A Catchment in Transition: Observing Post-Retreat Land-Cover Evolution and its Hydrological Consequences at Bridge Glacier, Canada

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INTRODUCTION

Background and objective

As glaciers shrink, most modelling studies replace glacier cover with open or alpine land-cover following retreat and have not accounted for vegetation or soil development on deglaciated areas or formation of proglacial lakes.

This study combines field observations and remotely sensed data to document glacial retreat and the ongoing evolution of deglaciated forelands and valley walls with a focus to answer the following objectives:

1. **What is the rate of landcover change within the basin?**
2. **What are the primary controls on vegetation development?**
3. **How much are lake surface and river outlet temperatures increasing?**

Field site and data sets

The study focuses on Bridge Glacier, a 75 km^2 valley glacier in the southern Coast Mountains of British Columbia. The catchment at the water survey gauge spans 140 km^2.

Glacier extents

- Landsat imagery in Google Earth Engine (GEE) for 1972, 1980, and annually 1984-2020.
- Airphotos from 1947 and 1964 (georeferenced).
- Lichenometry dates from Allen and Smith (2007) combined with moraines from 1-m resolution LiDAR (Light detection and ranging) hillshades for 1915 and ca. 1850.

Normalized difference vegetation index (NDVI) and surface temperature

- Landsat 5, 7 and 8 after Ermida et al. (2020) GEE algorithms
- Water Survey Canada (WSC) measurements

