

The location I will be looking at is in and around Buffalo, NY. Several geohazards are possible in this area, though most are on the mild side compared to their danger in other places around the country (or world). Let's look at a couple of these.

The region around Buffalo, New York is occasionally subject to small earthquakes. Most are barely strong enough to be felt, and relatively uncommon. Figure 1 below shows recent earthquakes over the last 4 years, and none are stronger than 2.6. If you sort the quake data for the biggest quakes, a 3.8 appears to be the strongest in recent years (Earthquake Track, 2022). Further down the lakeshore in NE Ohio, they can get as large as a 5.0, and in 1966, the Buffalo area saw a 4.7, but still far from the devastating quakes common on the West Coast (World Media Group, LLC, 2022).

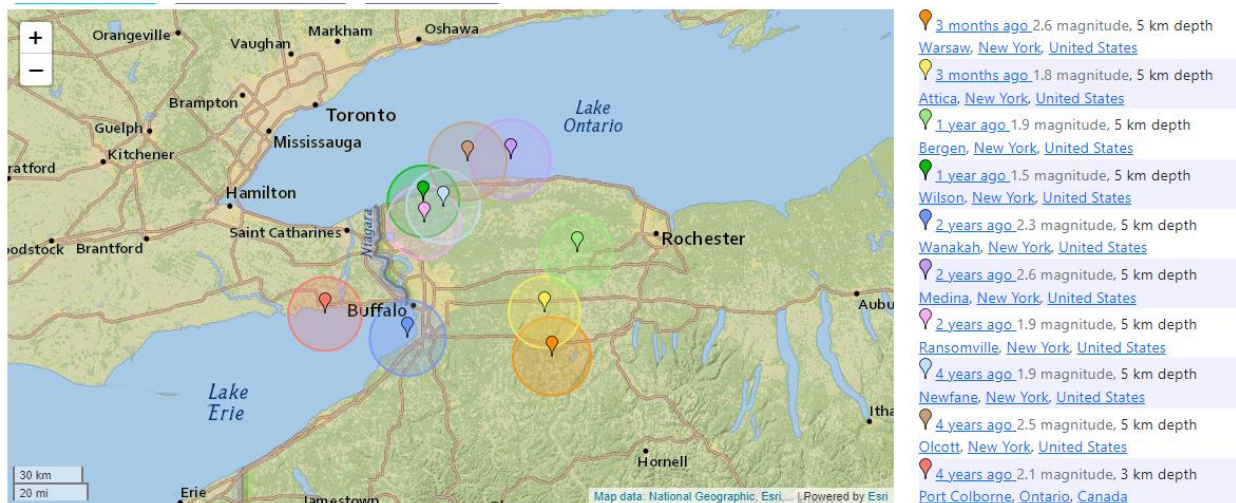


Figure 1. A map of recent earthquakes in the Buffalo, NY area. (Earthquake Track, 2022)

The area does see some risk of tornadoes, though certainly not to the same degree as Tornado Alley. The largest was an EF3. So, this is something the area has to concern itself with, but it is not as regular a hazard as some other types of events (democratandchronicle.com, 2022).

Not tracked on this map are waterspouts, which do also occur and can present hazards to local boaters on the Lake.

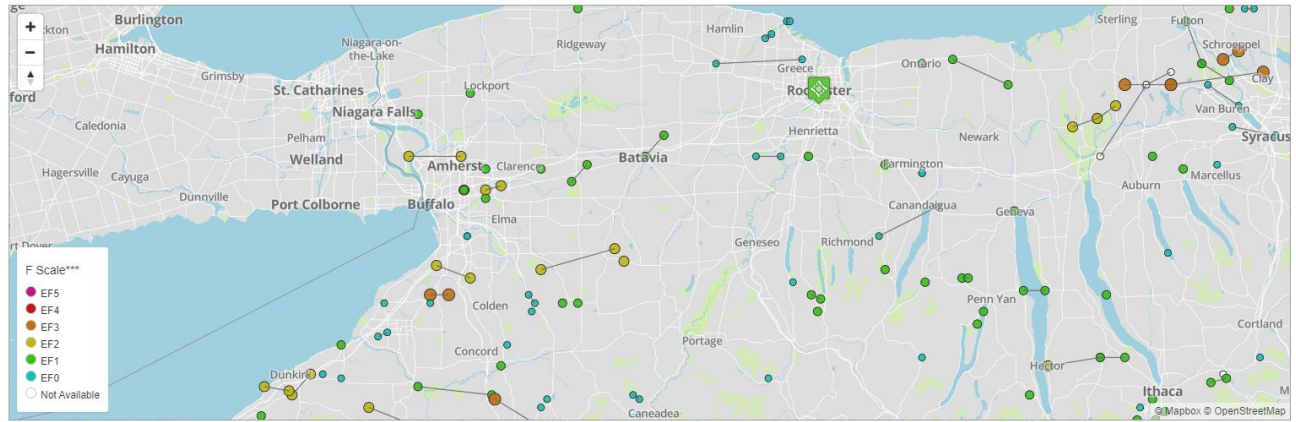


Figure 2. Tornado tracks over the last 70 years in Western New York. The most severe tornadoes have been EF3 (democratandchronicle.com, 2022).

A nice summary of the geohazards faced in Buffalo, NY comes from (World Media Group, LLC, 2022). Table 1 shows a summary of counts of common extreme weather events since 1950 (to 2010). The most common hazard on here is thunderstorm winds, but the next highest is hail. Blizzards, Ice Storms, Heavy Snow, Winter Storm, are all related to each other and together represent the next most common hazards. It’s not clear from this source how these are differentiated from each other, or what the “other” category represents.

