Tracking Storms from 1980 through 2010

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Describing the Project and Looking at the Cleaned Data

For this project, we were assigned to look at the IBTRACS data for storms in the North American basin, from 1851 through 2013. The data in its original hurdat format was taken from the IBTRACS website and then cleaned to make it feasible to analyze later in the project. The end result of this was creating the storms.csv and tracks.csv files that you see below. The bulk of the analysis will shrink the aforementioned time-frame to the 30 years between 1980 and 2010.

```
head(storms)
```

```
## Source: local data frame [6 x 4]
##
##   id       date days    NAME
## 1  1 06/25/1851    4 MISSING
## 2  2 07/05/1851    1 MISSING
## 3  3 07/10/1851    1 MISSING
## 4  4 08/16/1851   12 MISSING
## 5  5 09/13/1851    4 MISSING
## 6  6 10/16/1851    4 MISSING
```

```
head(tracks)
```

```
## Source: local data frame [6 x 9]
##
##   tracks_id tracks_date tracks_period tracks_stage tracks_latitude
## 1         1  06/25/1851           00H      cyclone            28.0
## 2         1  06/25/1851           06H      cyclone            28.0
## 3         1  06/25/1851           12H      cyclone            28.0
## 4         1  06/25/1851           18H      cyclone            28.1
## 5         1  06/26/1851           00H      cyclone            28.2
## 6         1  06/26/1851           06H      cyclone            28.3
## Variables not shown: tracks_longitude (dbl), tracks_wind (int),
##   tracks_pressure (int), year (dbl)
```

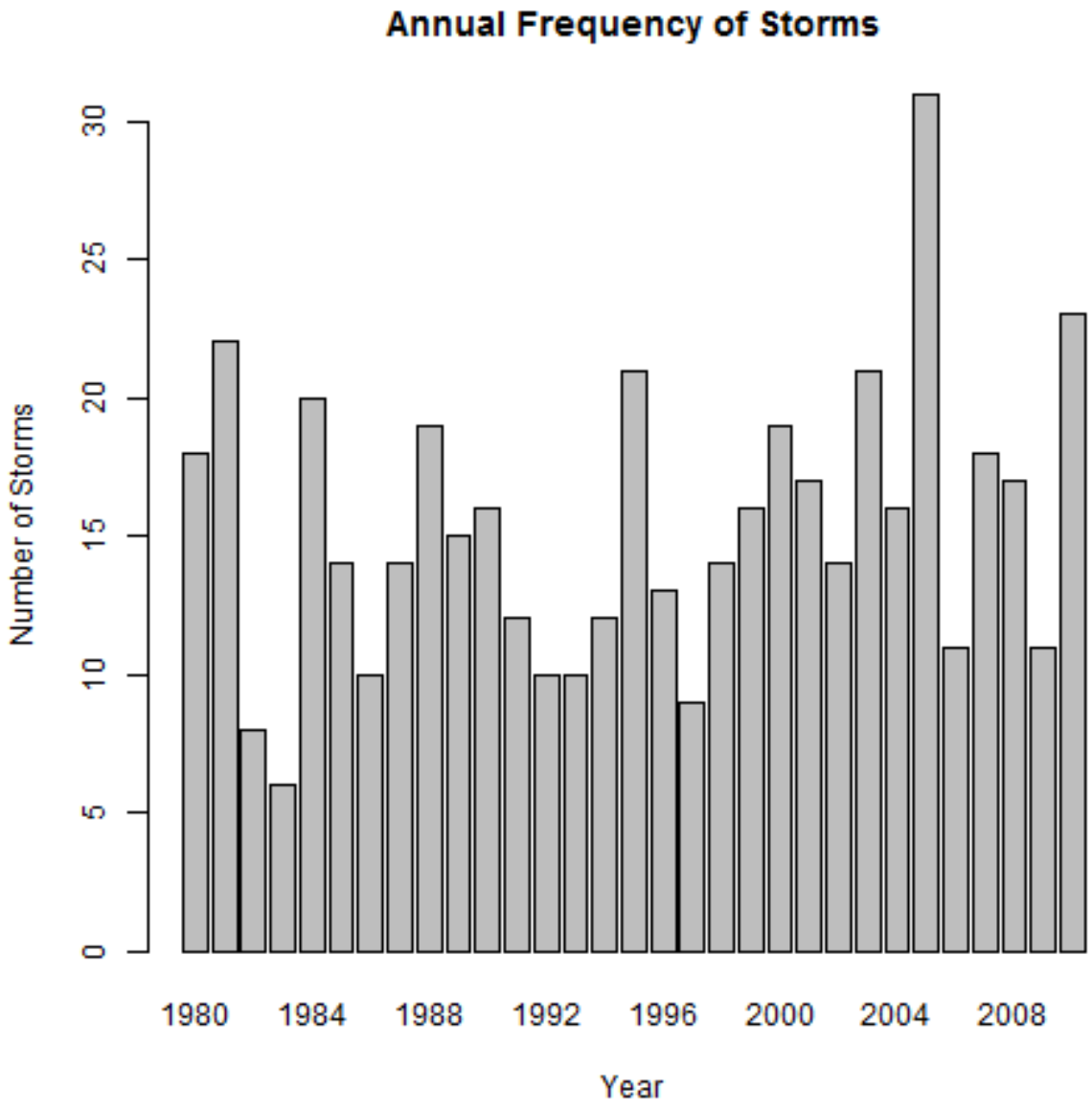
The four columns under storms are self-explanatory, with the names column outputting as missing due to the process of naming tropical storms not yet established in 1851. The eight columns of tracks are equally apparent, each relating to the condition or position of the storm.

Categorizing each Storm and then Plotting Annual Frequencies

This section will introduce nuance as to what constitutes a storm versus a tropical storm, a stage 1 hurricane, or a stage 3 hurricane.

First, the total number of storms per year from 1980-2010

```
## 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994
##   18   22    8    6   20   14   10   14   19   15   16   12   10   10   12
## 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009
##   21   13    9   14   16   19   17   14   21   16   31   11   18   17   11
## 2010
##   23
```

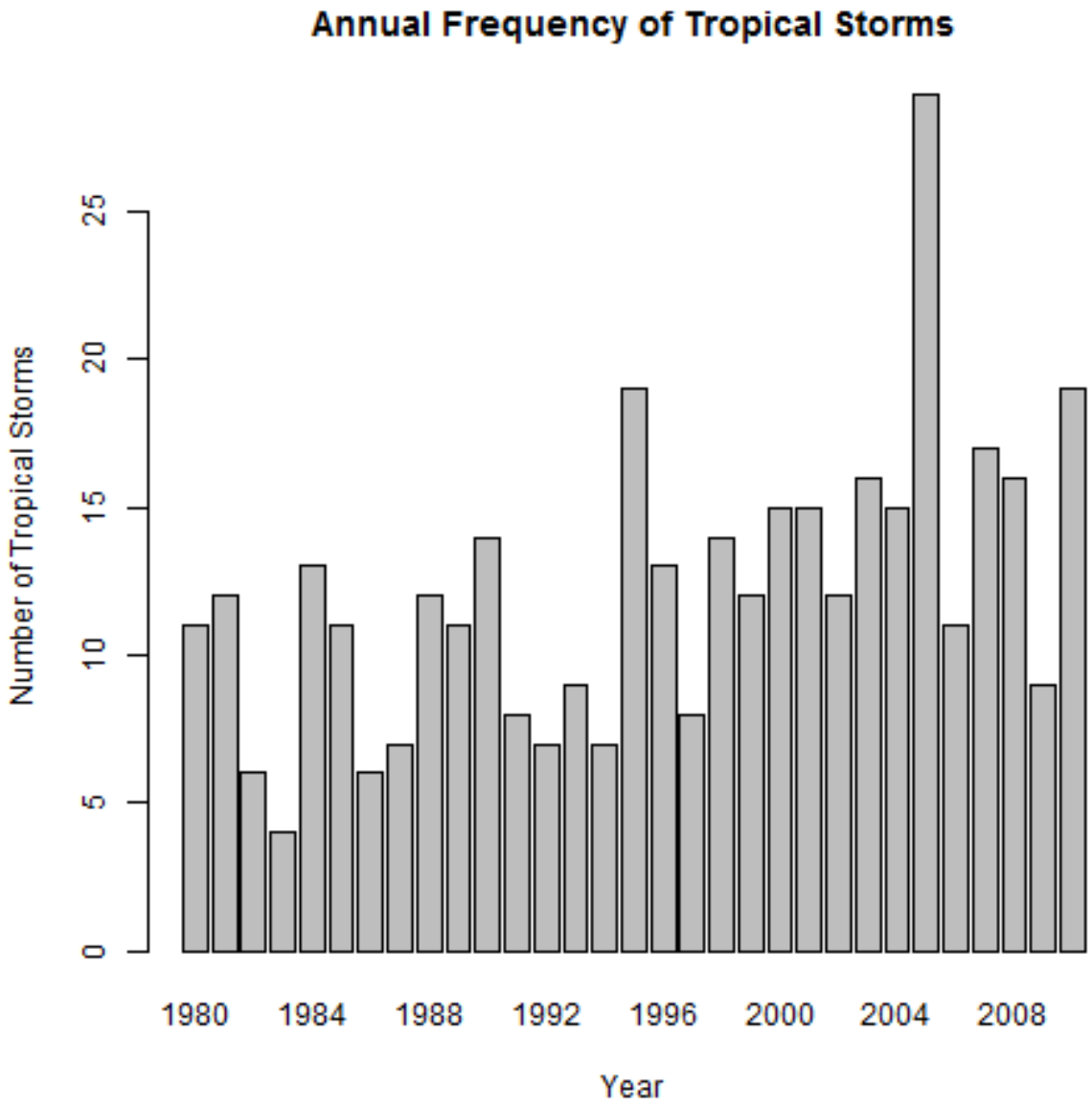


As is apparent from the plot, the total number of storms per year has fluctuated within a stable range, with the exception of 2005, which saw a total of 31 storms.

