When a River Disappears: Analyzing the Effects of Stream Capture in the Yukon Territory, Canada

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Abstract

In May 2016, the Slims River in the Yukon Territory was captured by the Kaskawulsh River due to the retreat of the Kaskawulsh Glacier. This study aimed to continue the preliminary work of Shugar et al. (2017) by monitoring the effects of the stream capture for the years since 2016. River and lake gauge data for the Alsek River (downstream of the Kaskawulsh River) and Kluane Lake were studied to quantify any differences in water flow and level due to the stream capture. The average volume of water post-capture flowing into the Alsek River has increased by ~18% from the pre-capture average. Before the capture, the water level of Kluane Lake would increase by ~2m every summer. Since the capture, the water level in Kluane Lake has only reached a maximum summer increase of ~0.5m. Change in drainage area for both rivers was analyzed to determine how significant the stream capture was for downstream locations. The percent change in drainage area on the Slims River falls to 10% ~221km downstream of the point of capture, while the increase in drainage area on the Kaskawulsh River falls to 10% at ~144km downstream. Mid- and high-resolution (Landsat, PlanetLabs) satellite imagery for the years 2015, 2016, 2017, and 2018 were compared and analyzed using the Image Classification and hydrology tools in ArcGIS. Image classification results show that the wetted area in the Slims River channel has been reduced by 61.2% and the wetted area in the Kaskawulsh River channel has increased by 431% since the capture. Continued observation of this stream capture event is important to fully understand the implications of changing hydrologic systems as a result of climate change.

Background

Stream Capture Event:

- May 2016 – headwaters of the Slims River were captured due to the retreat of Kaskawulsh Glacier
- Meltwater carved an ice-canyon that redirected water south into the Kaskawulsh River
- Reduced the distance glacial melt traveled to the ocean from ~2000 miles to ~180 miles
- Slims River was the most significant supply of water to Kluane Lake, the largest lake in the Yukon Territory
- Precipitation data do not strongly correlate with the water level in Kluane or the discharge of the Alsek River

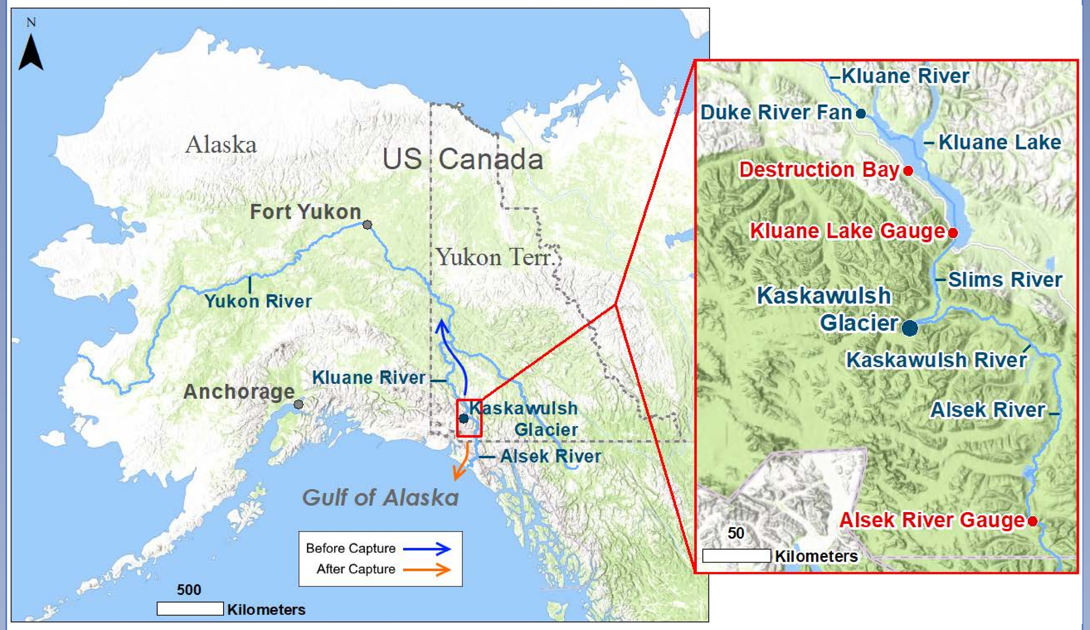


Figure 1. Map of the study area. Before the capture, most of the water from Kaskawulsh Glacier flowed north through Kluane River into the Yukon River. Now, the water flows south through the Alsek River and into the Gulf of Alaska

