The Wonders Behind Lake Effect Snow: How it Forms and Why?

We're approaching the time of year rather quickly, where we begin to see cooler air masses shift down into the U.S. from Canada, first frosts, and quickly evolving changes toward winter. One phenomenon in particular is lake effect snow, which will become relevant in the coming weeks with chances arising as we progress deeper in the fall season. Before you know it, computer models will begin to show those blue stripes stemming off the Great Lakes.

<u>FORMATION</u>

A trough of cold, dry air is what you look for in forecasting lake effect snowfall. This specific type of air, originating typically from Canada (or the Arctic), shifts across the open bodies of water that are which of course the Great Lakes. As this cold relatively dry air begins to flow across the water, parcels of air that are continuously evaporating and rising from the generally "warm" lake, mixes with the cooler air above. Water contains latent and sensible heat, which is important to know. These now saturated, "warmer" air parcels surrounded by the cooler ambient air now rise because it's less dense. This rising motion ultimately leads to clouds and snowfall on the leeward side of the lakes.

KEY ELEMENTS

1.) **FETCH**: Technically, fetch is the distance that air travels over a body of water. If you have air that can span a large body of water, it has more of a residency component to it because the air is "soaking" up the warmth (energy in the form of heat) and moisture. Once saturated and rising air reaches land, condensation occurs bringing those snow bands. A longer fetch produces much more precipitation. You typically want to have a fetch of at least 30 miles. The more fetch, the better the lake-effect potential!

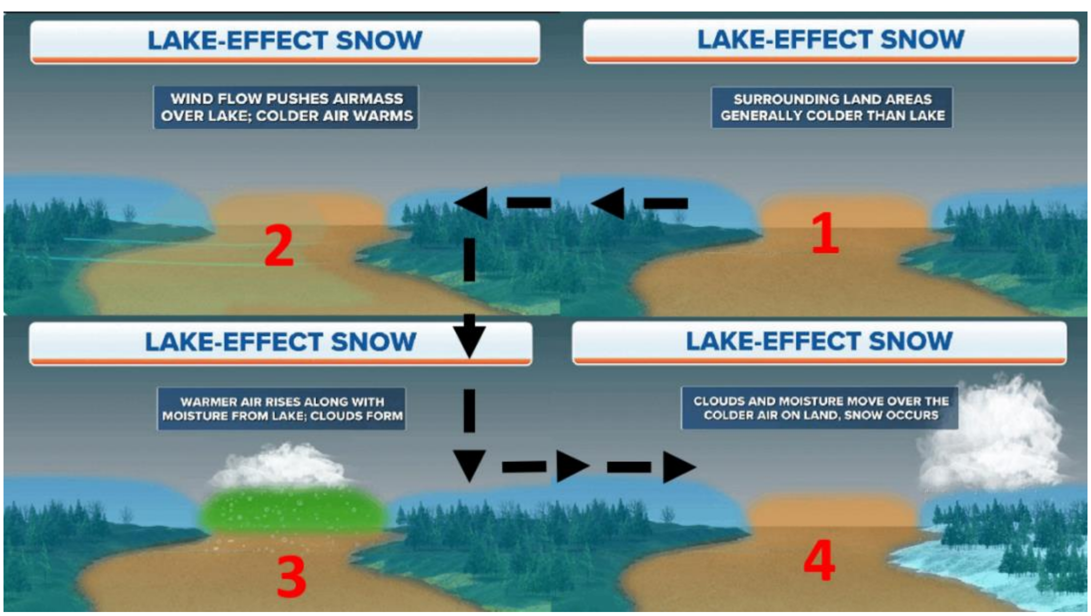
2.) **INSTABILITY**: One absolute key element to getting lake-effect snowfall in the first place is that the difference between the lake's surface temperature, and the temperature of the air crossing the water must be at least 13*C (23*F) within the lowest 5,000 feet. Ideally, you want at least 15*C. Greater the difference in temperature, the more robust the lake effect snow can be. As aforementioned, warm air rises when the surrounding air is cooler (e.g. convection). The colder the ambient air is and the warmer the rising parcels are, this creates a much more unstable environment. Those parcels want to accelerate fast vertically, creating a taller cloud. A taller cloud essentially facilitates a much higher snowfall rate.

