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Air Temperature and Latitude Impacts on the Ice Duration of Twelve Ontario Lakes

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Abstract
There has been an increasing number of high-temperature days recorded in the past eight years globally (Hansen et al., 2010). This study documents the change in the ice duration, how many days, ice remains on a lake between the first ice cover and the last ice cover, to the changes in temperature in twelve Ontario lakes over an eight-year period (2004 - 08). This study also considers the impacts of latitude and lake area on the length of the ice duration. Lakes have recreational and biological values, and a change in the ice duration can greatly impact these values. Results of this study demonstrate that there was an increase in high-temperature days and a decrease in the ice duration in each lake. However, the changes in the overall temperature and ice duration are currently not statistically significant, only a trend. Emphasizing the importance of long-term ice duration data in elucidating these relationships.

Keywords
Lakes — Air temperature — Ontario — Latitude — Ice duration

1. Introduction

Global air temperatures have been increasing in the past eight-years due to increasing amount of greenhouse gases in the atmosphere (Hansen et al., 2010). Air temperature is one of the main metrological variables that affect lake ice cover (Livingstone & Adrian, 2009). The goal of this study was to determine if an increase in air temperature will impact ice duration over time. Ice duration is the number of days between the first ice cover of the lake and the last lake ice cover, this cover can be both intermittent and continuous (Livingstone & Adrian, 2009). Latitudes of each lake was considered in this study as, as latitude increases the average air temperature decreases which could impact the ice duration of northern lakes (Vincent & Gullet, 1999). Lake area was also taken into consideration as it can impact the rate in which the ice can freeze and the ice duration (Lepparanta, 2014).

Ontario lakes have many biological and recreational values, all of which would be extensively impacted if there were major changes in the duration of ice on the lakes (Scott et al., 2005). With the closure of research stations across Canada during the Harper government era (2008 – 2015), there was a loss of accessible ice data from seven of the eight lakes in this study that has had an impact on long-term ice duration studies. It is important to have long-term ice-duration studies as they provide an assessment of the impact that rising temperatures have on lakes, surrounding communities, and the ecosystem, which can be used to help plan for the future.

2. Methods

This study was a meta-analysis of eight years (2004 – 2012) of ice duration and air temperature data from twelve Ontario lakes, three from northern Ontario (Missisa Lake, Big Trout Lake and Northern Caribou Lake), five from western Ontario (Umfreville Lake, Lac Seul, Rainy Lake, Lake of the Woods, and Lake Nipigon), and four from southern Ontario (Trout Lake, Nipissing, Gull Lake and Lake Simcoe) (Figure 1.). These lakes were chosen based on the availability of lake ice data.

Data for this study was collected and compiled from the National Snow and Ice Data Centre (NSIDC), Canadian Cryosphere Information Network (CCIN), and the Weather Network Archives. The NSIDC and CCIN provided ice duration data for the lakes, lake latitude and lake area. The weather network archives provided an average temperature for the winter season (between November and March) of each year in the Ontario region closest to each lake.

Temperature and ice duration were graphed together (Figure 2., Figure 3., Figure 4.), which provided an R^2 value for each lake demonstrating variability. The temperature and ice duration data were then placed in a two-way analysis of variance (ANOVA), with an alpha value of 0.05.

Latitude and ice duration were compared after the p-values were found. The lakes were ranked based on latitude, from the lowest (southern) to the highest (northern) latitudes (Table 1.). The P-values of each lake were placed in a column beside the lake and then compared to the alpha value of 0.05 to determine if there was a statistical significance between air temperature and ice duration.