Type	Count	Type	Count	Type	Count	Type	Count	Type	Count
Avalanche:	0	Blizzard:	1	Cold:	15	Dense Fog:	0	Drought:	5
Dust Storm:	0	Flood:	185	Hail:	255	Heat:	1	Heavy Snow:	122
High Surf:	0	Hurricane:	0	Ice Storm:	2	Landslide:	0	Strong Wind:	54
Thunderstorm Winds:	810	Tropical Storm:	0	Wildfire:	0	Winter Storm:	13	Winter Weather:	0
Other:	52								

Table 1. List of extreme weather event types and their frequency in Buffalo, NY (World Media Group, LLC, 2022).

One potential geohazard I want to mention here is not a present concern but perhaps is likely to be a future one, and that is algal blooms on Lake Erie. They have become quite severe in recent years in the western part of Lake Erie and continue to increase in size. The algae can

contaminate the water supply and has triggered boil water orders for cities that rely on lake water for their city water supplies. As Buffalo relies on the lake for its water supply, it is something the region is going to have to remain on the look out for and take steps to address in the future (NOAA, 2017).

The geohazard I will be examining in greater depth is winter storms, and specifically lake effect snowstorms. I will discuss lake effect storms broadly, but my focus will be on the eastern shore of Lake Erie, and even more specifically, around Buffalo, New York. Buffalo is well-known nationally for dealing with heavy amounts of snow and when it comes to geohazards, this is probably the one that stands out the most.

In the northern parts of the United States, winter brings snow all over this part of the country. But the kind of snowfalls received in a place like Columbus, Ohio or Pittsburgh, PA, are quite different than the kind of snowfalls received just 150 miles away in Northeast Ohio, or Western New York. There are similar differences all over the Great Lakes region. Areas that are a little bit inland or on the western shores of the Great Lakes have much lower snowfall amounts annually than do the eastern shores. This difference is the result of lake effect snow. (NOAA, n.d.) Lake effect snows produce regions with higher annual snowfalls, and therefore produce greater winter hazards related to it that must be managed and planned for.

To put some numbers to these differences, a city like Columbus, Ohio averages about 22 inches per year, compared to a national average of nearly 28 inches per year (BestPlaces.net). By comparison, Buffalo, New York measures 85 inches per year, and that is at the airport, which is actually north of where the deepest snowfalls occur in the area (Current Results Publishing Ltd., 2022).

The map below shows the regions in red with the greatest amounts of lake effect snow. You can see clearly in Figure 3 how the highest snowfall amounts are to the east and southeast of the lakes. The mountains away from the lake also produce some deep snows, but you can see how deep the average accumulations can get on the eastern shores of the lakes compared to typical snowfall amounts further inland or on the western shore, even at the same latitude. (NY Ski Blog, 2022)

