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From needle ice to deep permafrost

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Preface

The second Asian Conference on Permafrost (ACOP 2017) was convened at Hokkaido University, Sapporo, Japan, July 2-6. The conference organizers and co-sponsors were the Arctic Research Center, Hokkaido University, Japanese Society of Snow and Ice, Tokyo Geographical Society, Sapporo Convention Center, Kajima Co., Shimizu Co., Meiwafosis Co., LI-COR, Chemical Grouting Co., Seiken Co., Cubic-I Co., Campbell Scientific, Climate and Cryosphere (CliC), Arctic Challenge for Sustainability (ArCS), and the International Permafrost Association (IPA).

A total of 180 participants from 18 countries including accompanying persons attended: Austria (1), Canada (7), China (62), Denmark (1), France (4), Germany (5), Hong Kong (2), Indonesia (1), Japan (55), Mongolia (6), Norway (18), Portugal (2), Republic of Korea (2), Russia (23), Slovenia (1), Switzerland (2), and the USA (6). The ACOP 2017 LOC provided travel grants to 20 persons including young researchers and keynote speakers.

The sessions covered all aspects of frozen ground research, from needle ice to deep permafrost, from frozen ground engineering in cities to permafrost on volcanoes, and from links between frozen ground and ancient cultures to present-day outreach. The daily sessions started with plenary talks from senior and young keynote speakers: Tazio Strozzi (Switzerland), Norikazu Matsuoka (Japan), Kabir Rasouli (Canada), Arne Instanes (Norway), Hisao Izuta (Japan), Sonia Tomaskovicova (Denmark), Anna Liljedahl (USA), and Jens Strauss (Germany). A total of 86 oral and 55 poster submissions were presented in a series of two concurrent sessions. In the first day of the conference, a joint workshop between the IPA's Mapping Initiative and GlobPermafrost took place to discuss current conditions and future collaboration on permafrost mapping and remote sensing. On the same day, Arctic adventurer Yasunaga Ogita and Professor Emeritus at Hokkaido University, Masami Fukuda, kindly provided general lectures to the public at the museum of Hokkaido University.

The abstracts submitted to the conference were compiled, and distributed in a USB memory to the participants at the registration. After the conference, however, we received a number of enquiries from those who could not attend the conference, asking for publication of the ACOP2017 abstracts in a more accessible and citable form. The local organizing committee of the ACOP2017 decided, following internal discussions, that we should publish with a doi. Finally, total of 141 abstracts were published in this Book of Abstracts, ACOP2017.

- Kazuyuki Saito and Mamoru Ishikawa, 2020.

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PLENARY SESSIONS

SOIL-STRUCTURE INTERACTION, HUMAN ACTIVITY AND PERMAFROST. ENGINEERING CHALLENGES AND SOLUTIONS

Arne Instanes [1,2]

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Keywords: Engineering, permafrost, experience, solutions, climate change

Climate change is predicted to strongly affect the evolution of the Arctic over the coming decades (Instanes, 2016). The warming trend observed in Svalbard and northwest Russia since the 1980s are creating concerns related to the stability and durability of existing infrastructure on permafrost and uncertainties related to the design of new structures and infrastructure in the regions. This plenary session addresses the potential impact of future climate on infrastructure on permafrost and change on water resources in the Arctic and how Arctic infrastructure and exploration and production of natural resources are affected. Freshwater availability may increase in the Arctic in the future in response to an increase in middle- and high-latitude annual precipitation (Instanes et al., 2016). Changes in type of precipitation, its seasonal distribution, timing, and rate of snowmelt represent a challenge to municipalities and transportation networks subjected to flooding and droughts and to current industries and future industrial development. Potential negative impacts of climate warming on water resource management include the increase in active layer thickness and permafrost temperature resulting in the increased risk of contamination of freshwater resources associated with municipal and industrial waste disposal. There will likely be some potential positive municipal effects which include reduced heating costs. An increased potential for hydropower production is projected because of higher rates of mean annual runoff and winter low flows. There may even be an emerging opportunity for Arctic residents to develop small-scale hydroelectric production in areas that previously had been unfeasible from a water supply point of view.

An increase in ground temperatures may reduce the bearing capacity and increase settlement rates and subsidence of foundations, and stability of natural and engineered slopes. The effect of climate warming in permafrost regions may cause unacceptable risks according to existing engineering design criteria. Depending on the soil conditions and current permafrost temperatures, the sensitivity to climate warming vary from small or negligible to considerable.

Recent experiences from engineering projects, challenges and solutions in the circumpolar Arctic is presented and discussed.

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ARTIFICIAL GROUND FREEZING TECHNOLOGIES FOR FROZEN SOIL WALL DEVELOPED IN JAPAN

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Keywords: artificial ground freezing method, excavation, engineering, control technology, frost heave

Artificial Ground Freezing (AGF) method enables safe deep excavation even in metropolitan areas where underground structures exist complexly (Subcommittee of Ground Freezing, 2014). Author is intending to explain the artificial ground freezing technologies developed during the last 50 years in Japan in this keynote speech (Izuta, 2003). AGF method becomes well known these days in the world by the utilization in the Fukushima Daiichi Nuclear Power Station for groundwater control. However, the major applications of the method in Japan are the construction of trunk water pipelines, gas pipelines, electric power lines, subways, underground dams, and highway tunnels. And the applications have been utilized for more than 600 sites. The first execution of AGF method in Japan was in 1962, and so far we have utilized the method in metropolitan areas of Japan and Asia.

At an early stage, the technologies for construction and maintenance of artificial frozen ground have not been established, and various troubles occurred. Therefore we had to advance the technologies. The main three technologies were;

1) Control on freezing: If just only 1% of volumetric unfrozen soil remains in frozen wall may cause serious trouble such as cave-in. In order to avoid the trouble, reliable estimation technology of frozen soil wall has to be required for AGF method, which is conducted in unseeable deep ground. Therefore ground temperature monitoring and thermal simulation of target ground, and the combination of these are performed on-site 24 hours a day, during the construction and maintenance. These procedures enable 100% ground improvement on-site. In addition the freezing control is also available to avoid the extra frozen soil growth and then the minimization of frost heaving damage may be available.

2) Control on mechanical stability: Since AFG method is the money consuming auxiliary construction one, the minimization of frozen ground is usually important. However if the frozen soil wall has insufficient mechanical quality, some kind of minor defect may cause trouble. In order to avoid such a kind of trouble, we have conducted huge number of laboratory element tests on frozen soil strength with tens of thousands soils specimens, which were sampled from more than five hundred soil layers over 40 years, and we have good database of mechanical properties of frozen soils. In other words, we have accumulated and systematized almost of the mechanical properties, which are needed on design of the method. In addition, not only tests mentioned above, model tests using disk shape and hollow cylinder shape specimens have conducted so far.

3) Control on the influence of frost heave expansion (frost heave): The frost heave expansion of clayey soil may cause harmful deformation against adjacent structures such as building foundations, buried pipes, tunnels, and so forth. Technology concerning with frost heave expansion is consist of frost heave prediction and reduction of frost heave damage. For the establishment of accurate frost heave prediction, reliable test apparatus and procedure have developed and unique empirical formula of frost heave expansion ratio with overburden pressure and freezing speed has proposed as Takashi's formula (Orai & Yamamoto, 1991). After the practical use and the good reliability on more than one hundred construction sites, the empirical formula has been compiled in Japanese Standard (JGS 0171-2003). During our experience, we have successfully designed and managed almost one million m^3 of artificial frozen ground, we can predict and manage frost heave amount in millimeters three dimensionally. Finally I hope this presentation may help the better understanding between frozen soil science and engineering.

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ARCTIC STREAMS – THE VEINS AND CAPILLARIES IN A CHANGING CRYOSPHERE

Anna Liljedahl [1], Michel Baraer [2], Anna Chesnokova [2], Ronald Daanen [3], Gerald Frost [4], Anne Gaedeke [1], Lyudmila Lebedeva [5], Olga Makarieva [5,6], Shad O'Neel [7], Natalya Nesterova [6], Ina Timling [8]

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Winter and annual stream discharges have increased across the Arctic in recent decades as documented by the scientific literature and local knowledge. Most, if not all, of the measurements have been limited to one location per stream or, at best, included the main river channel and some of its tributaries. Here we propose hydrological interactions of streams with their surrounding landscapes that go beyond the stream serving as an end-receiver of water from the permafrost-affected catchment that it drains. Informed by field measurements, laboratory analyses, remote sensing and modeling we present findings from across the Arctic that link streams to permafrost, mountain glaciers, riparian vegetation and soil microbes at time scales spanning several decades, and across space-domains from a single microbial gene to a large Siberian river. We have found that a single stream can have sections where it receives (gains) water from the landscape, while returning (losing) water in other sections. In the cold continuous permafrost region, gaining and losing stream segments are linked to riparian shrub cover where tall shrubs are found along losing stream sections and its underlying taliks. We propose that the well documented increase in shrub cover along Arctic riparian corridors is an indicator of streams shifting from gaining to losing discharge regimes due to permafrost thaw and subsequent talik formation. We have also found that mountain glaciers, despite their limited spatial extent, contribute significantly not just to summer but also winter stream flows. Thus glacierized headwater streams serve as aquifer recharge corridors in summer, while water is released to larger lowland river systems in winter. Finally, our results suggest that stream drainage (losing versus gaining) exerts a larger control on riparian soil microbial composition than location (the same stream) as both microbial taxa and their genetic variation are more different within a single stream than between sections of different streams with similar discharge regime. Our findings will hopefully improve understanding of the complexity of streams that drain deep and shallow permafrost regions. At the end of the day, the well-documented changes of individual Arctic system components, such as riparian shrubs encroachment, increasing river discharge, thawing permafrost, degrading ice-wedges and receding mountain glaciers, are all part of stream networks— the veins and capillaries of the Arctic. Accordingly, continued and expanded discharge measurements would allow us to track the pulse of the Arctic system in a rapidly changing climate.

FROM NEEDLE ICE TO DEEP PERMAFROST: CLASSIFYING PERIGLACIAL ENVIRONMENTS BASED ON PREVAILING FROST ACTION

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Keywords: climate change; freeze-thaw; frost action; periglacial environment; permafrost; seasonal frost.

Freeze-thaw or permafrost processes, here collectively called 'frost action', characterize landscape in periglacial environments, although non-frost processes also contribute or, in places, even dominate in the landscape dynamics. Types of frost action spatially variable, dependent on thermal conditions (mean annual temperature, annual and diurnal amplitudes and the presence of permafrost), precipitation (type, timing and amount), vegetation and substrate. Here I propose a physically-based classification of periglacial environments into five zones (I to IV), with subdivisions (a and b) for zones III and IV, in terms of the prevailing frost action. The zone transition is primarily constrained by the freeze-thaw depth and permafrost temperature, while intra-zone variations in the type and magnitude of processes depend also on surface (snow/vegetation) and subsurface (moisture/material) conditions.

Zone I occurs in Antarctic nunataks and equivalent conditions, where air temperature never exceeds 0°C. Daytime insolation, however, can induce diurnal shallow thawing (<0.2 m in soil) in midsummer, allowing superficial frost weathering and creep where moisture source is available.

Having relatively shallow active layers (<1 m in soil) underlain by cold permafrost, Zone II shows typical permafrost landscape. Two-sided freezing allows intensive ice segregation near the permafrost table in both rocks and soils, resulting in large-scale rockfalls, sorted patterned ground and active-layer detachment slides. Ice-wedge polygons dominate where intensive cooling takes place in winter, and closed-system pingos may develop in thermokarst depressions.

Deep active layers (1-2 m in soil) underlain by warm permafrost (~0°C) is typical in Zone IIIa, promoting one-sided freezing with ice segregation mainly in the upper active layers. Permafrost creep and solifluction are most active in this zone, resulting in highly dynamic mountain environments. Flat terrains show medium-scale patterned ground and frost mounds.

Lacking permafrost but undergoing deep (one-sided) seasonal freezing (~1 m in soil), Zone IVa experiences seasonal rockfalls and solifluction. Shallow but rapid movements prevail particularly where subjected to frequent diurnal frost, producing small-scale patterned ground and slope features. In mountain areas the tree line virtually defines the lower limit of this zone.

Zone V is defined by extrazonal periglaciation. This zone occurs below the general tree line, particularly where vegetation is lacking due to aeolian, fluvial or coastal processes, steep slopes or an artificial disturbance. Shallow freeze-thaw processes including needle-ice activity promote seasonal and small-scale rockfalls, soil movements and resulting small-scale periglacial features.

Zones IIIb and IVb (subtypes of Zones IIIa and IVa) mostly occur in tropical high mountains and Subantarctic islands, where the annual temperature amplitude is extremely small. These areas experinece highly frequent diurnal freeze-thaw cycles, often in excess of 300 cycles per year, with the presence (IIIb) or absence (IVb) of permafrost. Such a condition favours shallow frost creep and cryoturbation within the top 20 cm, resulting in regular, small-scale sorted patterned ground and shallow lobes.

Climate change may shift a periglacial zone to another one. The most significant effect occurs where Zone IIIa shifts to Zone IVa, where degradation of permafrost may trigger large-scale rockfalls and landslides, inactivation of rock glaciers often accompanied by debris flows and significant ground subsiding. At the margin of Zone V climatic warming results in the cessation of frost action, or fossilization of periglacial landscapes.

THE ROLE OF SOIL FREEZING AND THAWING IN HYDROLOGICAL PROCESSES: CANADIAN CASE STUDIES

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Keywords: depressions, frozen ground, ground temperature, infiltration, permafrost, soil moisture

Soils freeze permanently or seasonally in about one-third of the Earth land surface. Energy available for thawing the frozen soils varies with latitude and time of the year. Freezing and thawing fronts and weather conditions affect rainfall-runoff and snowmelt-runoff over frozen soils with altering infiltration rate, subsurface flows, and groundwater recharge. Coupling interactive water and energy fluxes in frozen soils are challenging as hydraulic and heat conductivity along the soil profile is usually heterogeneous and estimation of ground temperatures and infiltration rates over frozen soil are very uncertain. In addition to soil properties, soil moisture affects hydraulic and heat conductivity between ground surface and frost table and vegetation height/density can affect snowmelt infiltration by controlling the snow redistribution and sublimation. The root zone has a key role in infiltration, runoff, and ice formation in soil macropores. To simulate ground surface temperature with sufficient accuracy, which is essential for capturing frost table dynamics, four sites with detailed hydrometeorological measurements in western Canada were selected. To investigate midwinter snowmelt and refreezing, which are controlling spring infiltration, runoff, flood, and groundwater recharge, another site in the Canadian prairie was also selected in this study. In this plenary session, main concepts of water movements over and through permafrost and seasonally frozen grounds will be reviewed (Hayashi, 2013). In first section, a radiative–conductive–convective approach for estimating the ground temperature as an upper boundary condition and a modelling approach for simulating frost table dynamics will be introduced (Krogh et al. in press, Rasouli 2017, Williams et al. 2015, Xie & Gough 2013). Numerous topographic depressions exist in the Canadian prairies, which play a key role in runoff retention and groundwater recharge (e.g., Ehsanzadeh et al. 2012, Hayashi et al. 2003). In the second section, the role of freezing and thawing processes in snowmelt runoff generation and groundwater recharge in the Canadian prairies with seasonally frozen ground (Hayashi et al. 2003) will be discussed. The results from small-scale field measurements of snow accumulation, snow redistribution by blowing wind, snowmelt-runoff, and snowmelt infiltration to frozen soils in general and through topographic depressions in particular help to understand regional-scale hydrological processes in cold regions under land-cover and climate changes.

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DEEP ICE-RICH PERMAFROST AND ITS CARBON VULNERABILITY

Jens Strauss [1], and the members of the IPA Action group "The Yedoma Region"

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Keywords: Arctic; Climate feedback; Greenhouse gas source; Late Pleistocene; Thermokarst; Yedoma

Arctic landscapes, especially those underlain by permafrost, are threatened by climate warming and may degrade in different ways, including active layer deepening, thermal erosion, and development of thermokarst features. In Siberian and Alaskan late Pleistocene ice-rich Yedoma permafrost, rapid and deep thaw processes cause surface subsidence due to loss of ground ice (Ulrich et al., 2014) and may mobilize deep organic carbon. With thawing, currently freeze-locked organic matter can be remobilized and contribute to the carbon-climate feedback, a process of global significance if formerly inactive, old carbon is re-introduced into the active carbon cycle as greenhouse gases, which accelerate warming and inducing more permafrost thaw and carbon release.

Yedoma permafrost, which is widespread in Siberia and Alaska, is estimated to presently store between 83±12 and 129±30 Gt frozen organic carbon (Strauss et al., 2017). During the last glacial period Yedoma deposits potentially stored about 657 ± 97 Gt (Strauss et al., 2017). Focusing on the estimates for the present and including deposits in degradation features, such as thermokarst lakes and basins, we found ~398 gigatons thaw-susceptible carbon in the Yedoma domain. This is more than 25% of the frozen carbon of the permafrost area, while the Yedoma domain is covering only 7% of the permafrost region.

We suggest that greenhouse gas release from the Yedoma domain is orders of magnitudes lower than current human-caused emissions, but will be a persistent source that increases in the future. Based on incubation experiments, up to 10% of the Yedoma carbon is considered especially decomposable and may be released upon thaw (Schädel et al., 2014). In conclusion, the substantial amount of ground ice in Yedoma makes this type of permafrost deposit highly vulnerable to disturbances such as thermokarst and thermo-erosion processes and as a result, mobilization of permafrost carbon is expected to increase under future climate warming. Our results underline the need of accounting for Yedoma domain carbon stocks, as well as rapid thaw processes like thermokarst, in next generation Earth-System-Models for a more complete representation of the permafrost-carbon feedback.

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DETECTING AND QUANTIFYING MOUNTAIN PERMAFROST CREEP FROM RADAR INTERFEROMETRY

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Keywords: mountain permafrost; radar interferometry; rockglaciers; satellite; terrestrial

Rockglaciers are the best visual expression of mountain permafrost and can be mapped directly using remotely sensed data. Studies carried out in various parts of the European Alps have shown surface acceleration of rockglaciers over the two last decades (Kääb et al. 2007). Changes in rockglacier motion are therefore believed to be the most indicative short- to medium-term response of rockglaciers to environmental changes and thus an indicator of mountain permafrost conditions in general.

In the Oberwallis region in Switzerland we are studying since many years the movement and relative changes of rockglaciers using satellite and terrestrial radar interferometry (Strozzi et al., 2004). Our area of interest encompasses numerous active rockglaciers with deformation rates ranging typically between 0.1 and 2.0 m/yr, recently destabilized (or “surging”) rockglaciers showing morphological indices of landslide-like mass wasting and with rates of motion well above 5.0 m/yr, and many other much more slowly moving permafrost landforms. We first applied radar differential interferometry with the high-resolution satellite radar data (spatial resolution on the order of 20 m) of the ERS-1/2 SAR and JERS-1 sensors during the 1990's with acquisition time intervals from 1 day to several years to compile an inventory of slope movements with deformation rates sorted into different classes. Since then, new SAR sensors, advanced processing techniques, and very-high resolution Digital Elevation Models (DEM) to more accurately compensate for the topography related phase have become available. In the last years, very-high resolution SAR data with spatial resolution on the order of 3 m from the TerraSAR-X and Cosmo-SkyMed missions were used complementing the investigations performed with the high-resolution data of the ENVISAT, Radarsat-2 and ALOS PALSAR-1 sensors and permitting to partially overcome some of the limitations of the technique. Nowadays, the Sentinel-1 mission represents the newest approach to SAR mission design with acquisitions regularly available over nearly all mountainous areas worldwide every 6 to 24 days. Nevertheless, the spatial resolution of Sentinel-1 is lower than that of other current missions which represents a challenge in the case of surface motion affecting small areas. Besides satellite sensors, terrestrial instruments were in use in many cases. A terrestrial radar interferometer compliments satellite SAR data in time and space, allowing the measurement of additional displacement vectors and velocity classes.

In this contribution we review the radar-interferometric monitoring techniques applied during the last 20 years in Switzerland to detect and quantify mountain permafrost creep, show selected results obtained with the various satellite and terrestrial sensors of different spatial resolution and acquisition time intervals on well known permafrost landforms, and give an outlook to ongoing studies on other mountain regions in Northern Tien Shan, Alaska, and the Andes.

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FIELD INVESTIGATIONS AND NUMERICAL MODELLING FOR INFRASTRUCTURE PLANNING IN GREENLAND

Sonia Tomaskovicova [1],
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Keywords: Greenland, geotechnical investigations, permafrost monitoring, fine-grained permafrost, infrastructure development, coupled modelling

This talk aims to provide an introduction to challenges and approaches to site investigations for infrastructure planning and development in Greenland. Much of the existing infrastructure in Greenland - including residential buildings, roads and airport runways - is poorly adapted to existing conditions and is subject to deterioration or damage (Ingeman-Nielsen et al., in press). Built infrastructure affects permafrost conditions and may itself induce permafrost degradation. Climate change acts as an amplifying factor and with current predictions, it is expected to play an increasing role.

Meanwhile in Greenland, demands on infrastructure are rising due to increasing tourism and migration of population into larger towns. In the last two years, expansion or building of five airports, together with supporting infrastructure, have been decided by the Greenlandic Home Rule (The Government of Greenland). Structures such as airports and roads are distributed over broad areas, and therefore cross variety of environments. With permafrost in all of its forms affecting virtually the entire ice-free area in Greenland, there is a need for better permafrost knowledge and more reliable permafrost projections to support infrastructure design choices and justify the high cost associated with new engineering solutions and adaptation measures. Better projections require more engineering monitoring surveys and in-situ experimentation, as well as more spatially distributed and longer-term permafrost monitoring time series.

At numerous sites in Greenland, the geological history has resulted in a complex ground profile consisting of an upper ice-rich part and a lower zone with high residual salinity in pore water, high unfrozen water content, low or no ice content and low bearing capacity (Foged, 1979; Ingeman-Nielsen, 2008). In such settings, inadequate site investigation methods may fail to document these anomalies and thereby lead to poor choices of foundation design.

Two case studies of ongoing site investigations for large infrastructure projects in Greenland (a new airport in Ilulissat and a general geotechnical characterisation of permafrost conditions in Qaanaaq (Thule)) will illustrate the complex approaches for a more reliable assessment of ground geotechnical properties. We apply a range of methods, from studies of archive data, geophysical surveys, geotechnical drilling and borehole temperature monitoring for an integrated description of permafrost conditions. Aiming for a more spatially-distributed, longer-term predictions of ground thermal state, we develop and test alternative monitoring approaches, combining geophysical and thermal observations in a numerical modelling scheme. We share our practical experiences from these applications.

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GENERAL SESSIONS

TOWARDS HIGH-RESOLUTION SNOW DEPTH MAPPING IN PERMAFROST REGIONS BASED ON SATELLITE-DERIVED SNOW EXTENT DATA

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Keywords: snow; remote sensing; modeling; subgrid distribution; data assimilation

With its high albedo, low thermal conductivity and large water storage, snow strongly modulates the surface energy and water balance in permafrost regions. However, its distribution in space is governed by a range of factors, such as precipitation and landcover influencing wind redistribution. As both remote-sensing and atmospheric model based data sets have coarse spatial resolutions of 25 km and more, estimation of the snow depths is a major bottleneck in spatially distributed permafrost models.

To constrain this uncertainty we develop a modular ensemble-based subgrid snow data assimilation framework (ESSDA) for satellite-era snow distribution reanalyses. The basic idea is to infer the pre-melt snow distribution based on the surface energy balance during the melt period, and the melt-out data which can be detected in VIS satellite imagery.

ESSDA makes use of an ensemble Kalman smoother (EnKS) approach to assimilate MODIS, Sentinel-2 and LandSat retrievals of snow cover fraction into a subgrid snow distribution submodel. The potential of the framework is presented through both synthetic and real experiments. The latter are carried out for the Bayelva catchment near Ny-Ålesund (79°N, Svalbard, Norway) where independent ground-based observations of snow cover and snow depth distributions are available. Our evaluation demonstrates that ESSDA provides robust estimates of the evolution of the snow distribution over almost a decade long validation period. We subsequently discuss the potential of the method to improve numerical modeling of the ground thermal regime over a range of scales.

DEGRADING PALSA MIRES IN NORTHERN NORWAY SIMULATED WITH A REGIONAL CLIMATE MODEL WITH A SUBGRID SNOW SCHEME

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Keywords: climate change; palsa mires; permafrost degradation; numerical modeling; snow;

Rapid and accelerating degradation of palsa mires and peat plateaus has been reported in northern Norway during the last decades (Borge et al. 2017), following rising air temperatures and changes in precipitation. In order to understand these changes, and predict the magnitude and timing of future permafrost degradation in this and other permafrost regions we need accurate simulations of both local climate conditions and the small-scale land surface processes.

Here we present results from high-resolution, regional climate simulations over northern Norway at a resolution of 3 km, which is sufficient to represent the conditions on individual palsa mires. Simulations are performed with the regional climate model WRF, covering both the recent history and two different future climate scenarios (RCP8.5 and RCP4.5). The observed changes at these mires are evaluated in light of the simulated change in climate variables on local scale, and the simulated future changes. The effect of individual climate variables is discussed. We discuss how snow conditions have changed, how they are expected to change in the future, and how these changes affect the ground thermal regime. Differences between costal and more continental sites are also discussed.

In a second step, we evaluate the effect of inhomogeneous snow distribution within each palsa mire. Systematic measurements of snow depths from four mires in this region shows that this can be well represented by log-normal distributions. Based on this we perform a set of offline simulations for each mire with land surface models used in WRF (NoahMP and CLM), where snow is scaled according to the observed distributions. Accounting for small-scale snow depth variability with a set of subgrid "tiles" has already been tested online in WRF for southern Norway, resulting in improved near surface atmospheric conditions in high-mountain regions (Aas et al. 2017). Here we evaluate if this approach can also be a first step towards a better representation of small-scale permafrost processes in climate simulations. The results are compared with a large set of ground surface temperature measurements from these mires, as well as active layer thickness measurements. By testing this method in a region where temperatures are currently at the limit for sustaining permafrost, we also get a window into the likely future evolution of larger peat areas which is now located in the colder, continuous permafrost zone.

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FROST HEAVING OBSERVED IN THAWING PROCESS

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Keywords: Frost heave; ice lens; latent heat; super cooling; thawing process;

The 76 huge Liquefied Natural Gas (LNG) in-ground storage tanks are operating in Japan (Tokyo Gas HP). Since the temperature of LNG is cold as -162℃, the ground around the LNG in-ground storage tanks are cooled and then frozen. In order to manage the thickness of the frozen ground and frost heave, all the LNG in-ground storage tanks equips ground heating facilities (side heater) at about a few meters away from the outer side surface of the LNG in-ground storage tanks. After years of the operation, when the frozen ground thickness or frost heave amount exceeds a certain limiting condition, the temperature of the side heater is moved up to thaw the frozen ground from outer side surface and consequently heave force reduces. After the temperature of the heat fence is risen and thermally quasi-stable state is almost reached, earth pressure rise together with deformation parallel to heat flow which are similar to the behavior caused by frost heaving is confirmed around the LNG in-ground storage tanks.

However frost heave is the phenomenon which segregate thin ice layers called ice lenses perpendicular to the heat flow and expand in heat flow direction while freezing. Regarding to the heat budget at the segregating ice, the heat flux difference between frozen soil and unfrozen soil is equal to the latent heat required for the ice lens segregation (Akagawa 1990). Therefore the supply of the latent heat for ice lens segregation is only available while freezing and not thawing. As the result, it is generally accepted that the ice lens segregation only happens during ground freezing process.

However the layer of ice, which is identical to ice lens in the shape and optical properties, commonly growths in the laboratory thawing tests (Akagawa 1993). In this presentation, heave data including time-lapse image of ice lens segregation in thawing process is demonstrated.

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ACTIVE ROCK GLACIER AT SEA-LEVEL IN FINNMARK, NORTHERN NORWAY?

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Keywords: climate change; DEM; geomorphology; permafrost; rock glaciers

Permafrost in Scandinavia is widespread in mountainous areas. In northern Norway, the lower permafrost limit decreases from ca. 1000 meter at the west coast to below 500 meter in the continental interiors of the country. Active rock glaciers are indicators of continuous permafrost, and have previously been mapped countrywide by interpretation of air photos. In northern Norway, rock glaciers at sea level are abundant in the county of Troms, and have been acknowledged as fossil features.

However, in Hopsfjorden in Finnmark, located at 70.8° north and 28° east, several rock glaciers are located at sea-level. These rock glaciers appear to be active, and if proven to be active, this will be the first time active rock glaciers are observed at this altitude in Norway. We therefore believe that these coastal areas in the northernmost part of Finnmark should be considered as a part of the arctic permafrost zone rather than the mountainous permafrost zone of mainland Norway.

Similar rock glaciers systems terminating at or close to sea level are also found in the Arctic permafrost zone, such as in the Svalbard archipelago north of Norway. At present, permafrost is thawing at a large scale in the Arctic, and this location might serve as an analogue to how the landscape in the high Arctic would act in a changing climate.

In this study, we will use one year of surface temperature data (2015-2016) for one of these rock glaciers, which allow for considerations of the current climate. In addition, DEMs (digital elevation model) created from historical aerial photos of several years (1975, 1982 and 1992), and more recent drone images (2016) provides data for a change detection analysis between the various years. In September 2017 a second year of surface temperature measurements will be collected, the drone flight track will be repeated to collect a second set of high-resolution images, and ground resistivity measurements will be carried out in order to detect any ground ice.

THE POTENTIAL AND LIMITATIONS OF ACTIVE LAYER THICKNESS ESTIMATION FROM SAR BACKSCATTER INTENSITY AND ITS RELATION TO SOIL ORGANIC CARBON

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Keywords: active layer; remote sensing; Arctic; soil carbon

Remotely sensed data, especially from optical sensors, is frequently used to estimate active layer thickness (ALT) in polar regions. The Normalized Difference Vegetation index ranges are associated with certain ALT ranges. It is expected that NDVI is related to the amount of biomass and indirectly underlying soil properties. NDVI can be however not universally directly translated into amount of shrubs in tundra.

Synthetic Aperture Radar data from satellites provide additional information on surface properties including surface roughness leading to diffuse scattering and biomass from volume scattering. This has been demonstrated for X-band (~3 cm) backscatter intensity values for shrubs (Widhalm et al. in press) and for C-band (5.6 cm) regarding roughness (Widhalm et al. 2015). Especially the latter has been shown previously to relate to soil properties (organic carbon content) in tundra environments (Bartsch et al. 2016a).

Active layer measurements from across the Arctic (CALM network) have been used to assess the potential of C-band SAR for this study. Analyses are complemented by X-band measurements at selected sites. C-band SAR data from ENVISAT ASAR GM have been preprocessed for the entire Arctic (several thousand of images) and statistics for early winter acquisitions (exclusion of liquid water impact on backscatter) derived.

In general low roughness corresponds to wetter sites which have shallow active layer thickness values (< 60 cm). Higher roughness represents drier sites with a larger range of ALT. Results are assessed with respect to the previously established relationship of C-band backscatter with SOC. Analyses shows that the approach is limited to sites without higher shrubs. The potential of inclusion of roughness information in traditional land cover maps (Bartsch et al. 2016b) within the framework of the ESA DUE GlobPermafrost project is eventually discussed.

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ASSESSMENT OF THERMOKARST DEVELOPMENT IN CENTRAL YAKUTIA UNDER CHANGING CLIMATE

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Global warming has been a major concern since the late 20th century. Climate warming in turn leads to thawing of permafrost with attendant thermokarst. Development of thermokarst settlements and thaw lakes is an indicator of permafrost degradation.

Enhanced thermokarst activity has been observed in Central Yakutia during the last two decades. Melting of the tops of ice wedges is causing subsidence of the ground surface, deepening and expansion of thermokarst depressions, and increased water levels in thaw lakes. The development of thermokarst is mainly associated with human activities, including land cultivation, timber harvest and fires, as well as forest damage by the Siberian silk moth. With increasing population, the communities are faced with a shortage of suitable land for housing development. The municipal governments have often to allocate for development the abandoned lands where thermokarst has already initiated. Thermokarst therefore presents a serious problem for the population in Central Yakutia.

We performed several studies to assess the thermokarst development in permafrost landscapes of Central Yakutia under changing climate conditions. The purpose of this study was to identify and map thermokarst development near the town of Churapcha.

Satellite imagery acquired in the 1980s and 2012 were used to analyze the development of thermokarst in abandoned agricultural lands. The main materials used were Corona images from the 1980s and images from Landsat-5 TM and Landsat-7 ETM+, as well as high-resolution images from IKONOS and GeoEYE taken in 2012. Comparison of the images taken in the early 1980s and 2012 showed the active development of thermokarst landforms, the expansion of existing thaw lakes and the formation of new ones. The study area was categorized into three zones:

Zone A is located in the taiga dominated by larch and mixed birch-larch stands. It has a flat surface dissected slightly by a stream network and dotted with numerous lakes. Most lakes occur in thermokarst depressions, or alases, which are abundant here, forming the alas landscape. In the second half of the 20th century, forests were cleared and tilled for agriculture. Now abandoned, these lands have developed active thermokarst. Polygonal features, which were absent on a 1980 image, covered over 72% of the surface of the abandoned croplands in 2012. Of this, 4% represented thermokarst depressions with incipient lakes and two new lakes. In total, Zone A has over 40% of its open area occupied by polygonal features, including 4% covered by thermokarst depressions with small incipient lakes and over 3% by thermokarst lakes.

Zone B, named "Churapcha charan", is a forest-steppe on the ice complex. Long-term ground warming since the 1980s has induced thermokarst on disturbed and open meadow sites underlain by ice-rich permafrost. Thermokarst was most active during the 1990s and 2000s, when widespread ground subsidence occurred due to melting of the tops of ice wedges, resulting in hummocky polygonal landforms. The subsidence was greatest in the areas of anthropogenic disturbance, including the abandoned runway and croplands. While thermokarst polygonal features occupy over 11% of the total area of Zone B, some portions of the abandoned croplands have been completely degraded by thermokarst.

Zone C is located on the right bank of the Tatta River in the taiga zone dominated by larch and mixed birch-larch forests. Thermokarst has developed on the abandoned croplands, as well as on the forest sites disturbed by the Siberian silk moth. Large areas of the primary larch – mountain cranberry forests were killed by severe insect attacks in 2002. Today their surface completely consists of hummocky polygonal terrain with newly forming thermokarst lakes. Young thermokarst lakes occupy about 12% of the total area of Zone C. For comparison, they cover about 3% of Zone A and only about 0.1% of Zone B.

At present, the active growth of young thermokarst lakes, both in size and water volumes, is observed in Central Yakutia. Enhanced thermokarst observed since the early 1990s reached a peak in 2005-2007 due to anomalously high precipitation. Lake growth in thermokarst depressions has triggered environmental modification in ice-rich permafrost terrain.

Active thermokarst processes are detrimental not only for agriculture, but also for housing, roads and other community support infrastructures. Threats come not from long-term permafrost degradation, but from poor awareness and understanding of related risks among the communities. It is therefore our task to develop a system of preventive measures and teach people how to adapt to changes.

THE METHODOLOGY OF THE ASSESSMENT OF THE THERMAL AND MECHANICAL INTERACTION OF A LOW-TEMPERATURE COOLANT WITH THE SALTED SOILS CONTAINING CRYOPEGS

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Keywords: permafrost, termostabilization, liquid gas, cryopeg, fractures, frost cracks

In the permafrost propagation areas thermal interaction between constructions and foundation soil leads to the loss of soil bearing capacity due to transition of the soil state from plastic-frozen or even thawed state. The significant negative impact on this process is exerted by the salinity of soil, which is characteristic of seaside plains, areas of the shelf of the North Sea which can contain cryopegs. The freezing temperature of cryopegs and soils with high salinity can reach quite low negative values that results in the necessity to use various methods of thermostabilization of the soil bases of constructions if preserving it in a frozen state. The disadvantages of the use of the thermostabilizers (TS) which are using the cooling capacity of the atmospheric air during the winter period are: seasonality of work; rather low speed of a freezing, problem with the freezing of cryopegs and soils with high salinity. The disadvantages of machine cooling methods are: the high cost of tools and significant economic costs on functioning during big time periods.

The perspective problem solution of bearing capacity increasing of year-round functioning of the soil bases of infrastructure of gas-condensate fields on the plastic-frozen and salted soils can be partial use of a cooling capacity of a target product - liquefied natural gas, and also products of its rectification (ethane and propane) having low boiling point in the negative range of temperatures. Liquefaction of natural gas is important and even priority technology of gas import and usage. Technological norm of liquid natural gas (LNG) storage is estimated by value of liquefied gas in the tank storage daily evaporability, which is approximately 0.1% of the mass of the LNG in one tank. These losses are formed due to heat inflows of environment to the tank, where the LNG is kept under the temperature about -163 °C. It is suggested to use these technological outages with low freezing temperature for foundation soil thermostabilization, using for this purpose recuperative heat-exchanging facilities (Fild tubes).

The use of cooling capacity of the LNG complex allows: to provide reliable operation of a construction all the year round and irrespective of climatic conditions; to utilize selected gas for cooling of the foundation soil; to provide much higher rate of the soil frost penetration; to minimize effect of the frost heaving (the high rate of frost penetration provides minimization of volume of water migrating to the freezing front); to freeze cryopegs with various degree of a mineralization.

Besides obvious advantages of LNG utilization as a refrigerant liquid for soil thermostabilization it can lead to appearance of negative processes, such as cracking caused by appearance of big gradients of temperature near the wall of TS. For that matter, it is required to pay special attention to the determination of optimum value of LNG-inlet temperature and the constructive solution of TS, for the purpose of prevention of cracking. Also, the development of cracking processes according to the different by depth or in the plan view configuration of the groups of the TS is possible. It is related to the appearance of significant temperature gradients along the TS, determined by low values of input LNG temperatures of in combination with high intensity of heat interchange. Methodology of assessment of year-round TS and saline soil, containing cryopegs, interaction should take into account estimation of temperature regime as well as water-saline regime. Rate of mineralization largely determines ground freezing point, unfrozen water content, and thermal physical and mechanical characteristic of soil.

The results of calculations of frost penetration process of surrounding soil with various grain size compositions and salinity degree, and cryopegs with different mineralization are presented. The estimates of tension arising during the rapid frost penetration which allow us to find optimum values of LNG-inlet temperature and constructive solutions of TS, for the matter of minimization of process of cracking on the boundary between TS and soil are given. Also, different configurations of TS array in the context of optimization of frost penetration and preventing of frost cracking appearance in the interspace between TS are shown.

PERMAFROST IN TALUS SLOPES NEAR THUNDER BAY, ONTARIO, CANADA

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Keywords: Canadian Shield; canyon, extra-zonal permafrost; talus; thermal anomaly

Local knowledge has indicated the potential presence of extrazonal permafrost in talus deposits in southern Canada, near Thunder Bay, Ontario. According to people living in the region, ice often persists between talus blocks until mid to late summer at these locations (Wilkins 1994). The cooling effect of blocky materials and their ability to create isolated patches of permafrost is documented in case studies from around the world (Delaloye et al. 2003, Gude et al. 2003, Sawada et al. 2003, Gorbunov et al. 2004, Zacharda et al. 2007). Investigations are ongoing at two talus sites near Thunder Bay (Ouimet Canyon, 48.794˚N, 88.667˚W and Doghead Mountain, 48.999˚N, 88.222˚W) where MAAT is 2.5˚C or less, with the goal of determining whether isolated patches of permafrost are indeed present. The investigations include measurement of the basal temperature of the snow (BTS), spot measurement of near-surface temperatures within the talus, monitoring of air and rock surface temperatures on and within the talus, and monitoring of interstitial ice.

Measurement of BTS in winter 2011 and 2012 showed significant negative thermal anomalies in some talus slopes (Bishop-Legowski 2011, Moore 2012). Spot temperature measurements in 2011 confirmed that these anomalies persisted into the summer. Temperature sensors were installed in 2016 at various depths and elevations in two talus slopes to characterize their thermal regime and dominant heat transfer mechanisms. Interstitial ice was observed in August 2011 and through October 2016.

This paper will present the current understanding of the thermal regimes of the study sites and the results of the ongoing monitoring, based on the first twelve months of thermal data. The length of the zero curtain and the timing of freezeback will be discussed. The unique geology and geomorphology of the area which make this cold microclimate possible will also be discussed.

