Yukon University

Compendium of Yukon Climate Change Knowledge

2021 Supplement

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Yukon

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FOREWARD

The Compendium of Yukon Climate Change Knowledge is a comprehensive review of climate change knowledge of Yukon produced on an annual basis. It provides an overview of recent climate change work in and relevant to Yukon, Canada. The compendium is a reference document for use by the general public, governments, organizations, students, researchers, the scientific community and others, providing access to recent, relevant, and quality published research on climate change in Yukon. It focuses on written publications, with an emphasis on work available online, and contains various types of records including scientific journal articles, government publications, project and synthesis reports, synopsis summaries, conference proceedings, etc. It includes documents like climate change plans, strategies, policies, and assessments of different approaches to mitigation and adaptation. The 2021 version of the compendium is a supplement to previous versions (2003 - 2020), and while it focuses on work that was published between May 31, 2020 and June 1, 2021, it also includes work that was completed prior to May 31, 2020 and not included in previous compendium publications.

The compendium includes content that is related to climate change and its impacts on Yukon's physical landscape, plants and animals, economy, lifestyles, health, food security, hazards, and other related topics. It also includes content related to greenhouse gas emissions, carbon and methane release, energy consumption, and other climate change mitigation issues. The review mainly focuses on western scientific knowledge because it focuses on written publications, however Indigenous knowledge is included where it is the focus of or has been included in written publications. The content is directly relevant to Yukon, which includes a geographic focus on or in the Yukon, or a geographic focus bigger than but inclusive of the Yukon (e.g., northern Canada or circumpolar North). It also includes a geographic focus that bleeds into the Yukon (e.g., a watershed that bridges Yukon and another jurisdiction). The compendium does not include content that is produced in languages other than English or where the geographic focus is on nearby regions but does not include the Yukon.

The compendium is organized by broad topics, corresponding to broad topics in a related compendium database. Many records were assigned multiple broad topics, in this case the broad topic of 'best fit' was determined by the compendium editor. Each record is briefly summarized, and a local relevance section written by the editor highlights Yukon climate change information, and/or describes why the record was included in this compendium.

The following sources were used to search for records to include in the Compendium (note that records were not found at all sources searched):

- Arctic Institute of Community Based Research project listing
- ASTIS Database
- CIRNAC climate change adaptation project listing
- EBSCO; GeoBase, Google Scholar; JSTOR, Mendeley; ProQuest; ScienceDirect; Web of Science; Wiley Online; WorldCat Catalogue
- Food Secure Canada website
- Forest Management in a Changing Climate: Compendium of Information Sources
- Government of Canada and Government of Yukon websites
- Government of Yukon online Compendium of Science
- Hydrocarbon Impacts database

- Internal knowledge
- Kluane Lake Research Station Bibliography
- Natural Resources Canada project listing
- Northern Research Institute Fellowship Grants list
- Polar Data Catalogue
- University websites for theses/dissertations
- Wolf Creek Research Basin database
- Yukon Biodiversity Database
- Yukon Permafrost Network
- YukonU Research Centre website

YukonU's Climate Change Research group would appreciate notification of any relevant information that was not included in this version of the compendium, or of any errors made. Contact information and research updates on YukonU's climate change work can be found online at www.yukonu.ca/research.

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1.0 ANIMALS

Climate change increases predation risk for a keystone species of the boreal forest

Author(s)

Peers MJL, Majchrzak YN, Menzies AK, Studd EK, Bastille-Rousseau G, Boonstra R, Humphries M, Jung TS, Kenney AJ, Krebs CJ, Murray DL, Boutin S

Keywords

Canada lynx, habitat, keystone, population dynamics, snowshoe hares

Summary

Canada lynx (*Lynx canadensis*) and snowshoe hares (*Lepus americanus*) have a keystone predator-prey cycle that has a large impact on the North American boreal forest vertebrate community. This study explores the hypothesis that changes in winter snow conditions can impact over-winter survival in snowshoe hares and examines whether winter conditions differentially influenced mortality caused by lynx and coyote predation. This study also looks at whether snow depth in the study area of southwestern Yukon has changed over the last two decades. Researchers monitored daily survival and cause-specific mortality of 321 snowshoe hares across four winters (2015-2018) along with daily changes in temperature and snow conditions. It was demonstrated that hare mortality risk is strongly influenced by variation in snow conditions. Predation risk from lynx was unaffected by snow conditions, while coyote predation increased in shallow snow. Over the last two decades, maximum snow depth in the study area decreased by 33%. It was concluded that climate change could disrupt cyclic dynamics in the boreal forest.

Relevance

Climate change is driving broad scale changes to boreal ecosystems with much uncertainty on how these changes will affect different species. Lynx and snowshoe hares are keystone species, with their predator-prey cycle significantly affecting the boreal forest community. Because of their significance, it is important that they are monitored to inform wildlife management strategies. Although snow depth is generally increasing throughout the Yukon, it was shown to be decreasing in this particular study area. This gives insight into the variation that can exist across the Yukon with respect to the impacts of climate change, such as with snow depth, and how those can affect the ecosystem, including decreasing snow depth directly altering snowshoe hare predators.

Citation

Peers, M.J.L., Majchrzak, Y.N., Menzies, A.K., Studd, E.K., Bastille-Rousseau, G., Boonstra, R., Humphries, M., Jung, T.S., Kenney, A.J., Krebs, C.J., Murray, D.L., & Boutin, S. (2020). Climate change increases predation risk for a keystone species of the boreal forest. *Nature Climate Change, 10,* 1149-1153. 10.1030/s41558-020-00908-4

Foraging habitat drives the distribution of an endangered bat in an urbanizing boreal landscape

Author(s)

Thomas JP, Kukka PM, Benjamin JE, Barclay RMR, Johnson CJ, Schmiegelow FKA, Jung TS

Keywords

bats, boreal forest, endangered species, habitat models, urbanization

Summary

In this study, researchers investigate landscape features that influence the distribution of the endangered little brown bat in an urbanizing landscape to determine the effect climate change and landscape change may have on bat activity. It was thought that little brown bat activity would be influenced by proximity to available building roosts, that bats would use potential foraging habitat, such as waterbodies, and would avoid young and cluttered forests. Acoustic surveys were conducted at 210 sites distributed within a 50-km radius of Whitehorse, representing an area of rapid and sprawling development. Results showed that bats were equally active in urban areas and in rural areas because roosts were adequately available throughout the region. It is highlighted that habitat use was driven by the distribution of potential foraging habitat, particularly waterbodies due their source insects. Bats avoided young (<100-year-old) forests including areas regenerating after fire, probably due to poor foraging or roosting habitat. It is suggested that waterbodies and mature forests are important habitats for little brown bats, therefore they should be protected from urbanization.

