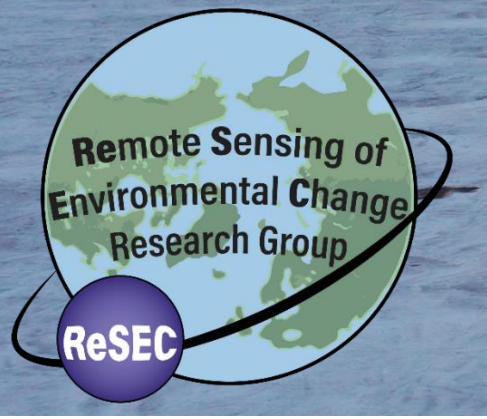
Advancing Modeling of Lake Ice Thickness and Phenology in High-Latitude Regions

Homa Kheyrollah Pour

G. Attiah, K.A. Scott, C.R. Duguay



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7th LAKES Workshop / 20-21-22 November / Milan
Parameterization of Lakes in Numerical Weather Prediction and Climate Modelling 2024

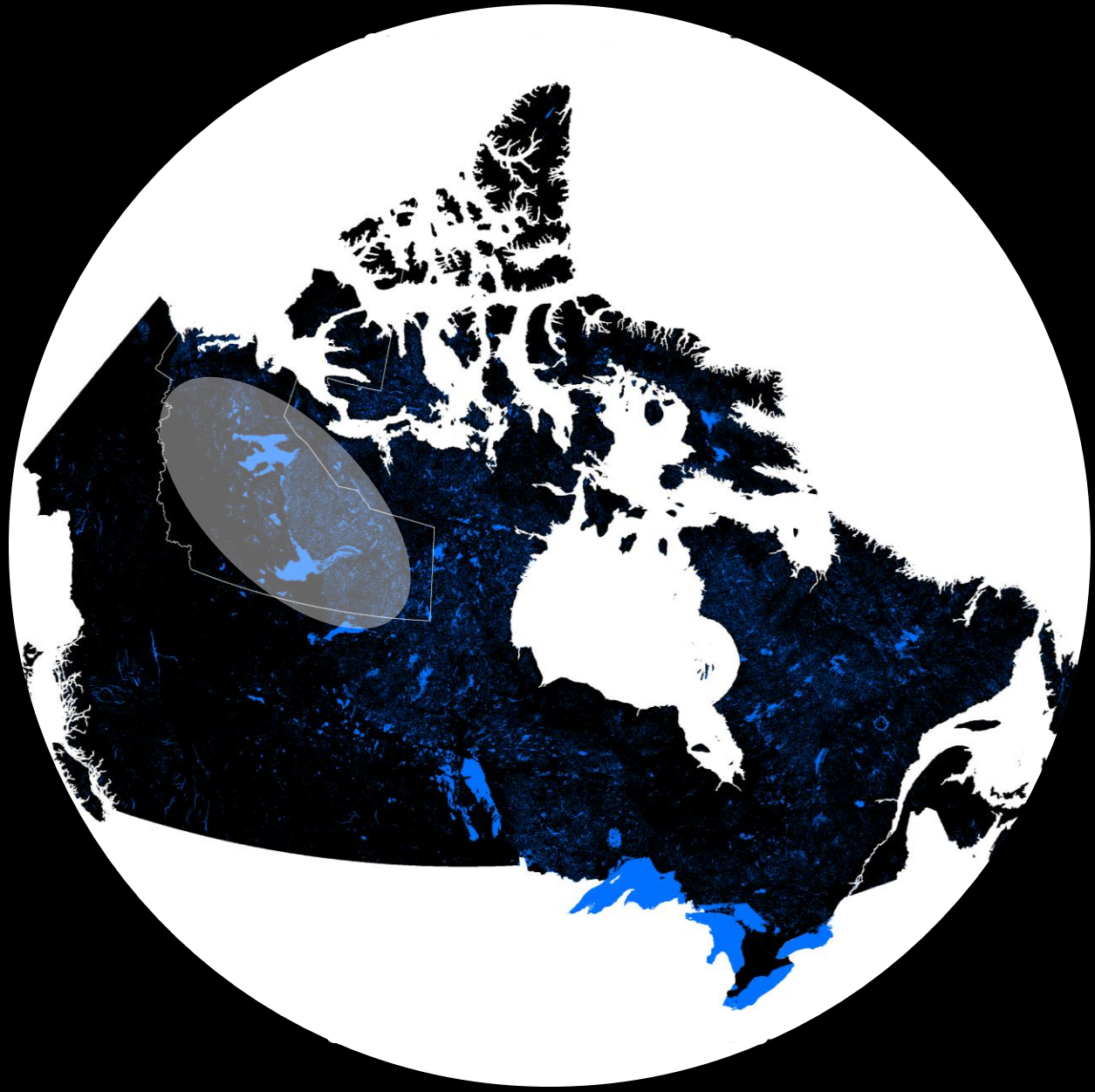
Lakes in Canada & Northwest Territories (NWT)

~2 million Lakes in Canada

>160,000 Lakes in NWT

> 8% of Canadian Lakes

Lakes in Canada & Northwest Territories (NWT)

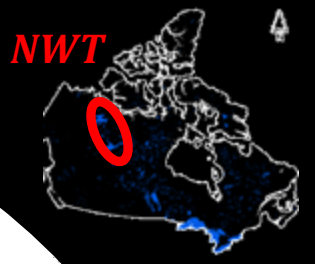


~2 million Lakes in Canada

>160,000 Lakes in NWT

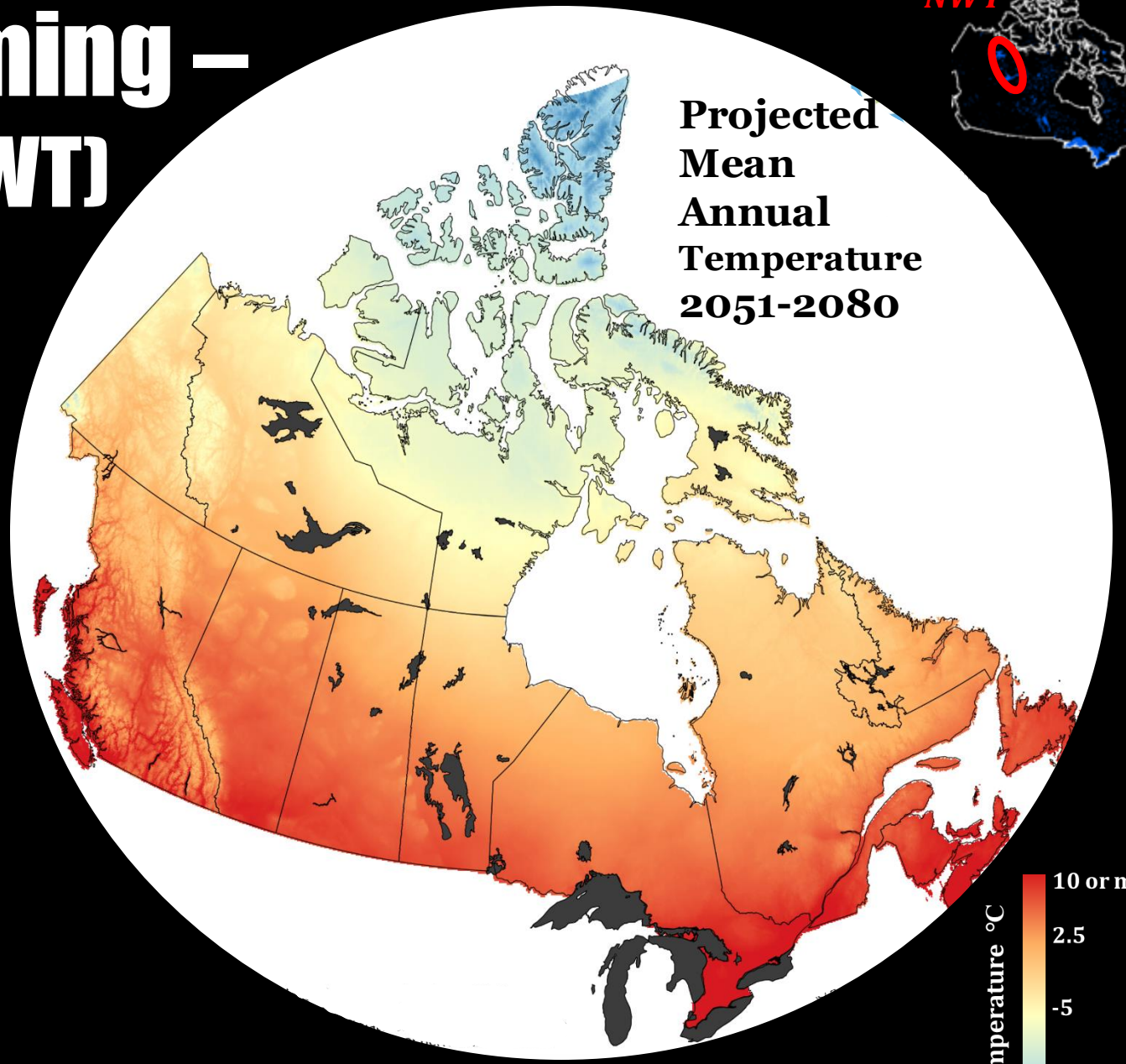
> 8% of Canadian Lakes

Winter Climate Warming – Northwest Territories (NWT)



NWT by 2080

- Annual Mean Temperature can increase by +5.6°C
- Winter Mean Temperature can increase by +7.8°C
- Winter Min Temperature can increase by +8.2°C



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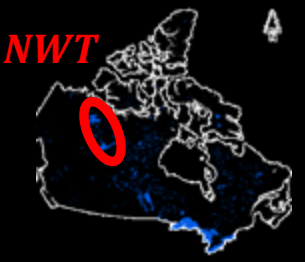
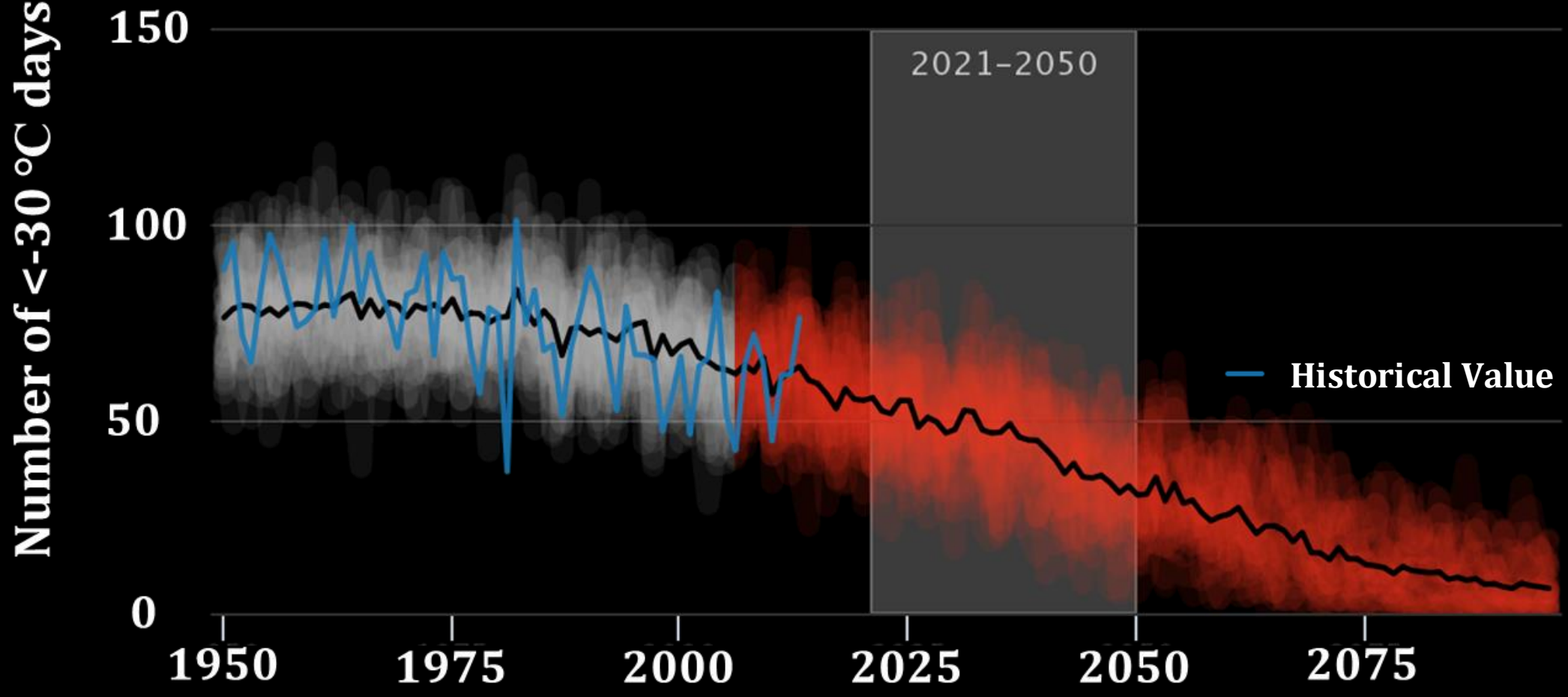
Winter Climate Warming – NWT





