Implications of Ice Thickness in Urban and Rural Locations

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2022 GLOBE International Virtual Science Symposium

Abstract

Arctic and subarctic ecosystems rely on ice for many reasons. There are many organisms that rely on ice formation and ice thickness. Observing changes in this process will help understand the future condition of the water system. How does ice thickness vary in urban locations versus rural locations? If they are different, what characteristics are associated with ice thickness? Ice thickness measurements in two contrasting (urban versus rural) slough locations were collected and observed at the end of October and again in mid-November in Interior, Alaska. This was to allow time for ice to begin forming. Three measurements of the following factors were taken: ice thickness, snow depth on ice, water depth, air temperature, water temperature and distance from shoreline. The results indicate that the rural location developed thicker ice than the ice formation in the urban location. GLOBE Observer Landcover and Fresh Eyes on Ice applications was used to capture vegetation, terrain, water coverage, structures, and impervious surfaces. It can be inferred that ice thickness in the rural slough location was thicker than in the urban slough location.

Research Questions

The research question for this study asks, how does ice thickness vary in urban locations versus rural locations? If they are different, what characteristics are associated with ice thickness? I hypothesize that the ice will be thicker in rural locations than in urban locations because the rural location has fewer impervious surfaces which absorb heat, therefore, warming the environment around it and contributes to an increase in runoff. GLOBE data supports a way to better understand the location and the terrain associated with it. Based on the data and photos, assumptions can be drawn based on the different characteristics at the rural and urban locations. Ice thickness and ice formation is an important piece of understanding ecological processes in Arctic systems. Ice thickness is critical for both local and global communities because Arctic communities rely on ice formation during the winter season as a way of life. Knowledge of ice thickness and factors that are associated with causing ice to form, are important to be familiar with. Climate change has played a major role in ice formation and thickness and is consequently altering ecosystems and lifeways.

This topic was of interest because ice formation and thickness are an important indicator of climate change and can also help determine how ice in rivers and sloughs may be affected by things like infrastructure, impervious surfaces, and pollution, and therefore affect water temperature, air temperature, ice thickness, snow depths.

In class we learned about a warming Arctic, which relates to this research and has provided insight into uncovering the effects landcover changes have on ice thickness and investigate additional factors and characteristics that may influence the results.

Introduction

Ice formation is an important ecological process in northern regions. Ice formation could be affected by several different factors. Observing the nature of ice formation in different locations is significant because it helps to gain a better understanding of the temporal and spatial analysis of the changes in and condition of freshwater ecosystems (Fresh Eyes on Ice, 2019). Ice formation in urban locations consist of impervious surfaces and runoff which may include negative factors and contribute to lower ice formation. These factors may include decreasing albedo, contributing to an increase in polluted runoff, and decrease vegetation which hold water in soils, trap snow and regulate temperatures. While in rural locations, vegetation is often prevalent, there are minimal impervious surfaces, and potentially less polluted runoff. GLOBE protocols were used with the eventual goal of determining if ice thickness is affected by different land cover types. Parameters associated with ice formation and thickness affect aquatic organisms' survival and their habitat (Prowse et. al). Timing of ice formation and thickness causes variances across hydrologic systems. Ice observations may help outline additional regional hydrologic conditions by defining how differences in landscape and location vary in ice thickness measurements (Arp et. al). Many communities in arctic locations rely on frozen lakes, rivers, and sloughs as resources such as travel, subsistence, and overall quality of hydrologic ecosystems for drinking water. This topic addresses issues with infrastructure, landscape changes, pollution, and impervious surfaces and their potential effect on ice thickness development in nearby sloughs.