Relevance

Bats are a taxonomic group with complex behaviors that are poorly understood and their importance as a species is undervalued. Bats play an essential role in pest control as well as in pollinating plants and dispersing seeds. More studies on the species are encouraged to help improve our understanding of their patterns and habitats, ultimately allowing for increased conservation efforts and improved land-use planning. Climate change coupled with increased land development negatively impact bat habitat, which requires proximity to water bodies for insects and old growth forests. This is relevant to the Yukon because climate change is severely affecting northern environments while land use and urbanization are increasing significantly due to a growing human population. Understanding bat habitat is key to inform conservation efforts and species management. Lack of information was highlighted in this study, prompting the need for more research to be done on little brown bats in the Yukon.

Citation

Thomas, J.P., Kukka, P.M., Benjamin, J.E., Barclay, R.M.R., Johnson, C.J., Schmiegelow, F.K.A., & Jung, T.S. (2021). Foraging habitat drives the distribution of an endangered bat in an urbanizing boreal landscape. *Ecosphere, 12*(3). 10.1002/ecs2.3457

Merging Indigenous and scientific knowledge links climate with the growth of a large migratory caribou population

Author(s)

Gagnon CA, Hamel S, Russell DE, Powell T, Andre J, Svoboda MY, Berteaux D.

Keywords

body condition, caribou, community-based monitoring, demography, icing events, Indigenous knowledge, seasonal, snow

Summary

This study seeks to understand the effects of climate change on the Porcupine Caribou Herd (PCH) by bridging long-term scientific and Indigenous knowledge. Typically, climate change correlates with a decrease in caribou populations, but in the case of the PCH, their population has increased in size over the last two decades and researchers want to understand this. It was anticipated that spring and fall body condition would worsen overtime as a response to increase in caribou density. Researchers also expected spring body condition to be mostly influenced by winter precipitation and fall body condition by summer temperature. To obtain results, researchers used a unique long-term dataset from an Indigenous community-based monitoring program that has documented spring and fall body condition annually since 2000. They analyzed temporal variations in the annual spring and fall condition of PCH caribou between 2000 and 2010, then quantified the influence of local seasonal environmental variables and large-scale climate proxies on spring and fall caribou condition over the same period. Weather data was gathered from the CircumArctic *Rangifer* Monitoring and Assessment (CARMA) network's caribou range climate database. It was shown that both spring and fall body condition improved from 2000 to 2010, despite a continuous population increase. Both snow conditions and spring temperatures improved during the study period, likely contributing to caribou population increase. While climate change has been shown to have detrimental effects on caribou populations, the results of this study suggest that these detrimental impacts are not ubiquitous.

Relevance

The Porcupine Caribou Herd are a keystone species on which northern Indigenous communities rely heavily. They are both ecologically and culturally important in the North and there are many studies and monitoring programs in place for this particular herd. The fact that they are doing well in a changing environment is of particular interest. This study comes with a couple of key takeaways. First, it demonstrates how data from Indigenous and community-based monitoring programs can improve ecological understanding of wildlife, encouraging respectful engagement with communities. Secondly, it shows that the detrimental effects that climate change is having on caribou cannot be generalized across all caribou populations.

Citation

Gagnon, C.A., Hamel, S., Russell, D.E., Powell, T., Andre, J., Svoboda, M.Y., & Berteaux, D. (2020). Merging Indigenous and scientific knowledge links climate with the growth of a large migratory caribou population. *Journal of Applied Ecology, 57,* 1644-1655. 10.1111/1365-2664.13558

Spring phenology drives range shifts in a migratory Arctic ungulate with key implications for the future

Author(s)

Severson JP, Johnson HE, Arthur SM, Leacock WB, Suitor MJ

Keywords

Arctic, caribou, migration, phenology, Porcupine Caribou Herd, range shift, *Rangifer tarandus*, resource selection

Summary

This paper explores the effects of spring snow melt and vegetation growth on the current and potential space-use patterns of the Porcupine Caribou Herd (PCH). Data from collared caribou (Yukon Government and Alaska Department of Fish and Game) were used to model caribou range selection for multiple phenology and habitat characteristics at several spatial scales to determine how annual variation in phenology affects range distribution. In years with early spring phenology, PCH predominately used habitat in Alaska, while in years with late phenology, they spent more time in the Yukon. Caribou exhibited strong, scale-dependent selection for both snowmelt and vegetation growth, selecting areas where the snow had melted, and vegetation was greening during calving season and selecting vegetation with intermediate biomass expected to have high forage quality during post-calving season. Future climate conditions were projected to advance spring phenology, shifting PCH calving and post-calving distributions further west into Alaska. This suggests that with climate change and advancing spring phenology, PCH calving and post-calving ranges will shift more into Alaska in the future. This underscores the importance of maintaining sufficient suitable habitat to allow for behavioral plasticity.

Relevance

The Porcupine Caribou Herd is an ecologically and culturally important species in the Arctic due to their effects on vegetation dynamics and social importance as a source of food and cultural resources to rural and Indigenous communities. Caribou range and migration is based on resource availability which is being affected directly by climate change. While caribou typically exhibit strong patterns related to their choice of calving grounds and summer ranges, some herds have been observed to shift their range by hundreds of kilometers. If the PCH range shifts further into Alaska, there could be effects on the herd from proposed oil development within the Alaskan calving and post calving ranges. It is important to know where caribou migration happens in order to make appropriate species and land management plans.

