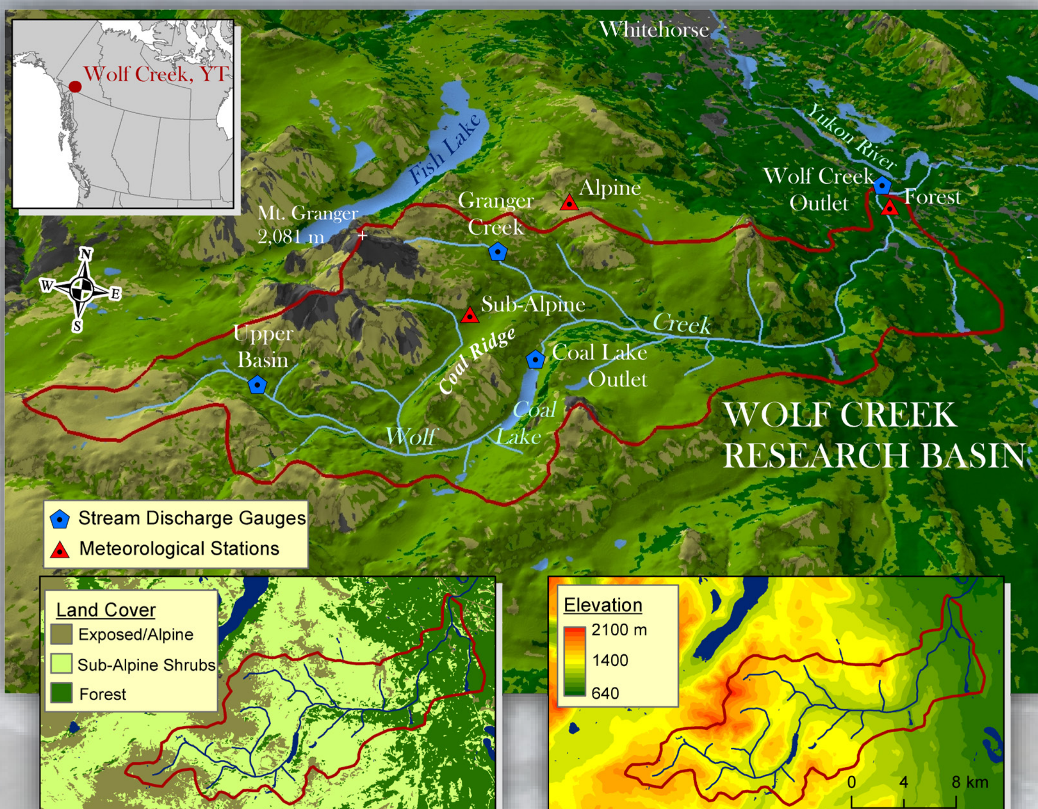
The Changing Environment of Western Canada: Sub-Arctic Mountains

Monitoring, Understanding, and Predicting the Changing Climate, Land, Vegetation, and Water Cycle at the Wolf Creek Research Basin, Yukon Territory

Wolf Creek is located in the sub-Arctic mountainous headwater region of the Yukon River, near Whitehorse, YT. The roughly 200 km^2 Wolf Creek drainage was instrumented as a research basin in 1992 to study the climate, water cycle, and ecology of this important northern ecoregion. Observations from three long-term automated meteorological stations, four stream level/discharge gauges, a groundwater monitoring well, and other specialized instrumentation continue to provide detailed information on the variable weather conditions and water flows across the basin. Research here has provided valuable insight into the snowmelt and rainfall-driven water cycle, the influence of frozen ground and vegetation, and the response of the hydrological system and its parts under a changing climate over the past several decades. Further, the observations and process-level understanding from decades of work provide a foundation for developing and testing computer models that can be used to simulate the behavior of the watershed and its future sensitivity and response to changing climate and extreme weather. Findings and models developed in Wolf Creek have been applied across the Yukon and in other similar regions and are essential tools to help us understand and manage uncertain water futures.



