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Climate Change in Buffalo, NY

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Abstract

The climate is changing globally and in the northeast United States. Evidence of climate change should also be found in Buffalo, New York, located along the eastern shore of Lake Erie. My hypotheses are that average winter temperatures and snowfall should be increasing, Lake Erie should be freezing at a later date, and Lake Erie's ice cover should affect snowfall amounts. The warmer temperatures would lead to Lake Erie's surface water temperature being higher, resulting in less ice cover. The lack of ice would lead to more lake effect snow over Buffalo.

The city of Buffalo, New York has experienced a limited change in climate over the past 67 years. Winter snowfall and December snowfall and temperatures have increased over time when a three year moving average is used to reduce the high variability in the raw data. Winter temperatures and January and February temperatures and snowfall amounts have not changed. Lake Erie's ice date did not change over time. A correlation test of the Lake Erie ice cover and winter snowfall did show a negative correlation.

The Changing Climate

Climate change is evident on a global scale. Winter temperatures have risen 1.3°F each decade over the last 150 years in the northeast (Spanger-Siegfried, 2006). Temperatures have also increased in the Great Lakes region. According to Wang et al., (2012), winter air temperatures increased by 1.5°C since 1973. Water surface temperatures for the Great Lakes have increased over the past two decades. The warmer temperatures are affecting lake ice cover. Great Lakes' ice cover has decreased by 71% since the 1970s.

Average winter snowfall has decreased in the northeast by 4.6 cm each decade since the 1960s (Braswell et al. 2008). However, along the eastern and southeastern shores of the Great Lakes, Burnett et al. (2002) have shown an increasing trend in snowfall for locations in the lee of the lakes. The increase is explained by lake effect snow. The lakes' surface water temperature is warmer than the air during the cold season which provides a destabilization of the lower atmosphere leading to precipitation (Sousounis, 2003).

The climate should be changing in Buffalo, New York. The purpose of this study is to see how the climate is changing in Buffalo. My first hypothesis is that average temperatures for the meteorological winter months of December, January, and February (DJF) should be increasing in Buffalo. Winter snowfall amounts should also be increasing since Buffalo's location is on the eastern edge of Lake Erie. Lake Erie should be freezing at a later date since air and water surface temperatures are increasing. My fourth hypothesis is a correlation should exist between winter snowfall amounts and when Lake Erie freezes over. When Lake Erie's ice cover changes then snowfall amounts should inversely change.

Documentation of Climate Change

Recorded data, evaluated by Hansen et al. (2010), shows average global surface temperatures warmed by 0.17°C during the past four decades. In another study, by Spanger-Siegfried (2006), found that average temperatures in the northern hemisphere have increased by 1°F during the last 150 years and in the northeast United States by nearly 0.5°F each decade since 1970. Braswell et al. (2008) showed that minimum and maximum temperatures have increased by nearly 0.5°F per decade from 1965 to 2005. The highest rate of warming is happening in the coldest months, specifically January and February. And yet another study, by Frumkin et al. (2008), agreed with the warming temperature trend and found that the global mean temperature has increased 0.6°C since the 1860s.

The increasing temperatures allow air to hold more moisture. Trenberth (2005) showed that air can hold about 7% more water per 1°C of warming. More moisture in the air results in greater amounts of precipitation. Another study revealed heavy precipitation days increased 26 percent among 34 northeast data collecting stations (Griffiths and Bradley, 2007). Since 1970, precipitation has increased by about 5% compared to the previous 70 years (Karl, 1996).

At the same time, less precipitation is falling as snowfall. Braswell et al. (2008) showed the number of snow-covered days in winter has dropped 8.9 days per decade since the 1960s. Data recorded daily at 11 weather observation sites from 1949 to 2000 showed a significant decreasing annual trend in snow to precipitation ratios (Wake, 2005). However, the eastern side of the Great Lakes is seeing increasing amounts of snow from lake effect snow. Burnett et al. (2002) showed a significant increasing trend in snowfall at hundreds of lake-effect sites around the Great Lakes between 1951 and 1980. The increased lake effect snow results from increasing surface water temperatures.

Lake effect snow is produced by large-scale weather systems during the cold season, when cooler air moves over the warmer lake water. The temperature difference causes air parcels to move upward, water vapor condenses out and forms precipitation. Sousounis (2003) found that strong sensible and latent heat fluxes warm and moisten the air near the surface causing instability in the atmosphere. Strong vertical motions develop and form precipitation. The lakes are climatologically warmer than the air and provide heat and moisture to destabilize the lower atmosphere. Enhanced precipitation is found along the lakeshores, downwind of the dominant airflow. The peak time for the greatest lake-air temperature differences is during the cold season. According to Niziol (1987), important weather parameters need to be present for the production of lake effect snow in Buffalo. First, the temperature difference between the lake surface water and the air at the 850 millibar level around 1500m must be at least 13°C. Second, the wind direction in the lower atmosphere from the surface up to about 3,000m needs to be from the west and southwest since Lake Erie's greatest length is from the southwest to the northeast. Air over the warmer lake water gains more moisture and can therefore precipitate.

The average winter water surface temperatures of the Great Lakes have increased since the 1990s (Burnett et al., 2002), which has led to a change in lake ice cover. The Great Lakes ice season has started increasingly later since the 1850s, and the amount of ice is decreasing. According to Wang et al., (2012) there was a significant drop in ice cover since the 1970s for all of the Great Lakes. Lake Ontario had the largest drop in ice cover at 88%, and Lake Superior dropped 79%. A lake with ice cannot produce nearly as much lake effect snow. Ice formation indicates cooler surface water of 32°F or below. The lake-air temperature difference therefore decreases and so does instability in the atmosphere. The increase in water temperatures results in a decrease in lake ice cover. Burnett et al. (2002) showed that the average surface water temperatures during the snow season for each of the Great Lakes showed an upward trend since the mid 1990s. The water temperature changes may be contributing to the increasing lake effect snowfall along the lees of the lakes. Richards (1964) showed ice cover lessens with maximum daytime temperatures just above 30°F. When the ice cover decreases, more heat energy can be transferred into the lower atmosphere and destabilize the air. When there is ice cover, less energy is transferred. Cordeira et al. (2008) shows surface sensible heat fluxes over a frozen lake are much less than over an unfrozen lake. Also, thicker ice decreases the heat energy available.

Recording Buffalo's Climate

Daily average temperature (F) data for the meteorological winter (DJF) of 1943-1944 to 2010-2011 was obtained from Buffalo climate data provided by the National Climatic Data Center (National Climatic Data Center, 2012) and the National Weather Service's website (National Weather Service, 2005). Winter snowfall amounts in inches were also obtained from the Buffalo climate data provided by the National Weather Service's website (National Weather Service, 2009). The temperatures and snowfall amounts were recorded at the weather observation station at the Buffalo Niagara International Airport in Buffalo, New York.

Winter Lake Erie surface water temperature data and ice cover start dates from the winter of 1943-1944 to 2010-2011 were obtained by the National Climatic Data Center (National Climatic Data Center, 2012) and the National Weather Service's website (National Weather Service, 2010). Lake Erie water temperature data is collected from the Buffalo Water Treatment Plant temperature gauge located on Lake Erie at the entrance to the Niagara River (National Weather Service, 2010). The water temperature information is used by the National Weather Service in Buffalo to determine a start date for when Lake Erie is covered with ice. Ice cover is determined by the lake water temperature being at 32° F and staying at or below that temperature. The rest of the lake is shallower and freezes over sooner. The ice dates of lake ice cover were verified using Lake Erie satellite imagery provided by the Great Lake Ice Atlas (National Oceanic and Atmospheric Administration; Figure 1). More than 90% of the NWS ice dates matched NOAA's available satellite imagery from 1973 to 2002. Satellite coverage wasn't available for meteorological use until the 1960's and resolution wasn't very good until the 1970's. The NWS observations match the historical satellite data.

The monthly temperatures for December, January, and February were averaged to get a winter temperature for each of the 67 years. The three monthly snowfall totals were summed to get winter snowfall for each year in the time period. The time period from the winter of 1943-1944 to the winter of 2010-2011 was determined based on the location of the temperature and precipitation gauge at the Buffalo Niagara International Airport. The gauge has not been moved during this time. Prior to the winter of 1943, the gauge had been located in downtown Buffalo along Lake Erie since 1884. The gauge was moved inland 10 miles to the Buffalo Niagara International Airport in the summer of 1943. A difference in temperatures and precipitation would be expected if the two locations were compared.

The gauge data had been recorded manually by a meteorologist until December of 1995 when it was switched to an Automated Surface Weather Observation Station (ASOS). A Two Sample T-Test will verify there is no difference in the temperature and snowfall data before the change over from a manual to an automated weather station.

A linear regression test will be used on the average temperature and snowfall data for the meteorological winter (DJF) from 1943-1944 to 2010-2011. The tests will show if there is a linear trend in temperature or snowfall over time and whether either has gone up over the 67 year period and by how much.

If there isn't a trend, then a linear regression test will be used on average temperature and snowfall data for each of the meteorological winter months. Lake Erie is often frozen in January and February when there may be more consistent temperatures and snowfall because the ice cover provides a more stable atmosphere and temperate conditions. The later winter months may be affecting overall results of the winter regression tests.

If a trend still isn't seen, then a three year moving average will be used on temperature and snowfall data for the winter and each of the winter months. In a moving average, the first three terms are averaged, then the next three starting with the second term, etc. Linear regression tests will be used on the three year moving average temperature and snowfall data for the meteorological winter as well as for each of the meteorological winter months.

A moving average helps smooth over short-term variation in a data set and lowers the variability. The method doesn't produce a trend but rather finds it. According to StatSoft (2013), using a moving average is a common technique to smooth the data and filter out the noise. The method produces results that are less biased by outliers and variability. A trend can more easily be seen in a data set with less variability since the extremes don't have a disproportionate influence on the end results. A three year moving average is relatively short compared to the length of the data in years and will not have as large of an effect on the data. A graph of the raw data and moving average show the same line with the same slope. The moving average is not fabricating data but reducing the variation so the trend becomes significant. The trend line isn't moved but is smoothed over the short term variation so the line isn't as varied and the tests have a clearer vision of a trend.

However, a study rebuts the use of a moving average. Hansen (2010) states that moving averages are sufficient to minimize variability, but running averages on data are ways to make the trends clearer without waiting for additional decades to pass, but trends may be enhanced inaccurately. It is possible to find almost any trend for a specific amount of time based on start and end dates but it doesn't mean it's a meaningful result.

A linear regression test will be used on Lake Erie's ice in date to show if Lake Erie is freezing at a later date over time. To complete the linear regression tests, first a T-test statistic will be calculated to determine if the slope of the regression line of data is equal to zero or not equal to zero. A zero slope will mean no change. The F-test portion of the linear regression test will also be conducted to determine if the line is statistically significant. Both the T-test and F-test statistics will be calculated by Minitab.

A correlation coefficient test will be used to see if a correlation exists between meteorological winter snowfall and Lake Erie ice cover. A Spearman Correlation Coefficient will be used because the boxplot for winter snowfall shows an outlier present in the data, and the sample size is large (Figure 2). The test will answer if snowfall amounts change when the lake's ice cover changes. A number system was used for the ice date data. December 31st was given the number 0. Any date previous to that is given a negative number and any date after December 31st is given a positive number.

Buffalo's Climate, Results

Two Sample t-tests were run on temperatures and snowfall amounts during a 15 year period before 1995 and after 1995. The results show there is no difference in the mean temperature and mean snowfall data between manually collected data and that from the automated weather station after 1995. Therefore the data before and after 1995 can be combined to form a larger data set. The 15 year period was chosen to compare the methodologies used before and after 1995. A longer period of time may have included climate change in addition to methodology.

Trend lines on scatterplots of winter temperatures and snowfall over time show a possible trend, especially for winter snowfall (Figures 3, 4). Linear regression tests were done on average winter temperatures and snowfall. Lines were not statistically significant (Tables 1, 2), so there is not a linear trend over time for either temperature or snowfall.

The meteorological winter months of December, January, and February were then tested separately for possible trends. Trend lines on scatterplots of monthly temperatures over time show a possible trend for December but not for January and February (Figures 5, 6, 7). Linear regressions were done for temperature data for the individual winter months, but the linear relationship between temperature and time for each month was not statistically significant (Table 1). However the T and F statistics were close to the critical values for December.

Trend lines on scatterplots of monthly snowfall over time show a possible trend for December but not for January or February (Figures 8, 9, 10). Linear regressions were done for snowfall data for the individual winter months, but the linear relationship between snowfall and time for each month was not statistically significant (Table 2). However the T and F statistics were close to the critical values for December.

Winter temperatures and snowfall have not changed over the past 67 years in Buffalo. There isn't a change in temperatures or snowfall over time for each winter month of December, January, and February. The statistical tests aren't picking up a significant change because of the high variability in the data sets, mainly for winter snowfall and December temperatures and snowfall. There is less variability for the months of January and February. A three year moving average was used to cut down the variability and extreme temperatures and snowfall. A trend can more easily be seen in data with less variability. Extremes can influence the end results.

A linear regression test was then used on the moving average winter temperatures and snowfall. The tests show a linear relationship between winter snowfall and time, but no change in temperatures (Table 3, 4). Trend lines on scatterplots of winter temperatures over time show no trend, however a trend is seen in increasing winter snowfall (Figures 11, 12). The change in winter snowfall proves my second hypothesis but no change in temperatures disproves my first hypothesis.

Linear regressions were done on the moving average temperature data for the winter months. December was the only month that showed a linear relationship between temperature and time (Table 3). Trend lines on scatterplots of the monthly temperature data show a trend for December but not for January and February (Figures 13, 14, 15).