Topography

- LiDAR DEMs, 2017, 2018

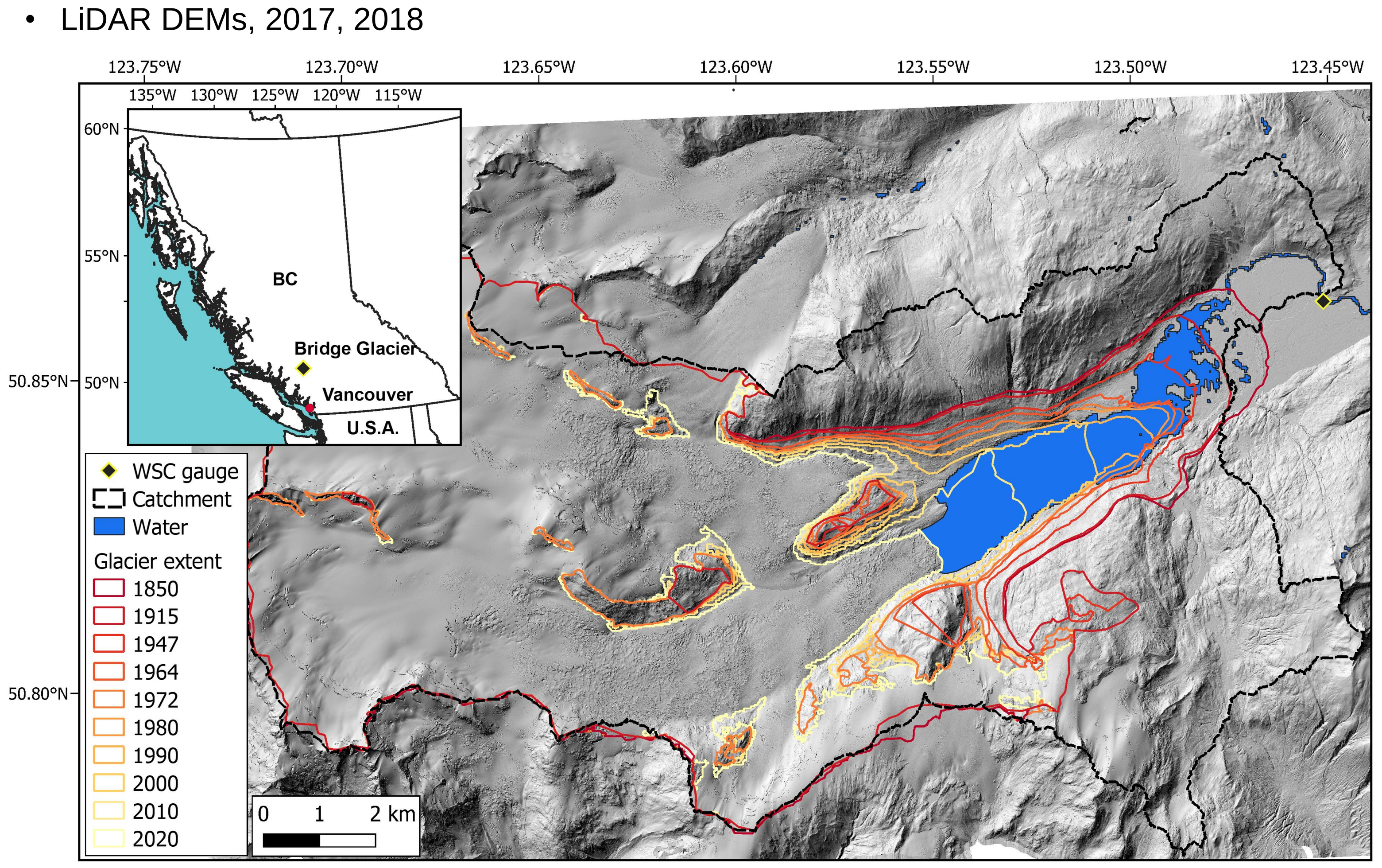


Figure 1 Bridge catchment at the Water Survey of Canada (WSC) gauge with glacier extents. Imagery is a LiDAR hillshade from September 2018.

