Journal of
Emerging Investigators

Increasing Average Yearly Temperature in Two U.S. Cities Shows Evidence for Climate Change

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Summary

The Climate Change 2014: Synthesis Report published by the United Nations Intergovernmental Panel on Climate Change identifies climate change as an artificial phenomenon that will affect people living all over the world. The research presented here analyzes the historical temperatures of two US cities in an effort to demonstrate that climate change is evident across the United States. We reviewed almost 90 years of monthly temperature data in Rochester, New York and over 60 years of monthly temperature data in Seattle, Washington. The results of this study clearly show a warming trend that impacts two very distant cities.

Received: September 18, 2017; **Accepted:** August 31, 2018; **Published:** September 20, 2018

Introduction

The purpose of this study was to analyze historical weather data to see if a warming trend could be observed within the United States. Two locations were chosen because of their distance from each other and their unique weather systems. One location is on the west coast of the United States and the other exists south of Lake Ontario.

This research was inspired by the work presented within the book, An Inconvenient Truth: The Planetary Emergency of Global Warming and What We Can Do about It (1). It was published in 2006 with the purpose of identifying the potential threat the world will face if climate change remains unchallenged. Another vital source of climate change data can be attributed to NASA and NOAA scientists. Their research suggested that if one were to look at the last 136 years of recorded global temperatures, one would find that sixteen of the warmest years have occurred since 2001. In addition, 2016 currently holds the record as the warmest year since reliable record keeping started (2). NASA also reported that there was a major temperature shift that began in the late 19th century. The average surface temperature of the Earth rose 2°F (1.1°C). The main cause of this temperature rise in the late 19th century and the 20th century is carbon dioxide emissions or other emissions by humans (2).

Not only has Earth become warmer over the last century and a half, but it appears to have warmed faster over the last decade. 2016 was the warmest year on record since 1880, and the third year in a row that a new heat record has been set, something that has occurred five times this century (2).

Another important source for understanding historical and future temperature trends is the Climate Change 2014: Synthesis Report that was published by the United Nations (UN) Intergovernmental Panel on Climate Change (IPCC). This report confirmed many of the facts NOAA and NASA had published, including the historical data that scientists used to support the hypothesis that climate change was real. In addition, the report highlighted other verifiable effects, including warming oceans and a loss of ice and snow across the globe (3). It also predicted that oceans would continue to rise because of these effects.

The IPCC also reports that continued emissions into the atmosphere will cause more warming that will lead to long lasting changes in the overall climate of the planet. This change may be irreversible and will severely affect ecosystems and the people who live in them. The only way we can minimize this impact will be to reduce greenhouse gas emissions (3).

In addition, the IPCC climate change report states that in the late 21st century, climate change projections suggest an increase in negative weather phenomena. One example is that surface temperatures are projected to steadily rise this century regardless of whether we reduce emissions. In this next century, warming will cause heat waves to last longer, and more extreme precipitation events will occur. The ocean will also continue to warm, acidify, and rise (4).

With all of this research in mind, the question arose:

does Rochester, New York experience the effects of climate change? The research previously discussed suggest that if local weather data over the last century is analyzed, there would be a clear warming trend in Rochester, New York because ecosystems all over the world have shown evidence of warming (3).

The data I gathered over this project suggests that Rochester and Seattle, two locations with very different climates, are potentially impacted by climate change. This paper also discusses the warming trend that has become prevalent during the 21st century.

Results

Results for Rochester, New York

To begin the investigation, I compared temperatures in 2016 to temperatures in previous years utilizing Weather Underground (5), a website that gathers and maintains recorded data from thousands of weather stations. The first location chosen was Rochester, New York. For this location, I gathered historical data, determined trends, and created supporting graphs. To see if there were other pockets of warming, I repeated this process for Seattle, Washington.

Although the data is noticeably different in Rochester and Seattle, they both show evidence of climate change. The average temperature in Rochester between 1926 and 1935 was 48.8°F (**Figure 1**). The average temperature for the next seven decades continued to fluctuate around 48°F. More specifically, the average temperature in the first eight decades of this data was 48.11°F. However, what does stand out is the sudden spike in temperature Rochester experienced between 2006 and 2016. The average temperature for this decade was just over 50°F, which was nearly a 2°F jump over the average temperature between 1926 and 2005. Even the warmest previous decade, 1946 to 1955, was 1.4°F colder (**Figure 1**).

This is a noteworthy change for the Rochester area and suggests that either the last decade was an anomaly or the beginning of a warming trend. What is clear is that further research on the effects of climate change throughout New York State should be studied.

