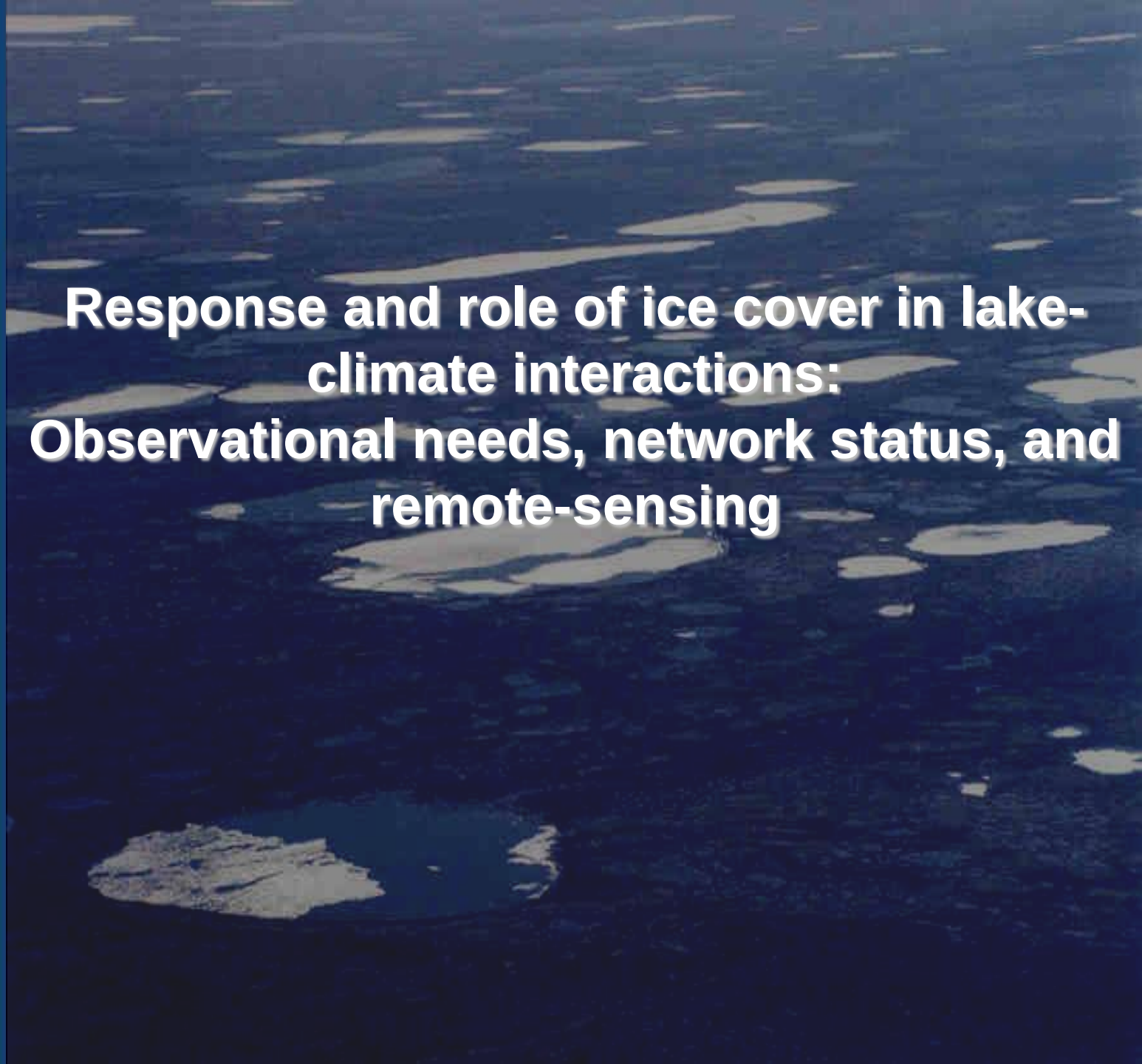

Response and role of ice cover in lake-climate interactions: Observational needs, network status, and remote-sensing

Interdisciplinary Centre on Climate Change

Claude Duguay
Laura Brown

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Workshop on Cold Regions Hydrology
Innsbruck, Austria
28-30 April 2010

Interdisciplinary Centre on Climate Change

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Laura Brown

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Outline

Observational needs: why lake ice?

- Response of lake ice to climate
- Role of lake ice in climate

Network status (*in situ*)

Satellite remote sensing

- Operational products
- Research products

Summary

Workshop on Cold Regions Hydrology
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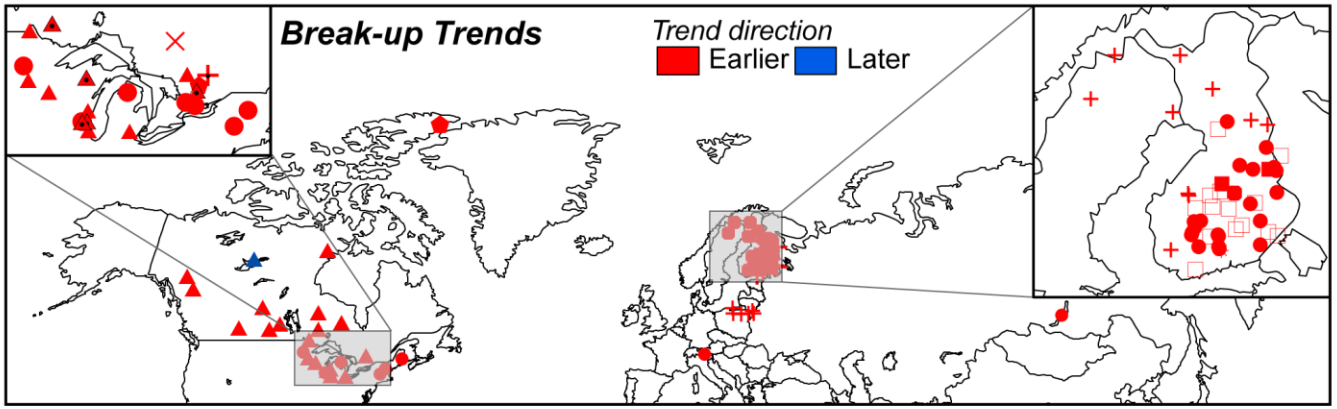
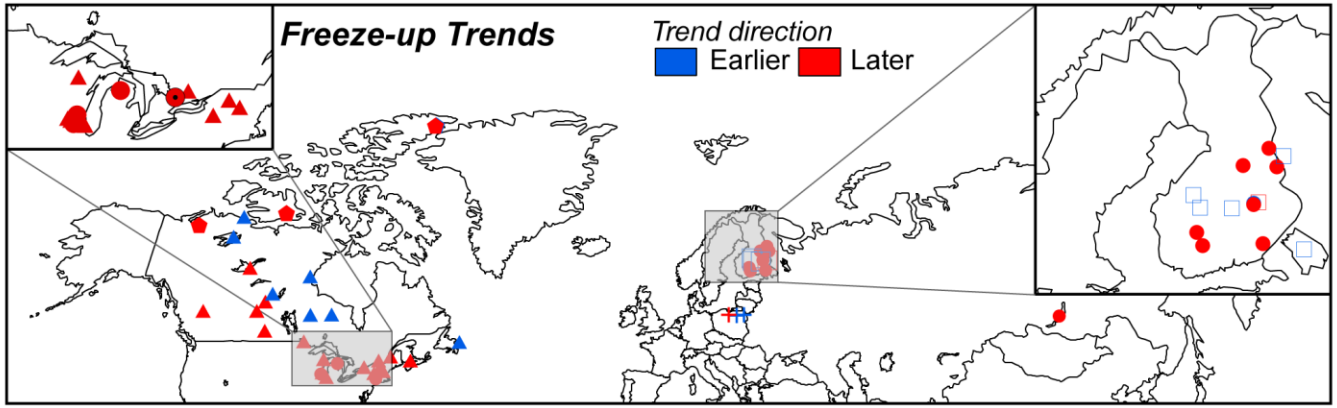
Response of lake ice to climate