#< -30 ℃ days can decease 28 days by 2050

#< -30 ℃ days can decease 51 days by 2080

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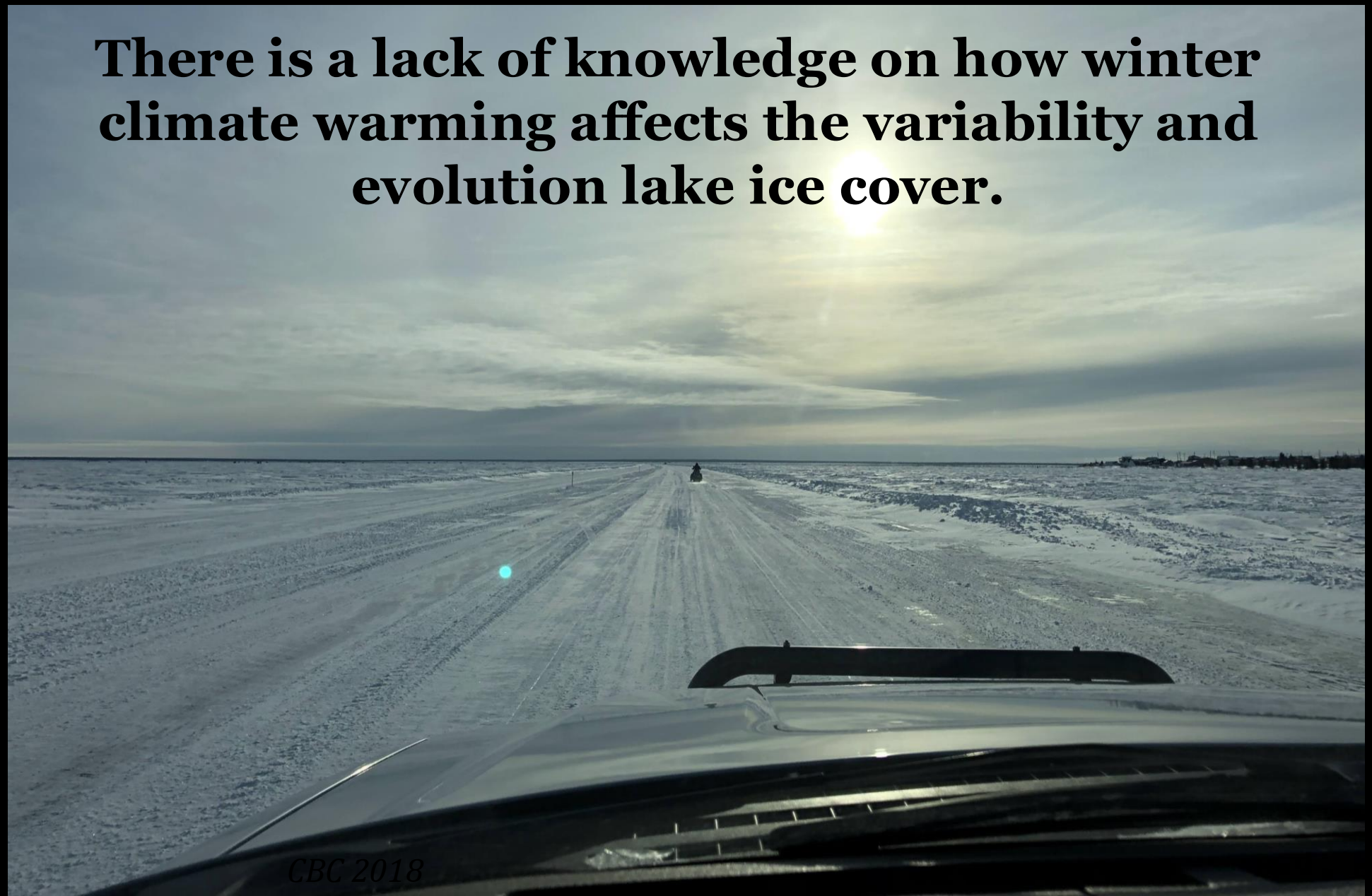
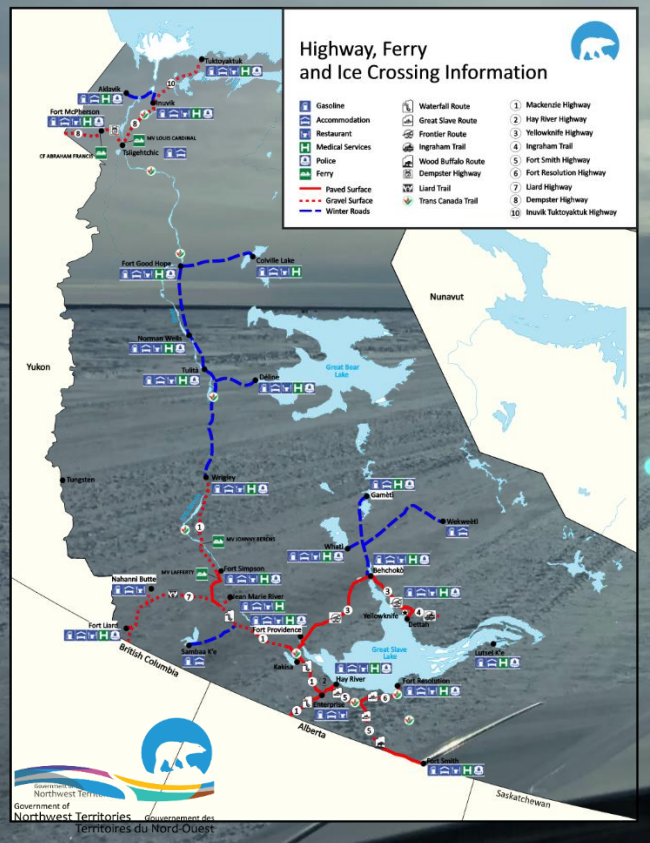
Climate Change & Ice Roads Safety



Climate Change & Ice Roads Safety

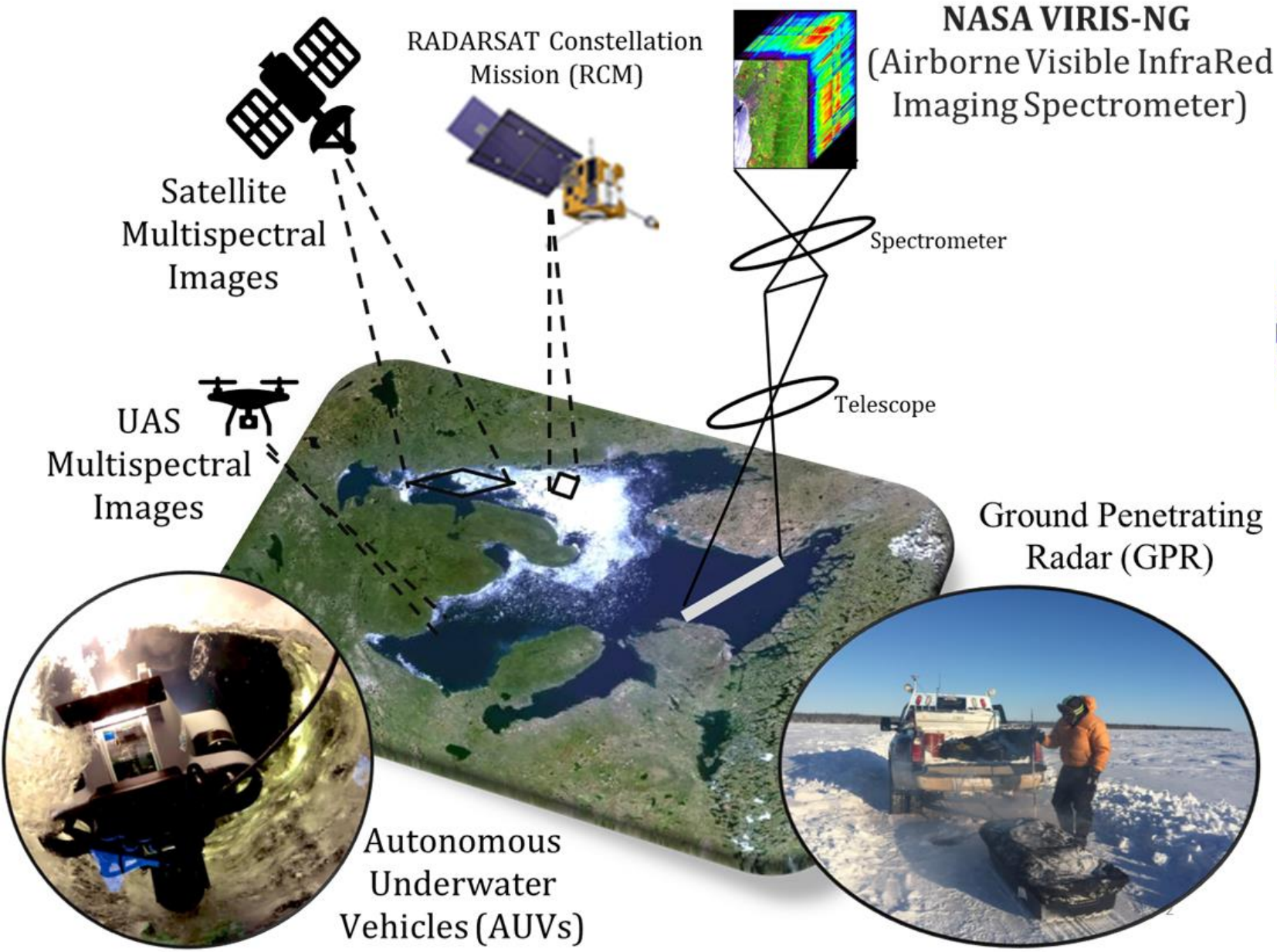
There is a lack of knowledge on how winter climate warming affects the variability and evolution lake ice cover.



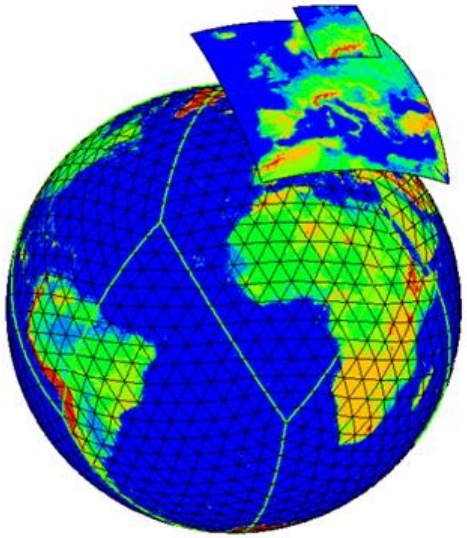
CBC 2018

CBC News

Multi-method Approach



Physical Models



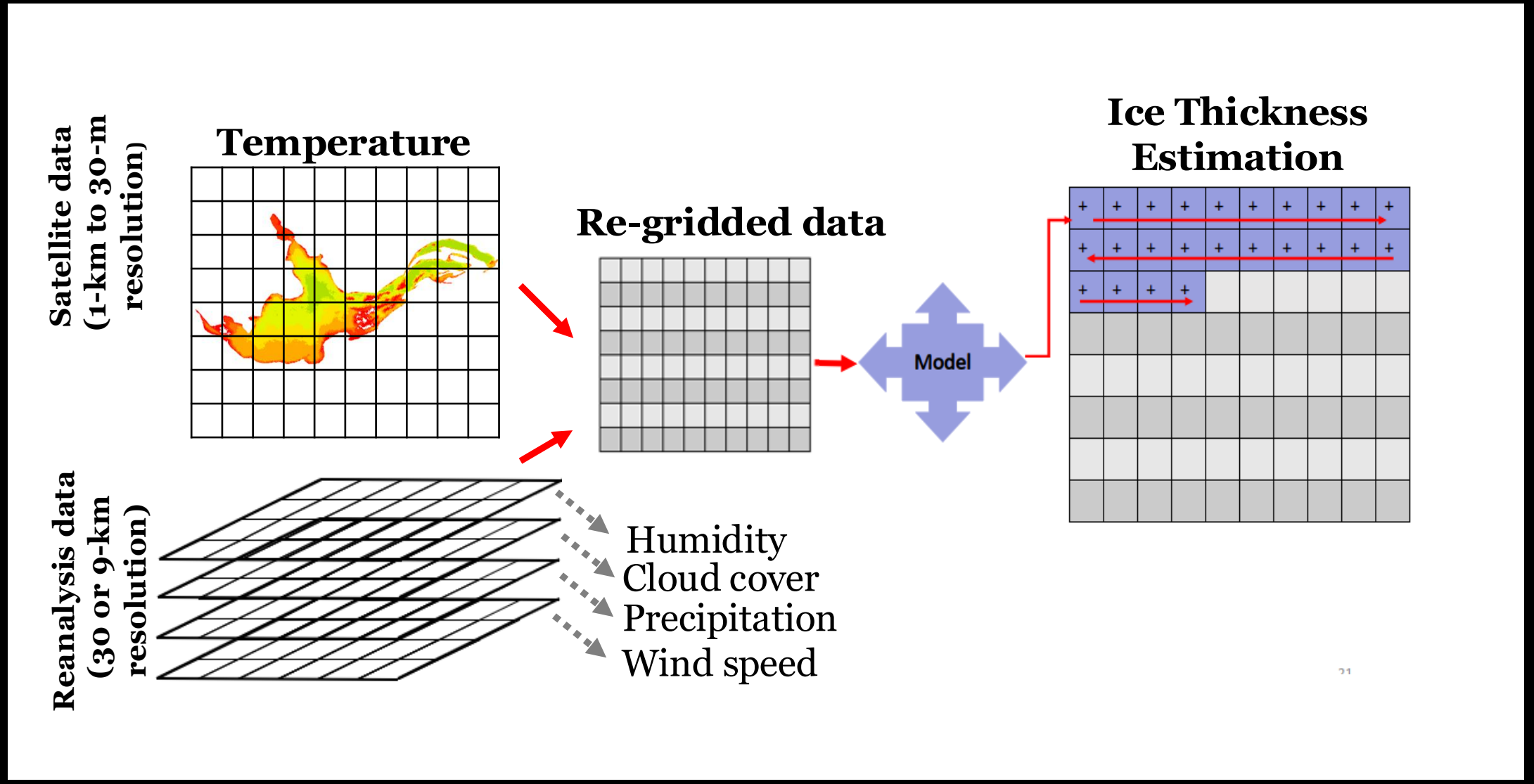
AI and Machine Learning Models

Traditional Knowledge (TK)

