GLACIERS in the CANADIAN COLUMBIA BASIN
A Summary
Glaciers in the Canadian Columbia Basin (the Basin) lost 15 per cent of their area from 1985 to 2005 and are projected to mostly disappear by 2000. Despite the importance of glaciers to the flow of the Columbia River and its tributaries, and the projected declines in glacier volume and area, little is known about the glaciers which feed the Columbia River Basin. Without detailed data, and knowledge specific to this region, communities are poorly equipped to address and adapt to the coming changes in the Basin.

The Canadian Columbia Basin Glacier and Snow Research Network (the Network) was formed in November 2013 with the goal to advance the understanding of the Canadian Columbia Basin’s snow and glaciers (also known as cryosphere), as well as their downstream contributions to water resources and ecosystems.

A key focus for the Network was to undertake a Coordinated Enhanced Observing Period of six Basin glaciers, their snow cover and downstream hydrology over a five-year period. In this project, which took place between 2014 and 2019, new data was collected using a combination of scientific field campaigns, automated monitoring stations and airborne surveys.

The data gathered can be used to better understand the characteristics of glaciers in the Basin, alpine snowpack, the relation of glaciers to the climate experienced today, and, ultimately, the Basin’s water resources.

- Summer conditions (dry and hot) play the biggest role in determining glacier mass balance—the net balance of snow gain during winter, minus snow and ice loss during summer. Therefore, an above average winter snowpack does not equate to positive mass balance or an increase in glacier size. With warmer and drier summers, glaciers are reducing in size.
- In Columbia River tributary streams and rivers with more than two per cent of the watershed covered by glaciers, glacier melt contributes significantly to summer streamflow, especially in August, helping those streams maintain flow when streams without glacier melt contributions would experience reduced flow.
- Glacier shrinkage over the last 40 years has reduced the ability of glaciers to maintain streamflow in these tributary streams and rivers during periods of hot, dry weather.
- Glaciers in the Basin lost an average of 80 cm of ice thickness per year from 2014-2018, a rate four times greater than the period 2000-2009.
- The study glaciers in the Canadian Columbia Basin received an average of 4.5 meters of snow per winter from 2014-2018, equal to about 2 meters of water depth; this information is valuable for future modeling of glacier runoff.
NEW KNOWLEDGE

The research undertaken by this project provides a baseline of real numbers, not models, of glacier mass balance in the Canadian Columbia Basin.

The Coordinated Enhanced Observing Period delivered a five-year snapshot of data collection, based on a five-year study that incorporated field work, automated monitoring stations, and LiDAR technology.

The research, which focused on six glacierized catchments (a watershed containing glaciers), quantified the amount of snowfall and ice melt over five years, the run-off produced, and the magnitude in which it has impacted stream flow in these catchments. The research also delivered data—for the first time on a larger scale—on how thick the snowpack is above the tree line. Real numbers have now been put to how much water is being contributed from alpine catchments or glaciers in the study area to their ecosystems or water networks. Researchers were also able to document how the weather, every year over the five years of research, influenced seasonal changes in the winter snowpack, the glaciers themselves, and, quite literally, the trickle down to ecosystems below.

Armed with data gathered from inside the region, organizations, industry and policy makers will be able to validate, develop or test improved models to project how glaciers will respond to future climate change. Improved projections allow policy makers, stakeholders, and people in the Basin to prepare for future changes of the Basin’s cryosphere.

In a warming climate, it’s essential to know how much snow and ice is up high and how fast it is being lost. It’s also important to understand how seasonal snow and melting glaciers impact run-off and stream flow. This information can be used for water governance, to improve flood forecasting, managing hydropower production, interpreting water quality, assessing changes in fish habitat, resource management and other purposes. But it’s also essential to recognize with a changing climate, comes changing data, so measuring glacier mass balance should be studied on an ongoing basis.

This research and the resulting technical report enhance the toolbox available to understand glacier mass balance. It provides concrete data regarding the rates and amounts of snowfall at high elevations, and glacier melt specific to the Canadian Columbia Basin.

Take that to the bank (But can we bank on it?)

Think of the glaciers in the Canadian Columbia Basin like they are our collective bank account. Due to the reduction in mass balance our withdrawals are greater than our deposits. So, it’s essential we obtain regular account statements that tell us our income (snowfall), expenses (snow and ice melt), and account balance (total ice remaining in the Basin) at any given time. The fact is, there’s a limited amount of water stored in our glaciers and we should really be keeping tabs on what’s there, what’s being spent and deposited, and, realistically, when our account might get depleted.

Ben Pelto on the Zillmer Glacier. Ben is standing across a stream on top of the glacier (supra glacial stream). This was in August 2016 during an annual balance trip, where researchers measured how much snow and ice melt had occurred over the summer.