Now, we will count the number of tropical storms per year in the same time-frame, where a wind speed of 35 knots or greater constitutes a tropical storm.

```
## 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994
```

```
##   11   12    6    4   13   11    6    7   12   11   14    8    7    9    7
## 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009
##   19   13    8   14   12   15   15   12   16   15   29   11   17   16    9
## 2010
##   19
```

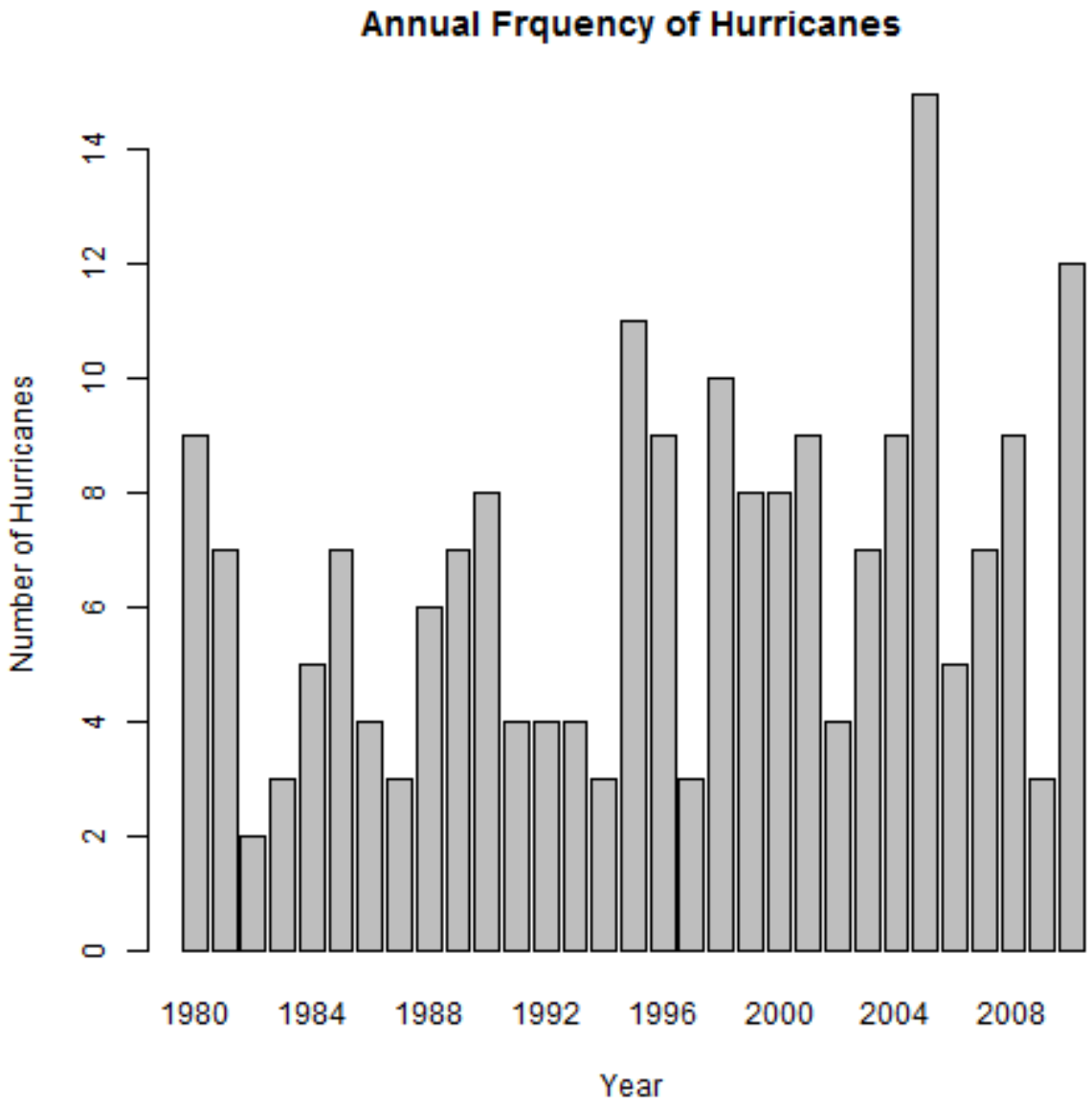


While the number of storms per year fluctuated in a relatively stable manner, plotting the number of tropical storms allows us to see a slight uptick in their number in recent years, indicating the increasing intensity of storms.

We now turn our eyes to the number of hurricanes per year, where a wind speed of 64 knots or greater indicates a hurricane.

```
## 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994
```

```
##    9    7    2    3    5    7    4    3    6    7    8    4    4    4    3
## 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009
##   11    9    3   10    8    8    9    4    7    9   15    5    7    9    3
## 2010
##   12
```

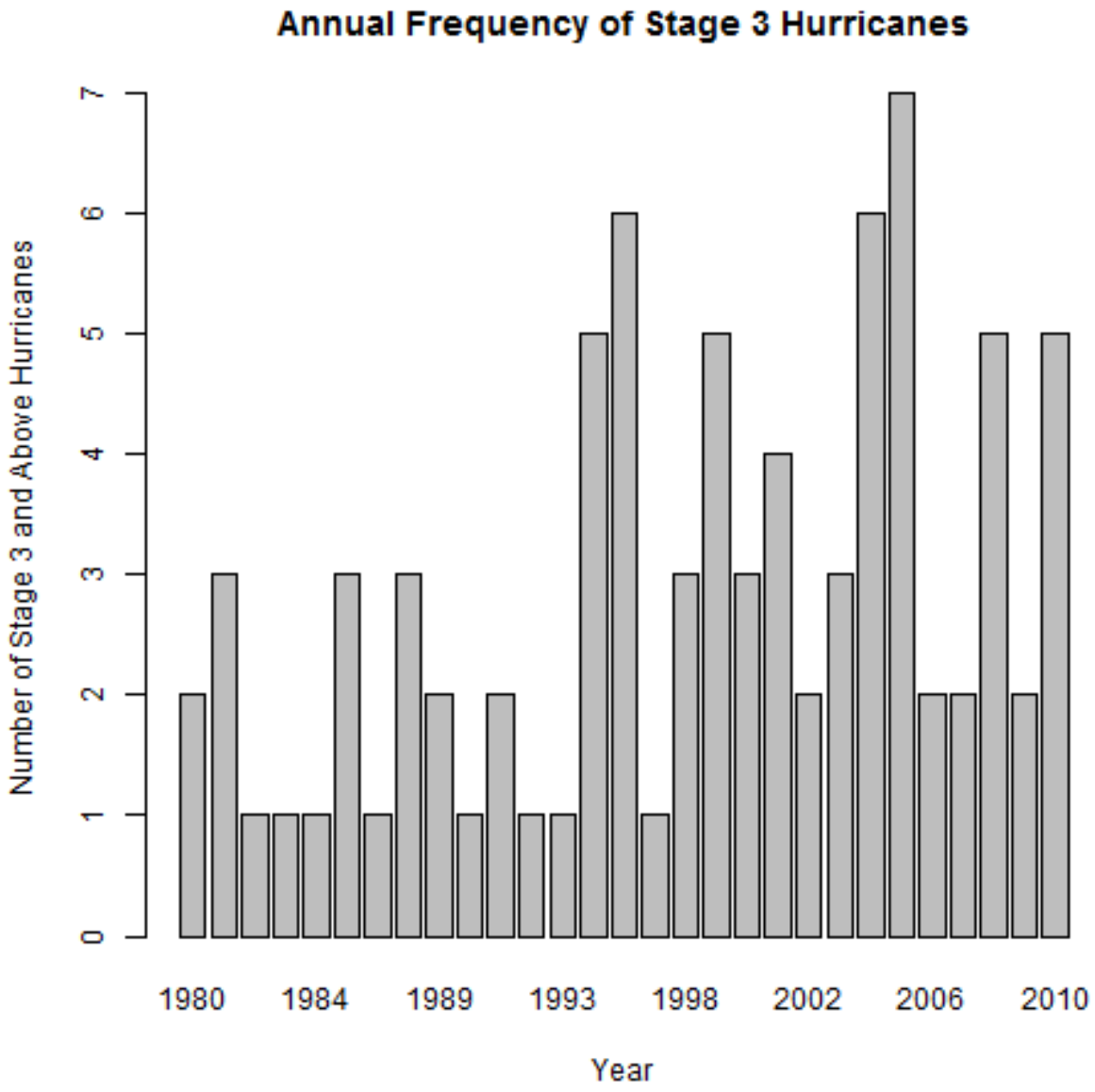


Once again we see a slight uptick in the number of hurricanes per year. This second occurrence then allows us to postulate as to the reason why. A possibility is that due to global warming, whereby humans produce such a great quantity of co2 emissions to induce a greenhouse effect, the intensity of storms has increased.

Lastly, we look at the number of stage 3 hurricanes per year, to add more credence to our hypothesis.

```
## 1980 1981 1982 1983 1984 1985 1987 1988 1989 1990 1991 1992 1993 1995 1996
##    2    3    1    1    1    3    1    3    2    1    2    1    1    5    6
```

```
## 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010
##    1    3    5    3    4    2    3    6    7    2    2    5    2    5
```



