# Analysis of Hurricane Frequency and Possible Causes for Fluctuations

Heather Ryan

**Abstract**

This study analyzes hurricane frequencies and whether there is an overall trend that is significantly different from zero. Hurricanes are one of the most threatening natural disasters for the globe, especially regions along the coast. A regression analysis was used to determine if there has been a significant trend in the hurricane frequencies from 1851-2009. A 15-year moving average plot was used to determine if there is a cyclical pattern to the hurricane frequencies. For the time frame for 1851-2009 the best line of fit for the regression plot was not significantly different from zero and therefore there is not a significant increasing or decreasing trend in the overall data set. But, there is a cyclical pattern to the hurricane frequency data indicating that outside forces could play a role in hurricane frequency. More research needs to be done to compare the hurricane frequencies to other forces that may be the cause of the cyclical pattern of the data set.

## Introduction

Hurricanes can cause extremely destructive damage to coastal regions and are responsible for the majority of loss of life caused by natural disasters in the developed world (Emanuel, et. al.). In developing countries, hurricanes are the leading cause of deaths and injuries due to natural disasters (Emanuel, et. al.). Due to this, it is important for meteorologist to be able to determine hurricane paths, frequencies, and intensities, before they hit the coast. In order to do this, an analysis of the hurricanes from the past must first be done. In this paper, the frequency of hurricanes from 1851-2009 will be analyzed to determine if there is an increasing trend in hurricane frequencies and possible causes of the fluctuations in hurricane frequencies will be discussed. There are many possible causes of the fluctuations in hurricane frequency, including, global warming, Él Niño, sea surface temperatures (SST), and wind shear. It is expected that the frequency of hurricanes has increased over the years and that this overall increase is accompanied by a somewhat cyclical pattern, in that there are multiple peaks and troughs.