Linear regressions were done on the moving average snowfall data for the winter months. December was the only month that showed a linear relationship between snowfall and time (Table 4). Trend lines on scatterplots of the monthly temperature data show a trend for December but not for January and February (Figures 16, 17, 18).

A linear regression was done on Lake Erie's freeze date (Figure 19). The test showed there is not a linear relationship between Lake Erie's freeze date and time. The F-statistic is 1.94 and the probability of outcome (p-value) is 0.169. An alpha of 0.05 was used. The relationship is not statistically significant. Lake Erie's freeze date has not changed over the past 67 years. The lack of change disproves my third hypothesis.

A Spearman's correlation coefficient test was conducted on meteorological winter (DJF) snowfall and winter Lake Erie ice cover. The correlation coefficient of -0.339 is statistically significant. The probability of outcome (p-value) is 0.005. An alpha of 0.05 was used. A correlation does exist between winter snowfall amounts and when Lake Erie freezes over (see appendix). When Lake Erie's ice cover increases then the snowfall amount decreases. Ice cover explains 11.5% of the variation of snowfall. The correlation between ice cover and snowfall proves my fourth hypothesis.

Buffalo's Climate Is Changing

Winter and December snowfall have been increasing over the last 67 years in Buffalo when a three year moving average was used. A moving average lowered the variability and allowed an existing trend to be seen. The results agree with my hypothesis. The study shows winter snowfall has gone up by 20.5 inches and December snowfall by 11.5 inches. The results concur with other studies done in the Great Lakes Region. As explained by Richards (1964), cities located on the lee side of a Great Lake have experienced increasing snowfall amounts over time. A study by Leathers (1996), showed when cold arctic air moves over the warmer lake water, from a larger scale system, air rises and condenses to form clouds and snowfall downwind of the lakes. Lake Erie is usually not frozen over in December, but is for much of January into February (National Weather Service, 2010). More moisture is available for lake effect snow to develop during the first part of winter. Ice cover and lack of moisture lowers the chance of lake effect snow later in winter. Results from my study showed snowfall amounts didn't change for January and February probably because there isn't as much lake effect snow relative to total snowfall.

Winter, January, and February temperatures did not change over time. The results contradict my hypothesis and other studies conducted across the Great Lakes Region and northeastern United States. A study by Spanger-Siegfried (2006), found that annual temperatures in the northeast have increased by more than 1.5° F since 1970. Seven weather observation stations collected daily temperature data since 1900 and showed increasing winter temperatures (Wake, 2005). However, my study showed that December temperatures increased by about 1.7° F over the 67 year period. The results agree with my hypothesis. Warmer pre winter temperatures in the summer and fall could be increasing December air temperatures and Lake Erie's water temperature. Then large scale winter events with arctic air drop the temperatures back to average for January and February. Also, strong northeastern winds cause upwelling on the northeastern end of Lake Erie near Buffalo and help quickly cool the lake and air temperatures.

All of the raw snowfall and temperature data sets had high variability. The highest variability was found in winter snowfall and December snowfall and temperatures. The three year moving average brought the extreme data points closer to the regression line in the highly varied data sets and a trend was statistically significant.

Lake Erie's ice date did not change over time. The results contradict my hypothesis and other studies on the Great Lakes Region. According to (Burnett et al., 2002), increasing surface water temperatures are decreasing ice cover on the Great Lakes.

The decrease in ice cover is leading to a later start to the lake being covered with ice. Another study, by Wang et al., (2012), found Lake Erie Ice cover declined by 50% since the 1970s. In my study, January and February temperatures are not changing therefore Lake Erie continues to freeze on average in mid to late January.

A negative correlation exists between Lake Erie's ice cover and winter snow amounts. As lake ice increases, snow amounts decrease. The results agree with my hypothesis and with Cordeira et al. (2008), who showed that more heat energy and moisture are available when a lake's ice cover decreases. This decrease in ice can lead to increased lake effect snow amounts.

There are inconsistencies and contradictions among climate change literature. Spanger-Siegfried (2006) found winter temperatures have risen 1.3°F each decade over the last 150 years in the northeast. But according to Wang et al., (2012), winter air temperatures have only increased by 1.5°C since 1973 in the same region. In my own research I also saw inconsistencies. My results in the correlation test found ice cover only explains 11.5% of the variation of snowfall even though literature shows lake effect snow is drastically increased when there is less lake ice cover. The inconsistencies in my research could be explained by not having the winter snow data broken up into lake effect snowfall versus larger scale snowfall snow events from a low pressure system. It's hard to tell which years had more snowfall from lake effect or from an increased frequency of larger systems moving through Buffalo.

For future work, I would take a three year moving average on the Lake Erie freeze date since there is high variability in the raw data set. I would run a linear regression test to see if there is a trend. Next, I would try to separate lake effect snow events from larger systems snow events and test to see if lake effect snow is changing over time. This would give a clearer picture of lake effect snow trends. Finally, I would look for an increasing trend in variability to see if extremes are becoming more common in winter temperature and snowfall data. The variability may also further explain why a trend is only found in winter snowfall and December snowfall and temperatures over time when using a three year moving average. Moving averages are more effective on data sets that have higher variability.

Conclusion

Buffalo's winter climate is changing. A three year moving average was used to smooth out variability in the raw data. The moving average data produced a statistically significant trend that showed the climate is changing. Winter and December snowfall has increased during the past 67 years. January and February snowfall has not changed. Winter, January, and February temperatures have not changed. December temperatures have increased. Winter and December snowfall and December temperatures have the highest variability in the raw data sets and are affected the most by the moving average.

Lake Erie is not freezing over at a later date. Lake ice cover and snowfall have a negative correlation. When ice cover decreases, lake effect snow increases. Lake Erie freezes over on average in mid January. The average ice in date is not changing. The lake doesn't usually freeze over in December and more lake effect snow can be produced. Air temperatures can fluctuate more when the lake isn't iced over. Pre winter warmth could be causing December temperatures to be warmer. Large scale winter systems finally bring down the air and lake temperatures. More research can be done to verify the meteorological causes. Similar testing of summer and fall temperatures in Buffalo could reveal trends that are impacting the winter climate.

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Tables:

Linear Regression Tests , 67 Years	**F-Statistic**	**Significance**
Winter Temps (F) Vs. Time	0.74	Not Significant (p= 0.393)
Dec. Temps (F) Vs. Time	1.56	Not Significant (p= 0.216)
Jan. Temps (F) Vs. Time	0.03	Not Significant (p= 0.862)
Feb. Temps (F) Vs. Time	0.10	Not Significant (p= 0.752)

Table 1. Linear regression tests of winter temperatures (F) and temperatures for December, January, and February from 1943 to 2011. An alpha value of 0.05 was used.

Linear Regression Tests , 67 Years	**F-Statistic**	**Significance**
Winter Snowfall (inches) Vs. Time	3.83	Not Significant (p= 0.055)
Dec. Snowfall (inches) Vs. Time	3.74	Not Significant (p= 0.57)
Jan. Snowfall (inches) Vs. Time	1.3	Not Significant (p= 0.257)
Feb. Snowfall (inches) Vs. Time	0.01	Not Significant (p= 0.938)

Table 2. Linear regression tests on winter snowfall (inches) and snowfall for December, January, and February from 1943 to 2011. An alpha value of 0.05 was used.

Linear Regression Tests With Moving Avg.	F-Statistic	Significance
Winter Temps (F) Vs. Time	0.83	Not Significant ($p = 0.366$)
Dec. Temps (F) Vs. Time	4.59	Yes Significant ($p < 0.05$)
Jan. Temps (F) Vs. Time	0.03	Not Significant ($p = 0.865$)
Feb. Temps (F) Vs. Time	0.13	Not Significant ($p = 0.82$)

Table 3. Linear regression tests with three year moving average of winter temperatures (F) and temperatures for December, January, and February from 1943 to 2011. An alpha value of 0.05 was used.

Linear Regression Tests With Moving Avg.	F-Statistic	Significance
Winter Snowfall (inches) Vs. Time	10.21	Yes Significant ($p<0.05$)
Dec. Snowfall (inches) Vs. Time	12.02	Yes Significant ($p< 0.05$)
Jan. Snowfall (inches) Vs. Time	3.82	Not Significant ($p = 0.055$)
Feb. Snowfall (inches) Vs. Time	0.13	Not Significant ($p = 0.72$)

Table 4. Linear regression tests with three year moving average on winter snowfall (inches) and snowfall for December, January, and February from 1943 to 2011. An alpha value of 0.05 was used.

Figures:

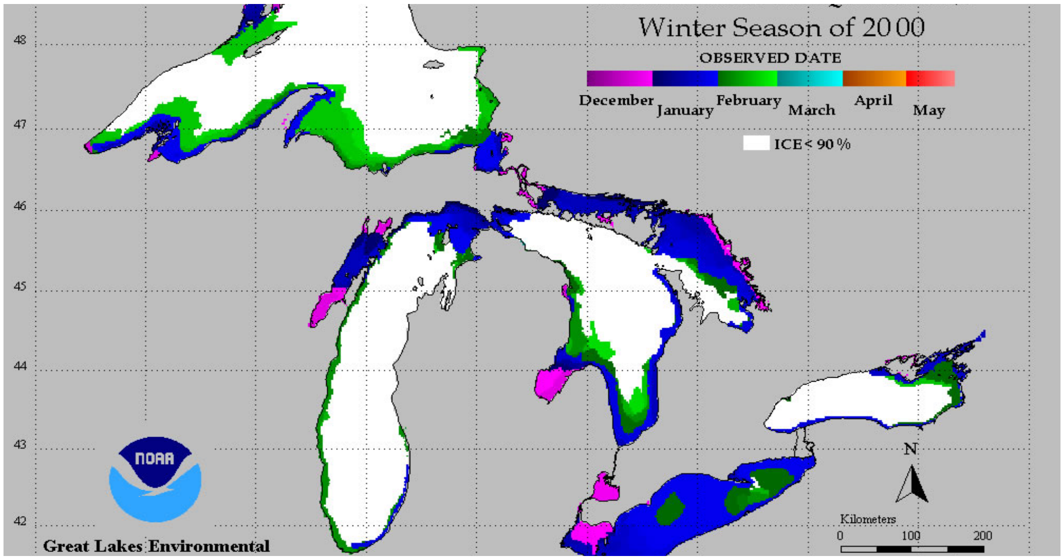

Figure 1. An example from the Great Lakes Ice Cover Atlas by NOAA for Winter 2000. Lake Erie was frozen over by late January in 2000, indicated by the blue and patchy dark green colors.

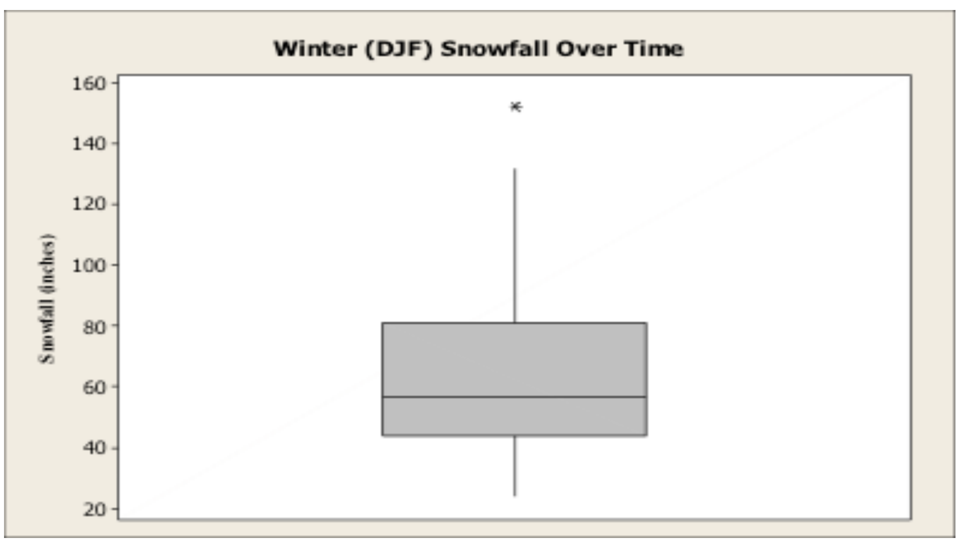

Figure 2. Boxplot showing an outlier in winter snowfall data from the winter of 1943-44 to the winter of 2010-2011.