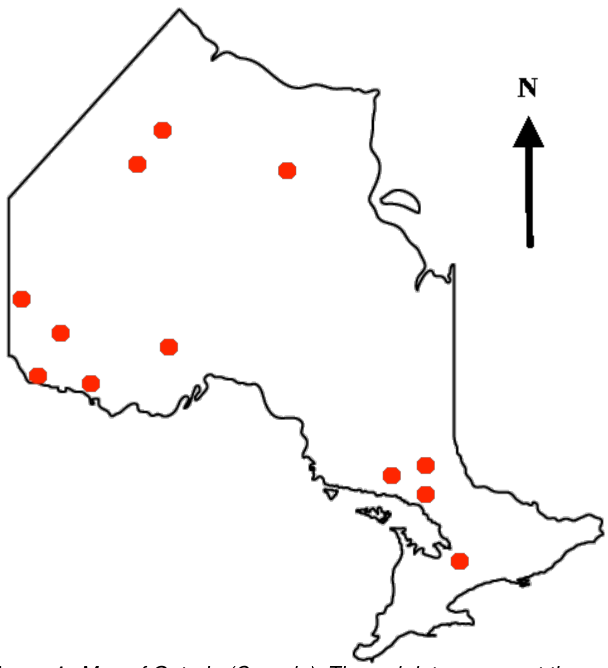

Figure 1. *Map of Ontario (Canada), The red dots represent the approximate locations of the twelve lakes in this study. The arrow indicates north.*

3. Results

In this study, there was a heavy reliance on government data records. These records were greatly impacted by the Harper governments closure of many research stations across Ontario. This resulted in the loss of ice duration data across the lakes in this study. Lake Simcoe's ice data was not disrupted because of records kept by the 'lake-simcoe.ca' citizen interest group. A line of best fit was placed in each graph to provide a visual placeholder for the missing data.

Lakes are represented separately, (Figure 2.), (Figure 3.), and (Figure 4.), based on latitude. Higher latitude resulted in a lower year-round temperature and generally a longer ice duration (Futter, 2003). This allowed for comparison of p-values of lakes of similar latitudes to observe if any were statistically impacted and to observe any visible patterns in the P-values.

4. Discussion

Using 8-years of ice data, this study demonstrated the decline of the ice duration on twelve Ontario lakes. Results of the data analysis from this study demonstrated no statistical significance between the increase in air temperature and the change in ice duration over eight years as the p-values of each lake were greater than the 0.05 alpha value, which means there was no statistically significant correlation.

Latitude and ice duration were not correlated (Table 4). There is no pattern of increase or decrease in p-values when placing the lakes in order from lowest (southern) latitude to highest (northern) latitude. There was a great margin of error in this study. The primary source of error is found in the

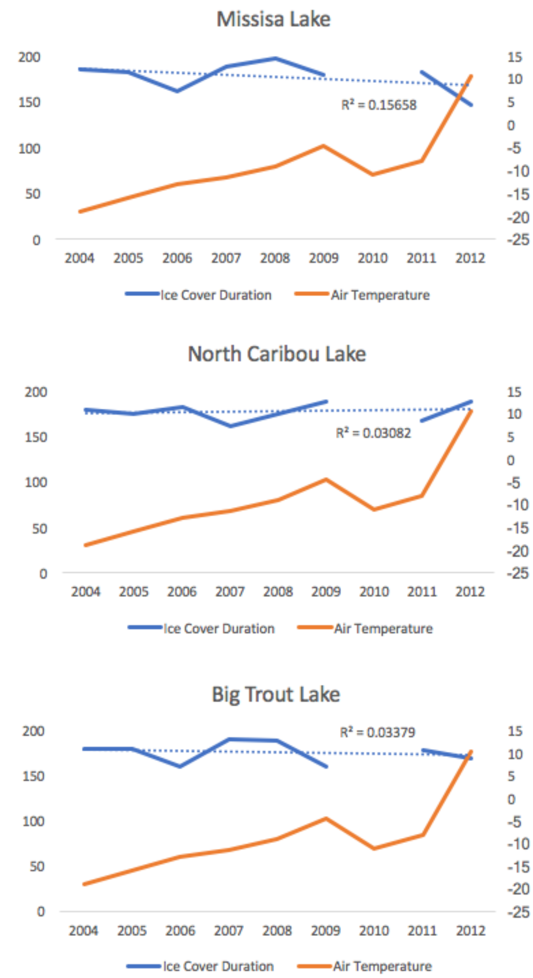

Figure 2. *Northern Ontario lake data comparing ice duration to temperature across an eight-year period. A line of best fit was placed in each graph to provide a visual placeholder for the missing data.*