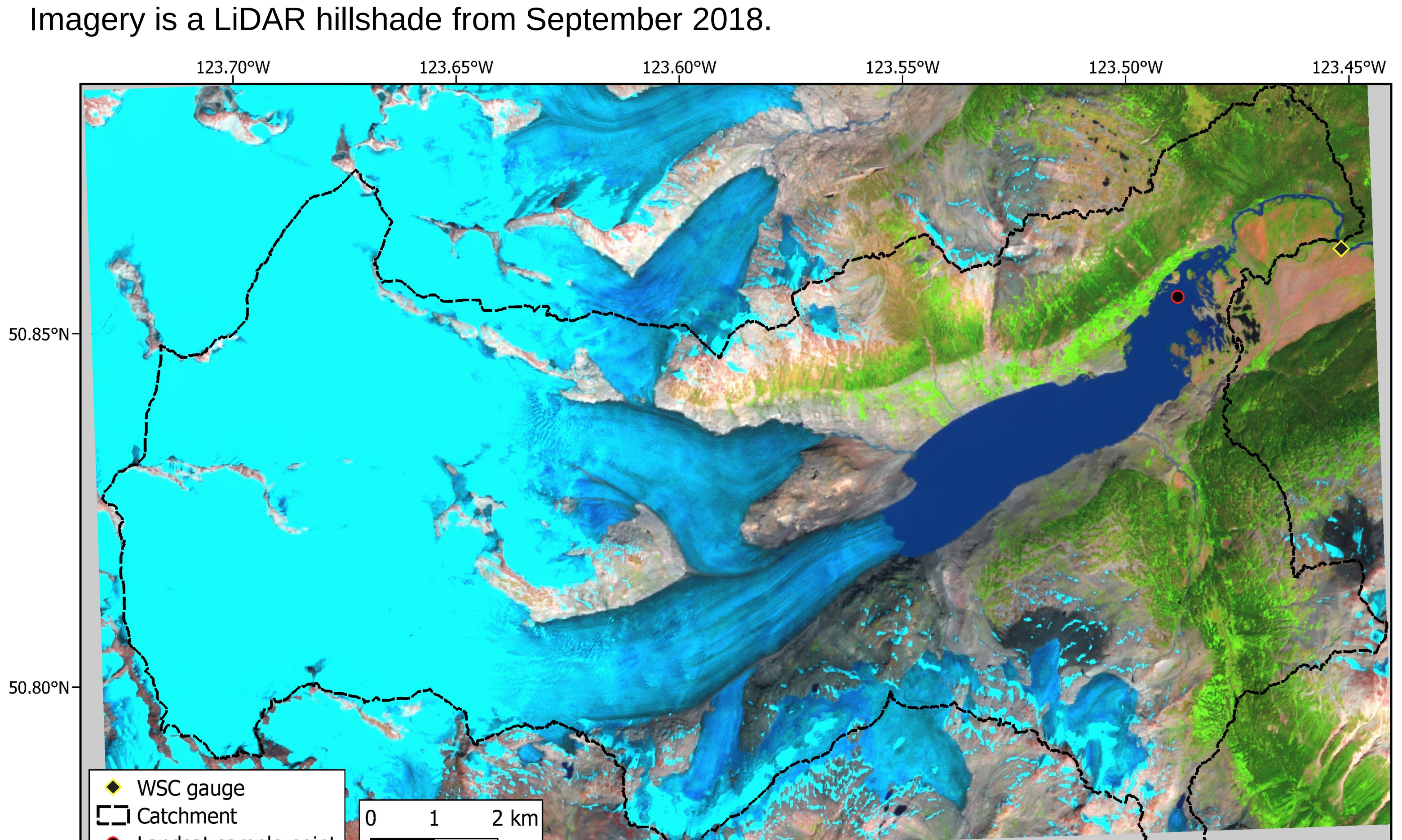