Methods

GLOBE landcover observations were collected to determine landscape differences between the two contrasting locations. Two contrasting locations consisted of sloughs of similar size (approximate width and depth). In the urban location (Chena slough), the landscape consisted of impervious surfaces, sloped land, low density of tree and shrub populations, and polluted runoff (reported to Department of Conservation. Figure 1 displays a satellite image of the urban (Chena Slough) location. Figure 3 displays a ground image of the urban (Chena Slough) location. In the rural location (Piledriver slough), landscape consisted of vegetation, minimal impervious surfaces, and little to no infrastructure in minimally sloped land, natural tree and shrub uniformity and denseness, and otherwise undisturbed and natural ecosystem. Figure 2 displays a satellite image of the rural (Piledriver Slough) location. Figure 4 displays a ground image of the rural (Piledriver Slough) location. Fresh Eyes on Ice protocols for ice thickness observations were efficient for this research and recorded to contribute to freeze-up observations. In both locations, three ice measurements were taken and observed in the early portion of the ice formation season (24 October 21). Two weeks later (7 November 21), three more measurements were taken to determine changes in ice thickness throughout time. Additionally, on the two separate days at the two contrasting locations, measurements of different parameters associated with ice thickness were observed and recorded. These measurements included ice thickness (cm), water depth (cm), snow depth on ice (cm), air temperature (°C), water temperature (°C) and distance from the shoreline (m). The urban location (Chena slough), which is in North Pole, Alaska behind the Badger Gas convenience store on the corner of Badger, Persinger and Peede road. The rural location – Piledriver slough, which is in Moose Creek, Alaska off Eielson Farm Road. To obtain measurements of ice thickness, three random locations on each slough were selected and measured. Due to it being early in the ice forming season, limitations on safely taking ice measurements were considered. Using a battery powered drill and drill bit, three ~ 5 cm holes were drilled at a linear angle atop of the ice. Each hole that was drilled was ~30 feet parallel from the next sample taken. A standard tape measure was used to acquire measurements from the bottom of the ice (in the water) to the top of the ice (outside of water) and was recorded on the data sheet. Water depth measurements were taken using a standard tape measure and were fed linearly into the water through the ice hole until it stopped at the bottom of the slough floor. Snow depth on ice was observed using a standard ruler by placing the ruler into the snow until it stopped at the ice. Air temperature was taken using a GLOBE calibrated alcohol-filled probe thermometer. The thermometer rested for ~two minutes before recording the temperature on the data sheet. Water temperature was obtained using an infrared thermometer with a thermal glove. The laser was directed into the water and where ice temperature and additional obstructions could be avoided. Distance from shoreline was taken using a standard tape measure. This distance was taken directly from the hole drilled in the ice to the most linear route to the shore. Calculations were used to carry out statistical analysis of ice thickness for each location to determine the relationship between location and ice thickness. Summary Table 1 displays the mean ice thickness, standard deviation, one-way p-value, and two-way p-value for each location. This statistical analysis was calculated and recorded using Microsoft Excel's ANOVA technology to determine this relationship. The P-value determines the level of marginal significance within the dataset. These methods help answer the research question because comparison between the two locations due to the measurements collected will help determine whether ice is thicker in rural or urban locations.