Ice Thickness

Great Bear Lake Ice (April 2022)

Canadian Lake Ice Model-Grid (CLIMoGrid Model)



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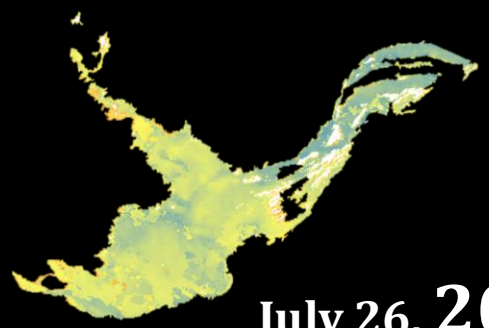
Lake Surface Temperature (LST)

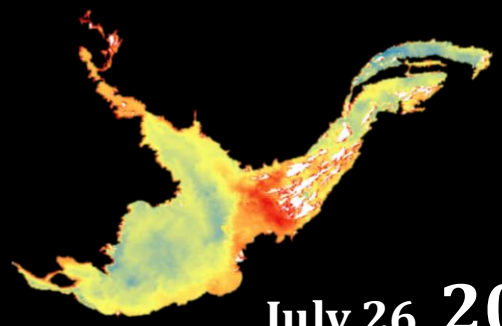
Great Bear Lake (June 2023)

Great Bear Lake (August 2023)

Satellite Derived – Monthly LST
Great Bear & Slave Lakes



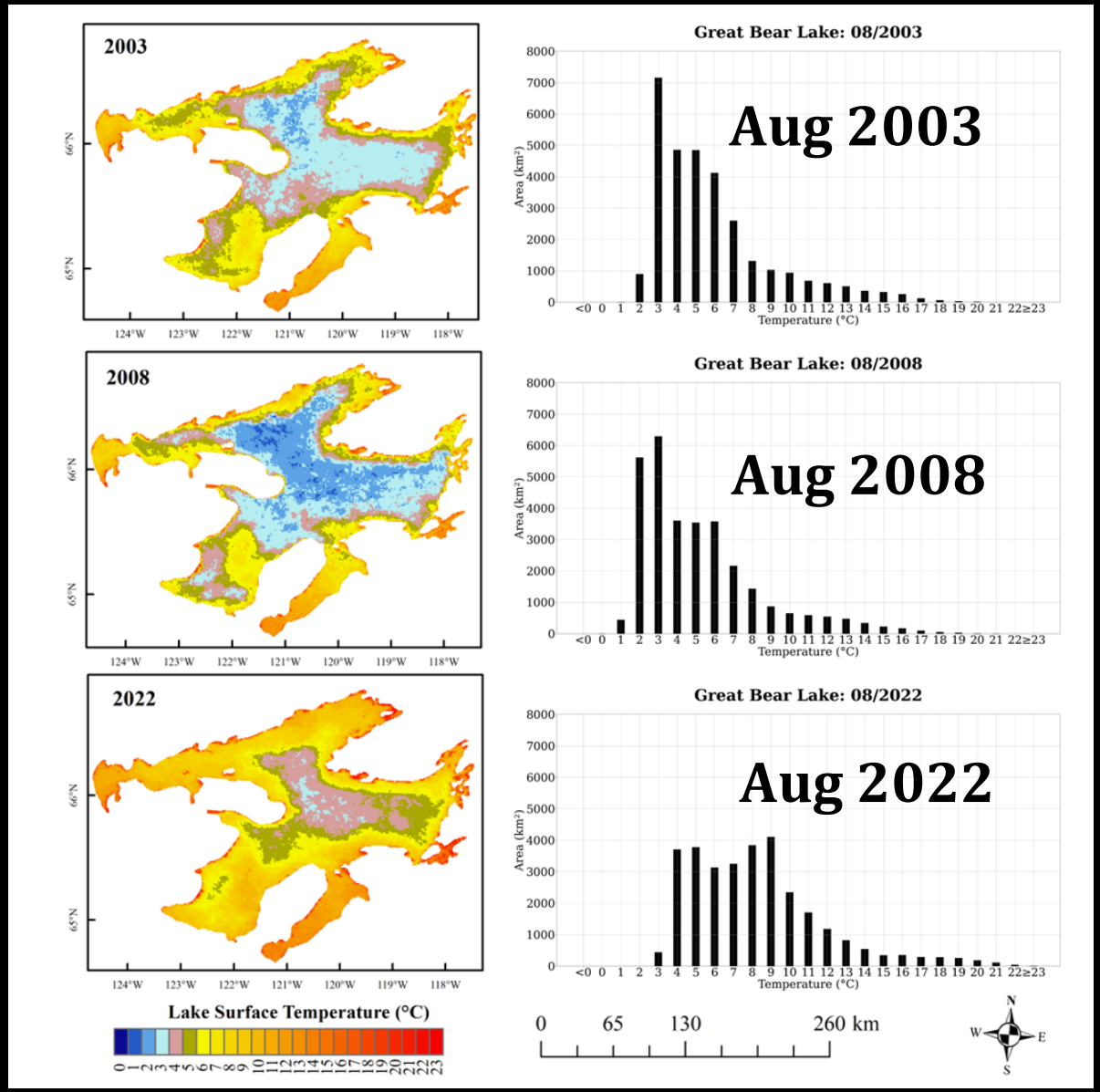
July 26, 2012



July 26, 2022

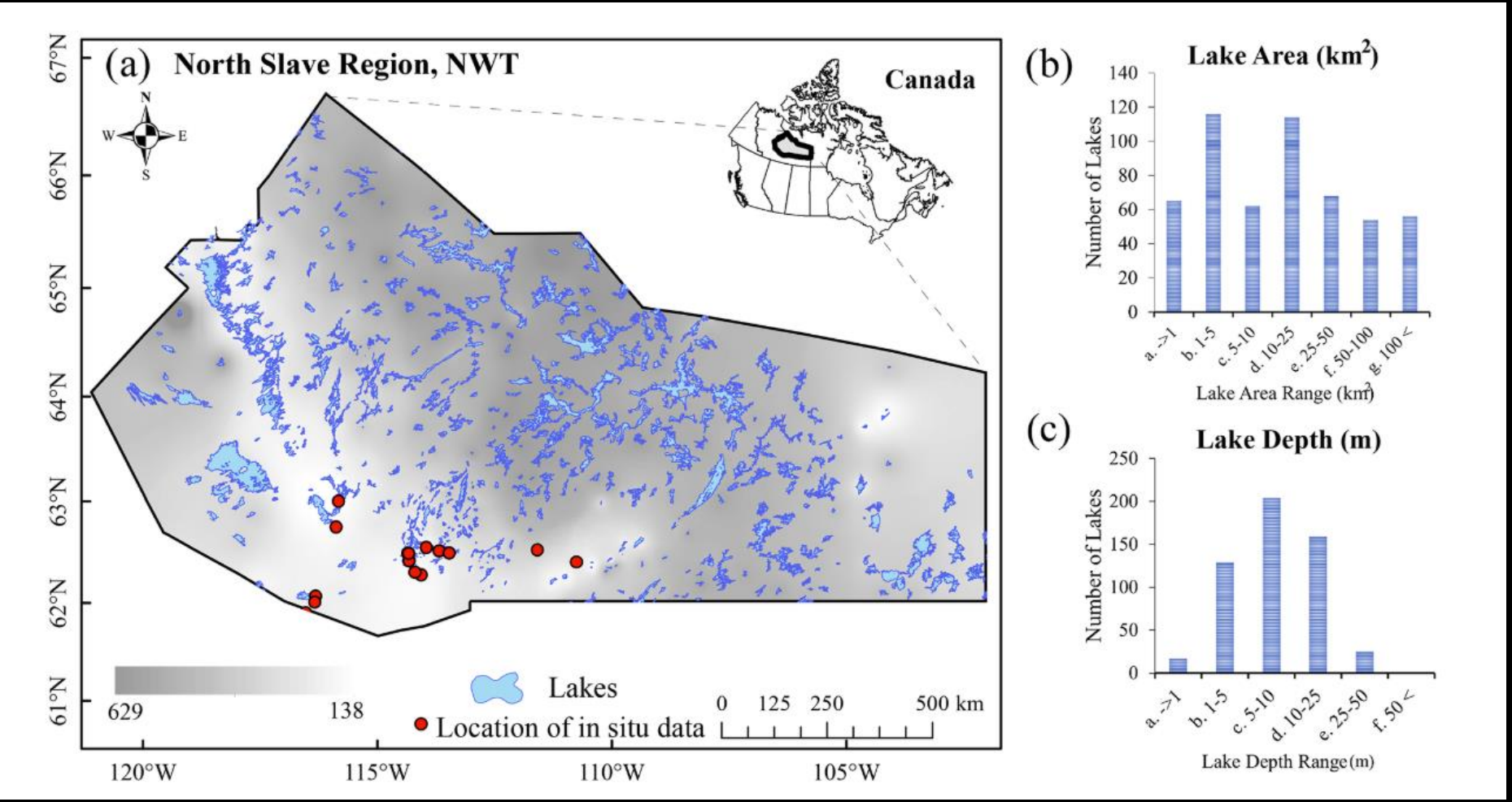
3 30

Lake Surface Temperature (°C)



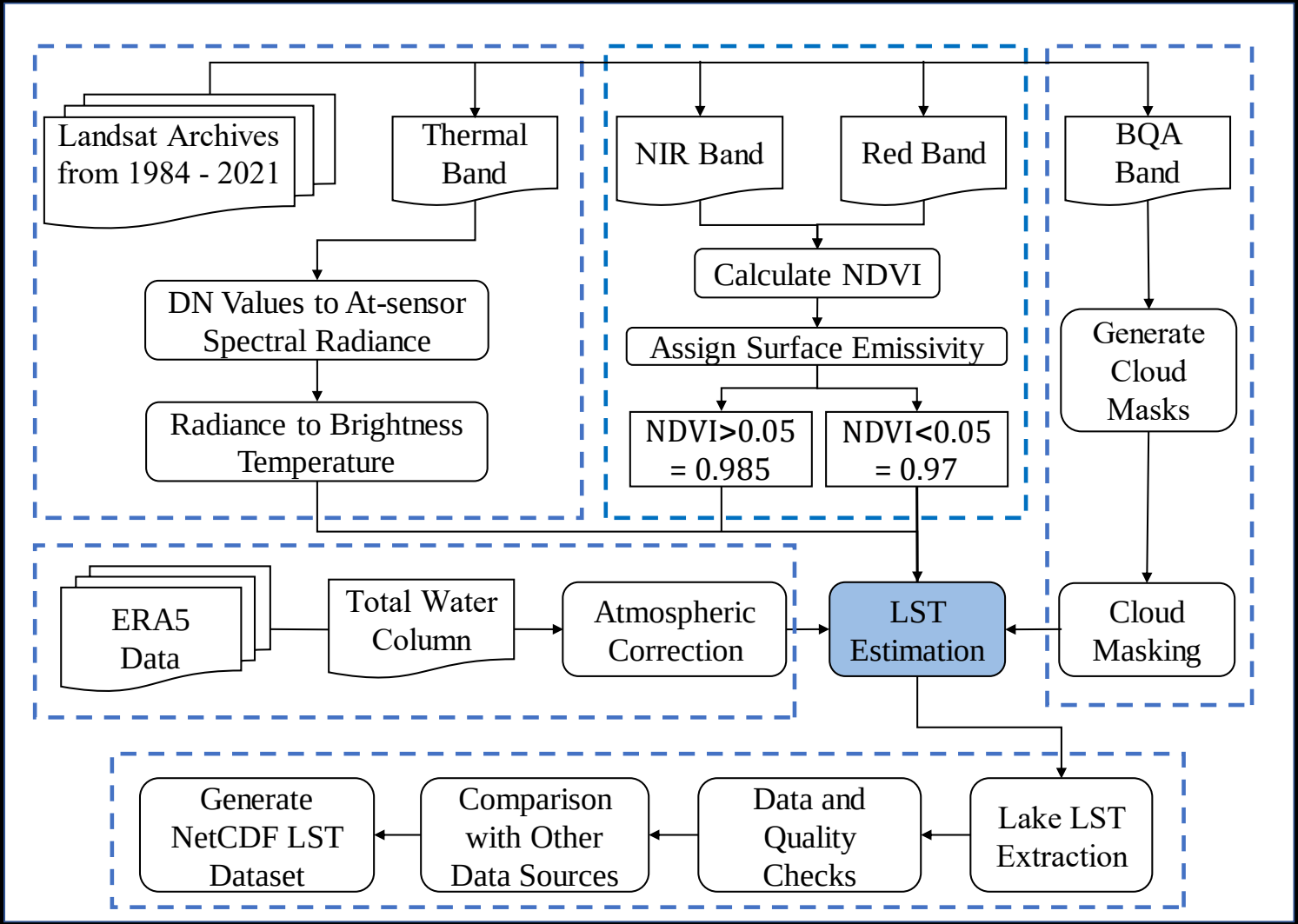
Carmack E., S. Vagle, and H. Kheyrollah Pour (2024) Journal of Geophysical Research - Earth Surface.