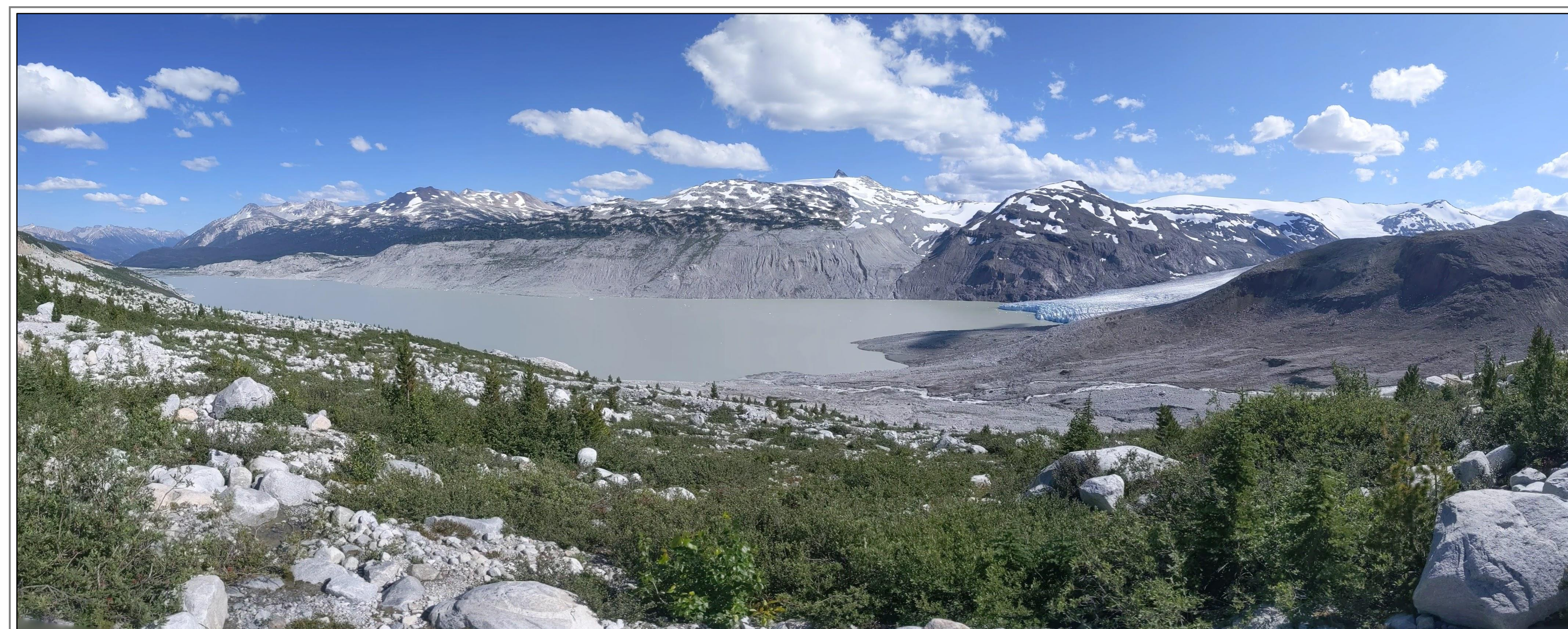