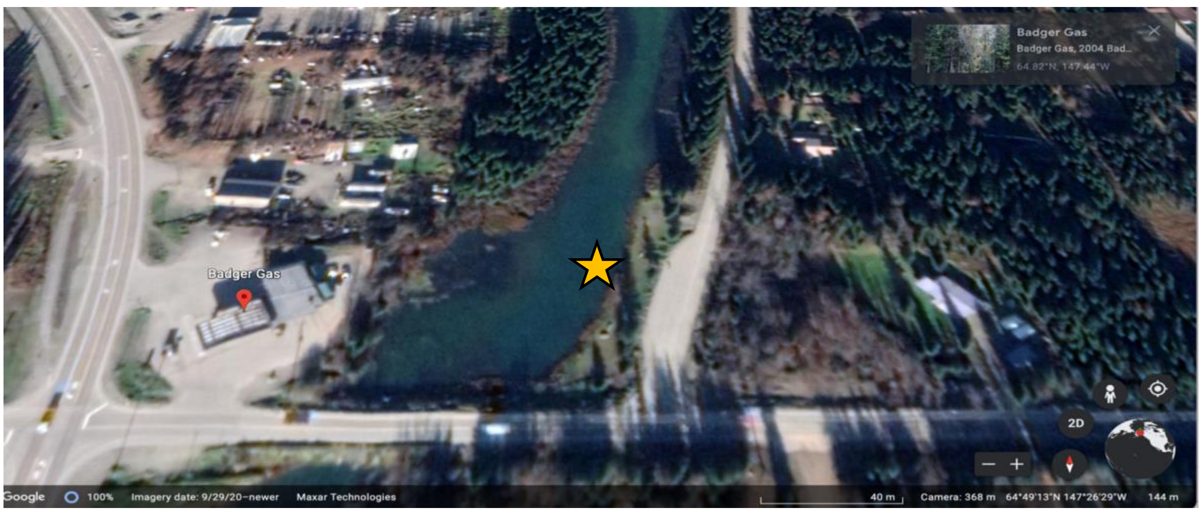


Figure 1
Google Earth satellite image of the urban (Chena Slough) location (Badger Gas convenience store in North Pole, Alaska).

Figure 2
Google Earth satellite image of the rural (Piledriver Slough) location (Eielson Farm Road in Moose Creek, Alaska).

Figure 3
Urban location (Chena Slough)

**Contains lower density of vegetation and more impervious surfaces

Figure 4
Rural location (Piledriver Slough)

**Contains higher density of vegetation and less impervious surfaces.

Results

The results of this research indicate that ice is thicker in rural locations than in urban locations for the data collected. As shown in Figure 5 and the supplementary Summary Table 1, a comparison between ice thickness at each of the two sites in correlation with the two days can be observed. Using a one-way ANOVA statistical analysis, the urban location suggested a P-value of 0.96. In the rural location, the P-value indicated a value of 0.22. The standard deviation at the urban location suggested a value of 2.12, while the rural location suggested a value of 1.34. Analysis at which determines whether ice is thicker in rural or in urban locations and additional characteristics associated with these results is displayed in Figure 6. Using a two-way ANOVA statistical analysis suggested a P-value of 0.038. This figure depicts parameters of water temperature, air temperature and snow depth in association with each of the two locations of ice thickness measurements. The results from Figure 5 suggest that site #4 and site #5 in the rural location of the Piledriver Slough displays the thickest ice for both data collection days. Additionally, as shown in Figure 6, the rural location displays slightly lower water temperature, but slightly higher air temperatures and slightly lower snow depths as compared to the urban location measurements taken. These results show that ice thickness may be determined by water temperature, while air temperature and snow depths may be associated with higher density in vegetation such as trees surrounding and insulating the outer layer of the ice on the slough. An overview of the analysis conducted addresses the research question because ice thickness measurements from data in Figures 5 and 6 suggest that rural locations acquire ice development more rapidly than in urban locations. A summary of the results from this study presents information suggesting that urban locations consist of more impervious surfaces which lead to conclusions of lowering ice formation due to having a lower albedo and ultimately warmer water temperatures than in rural locations. The rural location signifies lower water temperatures, lower snow depths and higher air temperatures, which suggests that an increase in ice thickness is due to lower water temperature. Yet, in this location, low snow depths and high air temperatures could raise speculation that the density of vegetation and spatial vegetation coverage thus acts as an insulator for the understory and for the ecosystem.

	24-Oct-21			7-Nov-21			Mean	Standard Deviation	P-Value
Urban - Ice thickness (cm)	5.715	6.985	9.843	8.255	4.763	9.843	7.56733333	2.11965749	0.95892445
Rural - Ice thickness (cm)	9.843	10.16	8.573	13.018	10.478	9.843	10.3191667	1.34392651	0.21702292

Summary Table 1
Indicates ice thickness in each location on each date and displays the ice thickness mean, standard deviation, and P-value (single-factor) of ice thickness at each location.

