The unaccounted-for side of permafrost carbon

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Climate change is at full force in the Arctic. The highest Arctic temperature on record was reported in 2020. These rising temperatures have knock-on effects on Arctic rivers and the permafrost soils that they drain.

Permafrost?

About one quarter of the exposed land surface in the Northern Hemisphere is underlain by perennially frozen ground, the permafrost, with a temperature below 0°C for two consecutive years or more. The pan-Arctic permafrost region includes large parts of Alaska, Canada, Greenland, Northern Europe (Scandinavia) and Russia.

Thawing or melting?

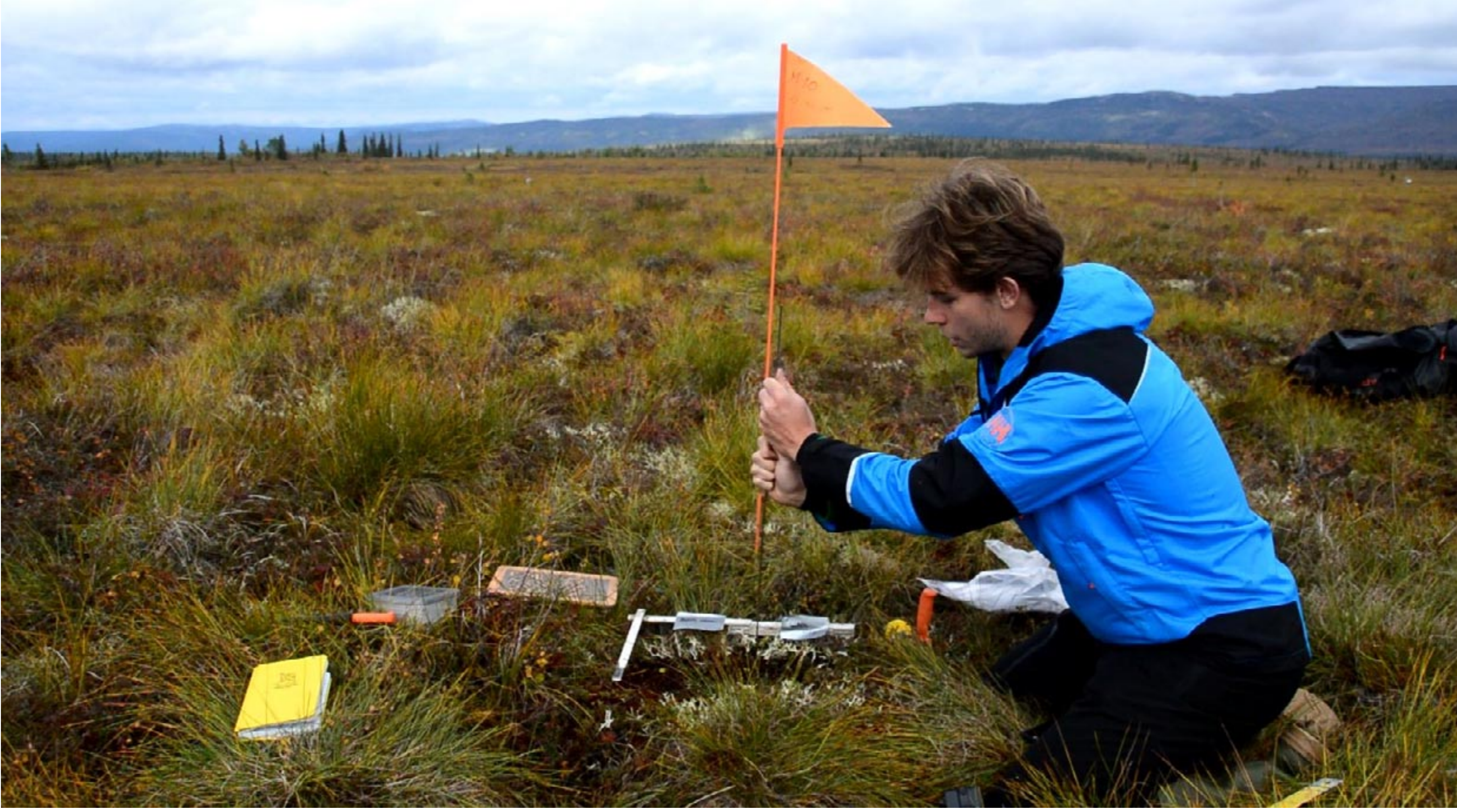
The Earth's high latitude regions are warming twice as fast as the global average. As a consequence, ice melts and permafrost thaws. Increasing permafrost temperatures have been recorded with consequences for the environment and infrastructure, including coastal erosion, ground subsidence, road and building collapse. With climate change, the permafrost extent is predicted to shrink by at least one third by the end of this century.