Freeze-up (ice-on) and break-up (ice-off), and ice thickness are important indicators (integrators) of regional climate variability and change



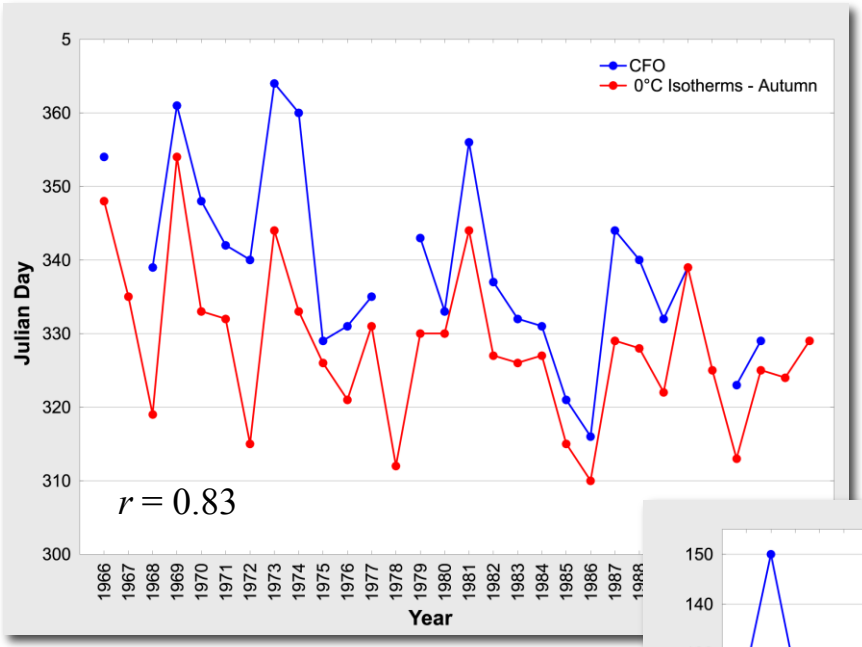


Time span of trend analysis

✕ 1990 ~ 2000	▲ 1970 ~ 2000	■ 1950 ~ 2000	● <1900 ~ 2000
⬟ 1980 ~ 2000	+ 1960 ~ 2000	□ <1950 ~ 2000	• time period ends ~1990

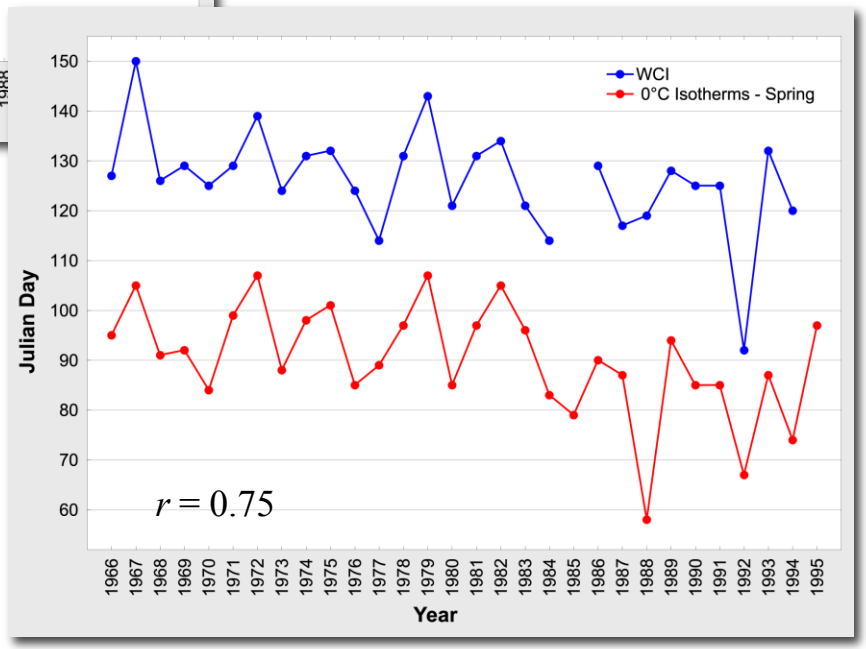
Brown, L. and C. Duguay (Accepted). The response and role of ice cover in lake-climate interactions. *Progress in Physical Geography.*

Response of lake ice to climate



Trends in freeze-up/break-up dates in relation to 0 °C fall and spring isotherm dates

Deadman's Pond, Newfoundland



Duguay, C.R., T.D. Prowse, B.R. Bonsal, R.D. Brown, M.P. Lacroix, and P. Ménard, 2006. Recent trends in Canadian lake ice cover. *Hydrological Processes*, 20: 781-801.

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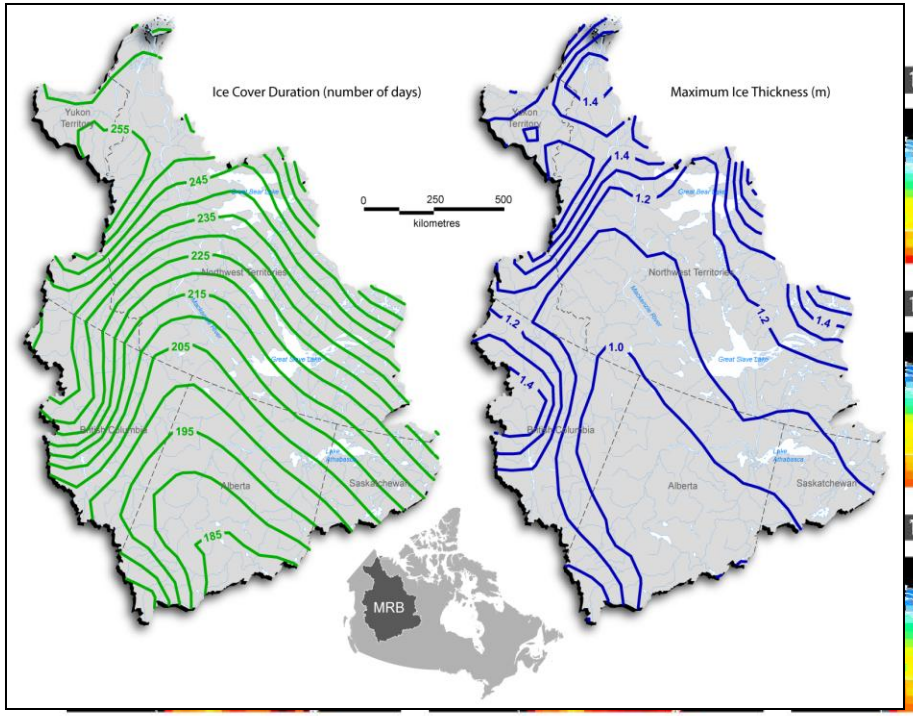
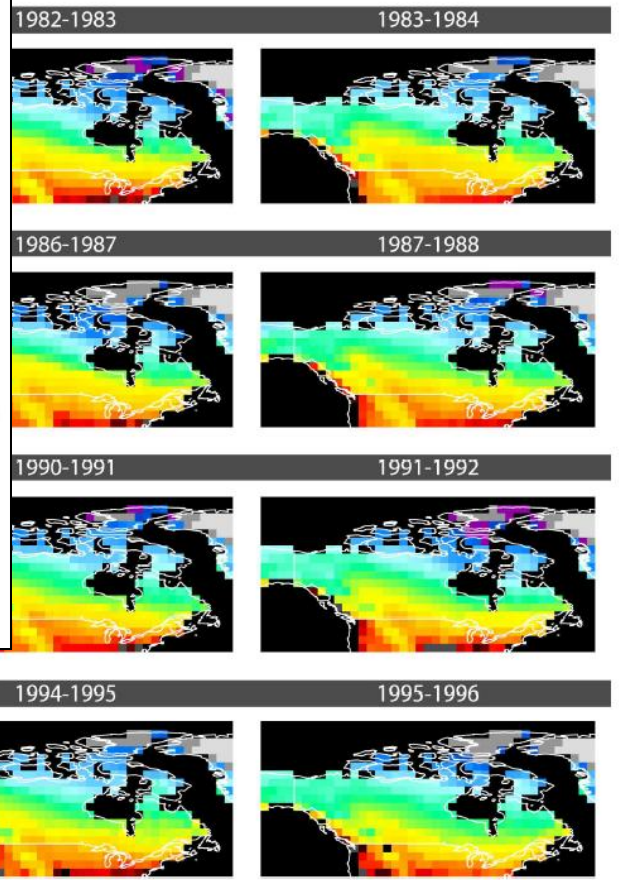
Response of lake ice to climate