LST Retrieval from Landsat



LST algorithm for >500 sub-Artic lakes over the past four decades

LST Retrieval from Landsat



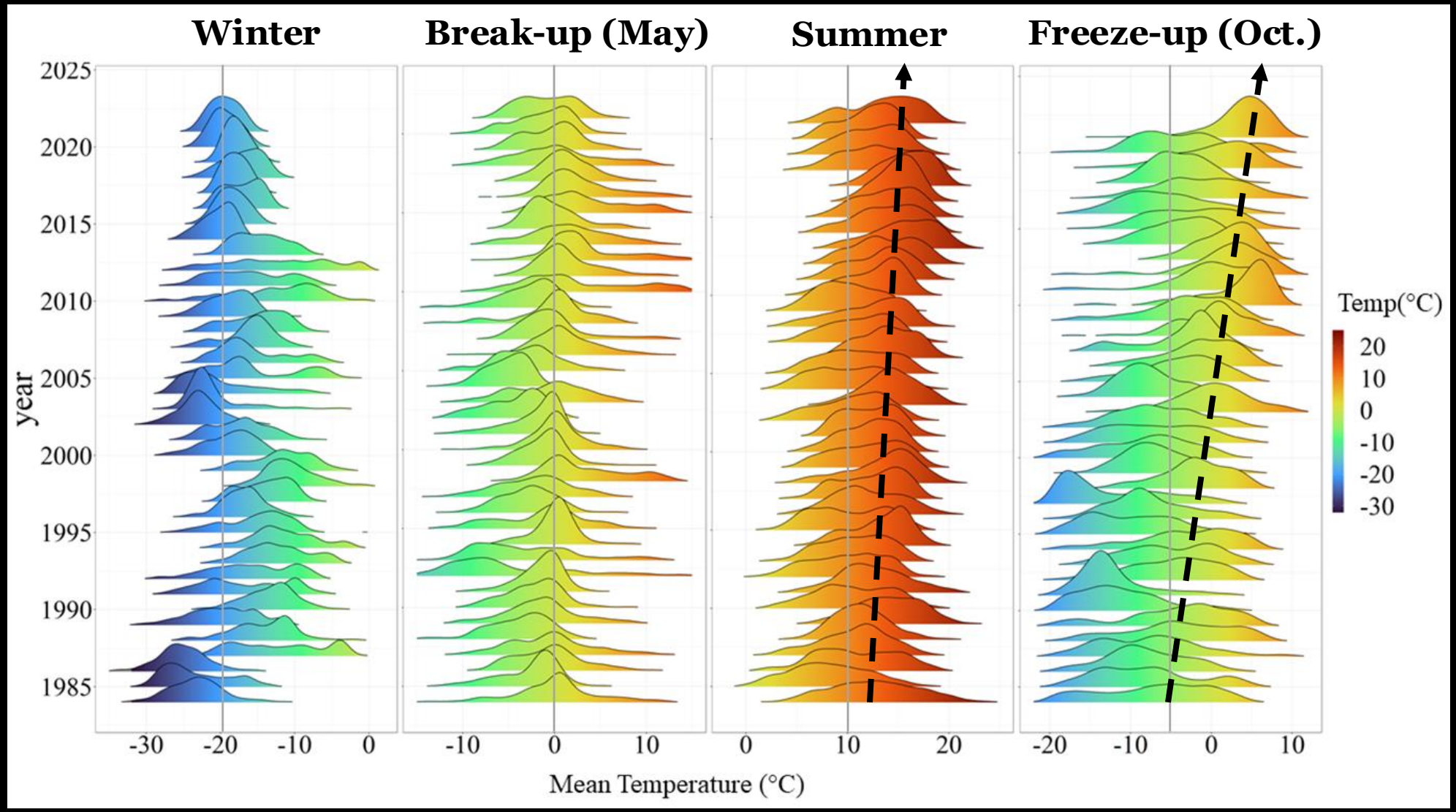
Retrieve LST from Landsat data (1984 to 2021)

Generate an open-access lake-specific LST dataset

Studying LST trends and spatial variability

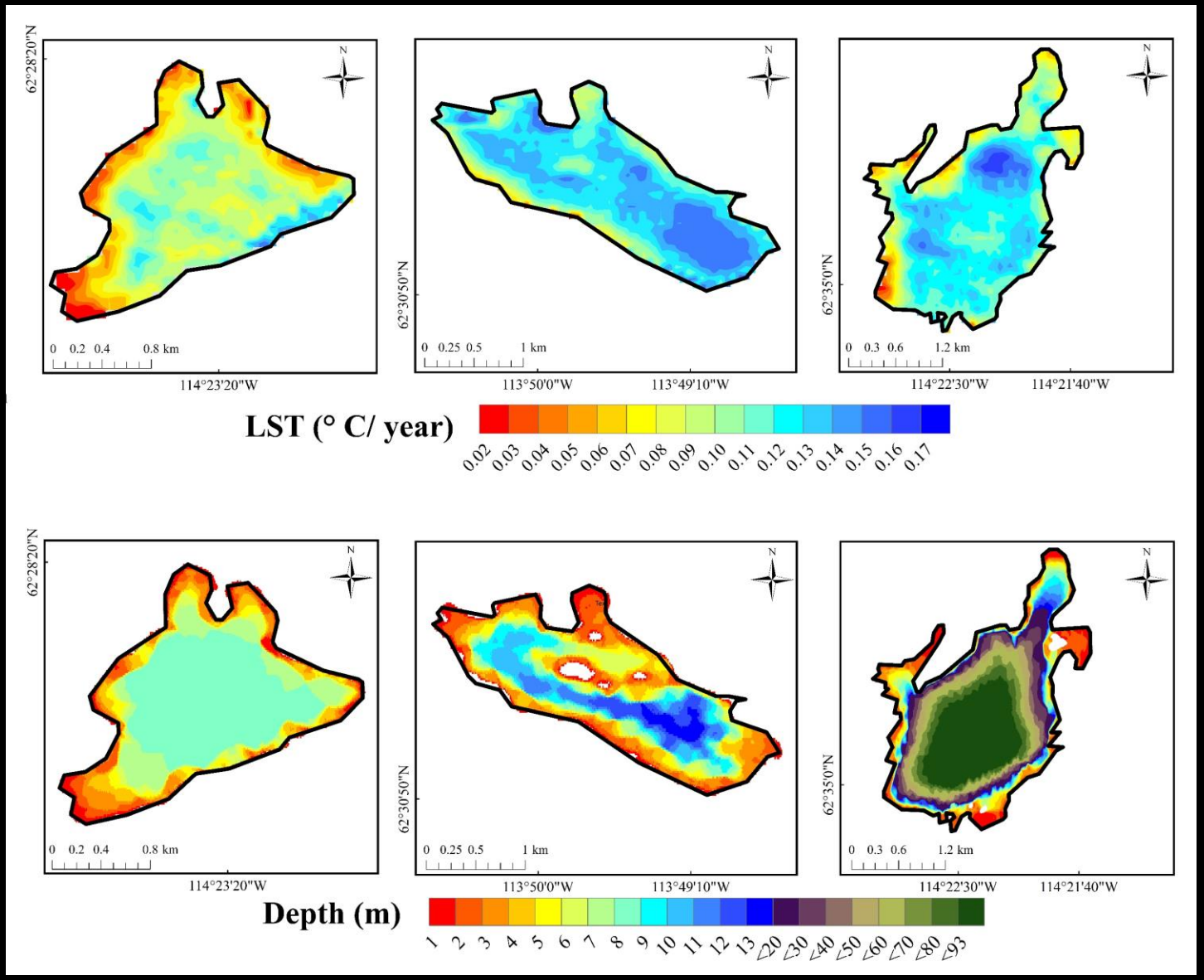
Attiah G., H. Kheyrollah Pour, K. A. Scott (2023a), Earth Syst. Sci. Data.

LST Seasonal Trends



Attiah G., H. Kheyrollah Pour, K.A. Scott (2023b), Journal oh Hydrology: Regional Studies.

LST Rate of Change



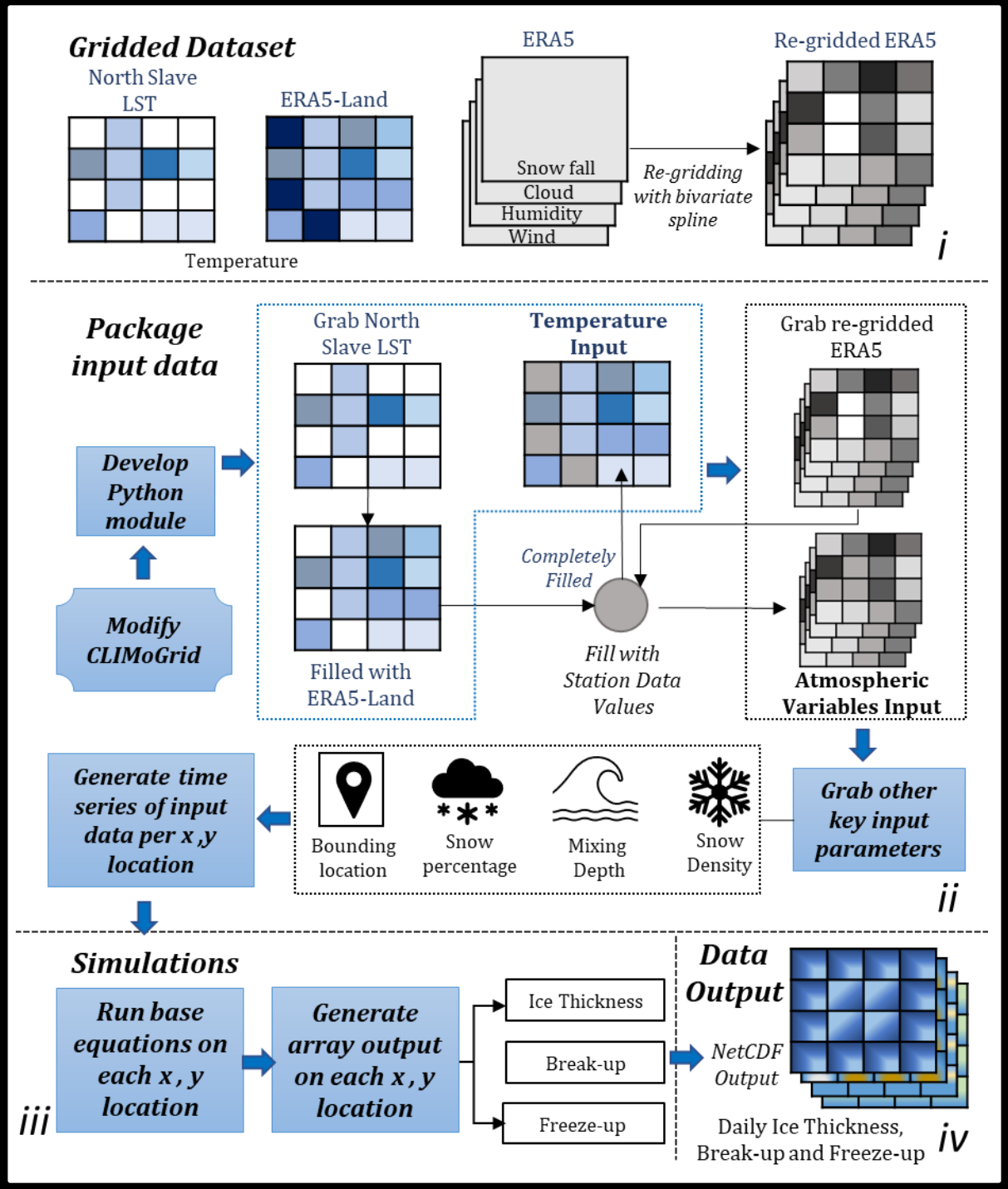
Attiah G., H. Kheyrollah Pour, K.A. Scott (2023b), Journal oh Hydrology: Regional Studies.

