Session 1: Impacts and interactions of climate and infrastructure in the Arctic

Response of permafrost environment to natural changes and human impact in the north of West Siberia (Yamal-Nenets Autonomous Okrug)

Marina O. Leibman, Artum V. Khomutov, Yu A. Dvornikov, Elena A. Babkina, Rustam R. Khairullin, Evgeny M. Babkin, N. Yu Fakashchuk

1 Earth Cryosphere Institute, Tyumen Scientific Centre SB RAS, Tyumen, Russia

Our main goal is studying natural permafrost environments and limited human impact caused by infrastructure development in the area close to gas fields, pipelines, railways, roads and quarries. Years of monitoring active layer, ground temperature and landslide activities at Vaskiny Dachi research station, we extended our studies. Spatially we extended monitoring westward to include gas-emission graters (GEC), and eastward to Tazovsky and Gydan peninsulas, south of, and north of Vaskiny Dachi research station latitude.

Research topics were extended as well. The following have been added to the research: (1) field studies (organic matter fate and hydrochemistry in the lake and GEC lake water; distribution and rate of thermocirque growth; dynamics of GEC width and depth); (2) laboratory studies (ionic and isotope analyses of lake and GEC-lake water; methane concentration in lake and GEC-lake water; dissolved organic matter in the lake water. Remote-sensing studies (processing optical images for monitoring GEC, thermocirques, peat plateaus, mapping tabular ground ice, methane emission in the lakes, predicting natural hazards).

We perform measurements of moisture content in the active layer, geochemistry of active-layer soils, bathymetry of lakes, including GEC lakes, snow survey and geochemistry of snow.

Results achieved so far are as follows. Since 2012 air temperature increase dramatically resulting in 20% deeper active layer, 0.5 degree higher ground temperature, activation of thermal denudation, formation of GEC transforming into lakes-successors.

It was revealed that the thaw depth increase in 2012 and 2013 reached the top of tabular ground ice and thermocirques were formed. In 2016, the growth of thermocirques speeded up.

Evidently, the presence of gas accumulations inside the permafrost caused by the increase in average ground temperature predetermined the release of gas formed during the dissociation of gas hydrates, with the formation of gas emission craters.

Human impact resulted in deeper active layer along the vehicle tracks, degradation of peat plateau crossed by the road, fast overgrowing of the quarries thanks to warmer summers.

Modeling of circumpolar permafrost and permafrost-thaw related geohazards affecting infrastructure

Olli Karjalainen, Juha Aalto, Miska Luoto, Sebastian Westermann, Vladimir E. Romanovsky, Frederick E. Nelson, Bernd Etzelmüller & Jan Hjort

1 University of Oulu, Geography Research Unit, Oulu, Finland
2 University of Helsinki, Department of Geosciences and Geography, Helsinki, Finland
3 Finnish Meteorological Institute, Helsinki, Finland
4 University of Oslo, Department of Geosciences, Oslo, Norway
5 University of Alaska Fairbanks, Geophysical Institute, Fairbanks, Alaska, USA
Degradation of permafrost poses a threat to the current and future infrastructure of the north circumpolar region. Rapid warming of the Arctic has led to rising permafrost temperatures and the potential for severe damage to infrastructure. The thermal state of permafrost in the near future must be considered carefully when planning future societal and industrial development of the Arctic.

Our aim was to assess permafrost-thaw related geohazards at an unprecedentedly high spatial resolution (< 1 km$^2$) across the entire circumpolar region for a near–future scenario. The possible consequences for human activity were estimated by quantifying the amount of basic infrastructure at risk (roads, railways, airports, pipelines, buildings, human settlements, and industrial areas). We first performed statistical ensemble modeling of permafrost properties (ground temperature and active-layer thickness) under current conditions. Next, we predicted permafrost conditions around mid-century using climate forcing scenarios that considered different pathways of human-induced greenhouse gas emissions. Finally, we formulated geohazard indices employing the projections of permafrost thaw, changes in active-layer thickness, and soil and terrain properties affecting permafrost stability.