Previous Work:

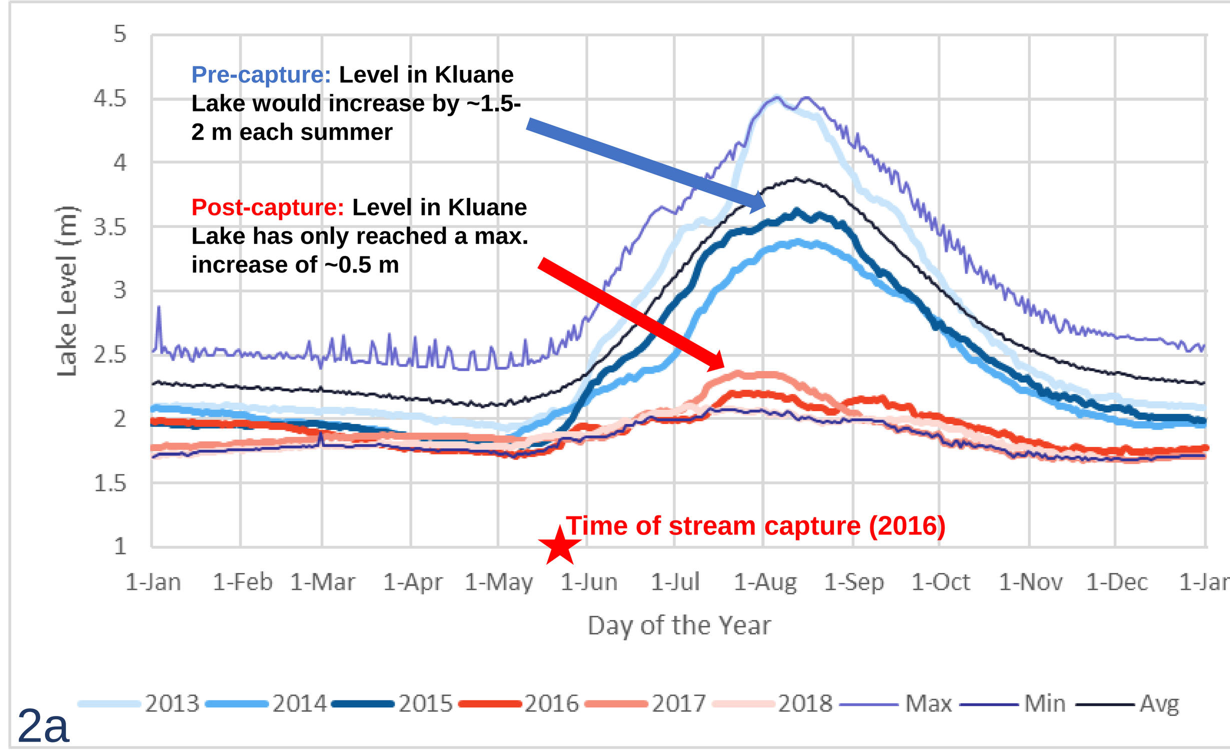
- Shugar et al. (2017) published a report detailing the immediate effects of the stream capture
- Kluane Lake reached record low levels, Kaskawulsh River was rapidly growing, and discharge of the Alsek River neared record-high values
- Massive dust storms from abandoned flood plain, decrease in sediment transport raises concern for spawning fish
- Temperatures on Kaskawulsh Glacier were 3.6 – 4.3°C warmer than average for the period January – April in 2016, capture would not have occurred under normal climate drivers
- Predicted the Slims River will change from braided river to meandering, Kluane Lake might become a closed basin
- Clague et al. (2006) predicted that the stream capture would happen due to the higher gradient of the Kaskawulsh River, yet they reasoned that it would take hundreds, if not thousands of years to occur