Citation

Severson, J.P., Johnson, H.E., Arthur, S.M., Leacock, W.B., & Suitor, M.J. (2021). Spring phenology drives range shifts in a migratory Arctic ungulate with key implications for the future. *Global Change Biology, 00,* 1-18. 10.1111/gcb.15682

2.0 CLIMATE

Yukon State of the Environment Report

Author(s)

Government of Yukon

Keywords

indicators, report

Summary

This report produced by the Government of Yukon reflects the status of the environment by summarizing environmental indicators and trends. Information is divided into 5 categories: climate change, air, water, land, and fish and wildlife. Information is this report was collected up until the end of the 2019 calendar year, and trend data is compared with 2016 data. Information was contributed by scientific experts, government agencies, and non-governmental organizations.

Relevance

The information in this report builds a baseline to compare past, present, and future environmental trends in the Yukon. Baseline data and climate projections are important tools for climate change adaptation and mitigation. This report provides a platform that can help guide future decision making and adaptation and mitigation planning.

Citation

Government of Yukon. (2020). *Yukon state of the environment report: a report on environmental indicators.* https://yukon.ca/sites/yukon.ca/files/env/env-yukon-state-environment-report-2020.pdf.

4.0 VEGETATION

Drone data reveal heterogeneity in tundra greenness and phenology not captured by satellites

Author(s)

Assmann JJ, Myers-Smith IH, Kerby JT, Cunliffe AM, Daskalova GN

Keywords

Arctic tundra, drones, landscape phenology, NDVI, RPAS, satellite, UAV, vegetation monitoring

Summary

Remote-sensing technologies now allow for the study of ecological variation in landscapes continuously across scales, which is especially useful in areas where plant growth happens at a very small spatial scale, such as in tundra ecosystems. This study set out to test the correspondence among satellite- and drone-derived seasonal change in tundra greenness to identify optimal spatial scales for vegetation monitoring on Qikiqtaruk - Herschel Island. Time-series of the Normalized Difference Vegetation Index (NDVI) from multispectral drone imagery and satellite data were combined with ground-based observations for two growing seasons (2016 and 2017). The peak in spatial variation were found at distances of ~0.5 m in the plots on Qikiqtaruk, demonstrating the grain size at which phenological information within the plant communities is best captured at this site. Key information is lost when observing the tundra at even decimeter or coarser scales, such as those of medium grain satellites (~10-30 m). Findings indicated that multispectral drone measurements can capture temporal plant growth dynamic across tundra landscapes.

Relevance

Arctic greening is a biome-scale response to climate change. Vegetation is becoming denser with shrubs encroaching on typical tundra grasses and moss. This impacts not only plants, but the wildlife and people who live in the region and depend on the local ecosystem. The technology outlined in this paper allows us to monitor and study ecological systems at greater and previously inaccessible scales, as well as providing ease of access to remote locations that formerly could not be studied in such detail. As a result, it helps increase our capacity to monitor change and fill in gaps in understanding related to Arctic greening in the Yukon and other parts of the Arctic. This study demonstrates the future of imaging technology and its usefulness monitoring greening in the Arctic, ultimately assisting in conservation and mitigation strategies.

Citation

Assmann, J.J., Myers-Smith, I.H., Kerby, J.T., Cunliffe, A.M., & Daskalova, G.N. (2020). Drone data reveal heterogeneity in tundra greenness and phenology not captured by satellites. *Environmental Research Letters, 15.* 10.1088/1748-9326/abbf7d

5.0 WATER/ICE

Characterization of contrasting flow and thermal regimes in two adjacent subarctic alpine headwaters in Northwest Canada

Author(s)

Fabris L, Rolick RL, Kurylyk BL, Carey SK

Keywords

energy balance, flow regime, heat budget, permafrost, regression analysis, stream temperature, subarctic alpine headwaters

Summary

There is little information on stream thermal regimes in the subarctic region and how they might respond to climate change. This study provides insights on the processes governing the thermal and hydrological regimes of Granger Creek and Buckbrush creek which are a part of the Wolf Creek Research Basin. The objectives were to (a) characterize and compare the flow regime dynamics, (b) quantify the relative contribution of different heat fluxes to the stream thermal balance through applying an energy budget approach, and (c) use high-resolution stream temperature data to characterize spatiotemporal thermal patterns. Data was collected throughout the summer of 2016. Results indicated that groundwater played a major role on the hydrologic and thermal response of sub-alpine headwater catchments by moderating both flow and stream temperature extremes. Additionally, in both streams, solar radiation and latent heat were both the most important heat source and sink. This study also highlighted that there has been a reduction of experimental long-term data collection and the importance that ongoing collection of field data has on supporting both empirical and model-based studies.

Relevance

Headwaters in permafrost regions have been shown to be among the most sensitive environments to climate change. Permafrost plays as a key controller in many hydrological processes such as water storage and connectivity. Decreases in perennial ground ice could lead to more active ground water systems and deeper routing of subsurface water causing these systems to gradually exhibit characteristics of groundwater dominated rivers, changing the landscape from its natural state. The Wolf Creek research basin is representative of much of the interior Subarctic Cordilleran landscape; research conducted here gives a broad representation of the effects of climate change on stream thermal regimes in the subarctic region. If we wish to improve abilities to predict future hydrological systems to design mitigation and conservation strategies, we need to understand how fluxes affect thermal regimes of water systems, especially in the Yukon where climate change is happening at three times the rate of the rest of the world.