Permafrost thaw: a tipping element in the climate system

Permafrost contains three times as much carbon as exists in the world's forests. With permafrost thaw, previously frozen organic carbon is exposed to microbial decomposition with subsequent emission of the greenhouse gases carbon dioxide and methane into the atmosphere, creating positive feedback on global warming, i.e., the permafrost carbon feedback. It is estimated that about 15 % of the permafrost organic carbon stock could be emitted as greenhouse gases by 2100. On an annual basis, this represents 22 to 31% of the current anthropogenic carbon emissions. Most of that carbon would be emitted as carbon dioxide but about 2.3% of the permafrost carbon emissions will be released as methane known for its larger global warming potential on a century time scale.

Precise estimates of permafrost carbon emissions are needed to better predict the rate of climate change and the remaining carbon budget

Decision-makers should be advised by the most precise scientific knowledge to make informed decisions. Permafrost carbon



Field measurement of permafrost thaw depth

emissions were not included in the models analysed by the Intergovernmental Panel on Climate Change (IPCC) in the last assessment report in 2013. These emissions reduce the remaining carbon budget to keep within the 1.5 or 2°C targets from the Paris Agreement on climate action. The recent Special Report of the IPCC on the Ocean and Cryosphere in a Changing Climate provides an estimate of the permafrost organic carbon stocks, and an evaluation of how this carbon pool would change following contrasting Representative Concentration Pathway (RCP) scenarios. This is a step forward, but efforts are still required to provide precise estimates of permafrost carbon emissions - a key parameter in the prediction of the rate of climate change and Earth's remaining carbon budget.

The precision of permafrost carbon emission estimates depends on how well the various processes affecting the fate of organic carbon upon permafrost thaw are constrained.

