ICE COVER ON THE GREAT LAKES

Ice formation observed on the Great Lakes is a clear signal of winter. In looking back in time, the lakes were formed over several thousands of years as mile-thick layers of glacial ice advanced and retreated, scouring and sculpting the basin. The shape and drainage patterns of the basin were in a constant state of flux resulting from the ebb and flow of glacial meltwater coupled with the rebound of the underlying land as the massive ice sheets retreated.

Ice cover provides us with an important connection to the past and also serves as a measure of the harshness of current day winter weather. Very important to us now is the major effect of ice on the Great Lakes, including how it impacts a range of societal benefits provided by the lakes, from hydropower generation to commercial shipping to the fishing industry. The amount of ice cover and how long it remains on the lakes vary from year to year. Our scientists have been observing long-term changes in ice cover as a result of global warming. Studying, monitoring, and predicting ice coverage on the Great Lakes plays an important role in determining climate patterns, lake water levels, water movement patterns, water temperature structure, and spring plankton blooms.

For the winter of 2012-2013, scientists predict that ice will form later than normal with maximum ice cover to 32 percent for the entire Great Lakes; this prediction is lower than the mean value of 55 percent ice cover.

Great Lakes Ice Cover Trends since 1973*

The following trends related to global warming have been observed over the past 39 years from 1973 to 2011.

- Annual average ice cover[1] showed a relative overall decline of 63% on the Great Lakes from 1973 to 2011
- Annual average ice cover on Lake Superior declined by 76%, the greatest decrease relative to 1973
- Annual average ice cover on Lake St. Clair declined by 22%, the least decrease relative to 1973
- Annual maximum ice coverage[2] for all of the Great Lakes has varied from year to year as illustrated by the following examples:
  - 95% ice coverage in 1979, the maximum on record
  - 11% ice coverage in 2002
  - 13% ice coverage in 2011-2012

*See next page for links to publications that document these trends.

[1]The average value of percent ice coverage from December to April.
[2]The maximum recorded value of percent ice coverage of the year.

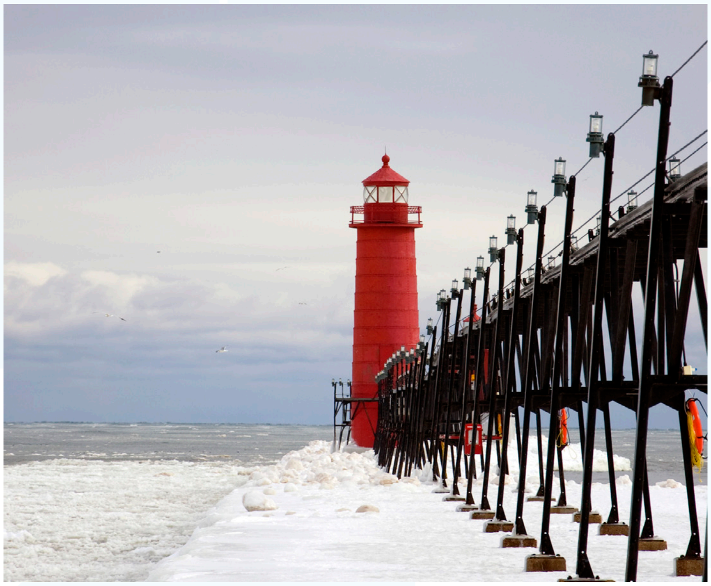


Photo credit: R. Greaves.

EFFECT OF ICE ON THE GREAT LAKES REGION

The Fishing Industry: In the shallow waters where whitefish spawn, ice cover protects their eggs from destructive wind and wave action. Ice cover with little or no snow cover allows light penetration at the surface to promote algae growth. At the base of the foodweb, algae support living organisms in the lakes, including valuable commercial and sportfish species. With $4 billion flowing into the commercial and sport fishing industry each year, ice cover can be a significant factor affecting the region's economy.

The Coastal Zone: In bays and other nearshore areas, ice forms a stable platform for winter recreational activity such as ice fishing. This stable ice also protects wetlands and the shoreline from erosion. Though these are positive effects, they also can have negative consequences. Huge ice jams can form in rivers connecting the Great Lakes. These jams constrict the flow of water from one lake to another, causing flooding upstream and less water for hydropower plants downstream. When the jam finally breaks, the resulting surge of ice and water can damage the shoreline and property.

Lake Water Levels and Navigation: Heavy ice cover in the winter can reduce the amount of evaporation from the Great Lakes, thus contributing to higher water levels. This is good news for shippers, increasing their capacity to transport cargo. However, heavy ice conditions in early spring can delay the shipping season and cause navigational problems. Higher lake levels are also a benefit to those who spend millions to dredge boat slips, channels, and harbors when lake levels were low.

MODIS satellite photos showing Lake Erie ice cover on March 4, 2009 (left), which was a high ice cover year, and on March 10, 2012 (right), which was a low ice cover year.