CLIMoGrid Model

For more details see poster

Spatially Distributed Modelling of Ice Thickness on Small and Medium Sub-Arctic Lakes

Gifty Attiah [1,2], K. Andrea Scott [3], Homa Kheyrollah Pour [1,2]
[1] Remote Sensing of Environmental Change (ReSEC) Research Group, Department of Geography and Environmental Studies
[2] Cold Regions Research Centre, Wilfrid Laurier University, Waterloo, Canada
[3] Department of Mechanical and Mechatronics Engineering, University of Waterloo, Waterloo, Canada

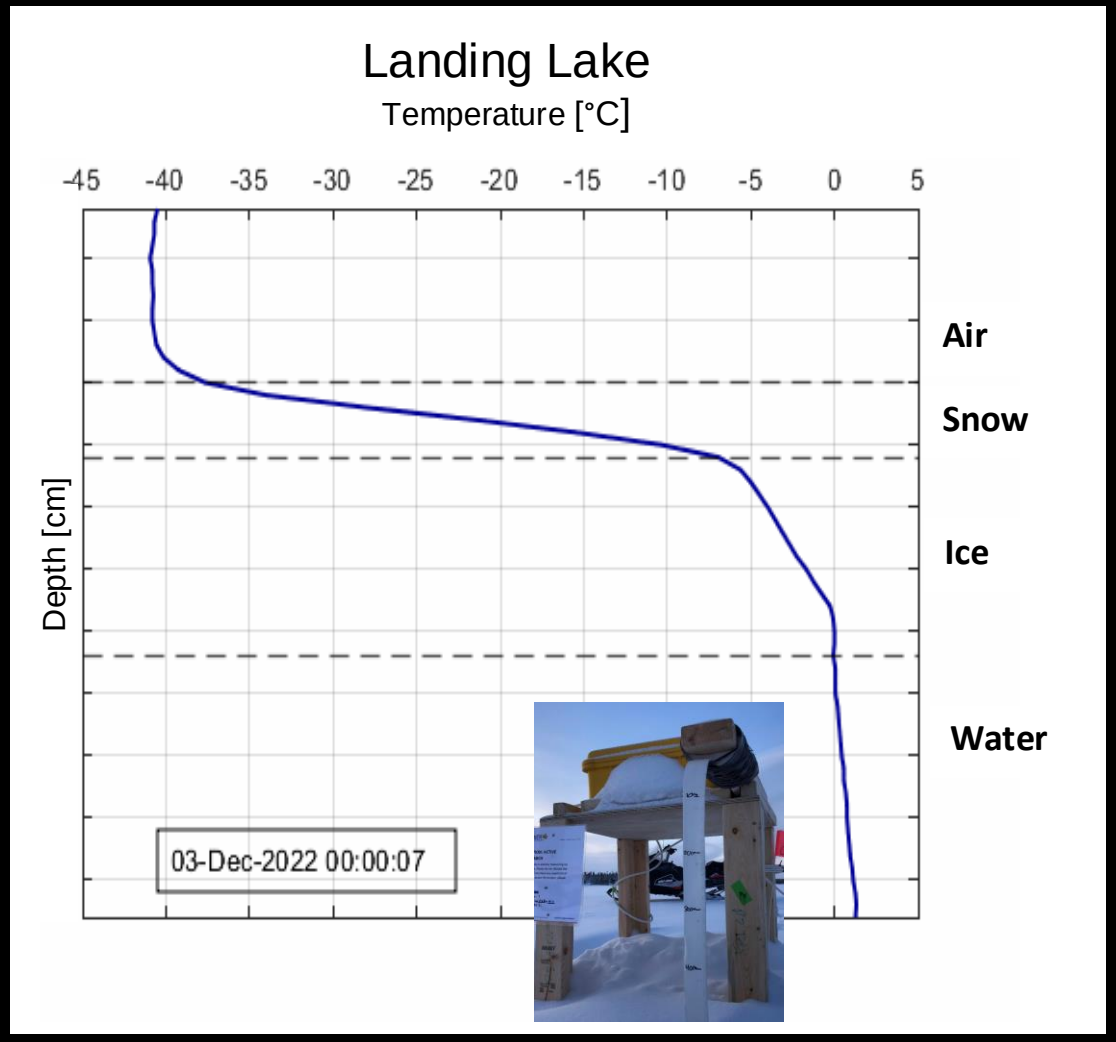


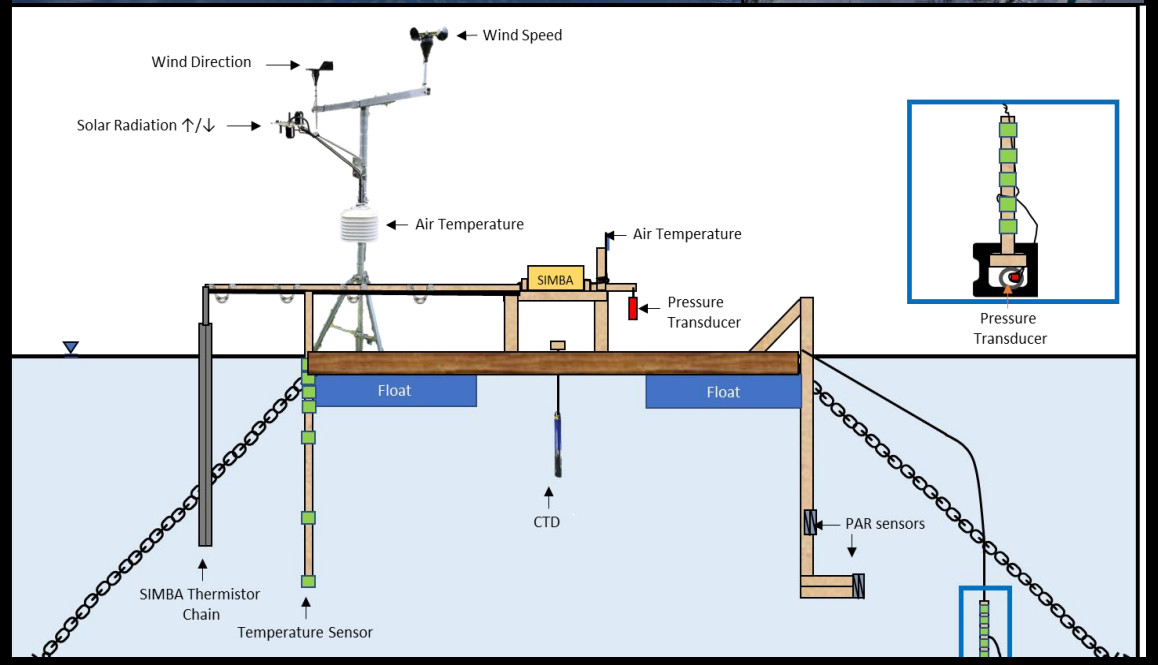
Real-time Lake Ice Monitoring

- **Great Bear Lake Délı̨nę Ice Road (×2)**
- **Great Slave Lake, Dettah Ice Road**
- **Great Slave Lake, Łutsel K’e (×2)**
- **Vee Lake Ice Road**
- **Landing Lake, Yellowknife**
- **Ryan Lake, Yellowknife**

8 Snow and Ice Mass Balance Apparatuses (SIMBA) stations in NWT

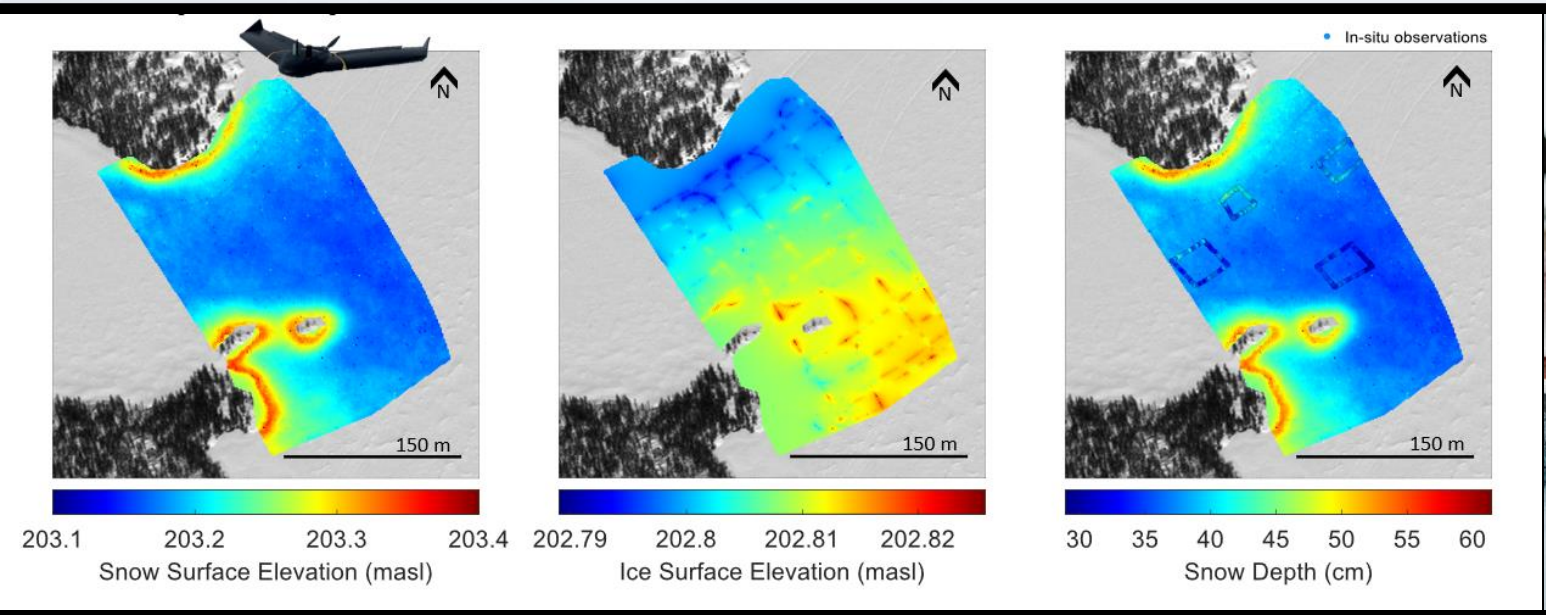
Real-time Year-Round Lake Monitoring





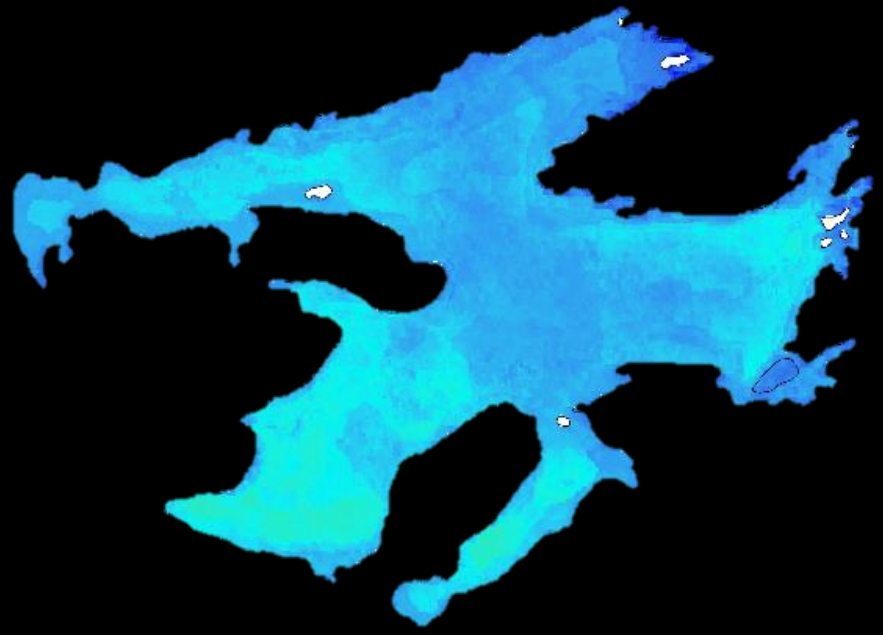
Rafat A., & H. Kheyrollah Pour et al., (2023), Journal of Cold Regions Science & Technology