Considering a moderate scenario, around 70% of the current infrastructure exists in areas where near-surface permafrost has high potential for thaw by mid-century. Moreover, one-third of the circumpolar built environment is located in high-hazard areas where thaw-related instability may cause severe damage. Sustainable development of Arctic communities and utilization of natural resources requires that these issues are addressed in planning at regional and local levels. Our modeling improves knowledge about large-scale variability in permafrost-thaw related geohazards, and facilitates targeting localized analyses.

---

**Impacts of climate change and infrastructure on reindeer herding in the Yamal peninsula**

*Roza Laptander$^1$ & Timo Kumpula$^2$*

$^1$Arctic Centre, University of Lapland, Rovaniemi, Finland  
$^2$Department of Geographical and Historical Studies, University of Eastern Finland, Joensuu, Finland

The traditional landuse in the Yamal is generally based on the Nenets reindeer herding. However, the hydrocarbon industry is presently the source of most ecological changes in the Yamal peninsula and socio-economic impacts experienced by nomadic Nenets reindeer herders who move annually between winter pastures at treeline and the coastal summer pastures nearby the Kara Sea.

In the central part of the Yamal peninsula, which is a permafrost area, both natural and anthropogenic changes have occurred during the last 50 years. We have studied gas field’s development and natural changes, like increases in shrub growth, cryogenic landslides, drying lakes in the region and these impacts to the Nenets reindeer herding.

The Nenets with collective and private owned herds of reindeer have proven adapt in responding to a broad range of intensifying industrial impacts, at the same time, as they have been dealing with symptoms of a warming climate and thawing permafrost phenomena.

The results of climate change together with the industrial development of the Yamal Peninsula have a serious impact to the Nenets nomadic reindeer husbandry. Their consequences made the Nenets reindeer herders change their migration routes and the way of working with reindeer. During
several years, we were doing interviews with the Nenets reindeer herders about the influence of climate change and industrialization of the tundra on the quality of the Nenets’ life and their work with reindeer. Reindeer herders said that the impacts of the industrial development have reduced their migration opportunities. Due to the concentration of a high number of reindeer in certain areas, nowadays the quality of pastures is quite poor. It has fatal effect during icing on the tundra in the winter. At the same time, in the summer reindeer have more food because of the increasing of green vegetation on the tundra.

Here we detail both the climate change impacts and spatial extent of gas field growth, landslides drying lakes, shrub increase and the dynamic relationship between the Nenets nomads and their rapidly evolving social-ecological system.

Session 2: Approaches to research and adaptation

Navigating the new Arctic: Landscape evolution and adapting to change in ice-rich-permafrost systems (NNA-IRPS)

Donald A. Walker¹, Amy Breen², Billy Connor³, Ronnie Daanen⁴, Lisa Druckenmiller¹; Robbin Garber-Slaght⁵; Jack Hébert⁶, Ben Jones⁷, Anja Kade⁷, Misha Kanevskiy⁸, Gary Kofinas⁹, Anna Liljedahl⁹, Dmitri Nicolsky⁸, Jana Peirce¹, Martha Raynolds¹, Vlad Romanovsky³, Yuri Shur⁷, Warwick Vincent⁷

1. University of Alaska Fairbanks, Institute of Arctic Biology, Fairbanks, Alaska, USA
2. University of Alaska Fairbanks, International Arctic Research Center, Fairbanks, Alaska, USA
3. University of Alaska Fairbanks, Institute of Northern Engineering, Fairbanks, Alaska, USA
4. Alaska Department of Geology and Geophysical Surveys, Fairbanks, Alaska, USA
5. Cold Climate Housing Research Center, Fairbanks, Alaska, USA
6. University of Alaska Fairbanks, Water and Environmental Research Center, Fairbanks, Alaska, USA
7. University of Alaska Fairbanks, Institute of Northern Engineering, Fairbanks, Alaska, USA
8. University of Alaska Fairbanks, Geophysical Institute, Fairbanks, Alaska, USA
9. Center for Northern Studies, Laval Université Laval, Québec City, Québec, Canada

Ice-rich permafrost is at the center of a web of interacting ecosystem components that we call the IRP system (IRPS). Our ultimate goal is to understand IRPS at local, regional and circumpolar scales. We are particularly interested in how differences in vegetation, water, and time influence the accumulation and degradation of ground ice in IRP landscapes, and how the loss of ground ice can radically change these landscapes, their components, and the infrastructure built on them. The proposed project offers a transformative view that places IRP at the center of change to social-ecological systems in many areas of the new Arctic. Our key questions are: “How are climate change and infrastructure affecting IRPS?” “What roles do ecosystems play in the development and degradation of IRP?” and “How can people and their infrastructure adapt to changing IRP systems?”