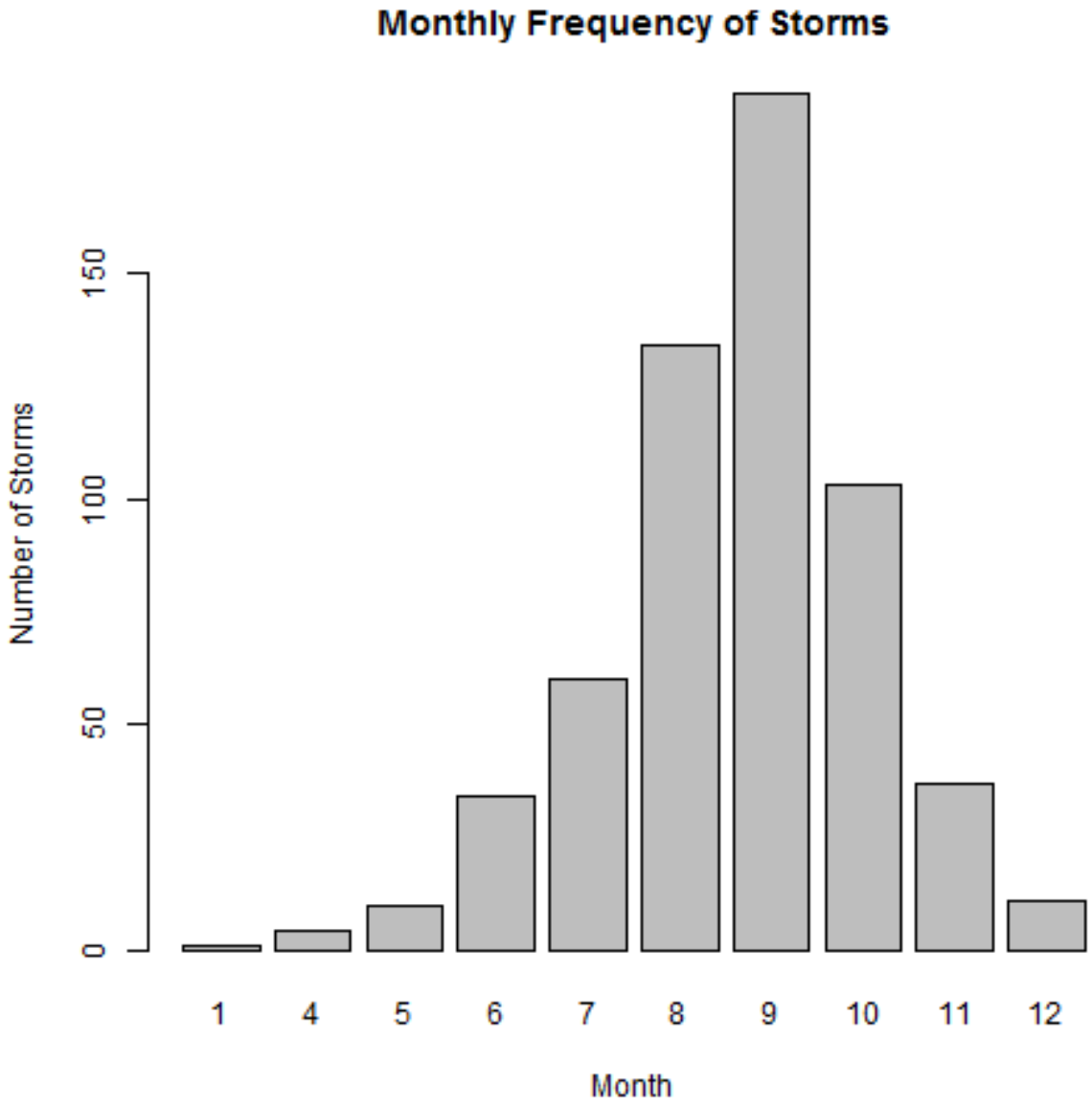
With this last plot, it is abundantly clear that storms have increased in intensity in recent years, an effect which can be attributed to global warming.

Categorizing each Storm and then Plotting their Monthly Frequencies

This section will once again introduce nuance as to what constitutes a storm versus a tropical storm, a stage 1 hurricane, or a stage 3 hurricane, but will focus on monthly data instead of yearly.

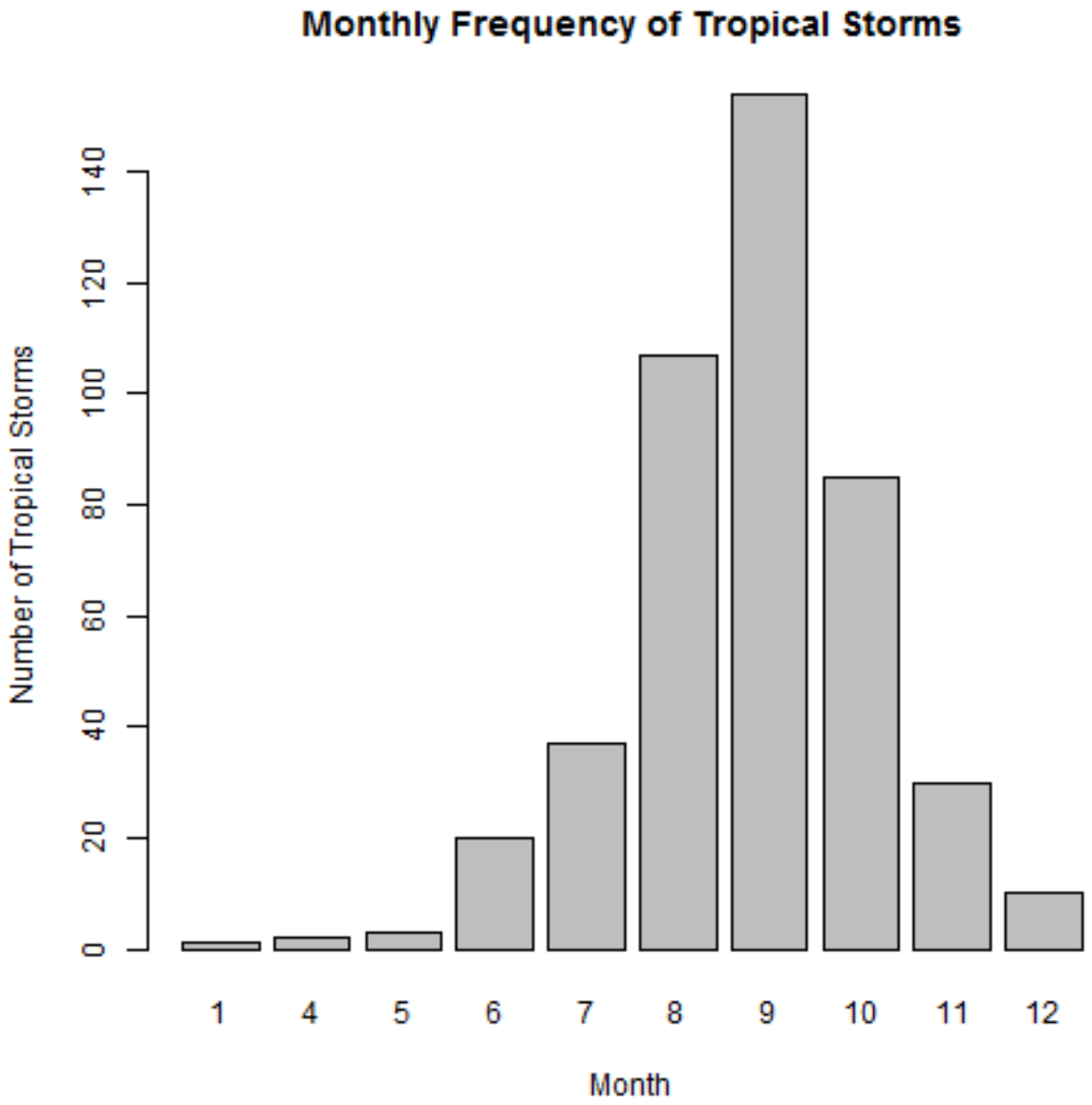
First, the total number of storms per month from 1980-2010

```
##    1    4    5    6    7    8    9   10   11   12
##    1    4   10   34   60  134  190  103   37   11
```



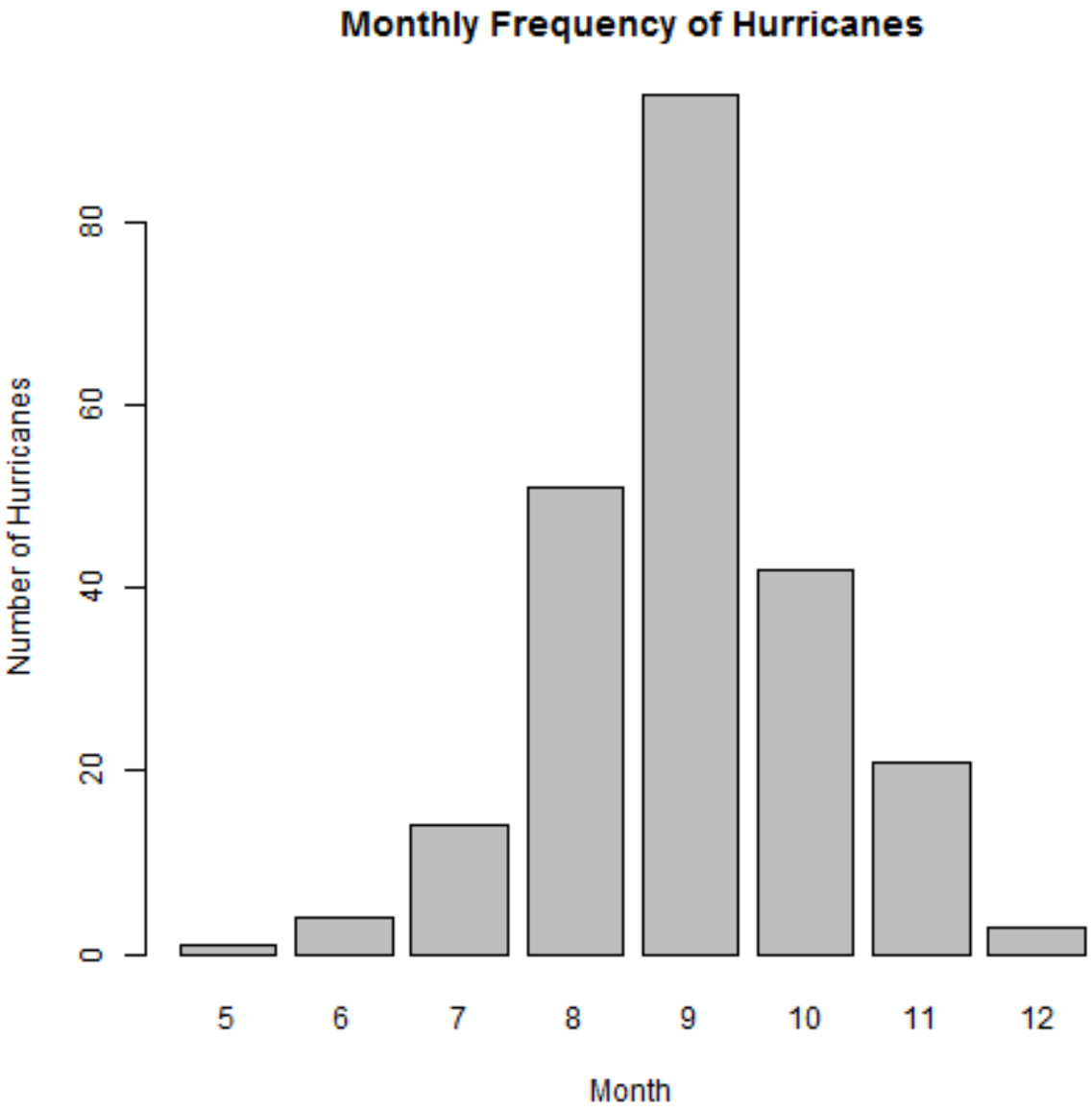
Now, we will count the number of tropical storms per month in the same time-frame, where a wind speed of 35 knots or greater constitutes a tropical storm.

```
##    1    4    5    6    7    8    9   10   11   12
##    1    2    3   20   37  107  154   85   30   10
```



