Identifying relations among active layer properties and land cover types in Old Crow Flats, Yukon, Canada

W. Brent Thorne[1] and Kevin W. Turner[2]

[1]Department of Earth Science, Brock University, St. Catharines, Ontario, Canada; [2]Department of Geography and Tourism, Brock University, St. Catharines, Ontario, Canada

Introduction

Modifications to permafrost, terrain and ecological conditions that are anticipated in response to climate warming suggest that importance of catchment processes on the chemistry and biology of Arctic lakes will intensify[2]. Active layer thickness (ALT) is a critical parameter for monitoring the status of permafrost and can be influenced by (1) climatological parameters, (2) land-surface properties, (3) vegetation cover, and (4) the physical, hydrological, and thermal properties of the surface cover and subsurface[1,3-5]. Further investigation into relationships between ALT and landcover characteristics is needed to develop better understanding of the significance that ALT plays in hydroecological systems in Arctic permafrost landscapes. Old Crow Flats (OCF) is a lake-rich permafrost landscape that covers an area of 5600-km2 (Figure 1a). Located ~25 km north of Old Crow, Yukon, OCF has a basin size of ~15,000 km2 and encompasses over 2,700 shallow lakes, which provide key habitat for abundant wildlife that Vuntut Gwitchin First Nation (VGFN) depend on for subsistence. OCF is presently warmer than it has been over the past 300 years[6]. Observations and traditional knowledge of the VGFN revealed that OCF is experiencing drastic landscape changes[7]. Quantitative analysis in OCF confirmed that hydrological behavior of lakes is strongly influenced by catchment vegetation and physiography[8].

Objectives

The main objective of this study is to determine the role of lake catchment land cover influence on the hydrological change occurring in OCF. Findings from this research can be used to refine future models of the hydrology and ultimately the landscape of OCF as well as other lake rich Arctic landscapes. We aim to accomplish this by (1) Identifying relationships between active layer thickness and land cover characteristics (i.e. dominant vegetation type); (2) developing a dominant vegetation type classification method for high resolution unmanned aviation vehicle (UAV) imagery; (3) determining relationships and processes among catchment land cover characteristics (e.g., ALT, soil moisture, vegetation) and their associated lake and river hydrology and chemistry; and (4) apply findings using up-scaled multispectral imagery to model lake and river hydrological and limnological conditions across the entire OCF landscape.

