Investigating Climate Change: A Comparative Analysis of Colonial and Modern Weather Data

By Marni Wasserman

Since 9th grade, I had always participated in science research at my high school. In 9th, 10th, and 11th grade, I performed biology experiments because I always thought of science research as something that was done in a laboratory with a scientific procedure leading to a conclusion. In 11th grade, I had to choose the project that I was going to submit to Intel. I chose a project much like the other projects that I had conducted in the past. However, this project did not run smoothly, as my prior projects had. I devised a procedure to carry out my experiment, but after reworking this procedure numerous times, I was not able to obtain any usable data. I was very discouraged and I did not know how to continue on with research. Then, my research teacher asked me one simple question, "How in love with this project are you?" At that moment, I realized that biology was not my passion. My teacher then continued to ask me what I was most interested in, and that was mathematics. I was a little anxious, since I had never done a math science research project, but since I truly loved math, I was excited to tackle this challenge.

My first task was to come up with a project idea. I have always loved statistics, so I wanted to do a project involving a lot of data and statistical analysis. I began looking on the internet to find some current research that was being conducted. I came across a man who was working with historical data. The data set that he was working with was ship log data taken by Benjamin Franklin to observe the Gulf Stream. In his possession, this man also had a data set by a less well known British colonist named Phineas Pemberton. I spoke with this man on the phone, and met with him at his office in New York City, where he told me more about the data set, and I became very interested. The data was taken in Philadelphia, Pennsylvania in the mid to late 1700s. This data is so significant because currently, if a climate scientist wants to do an

investigation involving temperature data, they only have reliable data through the mid to late 1800s, so this data set would open up an additional 100 years of data. This is very significant, because the farther back into the climate history we can go, the better the trends that can be noticed, and then the better the predictions that can be made for the future.

The data that was recorded had many different climate measurements. Twice a day, usually once in the morning and once in the afternoon, temperature in degrees Fahrenheit, barometric pressure, wind direction and weather conditions were recorded. A lot of data like this was recorded all throughout the thirteen original colonies as an order by King George III. The colonies were just beginning to be inhabited by the British and many felt that the colonies were not suitable places to live. The King required that weather data be recorded to convince the British that the colonies had desirable climates and to convince people to migrate to the colonies.

After learning more, I became very excited about the application of the data set, and the current importance of the data to real world happenings. In the end, I decided to conduct a study analyzing climate change, focused mainly on temperature data. The purpose of my study was to determine the effectiveness of using colonial era weather data to study trends in climate change over the past 300 years in the northeastern United States and to create a blueprint model that is easily adaptable for analyzing and comparing colonial era or other historical weather data to modern data. I then obtained the data sets that were required for my project and began to conduct my statistical analysis. I performed this investigation at my home, using Microsoft Excel for the statistical tests.

In all of my prior research projects, I had always performed a statistical analysis at the end on my data collection, so I was familiar with most of the statistical tests that I used in my project. However, statistics are a little different with temperature data. Temperature data has

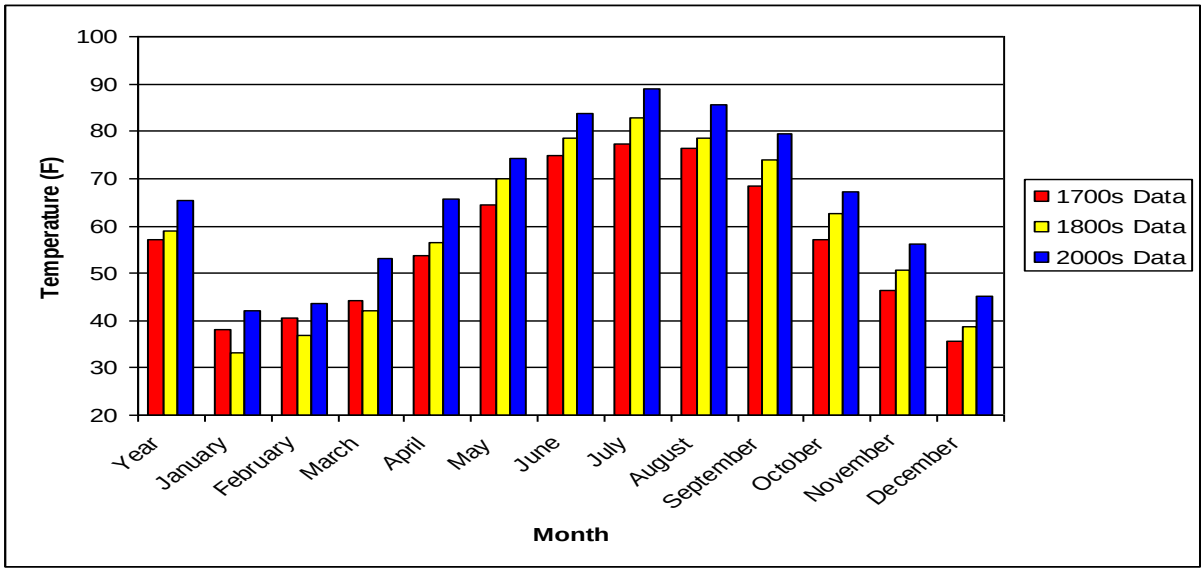
dependence. This means that there is a relationship between data points. For example, the temperature cannot go from 2ºF to 90ºF in one day; there is some relationship between one day, and the day after it. Due to this, many common statistical tests need to be altered to work for temperature data. Therefore, to perform this project, I had to learn how to alter the tests that I already knew to take into account the dependence of the temperature data.