Citation

Fabris, L., Rolick, R.L., Kurylyk, B.L., & Carey, S.K. (2020). Characterization of contrasting flow and thermal regimes in two adjacent subarctic alpine headwaters in Northwest Canada. *Hydrological Processes, 34*, 3252-3270. 10.1002/hyp.13786

Climate and surging of Donjek Glacier, Yukon, Canada

Author(s)

Kochtitzky W, Winski D, McConnell E, Kreutz K, Campbell S, Enderlin EM, Copland L, Williamson S, Main B, Jiskoot H

Keywords

Donjek Glacier, glacier surge, ice cores

Summary

This study investigates the role of snow accumulation, rain, and temperature on surge periodicity, area changes, and timing of surge initiation since the 1930s at the Donjek Glacier. Researchers used the history of eight surge events and three ice cores along with weather station records, climate reanalysis, digital elevation models, and remote sensing to examine the impacts of climate and ice kinematics on glacier surge behavior. They wanted to know why the surge recurrence interval of approximately 12 years remains consistent at Donjek Glacier given the current climate warming trends. Findings showed that although mean annual air temperatures increased by ~2.5°C from 1968 to 2017 at Burwash Landing, which is approximately 30 km from the Donjek Glacier terminus, no change was observed in the surge recurrence interval over this time period. They did find that each recent surge advance has become less extensive than the previous even though surge recurrence showed no change. The decline is surge area coincides with a rising snow line indicative of reduced glacier-wide mass balance. Cumulative snow accumulation is the most consistent climate variable between surge events, but results remain inconclusive as to the role of it in driving surge behavior. Results suggest that yet unknown subglacial processes are the primary driver of surging at the Donjek Glacier, and further investigations are needed to understand the relationship between glacier-wide surface mass balance and surging. The next surge event is predicted to happen mid-2020s.

Relevance

Many studies are being done on glaciers due to climate change causing unprecedented melt rates. In the Yukon, glaciers play important roles in hydrological processes, recreational activities, and have cultural significance. Surges represent an important history of glacier advance and retreat. Understanding how they respond to climate change is crucial to predicting how their retreat may affect downstream hydrology. Furthermore, understanding the mechanisms that drive surges can help focus efforts on monitoring and studying these specific mechanisms, which will be useful for the next surge which is expected to commence mid 2020s.

Citation

Kochtitzky, W., Winski, D., McConnell, E., Kruetz, K., Campbell, S., Enderlin, E.M., Copland, L., Williamson, S., Main, B., & Jiskoot, H. (2020). Climate and surging of Donjek Glacier, Yukon, Canada. *Arctic, Antarctic and Alpine Research, 52*(1), 264-280. 10.1080/15230430.2020.1744397

Detailed characterization and monitoring of a retrogressive thaw slump from remotely piloted aircraft systems and identifying associated influence on carbon and nitrogen export

Author(s)

Turner KW, Pearce MD, Hughes DD

Keywords

Arctic, carbon, cryosphere, disturbance, drone, geomorphology, nitrogen, permafrost, remotely piloted aircraft systems, retrogressive thaw slump, RPAS, UAV

Summary

Retrogressive thaw slumps (RTS) represent a dramatic landscape response to temperature and precipitation increase which are expected to magnify with climate change. To predict the duration and magnitude of impacts from RTS, knowledge of RTS geomorphological drivers and rates of change must be enhanced. To do this, researchers used remotely piloted aircraft systems (RPAS) and sediment samples to document volumetric change, associated drivers, and potential impacts of the largest active RTS along the Old Crow River in Old Crow Flats from 2016-2019. RPAS surveys showed that 29,174 m^3 of sediment was exported during an initial event June 2016 and an additional 18,845 m^3 continued to be exported until June 2019, with warmer dryer conditions during summer of 2017 resulting in more sediment exportation than in 2018. Sediment samples showed that an estimated 713 t of soil organic carbon and 58 t of total nitrogen were exported to the Old Crow River during the three-year study. This study highlighted the utility of RPAS datasets, and findings provide key insight into the processes driving the development of thaw slumps and the relationships between geomorphic and sediment nutrient compositions.

Relevance

The area of Old Crow Flats is of high interest due to the abundance of permafrost that resides in the landscape. With climate change, this permafrost is subject to thawing and therefore thaw slumping, changing the landscape and releasing sediment and organic materials into nearby water systems. As thaw slumping occurs, it can have variable influence on biogeochemical cycling in lakes and rivers. Organic carbon and nitrogen are nutrients associated with primary productivity in aquatic ecosystems. Large inputs of these nutrients, due to climate change induced RTS, into aquatic systems have the potential to alter the natural state of these systems.

Citation

Turner, K.W., Pearce, M.D., & Hughes, D.D. (2021). Detailed characterization and monitoring of a retrogressive thaw slump from remotely piloted aircraft systems and identifying associated influence on carbon and nitrogen export. *Remote Sensing, 13,* 171. 10.3390/rs13020171

Evolution of the firn pack of Kaskawulsh Glacier, Yukon: Meltwater effects, densification, and the development of a perennial firn aquifer

Author(s)

Ochwat NE, Marshall SJ, Moorman BJ, Criscitiello AS, Copland L

Keywords

aquifer, firn, glacier, Kaskawulsh Glacier, meltwater

Summary

The goal of this study was to investigate and understand the history of the Kaskawulsh Glacier. In the spring of 2018, two firn cores were extracted from the accumulation zone of the glacier and their stratigraphy and density were analyzed and compared against historical measurements made in 1964 and 2006. Observed ice content, surface energy balance, and firn modelling showed that the Kaskawulsh Glacier firn retained ~86% of its meltwater in the years 2005-2017. Results showed that the upper accumulation zone of the glacier firn has undergone significant changes since 1964, becoming denser and more ice-rich. Additionally, the firn contains a perennial firn aquifer which may have developed over the past decade. These findings illustrate how firn may be evolving in response to climate change in the St. Elias Mountains.

