

# Woods Hole Research Center



## WHO WE ARE

Woods Hole Research Center (WHRC) is an independent, non-profit research and policy center based in Falmouth, Massachusetts.

Our scientists investigate the causes and effects of climate change to identify and implement opportunities for conservation, restoration and economic development around the world.

## OUR WORK

We focus our research on the world's largest vulnerable reservoirs of land carbon: tropical forests and arctic permafrost. We work to control climate change by preventing carbon from being released to the atmosphere from these reservoirs by either direct human interventions like deforestation, or by climate change itself. To this end, we engage in climate policy processes at all levels, from communities, to states, nations, and international.

*WHRC has been recognized for two years running as the world's #1-ranked independent climate change think tank by the International Center for Climate Governance.*



## Tropical Forests

Forests help to control global and regional climate, preserve valuable ecosystems, and support local livelihoods. Our work aims to strengthen understanding of these roles of forests, the impacts of climate change on forests, and to inform policies that encourage forest-friendly economic development.

### › Brazilian Amazon

Amazon deforestation has impacted regional climate and ecosystems, and threatens the viability of agriculture and indigenous livelihoods. WHRC scientists are at the forefront of understanding these processes and developing policy remedies. Much of this work takes place at Tanguro Ranch, a 200,000 acre working farm in Mato Grosso state.

### › Democratic Republic of the Congo (DRC)

The Congo Basin contains the second largest forest on earth, and is one of the largest terrestrial storehouses of carbon. WHRC works with community leaders and partners in the DRC to identify forest-friendly economic opportunities, such as agroforestry and agricultural production and marketing techniques, high-efficiency charcoal production, and end-user technologies, such as fuel efficient stoves.



*"WHRC played a critical role in supporting the development and implementation of a national forest monitoring system in Mexico. Thanks to the technology and training WHRC provided, the Government of Mexico is now empowered to monitor and better manage its forests. Undoubtedly, WHRC's contribution will result in the conservation of much of Mexico's natural landscape for generations to come."*

*- José María Michel Fuentes*

*MRV officer responsible for technical support of the national forest monitoring system in Mexico*



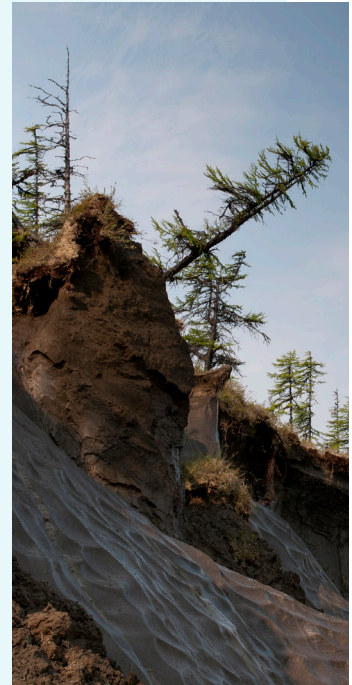
## The Arctic

The Arctic consists of two distinct biomes, expansive boreal forests and the wide open tundra. Both of these systems have experienced dramatic changes over the past few decades, greatly impacting the global carbon balance and by extension the global climate system. WHRC seeks to understand the changes that are occurring in the Arctic and the implications of these changes on the global climate.

### ► Permafrost

Locked within ancient frozen soils, known as permafrost, is more carbon than has been emitted through fossil fuel combustion to date, and more, in fact than is in the atmosphere, including natural and human contributions.

The potential release of greenhouse gases from thawing permafrost constitute a major global threat. WHRC's Permafrost Program works to identify how much carbon is contained in these frozen soils, how fast emissions are occurring and how these emissions will affect the climate.



### OUR RESEARCH HAS BEEN FEATURED IN



### OUR END-USERS AND PARTNERS INCLUDE



### ORGANIZATIONAL INFORMATION

WHRC relies on the generosity of our supporters. We are a Massachusetts nonprofit 501(c)(3) corporation with an annual budget of \$10M.

*Join us on the front lines of the climate change fight.*

### LEADERSHIP

Philip B. Duffy, President  
Scott Goetz, Senior Scientist & Deputy Director  
Wilhelm M. Merck, Chairman

*Make a donation at [whrc.org/support](http://whrc.org/support)*

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**Mission statement** *To advance scientific discovery and seek science-based solutions for the world's environmental and economic challenges through research and education.*



## Permafrost and Global Climate Change

Robert Max Holmes, Susan Natali, Scott Goetz, and Philip B. Duffy

### KEY MESSAGES

- Permafrost contains almost twice as much carbon as the atmosphere.
- As the Earth warms, permafrost thaws, releasing carbon dioxide and methane to the atmosphere.
- The amount of carbon dioxide and methane that will be released by thawing permafrost is not yet well understood and as a result it is not incorporated into global climate models. The amount and rate of this carbon release will greatly impact Earth's climate trajectory.
- Thawing permafrost carries unexpected threats as well. In the summer of 2016, a decomposing reindeer carcass – previously frozen in permafrost – caused an anthrax outbreak in northern Russia that killed one person and sickened dozens of others.

Carbon emissions from thawing arctic permafrost will become substantial within decades, likely exceeding current emissions from fossil fuel combustion in the United States. This will greatly complicate efforts to keep global warming below 2°C and adds urgency to limiting anthropogenic emissions. Unlike fossil fuel emissions, emissions from thawing permafrost build on themselves, because the warming they cause leads to even greater emissions. For this reason, emissions from permafrost could lead to out-of-control global warming.