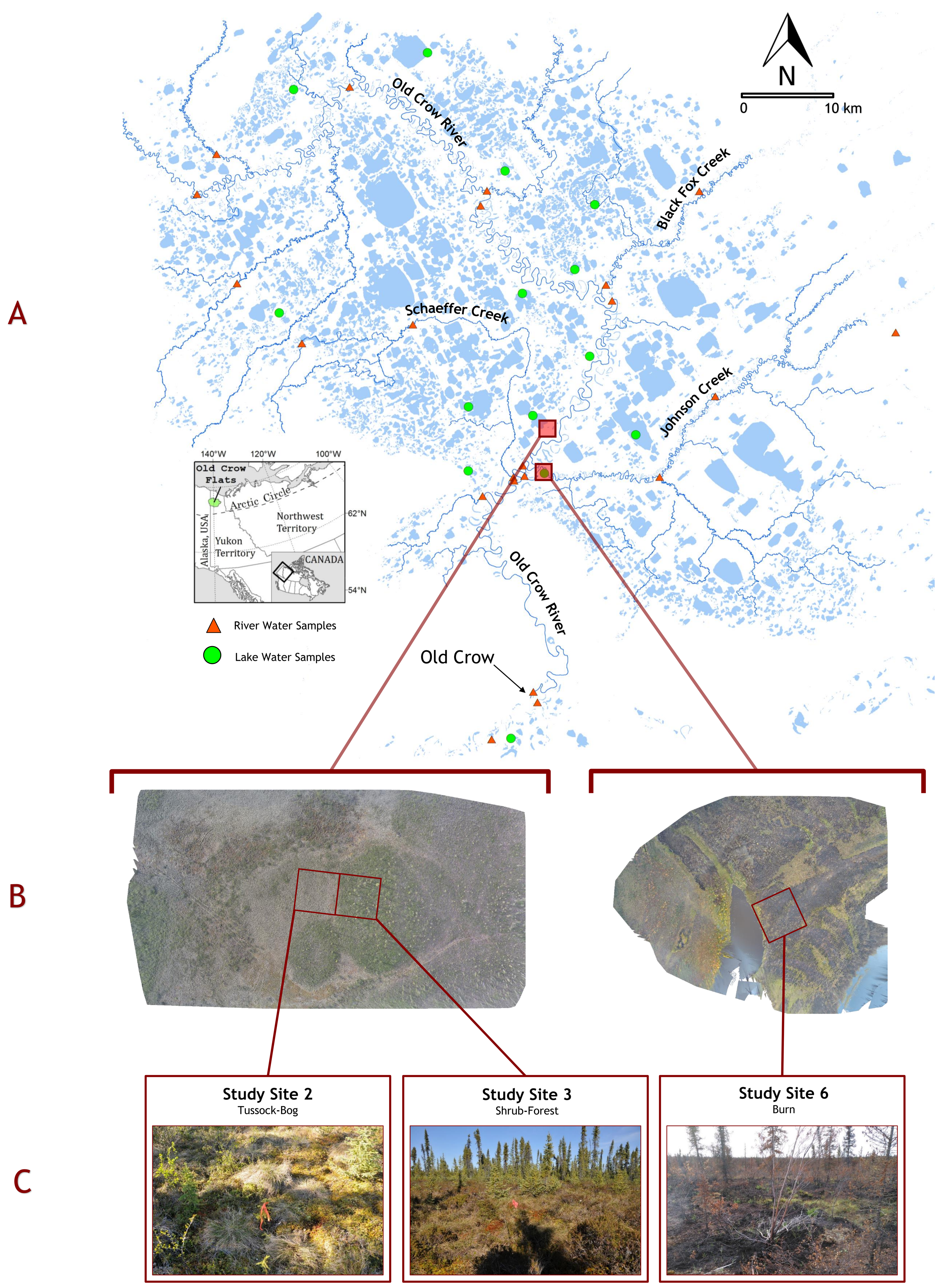

Figure 1. (a) Map of Old Crow Flats, Yukon lake and main river channel hydrology and specific study sites (red squares). (b) UAV obtained high resolution orthomosaic images of study sites 2 and 3 (left) as well as study site 6 (right) with red squares indicating the 100m x 100m plot at each site. (c) Examples of the three dominant vegetation land cover groups determined for plots represented in section b of this figure (tussock-bog, shrub-forest- and burn).

Methodology

Six 100m x 100m plots with two sample transects of 60m, each containing thirteen samples per transect (*n= 26/site*), were studied during June and August 2017 (Figure 2). Each plot was classified into one of three groups based on dominant vegetation land cover: *shrub-forest*, *tussock-bog*, and *burn* (Figure 1b-c). Data including active layer thickness, soil moisture, surface water, various vegetation parameters, and high resolution UAV imagery (Figure 2). Land cover data was collected in compliance with the NASA-ABoVE protocol to ensure compatibility with their airborne sensors which were flown over each of the six study sites during the 2017 campaign (Figure 3). Lake and river water samples were collected at 44 sites across OCF for analysis of water chemistry and isotopic parameters including dissolved inorganic and organic carbon (DIC/DOC) concentrations, water isotopic compositions ($\delta^{18}O$, δ^2H, and DIC and DOC $\delta^{13}C$) and total suspended sediments (TSS).

Figure 3. (Top left) Brent Thorne collecting active layer thickness data at Site #1 during June 2017. (Top right) Brent Thorne collecting soil moisture data using the Hydrosense II probe at Site #6 in September 2017. (Bottom left) Dr. Kevin Turner operating the UAV over Sites #2 and #3 during June 2017. (Bottom right) Clifton Nagwan operating the differential GPS unit used at all site for highly accurate spatial data for each sample location.

