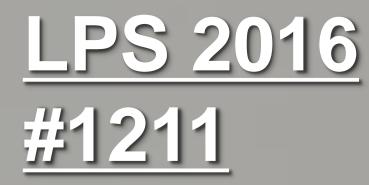# Improvement of lake ice thickness retrieval from MODIS satellite data using a thermodynamic model

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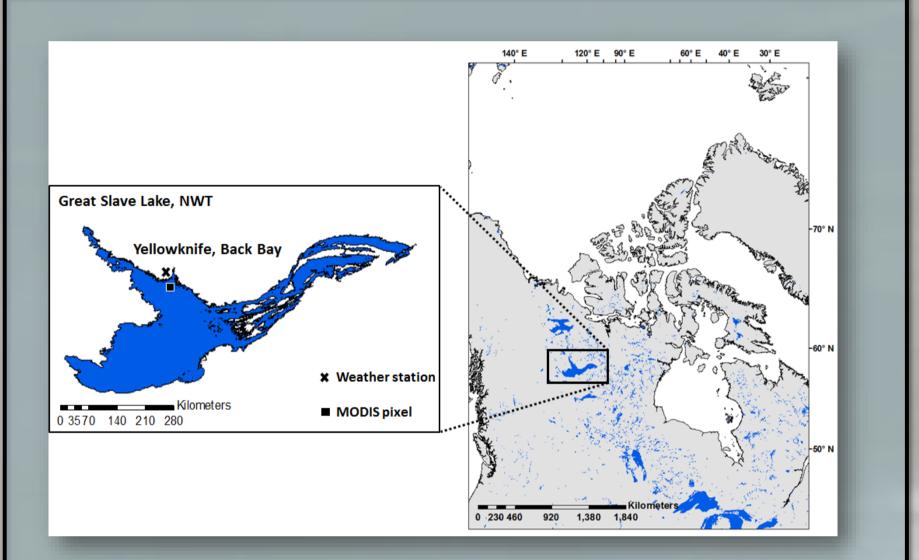K. Andrea Scott[2] (*ka3scott@uwaterloo.ca*), and Kyung-Kuk (Kevin) Kang[1] (*kev.kang@uwaterloo.ca*)

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Introduction

Knowledge of sea/lake ice thickness and the overlying snow cover is an important requirement when addressing interactions between the sea/lake and the atmosphere during winter at high latitudes. In particular, ice thickness and snow depth over seas and inland water bodies reduce the heat flux from the relatively warm water to the cold atmosphere [1]. The heterogeneity of ice thickness and depth of snow on ice leads to variations in thermal properties of the ice and snow, which in turn lead to variations in the heat flux [2]. Estimation of the amount of heat exchange between the sea/lake and the atmosphere, which is essential in numerical weather prediction and climate modeling, requires accurate information of ice thickness and on-ice snow depth. Despite the above noted requirement, knowledge about sea/lake ice thickness around the globe is remarkably limited. This is mainly due to difficulties in collecting measurements of ice thickness directly. In this study, a new approach is proposed using Lake Ice Surface Temperature (LIST) from the Moderate Resolution Imaging Spectroradiometer (MODIS). The approach is developed and evaluated over Great Slave Lake, NWT, Canada. Ice thickness is estimated for 12 ice seasons (2002-2014) and the accuracy of the retrieved ice thickness is compared with in situ observations from the Canadian Ice Service. The objectives of this paper are to: 1) improve the accuracy of ice thickness retrievals from MODIS LIST using the surface heat balance equation, and 2) assess the applicability of the new method to estimate lake ice thickness from MODIS LIST data greater than in previous studies (ca. 50 cm). This study contributes to work on thermal imagery-based ice thickness retrieval where snow depth data over lake ice is not available.

