Rapid Arctic Transitions due to Infrastructure and Climate (RATIC)

A synthesis of infrastructure and climate change consequences to permafrost, landscapes, and social-ecological systems

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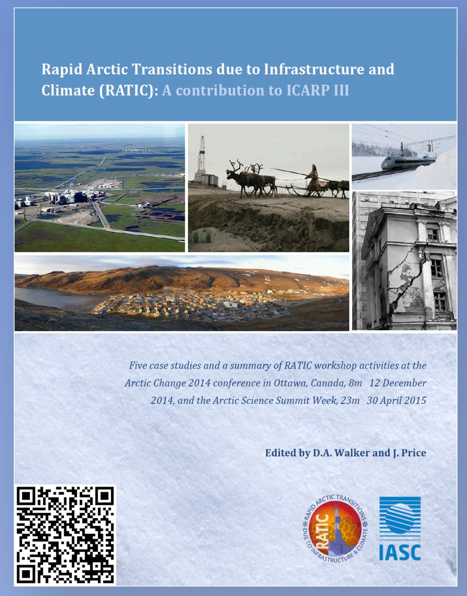

ABSTRACT: The Rapid Arctic Transitions due to Infrastructure and Climate (RATIC) initiative is a forum for developing and sharing new ideas and methods to facilitate the best practices for assessing, responding to, and adaptively managing the cumulative effects of Arctic infrastructure and climate change. An IASC white paper summarizes the activities of two RATIC workshops at the Arctic Change 2014 Conference in Ottawa, Canada and the 2015 Third International Conference on Arctic Research Planning (ICARP III) meeting in Toyama, Japan. Here we present an overview of five case studies with conclusions and recommendations presented at these conferences.

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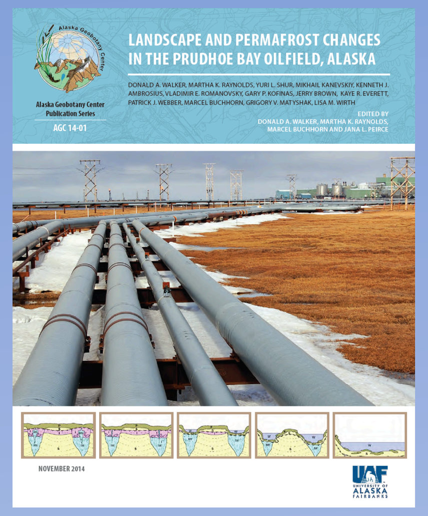
http://icarp.iasc.info/images/articles/Themes/RATICWhitePaper-ICARPIII.pdf

Case Study 1: Cumulative effects of infrastructure and climate in the permafrost landscapes of the Prudhoe Bay, Region



An historical (1949-2010) hierarchical analysis of oilfield infrastructure was conducted at two scales in the Prudhoe Bay region, Alaska. A regional analysis quantifies historical changes to roads, gravel pads, pipelines and other infrastructure for the North Slope. A landscape level analysis used integrated historical geoecological and disturbance maps to determine the direct and indirect consequence of dust, roadside flooding, and thermokarst to local permafrost, vegetation and landscapes in three areas of intensive development. Ice-wedge thermokarst developed and expanded over large areas — both adjacent to infrastructure and in areas distant from infrastructure. The most rapid changes occurred post-1990, and is attributed mainly to simultaneous changes in permafrost temperatures and increases in active-layer thickness resulting from recent regional warming, in addition to infrastructure related changes to soil temperature regimes. The analysis discusses the implications to ecosystems, social systems and adaptive management of infrastructure expansion.

Key references:

Raynolds, M.K., Walker, D.A., Ambrosius, K.J., Brown, J., Everett, K.R., Kanevskiy, M. et al. 2014. Cumulative geoecological effects of 62 years of infrastructure and climate change in ice-rich permafrost landscapes, Prudhoe Bay Oilfield, Alaska. *Global Change Biology*, (20), 1211–1224.
Walker, D.A., Raynolds, M.K., Buchhorn, M., & Peirce, J.L. (Eds.). 2014. *Landscape and permafrost change in the Prudhoe Bay Oilfield, Alaska* (pp. 1–84). Fairbanks, AK: Alaska Geobotany Center, University of Alaska, AGC Publication 14-01.