Figure 2 Bridge catchment with Sentinel 2 imagery from September 2021.

RESULTS



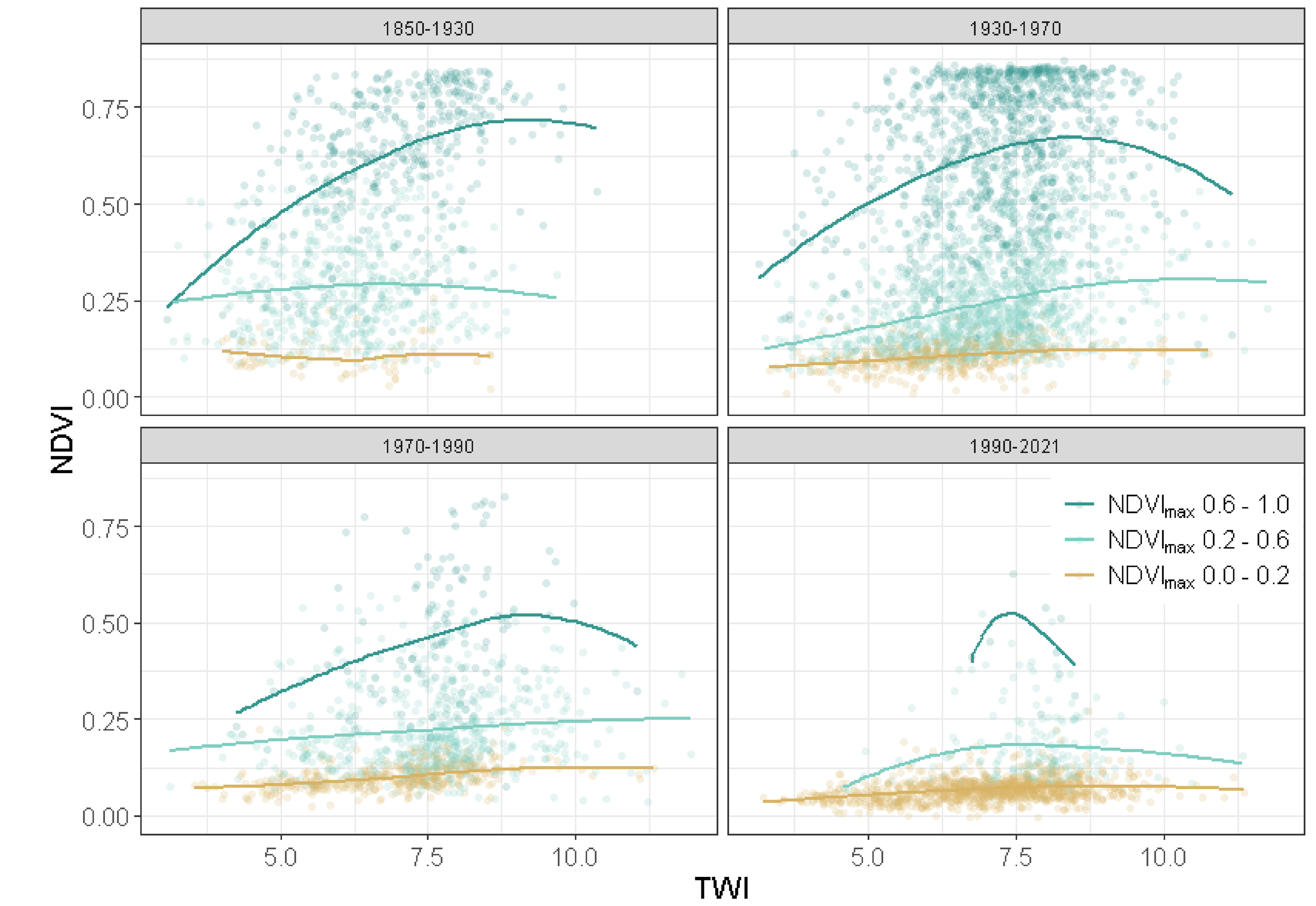


Figure 6 Topographic wetness index (TWI) versus NDVI shaded by $NDVI_{max}$ of the surrounding grid cells. Curves are a loess fit.

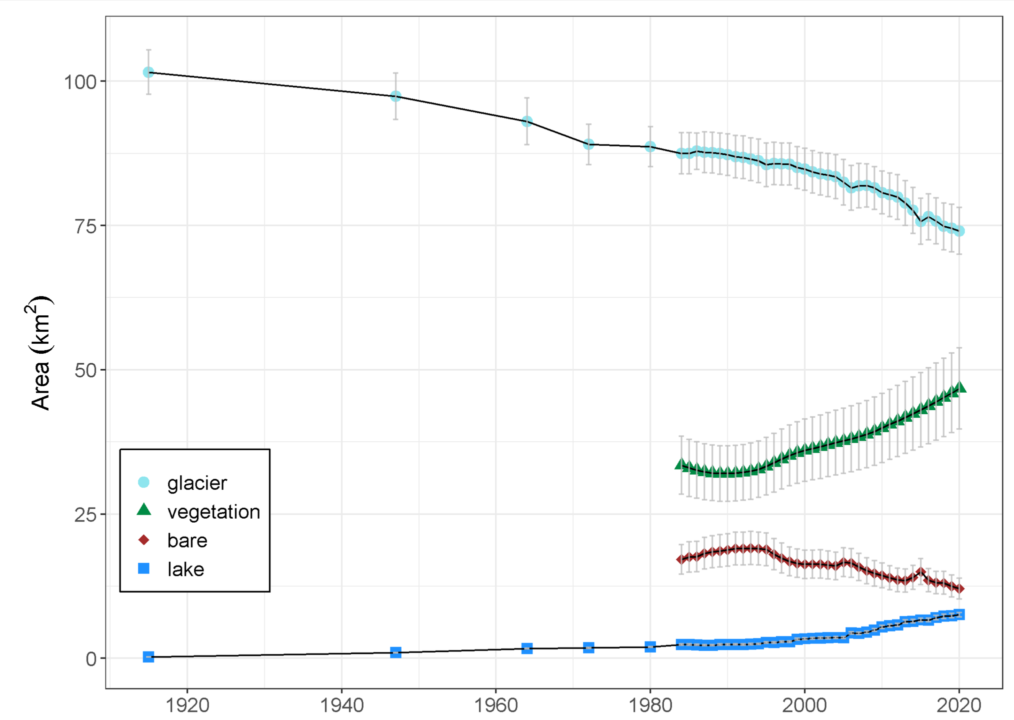


Figure 3 Landcover change from 1915 to 2020. Vegetation area is classified as pixels where NDVI > 0.2.

