How is the Climate Changing Across the United States

New Mexico

Supercomputing Challenge

Final Report

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Team 59

Los Alamos

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Abstract

This project investigates climate change and how much it is warming at locations across the United States. We downloaded daily weather data from across the United States from NOAA and took an average for each year. Then we graphed our data so we could see how many degrees Fahrenheit it was warming each decade.

On average over the entire earth, the temperature has warmed 1.4 degrees Fahrenheit over the past century. We investigated if we can see climate change in any specific location. We also investigated if climate change affects the amount of snow and precipitation for these locations. We also saw if different parts of the U.S. are warming different amounts than others, or if some places are even cooling.

Background

People have been burning fossil fuels since the industrial revolution in the 1860's. By burning these fossil fuels, we release greenhouse gasses into the air. This is what warms the earth. This is how it works: energy enters our planet as shortwave radiation, or sunlight. Carbon dioxide is transparent to sunlight, meaning the sunlight goes right through it without changing the light's course. Everything around us gives off longwave radiation, or infrared. When sunlight hits something on earth, it absorbs the sunlight and gives off infrared. The infrared then goes up into the atmosphere and the carbon dioxide causes it to disperse in every direction sending some of the energy back to earth. As levels of carbon dioxide rise, more and more energy is deflected back to earth which causes warming. From examining ice cores, we can see the very high correlation between the amount of greenhouse gasses in the air and the temperature of the earth. When the greenhouse gasses in the air go up, the temperature rises. Right now we have more greenhouse gasses in the air then in the past 800 thousand years. We are at about 400 parts per million. As we continue to burn fossil fuels, the CO2 concentration level continues to go up every year. Simulations of climate change also help us see the warming of the earth. It is predicted to warm 4 degrees C in the next 100 years if we continue to use the same amount of fossil fuels. However, if we lower the amount of fossil fuels we use, the temperature will even out and it will only warm one degree C in the next 100 years.

Climate change is harmful to our planet and many of the organisms on it. Warming temperatures are a major effect of increased carbon dioxide concentrations. The temperature of the earth has risen about 1.4 degrees F in the last 100 years. As NASA: Global Climate Change said about the effects of climate change,'Glaciers have shrunk, ice on rivers and lakes is breaking up earlier, plant and animal ranges have shifted and trees are flowering sooner." As the earth continues to warm, the two main ice sheets on earth, Antarctica and Greenland will melt, causing the sea level to rise. Even though this isn't a major problem for our generation, this will be a huge problem for future generations along the coast. Another effect of climate change is that our oceans are becoming more acidic. When we release carbon dioxide into the air, the ocean absorbs about half of it. This slows down climate change, but is very harmful to oceans. As National Geographics put it, "...the introduction of massive amounts of CO2 into the seas is altering water chemistry and affecting the life cycles of many marine organisms..." As the oceans become more acidic, it eats away at shelled sea life, such as coral reefs and microscopic algae, overall harming the ocean and its sea life. Climate change also causes more severe weather such as floods and droughts. With warming temperatures, there is also more evaporation which leads to more precipitation thus increasing the likelihood of major floods. On the other side of the mountains, where there isn't as much precipitation there is still just as much evaporation, causing severe droughts. These are only a few of the effects of climate change.

There are some solutions to help slow down climate change. The most obvious one is to lower fossil fuel usage. Instead of fossil fuels, we could use natural energy, such as solar energy, wind energy, and water energy. Scientists are also always coming up with new and creative ways to slow down climate change, such as geo engineering. When a volcano explodes, some ash stays in the air for about five years, reflecting some of the shortwave radiation that comes from the sun back into space. This temporarily cools the earth. Scientists think that if they put tiny, ash-like particles into the air, some of the energy from the sun will reflect off of them, and that will temporarily slow down climate change.

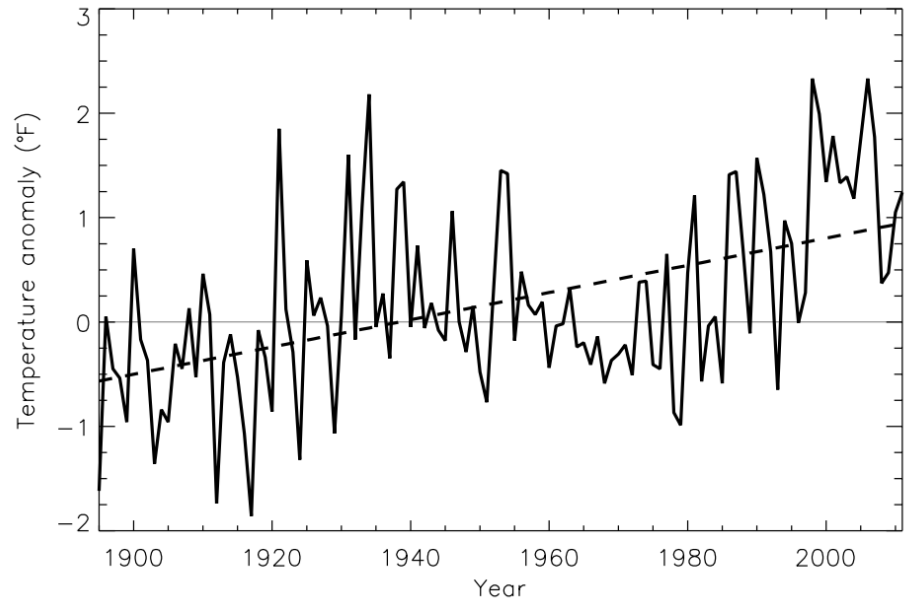


Figure 1. Temperature anomaly (deviations from the 1901-1960 average, °F) for annual contiguous U.S. The dashed line is the line of best fit. Source: NOAA 2013