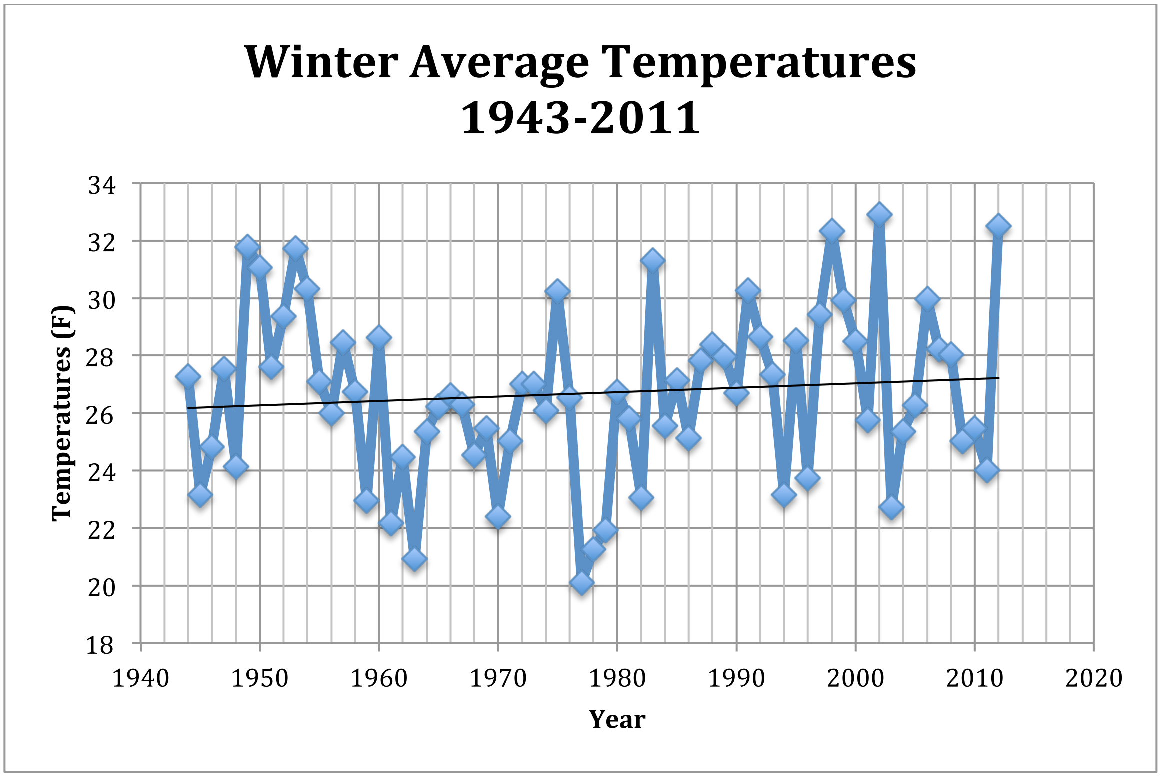

Figure 3. Scatterplot of winter temperatures from 1943 to 2011. The trend line shows a slight possible change in temperatures.

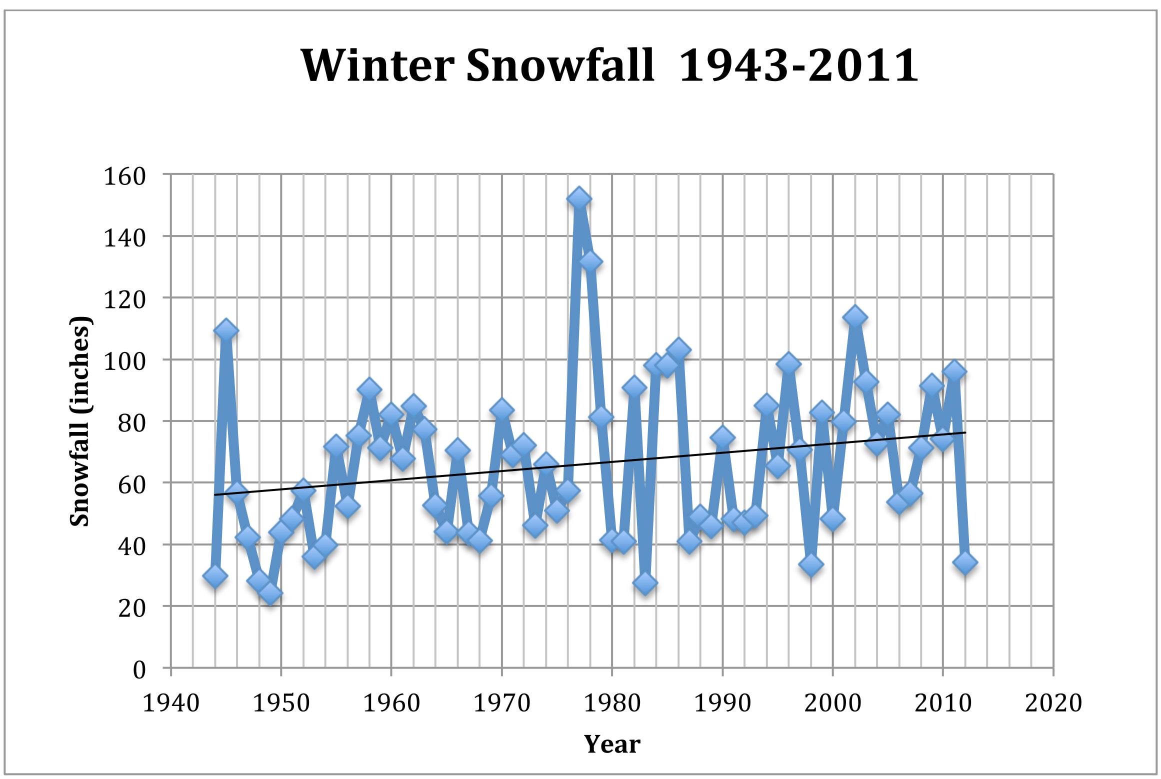

Figure 4. Scatterplot of winter snowfall from 1943 to 2011. The trend line shows a possible change in snowfall.

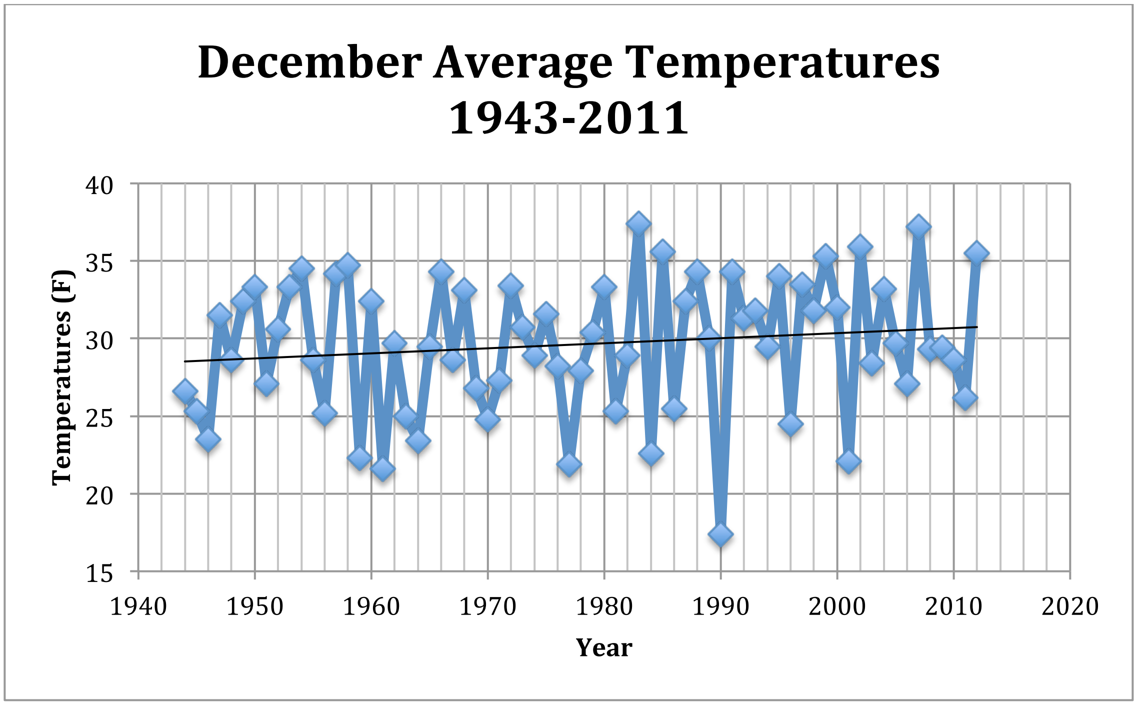

Figure 5. Scatterplot of December temperatures from 1943 to 2010. The trend line shows a possible change in temperatures.

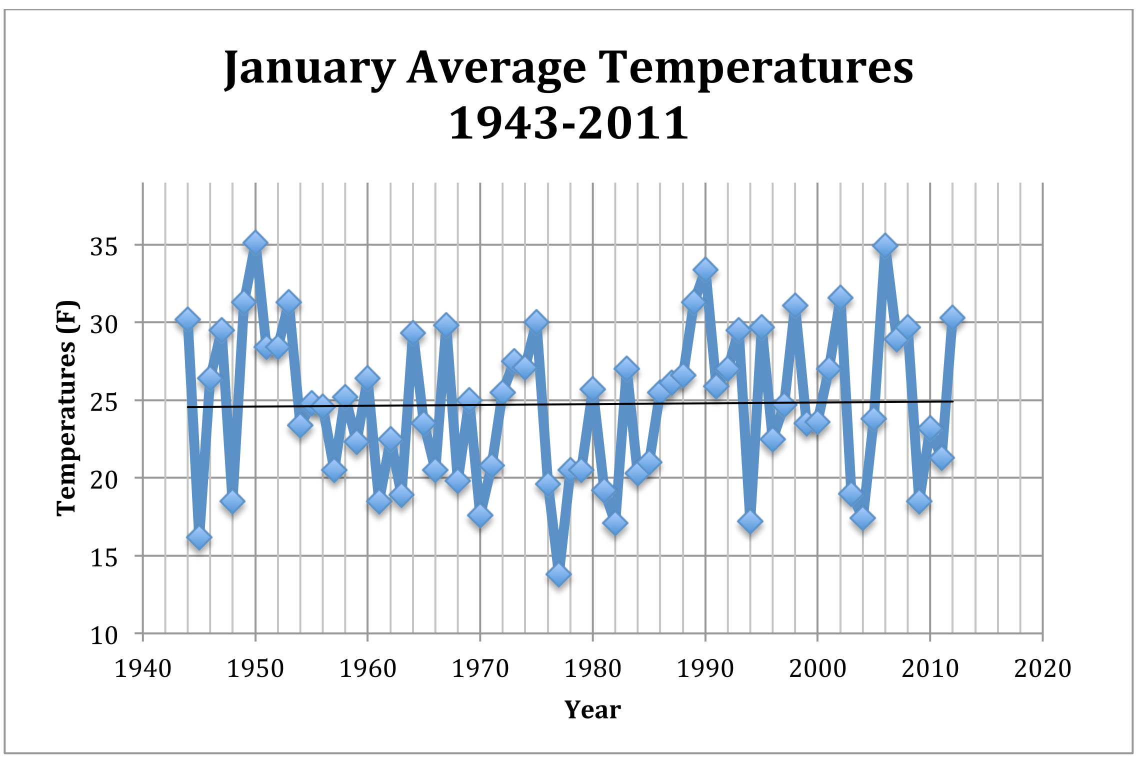

Figure 6. Scatterplot of January temperatures from 1943 to 2011. The trend line shows no change in temperatures.

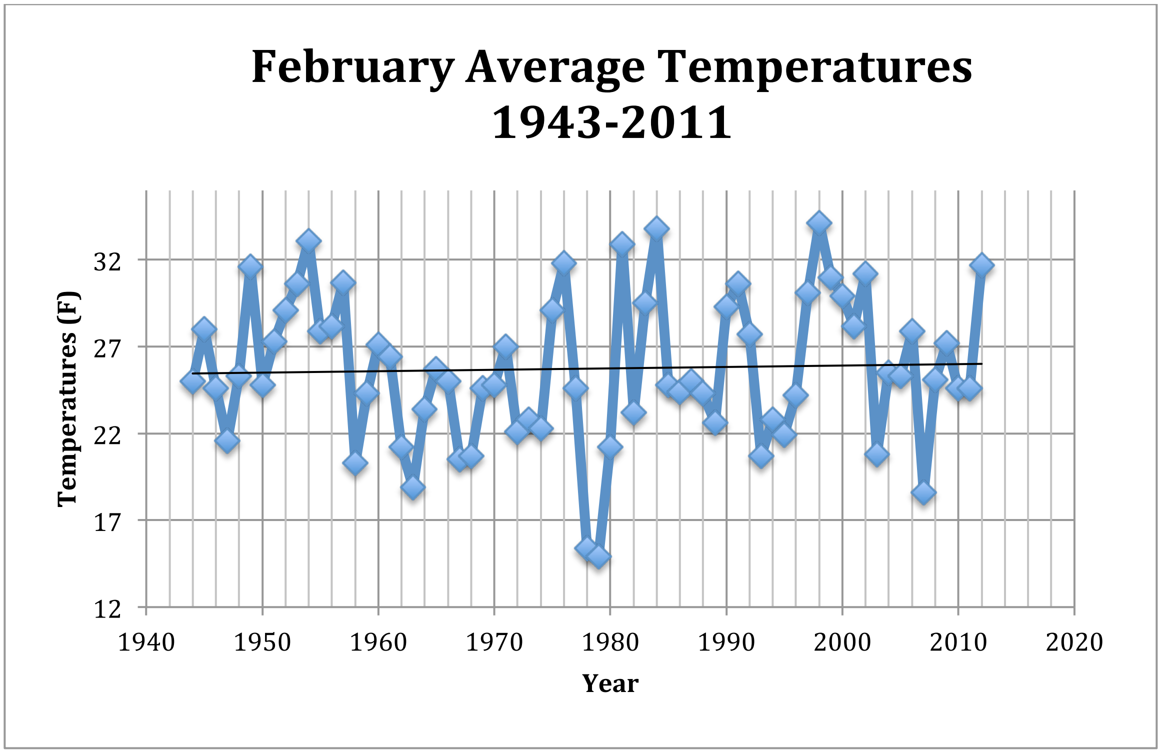

Figure 7. Scatterplot of February temperatures from 1943 to 2011. The trend line shows no change in temperatures.