Results for Seattle, Washington

The second source of data came from Seattle, Washington. Seattle was chosen because it allowed a comparison between a land locked location and a coastal location. In addition, it provided an opportunity to study an area where the jet stream has collected moisture from the Pacific Ocean. The data for Seattle required more analysis than Rochester, New York. With Rochester, the last decade clearly showed evidence of a warming trend. However, with Seattle the average temperature did not show a substantial change over previous decades.

Although Seattle was much warmer in the last decade when compared to the first decade data was available, the average temperature difference recorded over the last thirty years is negligible. However, when I focused on warm years that exceed the standard deviation, an unusual pattern emerged. There are two things that are worth noting. The first occurs when I analyzed the last five years of data between 2012 and 2016. When I calculated the average of these years, I saw that the average temperature was 55.4°F; this number is higher than the average temperature over the last 69 years, which is 53.1°F. The second unusual trend can be seen when you review how many years had an average

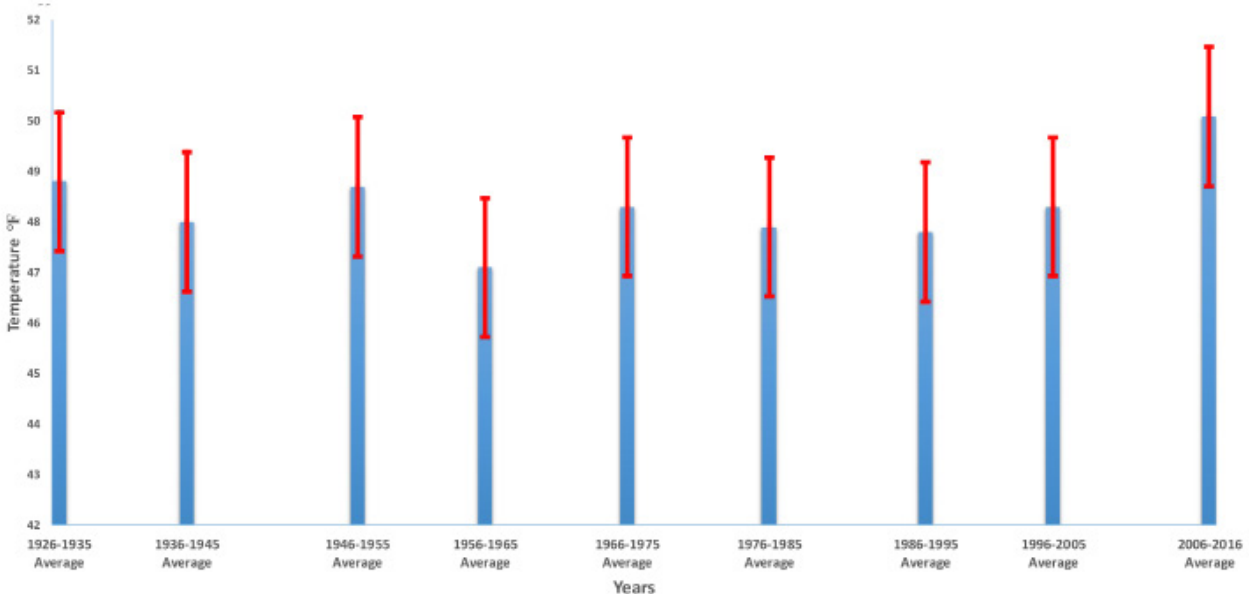

Figure 1. Average temperature by decade in Rochester, New York 1926 – 2016. The red bars represent standard deviation.