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IMPROVED SENSITIVITY ANALYSIS OF PERMAFROST MODELS TO PROJECTED CHANGES IN CONTINENTALITY, YUKON, CANADA

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Keywords: Mountain Permafrost, Continentality, Surface Lapse Rate (SLR), Yukon, AR5, Sensitivity

The distribution of permafrost in the mountain ranges of the Yukon differs from those in mid-latitudes because temperature dependence on elevation is non-linear and varies spatially. Permafrost may be present below treeline due to the high frequency of inversions which affect Surface Lapse Rates (SLRs), especially in winter. Inversion frequency and strength have been related to the temperature amplitude (continentality) of an area, defined as the difference in the mean temperatures between the warmest and coldest months (Lewkowicz & Bonnaventure, 2011). As a result, SLR can be calculated based on this magnitude and projected spatially across the region. Incorporation of the magnitude and sign of SLRs into empirical statistical permafrost modelling allows spatial trends in mountain permafrost distribution to be predicted for the present day and into the future. The nature and degree of SLR inversion controls how the permafrost distribution is expected to change as climate warms and equilibrium is re-established. Previous modelling has been based on uniform changes in mean annual air temperature (MAAT) (e.g. +1 to +5°C) (Bonnaventure & Lewkowicz, 2013). However, GCM predictions for the region indicate that the magnitude of warming will be greatest in winter and will be spatially variable. Our hypothesis is that changes to temperature amplitude will (i.e. continentality) will be associated with alterations to the pattern and magnitude of SLRs. Radiosonde records from Whitehorse (1958-2003) support this interpretation and show a clear link between warming and temperature amplitude. This study examines the impact of changes in continentality on high-latitude mountains through an improved analysis framework that incorporates more climate stations than prior work and is based on downscaled predictions from the IPCC fifth assessment report (AR5).
Permafrost probability across the mountainous regions of the southern Yukon and northern British Columbia was generated at a high spatial resolution (30 m). This model was produced for current climate conditions (2001-2015) using logistic regression driven by climate data (MAAT) and calibrated against nearly 800 physical observations of permafrost presence or absence. The MAAT field was then recalculated for the current period using temperature increases corresponding to (1) downscaled spatially variable GCM scenarios according to Representative Concentration Pathway (RCP) scenarios from AR5, and (2) downscaled RCP scenarios with adjustments for changes to local SLRs due to reduced annual temperature range caused by asymmetrical seasonal warming. The MAAT fields calculated with variable SLRs exhibited above-average warming in the valley bottoms and lesser amounts at high elevations. The different methods used to model MAAT affected both the total permafrost extent at the regional scale and the pattern of permafrost change in relation to the topography. The model taking into account continentality revealed greater spatial change of permafrost in valley bottoms in continental areas where warming will be amplified in comparison to adjacent mountain tops. We conclude that predictions of future permafrost probabilities for purposes such as infrastructure planning or rapid mass movement modelling should incorporate the impact of alterations to the pattern of air temperature change, as well as the magnitude of change.

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MONITORING MORENAS COLORADAS ROCK GLACIER CRYODYNAMICS IN THE CENTRAL ANDES, MENDOZA, ARGENTINA

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Keywords: Climate warming; Cryodynamics; GPS measurements; Permafrost; Rock glacier.

The distribution of Andean mountain permafrost and its response to climate warming has taken great importance in areas of mountain environments due to the potential of underground ice (ice-rich soils) such as storage of freshwater reservoirs, especially in regions where this resource is scarce as it is in semi-desert climates like in the Central Andes.

Rock glaciers have been recognized by their hydrological importance and represent the most important geoforms of the Andean periglacial environment. They are considered as the main geomorphological expression of mountain permafrost (Monnier & Kinnard 2013).

Cryodynamics in Morenas Coloradas rock glacier in the Central Andes was measured from October 2013 until February 2016. To estimate the glacier crydynamic activity a GPS network of 20 geodesic measurement points was installed on the rock glacier surface. During the study period, 5 sessions with 48 hours of continuous duration on each point were measured to eliminate noises of seasonal and daily cycles (Blewitt & Lavallée 2002). Bernese scientific software version 5.0 (Dach et al. 2007) was used to calculate the coordinates and velocities of the points using a dual-frequency differential processing (L1-L2) and IGS stations (International GNSS Service) as reference.

Morenas Coloradas denote signs of activity through fronts with slopes > 35 ° and a classic "wrinkle" morphology in the form of surface arcs indicating their flow movements (Trombotto et al. 1999).

The results show an important cryodynamics activity. Displacements goes from few centimeters to couple of meters. Most of the measured point have a South- East direction. Those that are in the zone of lower altitude show the greater displacements therefore the greater velocity, due to a loss of ice volume.

At a higher altitude, thermokarst are found which reveal a degradation of the permafrost at that site where high velocities predominate the zone.

The movement direction measured with the GPS is coincident with the direction of flow observed in that “wrinkle” morphology mentioned by Trombotto et al. (1999).

Some of the measured points show very little or almost no movement indicating inactivity of these lobes. It can be affirmed that those points belong to inactive or fossils lobes within the Morenas Coloradas rocks glacier. In addition, the morphology observed in these lobes are mostly structures of collapse and a chaotic surface with depressions. Stunted vegetation is also present in these kind of lobes.

Unlike other rock glaciers, Morenas coloradas presents a complex morphology formed by several lobes with differentiated cryodynamic activities.

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SIMULATING THE INFLUENCE OF COAL MINING ON THE SURROUNDING PERMAFROST AROUND THE OPEN PIT

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Key words: Influence simulation; coal mining; surrounding permafrost; open pit

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TEMPERATURE CHARACTERISTICS OF ADDITIVES AND CEMENT IN FROZEN SOILS DURING FREEZING AND THAWING

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Keywords: additives; freezing; permafrost; temperature characteristic; thawing; phase change

Permafrost is thermal sensitive to the environmental changes. In permafrost regions, stabilized frozen soil by cement and additives is effective to improve the mechanical properties and reduce the quantity of engineering diseases under climate warming (Ma et al. 2007, Qin et al. 2009). Therefore, stabilized frozen soil by cement and additives has great application prospects in permafrost regions, such as mixing piles and dry jet mixing pile (Bigga et al. 1993). The temperature characteristics of modified frozen soil is different from the one without cement and additives. The change trend of soil samples was measured at different dosages of additives during the procedure of freezing and thawing. The addition of cement and additives prolong the time of phase change in soil samples. The change characteristics of temperature was simulated by the theory of phase change in porous medium. Simulation results were verified by testing results. The simulation results show that, the theory of simulation is applicable in simulation on change trends of temperature. The simulation is helpful in temperature analysis and calculation of mixing piles and dry jet mixing piles in permafrost regions during the cycles of freezing and thawing.

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THE INFLUENCE OF GROUND FREEZING ON SLOPE DYNAMICS IN SVALBARD – A CASE STUDY FROM TWO STORMS IN AUTUMN 2016

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Keywords: active layer refreezing; mapping, rain storms; slope dynamics, Svalbard; radar satellite observations

Traditionally immediate and rapid slope responses to large precipitation amounts are rare in the high Arctic in autumn, because precipitation usually falls as snow at this time of year. However, two large storms during warm weather on Svalbard 14-15 October and 7-8 November 2016 affected the landscape bringing rainfall to the lowlands and snow in the uplands. During the first storm, 18-20 mm of rain was recorded in the Longyearbyen area with an intensity of up to 2.8 mm/hour over a period of about 12 hours. Numerous slope failures including slumps, active-layer detachment slides, and mudflows resulted on hillslopes in and around Longyearbyen. One large mudflow, initiated from an active-layer detachment slide high on a mountain side, crossed a main road in the Longyearbyen area. Laser scanning showed that 5000m^3 of sediment was deposited during this event. During the second storm, we recorded 75.3 mm rain in Longyearbyen, with intensities up to 8.3 mm/hour. The most exposed areas of Longyearbyen were evacuated as a precaution as slope activity was expected prior to the second storm. Snow fell during this event, and extensive avalanching was observed using radar satellite monitoring of the uplands surrounding the Longyearbyen area. The Longyearbyen dog yard was partly damaged by a medium-sized slump. Despite the second storm happening during the polar night with only minimum light available for observing, visual field surveys from the air and ground indicated much less slope activity following this storm, despite the greater recorded precipitation during the latter event. Extensive slope failure during the second event was likely prevented because the top of the active layer had started refreezing preventing water infiltration into the sediments. In contrast, the entire active layer was still thawed during the first rainstorm, due to the exceptionally warm autumn weather on Svalbard in September and October, which allowed rapid infiltration and saturation of the active layer above the hydraulically impermeable permafrost table.

CHANGES OF PHYSICAL PROPERTIES OF FOZEN HYDRATE-BEARING SEDIMENTS DURING POROUS GAS HYDRATES DISSOCIATION

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Keywords: gas hydrate, frozen soils, dissociation, self-preservation, properties

It is known that natural gas hydrates (ice-like compounds of water and gas, mostly methane) in permafrost can occur both in under-permafrost and intra-permafrost horizons. The intra-permafrost hydrates have been repeatedly observed during deep drilling operations in cold regions. Despite this, they are still poorly studied geological formations. Primarily this concerns the behavior of permafrost gas hydrate accumulations after changes of thermobaric conditions, when they are located in frozen rocks under non-equilibrium conditions and transferred to a metastable state due to manifestation of the self-preservation effect (Ershov et al., 1991; Chuvilin & Guryeva, 2008). Under metastable conditions, which are typical for shallow permafrost (up to depth 200 m), gas hydrates can slowly dissociate and this is accompanied by physical properties changes, for example thermal conductivity (Bukhanov at al., 2008). In the current research, we study changes of thermal conductivity, uniaxial strength and gas permeability of frozen methane hydrate-containing sediments under metastable P-T conditions during slow pore hydrate dissociation at temperatures below 0^{o}C. The experimental results show that gas permeability and thermal conductivity of frozen hydrate-bearing soils may change by several times during slow hydrate dissociation under pressures below equilibrium. The uniaxial strength of frozen hydrate-bearing sandy samples was reducing following decreases in hydrate saturation at metastable thermobaric conditions. In it should be noted that during slow gas hydrate dissociation, the total hydrate and ice saturation did not change.

The revealed features are associated with variations of the ice and hydrate ratio in the pore space and with structural and textural transformations of ice and hydrate components due to self-preservation processes of pore hydrate.

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TRANSIENT MODELING OF PERMAFROST IN ICELAND

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Keywords: Iceland; permafrost; transient modeling;

Globally, the distribution of mountain permafrost has been mapped and monitored mainly in locations with relatively continental climates characterized by a stable snow cover and low winter temperatures. In contrast, there is a paucity of systematic ground temperature investigations from maritime mountain areas such as Iceland and transitional areas between the Scandinavian mountain permafrost zone and the continuous permafrost in Svalbard. Knowledge of the present distribution and thermal characteristics is crucial for assessing the response of permafrost to climate change and its geomorphological and geotechnical impact.

In Iceland, systematic monitoring of the ground thermal regime has continued at four borehole sites since 2003. These measurements, combined with a first simple distribution modeling of permafrost based on gridded meteorological data indicate widespread permafrost in Iceland, roughly above 800 m a.s.l., and even below this level in sites where palsas could develop. However, the past and possible future development of permafrost in Iceland has not yet been assessed on a country-wide scale. In this study, we model the ground temperature evolution for the entire country on a weekly basis for the period 1960 to 2006 at a resolution of 1 km^2 using the transient permafrost model CryoGrid 2. CryoGrid 2 computes the ground temperature vertically for each individual grid cell. The ground temperature is assumed to be a result of the heat conduction and latent heat effects due to soil freezing and thawing. Gridded meteorological forcing data (temperature and precipitation) are based on the data sets described in Crochet & Jóhannesson (2011) and Crochet et al. (2007), respectively. In a first version, snow depth data are calculated using a degree–day based algorithm developed by the Norwegian Meteorological Institute (“seNorge”, Saloranta 2012).

The results of the modeling give an estimate of the total area of mountain permafrost in Iceland. Quantitative validation of the modeled ground temperature is accomplished based on the borehole temperature data. The numerical approach has a potential of giving quite good approximation of the ground temperature in Iceland. The results depend, however, on the input data, where snow depth and snow properties are undoubtedly the most uncertain data. Other effects, which are not accounted for in the CryoGrid2 model, e.g. “rain-on-snow” events in the wintertime can presumably increase the ground temperature, introducing further uncertainties in the results.

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INFLUENCE OF SITE- SPECIFIC FACTORS ON TEMPERATURES OF THE ACTIVE LAYER AND SEASONALLY FROZEN GROUND, MONGOLIA

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Keywords: temperature; active and seasonally frozen ground; site-specific factors

Factors that contribute on permafrost degradation are anthropogenic disturbances, including overgrazing, forest clear-cutting and forest fires. The forests are distributed in a mosaic pattern and overlap considerably the permafrost regions in central Mongolia; river discharges originate entirely from the high mountains and northern territory where permafrost occurs extensively (Dashtseren et al. 2014; Ishikawa, in press). Permafrost underlying forested north-facing slopes and seasonally frozen ground underlying mountain steppes on south-facing slopes co-exist within a small mountain basin that represents the most general landscape type in northern Central Mongolia, where we have been continuously measuring the micro climate components at two sites since 2003 and surface temperatures at 100 sites since 2015. The purpose of the article is to describe records of comparable hydro-meteorological parameters on these slopes, with a special focus on the site-specific factors controlling ground temperatures regime on these slopes with different exposition.

The result shows that the ground surface temperature (GST) in summer is exceeded air temperature at mountain steppe slopes, contrary to forested slopes. In contrast, GSTs in winter were lower at the mountain steppe slopes than at the forested north slopes. The mean annual ground surface temperature ranged from 0^{o}C to -2.4^{o}C at forested slopes and from 0^{o}C to $+7.0^{o}$C at steppe slopes. These differences in GST between the south and north exposed slopes could be mostly explained by solar radiation allocation and variations in snow covers on the slopes. Despite of different topographical conditions, the amounts of solar radiation over the slopes were similar in summer, but not in winter. Furthermore, the forest canopy prevents 33–86 % of the total annual amount of solar radiation reaching the forest ground. It suggests that the GST is usually related to forest cover and not to the site exposition. Soils at steppe slopes are characterized by low moisture. In contrast, soils in forested slopes contain abundant water, and they are covered by thick organic layer. The thermal conductivities (k) at steppe slopes were less variable with values ranging 0.92W/mK (winter mean) and 1.04 W/mK (summer mean). However, the forested slopes have high variability of k, ranging from 0.57W/mK (summer mean) to 1.14W/mK (winter mean) due to a combined effect of thick organic layer and soil moisture. It is therefore likely that the higher R and k at steppe slopes contribute to a warm soil layer during summer compared to soil layer at forested slopes. There is a less snow cover in winter and a similar amount of k during summer time in the steppe slopes, releasing more heat from ground to the atmosphere, enabling deep seasonal freezing at the steppe slopes. In winter, due to the higher value of k and low R, the ground temperature fell rapidly, which leads to quick refreezing of the active layer at forested slopes. This result may confirm that the forest occurrence and thick organic layer are the most important key factors controlling the existence of permafrost and seasonally frozen ground in this area.

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MONITORING AND THERMAL STATE OF PERMAFROST IN MONGOLIA

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Keywords: monitoring, boreholes, ground temperature regime, south boundary of permafrost

Permafrost distribution in Mongolia, which encompasses about 29% of the total land area, underlying the Altai, Khuvsgul, Khangai, and Khentii Mountains (Jambaljav et al. 2016), is mosaic-like because Mongolia is located at the southern boundary of the Siberian permafrost region (Dashtseren et al. 2014; Ishikawa, in press). The air temperature has increased by 2.07°C/70yr in Mongolia, and this increase has occurred more intensively in the mountain regions than in the Gobi and steppe regions (MARCC. 2014). Therefore, the permafrost in Mongolia can be vulnerable to climate and environmental changes. Permafrost acts as a water-resistant buffer against water penetration to sediments, playing an essential role in arid ecohydrological system and herders in Mongolia. For instance, the permafrost in Mongolia directly sustains the livelihoods of inhabitants because it produces locally wet soil conditions, even under a low annual rainfall (Dashtseren et al. 2014). Furthermore, the forests are distributed in a mosaic pattern and overlap considerably with permafrost regions, and river discharges originate entirely from the high mountains and northern territory where permafrost occurs extensively (Dashtseren et al. 2014; Ishikawa, in press). However, the characteristic of the Mongolian permafrost is not fully known due to widespread permafrost and less complex observation systems. To better understand the characteristic of the Mongolian permafrost, it is necessary to build up more monitoring sites over permafrost area.

In Mongolia, permafrost research has been conducted since the begging of 1960s. However, continuous measurements began mostly in the last decades. During the last several years, 180 permafrost monitoring sites (boreholes) were established in the different permafrost zones over Mongolia, and about half of the boreholes has equipped with HOBO U-12-008 temperature data-logger and TMC-HD temperature sensors. These boreholes were considered to be representative for the most landscape types in permafrost region. The depth of boreholes are ranged from 1.5 to 50 m, with the majority below 15 m. Also, some of these boreholes have a single temperature measurements from the late 1960s and early 1980s. Therefore, it is able to determine the changes of permafrost in some sites.

Monitoring of the ground temperatures over the past decades has indicated that the permafrost has been changing in the Mongolian territory. For example, mean annual ground temperature (MAGT) at 10-15 m depth increased by 0.02 − 0.03°C yr^{-1} in the Darkhad and Sharga depressions in the Khuvsgul Mountains, where ice-rich and cold permafrost occurs extensively. In the southern Khangai and Khentii Mountains with underlying warm permafrost, MAGT at the former depth increased by 0.01 − 0.02°C yr^{-1}. The increase in permafrost temperature is more pronounced in the cold permafrost than in the warm permafrost region. Active layer thickness varies between 1.8 – 2. 9 m in the Khuvsgul Mountains, 2.8 – 6.5 m in the Khentii Mountains, 2.1 – 7.8 m in the Alta mountains and 2.4 – 5.5 m in the Khangai Mountains, respectively.

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ACCELERATING VERSUS DECELERATING ROCK GLACIERS IN THE CONTEXT OF ONGOING CLIMATE WARMING

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Keywords: acceleration; deceleration; landslides; monitoring; permafrost creep; rock glaciers

The kinematical behavior of a set of more than 25 rock glaciers and permafrost-affected landslides located in the western and southern parts of the Swiss Alps has been monitored for the last 5 to 20 years on an annual basis, principally by means of DGPS surveys complemented in some cases by airborne imaging techniques. The basic motivation supporting such an effort is to provide many long and homogeneous time series. This is particularly important in a region affected by a high spatial variability of the annual precipitation rate and necessary to evidence the similarities and specificities of the creep behavior of rock glaciers.

The time series were started in 1994 at the earliest and in 2012 at the latest. Most of them are uninterrupted. On each rock glacier or landslide 10 to more than 100 marked points are measured once a year at approximately the same date. During their respective first year of survey, the selected rock glaciers were moving at a rate spanning from a few centimeters to several meters per year. No so-called destabilized rock glacier (displaying scarps or crevasses) was taken into consideration when starting a time series.

Our main observations can be summarized as follows:

A dramatic acceleration of the rock glacier creep rates has been observed since the initial measurements in response to the concomitant permafrost warming trend.

Interannual variations may be large – up to 50% – and are simultaneous for all rock glaciers within a sub-region. They are primarily linked to changes in the 2- to 3-years ground surface temperature (GST) mean.

The observation of permafrost-affected landslides is almost recent (less than 10 years long). Four landforms are monitored. Displacement rates are ranging between 5 and 80 cm/year. Their interannual behavior is so far not differing from those of active rock glaciers.

Three rock glaciers have accelerated abnormally and their behavior has migrated (far) away from the regional trend: these rock glaciers have changed their dynamics and entered a "destabilization" phase. Surface velocities have overpassed 10 m/year at two locations already. In all three cases the rock glacier longitudinal profile is convex and no external mechanical factor (e.g. large rock fall deposits) has triggered the destabilization. The cause for the acceleration is likely of thermal origin.

Conversely, two rock glaciers have decelerated in comparison to the regional signal. In both cases a surface lowering has been observed locally which cannot be attributed to an extending flow. We assume so far that such a deceleration could be caused by permafrost degradation (ice melt at depth), strong enough for increasing the friction between rock particles at the rock glacier shear horizon.

ASSESSEMENT OF LARGE STRAIN THAW CONSOLIDATION OF PERMAFROST BASED ON GENERALIZED THAWED SOIL PROPERTIES

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Keywords: Thaw consolidation; permafrost degradation; thaw settlement; hydraulic conductivity; compressibility

Rationale: The assessment of instabilities related to thawing soils is paramount for the sustainable design of infrastructure built on permafrost especially in the context of climate change.

Objective: There is a substantial incentive for developing a comprehensive engineering theory to predict the magnitude and rate of settlement as well as the magnitude of the pore water pressures generated upon thawing of a frozen soil.

A one-dimensional model for the consolidation of thawing soils is formulated in terms of large strain consolidation and heat transfer equations. The model integrates heat transfer due to conduction, phase change and advection. The hydro-mechanical behaviour is modelled by Gibson's large strain consolidation theory (1981). The equations are coupled in a moving boundary scheme developed in Lagrangian coordinates. Finite strains are allowed and nonlinear effective stress—void ratio—hydraulic conductivity relationships are proposed to characterize the evolution of the thawing soil properties. Initial conditions and boundary conditions are presented with special consideration for the moving boundary condition at the thaw front developed in terms of large strain consolidation. The proposed model is compared with small strain thaw consolidation theory in a theoretical working example of a thawing fine-grained soil. The modelling results presented in terms of temperature, thaw penetration rate, excess pore water pressures, settlements, thaw strain and degree of consolidation are thoroughly discussed.

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THERMAL CONDITIONS OF AN UNSTABLE HIGH ALPINE PERMAFROST-AFFECTED ROCK RIDGE: THE CASE OF THE COSMIQUES HUT (3613 M A.S.L., MONT BLANC MASSIF)

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Keywords: electrical resistivity tomography; infrastructure; Mont Blanc massif; permafrost; rock ridge.

The thermal state of steep permafrost-affected rock faces is crucial to assess safety and reliability of mountain infrastructures as permafrost degradation affects rock slope stability in high mountains (Krautblatter et al, 2013). In the Mont-Blanc massif, 23 infrastructures are built on permafrost-affected rock walls with 13 infrastructures characterized by a high risk of destabilization (Duvillard et al, 2015). So far, the main event happened few meters below the Cosmiques hut on the 21st August 1998 (Ravanel et al, 2013): a rockfall of 600 m^3 affected the SE face of the ridge and damaged the refuge which had to be closed for 8 months. The lower Cosmiques ridge is affected by an important rockfall activity with 18 events documented between 1998 and 2011 (direct observations and terrestrial laser scanning surveys).

In order to better assess the permafrost role in the past destabilizations and to gain insight on possible future geomorphic activity, we characterized the current permafrost conditions and simulated its changes up to the end of the 21st century using 3 complementary approaches. (i) ERT (Electrical Resistivity Tomography) surveys realized in October 2016 on the north and south faces, just below the refuge (next to the foundation level). This survey allowed highlighting the anthropic impact of the refuge on the permafrost distribution. (ii) The rockfall activity between 2011 and 2016 measured by Terrestrial Laser Scanning surveys on SE face showed three important events near the foundation. (iii) The modelling of the rock wall permafrost degradation from 2016 to the end of the 21st century on the ridge (Magnin 2016, in review).

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GAS-EMISSION CRATERS ON YAMAL AND GYDAN PENINSULAS – FUTURE LAKES

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Keywords: gas emission craters; Yamal; Gydan; lakes

We hypothesize that some of the lakes on the Yamal Peninsula have a non-thermokarst origin (specifically, they are not resulting from subsidence caused by the ground ice thaw). In 2013, gas emission craters (GEC) on Yamal and Gydan peninsulas were formed (Kizyakov et al., 2015). Members of our research group have visited Yamal GEC in 2014 (Leibman et al. 2014) and since then we continued monitoring of this feature. In summer of 2016 our group has also visited a GEC on Gydan peninsula close to a Antipayuta settlement.

In 2015 collected were water samples for dissolved methane tests from Yamal GEC. Observed concentrations were 614 nmol/L at the next to water surface and 10350 nmol/L at the depth of 14.5 m of the Yamal GEC lake (the maximal measured depth in 2015 was 23 m). Herewith, the mean dissolved methane concentration in nearest lakes was only 84 nmol/L. It can be concluded that after the event of avalanche-like gas emission and crater formation, the source of methane from the bottom kept active for some time providing gas seepage into the water column of the GEC lake.

While the maximum measured depth of Yamal GEC lake was 23 m in 2015, in 2016, the maximum measured depth in the center of GEC lake was about 8 m. At the same time, the area of GEC increased twofold. The maximum measured depth of the lake in Gydan GEC was only 3.5 m. Therefore, during first years of their lifetime the GEC lakes are being filled with water and coastal sediments.

Isotope samples taken from both GEC lakes have shown that the isotopic composition of the water is closer to that in tabular ground ice found in this region than to the composition in the nearest lakes. But from year to year the isotopic composition is becoming “lighter”. We then can conclude, that during first years the main source of the water in GEC lakes is thawing ice-bearing permafrost.

In addition, thawing of permafrost delivers a huge amount of suspended and particulate matter to the GEC lakes. Studied GEC-lakes water has a higher concentration of major ions, dissolved organic carbon, total suspended matter compared to regular lake water. But we expect that in the nearest future, after the feature stabilizes, the geochemistry of GEC lakes approach that of the regular Yamal – Gydan lakes.

Moreover, our bathymetric surveys in lakes of central Yamal have revealed that 18% of measured lakes have crater-like features with much higher depths than the average depth of the lake. These crater-like features are relatively small in area compared to total lake area and can be linked to either the thaw of permafrost underneath or to gas emission. These are the gaps that we need to bridge working on the GEC related issues. This work is supported by RSF grant 16-17-10203 and by Government of Yamal.

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SIMULATION OF THE DIELECTRIC PERMITTIVITY OF FROZEN, STRUCTURED SOILS

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Keywords: bound water; dielectric permittivity; soil ice content (SIC); soil liquid water content (SLWC); soil structure; time domain reflectometry

Despite sub-freezing temperatures, liquid water is still present in frozen soils and there are many examples in the literature where biogeochemical processes such as nitrification, denitrification and soil carbon mineralization are active at sub-freezing temperatures. Accurate measurement and simulation of transient soil moisture contents in frozen soils is key to understanding the environmental significance of these processes and the influence of climate change on these processes, but remains a challenge.

For unfrozen soils, the time domain reflectometry (TDR)-measured ε_{eff} over a range of known soil liquid water contents (SLWCs) is used to create the ε_{eff}-SLWC curve (i.e., TDR calibration curve). These calibration curves may be empirical or can be used to calibrate a dielectric mixing model. The similarity between soil freezing and drainage (i.e., the replacement of liquid water by another phase) is often used to justify the direct application of the ε_{eff}-SLWC curve measured in unfrozen soils to frozen soils. But, because the freezing process involves the replacement of water by ice, the ε_{eff} of a frozen soil with both liquid water and ice present will be greater than that of an unfrozen soil with the same SLWC because the dielectric permittivity of ice is three times greater than air (i.e., 3.2 compared to 1) (He and Dyck, 2013). Further, in frozen soils, the total volumetric fraction of water is present as two phases (liquid and ice), making frozen soils a four-phase mixture – 5-phase if bound water is included.

The permittivity of bound water in soils is lower than capillary water and dielectric mixing models have been used to demonstrate this (18). Changes in the volumetric fraction of and dielectric permittivity of bound water at sub-freezing temperatures are expected (25), but it is unclear whether the volumetric fraction of bound water increases or decreases with decreasing temperature. A recent investigation showed that the thickness of bound water films on soil particles decreases with decreasing temperature in frozen soils (25), but the dielectric permittivity of the bound water was not estimated.

Therefore, for frozen soils, physical dielectric mixing models are useful to better understand the effects of soil freezing on TDR-measured ε_{eff}. In this presentation, we will demonstrate the influence of soil structure and assumptions about the dielectric permittivity of bound water on the dielectric permittivity of frozen soils through simulations using multi-phase dielectric mixing models.

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WARMING AND DEGRADATION OF PERMAFROST IN NORTHERN NORWAY

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Keywords: Mountain permafrost; northern Norway; degradation; tallik

Permafrost is sensitive to climate change, modulating geomorphological process rates and ultimately landscape development. In Norway, since the 1980ies many studies have been carried out to evaluate the permafrost distribution, its changing state and its relation especially to climate and snow conditions. This knowledge has flown into numerical models, calculating ground temperatures in space and time.

At present Norway has an unique data set obtained from bore holes where we measure temperatures along both altitudinal and latitudinal gradients. In addition at all sites geophysical surveys are available using refraction seismic and electrical resistivity tomography, partly multi-temporal. Finally, daily gridded data sets of meteorological parameters such as air temperature, precipitation and associated snow cover are available back to 1957, allowing the evaluation of climate-ground thermal regime relations along regional gradients.

This presentation summarizes a c. 10 year record of ground thermal measurements and geophysical surveys from three main sites in northern Norway, along with new evaluations of changes in palsa distribution and size. For the first time we demonstrate the development of taliks in mountain permafrost in northern Norway, and relate and discuss the development of these taliks to changing atmospheric and snow conditions. The observations are also related to long-term change detection observations of palsa mires in the vicinity of the bore holes, highlighting accelerating thaw and degradation of permafrost during the last two decades.

THERMAL REGIME AND GEOMORPHOLOGICAL PROCESSES IN STEEP SLOPES IN TIME AND SPACE

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Keywords: permafrost; rock walls; weathering, Holocene

The role of the ground thermal regime on geomorphological processes in settings associated to steep slopes has received considerable attention in the past. It is evident from recent studies that e.g. rock walls have a profound effect on the thermal regime in mountain sides, a.o. influencing rock wall stability, weathering regimes and glacier-permafrost interaction in space and time. This presentation discusses the importance of the thermal regime in space and time on geomorphological processes in steep slopes. We combine direct observations of air, ground and rock wall temperatures with numerical simulations using a 2D transient thermal model (CryoGRID 2D). We analyze how thermal gradients in rock walls or coastal cliffs may influence important geomorphological processes related to weathering, talus developments, material accumulation and ice aggregation in coarse material. On longer time scales, permafrost dynamics associated with glaciation and deglaciaton phases, may have influenced the development and stability of large-scale valley systems.

DISTRIBUTION, SOURCE AND CYCLING OF ORGANIC CARBON AND NITROGEN IN PERMAFROST FROM AN ULTRAXEROUS ENVIRONMENT (MCMURDO DRY VALLEYS OF ANTARCTICA).

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Keywords: Biogeochemistry; Carbon cycling; Habitability; Terrestrial analog

The abundance and origin of soil organic carbon (SOC) and biogeochemical stoichiometry in the soils (C_{org}:N) of the McMurdo Dry Valleys (MDV) have mainly been studied in their warm-wet subxerous zone (Burkins et al. 2001; Barrett et al. 2004; Elberling et al. 2006). To date, little is known about the abundance, source and cycling of SOC and potential biogeochemical stoichiometry in the sediments of its much colder and drier ultraxerous zone. This study investigated the distribution, source and cycling of C_{org} and N in the sediments of University Valley, a small hanging valley in the Quartermain Mountains. To accomplish this objective, 16 ice-bearing permafrost cores (up to 1m in depth) were collected from 10 sites along the valley floor and analyzed for carbon (organic and inorganic) and nitrogen concentrations.

University Valley is a northwest facing valley situated in the ultraxerous zone of the MDV. The mean annual air temperature and relative humidity in the valley are –24.3°C and 48%, respectively, and the summer air temperatures are always below the freezing point; however, ground surface temperatures and moisture conditions separate the valley into two distinct zones: 1) a perennially cryotic zone (PCZ) that is characterized by ground surface temperatures always below 0ºC and that lacks geomorphic features associated with aqueous processes; and 2) a seasonally non-cryotic zone (NCZ) where ground surface temperatures can rise above 0°C for a few hours on clear summer days and that contains geomorphic features associated with aqueous processes (Lacelle et al. 2016).

In the PCZ, the average concentration of C_{org} and C/N ratio in the icy soils was 0.52 mg C/g^{-1} dry soil and 1.07, respectively, suggesting that geochemical processes dominated the soils. By contrast, in the NCZ, the average concentration of C_{org} was higher (1.48 mg C/g^{-1} dry soils) and the average C/N ratio (6.13) approached the Redfield stoichiometry ratio suggesting some biological cycling of nutrients. Throughout the PCZ, $\delta^{13}C_{org}$ composition of SOC (–26.8‰ and –25.6‰) approached that of endolithic-derived organic matter; as such SOC contained in the icy permafrost was derived from the deposition of organic carbon produced by cryptoendolithic communities living in the surrounding sandstone walls. However, the $\delta\ ^{13}C_{org}$ values in the NCZ were slightly lower (–29.9 to –25.7‰), suggesting *in situ* microbial consumption of endolithic-derived SOC, supporting the C/N ratios. The results from this study support previous findings of absence of microbial activity in the PCZ (Goordial et al. 2016); however heterotrophs might be presently active in the relatively warmer and wetter NCZ.

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SOCIAL AND ECONOMIC CONSEQUENCES OF CLIMATE WARMING-INDUCED DEGRADATION OF ICE-RICH PERMAFROST LANDSCAPES IN YAKUTIA

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The current climatic changes and anthropogenic disturbances have intensified the development of permafrost-related processes in Yakutia during the last two decades, adversely affecting the landscapes and socio-economic conditions in this permafrost region.

In Soviet times, when there were no problems with global warming, large areas of the ice complex were developed into farmland. Presently, much of this land has degraded due to anthropogenic impacts and global warming. Thermokarst development has made thousands of hectares of cropland useless for agriculture.

In rural communities, permafrost degradation is causing problems for buildings. In villages located in the Lena-Amga watershed, for example, 72% of respondents responded that their houses had foundation settlements. Because of the lack of available land with stable permafrost, sites for housing development are often allocated on degrading land.

Young thermokarst lakes in ice-rich permafrost terrain are growing at high rates, rapidly expanding in area. From 1980 to 2016, the area of young thermokarst lakes has increased 3 to 4 times. This has a negative impact not only on forests, but also on communication lines, roads, buildings and pipelines.

The causes for degradation of wedge ice are simple. Under the current climate warming, the depth of thaw in open, forest-free areas reaches the tops of ice wedges each year, resulting in their thawing. Our observations indicate that the rates of subsidence vary greatly, from 1-2 cm to 25 cm per year, depending on the landscape conditions.

The ice-rich permafrost landscapes which occupy about 25% of Yakutia are in a critical condition under the current climate warming. The results of field observations show that any anthropogenic impact can lead to permafrost degradation and deterioration of the socio-economic value of these landscapes. Alases, which are related to these landscapes, are the most populated areas in Yakutia. Understanding the trends in permafrost-landscape dynamics has therefore not only ecological, but also socio-economic, cultural and historical importance.

TWO DECADES OF GROUND TEMPERATURES FROM ACROSS THE CANADIAN ARCTIC

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Keywords: Arctic; Climate change; Permafrost; Ground temperatures; Numerical simulation

The Distant Early Warning Line (DEW Line) was constructed in 1957 to provide advance warning of intrusions in the airspace between Alaska and Greenland. Both the Canadian and American government collaborated to construct the over 50 radar stations which comprise the DEW Line (Lackenbauer et al. 2005). Eventually in the 1980s, the DEW Line was replaced by the North Warning System (NWS). To date many of the sites from the former DEW Line have been decommissioned. A total of 21 of the 42 sites within Canadian borders were decommissioned as early as 1960 (National Defense 2014). As environmental standards evolved, mitigation at the decommissioned sites was required to ensure they met with modern environmental expectations. Migration of contaminants such as hydrocarbons and PCBs as well as stabilization of existing landfills were a concern – clean up was completed in 2014 (National Defense 2014).

Environmental stewardship dictates that the sites continue to be monitored as to their performance with regards to original design as well as safety. Since the late 1990s and following, sites were instrumented to measure the spatial and temporal distribution of ground temperatures. As a result, over 20 years of ground temperature data was collected at sites which cover the longitudinal width of the Canadian Arctic. This presents a unique opportunity to analyze the ground temperature interaction with the arctic environment. A longitudinal study on ground temperature with depth over time at DEW Line sites is currently underway. There are three main long-term objectives to this study. The first is inputting historical climate data from the past two decades into numerical models to calibrate and validate the results with recorded ground temperatures. The second objective is examining trends in ground temperatures related to local weather effects. Finally, the third objective is to predict a range of potential climate change effects on ground temperature across sites for which historical data is available. Broad analysis of the ground temperature database created by the completion of these objectives will allow Canada to develop and maintain arctic communities, mobility, resources and defense systems.

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COOLING PROCESS OF A SCREE SLOPE AND ITS SIGNIFICANCE FOR PERMAFROST ENGINEERING

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Keywords: Scree slope; crushed rock; cooling mechanism; permafrost engineering

Permafrost is believed as a result of interactions between the cold climate and the earth. Most of the current permafrost formed during cold glacial periods, and has persisted through warmer interglacial periods. Overall, the low air temperature in the high latitude or high altitude regions is the decisive factor in permafrost development. However, robust permafrost far from the south boundary of the latitude permafrost was discovered in middle-temperature zone in middle north-east China, where the altitude is lower than 1,000 m, and the mean annual air temperature (MAAT) is 6-8°C. The permafrost is developed in a scree slope with blocks covered by peat soils. We analyze the scree slope through field monitoring, indoor testing and numerical simulation. The permafrost is caused by air convection in the porous rocky deposits covered by a 30-cm-thick fine soil and vegetation layer in winter time. The existence of the robust permafrost shows that the porous blocky structure can protect permafrost in the environment with the mean air temperature up to 6-8°C. We suggest that such natural structure of the scree slope can support the engineering usage of crushed rock layers for protecting permafrost subgrade with a long time, even under the global climate warming condition. And also, this low ground temperature phenomenon can be though as a successful application of crushed-rock layers in the roadbed construction of the Qinghai-Tibet Railway in permafrost regions, which is regarded as a milestone of permafrost infrastructure..

References:

ROCK GLACIERS IN THE BHUTAN HIMALAYAS

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Keywords: Mountain permafrost; rock glacier; Bhutan Himalayas; Google Earth; InSAR; Era-Interium.

In spite of the abundance of rock glaciers in the Bhutan Himalayas, the studies of rock glacier are limited. Previous study identified 32 rock glaciers in the northwestern part of Bhutan Himalayas in 1998 from field survey (Iwata et al. 2003). Since this study, no further research has been performed. In order to make a rock glacier inventory and identify the lower limit of mountain permafrost in the Bhutan Himalayas, rock glaciers were mapped in the field along the Snowman Trek route in 2014. Supplementary interpretation was made using interferometric synthetic aperture radar (InSAR) data and optical images from Google Earth.

We identified 55 active rock glaciers, 19 inactive rock glaciers and 7 fossil rock glaciers along the Snowman Trek route. The mean area of the rock glaciers is 0.12km^2. We further distinguish origins of the rock glaciers as 18 glacial-derived and the other 63 talus-derived.

Active talus-derived rock glaciers appeared above 4600 m ASL, at which mean annual air temperature (MAAT) were estimated to be < -0.8ºC using ERA-Interim reanalysis dataset from 1979 to 2013. These indicates that the lower limit of mountain permafrost in this region is around 4600 m ASL. Despite similar air temperature condition (MAAT at 5000m = about -2°C), this lower limit is slightly lower than that in Khumbu Himal (5300-5500 m ASL) (Jakob 1992, Fukui et al. 2007). We guess that abundance of glacial-derived debris above 4400 m ASL favors the formation of rock glaciers in the Bhutan Himalayas.

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VARIATIONS OF SOIL FREEZE-THAW PROCESS IN ALPINE MEADOW AND ALPINE STEPPE OF CENTRAL TIBETAN PLATEAU

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Keywords: alpine meadow; alpine steppe; freeze-thaw process; soil temperature; Tibetan Plateau

Tibetan Plateau (TP) is the largest region of permafrost and seasonally frozen soil outside the Arctic and Antarctic. The soil freeze-thaw process varied at different sites of TP and it complicated the understanding of changes in regional water resources and ecosystems under climate change. As the most widespread grassland types in the permafrost regions of TP, alpine meadow and alpine steppe ecosystem are the excellent study areas to investigate the variations in soil thermal regimes. Using the observational active layer temperature data from 2 sites in above typical ecosystems, we performed a comparative analysis of soil thermal regimes in terms of soil seasonal freeze depth, the onset and end dates of soil freeze, and the duration of soil freeze. The results showed that ground temperature above the depth of 20 to 25 cm in both alpine steppe and alpine meadow existed same evident daily variation with the same time of maximum and minimum values in each season and the phase of soil temperature lagged obviously with depth in both sites. The annual maximum ground temperature was in July and August in alpine steppe and alpine meadow respectively, while the minimum was both in January. However, the freeze depth and freeze-thaw process showed the difference between two sites. The freeze depth in alpine meadow (220cm) was less than alpine steppe (>320cm). Soil freeze of alpine steppe had around 20 days longer duration period with earlier onset and later end than alpine meadow. The alpine meadow had higher ground temperature compared with alpine steppe simultaneously. The differences were more significant in cold season. Higher vegetation coverage, which represented by normalized difference vegetation index (NDVI), provided more insulation effect on heat exchange of soil freezing process in alpine meadow than alpine steppe. Vegetation exerts a key role in controlling permafrost distribution and soil freeze-thaw process.

