Seasonal Precipitation Forecasts for Predicting Future Hurricanes and Tropical Storms in the Caribbean Sea

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ABSTRACT

Precipitation is a key factor for large storms, especially tropical cyclones. These tropical systems tend to drop large amounts of rain on an area, if the area is on the precipitation part of the storm (i.e., the northern side of a hurricane where rain bands are very prominent). With the help of hindcast computer models, there should be a much more noticeable amount of precipitation for a season with a lot of storms than a year with none. Examination of the months August and September, which is about midway through the hurricane season in the Atlantic, from 1979 to 2000 should show if our hypothesis was correct or not.

1. Introduction

Hurricanes and Tropical Storms cause large amounts of damage throughout the Atlantic, Gulf of Mexico, and the Caribbean Sea. Usually forming in warm waters, they have extremely fast winds that knock down manmade structures.

However, the real killer and producer of damage is the falling precipitation. As much as 10 inches can fall on an area within a short amount of time. Flooding will destroy more things than wind. Flooding will weaken building foundations, destroy agriculture, weaken hillsides, and saturate the ground on which we walk, thus causing it to be unstable and treacherous.

Motivation for this topic came from a study done by Pitter et al 2002, on seasonal forecasting of hurricanes using sea surface temperatures and the global circulation model. Ongoing research done by Dr. William Gray of Colorado State University (e.g., Gray 1984) also contributed to the motivation. With this motivation and background research, we looked at what parameters, as well as geographic area, on which we could focus.

Since these types of storm systems carry so much precipitation; there should be a way to predict the number of these systems that pass through an area based on precipitation rates. Since the Caribbean covers so much area, tropical systems should be the only main cause from displacement of normal precipitation rates.

With this research and analysis, we will try and develop a seasonal forecast for hurricanes and tropical storms based solely on the yearly average precipitation rate. We hope to also show that years with higher precipitation rates will produce more storms than other years.

2. Method

In order to get the numbers we were going to need to do our analysis, we had to use archived data. The National Weather Service lacked the data we needed, having precipitation rates going back only as far as 2001. Our data had to extend far back enough to be considered a climate. From the example in class, we decided to use the Hindcast model. The Hindcast produced ensemble forecasts over a period of 20 years. It produced these forecasts for up to six months into the future from the time the original run was taken. The output from the model run was a precipitation rate from a certain point that we plugged into the computer.

Since the Caribbean covers such an extensive area, we decided to break it into blocks. The overall region covered was that of 62W to 87W longitude by 12N to 22N latitude. The area was then broken into 25 equally sized grid boxes of 5 degrees longitude by 2 degrees latitude.

The final result was 36 grid points that had a precipitation rate. Using each of these grid points we could then compute the average of the Caribbean for that certain year.

Then based on month, the precipitation rates were plotted on a scatter chart to see how each month acted compared to each other. Also, to create more of a climate scenario two months were averaged together to get an overall picture of that part of the hurricane season for the Caribbean.

3. Data

As stated just above, 36 grid points were averaged per year to get an average total for the Caribbean of that year. These grid points could then be graphed and compared to each other. However, what would we be comparing them to?

The other part of this project, beforehand, is to know if any storms had actually occurred during these 21 years from the months of August to September. Using the National Hurricane Center of archived data, we were able to chart when and where each disturbance happened. Due to the fact that tropical depressions do not have any saved data in the archive, we only have tropical storms and hurricanes.

Listed below are the year, the name of the storm, what month it occurred in, and what its name was.

	1979 Storm Season	
Storm name		**Type of storm**
David	Aug 25 - Sept 7, 79	Hurricane
Frederic	Aug 29 - Sept 14, 79	Hurricane
Henri	Sept 14 - 24, 79	Hurricane

	1980 Storm Season	
Storm name		**Type of storm**
Allen	31 July - Aug 11	Hurricane
Georges	Aug 31 - Sept 8	Hurricane
Hermine	Sept 20 -25	Tropical Storm

1981 Storm Season

Storm name		Type of storm
Dennis	Aug 7 - 21	Hurricane
Gert	Sept 7 - 15	Hurricane

1982 to 1984 No Storms

1985 Storm Season

Storm name		Type of storm
Danny	Aug 12 - 20	Hurricane

1986 Storm Season

Storm name		Type of storm
Danielle	Sept 7 - 10	Trop Storm

1987 Storm Season

Storm name		Type of storm
Emily	Sept 20 - 26	Hurricane

1988 Storm Season

Storm name		Type of storm
Debby	Aug 31 - Sept 8	Hurricane
Gilbert	Sept 8 - 19	Hurricane
Isaac	Sept 28 - Oct 1	Trop Storm