3.) **WIND SHEAR**: Ever wanted to know why bands form into those narrow, shaped squall-like structures? It's because of the speed and directional wind changing with height, specifically within the lowest 5,000 feet. If you have unidirectional shear, you align bands in a way that produces intense bands. The direction of the lowest 1-2 kilometers of the boundary layer dictates where those bands setup. A rule of thumb is that you want to see no more than 60 degrees of a change of wind with height from the surface up to the height of the cloud layer. 30 degrees or less produces organized, strong bands. Furthermore, you don't want surface winds in the boundary layer don't want to exceed 40 knots nor be too weak like below 10 knots. Too much wind can fracture snowflakes, thereby reducing that "fluffy" potential and disseminate snowfall, while too weak of a wind reduces intensity of snow bands.

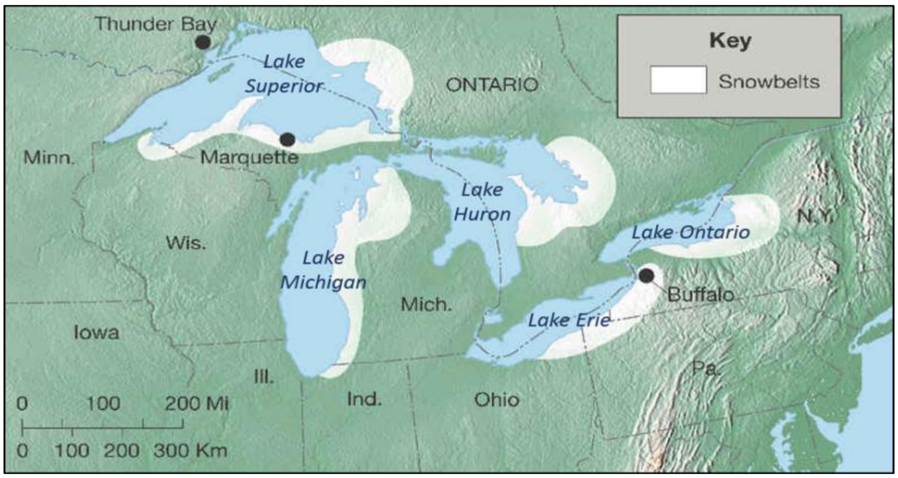
4.) **FORCING MECHANISM**: When meteorologists mention "forcing", we're talking about what type of synoptic (i.e. front) or mesoscale (i.e. convergence of surface winds) impetus it is. What drives those notable and significant lake effect events is when a deep, potent trough drives across the Lakes. However, it's when we see this trough digs (slower implication), tilts in a negative orientation (i.e. from NW to SE), and a vorticity max (ball of energy think of it as) focuses in an organized structure which creates an environment that allows for intense vertical motion. This especially enhances and exacerbates the general lake-effect event.

5.) **OROGRAPHY & TOPOGRAPHY**: While not necessarily as important really compared to above, this is something that can also augment the snowfall potential. Downwind of the lakes, you can get frictional convergence as the water meets the land, which can mean more intense snow bands. Orographically speaking, we see that in places like Michigan and upstate New York, elevation rises rather quickly as you trek further inland off Lake Superior, Erie, and Ontario. Furthermore, when air rises on the windward side of any mountain, it produces condensation as air then shifts to the leeward side. It's essentially the same thing here as the saturated air rises as it vertically climbs elevation, further enhancing those snow bands.

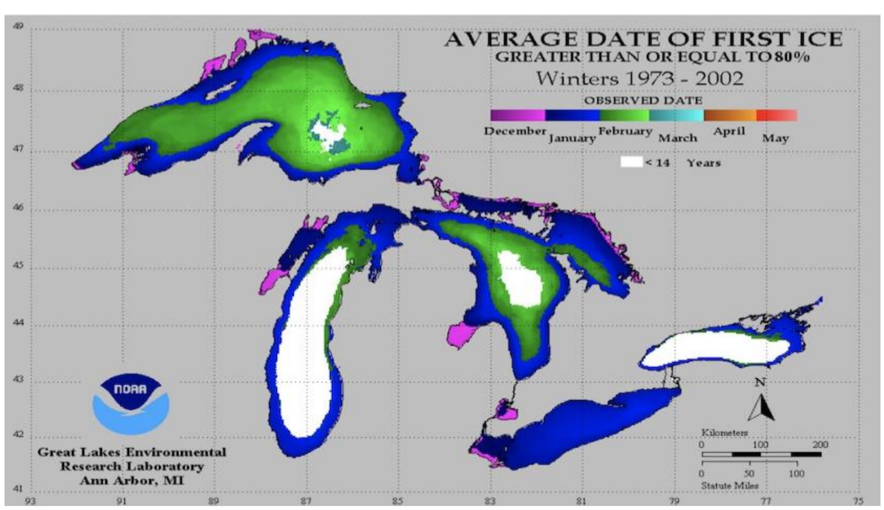
In a nicely formatted visual illustration from FOX Weather, here's a 4-step process that shows a very simple explanation in how lake effect snow occurs. As you see below, then compare all key elements above that are "ideal" in terms of long fetch, uniform wind shear and speed requirements, absolutely unstable environment (arctic air and warm waters), and augmentation from a strong digging trough allowing for strong upper level divergence; put this all together from an idyllic atmospheric setup and you get prolific lake effect snowfall events that you've seen or read almost unfathomable snow amounts in one local area!