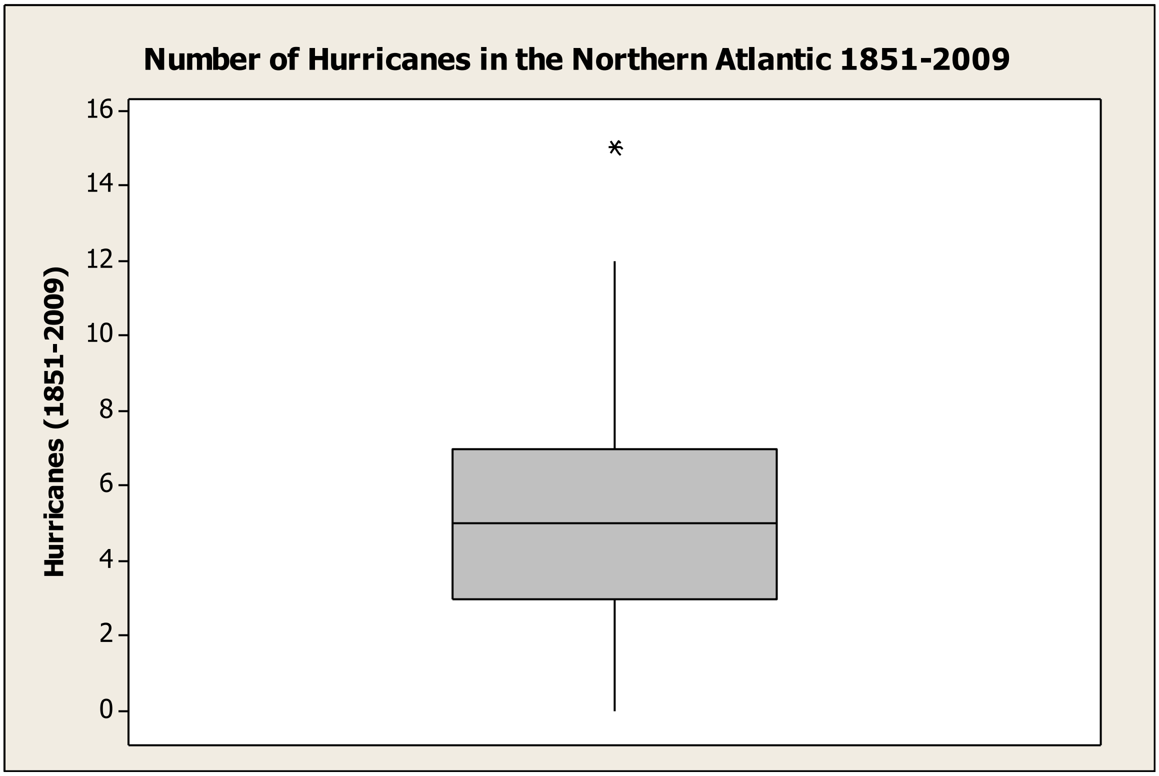
## Method

The data used in this analysis is from the North Atlantic hurricane data base (HURDAT), the revised HURDAT hurricane data for the Atlantic basin. This is the revised, official record of the tropical storms and hurricanes for the Atlantic basin, the Atlantic Ocean, Gulf of Mexico, and Caribbean Sea. Shortly after the end of World War II, around 1945, aircraft observations of tropical storms were used to acquire hurricane data but were ended in the western North Pacific Ocean in 1987. There is a possibility that some hurricanes or tropical storms were still missed using this method. Since 1970 satellites have covered the majority of the globe and have been the primary source for hurricane data (Emanuel, et. al.). The data, before technological advancements such as, the aircraft or satellite collections, was collected by written observations compiled by José Fernández-Partagás. These written observations included lists of tropical cyclones compiled by other authors, books and articles, and general and marine intelligence published newspapers (Fernández-Partagás, et. al.). At first a time series plot was created to determine if there is a trend in the hurricane frequency but due to too much variation in the data and on the graph, a 15-year moving average graph was created to observe if there is a cyclical trend in the data. A regression analysis was performed to determine if the slope of the line from the original time series plot was significantly different from zero.

**Results**

Resistant statistics were used to describe the data because the data is not symmetric. As illustrated in Figure 1 there is an outlier present in the data and therefore the mean of the data does not express the data. As shown in Table 1, the maximum number of hurricanes during this time frame was 15 in 2005 while the minimum was zero for multiple years. The 15 number of hurricanes in one year is also the outlier. The interquartile range of the data is 4 with the first quartile equaling 3 and the third equaling 7. The quartile skew of this middle fifty percent of the data is zero, indicating that the interquartile range is symmetric, even though the entire data set is not symmetric but skewed to the right.

**Figure 1.**




A boxplot of the number of hurricanes from 1851-2009.