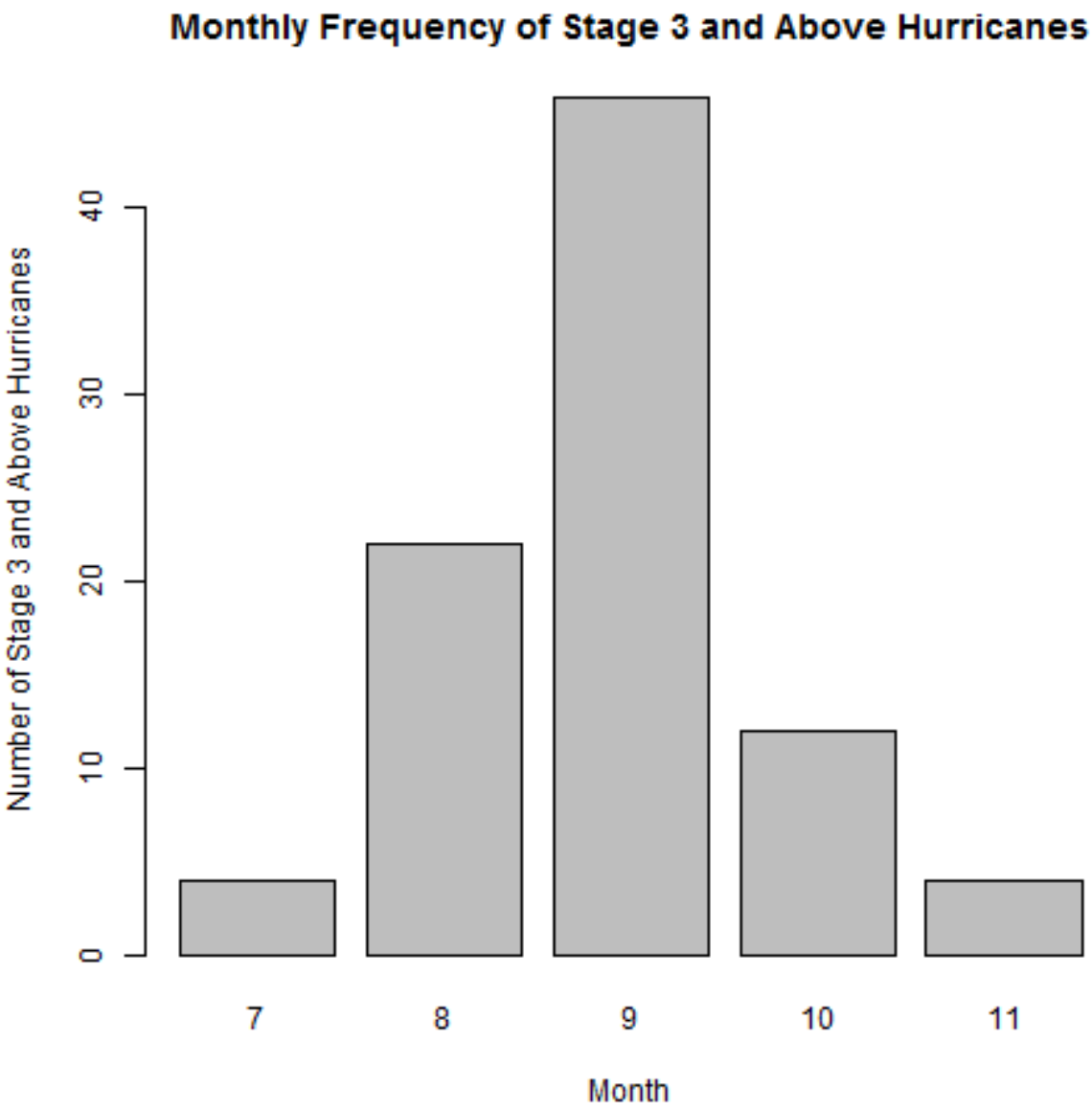
We now turn our eyes to the number of hurricanes per month, where a wind speed of 64 knots or greater indicates a hurricane.

```
##  5  6  7  8  9 10 11 12
##  1  4 14 51 94 42 21  3
```



Lastly, we look at the number of stage 3 hurricanes per month.

```
##  7  8  9 10 11
##  4 22 46 12  4
```



Each of these plots serves to tell us that storms occur with the greatest frequency in the summer to early fall months, where the temperatures are the highest. It also exhibits, through the intervals of months getting smaller in each successive plot, that each higher stage storm necessitates higher temperatures. This further adds credibility to our hypothesis that the increasing temperatures induced by global warming have led to the increasing intensity of storms.

Summary Statistics for the annual number of storms

```
##           Avg Std.Dev First.Quartile Median Third.Quartile
## 35 Knots 12.1    4.98            8.5     12             15
## 64 Knots  6.6    3.11            4.0      7              9
## 96 Knots  2.8    1.78            1.0      2              4
```

With these statistics presented in table for us, we can see the average in each case, and then go back and compare the average to each table.

First, we will compare the number of tropical storms in each year to the average.

```
##  1980  1981  1982  1983  1984  1985  1986  1987  1988  1989  1990  1991
## FALSE FALSE FALSE FALSE  TRUE FALSE FALSE FALSE FALSE FALSE  TRUE FALSE
##  1992  1993  1994  1995  1996  1997  1998  1999  2000  2001  2002  2003
## FALSE FALSE FALSE  TRUE  TRUE FALSE  TRUE FALSE  TRUE  TRUE FALSE  TRUE
##  2004  2005  2006  2007  2008  2009  2010
##  TRUE  TRUE FALSE  TRUE  TRUE FALSE  TRUE
```

With this, we can see that the time period from 1980-1995 had only three tropical storms surpassing the average, whereas the time period from 1996-2010 had 10.

Second, we will compare the number of hurricanes in each year to the average.

```
##  1980  1981  1982  1983  1984  1985  1986  1987  1988  1989  1990  1991
##  TRUE  TRUE FALSE FALSE FALSE  TRUE FALSE FALSE FALSE  TRUE  TRUE FALSE
##  1992  1993  1994  1995  1996  1997  1998  1999  2000  2001  2002  2003
## FALSE FALSE FALSE  TRUE  TRUE FALSE  TRUE  TRUE  TRUE  TRUE FALSE  TRUE
##  2004  2005  2006  2007  2008  2009  2010
##  TRUE  TRUE FALSE  TRUE  TRUE FALSE  TRUE
```

With this, we can see that the time period from 1980-1995 had only six tropical storms surpassing the average, whereas the time period from 1996-2010 had 11.

Last we will compare the number of stage 3 hurricanes per year to the average.

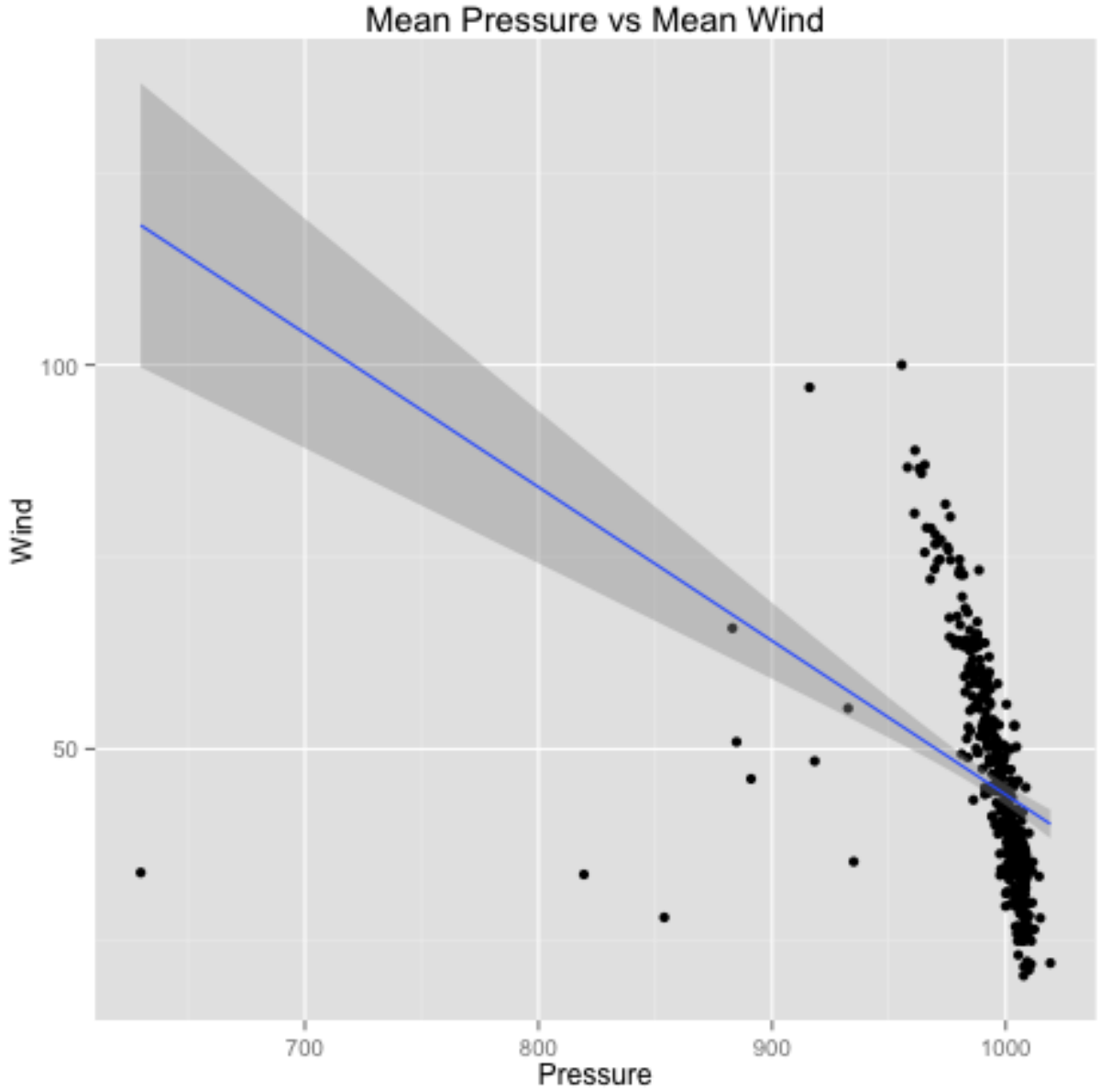
```
##  1980  1981  1982  1983  1984  1985  1987  1988  1989  1990  1991  1992
## FALSE  TRUE FALSE FALSE FALSE  TRUE FALSE  TRUE FALSE FALSE FALSE FALSE
##  1993  1995  1996  1997  1998  1999  2000  2001  2002  2003  2004  2005
## FALSE  TRUE  TRUE FALSE  TRUE  TRUE  TRUE  TRUE FALSE  TRUE  TRUE  TRUE
##  2006  2007  2008  2009  2010
## FALSE FALSE  TRUE FALSE  TRUE
```

With this, we can see that the time period from 1980-1995 had only four tropical storms surpassing the average, whereas the time period from 1996-2010 had 10.

