Changes in Land Cover Impact Temperature and Active Layer in Subarctic Regions

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Abstract
This research project looks at the relationship between land cover, permafrost and soil in the subarctic region of Fairbanks, Alaska. Permafrost acts as barrier holding water near the surface, creating poorly drained marshes with thick moss layers that act as insulation. In 1908 a section of black spruce forest -near the UAF campus -was clear cut for agriculture purposes transforming the land cover from black spruce to birch trees, ultimately increasing permafrost thaw. The thawing of permafrost in this area created huge mounds in the forest known as the “bicycle bumps.” How does the loss of permafrost affect soil moisture and soil temperature? Transect soil moisture samples were taken on October 31, 2021 at the permafrost location and November 1, 2021 at the thermokarst location. Snow depth, snow surface temperature, and soil temperatures 5cm and 10cm were also taken at both locations. The results showed a connection between land cover and snow depth, further gravimetric soil samples are needed for measurable soil moisture data. Going forward, addition gravimetric soil samples should be taken during summer months, with no snow cover. Additional tests on leaf litter and snow pack comparison for thermokarst and permafrost sites would be useful.

Research Questions
How has the clearing of black spruce affected the active layer in the thermokarst location? Does the an increased active layer(layer above permafrost that freezes and thaws each year) have an affect on soils moisture content and temperature? Increased land clearing could lead to further permafrost degradation and a water active layer above the permafrost, possibly causing declining snowpack.

Introduction
Climate change and development have created unique challenges around the world. One such challenge is the thawing of permafrost found in arctic and subarctic regions. Permafrost is the subsurface layer of soil that remains frozen throughout the year. This frozen layer holds water at the surface creating the wetland habitat important to animals and humans. Permafrost thaw concerns span across disciplines, from studying microbes and the implications of carbon dioxide and methane being released into the atmosphere, to buckling roads, infrastructure damages and towns along the cost eroding into the ocean(Bykova, 2020).

In a study affiliated with the International Permafrost Association(Chen, 2021), scientists looked at snow depth, land cover type, surface temperatures, and slope in relation to the thermal state of permafrost around the Alaska Highways(paras. 1). The study shows correlation between the snow depth, snow cover, and snow properties as well as how these factors affect heat fluxes and thaw underlying permafrost(2021). There have been further studies conducted in the Arctic and Boreal regions concerning warming temperatures and changing vegetating leading to an increased rate of permafrost thaw (Kropp, el al.,2020).

Along the UAF ski trail system there is a unique opportunity to study the effects of permafrost thaw from land cover change. Site one is an undisturbed black spruce forest that currently has a permafrost layer. The second site, now referred to as “the bicycle bumps,” was once a black spruce forest and is now a thermokarst area with bumpy topography.

Research methods

GLOBE data was collected on the ancestral lands of the Dena people of the lower Tanana River. The two data collection locations ran adjacent to one another, divided by a UAF hiking/ski trail. The site to the west of the trail has a birch forest landcover, and large thermokarst mounds known as the "bicycle bump,” to the east of the trail is a black spruce forests with a thick moss surface land cover and underlying permafrost.

In both locations transect soil moisture protocol was used to compare soil moisture in different land cover areas. 50 meters was measured and marked every 5 meters with 3 samples collected at 50m. A trowel and pickaxe was used to dig under the leaf and moss layer and at least 5cm into the soil. The soil was saved in a plastic bag and kept cold until they could be dried. Snow surface temperature was the collected at 9 random sites along with snow depth, to compare the difference between each landcover. Three soil moisture samples were taken at 5 and 10cm, 5m apart. GLOBE soil moisture, atmosphere, and surface temperature protocols were used at both thermokarst and permafrost sites.

Data was collected one time at each site. The sites where collected a day apart, this affected the atmospheric temperature during each day. Thermokarst air temperature was 0°C on 11/01/21 and 7°C on 10/31/21 during permafrost collections. There was no snowfall in between the data collections. Samples dried for 42 hours at 90°F.