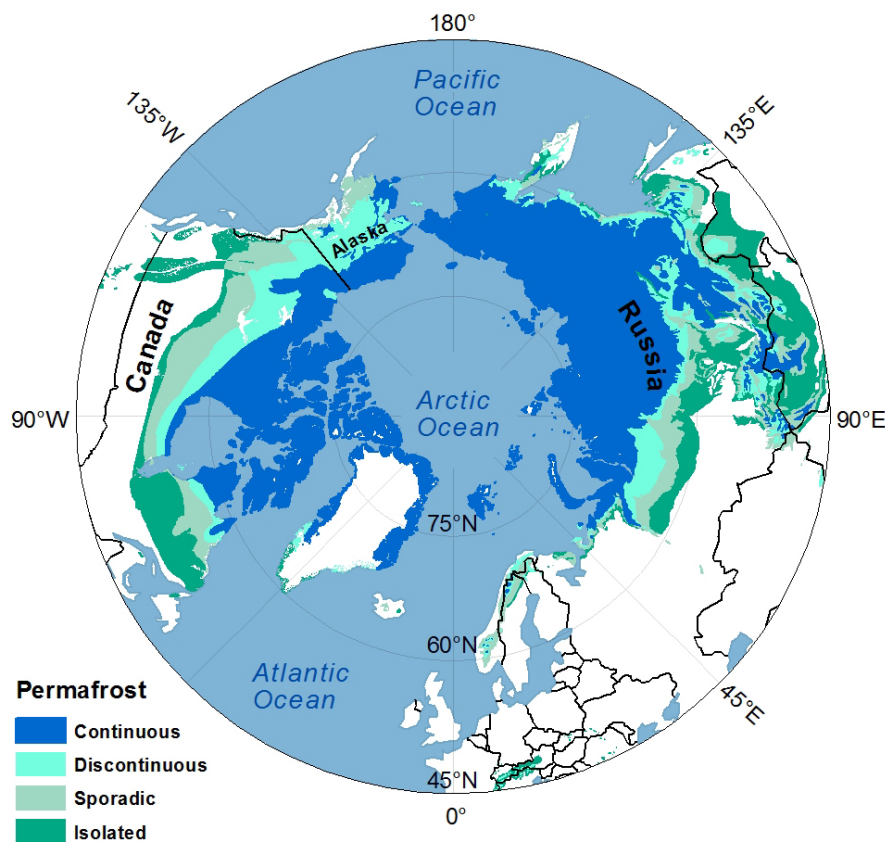
June 2015 White Fish Lakes fire in the Yukon Delta National Wildlife Refuge in southwest Alaska. Photo: Alaska Division of Forestry

### BACKGROUND

- Permafrost is “permanently” frozen ground, generally thousands of years old.
- Permafrost soils in the Arctic contain ~1500 billion tons of carbon, almost twice as much as is currently in the atmosphere.
- As the Earth warms, permafrost thaws.
- When permafrost thaws it releases carbon to the atmosphere, in the form of carbon dioxide or methane.
- A recent analysis<sup>1</sup> suggests that 130-160 billion tons of carbon might be released from thawing permafrost between now and 2100. Emissions from thawing permafrost will continue, or even accelerate, after 2100 unless climate change is controlled.
- For perspective, in 2013 the entire United States emitted 1.4 billion tons of carbon from fossil fuel combustion and cement production.
- Global climate models do not adequately account for carbon loss from thawing permafrost, so current projections of future climate tend to be too optimistic.

## IMPLICATIONS

- Permafrost carbon emissions will likely account for a large share of the remaining emissions allowable globally if we are to keep global warming below 2°C.
- Carbon emissions from thawing permafrost accelerate climate warming, so the potential exists for a catastrophic, self-reinforcing cycle of warming and thawing permafrost.
- It is unknown at exactly what level of warming this “tipping point” occurs; if less than 2 degrees, then the oft-cited 2-degree target would be too lenient.
- International scientific cooperation is essential to reduce uncertainties about the rate of carbon loss from thawing permafrost, because most arctic permafrost is in Russia.
- Permafrost thaw will also dramatically alter arctic and subarctic landscapes, impacting human infrastructure including building, roads, and pipelines, as well as impacting plant and animal communities.



Northern hemisphere permafrost extent.  
Data from Brown, et al. 2001 NSIDC

## RECOMMENDATIONS

**GREATLY REDUCE GLOBAL CARBON EMISSIONS** from fossil fuel use and deforestation, and take steps to limit black carbon deposition in the Arctic.

**LOCATE THE TIPPING POINTS** Undertake a large-scale effort to understand at what level of warming a self-reinforcing cycle of warming and permafrost thawing occurs. This should involve modeling, field measurements, and analysis of paleoclimate data.

**INTEGRATE PERMAFROST SCIENCE** into global climate change models.

**COMMUNICATE** about the threat of arctic permafrost thaw to policymakers and the public.

## FURTHER READING

<sup>1</sup>Schuur, E. A. G., A. D. McGuire, C. Schadel, G. Grosse, J. W. Harden, D. J. Hayes, G. Hugelius, C. D. Koven, P. Kuhry, D. M. Lawrence, S. M. Natali, D. Olefeldt, V. E. Romanovsky, K. Schaefer, M. R. Turetsky, C. C. Treat, and J. E. Vonk. 2015. Climate change and the permafrost carbon feedback. *Nature* 520:171-179, doi:10.1038/nature14338.

Schaefer, K., H. Lantuit, V. E. Romanovsky, E. A. G. Schuur, and R. Witt. 2014. The impact of the permafrost carbon feedback on global climate. *Environmental Research Letters* 9, 085003, doi:10.1088/1748-9326/9/8/085003.

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