What needs to be known by 2050 about Permafrost?

Permafrost is degrading

Permafrost (perennially frozen ground, Fig. 1) remains the most poorly documented component of a changing Arctic at the global scale, but is an essential structural feature of the land upon which millions of Arctic residents depend for their homes and livelihoods. The impacts of degrading permafrost are extensive and affect remotely located Arctic communities as well as global society. On the global scale, increased emissions of greenhouse gases following permafrost thaw will likely affect how fast climate change is happening. On the local scale, permafrost degradation damages infrastructure and impacts access to fish and wildlife, drinking water, trails, and rivers. By 2050, permafrost soil temperatures will have continued to increase causing wide-spread permafrost degradation and amplifying impacts associated with it.

Increased permafrost degradation has the following consequences by 2050:

- Previously frozen organic carbon that has been stored in permafrost for thousands of years is broken down by soil microbes and released to the atmosphere as carbon dioxide and methane. Permafrost zone soils contain carbon equal to 50% of the soil carbon found in ecosystems everywhere else. Release of additional greenhouse gases from permafrost to the atmosphere by 2100 could account for 130-160 billion tons of carbon. This is an equivalent of 61-75 ppm of atmospheric carbon dioxide, an increase of 15-19% to current atmospheric concentration (408 ppm in February of 2018). These permafrost carbon emissions accelerate climate change and incur additional societal costs for mitigation and adaptation.

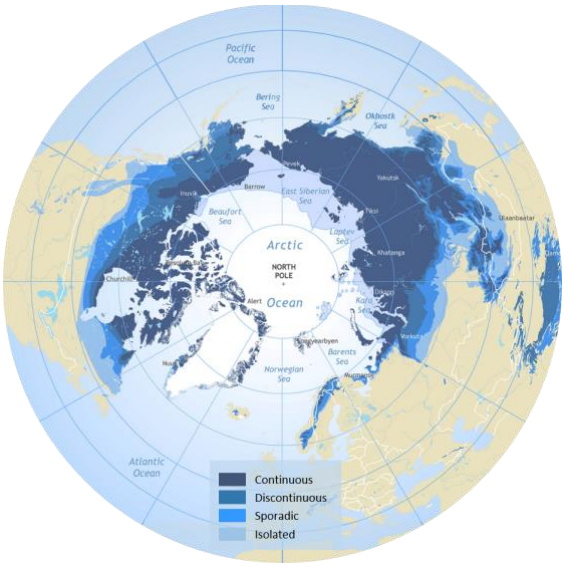

Fig. 1 Map of permafrost distribution. Darker shades of blue indicate higher percentage of permafrost. Map after Brown et al. 1997; International Permafrost Association

- The supply of fish and wildlife for subsistence or other uses will be altered because of the interaction of degrading permafrost with vegetation and hydrology. Modified surface water availability and access to potable water sources (e.g., lakes and rivers) will pose an additional challenge to Arctic residents and others who depend on these food resources. Altered transportation on land and water and access to trails due to permafrost degradation will make travel more difficult and may further isolate Arctic communities.
- Reduced permafrost stability and the fact that infrastructure (e.g., roads, buildings, railways, pipelines, airports) warms and degrades ground ice itself will cause

Fig. 2 Road damage in Bethel, Alaska, caused by thawing permafrost. Source: Lisa Demer/Alaska Dispatch News

widespread damage or failure of the infrastructure (Fig. 2). This will make building and maintaining infrastructure on permafrost much more costly and difficult. Annual damages to roads in Alaska alone are estimated to sum up to 118 million USD annually by 2050 with increasing costs each year thereafter.

Our current understanding of the consequences of permafrost degradation predicts that impacts on the local and global scale are large and multi-facetted and that immediate action can alleviate some of the worst impacts.

What additional knowledge is needed to adaptively respond to changes in Arctic environments by 2050?

More detailed knowledge on the impacts of permafrost degradation will need to focus on:

- How fast is carbon being released to the atmosphere and is it being released as carbon dioxide or methane? The higher climate forcing impact of methane compared to carbon dioxide could accelerate climate change. Further evidence is needed on how gradual top-down versus abrupt thaw induced after a disturbance (e.g. fire) will impact permafrost carbon release. These type of ecosystem disturbances affect plant carbon uptake and expose more organic carbon to microbial decomposition, which could speed net carbon release to the atmosphere. In addition, better representation of permafrost carbon processes in global models will narrow down the impact of permafrost carbon release to the global climate.
- Continued efforts are needed to quantify specific associations between permafrost degradation and the availability of ecosystem services (fish and wildlife for subsistence, drinking water, and access to trails and rivers for transportation). This includes spatially-explicit models of thermokarst vulnerability, which can link community-based information with comprehensive landscape modeling efforts. Evaluation of the interactions among permafrost degradation, erosion, river channel changes, river ice stability, and forest succession (especially increased shrubs in formerly graminoid (grass-like) tundra) is important for management decisions.
- Better characterization of the location and type of ice-rich ground in permafrost landscapes will be needed to assess the risk for damage to existing infrastructure. Alternatives for design and construction of infrastructure rely on better geotechnical information. Standardized best practices for planning, design, and construction of infrastructure on permafrost will help Arctic communities and nations to achieve sustainable growth and development while balancing national security and local community needs in the context of economic constraints.