G3–O1

GROUND THERMAL REGIME AND ACTIVE LAYER THICKNESS MONITORING AND MODELLING IN THE NORDIC AREA

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Since 2001 numerous shallow boreholes were equipped to monitor ground temperatures in the Nordic area, especially in Norway, Svalbard and Iceland. The total number of monitored boreholes is 42, of which 4 are located in Iceland, 20 in southern Norway, 16 in northern Norway and 12 in Svalbard. Most of these boreholes in northern Norway and Svalbard were established during the IPY campaign 2007-2009. They are set up to characterize the ground thermal regime in different environmental settings along altitudinal and continental transects, and to validate spatially distributed, equilibrium and transient permafrost models. Also as an important and integrative part of the IPY activities the Norwegian permafrost database, NORPERM was established. Most of the Norwegian permafrost data are today archived in the database, which is located at the Norwegian Geological Survey (NGU).

Permafrost data were used to calibrate a transient heat flow model for altogether 29 of our sites all over the study area. The model was forced with meteorological data over various time periods, ranging from the beginning of the instrumental data record at the end of the 18th century to down-scaled projections of climate scenarios for the future (2100). The results illustrate the potential evolution of permafrost conditions and the response to climate perturbations in sub-arctic mountains and high-arctic environments. Also the data were used to validate numerical spatial permafrost models for Norway.

Here we present the updated permafrost thermal state as observed in the borehole network, along with modeled ground temperature and active layer thickness (ALT) development since the end of the Little Ice Age and their potential future evolution. Also new spatial permafrost maps based on equilibrium and transient thermal modeling for the Nordic area will be presented.

G3–O2

PERMAFROST AND ACTIVELAYER MONITORING NETWORK IN ALASKAN COMMUNITIES

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The presence or absence of frozen ground has a strong effect on hydrology. Frozen soil acting as an impermeable layer affects water availability to root systems of plants and the recharge of groundwater reservoirs. The frost tube (active layer monitoring) program has been a great success in Alaskan communities because it is relatively easy to implement, is cost-efficient, and is a highly dynamic student activity. We have installed over 200 communities for a small one-channel data logger connected to an ground temperature sensor next to the frost tube. From the ground surface temperature data, freezing °C*days (freezing index) and thawing degree-days (thawing index) as well as mean annual temperature can be calculated. This program reveals much of the thermal structure of ground in Alaska, especially in many of the remote communities on the southern boundary of permafrost (i.e., the northern end of the seasonal frost region). Though there are many interesting aspects to this program, here we discuss (1) the distribution of the maximum freezing and thawing layer thickness, and (2) freezing and thawing °C*days ground surface distribution in Alaska.

G3–O3

THERMAL STATES OF MONGOLIAN PERMAFROST AND DEPLYOYING PERMAFROST OBSERVATORIES OVER THE ARCTIC

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Permafrost has been degrading over large areas of the world, although the warming rates show large spatial variations. Hence, it is important to organize and sustain to monitor the long-term thermal state of permafrost in various natural settings. We have been improving permafrost network over Mongolia, establishing new boreholes and recovering boreholes abandoned in the past. Currently available datasets showed that warming rate ranges between 0.01 and 0.03°C/a, and is more pronounced in the northern provinces with continuous permafrost. Permafrost partly disappeared at the southern boundary of the discontinuous permafrost in recent 30 years. Beside these country-scaled dynamics, strong influences of local geographic variations on permafrost temperatures could be observed. Cold permafrost occurs beneath topographic depressions, within ice-rich soils, and under forested slopes. Further applications of these borehole data are to develop high resolution permafrost map and to model future distribution of permafrost.

The permafrost dynamics over Mongolia would be the epitome of those in globe, since they involve the features of continuous, discontinuous, sporadic and mountain permafrost even in a small areas. Under the umbrella of GRENE and international collaborations, we are deploying permafrost observatories in Siberia and Canada where the spatial density of permafrost network is currently sparse.