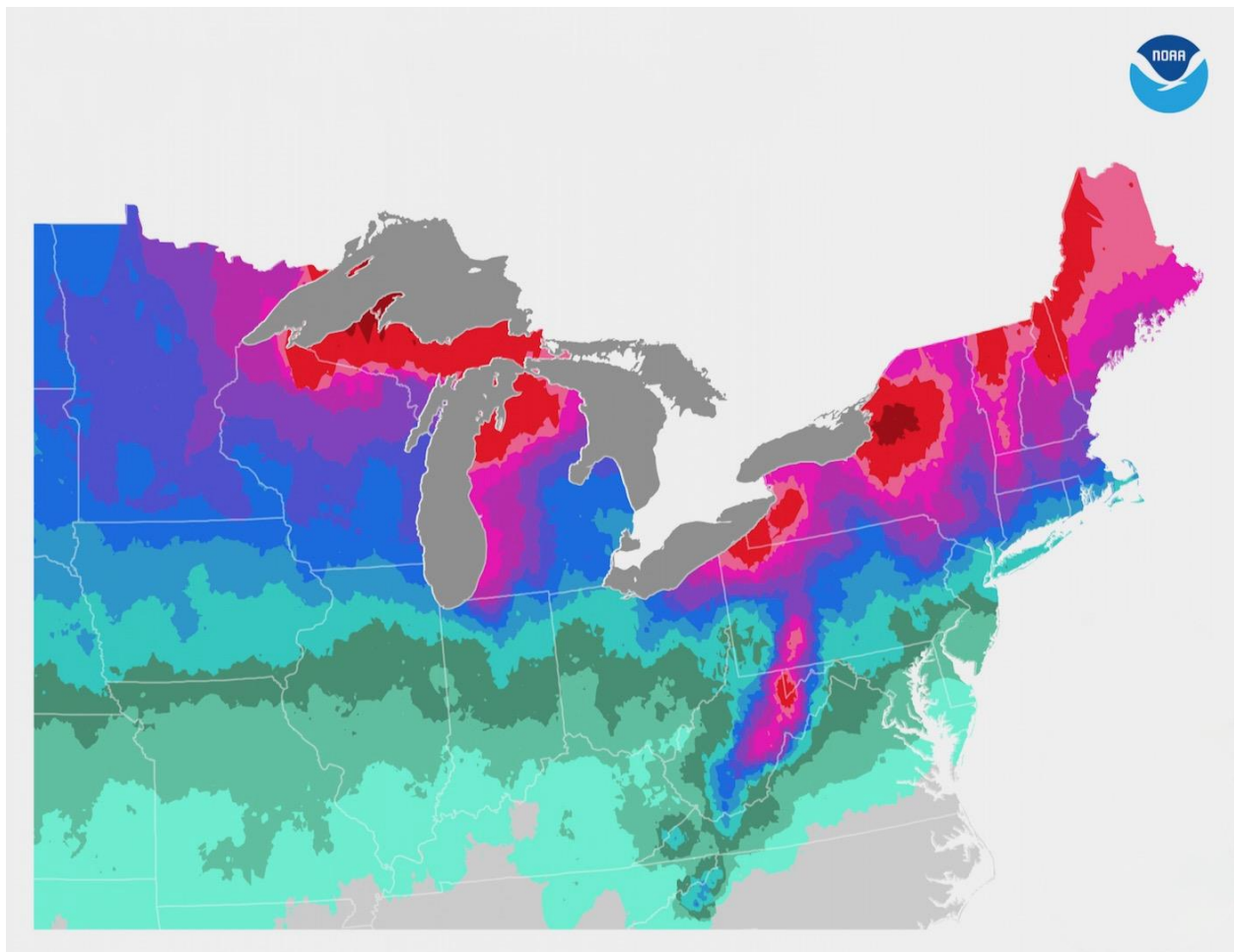


Figure 3. A map of annual snowfall averages from NOAA. The eastern and southeastern shores of the Great Lakes have high snowfall accumulations due to lake effect snow. (NY Ski Blog, 2022)

Lake effect snow is produced by the interaction of the atmosphere with the water of the lakes and the land. In the winter, the air is dry. Because it is so cold, it can hold less moisture. As it moves over the relatively warm lake water, it gains moisture. When the air moves over the land, the air rises which causes precipitation to fall because the air can hold even less moisture at higher altitudes. In the winter, this precipitation falls as snow (NOAA, n.d.). Figure 4 shows how the process works in general. The location of lake effect snow depends on the wind direction. Typically, the northern United States experiences prevailing westerlies, so the snow tends to fall on the eastern side of the lakes. However, in a specific storm event, the location of the lake effect snowfall can change and the direction of the wind changes. This can produce especially dramatic changes in an event like a nor'easter, or a bomb cyclone. The back end of the storm can have particularly strong southerly winds and occasionally even out of the east, depositing lake effect snow in locations that experience it less often (NOAA, n.d.)

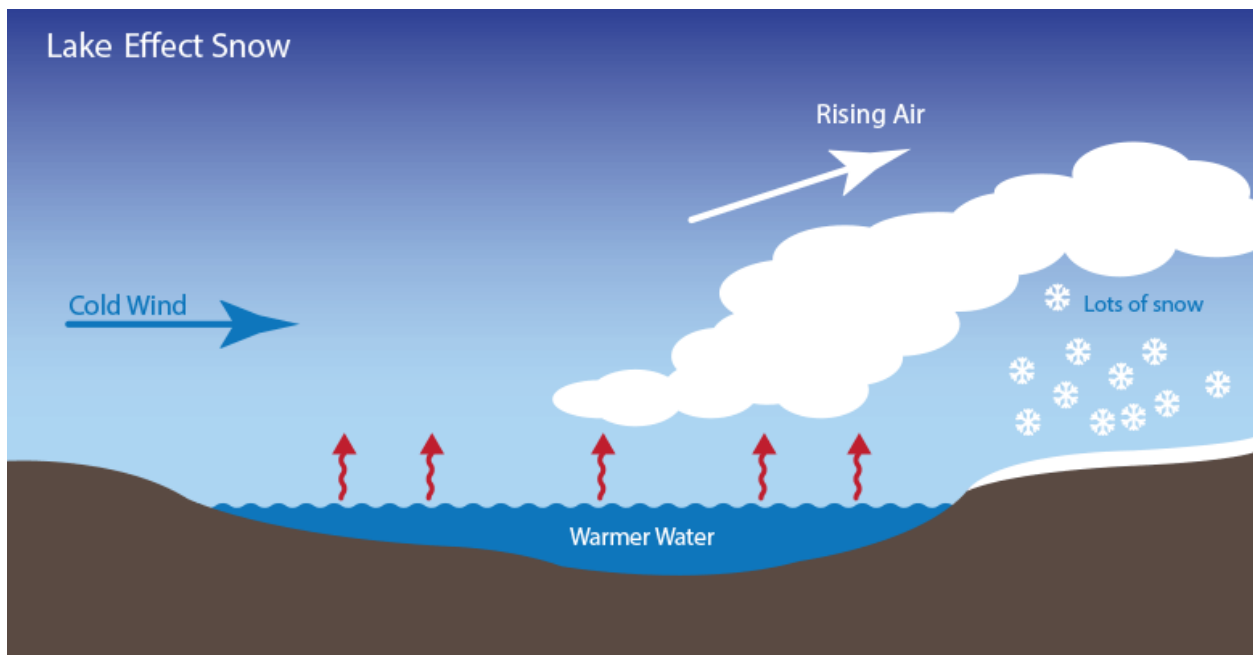


Figure 4. A diagram of how lake effect snow works. Warmer lake water evaporates into dry winter air. When the air rises as it moves over the land, it deposits snow on the shore. Since winds are typically coming from the west, the places with the highest lake effect snow amounts

are to the east of the Great Lakes. The location of a specific lake effect event depends strongly on wind direction. (NOAA, n.d.)

Lake effect snows in the best of times can be particularly challenging to predict. We've noted the wind direction issues previously. In addition, lake effect snows tend to form in bands, making specific locations and times of deep snowfall hard to predict. The bands make move over time. Places near each other may experience different snowfall amounts if the bands remain positioned over the same area. One location may fall under the band and someplace quite close may fall between the bands. This is why forecasts for snowfall amounts may have ranges measured in feet (Yulsman, 2014).