GLERL Research

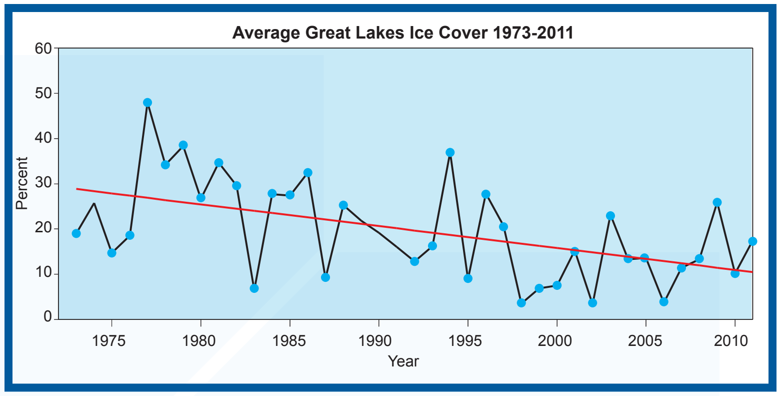
Forecast capability

The capability to forecast and predict ice cover is important for recreational safety and rescue efforts as well as for navigation, weather forecasting, adapting to lake level fluctuations and ecosystem studies. The need for forecast capability is illustrated by an incident that occurred during a warm sunny day in February of 2009 on Lake Erie when a large ice flow broke away from the shoreline. The floating ice block stranded 134 anglers approximately 1,000 yards offshore and also resulted in the death of one man who fell into the water. While the ice on the western sections of the lake was nearly 2 feet thick, rising temperatures caused the ice to break up, and southerly wind gusts of 35 mph pushed the ice off shore.

Short-term Forecasts: GLERL has added an ice forecasting component to its existing Great Lakes Coastal Forecasting System (GLCFS) which uses a computer model to predict ice formation and break-up. This ice model incorporated into GLCFS is now used by the National Weather Service to forecast short-term (5-7 day) ice concentration, thickness, and velocity as well as improving winter wave forecasts as ice cover significantly affects how surface waves behave. GLERL is also developing a Great Lakes Ice-Circulation Model (GLIM) for all five Great Lakes.

Long-term Forecasts: In addition to changes from global warming, Great Lakes ice coverage is heavily influenced by natural climate patterns, such as the ENSO (El Nino and Southern Oscillation) and the NAO (North Atlantic Oscillation) or AO (Arctic Oscillation). These long-term oscillations cause shifts in position of various high and low pressure systems that are defined in terms of a numerical index, representing the distribution of temperature and pressure over a wide ocean area that affects global weather patterns. For further information, refer to climate glossary of NOAA's National Weather Service Climate Prediction Center (www.cpc.ncep.noaa.gov/products/outreach/glossary.shtml#CONV).

For the winter of 2012-13, NOAA GLERL scientists predict a maximum ice coverage of 32% for the entire Great Lakes, which is lower than the mean of 55%. This prediction is based on the following two factors: 1) NOAA Climate Center 2012-13 winter index projections (Nino3.4 (+03) and the NAO (0.0)) inserted into GLERL's statistical ice model; 2) the extremely warm summer temperatures of 2012.



Arctic Sea Ice and the Great Lakes

The Arctic Ocean has been experiencing record low ice cover since 1995, with the lowest coverage thus far recorded in September 2012. Arctic sea ice and the Great Lakes ice variability are related due to the control of the AO also called the NAO via the Icelandic Low pressure system. Generally speaking, the AO can affect the Arctic Ocean and therefore the climate of the Great Lakes region based on the following relationship: if the AO produces a low pressure system (called a positive phase) in the Arctic, the Great Lakes will experience a warmer climate, leading to less ice cover. Conversely, if the AO produces a high pressure (negative phase) in the Arctic, the Great Lakes will experience a colder climate, leading to more ice cover.

Important Links:

Great Lakes Ice Cover Data: http://www.glerl.noaa.gov/data/pgs/glice/glice.html

Great Lakes Coastal Forecasting System: http://www.glerl.noaa.gov/res/glcfs/glcfs.html

Bai, X., J. Wang, C. Sellinger, A. Clites, and R. Assel. Interannual variability of Great Lakes ice cover and its relationship to NAO and ENSO. *Journal of Geophysical Research 117(C03002)* 25 pp. DOI:10.1029/2010JC006932 (2012). http://onlinelibrary.wiley.com/doi/10.1029/2010JC006932/abstract

Wang, J., R.A. Assel, S. Walterscheid, A. Clites, and X. Bai. Great Lakes ice climatology update: winter 2006–2011 description of the digital ice cover data set. NOAA Technical Memorandum GLERL-155, 37 pp. (2012). http://www.glerl.noaa.gov/ftp/publications/tech_reports/glerl-155/tm-155.pdf

Wang, J., H. Hu, D. Schwab, G. Leshkevich, D. Beletsky, N. Hawley and A. Clites. Development of the Great Lakes Ice-circulation Model (GLIM): Application to Lake Erie in 2003-2004. *Journal of Great Lakes Research* 36: 425-436, DOI: 10.1016/j.jglr.2010.04.002 (2010). http://www.sciencedirect.com/science/article/pii/S0380133010000584