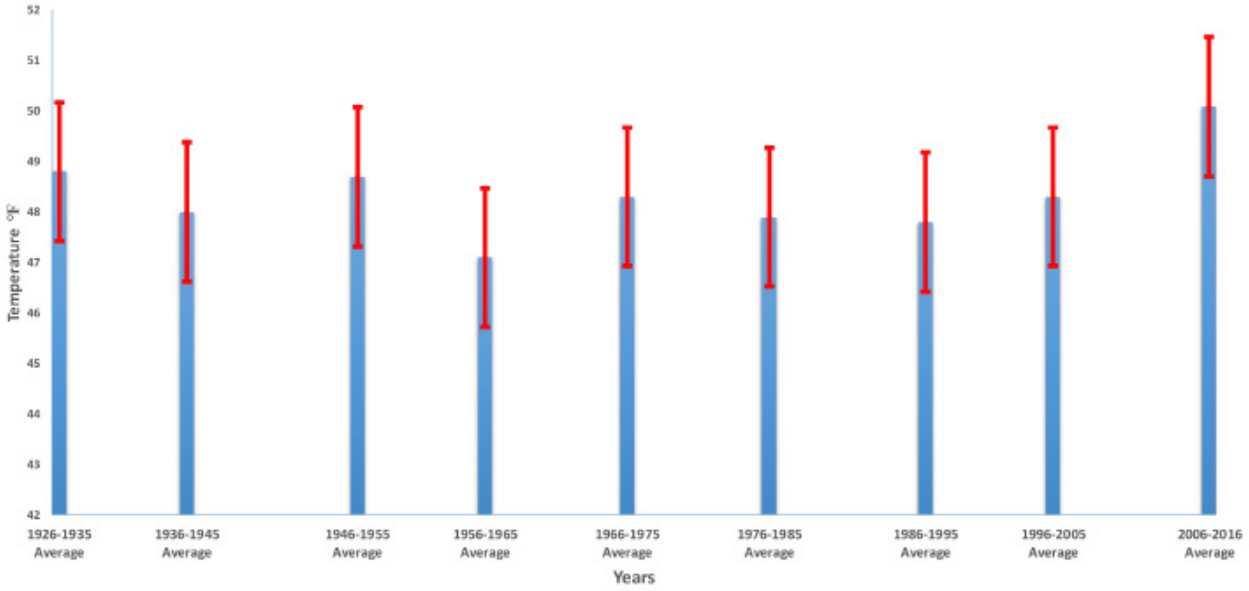

Figure 2. Average temperature by decade in Seattle, Washington 1948 – 2016. The red bars represent standard deviation.

temperature over 55°F each decade. **Figure 3** shows either a warming trend or temperature fluctuations with an overall increase in the number of above average years.

It is important to look at what the data shows when we applied simple linear regression. The Pearson Correlation Coefficient was used to determine how closely the independent variable and dependent variable are related. It shows that a correlation between temperature and time is more closely related in the latter part of the data range (1980-2016). When looking at this recent period, the data becomes less random as the correlation coefficient increases; suggesting a warming trend. This important trend can also be discerned when slope is calculated. Starting with the Rochester yearly temperature graph, the calculated temperature slope between 1926 and 2016 shows a value of .009714 (**Figure 4**). When the initial year is changed to 1948, to match the first available data in Seattle, the value rises to 0.0259. Interestingly, when I calculated the slope between 1980 and 2016 I obtained a value of 0.07207. Essentially, the slope of the line becomes steeper as I moved the data range closer to the latter part of the data range. A similar pattern appears when Pearson's Correlation Coefficient is taken into consideration. When we began to include data going back to 1926, it had a correlation of 0.186298, when the initial year is changed to 1948 it is 0.366212 and when we analyzed data from 1980 to 2016 the correlation is 0.498669. This final number suggests that there is a moderate correlation over the last 36 years.

1948-1955	1956-1965	1966-1975	1976-1985	1986-1995	1996-2005	2006-2016
0	1	0	1	2	2	3

Average Temperature of the last 5 years:	55.4	F
Average Temperature between 1948 and 2016:	53.11594	F

Figure 3. Number of years each decade with an average temperature over 55°F

Since there was minimal variation in temperature during the first half of the 20th century, it is difficult to assess just how much variation has occurred, as the early years dilute the years where climate change has accelerated. When we analyzed just the last 36 years, a warming trend was identified.

We also looked at Seattle's yearly temperature data using simple linear regression (**Figure 5**). The slope for the temperature from 1948 to 2016 is 0.031457, which means that there was a general upward trend over the years in Seattle. Also, Pearson's Correlation Coefficient for Seattle from 1948 to 2016 was 0.429141, which shows a moderate positive correlation between time and temperature for Seattle. This suggests that even though it was a subtler change than Rochester, it still showed a consistent temperature rise.

The slopes in **Figure 4** and **5** both showed a slight increase in temperature for most of the chart and then a larger increase in temperature in more recent years. For example, Rochester's average yearly temperature is 48.3°F (**Figure 4**). Between 1926 and 2005, the decade averages remained close to this. However, when we calculated the mean temperature between 2006 and 2016, it was slightly above 50°F, 2°F above the overall average. When we looked at Seattle (**Figure 5**), the temperature didn't drastically increase in the last 10 years like Rochester. Instead, the temperature slowly went up, oscillating between warmer and cooler decades. The

