Hakai

Cryosphere Report

July - December 2018

Recent Key Findings:

- *Snowline elevation exhibits tremendous variability during autumn and early winter on Klinaklini Glacier and other icefields*
- *Glacier mass loss in 2015 continues to be unprecedented based on annual LiDAR surveys*
- *Fivefold increase in glacier mass loss in southern Coast Mountains over the last 10 years compared to prior decade*
- *Demonstrated UAV capabilities for snow surveys at temporal scales not possible from traditional platforms*

Scientific Context and Goals

Water. It gives life, transports nutrients, and can be harnessed to generate power for communities both large and small. Yet for all we rely on water in British Columbia (BC), we know very little about how much of it flows through the ecosystem in a given year and even less about how that is changing with our evolving climate. This is especially true in remote areas of the Central and South Coast of BC.

On the rugged coast of BC, water begins its terrestrial journey as either rain or snow, depending on the season and elevation. While streamflow measurements are able quantify the liquid portion, quantifying the amount of water locked in snow or ice is more challenging. Since snow and ice provide a crucial reservoir that is released throughout the spring and summer, and we know that the climate of BC's southern and central coast is particularly sensitive to changes in temperature, it is vital for us to understand what this reservoir has contributed in the past, does contribute currently, and will contribute in future climate scenarios.

Recent studies have shown that ice is being lost at an alarming rate in western Canada and United States, but those studies have only sampled one glacier on our coast, a region rich with glaciers that contains half of all the ice cover in western Canada/US (outside of Alaska) and known to be dynamic. Our work fills these gaps by taking a closer look at these understudied areas not only to determine how much snow and ice is present

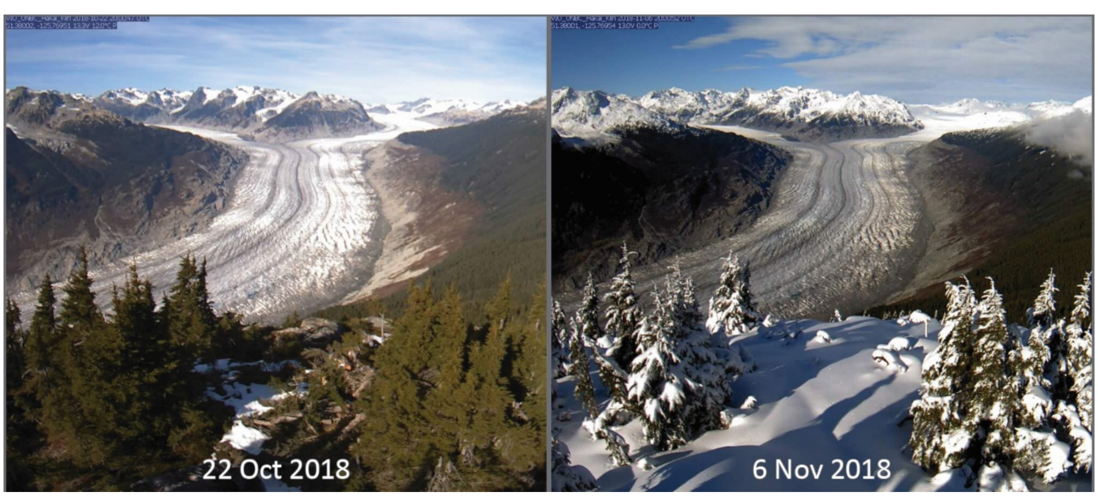

Figure 1: Variability in the snowline at Klinaklini Glacier is evident from our new weather station during fall.

