Permafrost Monitoring Network in the Northern Da and Xiao Xing'anling Mountains, Northeast China

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In addition to the latitudinal zonation, the development and distribution of permafrost in the northern Da and Xiao Xing'anling Mountains, Northeast China are affected by many local factors. The Xing'an permafrost is sensitive to climate change and surface disturbances, but there were only short-term observations and a paucity of ground temperature data. Hence, since 2009, an observational network has been gradually established at multi-locations in the northern Da and Xiao Xing'anling Mountains, Northeast China, including at least 43 ground temperature boreholes, 2 automatic meteorological stations (sets), 2 snow pillows (2 sets), and 10 sets of observation system for ground temperatures and soil moisture content of active layer. Some data have been obtained on the thermal regimes of active layer and permafrost (most to a depth of 20 m, one to 50 m, and two to 80 m). According to the data of last ten years (2009-2020), mean annual ground temperatures (MAGT) at 20 m in depth ranges from -2.83℃ (Nanwenghe) to -0.50 ℃ (Genhe), and the depth of permafrost table varies from 0.8 m (Nanwenghe) to 9.0 m (Hola Basin). The Da Xing'anling Mountains has been experiencing significant climate warming in the recent 60 years, and the changing trends of hydrothermal dynamics of near-surface permafrost and active layer in Xing'an permafrost regions vary greatly over time and space. Moreover, the MAGT in some regions of the ecosystem-protected Xing'an permafrost showed a cooling trend. This has demonstrated very complicated hydrothermal mechanisms of permafrost dynamics and history in Northeast China. These results can provide important information for regional development and engineering design and permafrost maintenance in Northeast China.

Permafrost warming in the Swiss Alps: current state and long-term trends

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The Swiss Permafrost Monitoring Network PERMOS documents the state and changes of permafrost in the Swiss Alps since the year 2000. Over the past two decades, its observation strategy was repeatedly evaluated and adapted based on evolving scientific methods and findings. Today, the monitoring strategy focuses on three observation elements: (1) ground temperatures near the surface and at depth, (2) changes in ground ice content, and (3) permafrost creep velocities. These three elements complement each other to capture not only the various effects of changing climate on permafrost conditions but also the specific responses of different topo-climatic and (sub-)surface settings. Results obtained during the warmest two decades ever measured in Switzerland show a consistent picture for all observation elements: permafrost is warming, containing less ice but more water, and is creeping faster. Ground temperatures show a clear warming trend near the surface and at larger depth throughout the entire Swiss Alps, especially between 2009 and 2016. The most pronounced warming trends are measured at cold permafrost sites like the rock glacier Murtèl, where an increase of +0.5°C has been observed at 20 m depth over the past 30 years, and +1°C increase at 10 m depth over the same period. In ice-bearing permafrost close to 0°C, temperature changes are minimal due to the latent heat effects. The latter, however, result in significant changes in electrical resistivity like at Schilthorn where repeated ERT measurements show an overall decreasing trend of resistivity since 1999 pointing to a substantial decrease in ice-water ratio in the subsurface, which cannot be captured by temperature measurements. Significantly increasing creep rates of Alpine rock glaciers further corroborate the warming trend, since the creep rates were shown to follow an exponential relationship with ground temperatures. In this contribution, we present the current state and long-term changes of permafrost in the Swiss Alps. More specifically, we quantify and analyse the observed warming rates and resistivity decrease using 20-year time series of continuous monitoring in mountain permafrost collected in the framework of the PERMOS network.

