Permafrost Carbon Feedback is reducing the opportunity to avoid global climate crisis

Report on the **3rd Permafrost Carbon Feedback Intervention Roadmap Dialogue**

The Permafrost Carbon Feedback may be stripping as many as four or five years from the time humankind has left to avoid breeching a dangerous threshold in global average temperature. Accordingly, we need to pursue global decarbonization, aggressively, and while regional permafrost thaw interventions have been suggested, they need to be researched more extensively, tested cautiously and under no circumstances used as a distraction from the decarbonization goal.

Merritt Turetsky, Director of the Institute for Arctic and Alpine Research at the University of Colorado, both energized the audience and captured the consensus in making those points at the third dialogue (March 18, 2021) facilitated by the privately sponsored Permafrost Carbon Feedback Action Group – part of a four-session virtual symposia addressing the science, technology, economics, policy, social and ethical implications of permafrost thaw.

The first dialogue (March 4, 2021) surveyed **Why Permafrost Carbon Matters** and garnered easy agreement: global permafrost is charged with approximately twice as much carbon as that in all the earth's atmosphere and, as it thaws, natural processes trigger the release of a portion of that carbon in the form of the greenhouse gases carbon dioxide (CO_2) and methane (CH_4), reinforcing atmospheric warming.

The second dialogue, **Avoiding Permafrost Thaw: Managing Temperature**, considered whether we have the capacity to intervene to limit permafrost thaw – and whether we should. (The answers being: yes and, tentatively, yes.) It also introduced the concept of an Arctic Premium, in which some interventions might prove more effective if applied directly at high latitudes.

The third dialogue posed the intervention question more directly, **Are Permafrost Thaw Interventions Possible?** Again, the response was positive but provisional. Global decarbonization, which could slow warming-driven permafrost thaw, isn't merely possible, it is crucial to avoid a global catastrophe. Localized interventions are also possible, though there is no evidence that any would be effective at scale. Still, after canvasing the extent to which scientists and policymakers now fully understand the global climate risk, Turetsky said, "I'm not in a mindset of gathering more information. I'm in a mindset of climate action." She also triggered what, in the Zoom world, must count as spontaneous and sustained applause when she added, "I'm not a fan of using this dialogue to distract from the main problem."

The third dialogue featured five presenters and, like the earlier two, attracted a large group of leading academics, government policy makers, technology investors, climate change activists and media who had tuned in online. The presenters are listed here in the order in which they spoke:

Steve Kokelj, Permafrost Scientist, Northwest Territories Geological Survey

Merritt Turetsky, Director, Institute for Arctic and Alpine Research, University of Colorado

Oliver Sonnentag, Associate Professor, Canada Research Chair, Department of Geography (Atmospheric Biogeosciences), Université de Montréal

Lisa Stein, Associate Chair (Research), Faculty of Science (Biological Sciences), University of Alberta

Duane Froese – Professor & Canada Research Chair in Northern Environmental Change, Faculty of Science (Earth & Atmospheric Sciences)**,** University of Alberta

Steve Kokelj began a lightning round of Permafrost 101, saying that permafrost is "simply ground that remains frozen for at least two years," adding, "We can consider it as the glue that holds northern landscapes together." As the only scientist in the group who is based in the north, Kokelj also said the issue is personal. "My house is built on permafrost." And "as a field scientist, I've had the opportunity firsthand to see how landscapes transform." Those transformations can be small and scattered or large and devastating. Kokelj offered the example of a base-level permafrost collapse that triggered a deep-seated landslide that deposited several kilometers of material and rock into the central McKenzie Valley. "My message here is that permafrost thaw is happening. But it manifests very differently in different places. … We need to keep observing because things are changing before our eyes."

Merritt Turetsky introduced herself as "a boots-on-the-ground peat lover." (Her Twitter handle is **@queenofpeat**.) She said she thinks of permafrost as a foundation. "This foundation is sitting within a region that's warming three to four times faster than anywhere else on our planet. ... and that surface warming is impacting permafrost temperatures, even at great depth. … with some of the most rapid thermal change occurring actually in our coldest permafrost." This warming triggers a double danger, undermining the landscape and infrastructure locally and accelerating climate effects globally.

Oliver Sonnentag (@atmosbios) weighed in to describe the global and local distribution of permafrost – and of the organic carbon contained within that frozen material. For example, the bulk of permafrost carbon in Russia is spread relatively evenly and concentrated across the top 100 centimetres of earth and ice, whereas permafrost is the Canadian north is distributed less evenly and includes high concentrations at depth, especially in the Mackenzie Valley and just south of Hudson Bay. Sonnentag also pointed out that permafrost is primarily a "two-gas problem" – thaw allows emissions of both carbon dioxide and methane, the latter being a much more powerful greenhouse gas.

As Turetsky had already mentioned, deeper, colder permafrost is not protected from thaw, especially if there is a lot of ice mixed in with organic material. So, Sonnentag said, "there are two important environmental dynamic boundaries that we have to keep in mind: one is the frost table, but also the water table," both because liquid water is an effective purveyor of heat and because liquid water can enhance conditions in which microbial activity turns organic soils into net emitters of carbon dioxide and methane.

As reported in a recent *Nature* article ("How microbes in permafrost could trigger a massive carbon bomb"), "Scientists are becoming increasingly worried that [permafrost] thaw will lead to an epic feast for bacteria and archaea (single-celled organisms that thrive in low-oxygen environments) that produce carbon dioxide and methane." In that context, Lisa Stein said, "I'm not a field scientist. I'm a lab-based scientist. I study the microorganisms that are involved in producing and consuming climate active gases." Across a broad landscape and in a variety of conditions, she said, "organic carbon is awakened in thawing permafrost through an integration of microbial cycles … and those microorganisms are actively

metabolizing organic carbon and changing them (for example), into the substrates that organisms like methanogens can then use to produce methane."