1989 Storm Season

Storm name		Type of Storm
Chantal	July 30 - Aug 3	Hurricane

1990 Storm Season

Storm name		Type of storm
Diana	Aug 4 - 9	Hurricane
Fran	Aug 11 - 14	Trop Storm

1991 to 1993 No Storms

1994 Storm Season

Storm name		Type of storm
Debby	Sept	Trop Storm

1995 Storm Season

Storm name		Type of storm
Marilyn	Sept	Hurricane

1996 Storm Season

Storm name		Type of storm
Dolly	Aug	Trop Storm

1997 No Storms

1998 Storm Season

Storm name		Type of storm
Georges	Sept	Hurricane

1999 No Storms

2000 Storm Season

Storm name		Type of storm
Dolly	Aug	Hurricane

Then the data from all the runs was collected, averaged per month, and then averaged into a season (i.e., August and September).

August 1979 to 2000 Precipitation Rate (mm/s)

1979	4.56E-005
1980	4.02E-05
1981	4.98E-005
1982	2.87E-05
1983	3.75E-05
1984	4.60E-05
1985	3.75E-05
1986	3.75E-05
1987	3.03E-05
1988	4.20E-05
1989	4.75E-05
1990	3.37E-05
1991	2.77E-05
1992	3.26E-05
1993	4.02E-05
1994	2.92E-05
1995	4.12E-05
1996	4.35E-05
1997	3.13E-05
1998	4.44E-05

1999	5.70E-05
2000	3.90E-05

From the hurricane and tropical storm chart, you can view that August has 10 named storms that began, ended, and passed through the Caribbean. Looking at the data even closer it is easy to see that the rainfall rate is not uniform from year to year. It does not consistently increase or decrease. Instead, it acts like a wave function.

September 1979 to 2000 Precipitation Rate (mm/s)

1979	4.72E-05
1980	5.80E-05
1981	5.06E-05
1982	3.42E-05
1983	4.76E-05
1984	4.61E-05
1985	3.78E-05
1986	3.78E-05
1987	3.40E-05
1988	5.21E-05
1989	5.21E-05
1990	4.47E-05
1991	3.02E-05
1992	3.58E-05
1993	3.44E-05
1994	4.10E-05
1995	4.17E-05
1996	4.08E-05
1997	3.53E-05
1998	4.52E-05
1999	6.54E-05
2000	4.34E-05

From the hurricane and tropical storm chart September can be shown as the much more active month than August. This makes sense because September is at about the prime of the hurricane season, and September 10 is considered by many to be the peak day. One can only expect to see the number of tropical systems increase as time gets closer to this month.

Viewing the actual precipitation charts it can also be noted, since all figures are a multiple of 10E-05 mm/s, that the rates for September are also higher.

Once again, we are trying to prove that the more precipitation that an area gets, the more active the named storm season shall be.

4. Analysis

The following statements were just conclusions from gathering of data. They were initial findings from the viewing of the precipitation rates compared to the number of storms.

In order to prove our hypothesis right or wrong, we must actually analyze our data.

Looking at Fig. 1, the chart on the next page is the August precipitation rates over the past 20 years. After analyzing the general flow, a trend line was added to see if precipitation rates were increasing or decreasing. In the case of August, precipitation rates increase over the years. They do not increase by much, but they still do.

Even though there is a general increase with the amount of precipitation, referring back to the years of storm activity, you should be able to see that August was much more active ten years ago than it is now. Between 1979 and 1990 there were two years where those years record two named storms. Looking further, seven of the ten named storms were recorded during those years.

Drawing from this, there is an increase in precipitation, but it cannot be found to be the result of hurricanes or tropical storms

Moving onto Fig. 2, September precipitation rates have an opposite trend than August precipitation. Instead of a gentle increase, the precipitation rates decrease by a small increment.

Still, September precipitation rates need to be analyzed to see if there is any relationship between its storms and the amount of precipitation received by the Caribbean Sea.