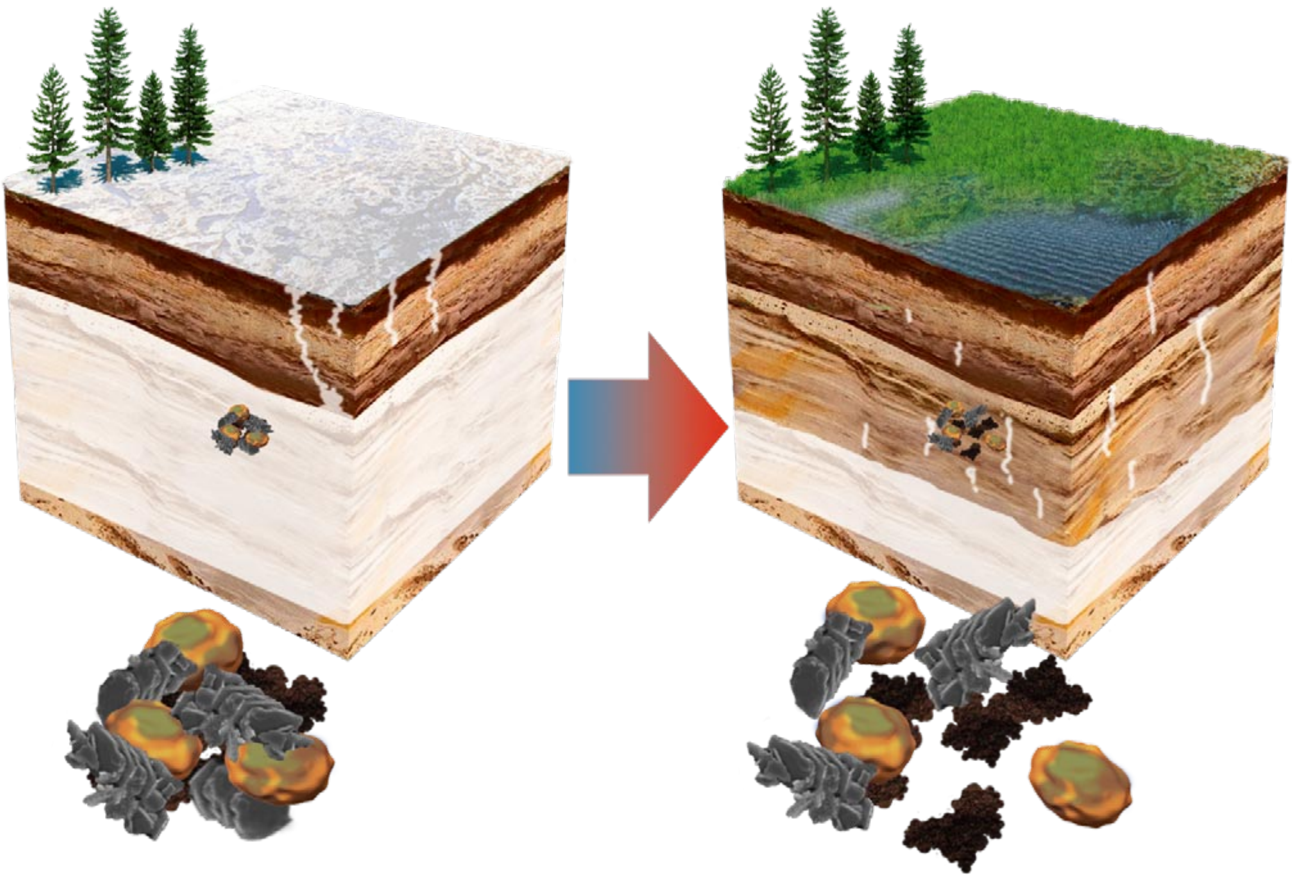
Sampling frozen soils

One unaccounted for factor is that organic carbon in permafrost is not alone but partly interacts with mineral constituents. With permafrost thaw, these interactions evolve along different pathways which largely depend on soil water saturation: some soils face a rise in their water table leading to wetlands, while other areas are drained resulting in drier soils. Therefore, permafrost thaw directly affects the stability of these interactions, a factor which may slow down or amplify permafrost carbon emissions. Not considering the evolution of the interactions between minerals and organic carbon upon thaw is likely to lead to over-confident projections of permafrost carbon emissions.

This is precisely why Sophie Opfergelt and her team of four scientists, Catherine Hirst, Elisabeth Mauclet, Arthur Monhonval and Maxime Thomas, are leading the project WeThaw funded by the European Research Council focusing on the role of mineral constituents on the modulation of permafrost carbon emissions.

The positive or negative influence of mineral constituents

The evolution of the interactions between organic carbon and minerals with permafrost thaw plays a key role in modulating (i) how much carbon will be available for greenhouse gases production, i.e., amplifying or mitigating permafrost carbon emissions, and (ii) how much carbon will be emitted as carbon dioxide or as methane, and hence the resulting net global warming potential.



The WeThaw team is carrying out field work in Alaska and gathering samples from Siberia, Canada and Greenland collected by collaborators to perform laboratory analyses with the aim of characterising changes in mineral constituents upon thaw and the implications for the fate of organic carbon. The overarching goal of WeThaw is to scientifically underpin the role of mineral constituents on the fate of organic carbon in thawing permafrost.