data used, where eight years of data is not a sufficient amount of information. The data available from the National Snow and Ice Data Centre (NSIDC) and the Canadian Cryospheric Information Network (CCIN) was limited to short periods of ice data, from 2004-2009 and 2011 – 2012. These periods of data were the most consistent and current of any available data.

5. Conclusion

Although there was not a statistically significant correlation between air temperature and ice duration, this study demonstrated that there was not enough sufficient and consistent recorded ice data available. Additionally, this study suggests the impacts that the Harper government era had on the collection of data in each lake. Planning for the future, this study should be done again with more long-term ice data from the past and current years and more lakes from Ontario.

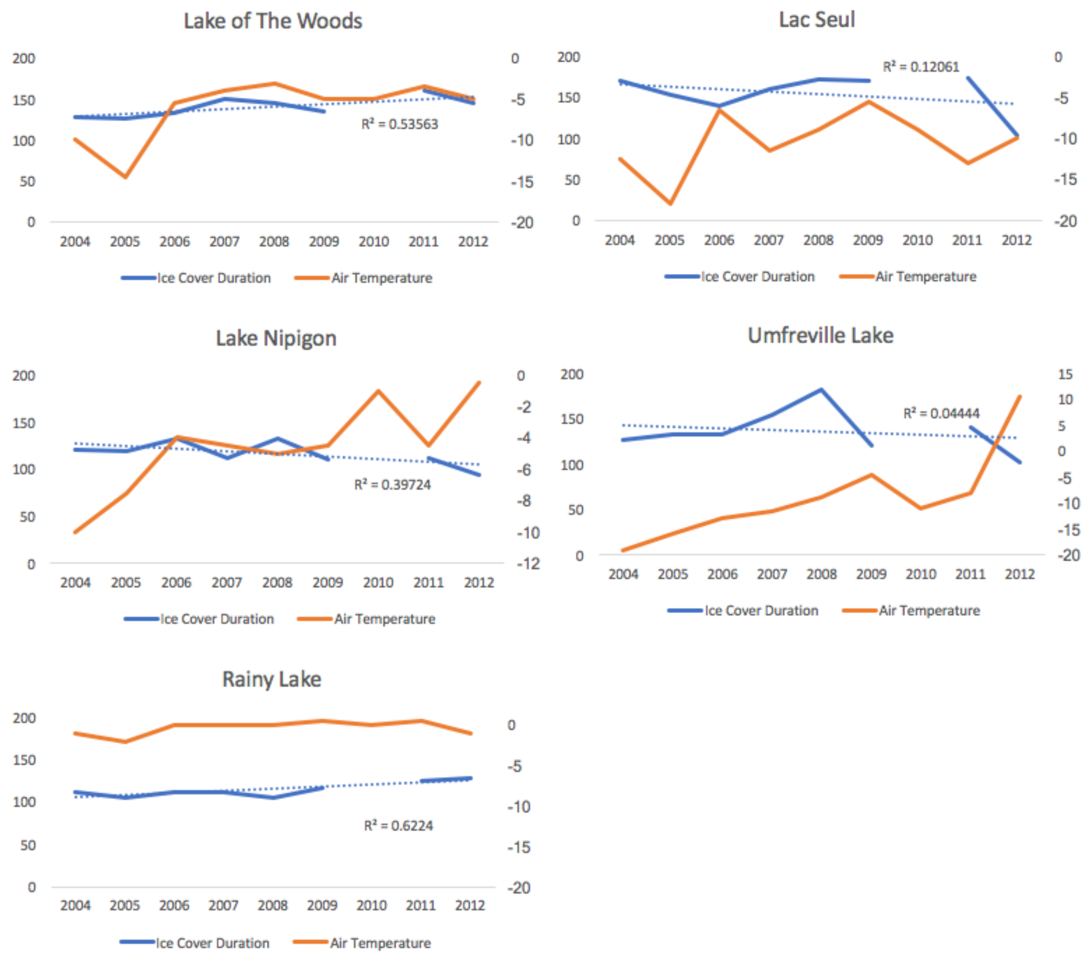