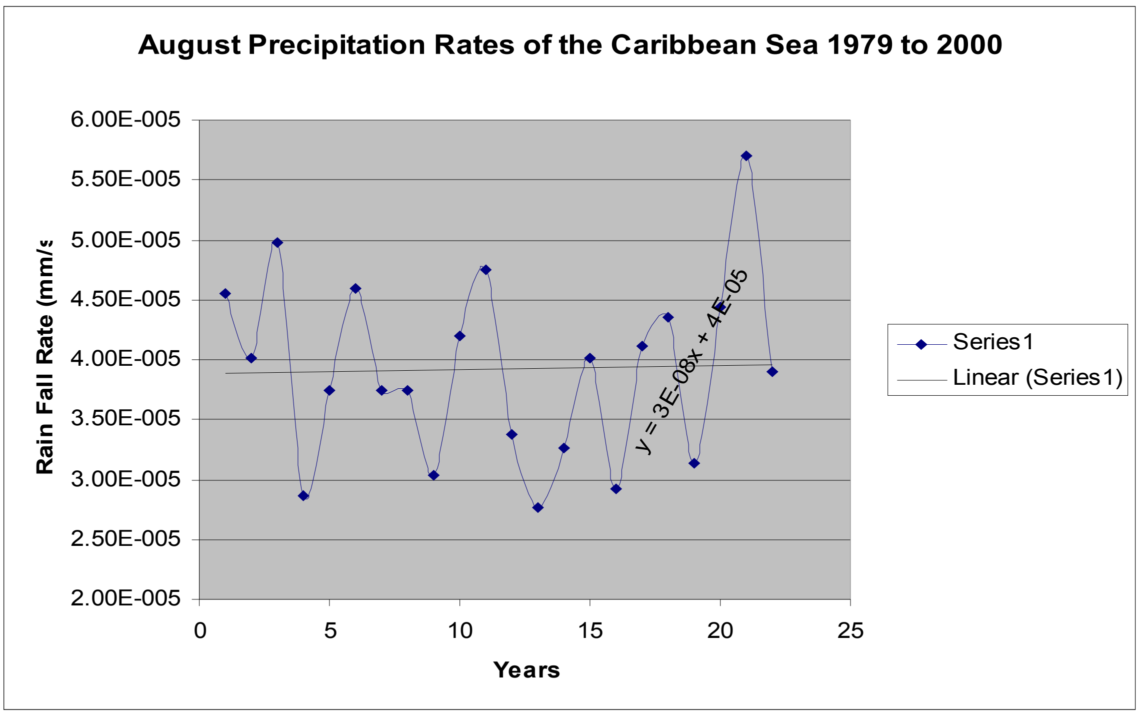

FIG. 1. August Precipitation Rate. Average values of precipitation are shown by the blue curve. The black trend line shows a somewhat consistent wave pattern of rainfall in the Caribbean.