Areas that are of course downwind of the Great Lakes include upstate NY, northwestern PA, MI, northern parts of WI, and the upper peninsula of MI, northeastern IL (depending on the wind direction off Lake Michigan), northern IN, and southwestern Ontario. Now while these areas are the main "hotspots", with just the perfect setup, you can get these snow squalls to hold together just long enough that they can make it all the way to the East Coast and impact major metro areas at a much lesser extent however relative to the common areas.



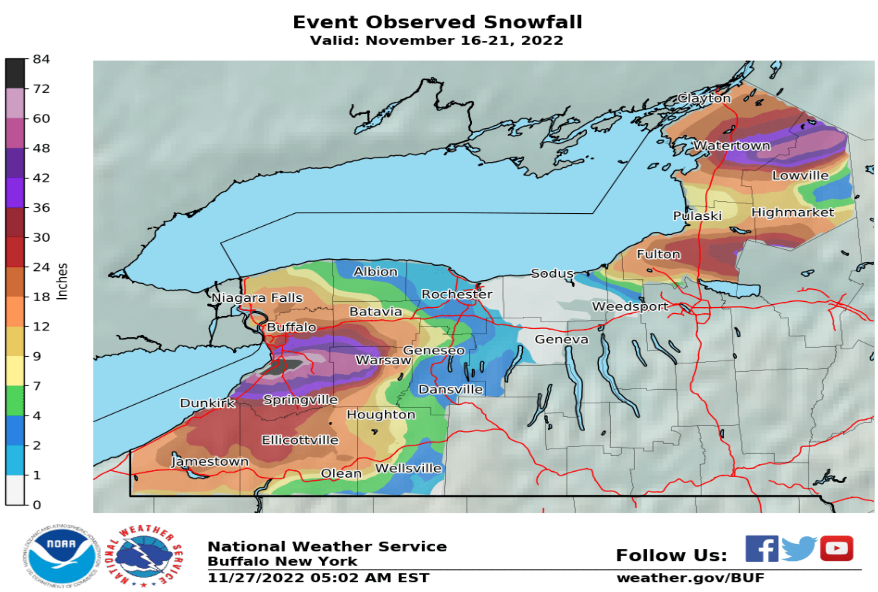
Now, ever wonder why maybe you don't hear about lake effect snowfall events later in the winter season? It's because as the winter progresses, colder air masses will continue to shift down into the U.S. eventually leading to the cooling of the surface of the lakes. Gradually, ice begins to form, and ice prevents the vertical distribution of heat and moisture. This eventually leads to the winding down of the lake effect, though it can certainly vary from winter to winter because milder winters obviously allow for the waters to remain relatively warmer. Below, NOAA's research over the span of 20 years reveals the average formation of ice across the lakes.



Now with the atmospheric processes and explanations out of the way, lets go over some of the most memorable snow-effect events over the last two decades. Here are easily the top three events in the last two decades that will easily be the most memorable of the 21st century.

