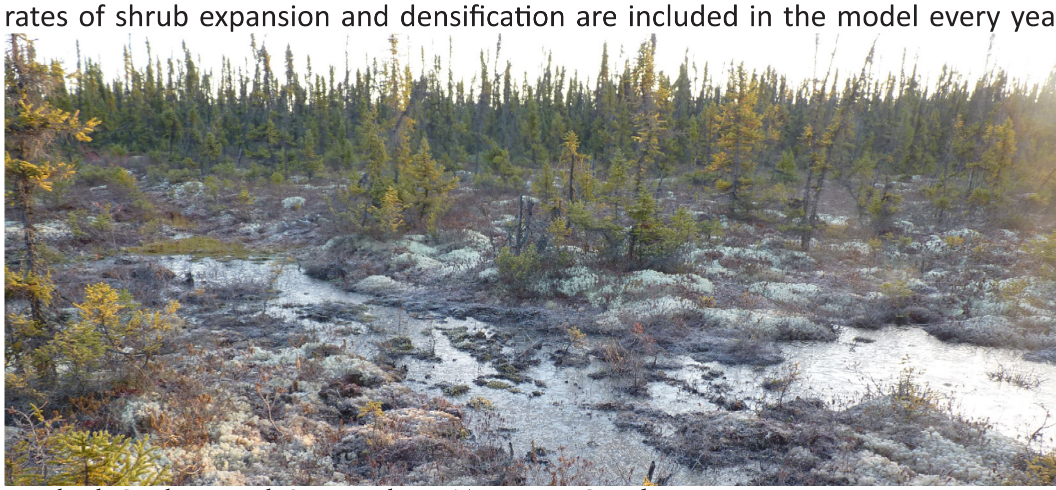
Impact of climate and vegetation changes on the hydrology of the Arctic treeline

Observed changes in Arctic climate and vegetation are impacting the hydrology of northern basins in a poorly understood way. Temperatures are increasing, permafrost is thawing, and shrubs are growing taller and colonizing the tundra. How these changes impact water resources distribution, magnitude and timing is unknown, presenting a great challenge for water resources managers and civil engineers.

Sebastian Krogh, PhD candidate at the University of Saskatchewan, aims to address these challenges by investigating the hydrology of a small Canadian Arctic basin using long-term observational records. The study site is Havikpak Creek (68.2°20'N 133°28'W), located 2 km north of Inuvik Airport in the Northwest Territories. It is a small basin (16.4 km2) dominated by taiga forest in the taiga-tundra transition, and it is underlined by continuous permafrost. Streamflow increases rapidly during snowmelt (May-June) during which peak flow occurs, followed by decreasing streamflow and sporadic summer high flows due to intense rainfall activity.

Sebastian conducts a snow survey in during a snow course in Finland.

To represent the hydrology of Havikpak Creek, Sebastian developed the Arctic Hydrological Model using the Cold Regions Hydrological Model platform. The Arctic Hydrological Model represents the physical processes of Havikpak Creek: snow accumulation and melt, blowing snow redistribution and sublimation, canopy interception of snow/rain and sublimation/evaporation, infiltration into frozen and unfrozen soil, ground freeze/thaw, runoff through organic terrain and snowpack, subsurface flow and streamflow routing. He reconstructed a 56 year period (1960-2016) time series of precipitation, air temperature, relative humidity and wind speed, from nearby weather stations to drive the Arctic Hydrological Model. To account for changes in vegetation cover, observed rates of shrub expansion and densification are included in the model every year.



Havikpak Creek Research Site, Northwest Territories, Canada.

Changing Cold Regions Network (CCRN)

CCRN is a Canadian research network that aims to understand, diagnose, and predict the rapid environmental change occurring in the interior of western Canada. The Network is funded over five years (2013-2018) by the Natural Sciences and Engineering Research Council of Canada (NSERC) through its Climate Change and Atmospheric Research Initiative.

www.ccrnetwork.ca

Sebastian Krogh, PhD

Sebastian received his MSc in Water Resources and Environment from the University of Chile in 2013. In 2014, he was awarded a scholarship from the Government of Chile to pursue a PhD abroad under the BECAS-CHILE CONICYT program where he moved to Canada to work under Dr. John Pomeroy at the University of Saskatchewan.

The model was tested against records of streamflow (from 1995 to 2015), snow surveys and active layer thickness (1993-2014). To isolate the individual effect of changes in climate and vegetation on the hydrology, two modelling scenarios were used: the first using the observed climate and a constant vegetation cover, and the second repeating a "normal" weather year for 56 years and the observed changing vegetation.

Taiga forest in Havikpak Creek Research Site, Northwest Territories, Canada.

Sebastian's study showed that over the 56 year period precipitation has not significantly changed and temperature has significantly increased by 3.9 °C since 1960, resulting in shorter winters and decreasing snowfall. Evapotranspiration and snow sublimation at Havikpak Creek have decreased about 19.6 mm and 12.3 mm since 1960, whereas streamflow has shown no trend. Larger changes were simulated for specific locations within Havikpak Creek; for example, snowdrifts in gullies have decreased considerably given warmer temperatures, and the increase in shrub cover and density have reduced blowing snow redistribution. Permafrost is thawing at a rate of approximately 2 cm/decade due to the warmer temperatures and the earlier snowmelt. Overall, changes in climate are the main drivers of hydrological changes, mostly due to the strong increase in air temperature; however, shrub densification and expansion into the tundra has significantly affected snow redistribution.

There is an apparent resilience of the streamflow regime in Havikpak Creek despite dramatic climate changes. This study shows the value in diagnostic modelling to understand the mechanisms and limitations of that resilience. This study also contributes to understanding the historical long-term role of vegetation and climate change on the hydrology of the Arctic treeline, showing the importance of including vegetation changes on hydrological studies and quantifying trends in hydrological processes. Understanding the interactions between climate, vegetation and hydrology is critical to anticipate to potential changes in water resources, and to design efficient and sustainable adaptation plans.

Cold Regions Hydrological Model

Developed by members at the Centre for Hydrology, University of Saskatchewan, the Cold Regions Hydrological Model is a process-based, flexible, modular hydrological modelling platform. The Cold Regions Hydrological Model allows the selection of different modules from an extensive library to create a custom hydrological model.

For more information regarding CRHM and the various projects it is used for, visit the Centre for Hydrology's website:

www.usask.ca/hydrology

Part of Sebastian's work was recently published:

Krogh, S., J. Pomeroy, and P. Marsh, 2017: Diagnosis of the hydrology of a small Arctic basin at the tundra-taiga transition using a physically based hydrological model, *Journal of Hydrology*, 550, 685-703, DOI: 10.1016/j.jhydrol.2017.05.042.

CCRN Changing Cold Regions Network   University of Saskatchewan   NSERC CRSNG