Submitted Abstract

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Abstract

Permafrost, ground material remaining at or below 0 °C for at least two consecutive years, is a key component of the cryosphere in high-latitude and high-altitude regions. As such it is globally observed as an Essential Climate Variable (ECV) of the Global Climate Observation System (GCOS). Mountain permafrost is permafrost in areas with steep topography and accounts for ca. 30% of the global area underlain by permafrost and can be found at low and high latitudes and in the Northern and Southern Hemispheres. We present an overview of long-term permafrost data from European mountain regions (the Alps and the Nordic countries, including Svalbard) – where most mountain permafrost data are available – and describe observed changes and patterns of permafrost evolution.

Permafrost temperatures are typically measured in boreholes. Ranges of permafrost temperature and warming rates in mountains are similar to those observed in lowland polar areas but with high spatial variability in atmospheric, surface and subsurface conditions due to the complex topography with large environmental gradients. The strongest warming was observed in the past decade for bedrock sites at high latitudes and high elevations, where permafrost temperatures are several degrees below 0 °C (e.g., in mountain sites on Svalbard or above 3500 m asl. in the Alps). Ground temperatures in ice-rich permafrost close to the lower permafrost boundary – for example in many rock glaciers in the Alps increase at a lower rate due to latent heat uptake during ice melt. Significant increase in active layer thickness (ALT) – the thickness of the layer above the permafrost that freezes and thaws annually – was observed. In the European Alps, ALT increased by meters since the start of observations 1–2 decades ago, even doubling at some sites.

In mountain regions, permafrost degradation can affect stability of infrastructure and steep mountain slopes. Although observed parameters and techniques applied to lowland permafrost in general also apply to mountain areas, the long-term collection of robust and comparable permafrost data is challenging due to steep topography, site access, harsh weather conditions, risk of natural hazards and the strong spatial heterogeneity of determining factors. The continuation of time series over decades highly depends on field laboratories permanently operated for long-term climate monitoring. Finally, their coordination in national or regional monitoring networks (such as, for example, PERMOS, SIOS, or PermaFRANCE) is key for standardization and comparability and to describe a consistent picture of the mountain permafrost state and changes.