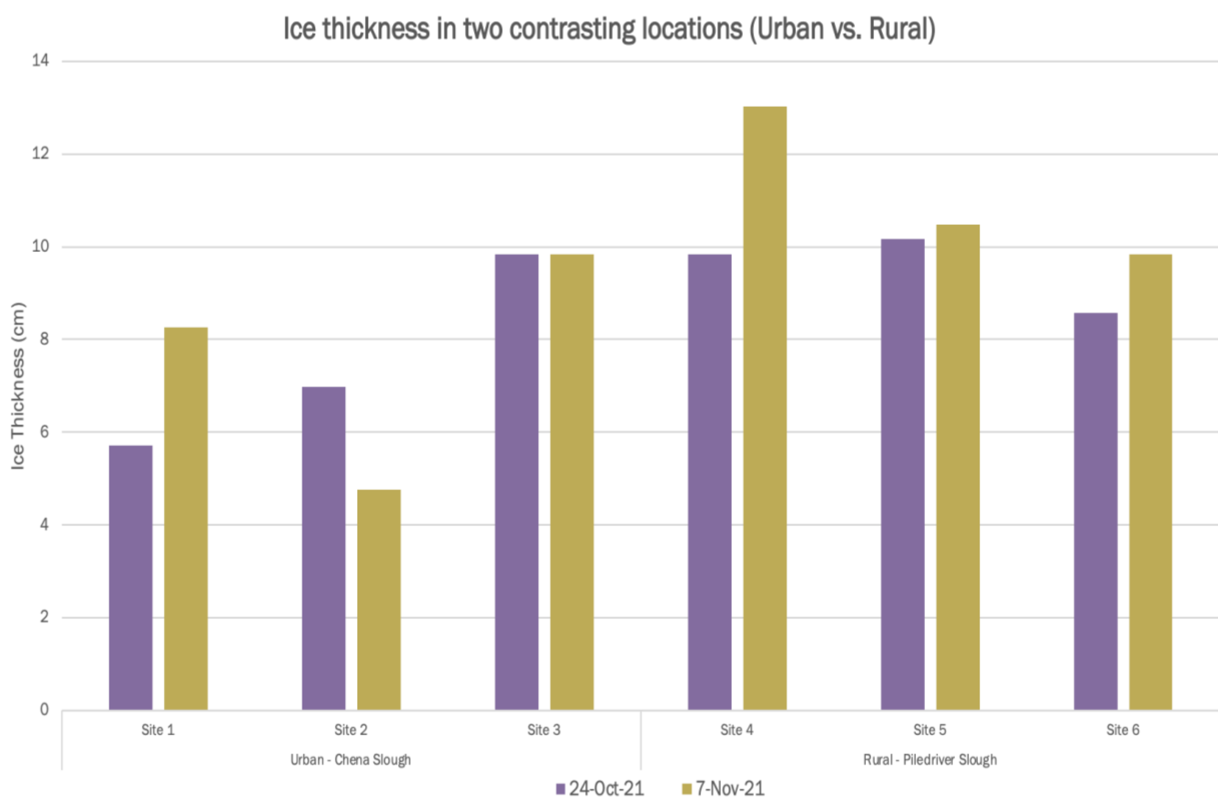


Figure 5
Displays ice thickness (cm) in urban and rural slough locations. The violet bars represent data collected on 24 October 21. The gold bars represent data collected on 7 November 21. Using single-factor ANOVA statistical testing indicated a P-value in the urban location:0.95892445 and standard deviation: 2.11965749.
Single-factor ANOVA P-value in the rural location:0.21702292 and standard deviation: 1.34392651.