Relevance

Glaciers are key indicators of a warming climate and play an important role in hydrological processes, making them a popular study subject in climate change science. There are many aspects and processes of glaciers which are poorly understood, including firn melt. Understanding firn melt is an important component of glacier mass balance, and meltwater retention in firn is important for estimating glacial run-off contributions to sea level rise. Little is known about these processes in mountain glaciers in other regions; acquiring this knowledge will improve estimates and models of glacier mass balance and associated sea level rise. The Yukon is abundant with glaciers, all of which are physically and culturally significant. Climate change is altering these ice landscapes, and significant change is happening within our lifetime. Understanding the dynamic systems that occur within glaciers will help us fine tune models that help predict climate change impacts on these mass landscapes.

Citation

Ochwat, N.E., Marshall, S.J., Moorman, B.J., Criscitiello, A.S., & Copland, L. (2021). Evolution of the firn pack of Kaskawulsh Glacier, Yukon: Meltwater effects, densification and the development of a perennial firn aquifer. *The Cryosphere, 15,* 2021-2040. 10.5194/tc-15-2021-2021

Heterogeneous snowpack response and snow drought occurrence across river basins of northwestern North America under 1.0°C to 4.0°C global warming

Author(s)

Shrestha RR, Bonsal BR, Bonnyman JM, Cannon AJ, Najafi MR

Keywords

climatic controls, global mean temperature change, large ensemble RCM, northwestern North America, snow drought

Summary

This paper assesses the maximum snow water equivalent (SWE_{max}) change in large river basins of the northwestern North America region (NWNA) using the Canadian Regional Climate Model 50-member ensemble under 1.0°C to 4.0°C global warming thresholds above the pre-industrial period. Research was focused on the large river basins that originate in the Canadian portion of the NWNA region and includes four major tributaries of the Mackenzie River (Peel, Liard, Peace, and Athabasca), along with the entire Yukon, Skeena, Saskatchewan, Fraser, and Columbia River basins. Modeling was primarily based on the large ensemble 0.44° CanRCM4 (CanRCM4-LE), a regional climate model that was developed under the framework of coordinated global and regional climate modeling. Results showed substantial declines in SWE_{max} in the coastal/southern basins (Skeena, Fraser, and Columbia), moderate decline in the interior basins (Athabasca, Peace, and Saskatchewan), and marginal increase or decrease in the northern basins (Yukon, Peel, and Liard), with more contrasting differences under higher warming thresholds. Findings showed that SWE_{max} is primarily temperature controlled, especially for the coastal/southern basins, with the influence of precipitation increasing in the North.

Relevance

Understanding snow water equivalence amounts under varied global warming thresholds allows for adaptation planning and water management which includes freshwater resources, species management, agriculture, hydroelectricity, recreation, travel, and culture. The majority of the Yukon's electricity is generated from hydroelectricity. Determining how climate change will increase and decline SWE_{max} will assist in hydropower planning as well as future renewable resource potential. Although this is a broad scale model, it does include the Peel, Liard, and Yukon rivers in the Yukon region.

Citation

Shrestha, R.R., Bonsal, B.R., Bonnyman, J.M., Cannon, A.J., & Najafi, M.R. (2021). Heterogeneous snowpack response and snow drought occurrence across river basins of northwestern North America under 1.0°C to 4.0°C global warming. *Climatic Change, 164*(40). 10.1007/s10584-021-02968-7

Holocene pore-ice δ18O and δ2H records from drained thermokarst lake basins in the Old Crow Flats, Yukon, Canada

Author(s)

Bandara S, Froese D, Porter TJ, Calmels F

Keywords

cryostratigraphy, epigenetic permafrost, Holocene climate, syngenetic permafrost, thermokarst lakes, $\delta^{18}O$ and $\delta^{2}H$

Summary

Thermokarst lakes form following the thaw of ice-rich permafrost and drain after a few decades to millennia. Drained thermokarst lake basins (DTLBs) become epicenters for peat accumulation and re-aggradation of ice-rich permafrost. Widespread thermokarst lake development has been

linked to the early Holocene thermal maximum. This study investigates the hypothesis that stable isotope records preserved in relict permafrost from DTLBs may provide insight into thaw lake evolution through time. Seven DTLBs were used as study sites in the Old Crow Flats, which is home to many thermokarst lakes. Information was gathered using cryostratigraphy, radiocarbon dating, and pore-ice $\delta^{18}O$ and $\delta^{2}H$ records. Cryostratigraphic evidence implies that only one of the seven studied DTLBs underwent multiple thermokarst cycles. Radiocarbon age-depth models demonstrate a slowdown in the rate of post-drainage peat accumulation with time. Pore-ice isotope analyses reveal a spectrum of possible post-drainage isotopic histories resulting from spatial variability in permafrost, vegetation, and hydrology. Unlike lacustrine silt, post-drainage peat contains relatively constant pore-ice isotope trends. These findings proposed that syngenetic peat permafrost in DTLBs preserve a warm-season sampling of local meteoric waters.

Relevance

These pore-ice records may aid millennial-scale paleoclimate investigations as Holocene climate change in northern Yukon is reconstructed. Little is known about thermokarst cycles in the Yukon. This study fills that gap, and provides information necessary to reconstruct how the thermokarst lake environment in the Old Crow Flats evolved over time.

Citation

Bandara, S., Froese, D., Porter, T.J., & Calmels, F. (2020). Holocene pore-ice $\delta^{18}O$ and $\delta^{2}H$ records from drained thermokarst lake basins in the Old Crow Flats, Yukon, Canada. *Permafrost and Periglacial Processes, 31,* 497-508. 10.1002/ppp.2073

Long-term variations of river ice breakup timing across Canada and its response to climate change

Author(s)

Chen Y, She Y

Keywords

breakup timing, correlation analysis, regional pattern, river ice, trend analysis

Summary

River ice breakup can have significant implications on cold-region hydrological, ecological and river morphological systems. This study focuses on trends and changes in breakup timing for five major Canadian river basins over the period of 1950-2016. General trends, as well as spatial and temporal patterns over terrestrial ecozones and selected river basins are discussed. The link between the discovered patterns and climatic drivers (air temperature, snowfall, and rainfall), as well as elevation and anthropogenic activities were analyzed. Data was retrieved from Water Survey of Canada HYDAT database. An overall earlier breakup trend was found across Canada, especially for the Pacific and Western Mountains, Central Plains, and Arctic, with the main driver being spring air temperature while spring snowfall generally delays breakup. Spring rainfall advances breakup dates while winter-rainfall can also delay breakup through refreezing. Breakup timing in main streams and large rivers seems to be less sensitive to warming trends than the headwaters and small tributaries. The findings in this study provide theoretical support for modelling the breakup process.