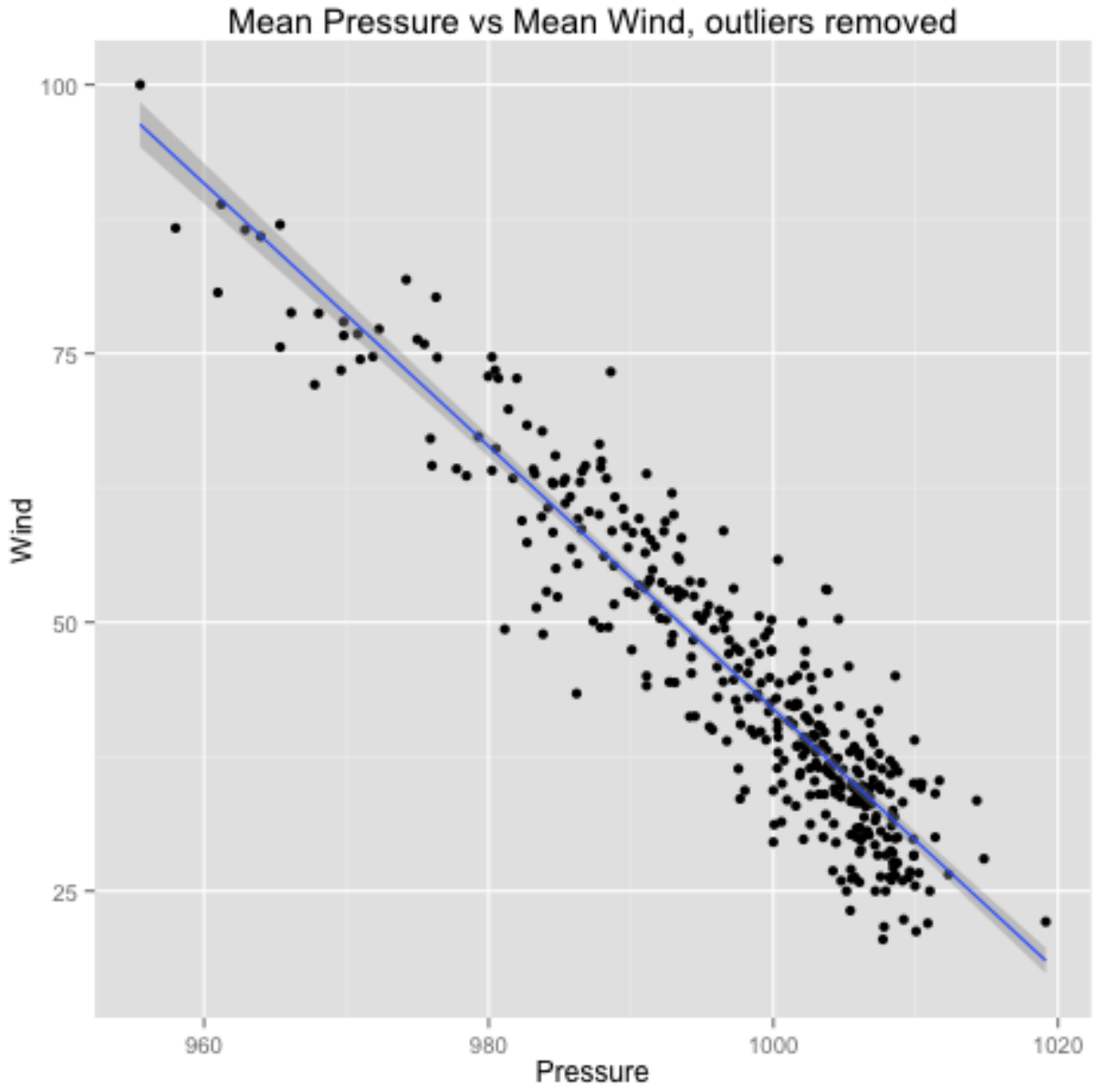
This adds numeric evidence to the already existing visual evidence that later stage storms have increased in frequency in the latter half of our data set, and thus in recent times.

A regression Analysis on Median and Mean Wind Speed and Pressure from 1980-2010

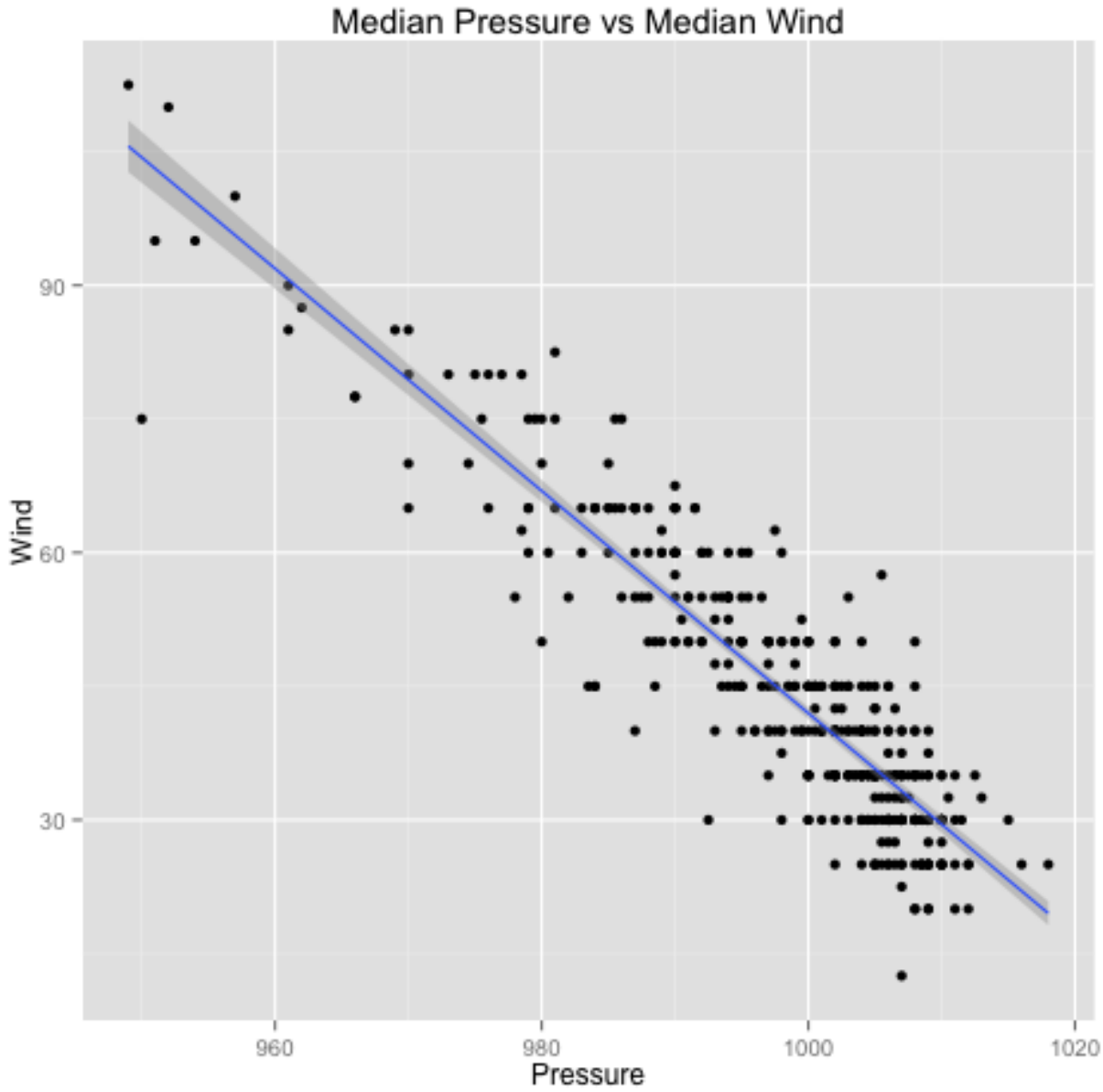
First we will look at a regression analysis on mean wind speed and pressure



The results from this first regression seem a bit skewed by the outliers present. Because of this we attempted to plot again without the outliers, and the following plot was obtained.