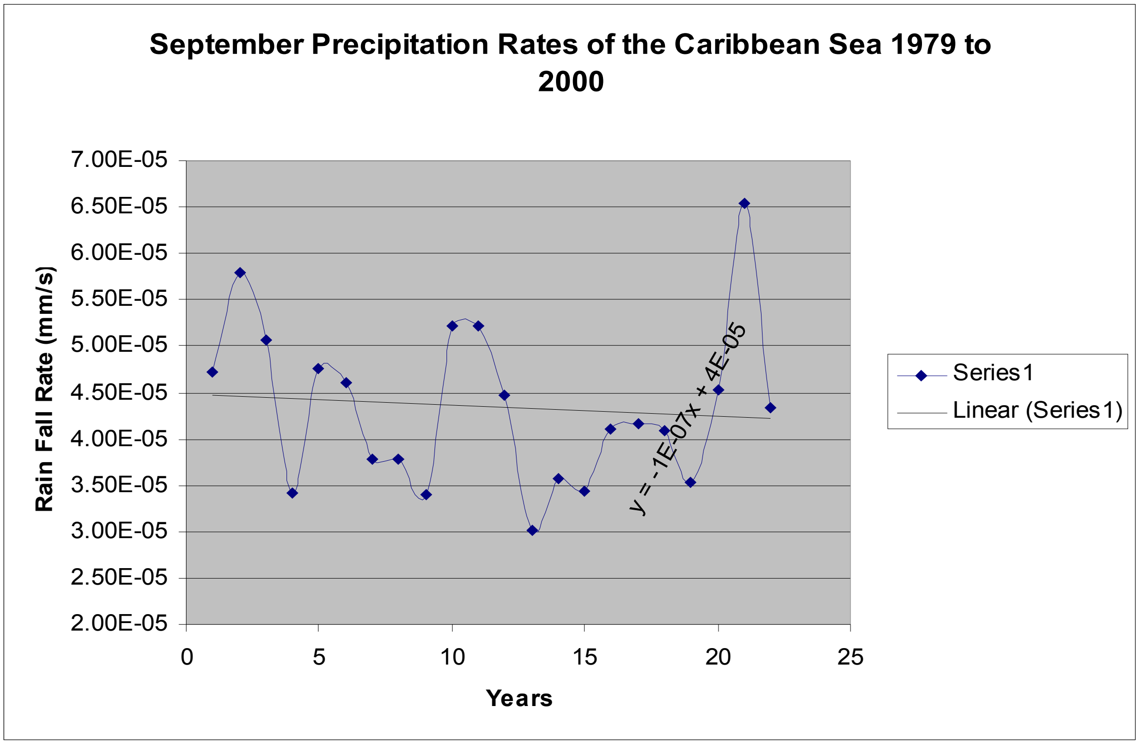

FIG. 2. September Precipitation Rate. Average values of precipitation are shown by the blue curve. The black trend line shows a somewhat consistent wave pattern of rainfall in the Caribbean.

September has had a total of 12 tropical systems pass through the Caribbean during 1979 and 2000. Most of those (9) passed on through before 1990. The recent decline in precipitation could be due to the lack of "big" storms in the Caribbean.

Even though that looks like enough evidence to say there is a relationship between number of storms and precipitation, at least in the month of September, we have not looked at other years. What about those years with no storm reports? What was the total amount of precipitation in this case? Will there be a significant drop in the amount of precipitation seen by the Caribbean?

There is simply only one way to find out.

First, looking back at Fig. 1, if you were to place the storms system chart and the precipitation rates side by side, you could check off what each year's total precipitation rate was, even the years with no storms. Taking that new idea and making it better, place it next to the graph of the precipitation rate for each year. Ultimately you will see that, for August at least, that there is no actual pattern.

For the years that had storms, only seven of them were above the trend line, while six were below it. Also note, this is for every storm, not just the ones in August.

Does September act differently? Looking at September the evidence is exactly the same. Seven storms are above the trend line while six remain below.

Some people might argue there is still a chance of a relationship between the two. The one last way to see is to combine both months into a seasonal average. With this we will see how the climate acts. Fig. 3 is where the climate average precipitation can be found for the Caribbean Sea. It has the nearly the same trend that both August and September have.

Now, instead of just looking at which storm years were above the trend line and which ones were not, we will look more at where the high storm precipitation rates ended up compared to years were no storms occurred. Going back to our hypothesis, we said that years with more named storms should receive more precipitation.

It is now time to classify what makes a year a high storm amount year. A high storm amount (H) is a year in which two or more named storms pass through the Caribbean. A year is classified as low if no named storms pass through the Caribbean during our designated time.

Back to the graphs, on Fig. 3, you should be able to plot high storm amounts as well as low storm amounts. All in all there should be four H's and nine L's. Viewing the graph that was just made it is easy to tell that there are no H's at the peaks of the precipitation rates, however, at two peaks, there are L's. Meaning, even though that area received no named storms, it was still able to receive a large amount of precipitation.

All the other years that were not marked were years that had only one named storm move through the Caribbean Sea. As you can also tell, the highest peak of precipitation was a year in which no named storm was reported.

The last area of analysis involved the spatially averaged precipitation and how much variance there was in these values. Variance is a way of showing how similar or how different the values are in each set of monthly values. Variance is found by squaring the individual values of standard deviation, averaging them spatially, and then taking the square root of each average. By adding and subtracting this value to the spatially averaged precipitation, we could show the variance graphically. Looking at Fig. 4, the bars show the variance of precipitation values in the Caribbean for August of each year. The same is done for September in Figure 6. Taking a look at both of these graphs, we noticed that, in general, the variance for September was more than the variance for August.