Study area

Great Slave Lake (GSL) is the second largest lake of the Mackenzie River Basin, NWT, Canada. The lake is large and deep, with the mean and maximum depth of 41-m and 614-m, respectively, and the area of 27,000 km². The lake is covered by ice usually from November to April. (Figure 1).
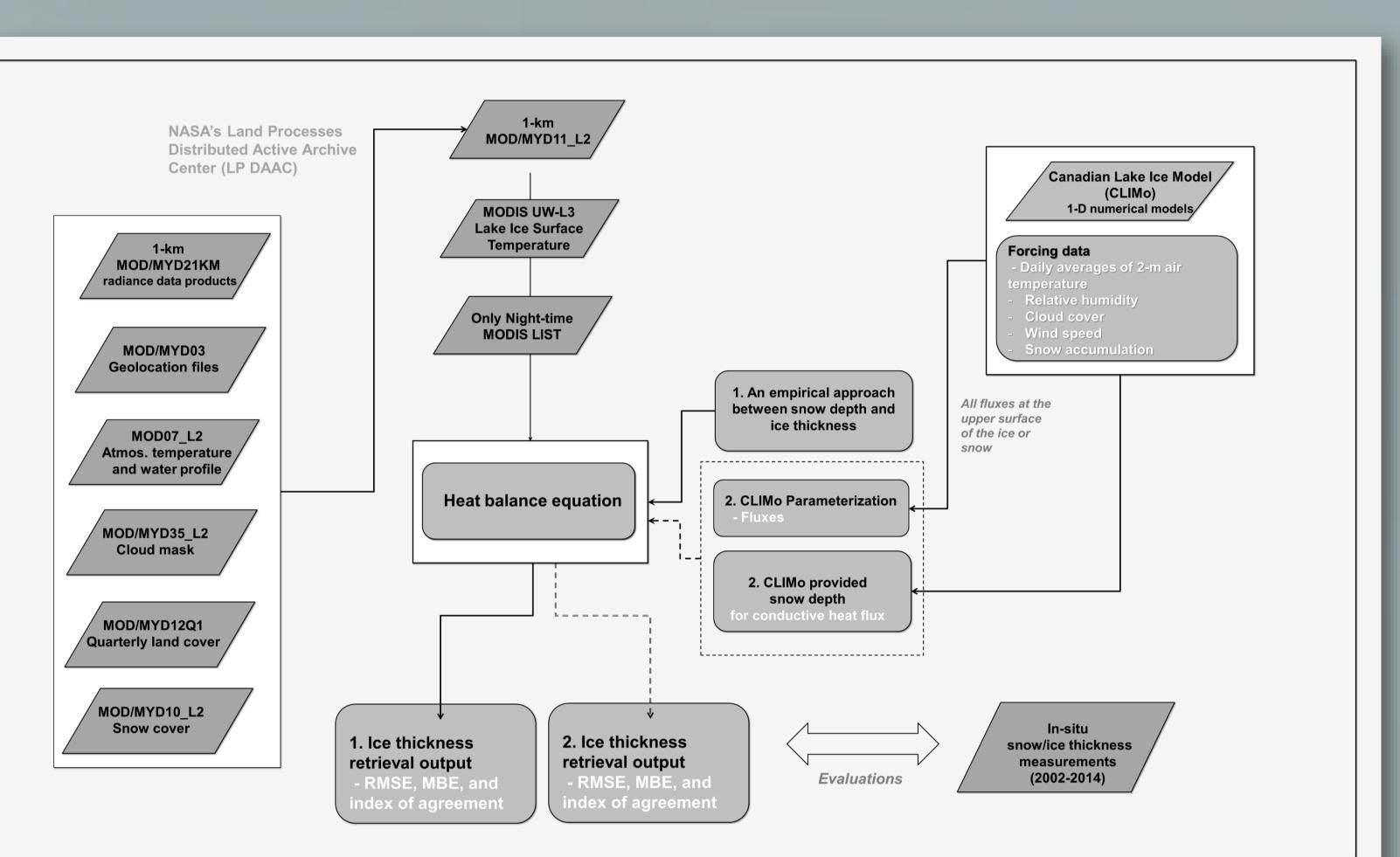

Figure 1: Maps showing the location of Great Slave Lake (GSL), and MODIS pixel location, as well as the meteorological weather station (Back Bay), Yellowknife, NWT, Canada.

