

**Temperature Change and its Effects on the Great Lake's  
Climate.**

**Ross Ellet**

**Professor: Matthew Huber**

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# **Temperature change and its effects on the Great Lakes climate.**

The Great Lakes create a very unique sub climate zone that is unlike most areas in the world. The Great Lakes act as a climate moderator. They contain some of the biggest fresh water lakes in the world. This allows temperature moderation to occur. Typically the lakes keep the eastward coastlines more humid. Since there is more humidity, clouds are more frequent. Thus the temperature fluctuation on a daily basis is a little less than areas not affected by the Great Lakes. This in turn affects the precipitation that falls, when it falls, and where it falls. In the winter time the cold air masses blow over the relatively warm water which creates lake-effect snowfall. This is a very important social and economical impact the climate has on the Great Lakes region. So what happens when a climate change occurs in this area? What types of impacts will it have on the Great Lakes region? Will it be any different than those areas directly west of the Great Lakes?

## **Theory and Research**

### **Aral Sea**

In order to understand climate change in the Great Lakes, first one must understand the dynamics of what is already occurring. The Great Lakes is unlike most lakes in the world due to its size, power, and potential to affect climate. However, there is another body of water that is just as significant. The Aral Sea, which is located in Uzbekistan and Kazakhstan, is an important tool to see how much a large body of water affects climate. There is really no way to know for sure how the climate would be different unless spontaneously the lake disappeared and one could observe over several years or decades the climate changes associated with it. This is exactly what happened with the Aral Sea.

In 1960, the Aral Sea was the fourth largest lake on the planet (Bissell, 2003) and the size of Lake Michigan which rested in between deserts in central Asia. Then, 36 years later it had shrunk to just one-third of its original size (Bissell, 2003). The Sea has been shrinking due to the irresponsible Soviet irrigation policies. Farmers have been using the inflow water to the sea for irrigation which has caused the sea to decrease in area and depth significantly. Since then the climate has drastically changed. The biggest finding was that there was less humidity in the air. The humidity values in the late 1990's were about 10 percent less than what they were in the 1960's (Delany, 2005). As a result there has been less cloud cover, which has allowed colder winters and hotter summers by about 2-3 degrees C (3.6°-4.8°F). Precipitation has dropped as well, and long dust storms have increased. The area is quickly falling into a climate like the deserts that surround them.

### **Great Lakes Climate**

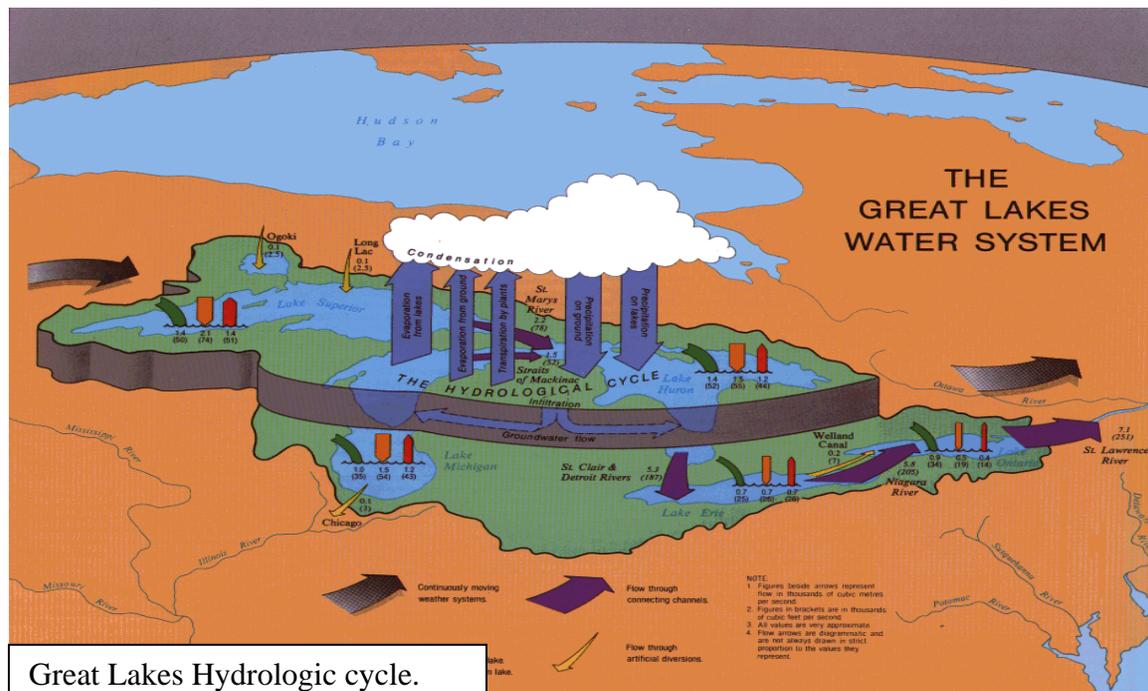
The Great Lakes Climate is somewhat similar to the Aral Sea in that it is a modifier of weather across the lake. More importantly the Aral Sea can be used as a tool to evaluate the Great Lakes Climate. We can also compare the Great Lakes sub climate zone to the areas west of the lakes that are not affected by the sub climate. Since the Great Lakes do not occur in the middle of a desert, such as the Aral Sea, the area does not

have quite the same impacts as the Aral Sea. In the winter time the average temperature is 1-3 degrees C (1.8°-4.8°F) warmer than areas not affected by the Great Lakes. However in the summer time the average temperature is less than 1 degree C cooler than areas not affected by the lakes (Ackerman and Knox, 2003). Perhaps, just like the Aral Sea it appears that the precipitation patterns that occur in the Great Lakes region are much different at times, than those areas not in the sub climate zone.

### Precipitation, Evaporation, Condensation

The Great Lakes Precipitation patterns are a bit more complex than other areas of the Midwest. The Great Lakes region is still experiencing the same hydrologic cycle as the rest of the world, but with the added moisture associated with the Great Lakes (Frederick and Tarbuck, 1995). As with the hydrologic cycle there is a certain amount of water in the world. The amount of water in the world never changes however; it can change locations and forms. We also know that there is a general balance world wide of net precipitation and net evaporation because our Oceans are not rising or falling over a long period of time.

On the other hand, if you narrow the scope to a particular section of the planet it gets more complicated. For Example, if the Great Lakes are the region under study during a harsh drought, one can conclude that the net evaporation is higher in that area then the net precipitation. Perhaps, the extra evaporation ends up leading to an increase in precipitation in the northeastern part of the United States and southeastern Canada. Therefore the hydrologic cycle is complete and all the precipitation and evaporation has balanced out.