FOLLOWING DEFORMATION OVER PERMAFROST ENVIRONMENT DURING A WHOLE FREEZE/THAW CYCLE USING POL-D-INSAR

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Keywords: Deformation; InSAR; Permafrost; Polarimetry; Stripmap; TerraSAR-X; Yakutsk

Thawing permafrost and the resulting microbial decomposition of previously frozen organic carbon is one of the most significant potential feedbacks from terrestrial ecosystems to the atmosphere in a changing climate. Permafrost has a profound influence on the hydrology, landscape and ecology of northern environments. The thawing is restricted to some meters below the top layer of soil and a permafrost layer remains frozen below the surface. In such areas, the top layer of soil that thaws during the summer and freezes in winter -known as the active layer- warms up enough to enable plants to grow during the spring and summer. For an accurate assessment of the carbon transfers, the active layer thickness over different soils and surface types needs to be known, as well as the dynamics of soil moisture during the annual freeze/thaw cycle.

In this initiating work, time series of X-Band SAR data are investigated for surface deformation estimation. The data has been acquired over two sites located around 50 km at east of Yakutsk (Central Siberia) every 11 days during one year to cover a whole freeze/thaw cycle. The selected polarimetric channels were HH and HV ensuring sensitivity to vegetation dynamics and enabling polarimetric optimization of the coherence and ground phase estimation under vegetation.

Several ground measurements have been performed over the two sites. Active layer depth, soil moisture gradient, vegetation height and type were collected. We also have used temperature vertical profiles continuously measured over instrumented sites during height years, from 2000 to 2008. These profiles were established over 5 typical East-Siberian environments: two alas (thermokarstic depressions) composed by grass and other herbaceous vegetation and lakes, and three other sites covered respectively by birch, larch and pine forests. A specific InSAR (Ferretti, et al. 2001, Bernardino et al. 2002) approach has been developed to follow the deformation in time, with a 11 day revisite resolution, in order to have a chance to estimate the non-linear ground movements affecting the periglacial environment. The sensor polarimetric capability is employed for polarimetric optimization of the coherence, to maximise the movement estimation between only two dates, and for ground movement estimation under vegetation, by exploiting the polarimetric diversity of the interferometric coherence (Garestier et al. 2014 a,b, Garestier et al. 2015a,b). The deformation patterns are then confrontated to the ground measurements for analysing the thermal and hydrological processes affecting the ground during the whole freeze/thaw cycle.

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EFFECTS OF CHANGES IN ALPINE GRASSLAND VEGETATION COVER ON HILLSLOPE HYDROLOGICAL PROCESSES IN A PERMAFROST WATERSHED

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Keywords: Alpine grassland; Vegetation degradation; Hillslope water cycle; Influence; Permafrost watershed

An understanding of water yield properties within the vegetation-soil system is critical to accurately forecasting the influence of global climate change on the water cycle in permafrost regions (Carey and Woo., 2001; DeFries and Eshleman, 2004). However, there are little knowledge on the mechanism of the impacts of the coupled soil thawing–freezing and vegetation system on the hydrological processes in permafrost region (Ishikawa et al., 2006; Wang et al., 2008). Two main types of grasslands, alpine swamp and alpine meadow, on the Qinghai-Tibet Plateau were selected for this study. The impacts of alpine grassland cover changes on hillslope water cycle were analyzed in terms of runoff generation, precipitation interception, dew water formation, and soil water dynamics of the active layer. The results showed that the two types of grasslands led to different runoff generation regimes. Runoff varied linearly with precipitation in alpine swamp, whereas in alpine meadow, runoff exhibited an exponential variation with precipitation. The reduced vegetation cover (degradation sites with vegetation coverage lower than 65%) in the alpine swamp led to a decreased soil moisture content in the top 20 cm of the soil, a delay in spring thaw start time, and a decreased surface runoff and subsurface interflow compared to the undisturbed sites with vegetation cove of 93%. In alpine meadow, the decreased vegetation cover led to a significant increase in the depth of topsoil moisture content during the thawing period, an earlier onset of thaw, and an increased runoff generation ratio. The alpine meadow vegetation canopy had a higher maximum interception ratio than alpine swamp vegetation. With the decrease in vegetation cover, the rainfall interception ratios decreased by almost an identical range in both the alpine meadow and alpine swamp grasslands. Dewfall commonly occurs on alpine grassland, accounting for about 12.5-16.5% of precipitation in the same period, and thus, is an important component of the water cycle. With the degradation of vegetation (vegetation cover reduction), the total dewfall (including condensed both from air and surface soil layer) decreased. However, the ratio of dew formed in the air to the total amount of dew water rose significantly. At the hillslope scale, the type of alpine vegetation and reduction in vegetation cover had a great influence on the water cycle, which were partly attributed to that the changes of alpine vegetation cover directly altered the surface energy balance, surface water cycle processes, and the thermal and hydraulic properties of soil.

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CRYOFACIES IN EPIGENETIC PERMAFROST – A DIVERSE ASSEMBLAGE OF GROUND ICE IN SEDIMENT CORES FROM ADVENTDALEN, SVALBARD

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Keywords: cryostratigraphy; ground ice; paleogeography; sedimentology

Adventdalen is a glacially and periglacially-modified valley located in central Svalbard. We reconstruct antecedent environmental conditions in Adventdalen using cryostratigraphic and sedimentological evidence from three ice-bonded sediment cores and existing knowledge of glacial history and sea-level variations. Cryofacies (defined by the bulk macroscopic characteristics of ground ice) allow for the determination of the nature of permafrost aggradation and conditions under which the sediment has accumulated. We identify nine cryofacies in the Adventdalen sediment cores: pore, organic, crustal, porphyritic, vein, lenticular, layered, suspended, and solid. In addition, detailed sediment analyses have resulted in a sedimentary facies model. We classify six sedimentary facies associations (FA), each representing a unique depositional environment or delta subenvironment: (1) glacial; (2) glaciomarine; (3) prodelta; (4) delta slope; (5) delta topsets; and (6) delta topset. 50 samples were dated by optically stimulated luminescence or ^{14}C AMS to establish temporal variations in sedimentation rates. The vertical distribution of cryofacies indicates that permafrost is epigenetic in FA 1-5 and syngenetic in FA 6. This suggests that permafrost in Adventdalen aggraded following the transition from subaqueous to terrestrial depositional environments. Dating results indicate that permafrost in Adventdalen is of Holocene age. Permafrost increases in age (becomes older) up valley, with distance from the contemporary delta front. These results suggest that permafrost in the valley bottoms throughout Svalbard is a Holocene phenomenon.

THE RESISTENCE OF FROZEN SOILS OF EASTERN SIBERIA TO CHEMICAL CONTAMINATION

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Keywords: ecological and geochemical situation; concentration coefficient; cryozem; occurrence rate; resistance of frozen soils; total index of soil contamination.

The northern ecosystems are known for their weak resistance to anthropogenic activities, predetermined by their low biodiversity, weak biological productivity and decreased trophic links (Danilov et al. 2005). This paper aims to identify the degree of resistance of frozen soils to chemical contamination and to assess their ecological and geochemical conditions. The research was conducted on the territory of Eastern Siberia within the industrial site of Nyurbinskiy mining plant. Research was performed in accordance with soil sciences methods. To assess the ecological and geochemical conditions we used the parameters of regional geochemical background, concentration factor (Kc) of chemical elements, total index of soil contamination (Zc) and occurrence rate (Hi). We suggest researching the resistance of frozen soils to chemical contamination through the indicators of sorption ability (Dyagileva 2013). The specific features of frozen soils, cryozems, are the undifferentiated or faintly differentiated mineral stratum on genetic horizons, closely underlying permafrost and nonpercolative regime. The zonal soil types in the studied territory are cryozems where the homogeneous-gley and homogeneous non-gley types prevail. Cryozems are characterized with a two-term profile by the granulometric composition (sandy and loamy), with weak acidic conditions of the soil in the upper organic horizons and close to neutral in the mineral part of the soil profile, by high humus content in throughout the soil profile, with medium capacity of cation exchange, undifferentiated or poorly differentiated soil profile by the composition of the major oxides and the presence of permafrost. Microelements were grouped into three clusters according to content of mobile forms and characterization of intraprofile distribution. For the elements of clusters I (Mn, Cu, Zn, Cd) and II (Co, Cr, Ni) the major criteria affecting the sorption are physical clay content and capacity of cation exchange. The main sorbent for elements of cluster III (As, Pb) is organic substance. In 2007 the ecological and geochemical situation was given the acceptable category of contamination according to mobile forms of trace elements content in epipedon (Zc=1,8-10,1). In 2011 the study area was characterized as moderately dangerous according to total index of soil mantle pollution (Zc=1,5-51,4). In 2014 it was assessed as a dangerous (Zc=2,9-362,6). We conclude that homogeneous suprapermafrost-gley cryozem and homogeneous non-gley cryozem have high sorption ability and low resistance to chemical pollution. While the gley podzolized cryozem has low sorption ability and high resistance. From 2007 to 2014 the ecological and geochemical situation in the study area has worsened with an increase of contamination area and its extent.

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TOWARD MAKING OF TEACHING MATERIALS FOR ENVIRONMENTAL EDUCATION RELATED TO SAKHA THERMOKARST

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Keywords: Environment Education; teaching material; thermokarst; alaas; Sakha (Yakutia)

The members of a subgroup of the Japanese Arctic research project "Arctic Challenge for Sustainability" (ArCS) has started to work for making of teaching materials for Environmental Education. Environmental Education (EE) is a teaching process advocated by UNESCO, by which individuals are expected to gain awareness of their environment and acquire proper knowledge, values, attitude, and practical skills to participate in solving environmental problems and in the management of the quality of the environment. According to the Tbilisi Declaration (1977), the Education utilizing the findings of science and technology should play a leading role in creating awareness and a better understanding of environmental problems. It must foster positive patterns of conduct towards the environment and nations' use of their resources (UNESCO 1978:24).

Our project aims to synthesize ethnographic materials and scientific results into the teaching materials for EE. They will be made by putting scientific knowledge of permafrost in collaboration with the local knowledge on human relations with surrounding nature, such as local knowledge concerning subsistence activities and local landscape. For instance, the land of a thermokarst process called *alaas* has been made so good use for hay making by Sakha people, that it is deeply entangled in symbolic and social relations among them. After the collective state farms disbanded, individual farm mangers become to open their stock raising bases at the places adjacent to *alaases* which are located far apart from villages. Since many of infrastructures constructed in the Soviet era have lost their functions today, village residents begin scattering among *alaases*. The recent changes of their lifestyle like these must have some influence on the environment.

In our ethnographic research, we found that Sakha people themselves have rich local knowledge concerning their surrounding nature and its minute transformation; such as that the forest type before deforestation is relevant to the speed of land degradation; that the degradation proceeds particularly on the abandoned crop field; and that some new plant and animal species appeared and some disappeared due to the climate change. But, they are not always aware of the significance of their knowledge, because it is more urgent for them to keep own livelihood well. Teaching materials for EE composed of narrative and visual materials will support to make their knowledge into awareness, which is indispensable to positive tackling with environmental problems.

Scientific knowledge of permafrost dovetailed with local knowledge will be returned to the local residents through the teaching materials, which contribute to their risk management such as taking measures against flood. Besides, the materials will not only be utilized in the local settings, but also be exhibited in Japan and other countries. That will promote the dissemination of knowledge and experiences over the permafrost to all over the world.

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ICE/SNOW COVERS ON PERMAFROST-AFFECTED ROCKWALLS: THERMAL PROPERTIES AND MULTI-DECADAL EVOLUTION IN THE MONT-BLANC MASSIF

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Keywords: ice/snow covers, Mont Blanc massif; permafrost-affected rockwall, surface evolution, thermal state.

Dynamics and evolution of the main Alpine glaciers have been vastly studied since the XXth century. Conversely, ice/snow covers on steep rock faces as part of the cryosphere remain poorly studied with only qualitative descriptions existing. The study of ice/snow covers is nevertheless primordial to further understand permafrost degradation in numerous high Alpine rock walls and to improve safety and prevention for mountain sports practitioners and infrastructure.

To highlight their thermal properties, the ice/snow covers of the North faces of the Tour Ronde (3792 m a.s.l.) and Triangle du Tacul (3970 m a.s.l.) in the Mont Blanc massif (France) have been drilled in their centre in Fall 2016, up to the rock surface. Boreholes are 8.9 and 1.0 m deep, respectively. 9 and 4 thermometers, respectively, have been placed along a high density PU tube in the boreholes to monitor temperature within the ice/snow covers and at the ice/rock interface at least throughout a year.

Furthermore, we quantified the evolution of ice/snow covers surface during the past century using a specially developed monoplotting tool. Combining digital elevation models and photographs covering a time-span of 110 years, we calculated the ice/snow cover surface for 3 study sites — North faces of the Tour Ronde, the Triangle du Tacul and the Grandes Jorasses (4208 m a.s.l.) — and deduced the evolution of their area throughout the XXth century. First results are showing several increase/decrease periods. The first decrease in ice/snow cover surface occurs between the 1940's and the 1950's. It is followed by an increase up to the 1980's. Since then, ice/snow covers show a general decrease in surface which is faster since the 2010's. Furthermore, the gain/loss during the increase/decrease periods varies with the considered ice/snow cover, making it an interesting cryospheric entity of its own.

PASTORALISTS IN PERMAFROST REGIONS: DRIVERS OF LANDSCAPE CHANGE?

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Keywords: indigenous peoples, land use, pastoralism, Northern Eurasia

Land use, including that of indigenous peoples, is currently receiving increased attention in research on permafrost. On the basis of the activities of the IPA Action Group on "Permafrost and Culture", this presentation will exemplify how diverse forms of pastoralism, such as reindeer husbandry and cattle breeding, have actively adapted to permafrost-related processes and feed back into them, sometimes with noticeable effects of landscape change. Illustrations from the Northern Urals and Yakutia will provide the background for a more general assessment of permafrost and pastoralism in circumpolar regions and Inner Asia.

FROST TUBE OUTREACH PROGRAM IN HOKKAIDO, JAPAN

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Keywords: Frost tube; Seasonal frozen ground; Outreach; Frost depth

Since 2011 winter season, an Outreach program measuring frost depth has started in Hokkaido, northern part of Japan, where the seasonal ground freezing occurs in winter (e.g. Harada et al. 2012). This program is made at elementary, junior high and high schools in order to emphasis their interest for earth sciences. At schools, seasonal frost depth was measured directly once a week at each school by students during ground freezing under no snow-removal condition. A lecture was made in class and a frost tube was set at schoolyard, as the same tube and protocol as UAF's Permafrost Outreach Program, using clear tube with blue-colored water.

In 2011 season, we started this program at three schools, and the number of participated school is extended to 30 schools in 2015 winter season, 24 elementary schools, 5 junior high schools and one high school. We visited schools in summer time or just before frost season to talk about the method of measurement, and the frost depth was measured by students. After the end of frozen period, we also visited schools to explain measured results of each school or another schools in Japan, Alaska, Canada and Russia.

The measured frost depths in Hokkaido ranged widely, from only a few centimeter to more than 50 cm. However, some schools had no frost depth due to heavy snow. We confirmed that the frost depth strongly depends on air temperature and snow depth. The lecture was made to student why the frost depth ranged widely, and the effect of snow was explained by using the example of igloo.

In order to validate the effect of snow and to compare frost depths, we tried to measure frost depths under snow-removal and no snow-removal conditions at the same elementary school. At the end of December, depths had no significant difference between these conditions, and the difference went to 14 cm after one month, with about 30cm of snow depth. After these measurements and lectures, students noticed snow has a role as insulator and affects the frost depth. The network of this program will be expected to expand, finally more than a hundred schools.

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USING RAPIDEYE SATELLITE DATA TO ASSESS THE TUNDRA–TAIGA TRANSITION IN ARCTIC SIBERIA (LAPTEV SEA AND EASTERN SIBERIAN REGION)

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Keywords: RapidEye satellite data; permafrost landscapes; tundra to taiga transition; thaw lake hydrology; WebGIS

Large parts of Eastern Siberia are characterized by remote uninhabited area not thoroughly mapped in terms of ecosystems and the links between biosphere-geosphere, cryosphere and hydrosphere not fully understood. The Siberian lowlands, where ice-rich permafrost produces strong thermokarst processes have also one of the highest thaw-lake densities. The RapidEye satellite mission offers an opportunity to gain large-area optical satellite data with high spatial resolution.

The study area is located in the Northern Siberian Laptev Sea and Eastern Siberian region to the Far East of Siberia consisting of North-South transects to capture the tundra taiga transition along a West-East gradient to discriminate climatic influences (temperature, humidity). During several expeditions in summer in past years, the North-South transects have been accessed via helicopter expeditions to sample and describe vegetation biomass and tree densities: At ground investigation sites, larch individuals on areas of at least 400 m^2 were examined and lake water constituents were sampled and analysed.

We will analyze the RapidEye satellite data for bio-physical variables such as LAI, NDVI and link values to stand densities derived from in-situ investigations. Our final aim is to map bio-physical vegetation variables and limnological data on a regional scale for the permafrost landscapes of Siberia. Our final aim is understanding the optical RapidEye satellite data in relation to tree densities, shrub height, vegetation color and water constituents in thaw lakes to understand the complex processes in taiga, taiga-to-tundra and tundra permafrost landscapes and vegetation and lake catchments.

We ty into activities of ESA GlobPermafrost project [2016-2019] and the German Helmholtz Alliance Remote Sensing and Earth System Dynamics [HGF EDA, 2012-2012]. The prototype and final remote sensing products and their metadata will be visualized in the Permafrost Information System PerSys WebGIS and described and searchable via the PerSys Data Catalogue. The WebGIS visualization is managed via the AWI WebGIS infrastructure maps@awi (http://maps.awi.de) relying on OGC-standardized Web Mapping Service and Web Feature Service technologies for data display and visualization.

POST-GLACIAL TIMING OF ROCK-SLOPE DESTABILISATION

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Keywords: rock-slope instabilities; displacement rates; TCN-dating; permafrost; 2D-modeling;

Western Norway's geography is characterised by glacially carved steep sided fjords and valleys settled down to the fjord line. This implicates a high risk for the population and infrastructure through natural hazards such as rock slope failures, rockslides and related displacement waves. More than 170 people have lost their lives in the last 100 years due to large rock masses dropping into the fjords, causing displacement waves of several tens of meters height. The processes influencing the triggering of the slope failures might vary in time and space.

While a number of rock slope failures can temporally be ranged into the first millennium after deglaciation, there is evidence that rock slope failures and rockslides have occurred in Norway throughout the entire Holocene. At present, more than 300 active rock slopes with post glacial deformation have been mapped, of which seven are classified as high-risk objects due to their sliding rates and potential impact. Most recently active rock slides have a complex structural set up and rock deformation and displacement velocities vary significantly over the slope. Since seismicity plays a minor role in Norway, we expect water pressure and altitudinal permafrost processes to have a significant impact upon gravity driven slope processes along complex pre-existing bedrock structures.

We aim to gain improved understanding of the potential influence of post-glacial permafrost dynamics on rock-slope failures. For this, we have modeled 2D post-glacial permafrost distributions and post-glacial variations through the Holocene and compared the results with terrestrial cosmogenic nuclide (TCN) dating along the sliding surfaces of three rock-slope instabilities. The Mannen instability in western Norway has moving rates up to 4 cm a^{-1} during the last few years and a 20 m high back scarp. The north facing steep rock slope reaches from the valley bottom (60 m asl) over 1200 m to the mountain plateau (1295 m asl) which is close to the current permafrost boundary. Preliminary TCN ages suggest that sliding started at around 8 ka BP at this site.

The Revdalsfjell 1 and Revdalsfjell 2 sites are situated in northern Norway and consist out of two adjacent but independently moving rock bodies with several meters high back scarps. Recent displacement rates are relatively slow with 2-3 cm a^{-1} and 6-7 cm a^{-1} at Revdalsfjell 1 and 2, respectively. Preliminary TCN dating results of the sliding surfaces suggest that sliding started at ca. 5.8 ka BP at the Revdalsfjell 1 site and at ca. 8.6 ka BP at the Revdalsfjell 2 site. The ages suggest that the back scarp did not form during cold conditions and deep permafrost presence, but became active close to the Holocene Climate Maximum (HTM) at ca. 8.5 ka BP, when mountain permafrost presence was probably at a minimum during the Holocene. This indicates that permafrost dynamics may have contributed to the timing of these rock-slope instabilities.

SOIL FROST CONTROL - YUKIWARI (SNOW PROWING) AND YUKIFUMI (SNOW COMPACTION) -

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Keywords: Adaptation, Climate change, Environmental control, Snow manipulation, Volunteer potatoes

The change in climate during winter affects the productivity of natural vegetation and agricultural crops in the cold region [1]. In the Tokachi region of eastern Hokkaido, Japan, earlier onsets of persistent snow cover since the late 1980's have shortened the time window for soil-surface cooling without insulation by snowcover, which drastically reduced the depth of soil frost [2]. This remarkable decrease in soil frost depth affected many factors in agriculture. In rotation crop fields, for example, numerous small potato tubers which were left unharvested in the fall used to survive in the winter and grow as weeds in the spring to summer. Such potato tubers are referred to as volunteer potatoes. To eliminate the emergence of volunteer potatoes, a method was found to manipulate field-scale soil-frost depths by artificial removal or compaction of snowcover. These methods are referred to as yukiwari [3], (i.e., snow-plowing in Japanese) or yukifumi (i.e., snow compaction in Japanese) [4]. We developed a new method to decide the appropriate timing of this operation by using numerical simulation model to estimate soil temperature from meteorological data [3, 5].

Field trials showed that frost depths were predicted within an accuracy of several centimeters. Based on the field and laboratory data, the daily mean soil temperature of −3°C was considered as the critical temperature for complete elimination of potato tubers. The optimal frost depth around 0.3 m was proposed as a compromise between the elimination of volunteer potatoes and minimum frost depth to prevent negative effects on agriculture, such as delay in the thawing for spring cultivation. The method was widely adopted by potato producers who use tractor-mounted snow ploughs or tire roller to remove or compact snowcover, respectively, over large scale fields. This method represents a new agricultural technology for adaptation to the climate change in the cold region [3, 6].

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ESTIMATING PERMAFROST GROUNDWATER AGE OF KHANGAI MOUNTAINS IN CENTRAL MONGOLIA

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Keywords: chlorofluorocarbons (CFCs); permafrost thawing; spring water; tritium (^{3}H) concentration

Detection of changes in the hydrological cycles of permafrost regions is a critical issue in hydrology. Understanding of groundwater dynamics in permafrost regions is needed to assess the vulnerability of the cryolithic water environment to changing climate. In order to estimate the permafrost groundwater age and to detect permafrost thawing in Khangai Mountains of central Mongolia, transient tracers including tritium (^{3}H) and chlorofluorocarbons (CFCs) were used to analyze spring water as a mixture of permafrost (ground ice-melt) water and shallow groundwater in the region.

We collected spring water samples at ten discharge sites including two thermokarst landscapes, which are the Chuluut (N 48° 05.142′ , E 100° 20.745′) and the Galuut (N 46° 33.441′ , E 99° 59.378′) sites, from 7 to 13 August 2015. We additionally took water sample at the Galuut site on 26 September 2015 and 17 May 2016.

^{3}H counting was conducted using a low-background liquid scintillation counter, Aloka model LB5, following electrolytic enrichment of ^{3}H by a factor of about 25 using Fe–Ni electrodes. Total analytical precision was better than ±0.23 tritium unit (TU) (± 1 σ). The ^{3}H measurements were conducted at the Geo-Science Laboratory Co. Ltd, Nagoya, Japan. CFC content in the same samples was measured using a purge and trap gas chromatography procedure with an electron capture detector (GC-ECD) at the Geo-Science Laboratory Co. Ltd, Nagoya, Japan. The procedure involved stripping 40 mL sample water of CFCs using ultra-pure nitrogen gas. The extracted CFCs were purified and concentrated using a cold trap, and finally injected into the GC-ECD. The precision and detection limit of the analysis were less than 2% and 1 pg L^{-1}, respectively.

The equivalent air concentration (EAC) of the three CFCs was calculated using Henry's solubility law (e.g., Warner & Weiss 1985), in which the solubility potentials of CFCs depend on the air temperature and air pressure when the precipitation fell. Because the water should be recharged above 0 °C, representative value of the temperature was assumed to be 0 °C in this study. If we assume piston-like groundwater flow, it is possible to estimate the groundwater age of the sampled water applying EAC of the three CFCs.

CFCs values of the spring water discharged at two thermokarst landscapes (Galuut and Chuluut sites) were very low and it was implied that the spring water from the two thermokarst sites contained ground ice-melt water. On the contrary, spring discharges from mountainous area contained higher CFCs except a large spring discharge at the Bayanbulag village (N 46° 48.222′ , E 98° 05.678′).

Compared with the results obtained by Hiyama et al. (2013), who estimated permafrost groundwater age in eastern Siberia, the water age in Khangai Mountains of central Mongolia has large variability. Next step of this research is to continue sampling and analyzing the CFCs and ^{3}H, and to detect rate of the permafrost thawing in the region.

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AUTOMATIC DETECTION OF THERMAL EROSION GULLIES FROM HIGH-RESOLUTION IMAGES IN EBOLING MOUNTAIN (QINGHAI, CHINA)

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Keywords: geographic object-based image analysis; high-resolution images; remote sensing; thermal erosion gullies;

Thermal erosion gullies, a kind of thermokarst landform, form associated with channelized surface runoff and the consequent thawing of ice-rich permafrost (Fortier et al. 2007). Mapping the location and the extent of thermal erosion gullies provides the basic knowledge about the spatial distribution and dynamics of thermokarst landforms (Poesen et al. 2003). Field observations and manual identification from remote sensing images are useful for local sites but are difficult or cost-ineffective to extend to large, regional scales. Automatic detection of thermal erosion gullies from remote sensing images is potentially an effective method for monitoring permafrost degradation over large areas. Here we applied Geographic Object-Based Image Analysis (GEOBIA) (Blaschke 2010, Comaniciu & Meer 2002, Huang et al. 2007, Huang et al. 2014) to high-resolution optical images over Eboling mountain, in the Qilian Mountains of northwestern China. The high-resolution images we used are Unmanned Aerial Vehicle (UAV) images and satellite images downloaded from Google Earth. The UAV images were acquired in summer 2016, and its spatial resolution is 0.06 meter. The acquired date of satellite images is summer 2015, and the spatial resolution is 0.6 meter. We first segmented the high-resolution optical images using the mean shift algorithm. Then we extracted the features that uniquely characterize thermal erosion gullies, including structural feature set (SFS) texture, edge information, and spectral information for each object. Using selected polygons with prior knowledge as training data, we used the support vector machine (SVM) algorithm to classify and identify thermal erosion gullies. Comparing with the gullies identified and outlined in the field using GPS-RTK, our results show that this method detected over 90% polygons that correspond to the thermal erosion gullies. Through this successful example, we demonstrate that automatic detection of thermal erosion gullies is possible from high-resolution optical images. Promisingly, this method can be extended to identifying and monitoring large-area thermokarst landforms and their changes.

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HYCENTERED POLYGON DEVELOPMENT DURING RECENT DECADE IN CENTRAL YAKUTIA, RUSSIA

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Keywords: Permafrost degradation; Thermokarst; active layer; grassland; boreal forest; Soil moisture

In the recent decades, many kinds of climate-driven landscape changes have taken place in Central Yakutia (CY), Sakh Republic, Russia. Development of thermokarst landscape is one of the important geomorphological evidences of melting ice complex (Yedoma) and subsequent landscape degradation along with climate change in continuous permafrost region in CY. Increases in active layer thickness have caused rapid thermokarst subsidence since 1990s (Fedorov and Konstantinov, 2003), which has negatively impacted boreal ecosystem and social environments. The rapid warming after 1990s and perennially we climate causing extensive waterlogged surfaces during 2000s enhanced the warming and deepening active layer (Iijima et al., 2016). The changes in interannual trends of thermokarst subsidence and subsequent channeling and ponding provide us further understandings on current status of permafrost instability against climate change.

The present study examined the relationship between permafrost degradation and eco-hydro-climatological changes in Churapcha where the apparent changes have been observed near the settlement, due to the unexpected climate–driven damages. We have attempted to extract the degraded boreal forest and dry grassland based on field measurements of active layer thickness and satellite remote sensing in relation to permafrost degradation after 1990s.

A clear difference in active-layer conditions was detected between troughs and the top of the high-centered polygons which are typical landscape degradation as thermokarst depression formed in the dry grassland. Active layer thickness (ALT) at the top of the polygon center reached 2.27 m, whereas ALT at trough reaches 1.8-1.9m with more 50-70cm of surface subsidence. Based on a detailed description of soil profiles, the distribution of silty loam soils was homogeneous, regardless of the presence or absence of underlying ice wedges in these grasslands. The top of the ice wedges appeared at depths around 2.2m at most measurement points in the dry grassland. Troughs, therefore, developed on melted syngenetic ice-wedges (Soloviev, 1959) and exhibited rapid thermokarst subsidence during recent decades. In addition, a very soft layer existed in the deeper part of the active layer below troughs. This soft layer had a high soil moisture content which was possibly due to a combination of melted ice wedge and the penetration of rainwater and snow meltwater along polygonal troughs. The existence of a wet (soft) layer in the deeper parts of the active layer is important for increasing thermal conductivity and heat capacity for further thawing permafrost layer. Consequently, the perennially wet active layer is a good measure for permafrost degradation under wet and warm climatic conditions during the last decade.

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DEBRIS SUPPLY AS A CONTROL ON THE MILLENNIAL DEVELOPMENT OF ROCK GLACIERS IN THE SWISS ALPS

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Keywords: debris supply; radiocarbon dating; rock glacier; rock wall; Swiss Alps

Recent acceleration of a number of rock glaciers indicates that climate change controls permafrost deformation within decades. Some researchers suggested that rock-glacier deformation through several millennia is also controlled by climate change. For example, inactive rock glaciers distributed at relatively warm location are thought to be active during colder periods such as the Little Ice Age. We challenge this hypothesis in this study. The distribution, size and activity of rock glaciers are discussed through systematic comparisons of topographical parameters related to the temperature conditions and debris supply. Digital elevation model and aerial photographs are the data sources to pick up the parameters with the help of a GIS software. In addition, absolute and relative ages of the studied rock glaciers were measured in the field. The study area is the Upper Engadin, Swiss Alps.

The ratios of lichen cover tended to increase from the active type to the relict type, which indicates that the active type is newest and the relict type oldest. Buried soil under a huge boulder of the lower end of one inactive rock glacier showed a radiocarbon age of 6 cal kyr BP. If the inactive type is an early Holocene product, the active type is younger and the older relict type was formed in the Late Glacial. The altitudes and aspects of the lower ends of the rock glaciers showed a distribution pattern that the active rock glaciers lie only on the north-facing slopes, while the inactive and relict rock glaciers lie in all directions but on altitudes lower than those of the active type. However, since the temperature in the early Holocene was slightly higher than the present, the distribution of the inactive type does not indicate that they developed in a colder period.

The average slope lengths of rock walls tended to decrease from the active type to the inactive type and from it to the relict type, and were generally larger on the north-facing than on the south-facing slopes. Such large north-facing rock walls can continuously supply coarse debris through seasonal freeze-thaw, which probably maintains the active rock glaciers. On the other hand, debris production from small and/or south-facing slopes is much less and prevents inactive rock glaciers advancing. Slope failures triggered by the stress release from large glaciers seem to have formed the inactive and relict rock glaciers in the early Holocene and Late Glacial in all directions.

SPATIAL MODELLING OF MONGOLIAN PERMAFROST -STATISTICAL AND STOCHASTIC APPROACHES-

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Keywords: continuous to isolated permafrost, Mongolia, multivariable regression analysis

The permafrost occurrences in Mongolia, the southern fringe of the Siberian permafrost, are highly dependent on the diverse local geographic factors such as elevation, slope orientation and aspect, soil wetness and types of land cover. The conventional permafrost map published by the International Permafrost Association has many issues on understanding permafrost states, since this map shows areal extent of permafrost in very rough and less quantified forms (i.e., continuous, discontinuous and sporadic), so that this map still remains ambiguities in understanding concurrent and future states of permafrost their related regional ecosystem services. This study aims to evaluate statistical correlations between the permafrost states (temperature and probability of permafrost existence) and local geographic factors, and to generate permafrost maps in more quantified, detailed and diverse forms.

The study areas are Altai Mountains, sporadic to continuous permafrost zones, Hovsgol area, continuous permafrost, and Khangai Mountains, sporadic to continuous permafrost zones. The analytical methods used here are statistical and stochastic approaches, in which multiple explanatory and objective variables are correlated quantitatively. As the objective variables 1m-deep ground temperatures, which reflect the occurrences of deeper permafrost, were measured at 56, 57 and 68 points in Altai Mountains, Hovsgol Area and Khangai Mountains, respectively, in summers, 2012, 2015 and 2016. The explanatory variables were taken from digital elevation model for estimating topographic parameters, Landsat OLI/TIRS image for calculating NDVI (Normal Difference Vegetation Index) and ESACCI (European Space Agency Climate Change Initiative) land cover datasets for categorizing land cover types. Multiple regression analysis correlated 1m-deep ground temperatures with multiple geographical factors. The best model for each study areas was selected through step-wise model reduction method. Probability of permafrost existence was evaluated by logistic regression analysis, in which the objective variables at 1m-deep ground temperature measurement points were categorized into either permafrost presence or absence on the basis of threshold values estimated by referring to deeper ground temperatures at other sites. The best combination of explanatory variables was determined by step-wise method and nonparametric test.

The multiple regression analysis found that the elevation primarily determines the ground temperatures in Altai and Khangai Mountains. In Khangai Mountains, the potential solar radiation and topographic wetness were also significantly correlated with ground temperature. On the other hand, the land cover types such as presence of forest cover, pasture and mosaic cropland, and latitude were equivalently important factors determining ground temperature in Hovsgol area. The logistic regression analysis achieved excellent discriminations (Area Under the Receiver-Operating Characteristic > 0.8) and revealed that the permafrost probabilities were directly correlated with elevation and NDVI in Altai Mountains, and elevation and forest cover in Khangai Mountains. Meanwhile, presence of pasture, topographic wetness and latitude were the most important factors governing permafrost existence in Hovsgol area.

The regional maps showing distribution of 1m-deep ground temperature and permafrost probability for three areas are all with sufficient statistical significance and high spatial resolution, potentially providing much information on permafrost states and ecosystem services over permafrost.

MELTING/FREEZING TEMPERATURE OF WATER CONFINED IN PORE SPACE OF SEDIMENTARY ROCK BY MEANS OF DIFFERENTIAL SCANNING CALORIMETRY (DSC)

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Keywords: Pore water, Melting/freezing temperature, DSC

The geomaterials have various scales pore from nanometer to the centimeter, and these pores are filled with air, water, oil and so on. In particular, water filled in the pore is the most common at the earth crust region, and it strongly relates to an earth scientific phenomenon, such as pore pressure, weathering, hydrothermal reaction, glacier flow. In recently, water of status in subsurface, which means same as pore water, in the Mars is one of research topics, and it is important to understand thermal behavior of water under low atmospheric pressure and low temperature conditions. The thermal behavior of pore water depends upon whether water is bound or unbound in pore space, particularly, it is the quantitative difference in melting and freezing temperature between the bound water and unbound water. That difference is caused by the thermodynamical specificity of the bound water, and it has been studied by using artificial silicate porous material in physics and chemistry (e.g Kittaka et al., 2011, Ito et al., 2016). For geomaterials, a lot of minerals in nature has nano-pore, however, the observed reports are only a few because it is not easy to observe nano-pore in geomaterials. Therefore, the thermal dynamics of geomaterials from the viewpoint of nano-micro scale does not clear.

In this study, we carried out measure Melting/freezing temperature of bound water in the pore of geomaterials (Shirahama sandstone, Berea Sandstone, kaolinite, bentonite and Diatomaceous rock) and by means of differential scanning calorimetry(DSC). Additionally, we try to determine the diameter of the nanoscale pore by comparing the artificial specimen with known diameter. Here, the relationship between the size of the pore diameter and melting/freezing temperature was determined by the results of the artificial specimen and geomaterials sample. As the result of the experiment, the melting temperature of diatomaceous rock has distinctive behavior comparing with other sedimentary rocks and granite. In the diatomaceous rock, the melting/freezing temperature is about -20°C. It means that the diatomaceous rock has a lot of nanoscale pores (it can not observe by means of SEM) and the confined water within the nanoscale pore present as the liquid under -20°C. The diameter of nanoscale pore in the diatomaceous rock is about 10nm by the relationship from the results using the artificial samples.

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IMPACTS OF A THICK FROZEN LAYER ON VERTICAL DISTRIBUTION OF SOIL NITROGEN AFTER SPRING SNOWMELT

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Keywords: nitrate nitrogen (NO_3^-); snowmelt infiltration; snow compaction; runoff ratio; soil frost depth.

Soil frozen layer sometimes reduces snowmelt infiltration, resulting in large amounts of surface runoff. In contrast, reduction of snowmelt infiltration by thick frozen layer will reduce leaching of nitrate to deep soil layer. To examine the relationships among the soil frost depth, runoff ratio, and nitrate movement in the agricultural field, field scale (approximately 1 ha of the total study area) experiment was conducted during three winters at an experimental field of National Agriculture and Food Research Organization, which is located in the Tokachi Region in Hokkaido, Japan.

A paired plot experiment was conducted. We kept snow cover as natural condition in one plot (control plot). The snow cover on the other plot was compacted to enhance soil frost penetration by increasing thermal conductivity of snow layer (treated plot). Soil frost depths were monitored at three places in each plot using frost tube. Runoff water was collected by the channels set at the side of each plot. The amount of runoff was monitored using V-notch weirs set at the soil pit located at the lowest part of the plot. Cylindrical shaped soil samples having 50 mm in diameter and 1 m in thickness were sampled using an auger having engine from 6 places in each plot. We sampled them before soil frozen and after snowmelt periods, and compared vertical distribution of nitrate nitrogen. A simple numerical simulation was conducted using the HYDRUS-1D software (Šimůnek et al. 2008) to check whether the reduction of snowmelt infiltration by thick frozen layer may be a factor to reduce the nitrate leaching.

Soil frost depths in the control plot were less than 0.2 m and remarkable runoff was not observed during the snowmelt period in all winters, which was comparable to the previous research shown by Iwata et al. (2008). In contrast, soil freezing front penetrated deeper than 0.4 m and large amount of snowmelt runoff were observed in the treated plot. Peaks of the nitrate profile after the snowmelt period were shallower in the treated plot comparing with those in the treated plot. A simple numerical simulation suggested that the increase of runoff ratio caused by the thick frozen layer will be a dominant factor to reduce leaching of nitrate in the treated plot. Runoff ratios of the treated plot were considered to be 0.28 – 0.55, which were comparable to the values calculated from the amount of snowmelt infiltration and snowmelt water supply monitored at the plot scale experimental site near the current study site (Iwata et al. 2010). These results imply that soil frost depth can be a factor to control the runoff ratio, snowmelt infiltration, and nitrate leaching when it was less than 0.4 m. On the other hand, the runoff ratio during the snowmelt period did not increase by the increase in soil frost depth when soil frost depths were more than 0.4 m, suggesting other factors may influence to the snowmelt infiltration at these fields as indicated by previous researches (e.g., Zhao & Gray 1999).

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PERMAFROST MODELING CYBERINFRASTRUCTURE

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Keywords: permafrost, modeling, easy-access

Permafrost is essential climate indicator that feedbacks to the global climate system through the impacts on the global carbon. Permafrost distribution and thermal dynamics are important for engineers, policy makers, indigenous communities, and the general public. Observations can assess the current state of permafrost, but models are eventually essential to make predictions of future permafrost extent.

The PermaModel project develops an easy-to-access and comprehensive cyberinfrastructure aimed at improving access to permafrost models and advancing permafrost modeling techniques. The PermaModel includes several permafrost models of increasing complexity. The Community Surface Dynamics Modeling System (CSDMS) is an existing cyberinfrastructure that have publicly accessible online modeling interface called Web Modeling Tool (WMT). The WMT provides easy-access to broad group of people interested in using permafrost models, but lack the expertise. PermaModel includes multiple sets of sample inputs, representing a variety of conditions and locations, to enable immediate use of the particular permafrost model. Here we present one of the first online permafrost modeling tools, which is envisioned to be the most suitable for teaching purposes. The model promotes understanding of a 1D heat equation and permafrost active layer dynamics under monthly temperature/climate drivers in an interactive environment. We will demonstrate how using historical dataset and a model one can quickly simulate permafrost distribution at a certain geographic region.