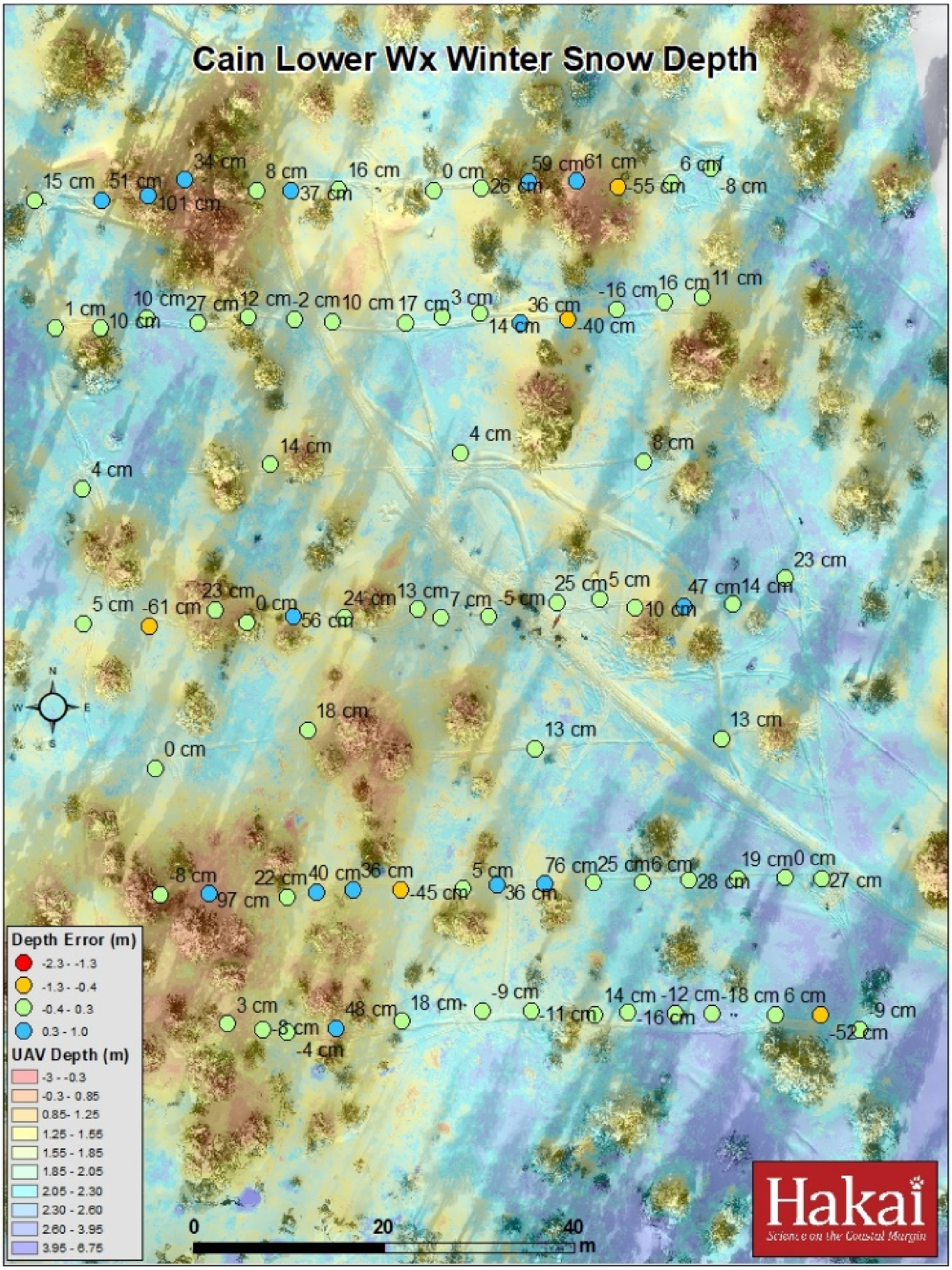

Figure 2: Sample of snow depth estimates from unmanned aerial vehicle (UAV) and probe measurements from Mt. Cain. Errors in UAV estimates are noted and color coded with a root mean square error of 30.7cm. Note that error is high where trees exist. (W. McInnes)

today, but also to determine how much ice used to be in these valleys.

Key to this work is determining the amount of water locked into the ice reservoir. This non-trivial task has traditionally relied on satellite or plane based observations that are both costly and limited to relatively large scale questions. New methods allow us to utilize records of aerial photos that go back to the 1940s, providing a vital historical perspective. We are excited to also have the opportunity to couple traditional methods with the capabilities of the Hakai Geospatial team to ask finer scale questions, both in time (within season) and space (within watershed), that weren't previously possible.

By applying all of the methods at our disposal, we aim to determine the mass of ice present in the glaciers today, the historic and present rate of ice loss, how much seasonal snow cover exists and its interannual variability, and how all of the melt water from these frozen reservoirs influences the rest of the hydrologic cycle. Along the way, we will examine questions about the rates of fire frequency and pollution deposition in the last thousand years and make an independent assessment of spaceborne estimates of glacier mass loss calculated from NASA's new IceSat-2 mission. In answering these questions we will significantly improve the understanding of the hydrologic cycle on the southern and central coasts of British Columbia.

Recent Progress

To work toward these goals we had a very busy, but successful field season where were able to accomplish all the major tasks that we had planned. This included conducting our regular spring snow surveys, both from the ground and in the air, planning and installing new weather stations, and processing existing imagery in preparation for publication.

In the field, we used both drones and plane based LiDAR for surveys of Mt Cain, Russell Creek, and all glaciers on Vancouver Island, in Garibaldi Provincial Park, and the Klinaklini Glacier. These several thousand square kilometers of surveys provide us with a seasonal-to-annual index of how much water is contained in the seasonal snowpacks and glaciers of the southern Coast Mountains. Our results from these surveys show that the ice loss observed in 2015 is still unmatched.