Team members are focussing their efforts on studying the evolution of mineral-organic carbon interactions (i) during transfer between soils and rivers, (ii) due to soil to plant transfer, (iii) induced by abrupt thaw, and (iv) recorded in geological archives.

This level of understanding is required to provide an integrated view of the evolution of interactions between organic carbon and minerals in a changing permafrost ecosystem, a necessary step to improve the next generation of decision tools based on permafrost carbon emissions.

Arctic rivers as windows into organic carbon stabilisation in permafrost soils

Arctic rivers, including the six large Arctic rivers (Ob', Yenisey, Lena, Mackenzie, Yukon, Kolyma) and their tributaries, are the arteries connecting the permafrost landscape to the Arctic Ocean. Their combined river discharge, calculated by the volume of water in the river and the speed at which the river is travelling, is more than 10 % of the world's river discharge. This makes Arctic rivers the largest supplier of waters to the Arctic Ocean. These rivers have a dynamic seasonal cycle: during the winter months, rivers are covered in ice and often frozen to their base; during a tumultuous period in spring, the river ice breaks up and rivers are fed by snowmelt; and during the summer months waters flow into the river along the surface of unfrozen permafrost soils. Rising temperatures in the Arctic are driving increased precipitation that in turn drives increased river water discharge which can change the amount of material that is transported from permafrost soils to the Arctic Ocean.

Permafrost soils, rivers and seasons

Permafrost is storing a vast stock of organic carbon. During spring and summer months, the upper surface of these soils, termed the active layer, is unfrozen and organic carbon is unlocked. Rising temperatures in the Arctic are warming the permafrost surface, increasing the thickness of the active layer during summer months and exposing a larger stock of organic carbon. This leads to an amplified release of organic carbon from permafrost soils, with a portion of organic carbon released vertically to the atmosphere as carbon dioxide and methane; and a portion of organic carbon transported laterally from the soil to Arctic rivers.

The role of mineral elements on carbon transport

Mineral elements, such as iron (Fe) and aluminium (Al) play a key role in stabilising organic carbon in soil waters and controlling the lateral transport of organic carbon from soils to rivers. In soils, mineral elements bind to organic carbon to form nano to micron-scale entities, termed colloids. When rain and snow percolate through the soil's thin unfrozen skin, they capture these mineral element bound-organic carbon colloids and transport them laterally into rivers. In this way, mineral elements stabilise organic carbon in soil and river waters.

But how is ongoing permafrost degradation affecting mineral element-organic carbon interactions? The WeThaw team seeks to answer this question by using river waters as a gauge of colloid formation in soil pore waters. They consider two pivotal moments in the Arctic river annual cycle that will capture the effect of permafrost degradation on the mineral element-organic carbon colloids: the spring flood and rain events.

During these periods, the pathway for colloid transport from soils to rivers is unobstructed and the mineral element-organic carbon colloids carry a fingerprint of the processes occurring in permafrost soils.

Colloids as 'fluvial seismometers'

The WeThaw team has sampled river and soil waters during peak flow events. In 2018 and 2019, the team ventured to Alaska to collect permafrost and river water samples during river ice break-up and a rain event. The team has established that during these peak events, mineral element-organic carbon colloids can act as a 'fluvial seismometer' to monitor the effect of permafrost degradation on organic carbon stabilisation in permafrost soils. Future work should target these crucial and understudied periods where the rapid changes allow for a direct connection between rivers and permafrost soils.

Webpage of the WeThaw project: https://sites.uclouvain.be/wethaw/

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Sampling river under the ice

Green and digital transition: More resilience and sustainable jobs for the EU

Virginijus Sinkevičius, European Commissioner for Environment, Oceans and Fisheries, explains the new Circular Economy Action Plan and argues that the green and digital transition can bring more resilience and sustainable jobs for the EU.

The pandemic has exposed and exacerbated vulnerabilities in our globalised and interconnected world. It has disturbed supply chains, wiped out jobs, and tested the response capacity of businesses and whole countries to the limit.