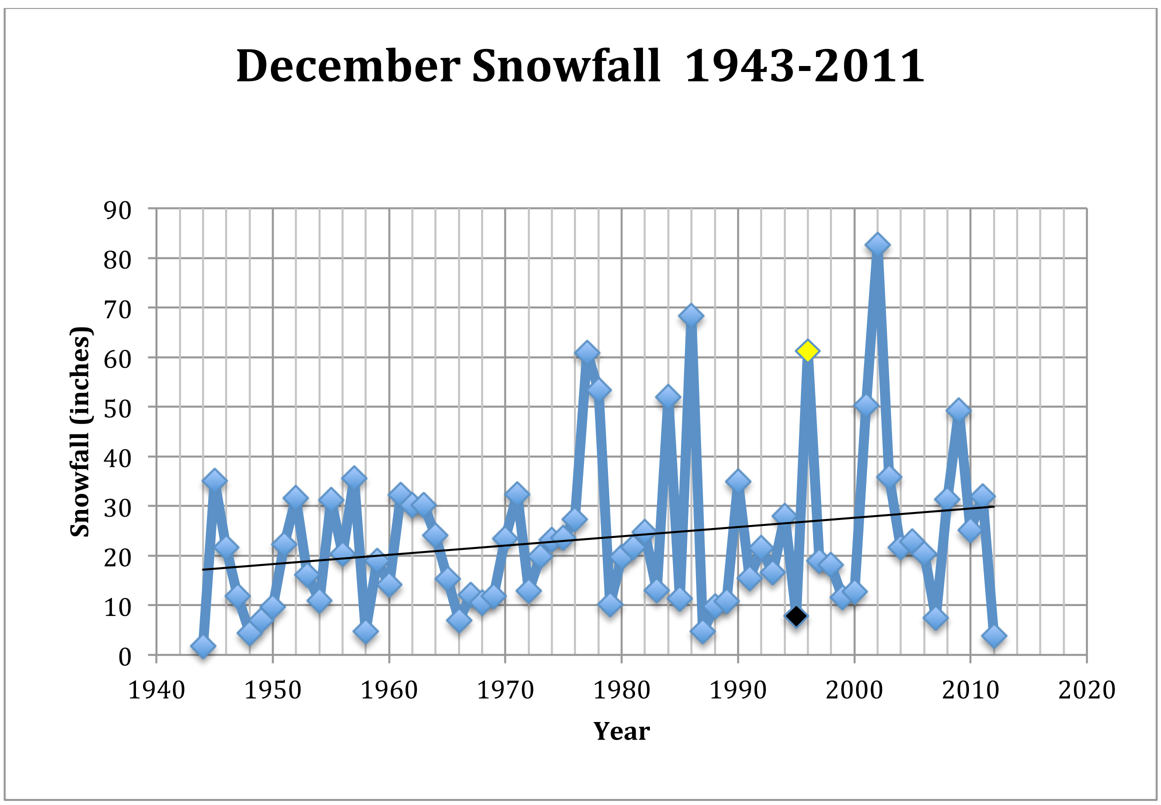

Figure 8. Scatterplot of December snowfall from 1943 to 2010. The trend line shows a possible change in snowfall.

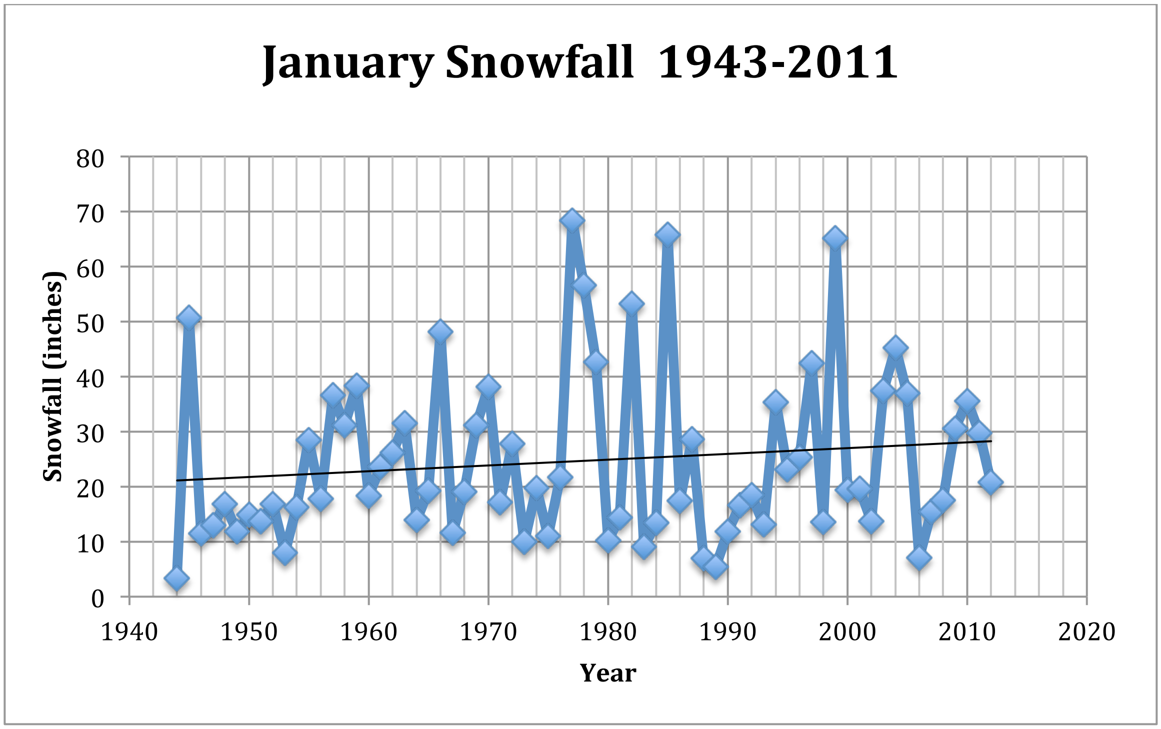

Figure 9. Scatterplot of January snowfall from 1943 to 2011. The trend line shows a slight possible change in snowfall.

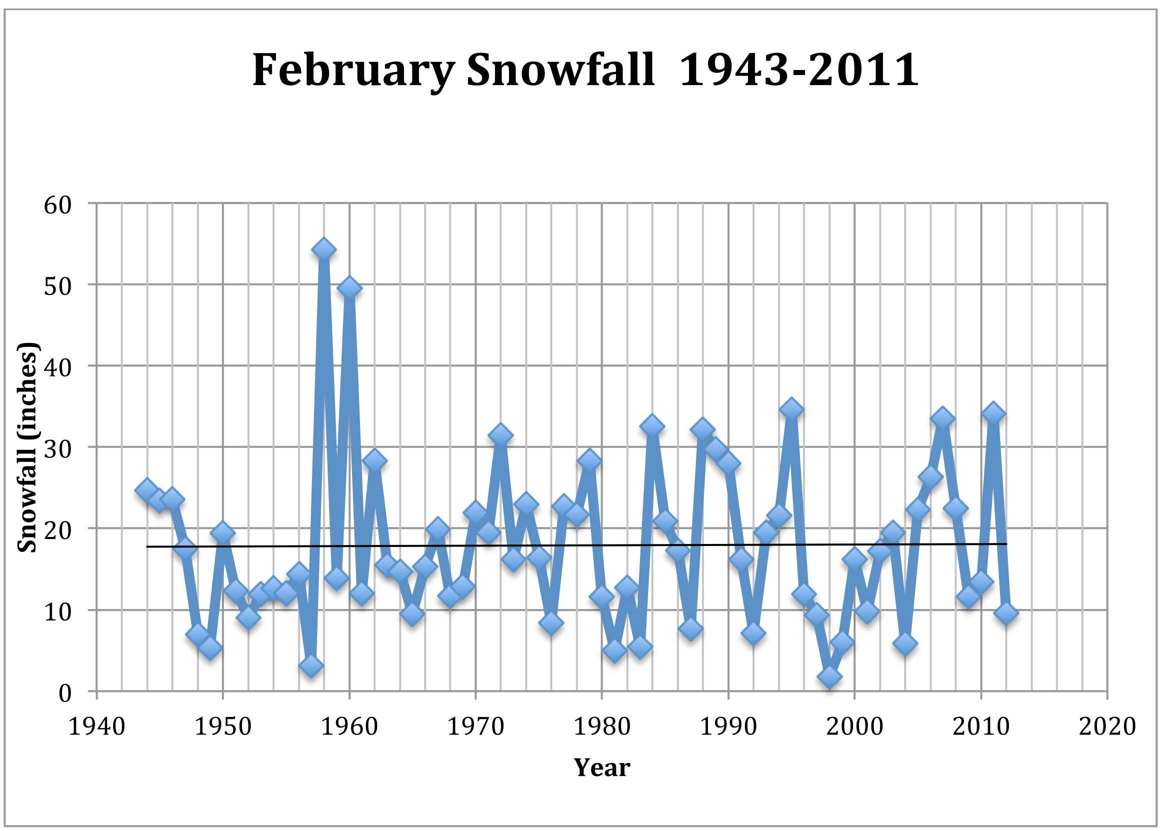

Figure 10. Scatterplot of February snowfall from 1943 to 2011. The trend line shows no change in snowfall.

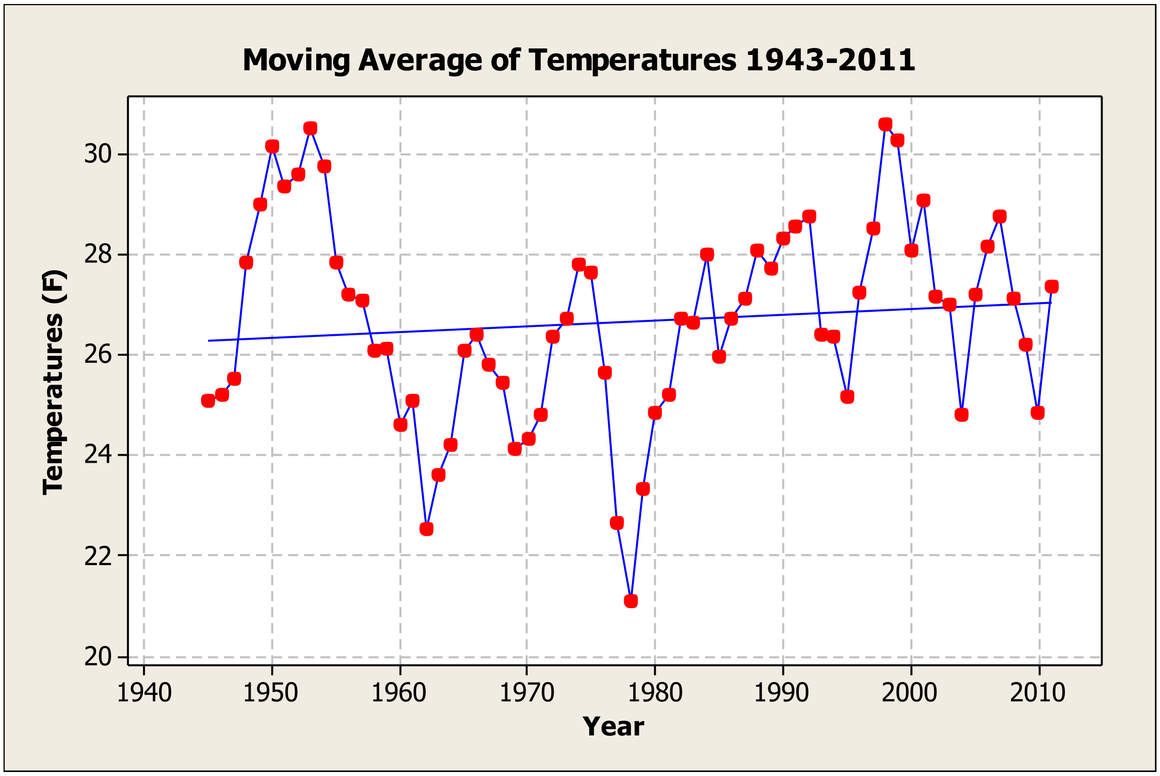

Figure 11. Graph of three year moving average of winter temperatures from 1943 to 2011. The trend line shows a slight possible change in temperatures.

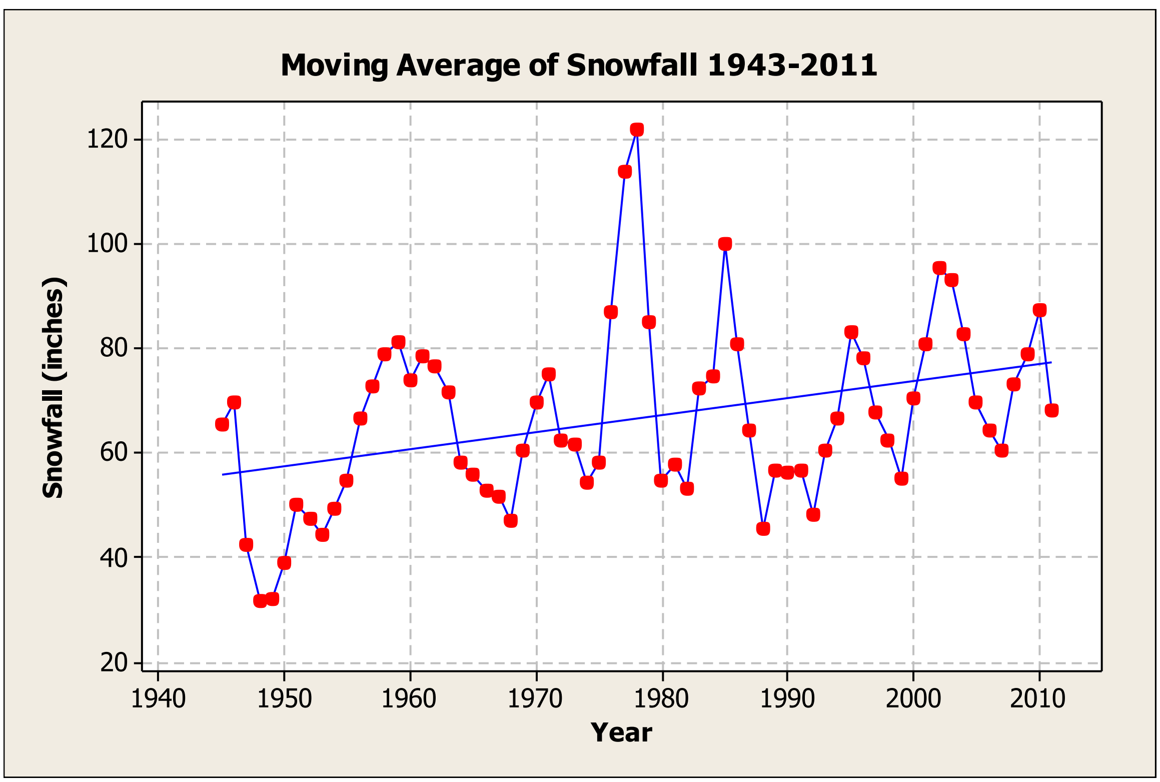

Figure 12. Graph of three year moving average of winter snowfall from 1943 to 2011. The trend line shows a possible change in snowfall.