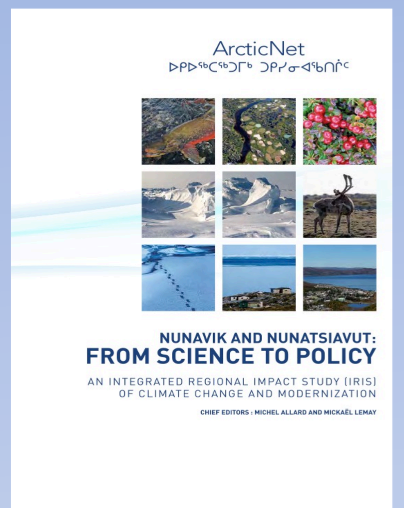
Case Study 2: Russian oil and gas development and climate change interactions

The Bovanenkovo Gas Field (BGF) is in the central Yamal Peninsula, of West Siberia. Highly erodible sands and the presence of massive tabular ground ice near the tundra surface contribute to landslides and thermo-denudation of slopes in the Central Yamal Peninsula. The BGF is also located in the traditional reindeer-grazing lands of the nomadic Nenets people. Long-term studies of the social-ecological effects of infrastructure and climate change have been conducted by several groups working in the region. Remote sensing is a practical way to trace rapidly expanding areas of infrastructure and extent of natural and anthropogenic disturbances in remote areas of the Arctic. However, small features such as vehicle trails and most patterned-ground features are impossible to detect with the course spatial resolution of common sensors, such as the Advanced Very High Resolution Radiometer (AVHRR, 1.1 km resolution), Moderate-Resolution Imaging Spectroradiometer (MODIS, 250 m), and Landsat Multi-Spectral Scanner sensor (MSS, 80 m). Only Very-High-Resolution (VHR) imagery—such as Quickbird (0.61 m resolution), Worldview (0.46 m), or Geoeye (0.41 m)—can sharply define common forms of indirect impacts such as off-road vehicle (ORV) trails and areas of thermokarst. The studies of have documented rapid changes in vegetation, extensive impacts to the traditional way of life of the Nenets, but also a resilient society that has flourished in recent years compared to most other reindeer-herding areas of Russia.

Key references

Forbes, B. C., Stammler, F., Kumpula, T., Meschtyb, N., Pajunen, A., & Kaarlejärvi, E. 2009. High resilience in the Yamal-Nenets social-ecological system, West Siberian Arctic, Russia. *Proc. Natl. Acad. Sci.*, *106*(52), 22041–22048. http://doi.org/10.1073/pnas.0908286106..
Kumpula, T., Forbes, B. C., Stammler, F., & Meschtyb, N. 2012. Remote sensing and gis analysis of anthropogenic and natural land use and land cover changes in tundra environments in Bovanenkovo gas field on Yamal Peninsula, Russia. Presented at the Third Yamal Land-Cover Land-Use Change Workshop, Rovaniemi, Finland.

Case Study 3: ADAPT and IRIS in Canada



Climate change and its impact on permafrost is a major concern for Canada given that much of the country is underlain by permafrost, and the integrity of many of its northern geosystems, ecosystems and engineered infrastructure is dependent upon the stability of these frozen lands. Canada is undertaking two large scale research projects that address the processes and implications of permafrost thawing and degradation: Arctic Development and Adaptation to Permafrost in Transition (ADAPT) and ArcticNet, the latter via its formulation of Integrated Regional Impact Studies (IRIS). An IRIS summarizes and combines knowledge and models of relevant aspects of the ecosystems of a region affected by change, with the objective of producing a prognosis of the magnitude and socio-economic costs of the impacts of change. The studies focus to a large degree on permafrost dynamics in natural and engineered environments. Several permafrost-infrastructure issues encountered in Nunavut partly come from the fact that much of its infrastructure was built at a time where climate warming had not yet been observed in the region and permafrost was thought to be permanently stable groundConsequently, construction designs of many buildings and infrastructure are not necessarily appropriate to their underlying permafrost conditions and adapted to cope with the climate change observed in Nunavut since the 1990s.

Key references

Allard, M., M. Lemay, C. Barrette, E. L'Hérault, D. Sarrazin, et al. 2012. Permafrost and climate change in Nunavik and Nunatsiavut: Importance for municipal and transportation infrastructures. Pages 171-197 *in* M. Allard and M. Lemay, editors. Nunavik and Nunatsiavut: From science to policy. An Integrated Regional Impact Study (IRIS) of climate change and modernization. ArcticNet Inc., Quebec City, Canada.
Vincent, W. F., M. Lemay, M. Allard, B. B. Wolfe. 2013. Adapting to Permafrost Change: A Science Framework. Eos, Transactions, American Geophysical Union **94**:373–375.