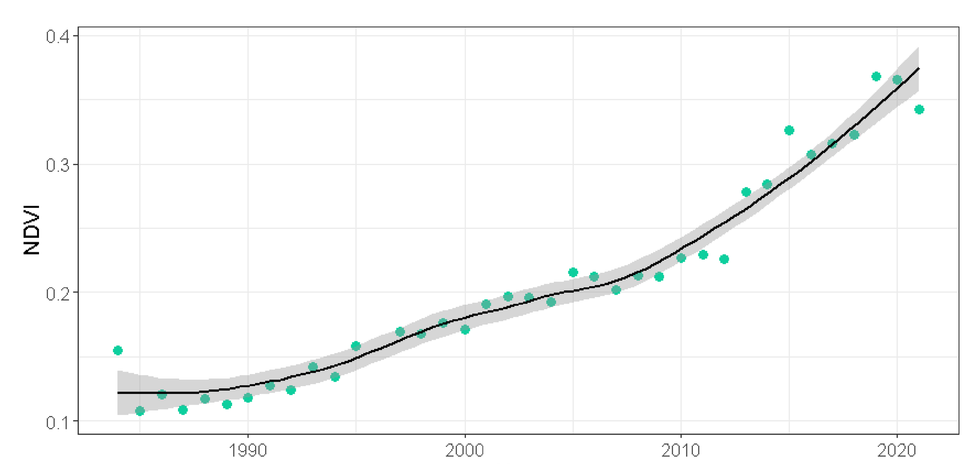


Figure 4 NDVI trend from Landsat 5, 7 and 8 for the slope north of the lake as depicted in Figure 5.