Figure 5, below, shows the lake effect snow bands coming off the Great Lakes in a satellite image. You can see the distinct bands in this image are particularly distinct over Lake Superior, but appear in all the cloud formations coming off all of the lakes.

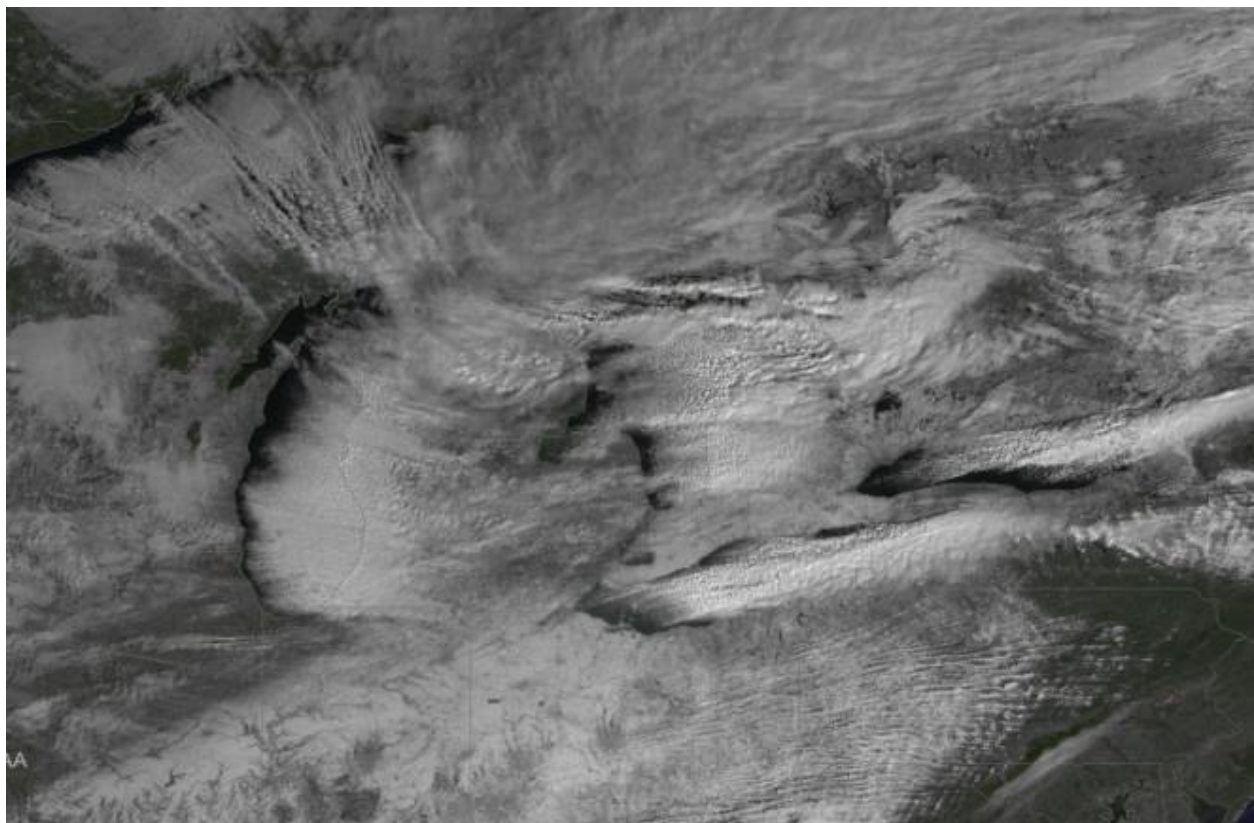


Figure 5. Satellite image of lake effect snow in progress. The bands of snow set up by lake effect snow can make specific locations of deep snow challenging to predict. (Yulsman, 2014)

Lake effect snow has changed over the decades due to climate change. When I was a kid growing up a bit further west along the Lake Erie shore, the lake would freeze over in the winter. Lake Erie is the shallowest lake and so shows the largest change in temperatures over the year. When the lake would freeze over, the lake effect snow machine would shut off, because the amount of moisture needed to power the lake effect storms was no longer available. So, lake effect would be most intense in November through maybe January, but then there would be much less snow around Lake Erie until the lake thawed in late March. Lake Erie hasn't frozen over completely since 1996. I remember the first time Put-in-Bay, Ohio ever kept their ferry service open all winter! This means that there is more open water that the atmosphere can draw moisture from, allowing lake effect snows to persist in varying degrees throughout the winter (Smith, 2022). Lakes that are deeper and larger aren't as prone to freezing over, and remain relatively warm all winter, and thus remain open all year for lake effect snow. As the climate continues to warm, it's possible that some snows will change over to lake effect rain, but in the short term, some places have seen more, not less, snow (Ruppenthal, 2017). The surface area of open water determines how much moisture the atmosphere is able to absorb so the amount of freezing is a key factor, in addition to the temperature of the atmosphere moving over it.

In addition to the usually persistent weather patterns of winter that enhance typical winter snowfall amounts, nor'easters and bomb cyclones, which have become more common due to climate change, can also contribute to lake effect snowfall. The map in Figure 6 shows the inland impacts of a late season nor'easter earlier this year (2022). While it was too late in the season to produce snowfall in some places (Buffalo received rain instead), nonetheless, you can see the regional impacts. Had this same storm occurred several months earlier, snowfall amounts

could have been spread over a much larger area. Nor'easters typically deposit their storm effects along the coast, but that need not be the case if they move inland as this one did (Storm, 2022).