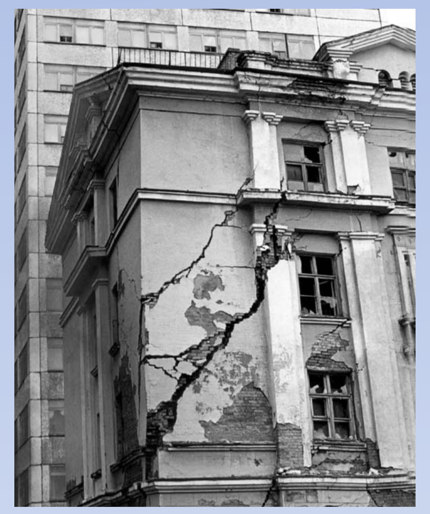
Case Study 4: Road infrastructure and climate effects in Norway

This short case study from subarctic Norway illustrates some of the regional variation related to frost heave and effects of climate change on areas outside the permafrost zone. The scenarios for future climate in Norway all predict milder winters. While one might expect that frost-related problems will be less severe or perhaps disappear altogether in the subarctic, it is more likely that both single-winter and year-to-year variations will increase. Thus in most of Scandinavia, roads in regions that previously enjoyed stable winter conditions are now subject to several freeze-thaw cycles each winter (Ministry of the Environment 2010, Grendstad 2012).

Key references

Ministry of the Environment. 2010. Adapting to a changing climate: Norway's vulnerability and the need to adapt to the impacts of climate change. Oslo, Norway.
Grendstad, G., editor. 2012. Adaptation to climate change. Conference of European Directors of Roads, CEDR Secretariat General, Paris, France.

Case Study 5: Urban landscapes on permafrost: the Oganer district of Norilsk, Russia



The economic development of industrial centers on permafrost mandates that housing be adequate to sustain the workforce that dwells in these centers. The foundation bearing capacity used as a quantitative indicator of the ability of foundations to support the structural weight of houses depends on permafrost properties. These properties are, in turn, affected by changes in climatic and environmental conditions and human activities, making bearing capacity an important comprehensive indicator of changes in urban landscapes on permafrost. The combination of climate warming and human activities in the Norilsk area has resulted in increased permafrost temperature and a decrease in foundation bearing capacity. This trend is likely to continue in the future if adequate measures fail to be taken by the city administration.

Key references

Grebenets, V., D. Streletskiy, N. Shiklomanov. 2012. Geotechnical safety issues in the cities of Polar Regions. Geography, Environment, Sustainability Journal **5(3)**:104-119.
Streletskiy, D. A., N. I. Shiklomanov, F. E. Nelson. 2012b. Permafrost, infrastructure and climate change: A GIS-based landscape approach to geotechnical modeling. Arctic, Antarctic and Alpine Research **44(3)**:368-380. doi:10.1657/1938-4246-44.3.368

Main Conclusions

- ***There is a pressing need to examine the cumulative effects of infrastructure in the context of Arctic social-ecological systems.*** *Each area has a unique set of social, economic, political, ecological, technological, and climatic ¨drivers of change" that require regionally appropriate adaptive management approaches to mitigate adverse changes.*
- ***Permafrost thawing and its associated impacts on natural and built environments were clearly identified as priority issues at all locations.*** *The specific issues related to permafrost differed in each region and require detailed ground-level knowledge for predicting change and planning purposes.*
- ***The indirect effects of infrastructure exceed the direct effects of the planned footprints.*** *Fragmentation of large intact ecosystems is a major impact that is inadequately addressed in Russia and North America. Assessments of infrastructure must address effects on the adjacent ecosystems, local communities, regions, and areas outside the Arctic.*
- ***New GIS and remote-sensing tools are needed to assess regional changes over large areas now affected by infrastructure and climate change.*** *The resolution of current global scale remote-sensing databases is inadequate to detect changes to fine-scale patterned ground features and to monitor details of infrastructure change. High-resolution imagery is great but is costly and not available for all areas, but can be used for hierarchical analysis of smaller regions.*
- ***The cumulative interactions between infrastructure and climate change are not adequately addressed by any national or international-level Arctic science plan.*** *NASA LCLUC is providing examples of scientific approaches to the issue of cumulative effects of infrastructure development in Russia and North America. Other examples are available from industry and other Arctic governments.*

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The white paper *Rapid Arctic Transitions due to Infrastructure and Climate (RATIC): A contribution to ICARP III* can be downloaded at: http://www.geobotany.uaf.edu/library/pubs/WalkerDAed2015-RATICWhitePaper-ICARPIII.pdf.

Invited poster: AGU Fall meeting, 14-19 Dec 2015, San Francisco, CA, poster no. GC31B-1183.