of Indian Affairs (BIA), Housing and Urban Development (HUD), and Environmental Protection Agency (EPA) to name a few. But the regulatory and funding landscape is disjointed. The Interagency Arctic Research Policy Committee (IARPC) presents a dedicated effort to improve coordination, and the latest Research Plan reinforces opportunities for collaboration across different disciplines. Given the rapid pace of environmental change in the Arctic, I can only emphasize the importance of leveraging this platform to engage Indigenous communities, academia, scientists, and government agencies in multi-disciplinary Arctic research.

Develop international solutions to permafrost thaw, which, like climate change, is an international issue. This means developing pathways for data exchange, grant funding, and equipment sharing that facilitate international cooperation. Explicit restrictions on data sharing and financing of foreign investigators under some agency programs impede knowledge-sharing and the development of cross-border research. To advance understanding of the global impacts of permafrost thaw, we need a transnational approach that will allow and incentivize the free flow of science (including experts, data, and equipment) across national boundaries.

Support the capacity of Alaska Natives to coproduce knowledge and lead climate change research. While there are BIA and HUD grants that are specifically designed for Tribes, funding for climate research is almost exclusively available to academic institutions. Through Permafrost Pathways, Woodwell is trying to overcome this challenge by collaborating with ten Alaska Native tribes to monitor permafrost thaw and other climate-caused environmental impacts and to support climate adaptation planning. Through this initiative, all monitoring, modeling, and other scientific and technical work is fully driven by Alaska Native communities' environmental observations, social and ecological knowledge, research priorities, and adaptation needs. That is to say, the research agenda is set out by the tribes themselves, not the scientists. The depth and breadth of Indigenous knowledge of the land and the climate far exceeds any understanding that can be gained by quantitative observations alone. Given the complexities and connections among Earth System components, a holistic understanding of the changing Arctic can only be attained through a combination of multiple ways of knowing. If the United States is truly committed to understanding the climate crisis in the Arctic, then the current funding process should be reevaluated with this goal in mind, including by directly funding Alaska Native tribes to continue to conduct Earth observations as they have for millennia and to guide decision making for protecting Arctic lands.

The loss of permafrost carbon is irreversible on a human-relevant timeframe, as is the damage to Alaskan communities who are being forced to fight for their survival—we cannot simply focus on limiting Arctic temperature rise or refreezing permafrost. The decisions we make today must be responsive to the urgent and immediate conditions currently experienced on the ground, while also taking into account ongoing commitments to global climate ambitions. That is why, even as we continue to refine policy solutions, we need champions in Congress to direct and implement actions.

This Committee has shown an unparalleled dedication to addressing the climate crisis through this and other hearings that present an open invitation for knowledge-sharing. As a research scientist, I too, recognize the value of obtaining the best available science to inform decisions about our planetary and public health. As I hope my testimony today has effectively conveyed, we must now decide next steps and take dedicated policy action. This immediacy of this issue requires an urgent response from this Congress, one which I hope the Members of this Committee will lead with my support and that of my fellow experts. Thank you.

/s/Susan M. Natali

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