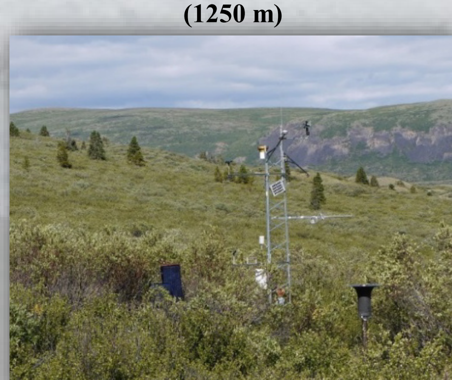
THE SUB-ARCTIC ALPINE AND BOREAL LANDSCAPE OF WOLF CREEK

Wolf Creek Basin ranges in elevation from about 660 m to just over 2,080 m, and is dominated by three major landcover types: boreal forest, sub-alpine shrub, and exposed alpine. Permafrost occurs over about 30% of the basin, mainly on north-facing slopes and at high elevations.

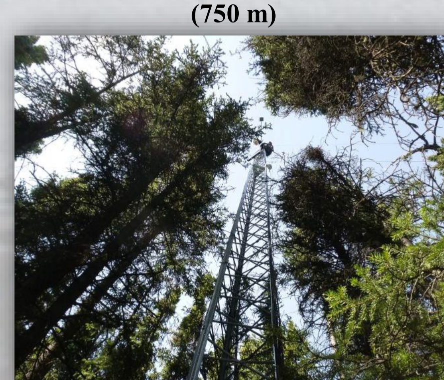
Granger Creek Discharge Gauge

Alpine Tundra Met. Station (1615 m)

Sub-Alpine Buckbrush Met. Station (1250 m)



White Spruce Forest Met. Station (750 m)



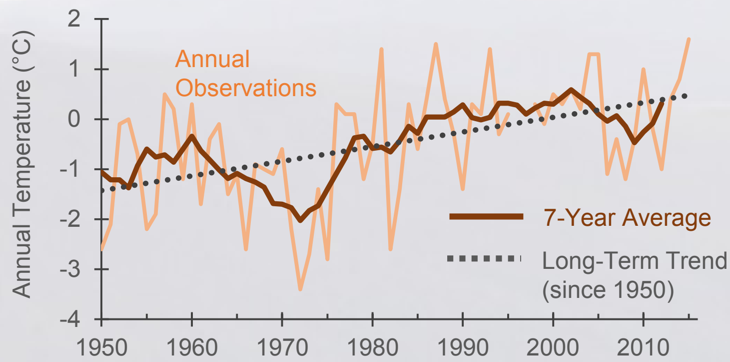
What changes have been observed at Wolf Creek and the surrounding region?

CLIMATE

The climate of the southern Yukon has changed considerably in recent decades. This includes:

- **Warming**: since 1950, mean annual temperature has risen by 2°C, and by over 5°C in winter
- **Wetter conditions**: annual precipitation has increased by about 50 mm (7%), mostly during summer and fall
- **Precipitation phase shift**: a greater proportion now falls as rain rather than snow (by about 10%)
- **Rain storms**: more frequent and intense rain events have been occurring, causing slope failure and landslides, and late-season flooding

Historical record of annual air temperature at Whitehorse, YT.



Data Source: Environment and Climate Change Canada (http://www.ec.gc.ca/dccha-ahccd/).

LANDCOVER AND VEGETATION

The climatic changes described above have affected the landscape, with observations and documentation of:

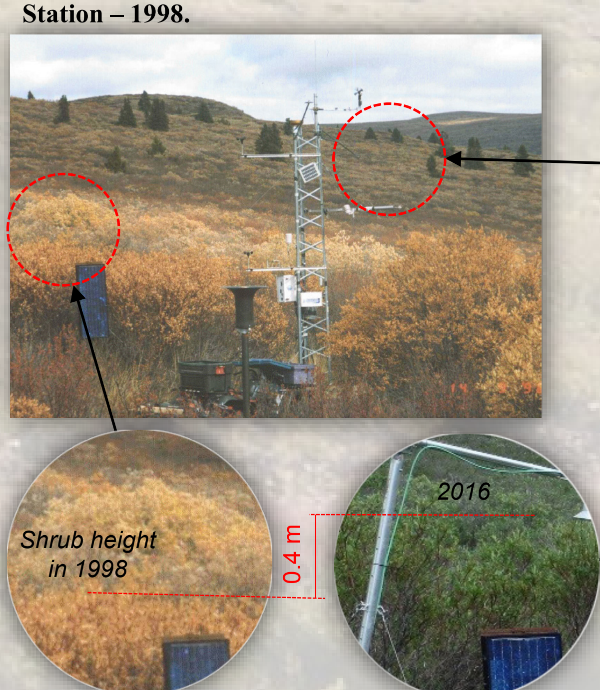
- **Thawing permafrost**: warmer conditions are causing permafrost to thaw and decline in extent, seasonal frost duration to become shorter, and the *active layer* (depth of seasonal thaw) to increase
- **Slowly advancing treeline**: sub-alpine fir stands have advanced upwards on south-facing slopes, while white spruce and lodgepole pine have shown varied responses—about 20% of the sub-alpine landscape has undergone tree infilling and new tree establishment since 1950
- **Rapid shrub expansion**: the height and abundance of shrubs has increased, with infilling and new shrub establishment occurring over about 60% of the landscape above tree-line since 1950

WATER STORAGE AND CYCLING

The warming and increasingly wet climate has influenced the snow regime and water flows as follows:

- **Earlier snowmelt and spring streamflow**: over the last several decades, snowmelt onset, ice cover breakup, rising and peak flows have occurred up to several weeks earlier
- **Minimal change in annual flows**: other characteristics of streamflow and water storage have shown little change over time, most likely due various complex and interacting effects, which can sometimes be compensatory and are not fully understood

Wolf Creek Buckbrush Meteorological Station – 1998.



Increase in shrub height and density

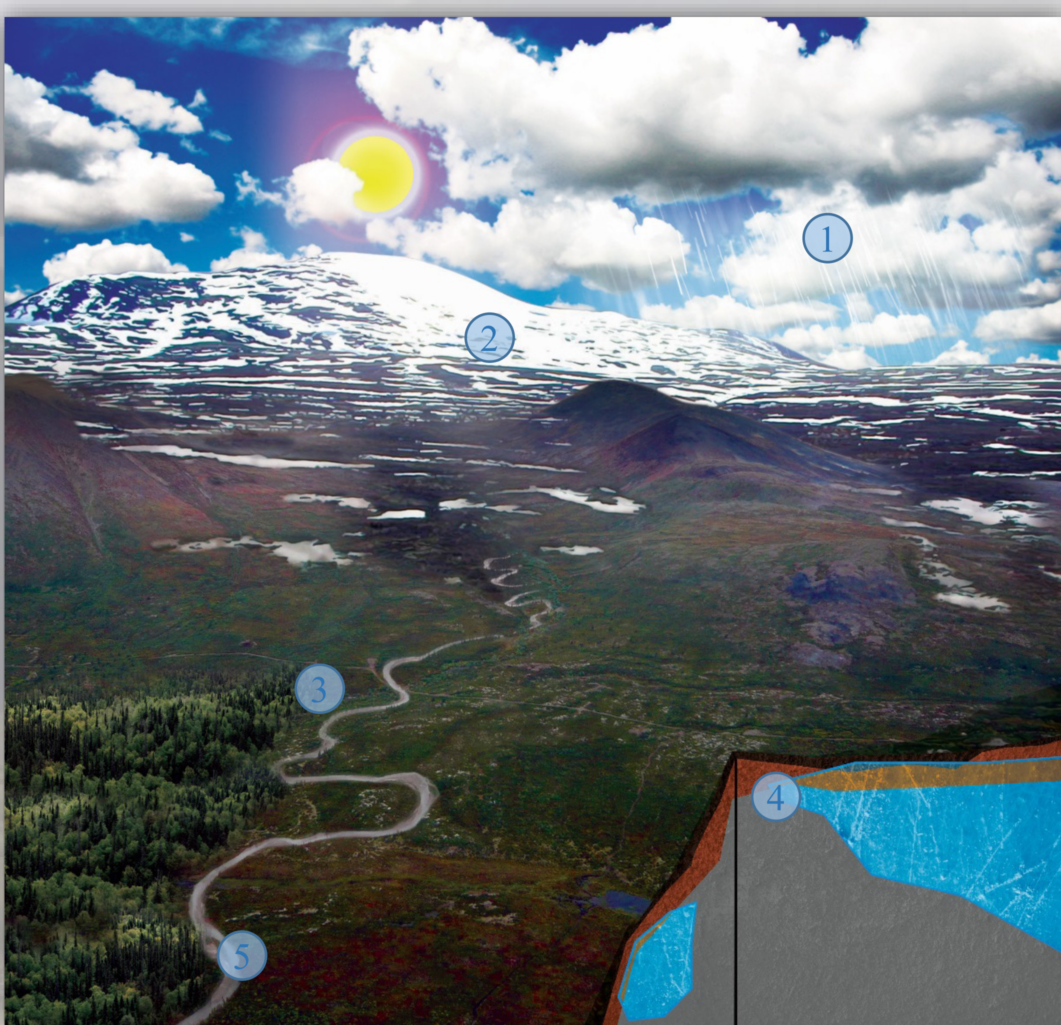
Infilling and growth of sparse, sub-alpine fir forest stands