Bomb cyclones can have similar effect. We've seen these events become more common in recent years. Western New York state can see up to 5 inches in 20 minutes of snow in one of these extreme events (2-3 inches per hour is considered heavy). "The tiny town of Montague, downwind from Lake Ontario, holds the "unofficial" world record 24-hour snowfall total of nearly 6½ feet, set on Jan. 11-12, 1997," according to USA Today (Rice, 2022). As the frequency of bomb cyclones increases, this will also increase the likelihood of these extreme events. Cities like Cleveland, Ohio or Buffalo, New York which experience high volumes of lake effect snow are generally prepared to keep the freeways open at an inch-per-hour of snowfall. But it's hard to prepare for five inches falling in under 20 minutes. As the weather warms, it's also possible these snowstorms could turn to ice storms more often, which are particularly damaging to trees and power lines.

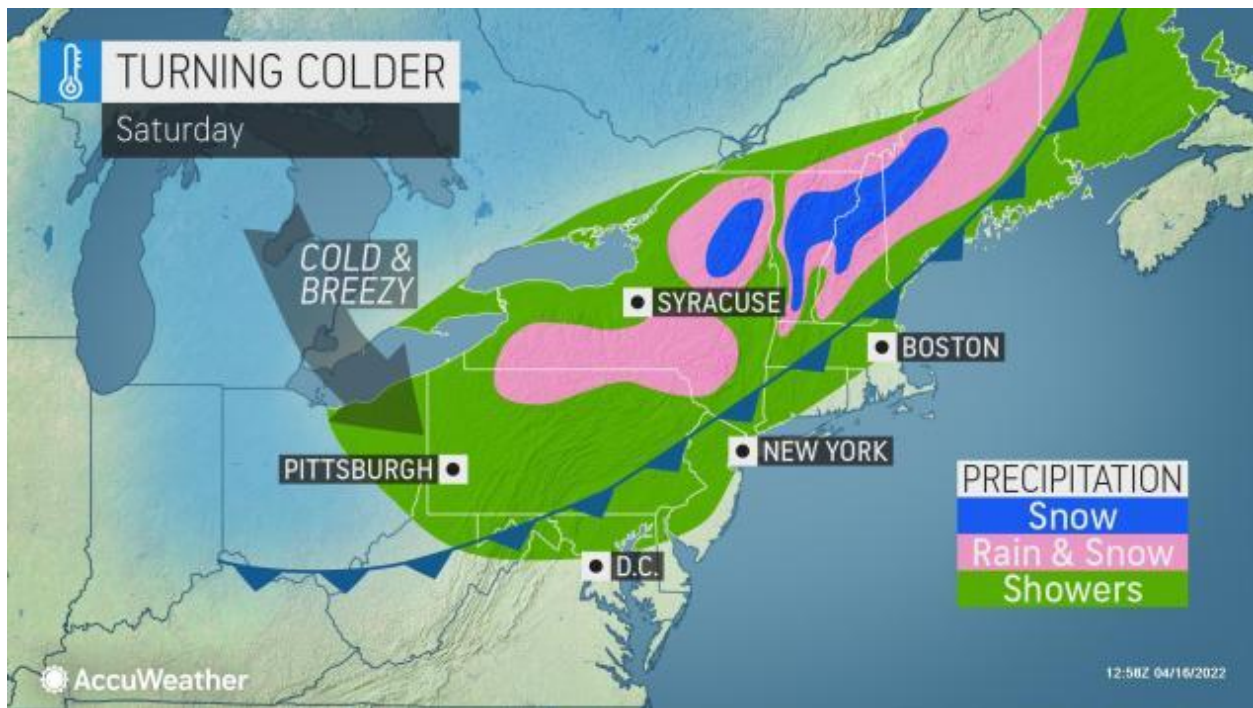


Figure 6. A nor'easter from April 2022 that contributed to winter storm effects far inland. (Storm, 2022)

I've lived in quite a few places, and it always amazes me how differently some places handle snow. Obviously, Maryland or Pittsburgh doesn't get as much as Buffalo, but there are lessons to be learned from the way Buffalo gets through it that maybe could be adopted elsewhere that aren't being done right now. Any advice I might give will be more about what strategies other places can adopt that they aren't doing right now but would help them cope with big storms.

The city of Buffalo averages around 85 inches of snow per year. Not as much as a place like Denver, CO, but 3-4 times as much as a place like Columbus, Ohio or Pittsburgh, PA, and that's mostly due to the lake effect snow. Further to the south of the county, the numbers are even higher. Some places get more 100 inches per season (Current Results Publishing Ltd., 2022). I grew up in Northeast Ohio, also along the shore of Lake Erie. My county also received about 80 inches of snow per year, and the county to my east, closer to 100-120 inches per year. So, my lived experience is quite similar to what I experience in my current location.

Managing winter weather in Buffalo (and in any place that gets a lot of snow) is done in layers. Snowstorms are not things that trigger evacuation orders, unless you count the "snowbirds" that flee to Florida for the entire season. Many cities that have a lot of suburban workers do sometimes shut down offices early in order to get people home and keep them off of dangerous roads, but there is no boarding up of windows or heading out of town until the snow melts. This is a geohazard that is weathered in place. That means that, for the most part, preparation is key. The city can't shut down for four months to wait for the snow to melt, so

strategies are put in place to help reduce the hazards when they are most acute, and then adopt methods that allow people to keep functioning while the snow remains.