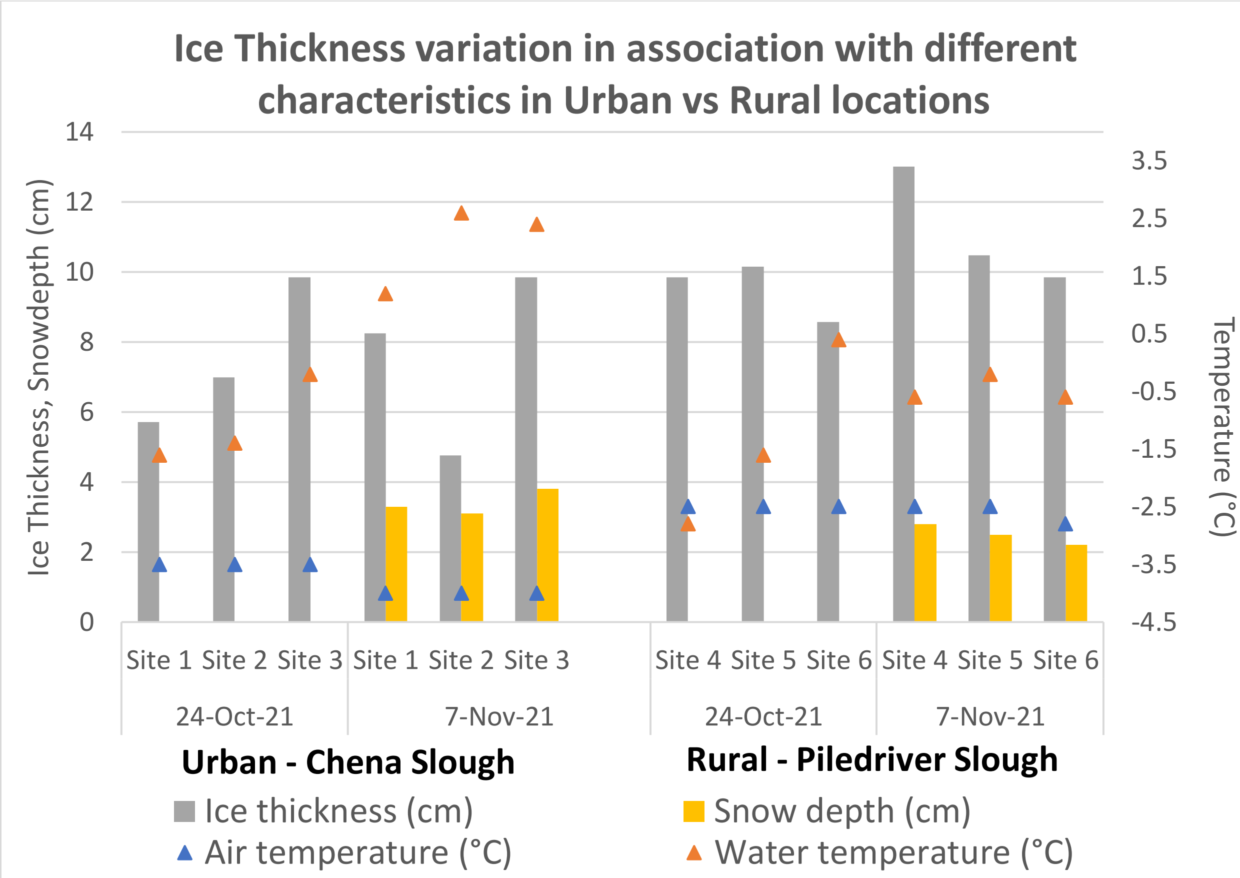
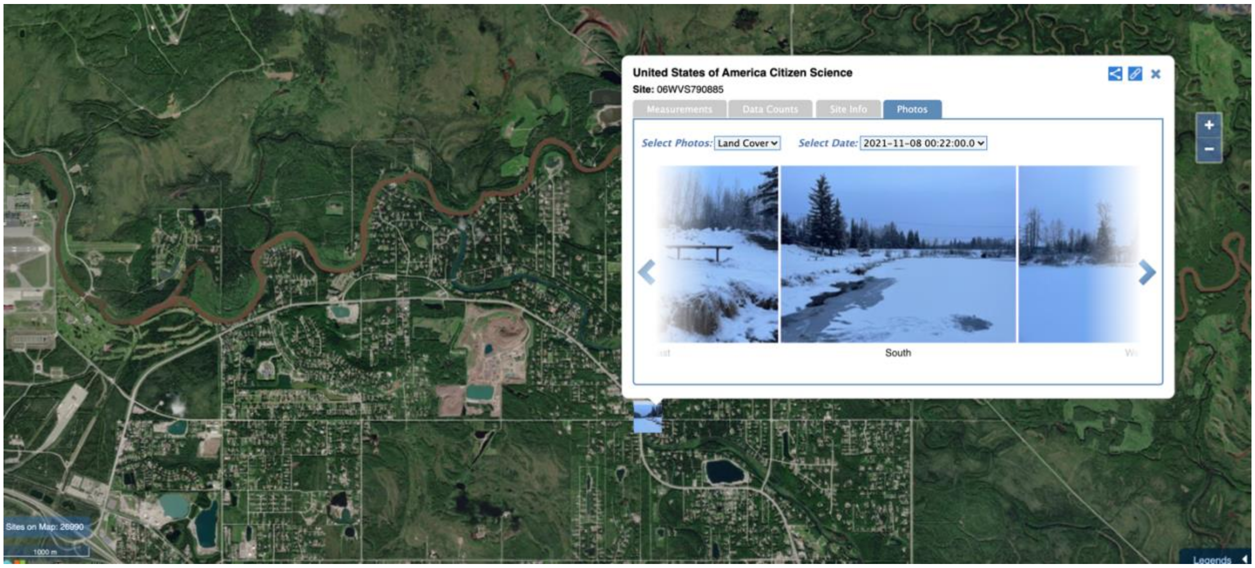