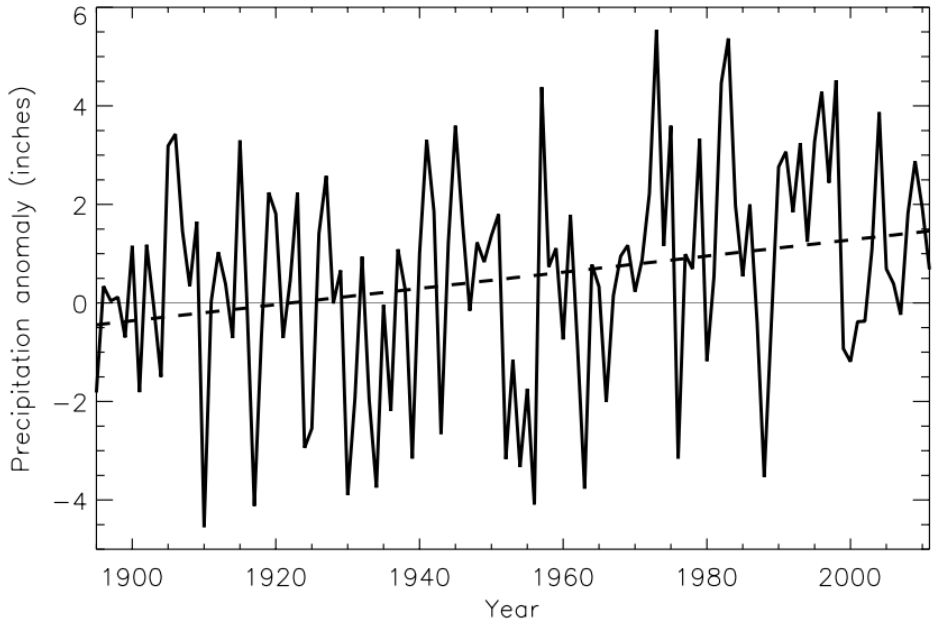


Figure 2. Precipitation anomaly (deviations from the 1901-1960 average, %) for annual contiguous U.S. The dashed line is the line of best fit. Source: NOAA 2013

According to NOAA, the average of the whole United States is getting warmer temperatures and more precipitation (Figures 1 and 2). Their plot show a warming of about 0.13 degrees per decade and 0.17 more inches of precipitation every decade.

Methods

In this section we will explain how we got our data and created the graphs. First, we downloaded daily maximum temperature, minimum temperature, precipitation, and snowfall from NOAA for many cities across the United States (source: Climate Data Online Search). We averaged this daily data for each month and year using python code we wrote (Figure 4). Next, we plotted the temperature in every city and found how much each place was warming for every decade on average. We also tried to find the correlation between the temperature increase and the amount of snowfall and precipitation for each location.

The formulas we used are as follows:

The average of N numbers, $x_1, x_2, x_3, ..., x_N$, is:

$$\mu_x = \frac{1}{N}\sum_{i}^{N} x_i$$

The python code we wrote to compute the average is:

```
def AvgList(x):
        xAvg=0.
        for k in range(len(x)):
                xAvg=xAvg+x[k]
        xAvg=xAvg/(k+1)
        return xAvg
```

The Standard Deviation measures the spread of the data. This is how to compute the standard deviation:

$$\sigma_x = \sqrt{\frac{1}{N}\sum_{i}^{N}(x_i - \mu_x)^2}$$

Our python code for the standard deviation is:

```
def stdDev(x): #function to compute standard deviation
        xAvg=AvgList(x)
        xdev=0.
        for k in range(len(x)):
                xdev=xdev+(x[k]-xAvg)**2
        xdev=xdev/(k+1)
        xdev=sqrt(xdev)
        return xdev
```

The Correlation is measured between -1 and 1. Where 1 means it is 100% correlated, and -1 means it is oppositely correlated. When the correlation is zero, it is completely random. If it is at least 0.05 away from zero, it is considered significant. Here is how to compute the correlation between a dataset x and a dataset y:

$$r_{xy} = \frac{\frac{1}{N}\sum_{i}^{N}(x_i-\mu_x)(y_i-\mu_y)}{\sigma_x \sigma_y}$$

Our python code for the correlation is:

```
def corr(x,y):
        xAvg=AvgList(x)
        yAvg=AvgList(y)
        rxy=0.
        n=min(len(x),len(y))
        for k in range(n):
                rxy=rxy+(x[k]-xAvg)*(y[k]-yAvg)
        rxy=rxy/(k+1)
        stdDevx=stdDev(x)
        stdDevy=stdDev(y)
        rxy=rxy/(stdDevx*stdDevy)
        return rxy
```

We also added the best fit line to our plots. The best fit line is the line that best fits the data. In other words, it is the line that is the least possible distance from all the points. The equation of a line is $y=mx+b$. We used a python library to compute the best fit line. The full

python code is attached at the end of this paper, which also shows how we read in data and made plots.

Results

In this section we will show you our results for many locations across the United States. These are shown in Figures 6-12. For each location we have shown the temperature, precipitation, and snowfall since the farthest back we could find data, in many cases 1950. Through these plots, we saw if we could see climate change in any particular location. We also used them to create multiple figures (Figures 3-5) that show all of our results.