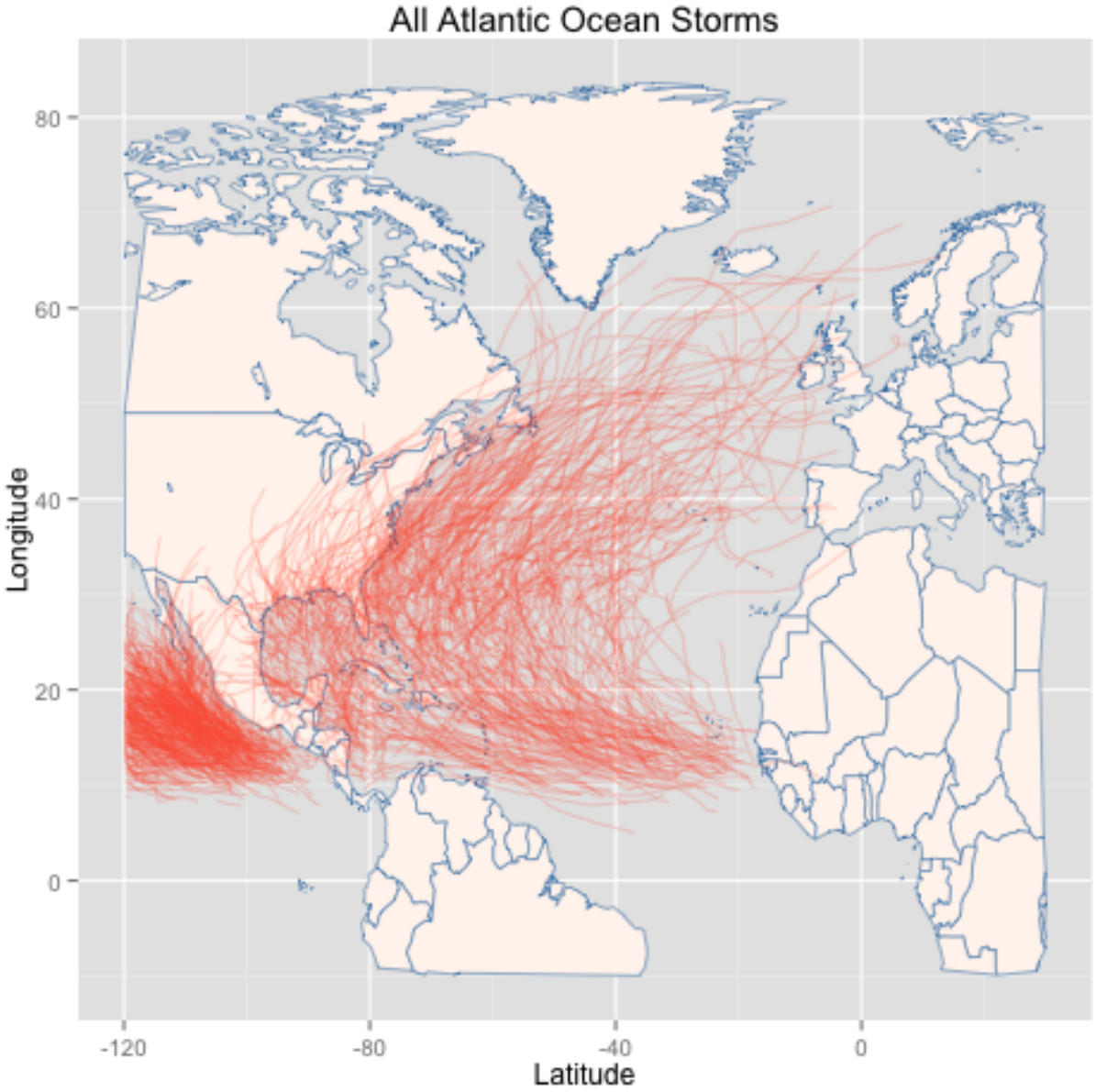
From this graph, it is apparent that there is a strong negative correlation between wind speed and pressure. Now we look at this same plot but for the medians

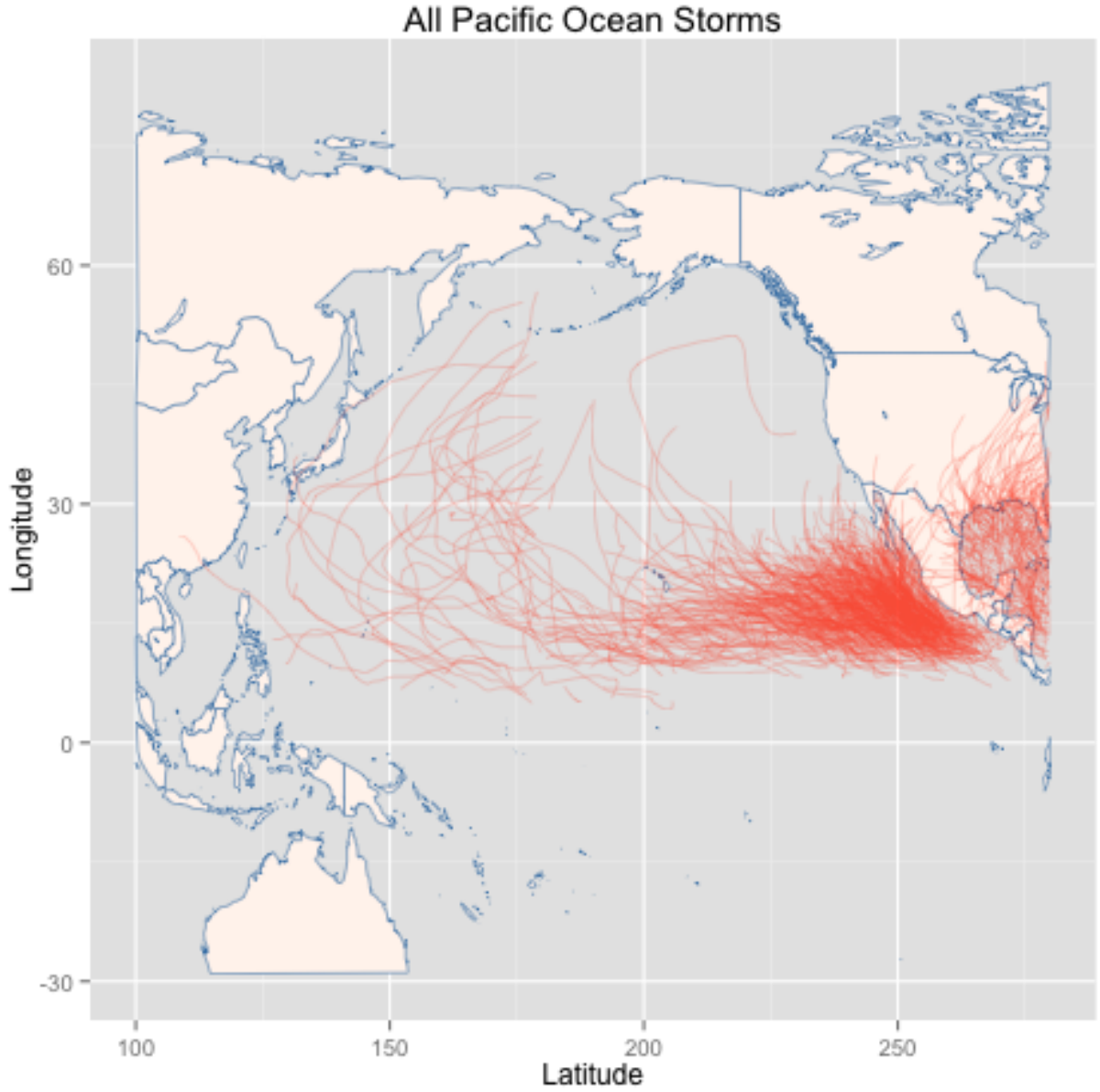


Once again we see a strong negative correlation between wind speed and pressure. This is outside the scope of this project, but there exists a causal relationship between pressure and wind, whereby the process of the pressure of the atmosphere going from higher to lower values induces higher wind speeds. This fact bears out in the regression analysis.

Tracking storms in the North Atlantic and Eastern Pacific from 1980-2010

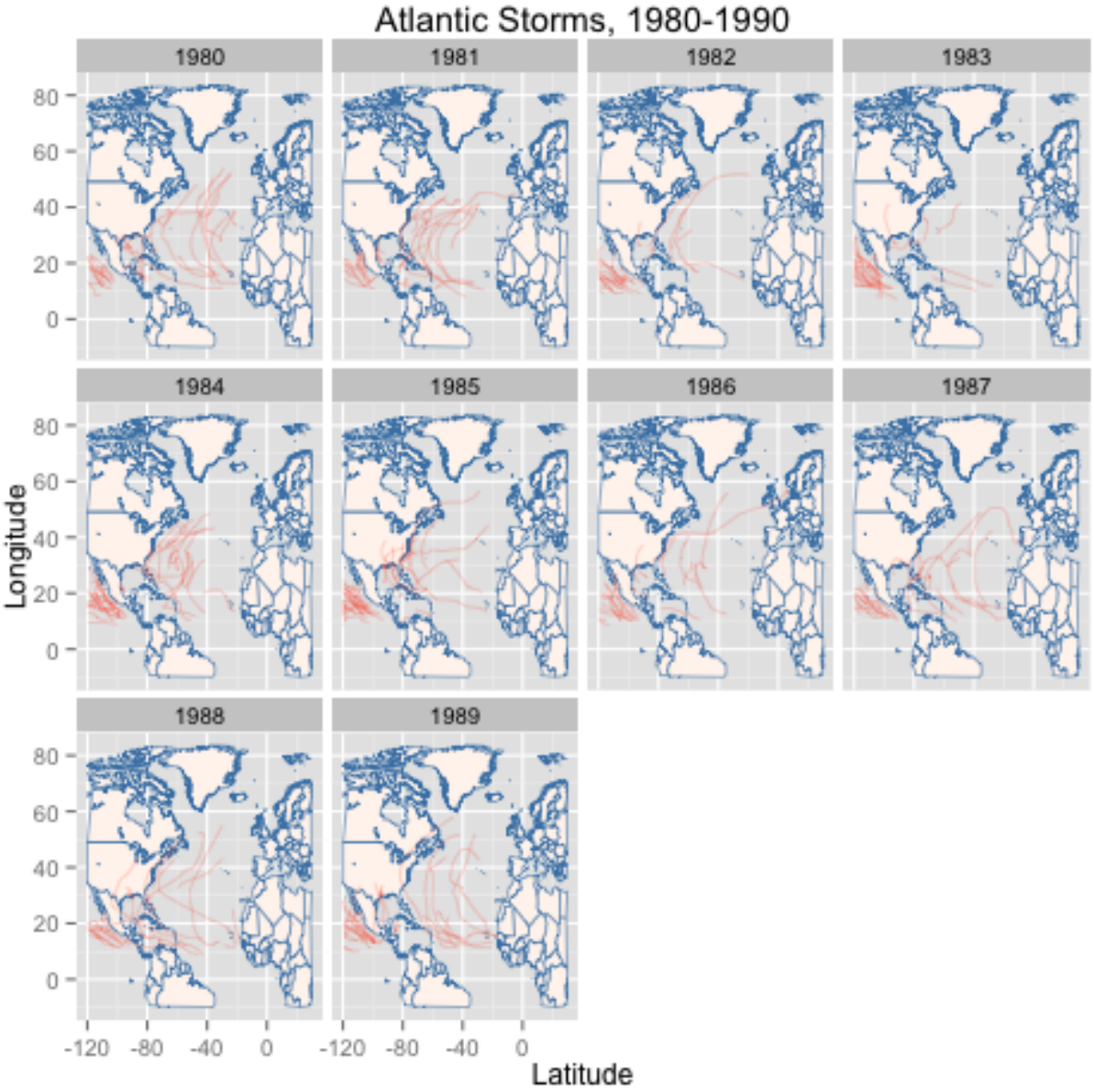
First we will compare the tracks of storms in the Atlantic and the Pacific

