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Wind and Waves and Waves and Wind

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Previously, we discussed the water currents of Flathead Lake, in particular at larger scales and at different depths. However, we did not discuss the primary driver of surface currents and waves on the lake: Wind.

The size and type of waves as well as surface current speeds are primarily determined by wind speed, the distance (fetch) over the water that the wind blows and the length of time (duration) that it blows. Since Flathead Lake is 28 miles long, its maximum fetch is 28 miles when the wind blows out of the due north (a north wind) or out of the due south (a south wind). When a strong, sustained wind blows from the north or south, waves form and get larger as they travel the length of the lake, ultimately crashing on beaches or sea walls at the opposite end.

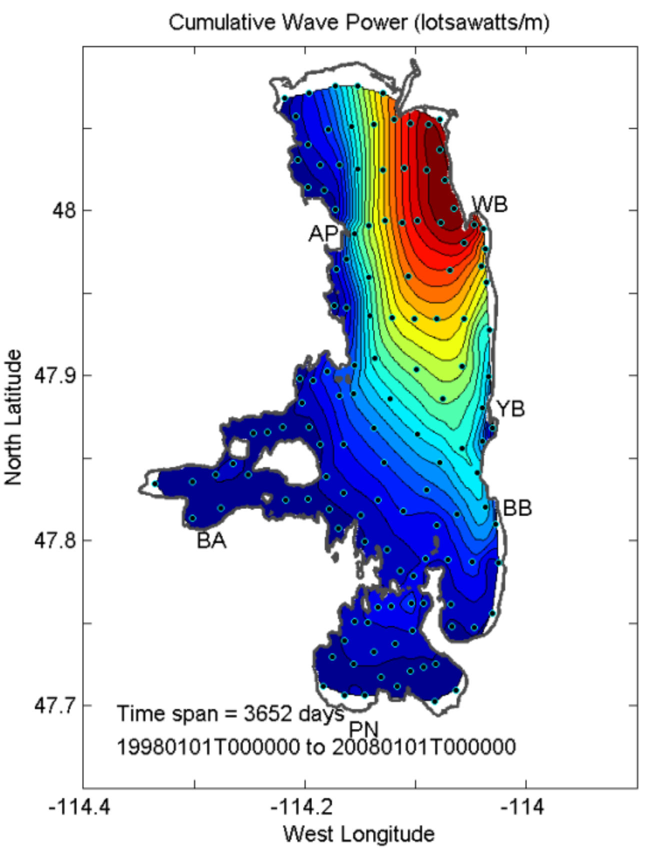
Flathead Lake wave heights are "fetch limited", and so for the length of our lake and the speed of strong sustained winds that can occur here (about 40-60 mph), physics dictate and calculations indicate that the largest surface waves that can occur are 1.5 meter high (nearly 5 feet). Not-so-coincidentally, the largest waves ever recorded on Flathead Lake by the Bio Station's physical lake ecologist, Dr. Mark Lorang, are 1.5 meters high. And the fastest surface currents recorded (associated with strong winds) are about 2.3 mph. Of note, a rogue wave of 3 meters (nearly 10 feet) could form in Flathead Lake if two of these 1.5 meter waves were to get in sync after one was reflected by the shoreline or a structure.

When a sustained wind blows in a consistent direction, another type of wave forms in Flathead Lake. It is called a seiche. Think about Flathead Lake as a large bathtub. When the wind blows from one direction for a period of time, the water builds up at the far end of the tub. Then, when the wind stops, the pressure on the water is released it sloshes back and forth in the tub in one very long wave. This sloshing wave is called a seiche, and its characteristics are determined by a lake's fetch, the shape of the lake bottom, as well as the speed and duration of the wind.

Again, the largest waves will occur along Flathead Lake's north-south axis, as the seiche rocks back and forth over a 90 minute period. Using pressure sensors and wave gauges, Mark has recorded seiches over 1 foot in height. If that happens during the summer, the lake level could temporarily be a foot higher than full pool in certain areas. Homeowners should take that into consideration when planning shoreline development, structures or vegetation.

However, the prevailing wind direction for Flathead Lake is from the southwest. Although the coldest winds usually come from the north and the most destructive winds often come from the east, the most common winds come from the southwest. Therefore, surface currents and waves most commonly travel from the southwest to the northeast. To better understand Flathead Lake waves, Mark and other Bio Station researchers and cooperators have installed and used wave gauges and wind sensors around the lake (now a part of the Bio Station's LakeNET weather network; data are available at http://flbs.umt.edu/lake/weather.aspx).

Mark and his international physical limnology team, which includes Chris Gotschalk from UC-Santa Barbara, Tom Lippmann from University of New Hampshire and Georgiy Kirillin from the Liebniz Institute in Germany, have modeled the wave energy/power in different areas around the lake. In fact, they have fed over 10 years of wind data into a model and calculated wave heights and periods for each hour. This data has shown that the cumulative wave power in Flathead Lake is greatest in the northeast portion of the lake, between Woods Bay and Bigfork (see figure below). The prevailing southwest wind direction and high wave power contribute to why so much wood accumulates, and why it appears that Flathead Lake is on a mission to destroy all the docks and sea walls in Woods Bay. You can watch animations of different wind directions and the resultant wave power on Mark's webpage at http://flbs.umt.edu/physlimn/Wind_Wave_Model.aspx.



All of this being said and even with all of this data, prevailing wind direction is a bit of a misnomer. When I installed LakeNET weather stations back in 2011, I expected to see most wind readings coming from the prevailing direction of southwest. However, instead what I found was dramatic variation between sites and during the course of the day. There certainly are times when all 9 of our weather stations around the lake report southwest winds, however there are many times when the all the stations are reporting different directions.

In fact, it is even common to see all stations reporting wind towards the center of the lake at certain times of day, while at other times of day all the wind is blowing out from the lake. These daily patterns are related to differential heating of land and water (it takes more energy to increase the temperature of water in comparison to land) and so wind will blow towards the land (onshore breeze) in the day when the land is warmer than the water. (Air pressure is lower above the warm land, and wind flows from high pressure to low pressure.) In contrast, in the evenings when the land is cooling faster than the water, you get the opposite, an offshore breeze blowing into the lake.

These winds caused by differential heating of land and water are most pronounced where there is more contact between land and water. This causes more consistent wind in parts of the lake like Big Arm and Dayton. Just ask the sailing community about the consistency of wind in those parts of the lake, as opposed to the dreaded midday lull that often occurs out in the center of the lake.

As I mentioned last time, these physical dynamics of the lake are the template and drivers for the biological community. Wind-driven waves and currents deliver nutrients and other needed materials to organisms in different parts of the lake (as well as dispersing the organisms themselves). However, there are also some practical implications for the human inhabitants of the Flathead Lake ecosystem. First of all, Mark's research can help property owners plan for the size and direction of waves that will be breaking on their shoreline, docks or other structures. To minimize and mitigate shoreline erosion caused by waves, Mark has designed and built numerous gravel beaches over the past 3 decades. But I will discuss shoreline erosion and beaches in detail in my next article.

Additionally, Mark's research team has created wind-driven models to determine where waves and surface currents would carry things in the lake. One practical management application is related to Aquatic Invasive Species. If a nonnative organism were introduced to Flathead Lake, Mark's Drifter Model can predict where it would end up in different wind scenarios (and therefore where scientists and resource managers should concentrate efforts looking for invaders). Mark has some of these animated scenarios posted on his webpage and they are pretty darn cool to watch (http://flbs.umt.edu/physlimn/Drifter_Model_Examples.aspx). So take a look and enjoy.