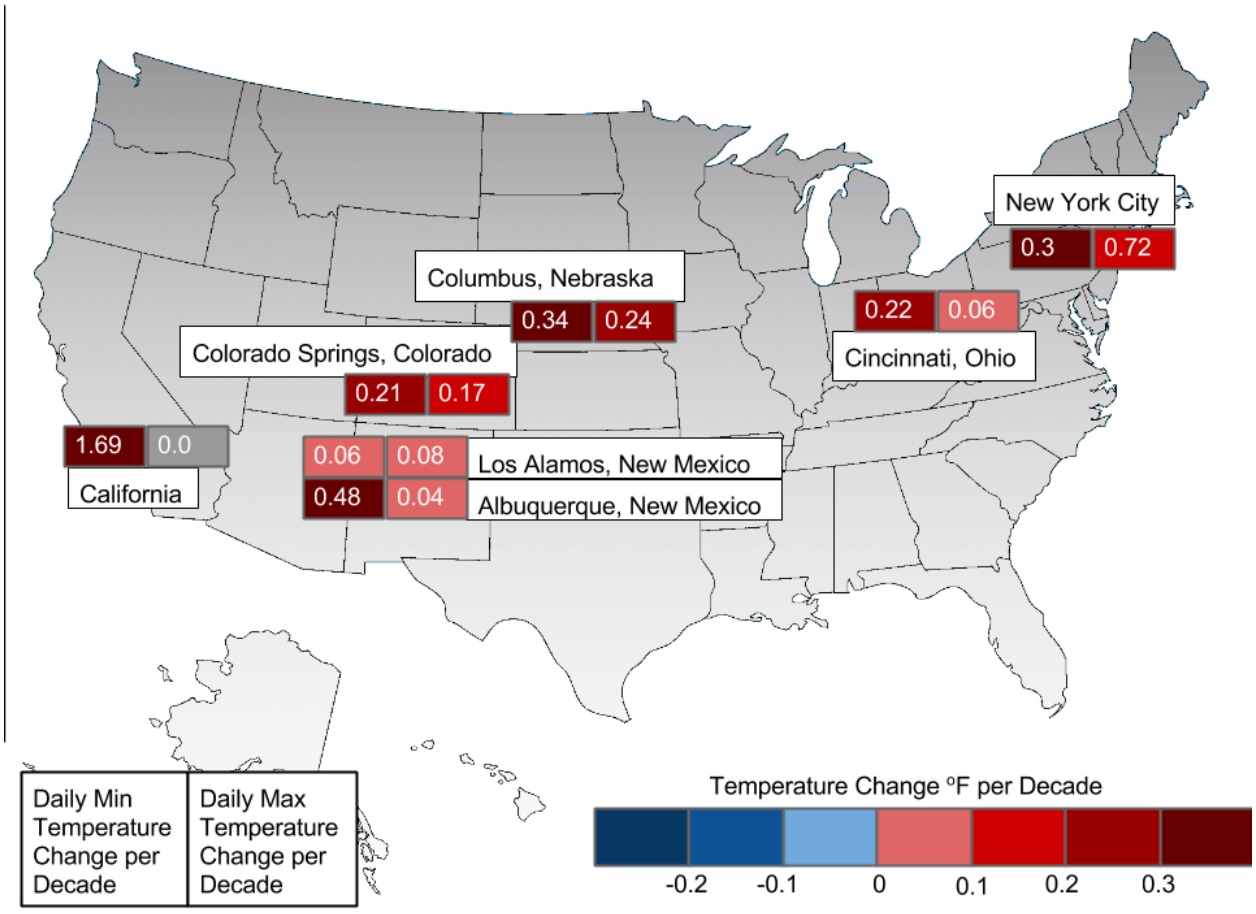


Figure 3. The change, in degrees Fahrenheit, that the locations across the United States are warming per decade. The left box shows the change of the minimum daily temperature and the right box shows the maximum temperature. Every location that we looked at across the United

States is getting warmer, and most of the min temperatures are warming more than the max temperatures. This means that for temperature, we can see climate change in every location that we looked at.