Both of these were compared against the number of storms for August (Fig. 5) and September (Fig. 7), respectively. When comparing the graphs side by side, it can be seen that there is no clear relationship present. Most of this is due to the fact that the variance amount, as shown by the bars, was fairly consistent from year to year. There were a few exceptions to this, however. One example is August of year 20, or 1998, had a large amount of variance, but the previous year had a small variance, in fact, the smallest during the entire period. Based on this information, a relationship between rainfall variance and number of storms was inconclusive.

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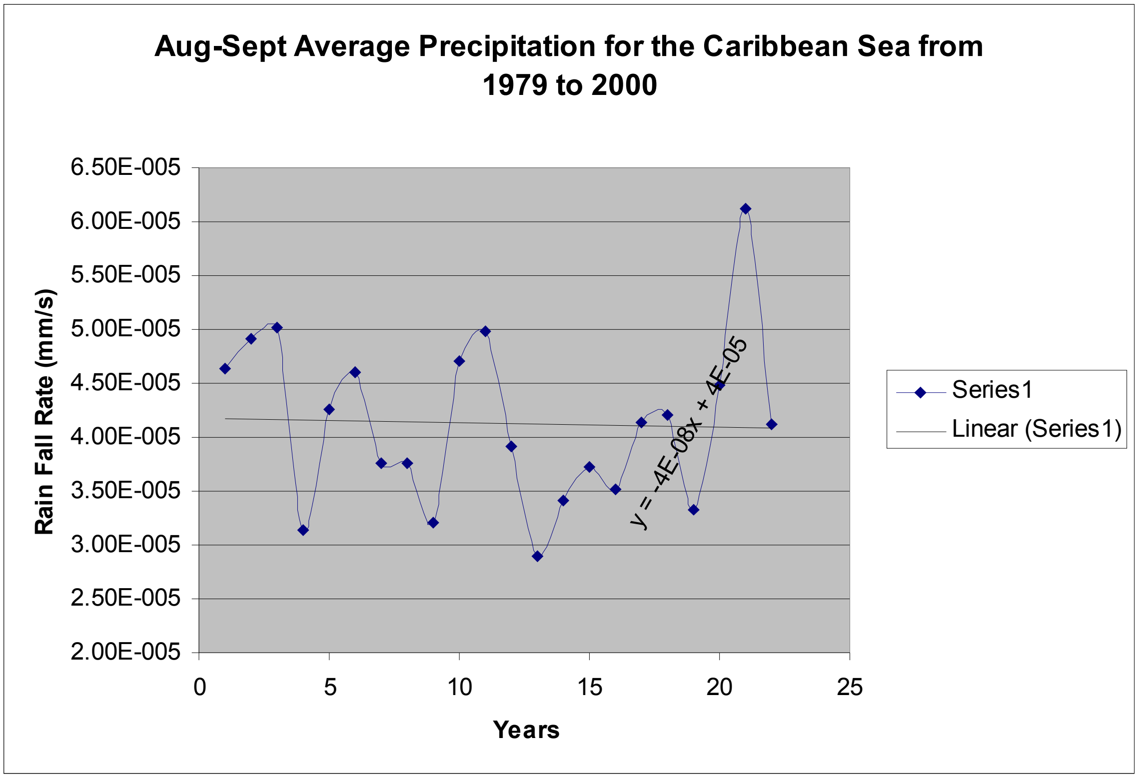

FIG. 3. Climate average precipitation rate. Average values of precipitation are shown by the blue curve. The black trend line shows a somewhat consistent wave pattern of rainfall in the Caribbean.