Relevance

Spatial and temporal breakup patterns under a changing climate are not well explored on a large scale. This paper compares rivers on a broad scale, giving us a picture of ice breakup across Canada while including rivers in the Yukon River Basin and the larger Mackenzie River Basin. Knowledge of river ice breakup in the Yukon is important because of its relation to winter travel, flooding, and icing events. Ice breakup timing is also important for Yukoners because it can indicate when waterways will be navigable, allowing for economic, social, and recreational transport.

Citation

Chen, Y. & She, Y. (2020). Long-term variations of river ice breakup timing across Canada and its response to climate change. *Cold Regions Science and Technology, 176.* 10.1016/j.colregions.2020.103091

Modeling the thermal response of air convection embankment in permafrost regions

Author(s)

Kong X, Doré G, Calmels F, Lemieux C

Keywords

air convection embankment (ACE), Alaska Highway, heat balance, permafrost degradation

Summary

Climate change is directly contributing to permafrost thaw which in turn can disrupt transportation infrastructure. Air convection embankments (ACE) have been proven to be an effective method in preventing permafrost thaw underneath roads by creating a natural convection, drawing heat away from the ground using porous and poorly graded granular material. In 2008, a large-scale ACE section was constructed along the Alaska Highway at Beaver Creek to investigate the heat extraction capacity of ACEs. In this report, researchers use data collected from this site to investigate the thermal performance of the ACE and calibrate a 2D thermal model based on the site. A relatively new approach based on heat balance at the embankment-soil interface is proposed for investigating the heat extraction capacity of ACEs. This paper describes the development of a rational method to design ACE for thermal stabilization of transportation infrastructure in northern regions.

Relevance

The Alaska highway links Alaska to the rest of the continent via the Yukon and British Columbia, passing through areas of warm and ice-rich discontinuous permafrost which is highly sensitive to degradation. The road is crucial as a transportation link bringing supplies to the region and for the economic development of northwestern Canada and the United States. As permafrost thaw increases with climate change, continuous efforts to mitigate subsequent impacts on the Alaska Highway will continue to be important in the future for the Yukon and other northern regions. Fine tuning ACE models used specifically for the Alaska Highway will help with applying this type of technology to northern infrastructure.

Citation

Kong, X., Doré, G., Calmels, F., & Lemieux, C. (2021). Modeling the thermal response of air convection embankment in permafrost regions. *Cold Regions Science and Technology, 182.* 10.1016/j.coldregions.2020.103169

Spatial variability of dissolved organic carbon, solutes, and suspended sediment in disturbed low Arctic coastal watersheds

Author(s)

Coch C, Ramage JL, Lamoureux SF, Meyer H, Knoblauch C, Lantuit H

Keywords

disturbance, Herschel Island, permafrost degradation, watersheds

Summary

This study investigates how permafrost thaw/degradation affects concentrations of dissolved organic carbon (DOC), total dissolved solids (TDS), suspended sediment, and stable water isotopes in adjacent Low Arctic watersheds. Research took place on Herschel Island in northern Yukon. Using aerial photographs from 1952-1970 and satellite images from 2011 and 2015, active physical disturbances in the past were identified in six catchment areas: Water Creek, Beach Creek, Fox Creek, Ice Creek West, Ice Creek East, and Eastern Gully. Water samples were collected at neighboring streams (Ice Creek West and Ice Creek East) to compare the impacts of local physical disturbances on hydrochemistry. Results showed that the area affected by disturbances has decreased by 41% between 1952 and 2015 and the total number of disturbances has increased by 66%. There was also a link in degradation changes in chemical water composition within the two neighboring streams. It was determined that all the disturbances are hydrologically connected, meaning that water needs to flow through these disturbances to mobilize the material and influence the concentration in streams.

Relevance

The Arctic is highly sensitive to change with permafrost thaw becoming more prevalent. Affects from permafrost thaw vary, including changes at the landscape, biochemical, and hydrochemistry scales. This study is important because it looks into river drainage systems that flow into the Arctic Ocean, which can change water quality when polluted with sediment released from permafrost thaw. This can in turn have consequences for animal and plant ecosystems in the ocean. This study aims at understanding processes controlled by hydrochemical variability and will ultimately help to establish a baseline of flux estimates of small rivers to the Arctic Ocean.

Citation

Coch, C., Ramage, J.L., Lamoureux, S.F., Meyer, H., Knoblauch, C., & Lantuit, H. (2020). Spatial variability of dissolved organic carbon, solutes, and suspended sediment in disturbed Low Arctic coastal watersheds. *Journal of Geophysical Research: Biogeosciences, 125.* 10.1029/2019JG005505

Terrestrial dissolved organic matter mobilized from eroding permafrost controls microbial community composition and growth in Arctic coastal zones

Author(s)

Bruhn AD, Stedmon CA, Comte J, Matsuoka A, Speetjens NJ, Tanski G, Vonk JE, Sjöstedt J

Keywords

Arctic coastal zone, chemostat, glacial deposits, marine microbial community, permafrost, terrestrial dissolved organic matter

Summary

Permafrost-dominated coasts are eroding faster due to climate warming, which is resulting in the additional supply of organic matter and nutrients into the coastal zone. This study investigates the impact of coastal erosion on the marine microbial community composition and growth rates in the coastal Beaufort Sea near Qikiqtaruk. Researchers used dissolved organic material (DOM) from three glacial deposit types (fluvial, lacustrine, and moraine) to cultivate marine bacteria using a chemostat setup. They tested if differences in DOM character can induce differences in bacterial community composition and bacterial growth efficiency. Findings indicate a clear substrate-driven control on marine microbial community composition, especially where the input of organic carbon and DOM in the Arctic coastal zone is dominated by release from coastal erosion of Cryosols. In conclusion, landscape type differently influences marine microbes.