Photo Credit: Erica Tung
Six glaciers in the study area were selected: Zillmer, Nordic, Illecillewaet, Haig, Conrad and Kokanee. In addition to their cultural, historical and/or recreational significance, glaciers were chosen based on a number of considerations:

- A large elevation range to maximize information on vertical gradients of accumulation and melt;
- Will not disappear over the next few decades to provide consistent data;
- Location within a gauged catchment between 10 and 1,000 km² in area;
- Relatively close to one or more climate stations, snow courses, or snow pillows; and
- Safe and relatively easy access.

Although these six research glaciers were selected to be representative of the Basin the findings from this project apply specifically to the selected glaciers only. About 70 additional glaciers near these sites were captured by the airborne LiDAR surveys.

The high elevation cryosphere forms the backbone of the Columbia River discharge. In addition to the existence of major dams and storage reservoirs, the Basin’s glaciers and snow cover provide a unique year-round water storage system, as well as essential late summer and early fall flow for the Basin’s watersheds. During times of drought, glaciers act as on-demand frozen reservoirs. They store water in the form of snow and glacier ice, and then release a portion of that water in the form of melt during the warm months of the year, especially June to September. Glacier runoff peaks in the driest, hottest months in the Basin, when community water demand is high, and salmon runs are occurring.
Glacier melt supplements late summer runoff when snowpacks are depleted or during years of drought, especially for catchments with at least two per cent of the area covered by glaciers. The graph below shows the contrast in streamflow between catchments with and without significant glacier cover during a dry year, like in 2003. The light blue line is the average, by date, of 26 catchments with less than two per cent glacier cover; the dark blue line is the average, by date, of nine catchments with more than two per cent glacier cover. For both sets of catchments, streamflow is similar until June, when melting of the seasonal snowpack is the main source of streamflow. Following the melting of seasonal snow, streamflow in the catchments with minimal glacier cover drops off through time until a rain event in October. In contrast, the glacier-fed streams maintain high flows through July and August as a result of contributions by glacier melt.

It’s no surprise that water discharging from a glacier is cold—usually close to 0 °C—and gradually warms as it flows downstream. The rate of warming decreases as the amount of flow increases. Therefore, by releasing relatively high volumes of cold water, glacier melt helps streams stay cool in hot summer weather.

The volume of glacier melt depends directly on the size of the glaciers. As glaciers retreat by melting, they lose area in their lowest portions, where the highest melt rates are typically found. Therefore, as glaciers shrink, their ability to maintain stream flow during periods of drought diminishes.

Being able to gauge the current rate of change allows for improved forecasts of continued glacier response to climate change in the Canadian Columbia Basin, which could impact everything from tourism and fish populations to energy, agriculture, policy, industry, water management, ecosystems, recreation, treaties and more.

In a changing climate, shifts in temperature and precipitation patterns affecting glaciers and snow cover will have downstream implications for ecosystems, communities, public safety and economic activities. Glaciers moderate changes in fall streamflow on a year-to-year basis, but with the shrinkage of the glaciers this buffering capacity is declining. Most streams show declining flows in late summer related to climate. In catchments where glaciers are shrinking, there is an even stronger decline of stream flow in summer, thereby exacerbating the problem.

Streams typically experience their lowest flows during late summer and early fall. Glacier contributions act as a buffer against low stream flows, which can be detrimental to fish and aquatic species due to thermal stresses.

Shrinking glaciers leading to lower flows in late summer results in less habitat for fish. It also likely means water temperatures will get warmer, negatively impacting colder-water species, like salmon and trout, which struggle with warmer temperatures.

For many, a primary and immediate concern of shrinking glaciers is fish.
How Accurate is LiDAR?

“We now have the capacity to monitor a broader range of glaciers and their mass balance more accurately.”

Ben Pelto, Glaciology PhD student at University of Northern British Columbia.

The researchers’ objective was to compare field versus LiDAR-based methods of measuring glacier change. The results of five years of research suggests the two types of data both produced comparable and reliable measures of glacier change, and thus LiDAR can be used to study larger areas.

“Our work showed that the LiDAR data supported the field work data within an acceptable margin of error, which means we can use the combination of the two data collection methods to more confidently produce estimates over a larger geographical area with more accuracy. If you want the LiDAR to be accurate, you still want to get field data because we need those densities (water quantity) of the materials (the snow). That’s one of the take-home messages of the study,” said Ben Pelto, Glaciology PhD student at University of Northern British Columbia. “In a region as vast the Columbia River Basin, both field and airborne methods are required to answer questions of snow and ice melt and gain.”