Research Goals

- This study aimed to continue the work of the published report by Shugar et al. (2017) by monitoring the effects of the stream capture for the years following 2016
- **Testable hypotheses**:
  - A continuous lowering of Kluane Lake
  - Decrease in wetted area on Slims River floodplain
  - Increase in wetted area on Kaskawulsh River floodplain
  - Increase in summer discharge on Alsek River

Methods and Results

River and Lake Gauge Data



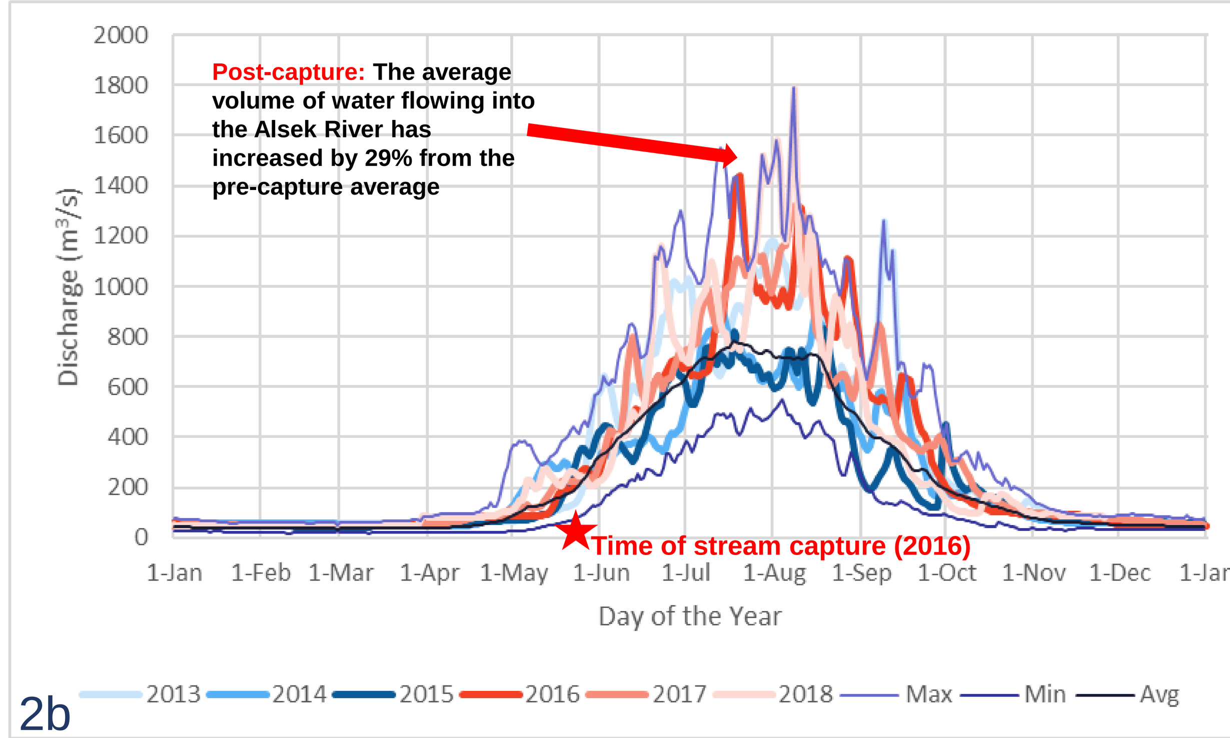


Figure 2a. Lake level in meters of Kluane Lake (N 61.0545 W 138.50586) for the years 2013 through 2018. Water level in Kluane Lake no longer increasing ~1.5-2 m in the summer, instead only rising ~0.5 m.
Figure 2b. Discharge of the Alsek River (N 60.11831 W 137.97775) for the years 2013 through 2018. The amount of water flowing through the Alsek River on average has increased by 29% compared to the average for the years pre-capture. The Alsek River reached a new record-high in 2018. Average line consists of data taken before the capture. Maximum and minimum lines consists of all years of recorded data. Red stars indicate when the stream capture occurred. Gauge data courtesy of Environment Canada.