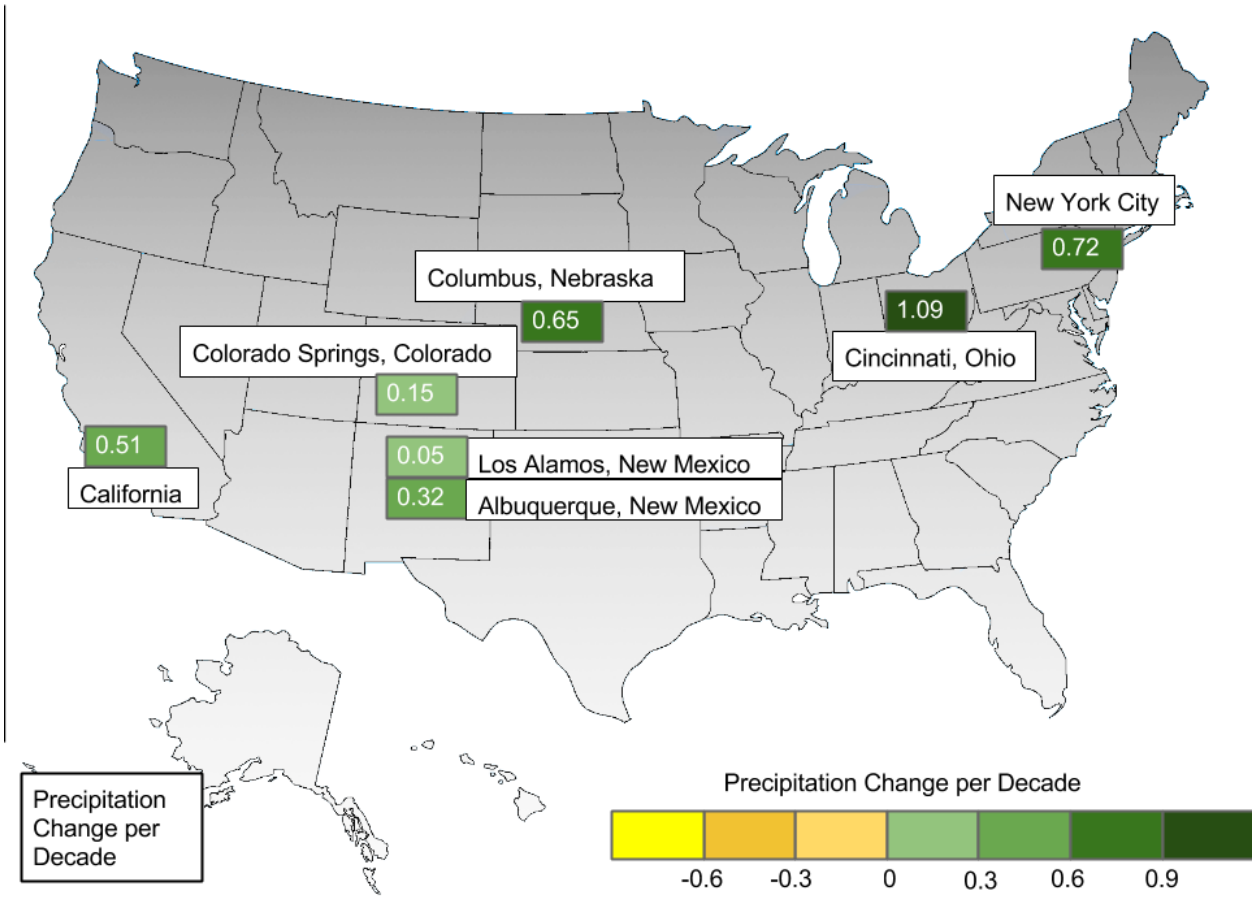


Figure 4. The change in the amount of precipitation that specific locations across the United States are getting. Every location is getting more precipitation. This is expected because with warmer temperatures, there is more evaporation, causing more precipitation.