The drone surveys were particularly interesting since we had not used that technology prior to our Tula Foundation support. We were able to complete three sets of drone surveys in four different locations around Mt Cain this season. By coupling those data with hundreds of manual snow cores for validation purposes, we were able to generate three dimensional renderings of the snowpack for the first time in our careers. It was truly amazing to see this capability come to life and imagine what it might bring in the future. This work was captured in a short (4 min) video produced by Hakai Media that has had over 1000 minutes of viewing in the first week since it was released.

In planning for the future, we spent much of our summer planning for the instrumentation at the Klinaklini and Homathko watersheds. This involved reconnaissance, choosing and testing the equipment and finally installing the new stations as the weather window closed in early fall. While this was one of the most challenging set of logistics in our professional career, the weather cooperated with dates set two months in advance and hourly observations will soon be streaming live online. Already we have noticed the tremendous variability in the snowline elevation at the Klinaklini Glacier since installation which is promising for insights yet to come.

Through this process we learned to increase our lead time even further since delays with the supplier limited some of the testing we had planned prior to deployment. However, it all worked out and we were even able to upgrade the Klinaklini station to a full weather station with some equipment we had on hand for another project (which will be replaced with next year's funds).

Work on campus made leaps forward as well. After renovating the space, we are proud to have opened the Hakai Cryosphere Node at the University of Northern British Columbia campus in Prince George. In this space we now have precision GNSS survey equipment to geolocate the new drones as part of our expanding unmanned aerial vehicle capabilities. The high performance computing equipment necessary to process the survey work that is planned for the coming years was also purchased and brought online. Much of this work will be done by two new postdocs who are still being identified through ongoing interviews.

On top of all this, over 30,000 satellite images have been processed to produce the first inventory of glacial mass change for Western North America since the turn of the century. This work showed that 117 gigatons of water has been lost from these glaciers each year, which over that period has increased global sea level by 0.32 mm. The paper has gotten wide media attention since it was released in mid-January 2019.

Looking Ahead

Currently, we're busy planning for the upcoming field season. This includes purchasing and testing equipment, method development and, of course, implementation at the beginning of the field season. We plan to purchase another set of drones and snow survey equipment that will enable us to be more efficient in the field and reduce the number of ground control points required. Before being trained on this new equipment, our new