MODELING HYDROTHERMAL INTERACTION WITHIN 2D HILLSLOPE

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Keywords: permafrost; hydrology; coupling

Arctic hydrological processes impose an important feedback on permafrost thermal conditions. Permafrost thermo-hydrology it is active area of the modern research. Changes in permafrost hydrology could accelerate its thawing, which could pave a positive effect on permafrost carbon feedback. Therefore, it is important to understand how geomorphic and other landscape processes control permafrost distribution and its properties such as soil saturation, ice content, active layer thickness (ALT) and temperature. The Arctic Terrestrial Simulator (ATS) is a collection of hydro-thermal processes designed to work within a flexible configured modeling framework. This model incudes includes all important soil physics energy balance such as ice, gas, and liquid water content, multi-layered soil physics, and unfrozen water related phase change representation. In this study, we model the effect of climate and environmental drivers and ALT on permafrost thickness and distribution along the subarctic hillslope.

ANALYSIS OF SOIL FREEZE/THAW DYNAMICS AND ITS IMPACT ON SOIL MOISTURE AND VEGETATION PHENOLOGY IN THE TIBETAN PLATEAU

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Keywords: permafrost; soil freeze/thaw; soil moisture; spring onset; Tibet Plateau

The Tibetan Plateau is underlain by the largest extent of permafrost in the mid- and low-latitude region of the world. Climate warming has induced significant changes in permafrost and seasonally frozen ground in this region, which have complex influences on land surface hydrology, ecosystems and engineering constructions. Therefore, it is important to understand the environmental controls on soil freeze/thaw dynamics in the Tibetan Plateau, and their potential impacts on soil moisture transfer and vegetation growth.

In this study, we used in-situ observations of soil temperature and moisture from the Asia-Australia Monsoon Project sites within the Tibetan Plateau domain (CAMP/Tibet, 1997-2007) and the National Meteorological Center of China (2009-2015) to analyze soil freeze/thaw dynamics and their correlations with soil moisture. We also used the Moderate Resolution Imaging Spectroradiometer (MODIS) enhanced vegetation index (EVI) to map vegetation condition and growing-season spring onset in the study area to explore their links with soil freeze/thaw and moisture dynamics. Our preliminary results showed different soil freeze/thaw dynamics in the seasonally frozen ground area along the southern Qinghai-Tibet railway and permafrost areas in the north. In the seasonally frozen ground areas, soil freezes downwards from the ground surface, while the thawing process may start both upwards from the soil bottom and downwards from the surface. A distinct zero curtain (a freeze/thaw characteristics closely related to phase changes in soil water) was also observed during the thawing period. In contrast, in permafrost region, soil freezes both downwards from the surface and upwards from the bottom during the freezing period with a distinct zero-curtain sustaining period, while thaws downwards from ground surface. Our results also indicated that the soil moisture in the seasonally frozen ground areas during the freezing process generally increases with soil depth, while minimum soil moisture occurs in the intermediate zone of soil column in the permafrost areas. The vegetation spring onset derived from MODIS data showed significantly positive correlation with the in-situ observed soil thawing onset in the permafrost areas, while the vegetation spring onset in the seasonally frozen ground areas showed a more variable response to soil thawing onset. This was likely caused by the different soil moisture movement during the soil freeze/thaw process between the permafrost and seasonally frozen ground areas indicated above. We will further investigate the links between environmental conditions (esp., soil moisture and vegetation cover) and surface freeze/thaw dynamics using satellite-based observations and a coupled soil water and heat transport model.

Supporting publications:

Yi Y., Zhang W., Yang K., Jafarov E., Kimball J.S. et al.: Investigating sensitivity of soil freeze/thaw conditions to environmental variables in the central Tibetan Plateau using multi-scale observations and a process model. Submitted to Journal of Geophysical Research-Atmospheres;

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CHARACTERISTICS OF FROST HEAVE STRESS AND STRAIN IN THE TRANSVERSE DIRECTION TO HEAT FLOW

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Keywords: Frost heave; new experimental apparatus;

stress in transverse direction to heat flow; strain in heat flow direction

When cohesive soil is frozen, a phenomenon known as frost heave may occur. Frost heave is the swelling of soil under freezing conditions caused by phase change of migrated and in-situ water. During frost heave, segregated ice lenses grow up continuously with water supply (Kinoshita 1982, and JGS 1982). For the evaluation of this phenomenon, various research has been conducted in order to establish an experimental equation which can predict actual frost heave amount, but most of those studies focus on the frost heave in the direction of heat flow. Recently, more attention has been paid to the freezing method of underground construction, because of its non-polluting characteristic to enhance the soil strength, and to prevent water leakage. This method needs precise understanding of freezing behavior and requires prevention technologies to mitigate against frost expansion, especially in populated urban areas. For the safe application of the freezing method for construction, it is necessary to understand the characteristics of expansion transverse to heat flow direction as well as that in the direction of heat flow (Hokkaido JSG 2009). Therefore, the authors developed a new indoor frost heave apparatus for experiment in order to measure stress transverse to the heat flow direction. This new apparatus consists of eight layers of acrylic resin rings, and each ring is equipped with strain gauges. Small water pressure gauges are also installed alternately. By these two measuring instruments, we could observe stress and strain behavior during frost heave process. Based on our experiments, we obtain the following findings:

For stress transvers to the heat flow direction, it increases abruptly when temperature changes from 0 to -1°C, but the stress increases gradually and slowly when temperature decreases under -1°C. We think this phenomenon is greatly affected by phase change of migrated and in-situ water. For cohesive soil, the larger the applied overburden pressure is, the smaller the frost expansion in heat flow direction becomes.

For strain, we conducted experiments with two mixed soil samples with different proportions of sand and kaolin (1:1 and 1:3). We evaluated the expansion strain transverse to the heat flow direction and the frost heave ratio in the direction of heat flow (Takashi et al, 1980, and Yuge et al, 2002). As a result, we note that there is a linear relationship between the parallel and transverse strains. In addition, we confirm that sand can restrain the frost heave ratio in the direction of heat flow, but it may promote the expansion transverse to the heat flow direction.

As a conclusion, the authors evaluate the characteristics of frost heave stress and strain in the transverse direction using an innovative frost heave experiment apparatus successfully. In our future research, the authors are going to clarify the strength of material used in the experiments for establishment of strain estimation with a better accuracy.

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MONITORING MELTWATER FLOW AT AN ALPINE PERMAFROST SITE USING ELECTRICAL SELF-POTENTIAL MEASUREMENTS

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Keywords: electrical self-potential, geophysical monitoring, meltwater flow, Alpine permafrost

Flow of (liquid) water plays a crucial role in the dynamics of coupled thermo-hydro-mechanical processes in terrestrial permafrost systems. To better understand these processes in the active layer of permafrost regions, with the ultimate goal of adequately incorporating them in numerical models for improved scenario prediction, monitoring approaches offering high spatial and temporal resolution, areal coverage, and especially sensitivity to subsurface water flow, are highly desired. This particularly holds for high-mountain slopes, where strong variability in topography, precipitation, and snow cover, along with significant subsurface soil/rock heterogeneity, gives rise to complex spatio-temporal patterns of water flow during seasonal thawing and freezing periods.

The electrical self-potential (SP) method is well known to, in theory, meet the above monitoring demands by measuring the electrical streaming potential which is generated at the microscopic scale when water flows along electrically charged interfaces (e.g., Revil et al., 2012). Despite its inherent sensitivity to subsurface water flow, the SP method has not yet been used for the monitoring of high-mountain permafrost sites.

Here we present results from an SP monitoring survey conducted at Schilthorn (2970 m asl), Swiss Alps, over the thawing period in 2015. SP data were recorded at a sampling rate of 10 min on a permanently installed array of non-polarizing electrodes covering an area of 35 m by 15 m. While the SP time series exhibit systematic daily variations, with part of the signal clearly correlated with temperature, in particular in the snow-free periods in summer, the largest temporal changes in the SP signal occur in spring, when the snow cover melts and thawing sets on in the active layer.

The results suggest that the SP method is a suitable tool for monitoring the spatio-temporal dynamics of meltwater flow at high-mountain permafrost sites. Current work is directed towards an improved field setup, as well as the quantitative analysis of the SP data based on laboratory calibration measurements.

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GROUND PENETRATING RADAR STUDY OF GLACIERS IN SOUTHERN SIBERIA: AN EXAMPLE OF NINA AZAROVA GLACIER

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Keywords: Glacier; Ground Penetrating Radar (GPR); glacier thickness; structure of glacier bed; three-dimensional model of the glacier; structural features.

Nowadays the study of dynamics of glaciers retreat has a great interest for International scientific community. Particular attention is paid to the glaciers located at the latitudes closer to the equator or low altitudes. This is due to their extreme sensitivity to even small changes in average temperature. These include the glaciers of Southern Siberia. Subsequently, it may help to assess the dynamics of global climate change the impacts. There are many known methods of monitoring of glaciers degradation on the area, including the use of satellite images, which don't t cause major difficulties as opposed to study of the glacier bed structure and definition of glacier thickness Involvement of new methods and techniques for remote study of glaciers opens up new possibilities in status and structure investigation of the glacier, including the definition of thickness over large areas with the greatest precision.

The aim of the present work is a complex of experimental researches for study the possibilities of impulse GPR survey use for cold glaciers investigation. We selected effective antenna frequency with 50 MHz, 150 MHz and 400 MHz, covering the range of frequencies ranging from 25 MHz to 600 MHz. Data processing was carried out on GeoScan_32 ("Logis-Geotech") program.

Experimental studies were conducted on Nina Azarova glacier, on Kodar ridge, in the field of modern glaciation. It stretches from the pass "Three Gendarmes" to the headwaters of Sredniy Sakukan river (Siberia, Russia). Cirque glaciers, its length is two kilometers, the area is around 1 square km. It is characterized by sharp longitudinal asymmetry of tongue and intense front of the moraine.

Measurements were taken from the surface of the glacier by profiling with a speed of 4 km per hour by transverse and longitudinal profiles, they are attached to the area by a receiver GPS - Garmin 62S.

Since some features of this glacier, the presence of large vertical cracks in particular, impacts of streams, the presence of large boulders in the eastern part of the slope in the glacier body, and on its surface as well as the presence of water on the surface could not be obtained the results with central frequency of GPR antenna 150 MHz and 400 MHz.

In the case of cirque glaciers, where there is a presence of high slopes it is necessary to conduct research by profiling and orientation of GPR antennas, especially with low frequency and unshielded, perpendicular to the ridge tops. In this case, the processing and interpretation of GPR data it would be very easy to identify the aircraft noise from the steep slopes of the side peaks.

Detailed studies were conducted on cross-GPR profiles, uniformly distributed over the surface of the glacier and the longitudinal profile, equidistant from the side ledges. GPR results of GPS measurements are linked, analyzed and summarized in a three-dimensional model of the glacier bed, indicating the glacier thickness at each point of measurement. The thickness of the glacier on average ranges from 55 ÷ 80 m (dielectric permittivity $\varepsilon = 3.2$). The maximum recorded glacier thickness is 99 meters.

According to the interpretation in glacier thickness we found some structural features, characterizing its bundle nearby the bed. The zone of possible bundles is traced area and it is marked by some GPR profiles.

The results of obtained study confirm the perspective of studies of GPR method for study cold glaciers of the Southern Siberia in details.

STUDY ON THE SEGREGATION POTENTIAL OF FAIRBANKS SILT UNDER DIFFERENT FREEZING MODE

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Keywords: frost heave tests, segregation potential (SP), Japanese Geotechnical Standard Test (JGST)

The Segregation Potential (SP) concept has been widely accepted and used in many engineering designs (e.g., highway, chilled pipeline). Konrad (1987) proposed a procedure to evaluate the SP value from frost heave tests. The purpose of this study is to measure the SP value of Fairbanks silt from the UAF experimental gas pipeline site by frost heave tests. Two different types of freezing mode were applied. One is step-freezing test, the other is the Japanese Geotechnical Standard Test (2003) (JGST) -freezing test.

The single-cell frost heave test equipment was used for a series of step-freezing tests (STEP), and the quadric-cell frost heave test equipment was for the JGST-freezing tests (JGST), respectively. Using the undisturbed soil sample, four step-freezing tests were conducted by changing thermal boundary conditions (e.g., temperature gradient, cooling rate) and overburden conditions. The undisturbed soil sample was enclosed in the single-frost heave cell, and then cooled to approximately the warm-end pedestal temperature. An overburden pressure was applied to the top pedestal in each test. Using the remolded soil samples, twelve JGST-freezing tests were conducted by changing the thermal boundary (cooling rate) and applied load. The remolded soil samples were enclosed in the quadric-frost heave cell.

In a series of step-freezing tests, the SP parameters for the undisturbed Fairbanks silt are determined by least square regression analysis as $SP_0 = 41.3\text{x}10^{-5}\text{mm}^2/(\text{sec x }^{o}\text{C})$, $b = 0.0156\text{kPa}^{-1}$, and $R^2 = 0.99$, at the formation of the final ice lens. In a series of JGST-freezing tests, The SP values for the remolded Fairbanks silt were defined as $SP_0 = 43.3\text{x}10^{-5}\text{mm}^2/(\text{sec x }^{o}\text{C})$ and $b = 0.0192\text{kPa}^{-1}$ with a demonstrated R^2 of 0.88.

The SP_0 determined from the JGST-freezing tests was very close to the value obtained from the step-freezing tests; the differences varied by less than 5%. Therefore, the author could show the possibilities to determine the SP value in different freezing mode.

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TEST OF UNFROZEN WATER CONTENT AND ULTRASONIC WAVE VELOCITY FOR FROZEN GRANITE SOIL AND CLAYEY

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Keywords: frozen soil; unfrozen water content; ultrasonic wave velocity; Poisson's ratio; modulus of elasticity

Unfrozen water content changes at the time of being frozen were measured using the TDR (Time Domain Reflectometry) equipment through the collection of weathered granite soil accounting for approximately 70% of the exposed ground in the Republic of Korea and clayey soil from the coast, and the ultrasonic wave velocity according to moisture content changes was measured using the Sing Around equipment. The Poisson's ratio and the modulus of elasticity per temperature change of the relevant soils were calculated from the ultrasonic wave velocity (longitudinal wave, transverse wave). And the relationship between the ultrasonic wave velocity and the unfrozen water content was analyzed. It was identified from such series of tests and the result analysis that the unfrozen water content of clayey soil was higher than the unfrozen water content of weathered granite soil in case of the same temperature condition. In addition, both weathered granite soil and clayey soil showed that higher ultrasonic wave velocity was shown as the moisture content was higher, and there was high correlation between the longitudinal wave and the transverse wave, too.

ASSESSMENT OF PERMAFROST VULNERABILITY AND ACTIVE LAYER THICKNESS INCREASES IN THE HIGH NORTHERN LATITUDES USING SATELLITE OBSERVATIONS AND PROCESS MODEL SIMULATIONS

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Permafrost extent (PE) and active layer thickness (ALT) are important for assessing high northern latitude eco-hydrological processes, and potential land–atmosphere carbon exchange. We developed a new approach to infer PE from satellite microwave remote sensing of daily landscape freeze–thaw status. Satellite microwave freeze–thaw observations define near-surface thermal status used to determine PE and vulnerability over a 30-year (1980–2009) satellite record. The PE results showed similar performance against independent site inventory and process model (CHANGE) estimates, but with larger differences over heterogeneous permafrost subzones and areas with variable insulating surface elements. A consistent decline in the ensemble mean of permafrost areas (−0.33 million km^2 decade^{-1}; $p < 0.05$) coincides with regional warming (0.4 °C decade^{-1}; $p < 0.01$), while more than 40% (9.6 million km^2) of permafrost areas are vulnerable to degradation based on the 30-year PE record. ALT estimates determined from satellite and global model reanalysis temperatures, and CHANGE simulations, compared favorably with independent field observations and indicate deepening ALT trends consistent with widespread permafrost vulnerability under recent climate change. The integration of remote sensing and modeling of permafrost and active layer conditions developed from this study may facilitate regular and effective regional monitoring of these parameters, and expand applications of remote sensing for examining permafrost-related feedbacks and consequences for biogeochemical and eco-hydrological cycles in the Cryosphere.

EFFECT OF RAINFALL ON PERMAFROST TEMPERATURE AND SEASONAL IN CENTRAL YAKUTIA, EAST SIBERIA

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Rainfallisone of the most importantfactorsinfluencingthe temperature and seasonal thaw of permafrost in Central Yakutia.Inyearswithhighrainfall, theamountoflatentheatin the active layer increases, accompanied by the greater insulating effect of the snow cover. Asaresult, freeze-upof the active layer lastslonger, reducing theperiodofgroundcooling during the winter season. Thisleadstoan increase in mean annual ground temperature, as well as in active-layer thickness. For the taiga landscapes of Central Yakutia, empirical quantitative relationships between the mean annual temperature of upper permafrost and the pre-winter soil moisture contents in the active layer have been obtained. Observation satthe CALM site in Central Yakutia have also provided data indicating the direct effect of rainfall on the active-layer thickness due to additional heat input by infiltrating water.

RESPONSE OF LARCH FOREST CO_2 EXCHANGE ON WETNESS VARIABILITY OF PERMAFROST ACTIVE LAYER IN EASTERN SIBERIA

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Keywords: eastern Siberia, larch forest, understory vegetation, active layer, soil moisture

This study investigated CO_2 exchange over a 10-year period (2004–2014) in larch-dominated forests in central Lena river basin, eastern Siberia. An unusually wet active layer during the warm season that was maintained from 2006 to 2009 was observed, after which the soil water close to the ground surface became dry but the deeper part remained relatively wet. Some mature larch trees in areas with poor drainage suffered because of waterlogging, whereas young birch and willow trees developed and grasses with water tolerance expanded. CO_2 fluxes were measured with the eddy covariance methods above forest canopy (whole forest flux) and inside forest (understory flux). For the whole forest, larger CO_2 uptake and respiration at the first half of the wet years and decrease at the later of the wet years, although soil water was retained at the depth at which the greater part of the larch roots occur. The understory canopy continuously increased CO_2 uptake and respiration toward recent years. Although this layer always acted as a CO_2 source in terms of the seasonal average throughout the study period, the source strength weakened and became a temporary sink on dairy base in the early summer. Higher temperature response of respiration flux was found at the understory and difference to the whole forest became larger. Sufficient soil water would lead to growth of understory vegetation, and, simultaneously, the partial decline of the larch crown altered the environment inside the forest by increasing light and enhancing turbulent mixing. The decline in the larch contribution was compensated for by understory growth, resulting in a relatively stable whole-forest exchange rate at least during this study period. Interactions between larches and understory vegetation would support the carbon and water cycle under environmental variability.

THREE-DIMENSIONAL FORM AND WEDGE STRUCTURES OF POLYGONS AROUND VASSDALEN, CENTRAL DRONNING MAUD LAND, EAST ANTARCTICA

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Keywords: polygon; wedge structure; structure from motion (SfM); periglacial; Antarctica

Recently, periglacial landforms of Antarctica have attracted growing interest as they are useful for inferring surface and subsurface environments of Mars (e.g., Marchant and Head, 2007; Levy et al., 2010). In particular, the scale and form of polygons discovered on Mars have been compared with those of inland Antarctica (Balme et al., 2013; Matsuoka, 2016). However, detailed three-dimensional form and size of Antarctic polygons, their change through time, and their relations to subsurface wedge structures are not well understood.

To resolve these problems, we conducted an unmanned aerial vehicle (UAV)-structure from motion (SfM) survey at Vassdalen in central Dronning Maud Land, east Antarctica, and produced a decimeter-scale high-resolution digital elevation model (DEM) over a ~1.5 km by ~3 km area that contains moraine surfaces with various abandonment ages and different polygon development. At some key polygons on key surfaces, we produced even higher-resolution DEMs using photographs taken from a high-view camera attached on a 3.5-m high pole through SfM analysis. We also conducted pit excavations across marginal troughs of these key polygons to examine subsurface wedge structures. We present results of these investigations including our effort to evaluate size distribution of polygons using a "ridgeness" parameter *I* (Chiba et al., 2008) calculated from the DEMs as well as logs of pit exposures, and discuss temporal changes of polygon sizes and the relation between subsurface wedge structures and surface three-dimensional form of polygons.

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INCORPORATING BIOGEOCHEMISTRY IN THE PERMAFROST MODEL CRYOGRID 3

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Keywords: carbon dioxide; methane; permafrost thaw; carbon cycle; computer model; permafrost carbon feedback

Permafrost ground contains vast amounts of carbon (C), and there is a well-known risk that increasing air temperatures and changes in precipitation can accelerate permafrost thaw and increase the decomposition of stored C. This may lead to increasing emissions of carbon dioxide (CO_2) and methane (CH_4) depending on the oxygen availability. Despite ongoing research efforts, the scale of this permafrost carbon feedback remains uncertain.

In this project, we incorporate biogeochemical processes into the land-surface model Cryogrid 3, which simulates the thermal state of permafrost, based on climate forcing and initial freeze-thaw conditions in the soil (Westermann et al. 2016). Our goal is to simulate the effects of surface temperature, precipitation, net primary production, carbon allocation and sedimentation on the rates of individual subsurface processes (e.g. heterotrophic respiration, methanogenesis and methanotrophy) and the resulting surface flux of CO_2 and CH_4.

The new model simulates sedimentation and decomposition of organic carbon across the Holocene, in order to improve our understanding of the balance between permafrost formation and C sequestration and on the other hand the increasing decomposition driven by climate changes.

We present model concepts and compare initial results with observations made at terrestrial permafrost sites in the North-Atlantic.

If the model is able to successfully reproduce local and/or regional carbon stocks, the resulting estimates can in the future be used as initial conditions for a simulation of the permafrost carbon feedback, given specific climate trajectories over the next century.

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A REVIEW OF PHYSICAL AND MECHANICAL PROPERTIES OF SALINE FROZEN SOIL

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Keywords: salt frozen soil; freezing temperature; mechanical strength; Pitzer model; water and solute transfer; unidirectional freezing experiment

Saline soil is widely distributed in cold regions of China. The water freezes and salt crystallizes in response to seasonal temperature variations. Detrimental frost heave and salt expansion may occur in the freezing process, which have significant implications on constructions. This interest has led to an increase in studying the effects of salt on the physical and mechanical properties of saline frozen soil. Herein, a general review is presented with a discussion including the effect of salt on unfrozen water content, soil freezing temperature depression, the change of mechanical strength with salt content, and water and solute transfer mechanism in unidirectional freezing experiments. The differences and similarities of phase change between pore solution and free solution are discussed. It is confirmed that non-uniform pore size is the main cause resulting in the differences. The temperature of phase change in soil deviates from that of free solution, and this deviation increases with unsaturated degree increasing. Apart from the phase change sequence, the relation between the soil freezing temperature and the radius of the ice crystallization is obtained. Moreover, the influencing factors of soil freezing temperature are analyzed. Based on the Pitzer model, the formula of soil freezing temperature is derived and used to explore the factors including salt content, water content, salt type, and salt crystallization. The freezing temperature of soil is lower than that of the corresponding solution which is controlled by water activity. When the pore solution is unsaturated, soil freezing temperature has the positive correlation with the salt content while inversely with the water content. If the concentration of pore solution is saturated or supersaturated, salt crystallization begins to influence the soil freezing temperature, which may be due to decrease of the liquid water content and large pores plogged with crystalline salt (e.g. $Na_2SO_4 \cdot 10H_2O$, $Na_2CO_3 \cdot 10H_2O$). In addition, the strengthes of sodium sulfate sand with different salt contents(0.0, 0.5, 1.5, and 2.5%, respectively) under confining pressures from 0 MPa to 16 MPa at -6 ℃ are investigated. As the content of sodium sulfate increases, the strength of frozen sand firstly increases and then decreases. Triaxial shear test suggests that the critical state line of saline frozen sand in p-q plane is a curve that doesn't pass through the origin. Soil particle has an initial anisotropy rotation angle and a characteristic of stress induced anisotropy rotation in loading process. Instead of shrinkage, Shear dilatancy occurs under the low confining pressures (smaller than 6 MPa). When the confining pressures are larger than 6 MPa, the shear shrinkage is more obvious. Finally, the water and solute transfer mechanism is investigated by a series of unidirectional freezing experiments, and the nucleation and growth mechanisms of salt and ice crystal are also discussed. The review not only confirms the effect of salt on the physical and mechanical properties of the saline frozen soil, but also provides a theoretical basis for further enriching solute transport theory and studying the damage mechanism of saline soils in cold regions.

HOW COULD SLOPE-SCALE KNOWLEDGE BE USEFUL IN REGIONAL APPLICATION OF HYDROLOGICAL MODEL IN DIFFERENT PERMAFROST ENVIRONMENTS?

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Keywords: active layer thickness; hydrological modelling; permafrost landscapes; research watershed; scaling problem; Siberia

There is significant lack of process long-term observations in polar and permafrost regions. Permafrost, hydrological and land-surface models that are used to evaluate current state and future evolution of Arctic environments are not often properly verified on field observational data. The aim of the study is to use field-based knowledge from small permafrost watersheds to parameterize and verify hydrological model for applications in middle-sized basins in two regions: mountains of North-Eastern Russia, Upper Kolyma River basin, and Central-Yakutian plain, middle part of the Lena River basin.

Although both study regions are covered by continuous permafrost they are characterized by contrasting hydrological conditions. Shestakovka River basin (area 170 km2) is a left tributary of the Lena River in the vicinity of Yakutsk. The climate is very dry and continental. Mean air temperature (MAT) is -9.5°C, precipitation is 240 mm/year. The Kontaktovy Creek basin (area 21.2 km2) is located in the Upper Kolyma plateau. It's characterized by colder (MAT -11.4°C) and wetter (290-460 mm/year) climate comparative to the Shestakovka River watershed. Both of the watersheds have been monitored for several decades. The Shestakovka River has slow and postponed reaction to precipitation. The correlation of total river runoff with last-year precipitation is larger than with this-year precipitation. It suggests that large and slow water storages in the basins are important chain in runoff generation. Such storages could be lakes and water-saturated taliks. On the contrary, Kontaktovy Creek is a reactive stream and has spiky hydrograph. Depending on the properties of the landscape and active layer snowmelt and rain water is quickly transmitted to the stream by surface or shallow subsurface flow.

The Hydrograph model used in the study explicitly simulates heat and water dynamics in the soil profile thus is able to reflect ground thawing/freezing and change of soil storage capacity through the summer in permafrost environments. The key model parameters are vegetation and soil properties that relate to land surface classes. They are assessed based on field observations. Model time step is daily, meteorological input are air temperature, precipitation and air moisture.

On the first step the model was tested against variable states – snow water equivalent and depth, active layer thickness, ground temperature and moisture. For both Shestakovka and Kontaktvy watersheds simulated soil and snow variable states have satisfactory agreement with observed data. On the next step the river runoff was modeled. The simulation results for the Shestakovka River show very high variability from year to year. Results for mean and wet years are generally better than for dry years. Modelling results for Kontaktovy Creek are satisfactory. The largest deviations occur in the spring flood period when presumably underground water pathway exists even in the frozen ground but are not accounted for by the model.

Model parameters adjusted in the small watersheds were transferred to several nearby middle-scale basins. Results showed that such transfer is efficient for the streamflow modelling in mountainous river basins in North-Eastern Russia. Although there is significant lack of meteorological input data for the middle-sized basins (with area 500-40 000 km2) simulations show satisfactory agreement with observed data with Nash-Sutcliffe coefficient higher 0.55. Parameter transfer from the Shestakovka river watershed to larger river basins in the Central Ykutian plain didn't lead to good agreement between observed and simulated streamflow. Precipitation doesn't significantly vary in Central Yakutia (240-400 mm/year). Mean annual runoff depth doesn't show strong dependence on precipitation and changes from 1 to 166 mm/year for different river basins. Careful analysis of azonal factors such as thermokarst, talik distributions, etc. is required for successful model application in Central Yakutia.

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DEVELOPMENT OF A GLOBAL PERMAFROST ELECTRICAL RESISTIVITY SURVEY (GPERS) DATABASE

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Keywords: electrical resistivity tomography; model validation; permafrost geophysics; spatial database

Hundreds, and perhaps thousands, of Electrical Resistivity Tomography (ERT) surveys have been undertaken over the past two decades in permafrost areas in North America, Europe, and Asia. Two main types of ERT configurations have been conducted: galvanic surveys using metallic rods as conductors and capacitive-coupled surveys using towed cable arrays. ERT surveys have been carried out in regions with mountain permafrost, lowland permafrost, and coastal saline permafrost, and in undisturbed, naturally-disturbed (e.g. fire-affected), and anthropogenically-affected sites (e.g. around buildings and infrastructure). Some surveys are associated with local validation of frozen ground conditions, through borehole temperatures, frost probing or creep phenomena. Others are in locations without boreholes or with clast-rich or bedrock active layers which preclude this direct confirmation. Most surveys have been carried out individually on particular dates but there are increasing numbers of repeated ERT measurements being made to detect change, either at intervals using a fixed array of electrodes, or at high frequency with a fixed and automated measurement apparatus.

Taken as a group, ERT profiles represent an untapped knowledge base relating to permafrost presence, absence, or partial presence (i.e. discontinuous permafrost), and in some cases to the thickness of permafrost and ice content. When combined with borehole information, ERT measurements can identify massive ice features and provides information on soil stratigraphy. The Global Permafrost Electrical Resistivity Survey (GPERS) database is planned as a freely available on-line repository of data from two-dimensional electrical resistivity surveys undertaken in permafrost regions. Its development is supported by the Permafrost Carbon Network and an application for an International Permafrost Association (IPA) Action Group is also underway.

When the future GPERS records are compared with the GTN-P database it will be possible to see which boreholes or CALM sites are associated with ERT surveys and which are not. This can be used to target particular sites for ERT surveys to provide a more holistic view of what GTN-P measurements represent. GPERS data will permit empirical analyses of relationships between measured resistivities and permafrost conditions, including ground temperature, ice and liquid water content, and sediment type. These analyses will assist researchers in interpreting their local surveys. The spatial coordinates of the surveys in the database will also permit reacquisition of data in the future to examine changes over years or decades.

The purpose of this presentation is to communicate the initiation of GPERS, to explore the level of interest in its development, and to help guide its maturation. In particular, we wish to discuss whether the database should initially focus on meta-data, including site location, vegetation type, and frozen ground conditions, or whether researchers would be willing to supply measurement data immediately which would lead to a more rapid development of GPERS but would also require more resources.

THERMOKARST LAKES AND PERMAFROST ALONG QINGHAI-TIBET ENGINEERING CORRIDOR

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Keywords: Qinghai-Tibet Plateau（QTP）; Qinghai–Tibet Railway (QTR); Thermokarst lake; Permafrost

Thermokarst lakes are common landscapes in permafrost regions, where ice-rich permafrost exists. Such lakes are characterized by the landforms that are developed as a result of thawing of ice-rich permafrost or melting of massive ground ice (*Hinzman et al., 1997*). Normally, the occurrence of active thermokarst indicates that permafrost is unstable and warming (*Serreze et al, 2000; Smith et al, 2005*). The ground temperature beneath lakes is higher than that of the surrounding permafrost because a more than or equal to 0 ºC temperature exists perennially in the lake bottom except those shallow lakes that the water body freezes through at the early cold reason. The size, water depth, and the chemical composition of water, etc. determine the mean annual temperature in lake-bottom, and further influence the configuration of the talik (*Burn, 2005*).

Numerous studies (*Hinkle et al., 2005; Smith et al., 2005; Yoshikawa and Hinzman, 2003*) indicated the thermokarst lakes are being experienced the process of the shrinking or disappearing. During the past nearly 30yr, the total lakes area and the lake count decreased about 6% and 11% in Arctic, respectively. In Three River Sources District (the Yangtze River, the Yellow River, and the Lantsang River) on the Qinghai-Tibet Plateau (QTP), the decline of the thermokarst lakes has seriously impacted the cold region hydrology and ecological environment. However, it is that in continuous permafrost regions along the Qinghai-Tibet Engineering Corridor (QTEC), the number of the lakes has been increasing. It is due to the persistent climatic warming accelerating permafrost degradation and thawing. The steadily increasing human activities, including the constructions of Qinghai-Tibet Highway (QTH), Qinghai-Tibet Railway (QTR), and Oil Products Pipeline etc., left many small pits on the surface by inevitable digging or rolling of construction vehicles, and subsequently filled with water. Such small water pits developed into thermokarst lakes after undergone long-term slumping and collapse.

Although the area of these lakes are relatively small (the largest lake is about 6×10^{4} m^{2}), and the water is not deeper (the deepest lake is about 2.8 m), they are close to the roadbed. The development of the thermokarst lakes has seriously affected the performance of structures constructed in permafrost regions (*Lunardini, 1996*), may cause the thaw settlement and the decreasing the bearing capacity of the permafrost due to the laterally thermal erosion of thermokarst lakes. Therefore, this study takes a representative region along QTEC as an example to investigate the distribution of the thermokarst lakes, lake depth, lake-ice thickness, and mean annual lake-bottom temperature.

The study area lies in the hinterland of the QTP, and is a major portion of the QTEC. It is an about 200 km-long and 20 to 50 km-wide zoon with the continuous permafrost and the fragile eco-environment. Approximately 85% of the length exceeds 4,500 m in elevation, and the QTH, QTR, and other engineering cross together this corridor.

The corridor has a typical paramos continental climate and the annual mean air temperature is <-4.0 ºC. The annual precipitation throughout the region, when is concentrated on the May–August, is about 50 to 400 mm. The sensitive permafrost environments in study area are controlled by periglacial processes, geography, geocryology and the local climate. The depth of the active-layer in study area is about 1 to 3 m except for 5m in Chumarhe High Plateau. The max thickness of permafrost is approximately 120m in Kunlunshan Mountain and Fenghuoshan Mountain Regions, and the min is 10 to 20m in Beiluhe Basin. The permafrost in these regions is featured by massive ground-ice and high ground temperature. The section of permafrost with ice content higher than 20% is 121km, the section with a mean annual ground temperature (MAGT) higher than -1.0 ºC (warm permafrost) is 69 km. The geothermal gradient is 1.5×10^{-2} to 4.0×10^{-2} ºC.m -1.

SOIL THERMAL CONDUCTIVITY WITHIN ACTIVE LAYER AT TANGGULA SITE IN NORTHERN QINGHAI-TIBET PLATEAU, CHINA

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Keywords: soil thermal conductivity, active layer, Qinghai-Tibet Plateau

The soil thermal conductivity (STC) is one of essential parameters for determining soil freezing and thawing depths, and the engineering stability. Relatively precise soil thermodynamic parameters of active layer in permafrost regions are the important data for predicting global changes and a prerequisite for the design and construction of engineering constructions in cold regions. During the freezing-thawing processes of active layer the thermal conductivity controls the response of energy and moisture exchanges between ground surface and permafrost.

In this study, the STCs were estimated by using the soil temperature gradient, heat fluxes and moisture collected at Tanggula site from October 2004 to December 2008. The results showed that the variation of STCs was characterized to be seasonal. In the frozen state (FS) STC is lower than that in the unfrozen state (UFS).The fine soil particle size and low moisture content might be the reason for the lower STC in FS. Soil particles with relatively slower molecule velocity under lower temperatures may be another reason to account for the decrease of STC with the decreasing temperature. The variation characteristics of STC were different at different SMC ranges. On average, STC increased by 0.038 (SMC<0.12 m3m-3) and 0.034 Wm-1K- 1(SMC>0.12 m3m-3). The effect of SMC on STC was greater in the FS than in the UFS.

There is a close relation between ground temperature and STC. When the ground temperature was greater than 0℃, STC increased with the increase of ground temperature. As the ground temperatures fell below the 0℃, the situations were complex. When the ground temperature ranged from -4 to 0.0℃, STC increased with the decrease of ground temperature. While the ground temperatures were less than -6.0℃, STC decreased with the decrease of ground temperature. Generally speaking, STC decreased with the decrease of ground temperature. Perhaps, soil particle with relative slower molecule velocity under lower temperature accounted for the STC decreased with the decrease of ground temperature.

Details of temperature analysis indicated that when the ground temperature is below the freezing point, STCs show different characteristics as soil temperature fluctuated. This attributes to the fact that the variation of unfrozen water content during the raising temperature was later than that during the dropping temperature. Comparing the variation curve of STC with the thawing process curve of active layer, we found that STC was consistent with thawing process curve well. As the active layer was frozen, the STCs decreased, while the thawing depth increased with the increase of the STCs.

Finally, an empirically-derived model is proposed for calculating the daily average STC values over TGL. Verification results further ensured that the proposed model accurately predicts daily STC values.

DECADAL CHANGES OF SURFACE ELEVATION OVER PERMAFROST AREA ESTIMATED USING REFLECTED GPS SIGNALS

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Keywords: Decadal Changes; GPS Reflectometry; Seasonal Thaw Settlement; Surface Elevation Changes

Conventional benchmark-based surveys and Global Positioning System (GPS) have been used to measure surface elevation changes over permafrost areas, usually once or a few times a year. Here we introduce a new method to measure temporal changes of ground surface elevation in the geocentric reference frame with reflected GPS signals. We use the data collected by a continuous GPS receiver (site code SG27) in Barrow, Alaska, underlain by continuous, ice-rich permafrost. Combing the vertical position of the GPS receiver antenna and the distance between the antenna and surface reflector under the antenna as retrieved using the GPS interferometric reflectometry technique, we obtain daily changes of surface elevation during July and August from 2004 to 2015. Our results show distinct temporal variations at three time scales: regular thaw settlement within each summer, inter-annual variability in the cumulative thaw settlement for each summer, and a secular subsidence trend of about 0.7 cm/year during 2004 and 2015. The inter-annual variabilities are associated with changes in summer air temperatures. And we postulate that warm summers may thaw the ice-rich transition layer and cause large seasonal subsidence and decadal subsidence trend. Our method provides a new means to fully utilize data from continuous GPS sites in cold regions for studying dynamics of frozen ground daily and consistently over a long time.

EXPERIMENTAL STUDY ON UNFROZEN WATER CONTENT AND THE FREEZING TEMPERATURE DURING FREEZING AND THAWING PROCESSES

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Keywords: freezing temperature; freezing and thawing processes; initial water content; surface free energy; silty clay; unfrozen water content; unfrozen water content

The unfrozen water content is a key factor controlling the moisture migration and causing frost heaven or thaw settlement during freezing and thawing processes. The freezing temperature is an important index to judge whether it is in a frozen state or not, and is also a significant input parameter in numerical simulation. Based on the Frequency Domain Reflectometry (FDR) technique, the characteristics of unfrozen water content and the freezing temperature during the freezing and thawing processes on Qinghai-Tibet silty clay, and their relationships with initial water content were analyzed. The results show that the freezing process can be divided into four stages: super-cooling stage, rapid increase stage, short constant stage and cooling stage. However, there is no overheating phenomenon in thawing process. The freeze of soil with larger initial water content is prior to the soil with smaller initial water content and is more sensitive to the temperature jump. The lag effect of the unfrozen water content between the freezing and thawing processes is affected by the initial water content, and the lag degree of unfrozen water content is mainly in the phase change zone, and the peak value of the lag unfrozen water content lowers with reducing the initial water content. The initial water content has little influence on the freezing temperature of soil when the water content is equal or greater than the liquid limit. The freezing temperature of soil lowers with reducing the water content if the initial water content is less than the liquid limit. For the soil without soluble salt, under the assumption that the freezing temperature is determined by the energy of the ice-liquid interface, a general equation based on the radius of the ice-liquid interface is proposed.

THAW-INDUCED SLOPE FAILURES IN QINGHAI-TIBET ENGINEERING CORRIDOR

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Keywords: Permafrost; slope failure; thaw slumps; stability analysis; Qinghai-Tibet Plateau

The permafrost in the Qinghai-Tibet Engineering Corridor (QTEC) has been degrading at a rapid rate under the combined influences of persistent climatic warming and steadily increasing human activities. As a result, a series of the thawing hazards occurred frequently, especially the thaw-induced slope failures, which had posed a potential threat to the engineering constructions and environment in the corridor. Thaw slumps and thaw-induce landslides are the mostly typical hazards of them. On the one hand, its development would result in the environmental deterioration and degradation of permafrost, including the thawing of massive ground-ice, rising of ground temperature, and destruction of ecological environment; on the other hand, if these slope failures locate nearly along the railway and highway, they would cause some troubles to the engineering construction and maintenance. At present, the distribution characteristic and the developing status of thaw-induced slope failures in the QTEC is still unclear, and the development process and formation mechanism have not been comprehended adequately. Therefore, this study focused on thaw-induced slope failures developed in the QTEC to summarize its main types, distribution characteristics, and morphological characteristics, and analyze the development process and hydrothermal characteristics of a typical slope failure based on filed monitoring. At the same time, slope stability analysis for the K3035W failure site was undertaken using in situ tested strength parameters. There are several main conclusions as following:

A large number of thaw-induced slope failures have spreaded in the QTEC, especially near the low hilly ares of the Beilu River and Hongliang River. These thaw-induced slope failures can be divided into three types; they are landslide, thaw slump, and solifluction, based on its formation mechanism. The type of landslide mainly includes thaw-induced shallow landslide, thaw slump mainly includes retrogressive thaw slump and retrogressive flow, and solifluction includes and surface gelifluction deep-seated gelifluction.

According to the statistical results, the spatial distribution of slope failures appears to be closely related to ice content, mean annual ground temperature, slope gradient, and slope aspect. In addition, landslides are generally larger than thaw slumps in terms of length and width. At the same time, these two types of slope failures are all arc-shaped and with long axis orientation in the NW direction.