Relevance

Climate change is causing erosion through soil destabilization when permafrost thaws. This results in more sediment being released into the water, causing disruptions to the surrounding aquatic environment. It is important to study the effects these disruptions have on the vulnerable marine ecosystem. An increase in dissolved organic matter from soil inputs can influence marine primary production cascading to higher trophic levels by increasing regenerated nutrients, creating competition for nutrients, altering carbon processing, and decreasing light penetration, ultimately putting stress on aquatic ecosystems. While this research focuses on the coastal area of Herschel Island, results can be applied to other Arctic glacial coastal zones.

Citation

Bruhn, A.D., Stedmon, C.A., Comte, J., Matsuoka, A., Speetjens, N.J., Tanski, G., Vonk, J.E., & Sjöstedt, J. (2021). Terrestrial dissolved organic matter mobilized from eroding permafrost controls microbial community composition and growth in Arctic coastal zones. *Frontiers in Earth Science, 9.* 10.3389/feart.2021.640580

The role of englacial hydrology in the filling and drainage of an ice-dammed lake, Kaskawulsh Glacier, Yukon, Canada

Author(s)

Bigelow DG, Flowers GE, Schoof CG, Mingo LDB, Young EM, Connal BG

Keywords

drainage, glacier, Kaskawulsh Glacier, outburst flood

Summary

In this study, researchers seek to characterize the roles of the englacial hydrological system during an outburst flood cycle at the Kaskawulsh Glacier. This reservoir is dynamic and volumetrically important. Its behavior is modulated by the hydromechanical interactions between the lake and the glacier. Geophysical and hydrometeorological data was collected in and around an ice marginal lake dammed by the Kaskawulsh Glacier to capture its 2017 filling and drainage. The response was monitored with shallow borehole water pressure sensors and spatial and temporal ice-penetrating radar surveys. The data combined with modeled water input to the lake allowed for estimating the water balance. The subaerial lake hit a maximum volume on August 17th before draining over the course of about 19 days. Hydromechanical interactions such as ice shelf uplift, faults, and fractures are linked to the redistribution of englacial water.

Relevance

Outburst floods from ice-marginal lakes are becoming more prevalent in a warming climate. These flood events can result in societal impacts on downstream populations and infrastructure. Although here are no established communities close to glaciers in the Yukon, research done here can inform modeling which can be applied to glaciers elsewhere. As well as being a hazard, outburst floods can act as a natural experiment that can be used to study the state and evolution of internal hydrological systems of glaciers. Through this monitoring, we can learn more about how glaciers are melting and use that information to plan around their disappearance in water management and flood planning processes.

Citation

Bigelow, D.G., Flowers, G.E., Schoof, C.G., Mingo, L.D.B., Young, E.M., & Connal B.G. The role of englacial hydrology in the filling and drainage of an ice-dammed lake, Kaskawulsh Glacier, Yukon, Canada. *Journal of Geophysical Research: Earth Surface, 125.* 10.1029/2019JF005110

7.0 POLICY

Our Clean Future: A Yukon strategy for climate change, energy and a green economy

Author(s)

Government of Yukon

Keywords

energy, green economy, greenhouse gas emissions, renewable energy, report, targets

Summary

This report was developed by the Government of Yukon in partnership with Yukon First Nations, transboundary Indigenous groups and Yukon municipalities over the course of 3 years. It highlights priority areas for acting on and responding to climate change over the next 10 years. These areas include transportation, homes and buildings, energy production, people and the environment, communities, innovation, and leadership. Four goals were set with 2030 targets to achieve a clean future: (1) reduce Yukon's greenhouse gas emissions, (2) ensure Yukoners have access to reliable, affordable and renewable energy, (3) adapt to the impacts of climate change, and (4) build a green economy.

Relevance

In the fall of 2019, following the footsteps of the Vuntut Gwitchin and the City of Whitehorse, the Government of Yukon declared a climate emergency. Acknowledging the urgency of the climate situation, the Yukon Government is taking steps in committing to a cleaner, greener future. Our Clean Future is a Yukon-wide strategy to address the climate emergency. This document provides the framework and tools needed to reduce the territory's greenhouse gas emissions and mitigate and adapt to the effects of climate change.

Citation

Government of Yukon. (2020). *Our clean future: A Yukon strategy for climate change, energy and green economy.* https://yukon.ca/sites/yukon.ca/files/env/env-our-clean-future.pdf.

Our Clean Future 2020 annual report

Author(s)

Government of Yukon

Keywords

energy, green economy, greenhouse gas emissions, report, targets

Summary

The first annual report released by the Government of Yukon provides updates on the progress of implementing the climate change, energy and green economy commitments found in *Our Clean Future*. The 2020 report tracks progress over the calendar year and reviews the steps taken to reach the territory's 2030 climate change goals. The report provides the most recent data on Yukon's greenhouse gas emissions and renewable energy electricity generation and

progress on key targets outlined in the previous publication. Of the 11 actions with a 2020 deadline in Our Clean Future, 9 were completed by the Government of Yukon and 2 are still in progress at the time of publication. Due to the urgency of the climate crisis, the Government of Yukon has increased the greenhouse gas reduction target from 30% to 45% by 2030, compared to 2010 levels.

Relevance

This report provides transparency and accountability by the Government of Yukon to the public. It is a communication tool showing what has been achieved and identifies areas where more progress is required in order to reach their 2030 goals. Our Clean Future was released in late 2020, therefore this annual report is only a partial progress report, but it sets the stage for future reporting.

Citation

Government of Yukon (2021). *Our clean future 2020 annual report.* https://yukon.ca/sites/yukon.ca/files/env/env-our-clean-future-2020-annual-report.pdf.