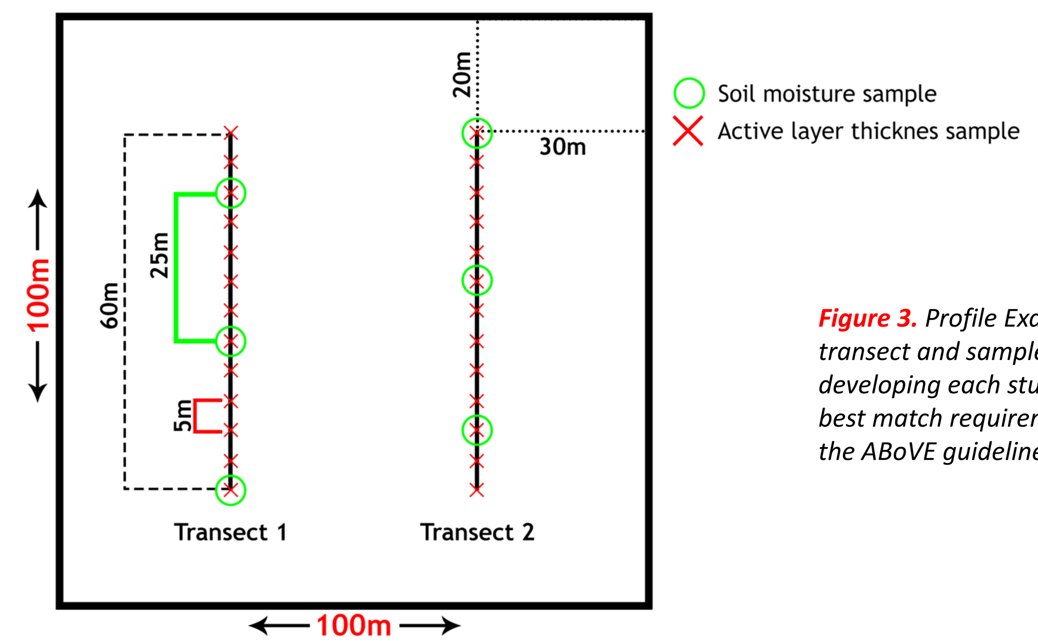

Figure 3. Profile Example of sample transect and sample location used for developing each study site in efforts to best match requirements provided by the ABoVE guidelines.

Results

Preliminary results from 2017 show high late thaw-season variability in ALT and soil moisture among tundra/bog, shrub/forest, and burned sites (Figure 4). Soil moisture in-situ volumetric water content (VWC) measurements, with 20 cm probe depth, show similar late-thaw season variability among tundra/bog (mean = 58.77%), shrub/spruce (mean = 43.44%), and burned (mean = 47.55%)(Figure 5).