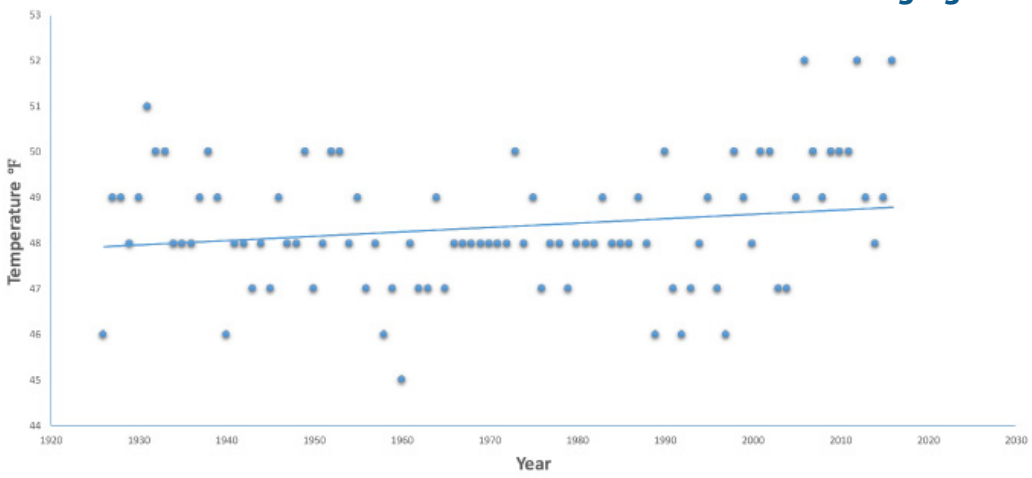

Figure 4. Rochester, New York scatter plot of temperature with trend line.

mean temperature over the first 28 years of recorded data was 52.42°F. Yet, the mean temperature between 2005 and 2016 was 53.7°F , a 1.3°F difference. When a trendline is created for both **Figure 4** and **Figure 5** they show, in the same manner as the slope calculations, an upward trend in average yearly temperature.

Discussion

This data suggests that Rochester and Seattle, two locations with very different climates, are potentially impacted by climate change. Both cities show a warming trend over many decades, and we hypothesize that if other students measure temperature trends in their cities, they may find further evidence to support climate change. If this trend is shown in other geographical locations, climate scientists should use this data to support their models. This research reinforces the conclusions of the UN intergovernmental Panel on Climate Change.

One of the limitations of this research project was that the temperature collection methods from the 1900s weren't as accurate as the methods in this century, so there could have been some errors. Also, the data available via Weather Underground was limited. The earliest year that temperature data became available was 1926 in Rochester and 1948 in Seattle. Therefore, information from the 1800's that might have supported the case for climate change was not available.

There are several additional research projects that could be used to support the case for climate change in Rochester, NY and Seattle, WA. It could be valuable to research how climate change affects local storms. Two summers ago, Rochester experienced a drought and last spring there was a season of extreme rainfall. Weather Underground could be used to collect data regarding the amount of precipitation per year or number of storms per year, and trends could be determined. A second reliable website should be used to avoid limitations such as inaccurate precipitation measuring and inaccurate storms counts, as well as to obtain historical precipitation data from as many years as possible. With new updates in affordable weather tracking tools, it will soon be easy for students to cloud source weather and temperature data across the world. The methods employed to complete this study could serve to provide far more data to climate models than scientists have had in the past.

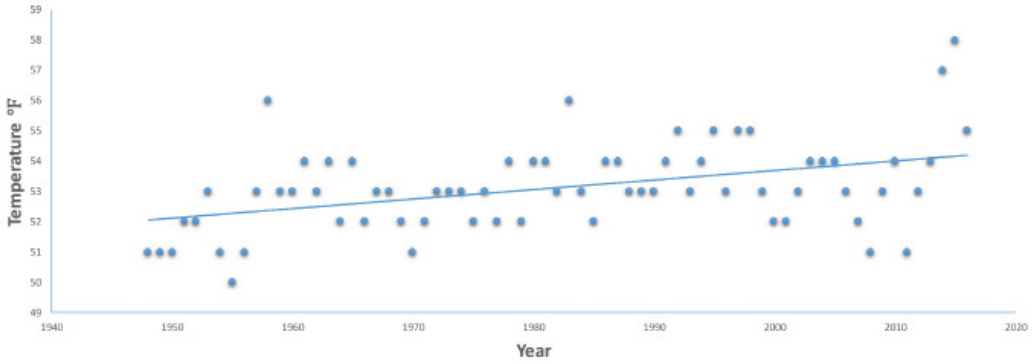

Figure 5. Seattle, Washington scatter plot of temperature with trend line.

Methods

To gather temperature data over the decades, the website Weather Underground was used. This is a resource that tracks current and historical data from thousands of weather stations across the world (5). The mean temperature was gathered for each month, and an average temperature was calculated for the year. For Rochester, data was obtained from 1926 to 2016, and for Seattle, data was collected between 1948 and 2016. After the average temperature by month was derived, points were plotted on a paper line graph. After ten years of monthly temperatures were obtained, the mean temperature for the decade was recorded. To show that the recent warming wasn't just a random phenomena, Pearson's Correlation Coefficient was calculated, and the slope was analyzed over different time periods. Finally, this information was inputted into Microsoft Excel to visualize trends in the data.

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