Mapping Lake Snow depth, Ice Thickness & Ice elevation

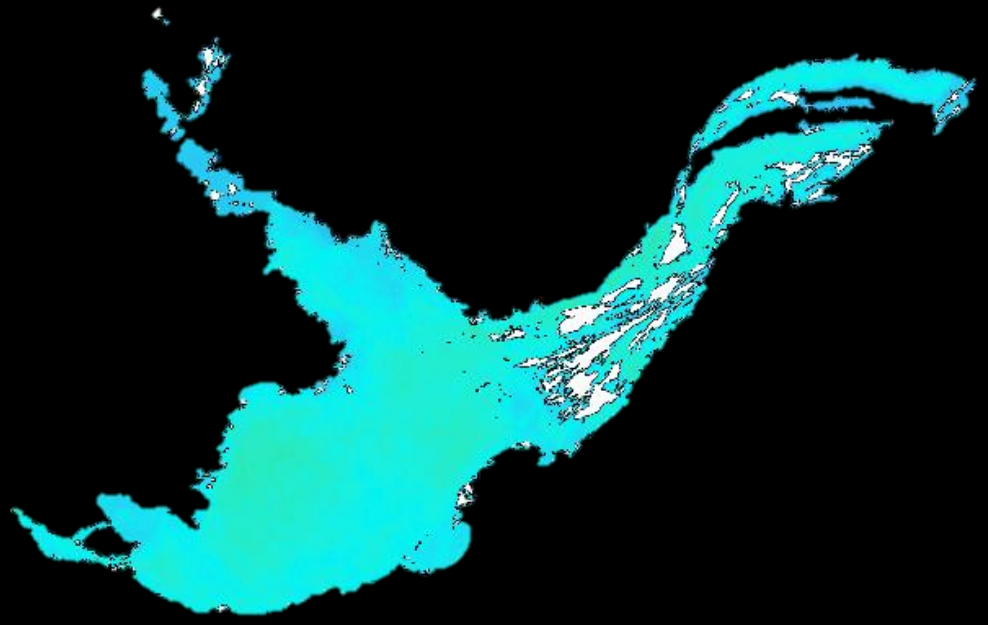


Pouw, A.F., H. Kheyrollah Pour, A. MacLean (2023), The Cryosphere

CLIMoGrid Model – Mean Yearly Ice Thickness



Great Bear Lake

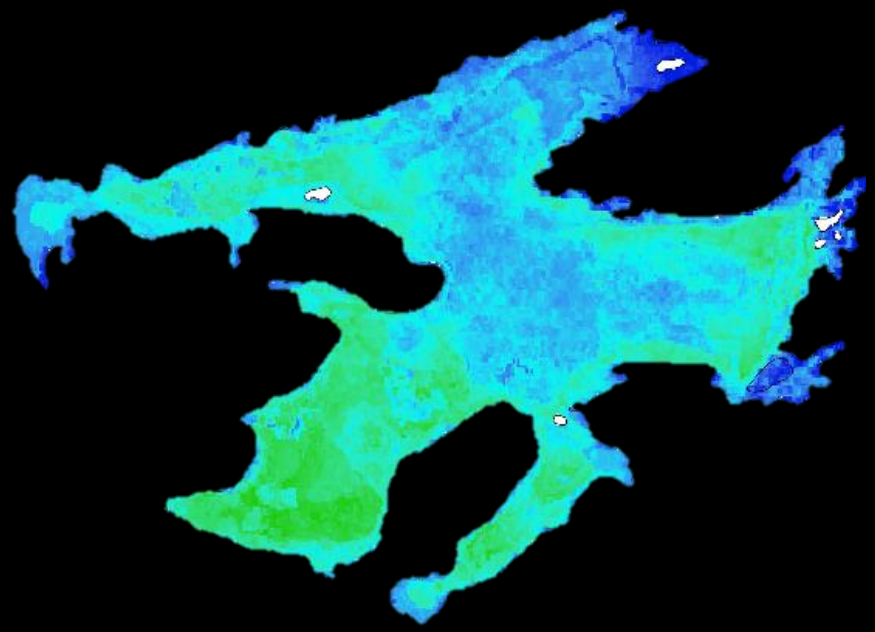


Great Slave Lake

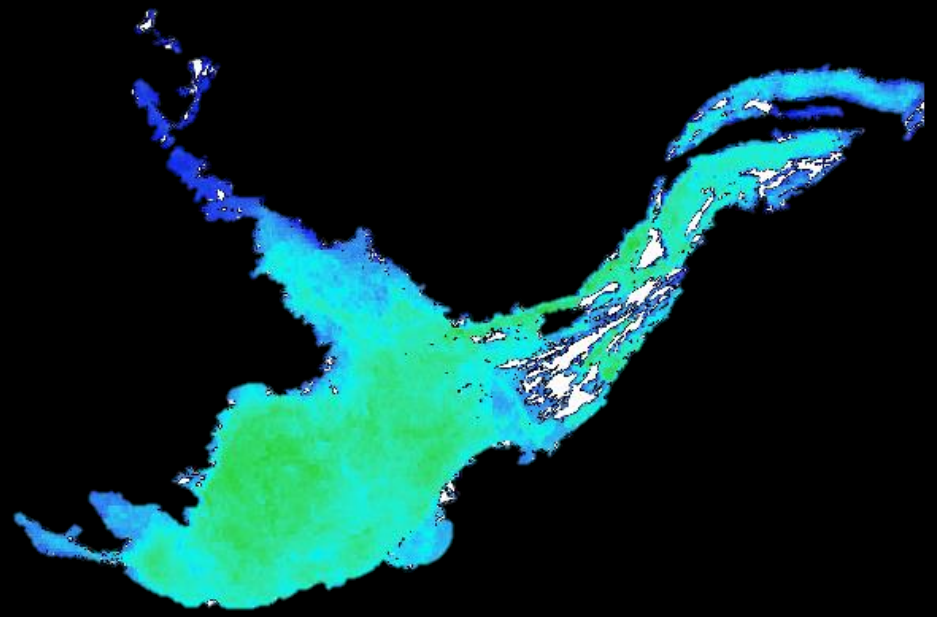
2003-2004

1 Ice Thickness (m) 1.5

CLIMoGrid Model – Daily Ice Thickness



Great Bear Lake

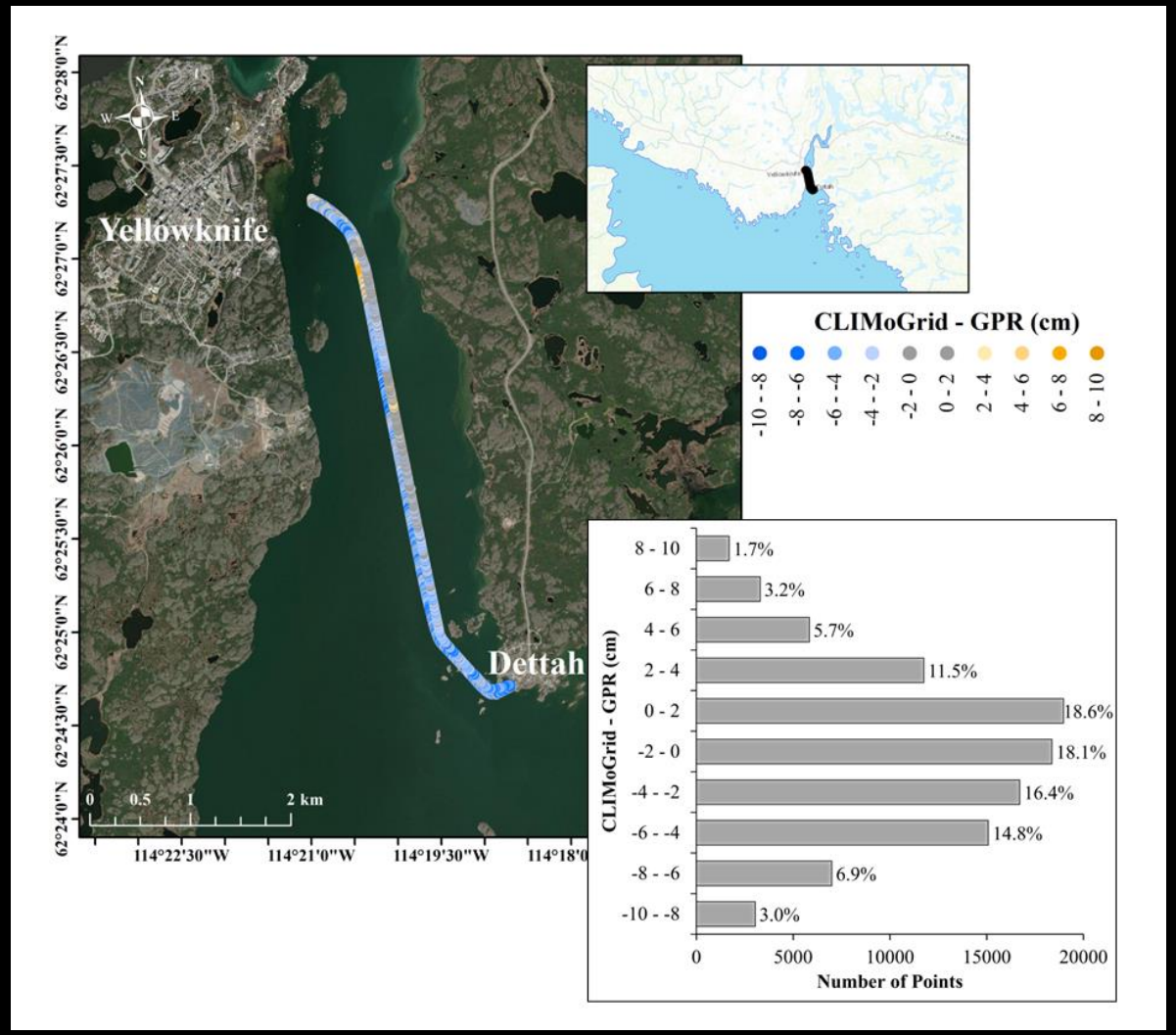