Figure 1. Permafrost site Black spruce trees with thick moss layer

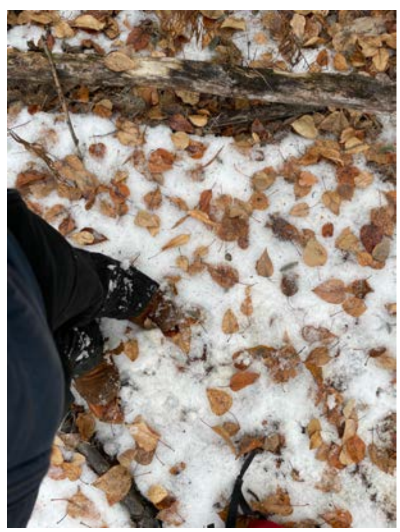
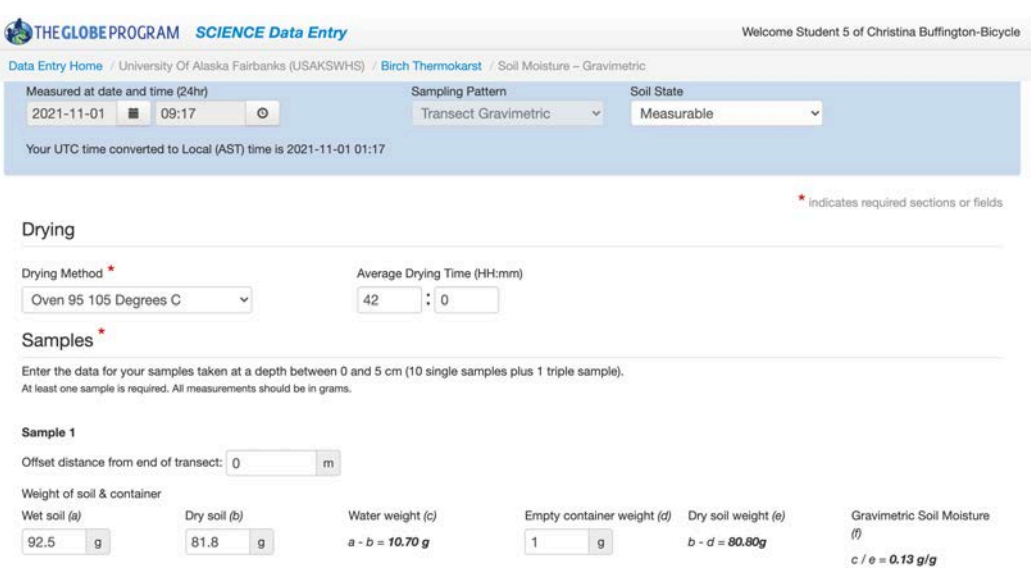


Figure 2. Thermokarst site Birch forest

Figure 3. Google map of permafrost(left)
and thermokarst(right) sites.


THE GLOBE PROGRAM SCIENCE Data Entry

Welcome Student 5 of Christina Buffington-Bicycle

Data Entry Home / University Of Alaska Fairbanks (USAKSWHS) / Birch Thermokarst / Soil Moisture – Gravimetric

Measured at date and time (24hr) 2021-11-01 09:17

Sampling Pattern: Transect Gravimetric

Soil State: Measurable

Your UTC time converted to Local (AST) time is 2021-11-01 01:17

* indicates required sections or fields

Drying

Drying Method * Oven 95 105 Degrees C

Average Drying Time (HH:mm) 42 : 0

Samples *

Enter the data for your samples taken at a depth between 0 and 5 cm (10 single samples plus 1 triple sample).
At least one sample is required. All measurements should be in grams.

Sample 1

Offset distance from end of transect: 0 m

Weight of soil & container

Wet soil *(a)*	Dry soil *(b)*	Water weight *(c)*	Empty container weight *(d)*	Dry soil weight *(e)*	Gravimetric Soil Moisture *(f)*
92.5 g	81.8 g	a - b = **10.70 g**	1 g	b - d = **80.80g**	c / e = **0.13 g/g**

Figure 4. GLOBE Data Entry

Results

After all soil samples were collected and dried in an oven for 42 hours at 90°F they were weighed a second time. The dry weights were then used to calculate the gravimetric soil moisture content. Figure 3. shows the soil moisture in both sites over a 50 meter profile location.

Table 1. Permafrost Summary Table

Permafrost 10/31/21	GSM g/g	Soil Temp 5 cm (C)	Soil Temp 10 cm (C)	Snow Depth (cm)	Surface Temps (C)	Air temp (C)
Mean	28.85	-0.33	-0.67	8.89	0.47	7
Max	5.30	0	0	11	2	
Min	1.39	-1	-1	1.5	-1.2	
Standard deviation	17.81	0.58	0.58	3.01	1.12	

Table 2. Thermokarst Summary Table

Thermokarst 11/01/21	GSM g/g	Soil Temp 5 cm (C)	Soil Temp 10 cm (C)	Snow Depth (cm)	Surface Temps (C)	Air temp (C)
Mean	0.35	0	-0.67	5.33	-0.05	0
Max	1.05	0	0	9	1.4	
Min	0.13	0	-1	4	-1.2	
Standard deviation	0.24	0	0.58	1.58	0.84	