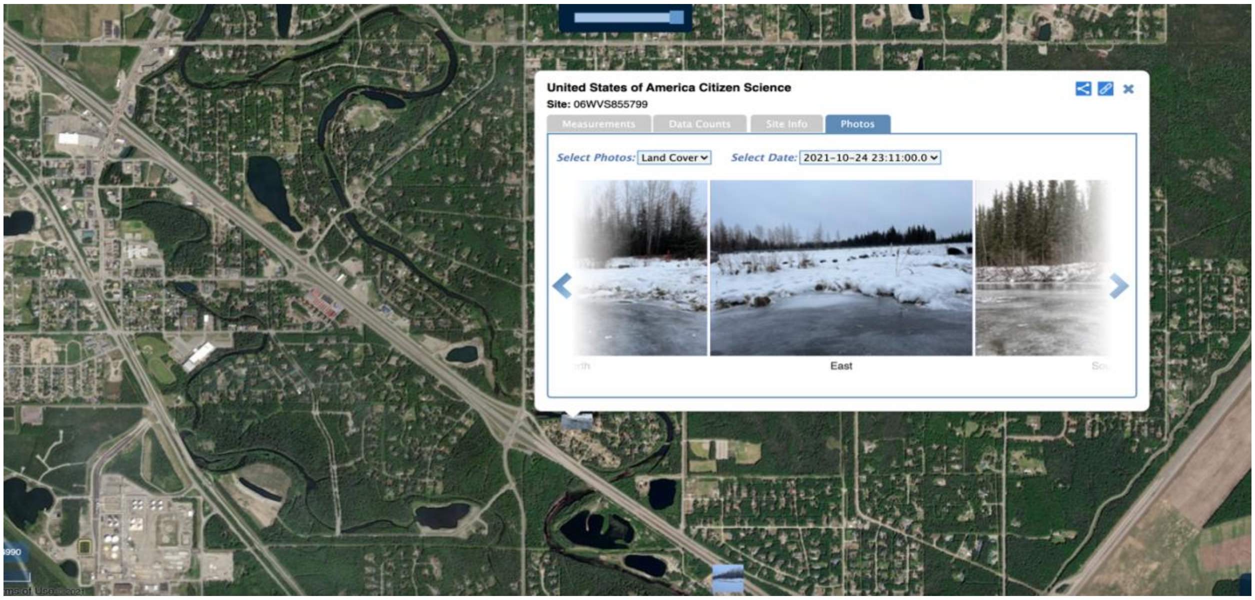