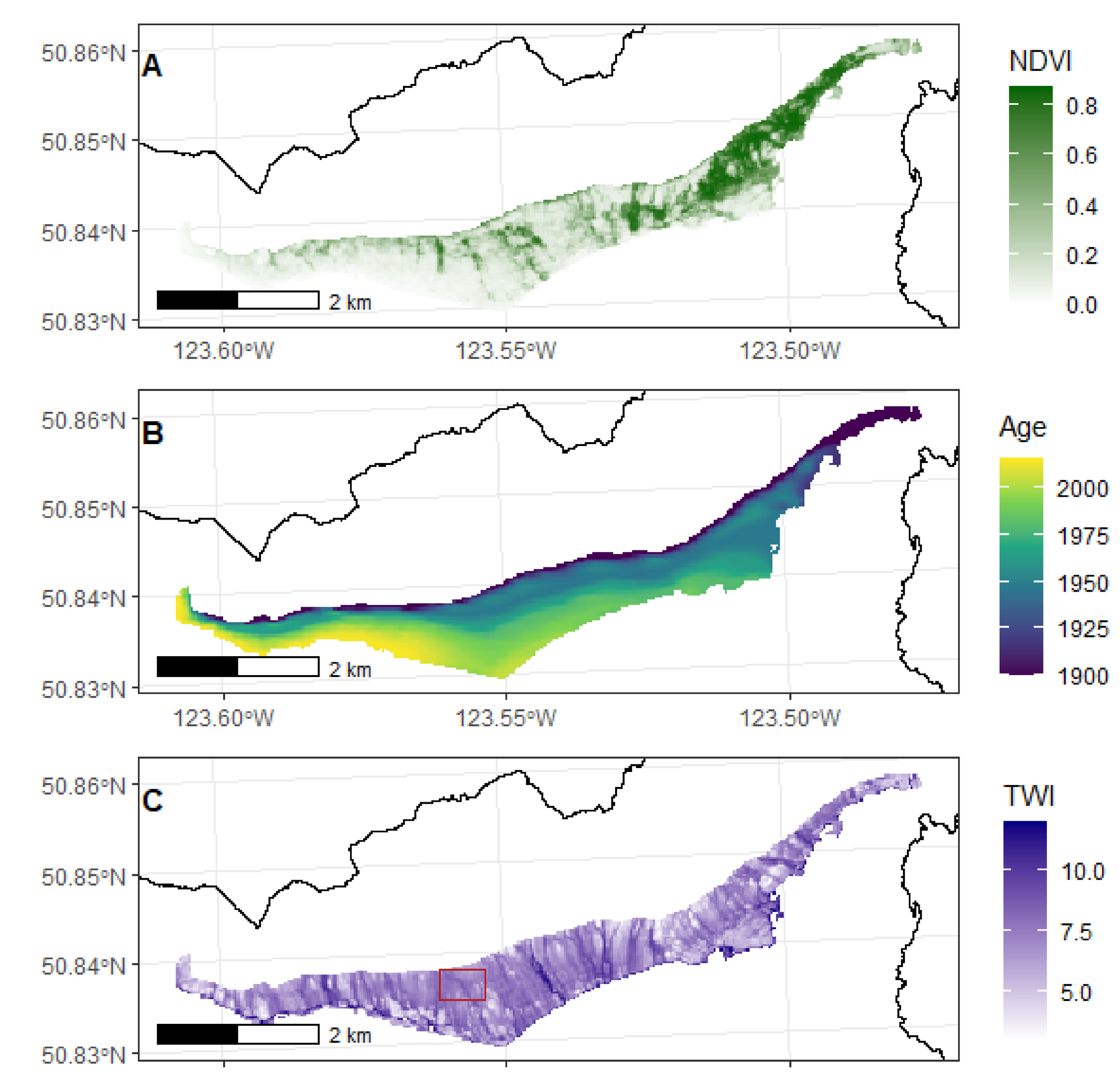


Figure 5 NDVI from Landsat 8, 2018 (A), exposure year (B), and topographic wetness index (TWI) from a 2018 LiDAR DEM (C). Red box marks the area of Figure 7.

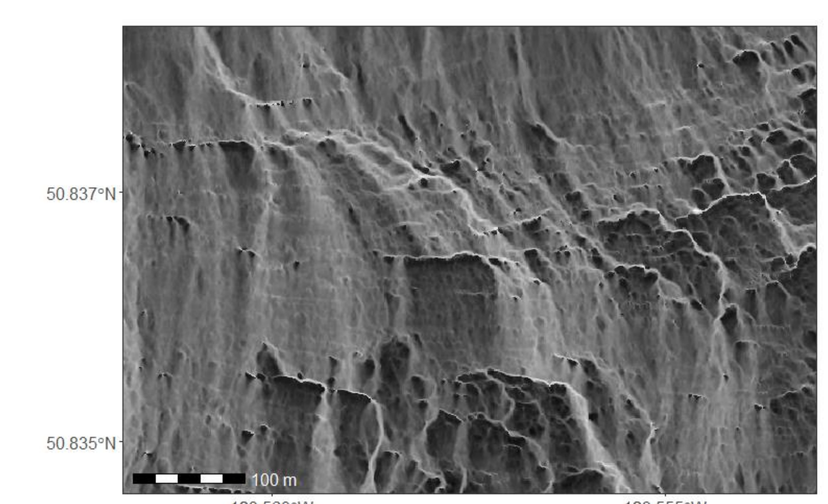


Figure 7 TWI from a 1 m resolution LiDAR DEM for the area of the red box in Figure 5C. Lateral moraines cause blocking and concentration of surface flow.