Its effects will be profound and long-lasting. But even before the pandemic, we were already faced with accelerating crises on the climate, biodiversity and resource fronts, and few would wish to return to the "old normal".

Now is the time to take the opportunity to sketch out a "new normal", where sustainability and resilience become the hallmark of the European Union. The EU Recovery Plan addresses this challenge, with a historic budget to power a job-rich recovery built around green and digital solutions.

The environment missions that highlight the necessity of land conservation

In the mission letter to Commissioner Virginijus Sinkevičius from President Ursula von der Leyen, she highlights some of the future policies that the EU is prioritising:

1. "I want Europe to lead global efforts to curtail biodiversity loss. You will put forward a new Biodiversity Strategy for 2030, looking at everything from Natura2000, deforestation, land degradation, protected species and habitats, and sustainable seas and oceans."

2. "I want you to lead the work on a new Circular Economy Action Plan to ensure sustainable resource use, notably in resource-intensive and high-impact sectors. This should support and feed into the new industrial strategy."

3. "Europe's seas and oceans, its landscapes and natural environment are part of the social fabric of our Union and a source of great natural and economic wealth. We must preserve and protect them, and make the most of their potential by investing in their future and ensuring that future generations can benefit from their beauty and the opportunities they create."

The new Circular Economy Action Plan

One central element in this recovery will be a swifter transition to a circular economy, where economic growth and prosperity are decoupled from resource use and environmental impacts. Adopted in March this year, the new Circular Economy Action Plan will guide Europe along this path. It is equipping our economy for the future with measures to prolong the life cycle of products, and ensuring that resources used in the EU are optimised and kept in the economy for as long as possible. In extracting more value and functionality from products and materials, the circular economy creates local jobs at all skill levels and provides opportunities for social and territorial integration and cohesion. Furthermore, new business models bring indirect employment, thus bringing value across the economy as a whole.

The new Action Plan aims to transform the way products are made, with a view to ensuring that sustainable products and services become the norm. And it sets out to ensure that consumers are not only better informed, but have increased rights to get products repaired.

The goal is to take circularity to the mainstream, tackling problems at source. This implies re-thinking how the economy meets the needs of our citizens in different sectors, particularly in high-impact areas like electronics, buildings, textiles and packaging. A new range of repair services, product-as-service models and digital solutions are expected to bring a better quality of life, innovative jobs and upgraded knowledge and skills.

With that in mind, the Circular Economy Action Plan foresees actions to make business more resilient. For example, when a company provides its products as a service, reuses or remanufactures them or incorporates recycled materials, it reduces its dependency on unpredictable supplies, while simultaneously lowering its structural costs. Public authorities that opt for circular products and services support the market for such innovative companies in their local cities, regions and countries. Digitally based technologies can also increase resilience, with 3D printing providing customised and locally delivered solutions and responding to urgent needs.

Permafrost and future environment policies

Since Permafrost contains three times as much carbon as the world's forests, the preservation of the natural landscape is a crucial element of the overall climate-neutral plan. Land degradation, especially in the North of Europe, is therefore an urgent priority for policy-makers.

Two proposed policies include:

1. A larger EU-wide network of protected areas: This would exist on land and at sea, building upon existing Natura 2000 areas, protecting at least 30% of the land and 30% of the sea in the EU;

2. And an EU Nature Restoration Plan: A series of concrete commitments and actions to restore degraded ecosystems across the EU by 2030, and manage them sustainably e.g. by more effectively protecting marine habitats and restoring at least 25,000 km of rivers to free-flowing rivers by 2030.

Greater sustainability: The European Green Deal

When your house burns down, you build it back better and more efficient. This is why in these times of hardship, our action must be geared towards those most in need, and to creating the sustainable wellbeing of the future. With Next Generation EU, Europe has a recovery plan for an economy that is more resilient, better equipped to deal with digital challenges, and above all, greener. In the wake of this crisis, Europeans will demand greater sustainability. And that's the thinking at the heart of the European Green Deal.