Photographs: Richard Janowicz, Yukon Environment.

What does the future of the region hold?

A CHANGING LANDSCAPE

Climate models project that temperature here will continue to rise, increasing from 2 to 6°C on an annual basis and as much as 8°C in winter by the end of this century. Precipitation is also expected to continue to increase, with some models projecting an additional 25% or more on an annual basis by that time. These changes will undoubtedly have significant impacts on the sub-arctic alpine and boreal landscape characterized by the Wolf Creek Research Basin.



1. Changing Precipitation & Moisture Availability

Despite an overall increase in precipitation, warmer temperatures will lead to further reduction in the amount falling as snow, especially in the fall and spring shoulder seasons. A shorter annual duration of snow cover on the ground and frozen conditions, together with a warmer climate, also increases the amount of moisture loss due to evapotranspiration, resulting in potentially drier conditions over the landscape.

2. Reduced Snowpacks and Winter Snow Cover Duration

Warmer conditions will cause reductions in end-of-winter snowpack accumulation, which is expected to decline by 30 to as much as 45% under a 5°C warmer climate. The most sensitive area is the sub-alpine shrub zone, where reduced blowing snow from alpine areas will be greatly reduced. Increasingly early melt in spring will cause a further shortening of the snow cover period, by up to several weeks or more.

3. Forest and Shrub Tundra Expansion

Projected future climate conditions will favor the rapid expansion of shrubs across sub-alpine areas. Most species here are fast-growing, drought resistant, and will flourish under warmer conditions. Fir and spruce trees will likely continue to grow and infill over the landscape, but at a slower rate and only in locations with favorable soil and moisture conditions.

4. Thawing Permafrost

A warmer climate will result in continued thaw of permafrost, where it exists in the basin, as well as increasing active layer thickness and reduced seasonal frost duration in all parts of the basin. Permafrost change depends on the changes in snowpack and vegetation, however, and it is not entirely clear how these will unfold. For example, reduced snowpack, which acts like an insulating blanket, may partly counteract warmer temperatures.

5. Changing Water Cycling and Storage

A warmer climate together with a large increase in precipitation will likely result in greater mean and winter low streamflow, while high flows depend more strongly on how much warming occurs. Increases of 5°C or more will greatly reduce high flows due to reduced snowpack and less synchronized snowmelt across the basin. Earlier snowmelt input will advance the timing of peak streamflow from several weeks to as much one month. As permafrost thaws and active layer thickness grows, water will infiltrate deeper into the ground and follow longer, slower sub-surface pathways, delaying the delivery of rainfall and snowmelt water to lakes and streams.