Figure 3. *Western Ontario lake data comparing ice duration to temperature across an eight-year period. A line of best fit was placed in each graph to provide a visual placeholder for the missing data.*

Table 1. *The Twelve Lakes studied in order by lowest (southern) latitudes to highest (northern) latitudes with corresponding p-values.*

Lake	P Value	Latitude (°N)	Area (km^2)
Simcoe	0.550	44.463	744
Gull Lake	0.488	44.852	206
Nipissing	0.595	46.273	832
Trout Lake	0.510	46.314	348.1
Rainy Lake	0.445	48.385	932
Lake of the Woods	0.110	49.198	3150
Lake Nipigon	0.587	49.723	4848
Umfreville	0.539	50.249	215
Lac Seul	0.525	50.332	1657
Messisa	0.521	52.328	183
North Caribou	0.108	52.957	95.75
Big Trout	0.491	53.758	661

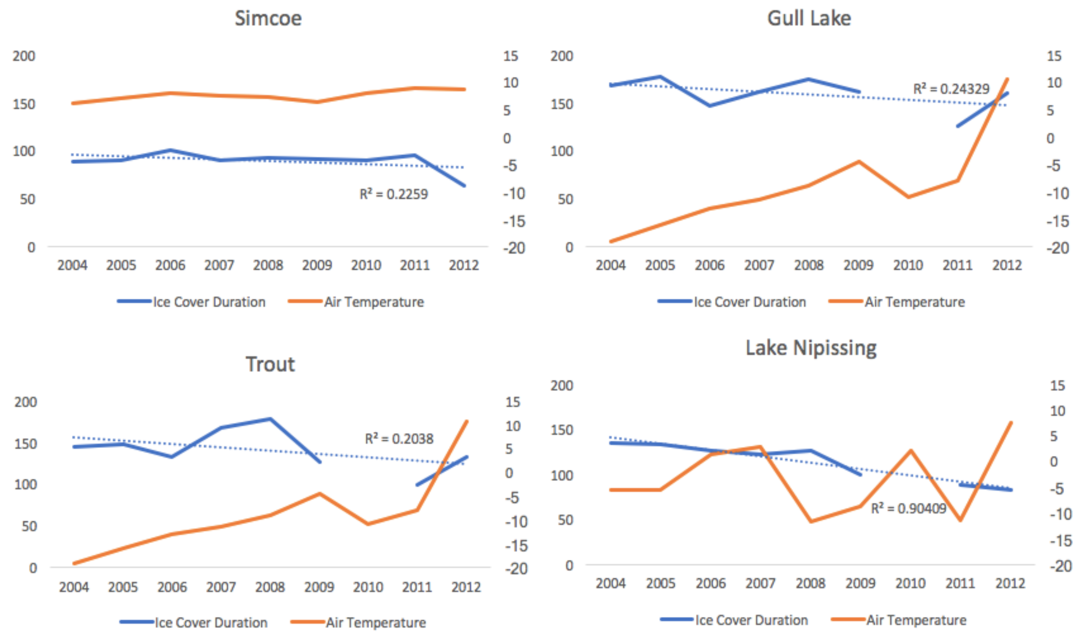

Figure 4. *Southern Ontario lake data comparing ice duration to temperature across an eight-year period. A line of best fit was placed in each graph to provide a visual placeholder for the missing data.*

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