According to satellite image and field investigation, the landslide of K3035W had occurred at least two times, and the last time is the end of September, 2010 or the beginning of October, 2010. The size of this landslide is about 230 m in length from the back scarp to the edge of the compressed area, 90 m wide in its middle part, 1.8m in the thickness of slide body, and 22,500 m3 in the total volume of moved material. The rate of headwall retreat of the thaw slump following the K3035W landslide was 4.5 m per year, and the retreat of the head scarp was greater in 2012 than in 2013. The occurrence of landslide had greatly modified the heat exchange between the air and ground surface and influenced the thermal regime of the underlying permafrost, which result in ground temperatures in the recently disturbed area and the scar area were significantly lower than in the undisturbed ground. In addition, due to the lateral heat flux near the headwall, the ground temperature in the undisturbed area close to the headwall was higher than that in the undisturbed ground.

The strength parameters (effective angle of friction is 11.0°, and effective peak cohesion is 0.53 kPa) in the basal zone of active layer in K3035W landslide site were acquired by two groups of in-situ shear tests. The factor of safety (Fs) of the undisturbed slope of the K3035W landslide site was 1.24, calculated using the above strength parameters. However, we determined that the slope would lose its stability when the ground water level over the permafrost table exceeded 1.42 m or when the seismic acceleration reached around 0.03g (g = 9.8 m/s2).

MEASURING AND MAPPING PERMAFROST ACROSS NORWAY

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Keywords: rock wall permafrost; rock surface temperature measurements; Norway; statistical modelling; mapping

The investigation of rock wall permafrost is of high relevance for geohazards assessment and for understanding cold-climate landscape evolution since its changes over time can cause slope instability and trigger rock falls. The destabilization of steep slopes is a serious threat to human activities and lives in Norway, especially because most of rock walls lie directly above houses, infrastructures and large water bodies with potential of high-energy displacement waves.

Rock wall permafrost has been investigated since the early 2010s in alpine massifs of western Norway thanks to the CryoLINK project (2008-2011). The CryoWALL project (2015-2019) aims at extending this preliminary study to the nation-wide scale. It consists in systematic measurements of rock surface temperature (RST) in order model and to map the spatial distribution of rock wall permafrost. In between August 2015 and August 2016, 20 RST loggers (Geoprecision mini data loggers, accuracy ± 0.1°C, precision 0.01°C, sensors PT1000) were installed at 10 cm depth of 7 selected sites. These loggers are distributed along a latitudinal transect (from 60°50'N to 69°46'N), cover various elevations and sun-exposures, and are completed by 4 other loggers installed in Jotunheimen in 2009 and 2010.

The RST time series are used for *(a)* characterizing the distribution of rock wall permafrost across Norway, *(b)* running steady-state and transient numerical models of rock wall permafrost at selected sites, and to *(c)* calibrate a general linear regression model that will be used to *(d)* predict the spatial distribution of rock wall permafrost at the national scale.

In this communication we will introduce the RST measurement installations and sites, as well as the first RST records that encompass 6 years of continuous measurements in Jotunheimen, and 1 year of record for 13 other loggers. The preliminary analysis shows that RST differs by 3°C between N and S faces in Southern Norway, with mean annual RST as low as -1.9°C at 1700 m a.s.l in a N face (Nordfjord, Sogn of Fjordane) during the measurement year which was about 0.8°C above normal (1981-2010). In Northern Norway, the RST difference between N and S faces is rather around 1.5°C due to the midnight sun and polar night effects, inducing similar RST in both aspects during December, January, May and June. Negative mean annual RST is found as low as 1200 m a.s.l in S-exposed faces (Kåfjorden, Troms) during the measurement year which was 1.1°C above normal in this area. The ice and snow coating the rock faces during winter appears as a significant warming factor that can raise the mean annual RST up to at least 1°C compared to bare rock conditions. This first data set is shown to be of high relevance for predictive modelling.

MODELLING THE THERMAL STABILITY OF PEAT PLATEAUS AND PALSAS IN NORTHERN NORWAY

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Keywords: Peat plateaus; Palsas; Thermal stability; Ground temperature loggers; Numerical modelling

Palsa and peat plateaus are geomorphological features often observed in zones of sporadic permafrost (Sollid and Sørbel, 1998). Their evolution shows a complex feedback with the climatic conditions, being both dependent on climatic parameters such as the mean annual air temperature and on local small scale evolutions of the topography and vegetation (Seppälä, 2011). As palsas characterize the warmest areas presenting permafrost, understanding their evolution is of critical importance to bring robust constraints on the permafrost-atmosphere interactions that may be expected in case of long term climate warming and large scale permafrost thawing (Koven et al., 2011).

In Northern Norway, palsas and peat plateaus have shown a clear trend of degradation over the last 60 years (Borge et al., 2016), giving the opportunity for process studies that can shed light in the evolution of vast permafrost peatlands e.g. in Siberia under a warmer climate. In 2015, around 200 loggers temperature were installed at the ground surface of four peat plateaus in Northern Norway to assess the spatial variability of the surface forcing and its driving factors. Changes in micro-topography over the investigated year were quantified using differential GPS, while thaw depth was obtained for each logger site by manual probing. Despite of recorded mean annual ground surface temperatures of up to +3 degree C, the palsas and peat plateaus were overall stable with ground subsidence restricted to localized spots.

Understanding the underlying processes and conceptualizing them in numerical frameworks is challenging, but these measurements provide an ideal benchmark dataset to guide model development. We use the permafrost model CryoGrid 3 (Westermann et al., 2016) with input climate forcing data derived from meso-scale atmospheric modelling (WRF model, 3km resolution, see Aas et al., 2015), which is a flexible scheme that can in principle be adapted to arbitrary locations. Based on 1D-realizations for different logger sites, we present a first analysis in how far the scheme is capable of reproducing the coexistence of permafrost and permafrost-free areas over distances of only a few meters. We test the importance of parameters such as the water balance, the snow cover build-up or the evolution of the micro-topography on the palsas stability. First results suggest a distinct role of the lateral fluxes in the water balance, affecting the spatial patterns of ground subsidence and thus the evolution of micro-topography.

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MULTI-METHOD MONITORING OF ICE WEDGE DYNAMICS IN CENTRAL SPITSBERGEN (2005–2016)

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Keywords: ice wedge; polygons; thermal contraction cracking; permafrost; interannual variability

Eleven years of multi-instrumental monitoring highlighted ice-wedge dynamics at a low-centered polygonal field in Spitsbergen, located in a marginal environment for ice-wedge formation. Three trough-rampart systems underwent monitoring of (1) 2D movements of three troughs and a rampart with extensometers, (2) timing of crack generation with acceleration loggers and subsurface copper wires, (3) ground thermal conditions well into the permafrost and (4) moisture in the active layer. This presentation addresses seasonal variability of ground deformation around ice-wedge troughs, interannual variability of ice-wedge activity and thermal thresholds for ice-wedge cracking.

The trough-rampart systems repeated seasonal activity primarily associated with frost heave and thaw settlement. Seasonal frost heave 2–3 cm of the ramparts in early winter was accompanied by outward expansion at the same time as the troughs contracted, while the opposite occurred during thaw settlement in summer. Deformation resulting from the net polygon movement led to tilting of the rampart benchmarks towards the center of the troughs. In mid- to late winter, temporary extension of troughs by thermal contraction cracking accompanied some rapid, significant cooling events. Following intensive ground acceleration events, the extensometer across a trough elongated rapidly and in some cases the copper wire broke. A common threshold for cracking in three troughs is that the ground surface is rapidly cooled below -20°C, alternatively given by a combination of TTOP<-10°C a thermal gradient in the frozen active layer less than -10°C/m. The threshold indicates that cracking requires both a brittle frozen layer and rapid cooling, and is also favoured by a minimum buffer layer (snow/vegetation).

Our observations show that in marginal thermal conditions for ice-wedge activity (MAAT~-4°C) the primary control on ice-wedge cracking is rapid cooling enhanced by the minimum snow cover. Short-term, rapid cooling can trigger ice-wedge cracking, while neither a low MAAT nor even a low winter average temperature is not necessary. In other words, ice wedge pseudomorphs do not indicate a maximum MAAT when cracking was active, but in a more appropriate sense, they do indicate former permafrost that experienced repeatedly cooling snaps in winter.

PERMAFROST CONDITIONS AFFECT FOREST STAND STRUCTURE IN CIRCUMPOLAR REGION

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Keywords: circumpolar; permafrost; forest ecosystem; stand structure; carbon storage

Boreal forest ecosystem research was conducted in circumpolar region, including Eastern and Central Siberia, Interior Alaska, Northwest Territories, Canada, and Finland-Estonia region. The research area includes four types of permafrost conditions, i.e. continuous, discontinuous, sporadic permafrost, and permafrost-free (seasonally frozen) soils. The dominant conifers among surveyed sites are region-specific. Evergreen conifers (*Picea* and *Pinus*) are dominant species, except in Eastern and Central Siberia. The deciduous conifer larch (genus *Larix*), is the only dominant in areas with continuous permafrost.

The permafrost larch forest ecosystem shows unique features in terms of stand biomass allocation and root system development (Osawa et al. 2010). Forest census and stand reconstruction results using tree ring analysis among several sites show specific growth patterns among sites. The ratio between above-ground and below-ground forest stand biomass was nearly 1 to 1 in the continuous permafrost region of Siberia (Matsuura et al. 2005, Kajimoto et al. 2006).

The moss-lichen complex organic layer that develops on the sparse coniferous forest floor plays a significant role in determining the depth of permafrost thaw (20 to 120 cm) during the growing season and patterns of biomass accumulation (Noguchi et al. 2012). Upland black spruce stands that develop on north-facing slopes with discontinuous permafrost following forest fires exhibit a critical relationship between permafrost thaw depth and biomass accumulation. In regenerated black spruce stands of the same age cohort, greater depth of thaw during the growing season results in greater biomass accumulation. Similar positive patterns of permafrost thaw depth and biomass accumulation were observed in Siberia and Interior Alaska.

Soil organic carbon (SOC) storage regime varies among ecosystems. The nature and origin of the soil parent materials greatly affects soil carbon storage. Although most of the circumpolar region was glaciated during the Pleistocene era, eastern and central Siberia, and central Interior Alaska were not glaciated. Such differences in geological history lead to a variety of SOC accumulation regimes in circumpolar forest soils. Soils in regions that were not glaciated during the Pleistocene, such as soils of the continuous permafrost region in Siberia, have much greater SOC accumulation, while soils that developed following glacier retreat have less SOC (Matsuura, unpubl.). The relationship between biomass accumulation and the environmental conditions that regulate belowground process may be one of the key ecological factors impacted under changing climate conditions in the future.

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ESTIMATION OF SOIL FREEZING DATE IN IITATE VILLAGE, FUKUSHIMA USING AIR TEMPERATURE REMOTELY MEASURED

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Keywords: freezing date, radiocaesium, decontamination, Iitate Village, Fukushima

Soil freezes in the winter of Iitate Village in Fukushima Prefecture. When soil freezes with an appropriate depth, it seems to be a perfect timing for removing the soil surface layer that contains most of radiocaesium fallout. We monitored air- and soil-temperatures at 20 different places all over Iitate Village so that we may estimate soil freezing date to start radiocaesium-contaminated-soil removal operation. Cumulative air temperature below zero was calculated for a reference site. At the reference site, soil freezing was detected using a soil moisture sensor installed at 5cm deep because the dielectric constant of ice was similar to that of soil particle.

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THERMAL CONDITIONS AND PERMAFROST EVOLUTION OF HIGH ALPINE ROCK SLOPES: A STUDY OF THE AGUILLE DES GRANDS MONTETS IN THE MONT BLANC MASSIF

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Keywords: Electrical Resistivity Tomography, Permafrost, Mont Blanc Massif, Rock Slope Instabilities.

Permafrost can significantly influence rock slope stability (Krautblatter et al., 2013). The investigation of temperature distributions with respect to recorded geomorphological destabilization processes on high-altitude rock faces can thus be of great importance to the assessment of permafrost related rock slope failures. This study was performed on the Aiguille des Grands Montets (3.295 m a.s.l.), a rocky peak of loose and highly fractured granite, located in the western part of the Mont Blanc Massif. The main objective was to gain insights on the distribution and development of the hidden permafrost body inside the summit. Therefore, three different approaches were combined.

(i) First, in a field survey performed in September 2016, the geophysical method of Electrical Resistivity Tomography (ERT) was applied to measure a cross-section of 315 m along the north and south face of the top. A complete scan of both opposite facing slopes was recorded in a 5 m spacing of 64 electrodes and two other measurements were taken separately for the 32 electrodes along both mountain sides. From this data, a 2D model of the ground resistivity was created, following the concept developed by Krautblatter and Hauck (2007). A distribution of the rock temperature was then derived from previous laboratory calibrations (Magnin et al., 2015). The obtained results quantify the present state permafrost distribution and reveal an expected temperature gradient from the north to the south side of the summit. Data from surface temperature logger and geotechnical extraction boreholes at site were used to evaluate the model outcome and suggest a slight underestimation of permafrost occurrence.

(ii) In a further approach, these results were compared to previous ERT measurements at site (Magnin et al., 2015). Thereby, a quantitative evidence of the degradation of the main permafrost body between the years 2012 and 2016 in the north face of the summit can be provided. A continued history of reported rock fall events in this period was attributed to the loss of resisting shear force in the rock masses, induced by the demonstrated degradation of the permafrost body.

(iii) Finally, the interpreted temperature distributions from the ERT scans were compared against results of physical temperature modelling (Magnin et al., in review) and used to discuss model predictions for the change in permafrost distribution until the end of the 21st century.

This study provides valuable information on the thermal conditions and permafrost evolution of high alpine rock slopes. However, to establish a more qualitative connection between rock slope failure and permafrost distribution, we need yet to develop and apply more advanced integrative exploration methods combining temperature, mechanical and hydrogeological processes.

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APPLICATION OF TERRESTRIAL ECOSYSTEM DYNAMICS MODEL TO A LARCH FOREST IN EASTRN SIBERIA

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Keywords: larch forest; nitrogen cycle; permafrost; terrestrial ecosystem dynamics model

The high latitude including boreal forest regions is predicted to experience intense warming over the 21st century, and the response of such boreal forests to climate change is becoming a key issue.

Sato et al. (2007) developed the Spatially Explicit Individual-Based Dynamic Global Vegetation Model (SEIB-DGVM). In this model, individual trees compete for light within a spatially-explicit virtual forest considering the effect of self-shading and shading of neighboring trees, and it simulates dynamics of population and community according to the ecophysiology of several plant functional types (PFTs). By integrating this SEIB-DGVM with the Noah land surface model (NOAH-LSM; Ek et al. 2003), Sato et al. (2016) analyzed the interactions between vegetation dynamics and thermos-hydrology in the larch forest in eastern Siberia. They predicted the increasing trend of NPP in the larch forest at Spasskaya Pad in eastern Siberia under RCP scenarios 2.6 and 8.5 by the end of 21th century, and found that the primary factors of this trend are air temperature and precipitation. On the other hand, their model did not consider the processes such as nitrogen limitation and waterlogging of soil that can affect the productivity response to a changing climate. Also, evapotranspiration is calculated for whole canopy, and eco-physiological processes are simplified in their model.

Based on the SEIB-DGVM, we developed a new model named S-TEDy (SEIB-DGVM-originated Terrestrial Ecosystem Dynamics Model) so that the transpiration and its control by stomata are calculated for each individual tree. The SEIB-DGVM explicitly incorporates local light competition among individual trees. By using this calculation, net radiation absorbed by leaves is calculated at each 10 cm thick crown disk, where leaf-level photosynthesis and stomatal conductance are calculated by the Farquhar model and Ball-Berry model, respectively. The individual tree transpiration is then calculated using net radiation absorbed by leaves in the crown, canopy stomatal conductance of whole crown, and aerodynamic conductance at the tree height. In calculating the transpiration, net radiation consumed by wet evaporation of the intercepted rainwater is taken into account which is subtracted from the net radiation for transpiration. Soil moisture dynamics within a root-zone is represented by the bucket model, considering gravity drainage and capillary rise flux by the Gardner-Eagleson parameterization, with the water retention characteristics represented by the Campbell model.

Most importantly, this S-TEDy *mechanistically* simulates "the way of life" of each individual tree so as to predict tree mortality under the future climate conditions reliably. By using this S-TEDy, individual tree transpiration, as well as above ground biomass, was successfully reproduced for a Bornean tropical rainforest.

To apply this model to the larch forest in eastern Siberia, we are developing the sub-model of soil physics to consider the effect of freezing-thawing processes. Also, the sub-model of nitrogen cycle will also be implemented. We'd like to show the preliminary results of the application of the revised S-TEDy to a larch forest of Spasskaya Pad in eastern Siberia.

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INFLUENCE OF GROUNDWATER ON GROUND TEMPERATURES AND SEASONAL FREEZING IN THE TUUL RIVER VALLEY NEAR ULAANBAATAR

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Key words: Ground, temperature, isopleths, borehole, freezing, water, level, depth, Tuul

In order to study an influence of groundwater on dynamics of ground temperatures and seasonal freezing, the authors monthly conducted year-round ground temperature measurements by data loggers in 11 boreholes with depths of 5-25m, located at central and upper sites of groundwater resources near Ulaanbaatar. Based on obtained data we generated ground temperature isopleths down to 5 m depth and monthly temperature curves down to 25 m depth of the boreholes (Anarmaa & Sharkhuu. 2016, unpublished report). Analysis of the ground temperature isopleths and curves shows the following pictures: Ground water, depending on its level and thermal transfer due to its movement leads to increase in mean annual ground temperature (MAGT) by about 1-3°C, and to decrease in depth of seasonal freezing (DSF) by about 0.5-2.0 m. Therefore, MAGT at 15 m depth of Tuul alluvial water bearing sand-gravely sediments are 3.5-5.3°C. In contrast, high temperature-shallow permafrost patches are found at some sites of the valley slope with clayey and silty sediments without ground water. DSF in the valley bottom sediments reaches 1.8-3.6 m when there is a groundwater present. Meanwhile, active layer thickness of permafrost on the valley slope reaches 3-5 m (Sharkhuu et al. 2015). Ground water level in the valley usually ranges within 1.5-5.0 m. Average amplitude of water levels in spring and autumn is 1-2 m (Dorjsuren et al. 2015). On summer and winter seasons, ground temperature gradient in soil layers above water level reaches 5-10°C/m. Water bearing alluvial sediments are characterized by low or without temperature gradient. Monthly ground temperatures in the boreholes located at water pumping wells are very changeable in depending on periodically pumping for water supply. In late 1990-s comparative temperature year-round measurements were made in boreholes located in large (Orkhon), medium (Burgaltai) and small (Chingeltei) river valleys (about 300 km north-west from Ulaanbaatar). According to these measurements, MAGT in the large, medium and small river valleys vary 6.5°C, 4.5°C and 1.2°C, respectively. Meanwhile, DSF of water bearing alluvial sediments in the large, medium and small river valleys were 1.7 m, 2.3 m and 2.7 m, respectively. Consequently, the Tuul river valley is related to medium size of valley with water bearing alluvial sediments.

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SORTED PATTERNED GROUND IN KARST CAVES: A CASE STUDY OF A CAVE IN SLOVENIA

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Keywords: Patterned ground; Ice caves; Cryoturbation; Karst; Frost heave; Sorted stripes

Periglacial landscapes are characteristic for high latitudes or high elevations. One of the most distinctive periglacial landscape landforms is patterned ground. Karst caves can be affected by cold air and ground temperature anomalies and can, due to their microclimatic setting, host perennial ice, permafrost and periglacial conditions in milder climates. Patterned ground has been reported from several karst caves in Slovenian Dinaric Mountains and Alps, Swiss Jura Mountains and West Carpathian Mountains in Slovakia. The aim of our study is to identify environmental conditions responsible for patterned ground formation in karst caves using cave Ledena jama pod Hrušico, Slovenia as an example.

The cave is located on the Hrušica plateau at an elevation of about 800 m. It consists of a spacious 20 m deep shaft, debris cone and two small passages. The perennial ice present in the debris cone is according to past observations quickly disappearing. One of the passages contains fine sediments, which are mixed with limestone debris. Sorted stripes are present on an inclined slope of this passage.

Thirteen 20-50 cm wide stripes of coarse limestone debris developed on fine cave sediment. The grain size of the fine sediment is predominantly silty (80 %), which makes it very susceptible to frost heaving. A geoelectrical survey and drilling revealed approximately one metre sediment thickness. One year of ground temperature measurements revealed no permafrost at the location of patterned ground. Several freeze-thaw cycles occur at the sediment ground surface in winter due to cave temperature fluctuations. Cave air temperature measurements show that surface air enters the cave only when its temperature drops below the cave air temperature, which results in preferentially cold and oscillating winter temperatures and the formation of a cool air pool in the summer.

Karst caves can contain significant amounts of silty sediments that accumulated during flood events when the cave was situated in the floodwater zone. Frost shattering of parent bedrock is a potential source for coarse debris. The cold climatic conditions that result from cave morphology sustain low ground temperatures in summer and cause freeze-thaw cycles in winter, which result in frost heaving that causes sediment sorting.

TOWARDS A REMOTE-SENSING BASED GLOBAL MAP OF PERMAFROST

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Keywords: Permafrost extent; Ground temperature; Ground thermal regime; Remote Sensing; Permafrost zonation

Permafrost cannot be directly detected from space, but many permafrost surface features and properties are observable with a variety of earth observation sensors. ESA's GlobPermafrost project develops, validates and implements different permafrost information products to support the research communities and related international organisations. Within GlobPermafrost project, we aim to produce a circum-polar map of permafrost extent and thermal state.

The thermal state of the ground cannot be directly inferred from spaceborne platforms with current remote sensing technologies. We overcome these limitations by combining the information content of several remote sensing products, namely time series of remotely sensed land surface temperature, snow cover and snow water equivalent. These products are employed to force ground thermal models at 1km resolution which deliver ground temperatures and probability of permafrost occurrence within a grid cell.

We ran this semi-empirical model for the land areas of Northern Hemisphere. Mean annual ground temperatures were estimated at a spatial resolution of 1 km at using MODIS land surface temperatures and ERA reanalysis products between years 2000 and 2016. The snow thickness and its variability have been estimated using GlobSnow and CCI Land cover products. Model parameters in different model realizations were set according to subcell distribution of land cover. The mean annual ground temperature (MAGT) results were compared to in-situ temperature measurements of GTN-P boreholes and showed accuracy of 2.3 °C. The number of model runs with MAGT below 0 °C indicates the probability of permafrost occurrence within a modelled cell. The permafrost zones (continuous, discontinuous and sporadic) defined from statistical modelling correspond well with known zonation on global scale.

FUNDAMENTAL STUDY ON GROUND DEFORMATION DUE TO THAWING OF PERMAFROST WITH INDOOR EXPERIMENT

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Keywords: global warming; permafrost; thermal erosion; topographical deformation;

It is known that approximately 15% of the earth surface is covered by permafrost where the ground is frozen up for over two years continuously (Akagawa 1990). In order to preserve the natural environment in permafrost regions, we have to carefully consider the heat flow balance within the ground including active layer located at the top of permafrost table and moss layer covering the surface. However, in recent years, it is concerned that the thickness of active layer is gradually getting larger than ever because of global warming and damage in moss layer. Thawing in permafrost degrades the strength of soil layer and it enhances heat flow in the foundation with water migration. As a result, topographical deformation may occur in wide area such as landslide and thermal erosion, for example. In addition, structures built in those regions may be also losing their stabilities. The process and mechanism of deterioration in foundation have not yet been fully examined and the purpose of this study is to learn the ground deformation due to thawing of permafrost with indoor experiments as well as numerical analysis.

The authors developed an indoor experimental apparatus to observe ground deformation due to thawing. The apparatus consists of acrylic container and a heat circulation system. After filling saturated soil material into the container, we put it in a cold room to make the soil material completely frozen up. Then, the heat circulation system is set at the top of the container to circulate hot air to thaw the foundation from the top and side surface. We recorded the deformation of the sample with a time lapse camera as well as the change in temperature of foundation. The amounts of water and soil flowing out from the container are also measured during the experiment.

As a first step of the experimental series, we adopted glass beads instead of real soil because frost heave never happens in glass beads foundation and it is easy to manage the freezing and thawing processes. In the thawing phase, glass beads started to move from thawed surface with water migration. As the frost front goes down into the deep portion of the specimen, fracture like landslide was observed and the foundation finally reached to a stable shape kept in the resting angle. The observation results were compared with analytical simulations to examine the behavior. For the heat transfer simulation, we applied a mixed hybrid FEM to evaluate the heat balance in each element with sufficient accuracy. For the evaluation of motion of beads, a distinct element method was introduced to simulate each particle. The authors are conducting the experiments with several soil samples and further findings will be reported in the conference.

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TRIAXIAL FROST HEAVE TESTS FOR IMPROVEMENT OF PREDICTION OF THE FROST HEAVE IN ARTIFICIAL GROUND FREEZING

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Keywords: Artificial ground freezing; Triaxial frost heave test; Frost heave ratio

In Japan, an artificial ground freezing method has been utilized for the water-saturated ground in urban area. The frozen soil wall with the high strength could support the soft ground and prevent ground water leakage. The ground is frozen, for example, near the shafts at the beginning and the end of shield machine, the place of the shield machines join together, the surrounding of a tunnel for widening the tunnel, etc.

Freezing of clayey soil causes water migration from the unfrozen ground to the freezing front, generally forming an ice lens. Because of the water migration, frost heave may occur and often damage the constructions. To study effects of frost heave stress on the ground, Takashi et al. (1974) performed one-dimensional vertical frost heave tests confining horizontal deformation of specimens. In this method, specimen could expand only in the parallel direction of the heat flow. These experiments showed that the frost heave ratio (FHR) was a function of effective stress perpendicular to the freezing front (parallel to the heating flow direction) and the freezing rate as described in Takashi's formula. Takashi et al. (1976) showed that the suction increase in the unfrozen area could give additional effective stress in the heat flow direction. In case of normally consolidated ground, Yamamoto et al. (1989) observed that unfrozen area especially near the freezing front was consolidated with the suction acting as additional effective stress at the freezing front.

In the cold regions, freezing front generally moves in one-dimensional vertical direction from the ground surface. In the case of artificial ground freezing, however, the front advances in three-dimensional all direction from the freezing pipe buried in ground. Yamamoto et al. (1994) performed the triaxial frost heave (TFH) tests, adjusting the horizontal stress as well, to study the relations between the FHR in the heat flow direction and the perpendicular direction. The FHR in each direction was found to be a function of effective stress in both direction. If horizontal stress is sufficient large, horizontal expansion does not occur. Under the condition, the function of FHR in the heat flow direction corresponds to the Takashi's formula.

In order to apply these laboratory studies to the ground freezing site, Ueda et al. (2005) expressed three-dimensional effective stress at the freezing front based on suction, consolidation in unfrozen ground, freezing earth-pressure, and proposed three-dimensional ground deformation analysis (Ueda et al. 2007). In the analysis, the FHR in heat flow direction could adjust depending on the position of freezing pipes and the shape of frozen ground.

This paper presents the TFH tests data for several soils, comparison between FHR in heat flow direction and the perpendicular direction based on the three-dimensional effective stress model for a simplified ground condition, and horizontal heaving pressure for the one-dimensional tests according to the coefficient of TFH for each soil.

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THE CRYOSEISMOLOGY OF ICE-WEDGE POLYGONS: THERMAL CONTRACTION CRACKING INFERRED FROM MINIATURE ACCELEROMETERS

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Keywords: ice wedges; thermal contraction cracking; active layer; ground ice; Svalbard

Determining the exact timing of ice-wedge cracking has always been a challenge. Therefore, five miniature accelerometers (shock loggers) were buried near the ground surface in the trough of a primary ice wedge within a network of low-centered polygons in Adventdalen, Svalbard, to test whether these instruments could be used to infer the dynamics of thermal contraction cracking. Data from 2003-2013 were analyzed to characterize cyroseismic signals in the ice-wedge trough. High magnitude shocks (up to at least 100 g) were typically registered in late winter when the top of permafrost had cooled to -10°C or below; these likely correspond to ice-wedge cracking within permafrost. Tensile stresses calculated from temperatures measured in the ice wedge trough are near reported tensile strengths for ice and active-layer sediments, supporting the interpretation that large accelerations are caused by thermal contraction cracking. Lower magnitude accelerations occurred throughout the freezing season, but nearly always as the ground surface temperature had been decreasing in the previous 1-2 days. These small shocks may be associated with (i) the initiation of small cracks in the active layer prior to ice-wedge cracking, or (ii) the horizontal and vertical progression of existing cracks. The results of this investigation indicate that these tough, miniature accelerometers are an effective, relatively inexpensive, and simple method to accurately determine the timing of ice-wedge cracking, and rates of crack propagation along a wedge trough.

LINKING DYNAMICS OF PERMAFROST AND DISSOLVED IRON PRODUCTION IN THE AMUR RIVER BASIN

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Keywords: dissolved iron; wetlands; Amur River; Sea of Okhotsk; climate change

Iron is the limiting nutrient of phytoplankton in the Sea of Okhotsk. It is estimated that about half of iron in this system originated from terrestrial system, especially from the Amur River. To understand the mechanism of dissolved iron production and transport through the Amur River, we constructed the hydrological model which incorporates the algorithm to calculate dissolved iron production (Onishi et al., 2010). Though the model successfully reproduced an average behavior of dissolved iron concentration of the basin, actual dissolved iron concentration shows very dynamic fluctuation. Especially, during the period of late 1990s', abnormal large peaks were recorded at many different observation stations. Since we had two possible hypotheses which might give an explanation of accelerating dissolved iron production in the basin, we attempted to incorporate these factors into the model. The first is flooding, and the second is huge amount of groundwater pumping for irrigation. Though the modified model was partly successful to simulate the change in dissolved iron concentration, it could not give a full explanation of observed data. Analysis of long-term dissolved iron concentration of the Amur River basin indicates that abnormal rise of dissolved iron concentration during the late 1990s' was ubiquitous throughout the basin, suggesting the prevailing phenomena such as climate conditions has a large influence on the dynamics of dissolved iron flux. A correlation analysis between dissolved iron concentration and temperature and precipitation showed that July temperature and October precipitation has strong influence on dissolved iron concentration. Supported by the fact that soil temperature also shows an increasing trend during the last several decades (Shamov et al., 2014), we hypothesize here that the permafrost dynamics should have a significant influence on dissolved iron concentration of rivers. Along with a newly collected field data in 2015 and 2016, the possibility of our hypothesis will be discussed.

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NON-CHANNELIZED PERIGLACIAL DEBRIS AVALANCHES IN NORWAY – SPATIAL DISTRIBUTION, TRIGGERING CAUSES AND SEDIMENT THICKNESS

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Keywords: Debris avalanche; climate; geomatics; geoscience; periglacial geomorphology

Debris avalanches often originate in water saturated slopes steeper than 25 degrees. The origin is in a point which suddenly initiates a mass movement. Some debris avalanches do not channelize, but rather expand to the sides and form a cone shape. This behavior is observed when the sediment thickness is low. These cone-shaped avalanches have been investigated by the Norwegian Geological Survey.

In this study, we map non-channelized debris avalanches in two counties in Norway, and analyze their distribution related to environmental parameters, climate, surface sediment and topographic setting. A special focus is related to triggering processes, as most of these landforms originate from block-rich periglacial surfaces in block-rich regolith. An important aspect is related to the sediment thickness in the path of the debris avalanche. Therefore, the study provides detailed investigation of sample landforms, utilizing terrestrial laser scanning and subsequent estimation of sediment thickness based on high-resolution digital elevation models.

LANDSCAPE PARTITIONING AND BURIAL PROCESSES OF SOIL ORGANIC CARBON IN CONTRASTING AREAS OF CONTINUOUS PERMAFROST

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Keywords: permafrost, soil organic carbon, upscaling, geomorphology

Recent studies have shown that permafrost soils in the northern circumpolar region store almost twice as much carbon as the atmosphere (Hugelius et al., 2014). Since soil organic carbon (SOC) pools have large regional and landscape-level variability, detailed SOC inventories from across the northern permafrost region are needed to assess potential remobilization of SOC with permafrost degradation and to quantify the permafrost carbon-climate feedback on global warming. This study provides high-resolution land cover and landform classification data on total SOC storage from contrasting regions of continuous permafrost (Russia and Greenland). Our results indicate large differences in mean SOC 0–100 cm storage among study areas, ranging from 4.8 kg C m^{-2} to 30.0 kg C m^{-2}, highlighting the need to consider numerous factors as topography, geomorphology, land cover, soil texture, soil moisture, etc. in the assessment of landscape-level and regional SOC stock estimates.

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CHANGES IN ARCTIC TERRESTRIAL EVAPOTRANSPIRATION BUDGET AND THE IMPACT TO HYDROLOGICAL CYCLE UNDER CLIMATE CHANGE

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Evapotranspiration (ET) that is a sum of transpiration (E_T), soil evaporation (E_S), and canopy interception (E_I) is one of components constituting to global energy and water budgets. Climate change can affect the evapotranspiration. The recent Arctic warming resulted in changes in the energy and water budgets, as were identified by in situ observations and model simulations. Previous results addressed increasing trends of ET dependent on the warming climates. To date, however, very few studies are available for quantitative values for changes in ET and the sequent influences on river discharge. A land surface model (CHANGE) is used to assess changes in the Arctic terrestrial ET and hydrologic budget from 1979–2013.

The pan-Arctic temperature and precipitation showed increasing trend from 1979–2013. The model also simulated increasing ET responding to the changes. The simulated pan-Arctic ET was compared with values derived from reanalysis datasets, showing generally good agreements. Both E_S and E_I were significantly increased, responding to earlier soil thawing and increased canopy interception combining with increased leaf area index and precipitation. Meanwhile, E_T showed a decreasing trend, with statistical insignificance. The decreased E_T was related to increased CO_2 concentration in the atmosphere, resulting in stomatal closure. This result was diagnosed by model sensitivity experiments treated the CO_2 concentration to 280 and 800 ppm. The contribution of the decreased E_T to ET was not relatively large, because the increase in both E_S and E_I did offset the decrease of E_T. The increased ET reduced the contribution of soil moisture to river discharge. However, the river discharge was primarily dependent on precipitation dynamics, because the changes of ET were not larger than those of precipitation.

PERMAFROST RESPONSE TO TRANSIENT VEGETATION AND CLIMATE CHANGES IN A NORTHERN MOUNTAIN BASIN, CANADA

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Keywords: Canada; climate change; mountain; permafrost; vegetation change; Yukon

Permafrost in the northern latitudes and high mountains with seasonal frozen ground controls the runoff process, subsurface storage, and the infiltration from snowmelt and rainfall. Permafrost degradation under warmer climates has important hydrological consequences and can substantially change runoff processes. Freezing and thawing mechanisms as well as response of the permafrost to future climatic conditions were examined in the Wolf Creek Research Basin (WCRB) in the Yukon Territory, Canada. Total soil moisture of all layers and depths from ground surface to freezing front and thawing front at different altitudes were studied under the current climate and both climate and transient vegetation changes. Under a combined climate and transient vegetation change scenario, soil moisture in the WCRB does not change and remains similar to that in the current climate. Results show that the impact of climate change on permafrost can be moderated by the impact of transient vegetation change. Under the current climate, the depth to thawing front starts to increase in May as the ground warms. Under climate change and vegetation changes, the depth to thawing front increases in winter and spring. Upward movement of the treeline and shrub tundra expansion at high altitudes in the WCRB counteract the impact of climate change. The results of this study will help to assess the vulnerability and resiliency of water resources in the North and high altitudes with frozen ground that are changing with degradation of permafrost or warming of the ground.

RAPID LAKE HYDROCHEMICAL AND ECOSYSTEM CHANGE IN HIGH ARCTIC LAKES DUE TO PERMAFROST CHANGE

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Keywords: Arctic; climate change; diatoms; hydrochemistry; limnology; otolith; permafrost

Climate-induced permafrost changes are expected to have important impacts on terrestrial and aquatic systems in the Arctic. Research has shown changes to river discharge, hydrochemistry and nutrient transport, and also major changes to pond ecosystems. Fewer studies have shown changes in larger lake systems, especially in the High Arctic where permafrost changes are expected to be limited to the uppermost portion of the system. We assess the impact of a recent period of record warm climate and permafrost perturbation in the Canadian High Arctic on the hydrochemistry and aquatic ecosystem in downstream large lakes. This work is carried out at the Cape Bounty Arctic Watershed Observatory (CBAWO), a comprehensive watershed and lake research site located on Melville Island, Nunavut (75°N, 109°W). We utilize an unique record of hydrochemical and related limnological measurements that span the 2003-2016 period, combined with terrestrial hydrological and permafrost observations. We further assess the impact of climate and permafrost change on the lakes through analysis of otoliths (ear bones) from Arctic char (*Salvelinus alpinus*) to identify geochemical changes related to the lake environment. Finally, we assess the diatom community in the lakes prior to the period of warming (2004) and after (2014) to determine changes in lake primary productivity.

The two primary lakes at CBAWO are freshwater, deep (31-34 m) and monomictic, and have 10-11 months of ice cover. Results indicate that there has been a sharp increase in solute loads in both of the lakes at CBAWO, particularly after 2010. In particular, sulfate (SO_4^{2-}) has increased 500% and 380% in the West and East lakes, respectively. The years with the greatest increases in the lakes follow record warm years and deep active layer development in the catchments. Active layer and permafrost cores indicate high solute loads are available in the transient layer and suggest that flushing of the deep active layer is the likely mechanism for the observed hydrochemical changes.

Otolith analysis indicates that most fish sampled show an abrupt increase in Mg and a corresponding decrease in Ba synchronous with observed sharp increase in lake solutes and metal concentration changes. Fish condition indicators (based on length and mass) show a prominent increase in apparent health and suggest that the fish are positively responding to the observed limnological changes. Diatom community analysis also shows a shift from predominantly benthic to small planktonic species, consistent with changes observed elsewhere in the Arctic and with the amelioration of climate at CBAWO.

Collectively, these results indicate that permafrost changes can impart rapid changes on large aquatic systems with measurable impacts on ecosystem elements. Our results suggest that large changes can occur in 2-4 years, rates previously not observed elsewhere in the Arctic.

LACUSTRINE THERMOKARST LANDSCAPE PATTERN ANALYSIS: SOME PROBLEMS OF THE MATHEMATICAL MORPHOLOGY OF LANDSCAPE BASIC MODEL

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Keywords: lacustrine thermokarst; landscape pattern; mathematical morphology of landscape

Mathematical morphology of landscape is a branch of geosciences that studies quantitative laws for patterns formed by natural units (landscapes). The basic concept behind mathematical morphology is the elaboration of a mathematical model for a landscape pattern (Victorov, 2007). Unlike other branches of landscape pattern analysis, the stochastic models and vector representation of landscape patterns are used.
The lacustrine thermokarst landscape has been investigated across Arctic cryolithozone using the mathematical morphology of landscape (Victorov et al., 2016). However, some problems have been revealed in the methodology of landscape pattern analysis and the model verification.
The lacustrine thermokarst landscapes may be considered as consisting of round lakes within a homogeneous field (background). After taking several assumptions we developed the basic model of the landscape pattern development and verified it using remote sensing data from SPOT-5, WorldView-2 and some other satellites for 16 study areas in Russia, Canada and Alyaska (Victorov et al., 2016).
The revealed problems of the landscape pattern analysis using the model are:

- What is the most suitable criteria for estimation of the thermokarst lake layout homogeneity?
- What is a connection between the thermokarst lake watershed area and its area and growth parameters?
- How does the thermokarst lake growth law depends on the current area of the lake?

These problems' analysis is the subject of the present study.
Three different methods were tested for the homogeneity estimation: calculation of the lake centers number within stochastically located round areas, investigation of the correspondence between the minimal distances for neighboring lakes distribution and Rayleigh distribution and investigation of the dependence of the lakes center number in a round neighborhood of the existing lakes and the neighborhood radii.
The basic model analysis (Victorov et al., 2016) shows that there is no connection between thermokarst lake watershed area and the lake's area and growth. However, the moisture volume accumulated within the lake is an important parameter for the heat flow estimation. So we tested this counterintuitive consequent of the basic model using the Arctic DEM Map data (http://arcticdemapp.s3-website-us-west-2.amazonaws.com/explorer/) for the watershed area approximation.
We found two different classes of thermokarst lakes of different size at several study areas within Lena river delta and Yamal peninsula. For each class a specific area growth model takes place. Threshold value of the area between two classes is close to 1 hectare. This result is particularly valuable considering that the small lakes under that threshold are a significant source of the methane emission in the atmosphere (Walter, 2007; Pokrovskiy, 2012).