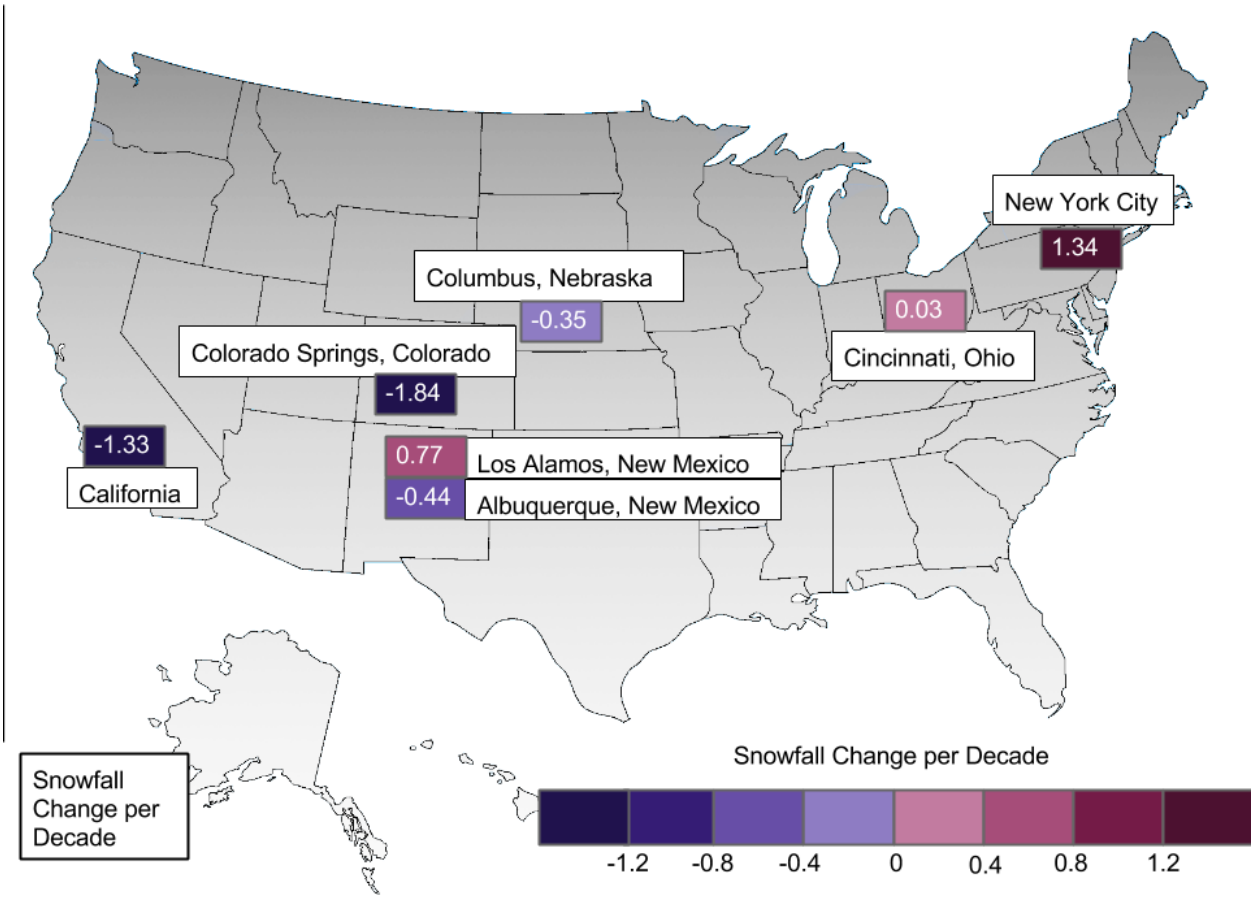


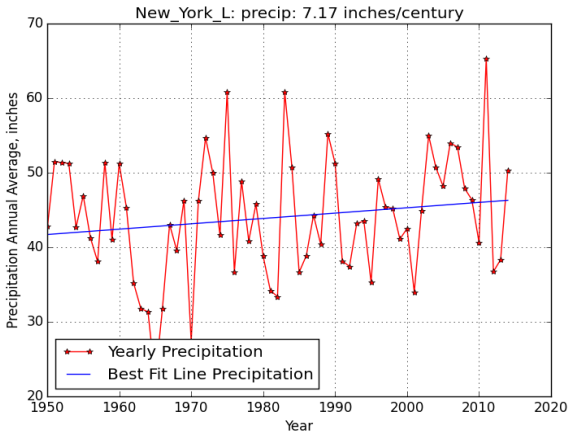
Figure 5. The change in snowfall in specific locations across the United States. Some places are getting more snowfall, but the average change is -0.26. This means that it is hard to see climate change through snowfall in any specific location, but once an average is taken, it is seen that overall the U.S. is getting less snowfall.

City	Precipitation change in inches/ decade	Snow change in inches/decade	Min Temperature change F/Decade	Max Temperature change F/Decade
New York City, New York	0.717	1.34	0.3	0.19
Columbus, Nebraska	0.65	-0.35	0.34	0.24
Los Alamos, New Mexico	0.052	0.77	0.06	0.08
California	0.507	-1.33	1.69	0.0
Colorado Springs, Colorado	0.146	-1.84	0.21	0.17
Cincinnati, Ohio	1.087	0.032	0.22	0.6
Albuquerque, New Mexico	0.315	-0.439	0.48	0.04

Table 1. The temperature, precipitation, and snowfall change for all of our cities across the U.S.

Data For New York City

a.



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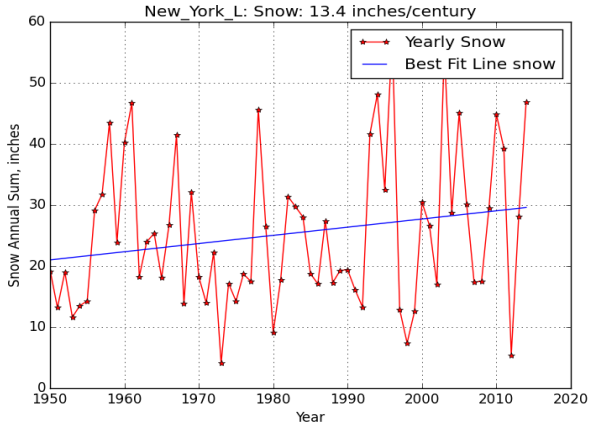

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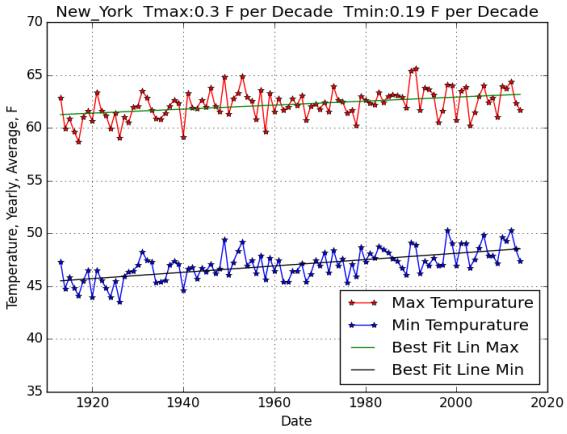
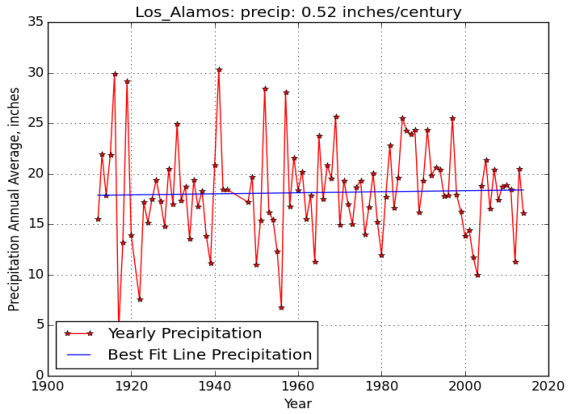


Figure 6. Temperature data for New York City. The maximum temperature is rising 0.3 degrees Fahrenheit per decade. The minimum temperature is rising 0.19 degrees Fahrenheit per decade. New York data goes from 1910 to the present, which is the longest time span we could find.