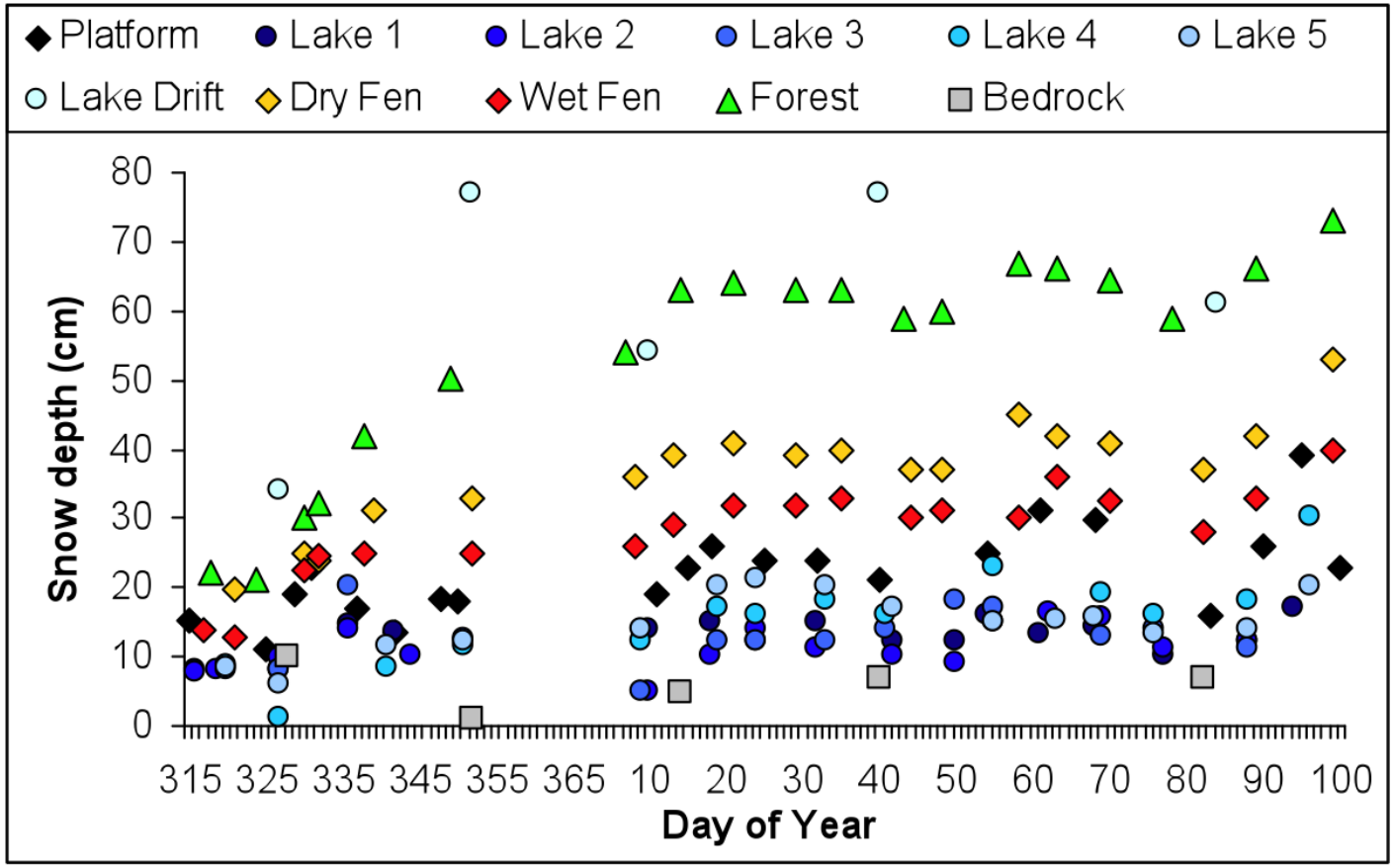
Lake ice modeling – 20th and 21st century conditions