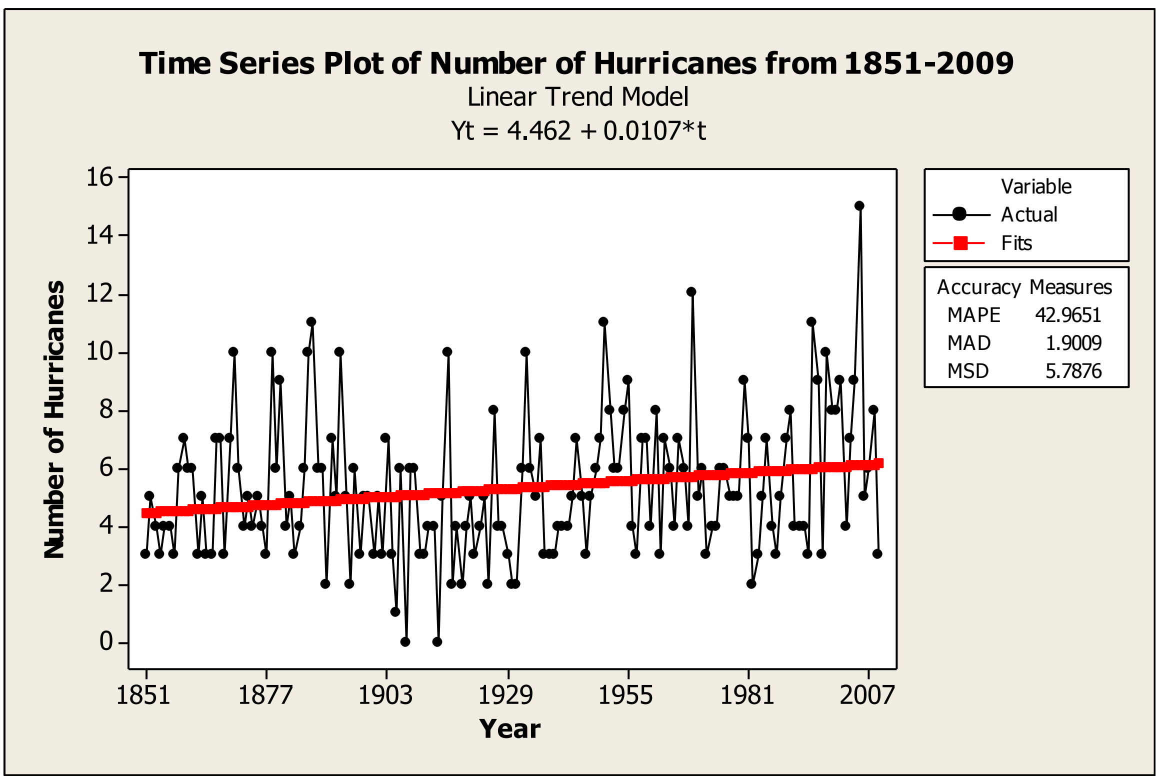
**Table 1.**

| Hurricane Resistant Statistics | |
|---|---|
| Median | 5 |
| Minimum | 0 |
| Maximum | 15 |
| Q1 | 3 |
| Q3 | 7 |
| IQR | 4 |
| Quartile Skew | 0 |

Table of resistant statistics for hurricanes from 1851-2009.

A regression analysis was used to determine if the best line of fit for the time series of number of hurricanes per year plot (Figure 2.) is significantly different from zero. As shown in Table 2, the t-sample is smaller than the t-critical at 156 degrees of freedom and $\alpha=0.05$, therefore the null hypothesis is accepted. The slope of the best line of fit is not significantly different from zero. The frequency of hurricanes is not changing at a significant rate according to this data set. The slight increase in hurricane frequency is also shown in the $R^2$ value on Figure 3. But because the percentage of data points that fall on the best line of fit is only 4.0 %, the best line of fit does not describe the data accurately.

**Figure 2.**



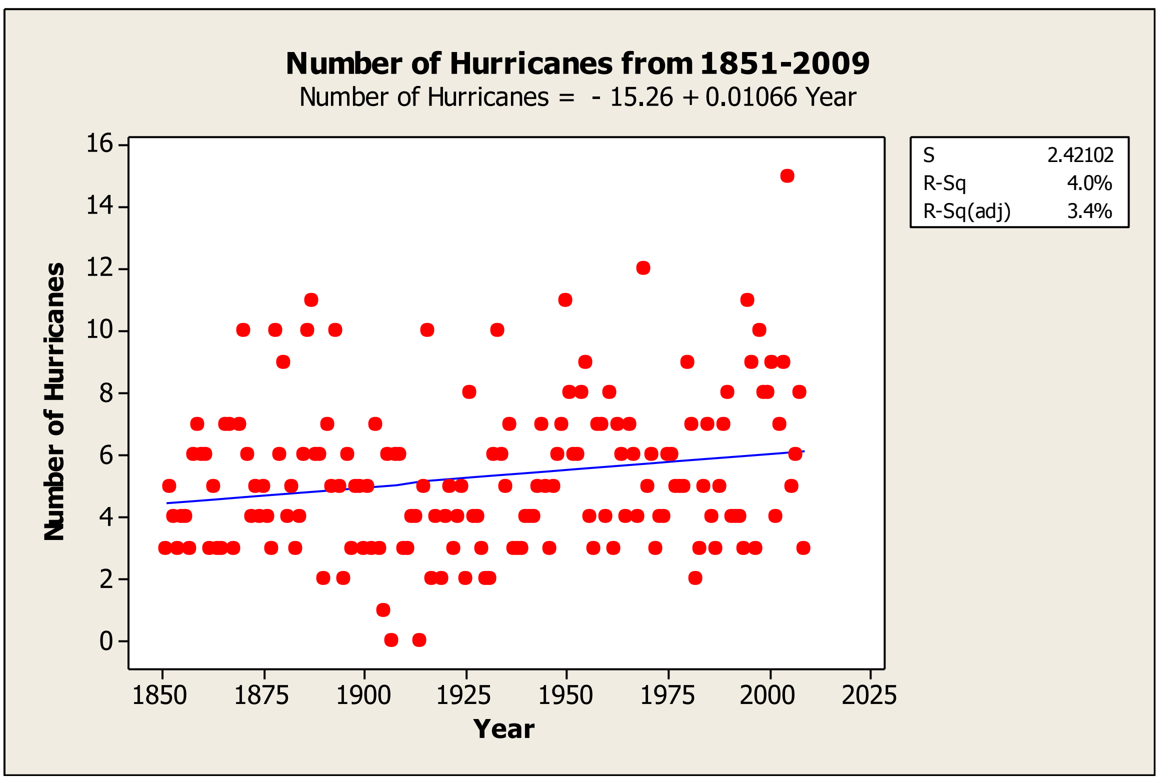

A time-series plot of the number of hurricanes from 1851-2009.