Image Classification

I quantified different land cover types in PlanetScope (3m) and RapidEye (5m) raster satellite images using the Image Classification tools in ArcGIS. Measurements focused on percent changes of water coverage in the floodplains of the Slims and Kaskawulsh Rivers. This was done for images taken during June and September for the years 2015 and 2018.

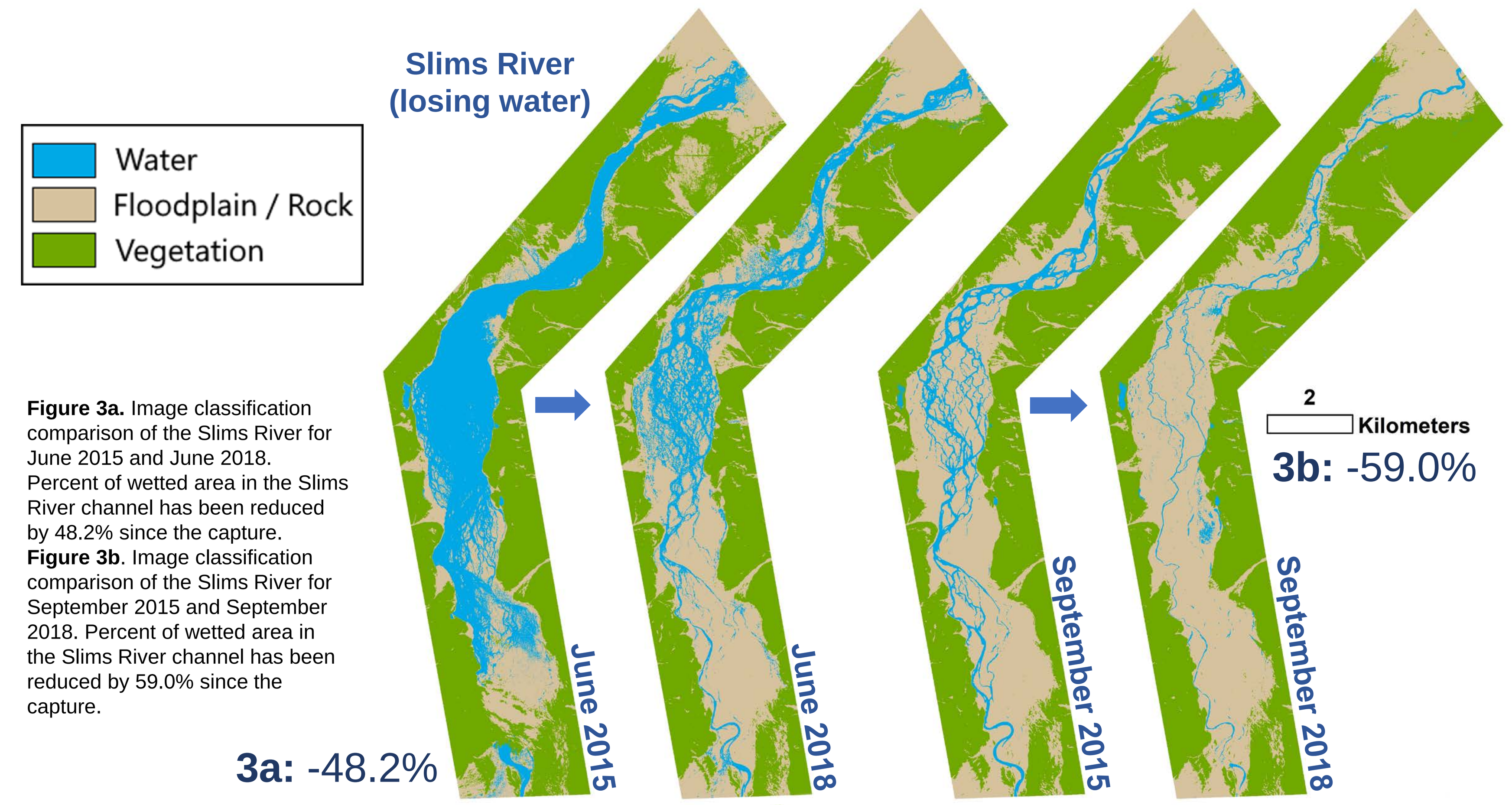


Figure 3a. Image classification comparison of the Slims River for June 2015 and June 2018. Percent of wetted area in the Slims River channel has been reduced by 48.2% since the capture.
Figure 3b. Image classification comparison of the Slims River for September 2015 and September 2018. Percent of wetted area in the Slims River channel has been reduced by 59.0% since the capture.