Automated Monitoring Stations

Automated climate and surface water monitoring stations were installed in and near the research catchments. These stations measure variables such as air temperature, relative humidity, precipitation, snow depth, snow water equivalent, wind speed and direction, water level and flow and water temperature. Some of the stations report data in real-time via satellite link.

RESEARCH METHODS

Field Work

The primary method for data collection was field work on six study site glaciers, over the period of five years. Researchers visited the sites twice a year. In spring, the task was to measure the snow accumulated over the winter, including its depth and density. The researchers returned in the early autumn to measure how much mass was lost during summer using long poles drilled into glacier ice to measure ice melt and by recording the depth and density of snow that remained on the glaciers above the snow line. Their objective was to find out how much the snow and ice melted and how much run-off was being produced below. Researchers also measured the thickness of the glaciers using a radar imaging system.

LiDAR

LiDAR, short for light detection and ranging, is a quick and reliable method to measure elevation change of glaciers. LiDAR imagery was captured from an airplane and measured the elevation of the glaciers and how they changed over time. Elevation change during winter is interpreted as snow depth, or between subsequent end-of-summer surveys, as snow and ice melt, as seen on page 3.

It’s challenging and expensive to visit many glaciers, especially large ones. LiDAR allows one to sample many glaciers for a given area. Using LiDAR, researchers surveyed about 100 km² of glacier, over three times more area than covered by field surveys. While LiDAR has greater coverage, fieldwork is required to validate the LiDAR analyses, and provide data such as the density of snow that cannot be captured using remote sensing methods.
Glaciers in the Canadian Columbia Basin are receding. However, until recently, the characteristics of glaciers were not known. Accurate data on how much snow and ice is being lost and why, and what that meant to the tributary river systems, was simply not available. There have been estimates, which are used by some organizations in the absence of studies such as this one, but they are based on assumptions driven by data collected outside of the Basin.

Researchers have now compiled and documented five years of mass balance data, which includes, for the first time, snow data on a larger scale from the portion of the Basin above the tree line. It’s important to note this information becomes increasingly more valuable over time, as more is learned, studied and documented.

“Our work aimed to establish current rates of glacier mass change, and how glaciers contribute to glacier runoff. By studying our local glacier response to climate change, this work provides the first large-scale estimates of glacier mass change in the Basin.”

Brian Menounos, Professor, Geography, at University of Northern British Columbia and Canada Research Chair in Glacier Change.
ACKNOWLEDGEMENTS

The work summarized here is based on a technical report authored by Brian Menounos, Ben Pelto, Frank Weber, R.D. (Dan) Moore, Dave Hutchinson, Janice Brahney and Sean W. Fleming. It originated from research completed under the Western Canadian Cryospheric Network (WC2N), a research network that operated between 2005-2012. A central objective of WC2N was to project the fate of alpine glaciers in western Canada. In 2010 several researchers of that network (Menounos, Clarke and Moore) presented some of their initial findings to people living in the Columbia Basin in Golden, British Columbia. What became clear was that people in the Basin wished to know much more about glaciers and their fate in the Basin.

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DEFINITIONS

Cryosphere
Earth’s frozen water system network. Where water is in its solid form, frozen into snow and ice. The cryosphere plays a fundamental role in Earth’s climate system.

Glacier Mass Balance (Mass Balance)
The sum of snow gain during winter, and snow and ice loss during summer. Long term changes in glacier mass balance lead to changes in the geometry of a glacier, namely changes in its thickness, surface area and volume – thus the size of the glacier.

Columbia River Basin
The Columbia River Basin is the sixth largest river basin by area in North America. It covers 668,000 km² and covers area in seven states (Washington, Oregon, Idaho and Montana as well as small parts of Wyoming, Utah and Nevada) and one province (British Columbia).

The Canadian Columbia Basin (the Basin)
Located in the southeast of British Columbia and incorporates the headwaters and upper portions of the Columbia River watershed. Its geographical area consists of approximately 100,000 km², approximately 30 communities, several First Nations traditional territories, and many small settlements. The Canadian portion of the Columbia Basin represents 15 per cent of the watershed’s total area, yet provides around 30-40 per cent of total runoff, largely due to the presence of mountainous terrain that hosts alpine glaciers, relatively high precipitation and a deep, seasonal snowpack.

The Study Area
The six glaciers chosen situated within the Canadian Columbia Basin: Zillmer, Nordic, Illecillewaet, Haig, Conrad and Kokanee.

LiDAR
Stands for light detection and ranging. LiDAR is a remote sensing technology which uses laser light to measure distances between objects. LiDAR can be used to create 3D models and maps of objects and environments, including changing glaciers.