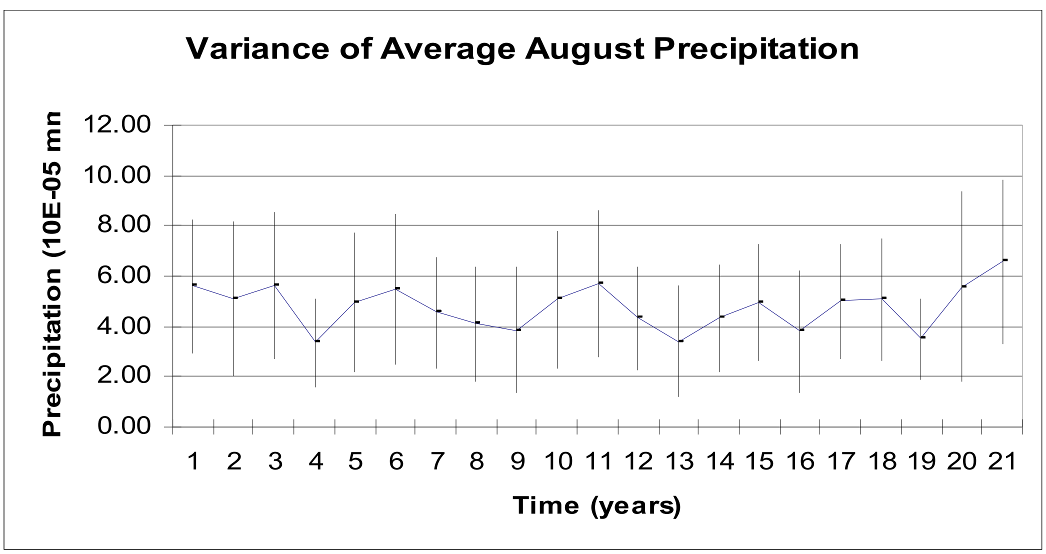

FIG. 4. Spatially-averaged precipitation with variance bars. The values of average precipitation are shown with a blue line, while the variance values for each year are denoted by the vertical bars.

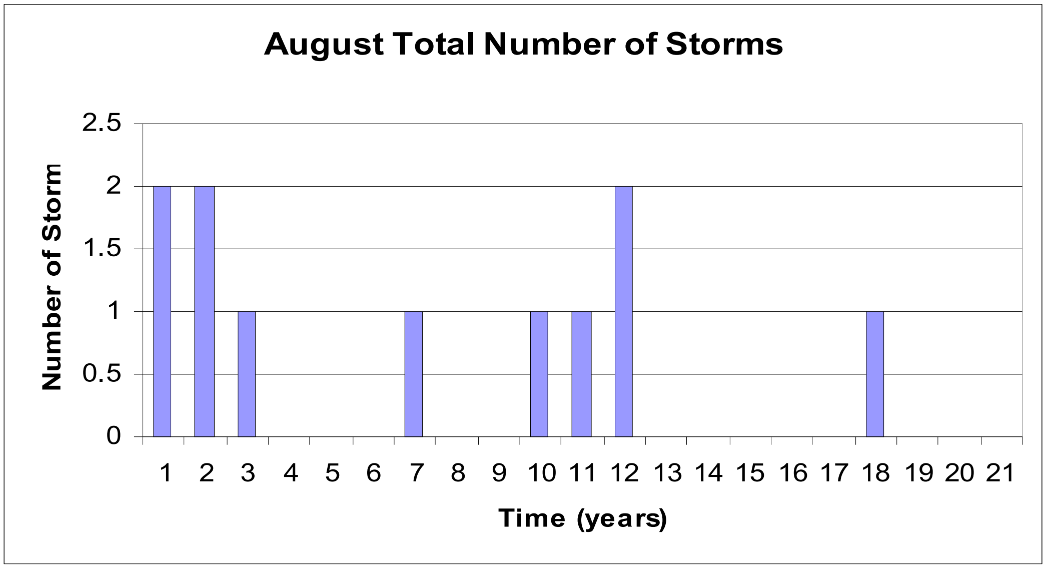

FIG. 5. Total number of named storms for August. This was compared against Fig 4 to find a possible relationship between variance and number of storms.