PERMAFROST MAP IN RUSSIA USING COMMUNITY-BASED PERMAFROST AND ACTIVE LAYER MONITORING NETWORK

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In 2008, an approach to mapping permafrost based on thermal conditions was introduced during the Ninth International Conference on Permafrost (Jorgensen et al., 2008). This approach maps permafrost distribution using the annual mean air temperature model (PRISM) and surficial geology (the GIS platform). A thermal offset or gap occurs between air and ground surface temperatures mainly because of snow cover or other thermal effects. Use of the annual mean ground temperature model instead of air temperature will produce better results. Our community-based permafrost and active layer monitoring network measures ground temperature year-round at hundreds of locations. These data are useful for calibration or verification of the new model. The original objective of this network was to establish long-term permafrost monitoring sites near communities and schools so that students and teachers could be involved in installation of the monitoring equipment and data gathering. Permafrost condition is an important indicator of climate change, since permafrost is directly influenced by climate. Permafrost affects local ecosystems and hydrological regimes, and is a factor in natural disasters related to ground stability. Once we develop a station, data are available to the public for science, engineering, and education purposes. An important project related to the permafrost monitoring stations is the mapping/modeling of permafrost. Our community-based monitoring system will contribute to the production of a more-accurate permafrost map. With improved mapping/modeling in mind, we plan to finish the Alaska permafrost map, then develop the same method in Russia as in Alaska by establishing monitoring stations in Sakha Republic and other parts of Russia. To begin with, however, we will focus on establishing this network over the next several years.

G3–O5 Cancelled

PARAMETRIZATION OF RUNOFF FORMATION MECHANISMS IN MOUNTAINOUS PERMAFROST CONDITIONS OF RUSSIA AND CANADA (THE KOLYMA WATER BALANCE STATION AND WOLF CREEK RESEARCH WATERSHED)

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The parameterization of process-based hydrological models reflects natural conditions of runoff formation processes and should be developed and tested on the basis of detailed and long-term measurements at research watersheds. Very limited number of such catchments exists in the permafrost zone.
The aim of the study was the development of parameterization schemes describing mountainous territories of Russian Northern East and Canadian part of the Yukon River basin for the purposes of hydrological modelling.
The study included the following steps: i) comparative analysis of flow formation processes in two research watersheds of Russia and Canada at slope and catchment scales ii) deriving soil and vegetation parameters by additional sources of information and modelling experiments at slope scale iii) transferring the parameters from slope to catchment scale and performing runoff simulations iiii) analysis of the results and conclusion about workability and limitations of developed parameterization scheme.
Two research watersheds, the Kontaktovy Creek and the Wolf Creek basins (21.2 and 195 km^2 respectively) were studied. Although both of them are covered by permafrost and relate to the zone of mountainous taiga and tundra, they have significant differences in runoff formation mechanisms.
The Kontaktovy Creek basin is characterized by continuous permafrost while in the Wolf Creek basin permafrost occupies only northern slopes and headwaters. It leads to predominance of surface and shallow subsurface flow formed in active layer at the Kontaktovy Creek watershed, while the underground flow dominates in the Wolf Creek basin. At both watersheds different slopes show specific thermal and water regime due to difference in solar radiation income and dominant landscapes.
Observable land cover properties were derived from literature review and used as the model parameters to simulate soil thaw/freeze depths, soil moisture and temperature, snow accumulation and melting.
Soil and vegetation parameters were initially refined at slope scale on the base of multiple modelling experiments and then transferred to the watershed scale without change. Good agreement between observed and simulated runoff confirmed the effectiveness of the parameterization.
The Hydrograph model applied to both watersheds at slope and catchments scales is a process-based hydrological model. It adequately describes land hydrological cycle based on standard daily input information. Sufficient algorithm of water and heat dynamics in the soil enables to use this model in various condition of permafrost.
We propose that gained parameterization scheme and the Hydrograph model can be applied to ungauged and poorly gauged basins at the Yukon River in Canada and the Upper Kolyma River in Russia.