A Thermokarst Monitoring Network for Alaska

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Once permafrost starts to thaw, all components of the affected ecosystems change, and there are strong positive and negative feedbacks that control how degradation progresses. Thermokarst features occur across a wide range of terrain and ground-ice conditions, develop into a wide range of sizes (m2 to km2), and have numerous degradation and stabilization stages that can span a wide range of ages. Grappling with this heterogeneity of terrain, dynamism, size and ages requires a multi-component and multi-scale approach. Accordingly, we have been developing a monitoring network for Alaska that integrates regional, landscape and local scale monitoring strategies. For regional assessment of the nature, extent, and trends of thermokarst features, we are using two approaches. First, we acquired high-resolution stereo airphotos at 10-km spacing along longitudinal transects across Alaska in 2006 and determined the absence or presence of thermokarst and its type in the center of each of the 655 airphotos. Determinations at the systematically distributed points were done through photo-interpretation of vegetation, geomorphology, topography, and pattern recognition based on experience gained from field surveys. This network is intended to be updated every ~10 yrs with high-resolution satellite imagery, but without georectification. Second, we established 50 random remote sensing monitoring grids (2 x 2 km, with 100 points at 200 m spacing) across northern and central Alaska to quantify historical rates of change back to the 1940s using the same photo-interpretation technique as previously described. These repeat monitoring grids use a time-series of georectified imagery to track changes at 5000 points to provide more robust analyses of state transitions. For landscape-level monitoring of change, we established 33 study areas widely distributed across Alaska with active thermokarst where we have been mapping thermokarst features within 2–5 km2 areas at 1:2,000 scale using airphotos and satellite imagery from ~1950, ~1980, and ~2010 to document intermediate-term changes. For local-scale monitoring and evaluation of thermokarst processes, a comprehensive set of ecological components have been sampled along 200–300 m transects at the 27 study areas, representing different landscapes, including topography (surveying, ground-based LiDAR, airborne LiDAR, or photogrammetry), hydrology and snow (water-table surveys, water-level recorders, time-lapse photography), soils and ground ice (coring and sampling for ground-ice and soil organic carbon content), paleoecology (peat and stratigraphic interpretation, radiocarbon dating), thaw depths and permafrost table (probing and geophysical surveys), soil and water thermal regimes (dataloggers), and vegetation (occular estimates or point sampling by species). At the most intensive study areas, sampling for the entire suite of components has been stratified into 4–6 degradation/stabilization stages with each stage replicated at three plots. These monitoring transects initially were established on state and federal lands as part of NSF-funded studies of permafrost degradation, with the first study areas established in 1994. We have been partnering with agency personnel to continue long-term monitoring at the study areas. The field surveys and remote sensing are designed to be repeated every 5 and 10 years, respectively.

Global Long-Term Active Layer Thickness Trends

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Active layer thickness (ALT) is defined by the World Meterological Organization's Climate Observing System (GCOS) as an "essential climate variable" for the characterization of cold region processes with impacts for the global climate system. Within the GCOS Global Terrestrial Network for Permafrost (GTN-P) is the Circumpolar Active Layer Monitoring (CALM) program. The CALM program constitutes 293 currently registered monitoring sites distributed throughout permafrost regions in the Arctic, mid-latitude alpine regions (265 sites total in the CALM-North network), and Antarctic (28 sites in the CALM-South network). Established in the early 1990s, the publically-available CALM database (https://www2.gwu.edu/~calm/) offers long-term, standardized ALT records from a variety of regionally representative periglacial landscapes. A synthesis of regional trends from around the globe will be presented and discussed in this presentation. This analysis is based only on sites that have reported data within the last four years and with a minimum decade of continuous records. Around the globe ALT is generally thickening, but at variable rates and statistical significance. The most drastic increasing trends, in excess of 10 cm per year, are observed at sites on bedrock in the European Alps. The majority of sites on unconsolidated sediments in the Arctic exhibited trends ranging from 0.2 from the Alaskan North Slope to 3.5 cm per year from the Russian European North and Northwest Siberia. Minor to statistically insignificant trends were observed in the Antarctic. Pervasive increasing trends in ALT have profound implications for natural and anthropogenic processes necessitating the continuation and expansion of monitoring for this essential climate variable.

DEVELOPING REGIONAL PERMAFROST MONITORING SYSTEM IN YAMALO-NENETS AUTONOMOUS OKRUG, RUSSIA

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The Yamalo-Nenets autonomous district with its developed energy sector lies on the southern limit of permafrost. According to the recent assessments made independently by researchers from Finland, USA, and Russia the zone with continuous permafrost will move 300-500 km northwards by 2050 leaving mass destructions. In order to develop timely Adaptation plan, the District Administration initiated the series of actions aimed to collect knowledge on the current state and recent dynamics of permafrost both in natural settings and under infrastructure.

More than 80 boreholes were drilled and equipped with thermistor strings connected to the modern GSM transmitting dataloggers in cold ventilated cellars of residential buildings of Salekhard and Novy Urengoy. Features of soils are analyzed in the lab and put into GIS database, so that the bearing capacity of sediments could be estimated for different types of basements. The unique early warning system based on bearing capacity modeling is under development. Issues with leaking communications, artificial icing formation encourage us to propose the regional construction and exploitation guidelines supplementing the federal standards.

To discover the trends in permafrost dynamics we derived historical measurements of temperature of permafrost in geological settings common for a town, but in undisturbed landscapes close to it. The new temperature boreholes are drilled on the historical sites to get the long-term change in temperature. Permafrost temperature change during up to 50 years became available. In all of the 13 boreholes we found the warming tendency. The record high shift was over 4 degrees Celsius from -6.7 degrees C. On the southern limit of permafrost in several location the depth of annual amplitudes decreased with temperature getting closer to 0 to -0.1 from about -1 to -0.2 degrees C.