Data For Los Alamos, NM



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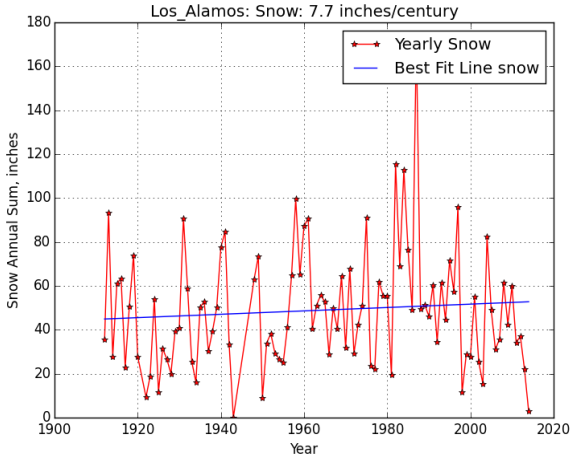

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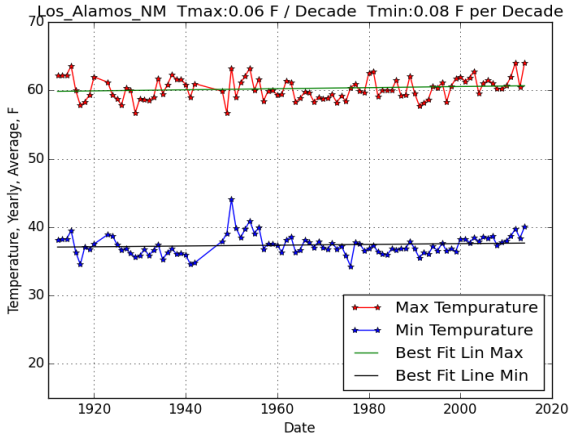
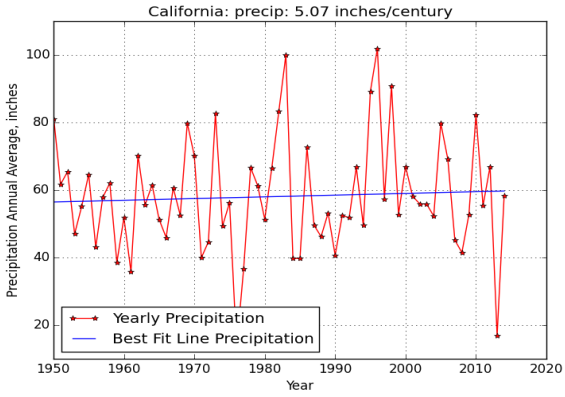


c.

Figure 7. Figure 3a shows that Los Alamos,NM is getting more precipitation over time. Figure 3b shows that snowfall is about the same, and Figure 3c shows slightly warmer temperatures since 1910.

Data For California



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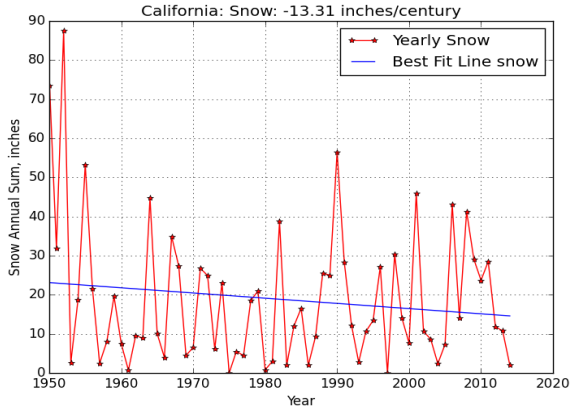

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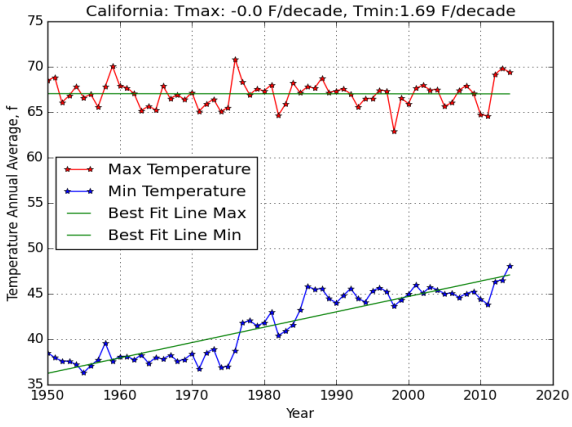
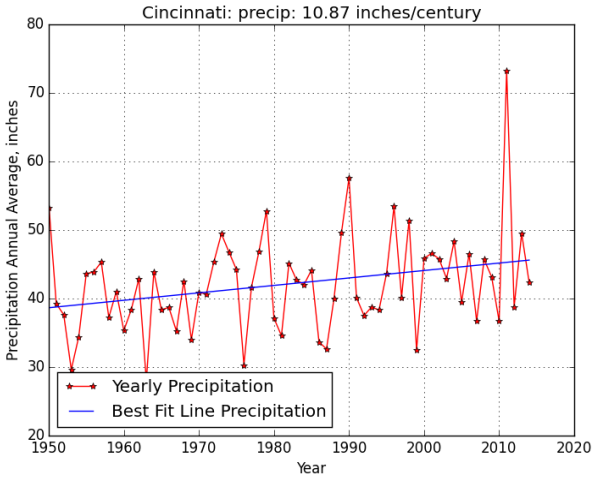


c.

Figure 8. Figure 4a shows that California is getting more precipitation over time. Figure 4b shows decreasing snowfall, and Figure 4c shows that the average minimum temperature is rising rapidly. However, this might be bad data because jumps in data could be an indication of a changes in equipment resulting in better accuracy of data collection.