Water Surface Temperature

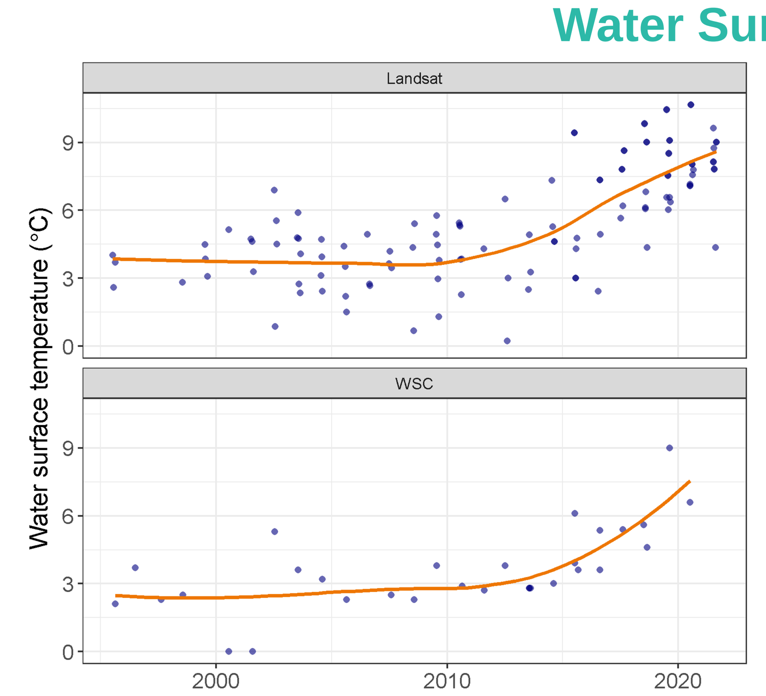


Figure 8 Water surface temperature from Landsat 5, 7 and 8 after Ermida et al. (2020) at the sample point (Figure 2), and stream temperature from WSC field spot measurements at the gauge (Figure 2).

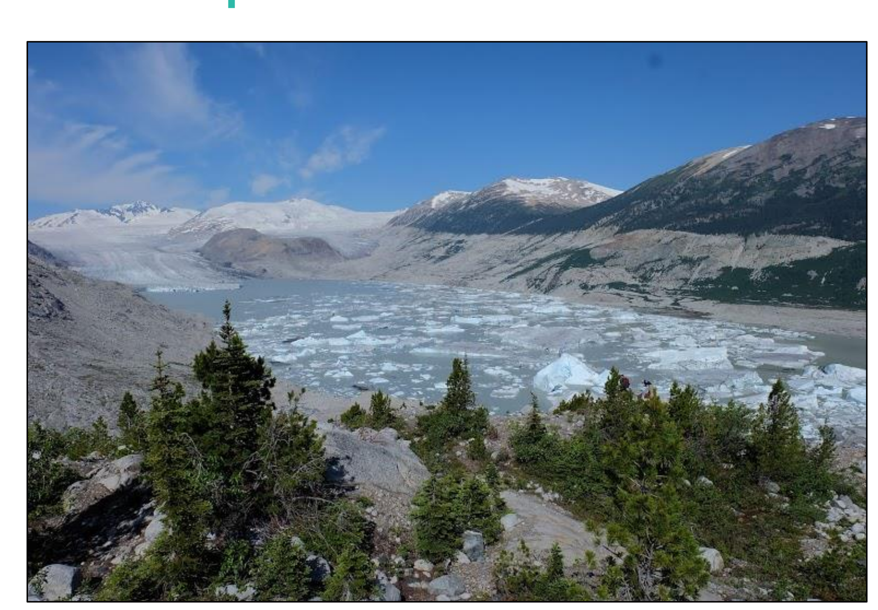


Photo: Bridge Lake in 2014. Fractional iceberg coverage was 0.30 to 0.45, and now is near 0.0.

Take home points

- Bridge catchment is rapidly transitioning from a predominantly glacierized catchment to a catchment with a more even mix of vegetation and glacier cover.
- Bridge Lake has expanded from 1.95 km^2 in 1980 to 7.6 km^2 in 2020.
- Lake outlet surface temperatures are warming, reaching over 10°C in July 2019 and 2020.
- Vegetation development is controlled by exposure year, TWI and proximity to established vegetation.

Ongoing work is focused on using these data to inform a model to simulate the hydrologic response of the Bridge catchment to continued glacier retreat and vegetation development.

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