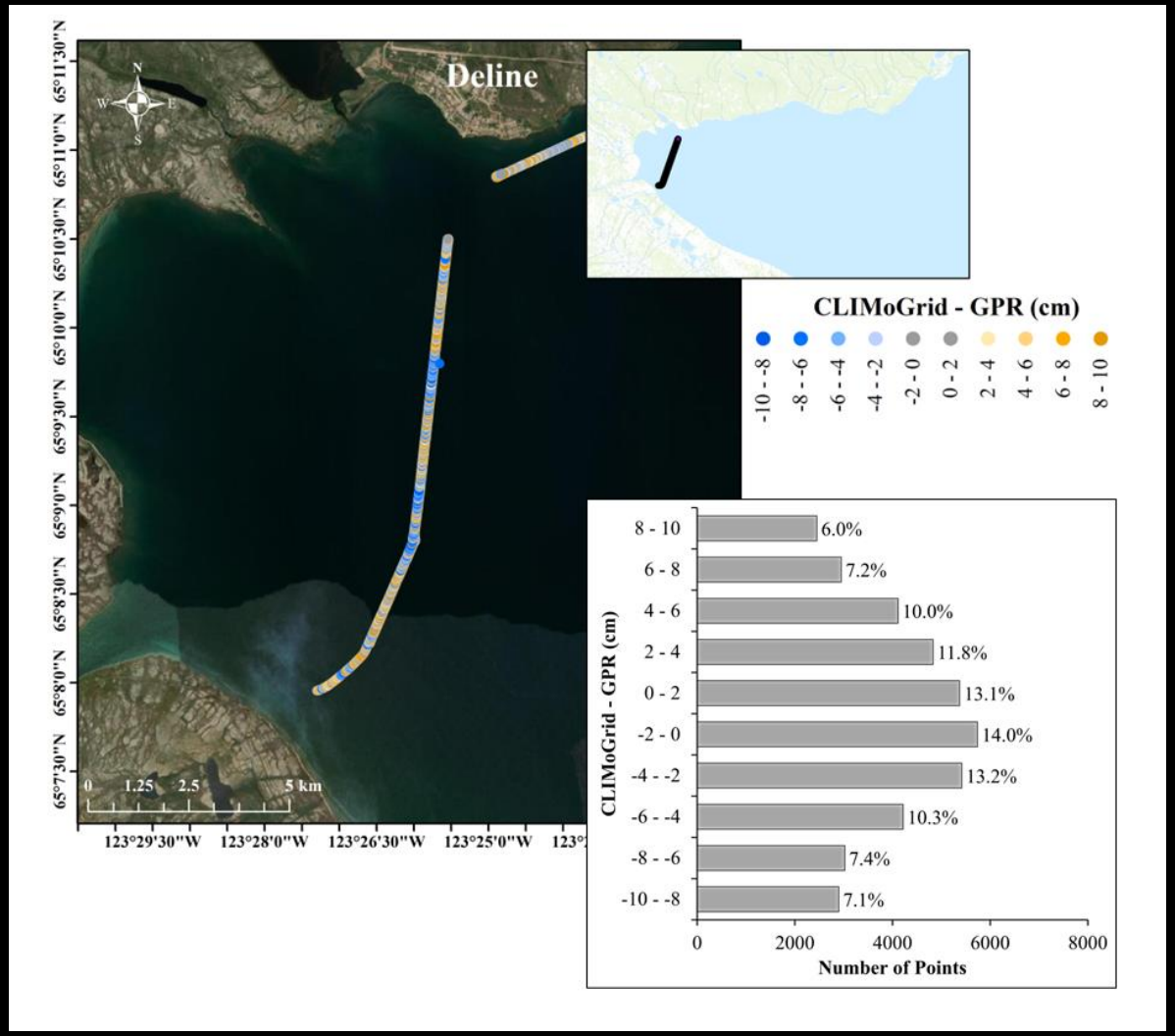
Great Slave Lake

April 01, 2004

1 Ice Thickness (m) 1.5

CLIMoGrid Model – Validation





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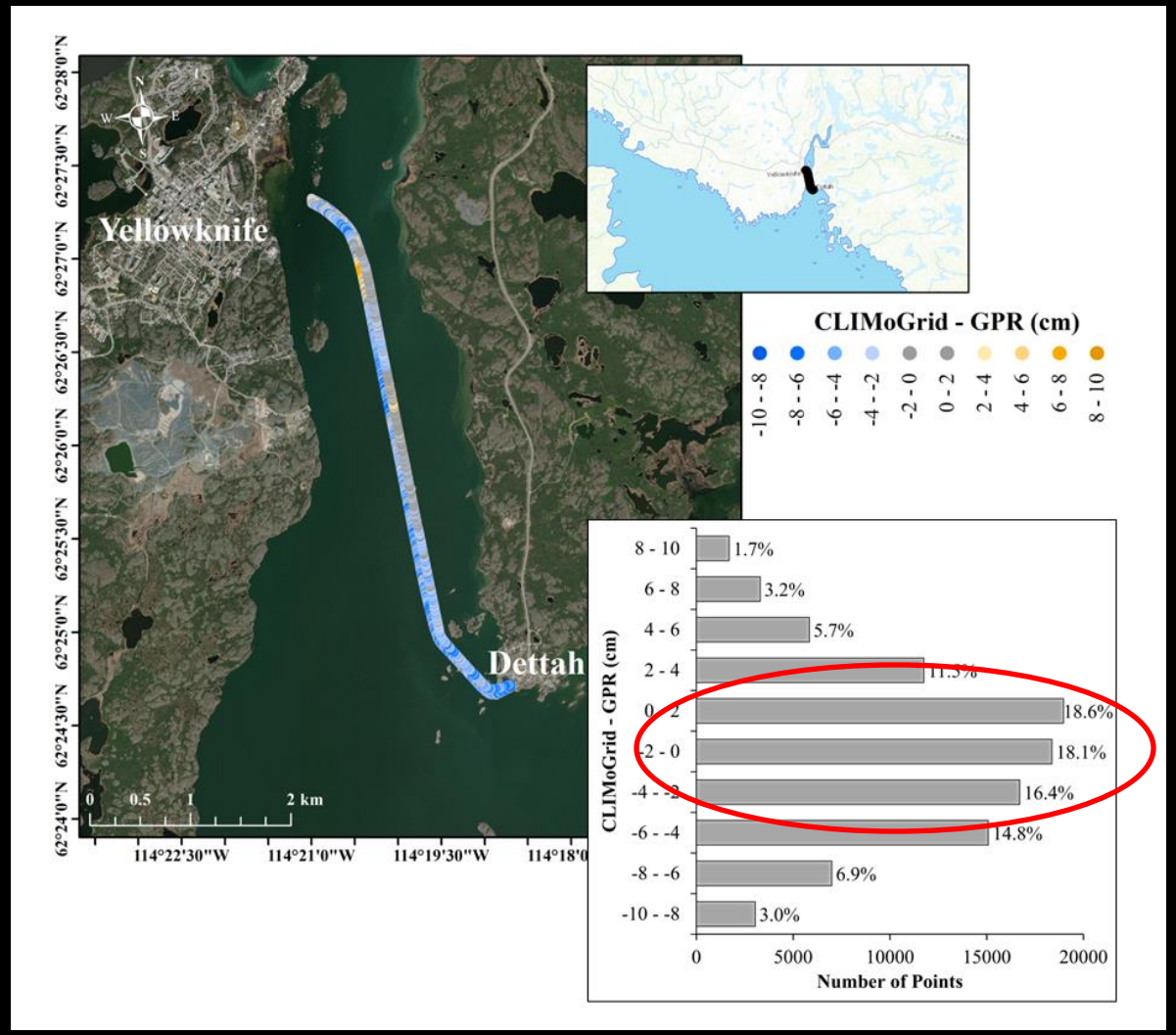
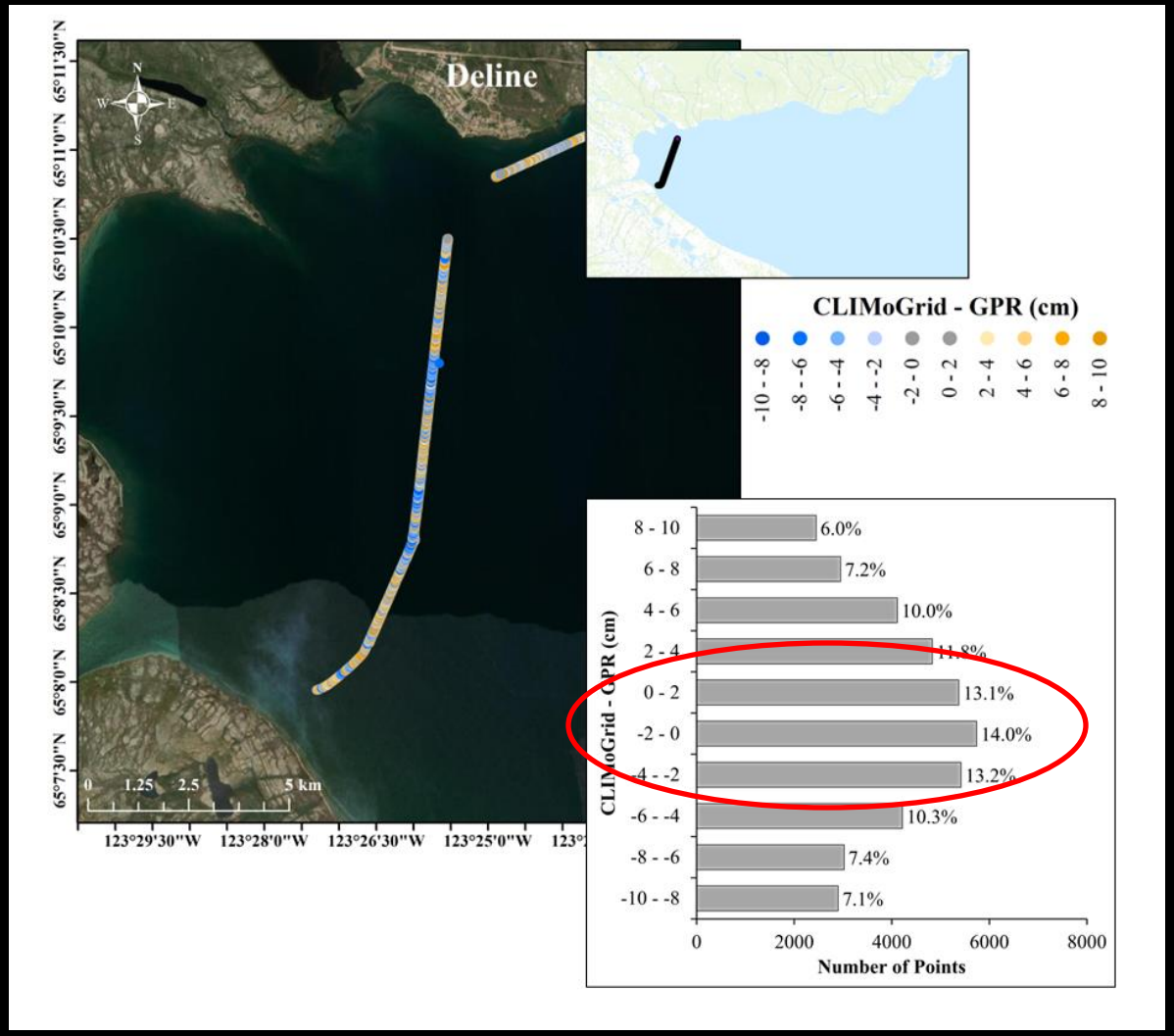
CLIMoGrid Model – Validation





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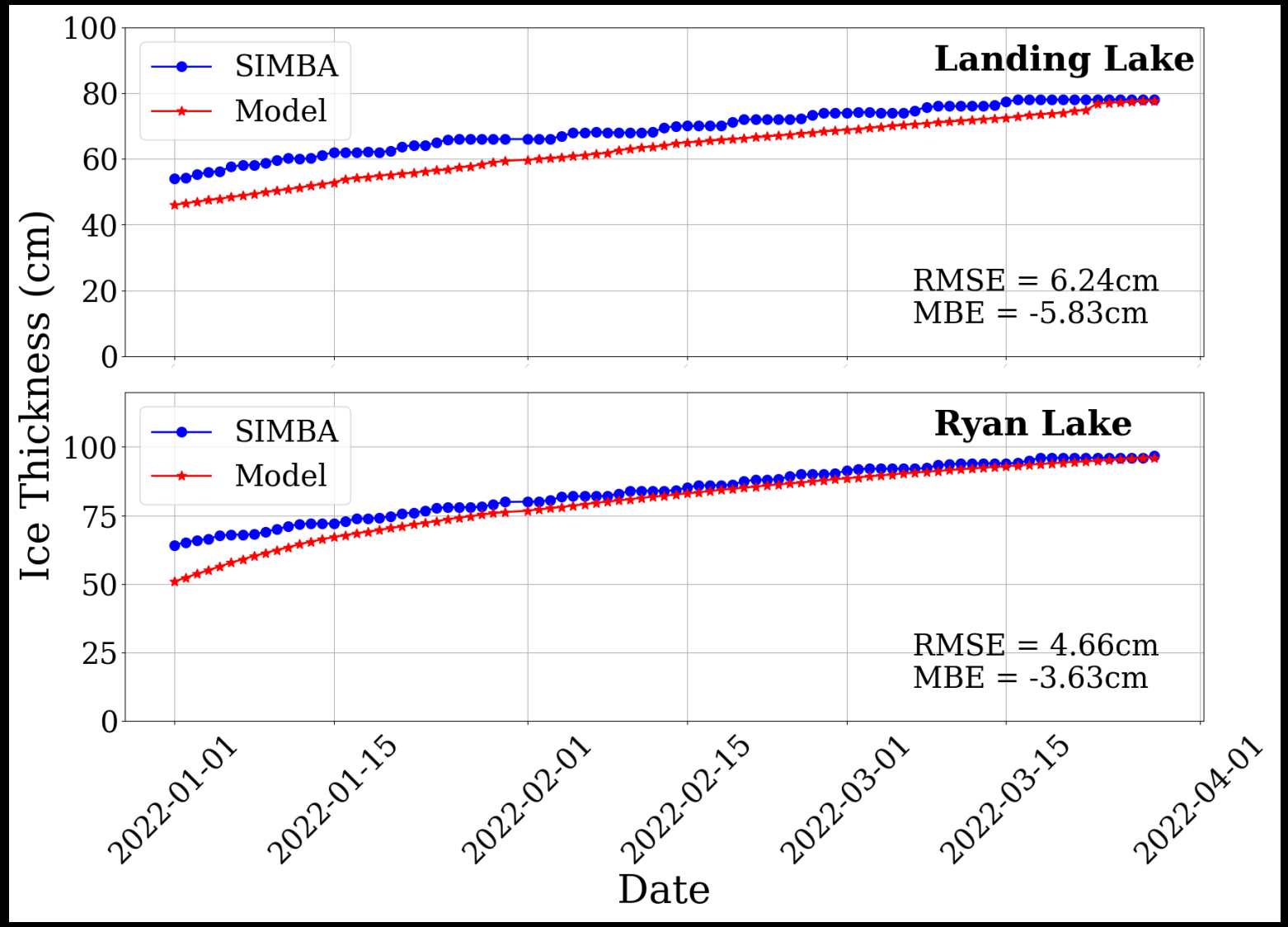
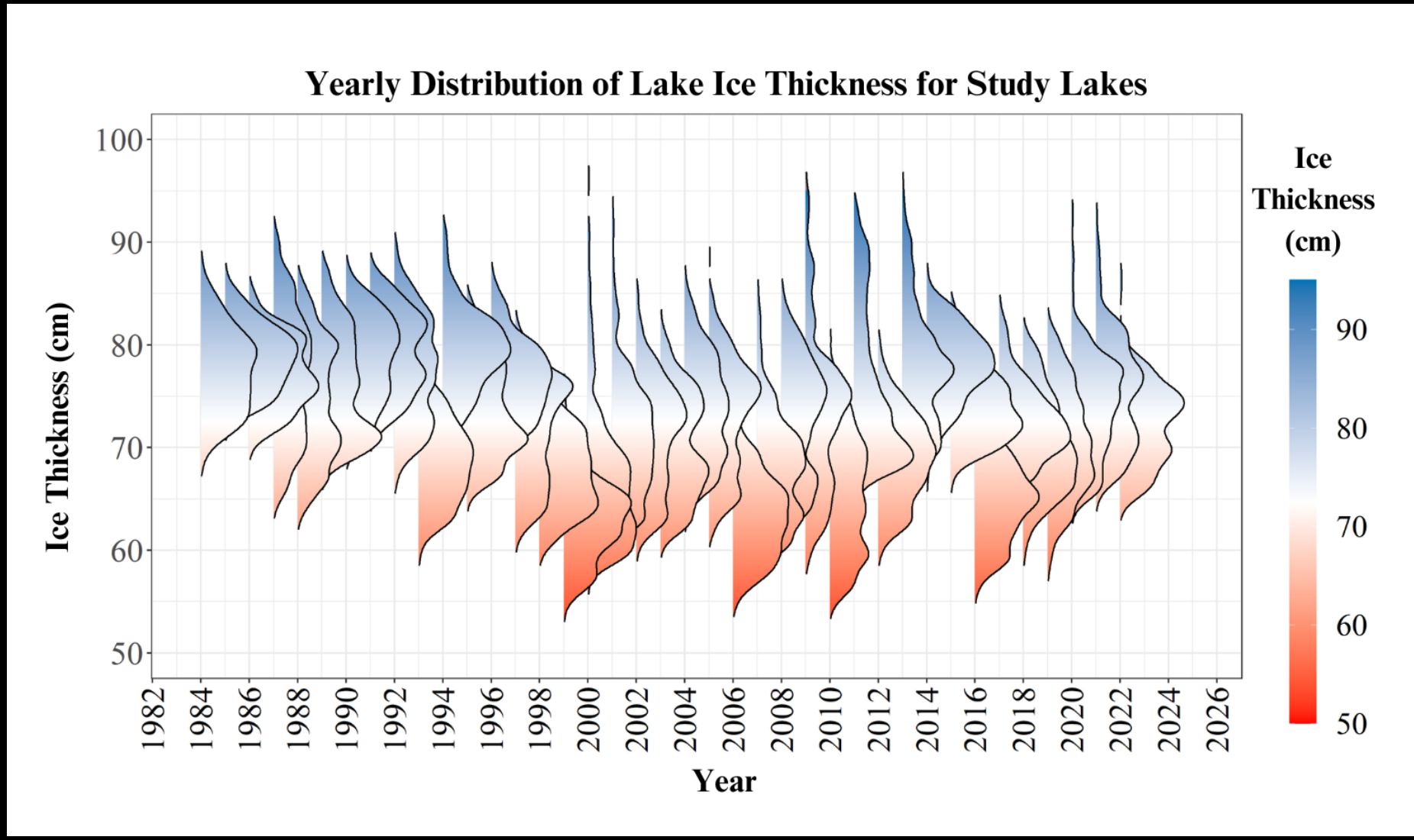
Validation: Model vs. SIMBA (In Situ)