Data For Cincinnati, OH



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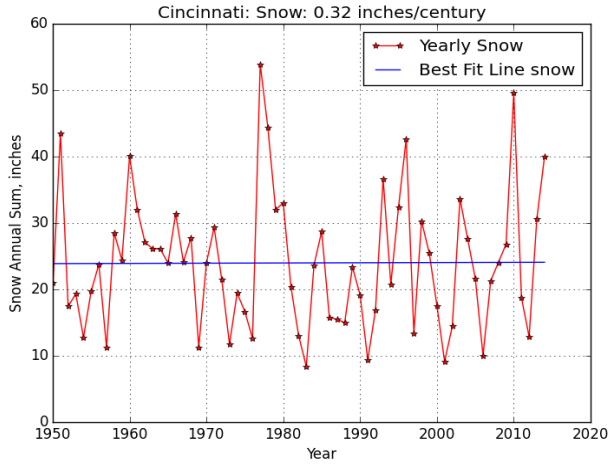

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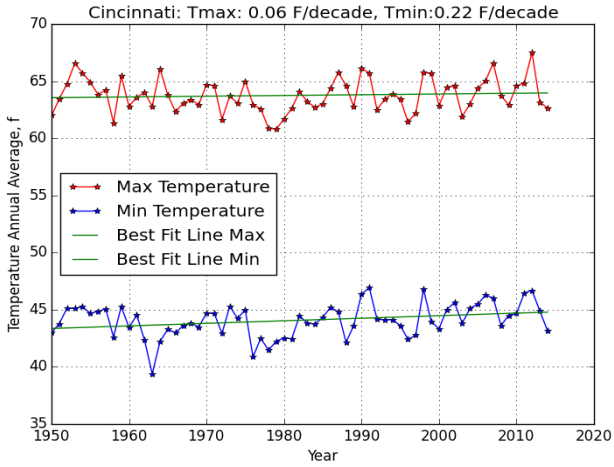
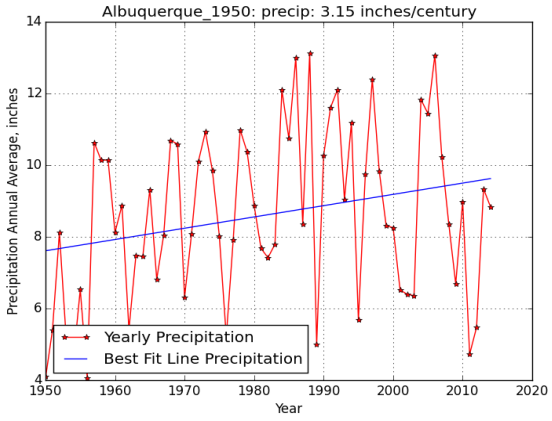


c.

Figure 9. Figure 5a shows that Cincinnati, Ohio is getting more precipitation. Figure 5b indicates a bit more snowfall, and Figure 5c shows warmer temperatures.

Data For Albuquerque, NM



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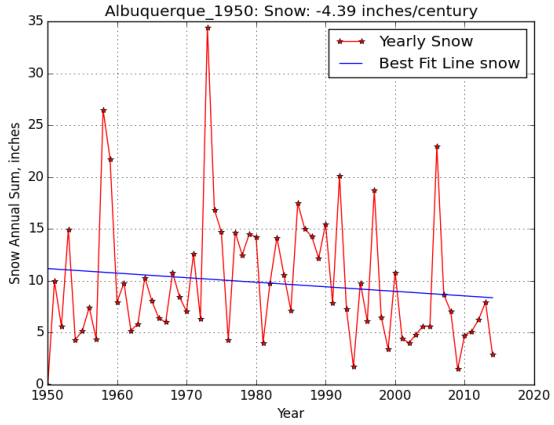

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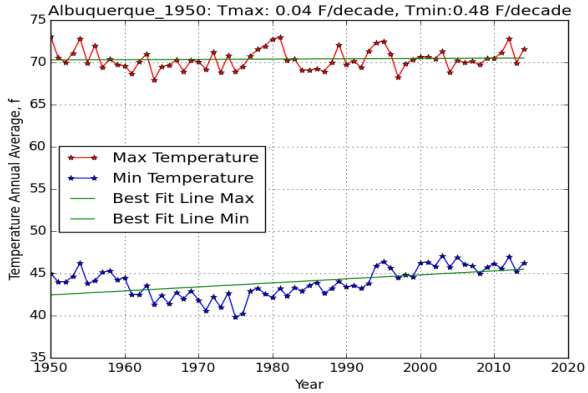
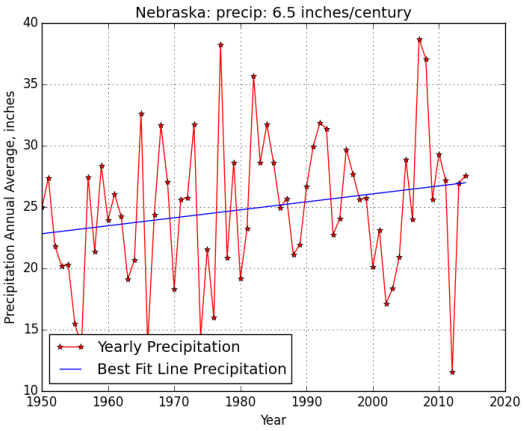


c.

Figure 10. Albuquerque, NM precipitation (a), snowfall (b) and temperature (c) since 1950. Albuquerque is getting more precipitation, less snow, and warmer temperatures. The min temperature is also warming more than the max temperature. Our plots show that most cities across the U.S. are changing in the same ways with the minimum temperatures rising faster then maximum temperatures.