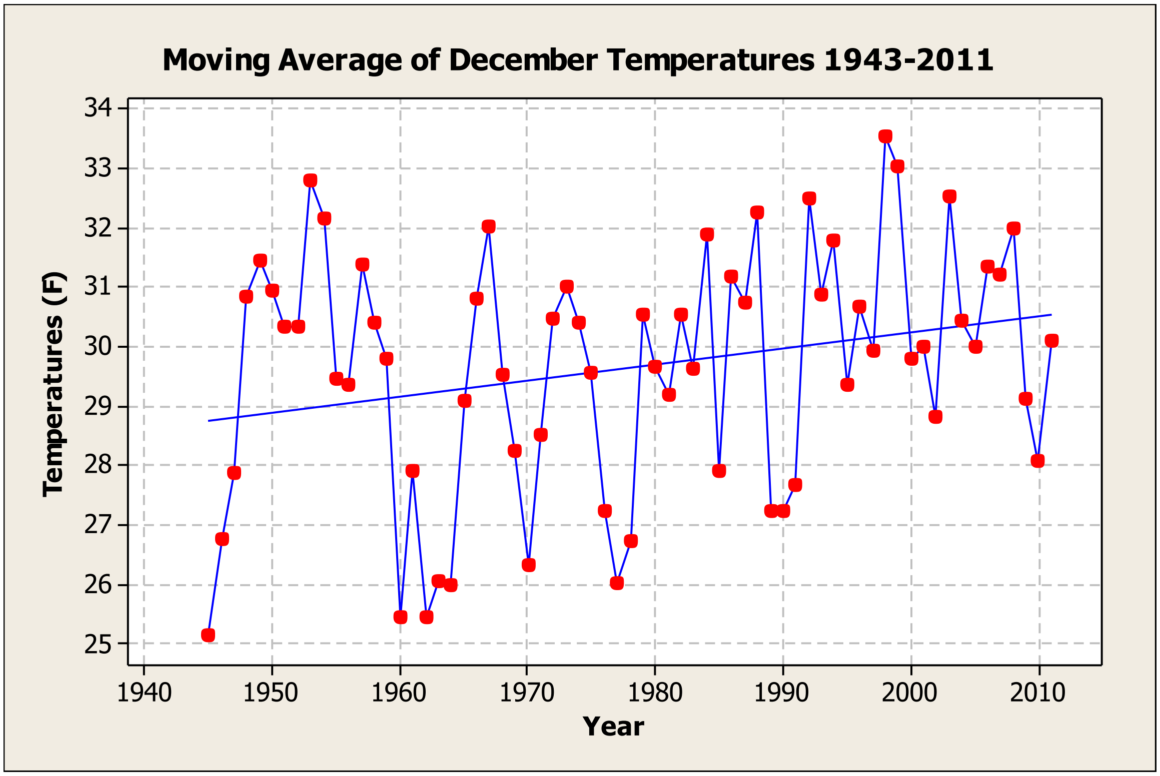

Figure 13. Graph of three year moving average of December temperatures from 1943 to 2010. The trend line shows a possible change in temperatures.

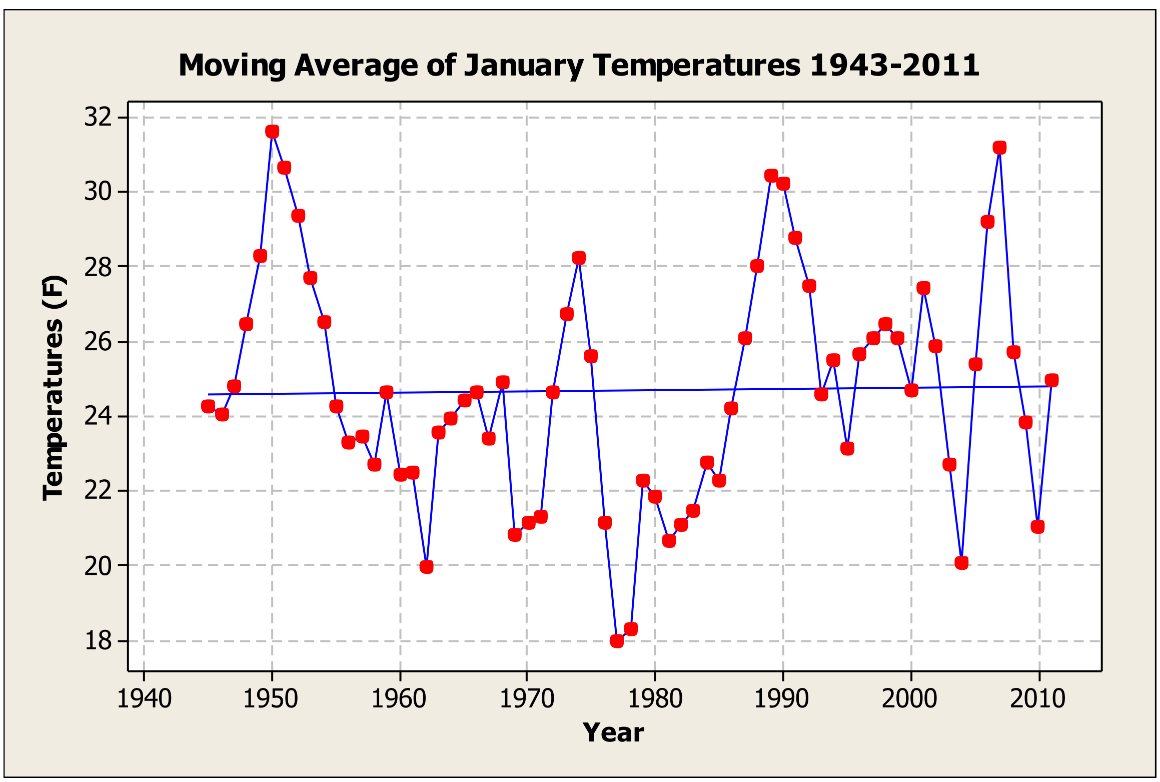

Figure 14. Graph of three year moving average of January temperatures from 1943 to 2011. The trend line shows no change in temperatures.

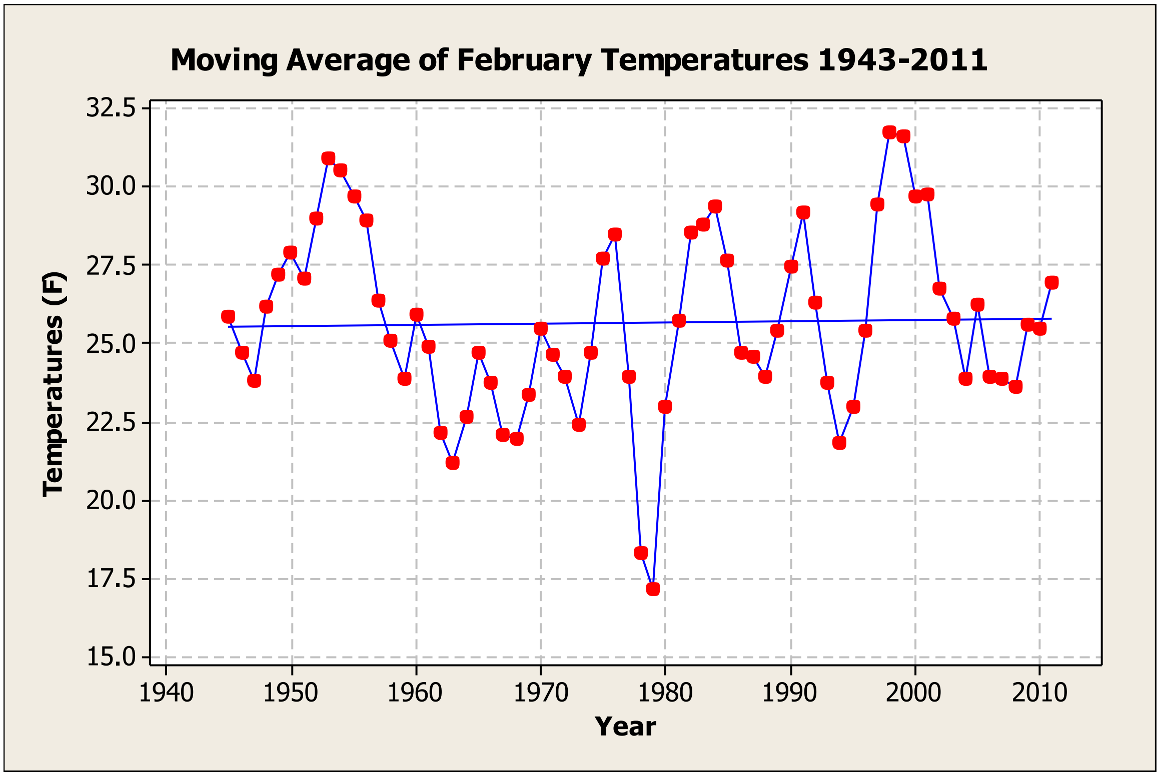

Figure 15. Graph of three year moving average of February temperatures from 1943 to 2011. The trend line shows no change in temperatures.

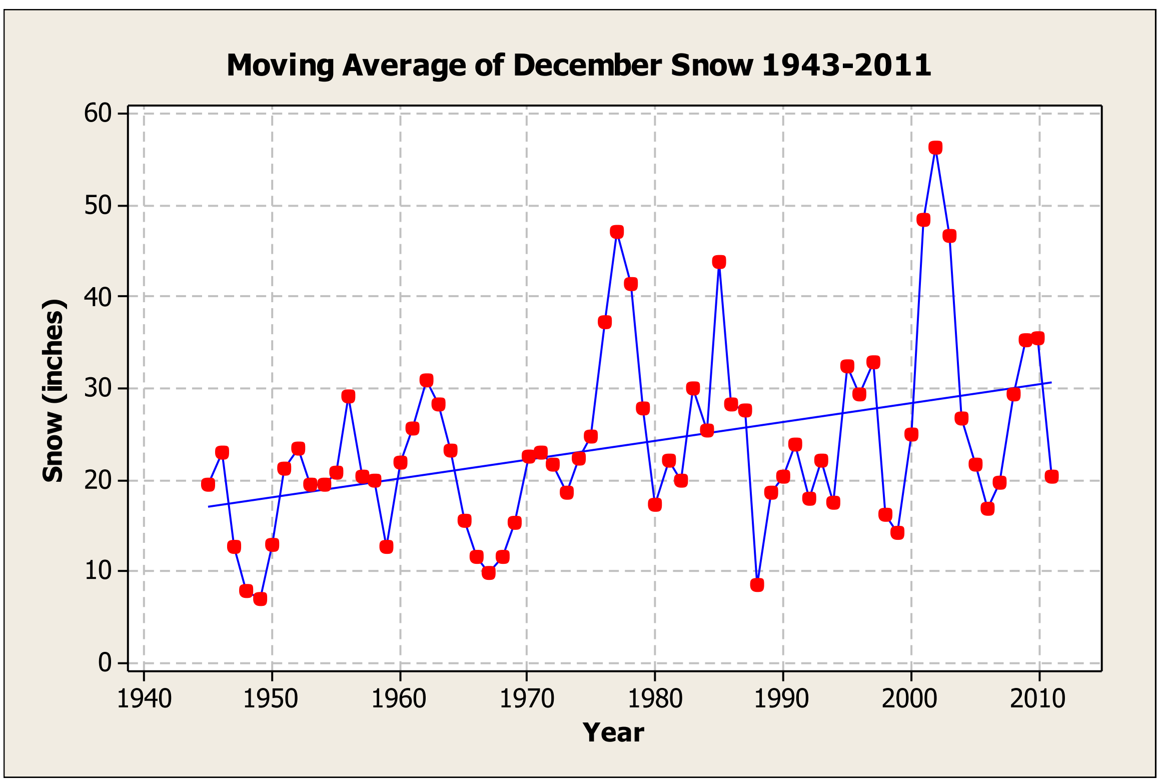

Figure 16. Graph of three year moving average of December snowfall from 1943 to 2010. The trend line shows a possible change in snowfall.