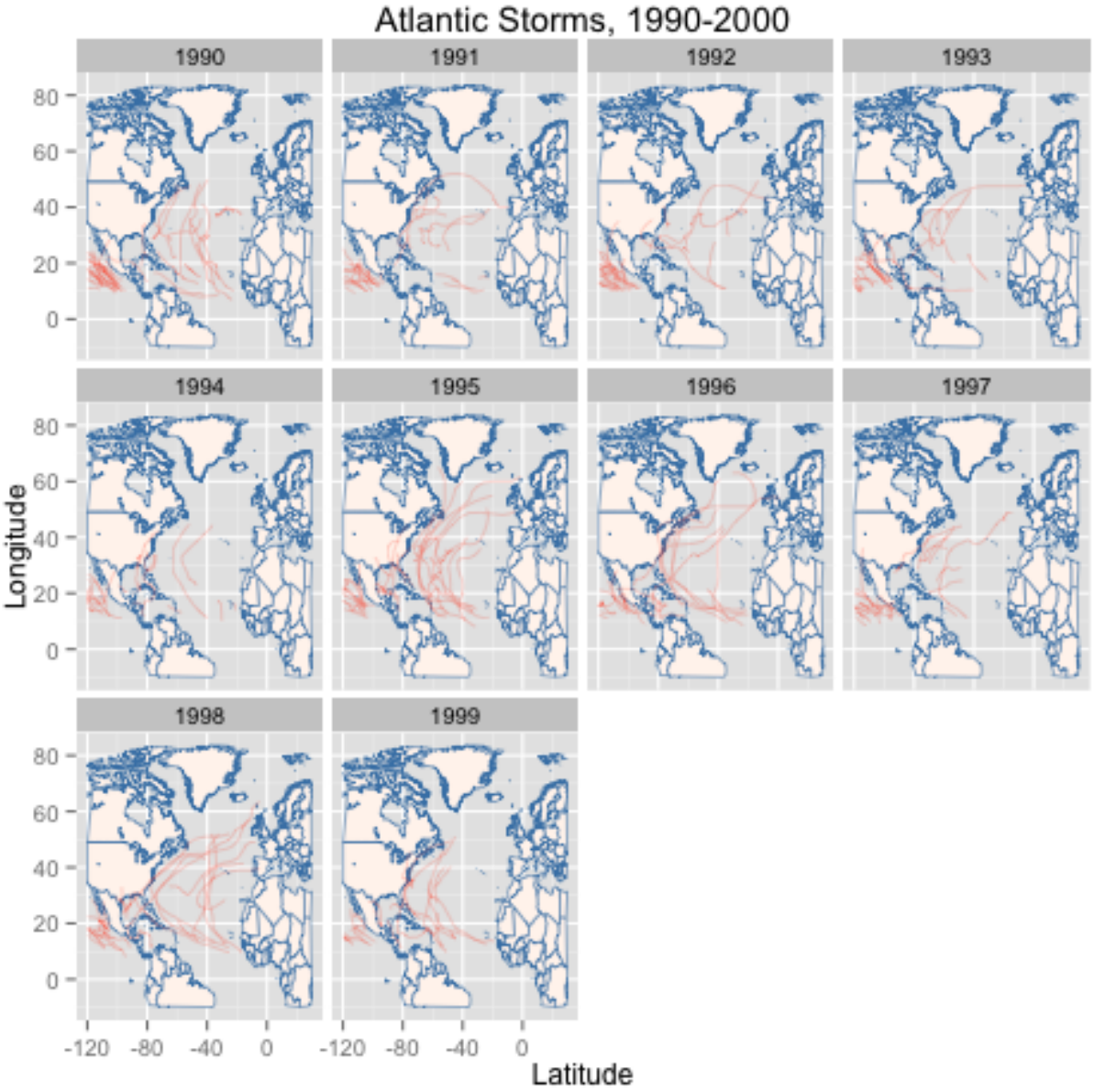

All Atlantic Ocean Storms
80
60
40
20
0
Longitude
-120
-80
-40
0
Latitude

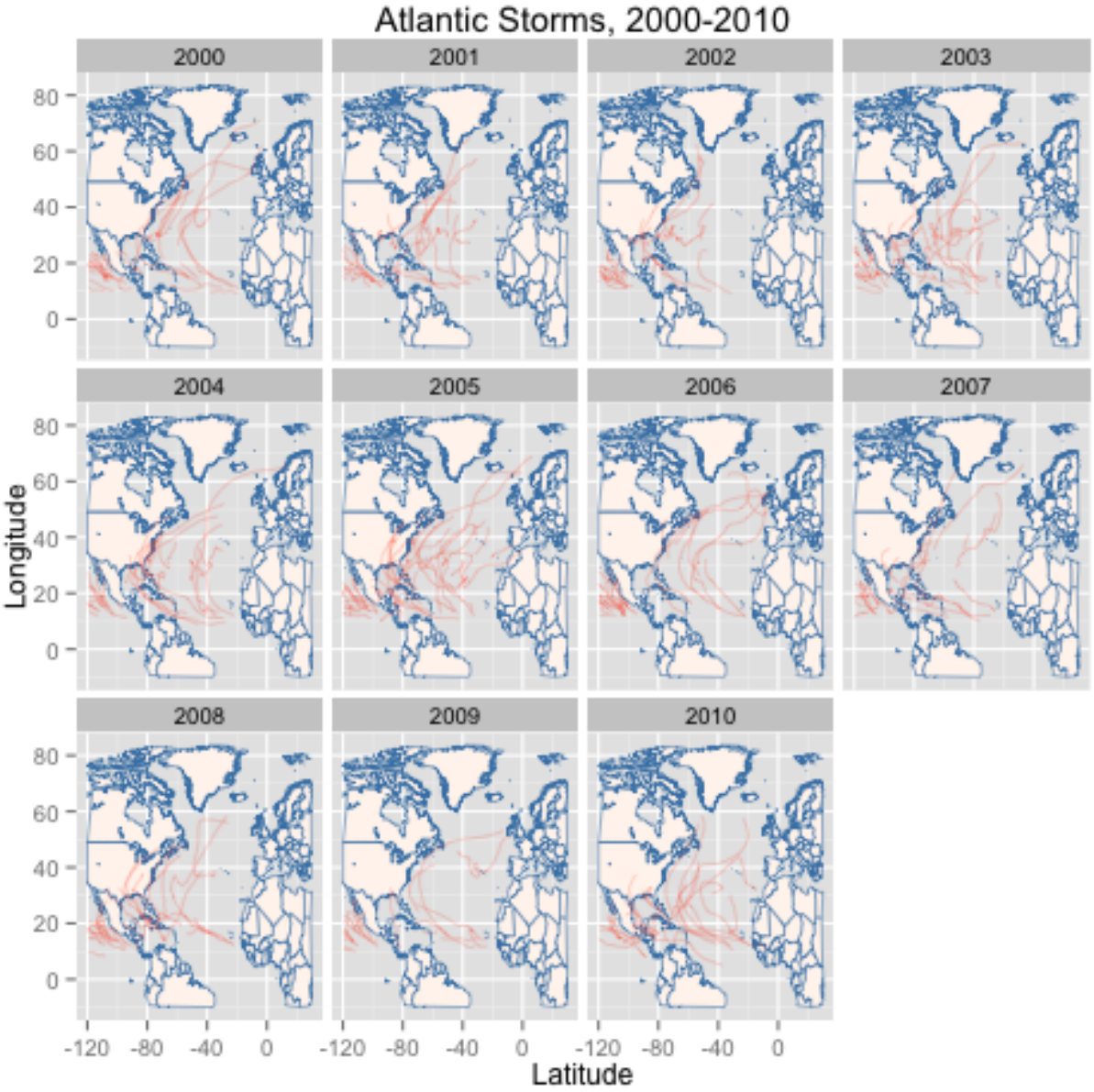


In the Atlantic basin, we see that storms are pretty spread out between the North American and African/European continents. In the Pacific basin, we see that most of the storms are concentrated near the western coast of Mexico, with few moving towards Japan or the western Canadian coast.

Next we will split along basin and compare those storms in each decade to each other, starting with the Atlantic basin