Areas with big winter storm potential generally encourage residents to begin preparations for the possibility that they may lose power or that it will take some time to clear streets. Therefore, some preparation must be done by individuals and households in advance. Let's first look at household or business preparation first, then individual or vehicle preparation.

Businesses should prepare for the possibility of reduced manpower. Businesses should set snow day policies when workers cannot make it into the office. Snowfall, particularly with lake effect that can come in bands, can affect different areas of the region differently. It's possible that some employees will be able to make it into work, while others will not because they received much more snow, or lost power. Businesses should plan ahead for how to manage such eventualities that recognizes reality. Indeed, even government agencies must have plans in place for this type of event. The plan for the City of Buffalo includes contingencies for reduced manpower (in case people can't get to work), GPS monitoring of ongoing plowing operations and procedures for whether the city remains open, or when the city mostly elects to close down for an event (City of Buffalo, 2016).

Businesses, especially those like hospitals that must remain open during a snow event, or places like grocery stores that are at risk of losing inventory if power is lost, should have generators as a backup power supply (along with the fuel), to ensure their ability to keep food from spoiling or patients alive, until the grid can be restored. Power outages tend not to be as severe as in a high wind event like a hurricane, but ice storms can bring down power lines and trigger outages (New York City, 2022)

Structures should be built to withstand the weight of the snow and the potential for high winds with winter storms. In a large snowstorm I experienced in 1996, a flat-roofed building collapsed under the weight of the snow. In very large storms, some building owners may want to remove snow from the roof before the weight damages the building. This isn't something one generally has to worry about in your average winter storm, but large ones where the snow is wet and persistent, it is something that is worth thinking about. Flat roofs tend to be an industrial construction staple, so this is something business owners might need to put on their preparation list.

Individuals need to make their own preparations for themselves, their families, homes and vehicles. Residents are recommended to purchase fuel for their generators, if they have them. Winterize their tires if needed (uncommon in this part of the country). Prepare supplies in case they are stuck at home without power for several days (ice and wind can bring down power lines). New York City suggests you have enough for 7 days without power (New York City, 2022). Personally, I've never experienced a storm that left us without power that long, but I have experienced a three-day power outage. As with many things, though, you never know you need it until you do, so best to be prepared. Keep food supplies that can be eaten straight out of the package.

Some home preparations, like fuel for generators, is going to depend on what you have. If you have a fireplace and want that to keep you warm, get the wood ready. Don't wait to try to dig it out from the snow. Keep it inside or in the garage. You may want space heaters if it's especially cold. If so, check your fire extinguisher. Make sure you have batteries. Prep your snow removal equipment like snow blowers, shovels, salt, etc. (New York City, 2022). Some of these things can be done well in advance of a storm so that you are not waiting in

long lines at the last minute. Doing these things at the start of the season also can help you avoid inventory shortages, and the potential for price gouging.

You should also winterize your car/vehicle. If you have a truck, do you have a plow for it? That's an option. This part of the country doesn't tend to do chains (these are more common in places with steep hills), but some cars do need to switch out to winter tires. You may need to replace the oil in the winter. Check things like batteries, lights, etc. It's also a good idea to keep supplies in the car in case you get stuck. Growing up, we always would put things like chocolate bars in the glove box, a shovel in the trunk, and often something like cat litter (non-clumping), in case we got stuck it could provide traction under the tires. A bag of sand is an alternative for the cat litter. Keeping a blanket in the car can help keep you warm in case you are stuck and waiting for a tow truck. Depending on your mechanical skills tool sets, and jumper cables are also good to have, and things like flares are good too (New York City, 2022). In a blizzard, you want people to see you before they hit you!

Learning to drive in a winter storm is an essential skill. I can go almost anywhere in my old Civic, but I've had to deal with people in big 4-wheel drive vehicles creeping along afraid of even the smallest amount of snow. Technology has come a long way to help out. Anti-lock brakes are designed to prevent a skid. If you start to spin out, turn into the spin to regain control. Down shift and let the engine drag help you break. Increase your spacing between vehicles. Keep both hands on the wheel to help maintain control of the vehicle. Yes, drive slower than usual. It's best to drive in the tire tracks of the vehicle in front of you. It will help wear the snow down to the road level so you'll have more traction. If you are not accustomed to driving in the snow, stay in the right lane so that more experienced drivers are able to pass you. If the visibility drops, slow down even further and maybe pull off to the side

of the road. Plunging headlong into white-out conditions is how 80-car pileups happen. If you can delay your travel, do.

If you do lose power at home, there are additional steps to take so pipes don't freeze, such as letting the water drip. My apartment manager usually sends out email reminders when the temperature drops about what we should and shouldn't do in this regard. Dress in layers to preserve heat. Eat: your body needs calories to stay warm. If power remains out for too long, but roads are passable, do you have friends or family you can go to until power is restored? Building codes in this area generally require higher levels of insulation to help mitigate the energy loss during the cold weather months.

Winter storms, even lake effect storms, usually come with plenty of warning. The National Weather Service issues alerts, and the city will put out its own notices if it's a particularly big storm. They will provide information about early closures, remind people of safety measures and so forth. There are not sirens or things of that sort since we usually have days of advance notice. While the specifics of where the lake effect snow will be the strongest may not be known that far in advance, everyone in the area knows to prepare for it like it could hit them. The city and county can begin their preparations to keep the city as open as much as possible.

The first step for the city is to prepare for a pending snow effect by applying salt, sand or other chemicals to the roads to provide traction or prevent freezing. The city plan provides guidelines for when certain types are appropriate to apply and when they are not. Some materials don't work well below a certain temperature, and so can't be used in all circumstances. We had some nights last winter that fell below zero, so those temperature

constraints matter (City of Buffalo, 2016). Some localities use cinders instead of sand, but this is partly due to what is available.

The city has different levels of alert, including snow emergencies when special rules kick in. For the public, this is typically about preparation to stay off the roads (closing schools and businesses early so that drivers aren't caught on the freeway in the heavy snowfall), but can also mean changes to parking policies along some streets to allow for effective snow removal. The plan from 2016-2017, also includes a pilot plan for clearing downtown sidewalks, which is relatively uncommon. All told, the plan is 60 pages long (City of Buffalo, 2016).

The city's plan includes which locations are prone to snow drift. The plan also includes priorities in terms of snow clearing after an event such as main roads, any hazardous areas such as steep inclines and bridges/overpasses, and various secondary and residential streets. Emergency routes are the highest priority to maintain access to police and hospitals. The plan breaks down the city into plow districts in order to help organize available vehicles and manpower and create plowing routes in each area (City of Buffalo, 2016).

For a place that gets lake effect snow, a detailed and well-organized plan for dealing with snow is essential. The plan in the Cleveland area (a little further from the deep dark heart of lake-effect country) can keep their freeways open when the snow is falling at 1" per hour, but in one particular storm this last winter, Buffalo airport saw 4" in one hour. 30" in a day or two is not all that uncommon up here, and it's not like the city can just shut down for a week when that happens (not the way Baltimore and DC did for Snowmagedon). Some smaller communities, like the one I grew up in, often put landscapers with plows on their trucks, on contract for the winter to assist with snow removal. The landscapers like it because it gives

them the potential for work in the winter, and it gives towns more ability to clear streets quickly without having to invest in large numbers of industrial snowplows.

From time-to-time, even the best laid plans need supplements. There have been a couple of winters in lake effect territory where cities have run out of salt for the roads. Fortunately for Buffalo, there is a Morton Salt mine not far away in Northeast Ohio. When I lived in Pittsburgh there was particularly heavy snow year there and they city ran out of salt, and it took some time and expense to obtain more. It was difficult to keep the city fully functioning in the interim.

Climate change is causing changes to the way and when lake effect snow happens. The lake doesn't freeze over as much as it used to, so that can generate more snow for more of the year. As the climate warms, there is also the potential for more icing events. Big storms moving inland like bomb cyclones and nor'easters can sometimes increase snow events. All of these need to be considered, and beyond just snow-removal infrastructure. Ice storms tend to bring down power lines, so, for example, mitigation efforts might want to consider the benefits of putting more power lines under the ground rather than waiting for the poles to collapse and leave people without power: definitely not fun when it's -5 outside.

When removing snow from your own property, don't over-exert yourself. This is a really common way for people to trigger heart attacks. Shoveling frequently is smarter than waiting until it's all over. Help your neighbors with disabilities. Cover your mouth when working outside for a long time. Be wary of fingers and toes because they are the easiest to get frostbitten (New York City, 2022).

Cities are typically responsible for clearing public roadways, but not private drives, driveways or sidewalks. Power companies deal with the consequences of ice bringing down

power lines. As previously noted, though, this is changing somewhat in Buffalo, at least in the downtown area (City of Buffalo, 2016).

Stay away from frozen water. This is a common winter hazard. Ponds may freeze but you don't know how thick the ice is, and you don't want to fall into the water when it's near freezing. Hypothermia can be deadly, and retrieving people from water in the winter can need special equipment. If the snow remains on the ground a long time, when it does melt, especially if it does so suddenly, it can cause flooding or even ice dams on rivers. Although, with climate change, this is less often a concern than in prior decades because with the variability of the weather, the snow melts earlier and more frequently, instead of accumulating and melting all at once in the spring.

One consequence of the variability of the weather is that freezing and thawing cycles can actually be really hard on asphalt. This is why northern cities get a lot of potholes. There has been some movement (they do this on some freeways in Cleveland) to move to rubberized asphalt that is more flexible and gets less damage with the freezing and thawing. Otherwise, during thaw periods, road crews have to go around town and patch potholes until the weather warms enough to do a more permanent fix (for another year at least). The use of rubberized asphalt is spreading (Ecogreen, 2021). Anyone who has hit a giant pothole knows the costly damage it can do to vehicles and the hazard it can pose to drivers trying to dodge them. Using shredded tires in asphalt is also a more ecologically friendly way to recycle old tires than some older strategies.

One road-related improve that might be conceivable is heated roadways to avoid freezing. This is done on a smaller scale with driveways. Doing it citywide would currently be quite expensive, but innovations that include turning roadways into solar panels could

generate the electricity required to heat the road. Heated roads would not need plows or salt and would not experience the freeze-thaw cycle that creates the damage to roadways that we see in winter. As with many technological innovations, this can seem crazy at first, until someone makes it work.

Since winter storms are a geohazard that the area deals with every year, most people are well familiar with what to do, but reminders are always helpful. When big storms are approaching, we might want to offer early preparedness warnings so that fewer people are waiting until the last minute. We could remind people with city alerts or on the news things they can plan ahead for, reminders about driving in snow (especially for the first snowfall of the year). We could develop driving simulations to get more new drivers more accustomed to driving in winter conditions before they end up in a ditch several times. The city could offer free vehicle winterizing kits.

Other cities can learn a lot from how snowy cities manage winter storms. Putting landscapers on contract with the city is one idea that cities that don't get as much snow could adopt. If there is no snow, they don't have to pay anything, but if someone has a plow, they would have the opportunity to help out if case they are needed. As climate becomes more variable, areas that aren't accustomed to having big snows could see them. Having a plan like this in place could help mitigate closure times compared to having only city-owned vehicles clearing the streets. In locations that don't receive consistent snow like Buffalo does, preparing the way Buffalo does isn't really feasible. Compromise solutions like the one discussed above can help improve preparedness without the large upfront investments, and it would encourage civic engagement.

One major area of improvement in predictive modeling is needed: improving predictions of lake effect snow. Lake effect snow events can often be seen setting up days in advance, but predicting specific areas of heavy snowfall often can't be done until several hours out from the event. This is more than tornadoes get, but still can be a narrow window in which to prepare if the city needs to prepare roads, cancel airline flights and send workers home. Improving this window would tend to reduce cost and fatalities.

References

BestPlaces.net. (n.d.). *Climate in Columbus, Ohio*. Retrieved from BestPlaces.net:

<https://www.bestplaces.net/climate/city/ohio/columbus>

City of Buffalo. (2016). *City of Buffalo Snow Removal Plan, 2016-2017*. Retrieved from

<https://www.buffalony.gov/DocumentCenter/View/2985/City-of-Buffalo-Snow-Plan>

Current Results Publishing Ltd. (2022). *Buffalo - Extreme Daily Snowfall for Each Year*.

Retrieved from Current Results: [https://www.currentresults.com/Yearly-](https://www.currentresults.com/Yearly-Weather/USA/NY/Buffalo/extreme-annual-buffalo-snowfall.php)

[Weather/USA/NY/Buffalo/extreme-annual-buffalo-snowfall.php](https://www.currentresults.com/Yearly-Weather/USA/NY/Buffalo/extreme-annual-buffalo-snowfall.php)

Current Results Publishing Ltd. (2022). *Buffalo Snowfall Totals & Accumulation Averages*.

Retrieved from Current Results: [https://www.currentresults.com/Weather/New-](https://www.currentresults.com/Weather/New-York/Places/buffalo-snowfall-totals-snow-accumulation-averages.php)

[York/Places/buffalo-snowfall-totals-snow-accumulation-averages.php](https://www.currentresults.com/Weather/New-York/Places/buffalo-snowfall-totals-snow-accumulation-averages.php)

democratandchronicle.com. (2022). *A history of twisters: Tornadoes in New York since 1950*.

Retrieved from NY Databases.com: <https://data.democratandchronicle.com/tornado-archive/>

Disaster Center. (1999). *Winter Storm*. Retrieved from Disaster Center:

<https://www.disastercenter.com/guide/winter.html>

Earthquake Track. (2022). *Recent Earthquakes Near Buffalo, New York, United States*. Retrieved

from Earthquake Track: <https://earthquaketrack.com/us-ny-buffalo/recent>

Ecogreen. (2021). *How Rubberized Asphalt Is Changing Our Roads*. Retrieved from Tire

Shredders Blog: <https://ecogreenequipment.com/how-rubberized-asphalt-is-changing-our-roads/>

New York City. (2022). *New York City Emergency Preparedness*. Retrieved from

<https://www1.nyc.gov/site/em/ready/winter-weather-prep.page>

NOAA. (2017). *Lake Erie Harmful Algal Bloom Forecast*. Retrieved from National Centers for

Coastal Ocean Science: <https://coastalscience.noaa.gov/research/stressor-impacts-mitigation/hab-forecasts/lake-erie/>

NOAA. (n.d.). *What is a Lake Effect Snow?* Retrieved from Weather.gov:

<https://www.weather.gov/safety/winter-lake-effect-snow>

NOAA. (n.d.). *What is a Nor'easter?* Retrieved from Weather.gov:

<https://www.weather.gov/safety/winter-noreaster>

NY Ski Blog. (2022). *Great Lakes Snowfall Map*. Retrieved from New York Ski Blog:

<https://nyskiblog.com/directory/weather-data/northeast-us/great-lakes-snowfall-map/>

Rice, D. (2022, January 12). *What is lake effect snow? Here's how it happens and how much snow it can bring with it*. Retrieved from USA Today:

<https://www.usatoday.com/story/news/nation/2022/01/12/lake-effect-snow/9174973002/>

- Ruppenthal, A. (2017, November 15). *Global Warming's Impact on Lake Effect Snow: Fewer Flurries, More Rain*. Retrieved from WTTW: <https://news.wttw.com/2017/11/15/global-warming-s-impact-lake-effect-snow-fewer-flurries-more-rain>
- Smith, E. (2022, January 26). *Arctic cold during January aided in ice development across Lake Erie*. Retrieved from WGRZ: <https://www.wgrz.com/article/weather/arctic-cold-throughout-january-aided-ice-development-across-lake-erie/71-5a7631ae-8566-4fb4-bccd-cf9a6377aa2c>
- Storm, J. (2022, April 16). *Powerful nor'easter to bring late blast of winter next week*. Retrieved from Accuweather.com: https://www.upi.com/Top_News/US/2022/04/16/noreaster-blast-winter-next-week/2081650130250/
- US Department of Homeland Security. (2022, January 11). *Winter Weather*. Retrieved from Ready.gov: <https://www.ready.gov/winter-weather>
- World Media Group, LLC. (2022). *Buffalo, NY Natural Disasters and Weather Extremes*. Retrieved from USA.com: <http://www.usa.com/buffalo-ny-natural-disasters-extremes.htm>
- Yulsman, T. (2014, November 20). *Stunning New Satellite Image of Brutal Lake Effect Snow*. Retrieved from Discover Magazine: <https://www.discovermagazine.com/environment/stunning-new-satellite-image-of-brutal-lake-effect-snow>