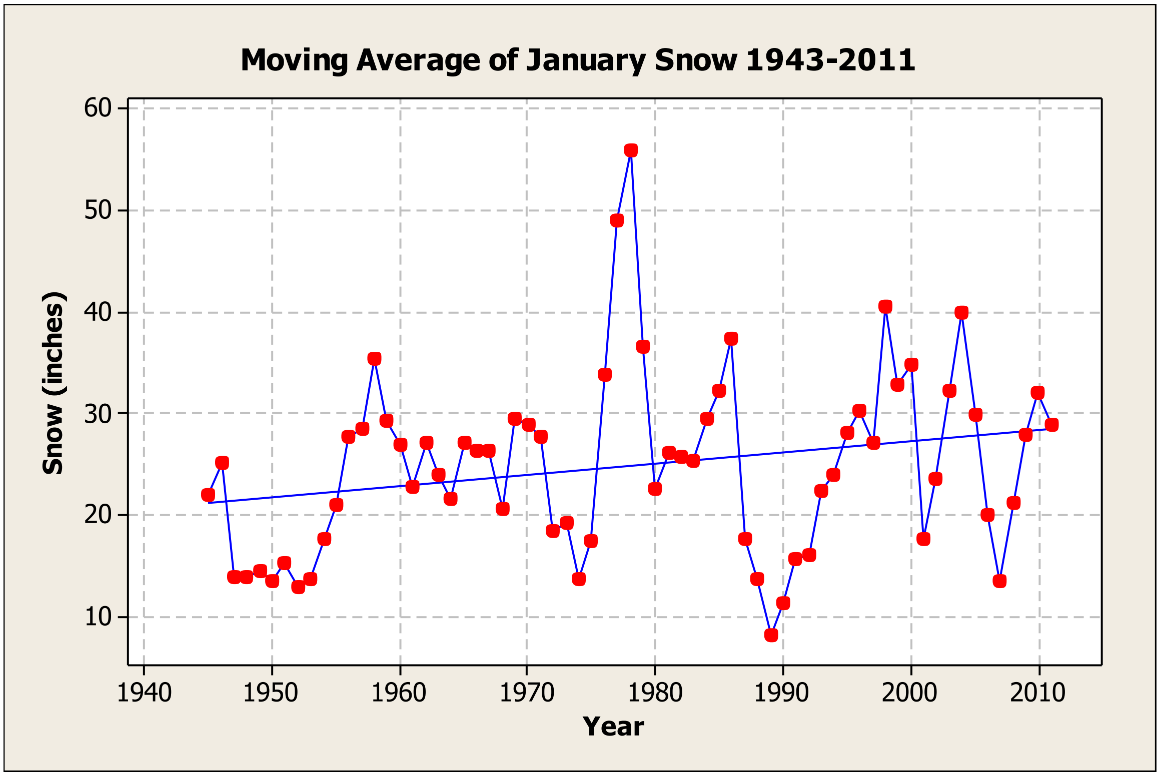

Figure 17. Graph of three year moving average of January snowfall from 1943 to 2011. The trend line shows a possible change in snowfall.

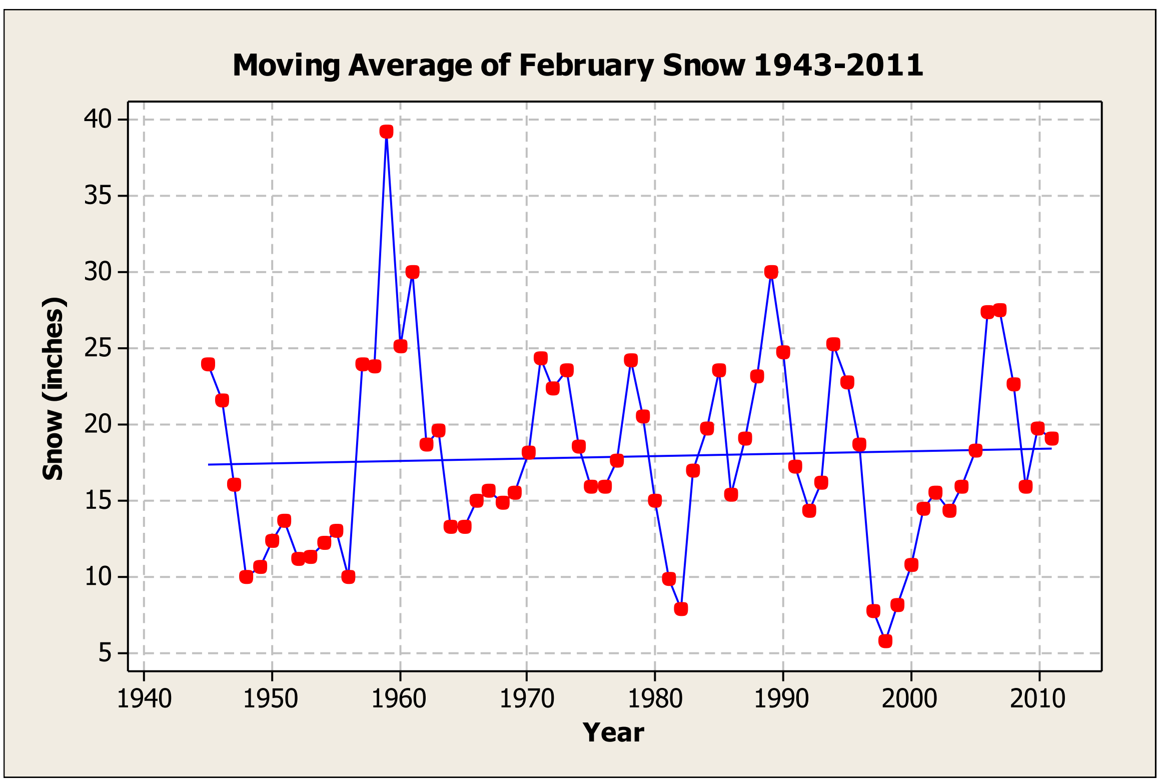

Figure 18. Graph of three year moving average of February snowfall from 1943 to 2011. The trend line shows no change in snowfall.

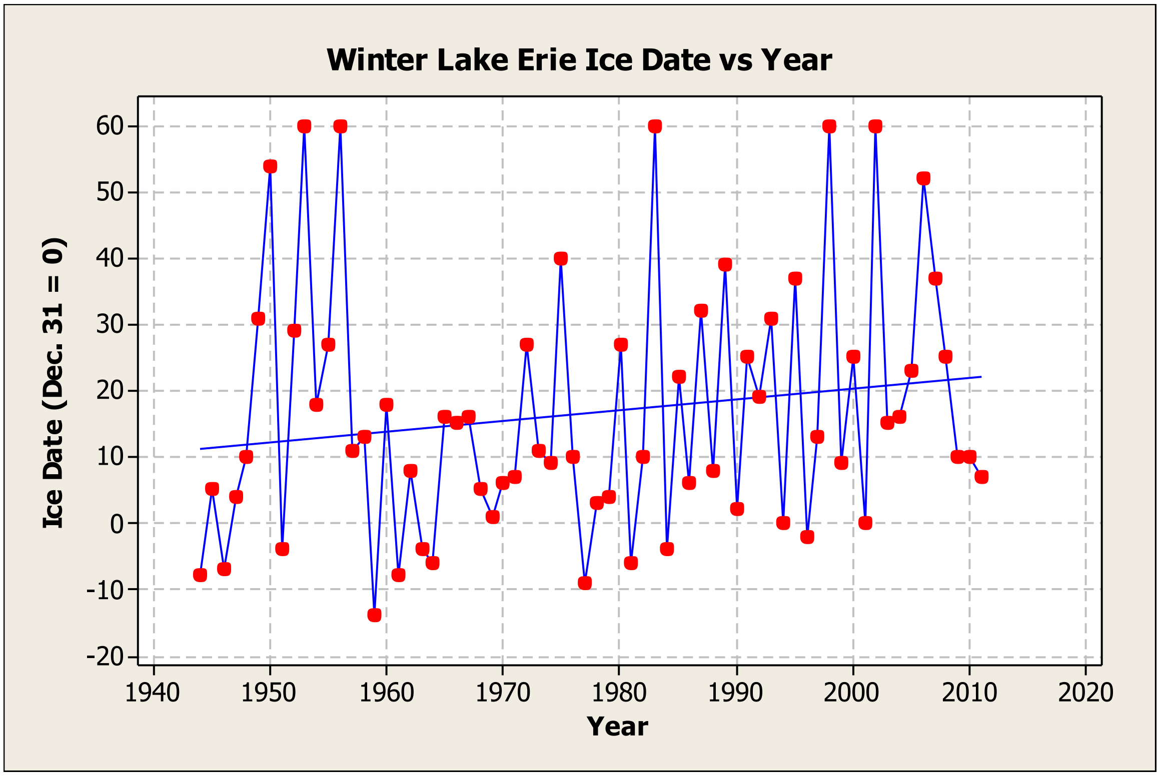

Figure 19. Graph of three year moving average of winter Lake Erie ice cover from 1943 to 2011. The trend line shows a possible change in the ice date.

APPENDIX:

Linear Regression Results Tables

Linear Regression Tests , 67 Years	Winter Temps (F) Vs. Time	Winter Snowfall (inches) Vs. Time
T-Statistic	0.86	1.96
T-Critical	2.0	2.0
Null hypothesis	Accept	Accept
Significance	No	No
F-Statistic	0.74	3.83
F-Critical	4.0	4.0
Null hypothesis	Accept	Accept
Significance	No	No

Linear regression tests of winter temperatures (F) over time (year) and winter snowfall (inches) over time (year) from 1943 to 2011.

Linear Regression Tests , 67 Years	Dec. Temps (F) Vs. Time	Jan. Temps (F) Vs. Time	Feb. Temps (F) Vs. Time
T-Statistic	1.25	0.17	0.32
T-Critical	2.0	2.0	2.0
Null hypothesis	Accept	Accept	Accept
Significance	No	No	No
F-Statistic	1.56	0.03	0.1
F-Critical	4.0	4.0	4.0
Null hypothesis	Accept	Accept	Accept
Significance	No	No	No

Linear regression tests on temperatures (F) for December, January, and February over time (year) from 1943 to 2011.

Linear Regression Tests, 67 Years	Dec. Snowfall (inches) Vs. Time	Jan. Snowfall (inches) Vs. Time	Feb. Snowfall (inches) Vs. Time
T-Statistic	1.94	1.14	0.08
T-Critical	2.0	2.0	2.0
Null hypothesis	Accept	Accept	Accept
Significance	No	No	No
F-Statistic	3.74	1.3	0.01
F-Critical	4.0	4.0	4.0
Null hypothesis	Accept	Accept	Accept
Significance	No	No	No

Linear regression tests on snowfall (inches) for December, January, and February over time (year) from 1943 to 2011.

Linear Regression Tests With Moving Avg.	Winter Temps (F) Vs. Time	Winter Snowfall (inches) Vs. Time
T-Statistic	0.91	3.20
T-Critical	2.0	2.0
Null hypothesis	Accept	Reject
Significance	No	Yes
F-Statistic	0.83	10.21
F-Critical	4.0	4.0
Null hypothesis	Accept	Reject
Significance	No	Yes

Linear regression tests with three year moving average of winter temperatures (F) over time (year) and winter snowfall (inches) over time (year) from 1943 to 2011.

Linear Regression Tests With Moving Avg.	Dec. Temps (F) Vs. Time	Jan. Temps (F) Vs. Time	Feb. Temps (F) Vs. Time
T-Statistic	2.14	0.17	0.46
T-Critical	2.0	2.0	2.0
Null hypothesis	Reject	Accept	Accept
Significance	Yes	No	No
F-Statistic	4.59	0.03	0.05
F-Critical	4.0	4.0	4.0
Null hypothesis	Reject	Accept	Accept
Significance	Yes	No	No

Linear regression tests with three year moving average of temperatures (F) for December, January, and February over time (year) from 1943 to 2011.

Linear Regression Tests With Moving Avg.	Dec. Snowfall (inches) Vs. Time	Jan. Snowfall (inches) Vs. Time	Feb. Snowfall (inches) Vs. Time
T-Statistic	3.47	1.95	0.3
T-Critical	2.0	2.0	2.0
Null hypothesis	Reject	Accept	Accept
Significance	Yes	No	No
F-Statistic	12.02	3.82	0.13
F-Critical	4.0	4.0	4.0
Null hypothesis	Reject	Accept	Accept
Significance	Yes	No	No

Linear regression tests with three year moving average on snowfall (inches) for December, January, and February over time (year) from 1943 to 2011.

Minitab Output:

Two-Sample T-Test and CI: winter temps pre 1995, winter temps post 1995
Two-sample T for winter temps pre 1995 vs winter temps post 1995

	N	Mean	StDev	SE Mean
winter temps pre 1995	18	26.02	3.09	0.73
winter temps post 1995	18	27.71	3.10	0.73

Difference = mu (winter temps pre 1995) - mu (winter temps post 1995)
Estimate for difference: -1.69
95% CI for difference: (-3.79, 0.41)
T-Test of difference = 0 (vs not =): T-Value = -1.64 P-Value = 0.111 DF = 33

Two-Sample T-Test and CI: winter snow pre 1995, winter snow post 1995
Two-sample T for winter snow pre 1995 vs winter snow post 1995

	N	Mean	StDev	SE Mean
winter snow pre 1995	18	72.5	34.8	8.2
winter snow post 1995	18	73.2	21.9	5.2

Difference = mu (winter snow pre 1995) - mu (winter snow post 1995)
Estimate for difference: -0.67
95% CI for difference: (-20.54, 19.19)
T-Test of difference = 0 (vs not =): T-Value = -0.07 P-Value = 0.945 DF = 28
Explanation: Compared the mean snowfall amount before and after the 1995 and found no significant difference at an alpha at 0.05 and not assuming equal variance.