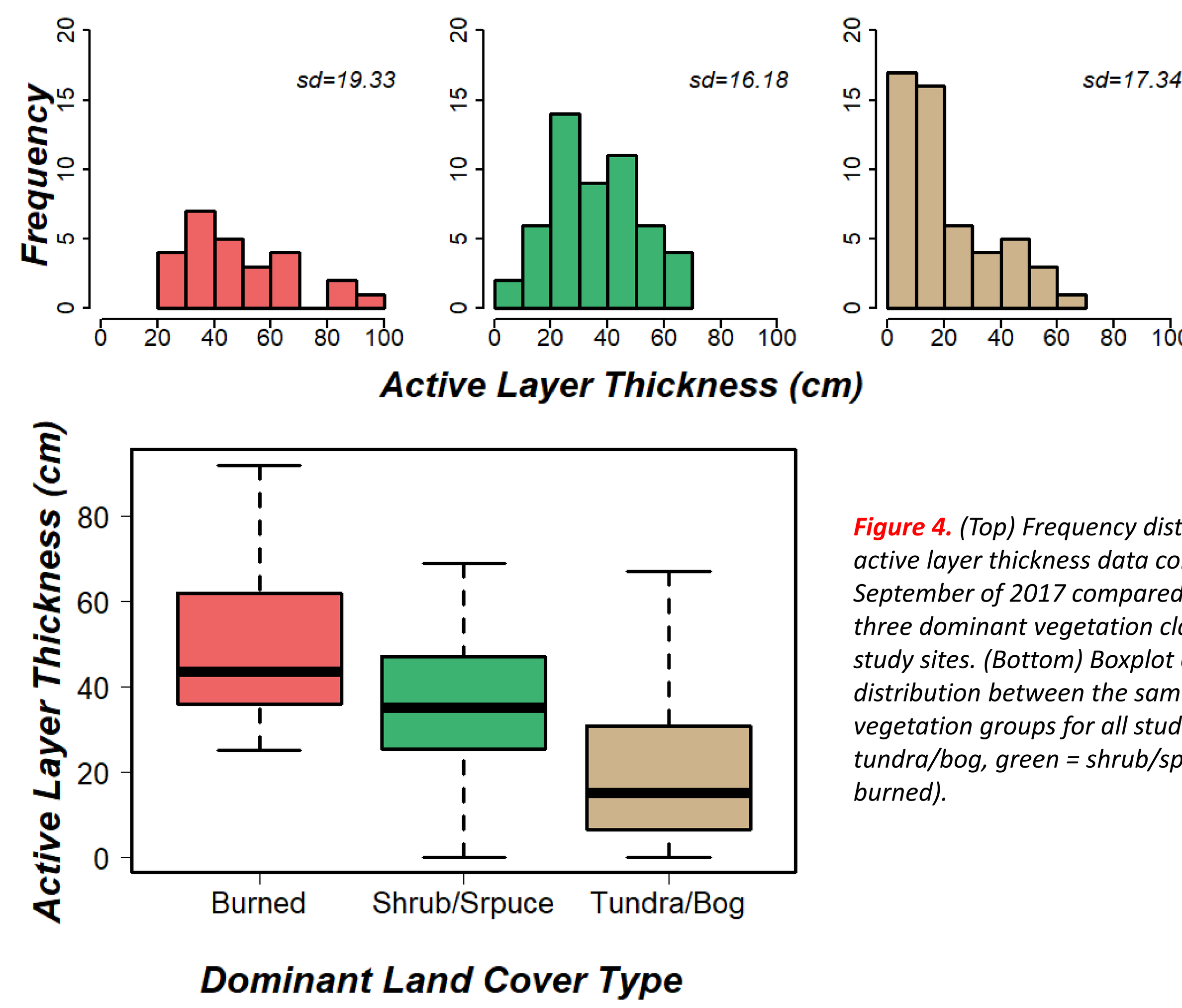

Figure 4. (Top) Frequency distributions of active layer thickness data collected in September of 2017 compared between the three dominant vegetation classes for all study sites. (Bottom) Boxplot of ALT distribution between the same dominant vegetation groups for all study sites. (brown = tundra/bog, green = shrub/spruce, and red = burned).