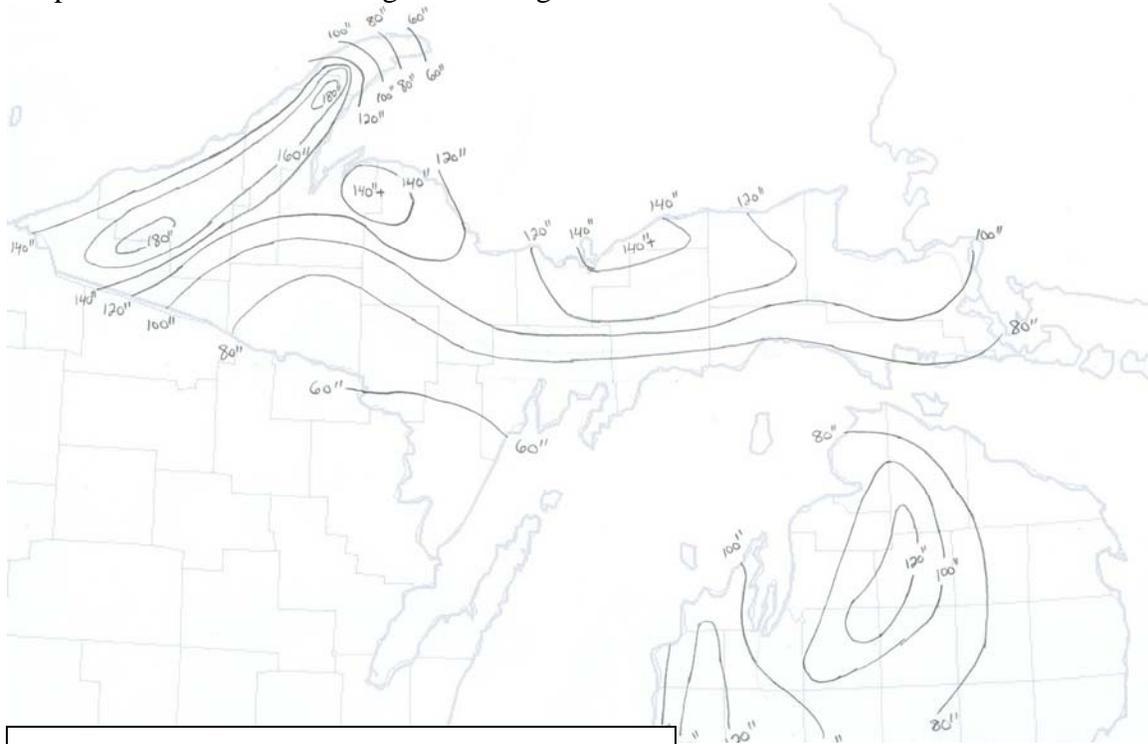


Great Lakes Hydrologic cycle.  
 Courtesy of the EPA

The main concern today when Climatologists predict climate change in the Great Lakes region, is the Great Lakes themselves. If a climate change persists over a course of decades or even centuries, which for some reason causes a significant decrease in

precipitation, then it is possible that slowly the Great Lakes will decrease in size and begin to dry up. On the other hand, if a climate change shifts precipitation toward a significant increase then perhaps the Great Lakes would begin to expand and flood nearby coastal cities. Either way this would cause a significant impact of every citizen that lives in the 9 state areas. The concern is realistic because the Great Lakes are constantly changing to adapt to there environment. They are the product of melting glaciers thousands of years ago. Before this time, it is believed that the Great Lakes region was mostly consisted of land instead of the 5 Great Lakes and thousands of other fresh water lakes that dot the region.

Precipitation is composed of snowfall for several months of the year in this region. It makes up a large percentage of the yearly precipitation, and it impacts residents in these areas heavily. For many the heavy snowfall the Great Lakes region is a nuisance. On the other hand, this part of the country depends upon it. Parts of Michigan and New York have hundreds of winter time ski resorts and the Upper Peninsula draws strong snowmobiling tourism. These are areas that many years receive more than 100 inches of snow a year and they have built there lives around it. Therefore, snowfall and more specific lake-effect snowfall, impacts the Great Lakes region more than any other weather factor. Due to this, any fluctuation in snowfall patterns in this region due to temperature and climate change is on a high order of concern.



Annual average snowfall for Northern Michigan.

Courtesy of the Midwest Climate Center

There has been some research done on what will happen to lake-effect snowfall if a climate change occurs in this area. A general finding is that over the past 50 years lake-effect snowfall over much of Michigan has increased (Ruhf, 2004). Ruhf stated that the records at Muskegon, Michigan show that an average of 60 inches of snow a year was typically observed prior to 1940. Today the running 10 year averages are just over 100 inches. Muskegon is a rather extreme example compared to other cities in the state. On

the other hand, most cities showed an increase in lake-effect snowfall. However, the records obtained at Lansing and other cities not affected as much by lake-effect snowfall showed very little change in snowfall trends. One explanation of the drastic increase in lake-effect snowfall is due to an increase in heat and pollution from increased urbanization and industrialization.

### **Realistic Climate Change in the Future**

Fortunately, we know a great deal about the climate of any given place on earth. This includes the Great Lakes region. Therefore, none of these studies means a whole lot if climate has never changed and never will change. On the other hand we also know that climate for any given location is not constant with time. Climatologists have begun to speculate on climate change and what will happen as a result. There are two very realistic possibilities over the next several thousand years that could drive climate change.

### **Global Warming**

Global Warming is the process of the earth warming due to human intensification. The burning of fossil fuels releases green house gases into the atmosphere which in turn helps to warm our planet over time. This is believed to be happening right now and forecasted to drastically impact citizens worldwide in the coming decades. Over the past century the average temperature has raised less than a degree Centigrade (1.8°F) but most of that warming has been since the late 1960's (Brrroughs, 1997). The Climate models suggest an increase in global temperatures by about 1-3 degrees Centigrade (1.8°F-5.4°F) over the next 50 years. By the year 2100 the global temperature is forecasted to reach 2-10 degrees Centigrade (3.6°F-18°F) above today's global average. This would be a significant change, and that would affect the entire world.

The increase in temperatures would help to trigger a variety of climate changes. First, more precipitation would fall globally. Second, sea ice would be drastically reduced in the northern hemisphere which would trigger a higher sea level. The sea could increase 1-2 feet on average by the year 2100. This could cause a significant problem for low lying areas. Also, there is a debatable theory of more extreme weather across the globe. More extreme weather could be classified as severe weather, blizzards, droughts, floods, and hurricanes.

### **Global Cooling**

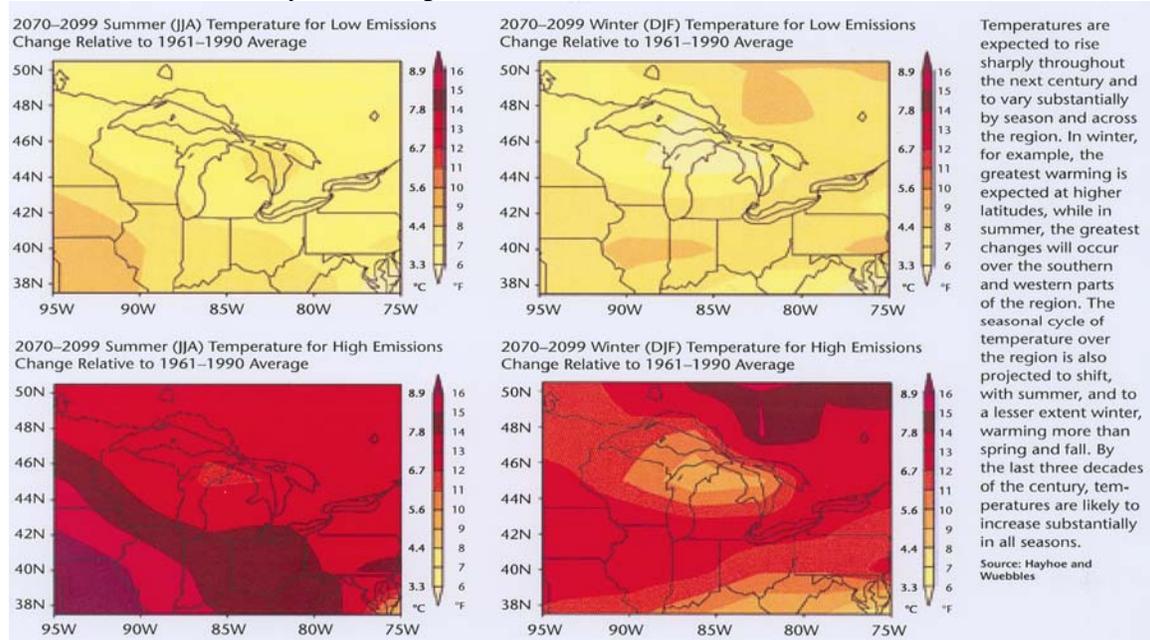
A second possibility of climate change in the future is Global Cooling. In this case Global Cooling is referring to an up coming ice age. Since Climatologists have only been taking precise data collection over the past 200 years or so, we do not have an exact climate record of the past. On the other hand ice cores and fossils have helped us to identify general climate patterns over the past several thousands of years. There is a direct influence between the sun and the earth's temperatures. The earth's rotation around the sun is variable over thousands of years and it has a major impact on our climate.

There are several Climatologists that have different opinions of when the next ice age will be. The extreme theories are that the earth could plummet into another ice age in the next few centuries while more conservative estimates have the next ice age coming 50,000 years from now. At that time, the earth is believed to be receiving less solar

radiation. (Macdougall, 2004). However, past climate records show that no Pleistocene interglacial period has lasted more than about 12,000 years, and most have had lifespan of about 10,000 years. Today's interglacial period has lasted 10,000 years. Therefore this would suggest that the next ice age could be approaching within the next few centuries. A more common perspective is that an ice age could approach 18,000 years from now. At any rate, this is all assuming that an increase of greenhouse gasses from today's industrialization has little or no effect on this process. An ice age would provide temperatures of at least 6°C (10.8°F) cooler than today (Imbrie, 1986). This would lead to a decrease of precipitation, increase in sea ice, glaciers, and a decrease in sea level.

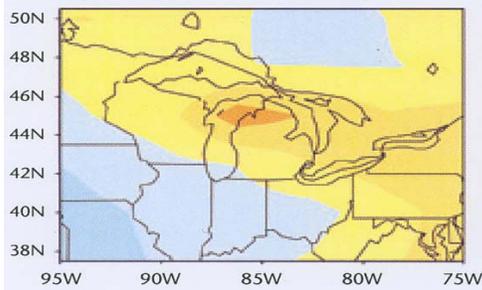
### Confronting Great Lakes Climate Change

There are very few published theories of how an increase or decrease in temperature would affect Great Lakes Climate. However, the Union of Concerned Scientists and The Ecological Society of America published their findings, predictions, and impacts global warming would have in the following century. This report projected that by the year 2100, the Great Lakes region will warm 3-7°C (5-12°F) in the winter. In the summer, the area will warm 3-11°C (5-20°F). The night time temperatures are likely to warm more than day time temperatures (Union, 2003).

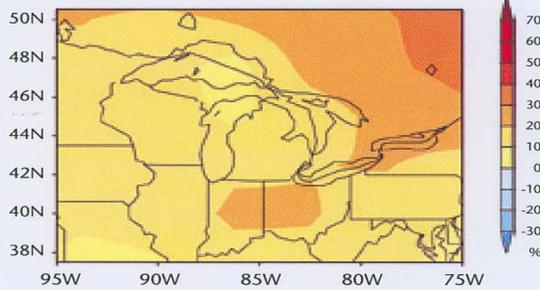


The annual average precipitation is believed to stay constant and evaporation will be higher. Thus the area may become drier. This could lead to lower lake levels. Also, the general consensus is that the frequency of extreme weather may increase. They found that in recent years the frequency of extreme 24-hour rainfall events and extreme 7-day rainfall events has increased. Based on this, they believe extreme rainfall events will increase in the future. Winter precipitation is expected to increase while summer precipitation is expected to decrease. As a result the average precipitation is expected to stay constant. Since extreme weather could increase along with increased winter precipitation, spring floods could become more common.

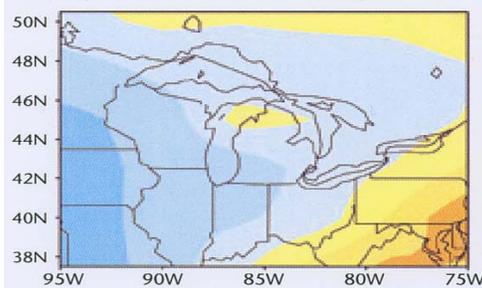
2070–2099 Summer (JJA) Precipitation for Low Emissions  
% Change Relative to 1961–1990 Average



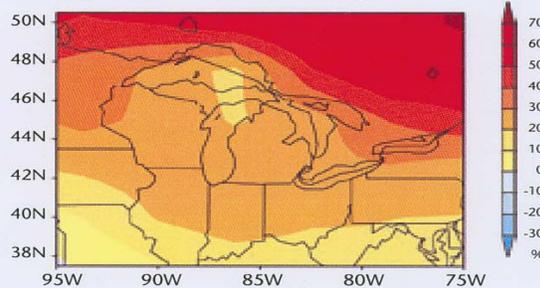
2070–2099 Winter (DJF) Precipitation for Low Emissions  
% Change Relative to 1961–1990 Average



2070–2099 Summer (JJA) Precipitation for High Emissions  
% Change Relative to 1961–1990 Average

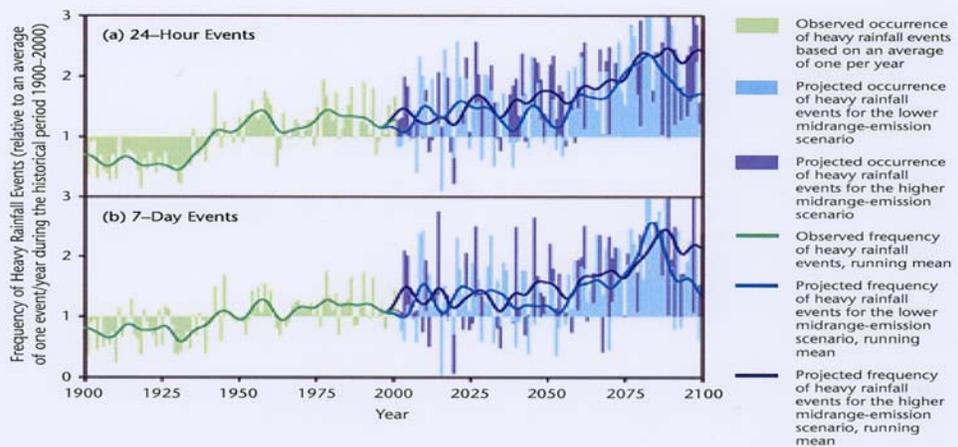


2070–2099 Winter (DJF) Precipitation for High Emissions  
% Change Relative to 1961–1990 Average



The next several decades will almost certainly see continued increases in heavy rainfall—perhaps doubling by 2100—with longer dry spells in between. The intensity of extreme rainfall events may also increase. Upgrading water control infrastructure based on historical frequencies of extreme events will thus be inadequate in a warming world, especially as more frequent downpours interact with more impervious surfaces.

Source: Hayhoe and Nuebbles



## Data Analysis and Research

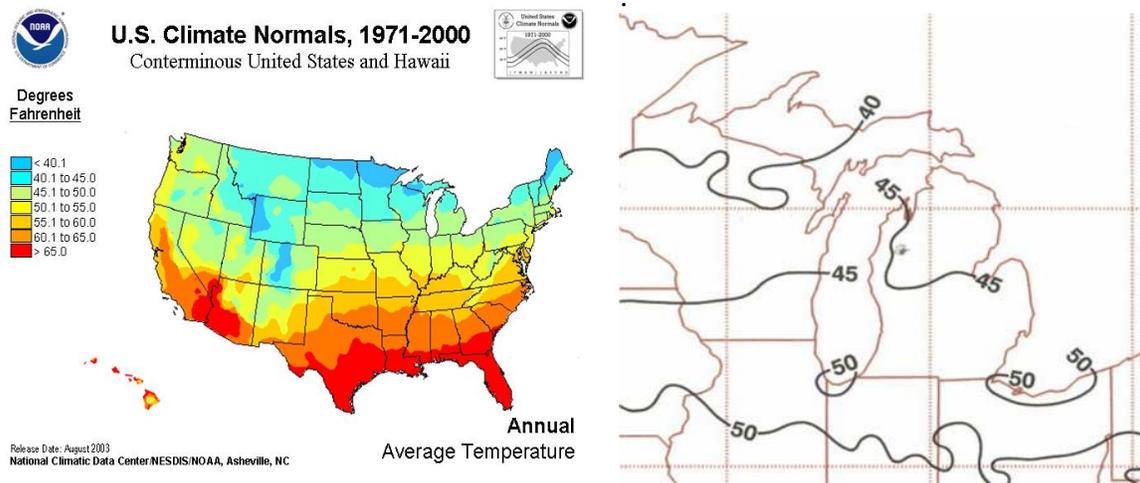
One way of predicting a climate change is to observe and analyze weather data. The idea behind this research was to find a relationship between temperature and precipitation, snowfall, lake levels, and extreme weather. There are two ways this data analysis was done. First, four different focus areas were selected in the Great Lakes region from NOAA. In these areas temperature, precipitation, and snowfall maps were collected and analyzed. The focus areas included Northern Ohio, Northern Indiana, Northern Michigan and a control area which was Northern Illinois and Wisconsin. The control area was set up to find relationships between the Great Lakes climate patterns and areas west of the Great Lakes that are not affected, or very little by the Great Lakes.

Secondly, data for 5 focus cities were collected. In these cities, monthly temperature, precipitation, lake level, and snowfall data was collected from the Midwest Climate Center and the United States Army Corps Engineers. Also, daily precipitation and snowfall data was collected. In both of these data sets the range of years that data was

collected was from 1951-2004. This data was collected to help find a correlation between temperature and other climate factors. First, this was done by finding the warmest 10 years in the data set and the coolest 10 years. Then once this data was found, it was plotted out and compared to other climate factors. Then once all of this data was found, it was analyzed by comparing it with average, comparing it with the control cities, and by graphing the data in order to find correlations. The daily precipitation and snowfall data was collected in order to find the number of days a year a city experienced extreme weather. For this situation, extreme weather was defined as the number of days a year a city experienced at least 1 inch of rain within a 24-hour period. Also, a second test included the number of days a city experiences 6 inches or more of snow in a 24-hour period. This data was then plotted with temperature to find a relationship between the two. The focus cities included Cleveland, OH, South Bend, IN, and Grand Marais, MI. The control cities are Spooner, WI, and Peoria, IL.

### Focus Areas

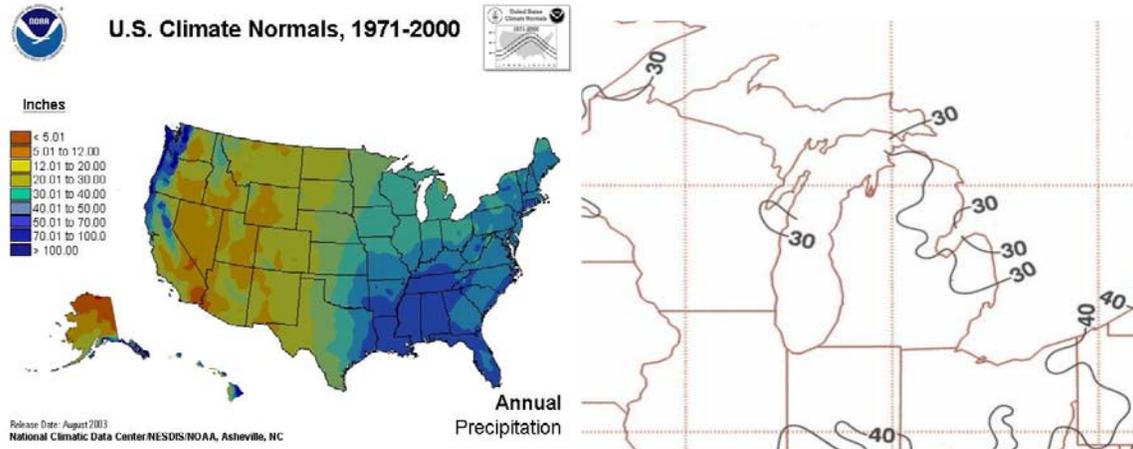
Northern Michigan, Northern Ohio, and Northern Indiana all show warmer climates on a yearly average than areas in Wisconsin. From these maps, it appears that in the summer all of the focus areas are slightly cooler than areas in the control area of Wisconsin. The relatively cool waters of Lake Erie, Lake Michigan, and Lake Superior all help to keep around a cooler climate. This trend seems stronger in Northern Michigan than in Northern Ohio. The reason is Lake Erie has a shallow depth and thus can not store as much energy. In this case the surrounding warm temperatures warm the lake quicker, which lessens the lake's ability to cool its surroundings. However, Lake Michigan and Superior have the potential to hold much energy so it takes longer for the lakes to warm and thus it is cooler than the surrounding the lake. The opposite is true in the winter. The relatively warm lakes help to warm areas near the coast significantly. This trend is visible in all three areas but it occurs stronger towards Northern Michigan.



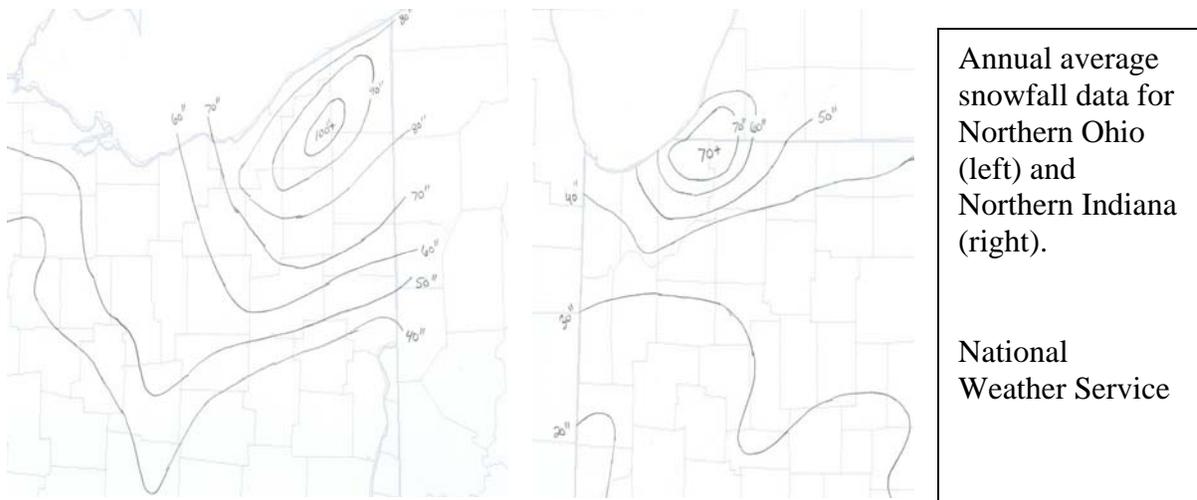
Overall, the Great Lakes are warmed due to the surrounding lakes because the Lakes warm the surrounding land in the winter much more than they cool them in the summer.

Precipitation trends on a large scale do not seem to differ much in the Great Lakes region compared to areas in Wisconsin. However, there is a trend of increased precipitation in Northern Michigan. The increase is slight but visible towards the eastern part of the area. This is due to an increase in winter precipitation which is a result of more

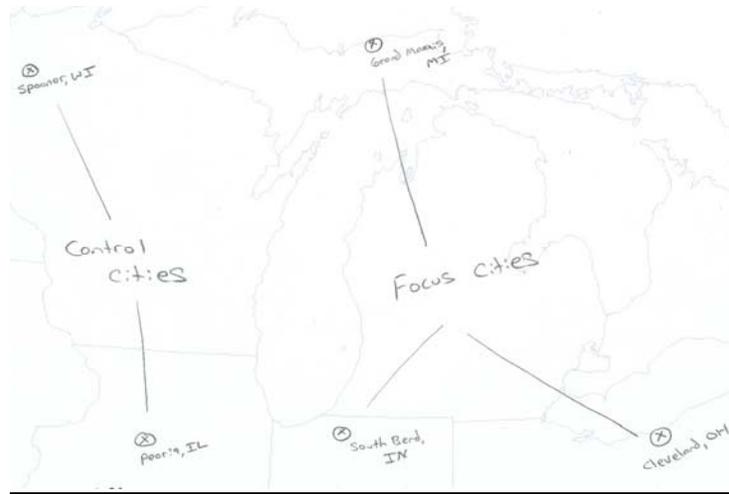
clouds, humidity, and lake-effect snow. This is all a result of Lake Michigan and Lake Superior.



Snowfall varied significantly from focus areas to area. In Northern Ohio most of the area averaged 40-60 inches of snowfall a year. On the other hand, the average snowfall east of Cleveland ranged from 60-100 inches per year. This is because lake-effect snowfall can have more of an effect in this area due to the coastline heading further north which would intersect westerly moving snow bands and since the fetch increases significantly with location. Northern Indiana averages 30-50 inches of snow a year with the exception of the South Bend regions which experiences nearly 70 inches a year. Northern Michigan becomes much more complex. Typically this area receives anywhere from 80-180 inches of snowfall a year. The location of snowfall maxes depends largely on topography, and location compared to Lake Michigan, and Superior. This can be compared to Northern Wisconsin which receives between 40-60 inches of snow on average.



**Focus Cities**

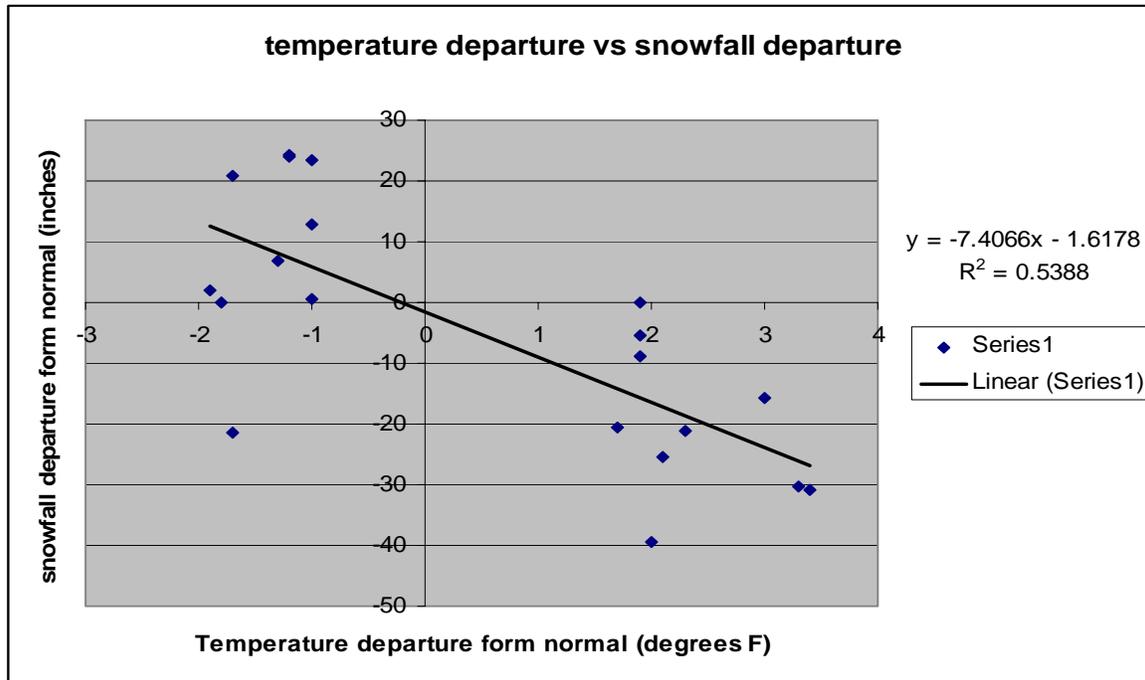


### **Cleveland, OH**

Cleveland, Ohio was chosen as a focus city due to its location along central southern coast of Lake Erie and its rich history of data. The city represents one of the warmest cities in the region and is along the southern most boundary of the Great Lakes region. First, the 10 top warmest and 10 coolest years from 1951-2004 was compared with precipitation departure. The relationship was a very slight, nearly immeasurable, decrease of precipitation with increasing temperature. However the correlation was not impressive to say the least with an R squared value of 0.0004. Next, the relationship between Lake Erie's water depths was compared to temperature. It was found that there was a strong correlation between temperature and lake depth. Approximately for every 1°F increase in temperature the lake rose 0.0445 meters. Temperature and snowfall had a fair correlation which showed snowfall decreasing with a temperature increase. The annual snowfall decreased on average by 1.6 inches per 1°F increase in temperature. In this case extreme weather seems to have a weak to fair dependency on temperature. However in this data set, both extreme snowfall days and extreme rainfall days increased with increasing temperature.

### **South Bend, IN**

South Bend, Indiana was chosen as a focus city due to its location just southeast of the Lake Michigan shoreline. It is in a spot that is a near snowfall maximum due to lake-effect snowfall along Lake Michigan. First, the relationship between temperature and precipitation observed shows that precipitation decreases with increasing temperature. For every 1°F the precipitation decreased by 0.82 inches. The correlation was fairly weak with an R squared value at 0.0545. Second, the relationship between temperature and Lake Michigan's water depth was plotted. The strong correlation showed that for every 1°F increase in temperature the lake level increased by 0.0556 meters. Next, the temperature and snowfall dependency was found. There was a surprisingly high correlation between the two with an R squared value of 0.538. The correlation showed a very sharp downward trend of snowfall with increasing temperature. For every 1°F temperature increase, snowfall decreased by 7.4 inches.



Extreme weather trends with temperature showed weak to no correlation. The extreme snowfall trends with temperature had a nearly constant trend but it had nearly no correlation as well. Extreme rainfall days decreased with increasing temperature with a weak correlation.

### Peoria, IL

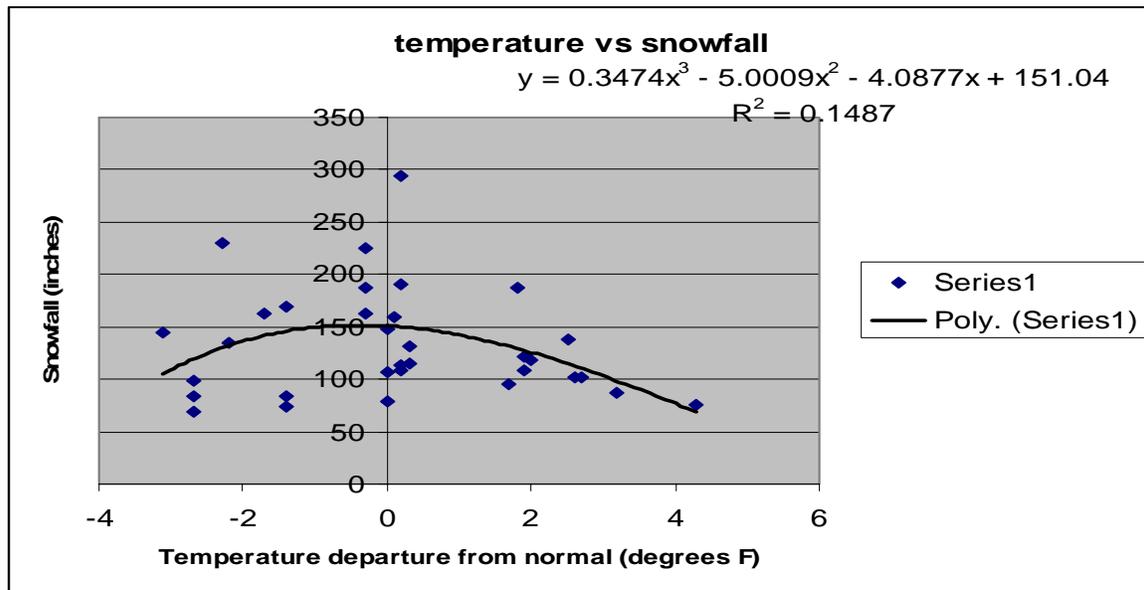
Peoria, Illinois in this experiment is considered the control city. This means that Cleveland, OH and South Bend, IN are compared to Peoria, IL because all three of these cities are along similar latitude and usually are affected by the same weather systems. Peoria was chosen as a city to evaluate due to its quality of data. No other city in that area has weather data that is complete all the way through the 1950's. The temperature and precipitation relationship for this city shows that precipitation increases by about 0.76 inches per 1°F increase in temperature. On the other hand the correlation is fairly weak. A stronger correlation shows that snowfall decreases by about 2.3 inches for a 1°F increase in temperature. Extreme weather trends with temperature showed weak to no correlation. The extreme snowfall trends with temperature had a nearly constant trend but it had nearly no correlation as well. Extreme rainfall days increased with increasing temperature with a weak correlation.

### Grand Marais, MI

Grand Marais, Michigan was chosen as a focus city due to its unique location in the Upper Peninsula in Michigan. The city averages just over 131 inches of snow per year. The city is popular for a variety of winter time activities. Pictured Rocks National Lakeshore borders the city to its west. The city has some of the best quality data in the Upper Peninsula of Michigan and perhaps the best weather data compared to other areas affected so greatly by the Great Lakes. A fair correlation was found between temperature and precipitation. For every 1°F increase in temperature the precipitation dropped about 0.68 inches. The relationship between temperature and the water depth of Lake Superior

seemed nonexistent. It had one of the lowest correlations of any data set in all the relationships found in this experiment.

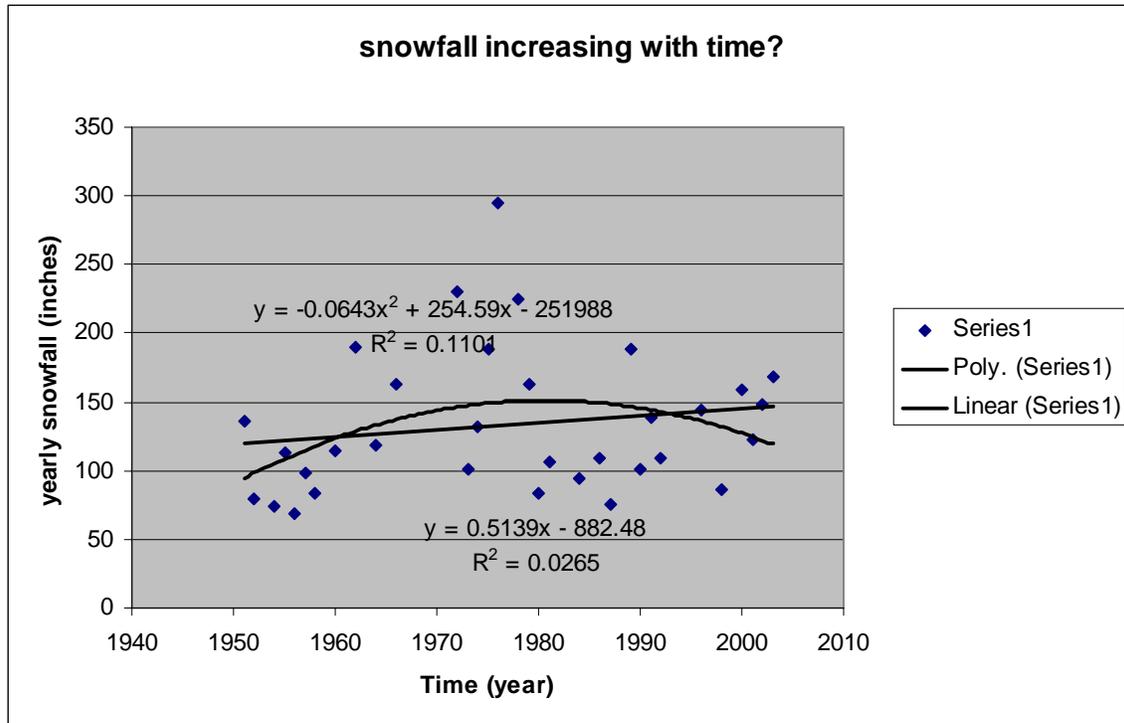
The relationship between extreme weather and temperature were interesting. The extreme rainfall days increased when temperature increased. For every 5°F increase in temperature the days of extreme rainfall increase by 1 day. However, this is still well within the error for any given year. Extreme Snowfall days seemed to max out at -0.2°F. This means that the best fit curve for this graph shows that a much colder or much warmer year than normal yields less extreme snowfall days than years that are closer to normal. This brought up the question, why? To understand this it may be useful to know about the general snowfall trends compared to temperature. This perhaps was the single most unique finding of all the research done. After plotting the temperature and snowfall on a graph it was clear it followed a similar pattern as the extreme snowfall days. After some careful comparisons, data was then added to the data set to include another 12 years of data that were within 0.3°F of average in order to make sure the previous samples were indeed correct. The third data set supported this trend to an even better fit. The correlation has an R squared value of 0.1487.



The highest point along the curve is when temperature is -0.1°F. The reasoning for the peak during a year with normal temperatures is thought to be due to a couple different factors. There are two types of snowfall Grand Marais receives every year: system snow and lake-effect snow. As understood with the control cities, system snowfall decreases when temperature increases, and increases when temperature decreases. However, if an area's winter temperature is substantially cold enough then there becomes a certain point where lake-effect snowfall decreases with a decreasing temperature because the lake will freeze over which will reduce evaporation and in turn reduce condensation and lake-effect snow. This in turn creates a situation where normal temperatures in the Upper Peninsula tend to produce above normal snowfall where warmer and colder years produce less snowfall than normal.

One other interesting correlation compares to an earlier study mentioned. The theory claimed that snowfall has been increasing in Michigan over the past 50 years or so. So in order to prove this to be true, I plotted the three sets of data on a graph. The

graph showed a linear fit which increased with time. However a closer observation showed the graph was not linear. The graph fit a polynomial fit even better which paints a better picture of changing snowfall patterns. It shows that the 1960's and 1970's were abnormally snowy. This helped to shift the linear fit upward, when in all reality snowfall was not increasing with time at Grand Marais, Michigan.



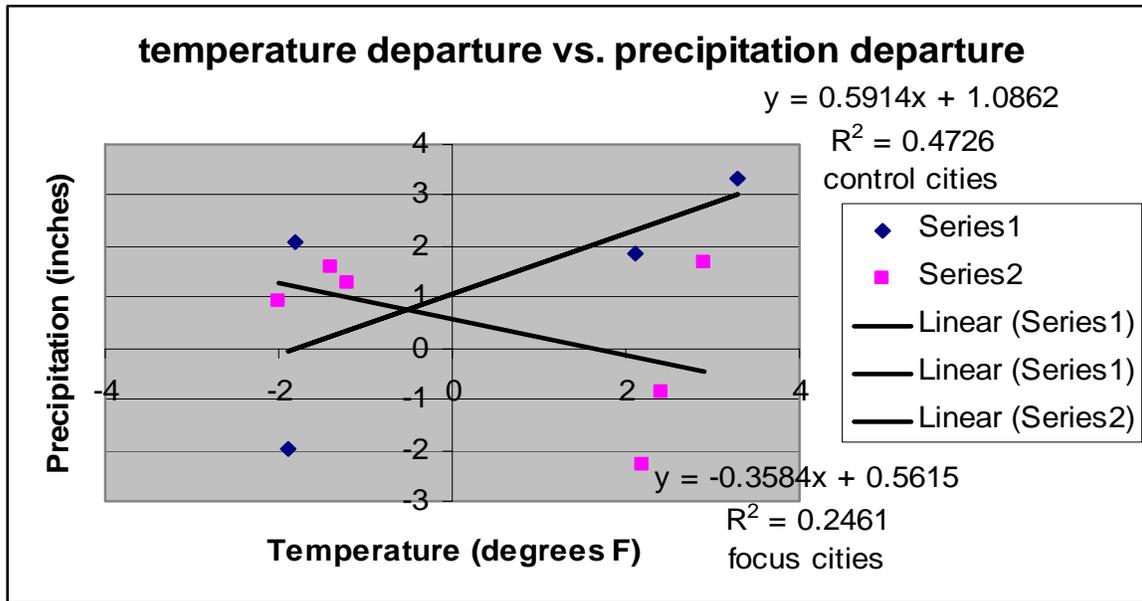
### Spoooner, WI

Spoooner, Wisconsin is the control city for Grand Marais, Michigan. The two cities are along similar latitude and are affected by the same weather systems most of the time. Spoooner, Wisconsin is located in the northwest portion of Wisconsin, but far enough west and south of Lake Superior to be not affected by the Lake in climate terms. The city is very small but rich with weather data dating back to the turn of the century. It was found that there is not a strong correlation, between temperature and precipitation in this example. However, there is a very strong correlation, with an R squared value of 0.4419, between temperature and snowfall. For every 1°F temperature increase the snowfall dropped 4.15 inches on average. For extreme weather, the correlation was very weak, but it appeared that both extreme rainfall and snowfall days may drop with a temperature increase.

### General consensus vs. control cities

After all of the data analysis was done, a comparison was done between the cities focus cities and the control cities. This was done by averaging out all the numbers for all the cities labeled as a focus city and compared them on the same graph with the control cities. The findings for temperature versus snowfall had the same relationship. Both the control cities and focus cities sampled had an average decrease of 3 inches of snow for every 1°F increase in temperature. The correlations on both graphs were very high. They had an average R squared value of 0.6. Temperature versus extreme weather was a bit more inconclusive. The correlation was very weak but for both focus and control cities

the trend was slightly more extreme weather with a temperature increase. Extreme snowfall days were constant while extreme rainy days were up slightly. The only major clash in behavior with a change in temperature was its relationship with precipitation. For the control cities it appeared that with increasing temperature, precipitation increases. On the other hand, it also appeared that for the focus cities that an increase in temperature would actually result in a decrease in precipitation.



The only other finding that had nothing to do with the control cities was the dependency of lake water depth upon temperature. There was a very good correlation between temperature and water depth with an R squared value of 0.3766. As temperature increased by 1°F the average water depth increased by 0.0346 meters on Lake Michigan, Erie and Superior. Therefore, the total precipitation in the surroundings water shed must be more than the total evaporation over the lakes for a warm year compared to a colder year.

### Summary of Findings

Temperature has an impact on precipitation distribution and amount. However, it is relatively small. Areas west of Lake Michigan have an increase in precipitation with increasing temperature while areas downwind of Lake Michigan, Superior, and Erie have little organized change to a decrease in overall precipitation. Precipitation, along with evaporation controls the Great Lakes water depth. The water depth is increasing on average when the temperature increases. Therefore, the net precipitation of the entire watershed must be increasing at a faster rate than the evaporation rate of the Great Lakes.

Temperature has a large impact on the total amount of snow an area will receive. At every location sampled, snowfall decreased with increasing temperature. However, there was one exception to the rule. While the snowfall decreased at Grand Marais when temperature increased, it also decreased when temperature decreased which created a peak in snowfall at -0.1°F. This is thought to be a result of the lake-effect snow patterns in the Upper Peninsula of Michigan. System snowfall decreases with increasing temperature and increases with decreasing temperature. On the other hand, lake-effect snowfall can only increase with decreasing temperature until the lake becomes cold

enough to freeze. At that point the ice shuts off evaporation which in turn prohibits condensation and precipitation from occurring. In turn lake-effect snow increases initially with increasing temperature and then begins to fall since temperature gradient also helps to drive lake-effects snow patterns. Therefore, due to the location, average temperature, and unique sub-climate effects at Grand Marais, snowfall decreases with increasing or decreasing temperature.

Snowfall does not appear to be increasing with time, despite the research done that suggests that it is increasing with time. The 1960's and 1970's shift a linear slope upward which suggest that it is increasing, but a better fit graph helps to show the unusually high snowfall in the 1960's and 1970's. Extreme weather overall seems to have a two sided approach with temperature change. First, it does appear that extreme rainfall events increase slowly with temperature change. Second, it appears that extreme snowfall events decrease at an even slower magnitude with a temperature change. If you define extreme weather as the sum of both extreme rainfall events and snowfall events, then according to the data, extreme weather events are increasing at the rate of 1 more days with an extreme weather event for every 65°F increase in temperature. However this does not take into effect the error of this data, which is high, or other forms of extreme weather such as drought, floods, or gale winds that the Great Lakes region encounters.

## **Predictions**

### **Global Warming**

Assuming global warming occurs, it is predicted to increase global temperatures 2-10°C (3.6°F-18°F) by the year 2100. This is a large temperature span and depends largely upon the greenhouse gas levels in the future. However, predictions can be formulated for the Great Lakes region based on previous research and the data analysis that was mentioned earlier. For these predictions, an expected increase of 6°C (10.8°F) in temperature by the year 2100 will be used.

Precipitation may decrease primarily in areas downwind of Lake Michigan, Superior, and Erie. The annual precipitation may decrease by 2-4 inches. On the other hand, areas west of Lake Michigan, north and west of Lake Superior, and areas of southern Ontario could increase in annual precipitation by 6-8 inches. This increase in precipitation would help to increase the lake-levels. The average water depth of Lake Michigan, Superior, and Erie would rise by ½ a meter. This would not affect the overall system of the Great Lakes by much. However the average maximum in the lake-level oscillations that occur from year to year could begin to cause more noticeable changes. These changes could include the decreasing sizes of coastal beaches and dune formation. Snowfall would decrease significantly across the entire Great Lake's region. Snowfall may decrease by an average of 30-35 inches across much of the area. In the Upper Peninsula snowfall may decrease by as much as 45-50 inches in localized areas. Extreme weather will increase slightly, but may be unnoticeable. Extreme rainfall events may increase while extreme snowfall events may decrease.

### **Global Cooling**

Assuming global cooling occurs, it is predicted to decrease global temperatures at least 6°C (10.8°F) sometime in the next 50,000 years. Despite the uncertainty of the next ice age, the best approximation is that the height of the next ice age will be about 18,000 years from now. Predictions can be formulated for the Great Lakes region based on previous research and the data analysis that was mentioned earlier. For these predictions, an expected decrease of 6°C (10.8°F) in temperature will be used.

Precipitation may increase primarily in areas downwind of Lake Michigan, Superior, and Erie. The precipitation may increase by 3-6 inches a year. On the other hand, areas west of Lake Michigan, north and west of Lake Superior, and areas of southern Ontario could decrease in annual precipitation by 4-6 inches. This decrease in precipitation would help to decrease the lake-levels. The average water depth of Lake Michigan, Superior, and Erie would fall by 1/3 of a meter. This would not affect the surroundings much. However the average minimums in the lake-level oscillations that occur from year to year could expose more coastal beach area. These results would be more obvious on Lake Erie due to its shallow water depth. Snowfall would increase significantly across the entire area with the exception on Northern Michigan. In those areas snowfall may decrease due to less evaporation and lake-effect snowfall. Snowfall may increase in much of the Great Lake's region by 25-30 inches. In Northern Michigan snowfall may decrease by as much as 30-35 inches. This would lead to a shift in snowfall maximum to Central Michigan opposed to the Upper Peninsula as seen today. Extreme weather will decrease slightly, but it may not be noticeable. Extreme rainfall events may decrease while extreme snowfall events may increase.



Picture taken by Ross Ellet

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