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DETECTION OF THERMOKARST DEVELOPMENTS USING UAV AND SFM-MVS PHOTOGRAMETRY

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Keywords: Thermokarst; High-centered polygons; UAV; SfM-MVS photogrammetry; The eastern Siberia

The eastern Siberia is characterized by widespread thaw of permafrost and subsequent thermokarst development. Dealing with predicted increase in precipitations and temperatures due to climate change requires quantitative knowledge about the spatial distribution of thermokarst and these developments. In the last few years, small unmanned aerial vehicles (UAVs) and structure-from-motion multi-view stereo (SfM-MVS) photogrammetry have attracted a tremendous amount of interest for the creation of high-definition topographic data. This study detected thermokarst developments using small UAVs and SfM-MVS photogrammetry in abandoned farm lands (~ 6 ha) in Churapcha in the right bank of Lena river. We obtained ortho-rectified photographs and digital surface models with spatial resolutions with 0.05 m and 0.10 m, respectively. Preliminary results showed that more than 600 high-center polygons were developed after 1990s with averaged diameters and areas 8.2 m and 45.1 m^2, respectively. These high-definition data showed the detailed thermokarst development in the study area.

ASSESSING AND PROJECTING GREENHOUSE GAS RELEASE DUE TO ABRUPT PERMAFROST DEGRADATION

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Keywords: Ice-rich permafrost degradation; Methane; climate change; tipping point

Permafrost is a large reservoir of frozen soil organic carbon (SOC; about half of all the terrestrial storage). Therefore, its degradation (i.e., thawing) under global warming may lead to a substantial amount of additional greenhouse gas (GHG) release. However, understanding of the processes, geographical distribution of such hazards, and implementation of the relevant processes in the advanced climate models are insufficient yet so that variations in permafrost remains one of the large source of uncertainty in climatic and biogeochemical assessment and projections. Thermokarst, induced by melting of ground ice in ice-rich permafrost, leads to dynamic surface subsidence up to 60 m, which further affects local and regional societies and eco-systems in the Arctic. It can also accelerate a large-scale warming process through a positive feedback between released GHGs (especially methane), atmospheric warming and permafrost degradation. This three-year research project (2-1605, Environment Research and Technology Development Fund of the Ministry of the Environment, Japan) aims to assess and project the impacts of GHG release through dynamic permafrost degradation through in-situ and remote (e.g., satellite and airborn) observations, lab analysis of sampled ice and soil cores, and numerical modeling, by demonstrating the vulnerability distribution and relative impacts between large-scale degradation and such dynamic degradation. Our preliminary laboratory analysis of ice and soil cores sampled in 2016 at the Alaskan and Siberian sites largely underlain by ice-rich permafrost, shows that, although gas volumes trapped in unit mass are more or less homogenous among sites both for ice and soil cores, large variations are found in the methane concentration in the trapped gases, ranging from a few ppm (similar to that of the atmosphere) to hundreds of thousands ppm We will also present our numerical approach to evaluate relative impacts of GHGs released through dynamic permafrost degradations, by implementing conceptual modeling to assess and project distribution and affected amount of ground ice and SOC.

100M TUNNEL EXCAVATION WITH ARTIFICIAL GROUND FREEZING RING SUPPORT FOR THE MTR WEST ISLAND LINE C704 IN HONG KONG

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Keywords: Artificial ground freezing; Tunnel; Temporary support; Creep; Numerical thermal analysis

West Island Line Contract 704 includes 2 underground stations (i.e. Sai Ying Pun Station and HKU Station), total length 5.7 km of railway and passenger tunnels and 11 numbers of shafts. Total excavation volume is 530,000 m^3 and the scheduled construction period is 52 months.

The geological condition is mainly hard granite but the passenger adits B3 is in the completely decomposed granite, which strength is C'=5 kPa and ϕ'=39° . Because of the existence of the several old buildings above the tunnel, artificial ground freezing ring is chosen as temporary support for the tunnel in order to keep the settlement within the allowable value stated in the existing building assessment.

The construction of Adit B3 is separated into two phases. The first phase is 80m, the second phase is 20m and total 100m in length. The artificial frozen ring is designed to support tunnel for two weeks without any other support for the D=6.3m full face excavation. The thickness of the artificial frozen ring is required minimum 1.3m with the average temperature -10 (℃) assuming the visco-plastic behavior based on the laboratory test.

293mm thick shotcrete with steel fiber and steel ribs H-203x203 spacing 1m are required to be set in place within two weeks after the excavation in design.

The tunnel excavation was commenced in Nov. 2013 and was completed in Nov. 2015. The MTR Island Line was extended to Western district in December 2014, serving passengers at the HKU and Kennedy Town stations. Sai Ying Pun Station was then opened in March 2015 (the last entrance of Sai Ying Pun Station at Ki Ling Lane is targeted to open in March 2016.

Directional drilling technique for the installation of freezing pipes, laboratory test result of the frozen soil, design of the temporary support, numerical thermal analysis, monitoring and back analysis are shown in the presentation.

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METHOD OF IMPROVING UNSUITABLE SOIL WITH HIGH MOISTURE CONTENT BY USING THE COLD CLIMATE AND LARGE SANDBAGS

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Keywords: freezing-induced dehydration, frost heave, high-moisture-content soil, improvement, large sandbags

In cold regions such as Hokkaido, the ground is known to undergo frost heave in winter, which results in the formation of pieces of ice called ice lenses. When ice lenses form in the ground, structures on the ground are sometimes affected by the resulting deformation. The authors attempted to develop a method for improving high-moisture-content soil that involves the formation of ice lenses.

When the air temperature becomes low and ice lenses form in the ground, the moisture in the unfrozen soil moves toward the ground surface. This movement of moisture from the unfrozen part to the frozen part of the soil can be used to improve high-moisture-content soil by reducing its moisture content. Under natural conditions, only the surface of the ground is exposed to the air, and moisture moves in only one direction: from the unfrozen part of the ground to the frozen part. When high-moisture soil is put in a large cylindrical sand bag and placed on the ground during the cold season, it is possible for it to cool from the top and sides. In such a configuration, ice lenses form in many of the parts that are exposed to the air. More of the soil is exposed to the cold air than in the case of soil in the natural ground. Because of this exposure of high-moisture-content soil to the cold air, the moisture content inside the large sandbag decreases. The moisture that moves from the interior outward towards the surface of the soil in the sandbag evaporates through the sandbag, which additionally contributes to improvements in the high-moisture soil.

The simple experiment involved putting dredged soil with high moisture content into large sandbags, where it was left to freeze, and measuring the moisture content at fixed intervals. The moisture content of the dredged soil was found to be reduced from the initial value of 420% to the value of 140% in a year, a reduction that improved the soil.

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TOPOGRAPHIC CONTROLS ON THE ABUNDANCE OF SIBERIAN LARCH FOREST

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Keywords: Drought; Inundation; Larch; Permafrost; Siberia; Topography

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LABORATORY EXPERIMENTS ON SIMULTANEOUS FROST AND SALT WEATHERING: EFFECTS OF DISSOLVED SALTS ON FROST SHATTERING

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Keywords: Equotip hardness; freeze-thaw; freezing strain; longitudinal wave velocity; rock breakdown; Weathering Susceptibility Index

Weathering experiments were carried out to investigate the effect of dissolved salts on freezing behaviors using three types of salt solutions (sodium chloride, sodium sulphate and magnesium sulphate) and four types of rocks (two tuffs, one sandstone and one andesite). Cubic specimens with a side of 5 cm in length were separately immersed in saturated salt solution of NaCl, Na_2SO_4, $MgSO_4$ on 10°C or distilled water for 72 h. After immersion, the specimens were covered with foil and subjected to daily freeze-thaw cycles up to 120 cycles in a cold chamber. Air temperature ranges from -30°C to 10°C with a cooling rate of -4°C/h.

Temperature and strain on the surface of the specimens were measured with type-K thermocouples and liner strain gauges at 5 min intervals. Freezing points of salt solutions were decreased by dissolved salts, particularly, the solution of NaCl did not freeze under -25°C. The specimens immersed in Na_2SO_4 and $MgSO_4$ solutions showed greater freezing strains than those immersed in distilled water. The large part of these strains was induced by salt crystallization associated with freezing. Freezing strains induced by NaCl solution are comparable to those by distilled water. The magnitude of freezing strains mostly correlated with the Weathering Susceptibility Index (WSI) (Matsukura & Matsuoka 1996), which represents susceptibility of rocks to salt weathering.

Breakdown of specimens with salt solutions was more obvious than that with distilled water, though andesite showed no signs of breakdown. In the case of a type of tuff with low tensile strength, rock breakdown was mainly induced by granular disintegration and flaking. Centimeters-scale cracks were observed on some of specimens with high tensile strength, specifically another type of tuff and sandstone. The longitudinal wave velocity (Vp) and the Equotip hardness value (L-value) (Verwaal & Mulder 1993) of the specimens were measured every 10 freeze-thaw cycle. The reduction rates of Vp and L-value were also correlated with the index. These reduction rates under the condition, in which salt weathering and frost shattering simultaneously occurred, were rather greater than single salt weathering (Sato et al. 2014) or frost shattering (Matsuoka 1990).

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MONITORING OF GROUND ICE CHANGES WITH COMPACT DIGITAL CAMERA WITHIN A TALUS SLOPE IN ODATE, JAPAN

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Keywords: scree slope; ice formation; extra-zonal permafrost

Sporadic occurrence of small permafrost in scree or talus slope gathers great concern for a decade. Most of those studies are mainly focused on heat anomaly between upper and lower part of talus slopes. Meanwhile, only few studies focused on formation process of ground ice in the slopes. We monitored changes of ground ice in spring with an interval digital camera with flush light, and found the ice was formed by refreezing of snow-melt water percolated into pore-spaces in the talus slope.

Study site is located in lower part of western-facing slope in Mt. Kunimiyama in Odate city, Akita prefecture. MAAT of 30 years average in the nearest metrological station is +9.4°C. The area is designated as a natural monument to protect alpine plants which cover colder area of the talus slope. Local people made several small cold storages in 100 years ago. These storages are currently not in use, and opened for public sightseeing. The storages are constructed under the ground surface, enabling direct observation of ground ice formation and ablation which occurs every year.

A compact, water-proof digital camera (PENTAX Optio W20) with external lithium batteries are placed in a cold storage (190m a.s.l.), to take pictures of ice which is formed on rock-piled wall. Monitoring was carried out from 28 March to 1 June (94 days), at intervals of 90 minutes. Inside and outside air temperature were also monitored with small data-loggers. We measured heights of ice mass formed on the horizontal steel beam supporting the rock-wall. In addition, occurrence of percolating water is visually checked in the pictures.

Timing of ice formation is controlled by infiltration of snow-melt water into the storage. The outside temperature had started to fluctuate between -5 and +10°C from 25 March. In this period, melting of the snow pack may start, due to positive temperature and heavy rain fall in 28-30 March. On 1 April, ground water appeared on the rock-wall of the storage, and formation of ice began. In this time, the inside air temperature was -2°C. The water percolation and ice accumulation occurred intermittently until end of the freeze-thaw period of outside temperature. Continuous accumulation of ice continued until the inside temperature reaches to 0°C (6 May). We conclude the percolating water and sub-zero inside temperature are fundamental conditions for ice growth within the talus slope.

THE EFFECTS OF GROUND SURFACE CONDITIONS ON SOLIFLUCTION SPEED ON A TEMPERATE LOW-MOUNTAIN PEAK IN NORTHEASTERN JAPAN

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Keywords: ground surface conditions; Goreibitsu pass; low mountain; solifluction speed

Surface stone movement by periglacial processes has been observed and recorded mostly in the areas of high altitude or high latitude. Similar processes can occur in the low montane zones when forest cover was removed, as reported by Sawaguchi (1987) on the Kitakami Mountains in northeastern Japan. Some differences may intervene, however, between the apparently similar processes in different climatic zones.

Connecting the Inawashiro Basin to the west and the Koriyama Basin to the east, Goreibitsu-toge is a pass across the Ou Backbone Range of northeastern Japan at about 37°N. The Inawashiro Basin is known as to contain some spots of deep snow accumulation exceeding 3m. Deciduous forest which is dominant in the mountains is lacking in relatively small areas on the western sides of the main divide including the pass, where westerly wind is very strong particularly in winter. The strong wind may hinder the growth of tall trees and is enough to blow off snow. Geologically the area around the pass is composed of mid-Miocene tuffaceous sandstone which tends to exfoliate easily from thin laminae.

We have carried out the measurement of surface stone dislocation every winter since 2006 using a paint-line method. At the same time, we observed ground-surface condition, e.g., accumulation of flat stones, exposure of soil, etc. Also, air temperature and soil temperature were observed continuously. Comparison of ground- and soil-temperature suggests that freezing occurred in the very shallow soil horizon less than a few centimeters below the ground. Needle ice development up to 7cm high was also observed in the same horizon. In the climatic condition that is annually temperate and rather severe in winter, active downslope dislocation of surface stones up to 1m or more was recorded every winter. The maximum dislocation in a winter season reached 1.2 m and each straight paint-line was deformed downslope to a zigzag one with lobes where long-distance dislocation was observed.

Ground-surface condition is divided into the following two types: C type which is covered with angular flat stones, and the F type where fine earth is exposed. Seto et. al. (2014) revealed that solifluction speed was bigger in F type ground than C type one, based on the observation of the ground-surface type of rather small area where each dislocated stone reached. The present study investigated the relation between solifluction speed and ground-surface condition which was surveyed more extensively using UAV system.

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STUDY ON GROUND THERMAL REGIME OF A CAST-IN-PLACE PILE IN UNSTABLE WARM PERMAFROST REGIONS DURING CONSTRUCTION

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Keywords: Permafrost regions; bridge; cast-in-place pile; ground temperature field

Abstract: A pile foundation of Huashixia test site which is belong to unstable warm permafrost regions (-1.0 ℃≤TCP<-0.5 ℃) along the Xining-Yushu Highway 214 was chosen to analyze the characters of ground temperature of a pile foundation during construction. Based on the temperature field observation of permafrost around the pile foundation, the influence of concrete hydration heat on the ground thermal regime was simulated. Results show that the thawed depth and the temperature of the pile-side decrease with time. The thawed depth of the pile-side was 1.6 m deeper than that in natural condition and the mean temperature of the pile-side was 0.36 ℃ higher than the natural after the pile constructed 1 year. The influence difference of concrete hydration heat was not obvious when the concrete model temperature increases from 5 ℃ to 10 ℃, so the reasonable model temperature is recommended to be 10 ℃. When the model temperature was 10 ℃, the environment temperature of pile would be above 0 ℃ in 30 days after pile construction. Experiences learned from this study will be of value for future construction of pile foundation in unstable warm permafrost regions.

THERMAL INSULATION OF VEGETATION AND SNOW COVERS AND ITS EFFECT ON PERMAFROST CONDITIONS IN MONGOLIA

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Key words: Thermal insulation, snow, vegetation, temperature, permafrost, soil, Mongolia

One of main parameters for estimating temperature regime in formation of permafrost is thermal insulation (TI) value of vegetation and snow covers (Kudryavtsev et al. 1974). During last 10 years, the TI of soil surface cover in Mongolia has been studied by recordings of temperature data loggers at a number of experimental sites located in Dalbay (Eastern Hovsgol) and Selbe (near Ulaanbaatar) valleys, Hustai, and other areas. As a result of the experimental studies, the authors estimated TI values of different vegetation and snow covers which can affect values of change in mean winter, summer and annual soil surface temperatures. As compared to Arctic zone, these TI values in Mongolia are high, due to high air (summer and winter) temperature amplitudes. The results are as follows: In summer vegetation cover protects soil from strong heating. Therefore, summer soil surface temperatures under vegetation cover due to its TI are colder than bare surface. TI value of vegetation depends on its species, biomass and shadiness. Maximum TI value up to 10-15°C is observed in hot days of July. Average summer TI value of different vegetation (dense grass, shrub, bush, forest and moss) covers in the Dalbay valley varies 2-9°C, as compared to bear surface (Anarmaa et al. 2008). There was a direct relationship between biomass and TI value of grass on Hustai steppe (Sharkhuu & Anarmaa. 2012). In winter, snow cover becomes TI factor protecting soil from strong cooling. Average winter TI value of snow cover with 10-20 cm thickness and 0.15-0.25g/cm^3 density in Selbe valley and Hustai area was about 3-5°C. In the coldest January, TI value of 15 cm thick snow in the Selbe valley reaches 0-5°C in daytime and 10-15°C in night-time (Sharkhuu & Anarmaa. 2015). Meanwhile, snow cover sometimes manifests a slight negative TI effect or good conductive effect for short-time in November and April. Cooling TI effects of vegetation in summer compensates warming TI effects of snow covers in winter. Consequently, mean annual TI values of cooling vegetation or warming snow covers vary within 0.5-1.5°C. For example, when thickness of snow was 15-20 cm, the summer and annual TI values of cooling larch forest with dense canopy in Ardag Mountain (Hovsgol) were 3.4°C and 1.0°C, respectively. These results show that vegetation and snow covers have strong effects not only on soil temperature regime, but also on permafrost conditions such as permafrost distribution, active layer thickness and some cryogenic processes. In particular, patchy and island permafrost in Mongolia usually occurs at sites with forest, moss and dense shrub covers. In comparison with grassland, active layer thickness in forest decreased by about 15-30%. Dynamics of frost crack, heaving and icing from cryogenic processes depends on TI effect of snow cover on considerable degree. Besides, depths of seasonal freezing of ground vary by about 5-20% in relation to different thickness of snow cover.

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ESTIMATION OF ACTIVE LAYER THICKNESS IN DISCONTINUOUS PERMAFROST AREA, IN CONNECTION WITH GROUNDWATER

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Key words: active layer thickness; ground temperature; water, Mongolia; n-factor

Permafrost in semi-arid mountainous areas plays in an important role in hydrology and it governs ecosystem functions (Walker et al. 2003, Ireson et al. 2013). Particularly, changes in active layer thickness due to climate change can affect groundwater storage, base flow, streamflow and nutrient transport (Carey & Woo 2005, Frey & McClelland 2009, Muskett & Romanovsky 2009). Thus, the seasonal freezing depth and active layer thickness are important variables.

In order to study active layer thickness in discontinuous permafrost area, in connection with hydrology, Kudryavtsev's approach (Kudryavtsev et al. 1974) was used to estimate the active layer thickness. Meteorological data, local data on snow cover, vegetation, soil moisture, thermal properties etc. are used to simulate active layer thickness spatially in Baga Bayan watershed, near Ulaanbaatar, Mongolia. In addition to locally obtained surface temperature data, we also used MODIS LST (land surface temperature) products. The output of the Kudryavtsev's approach is validated against temperature data obtained from year-round measurements made in four boreholes drilled across the Baga Bayan valley. Preliminary results show that the estimated active layer thickness using Kydryavtsev's approach was consistent with the estimated active layer thickness using ground temperature data from borehole measurements. The estimated active layer thickness using Kydryavtsev's approach ranged between 1.8-2.2 m on average in this watershed. While the maximum active layer depth estimated from borehole temperature was 3 m, the average active layer depth was 2.5 m. Further, n-factor which is a ratio of freezing degree days (FDD) and thawing degree days (TDD) of ground surface temperature and FDD and TDD of air was estimated to improve model and to take account of snow and plant insulation effect. When we updated our models using the n-factor the updated models fitted better than the original models according to the maximum likelihood analysis.

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HIGH-RESOLUTION MAPPING AND SPATIAL VARIABILITY OF SOIL ORGANIC CARBON IN PERMAFROST ENVIRONMENTS

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Keywords: Soil; Organic Carbon; Spatial Variability; Remote sensing; Digital Soil Mapping

Mapping soil organic carbon (SOC) provides a first order variable for predicting the carbon balance of permafrost environments under a changing climate. We present high-lights from mapping SOC at very high spatial resolution from five study areas in the northern circum-polar permafrost region. These study areas are located in Siberia (Kytalyk, Spasskaya Pad / Neleger, Lena delta), Northern Sweden (Abisko) and Northwestern Canada (Herschel Island).

We show improvements in thematic mapping methods using very high-resolution satellite imagery (<6.5 m), such as the use of object-based classification methods and data-fusion. New machine-learning methods such as support vector machines, artificial neural networks and random forests are explored for digital soil mapping of SOC as a continuous variable. We present statistical analyses that give insights to the spatial and vertical distribution of key soil variables.

Overall, we find higher SOC storage in Arctic tundra soils compared to Boreal and sub-Arctic taiga soils. However, less SOC is actively cycling through the ecosystems in the tundra as the active-layer is significantly shallower. The vast majority of total ecosystem C is stored in soils, as opposed to vegetation, suggesting that increased vegetation growth is unlikely to fully offset the release of previously frozen SOC under warming (Siewert et. al 2015). For all five study areas we find a very strong influence of land forms and geomorphology on the spatial and vertical distribution of SOC. This geomorphic control is documented from the scale of individual soil horizons to the landscape scale. We emphasize that the main limiting factor for detailed mapping of permafrost carbon is the low availability of high-quality field-data. Newly collected soil pedon data should distinguish at least into the surface organic layer, the mineral subsoil and organic enriched cryoturbated or buried soil horizons and should further differentiate into the active layer and permafrost (Siewert et al. 2016).

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GROUND FREEZING METHOD UTILIZING CO_2 LIQUID GAS TWO PHASE FLOW
RESULTS OF A PERFORMANCE TEST, AND A CASE STUDY OF THE APPLICATION TO TBM ARRIVAL TO THE SHAFT

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Keywords: NH_3/CO_2; CO_2 emission; environmentally friendly;
energy saving; ground freezing; TBM tunnel

Soil freezing is widely recognized as an environment friendly method because the ground is firmly consolidated by only freezing pore water in soil and nothing is left in the ground after it melts. Strength and water tightness of frozen soil is comparable to that of concrete, and it is often used as an auxiliary for tunnel construction for urban soft ground at a large depth under high water pressure. In Japan, large-scale projects of railway/trunk road are being promoted towards Tokyo Olympic Games in 2020, and it is expected that many ground freezing methods will be adopted.

In recent years, NH_3/CO_2 system has been spreading remarkably in the refrigeration and air conditioning industries, CFC elimination should also be promoted in the field of civil engineering in considering mitigation of global warming. By combining NH_3/CO_2 system with the ground freezing method, many merits can be obtained. Not only will the refrigerator uses natural refrigerant, but the flow rate of CO_2, in the place of brine, circulating in the underground freezing pipe becomes 1/10 of that of conventional brine, so that the liquid feed pump, the heat exchanger, and freezing pipe can be downsized, and that leads to the saving in the power consumption by 40%. With a small amount of CO_2 to efficiently withdraw heat from the ground, a flat porous pipe made of aluminum (aluminum microchannel) was used. This aluminum microchannel is light weight (300 grams/meter), free to bend and stretch, and can be manufactured seamlessly up to about 100meters. Therefore, it does not need to weld pipes at the site, it will be the work to only insert pipe into the ground by human power.

In order to determine optimum ground freezing specification, we carried out a total of three experiments including basic experiment in a small (2m3) water tank, demonstration experiment at an experiment shaft, and demonstration experiment in the real ground. CO_2 circulating through the freezing pipe has a temperature of -30 to -45 degrees C, and a pressure of 0.7 to 1.5 MPa, however, there was no problem in control of temperature and pressure during operation, which was stable for more than a month and proved to create frozen soil equivalent to or more than the one using conventional system. In the demonstration experiment in the real ground, we drilled to 15 meters deep, and installed 10 freezing pipes to create frozen soil. 5 of those having freezing part set at the interval for 5 meters from the bottom while 10 meters from the ground was set unfrozen. In either case, frozen and unfrozen soil was created as expected. Assuming that CO_2 is flown over long distance at the site, CO_2, flown through a 150 meter long steel pipe of 20A to 80 A connected to the freezing pipe, was confirmed to have reached freezing pipe with a liquid of a predetermined temperature.

In this fiscal year, the ground freezing method using NH_3/CO_2 system was adopted for the first time for the shield tunnel construction for a power station in Japan. The tunnel is 4.7 meters in diameter and 1 kilometer in length, and is for releasing seawater pumped and used as cooling water out of the bay. For creating frozen soil to stabilize the opening upon the TBM arrival at the shaft, freezing pipes were installed inside TBM. The model experiment was carried out prior to construction and obtained good results. The freezing period at the site is scheduled for January to March 2017, and we will report on the results of actual construction at the July meeting. The improvement in environmental aspects and the construction cost are expected by implementing this system. We expect that introduction of this system increases the adoption of ground freezing method which improves in terms of environment and cost, and is friendly to the natural environment.

MONITORING OF SURFACE STONE MOVEMENT ON THE GOREIBITSU PASS IN FUKUSHIMA PREFECTURE, JAPAN

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Keywords: Freeze-Thaw; Monitoring; Surface stone movement; Windward bare ground

Patches of windward bare ground are distributed on a mountain peak in the temperate forest zone of Japan. The altitude of the peak is 980m above sea level and MAAT is about 8 degrees C. Bare ground patches result from the strong prevailing wind which blows off snow from the ground surface in winter. Freeze-thaw days occur from November to April, and needle ice is sometimes visible on the bare ground in a freeze-thaw season.

Continuing observation revealed that maximum displacement of stones in winter reaches about 1m on a sloping ground about 10 to 20 degree slant near the Goreibitsu Pass, Fukushima Prefecture, Tohoku district, Japan (Seto et al. 2011). We observed continuously the surface stone movement and elucidated that the major movements of the stone occurred during thawing periods (Sone et al. 2013)

The monitoring site is situated on a bare ground patch dipping 30 degrees to the west. We measured the surface stone movement using the real-time monitoring method (Harris et al. 2007) since 2010. Two linear displacement sensors were installed on the stable mounting frames. These sensors are arranged in an inverted triangular configuration with the triangle apex linked to a small footplate embedded in the target stone. They allow continuous monitoring of frost heave, thaw settlement and downslope surface displacements. The values of the resistive sensors were stored to a data logger at 1 hour interval. The size of the target stone is 20 x 15 x 2cm. The bottom temperature of the target stone and ground temperatures at the depths of 2, 4, 6, 8, 10, 20, 30, 50cm were measured at 1 hour interval. A time-lapse camera was also installed to analyze the surface stone movement.

Data are presented illustrating the contrasting thermal regimes, and timing of frost heave and thaw settlement. PFC (potential frost creep), and solifluction processes, and the contributions of diurnal and seasonal frost to the stone movements are discussed.

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MONITORING OF FREEZE-THAW DEPTH USING LARGE NUMBERS OF TEMPERATURE SENSORS

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Keywords: Arduino; Freeze-thaw depth; Monitoring; One-wire temperature sensors

In order to monitor freeze-thaw depth automatically and continuously we measured ground temperatures at 2cm depth intervals from the ground surface to a maximum depth of 60cm in seasonal freeze-thaw area in 2015-2016. The results of the interpolated freezing depths were compared to the manual measurements with frost tubes.

To detect freeze-thaw depth by ground temperatures, it is favorable to measure ground temperatures at many different depths. However, as normal temperature sensors such as thermistor and Pt100 sensors have own cables, the number of the sensors is limited to install in a borehole. For this reason we applied one-wire temperature sensors which have the advantage of installation (Sone et al. 2014). They are able to be installed at a borehole with an inside diameter of as small as 10mm. DS18B20 are semi-conductor temperature sensors with resolution of 0.0625 degrees C. The sensors are configurated at intervals of 2 cm on the circuit board of 8 mm wide and 200 mm long. Three circuit boards are linked to extend the depth of 60 cm. They were inserted into 13 mm outside diameter radiant heat tube (inner tube). The inner tube was inserted into 16 mm inside diameter CPCV Pipe (outer tube) buried in the soil. Data loggers were developed using Arduino, which is a low-cost device based on the use of open-hardware electronics. Acquired data are stored into a Micro-SD card. A set of the logger and sensors can operate for more than one year at hourly intervals with 3 AA dry batteries under field conditions. From the point of view of management, this device is superior to FTS (Freeze-Thaw Sensors; Mori & Sone, 2014) which is also suitable for the monitoring freeze-thaw depth in a small diameter borehole.

Test sites are situated in Tokachi and Kushiro districts, in eastern Hokkaido, Japan. At both test sites freezing depths were measured by frost tubes. The sensors were calibrated in a laboratory before the installation.

Both data from temperature sensors and frost tubes are presented illustrating the ground thermal regimes.The accuracy and the advantages of the instruments are discussed.

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ACTIVE LAYER THICKENING IN THE NORDIC REGION, OBSERVED THROUGH THE CIRCUMPOLAR ACTIVE LAYER MONITORING (CALM) PROGRAM

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Keywords: active layer thickness; Arctic; Greenland; permafrost thaw; Svalbard; Sweden

Manual active layer probing in northern Sweden, northeast Greenland, and central Svalbard reveals active layer thickening has occurred since the inception of the Circumpolar Active Layer Monitoring (CALM) program. Interannual variability in active layer thickness (ALT) is unique to each site. Measurements made near Abisko, northern Sweden, indicate an increase in ALT by 21-46 cm, depending on the specific subsite, since 1978. Lowland permafrost disappearance is also occurring in this area of discontinuous and sporadic permafrost. In Zackenberg, northeast Greenland, two grids, ZEROCALM1 and ZEROCALM2, have been probed at 14-day intervals during the thaw season since 1996. Changes in ALT are similar in the two grids, though ZEROCALM2 exhibits a consistently thinner active layer due to greater snow accumulation in the winter. From 1996 to 2016, ALT increased 1 cm per year at ZEROCALM 1 and 0.7 cm per year at ZEROCALM 2, estimated via linear regression. Thaw progression and ALT measurements in the Advent Valley, central Svalbard, show an increase in ALT since 2000 of approximately 0.8 cm per year. Since 2006, ALT has been 1 m or greater. The variability in estimated ALT increase is 0.6-1 cm per year among the Nordic sites. The comparison of ALT at the presented sites with meteorological parameters (e.g. summer air temperature, cloud cover, and precipitation, in addition to the timing and depth of snow cover) indicates that meteorology's influence on ALT is location-dependent. For example, annual ALT in central Svalbard does not correlate with summer air temperatures, whereas ALT in northern Sweden and northeast Greenland does exhibit this relationship. Winter conditions better explain measured ALT in Svalbard, as ALT correlates with the sum of daily air temperatures during the winter preceding thaw.

FILLING A WHITE SPOT ON THE YEDOMA MAP: THE BALDWIN PENINSULA, WEST ALASKA

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Keywords: Alaska; Arctic; Deep Carbon; Degradation; Syngenetic Permafrost; Thermokarst

Vast regions of Arctic Siberia, Alaska and the Yukon are covered with ice-rich silts penetrated by large ice wedges, resulting from syngenetic sedimentation and freezing during the Pleistocene. These deposits are termed yedoma permafrost. Because of rapid incorporation of organic material into permafrost during sedimentation, yedoma deposits are expected to store poorly degraded organic matter. The total amount of organic carbon in the yedoma region is estimated to be approx. 400 gigatons. As a consequence of the high ground ice content, yedoma deposits are especially prone to degradation triggered by climate changes and/or human activity. When yedoma deposits degrade, large amounts of previously sequestered carbon as well as nutrients will be released which is of global significance for the climate system.

Following on the tracks of permafrost pioneer David M. Hopkins, who studied this region during his conceptualization of the Bering Land Bridge in the 1950/60s (Hopkins et al. 1959, 1962), we conducted a field campaign to the Baldwin Peninsula in West Alaska. Based at the town of Kotzebue, one of the aims of this expedition was to describe yedoma landscapes and start a carbon inventory of this previously undocumented part of yedoma. The intention was to search for and characterize yedoma deposits whose presence was inferred from landscape morphometrics typical for yedoma (deep thermokarst lake basins, multiple overlapping lake basin generations, rolling hills with uplands where small deep thermokarst ponds are found, steep erosion margins along lake and coastal shores) on the neighboring Seward Peninsula and in Siberia as identified in remote sensing imagery. We were able to identify several yedoma upland exposures eroded by the Chukchi Sea on the western shore of the Baldwin Peninsula. We found clear evidence of yedoma permafrost occurrence at Cape Blossom, 20 km south of Kotzebue. We used a cryostratigraphical approach to sample yedoma and drained thaw lake basin exposures at this site. Moreover, different generations of drained lake basins in the hinterland of the cape were sampled with a SIPRE permafrost auger. For landscape scale estimation we used Landsat and high resolution WorldView imagery, airborne IfSAR digital elevation datasets as well as aerial survey flights during the expedition.

The yedoma layer at Cape Blossom was characterized by a height of approx. 12 m including massive syngenetic ice wedges. The mean carbon content of the 7.8-m high sampled profile was 2.0 wt%. The average ice content for the sediment, not including ice wedges, was 45.2 wt%. Another bluff close by exposing sediments of a drained thermokarst basin contains 6.8 wt% carbon and 41.1 wt% pore ice. We were able to detect a chaotic layer at the bottom of the sediment sequence indicating lake initiation.

This study gives evidence for the occurrence of ice-rich late Pleistocene yedoma deposits in Western Alaska. This yedoma is of importance because of its paleoenvironmental implications for the widespread occurrence of yedoma in the Bering Land Bridge region (e.g. mammoth steppe conditions), as well as for the future vulnerability of the landscape to thaw because of its high excess ground ice content. Permafrost thaw will affect these yedoma areas first, as its location is close to the continuous/discontinuous permafrost zone border, with the result that a considerable amount of carbon becomes available for microbial activity.

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INFLUENCE OF GROUND FREEZING ON GROWTH OF *LARIX KAEMPFERI* IN SEASONALLY FROZEN GROUND REGIONS THROUGH TREE RING ANALYSIS

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Keywords: Annual maximum frost depth; Ground freezing; *Larix kaempferi*; Rootlet; Tree ring analysis

In seasonally freezing area, the ground freezing has been changing under global climate changes (Venalainen *et al.*, 2001, Zhao *et al.* 2004, Harada *et al.* 2009). Further, the climate is well known to influence the growth of trees, thereby the past meteorological information is recorded as the tree ring width (Fukazawa 1990). The tree ring width has been investigated the correlation with some meteorological factors, such as the annual maximum temperature (Takeichi 1988) and the relative humidity (Liang *et al.* 2013), however it has hardly any relation with the frost depth. In order to evaluate the influence of ground freezing on the growth of larch (*Larix kaempferi*), a correlation analysis was conducted between tree ring width and meteorological factors in Tokachi district, eastern Hokkaido in Japan, which is characterized by low temperatures and thin snow cover in winter.

In the methodology, it prepared 40 samples for the tree ring analysis which were taken each 2 samples by an increment bore, 10 mm diameter, from 20 trees selected in the larch trees to compose the windbreaker in this study district. Pictures of specimen adjusted a sample to 1.5 mm in thickness was captured by the scanner and was analyzed by the software "Win DENDRO". Further, the information of tree ring width was standardized by the program ARSTAN (Cook & Peters 1981) and presented as TRI (tree ring index).

As a result, TRI among the 20 trees has a correlation coefficient of 0.646, presented as the standardized tree-ring chronology in this study area. The TRI using a 32 years series, shows a negative relation with the annual maximum frost depth with a correlation coefficient of -0.451 ($p<0.01$), however it does not any correlation with freezing index. It instead shows a weak correlation (0.312, $p=0.08$) with the annual maximum snow depth. Further, it has a weak correlation (0.28, $p=0.08$) with the annual average temperature. The average value of annual maximum frost depth is 0.25 m, which is equal to the distribution range of larch tree rootlets (Karisumi 1979). Taking into account that the surface soil around larch roots is frost-susceptible, frost heave increases the risk of rootlets damage increasing annual maximum frost depth. The rootlet damage suppresses growth of larch so that the width of tree ring decreases.

Based on these findings, the growth of trees in the seasonally frozen ground regions is closely related to the soil frost depth and the snow depth.

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IBED DRILLING SYSTEM FOR CORING IN POLAR ICE AND SUBGLACIAL PERMAFROST

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Keywords: subglacial drilling, movable drilling shelter, cable-suspended electromechanical drill

Antarctica contains 37% of the world's permafrost (Bockheim and Hall, 2002). Permafrost exists throughout ice-free areas of the Antarctic, as well as underneath about one-fourth area of the Antarctic Ice Sheet. Samples of basal and subglacial material contain important paleo-climatic and paleoenvironmental records and provide a unique habitat for life, give significant information on basement deformation beneath the ice sheet, subglacial geology, and tectonics. Drilling operations in Antarctica are complicated by extremely low temperature at the surface and within ice sheet, by ice flow, the absence of roads and infrastructures, storms, winds, snowfalls, etc. All those are the reasons that up to the present moment bedrock cores were never obtained at inland of Antarctica (Talalay, 2013). To get samples of subglacial rocks in the frozen-bed conditions (in order to avoid contaminating the subglacial hydrologic environment areas), the use of cable-suspended drilling technology is proposed. All drilling equipment is installed inside a movable, sledge-mounted, temperature-controlled, and wind-protected drilling shelter and workshop connected by steel pathway. To drill through ice and bedrock, a new version of the cable-suspended Ice and Bedrock Electromechanical Drill (IBED) was designed and tested. The IBED drill has a modular construction that permits the accomplishment of three different tasks: (1) a large-diameter auger for dry core drilling in the upper snow–firn layers, (2) an ice core drill with near-bottom fluid circulation, and (3) a bedrock core drill. The different sections of the drill are easily replaced. The upper part is almost the same for all variants and includes four sections: cable termination, a slip-rings section, an antitorque system, and an electronic pressure chamber. The inner diameter/outer diameter (ID/OD) of the ice core drill head is 105/136 mm. The ID/OD of the diamond bit is 41.5/60 mm. During the 2017–18 season, the drilling shelter and workshop will be assembled near the Zhongshan Station, and trial operational inspections will be conducted near the station. Drilling for bedrock at the central part of East Antarctic Ice Sheet is planned as soon as full financial and logistical support is obtained for the project.

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GEOMORPHOLOGICAL MAP OF A POST GLACIAL-PERIGLACIAL LANDSCAPE: BRAMADERO RIVER BASIN (CENTRAL ANDES, ARGENTINA)

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Keywords: Geomorphology; mountain permafrost; Central Andes; Argentina

This work presents a detailed geomorphological map of a relatively little studied region in the Central Andes of Argentina. Here, we combine geomorphological and geocryological investigations in the post-glacial landscapes in the Bramadero river valley (located in the homonymous basin) in the Central Andes of Argentina in order to reconstruct the relationship between glacial and periglacial phenomena, as well, as to outline a chronological model of their evolution. Final map presented at 1.10.000 scale indicates the presence and extension of geoforms and geomorphological process above an area of 250 km^2 and is the result of a detailed interpretation based on imagery from different sensors and data extraction using digital elevation models.

Bramadero river valley is located in the Central Andes of SW San Juan (Argentina) at 31° 50' S and 70° 00' W. Weather conditions in the region show a well-defined seasonal regime with maximum precipitation (300-400 mm/yr) during the cold season (April-October) and scarce precipitation during warm season (November-March). A weather station placed on the bottom of main valley recorded a MAAT (Mean Annual Air Temperature) of -2.15 °C between 2009-2014 at a height of 4019 m asl.

Based on the digital analysis of high-resolution images five groups of geoforms were discriminated according to morphogenetic criteria: 1) glacial geoforms and related deposits; 2) periglacial geoforms; 3) mass wasting deposits; 4) alluvial and fluvial geoforms and 5) polygenetic geoforms. Extraction of topographic parameters from a digital elevation model also allowed the quantification of topographic determinants for each one of them.

Only 34% of the total surface (ca. 87 km^2) is occupied by bedrock, while 66% (167 km^2) exhibits geoforms resulting from active processes. Rock glaciers are the conspicuous cryoforms in the landscape and the most representative form of creeping permafrost together with protalus lobes and protalus ramparts; other periglacial cryoforms include cryoplains and frozen talus slopes. Igneous bedrock outcrops are widespread on the west and middle sides of the basin while towards the eastside, sedimentary bedrock is exposed. Soli- and gelifluction, debris flows, snow-debris avalanches among other mass wasting processes, fluvial erosion, nivation and deflation are the most common processes on the upper slopes. These, supply the lower slopes with coarse-grained and block-sized sediment that accumulates on different geoforms that aggrade below free bedrock surfaces (debris cones, non-vegetated alluvial fans, protalus forms and rock glaciers in different stages of development) resulting in a highly active system in continuous evolution under periglacial present conditions.

Bramadero river basin was largely glaciated during the last glaciation, even today it is possible to recognize erosive forms and glacial deposits all over the main valley and subordinated creeks. Remnants glaciers bodies (glaciers and debris covered glaciers) only cover up to 2% of basin surface (ca. 0.8 km^2) above 4300 m asl, while Holocene glacial deposits occupy 11.5% of the basin (ca. 30 km^2), and can be found downstream up to ca. 2700 m asl. Currently, periglacial processes are active in elevations exceeding 2700 m asl (lowest limit of seasonal freezing), however, a wide variety of periglacial deposits and permafrost indicators cryoforms occurs between 3500 and >4500 m asl (permafrost periglacial belt) (Tapia & Trombotto 2015). Concluding, Bramadero river valley exhibits evidence of past periods with enhanced glacial and periglacial activity. The degree of post-glacial periglacial landscape transformation is likely linked to climatic trends as well to geological and hydrological settings.