Before doing this project, I knew that I loved both science and math, but I mainly treated them as two completely separate subjects. To me, science was experimentation, and math was computation. After performing this project, I realized how closely related the two subjects actually are, and I truly believe that you cannot have one without the other. Science and math are so intermingled, and this project allowed me to see this very clearly. To other students interested in both science and math, I recommend performing a project that combines the two subjects. By doing such a project, it allows you to learn more about both subjects. There is data and statistics for almost anything that you could be interested in, so there are countless projects that can be done to satisfy any passion. I enjoyed performing my investigation into both math and science, so much so that I believe that this is what I would like to pursue in college. I have grown to love statistics even more and I want to be able to notice more scientific relationships using statistics and mathematics.

For my project, the first thing that I had to do was to manually enter data from five years worth of data in each of the mid 1700s, late 1800s and early 2000s into Microsoft excel because this data was only available in a print version. I needed to make the data into a usable form so that I could conduct the statistical tests. I had to keep many constants when working on my project. Throughout the 250 year time period that I was recording data for, I had to make sure that all of the data was recorded at the same location which was two miles west of the center of

Philadelphia, Pennsylvania. I also had to make sure that the data readings were taken at the same time during the day. One very important factor that I had to take into account was the accuracy of the thermometer that was used for the data from the 1700s. At this time, the modern thermometer was in its early stages of creation and the thermometer technology in the later time periods was obviously more advanced. I had to make sure that the thermometer from the historical data was comparable to that of a modern thermometer, because if it was not an accurate thermometer, then the temperature reading as well as any trends that I noticed would be completely meaningless. To determine if the thermometer was accurate enough, I looked at days where the temperature was around 32ºF and had precipitation. I tried to match the precipitation to the temperature, for example, if the temperature was above 32ºF, there should have been rain, and if the temperature was below 32ºF, then there should have been snow. I found that in almost all comparisons, the temperature matched the precipitation, so I concluded that the thermometer was accurate enough to compare to more modern data, and I could continue on with my analysis.