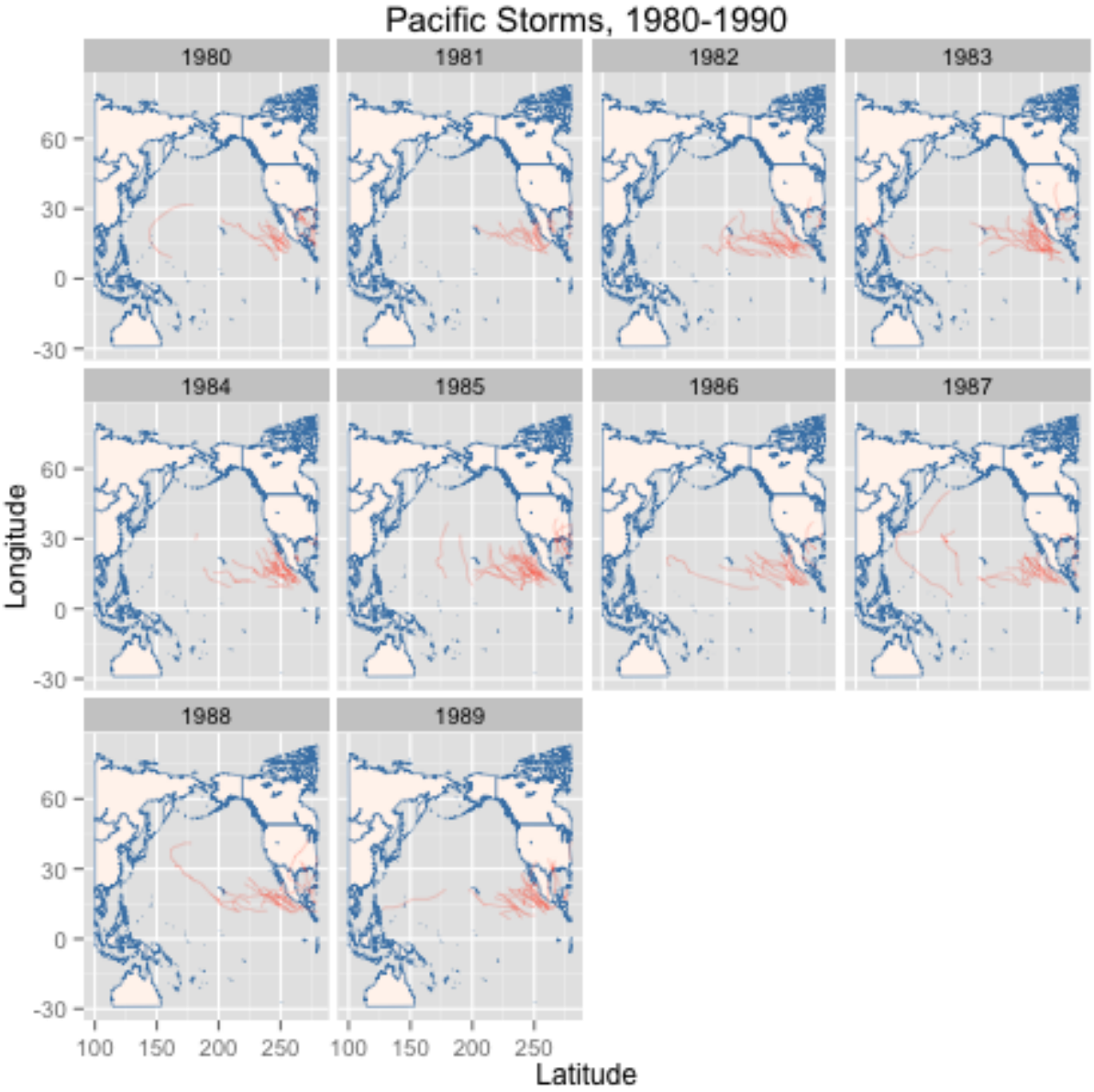

Atlantic Storms, 1980-1990
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
Longitude
Latitude
80
60
40
20
0
-120
-80
-40
0

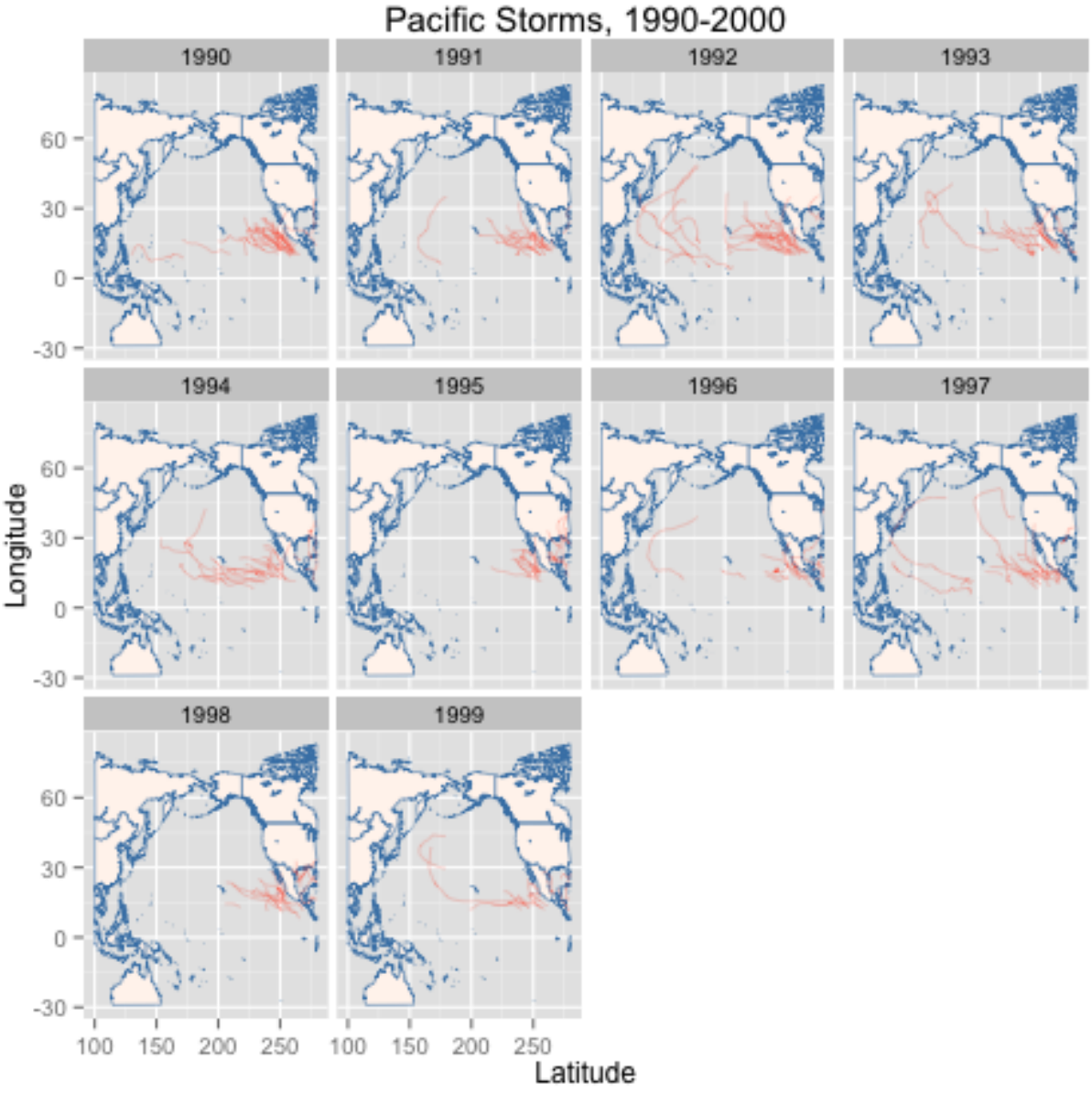

Atlantic Storms, 1990-2000
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
Longitude
80
60
40
20
0
-120
-80
-40
0
Latitude

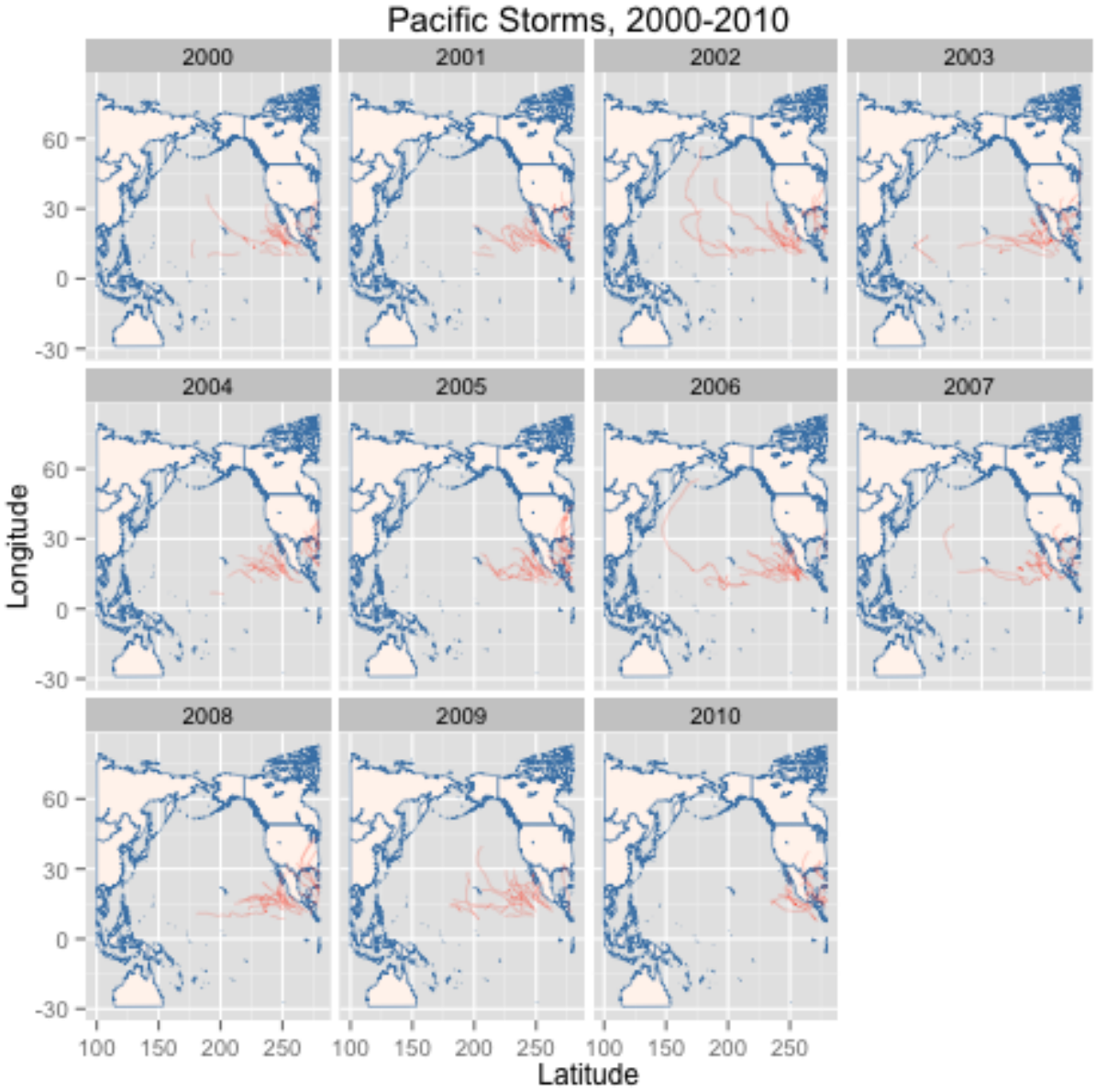


Once again, these plots appear to depict the fact that there have been higher concentrations of storms in the latter decades of our time frame, at least in the Atlantic basin.

Now we compare those in the Pacific basin


Pacific Storms, 1980-1990
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
Longitude
60
30
0
-30
100
150
200
250
Latitude


Pacific Storms, 1990-2000
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
Longitude
60
30
0
-30
100
150
200
250
Latitude



Based on the longer tails, and the higher concentrations, it appears that once again storms have gotten worse in the latter decades of our time frame, this time as manifested in the Pacific basin.

Conclusion

In conclusion, from all the data present, we believe there is sufficient evidence to believe that storms have gotten worse in frequency and intensity in the latter half of the time frame selected. Though it is only a small window, we believe that this effect can be attributed to the rising temperature values of the earth caused by global warming, a fact which bears out by there being both a higher frequency and intensity of storms in the summer months where temperature is the highest.

Extra Credit

Github Repo: https://github.com/PaulKim1995/Final_Project

Social Media Evidence: