Yukon University

Compendium of Yukon Climate Change Knowledge

2020 Supplement

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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 2020 version of the compendium is a supplement to previous versions (2003 - 2019), and while it focuses on work that was published between May 31, 2019 and June 1, 2020, it also includes work that was completed prior to May 31, 2019 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

Demography of snowshoe hare cycles in Canada's boreal forest

Author(s)

Oli MK, Krebs CJ, Kenney AJ, Boonstra R, Boutin S, Hines JE

Keywords

boreal ecology, boreal forest, population demographics, snowshoe hare

Summary

The 10-year cyclic nature of snowshoe hare populations is well known, and an important driver of boreal ecology. Snowshoe hares are one of the most important components of the boreal food web, but what drives the 10-year cycle is poorly understood. Three mechanisms controlling the 10-year cycle are offered, predation, stress associated with predation and winter food shortages. To explore these mechanism long term field data (40 years!) and mark recapture modeling studies are used to answer the following questions:

- What changes to population demographics cause a population to stop growing and then decline?
- What changes to population demographics trigger rapid population growth?
- Are there consistent demographic changes throughout cycles of abundance?
- What causes variation in maximum population density across cycles?

The data for this project was collected near Kluane Lake in southwestern Yukon. Hares were live captured and tagged at 2 intervals each year for 40 years. Hare populations declined at 13-19% during winter months, and grew at 13-40% depending on which part of the 10 year cycle the population was in. Accounting for other factors the researchers conclude that during the increase phase of the 10-year cycle hare populations would double each year and decline by 60% during the decline phase. These patterns are common across cycles.

Relevance

Snowshoe hares, and the population cycle they drive underpin boreal food webs and therefore have a large impact on the ecosystem. Climate change is driving broad scale changes to boreal ecosystems and there is a large amount of uncertainty around the nature of these changes. This study provides long term data and insight into the dynamics of snowshoe hare population cycles which are still to this day poorly understood. Gaining insight into population dynamics of an animals with a 10-year cycle is particularly challenging due to the length of data required. This study fills a variety of knowledge gaps such as:

- It is the first empirical demographic characterization of the rates of population change that need to be explained.
- It provides evidence, over 5 population cycles, that there is a repeatable pattern to demographic changes.

- It begins to demonstrate the mechanisms that drive the different phases of demographic change in snowshoe hare population.
- It attempts to explain maximum population density variation across cycles.

The researchers also claim that the demographic understandings gained in this research may apply to other species that exhibit cyclic populations.

Citation

Oli, Madan K., Charles J. Krebs, Alice J. Kenney, Rudy Boonstra, Stan Boutin, and James E. Hines. 2020. “Demography of Snowshoe Hare Cycles in Canada’s Boreal Forest.” *The Bulletin of the Ecological Society of America* 101 (2): e01678. https://doi.org/10.1002/bes2.1678.

Environmental influences on Dall's sheep survival

Author(s)

Van de Kerk M, Arthur S, Bertram M, Borg B, Herriges J, Lawler J, Mangipane B, Lambert CK, Wendling B, Prugh L

Keywords

Dall’s sheep, GPS, precipitation, population, temperature

Summary

Changes to climate, particularly temperature and precipitation can impact the population dynamics of animals. There are both direct changes (metabolic impacts of weather condition) and indirect changes (habitat modification) as well as interactions between the two and predation which lead to difficulties understanding how various changes impact the ultimate survival of animal populations. However, by untangling these complex interactions a model of Dall’s sheep survival can be created that will aid the management of populations as they experience climate change. Dall’s sheep typically occur at high elevations and high latitudes, regions that are vulnerable to climate change. Additionally, Dall’s sheep are one of the largest herbivores residing at high altitudes and thus can have a large impact on vegetation communities, are an important prey species and are also an important food source and trophy hunting species.

This paper seeks to understand the effects of climate and vegetation productivity on the survival of Dall’s sheep throughout their range. To obtain data on sheep survival rates data were obtained from other research projects using GPS collars, as well as aerial surveys and carcasses. Climatic data were obtained from meteorological stations in the study areas and vegetation productivity data were collected from remotely sensed imagery. The researchers find that adult sheep survival is mostly impacted by freeze-thaw events in the winter, while the survival of lambs is impacted by summer vegetation productivity.

Relevance

Climate change is having sweeping impacts across Yukon and these impacts are enhanced at higher altitudes. Dall's sheep are an important species for outfitting, local hunters and First Nations as well as one of the only large herbivores living at high altitudes. Their survival is influenced by a large variety of interacting factors which introduce uncertainty into management decisions. This study models some of these factors and their interactions to produce a series of models which attempt to reduce some of the uncertainties in management choices. The researchers claim that by using the models produced in their work, management can shift from reactive management to adaptive management strategies better suited to conserving the future of Dall's sheep. One example offered of this is as climate change moves sheep to new ranges, these ranges can be identified and protected in advance.

Citation

Van de Kerk, Madelon, Stephen Arthur, Mark Bertram, Bridget Borg, Jim Herriges, James Lawler, Buck Mangipane, Catherine Lambert Koizumi, Brad Wendling, and Laura Prugh. 2020. "Environmental Influences on Dall's Sheep Survival." *The Journal of Wildlife Management* 84 (6): 1127–38. https://doi.org/10.1002/jwmg.21873.

Signals of large scale climate drivers, hatchery enhancement, and marine factors in Yukon River Chinook salmon survival revealed with a Bayesian life history model

Author(s)

Cunningham CJ, Westley PA, Adkison MD

Keywords

Bayesian estimation, Chinook salmon conservation, climate change, environmental regulation of survival, hatchery, life cycle models, marine and freshwater mortality, salmon assessment, Yukon River

Summary

This project uses Bayesian life history models to disentangle some of the many and often intertwined factors, that occur at many different scales and determine how they influence Chinook salmon populations. Chinook salmon require both marine and freshwater systems to be successful and in both systems are subject to pressure from human fisheries. Chinook salmon returning to the Yukon River Watershed have declined by 45% between 1998 and 2010 leading to limitations on both commercial and subsistence harvest. This vast reduction in the number of returning fish has driven interest in better understanding the factors that influence numbers of returning salmon. Historical research has considered fresh water and marine systems in isolation when identifying factors that influence the survival of salmon. In order to look at these factors at once this research tests a variety of hypothesis and uses Bayesian statics to evaluate the interplay between differing hypotheses.

Relevance

To better understand how salmon will respond to climate change the impacts of past environmental variations need to be understand. Chinook salmon are a vital transportation mechanism, moving marine nutrients vast distances in land. They are also an important fishery, in both marine and freshwater systems and a vital traditional food source. Despite the ongoing and predicted climate change impacts in the Yukon River Basin their impact on salmon is not well known.

In some cases, the subsistence harvest limits are below what is needed for rural communities threatening their food security and way of life. While this paper focuses mainly on impacts to Alaskan fisheries, Yukon is the spawning ground for a large proportion of the Chinook salmon population. These fish are also of great importance to Yukon people, and a source of marine nutrients for Yukon ecosystems.

Citation

Cunningham, Curry J., Peter A. H. Westley, and Milo D. Adkison. 2018. “Signals of Large Scale Climate Drivers, Hatchery Enhancement, and Marine Factors in Yukon River Chinook Salmon Survival Revealed with a Bayesian Life History Model.” *Global Change Biology* 24 (9): 4399–4416. https://doi.org/10.1111/gcb.14315.

The seasonality of a migratory moose population in Northern Yukon

Author(s)

Cooley D, Clarke H, Graupe S, Landry-Cuerrier M, Lantz T, Milligan H, Pretzlaw T, Larocque G, Humphries M

Keywords

Alaska-Yukon, alpine, Cervidae, habitat selection, migration, seasonality, subsistence, thermal ecology, Traditional Ecological Knowledge, winter

Summary

This article describes the seasonal movements of moose living at the northern edge of their range. Nineteen animals of mixed genders were fitted with GPS collars to monitor year-round movement patterns. While more southern moose populations are facing declines in both population and range, northern populations are increasing in both population and range. Many moose populations are not typically described as migratory, but local movements between summer and winter ranges are quite common. These local movements happen when there are elevation changes in overall range of the moose population. Moose prefer lower elevations in late winter and early autumn and move to higher elevations for the remainder of the year. The distance of some of these movements is long enough in some groups of moose that they can be classified as migratory. This paper attempts to catalogue and understand the seasonal movement of Northern moose populations.

Relevance

Moose inhabit highly seasonal environments throughout the year and are well adapted to this lifestyle. However, seasonal extremes can adversely impact populations. Climate change is driving increases in summer and fall temperatures which have been shown to affect how moose select habitat. A variety of other factors including, diet, insects, and predation were found to influence both summer and winter habitat selection, all of which are impacted by climate change. Moose are an important food source for both local and traditional people.

Citation

Cooley, D., H. Clarke, S. Graupe, M. Landry-Cuerrier, T. Lantz, H. Milligan, T. Pretzlaw, G. Larocque, and M. M. Humphries. 2019. “The Seasonality of a Migratory Moose Population in Northern Yukon.” *Alces* 55: 105–30.

2.0 WATER/ICE

'Boundary': mapping and visualizing climatically changed landscapes at Kaskawulsh Glacier and Kluane Lake, Yukon

Author(s)

Shugar HH, Colorado KA, Clague JJ, Willis MJ, Best JL

Keywords

climate change, glacier, boundary, mountain, river piracy sculpture

Summary

This paper combines the perspectives of geoscientists and visual artists viewing the same landscape at Kaskawulsh Glacier and Kluane Lake, Yukon. Scientific mapping and historic photograph comparisons are combined with sculpture at a variety of sites to interpret changes to the Kaskawulsh Glacier that occurred in 2016. Mainly the rerouting of the Slims River due to a glacial surge. The researchers were particularly interested in the slow, gradual change that lead to a dramatic tipping point when the glacier surged and blocked the river. They describe this tipping point as a boundary, both on a metaphysical level as well as environmental. By combining natural observations with artistic installations, they hope to reach and connect with a broader audience.

Relevance

Climate change is having far reaching impacts throughout Yukon, many of these impacts are only explained or understood from a purely scientific lens. Experiments are conducted and observations are collected but the human impact is ignored. In other parts of Yukon, the human impact of climate change is felt by people who find their ways of life changing but are struggling to have their voices heard and their needs understood. By combining the product of scientific investigation with a series of artistic installations the researchers hope to, in their words, “bring climate change and it’s resulting effects to the viewer in a deep visceral way.”

Citation

Shugar, D. H., K. A. Colorado, J. J. Clague, M. J. Willis, and J. L. Best. 2019. “‘Boundary’: Mapping and Visualizing Climatically Changed Landscapes at Kaskawulsh Glacier and Kluane Lake, Yukon.” *Journal of Maps* 15 (3): 19–30. https://doi.org/10.1080/17445647.2018.1467349.

Coastal erosion of permafrost soils along the Yukon coastal plain and fluxes of organic carbon to the Canadian Beaufort Sea

Author(s)

Couture NJ, Irrgang A, Pollard W, Lantuit H, Fritz M

Keywords

Beaufort Sea, carbon, coastal erosion, permafrost, sediment

Summary

Rapid environmental changes in the Arctic can drive greater mobilization of carbon. The amount of organic carbon in Arctic coastal permafrost soils is quantified to aid in understanding carbon cycling and provide insight into annual carbon fluxes. The researchers assessed various pieces of terrain based on the geology, morphology, and permafrost. To calculate carbon content of soils, an average ground ice volume was subtracted giving a range of 30 – 662kg of carbon per $1m^3$ soil column. The researchers concluded that 80 percent of the shoreline was erosive and using an annual erosion rate of -0.7m/year, calculated an annual average carbon influx of 132kg per meter of coastline, per year. Extrapolating these values across the Beaufort Sea, the researchers conclude the coastal carbon influxes may be 3 times higher than previously thought. The amount of carbon deposited in the Beaufort due to coastal erosion will continue to increase as the rate of erosion continues to increase. The researchers also collected marine sediment samples offshore. In these samples they find that more than 90% of the carbon found in these sediments is of terrestrial origin.

Relevance

Oceans slow the buildup of atmospheric carbon dioxide by acting as a sink. However, influxes of carbon from other sources can reduce the rate of atmospheric sequestration. Environmental changes in the Arctic such as longer open water seasons, rising sea levels, and warmer, air, water and soil temperatures are increasing the rate of coastline erosion across the Arctic, and therefore carbon fluxes from terrestrial sources into the sea. Most of the Yukon Coast is underlain by permafrost and is becoming more and more susceptible to erosion as the climate warms. There are limited data available on soil carbon content for the Yukon Coastal Plain, and the highly variable, volume of ice in the soil further hampers determining carbon contents. Because of this, the impact of terrestrial carbon is poorly understood on marine systems and may impact our understanding of the global carbon cycle.

Citation

Couture, Nicole J., Anna Irrgang, Wayne Pollard, Hugues Lantuit, and Michael Fritz. 2018. “Coastal Erosion of Permafrost Soils Along the Yukon Coastal Plain and Fluxes of Organic Carbon to the Canadian Beaufort Sea.” *Journal of Geophysical Research: Biogeosciences* 123 (2): 406–22. https://doi.org/10.1002/2017JG004166.

Linking mountain glacier retreat and hydrological changes in southwestern Yukon

Author(s)

Chesnokova A, Baraer M, Laperriere-Robillard T, Huh K

Keywords

climate change modelling, glacier, hydrology, peak water analysis

Summary

The purpose of this study is to understand how a reduction in glacier cover can impact river discharge. Typically, when glaciers retreat continuously there is an initial increase in run off, as the mass of the glacier shrinks this runoff tapers. The point of maximum discharge is known as peak water. This study analyzed 8 different watersheds in Yukon and found that only 6 of them have reached peak water. The remaining 2 watersheds could see a doubling of glacier driven discharge values. Historical analysis and modelling are the two most common methods for identifying trends in hydrological changes, however it is difficult to isolate glacier retreat from other hydrologic changes. Both approaches are hampered by lack of data. By combining these two methods the researchers hope to overcome data restrictions.

Relevance

Climate change is driving large scale changes to the snow, ice, and permafrost in alpine environments. These are an important source of water in these regions and loss, or changes to this water can have far reaching impacts across a broad range of sectors. As hydrological systems are complex and underpin ecosystems, understanding all the potential sources of changes to them is of importance.

Citation

Chesnokova, A., M. Baraër, T. Laperrière-Robillard, and K. Huh. 2020. “Linking Mountain Glacier Retreat and Hydrological Changes in Southwestern Yukon.” Water Resources Research 56 (1): e2019WR025706. https://doi.org/10.1029/2019WR025706.

Meltwater storage in the firn of Kaskawulsh Glacier, Yukon Territory, Canada

Author(s)

Ochwat N, Marshall S, Moorman B, Criscitello A, Copland L

Keywords

firn, glacial mass balance, melt, refreezing

Summary

Firn is glacial snow transitioning to ice and is an important component of melt water retention and understanding glacial mass balance. Using surveying techniques to measure glaciers relies on a series of assumptions including estimated snow, firn and ice depth and that these values do not change between measurement dates. Over long time periods firn depth estimates generally have little impact on glacier mass balance, but over shorter time frames movement of melt water, and refreezing in the firn layer can introduce uncertainties to estimates. These uncertainties also make it difficult to determine the impact of changes to firn layer on global sea level rise.

In this project two firn cores were taken on the Kaskawulsh Glacier. These cores were then analyzed for density and the effects of melt water movement and freezing. Based on their analysis the researchers find evidence of widespread glacier melt and refreezing.

Relevance

Climate change is driving changes to glaciers that have large implications for downstream hydrology and connected systems. However, there is a large amount of uncertainty about what these changes will look like. How much water will be released as glacier runoff? How is it different from normal melt? The amount of glacial melt is typically calculated using mass balance measurements from surveyed values. However, glaciers are dynamic and there are uncertainties in the measuring process that compound with other uncertainties. By understanding the intricacies of different components of glaciers and their contribution to melt water we can better predict downstream changes and associated adaptation strategies.

Citation

Ochwat, N. E., S. J. Marshall, B. J. Moorman, A. S. Criscitiello, and L. Copland. 2020. "Meltwater Storage in the Firn of Kaskawulsh Glacier, Yukon Territory, Canada." *The Cryosphere Discussions* 2020: 1–21. https://doi.org/10.5194/tc-2020-119.

Monitoring ground temperatures in permafrost along the Dempster Highway, Yukon and NWT

Author(s)

Stockton EJ, Burn CR, Idrees M, Calmels F

Keywords

highways, permafrost, snow, thermal regime

Summary

The Dempster Highway, built in 1979, is the only overland route to the Canadian Arctic. It was constructed almost entirely on permafrost using techniques to mitigate thawing common for the time period. However, there was little understanding of potential climate change impacts. These impacts have led to increased precipitation and changes to the permafrost regime underlying the Dempster Highway. To study these impacts four monitoring stations were installed in Yukon and NWT recording atmospheric data and ground temperatures. This paper summarizes the first four years of monitoring. Soil temperature data was collected to a depth of 10 m at various locations at each site, though bedrock at one site prevented drilling to the full 10m depth.

Monitoring has shown that:

- The active layer, or depth of thawed ground at each site has increased, and permafrost at some locations at one sampling site has completely degraded.

- Snow removal on the highway can drive changes to ground temperature. This snow is deposited next to the highway by snowplows and insulates these areas from temperature changes.
- Changes to the shrub regime due to clearing also impacts the permafrost regime.

Relevance

As the only overland link to the Canadian Arctic, the Dempster Highway is of importance to people in the Arctic and has a potential link to Canadian Arctic Sovereignty. Understanding potential impacts to infrastructure underlain by permafrost as the climate changes is important for the Dempster Highway as well as other Arctic linear infrastructure. In many cases, like the Dempster Highway, infrastructure was planned prior to understanding the full impacts of climate change and may be vulnerable to permafrost thaw. In many regions throughout Yukon, structures and roadways have been built using permafrost to stabilize the ground. As the permafrost regime changes these structures and roadways could be damaged or destroyed. In many cases there is only a single overland link to communities in the North and if this link is interrupted communities can be cut off. Because of the remoteness of many roadways in the North understanding how permafrost can threaten them, prior to infrastructure failure and the associated disruption to transportation is important. Additionally, the construction, maintenance and use of roadways has specific impacts on permafrost.

Citation

Stockton, E. J., C. R. Burn, M. Idrees, F. Calmels, and K. Elmer. 2019. “Monitoring Ground Temperatures in Permafrost along the Dempster Highway, Yukon and NWT.” In Cold Regions Engineering 2019, 92-101. https://doi.org/10.1061/9780784482599.011.

Permafrost-carbon mobilization in Beringia caused by deglacial meltwater runoff, sea-level rise and warming

Author(s)

Meyer VD, Hefter J, Kohler P, Tiedmann R, Gersonde R, Wacker L, Mollenhauer G

Keywords

atmospheric CO2, Beringia, Bering Sea, biomarker, deglaciation, meltwater, Northwest Pacific, permafrost decomposition

Summary

It is assumed that during ancient ice-free periods flooding and warming would have led to large scale melting of permafrost soils in the North. The associated release of organic matter could have contributed to a rise in atmospheric CO2; however, this link is not well understood. This study uses radiocarbon signatures and mass-accumulation rates in 4 marine sediment cores to trace the movement of organic matter from permafrost. By investigating ancient permafrost decomposition, the researchers hope to better understand how modern permafrost will react to climate change and expected impacts. Studies tend to

rely on indirect, or modelled approaches when considering the larger carbon cycle, however the timing of carbon released as permafrost degrades is not known. This study is the first of its kind to use mass accumulation and biomarkers to analyze the carbon released from ancient permafrost.

Relevance

The impacts of permafrost on the carbon cycle are not well known, despite the potential of permafrost to be a major contributor to the cycle. By using proxy data, rather than modelled data of ancient, large scale changes to permafrost we can gain an understanding of how permafrost will contribute to the carbon cycle in modern times. Much of Yukon is underlain by permafrost, and changes to it can and are driving changes to ecosystems and threatening infrastructure.

Citation

Meyer, Vera, Jens Hefter, Peter Köhler, Ralf Tiedemann, Rainer Gersonde, L. Wacker, and Gesine Mollenhauer. 2019. “Permafrost-Carbon Mobilization in Beringia Caused by Deglacial Meltwater Runoff, Sea-Level Rise and Warming.” *Environmental Research Letters* 14 (June). https://doi.org/10.1088/1748-9326/ab2653.

Postdepositional mercury mobility in a permafrost peatland from central Yukon, Canada

Author(s)

Bandara S, Froese DG, St. Louis VL, Cooke CA, Calmels F

Keywords

mercury, ombrotrophic peat, permafrost, postdepositional mobility, Yukon, δ18O, 210Pb

Summary

A core sample from a peat bog near Dawson City is analyzed to reconstruct natural and anthropogenic mercury deposition rates. There is a link between overall mercury concentration and pore-water ice in the sample, which may indicate that mercury travels downwards through the soil until it reaches permanently frozen soil. Approximately 400 years of mercury accumulation are shown in the core sample. This includes the time of the Klondike gold rush, and the authors of the study hypothesize that there will be an obvious mercury flux in their sample during those years. However, this is not the case, and instead evidence of downward travel through the soil sample is found. This suggests that the core may not reflect the history of mercury deposition accurately.

Relevance

Mercury is cycled globally via natural and anthropogenic systems and is a contaminant. While there are natural sources of mercury, the most common source is from human emissions. However, to effectively assess the amount of mercury deposited by these emissions an understanding of natural levels must be gained. This is complicated by many

years of mercury deposition and its extreme mobility in the atmosphere. Other sources of mercury, particularly in the Dawson region include historical mining activities where it was used to extract placer gold.

Citation

Bandara, Sasiri, Duane G. Froese, Vincent L. St. Louis, Colin A. Cooke, and Fabrice Calmels. 2019. “Postdepositional Mercury Mobility in a Permafrost Peatland from Central Yukon, Canada.” *ACS Earth and Space Chemistry* 3 (5): 770–78. https://doi.org/10.1021/acsearthspacechem.9b00010.

Rapid retreat of permafrost coastline observed with aerial drone photogrammetry

Author(s)

Cunliffe AM, Tanski G, Radosavljevic B, Palmer WF, Sachs T, Lantuit H, Kerby JT, Myers-Smith IH

Keywords

climate change, coastal erosion, permafrost, photogrammetry, UAV

Summary

Coastal erosion is just one impact of climate change induced changes to permafrost. This project uses a combination of drones, satellite imagery, and historic aerial photographs to measure the retreat of permafrost coastline on Herschel Island. The goals of this study are to:

- Assess finely scaled coastal erosion dynamics
- Study short-term changes to shorelines, and how they compare with longer term observations
- Evaluate the use of UAVs or drones as a tool to study changes to coastline and inform management practices.

This study specifically focuses on short term coastline dynamics, research on this topic often focuses on multi-seasonal changes rather than inter-seasonal changes. Repeated drone surveys are used to look at changes to a coastline over a 13-month period, and these changes are then compared to the historic record of 65 years by using aerial photos. The researchers also produced digital elevation models of changes to the shoreline.

Relevance

Erosion is one of the main processes degrading permafrost on the coast. Large amounts of sediments and organic materials are deposited into oceans impacting marine systems and at a larger scale, reducing the capacity of oceans to sequester carbon. Coastal erosion also threatens historic sites and current human use of the region. Inaccessibility to these sites

reduces the ability of researchers to understand changes to these sites, while the lack of information prevents locals from planning effectively.

Citation

Cunliffe, A.M., G. Tanski, B. Radosavljevic, W.F. Palmer, T. Sachs, H. Lantuit, J.T. Kerby, and I.H. Myers-Smith. 2019. “Rapid Retreat of Permafrost Coastline Observed with Aerial Drone Photogrammetry.” *The Cryosphere* 13: 1513–28. https://doi.org/10.5194/tc-13-1513-2019.

3.0 CLIMATOLOGY

Evidence for elevation-dependent warming in the St. Elias Mountains, Yukon, Canada

Author(s)

Williamson SN, Zdanowicz C, Anslow FS, Clarke GK, Copland L, Danby RK, Flowers GE, Holdsworth G, Jarosch AH, Hik DS

Keywords

climate, elevation, ice cores, warming

Summary

The climate at higher elevations is warming more rapidly than the global average. Also, the climate in the Arctic is warming at higher rates than the global average. However, there is little understanding of how Arctic warming rates compound with elevation dependent warming rates, as research that looks at elevation dependent warming rates has typically taken place at more southern latitudes. There are a variety of hypotheses on what drives elevation dependent warning such as:

- As snow melts at higher elevations less solar energy is reflected causing localized warming. This creates a feedback effect that further reduces snow cover.
- Airborne particles that capture reflected solar radiation are more effective at higher altitudes.
- Cloud cover and water vapour are more effective at capturing reflected radiation at higher altitudes.
- The troposphere is warming.

This study uses the measurements from weather stations in the St. Elias Mountains and Ice Fields to validate modelled air temperatures for the region and quantify elevation dependent warming. It also considers some of the drivers of this warming by looking at different climate trends. Long term climate information is also gathered from ice cores.

The authors find that there is a strong trend of warming as elevation increases and that this trend has been steadily increasing since 1979. The greatest rates of warming were found above 5500m, and warming patterns tend to match those observed in the rest of the Arctic.

Relevance

Climate change is having a sweeping impact on Northern systems, both human and natural. The magnitude of these effects is bound to continue and there are many uncertainties about the future of the Northern climate. Regional climate models typically exclude more localized topographic features. As Yukon is largely mountainous, understanding changes to climate at high elevations will also increase the accuracy of regional scale climate models and potentially reduce uncertainty around climate predictions. Most of Yukon’s glaciers occur at higher elevations, and increased warming and associated melt can have large hydrologic implications.

Citation

Williamson, Scott N., Christian Zdanowicz, Faron S. Anslow, Garry K. C. Clarke, Luke Copland, Ryan K. Danby, Gwenn E. Flowers, Gerald Holdsworth, Alexander H. Jarosch, and David S. Hik. 2020. “Evidence for Elevation-Dependent Warming in the St. Elias Mountains, Yukon, Canada.” *Journal of Climate* 33 (8): 3253–69. https://doi.org/10.1175/JCLI-D-19-0405.1.

State of the mountains report

Author(s)

Alpine Club of Canada

Keywords

alpine, glaciers, mining, mountains

Summary

A very broad level report on mountainous regions in Canada. This issue highlights Covid-19 impacts to mountain-based activities, particularly tourism as well as how climate change is impact mountains. It also summarizes various research activities that involve mountains. Some of these activities include learning about the downstream impacts of mining, changes to glaciers and how alpine temperature patterns are changing.

Relevance

The focus of this version of the State of Mountains reports focuses heavily on anthropogenic impacts to mountain environments in western Canada. It features many sections that discuss threats to mountain systems relevant to Yukon such as climate change, and mining. It also discusses the importance of documenting current biodiversity in order to understand how systems are changing. It is ultimately a snapshot or highlight document of threats to mountains, many of which are seen in Yukon.

Citation

Alpine Club of Canada. 2020. “State of the Mountains Report.” The Alpine Club of Canada.

Summer rainfall dissolved organic carbon, solute, and sediment fluxes in a small Arctic coastal catchment on Herschel Island (Yukon Territory, Canada)

Author(s)

Coch C, Lamoureux SF, Knobluach C, Eischeid I, Fritz M, Obu J, Lantuit H

Keywords

carbon, permafrost, hydrology, lateral fluxes, hysteresis, climate change

Summary

Climate change is predicted to increase the frequency and intensity of rainfall in the Arctic. This could cause the mobilization of organic matter, sediments, and nutrients from coastal areas into the Arctic Ocean. The movement of organic matter, sediment and nutrients is strongly affected by permafrost coverage, ground ice, topography, soil types vegetation cover, and can be highly variable. In particular, the role of summer rain fall in the movements of these things is not well understood and this study seeks to:

- Determine discharge characteristics associated with summer rain fall and establish a baseline or normal rain fall discharge rate.
- Quantify organic matter, sediment and nutrient inputs associated with summer rain fall.
- Understand how and if similar Arctic watersheds will respond to rainfall.

This study takes place in the Ice Creek West watershed on Herschel Island. The researchers collect atmospheric, hydrologic and sediment/water chemistry data using remote loggers over a two-year period. They find that during rain events water flows over land which leads to a large flux of organic materials and other dissolved solids, whereas during base flow events water travels below the surface and transports nutrients. Increased summer rain fall will likely lead to an increase in both organic material and other dissolved solids.

Relevance

Climate change is driving broad scale and rapid changes to the Canadian Arctic. However, our understanding of many Arctic systems is limited due to the remoteness, and vastness of the region. Not only is there uncertainty about how Arctic systems will change, there is also uncertainty about how those changes will impact Arctic systems. It is predicted that summer rainfall will increase, yet the degree of increase is not known with certainty, and the impacts of rainfall increase is also not well known. While this project doesn't touch on how much arctic rain fall will increase due to climate change is does begin to increase our understanding of what increased rainfall could mean for Arctic systems.

The transport of material to oceans connects to the larger world. The Arctic ocean is an important sink for atmospheric carbon sources, and terrestrial inputs can reduce the efficacy of this. Understanding the amount of carbon deposited in oceanic systems from terrestrial sources can improve our understanding of changes to global carbon cycles. Closer to home, the Arctic ocean is important to the traditional lifestyles of many people living in the Arctic and carbon and sediment inputs (among other things) can have far reach impact on marine systems.

Citation

Coch, Caroline, Scott F. Lamoureux, Christian Knoblauch, Isabell Eischeid, Michael Fritz, Jaroslav Obu, and Hugues Lantuit. 2018. "Summer Rainfall Dissolved Organic Carbon, Solute, and Sediment Fluxes in a Small Arctic Coastal Catchment on Herschel Island (Yukon Territory, Canada)." *Arctic Science* 4 (4): 750–80. https://doi.org/10.1139/as-2018-0010.

4.0 VEGETATION

Eighteen years of ecological monitoring reveals multiple lines of evidence for tundra vegetation change.

Author(s)

Myers-Smith IH, Grabowski MM, Thomas JD, Angers-Blondin S, Daskalova GN, Bjorkman AD, Cunliffe AM, Assmann JJ, Boyle JS, McLeod E, McLeod S, Joe R, Lennie P, Arey D, Gordon RR, Eckert CD

Keywords

climate change, community composition, greening, growth, permafrost, phenology, tundra, warming

Summary

The Arctic tundra is warming rapidly, with average annual temperatures increasing by 2C since 1978. This is potentially driving broad changes to vegetation communities across the tundra. However, the mechanisms that link warming and these changes are not well understood. In order to increase this understanding, the data from 18 years of ecological monitoring is analyzed and compared with the observations of people who reside and spend time in the tundra. Researchers found that:

- Vegetation communities are reaching ‘spring’ 9 days earlier per decade.
- The average canopy plant height is doubling each decade.
- Shrubs and graminoids are doubling in abundance, while bare ground is reduced by half per decade.

These changes match satellite imagery of tundra greening, and the authors conclude that warming from increased growing season, warmer soil temperature and increased active layer depth are driving these changes.

This study incorporated data from a variety of projects, across the circumpolar arctic to produce the long-term data needed. Data were collected from community-based research, government monitoring programs and academic research.

Relevance

Arctic systems are experiencing climate change at a greater rate than the rest of the world, they are also vulnerable systems that in many cases have been poorly understood. Because of logistical challenges, namely remoteness and limited access outside of the summer season long term data sets are often not available or lacking in temporal resolution. By combining the results of 18 years of monitoring, at a relatively high spatial resolution this research provides insight into how plant communities and entire ecosystems are responding to climate change. Furthermore, this study highlights the importance of including the broader community into monitoring projects and is an example of how this collaboration can improve existing monitoring programs.

Citation

Myers-Smith, Isla H., Meagan M. Grabowski, Haydn J. D. Thomas, Sandra Angers-Blondin, Gergana N. Daskalova, Anne D. Bjorkman, Andrew M. Cunliffe, et al. 2019. “Eighteen Years of Ecological Monitoring Reveals Multiple Lines of Evidence for Tundra Vegetation Change.” *Ecological Monographs* 89 (2): e01351. https://doi.org/10.1002/ecm.1351.

NDVI–Climate relationships in high-latitude mountains of Alaska and Yukon Territory

Author(s)

Verbyla D, Kurkowski TA

Keywords

Alaska, alpine tundra, climate warming, gridded, climate, high latitude, mountain class, NDVI, summer warmth, lapse rate, Yukon

Summary

Remotely sensed vegetation data is used as a proxy for temperature changes in high altitude systems. Long term, and interannual data sets are used to proxy the maximum season of photosynthetic activity, which is then compared with altitude, precipitation, and temperature data. This study had three main questions:

- Does alpine vegetation decrease linearly as July temperatures decrease linearly, with elevation?
- What is the relationship between long term vegetation cover data and long-term temperature and precipitation?
- Does increasing summer warmth correlate with increased vegetation cover?

Vegetation growth at altitude is limited by cold temperatures and length of growing season, the researchers predict that vegetation cover will increase with climate change driver temperature increases. However, at higher altitudes precipitation is not expected to increase so vegetation may become limited by that.

Relevance

Northern Canada is rapidly experiencing changes to its climate. There is much uncertainty about the nature of these changes and how people and systems will be impacted. This uncertainty is compounded by lack of data. The North is remote and difficult to access. Climate predictions are typically done at a larger scale, that may or may not account for unique northern systems and topography. By using remote sensed vegetation as a proxy for temperature information more finely scaled understanding of the changing Northern climate is possible.

Citation

Verbyla, David, and Thomas A. Kurkowski. 2019. “NDVI–Climate Relationships in High-Latitude Mountains of Alaska and Yukon Territory.” *Arctic, Antarctic, and Alpine Research* 51 (1): 397–411. https://doi.org/10.1080/15230430.2019.1650542.

5.0 HUMANS

Climate change resilience in the Canadian Arctic: The need for collaboration in the face of a changing landscape

Author(s)

MacDonald S, Birchall SJ

Keywords

adaptation, resilience, landscape change

Summary

The Canadian Arctic is one of the region's most vulnerable to climate change in the country. Human and natural systems are already experiencing large changes and current policy to not adapting fast enough to these changes. Collaboration and engagement with the people that live in the Arctic is considered a crucial step in reevaluating policy to better suit the unique needs of this region and its people. The authors propose developing better resilience to climate change at a community level, but that this process is hampered by limited resources and community level adaption is often done reactively or to respond to immediate concerns. By mainstreaming climate change adaptation into existing policy and planning is one way to improve resilience.

Relevance

This paper is broadly focused on the entire Canadian Arctic, and quite limited on specific content. However, its overarching purpose is to encourage community involvement in climate change policy and planning. Many Yukon communities are already experiencing the impacts of climate change and experience the lack of resources for adaptation common to many Arctic communities. This paper draws attention to the need for stakeholder involvement in adaptation policy and planning as well as the need for adaptation to be mainstreamed across different levels of government.

Citation

MacDonald, Seghan, and S. Jeff Birchall. 2019. "Climate Change Resilience in the Canadian Arctic: The Need for Collaboration in the Face of a Changing Landscape." *The Canadian Geographer / Le Géographe Canadien* 64 (3): 530-534. https://doi.org/10.1111/cag.12591.

The right to food in Canada's North: Food security and sustainability in Yukon Territory

Author(s)

Hou S, Sneyd L

Keywords

food security, Yukon Territory, Right to Food, diet, nutrition transition, sustainability

Summary

This paper uses Olivier De Schutter's Right to Food Framework to analyze the food security of people in Yukon. The input of various stakeholders is compared with data from a literature review. Based on the results of this study it appears that for many people in Yukon food security is or may become an issue they face. Three factors are largely responsible for actual or potential food security in Yukon, climate change impacts to country food, challenges associated with local agriculture, and the vast distances food needs to be transported. Combined with climate change impacts to natural systems, the cost of obtaining country food prevents it from adequately securing food supplies in Yukon. The cold, semi-arid climate and short growing season of Yukon prevents large scale agriculture. However, the authors of this paper claim that to improve the food security of Yukon, both country food and locally supplied food must be used.

Relevance

Many people in Yukon rely on country foods to sustain them. As climate change modifies the environment food sources that people have depended on may become unavailable. Additionally, social issues, and a colonial legacy may indirectly threaten people's ability to harvest country foods leaving them in a state of food insecurity. The fragility of Yukon's imported food systems was highlighted in 2012 when the Alaska Highway was closed for several days, reducing the stock in local grocery stores to almost nothing. In essence, the current food security of Yukon will not improve as the climate changes, and food insecurity can be a major barrier to adaptation efforts. By establishing the state of food insecurity in the Yukon this paper provides a baseline for considering alternative food systems and methods to ensure country foods are available.

Citation

Hou, Sophia, and Lauren Sneyd. 2020. "The Right to Food in Canada's North: Food Security and Sustainability in Yukon Territory." *SURG Journal* 12 (1).

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