Further Resources and Information on Wolf Creek Research Basin

JOURNAL ARTICLES AND REPORTS

There have been many publications describing the scientific activities and history of research at this basin, as well as those detailing the observations and projections of environmental change. Some key articles and reports include:

- Carey, S.K., Boucher, J.L., and Duarte, C.M,. Inferring groundwater contributions and pathways to streamflow during snowmelt over multiple years in a discontinuous permafrost subarctic environment (Yukon Canada), *Hydrogeology Journal,* 21, 67–77, 2013. http://link.springer.com/article/10.1007%2Fs10040-012-0920-9
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- Janowicz, R.J. Wolf Creek Research Basin – Overview, In: *Wolf Creek Research Basin: Hydrology, Ecology, Environment*, Proceedings of a workshop held in Whitehorse, Yukon, March 5–7, 1998, Pomeroy, J.W., and Granger, R.J. (editors), Environment Canada, National Water Research Institute, Publication 37-121/1999E, 121–130, 1999. Available at: http://www.ccrnetwork.ca//documents/Publications/Janowicz_1999_Wolf_Creek_Research_Basin.pdf
- Mamet, S.D., Young, N., Chun, K.P., and Johnstone, J.F. What is the most efficient and effective method for long-term monitoring of alpine tundra vegetation? *Arctic Science*, 2, 127–141, 2016. http://www.nrcresearchpress.com/doi/abs/10.1139/AS-2015-0020#.V9cSgfkrLRZ
- Ménard, C.B., Essery, R., and Pomeroy, J.W. Modelled sensitivity of the snow regime to topography, shrub fraction, and shrub height, *Hydrology and Earth System Sciences*, 18, 2375–2392, 2014. http://www.hydrol-earth-syst-sci.net/18/2375/2014/
- Pieper, S.J., Loewen, V., Gill, M., and Johnstone, J.F. Plant responses to natural and experimental variations in temperature in alpine tundra, southern Yukon, Canada, *Arctic, Antarctic, and Alpine Research*, 43, 442–456, 2011. http://www.bioone.org/doi/abs/10.1657/1938-4246-43.3.442
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- Rasouli, K., Pomeroy, J.W., Janowicz, J.R., Carey, S.K., and Williams, T.J. Hydrological sensitivity of a northern mountain basin to climate change, *Hydrological Processes*, 28, 4191–4208, 2014. http://onlinelibrary.wiley.com/doi/10.1002/hyp.10244/full

*See references within these key publications for further details

KEY RESEARCH PARTNERS

The principal research groups responsible for operations and current research activities at Wolf Creek include:

- Water Resources Branch, Yukon Department of Environment (http://www.env.gov.yk.ca/air-water-waste/hydrology.php)
    - Contact: Richard Janowicz, Senior Scientist, Hydrology
      richard.janowicz@gov.yk.ca; (867) 667-3223
- Centre for Hydrology, University of Saskatchewan (http://www.usask.ca/hydrology/)
    - Contact: Professor John Pomeroy, Director
      john.pomeroy@usask.ca; (306) 966-1426
- Watershed Hydrology Group, McMaster University (http://www.science.mcmaster.ca/watershed/)
    - Contact: Professor Sean Carey, Principal Investigator
      careysk@mcmaster.ca; (905) 525-9140 ext. 20134
- Northern Plant Ecology Lab, Department of Biology, University of Saskatchewan (http://npelusask.weebly.com/)
    - Contact: Professor Jill Johnstone, Principal Investigator
      jill.johnstone@usask.ca; (306) 966-4421

The Changing Cold Regions Network (CCRN) is a Canadian research network that aims to assess, understand, and predict the rapid environmental change occurring in the interior of western Canada. CCRN includes an inter-disciplinary team of over 40 university and federal government research scientists from across Canada, specializing in atmospheric science, hydrology, and ecology. The Network is supported by funding over five years (2013–2018) from the Natural Sciences and Engineering Research Council of Canada (NSERC) through its Climate Change and Atmospheric Research Initiative. To learn more, visit our webpage at www.ccrnetwork.ca.

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