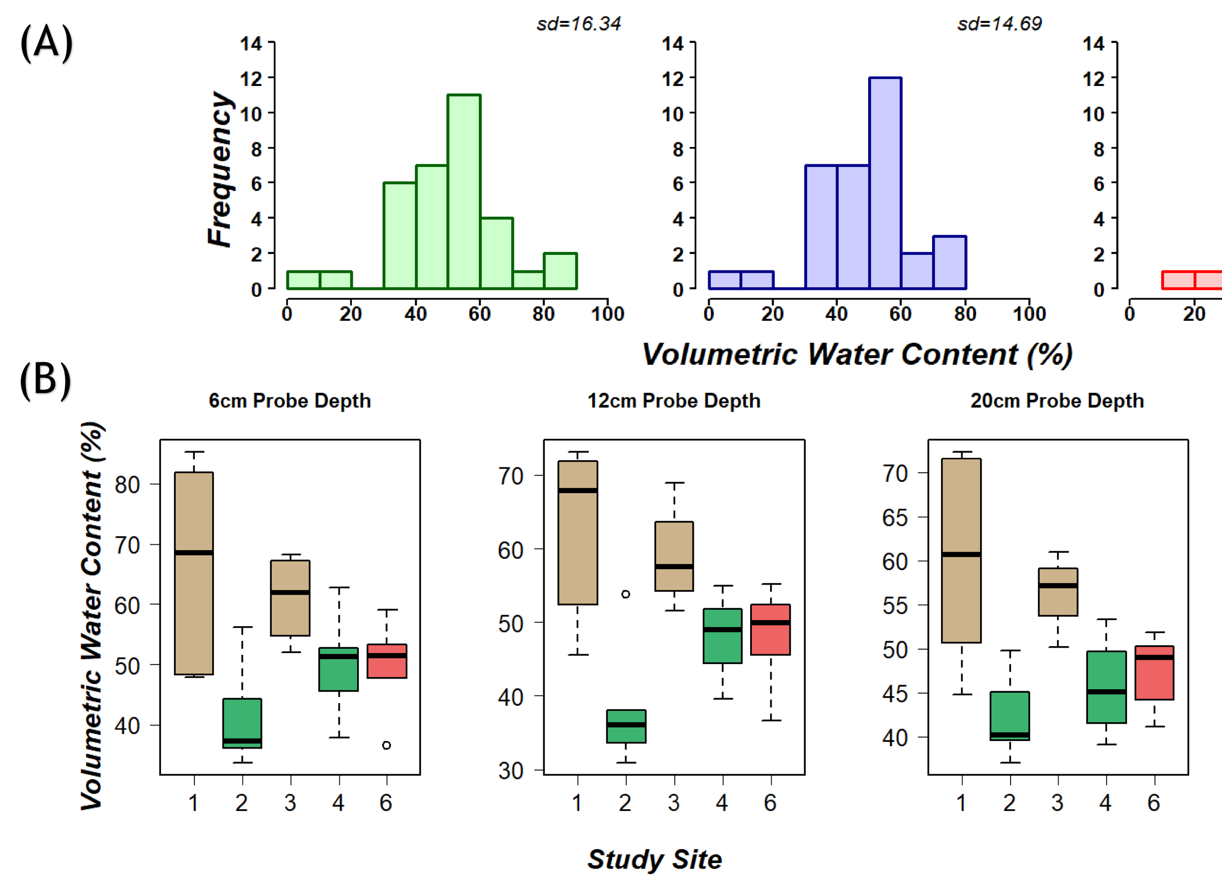

Figure 5. (A) Histograms representing frequency of volumetric water content for all sites combined based on probe depth. (B) Boxplots of volumetric water content grouped by dominant land cover group (brown = tundra/bog, green = shrub/spruce, and red = burned).