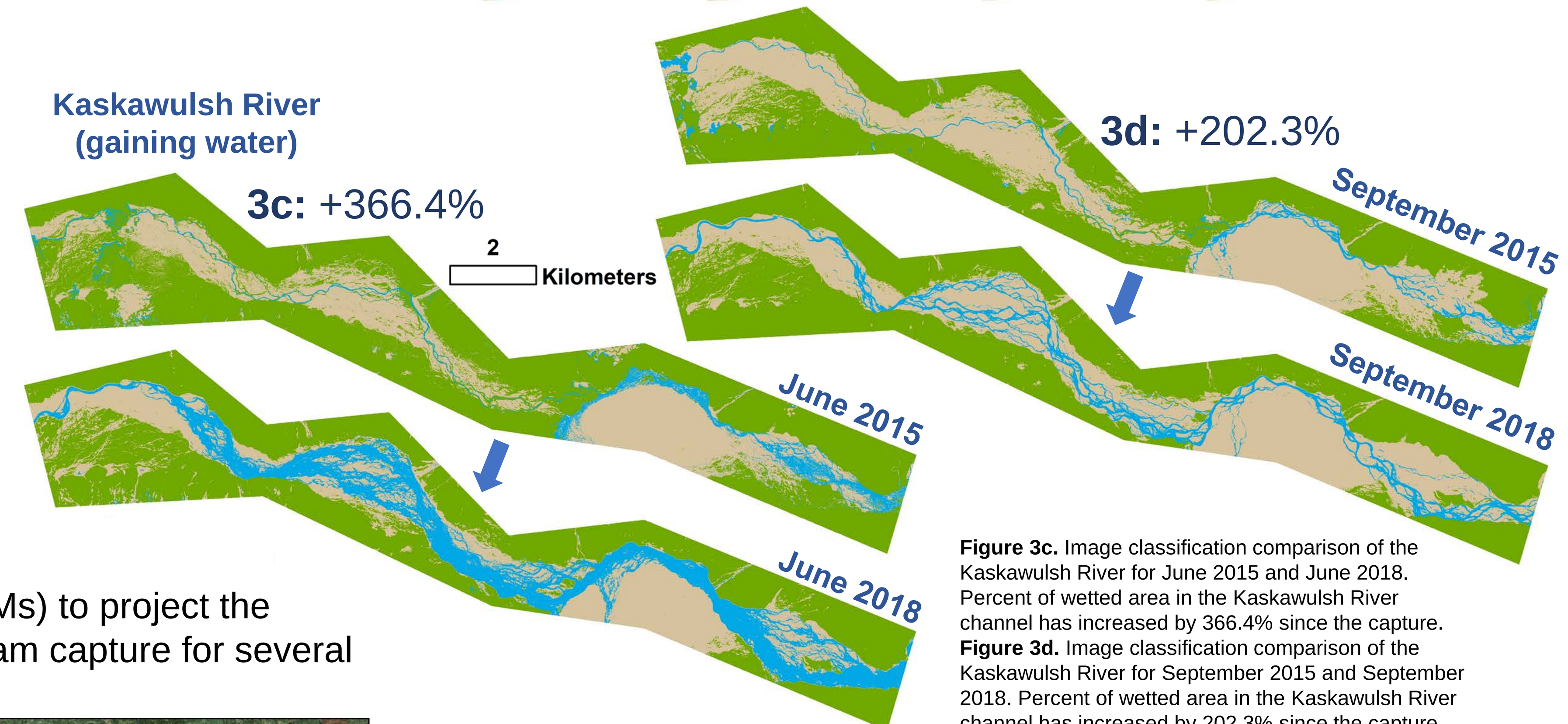


Figure 3c. Image classification comparison of the Kaskawulsh River for June 2015 and June 2018. Percent of wetted area in the Kaskawulsh River channel has increased by 366.4% since the capture.
Figure 3d. Image classification comparison of the Kaskawulsh River for September 2015 and September 2018. Percent of wetted area in the Kaskawulsh River channel has increased by 202.3% since the capture.

Changes in Drainage Area

Hydrology tools in ArcGIS employed Digital Elevation Models (DEMs) to project the possible percent changes in drainage areas as a result of the stream capture for several points along the Slims River and Kaskawulsh River corridors.