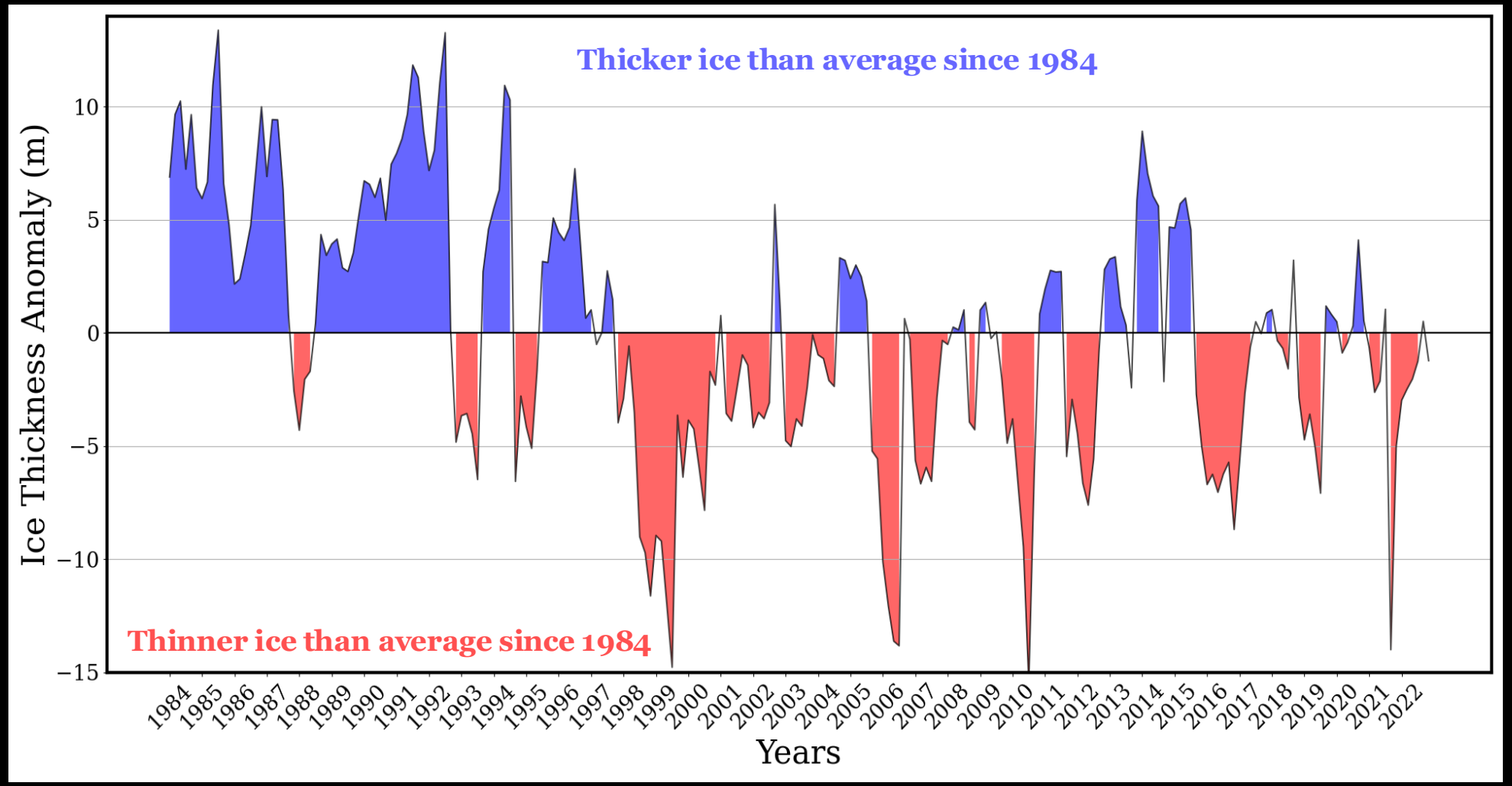
Comparison of daily simulated lake ice thickness from January to March 2022 with thickness derived from a Snow and Ice Mass Balance Apparatus (SIMBA)

Yearly Ice Thickness Distribution (1984 –2022)



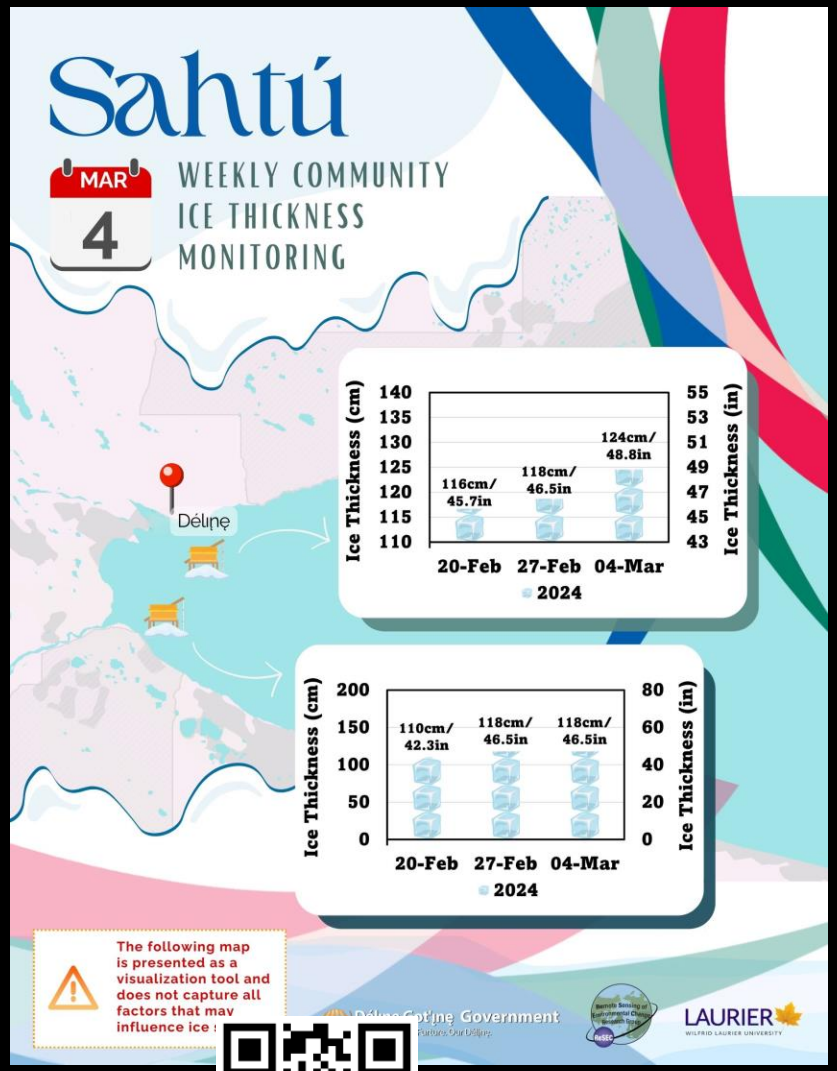
Significant Decrease in Ice Thickness

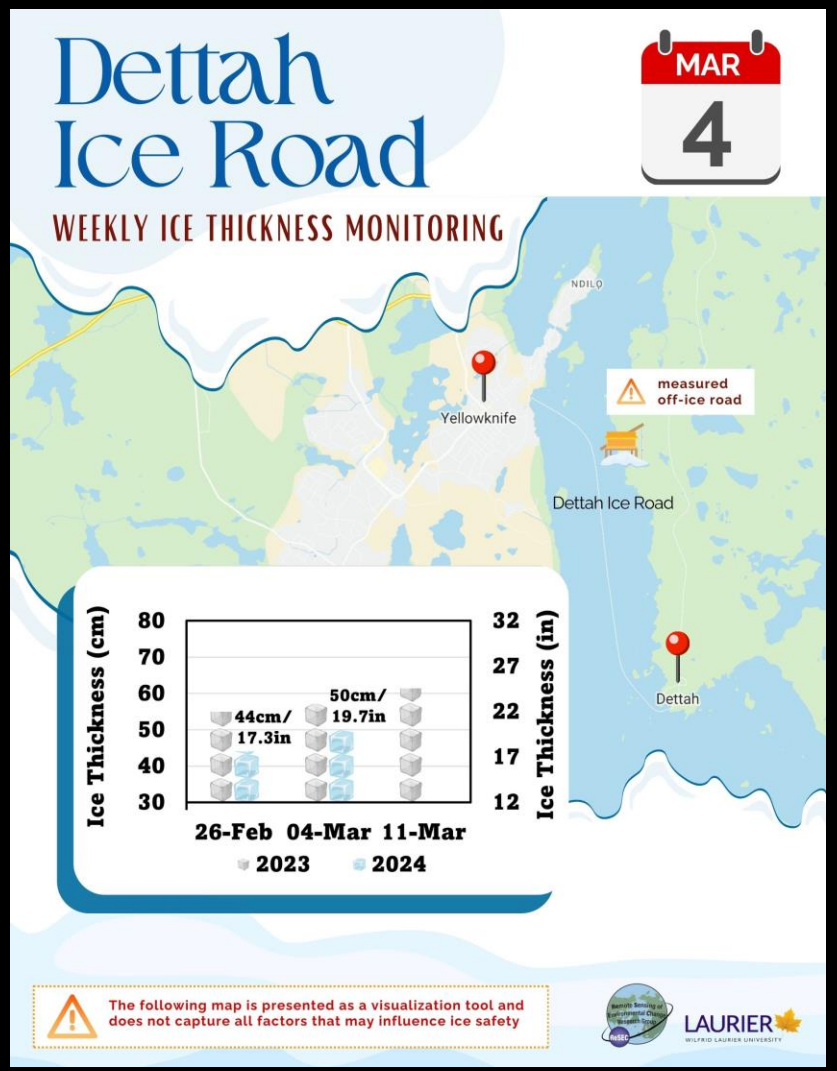
Lake Ice Thickness Anomaly (1984 –2022)

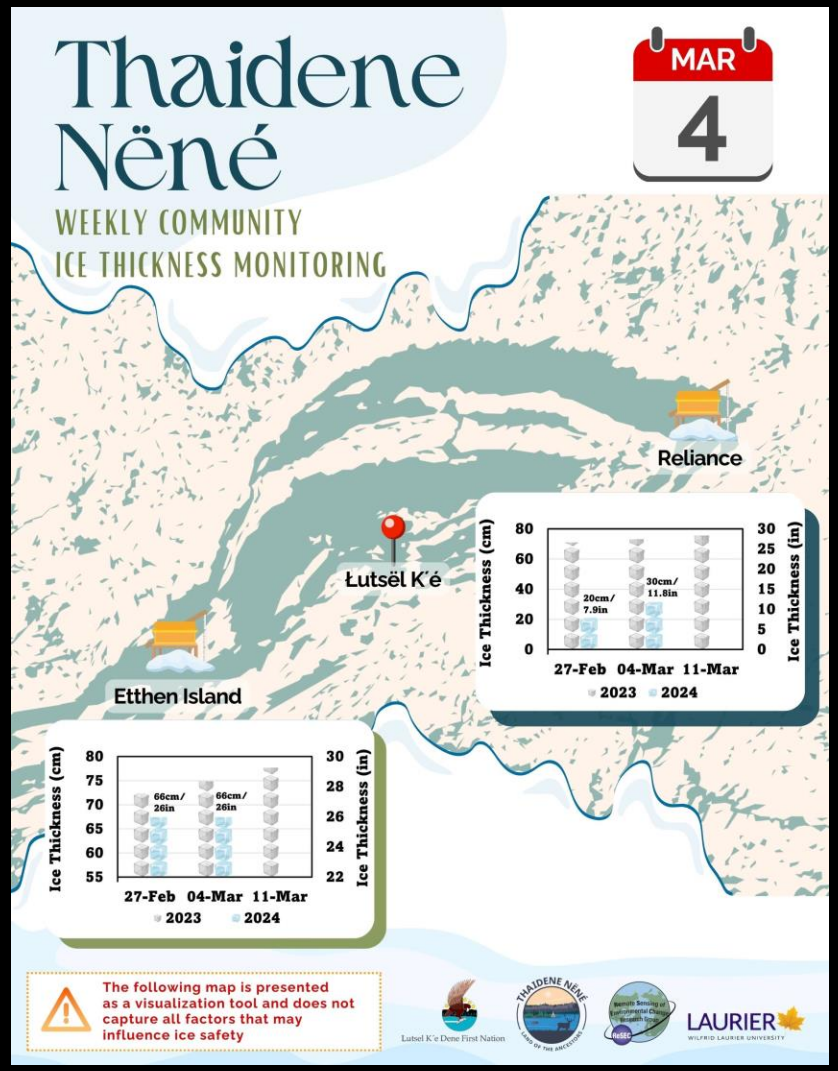


Significant Decrease in Ice Thickness

Weekly Community Ice Thickness Monitoring







https://reseclabmap.ca/ice-thickness

Thanks!

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