Trends and Variability for Ice Cover on Inland Lakes

John J. Magnuson
Barbara J. Benson

Center for Limnology
University of Wisconsin-Madison
Lake Ice Data and Coherent Dynamics
Spatial Pattern across the Great Lakes Region
Updated Lake Ice Global Database and Analyses
The Longest Lake Ice Record
Ice Duration on Lake Mendota

10 longest ice covers

10 shortest ice covers

19 days less per 100 years

Magnuson 2007
External Dynamics Impart Lake Dynamics

Magnuson et al. 2004
Definition of Coherence or Synchrony

Is the degree to which different locations (lakes) behave similarly or dissimilarly through time.

Is measured by the correlation between time series of the same parameter on pairs of lakes. (usually r or r²)
Long-Term Ecological Research (LTER) Lakes in North Central Wisconsin

Kratz et al. 2006
Coherent Dynamics in Ice-Off Dates

**Graph: LTER Lakes N. WI**

- **Ice-Off Date**: Feb., Mar., Apr., May
- **Year Range**: 1980 to 2000
- **Data Points**:
  - Trout Lake
  - Sparkling
  - Big Muskellunge
  - Trout Bog
  - Crystal Lake
  - Allequash
  - Crystal Bog

**Statistical Data**:
- **r² for Northern Wisconsin**: 0.92
- **r² for Southern Wisconsin**: 0.82

**Reference**:
Magnuson et al. 2004
Physical Variables

Magnuson et al. 2004

Ice-Off Date
$r^2 = 0.92$

Water Temperature Bottom
Summer
$r^2 = 0.07$

Water Temperature Bottom
Winter
$r^2 = 0.31$

Water Level
$r^2 = 0.26$

Ice-on Date
$r^2 = 0.62$

Epilimnion Thickness
$r^2 = 0.26$

Water Temperature at 1m
Summer
$r^2 = 0.86$

Water Temperature at 1m
Winter
$r^2 = 0.29$

Ice-Off Date
$r^2 = 0.92$
Lake Ice-off Sites in Great Lakes Region since the mid 1970s
Coherent Dynamics and Spatial Pattern

Magnuson, Benson, Jensen, et al. 2004
Area Differences in Coherence

$r^2$ in respect to Minnesota

Magnuson, Benson, Jensen, et al. 2004
Spatial Pattern
Trends in Ice Out Dates

Jenson, Benson, Magnuson et al. 2007
Moving States - Going to Arkansas?

Source: UCS/ESA 2003
Observed Northward Movement of the April 15 Lake Breakup Date by 5-year Intervals from 1975 to 2004

Jenson, Benson, Magnuson et al. 2007
Update on Long-Term Dynamics of Lake Ice Phenology across the Northern Hemisphere

winter 1855-1856 through winter 2004-2005

Barbara Benson, Olaf Jensen, and John Magnuson
Ice Data

- 150 years
- No more than 15 years missing/lake
- Lake Ice Analysis Group database + more recent data and updates
- 9 freeze and 17 breakup time series
- 18 lakes

Benson et al. In progress
Mean Ice Breakup Anomalies (17 lakes) vs Spring N. Hemisphere Temperature Anomalies

R² = 0.3

Benson et al. In progress
What are the long-term (150 year) trends in ice freeze and breakup dates across the Northern Hemisphere?
150 YEAR TRENDS (days/century)

Benson et al. In progress
How do the long-term trends compare with the recent period (30 years)?
TRENDS (days/decade): ICE BREAKUP

150 year data

12 out of 17 more rapid trend in last 30 years

Benson et al. In progress
Northern Hemisphere Winters
1855-1856 through 2004-2005

• Substantial shared variance of ice breakup anomalies with air temperature anomalies.

• Trends of freeze date are consistently toward later freeze (8.4 days/century) and earlier breakup (8.5 days/century).

• Rates of change in freeze and breakup dates have been more rapid in the last 30 years.

• More rapid global warming in past thirty years has been expressed differently in the ice phenology in different regions of the Great Lakes.

• Shared variance in ice off dates is large across the Great Lakes region.
The Longest Lake Ice Observations
1443-Present
Lake Suwa, Japan, Ice-on Time Series from 1443 - 1993
(30 days subtracted from years before 1880)

1443-1825 -- ice on later by **1 day** per century

1800-1993 -- Ice off later by **19 days** per century

Magnuson et al. preliminary
Lake Ice Data versus Thermometer & Paleo Measurements

- **NORTHERN HEMISPHERE**
- **Departs in temperature (°C)**
- **from the 1961-1990 average**

**Ice Cores and Tree Rings**

- **Suwa Ko Lake Ice**
- **Wisconsin Lake Ice**
- **Thermometer Readings**

Year:
- 1000
- 1200
- 1400
- 1600
- 1800
- 2000

IPCC 2001