Linear Regression test for Winter Temperatures (F) over time (year) from 1943-44 to 2010-2011:

This is the procedure for all the linear regression tests. The hypothesis were the same for all. The critical statistics varied depending on sample size

Regression Analysis: AVG winter temps_1 versus Year
The regression equation is
AVG winter temps_1 = - 3.6 + 0.0153 Year_3

Predictor	Coef	SE Coef	T	P
Constant	-3.60	35.28	-0.10	0.919
Year_3	0.01532	0.01784	0.86	0.393

S = 2.95075 R-Sq = 1.1% R-Sq(adj) = 0.0%
Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	6.423	6.423	0.74	0.393
Residual Error	67	583.365	8.707		
Total	68	589.788			

Linear Regression Test:

T-Test:

Ho: The slope = 0

H1: The slope does not = 0

-Significance Level (a) is = .05
-Number of degrees of freedom (v) :
N= 68
N= 68-2
N=66
-t critical (from the table) = t= 2.0
(two tailed t test)

-t statistic from sample (minitab output): T= 0.86
-I accept the null hypothesis because the test statistic is less than the critical value.
-The slope does equal zero.
-There is not a linear relationship between temperature and time.
F-Test:

Ho: The explained mean square is less than or equal to the unexplained mean square.

H1: The explained mean square is greater than the unexplained mean square.

-Significance Level (a) is = .05
-Number of degrees of freedom (v) :
Vn= 1
Vd = 66
-F critical (from the table) = 4.0
(one tailed F test)
-F statistic from sample (minitab output): F= 0.74
-I accept the null hypothesis because the test statistic is less than the critical value.
- The explained mean square is less than or equal to the unexplained mean square.
-The line is not statistically significant.

Goodness of fit: 1.1 %

<u>Linear Regression test for Winter Snowfall (inches) over time (year) from 1943-44 to 2010-2011:</u>

Regression Analysis: total winter snow versus year
The regression equation is
total winter snow_2 = - 520 + 0.297 yearss

Predictor	Coef	SE Coef	T	P
Constant	-520.5	299.8	-1.74	0.087
yearss	0.2966	0.1515	1.96	0.055

S = 25.0704 R-Sq = 5.4% R-Sq(adj) = 4.0%
Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	2407.1	2407.1	3.83	0.055
Residual Error	67	42111.3	628.5		
Total	68	44518.4			

Linear Regression Test:

T-Test:

Ho: The slope = 0

H1: The slope does not = 0

-Significance Level (a) is = .05
-Number of degrees of freedom (v) :
N= 68
N= 68-2
N=66
-t critical (from the table) = 2.0
(two tailed t test)
-t statistic from sample (minitab output)= 1.96
-I accept the null hypothesis because the test statistic is less than the critical value.
-The slope does equal zero.
-There is not a linear relationship between snowfall and temperature.
F-Test:

Ho: The explained mean square is less than or equal to the unexplained mean square.

H1: The explained mean square is greater than the unexplained mean square.

-Significance Level (a) is = .05
-Number of degrees of freedom (v) :
Vn= 1
Vd = 66
-F critical (from the table) = 4.0
(one tailed F test)
-F statistic from sample (minitab output): F= 3.83
-I accept the null hypothesis because the test statistic is less than the critical value.
-The explained mean square is less than or equal to the unexplained mean square.
- The line is not statistically significant.

Goodness of fit: 5.4 %

Linear Regression test for December Temperatures (F) over time (year) from 1943-44 to 2010-2011:
Regression Analysis: dec temps versus Year
The regression equation is
dec_1 = - 34.8 + 0.0326 Year_3

Predictor	Coef	SE Coef	T	P
Constant	-34.80	51.54	-0.68	0.502
Year_3	0.03257	0.02606	1.25	0.216

S = 4.31071 R-Sq = 2.3% R-Sq(adj) = 0.8%
Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	29.04	29.04	1.56	0.216
Residual Error	67	1245.01	18.58		
Total	68	1274.05			

Linear Regression Test:

T-Test:

Ho: The slope = 0

H1: The slope does not = 0

-Significance Level (a) is = .05
-Number of degrees of freedom (v) :
N= 68
N= 68-2
N=66
-t critical (from the table) = t= 2.0
(two tailed t test)
-t statistic from sample (minitab output): T= 1.25
-I accept the null hypothesis because the test statistic is less than the critical value.
-The slope does equal zero.
-There is not a linear relationship between temperature and time.

F-Test:

Ho: The explained mean square is less than or equal to the unexplained mean square.

H1: The explained mean square is greater than the unexplained mean square.

-Significance Level (a) is = .05
-Number of degrees of freedom (v) :
Vn= 1
Vd = 66
-F critical (from the table) = 4.0
(one tailed F test)
-F statistic from sample (minitab output): F= 1.56

-I accept the null hypothesis because the test statistic is less than the critical value.
- The explained mean square is less than or equal to the unexplained mean square.
-The line is not statistically significant.

Goodness of fit: 2.3 %

Linear Regression test for January Temperatures (F) over time (year) from 1943-44 to 2010-2011:
Regression Analysis: jan temps versus Year
The regression equation is
jan_1 = 14.4 + 0.0052 Year_3

Predictor	Coef	SE Coef	T	P
Constant	14.37	59.41	0.24	0.810
Year_3	0.00524	0.03004	0.17	0.862

S = 4.96905 R-Sq = 0.0% R-Sq(adj) = 0.0%
Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.75	0.75	0.03	0.862
Residual Error	67	1654.33	24.69		
Total	68	1655.08			

Linear Regression Test:

T-Test:

Ho: The slope = 0

H1: The slope does not = 0

-Significance Level (a) is = .05
-Number of degrees of freedom (v) :
N= 68
N= 68-2
N=66
-t critical (from the table) = t= 2.0
(two tailed t test)
-t statistic from sample (minitab output): T= 0.17
-I accept the null hypothesis because the test statistic is less than the critical value.
-The slope does equal zero.
-There is not a linear relationship between temperature and time.

F-Test:

Ho: The explained mean square is less than or equal to the unexplained mean square.

H1: The explained mean square is greater than the unexplained mean square.

-Significance Level (a) is = .05
-Number of degrees of freedom (v) :
Vn= 1
Vd = 66
-F critical (from the table) = 4.0
(one tailed F test)
-F statistic from sample (minitab output): F= 0.03
-I accept the null hypothesis because the test statistic is less than the critical value.
- The explained mean square is less than or equal to the unexplained mean square.
-The line is not statistically significant.

Goodness of fit: 0 %

Linear Regression test for February Temperatures (F) over time (year) from 1943/44 to 2012:
Regression Analysis: feb temps versus Year
The regression equation is
feb_1 = 9.6 + 0.0081 Year_

Predictor Coef SE Coef T P
Constant 9.62 50.82 0.19 0.850
Year_3 0.00814 0.02569 0.32 0.752
S = 4.25067 R-Sq = 0.1% R-Sq(adj) = 0.0%
Analysis of Variance
Source DF SS MS F P
Regression 1 1.82 1.82 0.10 0.752
Residual Error 67 1210.57 18.07
Total 68 1212.39

Linear Regression Test:

T-Test:

Ho: The slope = 0

H1: The slope does not = 0

-Significance Level (a) is = .05
-Number of degrees of freedom (v) :
N= 68
N= 68-2
N=66
-t critical (from the table) = t= 2.0
(two tailed t test)
-t statistic from sample (minitab output): T= 0.32
-I accept the null hypothesis because the test statistic is less than the critical value.
-The slope does equal zero.
-There is not a linear relationship between temperature and time.

F-Test:

Ho: The explained mean square is less than or equal to the unexplained mean square.

H1: The explained mean square is greater than the unexplained mean square.

-Significance Level (a) is = .05
-Number of degrees of freedom (v) :
Vn= 1
Vd = 66
-F critical (from the table) = 4.0
(one tailed F test)
-F statistic from sample (minitab output): F= 0.1
-I accept the null hypothesis because the test statistic is less than the critical value.
- The explained mean square is less than or equal to the unexplained mean square.
-The line is not statistically significant.

Goodness of fit: 0.1 %

Linear Regression test for December Snowfall (inches) over time (year) from 1943-44 to 2010-2011:

Regression Analysis: dec snow versus year
The regression equation is
dec = - 346 + 0.187 yearss
Predictor Coef SE Coef T P
Constant -345.9 190.9 -1.81 0.074
yearss 0.18677 0.09651 1.94 0.057
S = 15.9669 R-Sq = 5.3% R-Sq(adj) = 3.9%
Analysis of Variance
Source DF SS MS F P
Regression 1 954.8 954.8 3.74 0.057

Residual Error 67 17081.1 254.9
Total 68 18035.8

Linear Regression Test:

T-Test:

Ho: The slope = 0

H1: The slope does not = 0

-Significance Level (a) is = .05
-Number of degrees of freedom (v) :
N= 68
N= 68-2
N=66
-t critical (from the table) = 2.0
(two tailed t test)
-t statistic from sample (minitab output)= 1.94
-I accept the null hypothesis because the test statistic is less than the critical value.
-The slope does equal zero.
-There is not a linear relationship between snowfall and temperature.

F-Test:

Ho: The explained mean square is less than or equal to the unexplained mean square.

H1: The explained mean square is greater than the unexplained mean square.

-Significance Level (a) is = .05
-Number of degrees of freedom (v) :
Vn= 1
Vd = 66
-F critical (from the table) = 4.0
(one tailed F test)
-F statistic from sample (minitab output): F= 3.74
-I accept the null hypothesis because the test statistic is less than the critical value.
-The explained mean square is less than or equal to the unexplained mean square.
- The line is not statistically significant.

Goodness of fit: 5.3 %

Linear Regression test for January Snowfall (inches) over time (year) from 1943/44 to 2012:
Regression Analysis: jan snow versus year
The regression equation is
jan = - 183 + 0.105 yearss

Predictor	Coef	SE Coef	T	P
Constant	-182.9	181.8	-1.01	0.318
yearss	0.10496	0.09188	1.14	0.257

S = 15.2011 R-Sq = 1.9% R-Sq(adj) = 0.4%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	301.5	301.5	1.30	0.257
Residual Error	67	15481.9	231.1		
Total	68	15783.4			

Linear Regression Test:

T-Test:

Ho: The slope = 0

H1: The slope does not = 0

-Significance Level (a) is = .05

-Number of degrees of freedom (v) :
N= 68
N= 68-2
N=66
-t critical (from the table) = 2.0
(two tailed t test)
-t statistic from sample (minitab output)= 1.14
-I accept the null hypothesis because the test statistic is less than the critical value.
-The slope does equal zero.
-There is not a linear relationship between snowfall and temperature.

F-Test:

Ho: The explained mean square is less than or equal to the unexplained mean square.

H1: The explained mean square is greater than the unexplained mean square.

-Significance Level (a) is = .05
-Number of degrees of freedom (v) :
Vn= 1
Vd = 66
-F critical (from the table) = 4.0
(one tailed F test)
-F statistic from sample (minitab output): F= 1.3
-I accept the null hypothesis because the test statistic is less than the critical value.
-The explained mean square is less than or equal to the unexplained mean square.
- The line is not statistically significant.

Goodness of fit: 1.9 %

Linear Regression test for February Snowfall (inches) over time (year) from 1943-44 to 2010-2011:

Regression Analysis: feb snow versus year
The regression equation is
feb = 8 + 0.0048 years

Predictor	Coef	SE Coef	T	P
Constant	8.4	122.0	0.07	0.946
yearss	0.00483	0.06167	0.08	0.938

S = 10.2031 R-Sq = 0.0% R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.6	0.6	0.01	0.938
Residual Error	67	6975.0	104.1		
Total	68	6975.6			

Linear Regression Test:

T-Test:

Ho: The slope = 0

H1: The slope does not = 0

-Significance Level (a) is = .05
-Number of degrees of freedom (v) :
N= 68
N= 68-2
N=66
-t critical (from the table) = 2.0
(two tailed t test)
-t statistic from sample (minitab output)= 0.08
-I accept the null hypothesis because the test statistic is less than the critical value.

-The slope does equal zero.
-There is not a linear relationship between snowfall and temperature.
F-Test:

Ho: The explained mean square is less than or equal to the unexplained mean square.

H1: The explained mean square is greater than the unexplained mean square.

-Significance Level (a) is = .05
-Number of degrees of freedom (v) :
Vn= 1
Vd = 66
-F critical (from the table) = 4.0
(one tailed F test)
-F statistic from sample (minitab output): F= 0.01
-I accept the null hypothesis because the test statistic is less than the critical value.
-The explained mean square is less than or equal to the unexplained mean square.
- The line is not statistically significant.

Goodness of fit: 0 %

<u>Linear Regression Test with a 3 Year Moving Average, December Snowfall (inches) over time (year) from 1943-44 to 2010-2011:</u>

Regression Analysis: MA dec snow versus MA year
The regression equation is
MA dec snow = - 379 + 0.204 MA year

Predictor	Coef	SE Coef	T	P
Constant	-378.8	116.2	-3.26	0.002
MA year	0.20357	0.05872	3.47	0.001

S = 9.29541 R-Sq = 15.6% R-Sq(adj) = 14.3%
Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	1038.4	1038.4	12.02	0.001
Residual Error	65	5616.3	86.4		
Total	66	6654.7			

Linear Regression Test:

T-Test:

Ho: The slope = 0

H1: The slope does not = 0

-Significance Level (a) is = .05
-Number of degrees of freedom (v) :
N= 68
N= 68-2
N=66
-t critical (from the table) = t= 2.0
(two tailed t test)
-t statistic from sample (minitab output): T= 3.47
-I reject the null hypothesis because the test statistic is greater than the critical value.
-The slope does not equal zero.
-There is a linear relationship between temperature and time.
F-Test:

Ho: The explained mean square is less than or equal to the unexplained mean square.

H1: The explained mean square is greater than the unexplained mean square.