G3–O6

TEMPORAL SEQUENCING OF ANNUAL SPRING RUNOFF IN FOUR MAJOR ARCTIC-DRAINING RIVERS

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Warming in the Arctic has significance as an indicator of global climate change and through feedbacks to the global climate system. The influx of freshwater to the Arctic Ocean has the potential to influence global climate through modification of the intensity of the thermohaline circulation. This emphasizes the importance of understanding climate-discharge linkages in Arctic-draining rivers, which are the dominant source of freshwater input to the Arctic Ocean. To date, no research has evaluated trends in the magnitude and sequential timing of the spring freshets – the dominant hydrologic event occurring on these nival river systems – or of the atmospheric circulation patterns that control them. To address these shortcomings, historic daily discharge data from selected hydrometric stations within the four largest Arctic-draining watersheds (Mackenzie, Ob, Lena, Yenisei) have been analyzed to extract data about the timing, magnitude and characteristic shapes of the spring freshet hydrographs. Discussion of results focus on: the temporal sequencing of spring discharge at stations draining directly to the Arctic Ocean along the Mackenzie, Ob, Lena, and Yenisei rivers; the discharge linkages with controlling patterns of temperature and precipitation; and the major atmospheric teleconnection patterns associated with extreme high and low flow years.

G3−O7

ICE MOVEMENT IN THE LENA RIVER AND THE TYPOLOGY OF SPRING FLOOD: AN INTERPRETATION OF LOCAL SOURCES INTEGRATED WITH SATELLITE IMAGERY USING A MULTIDISCIPLINARY APPROACH

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Spring flooding of northern rivers in both Arctic and sub-arctic regions is a regular seasonal event. As snow and ice thaw, floating freshwater ice appears in the rivers and flooding occurs, which is critical for the regional ecosystem and for water circulation. Theoretically, climate change should have some effect on this phenomenon, but due to regional variations and the complex interplay of elements, scientific data on how the climate is altering the freshwater ice process is still unclear. At the same time, since the spring river ice process and flooding have definite effects on human societies, these are now becoming issues of focus and urgency for social scientists and disaster management policymakers. From the human-dimension perspective, river ice is an important regional infrastructure because it is used for major winter transportation and local subsistence activities. Understanding the process of river ice breaking and consequent flooding is important for interdisciplinary area studies because they are closely related to local societal-technological aspects and the regional environment. This paper explores the concrete process of spring flooding through a case study of the Lena River in eastern Siberia. Recently, the frequency of disastrous spring flooding has increased in this region. Although a decisive explanation is not yet available, the local government is urgently demanding adequate policies and measures. In what conditions does the process of spring flooding develop in the Lena River? We will describe concrete processes such as ice movement and velocity, the locus of the flooding outbreak, and the disastrous results. The method of analysis is an interpretative approach using multi-disciplinary data from satellite imagery, literature sources, and fieldwork. At the same time as Landsat or large scale resolution images of flooding from a bird's-eye view provides the general outlook, the information of ice monitoring and flood reporting from local newspapers will be visualized using GIS software (Google Earth), and ALOS satellite or high resolution imagery of a particular flooding event is interpreted based on anthropological field data. Through these means, we identify several types of flooding and examine their implications for human societies.

G3–O8

WATER BALANCE OF ARCTIC WETLANDS WITH DIFFERING ICE WEDGE POLYGON TYPE

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Ice wedge polygons are common in landscapes underlain by permafrost. Still, their role on watershed-scale hydrology is constrained. We combined field measurements with mass and heat transfer modeling to assess the effect of ice wedge polygon type on landscape-scale hydrologic fluxes and stores. The physically-based model WaSiM was applied to airborne LiDAR and schematic DEMs, and forced by climate data from an Arctic wetland, Barrow, Alaska. Simulations and field measurements were concentrated to four sites, i.e. landscape types: high-centered, low-centered, and two transition polygon sites (the latter having both low-centers and troughs). Model simulations suggest that low-centered polygons, through elevated rims, reduce runoff while increasing evapotranspiration and water storage. The high-centered polygon landscape favors runoff, while storage and evapotranspiration drastically decrease. Continuous field measurements in neighboring, individual ice wedge polygons presents drastically different seasonal variability in water tables between study sites, despite the same landscape-scale end-of-winter snowpack water storage. It is evident from the field and modeling analyses that microtopography plays an important role on low-gradient Arctic wetland watershed-scale hydrology. Further, the fine microtopographical variability results in hydrologic characteristics that can present important geomorphological feedbacks. A shift in ice wedge polygon type could potentially dominate the initial effects of altered climate on Arctic wetland hydrology.