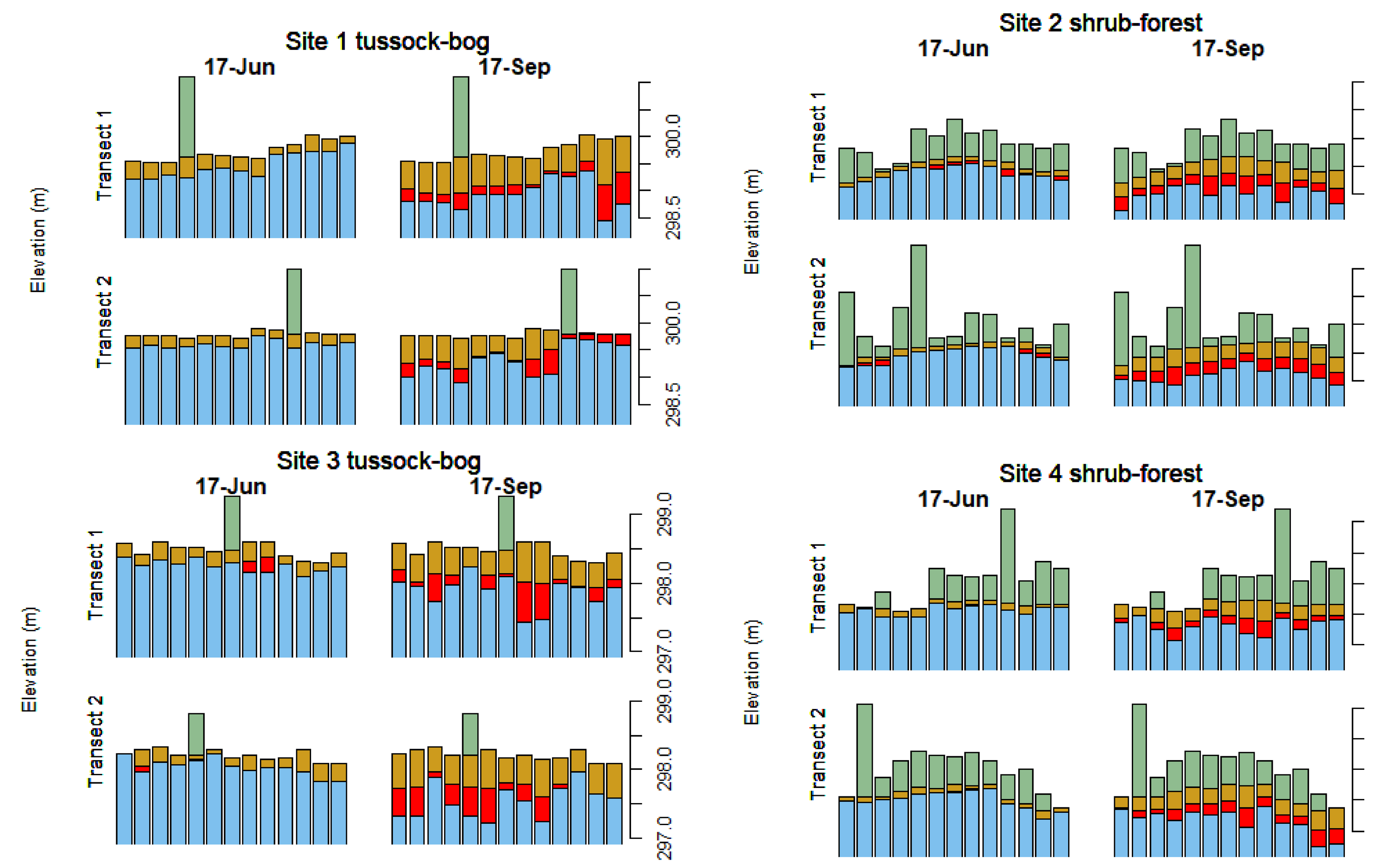

Figure 3. Profile bar graphs of each individual sample location collected per transect for sites 1 to 4. Each site contains four bar graphs where the two on the left represent data collected in the early thaw season, June 2017, and the two on the right represent the repeated data collected at the same locations in early September 2017. It is important to note that the y-axis (elevation in meters) scale is only consistent when comparing graphs within a single site and not across sites. Knowing this, shrub-forest sites appear to have a more consistent increase in ALT over the time period between sampling as compared to tussock-bog sites.

Conclusion and Next Steps

Integrated approaches being developed here will enhance our knowledge of the complex relations affecting lake-rich permafrost landscapes as climate continues to change. Further analysis will include geocomputation of orthomosaic UAV imagery using Pix4D software, statistical comparison of collected data such as ALT across the varying land cover types between sites, 3D visualization of each study site using interpolated values between samples collected, comparison of UAV-obtained imagery to NASA-ABoVE airborne sensors to determine scalability, and identification of relationships among catchment properties and water chemistry and isotope results.

During the spring and late summer of 2018, we will be focusing on deploying climate, ground, vegetation and lake level measurement equipment, and acquiring aerial multispectral imagery in several locations at much greater scales than previously surveyed. The aerial surveys will be completed using newly acquired unmanned aviation vehicles (UAVs) equipped with a high-resolution camera and multi-sensor. We will map several locations in OCF where landscape changes have occurred. These changes include catastrophic lake drainage, vegetation proliferation, fire, and permafrost thaw slumps along the shoreline of the Old Crow River where NASA ABoVE airborne data was collected.

References

1. Brown, J., Hinkel, K. M., & Nelson, F. E. (2000). The circumpolar active layer monitoring (calm) program: Research designs and initial results 1. Polar Geography, 24(3), 166–258. https://doi.org/10.1080/10889370009377698
2. Harris S.A., French H.M., & Heginbottom J.A. (1988). Glossary of permafrost and related ground-ice terms. Ottawa,Ontario,Canada.
3. Kokelj, S. V., Zajdlik, B., & Thompson, M. S. (2009). The impacts of thawing permafrost on the chemistry of lakes across the subarctic boreal-tundra transition, Mackenzie Delta region, Canada. Permafrost and Periglacial Processes, 20(2), 185–199. https://doi.org/10.1002/ppp.641
4. Porter, T. J., & Pisaric, M. F. J. (2011). Temperature-growth divergence in white spruce forests of Old Crow Flats, Yukon Territory, and adjacent regions of northwestern North America. Global Change Biology, 17(11), 3418–3430. https://doi.org/10.1111/j.1365-2486.2011.02507.x
5. Schaefer, K., Liu, L., Parsekian, A., Jafarov, E., Chen, A., Zhang, T., … Schaefer, T. (2015). Remotely Sensed Active Layer Thickness (ReSALT) at Barrow, Alaska Using Interferometric Synthetic Aperture Radar. Remote Sensing, 7(4), 3735–3759. https://doi.org/10.3390/rs70403735
6. Turner, K. W., Wolfe, B. B., Edwards, T. W. D., Lantz, T. C., Hall, R. I., & Larocque, G. (2014). Controls on water balance of shallow thermokarst lakes and their relations with catchment characteristics: a multi-year, landscape-scale assessment based on water isotope tracers and remote sensing in Old Crow Flats, Yukon (Canada). Global Change Biology, 20(5), 1585–1603. https://doi.org/10.1111/gcb.12465
7. Vincent, W. F., Lemay, M., & Allard, M. (2017). Arctic permafrost landscapes in transition: towards an integrated Earth system approach. Arctic Science, 3(2), 39–64. https://doi.org/10.1139/as-2016-0027
8. Wolfe, B. B., Humphries, M. M., Pisaric, M. F., Balasubramaniam, A. M., Burn, C. R., Chan, L., … others. (2011). Environmental change and traditional use of the Old Crow Flats in northern Canada: an IPY opportunity to meet the challenges of the new northern research paradigm. Arctic, 64(1), 127.