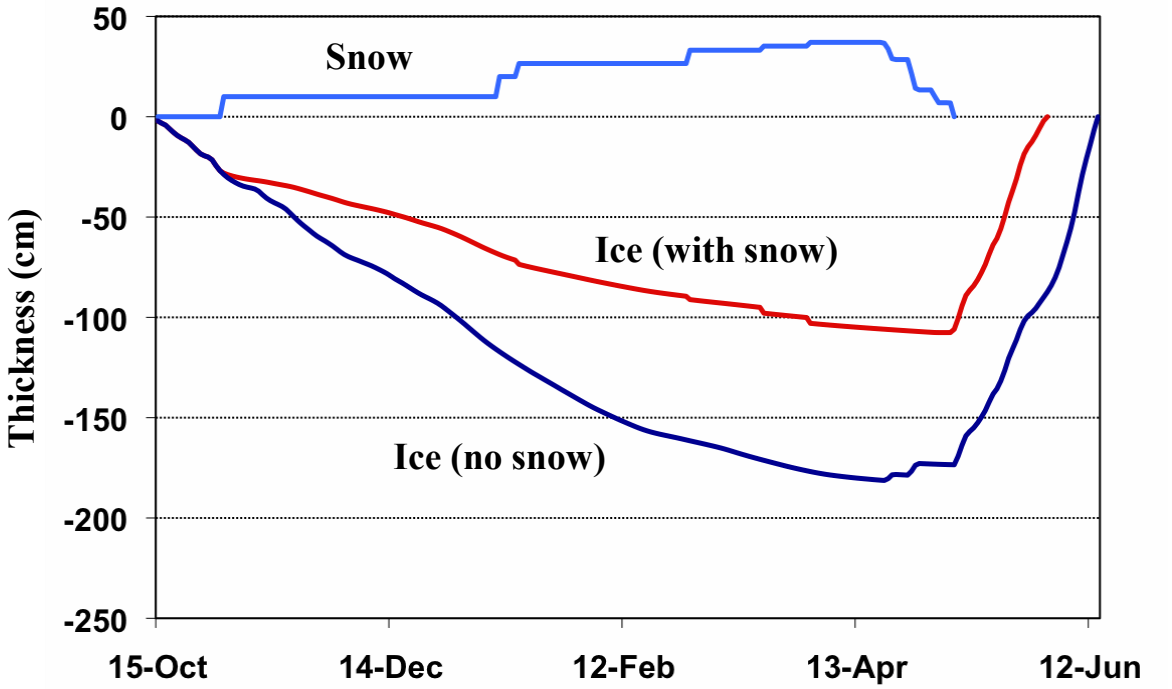
Response of lake ice to climate

Lake ice modeling – importance of proper representation of snow on lake ice



Response of lake ice to climate

Lake ice modeling – typical representation of snow

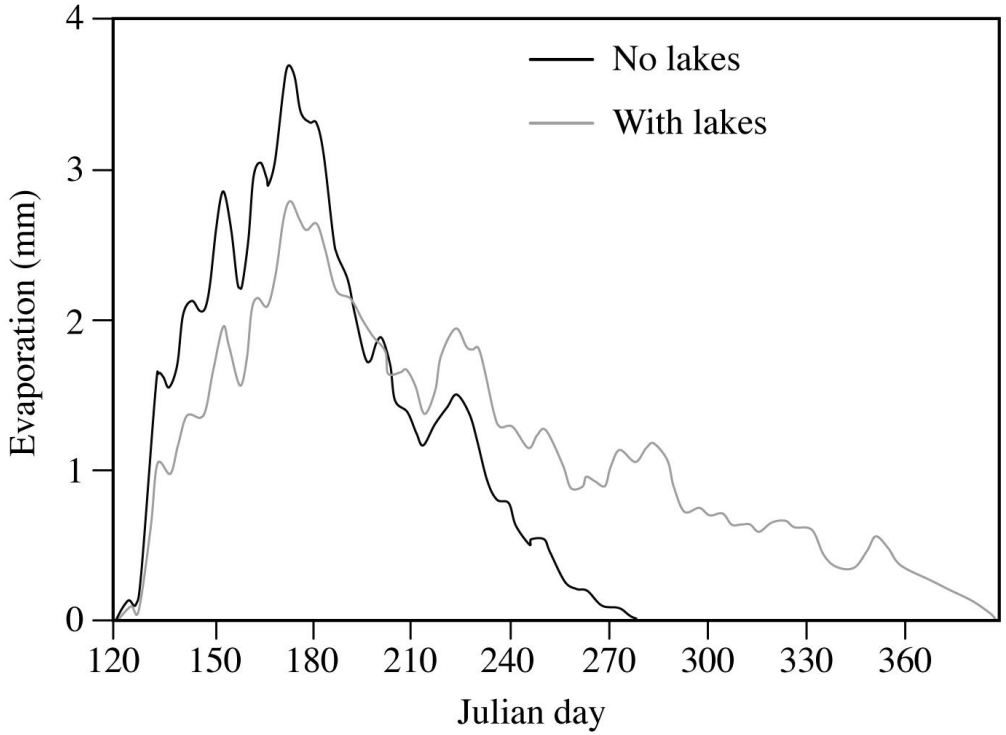


Canadian Lake Ice model simulation

- Snow accumulation (SWE) has a large impact on lake ice growth.
- Lack of adequate snow measurements are a source of uncertainty in lake (ice) models (ice thickness, snow ice formation, break-up dates).

Role of lake ice in climate

Average evaporation patterns for a region with no lakes and a region with lakes



Rouse, W.R., Binyamin, J., Blanker, P.D., Bussières, N., Duguay, C.R., Oswald, C.J., Schertzer, W.M. and Spence, C. 2008b: The influence of lakes on the regional energy and water balance of the central Mackenzie. Chapter 18 in *Cold Region Atmospheric and Hydrologic Studies: The Mackenzie GEWEX Experience Vol 1, 309-325.*

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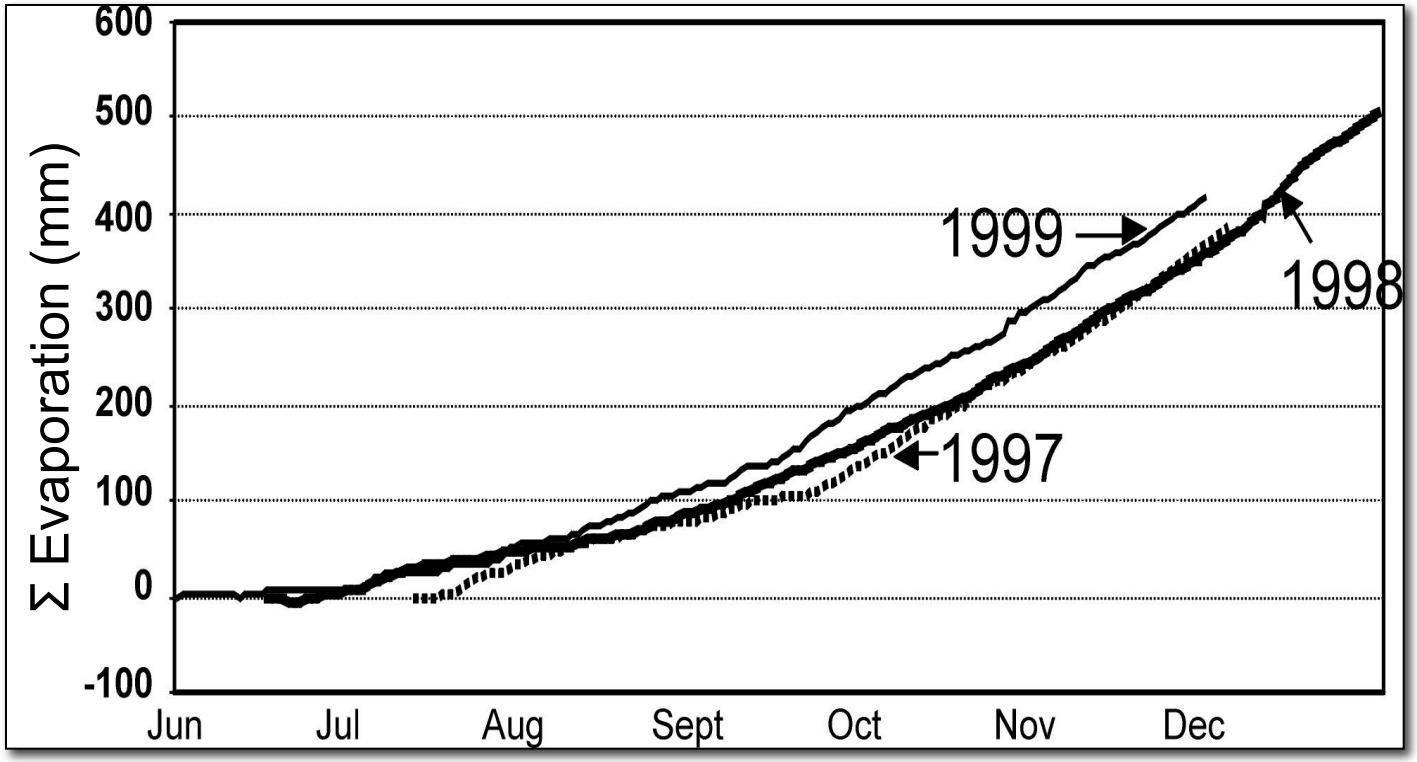
Role of lake ice in climate