Along with doubtless practical application monitoring permafrost on the southern limit provides an interesting insight on the fundamentals of permafrost degradation processes.

Permafrost Measurements Best Practice: GCW's contribution to standardization of global observations

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The Global Cryosphere Watch (GCW), in the context of the framework of the World Meteorological Organization (WMO), published the Measurement of Cryospheric Variables, Volume II of the Guide to Instruments and Methods of Observation in 2018, in which best practice for observations of snow parameters was included. As a follow-up effort, measurement best practices for the other cryosphere components are under development, including permafrost and seasonally frozen ground.

The measurement best practice for permafrost aims to define reference methods for the configuration and ongoing operation of stations for in situ observations in high mountains and polar regions. It will: address gaps in the existing permafrost monitoring systems, define methods for improving traceability and comparability, recommend instrumental characteristics and provide measurements uncertainty evaluation. A further objective is to support capacity building of countries in terms of developing a permafrost observation network.

A Task Team within the framework of GCW was established, to lead the development and publication of a complete guide to the measurements of permafrost variables. The documents in preparation will be coordinated with the ongoing revision of Products and Requirements of the Global Climate Observing System (GCOS) Permafrost Essential Climate Variable (ECV), including existing variables measured by the GTN-P (Global Terrestrial Network for Permafrost). Further, the needs of developing Essential Arctic Variables (EAV) and Shared Arctic Variables (SAV) identified at the Arctic Observing Summit (AOS) are considered. The work will be based on existing methodologies, promoting and recommending methods to improve data reliability and traceability, also for the implementation of new stations.

Climate-related operational permafrost monitoring in Svalbard and Norway

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The web portal for cryospheric information of the Norwegian Meteorological Institute (MET Norway), https://cryo.met.no, provides access to the latest operational data and products and the current state of sea ice, snow and permafrost in Norway, the Arctic and the Antarctic. The subjects of this contribution are the operational permafrost monitoring at MET Norway and the new permafrost monitoring products on cryo.met.no. Systematic long-term monitoring of permafrost in Svalbard and Norway essentially began 23 years ago under the European Union-funded Permafrost and Climate in Europe (PACE) project, with the installation of ground temperature measurements in deep boreholes. More than 35 additional instrumented boreholes have been established in Norway and Svalbard since then. In recent years five new permafrost boreholes have been established at remote locations on Svalbard. Here we present methods for visualising real-time permafrost temperature data from operational monitoring sites in Svalbard and Norway. The latest permafrost temperatures are compared to the climatology generated from the station's data record, providing median, confidence intervals, extremes and trends. At these locations, there are also operational weather stations with extended measurement programs. The collocated monitoring provides daily updated data to study and monitor the current state, trends and the effects of e.g. extreme climate events on permafrost temperatures. The operational monitoring provides information more rapidly than at any time in the past and may contribute to early detection of e.g. record-high active layer thickness, pronounced permafrost temperature increases and early warning systems for natural hazards associated with permafrost warming and degradation. Currently, data and metadata are reported to the international Global Terrestrial Network for Permafrost manually. Work is in progress to develop operational permafrost data services through the WMO Global Telecommunication System to support e.g. the WMO Global Cryosphere Watch datastream.

Standardized monitoring of permafrost thaw: a user-friendly, multi-parameter protocol

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There is an urgent need for data collection to better understand permafrost thaw and its interaction with vegetation, hydrology, soil and snow. Greater spatial coverage, and improved coordination and consistency of measurements is particularly needed. To enable this, the Permafrost Thaw Action Group of T-MOSAiC have developed a data collection protocol and a user-friendly app (myThaw) aimed at non experts to facilitate collection and synthesis of data from across the Arctic.

Recognising the fundamental role of interactions between the different components of the permafrost system, we addressed the need to measure the interconnected parameters of snow, vegetation, hydrology and permafrost in a single protocol so that measurements will be co-located in space and time, allowing relationships between variables to be disentangled. In particular the protocol locates all measurements on 10-30m transects that are revisited throughout the year. The measured variables include snow depth, vegetation height, soil texture and type, water level and permafrost thaw depth.

This protocol uses simple measurements so more difficult-to-measure parameters are not collected, but the lack of specialist equipment and skills should enable a much greater participation in data collection and thus an improved coverage of the permafrost region, which is a central goal of this action group.

Along with the protocol and the myThaw app, we present here the first results from the data collection which has been live now for several months, and details of how to get involved.