Data For Columbus, NE



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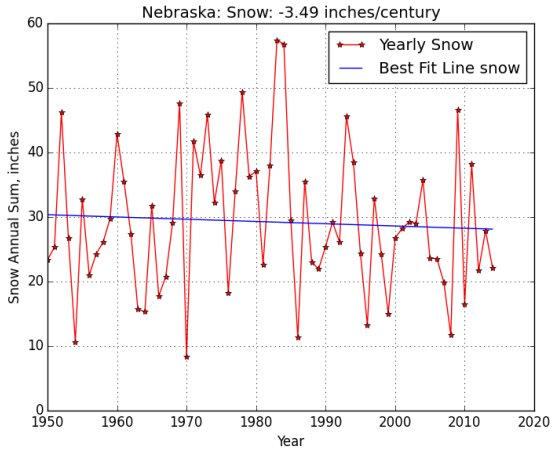

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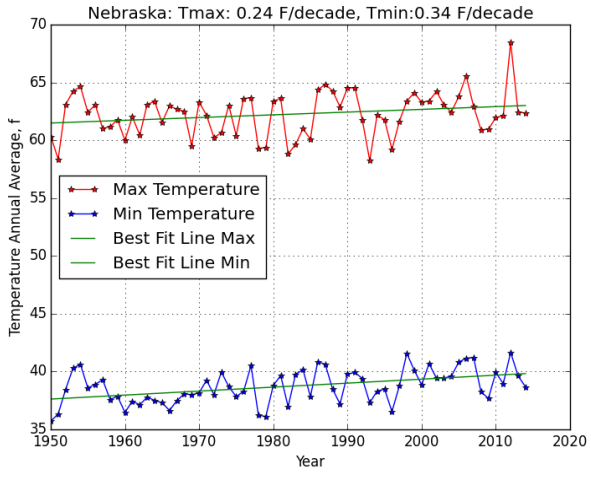
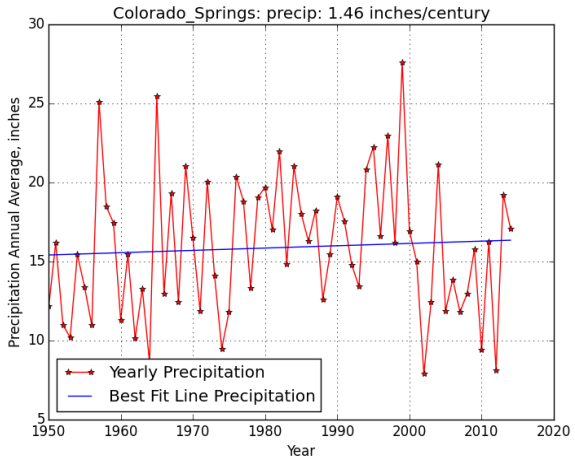


c.

Figure 11. The precipitation (a), snowfall (b), and temperature in Columbus, Nebraska since 1950. Nebraska is also getting more precipitation, less snow, and warmer temperatures, with the minimum temperature warming more than the maximum.

Data For Colorado Springs, CO



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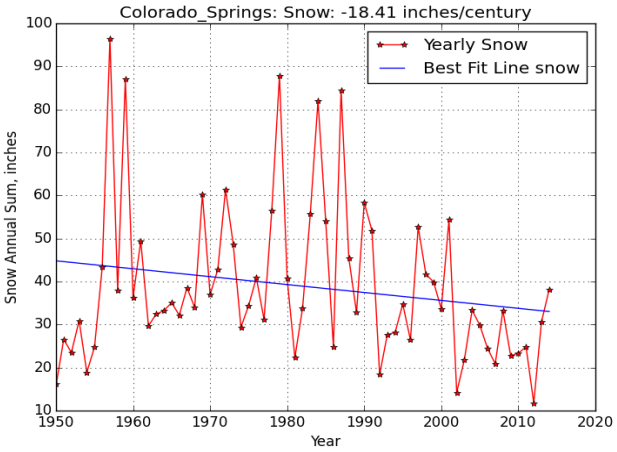

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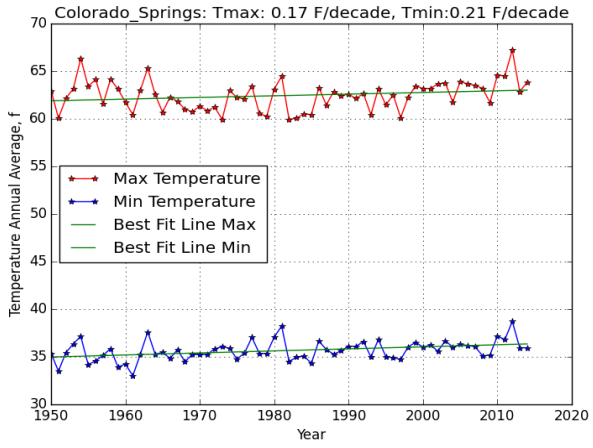

c.

Figure 12. Colorado Springs, CO is also getting more precipitation (a), a lot less snow (b), and warmer temperatures, with the min temperature warming more than the max.

Conclusion

This project investigates how climate change is affecting precipitation, snowfall and average temperatures in specific locations across the U.S. Climate change was very easy to see in all of the locations that we chose. All of the locations were getting warmer temperatures and more precipitation, and most were getting less snowfall. Climate change is affecting every location. In the cities that I chose, the warming per decade ranged from 0.0 to 1.69. according to NOAA, the average warming per decade across the U.S. was 0.13. The average of all of the locations that I picked was 0.33 per decade.

References

- "Climate Data Online Search, NOAA." http://www.ncdc.noaa.gov/cdo-web/datatools/findstation
- NOAA. 2013b. Regional Climate Trends and Scenarios for the U.S. National Climate Assessment. Part 9. Climate of the Contiguous United States. Kunkel, K.E, L.E. Stevens, S.E. Stevens, L. Sun, E. Janssen, D. Wuebbles, and J.G. Dobson. NOAA Technical Report. National Environmental Satellite, Data, and Information Service (NESDIS) 142-9, 78 pp