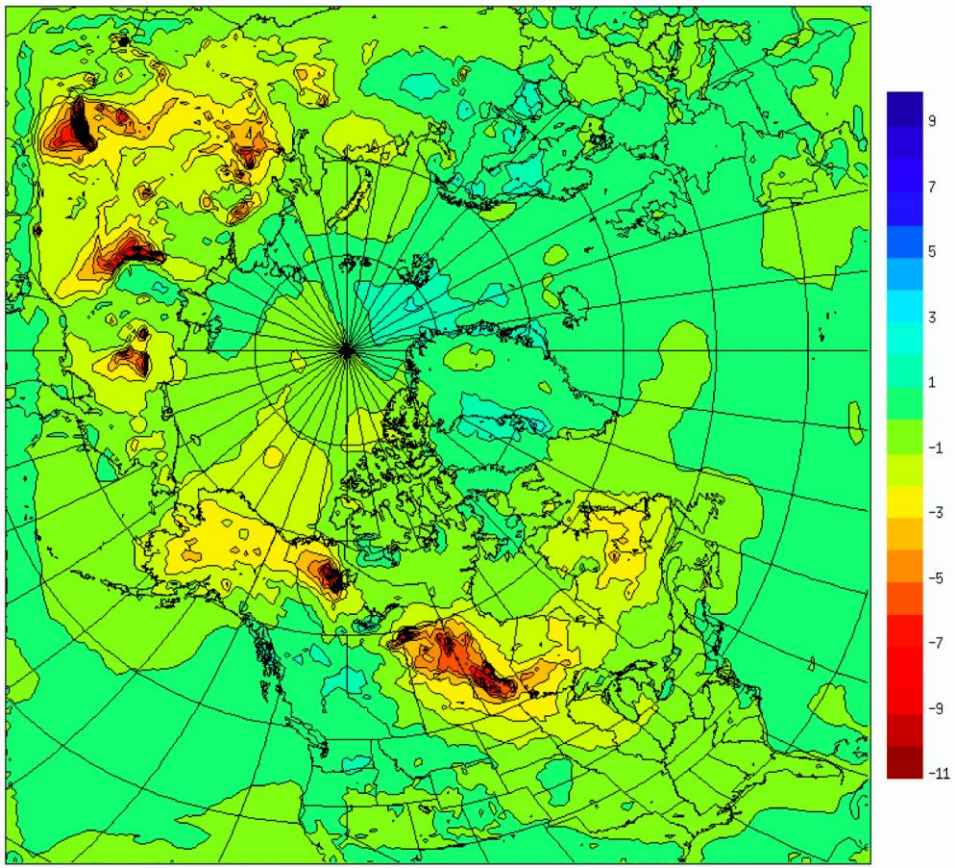
Ice cover fraction has a major influence on the magnitude of lake-atmosphere exchanges in winter at northern latitudes



The <u>date of final ice melt</u> in June exerts the largest single control on the seasonal thermal and energy regimes of this large northern lake. An early thaw greatly enhances the magnitude of absorbed solar radiation in the high sun season. This becomes stored heat energy that drives the large sensible and latent heat fluxes during fall and early winter.

Role of lake ice in climate

Impact of lakes on weather and climate predictions

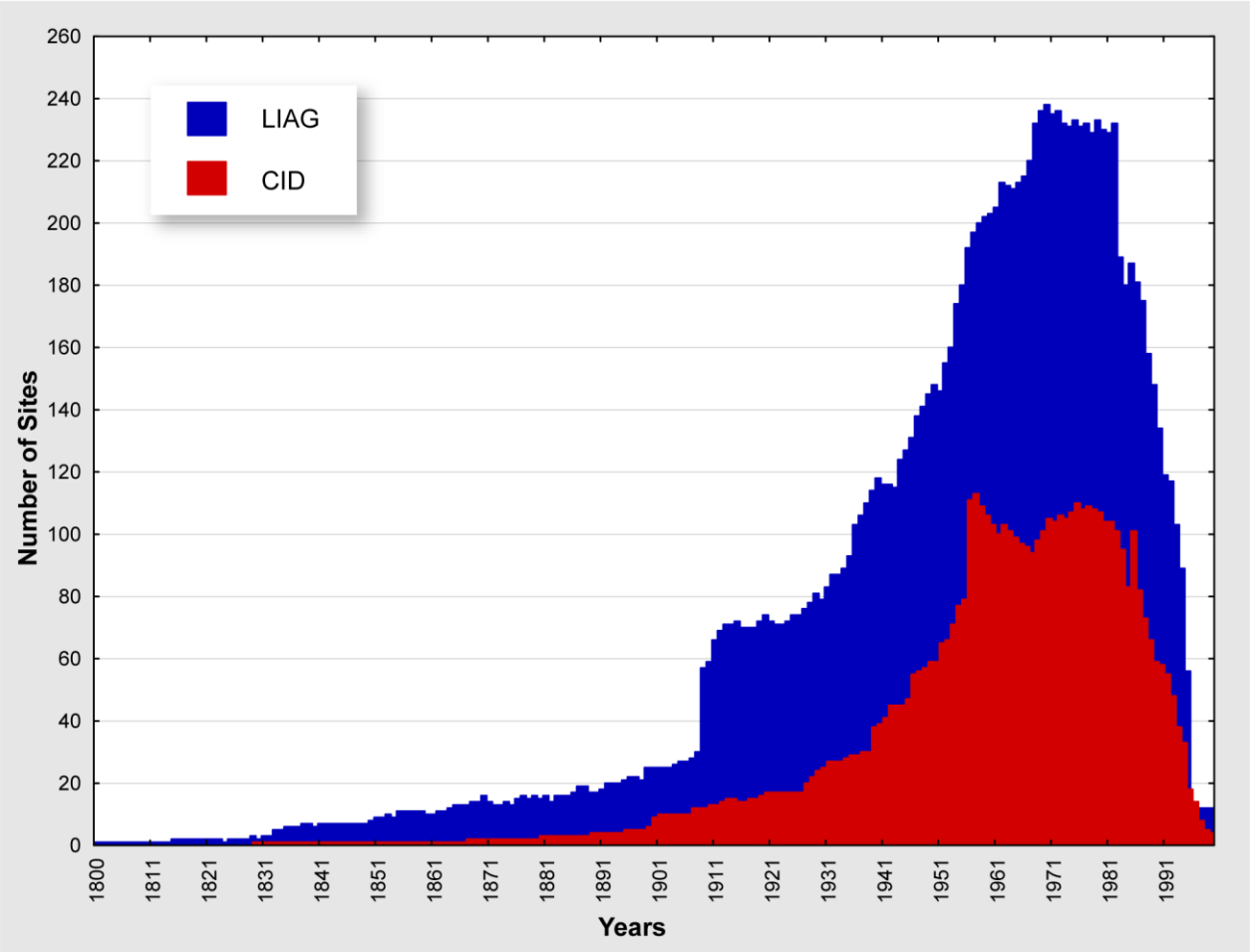


Mean winter temperature difference (°C)
(with ice – no ice)
(Source: Winger and Brown, pers. comm., 2008)

- **Improper representation of lake ice can lead to substantial errors in weather and climate models (e.g. air temperature, lake effect snowfall).**
- **Improved representation of ice and snow on ice is needed.**

Global ice cover network status

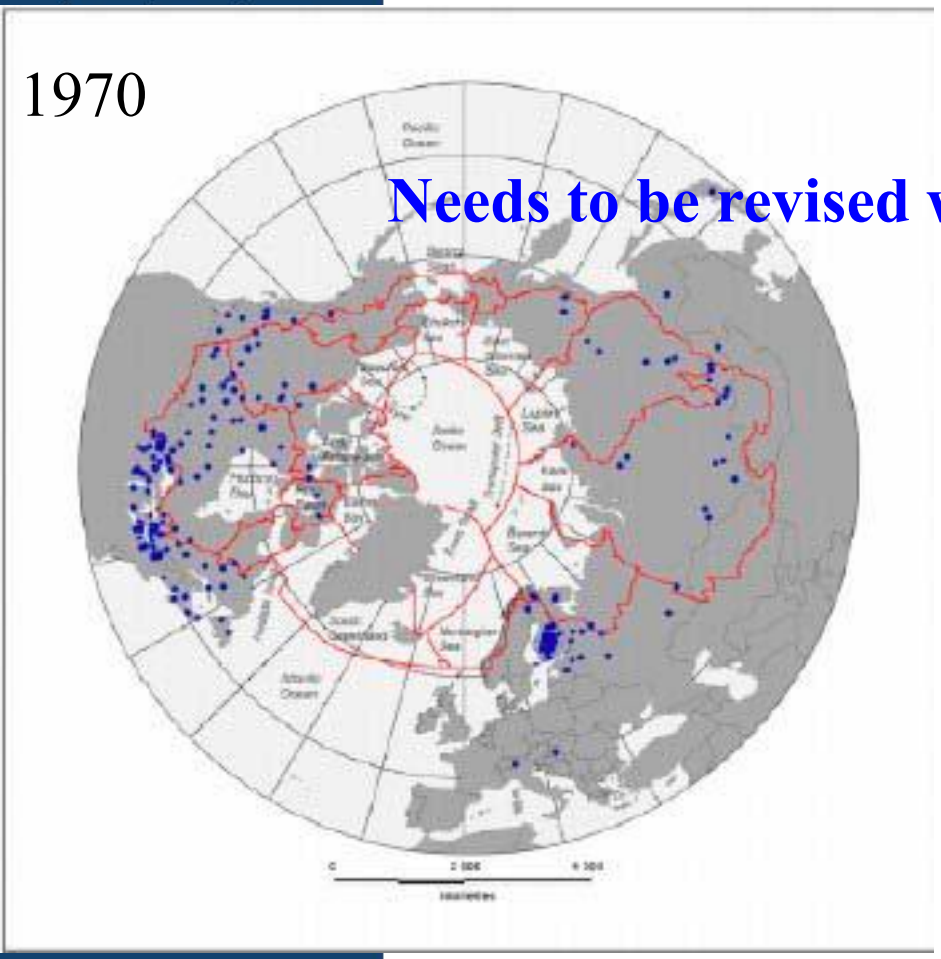
Historical evolution of surface-based network



Global ice cover network status

Historical evolution of surface-based network

1970



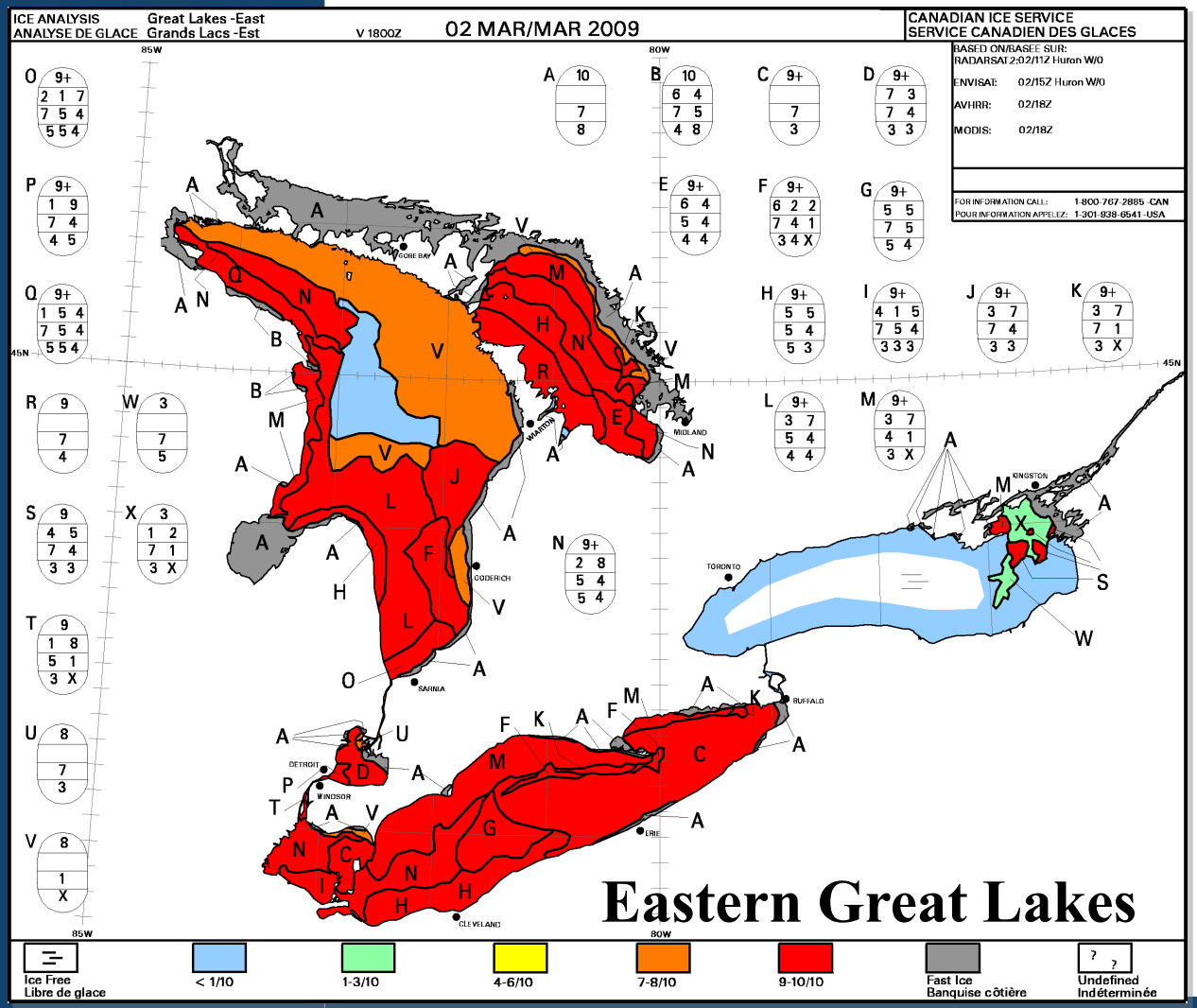
1995

Needs to be revised with "new" data from Russia

IGOS Cryosphere Theme Report (2007)

Satellite remote sensing

Operational products - Great Lakes weekly ice charts (CIS/NOAA): 1960-on



- **Based on visual interpretation of optical and SAR data (also airplanes and ships) compiled during the week.**
- **Provides information on ice fraction and ice types.**
- **Location of open water areas is known.**

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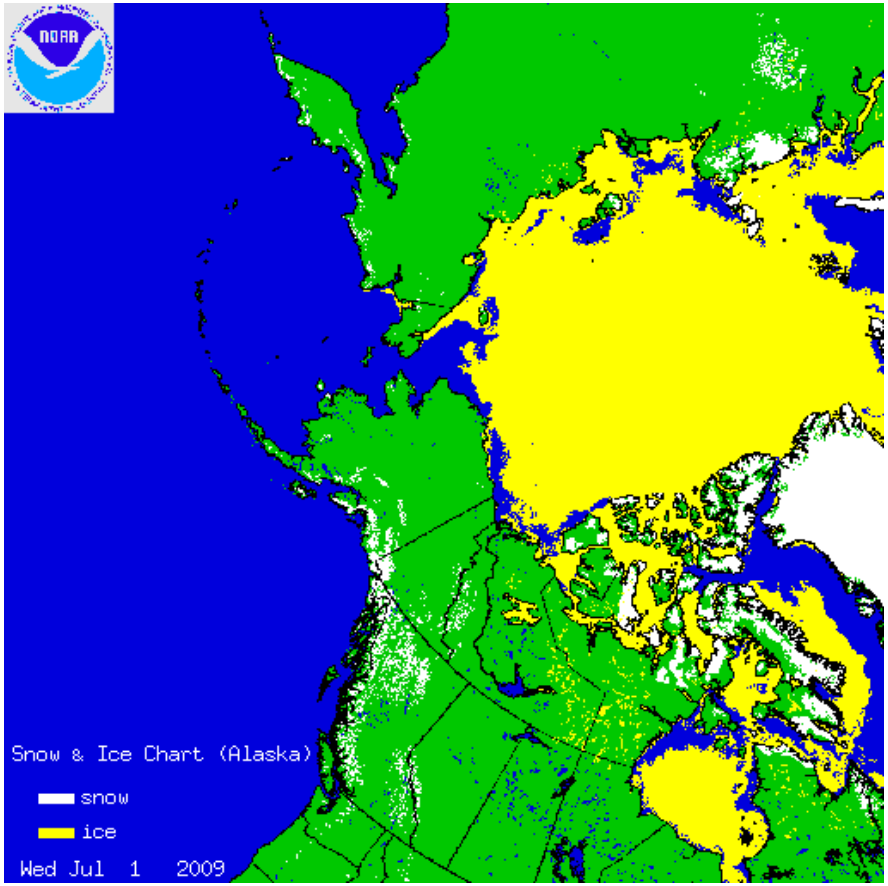
Satellite remote sensing

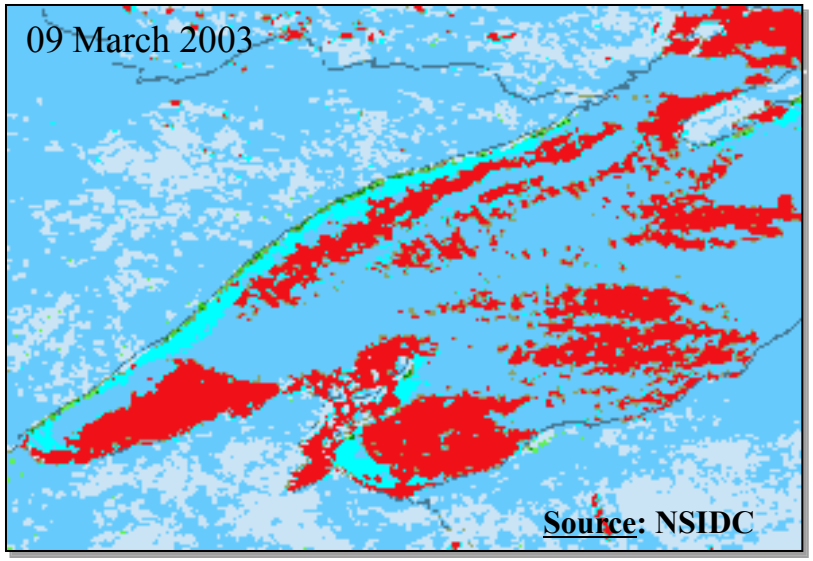
Operational products - IMS daily ice cover fraction at 4 km resolution: 2004-on

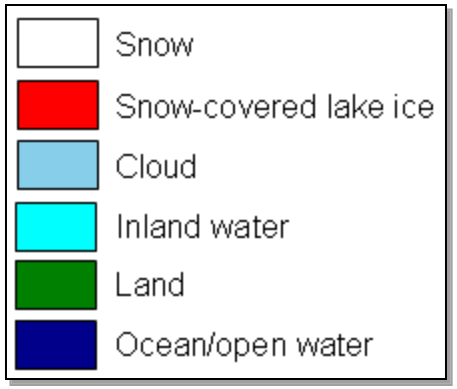


- **Based on the use of AVHRR, GOES, and SSM/I data.**
- **Relatively coarse resolution and short time series.**

Satellite remote sensing

Operational products - MODIS daily snow product (NASA): 2000-on



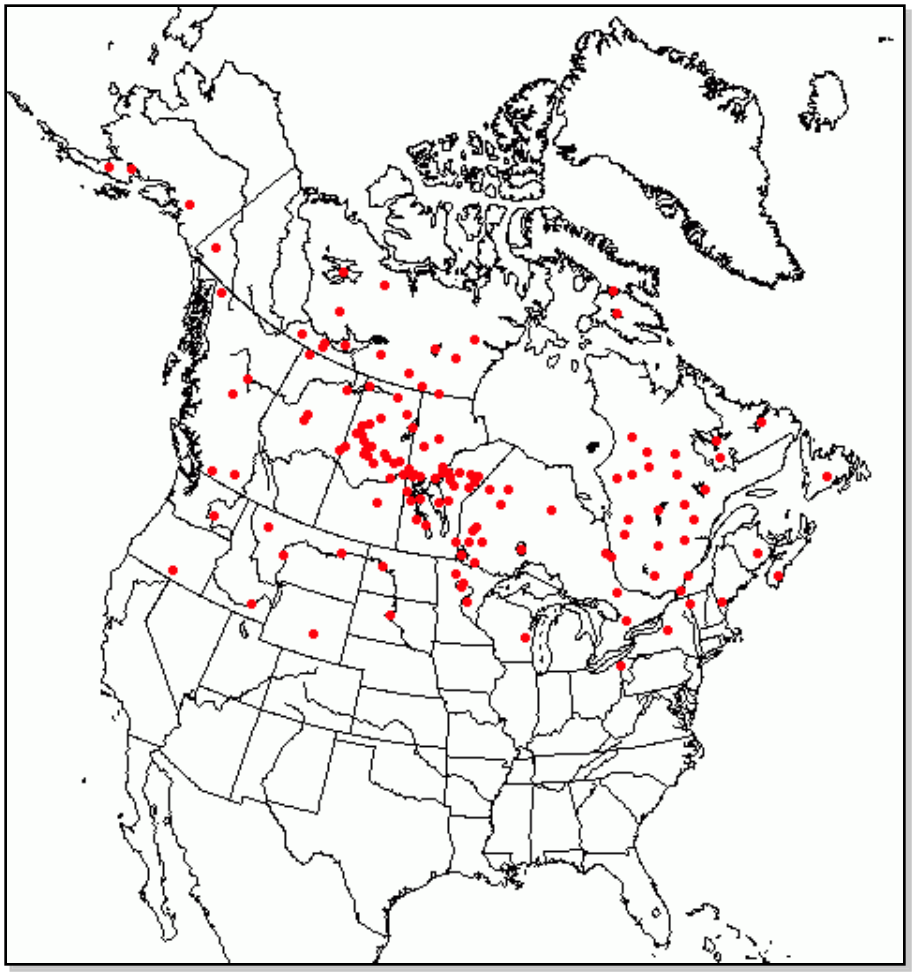


- **The MODIS snow algorithm still has limitations, particularly in discriminating clouds from snow-covered lake ice and the detection of ice cover when snow on ice is absent.**
- **Cloud cover and darkness are a problem in polar regions during fall/early winter.**
- **The product has not been validated for lake ice.**

MODIS/Terra Snow Cover Daily L3 Global 500m Grid data

Satellite remote sensing

Operational products - <u>Weekly</u> ice cover from Canadian Ice Service (CIS): 1995-on



- **Ice cover is monitored weekly by CIS on about 136 lakes since 1998 (34 lakes 1995-1998).**
- **Based on visual interpretation of AVHRR (1-km) and Radarsat-1/2 ScanSAR images compiled during the week for largest lakes in Canada and part of U.S.**
- **A value between 0 and 10 assigned for each lake.**
- **Location of open water areas is unknown.**

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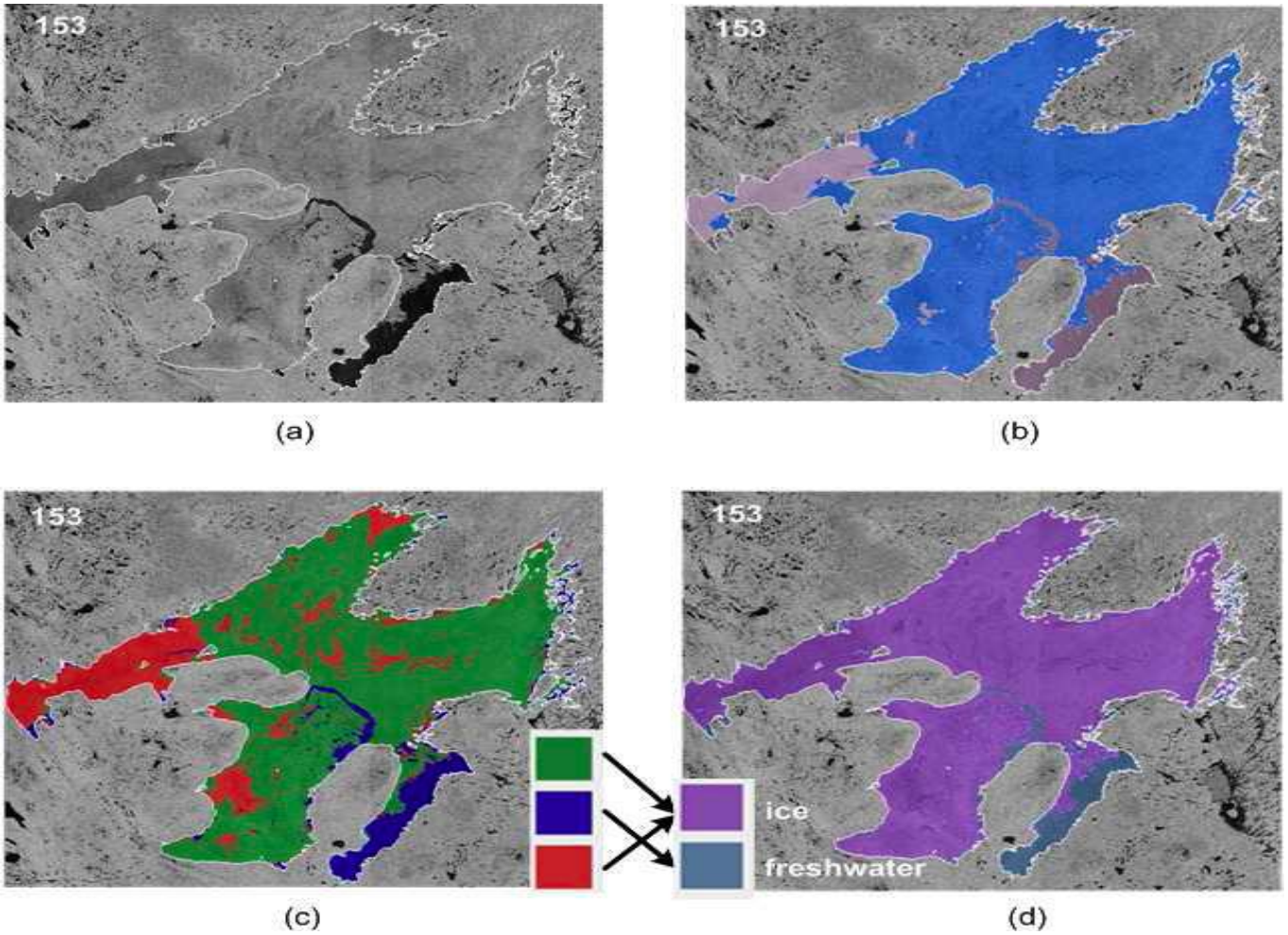
Satellite remote sensing

New development – ice cover with Radarsat ScanSAR



Fully automated procedure for lakes monitored by CIS

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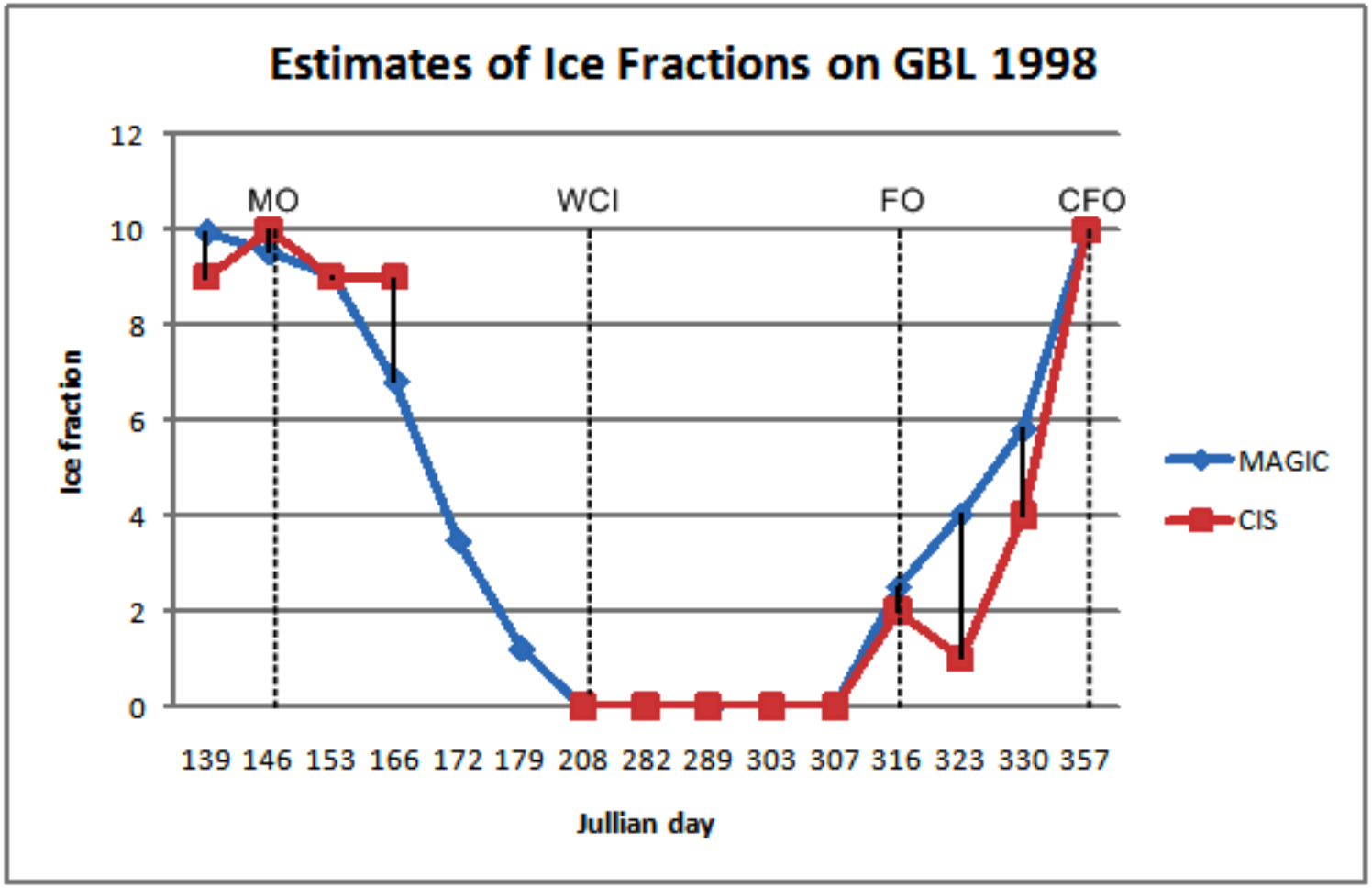
Satellite remote sensing

New development – ice cover with Radarsat ScanSAR



Comparison visual vs automated approach

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Satellite remote sensing

Prospects - Current and future EO missions

- **1-2 days to 1 week ice cover (fraction) product(s) needed to meet the needs for climate monitoring and numerical weather prediction/regional climate modeling. Ideally (target), daily product at 50-100 m resolution.**
- **3-day/weekly, 100-500 m: MODIS, MERIS, Envisat ASAR (WS or Global), Radarsat-2 (ScanSAR).**
- **1-2 days, 100 m, Sentinel-1, 2, 3 (2011-2012):**
  - **Sentinel-1: C-band SAR, extra-wide swath mode (400 km; 25x100 m)**
  - **Sentinel-2: 443-2190 nm, swath 290 km, 10-60 m**
  - **Sentinel-3: VIS-SWIR-MWIR-TIR (500 m- 1 km)**
- **Radarsat constellation (2014-2016): daily, 50-100 m**
- **CoReH2O: snow on lake ice (and ice thickness)**

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Summary

- **Surface-based observations were once the most important source of information regarding lake ice conditions (trends and variability in response to climate).**
- **The declining state of the surface-based network since the mid 1980s has led to serious geographical and temporal gaps for several lake ice parameters.**
- **Remote sensing is only starting to be used to reconstruct part of the lost network, but much work remains to be done.**
- **Meteorological services and climate centres worldwide are now incorporating lake parameterization schemes into numerical weather prediction and regional climate models.**
- **Remote sensing observations are needed for validation and improvement of lake (ice) models.**

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