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MODELING THE GROUND RESISTIVITY FROM UNFROZEN WATER CONTENT IN FINE-GRAINED HIGH-LATITUDE PERMAFROST

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Keywords: time lapse electrical resistivity tomography; unfrozen water content; coupled modeling; permafrost monitoring; fine-grained permafrost

Combination of time lapse electrical resistivity tomography (ERT) measurements, soil water content and borehole temperature measurements promises to hold better calibration for permafrost models (e.g. Pellet et al., 2016). The coupled modeling approaches rely on identification of valid petro-physical relationships, calibrated for the given geological setting. In this work, we use three years of monitoring data from a high-latitude permafrost site to model the relationships between ground temperature, unfrozen water content (UWC) and resistivity. 1D resistivity soundings were measured daily, and ground temperature and water content were monitored at three-hourly intervals at a site in continuous, fine-grained permafrost near Ilulissat, West Greenland (69° 14′ N, 51° 3′ W, 33 meters above sea level).

Between onset of freezing and ground temperature decrease down to -4°C at 0.3 meters depth, the volumetric UWC is reduced from 70% to 25%. This is accompanied by an increase in ground resistivity by two orders of magnitude, from $10^2\Omega$m to $10^4\Omega$m, within a period of three weeks. The minimum observed winter temperature at this depth is -17°C, and the corresponding minimum UWC is 18%. The resistivity at these temperatures could not be measured due to high electrode grounding resistances reaching up to 170 kΩ (Tomaskovicova et al., 2016). However, the maximum recorded resistivities are in the range of $4\times10^4\,\Omega$m at a ground temperature of -10°C.

The UWC is the main parameter effectively controlling measured electric response of the ground at subfreezing temperatures. To test how the two are linked, we use the measured UWC to calculate a theoretical effective ground resistivity and compare it to the inverted resistivity measured at the field site. Knowing the UWC, volumetric fractions of ice and soil matrix can be calculated while assuming fully saturated soil and constant porosity throughout the simulation. The effective ground resistivity is estimated through geometric mean of specific resistivities of the respective soil constituents.

The model reproduces the observed increase in ground resistivity upon freezing very well. However, although there is good correlation between fluctuations in the observed and modelled ground resistivities in the frozen period, the amplitudes of the observed resistivity fluctuations are larger than those of the predicted. We speculate that variation in the electrode grounding resistances (correlated with surface temperature) contributes to larger amplitude excursions of the observed resistivities – a behavior that cannot be reproduced from UWC alone. During the thawing, the rate of decrease in ground resistivity is faster than increase of UWC. Consequently, for comparable UWC the observed resistivity during thawing is one order of magnitude lower than the resistivity during freezing. A plausible explanation is that even a slight increase in UWC during thawing creates current pathways sufficient for reduction of the ground resistivity. Microscopic processes of ice formation and melting likely contribute to different relationship patterns during freezing and thawing.

Our results indicate that timeseries of complete freeze-thaw cycles with sufficient sampling frequency (daily measurements for resistivity, up to 8 measurements per day for UWC) are necessary to accurately map fast temporal changes in UWC and ground resistivity during phase change, particularly if relationship between the two variables is to be used in calibration/validation of permafrost models.

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MODELING IN-SITU HYSTERETIC VARIATION OF UNFROZEN WATER CONTENT IN HIGH-LATITUDE FINE-GRAINED PERMAFROST

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Keywords: unfrozen water content, freeze-thaw hysteresis, thermal modeling, fine-grained permafrost

Unfrozen water content (UWC) is one of the key variables in modeling of thermal regime of permafrost as it influences calculation of bulk soil thermal parameters (e.g. Romanovsky & Osterkamp 2000). However, in-situ UWC measurements from periglacial environments are sparse and continuous timeseries over several complete freeze-thaw cycles are rarely available for validation of UWC parameterization schemes.

One of the models that describe variation of UWC with sub-freezing temperature T in fine-grained soil is a power function: $\theta(T) = a|T|^{-b}$ where $a, b > 0$ for $T < T^* < 0°C$ (Lovell, 1957). a and b are empirical parameters that require site-specific calibration. T^* is the lowest temperature at which all water in the soil sample is unfrozen; it depends on the soil grain size and freezing point of the pore water as a free substance.

With availability of 3 years of in-situ monitoring data from fine-grained high-latitude permafrost, we describe seasonal UWC dynamics in the active layer. We calibrate the parameters of the UWC model using one year of UWC and ground temperature records. We then use the calibrated model to predict UWC from ground temperatures in the following two years. The UWC was monitored at a site in Ilulissat, West Greenland (69° 14' N, 51° 3' W, 33 m above sea level), situated in continuous permafrost with mean annual air temperature -5.1°C (years 2003 - 2012). Core samples from the site contain up to 55% clay (grain size < 2µm) and 25% fine silt (grain size 2 - 6µm). Active layer thickness is 0.9 meters. The volumetric UWC and ground temperature are measured in 3-hourly intervals, 8 times per day, with two Steven's Hydra Probe II SD-12 sensors employing frequency domain reflectometry technology. The two sensors are placed at depths of 0.3 and 0.55 meters respectively.

The UWC dynamics are distinctly different between periods of soil freezing and thawing respectively. UWC during freezing is up to 50% higher than during thawing at the same ground temperature. Zero-curtain conditions during freezing lasts for ca. 3 weeks, during which UWC decreases steadily. On the contrary, the thawing of same volume of water happens abruptly over the course of ca. 2 days according to the sensor measurements. Microscopic processes of ice formation and melting likely contribute to different rates of freezing and thawing. Different freeze-thaw patterns can be observed even during events of partial thawing during frozen period. Nevertheless, we observe that the freezing and thawing patterns respectively remain the same every year. Between ca. 15th June – 31st August, the ground is unfrozen at the sensor depth and soil drying and possibly water runoff dominate the UWC variation despite low hydraulical conductivity of the soil.

Due to the observed freeze-thaw hysteresis, we split the UWC calibration into two seasons and calibrate two sets of a and b parameters on UWC measurements. Freezing season starts around the time when maximum depth of active layer is reached (1st September) and lasts until 28th February when the lowest ground temperatures are recorded. In the thawing season, only days between 1st March – 15th June (while the UWC variation is dominated by ground temperature as opposed to water circulation) are used for calibration. The model calibrated on freezing and thawing seasons 2012/2013 predicts UWC measurements in the following two years 2013/2014 and 2014/2015 within 5%.

In this work, we demonstrate that the calibrated model is able to predict the future UWC dynamics from measured or modeled ground temperatures with high accuracy. We also show that the freeze-thaw hysteresis is an important factor and its influence on heat transport in the ground should be considered when accounting for the UWC in permafrost models.

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PRELIMINARY RESULT OF THE RISK ASSESSMENT OF INFRASTRUCTURE IN THE PERMAFROST AREAS IN MONGOLIA

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Abstract

Climate change has been recorded everywhere with increasing trends and mean annual air temperature has raised by 2.07°C in Mongolia (MARCC, 2014). Under the changing climate, the existed and developing infrastructures should be planned to consider engineering and geotechnical solutions on permafrost area in Mongolia because of permafrost occupies 29.3% of the territory of the country, from continuous to sporadic distribution (Jambaljav et al, 2016). Moreover, there are some buildings and roads are beginning to cause engineering and geotechnical problems in the permafrost region and thaw subsidence around buildings and under paved roads are now widespread phenomena in Mongolia.

In this study, we estimated the areas at potential risk of infrastructures due to permafrost degradation. The estimation was implemented using the GIS technique to overlay and assess the latest permafrost distribution map and related infrastructure information.

According to the estimation, of the 330 sub-provinces (soums) in Mongolia, 9 soums are located in the continuous permafrost region. Moreover, 15 soums are located in the discontinuous permafrost area. In the isolated and sporadic permafrost region, 28 soums 41 soums are located, respectively. Approximately 3.8% of total roads run through the continuous permafrost areas (5.7% - discontinuous, 8.6%- isolated, 8.9% - sporadic). For the wells, 0.2% of total wells were constructed in the continuous permafrost region. About 1.0%, 2.3% and 3.5% of total wells were situated in the discontinuous, isolated and sporadic permafrost areas, respectively.

Further study will be focused on ranking of the risk assessment of infrastructure due to permafrost changes and it will be contributed to develop an engineering strategies and solutions to prevent negative measures for the existed and planned infrastructure.

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CONTROL METHODS OF FROST HEAVING AND THAW SETTLEMENT IN ARTIFICIAL GROUND FREEZING CONDUCTED IN SOFT FROST SUSCEPTIBLE GROUND AT A SHIELD MACHINE ARRIVAL SECTION

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Keywords: Artificial Ground Freezing; Frost heaving; Frozen soil;

Shield machine arrival; Thaw settlement; Removing underground obstruction

The sewer construction with shield tunneling method has been planned for an anti-inundation measure in Chugoku District, Japan. During the planning, the steel sheet pile wall, which had been installed at the time of the NTT telephone tunnel construction has confirmed to be left in the passage of shield machine section of 5.4m in diameter just in front of the arrival shaft. Therefore the shield machine has to be stopped in front of the sheet pile wall, and another tunneling method has to be introduced to excavate remaining 16m to the arrival shaft eliminating obstacles. In addition, the site conditions were so harsh, such as 1) other underground structures were anticipated in the passage of the shield, 2) the soils in the excavation depth were soft and frost susceptible Alluvial soil of which N-values were around 2 to 3, and 3) the soil improvement work was impossible from the ground surface. Under these conditions, Artificially Ground Freezing (AGF) method, which has high safety and reliability among soil improvement methods, has adopted for the substitution.

AGF method was adopted to ensure the safety and reliability of the shield machine arrival connection by developing strong and watertight cylindrical frozen soil walls. The freezing was executed by circulating chilled antifreeze liquid in freezing pipes, which were installed with horizontal drilling from the shaft and the excavation was started when the thickness of the frozen soil reaches approximately 1.8m. Since the predicted upheaval of the NTT telephone tunnel was greater than 70mm, which was the allowable upper limit, the field observation of the tunnel displacement and the measures to control frost heaving and thaw settlement were found to be required.

In order to repress the frost heaving, internal groundwater pressure of the cylindrical frozen soil wall was lowered by sucking groundwater while developing the cylindrical frozen soil wall. After the cylindrical frozen soil wall was formed, operation of freezing pipes was thinned-out to restrain the growth of the cylindrical frozen soil wall. According to the measures mentioned above, and the inner space displacement due to the excavation of the unfrozen soil in the cylindrical frozen soil wall and consolidation of the Alluvial layers which lie between the cylindrical frozen soil wall and the NTT telephone tunnel, the displacement was reduced to approximately 30% of the prediction. In order to control the thaw settlement, ground around the frozen soil wall was grouted during the frozen body was thawed by circulating the heated antifreeze liquid in freezing pipes. Finally the excavation to the arrival shaft was completed successfully with keeping the displacement of NTT tunnel within allowable upheaval.

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CRYOGENIC LANDSLIDE ACTIVITY 1970 – 2014 IN CENTRAL YAMAL, RUSSIA, OBSERVED FROM SATELLITE IMAGE TIME SERIES

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Keywords: Cryogenic landslides; Remote sensing; Satellite imagery; Yamal

Cryogenic landslides, commonly divided into active-layer detachments (ALDs) and retrogressive thaw slumps (RTSs), are one of the most important geomorphological processes on Yamal peninsula. In 1989, increased precipitation and wetting of the active layer triggered hundreds of landslides in central parts of the peninsula (Leibman & Egorov 1996). A database of satellite images was collected to follow landslide activity before and after the 1989 landsliding event. High resolution (HR) satellite imagery used included CORONA (1969), KH-9 (1976), Landsat MSS/TM/ETM+7 (1984, 1988, 1990, 2014) and SPOT (1993, 1998). In addition, very high resolution (VHR) images from Quickbird-2 (2004) and WorldView-2 (2013) were used to investigate small scale changes. ERDAS Imagine 2015 and ArcGIS 10.4 were used for data analysis.

Apart from the 1989 event, which is clearly visible when Landsat TM images from 1988 and 1990 are compared, the time series revealed another large set of landslides in the same area in the early 1970's. Totally in the study area about 3700 landslides occurred in the 1970's and about 3978 in the 1989 event. Most of the slides are spatially small scale with average size of 0,6 ha while the largest were as vast as 27 ha. Analysing multispectral HR or VHR optical satellite imagery was found most effective as a method for mapping the landslides. HR Landsat TM and SPOT images were found useful for mapping extensive, < 20 years old ALDs, whereas VHR images from QuickBird-2 and WorldView-2 performed well in detection of smaller RTSs and little vegetated ALD surfaces even after 24 years since landslides occurred. Change detection using the Normalised Difference Vegetation Index (NDVI) identified clearly larger slides, but was not generally reliable enough alone to estimate their occurrence and size. Further research will focus on possibilities to identify the landslides of the early 1970's from more recent VHR satellite data to provide new information about evolution of revegetation on shear surfaces in Central Yamal conditions.

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GROUND SURFACE TEMPERATURE REGIMES IN THE HIGH AND MIDDLE ATLAS (MOROCCO): CHARACTERISTICS AND IMPLICATIONS FOR THE PRESENT-DAY PERIGLACIAL DYNAMICS

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Keywords: Enter up to six keywords on this line, alphabetized and separated by semicolons

The High and Middle Atlas of Morocco are two major mountain ranges in North Africa, the former reaching 4,167 m at Jbel Toubkal and the latter reaching 3,340 m at Jbel Bou Naceur. The Atlas crosses Morocco from SW to NE being the largest mountain chain in North Africa. Both ranges are extremely important for economy since they are a major source of water resources both for montane and piedmont agriculture, as well as for drinking water supplies. Millions of people depend directly on water produced in the Atlas and the ranges also rely on tourism activities, including winter sports, with ski resorts in both the High (Oukaimeden) and the Middle Atlas (Ifrane, Michlifen). However, very little is known and quantified on the climate and geomorphological dynamics of the Moroccan high mountains. References to the presence of relict permafrost related features, such as rock glaciers occur in the literature, but no systematic research has ever been conducted. Also detailed observations and monitoring of seasonal and diurnal frost activity are lacking and a characterization of the high mountain periglacial environment has not been done yet.

In the framework of the project COLDATLAS – Does permafrost occur in North Africa?, we have installed ground surface temperature (GST) miniloggers across altitudinal and latitudinal gradients in the Middle Atlas (Jbel Bou Iblane and Jbel Bou Naceur massifs) and the High Atlas (Jbel Toubkal massif), in order to preliminarily characterize the frost regimes and the present-day periglacial environment. Hourly GST data was obtained from June 2015 to July 2016.

Results from the Toubkal massif show that snow plays a major role on the thermal regime of the shallow ground, inducing important spatial variability. The site at 3,210 m showed a regime with frequent freeze-thaw cycles during the cold season but with a small number of days of snow. When snow sets, the ground remains isothermal at 0 ºC and the thermal regime indicates the absence of permafrost. The highest sites at 3,980 and 4,160 m a.s.l. showed frequent freeze-thaw cycles and a small influence of the snow cover on GST, reflecting the lack of snow accumulation due to the wind-exposed settings in a ridge and in the summit plateau. The site located at 3,815 m showed a stable thermal regime from December to March with GST varying from -4.5 to -6 ºC, under a continuous snow cover. The stable and low GST are interpreted as a strong indicator of the probable presence of permafrost at this site, an interpretation which is supported by the presence of lobate and arcuate forms in the talus deposits. These results have been published in Vieira et al. (2016).

The data from the Middle Atlas range was obtained for sites at similar altitudes (2,610 and 2,720 m), but located across a NW-SW gradient aiming at characterizing differences in precipitation from the Jbel Bou Iblane to the Jbel Bou Naceur, which is located close to the desert border. GST in the cold season showed frequent freeze-thaw events, with the snow lasting for longer at the Jbel Bou Iblane area, a fact that induced longer isothermal regimes in the ground. This data is still being analysed and the results will be presented in the conference, together with an overview of the periglacial environment for both the High and Middle Atlas.

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WATCHING ICE MELT: GEOPHYSICAL MONITORING OF A PERMAFROST WARMING EXPERIMENT

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Keywords: Fiber optic; Geophysical measurements; LiDAR; Permafrost; Subsidence; Thawing;

An artificial warming experiment was performed to thaw the topmost layer of permafrost at a discontinuous permafrost site in Fairbanks, Alaska, United States. The objective of the experiment was to investigate the potential utility of fiber optic distributed sensing technologies (seismic, strain, and temperature) as an early detection system for permafrost thaw, primarily to mitigate infrastructure hazard. The heated area (approximately 140 m^2) was heated with 122 60-Watt vertical heaters. The depth to permafrost was initially between 4 – 4.5 m below surface and the heating elements were between 3 - 4 m, below the ground surface. At the site, about 5 km of fiber optic cable was installed horizontally in shallow trenches (20 cm depth) and soil temperatures were monitored with a distributed temperature system (DTS) at 12.5 cm increments along the length of the fiber. Vertical fiber optic cable was also installed inside and outside the heater plot to a depth of 10 m in small diameter (2 cm) boreholes. Several thermistor strings were installed coincident with the vertical fiber optic sensors to enable calibration.

The heaters were turned on August 5, 2016 and subsurface heating continued through November 11, 2016. By the time the heaters were turned off the soil temperature at the heaters had increased from 3.5 to 45 °C at 3.5 m. At the center of the heated plot, the depth to the permafrost table was increased by about 1 m during the heating process.

To retrieve temperature data every 12.5 cm over the 5 km fiber optic array Fiber Optic DTS calibration methods were implemented. During the calibration step, losses were observed due to bends in the cable near the fiber minimum critical bend radius, in particular at the base of the PVC wells. Correlated step losses in both Stokes and Anti-stokes Raman spectra were corrected prior to solving for temperature as a function of fiber location in a three-point calibration using hot (40 °C) and cold (0 °C) circulating baths (Hausner et al. 2011; Hausner et al. 2016).

Soil temperatures were simulated using a 3D finite element model (SVOffice5). A dry density of 800 kg/m^3, a volumetric water content of 40%, and a thermal conductivity of 0.55 W/mK were assumed for the soil properties. The simulated temperatures closely matched the measured soil temperatures at depth, suggesting that these assumptions were reasonable.

In order to examine impact of heating on surface deformation hazard, the deformation of the ground surface was measured using a combination of traditional surveying techniques and LiDAR (Light and Detection and Ranging) scanning. An area with the greatest amount of subsidence was found to be between 0.04 to 0.10 m of change. Using repeated LiDAR scans and continuous distributed strain sensing data, we compared the timing, rate, and spatial distribution of thaw. Our experiment demonstrates a viable approach for simulating both deep permafrost thaw and the resulting surface subsidence, an integrated platform for testing sensor systems targeting such processes.

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UNFROZEN WATER POTENTIAL GRADIENT IN A DIRECTIONALLY FREEZING AND THAWING SOIL

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Keywords: Chilled mirror hygrometer; Clausius-Clapeyron equation; Column experiment; Non-equilibrium ice growth; Unfrozen water pressure; Unsaturated soil

Estimating the water flow in unsaturated soils during freezing and thawing is important in agricultural management and water balance calculation in cold regions. Water in an unfrozen soil is induced to flow to the freezing front due to the low water potential in the frozen soil, and flows through the partially frozen soil under the potential gradient of unfrozen water. However the unfrozen water potential is difficult to directly measure because of the low water pressure and the non-equilibrium pore ice growth. A micro-chilled-mirror hygrometer that does not require a sampling chamber and has a rapid response time has recently been developed. The sensor head can be inserted into a soil sample. In this study, we first determined the suitability of this micro-hygrometer for direct measurement of the water potential in frozen soils under equilibrium and non-equilibrium states. We then used the micro-hygrometer to directly measure the water potential gradient in directionally freezing and thawing soils.

The sample used here is an Andisol, which was collected from the A horizon at an experimental field of Iwate University. The 1:5 soil/water extract electrical conductivity of the Andisol was 0.05 S m^{-1}, and we assumed the molar depression of the freezing point of the soil water was negligible. The sample was mixed with distilled, deionized water and then packed into a brass cylindrical container (50-mm i.d., 108-mm height) at a constant water content of 0.20 m^3m^{-3} and a constant bulk density of 1.0 Mg m^{-3}. The hygrometer was inserted vertically into the soil sample to a depth of 45 mm. Three thermocouples were also set into the soil on the upper, middle, and lower sides of the hygrometer. The brass cylinder was then sealed using a rubber stopper and placed into coolant at −8°C in a constant-temperature bath, and allowed to settle for 24 h. The temperature of the coolant was then raised from −8 to 0°C and dropped back down to −8°C in stages. At each stage, the temperature was held constant for at least 4 h. During this procedure the dew point and soil temperature was measured to estimate the water potential. We confirmed that the hygrometer directly and quickly measures soil water potential in frozen soil at temperatures between −8 and −2°C. At equilibrium, regardless of freezing–thawing processes, the measured potential h_{RH} corresponded to the calculated potential h_{CC} determined using the Clausius–Clapeyron equation. Soil water potential was found to require time to reach equilibrium after a temperature change. This is thought to be because ice in the soil pores required time to acquire a new equilibrium geometry.

Secondary, the sample was packed into an acrylic column with inner diameter of 78 mm and height of 350 mm, with water content of 0.36 m^3m^{-3} and a constant bulk density of 1.14 Mg m^{-3}. The column was set between two temperature control units that regulated the top and bottom temperatures. Thirty-four thermocouples (placed at 10-mm intervals), seven time-domain reflectometry probes (placed at 50-mm intervals), seven tensiometers (placed at 50-mm intervals), and two hygrometers (at 75 and 125-mm depth) were inserted horizontally into the column, and the side wall of the column was insulated with a 10-mm rubber sheet and a 50-mm glass wool layer. The experiments were conducted in a room at constant temperature of 4 °C. The soil columns were acclimatized to the room temperature for more than 48 h to establish equilibrium water content profile and soil temperature. The column was then frozen from the upper end by setting the top and bottom temperatures at −15 and 3 °C for 48 h, respectively, and thawed by setting the top and bottom temperatures at −10 and 3 °C for 48 h. During the experiment, soil temperature, liquid water content, water pressure, and dew point were monitored. No frost heave had occurred in the sample. Under the high cooling rate in the column freezing experiment, the measured unfrozen water potential h_{RH} was higher than the calculated potential h_{CC} from temperature through the Clausius–Clapeyron equation. As the cooling rate decreases, the h_{RH} reaches the h_{CC}. This indicates that the potential gradient of unfrozen water in directionally freezing ground tends to be underestimated near ground surface and overestimated near the freezing front, if it derived by the h_{CC}.

GROUND THERMAL REGIME OF SOIL-WEDGE CRACKING IN THE DAISETSU MOUNTAINS, HOKKAIDO, JAPAN

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Keywords: Active-layer soil wedge; Japan; Permafrost; Thermal contraction cracking

The temperature thresholds of thermal contraction cracking have been evaluated for ice-wedge polygons in fine sediments (e.g. Matsuoka & Christiansen, 2008). However, the critical temperatures have not yet been defined for thermal contraction cracking in coarse sediments. Non-sorted polygons accompanied with active-layer soil wedges distribute sporadically on volcanic plateaus in the Daisetsu mountains, Hokkaido, Japan (Koaze, 1965). Sone and Takahashi (1986) observed that polygon troughs expand in winter and shrink in early summer, indicating the activity of soil-wedge cracking under the current climatic condition. This study aims to know the timing and temperature threshold of soil-wedge cracking in volcanic coarse sediments.

At the beginning of October 2014, we installed some automatic monitoring systems in polygon troughs to detect timing and thermal regime of soil-wedge cracking. The systems consist of thermistors and horizontal extensometers. Ground temperatures were measured hourly at several depths up to 100 cm deep. Extensometers, attached to two steel frames anchored in ground, measured horizontal displacements across the troughs every hour. Additionally, subsurface cables made of very thin copper wires were installed across the troughs in October 2015. The timing of soil-wedge cracking is recognized by the loss of electrical voltage when the wire is cut.

The horizontal extensometers showed seasonal slow movement of the troughs expanding in early winter and shrinking in early summer, reflecting thermal contraction and expansion of topsoil layer. The ground temperature at 100 cm depth never dropped below −10°C during the two years monitoring period, implying warm permafrost temperature. In the winter of 2014–2015, ground surface temperature showed large fluctuation and recorded its minimum value (−21°C) at the beginning of February 2015, reflecting thin snow cover during the winter. The largest expansion ratio (0.9 mm/h) was recorded at the end of November 2014 when ground surface temperature decreased to −13°C with a cooling rate of 0.4°C/h. In the winter of 2015–2016, ground surface temperature showed small fluctuation and never dropped below −17°C, implying thick snow cover in comparison with previous winter. The largest expansion ratio (0.7 mm/h) was recorded in the middle of January 2016 when ground surface temperature dropped to −14°C with a cooling rate of <0.2°C/h. A copper wire installed at 5 cm depth remained connected at this time, but was cut after six days without distinctive thermal change. Although the cause of this time lag is unclear, monitoring data indicated that soil-wedge cracking occurred when ground surface temperature was cooled to below −13°C in coarse volcanic sediments of the Daisetsu mountains. This temperature threshold is higher than the temperature requirements for ice-wedge cracking in fine sediments (e.g. Matsuoka & Christiansen, 2008). Non-viscous coarse sediments would permit the occurrence of thermal contraction cracking in relatively high ground thermal condition.

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THAW PROGRESSION AND ACTIVE LAYER THICKNESS BY DRIVING PERMAFROST MODELS WITH SATELLITE DATA

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Keywords: active layer, thaw progression, remote sensing, modeling

The seasonal thawing of the active layer is of critical importance for permafrost ecosystems, e.g. influencing surface hydrology and the carbon cycle. Deepening of the active layer in a changing climate can be a first step towards talik formation so that monitoring of active layer thickness can be regarded an "early-warning" tool – on the other hand, melting of excess ground ice can trigger ground subsidence, thus leading to unchanged thaw depths despite of ongoing degradation.

With current remote sensing technologies, it is not possible to directly infer thaw depths from spaceborne platforms. However, operational satellites provide dense time series of land surface temperatures (LST) which are intimately related to ground thawing. First, we investigate whether simple analytical models based on Stefan's equation can provide a satisfactory representation of thaw depths when forced by thawing degree days obtained from remotely sensed LST. While the absolute values of thaw depth cannot be reproduced without additional information on ground properties, there is significant potential for anomaly and trend detection on regional to continental scales.

Furthermore, we explore transient modeling of ground temperatures driven by remotely sensed LST, snow extent (SE) and snow water equivalent (SWE). Hereby, satellite-derived SWE clearly constitute the "bottleneck", with spatial resolutions of 25km and large uncertainties in mountain and tundra areas. Using the CryoGrid permafrost models for a site in N Siberia, we show that the simulated thaw depth is significantly less affected by shortcomings in the SWE input compared to ground temperatures, so that a satisfactory representation of thaw progression and maximum thaw depth is indeed feasible. However, information on subsurface stratigraphies including the distribution of ground ice is required to achieve this accuracy which is currently not available from remote sensing products alone. Finally, we demonstrate that excess ice thaw can be represented by simple modifications of the CryoGrid model physics.

SIMULATIONS OF WATER, HEAT, AND SOLUTE TRANSPORT IN PARTIALLY FROZEN SOILS

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Keywords: Frozen soil; Solute; Uncertainty; Freezing point; Salinization

Abstract
Soil freezing/thawing processes were monitored in two seasonally frozen agricultural fields in northern China during 2011/2012 and 2012/2013 winter seasons, respectively. Mass balance was checked based on measured data at various depths. Simulation work was conducted by combining the CoupModel (Jansson and Karlberg, 2009) with Monte-Carlo simulations to achieve parameter sets with equally good performance. Uncertainties existed in both measurements and simulations due to the complexity of freezing/thawing processes as well as in surface energy partitioning. Parameters related to surface radiation and soil frost were strongly constrained with datasets available from two sites. Simulated soil heat processes were better described than soil water processes given the data obtained for calibration. Model performance was improved with consideration of solute effects on freezing point depression. Simulation of solute transport processes in the CoupModel would be improved by accounting for processes such as diffusion and expulsion based on more precise experimental results. Generally, a combination of measurements with process-based model simulation using Monte-Carlo methods provided an approach for understanding of solute transport as well as its influences on soil freezing/thawing in cold arid agricultural regions. Incorporating more detailed descriptions of processes for frozen soil in the model can be justified if uncertainties in measurements can be reduced by introducing high-precision novel technologies.

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COOLING EFFECTS OF THERMOSYPHONS INSTALLED IN SHALLOW BURIED SECTION OF TUNNEL PORTAL IN THE QINGHAI-TIBET PLATEAU

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Keywords: Permafrost regions; thermosyphons; tunnel portal; ground temperature field

Abstract: Both the high altitude and the extremely cold climatic of the Qinghai-Tibet Plateau were not conducive to tunnel portal with the shallow buried condition in permafrost regions. The excavation makes the permafrost exposing to the air, then decrease the stability of tunnel because of the thawing. Therefore, it is necessary to study how to quickly cool down the shallow burried tunnel portal. In this paper, a tunnel located at Jiangluling mountain along the national road 214, which is from Xining to Yushu in the Qinghai Province, was taken as a case to study the cooling effects of thermosyphons intalled in the portal sections (Fig. 1). Totally 165 thermosyphons were installed with a interval of 3.0 m in a range 21 m in width and 63 m in lenghth (mileage K329+750 to K329+813). Two monitored sections for ground temperature recording were desinged at the mileage of K329+750 and K329+813, respectively. The monitoring time from January in 2013 to July in 2014. The results showed that: the natural maximum thaw depth was 2.5m. the average thaw depth respectively were 1.43m,1.58m and 1.78m (in 2003 summer) for the distance from the thermosyphon was 0.5m, 1.0m and 1.5m. The cooling depth of thermosyphon was always from the ground surface to 8.5m, and it would be no cooling effects if the depth was more than 8.5m. The average of the highest cooling amplitude (January in 2003), which was compraed with the nature temperature, were respectively 2.1℃, 1.21℃ and 1.14℃ for the distance from the thermosyphon was 0.5m, 1.0m, and 1.5m, and the average of the highest cooling amplitude (January in 2004) were respectively 4.08℃, 3.50℃ and 3.06℃. From above results, it could be seen that the heat energy which came from construction was very big and the quick cooling effects by installing thermosyphons were very outstanding. With the affect of construction disturbance becoming more and more weak, the cooling effects would further remarkable. To sum up, the thermosyphons which was applied to the shallow buried section of tunnel portal with high attitude and extremely cold climatic could get a very good quick cooling effects.

IRRIGATION AND ARTIFICIAL DRAINING AS POTENTIAL FACTORS OF PERMAFROST DEGRADATION: AGRICULTURE IN THE AMGA AND VILYUY CATCHMENT AREAS, YAKUTIA

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Keywords: agriculture, draining, irrigation, land use, thermokarst, Yakutia

Permafrost degradation depends on a large range of factors, including the activities of local land users. The scale and form of impact of extensive forms of land use in different parts of the Far North have thus far been rarely researched. This presentation will explore the ways in which agriculture -- mainly livestock breeding but also crop production -- in two regions of the Republic of Sakha (Yakutia) has utilized but also modified permafrost-based landscapes. In particular, the authors will portray and discuss archival and other data on artificial draining of grasslands in thermokarst basins (alas) and irrigation of grasslands and fields in Soviet times, mainly since the 1960s. Documents show that both these forms of agricultural landscape improvement have repeatedly triggered and/or accelerated thermokarst development. By presenting their insights in the interdisciplinary frame of ACOP, the authors intend to discuss consequences of land use with hydrologists and soil scientists.

NEW MAP OF MONTANE PERMAFROST IN MONGOLIA

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Keywords: geocryology; Mongolia; N-factor; montane permafrost;

Mongolia is located in the transition zone between the world largest permafrost area of Siberia and the Mongolian Gobi. North of the country has permafrost and there is not a permafrost in the south. Thus, the mapping of permafrost is a challenge for scientists working in this field. We have some maps of permafrost on a national and local scales. Due to limited data sources, southern limits of permafrost were drawn differently (Jambaljav 2009). The most famous is geocryology map with a scale of 1: 1,500,000. This is called as the Gravis map, which was generated in 1971. According to Gravis map, the general regularities of permafrost distribution are determined by latitudinal and altitudinal zonality of changes in climatic and topographic factors. Mongolia is divided into five permafrost zones, as continuous, discontinuous, islands, scattered islands and sporadic (Gravis et al. 1974).

New map of permafrost distribution was generated based on the TTOP (temperature on top of permafrost) modelling approach as follow (Smith and Riseborough, 1996, Riseborough et al. 2008, Westermann et al. 2015).

We have used the MODIS (Moderate Resolution Imaging Spectroradiometer) LSTs (Land Surface Temperatures) as input parameter of this TTOP model. We assumed the MODIS LSTs as air temperatures. The N-factors and the thermal conductivities have been derived from NDVI (MOD13A2) 16 daily image during the warm season, snow cover (MOD10A2) eight daily image and Snow water equivalent (AMSR-E/Aqua L3 Global EASE-Grids) five daily image during the cold season derived from Moderate Resolution Imaging Spectroradiometer (MODIS) sensor aboard the Terra and Aqua satellite platforms (2004-2013) and were validated by ground based measurements at different sites.

As results of this TTOP model, the permafrost occupies one third of country area and we have divided the country area into five zones based on modelled temperature at top of permafrost, such as continuous, discontinuous, sporadic, isolated, and zone of seasonally frozen ground. Continuous permafrost zones with temperature less than -2°C concentrate at high elevation areas, in center of vast depressions, and in far north of country. Discontinuous (with temperature between -1°C and -2°C), sporadic (with temperature between -1°C and 0°C) and isolated (with temperature between 0°C and 1°C) permafrost zones belt the continuous permafrost zones.

Permafrost underlies about $462.8*10^3$ km^2 or about 29.3% of total area of Mongolia including glaciers and lakes. Of this total area, continuous permafrost underlies $118.3*10^3$ km^2 or about 7.5%, discontinuous permafrost underlies about 127.7*103 km^2 or about 8.1%, sporadic permafrost underlies about $112.4*10^3$ km^2 or about 7.1%, isolated permafrost underlies about $104.4*10^3$ km^2 or about 6.6% of total area of Mongolia respectively.

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THE INTERACTION BETWEEN PEAT AND PERMAFROST IN MONGOLIA

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Keywords: Mongolia; peatland; permafrost;

There are a number of publication analysing the interaction between peat and permafrost in high latitudes. Most of the peatlands in Canada, Alaska, Scandinavia and West Siberia are so-called permafrost peatlands – polygon mires, palsa and plateau mires. There are a number of publications describing the dynamics of these peatlands related to permafrost thawing due to increases in mean annual air temperature followed by positive impacts to climate change via increases of GHG emissions (Zoltai 1993; Robinson, 2003; Rydin and Jeglum, 2013; Swindles et al., 2015). There are significantly less publications demonstrating the role of peatlands and peat, as material, in protecting permafrost from thawing (Shuhua, 2007) and as a factor supporting the distribution and preservation of permafrost on the southern limits of distribution and in highlands.

The phenomenon of permafrost distribution in connection to the presence of a peat layer is mentioned in some general Russian language publications on permafrost for the North-Eastern European part of the country (Timano-Pechyora lowland) and Eastern Siberia (Sumgin, 1937).

However, this connection has not been demonstrated for highland permafrost and there are no clear investigations showing correlations between the presence of peat and the status and distribution of permafrost.

Peatlands in Mongolia cover around 1,7 % of the country's area and play a crucial role for carbon storage, water regulation, maintenance of biodiversity and livelihoods (Minayeva et al., 2005). To a large extend the status of peatlands depends on the presence of permafrost. Permafrost also plays a key role in water supply and regulation of Mongolian rivers, while peatlands could serve as protection for permafrost from thawing.

In order to prove this hypothesis, during the field seasons of 2015 and 2016, with the support of an ADB Technical Assistance project, integrated expeditions were undertaken for mapping peatlands in the Eastern (Dornod province) , Northern (Khubsugul Province) and Central (Uvurkhangai, Arkhangai, Zavkhan provinces) areas of Mongolia. Of the 40 peatlands studied, 34 were underlain by permafrost. The geophysical studies in connection with manual probing in more than 350 points along the profiles provided the possibility to assess the permafrost and active layer depth in correlation with peat depth, soil and air temperature, peat moisture and vegetation cover.

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GROUND DEFORMATION MAPPING BY ALOS1/2 INSAR: CASE STUDIES AT HERSCHEL ISLAND, CANADA, AND BATAGAIKA CRATER, SIBERIA

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Keywords: ALOS; InSAR; deformation; remote sensing; slump; thermokarst

Thawing of permafrost can lead to ground surface deformation. Ground deformation has been considered as a serious problem in the Arctic Ocean coastal area such as Russia for a long time, because the deformation causes damage to architectures at these areas. However, there have been no quantitative observation data, and the spatial and temporal distributions have hardly been investigated. On the other hand, in relation to the recent global warming, the importance of organic carbon emission stored in permafrost is pointed out. Although the release of methane gas is confirmed in some thermokarst lakes, it is very difficult to observe the permafrost in a wide area by field study. Instead, it is technically possible to monitor the subsidence and uplift of the ground over the permafrost area, which could potentially make a significant contribution to the monitoring thawing process of permafrost.

In this study, we attempted to detect ground deformation signal in permafrost area by using interferometric synthetic aperture radar (InSAR). Using the data of two SAR satellites ALOS and ALOS2 launched by JAXA, we observed recent ground deformation from 2007 to 2016. Focusing on the slump terrain with relatively fast fluctuation velocity as the observation target, we detected ground subsidence in Herschel Island in Canada and Batagaika Crater in Russia. In Herschel Island, Short et al (2011) has reported up to 30cm displacement in the line-of-sight direction at the coastal area using ALOS1 InSAR data. We observed the subsidence and coastal erosion in recent years by ALOS2 which has not been reported. At the Btagaika Crater, however, it is not yet certain if the detected signals really indicate subsidence, because the employed digital elevation models seem to have biases.

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HOT-WATER CORING SYSTEM IN SUBGLACIAL PERMAFROST REGIONS

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Keywords: hot-water drill; PDM corer; subglacial permafrost

Research based on subglacial permafrost core addresses a wide range of interdisciplinary research goals and great significance. These give unique opportunity to research reconstruction of the paleo-climate, biological evolution, cosmobiology, ground ice characterization, geothermal activity, creep deformations, global environmental change. Hot-water drilling system is considered to be the fastest way to reach the base of glaciers and ice sheets (Zacny et al., 2016). It is planned to change hot-water drill nozzle to the combination of positive displacement motor (PDM), core barrel and drill bit (Das et al., 1992). PDM converts hydraulic pressure of hot-water flow into rotation and torque, and reliable anti-torque system is also necessary for balance. The drill bits will be designed to two versions. The first one is designed and suitable for ice core drilling, the drill system doesn't need chips chamber, because hot-water will melt all the ice chips while drilling. The second version is designed for ice with rocks or soil, coring system need chips chamber for chips collection. The core samples are protected in the inner core barrel from thermal and mechanical erosion caused by hot-water circulation. The detailed concept of ice and subglacial bedrock PDM corer is being worked out.

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ACTIVE THERMOSYPHONS FOR ARTIFICIAL GROUND FREEZING

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Keywords: Ground Freezing; Refrigeration; Thermosyphons

Thermosyphons have been used since 1960 (Long, 1963) to passively refrigerate foundations in permafrost soils in Alaska. The passive two-phase refrigeration systems are driven by the cold ambient winter air temperatures. When properly sized, the thermosyphons withdraw enough heat during the freezing season to keep the permafrost stable all year. In Alaska, thermosyphons are used for a myriad of ground cooling applications in the North Slope oilfield, on the Trans Alaska Pipeline, and on many building and earth structure projects across the permafrost zone (Yarmak, 2015). Likewise, thermosyphons have been used on many projects in Canada, Russia, and China to keep permafrost from degrading.

It is not always cost effective or practical to wait for or rely on cold weather to drive the thermosyphons to cool the ground. At permafrost sites, foundations installed in summer using thawed materials may not be stable or able to be loaded until the thawed materials are frozen. Actively refrigerating the thermosyphons is a way to accelerate freezeback and shorten construction time. The most efficient way to actively refrigerate thermosyphons is with an internal heat exchanger that cools the inside of the units just at or above the level in the ground that the refrigeration is desired. Because the thermosyphons may function in either an active or passive mode, they are dubbed hybrid thermosyphons. For the ultimate in efficiency, the internal heat exchangers are cooled with direct expansion refrigeration. And in such, no brines or antifreeze fluids are pumped though the system that could potentially leak and detrimentally affect the permafrost.

At locations where there is not enough winter to provide reliable passive cooling, the thermosyphons need not be fitted with passive air-side condensers and the hybrid heat exchangers are used for the primary cooling of the thermosyphons. This type of system was chosen by the US Department of Energy to freeze a barrier to contain aqueous radionuclides at Oak Ridge National Laboratory in 1997 (Phillips and Yarmak, 2014). The hybrid thermosyphon system operated successfully and economically for 6 ½ years.