There is an immediate need to develop more strategic approaches to mitigation and adaptation informed by science and engineering in collaboration with local observations, knowledge, and preferences. Much of the response to permafrost-related damage has been incremental actions driven by the necessity to repair and stabilize existing roads and structures. Our initial focus is at Prudhoe Bay and Point Lay, Alaska, where permafrost temperatures are changing rapidly with large impacts to ecosystems, infrastructure, and communities. Both areas provide excellent examples of IRP-related issues relevant to many other areas of Alaska and the Arctic. We will develop three IRP observatories: 1) Roadside IRP Observatory in the Prudhoe Bay oilfield; 2) Natural IRP Observatory remote from infrastructure; and 3) Village IRP Observatory at Point Lay. The Prudhoe Bay region has the best historical record of geocological change within the Arctic with key legacy.
datasets and good collaboration between industry and science. We will revisit permanent plots and remap Prudhoe Bay vegetation and landscapes first studied in the 1970s.

Point Lay has received less research and agency attention than other climate-impacted communities, yet its thaw related issues are among the most severe. The Cold Climate Housing Research Center will work with the Regional Housing Authority, community residents, local high school students and regional planners to collaboratively produce adaptive housing strategies. A permafrost and infrastructure symposium hosted by the community will bring together US-Canadian science and engineering expertise to discuss a range of public infrastructure issues relevant to many Arctic villages. Our team’s work with the Alaska Department of Transportation will advance knowledge on IRP-related impacts to roads and industrial infrastructure and contribute to best practice guidelines for road and airport construction. Science education and training components will reach K-12, undergraduate, graduate, and post-doctoral students.

### Sustainable housing in rural Alaska

*Robbin Garber-Slaght, PE*

1 Cold Climate Housing Research Center, Fairbanks, Alaska

Alaska contains some 300 Native villages scattered across 360 million acres ranging from temperate rainforests in the southwest to Arctic tundra in the north. Most are only accessible by airplane. There are few services and most of the food, fuel, and supplies are brought in by barge (in the summer) or plane. Alaska’s coastal communities are feeling the brunt of climate change today.

The community of Newtok on the southwest coast has been battered by a changing climate for over 15 years. Because of melting sea ice that used to protect their shore, the village regularly floods during the fall storm season. They have lost their sewage loon and landfill to flooding, and every year they lose about 24 m of coastline. The closest homes are within five meters of the edge. Like many Alaska Native communities, Newtok was never a permanent settlement. But because permanent infrastructure was built there by outside agencies, it became permanent which has led to many of the sustainability problems we are seeing today.

CCHRC is working with the community of Newtok to provide housing that is more sustainable than what they currently have, in a location that is better suited for permanent settlement. This presentation will highlight CCHRC’s work with rural Alaskan communities to develop a process for locally driven sustainable housing that is being used as part of the Newtok relocation.

### Adaptive management in the oilfield

*Christina Pohl*

1 BP Exploration (Alaska), Inc.

### Infrastructure stability estimation: Usage of GTN-P data and permafrost forecasting

*Dmitrii Sergeev & Irina Utkina*

1 Sergeev Institute of Environmental Geoscience, Russian Academy of Sciences, Moscow, Russia

The long range linear structures are under influence of local permafrost diversity of various landscapes as well under the different microclimate variabilities. An example of the features of the evolution of the natural-technical system of a railway embankment under the conditions of the Vorkuta tundra demonstrates the complexity of this task.
A possible (although time-consuming) solution is to develop individual forecasts for typical combinations of landscapes and engineering structures. Such forecasts need special discussion about input data preparation rules. Possible sources of models’ input are geological surveys (to clarify the local landscape features), regional GTN-P data from the monitoring of the undisturbed permafrost conditions (for calibrating the regional models of permafrost response to climate change) and regional climate models (for specifying the climate impact scenarios).