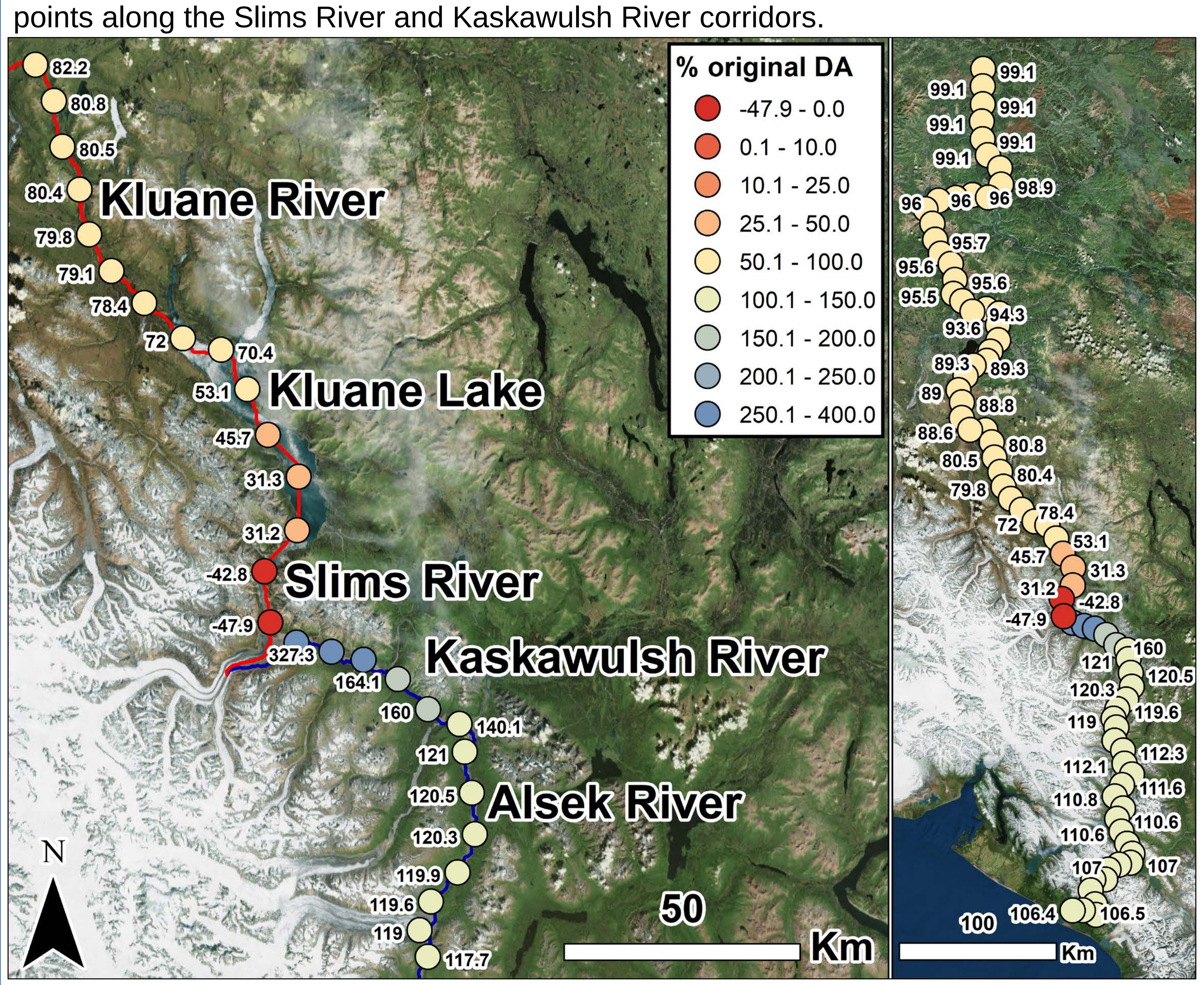


Figure 4. Drainage area analysis for the Slims River corridor through Kluane River and the Kaskawulsh River corridor through Alsek River. Significant changes in drainage area occur ~221km down the Slims River corridor and ~144km down the Kaskawulsh River corridor, however, these are likely underestimates. Numbers next to the points indicate the calculated values in percent for the increase or decrease in drainage area for that point.

Visual Analysis

Changes in land cover between the years 2015, 2016, 2017, and 2018 were qualified through the inspection of Landsat 8 (30 m) satellite imagery with the band combination 6/5/4 due to its utility for land and water observations.