G3–O9

VEGETATION WATER USE COMPARISON IN A SUB-ARCTIC, BOREAL FOREST ENVIRONMENT USING HYDROGRAPH ANALYSIS

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The sub-Arctic environment is in the zone of discontinuous permafrost. The extreme energy influx from winter to summer has a strong influence on water storage and release processes at the watershed scale. For example, the seven months of snow accumulation are followed by a short 2-4 week period of snow ablation in which approximately 1/3 of the annual precipitation is released into the watershed. In permafrost soils, the soils begin to thaw immediately at the conclusion of snow melt, increasing the storage capacity of the soils. The storage capacity of the soils reaches a maximum in late summer then rapidly decreases during the freeze-back period in October. In permafrost-free soils dominated by deciduous vegetation, the trees appear to have a major role in taking up and transpiring liquid precipitation to back to the atmosphere. Conversely, in permafrost soils dominated by coniferous vegetation, the trees appear to have a minor role in the cycling of liquid water during precipitation events.

The overarching goal of our research is to quantify the relative roles of vegetation water use and soil storage dynamics associated with permafrost presence/absence in determining the magnitude and timing of water pathways in the sub-Arctic boreal forest. As part of this goal, we quantified the Horton Index - a metric that describes vegetation water use relative to available soil water - in two small sub-basins of the Caribou-Poker Creeks Research Watershed, located near Fairbanks, Alaska. The C2 (5.2 km^2) and C3 (5.7km^2) sub-basins are underlain by approximately 2 and 53% permafrost, and are dominated by deciduous (*Betula neoalaskana* and *Populus tremuloides*) and coniferous vegetation (*Picea mariana*), respectively. Catchment scale calculations of the Horton Index are made using stream flow analysis and during snow-free precipitation events over a 13-year period. In each sub-basin, the Horton Index varies with time with the greatest variation occurring in the spring and fall shoulder seasons. During the middle of the summer growing season, the Horton Index reaches its maximum value (indicating the highest fraction of available soil water is taken up by plants) with generally larger values in the low-permafrost, deciduous dominated sub-basin. Results from this study will be used to compare results from a storage-based hydrologic model that is being developed to better understand the relationships between vegetation, permafrost, water and climate in the boreal forest ecosystem.

G3–O10

ICE COVER OF EURASIAN LAKES AND INLAND SEAS FROM SATELLITE AND IN SITU OBSERVATIONS

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Because of its response to regional and global variations in the climate system, arctic and sub-arctic lakes and internal seas are not only an integrator of climate processes, but also strong indicator of existing or potential change. It is important to well understand what are temporal and spatial scales of variability of natural parameters, what are teleconnections, feedbacks and mechanisms responsible for the changes, what are natural and anthropogenic causes of recent and historical changes in the hydrophysical and meteorological parameters. Changes in natural parameters are important for human activity (navigation, transport, fisheries, tourism etc) and affect large population living around.

We present studies of ice and snow cover of continental water bodies using the synergy of more than 15 years-long simultaneous active (radar altimeter) and passive (radiometer) observations from radar altimetric satellites (TOPEX/Poseidon, Jason-1, ENVISAT and Geosat Follow-On) complemented by SSM/I passive microwave data. Five largest Eurasian continental water bodies - Caspian and Aral seas, Baikal, Ladoga and Onega lakes are selected as examples. An ice discrimination approach based on a combined use of the data is presented, as well as validation of this approach using *in situ* and independent satellite data in the visible range. We then analyse the long-term evolution of ice conditions for these lakes and inland seas using historical data and recent satellite observations. We also present our results of the field studies on the lakes Ladoga and Baikal.

We address another interesting phenomenon - formation of giant rings on Baikal Lake ice. These rings (diameter 5-7 km, thickness of dark layer - 1 - 1.8 km) have almost perfect circular shape. The rings have been observed since the early 1970ies by satellite imagery in various regions of the lake. We present several existing hypotheses of the origin of these rings and discuss strengths and weaknesses of each hypothesis. We present observation of the formation, development and disappearance of these rings using various satellite data. We discuss the conditions needed to create and maintain these rings, the timing of and duration of their existence, as well as horizontal and vertical structure of ice and snow cover and of temperature and conductivity before and during the appearance of rings.

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