Data and methods

Figure 2: Flowchart of ice thickness retrieval using MODIS-LIST products.

Results

Ice thickness is estimated using first, an empirical relationship between snow depth and ice thickness as well as using a prognostically calculated snow depth provided by Canadian Lake Ice Model (CLIMo). Both methods use heat fluxes calculated from CLIMo, except for the conductive flux, which is calculated independently (**Figure 3**).

Figure 4 shows the variations in ice thickness obtained with the two methods. MODIS indicates relatively thicker ice than in situ measurements for years 2006-2009 and 2011. MODIS estimated ice thicknesses from ice seasons 2004-2005 and 2006-2007 are compared to those measured in the field (**Figure 5**). Retrieving ice thickness using the surface heat balance equation depends highly on snow depth.
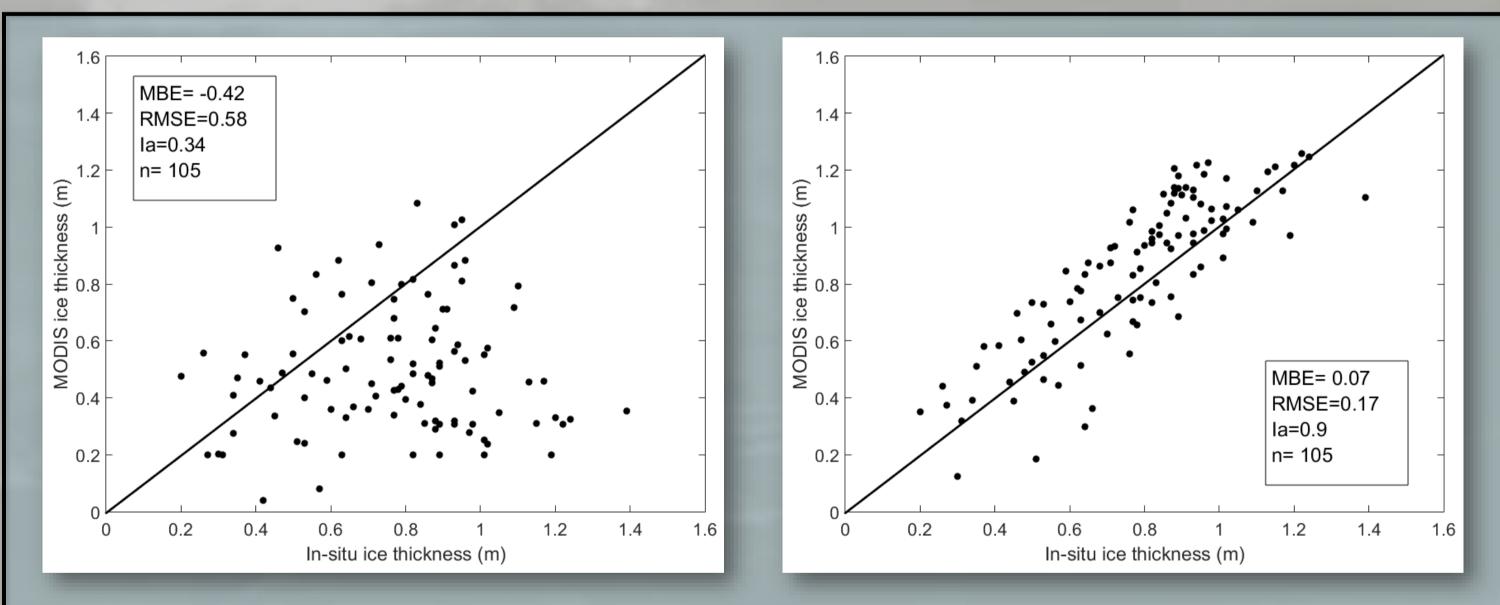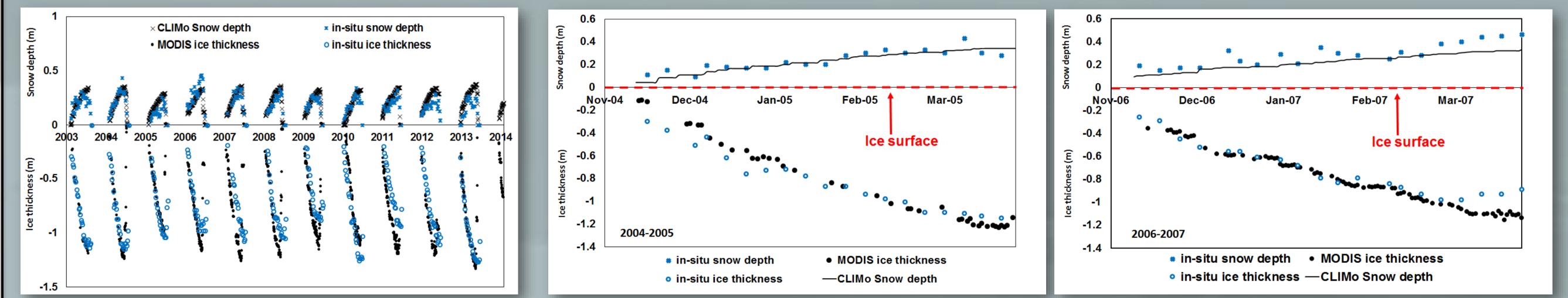