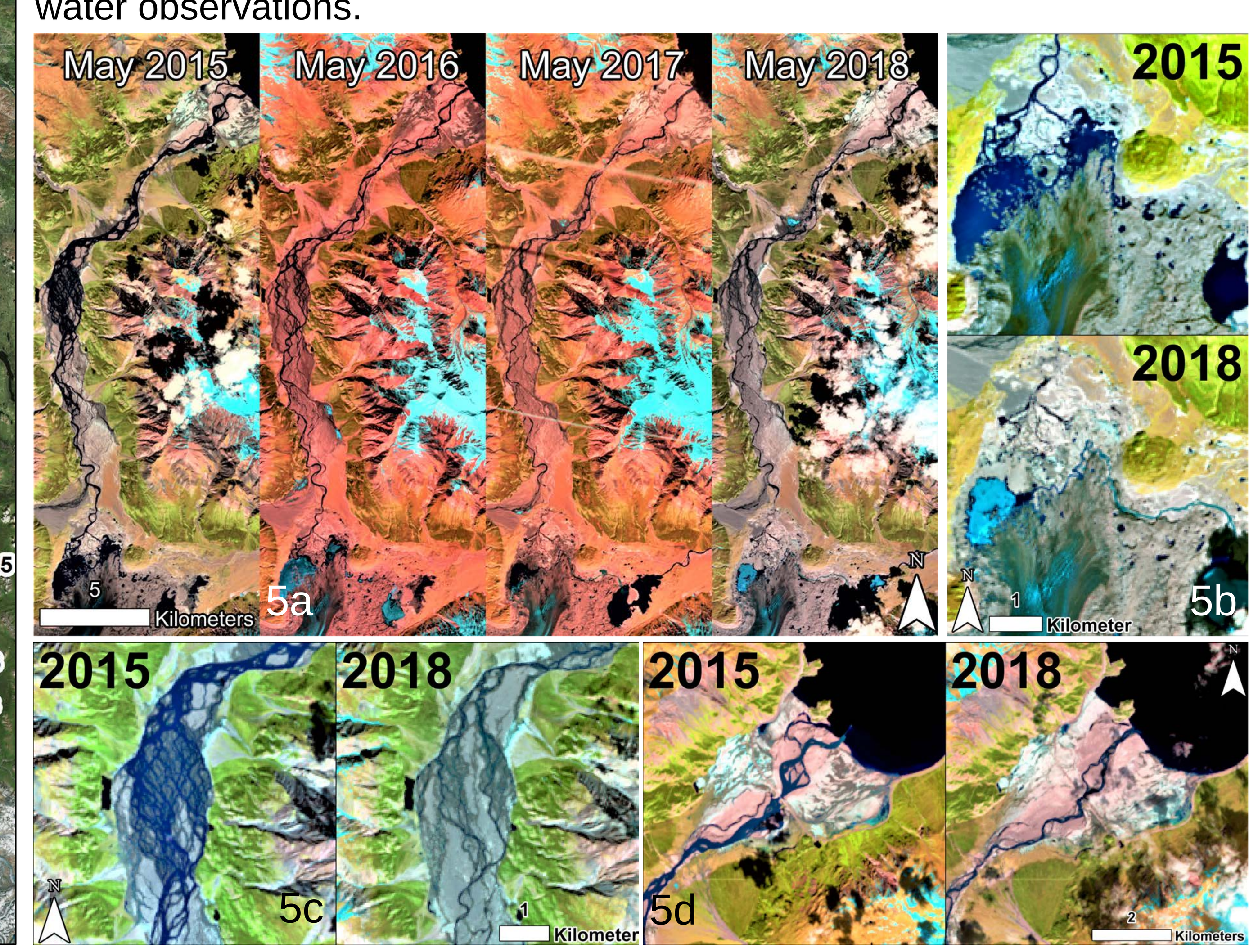


Figure 5a. Landsat 8 satellite imagery of the Slims River the year before, the month of, the year after, and two years after the stream capture (from left to right). **Figure 5b.** Glacier front of the Kaskawulsh Glacier leading into the Slims River. **Figure 5c.** The widest part and main braided segment of the Slims River. **Figure 5d.** The Slims River delta leading into Kluane Lake.

Discussion

Changes Since 2016

- Results show that the effects of the stream capture are permanent and may be strengthening
- News reports of the area indicate that the decrease in water level has become a major concern for residents
- The reduced flow of glacial meltwater into Kluane Lake will likely continue to impact the surrounding communities and businesses
- The amount of wetted area for the months of June and September has decreased for the Slims River, this has resulted in massive sandstorms in the area, affecting air quality and likely the surrounding vegetation and wildlife
- Significant changes in drainage area (decrease or increase to 10% of original) occur ~221 km down the Slims River corridor and ~144 km down the Kaskawulsh River corridor

Uncertainties

- Changes in drainage area are likely underestimates as they are only changes in area, not volume, and are based off of assumptions that everywhere contributes the same amount of water
- Image classification technique is not exact in determining water versus other elements
- Lack of consistently available and cloud-free high-resolution satellite imagery made making accurate comparisons difficult

Future Work

This stream capture was a recent event and research needs to continue to monitor its effects so that local governments can react accordingly. Glacial fronts are highly dynamic areas, and more cases of stream capture are likely to occur as climate change exacerbates. This is important as the world's hydrological systems are altered by climate change and the demand for available freshwater increases.

Conclusions

- Gauge data show that there is a continuous lowering of Kluane Lake and an increase in river discharge for the Alsek River, even beyond historical record-highs
- Image classification results show that the wetted area for June and September in the Slims River floodplain has decrease by 48.2% and 59.0%, respectively, and the wetted area for June and September in the Kaskawulsh River floodplain has increased by 366.4% and 202.3%, respectively
- The reduction in the drainage area for the Slims River corridor and increase in drainage area for the Kaskawulsh River corridor may not extend as far downstream as hypothesized

References and Acknowledgements

Clague, J.J., Luckman, B.H., Van Dorp, R.D., Gilbert, R., Froese, D., Jensen, B.J., and Reyes, A.V., 2006, Rapid changes in the level of Kluane Lake in Yukon Territory over the last millennium: Quaternary Research, v. 66, no. 2, p. 342-355.

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