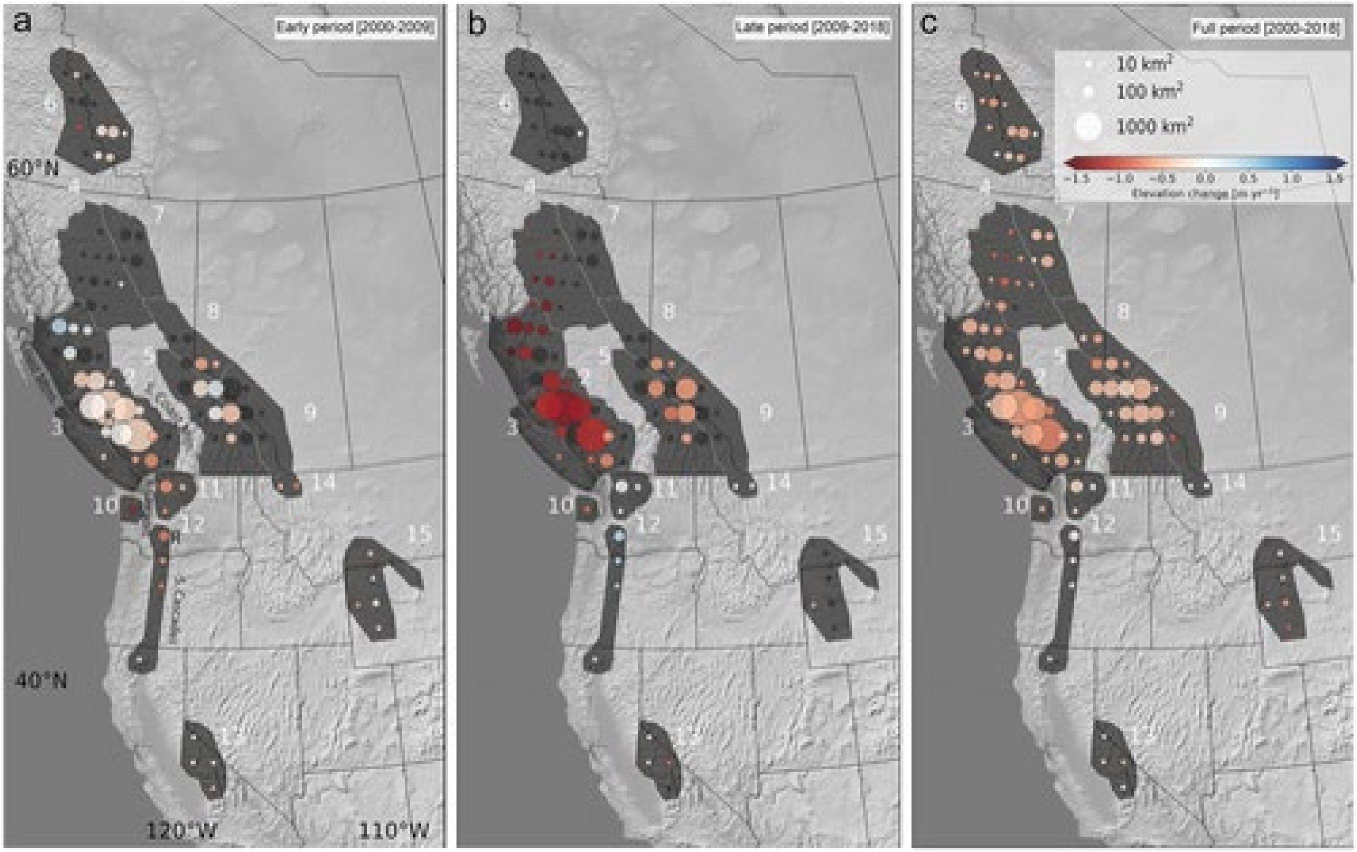

Figure 3: Gridded (1 × 1°) glacier elevation change (m yr⁻¹) for western North America. Circle diameters are scaled to area represented by grid point. Grid points with less than 30% of sampled ice are shown as dark gray. (a) early period (2000–2009), (b) late (2009–2018), (c) full (2000–2018). Numbers refer to subregions and letters "K" (region 03) and "R" (region 12) respectively denote approximate location of Klinaklini Glacier and Mount Rainier. (Menounos et al. 2018)

students and postdocs will work with data from 2018 to begin developing the methods necessary to estimate snow density at survey locations. Our new students will be able to get their feet in the snow through early season visits to the high elevation weather station network and the Russell Creek Experimental Watershed. Also, we are excited to utilize the new airborne coastal observatory early this coming season to quantify changes to the cryosphere of the southern coast as a bridge between the drone and spaceborne observations. The coming season looks to be our most productive season yet and we're excited for the new insights that are sure to come.

Collaborations and Summary

Our work has leveraged support from many sources to make such an intensive field program possible. The Comox Valley Regional District has contributed over $150,000 this past year to fund a weather station and LiDAR surveys on Vancouver Island. We are currently discussing similar collaborations with both the Nanaimo and Capital regional districts to see if they would contribute to funding work in their watersheds for similar research to that done in the Comox Valley.

While our three current graduate students are being supported through NSERC and Canada Research Chair funds, we have also successfully gotten preliminary approval for $45,000 annually to support students over the next five years to work on Provincial priorities closely tied to the ongoing work. These students are expected to begin in Fall 2019.

In kind support from both the Provincial Government and Vancouver Island University for B. Floyd continues to be important providing him with space, salary, and equipment that help make our research possible. Support from Environment and Climate Change Canada Network of Networks is facilitating the integration of these data into the High Elevation Weather Station Network, a province-wide system managed by B. Floyd and supported by both Vancouver Island University and the Provincial Government.

All of this work is documenting the dramatic changes that have occurred in our coastal mountains and will continue to occur for years to come. Through our development of an accurate universal water inventory of the coast today, we enable preparing for an inconsistent future.

Publications (n = 1)

(Hakai researchers in bold)

Menounos, B., Hugonnet, R., Shean, E., Gardner, A., Howat, I., Berthier, E., Pelto, B., Tennant, C., Shea, J., Noh, M., Brun, F., Dehecq, A. (2018). Heterogeneous changes in western North American glaciers linked to decadal variability in zonal wind strength. *Geophysical Research Letters,* 45. https://doi: 10.1029/2018GL080942

Conferences and Presentations (n = 2)

Floyd, WC and **Menounos, B**. The Cryosphere Project. *Comox Valley Watershed Advisory Group Semi Annual Meeting*, Comox BC, Nov 26, 2018.

Menounos, B., Murherjee, K., Shea, J. and Pomeroy, J. Airborne measurement of seasonal snow in western Canada. G*lobal Water Futures Annual Meeting*, Hamilton, ON, 3-6 June, 2018.

External Media Coverage (n = 12)

Interviews with B. Menounos, B. Floyd, and E. Peterson were given on three radio stations and in print to the Prince George Citizen following the opening of the UNBC node.

Coverage of the glacial ice melt paper through The Guardian, Vancouver Sun, Gizmodo, Scientific American, and other outlets.