Figure 6
Displays ice thickness variation in association with different characteristics in urban and rural slough locations based on the date of collection at each site.
Red bars represent ice thickness (cm). Teal bars represent snow depth on the ice (cm).
Yellow triangles represent air temperature (°C). Blue triangles represent water temperature (°C)
Rural and urban ice thickness Two-way ANOVA statistical testing indicates a P-value: 0.03799715. ($P<0.05$)



Globe Observer Visualization Page Screenshot
Urban location (Chena Slough) photos from four cardinal directions.



Globe Observer Visualization Page Screenshot
Rural location (Piledriver Slough) photos from four cardinal directions.

Discussion

Results pertaining to this study can be inferred that there is a statistically significant relationship between ice thickness measurements and urban vs. rural locations ($P < 0.05$). Rural locations displayed greater ice thickness measurements in comparison to urban locations. (P-value of 0.038). Additionally, assumptions can be built following the measurement results from additional ice formation and related factors (snow depth, water temperature, air temperature and water depths). An ANOVA (analysis of variance) statistical analysis was used to explore the effect of ice formation variables on ice thickness at both the urban and rural locations. A lower P-value in the rural location suggests a stronger interaction effect within the ice thickness variables and the resulting mean ice thickness than in the urban location. Using the single-factor ANOVA analysis, the urban location indicated a P-value of 0.95892445. The rural location indicated a P-value of 0.21702292. These values indicate that there is not a statistical relationship between the ice thickness means and the dates of measurement collection. These results mean that ice thickness is influenced by location, vegetation, impervious surfaces, disturbances, and infrastructure. This study is important to science and our community because ice development is critical in Arctic hydrologic and terrestrial ecosystems. Communities rely on ice formation, thickness, and timing which supports culture, customs and traditions, family beliefs, and values. Comparing the results of this study to similar studies by other researchers reveals similar results as compared to rural versus urban locations in the Arctic. The results help answer the research question of this investigation because the outcome of different sites at the two contrasting locations determined that one location (rural) presented thicker ice at most sites than that of the opposing (urban) location throughout the timing of observations. The results support the hypothesis because it was suggested that the rural location (Piledriver slough) would represent thicker ice than the urban location (Chena slough). There were minor complications while collecting data for this research due to the timing of this study. This was largely due to ice formation barely beginning in the two locations. Analyzing data was slightly difficult due to decisions in which graphing technique to use to display the best results from this study. Uncertainties and limitations in this research process may indicate weak results due to few observations. Additional measurements of the parameters included in this research, over a longer time frame would present stronger evidence and results for this study.

Conclusion

Ice thickness appears to be influenced by location and/or landcover that surround the location of the slough. For this research, the rural location indicated larger measurements of ice thickness in comparison to urban locations. Ice formation and thickness is an important ecological process in the northern regions.

Additional methods for determining ice thickness in two opposing locations could include more time for data collection to capture additional ice thickness measurements and further implications of testing factors relating to ice formation. Improvements in the methods could include using an actual ice auger to drill slightly larger holes in the ice. Recommendations for follow-up research could include examining additional measurable parameters: vegetation density or impervious surfaces to indicated if the results are the same or similar. This conclusion is supported by the results because the rural location where there were less impervious surfaces and more vegetation also represented larger ice thickness measurements than in the opposing urban location with more impervious surface coverage and less vegetation. Conducting this research for GLOBE and NASA is appreciated because it is a contribution and support towards the community and environment. This study contributed to gaining a better understanding and evaluation of ecological processes that occur in Arctic and winter environments all around the world.

Acknowledgement and impact of working with a mentor

I would like to thank our GLOBE teacher and mentor Christina Buffington for her support, dedication, and introduction to the GLOBE program. Through her guidance and advice throughout this semester has personally helped me gain a better understanding of watershed management and ecological processes as well as develop additional knowledge and skills that will be beneficial in my continuing education and future employment as a Natural Resource Manager and/or in the related field.

I would also like to thank our guest speakers and those that have contributed to assisting in our labs and research projects.

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