SAMPLE

Earth's Dynamic Systems: Permafrost

The Thawing North

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This free sample contains the Introduction and Chapter 1. The complete book contains the full contents above.

Introduction

Permafrost (from perma- 'permanent' and frost) is soil or underwater sediment which continuously remains below 0 °C (32 °F) for two years or more; the oldest permafrost has been continuously frozen for around 700,000 years. Whilst the shallowest permafrost has a vertical extent of below a meter (3 ft), the deepest is greater than 1,500 m (4,900 ft). Similarly, the area of individual permafrost zones may be limited to narrow mountain summits or extend across vast Arctic regions.

The ground beneath glaciers and ice sheets is not usually defined as permafrost, so on land, permafrost is generally located beneath a so-called active layer of soil which freezes and thaws depending on the season. Around 15% of the exposed land surface of the Northern Hemisphere, and 11% of the global land surface, is underlain by permafrost, covering a total area of around 18 million km2 (6.9 million sq mi). This includes large areas of Alaska, Canada, Greenland, and Siberia.

It is also located in high mountain regions, with the Tibetan Plateau being a prominent example. Only a minority of permafrost exists in the Southern Hemisphere, where it is consigned to mountain slopes like in the Andes of Patagonia, the Southern Alps of New Zealand, or the highest mountains of Antarctica.

Permafrost contains large amounts of dead biomass that has accumulated throughout millennia without having had the chance to fully decompose and release its carbon, making tundra soil a carbon sink.

As global warming heats the ecosystem, frozen soil thaws and becomes warm enough for decomposition to start anew, accelerating the permafrost carbon cycle. Depending on conditions at the time of thaw, decomposition can release either carbon dioxide or methane, and these greenhouse gas emissions act as a climate change feedback. The emissions from thawing permafrost will have a sufficient impact on the climate to impact global carbon budgets.

Across the Arctic, buildings, roads and pipelines were erected on ground assumed to stay frozen, and much of that infrastructure is at risk as the ground thaws.

Some researchers also raise the possibility of horizontal gene transfer between thawed ancient bacteria and modern ones, which could introduce novel antibiotic resistance genes into living pathogens and compound an already growing problem.

In physical geography, a tundra () is a type of biome where tree growth is hindered by frigid temperatures and short growing seasons.

The amount of native tundra biomass depends more on the local temperature than the amount of precipitation.

Chapter 1: What Permafrost Is and Where It Lies

Formerly frozen ground often contains enough ice that when it thaws, hydraulic saturation is suddenly exceeded, so the ground shifts substantially and may even collapse outright. Many buildings and other infrastructure were built on permafrost when it was frozen and stable, and so are vulnerable to collapse if it thaws.

Estimates suggest nearly 70% of such infrastructure is at risk by 2050, and that the associated costs could rise to tens of billions of dollars in the second half of the century. Furthermore, between 13,000 and 20,000 sites contaminated with toxic waste are present in the permafrost, as well as natural mercury deposits, which are all liable to leak and pollute the environment as the warming progresses.

Lastly, concerns have been raised about the potential for pathogenic microorganisms surviving the thaw and contributing to future pandemics. However, this is considered unlikely, and a scientific review on the subject describes the risks as "generally low". Permafrost is soil, rock or sediment that is frozen for more than two consecutive years. In practice, this means that permafrost occurs at a mean annual temperature of 0 °C (32.0 °F) or below.

In the coldest regions, the depth of continuous permafrost can exceed 1,400 m (4,600 ft). It typically exists beneath the so-called active layer, which freezes and thaws annually, and so can support plant growth, as the roots can only take hold in the soil that's thawed.

Active layer thickness is measured during its maximum extent at the end of summer: as of 2018, the average thickness in the Northern Hemisphere is ~145 centimetres (4.76 ft), but there are significant regional differences.

Northeastern Siberia, Alaska and Greenland have the most solid permafrost with the lowest extent of active layer (less than 50 centimetres (1.6 ft) on average, and sometimes only 30 centimetres (0.98 ft)), while southern Norway and the Mongolian Plateau are the only areas where the average active layer is deeper than 600 centimetres (20 ft), with the record of 10 metres (33 ft). The border between active layer and permafrost itself is sometimes called permafrost table.

Around 15% of Northern Hemisphere land that is not completely covered by ice is directly underlain by permafrost; 22% is defined as part of a permafrost zone or region. This is because only slightly more than half of this area is defined as a continuous permafrost zone, where 90%-100% of the land is

underlain by permafrost. Around 20% is instead defined as discontinuous permafrost, where the coverage is between 50% and 90%.

Finally, the remaining <30% of permafrost regions consists of areas with 10%-50% coverage, which are defined as sporadic permafrost zones, and some areas that have isolated patches of permafrost covering 10% or less of their area. Most of this area is found in Siberia, northern Canada, Alaska and Greenland. Beneath the active layer annual temperature swings of permafrost become smaller with depth. The greatest depth of permafrost occurs right before the point where geothermal heat maintains a temperature above freezing.

Above that bottom limit there may be permafrost with a consistent annual temperature--"isothermal permafrost". Permafrost typically forms in any climate where the mean annual air temperature is lower than the freezing point of water. Exceptions are found in humid boreal forests, such as in Northern Scandinavia and the North-Eastern part of European Russia west of the Urals, where snow acts as an insulating blanket. Glaciated areas may also be exceptions.

Since all glaciers are warmed at their base by geothermal heat, temperate glaciers, which are near the pressure melting point throughout, may have liquid water at the interface with the ground and are therefore free of underlying permafrost. This is evident from temperature measurements in boreholes in North America and Europe.

The below-ground temperature varies less from season to season than the air temperature, with mean annual temperatures tending to increase with depth due to the geothermal crustal gradient. Thus, if the mean annual air temperature is only slightly below 0 °C (32 °F), permafrost will form only in spots that are sheltered (usually with a northern or southern aspect, in the north and south hemispheres respectively) creating discontinuous permafrost.

Usually, permafrost will remain discontinuous in a climate where the mean annual soil surface temperature is between ?5 and 0 °C (23 and 32 °F). In the moist-wintered areas mentioned before, there may not even be discontinuous permafrost down to ?2 °C (28 °F).

Discontinuous permafrost is often further divided into extensive discontinuous permafrost, where permafrost covers between 50 and 90 percent of the landscape and is usually found in areas with mean annual temperatures between ?2 and ?4 °C (28 and 25 °F), and sporadic permafrost, where permafrost cover is less than 50 percent of the landscape and typically occurs at mean annual temperatures of 0 to ?2 °C (32 to 28 °F).

It is difficult to accurately predict how much greenhouse gases the permafrost releases because the different thaw processes are still uncertain. There is widespread agreement that the emissions will be smaller than human-caused emissions and are not large enough to result in runaway warming. Instead, the annual permafrost emissions are likely comparable with global emissions from deforestation, or to annual emissions of large countries such as Russia, the United States or China.

Apart from its climate impact, permafrost thaw brings more risks.

End of free sample. The full book is available at putrabooks.github.io

ABOUT THE AUTHOR

Aira Astralis is a science writer specializing in astronomy and space exploration. Her work spans the full breadth of humanity's relationship with the cosmos -- from the earliest naked-eye observations to the engineering marvels of modern space missions.

Her books are built on a foundation of primary sources: peer-reviewed research, mission archives, and direct engagement with the scientific community. She writes for readers who want to understand not just what we know about the universe, but how we came to know it.

She believes that the most important frontier is not out there but in the gap between what scientists discover and what the public understands. Her books exist to close that gap.