But these processes are complicated and not always destined to release carbon, Stein said. "There's been quite a lot of work looking at the microbiome associated with *Sphagnum* (moss), and what's been found is that there is a rich population of methane *consuming* microbes that are associated with peat moss." Accordingly, some scientists are looking at the potential of peat to become a carbon sink instead of a net source.

Turetsky agreed, saying, "We know that permafrost thaw often triggers rapid destabilization of soils, vegetation and also of carbon stocks in those ecosystems. But that is often followed by a period of stabilization and even recovery of those carbon pools. So, can we target portions of this lifecycle? Can we … think about mechanisms to kick the ecosystem out of that emitting phase into the more stabilizing (carbon) accumulating phase?" Picking up the thread later, she said, "Thawed drained lakes, for example, are very efficient incubators and growers of peat over time, and those can accumulate permafrost, but on Millennial scales. That is a really great example, where that mature phase of thaw development is a net carbon sink."

Turetsky also pointed to the potential to manage fire to protect carbon reserves instead of timber values. She said, the northern permafrost "is the last biome on our planet that has large free ranging wildfires. We might be able to use indigenous fire practices or other ways of bringing "good" fire back onto the landscape with the goal of conserving permafrost, keeping permafrost soils cold or protecting carbon stocks. Peatland carbon sequestration requires fire – not frequent fire, not severe fire, like we're starting to see – but low levels of burning. It opens up the landscape. It keeps *Sphagnum* moss in place, and not being taken over by other kinds of dry or non-carbon-accumulating ground cover like lichens."

Stein suggested that beyond working with the groundwater table, other options for bioremediation might include managing permafrost for oxygen and for nutrients like nitrogen and iron that affect microbial activity. She also pointed to research on "capturing methane in order to have microbes convert that methane into valuable products." Methane capture is already practiced at oil wells and wastewater treatment plants, she said, adding, "I don't know if it's possible to capture methane on a large scale, but we could do it at a municipal level."

As presenters made cautious forays into describing direct intervention, it's notable that the term "moral hazard" was never spoken, though most presenters and audience members expressed concern that any suggestion of a technical carbon solution might be used as an excuse to delay efforts to reduce emissions. Turetsky led this discussion at several points, saying,

"If you just imagined a world without permafrost carbon feedback to climate, there's ample evidence of the need to decarbonize and to decarbonize quickly, to meet a two degrees centigrade threshold or 1.5. … We don't have a lot of time to meet those thresholds. Now, introduce … the feedback and we have less time … maybe on the order of four or five years less. … Our best chance of saving permafrost or keeping permafrost carbon in the ground and out of the atmosphere is to decarbonize, full stop! The worst option is to focus on carbon removal technologies that don't exist at any meaningful scale yet." And when she punctuated this point, saying, "I'm not a fan of using this dialogue to distract from the main problem," the chatline erupted with comments in support ("Yes! Climate action. AGREED." "Totally agree, Merritt!" "Once again, Merritt in my opinion knocks it out of the park with this response").

Steve Kokelj touched a similarly lively nerve in calling for more research – and more researchers – in the north. He said, "The actual physical processes of thawing permafrost are not that well studied." Mostly for lack of research funding and attention, "the basic description is not being that well done. So, I think it's a huge opportunity for the scientific community. Because there's new things to learn. Every time we go into the field, and we start to observe from a physical sciences perspective, these processes that are unfolding, we''re learning new things."

On that count, when dialogue moderator Chris Henderson asked panelists how they would divide a virtual $100 for research or development, they mostly picked up Kokelj's challenge. Duane Froese said, "I would probably put it in the north, And I would probably put it around capacity (building) and amplifying voices. We need to support the people that are most affected by this issue."

Turetsky said we need to double down on producing new climate leaders. Kokelj had spoken about the inevitable complexity of climate modeling, saying, "The models are great. But we need to have a stronger empirical basis to support the models." Which prompted Turetsky to talk about an "adopt-a-modeller program – a wonderful collaboration between field-based scientists like myself, who are down in the trenches of peat, and some of the folks trying to represent these complex issues in models."

But given $100, Turetsky said, "I would probably take $75 and actually try to amplify Arctic voices, those who are on the frontlines of climate change." There is a tendency for those at great distance to ignore this issue, she said, because "it's not impacting you and your loved ones. But these Arctic voices have such compelling stories to tell about climate change and about their ecosystems being disrupted." Specifically, Turetsky recommended the Inuit activist Sheila Watt Cloutier's book, *The Right to be Cold,* adding, "It changed my life**."**

Lisa Stein endorsed capacity building, but said, "I would love to see some way to test some of these (bioremediation) strategies, and just see whether they'll work or not. Because we don't really know how. … But with the stuff that we *do* know, I think that we can start getting some boots on the ground strategies and really see if they can work."

Duane Froese also seemed to speak for the group when he concluded that permafrost thaw "is a defining issue for Canada in the 21st century. So, we really need to be thinking decades out, not just the next couple years."

Key Messages

1. The Permafrost Carbon Feedback may be stripping as many as three to four years from the time humankind has left to avoid breeching a dangerous threshold in global average temperature.
2. From bioremediation to fire management, there are a selection of local interventions that should be researched and tested simultaneously, so we will better understand their efficacy and their capacity to scale up.
3. We need to support research, and develop human capacity in the north – including by amplifying the voices of those who are already feeling the effects of climate change and permafrost loss.