Design elements for hybrid systems are discussed and compared to conventional brine-type ground freezing systems.

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MICROSCOPIC FAILURE MECHANISM OF SALINE SOIL CONSIDERING SALT TRANSPORT AND PHASE CHANGE UNDER FREEZE-THAW CYCLES

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Keywords: saline soil; freeze-thaw cycles; salt transport and phase change; salt crystallization model; microstructure model; failure mechanism

Rationale Numerous engineering problems including frost heave and thaw settlement, as well as salt heave and dissolution settlement, caused by temperature change and salt transport commonly occur commonly during construction in seasonally frozen saline soil regions. Microstructure transformation is thought to be the main failure mechanism of saline soil (Sasanian, S., et al. 2013; Romero, E., et al. 2008).

Objective The objective of this project is to provide theoretical guidance to the design of bearing capacity and the measurements of preventing subgrades from salt and frost heave in seasonal saline frozen soil districts.

Methods Focused on saline soils dominated by sodium sulfate in seasonally frozen regions, this research utilizes a comprehensive approach that combines macroscopic and microscopic, experimental and theoretical methods.

Based on freeze-thaw cycles, CT scanning, MIP and SEM tests, water and salt transport characteristics and the mesoscopic damage evolution law of saline soil are obtained. The pore size distribution characteristics are analyzed to calculate crystallization pressure and induced effective stress and then the model of crystallization pressure of saline soil is established.

Results The porosity increases firstly and reduces with the rising salt content, with the salt content of 1.5%. The fractal dimension is affected slightly ranging from 1.18 to 1.23.

A small amount of salt crystals were produced in the early stage and then increased with increasing freezing time. Salt crystals are layered and discontinuously distributed along the height of soil column with the direction perpendicular to heat transfer.

Depending on the amount of precipitated crystal, the macroscopic crystallization stress destroys the pore structure and induces the soil deformation.

Conclusion According to the microstructural characteristics, the contact and sliding model among particles is formed considering freeze-thaw cycles and salt transport, and it is used to calculate the macro deformation, and predict the variations of salt and frost heave.

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INFLUENCE OF SNOW COVER ON THE THERMAL REGIME OF FROZEN SOIL IN THE EAST TIANSHAN MOUNTAINS, CHINA

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Abstract: Snow cover has a significantly effect on the thermal state of underlying frozen soils and is a critical factor affecting the development and existence of permafrost in mid-latitude high mountain regions. This paper discusses the influence of thin snow cover on the thermal regime of active layer based on snow depth, soil heat flux (5 cm and 10 cm) and soil temperature data(0-200 cm) observed from Nov. 1,2014 to Nov. 1 ,2016 in the East Tianshan Mountains. The results indicate: (1)The melting and sublimation of the thin snow (<10 cm) in the autumn may accelerate heat release process of the surface soil, so snow play a cooling effect on the shallow ground.(2) In winter, snow depth is generally less than 10 cm and snow cover maintain a long time. Snow cover continues to cool the soil mainly through the reflection of solar radiation. But when the snow depth is greater in some areas, the snow will play the role of thermal insulation.(3) The snow melt water infiltrates into the soil in the spring, and the evaporation process will delay the response of the soil to the air temperature rise. In general, thin snow cover is beneficial to the development and preservation of frozen soil.

Keywords: snow cover, frozen soil, Thermal Regime, Tianshan Mountains

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SOIL MOISTURE DOMINATE ALPINE MEADOW CARBON BALANCE IN THE PERMAFROST REGION OF THE QINGHAI-TIBETAN PLATEAU

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Keywords: Alpine meadow; Carbon balance; Permafrost; Qinghai-Tibetan Plateau

Permafrost playing an important role within the global carbon cycle because permafrost ecosystems are thought to be a significant sink of natural carbon emissions and permafrost region contains huge organic carbon pool. The Qinghai–Tibet Plateau (QTP) is the most extensive high-altitude permafrost distributing regions in the world. Alpine meadow is the dominant vegetation type in the permafrost region on the QTP. Information on the alpine meadow carbon balance is still limited due to their wide distribution over QTP with a great variety of soils. To better understand the regional difference on carbon balance from the permafrost region of the QTP, we compiled a 4-year eddy CO_2 flux and environmental factors field observation from January 2009 to 2012 over the Tanggula (TGL,91°56'E, 33°04'N, 5133 m asl)and Xidatan (XDT, 94°07'E, 35°43'N, 4538 m asl) monitoring sites of the alpine meadow ecosystem. Analysis of 4 four years of data revealed that both TGL and XDT alpine meadow seasonal variations in CO_2 flux exhibited a bimodal pattern with high emission in both spring and autumn, weak absorption in summer, and weak emission in winter, but with obviously differences: CO_2 flux was negative from July to September with the maximum uptake rate 0.04 $mg^{-2}s^{-1}$ in TGL region, whereas CO_2 flux was negative from May to September with the maximum uptake rate 0.09 $mg^{-2}s^{-1}$ in XDT region. Further, cumulative CO_2 flux shown that XDT alpine meadow was a net sink for atmospheric CO_2 with the mean uptake rate of 32.1 $gm^{-2}yr^{-1}$(21.8-47.1 $gm^{-2}yr^{-1}$) over the 4 years' observation. Compared with XTD, TGL alpine meadow showed a net source for atmospheric CO_2 with the mean emitted rate of 142.3 $gm^{-2}yr^{-1}$ (112-164.4 $gm^{-2}yr^{-1}$).We found that alpine meadow is a source for atmospheric CO_2 when the average topsoil moisture content in thawing period less than 20%. Soil moisture dominate alpine meadow carbon balance in the permafrost region of the Qinghai-Tibetan Plateau. The public and reported data about alpine meadow carbon balance in the permafrost region of the QTP support our find. Our results suggested that the alpine meadow in permafrost region of the QTP will have the potential to exert a positive feedback on climate considering the increasing warming and drying.

THE APPLICATION OF MIXED HYBRID FEM FOR THERMAL ANALYSIS IN HIGH-SPEED RAILWAY FOUNDATION

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Abstract

In this study, we apply a modified Finite Element Method which is called as Mixed Hybird FEM (MHF) for the thermal analysis in High-Speed Railway foundation. MHF allows simultaneous computation of boundary temperature, element temperature and heat flux. We apply MHF for the thermal analysis in the frost heave prediction model which considers the phase change and latent heat influence. Since freezing rate will affect the accuracy of frost heave prediction, therefore accurate thermal analysis is highly significant for the frost heave amount evaluation. In order to demonstrate the advantage and the applicability of MHF in the application of frost heave simulation, we compare the numerical simulation results obtained by FEM and MHF with field monitored data from High-Speed Railway foundation respectively. The real field monitored data from High-Speed Railway foundation demonstrate that, under sine-curved air temperature changes, MHF shows a better accuracy for the thermal distribution in High-Speed Railway foundation compared with FEM. In addition, MHF has a slower freezing rate and a much more continuous freezing period compared with FEM as well. Through this study, we conclude that MHF could improve the accuracy of thermal analysis obviously. Consequently, we recommend to adopt the MHF in the thermal analysis of frost heave evaluation.

Keywords: mixed hybird FEM; FEM; thermal analysis; High-Speed Railway foundation.

EMPIRICAL ESTIMATION OF LAND SURFACE TEMPERATURE FROM MODIS CONSIDERING SNOW AND VEGETATION COVER EFFECTS

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Keywords: land surface temperature; Kudryavtsev approach; thawing depth; mean annual ground temperature

Land surface temperature is one of the main inputs to estimate mean annual ground temperature and annual temperature amplitude at land surface. This data is crucial to map the distribution of mean annual ground temperatures and thawing depths underlying the permafrost region through the Kudryavtsev approach. For this purpose MODIS LST (land surface temperature) products have been used for permafrost studies in recent years taking into account the sparseness of observational data.
The study provides an empirical estimation of ground temperature by analyzing daily LST datasets of MODIS/Aqua in combination with observed land surface temperatures as well as snow and vegetation covers in the period 2005-2010. Land surface temperature was measured at seven permafrost boreholes with elevation ranges between 1547-1885 m in the Khuvsgul region of Mongolia. Analysis showed that observational and MODIS land surface temperatures were highly correlated (R^2=0.91) during a year. The determination coefficients become weaker if LST is split into winter and summer period or period with or without snow cover. during periods with snow cover it is R^2=0.82 and during periods without snow cover it is R^2=0.55. For snow cover days, mean surface temperature biases range between 0.07°C and -5.7°C. The bias becomes stronger where the surface is covered with vegetation where the bias is between 0.05°C to -11.5°C. Simple empirical estimates were derived for the daily MODIS LST. That made it possible to improve the mean annual ground temperature and thawing depths maps by means of the Kudryavtsev approach.

A NEW MAP OF THE PERMAFROST DISTRIBUTION ON THE TIBETAN PLATEAU

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Keywords: MODIS LST; Permafrost distribution; Tibetan Plateau; TTOP

The Tibetan Plateau (TP) possesses the largest areas of permafrost terrain in the mid- and low-latitude regions of the world. A detailed database of the distribution and characteristics of permafrost is crucial for many physical and social applications. Although some permafrost distribution maps have been compiled in previous studies and have been proven to be very useful, high uncertainty still exists in the mapping due to the limited data source, ambiguous criteria, little validation, and the deficiency of high-quality spatial datasets. In this paper, a new permafrost map was generated mostly based on freezing and thawing indices from modified Moderate Resolution Imaging Spectroradiometer (MODIS) land surface temperatures (LSTs) and validated by various ground-based datasets. The soil thermal properties of five soil types across the TP were estimated according to an empirical equation and in situ observed soil properties (moisture content and bulk density). The Temperature at the Top of Permafrost (TTOP) model was applied to simulate the permafrost distribution. The results show that permafrost, seasonally frozen ground, and unfrozen ground covered areas of 1.06×10^6 km^2 (40%), 1.46×10^6 km^2 (56%), and 0.03×10^6 km^2 (1%), respectively, excluding glaciers and lakes. The ground-based observations of the permafrost distribution across the five investigated regions (IRs, located in the transition zones of the permafrost and seasonally frozen ground) and three highway transects (across the entire permafrost regions from north to south) have been used to validate the model. The result of the validation shows that the kappa coefficient varies from 0.38 to 0.78 with an average of 0.57 at the five IRs and 0.62 to 0.74 with an average of 0.68 within the three transects. The result of TTOP modeling shows more accuracy in comparison with two maps, compiled in 1996 and 2006 and could be better represent the detailed permafrost distribution than other methods. Overall, the results provide much more detailed maps of the permafrost distribution and could be a promising basic data set for further research on permafrost on the Tibetan Plateau.

APPENDIX

Appendix A: Program

Oral Sessions

Date	Slot Session Conveners	First author	Title
2017/7/3	PM1 #09 Etzelmüller, B. Ishikawa, M	Kotaro Fukui	ROCK GLACIERS IN THE BHUTAN HIMALAYAS
		Jingyi Zhao	INFLUENCE OF SNOW COVER ON THE THERMAL REGIME OF FROZEN SOIL IN THE EAST TIANSHAN MOUNTAINS, CHINA
		Ren Li	SOIL THERMAL CONDUCTIVITY WITHIN ACTIVE LAYER AT TANGGULA SITE IN NORTHERN QINGHAI-TIBET PLATEAU, CHINA
		Dashtseren Avirmed	MONITORING AND THERMAL STATE OF PERMAFROST IN MONGOLIA
		Mamoru Ishikawa	SPATIAL MODELLING OF MONGOLIAN PERMAFROST -STATISTICAL AND STOCHASTIC
	PM2 #01 Christiansen, H.H. Matsuoka, N.	Toshio Sone	MONITORING OF SURFACE STONE MOVEMENT ON THE GOREIBITSU PASS IN FUKUSHIMA PREFECTURE, JAPAN
		Jaroslav Obu	SORTED PATTERNED GROUND IN KARST CAVES: A CASE STUDY OF A CAVE IN SLOVENIA
		Masato Sato	LABORATORY EXPERIMENTS ON SIMULTANEOUS FROST AND SALT WEATHERING: EFFECTS OF DISSOLVED SALTS ON FROST SHATTERING
		Mariana Verdonen	CRYOGENIC LANDSLIDE ACTIVITY 1970 ? 2014 IN CENTRAL YAMAL, RUSSIA, OBSERVED FROM SATELLITE IMAGE TIME SERIES
		Yury A. Dvornikov	GAS-EMISSION CRATERS ON YAMAL AND GYDAN PENINSULAS ? FUTURE LAKES
		Norikazu Matsuoka	MULTI-METHOD MONITORING OF ICE WEDGE DYNAMICS IN CENTRAL SPITSBERGEN (2005-2016)
	PM1 #04 Liljedahl, A. Hiyama, T. Park, H.	Liudmila Lebedeva	HOW COULD SLOPE-SCALE KNOWLEDGE BE USEFUL IN REGIONAL APPLICATION OF HYDROLOGICAL MODEL IN DIFFERENT PERMAFROST ENVIRONMENTS?
		Tetsuya Hiyama	ESTIMATING PERMAFROST GROUNDWATER AGE OF KHANGAI MOUNTAINS IN CENTRAL MONGOLIA
		Sharkhuu Natsagdorj	INFLUENCE OF GROUNDWATER ON GROUND TEMPERATURES AND SEASONAL FREEZING IN THE TUUL RIVER VALLEY NEAR ULAANBAATAR
		Juan Chang	SEASONAL DYNAMICS OF SUPRAPERMAFROST GROUNDWATER AND ITS RESPONSE TO THE FREEING-THAWING PROCESSES OF SOIL IN THE PERMAFROST REGION OF QINGHAI-TIBETAN
		Kaitlyn E Roberts	RAPID LAKE HYDROCHEMICAL AND ECOSYSTEM CHANGE IN HIGH ARCTIC LAKES DUE TO PERMAFROST CHANGE
	PM2 #04 Liljedahl, A. Hiyama, T. Park, H.	Youngwook Kim	ASSESSMENT OF PERMAFROST VULNERABILITY AND ACTIVE LAYER THICKNESS INCREASES IN THE HIGH NORTHERN LATITUDES USING SATELLITE OBSERVATIONS AND PROCESS MODEL
		Taro Nakai	APPLICATION OF TERRESTRIAL ECOSYSTEM DYNAMICS MODEL TO A LARCH FOREST IN EASTERN
		Hisashi Sato	TOPOGRAPHIC CONTROLS ON THE ABUNDANCE OF SIBERIAN LARCH FOREST
		Genxu Wang	EFFECTS OF CHANGES IN ALPINE GRASSLAND VEGETATION COVER ON HILLSLOPE HYDROLOGICAL PROCESSES IN A PERMAFROST WATERSHED
		Hotaek Park	CHANGES IN ARCTIC TERRESTRIAL EVAPOTRANSPIRATION BUDGET AND THE IMPACT TO HYDROLOGICAL CYCLE UNDER CLIMATE CHANGE
2017/7/4	AM1 #05 Bartsch, A. Sueyoshi, T.	Jaroslav Obu	TOWARDS A REMOTE-SENSING BASED GLOBAL MAP OF PERMAFROST
		Defu Zou	A NEW MAP OF THE PERMAFROST DISTRIBUTION ON THE TIBETAN PLATEAU
		Jambaljav Hemchig Yamkhin	NEW MAP OF MONTANE PERMAFROST IN MONGOLIA
		Philip Paul Bonnaventure	IMPROVED SENSITIVITY ANALYSIS OF PERMAFROST MODELS TO PROJECTED CHANGES IN CONTINENTALITY, YUKON, CANADA
		Sebastian Westermann	THAW PROGRESSION AND ACTIVE LAYER THICKNESS BY DRIVING PERMAFROST MODELS WITH SATELLITE DATA
		Sarah Marie Strand	ACTIVE LAYER THICKENING IN THE NORDIC REGION, OBSERVED THROUGH THE CIRCUMPOLAR ACTIVE LAYER MONITORING (CALM) PROGRAM
	AM2 #05 Bartsch, A. Sueyoshi, T.	Lin Liu	DECADAL CHANGES OF SURFACE ELEVATION OVER PERMAFROST AREA ESTIMATED USING REFLECTED GPS SIGNALS
		Franck Garestier	FOLLOWING DEFORMATION OVER PERMAFROST ENVIRONMENT DURING A WHOLE FREEZE/THAW CYCLE USING POL-D-INSAR
		Lingcao Huang	AUTOMATIC DETECTION OF THERMAL EROSION GULLIES FROM HIGH-RESOLUTION IMAGES IN EBOLING MOUNTAIN (QINGHAI, CHINA)
		Sergey A. Sadkov	LACUSTRINE THERMOKARST LANDSCAPE PATTERN ANALYSIS: SOME PROBLEMS OF THE MATHEMATICAL MORPHOLOGY OF LANDSCAPE BASIC MODEL
		Sonia Tomaskovicova	MODELING THE GROUND RESISTIVITY FROM UNFROZEN WATER CONTENT IN FINE-GRAINED HIGH-LATITUDE PERMAFROST
		Junko Mori	MONITORING OF FREEZE-THAW DEPTH USING LARGE NUMBERS OF TEMPERATURE SENSORS
	AM1 #12 Habeck, O. Takakura, H.	Joachim Otto Habeck	PASTORALISTS IN PERMAFROST REGIONS: DRIVERS OF LANDSCAPE CHANGE?
		Aytal Yakovlev	IRRIGATION AND ARTIFICIAL DRAINING AS POTENTIAL FACTORS OF PERMAFROST DEGRADATION: AGRICULTURE IN THE AMGA AND VILYUY CATCHMENT AREAS, YAKUTIA
		Aleksandr N. Fedorov	SOCIAL AND ECONOMIC CONSEQUENCES OF CLIMATE WARMING-INDUCED DEGRADATION OF ICE-RICH PERMAFROST LANDSCAPES IN YAKUTIA
		Nikolay I. Basharin	ASSESSMENT OF THERMOKARST DEVELOPMENT IN CENTRAL YAKUTIA UNDER CHANGING
		Masanori Goto	TOWARD MAKING OF TEACHING MATERIALS FOR ENVIRONMENTAL EDUCATION RELATED TO SAKHA THERMOKARST
	AM1 #13 Harada, K.	Elchin Jafarov	PERMAFROST MODELING CYBERINFRASTRUCTURE
	AM2 #07 Dyck, M. Watanabe, K.	Tomoyoshi Hirota	SOIL FROST CONTROL- YUKIWARI (SNOW-PROWING) AND YUKIFUMI (SNOW COMPACTION) -
		Masato Oishi	TRIAXIAL FROST HEAVE TESTS FOR IMPROVEMENT OF PREDICTION OF THE FROST HEAVE IN ARTIFICIAL GROUND FREEZING
		Mousong Wu	SIMULATIONS OF WATER, HEAT, AND SOLUTE TRANSPORT IN PARTIALLY FROZEN SOILS
		Andreas Kemna	MONITORING MELTWATER FLOW AT AN ALPINE PERMAFROST SITE USING ELECTRICAL SELF-POTENTIAL MEASUREMENTS
		Kunio Watanabe	UNFROZEN WATER POTENTIAL GRADIENT IN A DIRECTIONALLY FREEZING AN THAWING SOIL
		Miles Dyck	SIMULATION OF THE DIELECTRIC PERMITTIVITY OF FROZEN, STRUCTURED SOILS

Date	Slot Session Conveners	First author	Title
2017/7/5	AM2 #08 Niu F. Kanie, S.	Dina Bek	THE METHODOLOGY OF THE ASSESSMENT OF THE THERMAL AND MECHANICAL INTERACTION OF A LOW-TEMPERATURE COOLANT WITH THE SALTED SOILS CONTAINING CRYOPEGS
		Shuangyang Li	CENTRIFUGE AND NUMERICAL MODELLING OF FROST HEAVE MECHANISM OF A CANAL IN COLD REGIONS
		Hao Zheng	THE APPLICATION OF MIXED HYBRID FEM FOR THERMAL ANALYSIS IN HIGH-SPEED RAILWAY
		Taichi Esaki	THE BASIC DESIGN OF THE FROZEN SOIL WALL AT THE FUKUSHIMA DAIICHI NUCLEAR POWER
		Wei Cao	SIMULATING THE INFLUENCE OF COAL MINING ON THE SURROUNDING PERMAFROST AROUND THE OPEN PIT
		Yasuhiro Uraguchi	CONTROL METHODS OF FROST HEAVING AND THAW SETTLEMENT IN ARTIFICIAL GROUND FREEZING CONDUCTED IN SOFT FROST SUSCEPTIBLE GROUND AT A SHIELD MACHINE ARRIVAL
	PM1 #08 Niu F. Kanie, S.	Veronique Fournier	TWO DECADES OF GROUND TEMPERATURES FROM ACROSS THE CANADIAN ARCTIC
		Satoshi Akagawa	FROST HEAVING OBSERVED IN THAWING PROCESS
		Anna M. Wagner	WATCHING ICE MELT: GEOPHYSICAL MONITORING OF A PERMAFROST WARMING EXPERIMENT
		Masaya Ogawa	FUNDAMENTAL STUDY ON GROUND DEFORMATION DUE TO THAWING OF PERMAFROST WITH INDOOR EXPERIMENT
		Wansheng Pei	THE OPTIMAL DESIGN OF EMBANKMENT STRUCTURE ON SLOPING GROUND IN PERMAFROST
	PM2 #08 Niu F. Kanie, S.	Teijiro Saito	100M TUNNEL EXCAVATION WITH ARTIFICIAL GROUND FREEZING RING SUPPORT FOR THE MTR WEST ISLAND LINE C704 IN HONG KONG
		Hiroshi Soma	GROUND FREEZING METHOD UTILIZING CO2 LIQUID GAS TWO PHASE FLOW
		Fujun Niu	COOLING PROCESS OF A SCREE SLOPE AND ITS SIGNIFICANCE FOR PERMAFROST ENGINEERING
		Edward Yarmak	ACTIVE THERMOSYPHONS FOR ARTIFICIAL GROUND FREEZING
		Hideyuki Terui	DEMONSTRATION TEST FOR FROZEN SOIL WALLS USING ARTIFICIAL GROUND FREEZING
		Atsuko Sato	METHOD OF IMPROVING UNSUITABLE SOIL WITH HIGH MOISTURE CONTENT BY USING THE COLD CLIMATE AND LARGE SANDBAGS
	AM2 #03 Ikeda, A.	Reynald Delaloye	ACCELERATING VERSUS DECELERATING ROCK GLACIERS IN THE CONTEXT OF ONGOING CLIMATE WARMING
		Bernd Etzelmuller	WARMING AND DEGRADATION OF PERMAFROST IN NORTHERN NORWAY
		Florence Magnin	MEASURING AND MAPPING ROCK WALL PERMAFROST ACROSS NORWAY
		Paula Hilger	POST-GLACIAL TIMING OF ROCK-SLOPE DESTABILISATION
		Hanne Hvidtfeldt Christiansen	THE INFLUENCE OF GROUND FREEZING ON SLOPE DYNAMICS IN SVALBARD - A CASE STUDY FROM TWO AUTUMN 2016 STORMS
		Ivan I. Khristoforov	GROUND PENETRATING RADAR STUDY OF GLACIERS IN SOUTHERN SIBERIA: AN EXAMPLE OF NINA AZAROVA GLACIER
	PM1 #11 Vieira, G.	Yuki Sawada	MONITORING OF GROUND ICE CHANGES WITH COMPACT DIGITAL CAMERA WITHIN A TALUS SLOPE IN ODATE, JAPAN
		Goncalo Vieira	GROUND SURFACE TEMPERATURE REGIMES IN THE HIGH AND MIDDLE ATLAS (MOROCCO): CHARACTERISTICS AND IMPLICATIONS FOR THE PRESENT-DAY PERIGLACIAL DYNAMICS
		Saille Bishop-Lagowski	PERMAFROST IN TALUS SLOPES NEAR THUNDER BAY, ONTARIO, CANADA
		Kazuo Takeda	INFLUENCE OF GROUND FREEZING ON GROWTH OF LARIX KAEMPFERI IN SEASONALLY FROZEN GROUND REGIONS THROUGH TREE RING ANALYSIS
		Yukiyoshi Iwata	IMPACTS OF THICK FROZEN LAYER ON VERTICAL DISTRIBUTION OF SOIL NITROGEN AFTER SPRING SNOWMELT PERIOD
		Yuanming Lai	A REVIEW OF PHYSICAL AND MECHANICAL PROPERTIES OF SALINE FROZEN SOIL
	PM2 #02 Strauss, J. Iijima, Y.	Yoshihiro Iijima	HYCENTERED POLYGON DEVELOPMENT DURING RECENT DECADE IN CENTRAL YAKUTIA, RUSSIA
		Graham Lewis Gilbert	CRYOFACIES IN EPIGENETIC PERMAFROST - A DIVERSE ASSEMBLAGE OF GROUND ICE IN SEDIMENT CORES FROM ADVENTDALEN, SVALBARD
		Jens Strauss	FILLING A WHITE SPOT ON THE YEDOMA MAP: THE BALDWIN PENINSULA, WEST ALASKA
		Brendan O'Neill	THE CRYOSEISMOLOGY OF ICE-WEDGE POLYGONS: THERMAL CONTRACTION CRACKING INFERRED FROM MINIATURE ACCELEROMETERS
		Hitoshi Saito	DETECTION OF THERMOKARST DEVELOPMENTS USING UAV AND SFM-MVS PHOTOGRAMETRY
		Kazuyuki Saito	ASSESSING AND PROJECTING GREENHOUSE GAS RELEASE DUE TO ABRUPT PERMAFROST

Date	Slot Session Conveners	First author	Title
2017/7/6	AM2 #06 Kotani, A.	Yojiro Matsuura	PERMAFROST CONDITIONS AFFECT FOREST STAND STRUCTURE IN CIRCUMPOLAR REGION
		Matthias B. Siewert	HIGH-RESOLUTION MAPPING AND SPATIAL VARIABILITY OF SOIL ORGANIC CARBON IN PERMAFROST ENVIRONMENTS
		Annett Bartsch	THE POTENTIAL AND LIMITATIONS OF ACTIVE LAYER THICKNESS ESTIMATION FROM SAR BACKSCATTER INTENSITY AND ITS RELATION TO SOIL ORGANIC CARBON
		Kabir Rasouli	PERMAFROST RESPONSE TO TRANSIENT VEGETATION AND CLIMATE CHANGES IN A NORTHERN MOUNTAIN BASIN, CANADA

Poster Sessons

Date	Session	First author	Title
2017/7/3	#01	Zhanju Lin	THERMOKARST LAKES AND PERMAFROST ALONG QINGHAI-TIBET ENGINEERING CORRIDOR
		Takushi Koyama	THREE-DIMENSIONAL FORM AND WEDGE STRUCTURES OF POLYGONS AROUND VASSDALEN, CENTRAL DRONNING MAUD LAND, EAST ANTARCTICA
		Tatsuya Watanabe	GROUND THERMAL REGIME OF SOIL-WEDGE CRACKING IN THE DAISETSU MOUNTAINS, HOKKAIDO, JAPAN
		Bernd Etzelmuller	THERMAL REGIME AND GEOMORPHOLOGICAL PROCESSES IN STEEP SLOPES IN TIME AND SPACE
		Masayuki Seto	THE EFFECTS OF GROUND SURFACE CONDITIONS ON SOLIFLUCTION SPEED ON A TEMPERATE LOW-MOUNTAIN PEAK IN NORTHEASTERN JAPAN
		Jing Luo	THAW-INDUCED SLOPE FAILURES IN QINGHAI-TIBET ENGINEERING CORRIDOR
		Kjetil Skarsvag Ovesen	NON-CHANNELIZED PERIGLACIAL DEBRIS AVALANCHES IN NORWAY - SPATIAL DISTRIBUTION, TRIGGERING CAUSES AND REGOLITH THICKNESS
		Vetle Aune	ACTIVE ROCK GLACIER AT SEA-LEVEL IN FINNMARK, NORTHERN NORWAY?
	#04	Elchin Jafarov	MODELING HYDROTHERMAL INTERACTION WITHIN A 2D HILLSLOPE
		Huiru Jiang	ANALYSIS OF SOIL FREEZE/THAW DYNAMICS AND ITS IMPACT ON SOIL MOISTURE AND VEGETATION PHENOLOGY IN THE TIBETAN PLATEAU
		Anarmaa Sharkhuu	ESTIMATION OF ACTIVE LAYER THICKNESS IN DISCONTINUOUS PERMAFROST AREA, IN CONNECTION WITH GROUNDWATER
		Leo Martin	MODELLING THE THERMAL STABILITY OF PEAT PLATEAUS AND PALSAS IN NORTHERN NORWAY
		Takeo Onishi	LINKING DYNAMICS OF PERMAFROST AND DISSOLVED IRON PRODUCTION IN THE AMUR RIVER BASIN
		Jambaljav Hemchig Yamkhin	THE INTERACTION BETWEEN PEAT AND PERMAFROST IN MONGOLIA
		Kjetil Schanke Aas	DEGRADING PALSA MIRES IN NORTHERN NORWAY SIMULATED WITH A REGIONAL CLIMATE MODEL WITH A SUBGRID SNOW SCHEME
	#05	Toshio Sone	MONITORING OF FREEZE-THAW DEPTH USING LARGE NUMBER OF TEMPERATURE SENSORS
		Masato Furuya	GROUND DEFORMATION MAPPING BY ALOS1/2 INSAR: CASE STUDIES AT HERSCHEL ISLAND, CANADA, AND BATAGAIKA CRATER, SIBERIA
		Kristoffer Aalstad	TOWARDS HIGH-RESOLUTION SNOW DEPTH MAPPING IN PERMAFROST REGIONS BASED ON SATELLITE-DERIVED SNOW EXTENT DATA
		Birgit Heim	USING RAPIDEYE SATELLITE DATA TO ASSESS THE TUNDRA-TAIGA TRANSITION IN ARCTIC SIBERIA (LAPTEV SEA AND EASTERN SIBERIAN REGION)
		Antoni G.	DEVELOPMENT OF A GLOBAL PERMAFROST ELECTRICAL RESISTIVITY SURVEY (GPERS) DATABASE
		Munkhtsetseg Zorigt	EMPIRICAL ESTIMATION OF LAND SURFACE TEMPERATURE FROM MODIS CONSIDERING SNOW AND VEGETATION COVER EFFECTS
		Justyna Czekirda	TRANSIENT MODELING OF PERMAFROST IN ICELAND
	#09	Anna Grigorievna Gololobova	THE STABILITY OF FROZEN SOILS EAST SIBERIA TO CHEMICAL POLLUTION
		Dashtseren Avirmed	INFLUENCE OF SITE-SPECIFIC FACTORS ON TEMPERATURES OF THE ACTIVE LAYER AND SEASONALLY FROZEN GROUND
		Anarmaa Sharkhuu	THERMAL INSULATION OF VEGETATION AND SNOW COVERS AND ITS EFFECT ON PERMAFROST CONDITIONS IN MONGOLIA
		Pavel Ya. Konstantinov	EFFECT OF RAINFALL ON PERMAFROST TEMPERATURE AND SEASONAL THAW DEPTH IN CENTRAL YAKUTIA, EAST SIBERIA
	#10	Carla Tapia	GEOMORPHOLOGICAL MAP OF A POST-GLACIAL/PERIGLACIAL LANDSCAPE: BRAMADERO RIVER BASIN (CENTRAL ANDES, ARGENTINA)
		Estefania Bottegal	MONITORING MORENAS COLORADAS ROCK GLACIER CRYODYNAMICS IN THE CENTRAL ANDES, MENDOZA, ARGENTINA
	#13	Koichiro Harada	FROST TUBE OUTREACH PROGRAM IN HOKKAIDO, JAPAN

Date	Session	First author	Title
2017/7/5	#03	Pierre-Allain Duvillard	THERMAL CONDITIONS OF AN UNSTABLE HIGH ALPINE PERMAFROST-AFFECTED ROCK RIDGE: THE CASE OF THE COSMIQUES HUT (3613 M A.S.L., MONT BLANC MASSIF)
		Christian Moertl	THERMAL CONDITIONS AND PERMAFROST EVOLUTION OF HIGH ALPINE ROCK SLOPES: A STUDY OF THE AIGUILLE DES GRANDS MONTETS IN THE MONT BLANC MASSIF
		Gregoire Guillet	ICE/SNOW COVERS ON PERMAFROST-AFFECTED ROCKWALLS: THERMAL PROPERTIES AND MULTI-DECADAL EVOLUTION IN THE MONT BLANC MASSIF
		Atsushi Ikeda	DEBRIS SUPPLY AS A CONTROL ON THE MILLENNIAL DEVELOPMENT OF ROCK GLACIERS IN THE SWISS
	#06	Havard Kristiansen	INCORPORATING BIOGEOCHEMISTRY IN THE PERMAFROST MODEL CRYOGRID 3
		Juri Palmtag	LANDSCAPE PARTITIONING AND BURIAL PROCESSES OF SOIL ORGANIC CARBON IN CONTRASTING AREAS OF CONTINUOUS PERMAFROST
		Ayumi Kotani	RESPONSE OF LARCH FOREST CO2 EXCHANGE ON WETNESS VARIABILITY OF PERMAFROST ACTIVE LAYER IN EASTERN SIBERIA
		Yonghua Zhao	SOIL MOISTURE DOMINATE ALPINE MEADOW CARBON BALANCE IN THE PERMAFROST REGION OF THE QINGHAI-TIBETAN PLATEAU
		Benoit Faucher	DISTRIBUTION, SOURCE AND CYCLING OF ORGANIC CARBON AND NITROGEN IN PERMAFROST FROM AN ULTRAXEROUS ENVIRONMENT (MCMURDO DRY VALLEYS OF ANTARCTICA).
	#07	Sonia Tomaskovicova	MODELING IN-SITU HYSTERETIC VARIATION OF UNFROZEN WATER CONTENT IN HIGH-LATITUDE FINE-GRAINED PERMAFROST
		Zhemin You	MICROSCOPIC FAILURE MECHANISM OF SALINE SOIL CONSIDERING SALT TRANSPORT AND PHASE CHANGE UNDER FREEZE-THAW CYCLES
		Simon Dumais	ASSESSMENT OF LARGE STRAIN THAW CONSOLIDATION OF PERMAFROST BASED ON GENERALIZED THAWED SOIL PROPERTIES
		Jianguo Lu	EXPERIMENTAL STUDY ON UNFROZEN WATER CONTENT AND THE FREEZING TEMPERATURE DURING FREEZING AND THAWING PROCESSES
		Evgeny Mikhailovich	CHANGES OF PHYSICAL PROPERTIES OF FROZEN HYDRATE-BEARING SEDIMENTS DURING POROUS GAS HYDRATES DISSOCIATION
		Takashi Kanauchi	CHARACTERISTICS OF FROST HEAVE STRESS AND STRAIN IN TRANSVERSE DIRECTION TO HEAT FLOW
		Yoshiharu Ito	MELTING/FREEZING TEMPERATURE OF WATER CONFINED IN PORE SPACE OF SEDIMENTARY ROCK BY MEANS OF DIFFERENTIAL SCANNING CALORIMETRY (DSC)
	#08	Xuyang Wu	THE QUICK COOLING EFFECT ANALYSIS OF SHALLOW BURIED SECTION OF TUNNEL PORTAL BY INSTALLING THERMOSYPHONS IN TIBET PLATEA
		Youngchin Kim	TEST OF UNFROZEN WATER CONTENT AND ULTRASONIC WAVE VELOCITY FOR FROZEN GRANITE SOIL AND CLAYEY
		Yunhu Shang	STUDY ON GROUND THERMAL REGIME OF A CAST-IN-PLACE PILE IN UNSTABLE WARM PERMAFROST REGIONS DURING CONSTRUCTION
		Yang Yang	HOT-WATER CORING SYSTEM IN SUBGLACIAL PERMAFROST REGIONS
		Xiaopeng Fan	IBED DRILLING SYSTEM FOR CORING IN POLAR ICE AND SUBGLACIAL PERMAFROST
		Mingtang Chai	TEMPERATURE CHARACTERISTICS OF ADDITIVES AND CEMENT IN FROZEN SOILS DURING FREEZING AND THAWING
		Koui Kim	STUDY ON THE SEGREGATION POTENTIAL OF FAIRBANKS SILT UNDER DIFFERENT FREEZING
		Jargaltulga Tsogtbayar	HOW DANGEROUS IS THE CHANGE OF PERMAFROST ON INFRASTRUCTURE IN MONGOLIA
	#11	Masaru Mizoguchi	ESTIMATION OF SOIL FREEZING DATE IN IITATE VILLAGE, FUKUSHIMA USING AIR TEMPERATURE REMOTELY MEASURED
		Haifeng Gao	VARIATIONS OF SOIL FREEZE-THAW PROCESS IN ALPINE MEADOW AND ALPINE STEPPE OF CENTRAL TIBETAN PLATEAU

Appendix-B: Organizations

Local Organizing Committee

Mamoru Ishikawa (Conference Chair)	Norikazu Matsuoka (Conference Vice Chair)	Yoshihiro Iijima (Conference Vice Chair)	Sei'ichi Saito (Conference Manager)
Shunji Kanie	Yuuki Komata	Toshio Sone	Minoru Tokunaga
Atsushi Ikeda	Yuji Kodama	Koichiro Harada	Tetsuo Sueyoshi
Kazuyuki Saito	Ayumi Kotani	Satoshi Akagawa	Kunio Watanabe
Yuki Sawada	Hisao Izuta	Tatsuya Watanabe	Takashi Ono
Atsuko Sugimoto	Shingo Tanaka		

International Scientific Committee

Anthony Lewkowicz (Canada)	Hanne Christiansen (Norway)	Sergey Marchenko (USA)	Jens Strauss (Germany)
Bernd Etzelmüller (Norway)	J. Otto Habeck (Germany)	Gonçalo Vieira (Portugal)	Dario Trombotto (Argentine)
Fujun Niu (China)	Michael Krautblatter (Germany)	Annett Bartsch (Austria)	Philip Bonnaventure (Canada)
Anna E. Klene (USA)	Christian Hauck (Switzerland)	Anna Liljedahl (USA)	Florence Magnin (France)

Appendix-C: field trips.

Pre-conference field trips

PRE1. Daisetsu Mountains in Hokkaido (Discontinuous and extra-zonal permafrost): 28 June – 1 July

The Daisetsu Mountains, composed of a number of andesitic volcanic cones higher than 2000 m ASL, are climatically characterized by low air temperature, huge amount of snowfalls and strong westerly window during winter. Mountain permafrost occur in wind-blown snow-free ground of the summit areas, and within open-work blocky materials in the low altitudes. This field trip visited permafrost observation sites of high and low altitudes, namely, the Daisetsu-zan National Park, the area referred to by the aboriginal Ainu people as *Kamui Mintara* or the "*the playground of the Gods (Bears)*", and Tokachi-Shikaoi geopark, respectively. Then, the party joined the PRE2.

PRE2. Shikaribetu lake in Hokkaido (extra-zonal permafrost and patterned ground): 30 June – 1 July.

This field trip was a shorter version of PRE1 field trip, visiting Shikaribetsu lake hot spa, and Higashi-nupukaushi-nupuri (extra-zonal permafrost in scree slope) with a BBQ party at night on the Day1, and Obihiro (seasonal frost and earth hummock) on the Day 2.

These filed trips were organized by Toshio Sone, Yuki Sawada, and Mamoru Ishikawa.

PRE3. Artificially frozen ground wall (Including Fukushima-Daiichi Nuclear Power Station): 30 June – 1 July

Artificial ground freezing (AGF) method is a powerful auxiliary method for civil engineering works because it enhance the ground strength greatly and reduce the risk of roof-fall accidents through excavation. Japan has considerable experiences of applying AGF method to the construction of roads and tunnels especially in the urban areas. Moreover, the huge frozen ground wall has been constructed around the Fukushima-Daiichi Nuclear Power Station (NPS) which were damaged by the gigantic tsunami following the Tohoku earthquake on 11 March 2011, in order to isolate the contaminated adjacent ground water from surrounding uncontaminated ground water environment. During this two-day pre-conference field trip, participants have visited a complex tunnel construction site where AGF method has been introduced in Tokyo and then the 1,500m long and 30m deep artificially frozen ground walls construction site in Fukushima-Diaichi NPS.

This field trip was organized by Satoshi Akagawa.

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Post-Conference field trip

Mt. Fuji (The highest and coldest place in Japan)

7 - 10 July

This post-conference field trip focused on going up to the top of the most symbolic mountain in Japan to see volcanic surface conditions having permafrost. The trip hiked up and down between 2300 m asl. and 3776 m asl. Despite the rainy season, we climbed up under clear sky and looked the borehole for monitoring permafrost. The day after the climbing, we visited a lava tunnel with ice (ice cave) and then looked some volcanic features around the mountain.

This field trip was organized by Atsushi Ikeda.

Asian Conference on Permafrost 2017

Sunday, July 2 to Thursday, July 6, 2017, Sapporo, Japan

HOKKAIDO UNIVERSITY