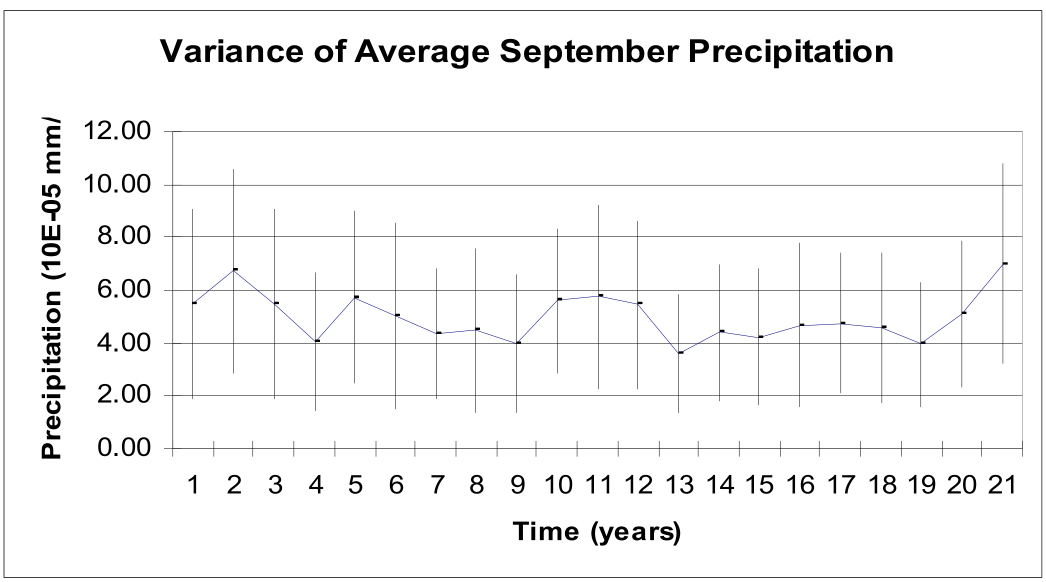

FIG. 6. Spatially-averaged precipitation with variance bars. The values of average precipitation are shown with a blue line, while the variance values for each year are denoted by the vertical bars.

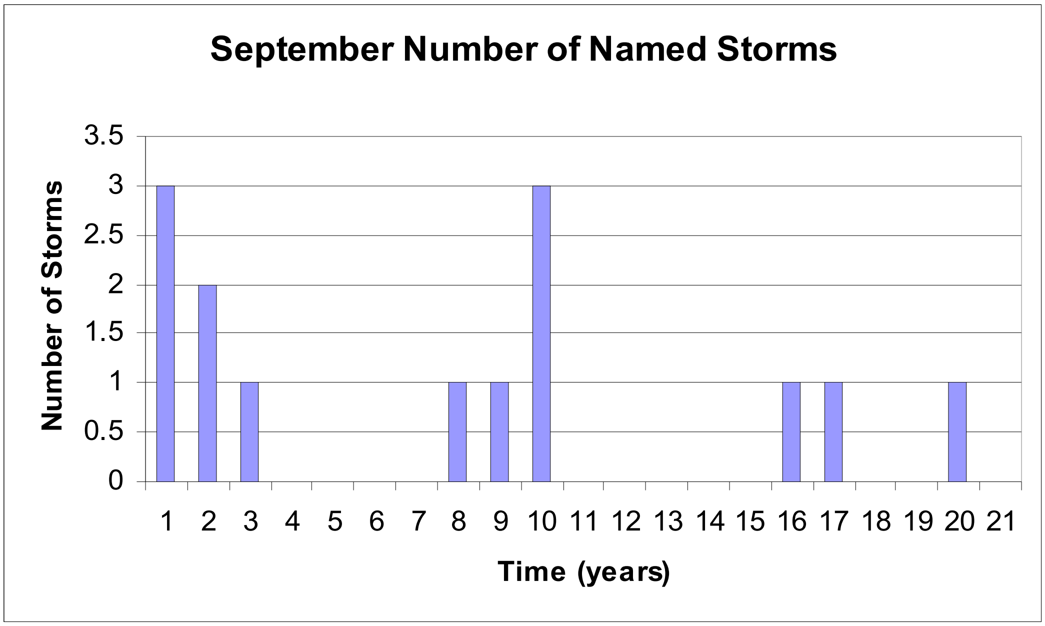

FIG. 7. Total number of named storms for September. This was compared against Fig 6 to find a possible relationship between variance and number of storms.

From all of the analysis done, it appears that there is no relationship between precipitation rates and named storms.

5. Conclusions

From the analysis done above there can be no known relationship between the amount of precipitation the Caribbean sees and the amount of named storms that passed through during these two months.

Reasons why our hypothesis was wrong can be looked at. First, the area we covered is one of the wettest places on earth. Rain totals from islands surrounding the Sea measure at almost three to four meters a year. A single event of six to 10 inches is not going put a huge mark into the yearly totals.

Second, a lot of storms do pop up in the Caribbean that can never make it to tropical storm strength or higher. Using a somewhat confined area such as the Caribbean limited the dataset that could be used in this study. There are many other factors that determine whether or not a storm will grow to such a large and devastating size. Factors such as sea surface temperature, which really would not be a problem in our area. Wind though, is a main reason for the dismantling of storms. 200mb wind shear can tear the tops off of forming storms so fast they can never fully develop.

As for now, using the instruments and models that are available, it seems quite impossible to predict strong tropical systems based off of just precipitation rates.

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