To ensure the comparability of the results of permafrost forecasting, a transparent description of the assumptions and setting boundary conditions is needed. In particular, the expected lifetime of the infrastructure affects the depth of research and the characteristics of the model. Forecasts with a duration of more than 50 years should be provided with data on direct downhole measurements with a depth of at least 300 m. It’s important for setting the correct initial temperature field configuration.

It is recommended to use the various key indicators of the state and dynamics of permafrost, which are correlated with the specifics of making management decisions. It’s recommended to use the indicator of the maximal depth of interannual temperature fluctuations to determine the depth of surveys and monitoring. It’s recommended to the annual average integral fraction of liquid moisture in a ten-meter layer of soil to estimate the bearing capacity of the ground soils, and the depth of permafrost table. They are important information for designers.

__Social science perspectives on Arctic infrastructure__

*Peter Schweitzer¹, Gertrude Saxinger¹, Olga Povoroznyuk¹*

¹ University of Vienna, Austrian Polar Research Institute, Vienna, Austria

Infrastructure, while planned and built by humans, has in turn significant impacts on people’s lives. Arctic infrastructure development often has even bigger impacts than similar projects in temperate zones, as it affects fragile ecosystems and remote communities. Social scientists have started to study infrastructure later than engineers but can bring important perspectives to the field. By engaging concepts such as “infrastructural violence”, “enclaves” and “uneven development”, Arctic social scientists attempt to understand the socio-political conditions, problems and benefits of infrastructure development in remote regions.

Arctic marine shipping (AMS) is projected to increase significantly due to shrinking sea ice and increased resource extraction activities. This requires the construction of new port and subsidiary facilities, which will further transform the natural, built and social environments of the High North. The so-called Northern Sea Route (NSR) is the most productive passageway for AMS. Current and planned research – that combines ethnographic methods with the analysis of satellite images will allow to quantify growth and decline – will be introduced.

Corporate Social Responsibility (CSR) activities are becoming increasingly important practices in infrastructural (mega) projects. However, not all CSR types and ways of their implementation are beneficial and some become issues of dispute between project proponents, locals and political actors. This section will address the nexus of social impact assessment, CSR and the social license and will raise further critical issues in the context of infrastructural development in the Arctic.

__T-MOSAiC and RATIC: Connections and opportunities__

*Warwick Vincent¹, João Canário², Donald A. Walker³, Jana Peirce³ & Vladimir Romanovsky⁴,⁵*

¹ Université Laval, Center for Northern Studies, Québec, Canada

² University of Lisbon, Instituto Superior Técnico, Lisbon, Portugal
MOSAiC (The Multidisciplinary drifting Observatory for the Study of Arctic Climate) is a multinational year-round study of the central Arctic Ocean to measure the coupling between atmosphere, sea ice, ocean and ecosystem processes. T-MOSAiC (Terrestrial Multidisciplinary distributed Observatories for the Study of Arctic Connections) brings that focus to land. It is an IASC pan-Arctic, terrestrial research program that extends the activities of the flagship MOSAiC program planned for 2019-2020. The objective of the T-MOSAiC satellite program is to coordinate complementary activities that will aid and benefit from MOSAiC by extending the work to the lands surrounding the Arctic Ocean and to the northern communities who live on those lands.

The defining focus of the RATIC initiative on the impacts and interactions of climate and infrastructure in the Arctic provides its own complement to the broad system-level focus of T-MOSAiC with its themes of connectivity, gradients, discontinuities and thresholds, feedbacks, extreme events, legacy effects and emergent properties. RATIC fills in the little “i” in T-MOSAiC through its goal of promoting sustainable Arctic infrastructure as a key research theme requiring collaboration across disciplines and geographic boundaries. RATIC workshops at IASC conferences provide a valuable forum for scientists to discuss research needs and priorities related to both RATIC and T-MOSAiC, to explore opportunities for international multidisciplinary collaboration, and to promote more involvement by early career scientists, local communities, governments, and industry. More information about RATIC is provided at www.geobotany.uaf.edu/ratie, and the Science Plan for T-MOSAiC can be downloaded at: www.tmosaic.com/science-plan.html.