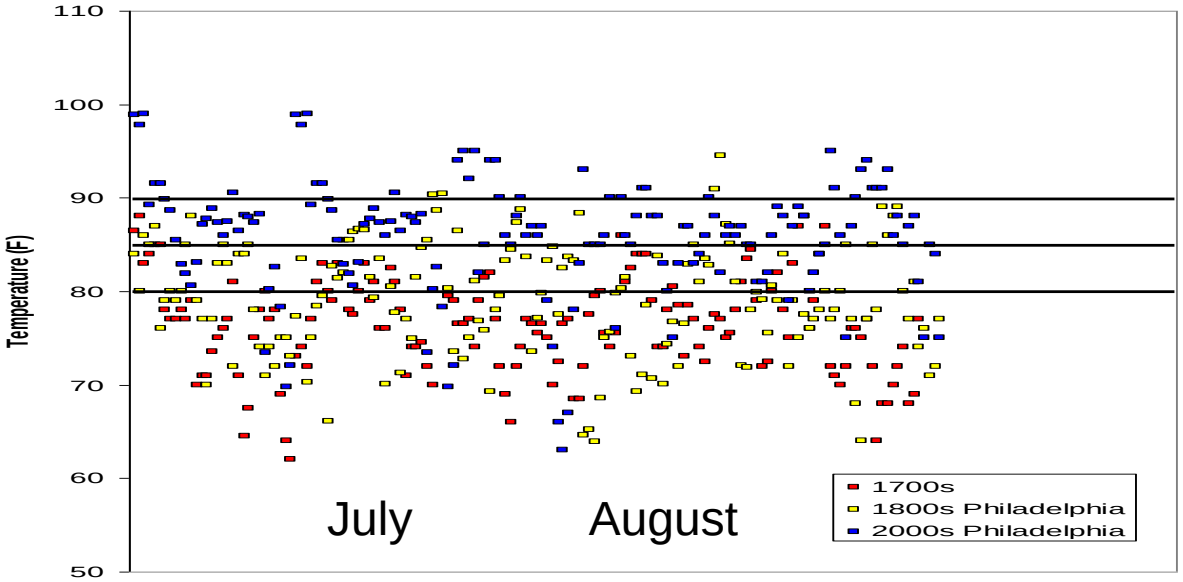
I then began to perform various statistical analyses. One significant comparison that I noted was to look at the mean temperature for each month and for the year as a whole for each of the three time periods. Here is the graph which shows this.



The first column represents the 5 year mean temperature for each century. Then the other columns are the 5 year means for each month from each century. This shows that the temperature in the 2000s was warmer than in either of the other two centuries for each month and for the year as a whole. Generally, the temperature increased as time progressed, however, in the winter months of January, February and March, the mean temperature in the 1700s was warmer than that of the 1800s.

In order to determine if the differences that I noted graphically were statistically significant, I performed a statistical analysis called a Student's *t*-test. This test analyzes data to determine if the difference between two different means has statistical significance. From my *t*-test, I was able to conclude that all increases in temperature were statistically significant and that all decreases in temperature were not statistically significant. This appears to support the hypothesis of global warming.

Another interesting graph from my research is this graph.



This graph shows the number of days in each time period where the temperatures were above 80ºF, 85ºF and 90ºF in the months of July and August. The temperature thresholds of

80ºF, 85ºF and 90ºF are indicated by the horizontal lines. It can be seen that in the 1700s, represented by the red points, there was not one day above 90ºF and the large majority of days were below 80ºF. Then, in the 1800s represented by the yellow points, there were a few days above 90ºF, but the majority of days were still below 80ºF. In the 2000s represented by the blue points, there were quite a few days above 90ºF, some reaching near 100ºF and there were more days above 80ºF than below it.

Based on the results, it is evident that colonial era weather data is valuable in evaluating climate change. The colonial data made it possible to see the overall increase in temperature since 1759 to the present day. However, from the colonial data it was possible to see that the temperature each month did not increase steadily since 1759 to the present. In the winter months, in the 1700s, the temperature was warmer than the 1800s temperature. However, in the year as a whole, the temperature appears to have increased constantly. A more detailed assessment of month-to-month differences over a longer period of time is needed to look for month-specific trends. From the model that was created to utilize colonial era weather data, it can be seen that the present time has the warmest temperature over the past 300 years. Based on the data from this investigation, it is clear that the temperature has been increasing, especially with respect to the summer months in the areas studied.

This investigation leads to many areas of future research. With this project, the investigation can be expanded to include all 12 months of the year to get a better picture of what occurred during each month. Additionally, instead of using 5 years from each century, 20 to 30 years can be observed to obtain a better picture of the climate trends over time. The investigation can also include an analysis of the barometric pressures at each location for each

time period. Finally, an analysis of the weather conditions and amount of precipitation can be observed to see how these factors have changed over the past 300 years.

In addition, to verify the results observed in this investigation, tree rings, ice cores, coral reefs and bore hole data can be used. These sources can tell the relative temperature of a series of years. By using these tools, it can be observed whether the years analyzed in this study were similar to the other years around them, or if they were unusually hot or cold years for the time period.

There are many historical society libraries and government archives all over the United States, and even in other parts of the world where there may be colonial era data or possibly data prior to the 1700s. These records can expand the data base of historical observations so that they are more accessible to others and can be used when analyzing global climate change over a long period of time. The most exciting part of this study is that it shows that historical data can be a fabulous new source of data to increase our understanding of global climate change and to improve models for future climate change predictions.