**Table 2.**

| Regression Analysis | |
|---|---|
| $H_0$ | b=0 |
| $H_1$ | b≠0 |
| t-sample | -1.89 |
| t-critical (for v=120) | 1.98 |
| v | 158-2=156 |
| α | 0.05 |

This table contains the information needed to determine if the slope of the best line of fit is significantly different from zero.

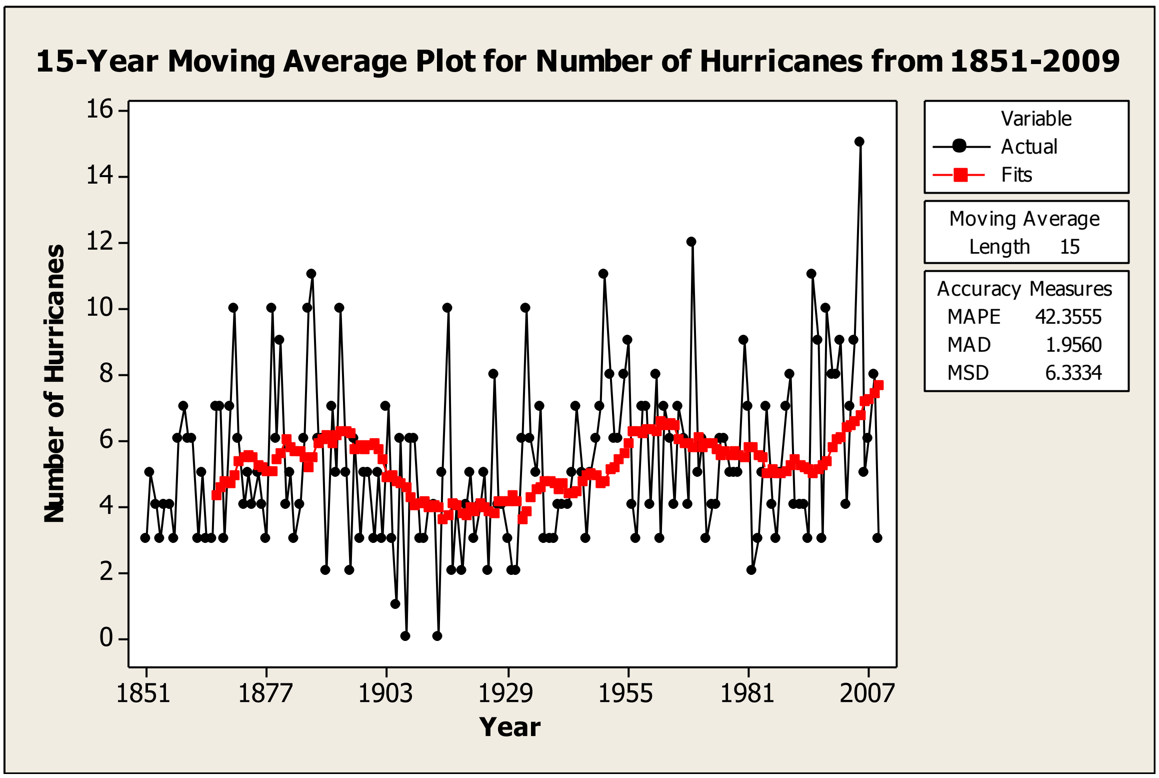
**Figure 3.**




A regression analysis graph, used to determine if the slope of the line is significantly different from zero.

A fifteen year moving average was applied to the frequency of hurricanes data to determine if there is a cyclical pattern to the data. As shown in Figure 4, there does appear to be a cyclical pattern in the hurricane frequency data. This cyclical pattern could be caused by other meteorological phenomenon, such as, sea surface temperature, Él Niño, the sea surface winds, or the higher altitude winds.