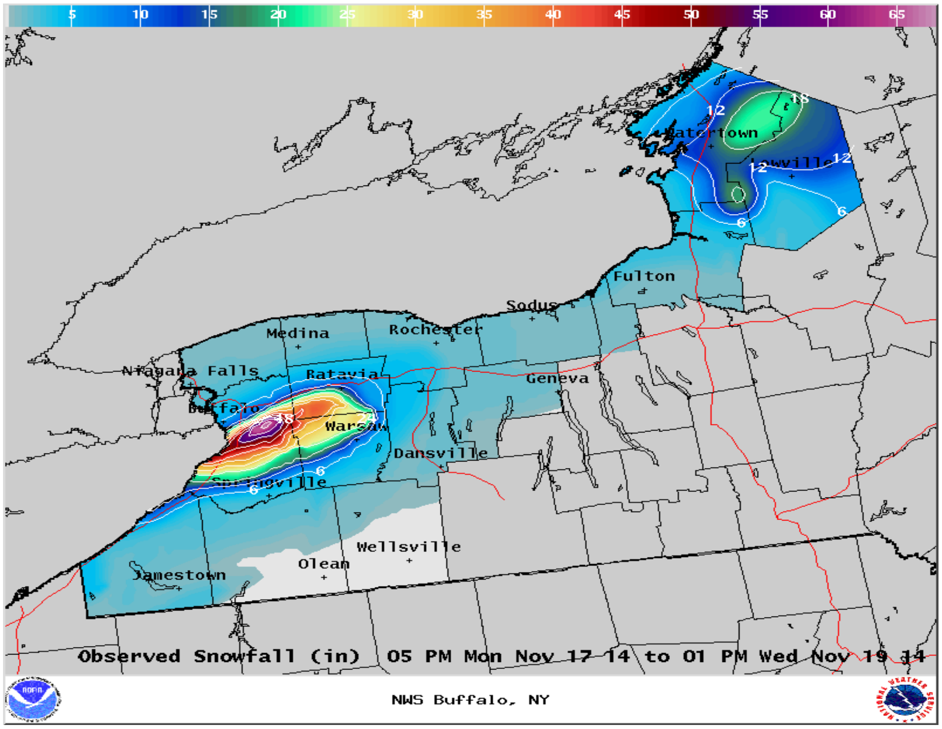
NOVEMBER 17TH-20TH 2022

A prolific snowfall occurred just last November, where areas south of Buffalo saw up to nearly 82'' of snow (over 6 feet!), with locations across upstate NY from Jamestown to Watertown seeing well over a foot. A remarkable event occurred where a primary low shifted off into southern Canada with a Miller B cyclone manifesting off the East Coast. It was behind this setup that allowed for deep cold air to blow over warm lakes, resulting in a stationary band that occurred across central and southern Erie county. Rates of 4-6''+ per hour resulted from deep convection and a mature snow band, with thundersnow. The New York state Thruway was completely shut down. Eventually, several more well-defined snow bands would make their way into the Buffalo area, causing rates of 3-5'' per hour before shifting north and then again back south. The Buffalo Bills game had to relocate since there was no way travel could occur. Hamburg, NY saw a record-breaking 81.2'' of snow with Blasdell coming in at 76''. Erie county saw a record-shattering 58.2'' in 48 hours with Genesee County coming in at 28.3'' in 24 hours. Truly, the magnitude of this event will be the most memorable of the 21st century.



NOVEMBER 17TH-19TH 2014

East of Buffalo, over 5 feet had fallen with an insanely tight gradient that would level off to a few inches north. The event began with a snow band that established itself within the vicinity of Buffalo that was about 20 miles wide. Within this band, snowfall rates exceeded 3-4'' per hour getting up to 6'' at an hourly rate and all of this occurred within 12 hours. Heading into November 18th, the band hadn't really budged and places from Lancaster, NY to Alden saw anywhere between 4-5 feet of snow. This band would go onto weaken and another band formed east of Lake Ontario impacting Watertown, NY dropping 1-2 feet with snowfall rates in excess of 3'' per hour. Some of the top reports would record 65'' for South Cheektowaga, 63'' in Lancaster, and 60'' in Gardenville. An event of this magnitude hadn't been seen since 1945!



OCTOBER 12TH-13TH 2006

One of the most intriguing lake effect snow events certainly would be in October 2006 for how unprecedent it was. This event would go on to be one of the earliest lake effect events ever dating back to records. The cold air was anomalous for the time of year and Lake Erie for instance was still in the 60's, so this created a completely unstable environment. What made this event so destructive was because of the leaves still left on trees, and the wet snowfall given the time of year still. Here, lake effect rain began that eventually changed over to snow. This band drifted between the north and south towns before settling over Buffalo. With the amount of intense rising motion, unique thermodynamics can occur where you get enough cooling to occur from meteorological processes that can change rain to snow in an instant. The aftermath of this event was quite astounding, as 22.6'' of snowfall was recorded at the Buffalo airport, smashing any October record, and setting up itself as the top 6th greatest snowfall ever for Buffalo. This event as mentioned was destructive given the time of year, trees with leaves still on, and downed powerlines that had left residents in the area without power for 5 days.

As previously mentioned, we're not far from the "prime" lake effect snowfall season with November being the official start from a climatological perspective as air masses trend colder with time, and daylight grows shorter. However, as you can also see, with just the right perfect setup, you can get anomalous events such as the one from October 2006. Lake effect snowfall is such a mesmerizing atmospheric phenomenon because what culminates to its manifestation, and how it can produce anywhere from a mere few inches up to several feet all within a couple miles. Winter is approaching!