Figure. 3: Comparison of estimated ice thickness from MODIS with in situ ice thickness measurements, Back Bay, Great Slave Lake (left) using empirical relationship between snow depths and ice thickness (right) with CLIMo parameterization.
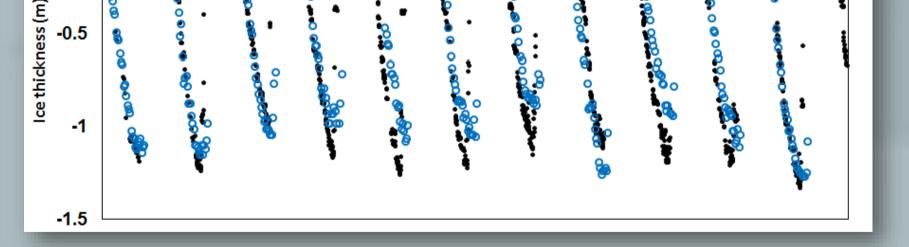

Figure. 4: Time series of estimated ice thickness from MODIS and simulated snow depth from CLIMo model (black) in comparison with the in situ measurements from CID (blue), Back Bay, Great Slave Lake.

Figure 5: Comparison of in situ and calculated snow depth (CLIMo) and ice thickness (MODIS) for winter seasons 2004-2005 (left panel) and 2006-2007 (right panel), Back Bay, Great Slave Lake.

Summary

✓ **T**his study investigated the estimation of ice thickness from MODIS LIST using two different methods of incorporating snow depth information in the ice thickness retrieval.

✓ Results show an improvement of ice thickness estimation, reducing the MBE by 0.35 m, when using snow depth from CLIMo in comparison to the approach using an empirical relationship between snow depth and ice thickness.

✓ The present study demonstrates that when more accurate snow depth information is available, the thickness of ice up to 1.2 m can be estimated. Previous studies using a similar approach for sea ice typically report limited accuracies of ice thickness for ice thicker than 0.5 m, with lack of knowledge of the snow depth as a plausible cause.

✓ Due to the spatial resolution of 1 km, the ice thickness from MODIS may be useful in regions where relatively high spatial resolution is required. The main limitations of using LIST from MODIS to determine ice thickness is that the number of clear-sky pixels may be limited.

✓ Further evaluations of the retrieval algorithm are planned over the entire area of GSL as well as the Laurentian Great Lakes.

References

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