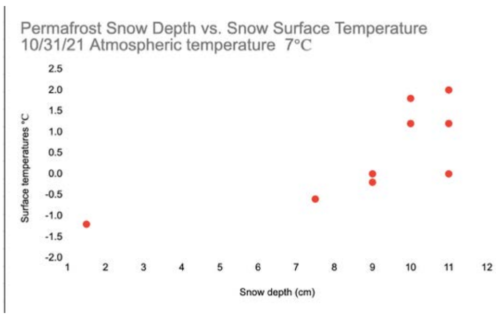


Figure 5. Permafrost snow depth vs surface temperature

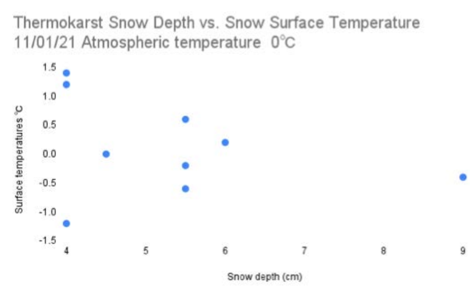


Figure 6. Thermokarst snow depth vs. temperature

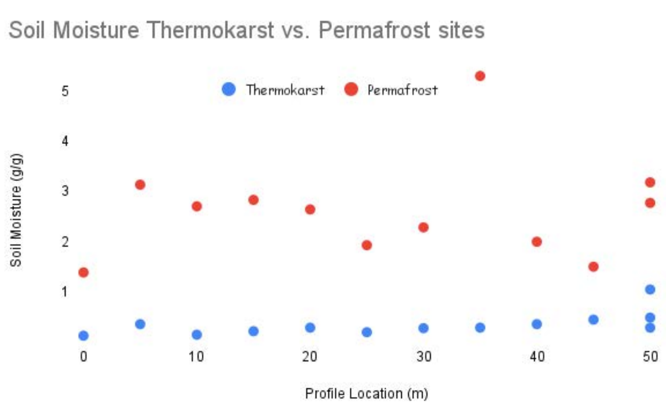


Figure 7. Soil moisture Thermokarst(blue) vs. Permafrost(red) sites

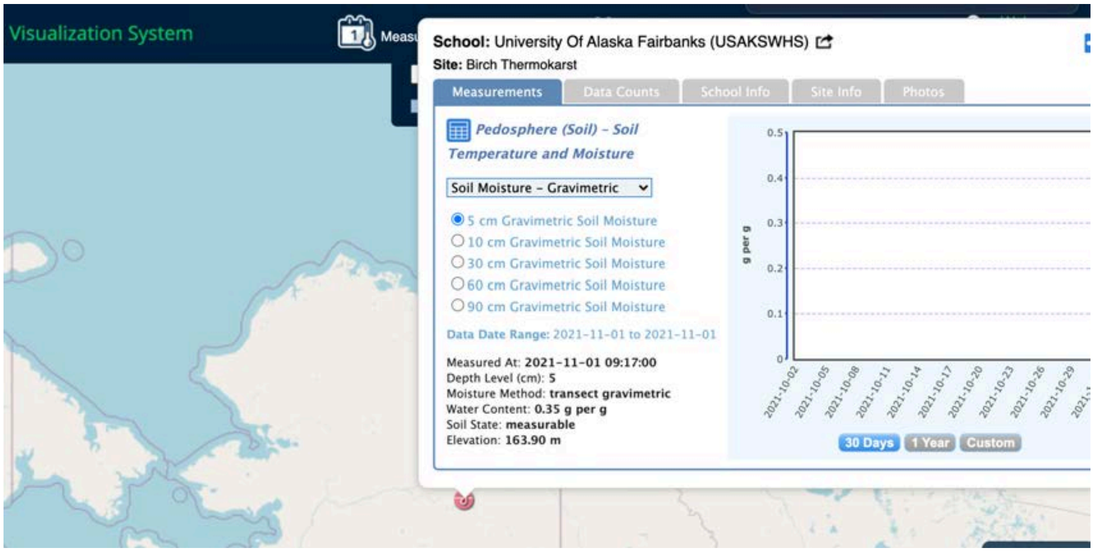


Figure 8. Globe Visualization

Discussion

The results from the gravimetric soil moisture procedure in figure 7 show a significant increase in soil moisture content. This coincides with my hypothesis that soil moisture will be greater in permafrost site because of the frozen soil layer will hold water closer to the surface. Figures 5 and 6 show the relationship between land cover, snow depth and snow surface temperature. Both graphs show around the same surface temperature but snow depths are different, permafrost land cover type having a deeper snow depth. Deep snow acts as an insulator and is an important aspect of maintaining permafrost in a location. Land cover can also have an impact on surface temperature, snow depth and permafrost thaw. Clear cutting the black spruce opened up the area and could have possibly allowed the soil to warm up, allowing for faster decomposition and a larger active layer.

Limitations of the methods included: frozen ground at permafrost site, data was collected different days, and only one sample was taken every 5 meters instead of 2 samples every 5 meters. However, because data was collected at the very being of the snow pack season it can be useful for future comparisons.

Human error: did not dig deep enough in permafrost area because ground was frozen.

Experimental error: using plastic bags for soil collection. Bags sightly melted in the oven.

Conclusion

The results show that the permafrost site has higher soil moisture content and deeper snow depth than the thermokarst site. The results also show a connection between land cover and snow depth. Because snow depth and other snow properties affect permafrost thaw, further research in the area could be interesting.

Improvements to the methods include: sampling before the ground freezes, an in-depth land cover observation, and taking soil temperatures at the same location as the soil moisture in order to make clear comparisons.

Lastly, working with Christina Buffington MS., M.ED has been incredibly helpful. In the past the idea of developing and completing a research project would have been incredibly intimidating, having a mentor explain the process step by step has made this experience attainable and fun.

I chose "make an impact" GLOBE badge because it highlights the importance of permafrost thaw research in Alaska and starts conversations around what changes to land cover may occur locally.

Bibliography

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