ICE COVER ON THE GREAT LAKES

Ice formation on the Great Lakes is a clear signal of winter. 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 provides us an important connection to the past and also serves as a measure of the harshness of current day winter weather. Understanding the major effect of ice on the Great Lakes is crucial because 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 varies from year to year, as well as how long it remains on the lakes. GLERL scientists are 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.

Great Lakes Ice Cover facts since 1973

- 94.7% ice coverage in 1979 is the maximum on record
- 9.5% ice coverage in 2002 is the lowest on record
- 11.5% ice coverage in 1998, a strong El Niño year
- The extreme ice cover in 2014 (92.5%) and 2015 (88.8%) were the first consecutive high ice cover years since the late 1970's.

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

www.glerl.noaa.gov/data/ice

US Coast Guard Cutter Mackinaw in Lake Superior coming into Duluth. March 24, 2014. Credit: NOAA

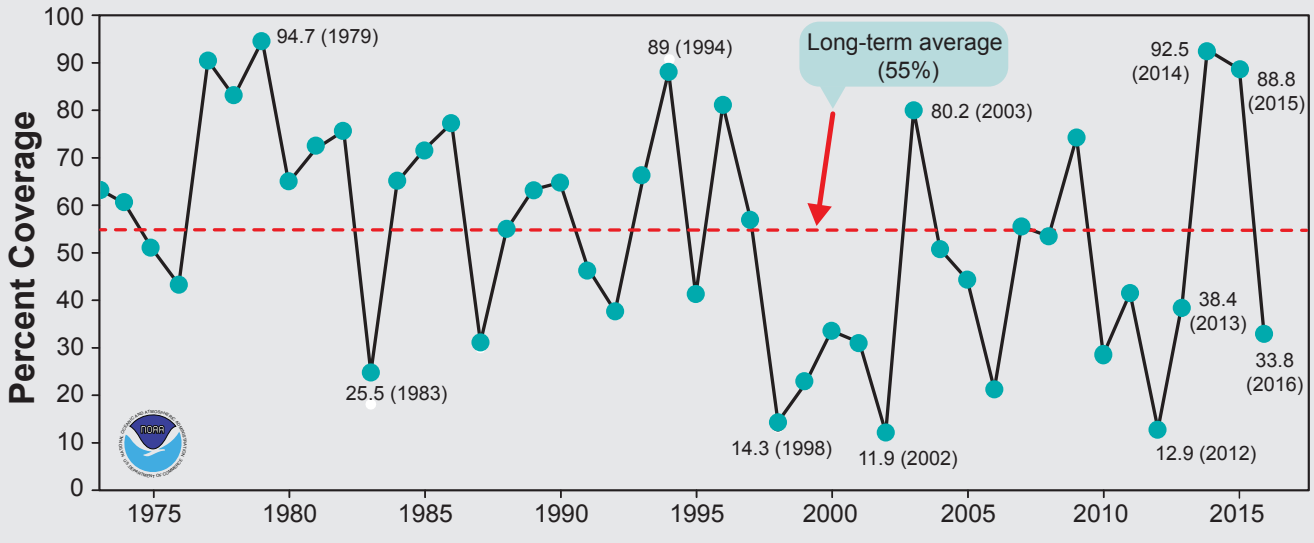
EFFECT OF ICE ON THE GREAT LAKES REGION

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. *(continued on back)*

On March 6, 2014, Great Lakes ice cover was 92.5%, putting winter 2014 into 2nd place in the record books for max ice cover.

coastwatch.glerl.noaa.gov/glsea/cur/glsea_cur.png

Great Lakes Annual Maximum Ice Coverage 1973-2016



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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 can reduce the amount of evaporation from the Great Lakes in the winter, 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 are low.

Tug stuck in the ice at the Soo Locks. March 20, 2014. Credit: NOAA

Important Links:

GLERL Ice Research Homepage: https://www.glerl.noaa.gov/data/ice

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

Great Lakes Ice Atlas (1973-2002): www.glerl.noaa.gov/data/ice/atlas

Great Lakes Coastal Forecasting System: 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).

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). 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).

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. This forecast need is illustrated by an incident that occurred in Lake Erie on a warm sunny day in February 2009 when a large ice flow broke away from the shoreline. The floating ice block stranded 134 anglers about 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 model is 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. A new GLCFS product under development is a sea spray vessel icing potential that will aid mariners late in the Great Lakes shipping season. GLERL has also developed a Great Lakes Ice-Circulation Model (GLIM) for all five Great Lakes.

Seasonal Forecasts: Great Lakes ice is heavily influenced by natural climate patterns, such as the ENSO (El Niño 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.

Winter 2016/2017 ice cover is projected to be influenced by the presence of a weak La Niña, a neutral North Atlantic Oscillation, and a weak Pacific Decadal Oscillation and Atlantic Multidecadal Oscillation. The NOAA Climate Prediction Center shows a greater than average chance for below-normal air temperatures in the western Great Lakes basin and above normal temperatures in the east. GLERL's statistical regression model predicts a maximum ice cover extent of 64%, which is greater than the long term mean of 55%. This year, for the first time, GLERL also used a 3 dimensional forecast model of the Great Lakes basin along with 6-hour atmospheric forcing (from NOAA's National Center for Environmental Prediction, NCEP) to produce a seasonal projection of ice including both spatial and temporal information. That model calls for a basin maximum ice cover extent of 44%. There is good agreement in the two forecasts for Lakes Michigan, Erie, and Ontario.

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).