8.0 BIBLIOGRAPHY

Assmann, J.J., Myers-Smith, I.H., Kerby, J.T., Cunliffe, A.M., & Daskalova, G.N. (2020). Drone data reveal heterogeneity in tundra greenness and phenology not captured by satellites. *Environmental Research Letters, 15.* 10.1088/1748-9326/abbf7d

Bandara, S., Froese, D., Porter, T.J., & Calmels, F. (2020). Holocene pore-ice $\delta^{18}O$ and $\delta^{2}H$ records from drained thermokarst lake basins in the Old Crow Flats, Yukon, Canada. *Permafrost and Periglacial Processes, 31,* 497-508. 10.1002/ppp.2073

Bigelow, D.G., Flowers, G.E., Schoof, C.G., Mingo, L.D.B., Young, E.M., & Connal B.G. The role of englacial hydrology in the filling and drainage of an ice-dammed lake, Kaskawulsh Glacier, Yukon, Canada. *Journal of Geophysical Research: Earth Surface, 125.* 10.1029/2019JF005110

Bruhn, A.D., Stedmon, C.A., Comte, J., Matsuoka, A., Speetjens, N.J., Tanski, G., Vonk, J.E., & Sjöstedt, J. (2021). Terrestrial dissolved organic matter mobilized from eroding permafrost controls microbial community composition and growth in Arctic coastal zones. *Frontiers in Earth Science, 9.* 10.3389/feart.2021.640580

Chen, Y. & She, Y. (2020). Long-term variations of river ice breakup timing across Canada and its response to climate change. *Cold Regions Science and Technology, 176.* 10.1016/j.colregions.2020.103091

Coch, C., Ramage, J.L., Lamoureux, S.F., Meyer, H., Knoblauch, C., & Lantuit, H. (2020). Spatial variability of dissolved organic carbon, solutes, and suspended sediment in disturbed Low Arctic coastal watersheds. *Journal of Geophysical Research: Biogeosciences, 125.* 10.1029/2019JG005505

Fabris, L., Rolick, R.L., Kurylyk, B.L., & Carey, S.K. (2020). Characterization of contrasting flow and thermal regimes in two adjacent subarctic alpine headwaters in Northwest Canada. *Hydrological Processes, 34*, http://doi.org/3252-3270. 10.1002/hyp.13786

Gagnon, C.A., Hamel, S., Russell, D.E., Powell, T., Andre, J., Svoboda, M.Y., & Berteaux, D. (2020). Merging Indigenous and scientific knowledge links climate with the growth of a large migratory caribou population. *Journal of Applied Ecology, 57,* 1644-1655. 10.1111/1365-2664.13558

Government of Yukon. (2020). *Our clean future: a Yukon strategy for climate change, energy and green economy.* https://yukon.ca/sites/yukon.ca/files/env/env-our-clean-future.pdf.

Government of Yukon. (2020). *Yukon state of the environment report: a report on environmental indicators.* https://yukon.ca/sites/yukon.ca/files/env/env-yukon-state-environment-report-2020.pdf.

Government of Yukon (2021). *Our clean future 2020 annual report.* https://yukon.ca/sites/yukon.ca/files/env/env-our-clean-future-2020-annual-report.pdf.

Kochtitzky, W., Winski, D., McConnell, E., Kruetz, K., Campbell, S., Enderlin, E.M., Copland, L., Williamson, S., Main, B., & Jiskoot, H. (2020). Climate and surging of Donjek Glacier, Yukon, Canada. *Arctic, Antarctic and Alpine Research, 52*(1), 264-280. 10.1080/15230430.2020.1744397

Kong, X., Doré, G., Calmels, F., & Lemieux, C. (2021). Modeling the thermal response of air convection embankment in permafrost regions. *Cold Regions Science and Technology, 182.* 10.1016/j.coldregions.2020.103169

Ochwat, N.E., Marshall, S.J., Moorman, B.J., Criscitiello, A.S., & Copland, L. (2021). Evolution of the firn pack of Kaskawulsh Glacier, Yukon: meltwater effects, densification and the development of a perennial firn aquifer. *The Cryosphere, 15,* 2021-2040. 10.5194/tc-15-2021-2021

Peers, M.J.L., Majchrzak, Y.N., Menzies, A.K., Studd, E.K., Bastille-Rousseau, G., Boonstra, R., Humphries, M., Jung, T.S., Kenney, A.J., Krebs, C.J., Murray, D.L., & Boutin, S. (2020). Climate change increases predation risk for a keystone species of the boreal forest. *Nature Climate Change, 10,* 1149-1153. 10.1030/s41558-020-00908-4

Severson, J.P., Johnson, H.E., Arthur, S.M., Leacock, W.B., & Suitor, M.J. (2021). Spring phenology drives range shifts in a migratory Arctic ungulate with key implications for the future. *Global Change Biology, 00,* 1-18. 10.1111/gcb.15682

Shrestha, R.R., Bonsal, B.R., Bonnyman, J.M., Cannon, A.J., & Najafi, M.R. (2021). Heterogeneous snowpack response and snow drought occurrence across river basins of northwestern North America under 1.0°C to 4.0°C global warming. *Climatic Change, 164*(40). 10.1007/s10584-021-02968-7

Thomas, J.P., Kukka, P.M., Benjamin, J.E., Barclay, R.M.R., Johnson, C.J., Schmiegelow, F.K.A., & Jung, T.S. (2021). Foraging habitat drives the distribution of an endangered bat in an urbanizing boreal landscape. *Ecosphere, 12*(3). 10.1002/ecs2.3457

Turner, K.W., Pearce, M.D., & Hughes, D.D. (2021). Detailed characterization and monitoring of a retrogressive thaw slump from remotely piloted aircraft systems and identifying associated influence on carbon and nitrogen export. *Remote Sensing, 13,* 171. 10.3390/rs13020171

9.0 INDEX