**<u>Figure 4.</u>**



## Discussion

This study only scratches the surface of analysis of hurricane frequency and understanding of hurricanes. The only factor taken into account was if there has been an increase in hurricane frequencies over a 158 year time span. In other studies, such as the study done by Fernández-Partagás, a smaller time frame was used which would potentially make the slope either significantly different from zero or not significantly different than zero, depending on what range of data was used. It is also important to take into account that there must be something that is causing these fluctuations and variability in the data. A study done by the Department of Meteorology at Florida State University, analyzed the fluctuations in hurricane frequency in the North Atlantic. In this study, they also analyzed the timing of Él Niño-Southern Oscillation (ENSO) events and what hurricanes took place at this time. They determined that when ENSO is in its Él Niño phase hurricane development is decremented due to increased convection in the central and eastern Pacific creating upper-level convergence at the equator (Elsner). They also determined that the frequency of hurricanes follows a biennial, semidecadal, and near-decadal timescale (Elsner). They determined this through time series analysis and physical reasoning, explaining more of the causation of the fluctuations in hurricane frequency than was done in this study.

Another study addressed that the data for hurricanes is not as accurate in the past as in the present, because satellites that cover the globe have only been in place since 1970 (Emanuel). They analyzed smaller portions of the data and compared the hurricane frequency of the best track of hurricane frequency to the synthetic data used in the reanalysis. It would have been more useful to analyze the data in smaller increments because then it could have been determined if there is an increase in hurricane frequency or not in more recent years. To improve the analysis that I performed, smaller increments of time could be used to determine if there was a certain time frame that an increasing trend in hurricane frequency was occurring. In addition to that, analysis of sea surface temperatures, ENSO events, or surface wind pressures could be added on top of the hurricane frequency analysis. This would begin to determine what causes the fluctuations in hurricane frequencies.

**Conclusion**

Due to the extreme damage that hurricanes can cause to not only the coastal regions but to the people as well, it is imperative to gain a greater understanding of why and when these natural disasters occur. Although there was an increasing trend in the hurricane frequencies of the data, it was not significant enough. This is due to the somewhat cyclical pattern that the hurricane frequency follows. For future study, more analysis will be done on smaller sections of the data to analyze the cyclical pattern and determine if some periods experience greater hurricane frequencies than others. These smaller segments of time to analyze can also aid in determining if more recent years have experienced increased hurricane frequencies and if so what has caused this. Much more research and analysis must be done to be able to understand more of why hurricanes act and strike when they do.

**References**

Elsner, J. B., A. B. Kara, and M. A. Owens, 1999: Functions in North Atlantic Hurricane Frequency. *American Meteorology Society*, 427-437.

Emanuel, K., R. Sundararajan, J. Williams, 2007: Hurricanes and Global Warming. *American Meteorology Society*, 347-367.

Fernández-Partagás, J., H. F. Diaz, 1996: Atlantic Hurricanes in the Second Half of the Nineteenth Century. *Bulletin of the American Meteorological Society*, 2899-2906.

**Appendix**

Descriptive Statistics Minitab Output

### Descriptive Statistics: Year, Number of Hurricanes

```
Variable                N  N*    Mean  SE Mean  StDev  Minimum      Q1  Median
Year                  159   0  1930.0     3.65   46.0   1851.0  1890.0  1930.0
Number of Hurricanes  159   0   5.314    0.195  2.463    0.000   3.000   5.000

Variable                  Q3  Maximum
Year                  1970.0   2009.0
Number of Hurricanes   7.000   15.000
```

| Hurricane Resistant Statistics | |
|---|---|
| Mean | 5.3 |
| Median | 5 |
| Minimum | 0 |
| Maximum | 15 |
| Q1 | 3 |
| Q3 | 7 |
| IQR | 4 |

Regression Analysis of Hurricanes per Year

### Regression Analysis: Number of Hurricanes versus Year

```
The regression equation is
Number of Hurricanes = - 15.3 + 0.0107 Year


Predictor       Coef   SE Coef      T      P
Constant     -15.255     8.076  -1.89  0.061
Year        0.010658  0.004183   2.55  0.012


S = 2.42102   R-Sq = 4.0%   R-Sq(adj) = 3.4%


Analysis of Variance

Source           DF       SS      MS     F      P
Regression        1   38.049  38.049  6.49  0.012
Residual Error  157  920.228   5.861
Total           158  958.277
```

| Regression Analysis | |
|---|---|
| $H_0$ | b=0 |
| $H_1$ | b≠0 |
| t-sample | -1.89 |
| t-critical (for v=120) | 1.98 |
| v | 158-2=156 |
| α | 0.05 |