-Significance Level (a) is = .05
-Number of degrees of freedom (v) :
Vn= 1
Vd = 66
-F critical (from the table) = 4.0
(one tailed F test)
-F statistic from sample (minitab output): F= 12.02
-I reject the null hypothesis because the test statistic is greater than the critical value.
- The explained mean square is greater than the unexplained mean square.
-The line is statistically significant.

Goodness of fit: 15.6 %

Linear Regression Test with a 3 Year Moving Average, January Snowfall (inches) over time (year) from 1943-44 to 2010-2011:

Regression Analysis: MA jan snow versus MA year
The regression equation is
MA jan snow = - 189 + 0.108 MA year

Predictor	Coef	SE Coef	T	P
Constant	-189.1	109.5	-1.73	0.089
MA year	0.10813	0.05534	1.95	0.055

S = 8.75950 R-Sq = 5.5% R-Sq(adj) = 4.1%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	292.97	292.97	3.82	0.055
Residual Error	65	4987.37	76.73		
Total	66	5280.34			

Linear Regression Test:

T-Test:

Ho: The slope = 0

H1: The slope does not = 0

-Significance Level (a) is = .05
-Number of degrees of freedom (v) :
N= 68
N= 68-2
N=66
-t critical (from the table) = t= 2.0
(two tailed t test)
-t statistic from sample (minitab output): T= 1.95
-I accept the null hypothesis because the test statistic is less than the critical value.
-The slope does equal zero.
-There is not a linear relationship between temperature and time.

F-Test:

Ho: The explained mean square is less than or equal to the unexplained mean square.

H1: The explained mean square is greater than the unexplained mean square.

-Significance Level (a) is = .05
-Number of degrees of freedom (v) :
Vn= 1
Vd = 66

-F critical (from the table) = 4.0
(one tailed F test)
-F statistic from sample (minitab output): F= 3.82
-I accept the null hypothesis because the test statistic is less than the critical value.
- The explained mean square is less than or equal to the unexplained mean square.
-The line is not statistically significant.

Goodness of fit: 5.5 %

<u>Linear Regression Test with a 3 Year Moving Average, February Snowfall (inches) over time (year) from 1943-44 to 2010-2011:</u>

Regression Analysis: MA feb snow versus MA year
The regression equation is
MA feb snow = - 10.5 + 0.0143 MA year

Predictor	Coef	SE Coef	T	P
Constant	-10.45	78.39	-0.13	0.894
MA year	0.01429	0.03963	0.36	0.720

S = 6.27326 R-Sq = 0.2% R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	5.12	5.12	0.13	0.720
Residual Error	65	2558.00	39.35		
Total	66	2563.12			

Linear Regression Test:

T-Test:

Ho: The slope = 0

H1: The slope does not = 0

-Significance Level (a) is = .05
-Number of degrees of freedom (v) :
N= 68
N= 68-2
N=66
-t critical (from the table) = t= 2.0
(two tailed t test)
-t statistic from sample (minitab output): T= 0.36
-I accept the null hypothesis because the test statistic is less than the critical value.
-The slope does equal zero.
-There is not a linear relationship between temperature and time.

F-Test:

Ho: The explained mean square is less than or equal to the unexplained mean square.

H1: The explained mean square is greater than the unexplained mean square.

-Significance Level (a) is = .05
-Number of degrees of freedom (v) :
Vn= 1
Vd = 66
-F critical (from the table) = 4.0
(one tailed F test)
-F statistic from sample (minitab output): F= 0.13
-I accept the null hypothesis because the test statistic is less than the critical value.
- The explained mean square is less than or equal to the unexplained mean square.
-The line is not statistically significant.

Goodness of fit: 0.2 %

Linear Regression Test with a 3 Year Moving Average, Snowfall (inches) over time (year) from 1943-44 to 2010-2011:

Regression Analysis: MA snowfall versus MA year
The regression equation is
MA snowfall = - 578 + 0.326 MA year

Predictor	Coef	SE Coef	T	P
Constant	-578.4	201.8	-2.87	0.006
MA year	0.3260	0.1020	3.20	0.002

S = 16.1481   R-Sq = 13.6%   R-Sq(adj) = 12.2%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	2662.9	2662.9	10.21	0.002
Residual Error	65	16949.5	260.8		
Total	66	19612.4			

Linear Regression Test:

T-Test:

Ho: The slope = 0

H1: The slope does not = 0

-Significance Level (a) is = .05
-Number of degrees of freedom (v) :
N= 68
N= 68-2
N=66
-t critical (from the table) = t= 2.0
(two tailed t test)
-t statistic from sample (minitab output): T= 3.20
-I reject the null hypothesis because the test statistic is greater than the critical value.
-The slope does not equal zero.
-There is a linear relationship between temperature and time.

F-Test:

Ho: The explained mean square is less than or equal to the unexplained mean square.

H1: The explained mean square is greater than the unexplained mean square.

-Significance Level (a) is = .05
-Number of degrees of freedom (v) :
Vn= 1
Vd = 66
-F critical (from the table) = 4.0
(one tailed F test)
-F statistic from sample (minitab output): F= 10.21
-I reject the null hypothesis because the test statistic is greater than the critical value.
- The explained mean square is greater than the unexplained mean square.
-The line is statistically significant.

Goodness of fit: 13.6 %

Linear Regression Test with a 3 Year Moving Average, December Temps (F) over time (year) from 1943-44 to 2010-2011:

Regression Analysis: MA dec temps versus MA year
The regression equation is
MA dec temps = - 23.8 + 0.0270 MA year

Predictor Coef SE Coef T P
Constant -23.77 24.94 -0.95 0.344
MA year 0.02700 0.01261 2.14 0.036
S = 1.99545 R-Sq = 6.6% R-Sq(adj) = 5.2%
Analysis of Variance
Source DF SS MS F P
Regression 1 18.269 18.269 4.59 0.036
Residual Error 65 258.817 3.982
Total 66 277.086

Linear Regression Test:

T-Test:

Ho: The slope = 0

H1: The slope does not = 0

-Significance Level (a) is = .05
-Number of degrees of freedom (v) :
N= 68
N= 68-2
N=66
-t critical (from the table) = t= 2.0
(two tailed t test)
-t statistic from sample (minitab output): T= 2.14
-I reject the null hypothesis because the test statistic is greater than the critical value.
-The slope does not equal zero.
-There is a linear relationship between temperature and time.

F-Test:

Ho: The explained mean square is less than or equal to the unexplained mean square.

H1: The explained mean square is greater than the unexplained mean square.

-Significance Level (a) is = .05
-Number of degrees of freedom (v) :
Vn= 1
Vd = 66
-F critical (from the table) = 4.0
(one tailed F test)
-F statistic from sample (minitab output): F= 4.59
-I reject the null hypothesis because the test statistic is greater than the critical value.
- The explained mean square is greater than the unexplained mean square.
-The line is statistically significant.

Goodness of fit: 6.6 %

<u>Linear Regression Test with a 3 Year Moving Average, January Temps (F) over time (year) from 1943-44 to 2010-2011:</u>

Regression Analysis: MA jan temps versus MA year
The regression equation is
MA jan temps = 18.1 + 0.0033 MA year
Predictor Coef SE Coef T P
Constant 18.11 38.62 0.47 0.641
MA year 0.00332 0.01952 0.17 0.865
S = 3.09023 R-Sq = 0.0% R-Sq(adj) = 0.0%
Analysis of Variance
Source DF SS MS F P
Regression 1 0.277 0.277 0.03 0.865

Residual Error 65 620.719 9.550
Total 66 620.996
Unusual Observations

Linear Regression Test:

T-Test:

Ho: The slope = 0

H1: The slope does not = 0

-Significance Level (a) is = .05
-Number of degrees of freedom (v) :
N= 68
N= 68-2
N=66
-t critical (from the table) = t= 2.0
(two tailed t test)
-t statistic from sample (minitab output): T= 0.17
-I accept the null hypothesis because the test statistic is less than the critical value.
-The slope does equal zero.
-There is not a linear relationship between temperature and time.

F-Test:

Ho: The explained mean square is less than or equal to the unexplained mean square.

H1: The explained mean square is greater than the unexplained mean square.

-Significance Level (a) is = .05
-Number of degrees of freedom (v) :
Vn= 1
Vd = 66
-F critical (from the table) = 4.0
(one tailed F test)
-F statistic from sample (minitab output): F= 0.03
-I accept the null hypothesis because the test statistic is less than the critical value.
- The explained mean square is less than or equal to the unexplained mean square.

-The line is not statistically significant.

Goodness of fit: 0.0 %

Linear Regression Test with a 3 Year Moving Average, February Temps (F) over time (year) from 1943-44 to 2010-2011:

Regression Analysis: MAfebtempsagain versus MA year

```
The regression equation is
MAfebtempsagain = 17.2 + 0.0043 MA year

Predictor     Coef  SE Coef     T      P
Constant     17.20    37.04  0.46  0.644
MA year    0.00428  0.01873  0.23  0.820
S = 2.96431   R-Sq = 0.1%   R-Sq(adj) = 0.0%
Analysis of Variance
Source          DF       SS     MS     F      P
Regression       1    0.460  0.460  0.05  0.820
Residual Error  65  571.162  8.787
Total           66  571.622
```

Linear Regression Test:

T-Test:

Ho: The slope = 0

H1: The slope does not = 0

-Significance Level (a) is = .05
-Number of degrees of freedom (v) :
N= 68
N= 68-2
N=66
-t critical (from the table) = t= 2.0
(two tailed t test)
-t statistic from sample (minitab output): T= 0.46
-I accept the null hypothesis because the test statistic is less than the critical value.
-The slope does equal zero.
-There is not a linear relationship between temperature and time.

F-Test:

Ho: The explained mean square is less than or equal to the unexplained mean square.

H1: The explained mean square is greater than the unexplained mean square.

-Significance Level (a) is = .05
-Number of degrees of freedom (v) :
Vn= 1
Vd = 66
-F critical (from the table) = 4.0
(one tailed F test)
-F statistic from sample (minitab output): F= 0.05
-I accept the null hypothesis because the test statistic is less than the critical value.
- The explained mean square is less than or equal to the unexplained mean square.
-The line is not statistically significant.

Goodness of fit: 0.0 %

<u>Linear Regression Test with a 3 Year Moving Average, Temps (F) over time (year) from 1943-44 to 2010-2011:</u>

Regression Analysis: MA temps versus MA year
The regression equation is
MA temps = 3.8 + 0.0115 MA year

Predictor	Coef	SE Coef	T	P
Constant	3.85	25.07	0.15	0.878
MA year	0.01154	0.01267	0.91	0.366

S = 2.00587 R-Sq = 1.3% R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	3.335	3.335	0.83	0.366
Residual Error	65	261.529	4.024		
Total	66	264.864			

Linear Regression Test:

T-Test:

Ho: The slope = 0

H1: The slope does not = 0

-Significance Level (a) is = .05
-Number of degrees of freedom (v) :
N= 68
N= 68-2
N=66
-t critical (from the table) = t= 2.0

(two tailed t test)
-t statistic from sample (minitab output): T= 0.91
-I accept the null hypothesis because the test statistic is less than the critical value.
-The slope does equal zero.
-There is not a linear relationship between temperature and time.

F-Test:

Ho: The explained mean square is less than or equal to the unexplained mean square.

H1: The explained mean square is greater than the unexplained mean square.

-Significance Level (a) is = .05
-Number of degrees of freedom (v) :
Vn= 1
Vd = 66
-F critical (from the table) = 4.0
(one tailed F test)
-F statistic from sample (minitab output): F= 0.83
-I accept the null hypothesis because the test statistic is less than the critical value.
- The explained mean square is less than or equal to the unexplained mean square.

-The line is not statistically significant.

Goodness of fit: 1.3%

Linear Regression Test, Lake Erie ice over time (year) from 1943-44 to 2010-2011:

Regression Analysis: Ice Date_2 versus Year_1_1
Winter ice date over time 1944-2011
The regression equation is
Ice Date_2 = - 304 + 0.162 Year_1_1

Predictor	Coef	SE Coef	T	P
Constant	-303.9	230.3	-1.32	0.192
Year_1_1	0.1620	0.1165	1.39	0.169

S = 18.8490 R-Sq = 2.8% R-Sq(adj) = 1.4%
Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	687.9	687.9	1.94	0.169
Residual Error	66	23448.9	355.3		
Total	67	24136.8			

Unusual Observations

Linear Regression Test:

T-Test:

Ho: The slope = 0

H1: The slope does not = 0

-Significance Level (a) is = .05
-Number of degrees of freedom (v) :
N= 68
N= 68-2
N=66
-t critical (from the table) = t= 2.0
(two tailed t test)
-t statistic from sample (minitab output): T= 1.32
-I accept the null hypothesis because the test statistic is less than the critical value.
-The slope does equal zero.
-There is not a linear relationship between lake ice date and time.

F-Test:

Ho: The explained mean square is less than or equal to the unexplained mean square.

H1: The explained mean square is greater than the unexplained mean square.

-Significance Level (a) is = .05
-Number of degrees of freedom (v) :
Vn= 1
Vd = 66
-F critical (from the table) = 4.0
(one tailed F test)
-F statistic from sample (minitab output): F= 1.94
-I accept the null hypothesis because the test statistic is less than the critical value.
- The explained mean square is less than or equal to the unexplained mean square.
-The line is not statistically significant.

Goodness of fit: 2.8%

Correlations: WinterIceRanked, WinterSnowRanked
Pearson correlation of WinterIceRanked and WinterSnowRanked = -0.339
P-Value = 0.005

The probaility of outcome (P-value) is less than .05 (alpha) so the correlation is statistically significant. A correlation of 0.339 (square it), comes to about 0.1 so there is a statistically significant association but a weak one.