Forecasting waves on the Great Lakes is a science

BY PATRICK LAPINSKI

Dan Miller

Weather can be a real trickster, often catching us off-guard or lulling us into a false sense of security. Separating our innate human senses into predictable patterns and accurate forecasts is the job of modern-day meteorologists. The more knowledge they have about weather, the better able they are to respond to its vagaries and dimensions, everything from a severe localized thunderstorm to a massive low pressure area affecting the entire Northland.

For Great Lakes meteorologists, the two biggest components taken into account when creating a marine forecast are wind and wave height. At a very basic level, a wave is created when wind makes contact with the surface of the water, causing a stippling effect, like what you see when a gust hits a shallow pool of water in a parking lot. On a deeper body of water, like Lake Superior, this stippling allows the wind to get a better grip on the surface of the water, increasing its pull and making wavelets which progressively increase in size as the wind continues blowing across its surface. So, how do these wavelets get to be six-foot waves? Let's take a step back to break down common characteristics of waves.

All waves have peaks and valleys; the highest part of a wave is its crest and the lowest point is its trough. The distance between crests is the wavelength, and, similarly, the vertical distance between the trough and the crest is the wave height. The length of distance that the wind can push on the water to produce waves is called its fetch. On the Great Lakes, this is where bathymetry, or underwater topography, comes into play.

"If you have a storm out in the middle of the ocean, it doesn't really matter where the storm is, all of the winds are over water. So, it's going to produce waves pretty much everywhere," said Dan Miller, science and operations officer with the National Weather Service (NWS) in Duluth. "Here on the shores of Lake Superior, the *direction* of the wind makes a very big difference as to what kind of wave response that you get."

Consider a northwest wind blowing roughly from Two Harbors toward Port Wing on the Wisconsin shore.

"At about 20 miles, it isn't a large fetch but still long enough to create some good waves," said Miller as he moved his hand eastward across the surface of a small map toward the center of the Lake. "Take that same wind direction and put it offshore from Thunder Bay. Here the fetch length is about a hundred miles versus maybe only 20 miles between Two Harbors and Port Wing, so you're going to get much bigger waves over the open waters."

Paul Sundberg

Waves pummel the North Shore of Lake Superior on Oct. 24.

Now rotate that axis to blow from the northeast, and the gale warning flags go up in Duluth as that long fetch pushes big waves directly toward the Twin Ports across the entire length of Lake Superior. It is a phenomenon well known to Great Lakes seafarers.

"Sometimes you'll get north of Isle Royale and you'll think you've got a straight shot down to Whitefish, but that takes you down through Superior Shoals and all of that stuff, so you've got to be kind of careful when you get down there," said Jack, a 40-year veteran of the lakes, explaining that it is important to get the sea on the stern so the boat will ride better. "You go full-speed and try to stay ahead of the waves as much as you can."

Jack has been on the thousand-footers for a long time. The pilothouse is a long way up, and sometimes it's hard to judge the wave height from that angle and distance.

"I don't know about any rogue waves, but I've seen some pretty big ones," he said. "I know about the three sisters, too. The first one will come underneath you, you'll roll up, you'll see it rolling underneath you and before that one gets back to the midway mark, you got the second one in there, so that's gonna lift you up even higher ... and about the time the third one gets there the first one is getting by your stern so it just kind of plunges your bow right down in the wave and the wave will wash over the bow."

The combination of wind speed and duration, coupled with an area of fetch determined by wind direction, allows forecasters to predict where the seas will build to dangerous levels. Wave forecasting is not really new science, but it's growing more complex, more intelligent and increasingly data driven. In addition to visual observations, such as reports from shore or vessels at sea, the National Weather Service relies on data it receives from open-water buoys, radar

and satellites. This field of remote sensing is at the leading edge of the science today. It sounds really impressive, right? Not so fast.

"Satellite data is really good for looking at the Lake in terms of ice coverage and how it has changed since yesterday or last week," said Miller. "But it doesn't really tell me all that much about the wave height."

Predicting wave height is like chasing the Holy Grail. Some days you've almost got it, and other days it slips through your fingers.

"Buoys are preferred, certainly by scientists, for a few reasons: number one, they're usually at the same latitude-longitude every year so the data sets from year to year are comparable," Miller explained. "They are also right there, going up and down with the waves, so it's an actual measurement of the swell or the wave and the wind."

The downside is that buoys are located at fixed points, so what is happening in one location could be very different from what a ship is experiencing a hundred miles away. There are three open water buoys on Lake Superior operated by the National Oceanic and Atmospheric Administration and similar numbers on the other Great Lakes. Private research buoys owned and operated by various universities and collaborative research projects, such as the University of Minnesota-Duluth Large Lakes Observatory and the Canadian government, also are deployed around the lakes. For instance, mid-Superior buoy station #45001 sits deep in the heart of Lake Superior, 60 nautical miles north-northeast of Hancock, Mich. Moored in over 800 feet of water, the buoy's instrumentation sends a string of data on air temperature, wind speed, sea temperature, barometric pressure and significant wave height data back to the National Data Buoy Center in Stennis Space Center, Miss., where it is combined with information from radar and satellite feeds into various weather models for analysis by the NWS.

Wave height also is influenced by seasonality. If you've ever wondered why it's often rougher on the Lake for a similar given wind speed in the fall versus the spring, this is due to the seasonal changeover that all lakes go through, even one the size of Superior. Miller defines these yearly periods as the "unstable season" (fall), and the "stable season" (spring and early summer). These are times when the Lake's surface temperature is either warmer (fall) or colder (spring/early summer) than the air temperature. While wind will always be the number one driver for wave production, the seasonal stability impacts how the air interacts with the surface of the water, right at the point where it is pushing on the surface. Warm water and cold air allow a coupling, thus an easier push.


Matt Silverness

The *Exeborg* navigates the Superior Entry during an April storm.

"In the unstable season, since the Lake is a constant heat source, it tends to keep what we call a mixed boundary layer over the water, so winds tend to be stronger and the wave generation tends to be much more efficient," said Miller. "Let's say for a given wind speed you normally get a 10-foot wave. During the unstable season, you might get more like an 11 or 12 foot wave. In the stable season, you might get an eight or nine foot wave."

Jack recalls a day on Lake Superior about 10 years ago. The weather report was forecasting winds late in the day or early morning, but nothing their vessel couldn't handle, so they followed a routine plan when a storm was coming—to get under Isle Royale and head over to the North Shore. Conditions changed very quickly.

"We got just about to the Keweenaw and all of a sudden we had 130 mph winds," Jack remembers. "We were pretty much just heading right into it because we couldn't turn to go for shelter. We were coming from the Soo, going to Superior, Midwest Energy, so we were light and didn't want to turn and put it in the gut because usually it would roll the s**t out of you, so we just checked everything back and headed right


Donald F. Donovan

A storm rolls in on Lake Superior.

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Legendary gales: *A show of force*

Sustained wind and waves often whip up the Great Lakes as winter approaches. Singer-songwriter Gordon Lightfoot immortalized the "gales of November" in *The Wreck of the Edmund Fitzgerald*, but sailors knew of their treachery long before that fateful day on Nov. 10, 1975.

This year, the gales struck early. On Tuesday, Oct. 24, a storm front produced monster waves on Lake Superior. One measured 28.8 feet at the Granite Island buoy located north of Marquette—the highest recorded on the big lake with modern technology.

A second high wind event hit the area three days later, with winds gusting to more than 60 mph and waves topping 15 feet. With water levels more than 10 inches above average, the surge created gigantic walls of waves that slammed against shorelines in Duluth-Superior, causing widespread property damage. Most vessels on Lake Superior altered their courses to sail in more sheltered waters. Several hugged the North Shore, while another group clustered northeast of Whitefish Point to wait out the storm.

Keweenaw County Repeater Association

Great Lakes tracking map shows ships taking refuge from the wind and waves of the Oct. 24 storm on Lake Superior.

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into it till we got over to the lee of the lake and then turned down. There were some pretty good waves there. That storm took housings off the deck winches up forward and blew them all the way down the deck. We buried the bow a couple of times ... so you gotta figure that's a good 25-foot sea there."

For marine forecasters, predicting what is called "significant wave height" is mission critical. By definition, significant wave height is the mean wave height of the highest third of all waves. Miller said if there is a misconception about waves, this is where you'll find it.

"It's important for people to remember that over the course of a three to six-hour wave event there should be a few waves in there that are on the order of 50 to 75 percent higher than that," said Miller. "So, for a forecast of four to six-foot waves in the nearshore forecast, it should be expected that there will be at least a couple waves an hour on the order of eight to nine feet. The way energy distribution works, the maximum expected wave height for any event with a duration longer than about six hours should be roughly double that of the significant wave height forecast."

Nothing brings people to the waterfront like a big storm. With the shipping season wrapping up soon, we reflect on storms of past, pray for safe passage through those to come, and leave the science to experts like Dan and other National Weather Service forecasters throughout the Great Lakes.

"If you look at the first part of the 20th Century where there really wasn't much of anything in the way of weather forecasting on the Great Lakes, people were largely flying blind," Miller said. "It isn't a coincidence that the number of shipwrecks and fatalities associated with shipping on the Great Lakes started a sharp decline in the 1950s that continues up until present day. The middle part of the 20th Century was the advent of regularly available marine wind and wave forecasts, and the quality of those forecasts has been steadily improving for the last 60 to 70 years."

We may joke about weather forecasters never being right, but, in reality, they're pretty darn good at telling us when to keep a weather-eye out and head for shelter.

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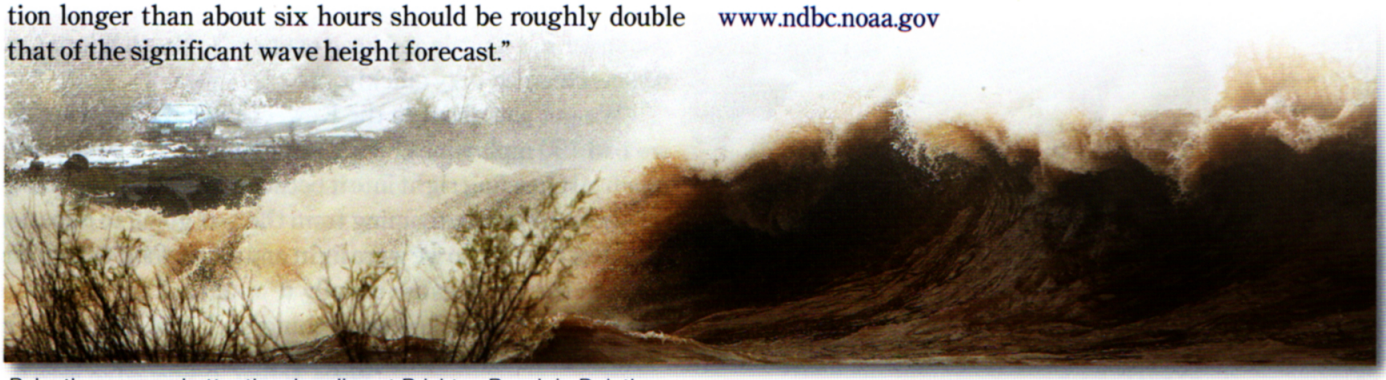

Bob King, *Duluth News Tribune*

Relentless waves batter the shoreline at Brighton Beach in Duluth.