An Evaluation of the Suitability of the Unsupervised K-Means Algorithm to Detect Total Lake Ice Breakup at Great Slave Lake, Northwest Territories

1) Introduction

The rise of northern hemispheric temperatures have illustrated a tendency of climate warming which has the ability to have drastic consequences on the natural systems that rely on climate for their structure and function[1] [2]. It has also been found that one of the most recognizable changes caused by rising temperature is the regime of ice on lakes throughout the winter period [3]. As a result of this claim, it is relevant and pertinent that policymakers and scientists have access to data which illustrates temporal changes in freshwater lake ice phenology.

2) Study Area

Great Slave Lake (GSL) is situated in the Mackenzie River Basin in Northwest Territories, Canada. GSL is the 10th largest lake in the world, and the 5th largest lake in North America [5]. GSL is fed by several rivers, including the Slave River in the south. The Mackenzie River drains lake water in the west, which eventually flows into the Arctic Ocean [5]. GSL is also frozen for over 8 months each year from about mid-October to mid-June [6]. Specifically, this study considered the pixel on the lake near Yellowknife, Northwest Territories where a weather station can be found. Selecting one pixel, located at 62.2100, -114.2100, was pertinent in this study due to the one-dimensional nature of the CLIMo

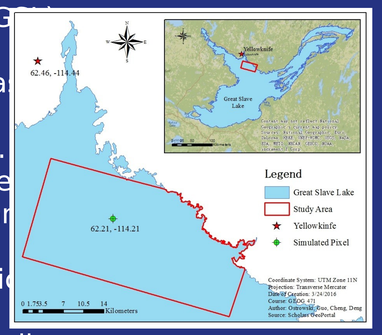

Figure 1 – GSL Region of Interest Map

3) Objectives

- Execute the K-Means classification algorithm on Great Slave Lake near Yellowknife, NWT from April to July for 2008-2012 inclusive to determine if it is a suitable computation for detecting total breakup of lake ice
- Evaluate classification results using CLIMo ice thickness and snow depth, and MODIS lake surface temperature data
- Produce a time-series analysis to determine how lake ice is changing on a long-term temporal scale
- Enumerate the ways in which stakeholders such as scientists and policymakers can use the time-series analysis to understand climate change

4) Methodology

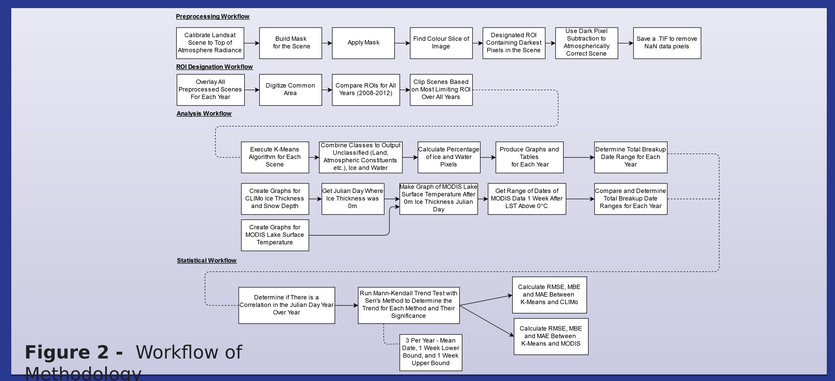

Figure 2 - Workflow of Methodology

5) Data

Satellite images used for this project were captured using the Landsat 5 TM and Landsat 7 ETM+ platforms. Landsat images were acquired from the USGS EarthExplorer website for the April to July period from 2008 to 2012 to run the unsupervised K-Means classification. CLIMo ice thickness, snow depth & Julian Day of breakup were used to compare to the output of the K-Means algorithm. Additionally, MODIS Lake Surface Temperature (LST) data was used alongside CLIMo output data. Both CLIMo and MODIS LST data were acquired from Dr. Kheyrollah-Pour.

6) Results

K-Means Classification Derived Breakup Dates

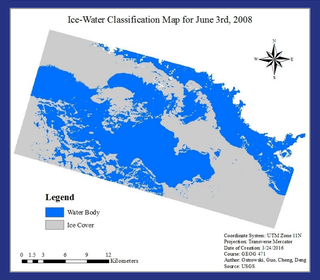

Figure 3 – Sample Classification

Each classification after combining classes output water, and ice pixels and atmospheric haze were removed the classifications, total breakup dates derived for the K-Means classification

- 2008 - 03/06/2008 to 22/07/2008
- 2009 - 06/06/2009 to 07/07/2009
- 2010 - 01/06/2010 to 17/06/2010
- 2011 - 20/06/2011 to 30/07/2011
- 2012 - 30/05/2012 to 22/06/2012

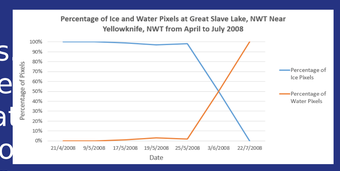

Figure 4 – Percentage Coverage for Ice and Water Surfaces

CLIMo & MODIS Derived Breakup

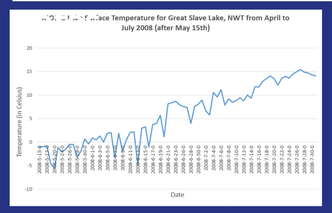

Figure 5 – MODIS LST After CLIMo Breakup Date

Breakup using MODIS LST data was determined by deriving the CLIMo breakup date for each year where ice thickness reached 0 metres. MODIS breakup was derived as a range when LST was above 0°C for 1 week.

Table 1 – Results of Mann-Kendall Test & Sen's

Year	CLIMo	MODIS (lower bound)	MODIS (upper bound)	K-Means (lower bound)	K-Means (upper bound)
p-value of Mann-Kendall Test	0.233	0.817	0.817	0.817	0.483
Sen's slope	-1.25	-1.583	-1.583	-0.75	-8

Table 2 – Comparison of

	RMSE	MAE	MBE
MODIS vs. K-Means	15.33	12.80	10.13
CLIMo vs. K-Means	31.47	30.20	-30.20

Statistical Results

Sen's slope was negative for each method indicating that breakup happened earlier each year. The Mann-Kendall test indicates that the trends were not significant. The K-Means and MODIS methods are most closely aligned in their prediction of breakup. The K-Means classification yielded earlier dates than MODIS yet later dates than CLIMo

7) Discussion & Conclusion

was found to be a suitable method of predicting total lake ice breakup with predictive accuracy of approximately one month. It was unable to detect total lake ice breakup down to the exact date as proven by the RMSE, MAE and MBE it had with the evaluator methods (CLIMo and MODIS LST data). This level of predictive accuracy could be attributed to both data and algorithmic limitations. This greater level of inaccuracy means that the use case of the results must be evaluated before they are employed, and who the stakeholders are must be considered. Further improvements to this study include using data with higher temporal resolution, and the employment of in-situ data to generate confusion matrices. Future studies should be conducted using a greater variety of lakes and climates, and using a longer duration of 20 years or greater to determine if the algorithm is truly suitable for this application.

ENVIRONMENT

References

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