Central America/Caribbean Landfall Probability Calculations

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A webpage that displays the probabilities of a tropical cyclone passing with 50 and 100 miles of various islands and landmasses in Central America and the Caribbean has recently been developed. Most individuals who live in Central America and in the Caribbean are unaware of the statistical chances of tropical cyclones passing within specified distances of their area in any particular year. This webpage is a joint project between the Tropical Meteorology Project at Colorado State University (CSU), Fort Collins, CO and the GeoGraphics Laboratory at Bridgewater State College, Bridgewater, MA.

## 1. Introduction

Probabilities of tropical cyclones passing within 50 and 100 miles of various islands and landmasses in Central America and the Caribbean have been calculated based upon climatological data over the period from 1900-2000. These probabilities are available for named storms (tropical cyclones with maximum sustained winds >= 39 mph), hurricanes (tropical cyclones with maximum sustained winds >= 74 mph) and major hurricanes (tropical cyclones with maximum sustained winds >=111 mph). All calculations were made using the ArcMap GIS software created by the Environmental Systems Research Institute (ESRI).

## 2. Calculating Probabilities

To calculate the probability of tropical cyclones passing within 50 and 100 miles of an island or landmass, several steps were required. First of all, the National Hurricane Center's best track dataset was downloaded in GIS format from the following website: http://maps.csc.noaa.gov/hurricanes/data/atl_hurtrack.zip. This dataset provides the best estimate at each six-hour interval of a tropical cyclone's position and intensity for every storm occurring in the Atlantic basin since 1851. An individual island or landmass was then selected using the country data available in ArcMap. Then, all tropical cyclones that tracked within 50 and 100 miles of each island or landmass were selected. Finally, each storm's maximum intensity when it was within 50 or 100 miles of an island or landmass was assigned as that storm's intensity while it was near the area in question. Figure 1 displays the tracks of all storms that passed within 50 miles of Barbados between 1900-2000, while Table 1 displays the maximum intensity of each storm within 50 miles of Barbados for the period between 1900-2000.

Figure 1: Tracks of all tropical cyclones while they were within 50 miles of Barbados over the period from 1900-2000.

Table 1: Maximum intensity for each tropical cyclone while it was within 50 miles of Barbados over the period from 1900-2000.

| Year | Month | Day | Name | Intensity (knots) |
|---|---|---|---|---|
| 1901 | 7 | 5 | Unnamed | 35 |
| 1916 | 7 | 12 | Unnamed | 35 |
| 1916 | 8 | 13 | Unnamed | 45 |
| 1917 | 9 | 20 | Unnamed | 40 |
| 1918 | 8 | 1 | Unnamed | 35 |
| 1918 | 9 | 9 | Unnamed | 35 |
| 1924 | 8 | 17 | Unnamed | 35 |
| 1931 | 8 | 16 | Unnamed | 35 |
| 1931 | 9 | 5 | Unnamed | 35 |
| 1941 | 9 | 23 | Unnamed | 40 |
| 1942 | 8 | 21 | Unnamed | 35 |
| 1943 | 10 | 11 | Unnamed | 45 |
| 1944 | 8 | 17 | Unnamed | 45 |
| 1949 | 8 | 31 | Unnamed | 45 |
| 1954 | 10 | 5 | Hazel | 60 |
| 1955 | 9 | 22 | Janet | 105 |
| 1958 | 8 | 30 | Ella | 35 |
| 1963 | 9 | 25 | Edith | 85 |
| 1966 | 9 | 29 | Judith | 45 |
| 1970 | 8 | 20 | Dorothy | 60 |
| 1974 | 10 | 1 | Gertrude | 40 |
| 1980 | 8 | 4 | Allen | 110 |
| 1987 | 9 | 21 | Emily | 40 |
| 1988 | 10 | 14 | Joan | 40 |
| 1994 | 9 | 10 | Debby | 45 |
| 1995 | 9 | 14 | Marilyn | 70 |

### A. Calculating historical probabilities

The total number of named storms, hurricanes and major hurricanes that passed within 50 and 100 miles of each island or landmass over the period from 1900-2000 were tabulated, and probabilities were derived from this information. For example, for Barbados, 26 named storms, 4 hurricanes and 2 major hurricanes passed within 50 miles of the island from 1900-2000. In calculating the probability for any particular year, one must consider that some years in the past had more than one storm approach the area. For example, the 26 named storms that passed within 50 miles of Barbados did so during 23 years. To approximate the future likelihood of storms, a Poisson regression model was used. Analysis of the numbers of landfalling tropical cyclones over the last century shows that landfalling frequency very closely conforms to a Poisson distribution. The formula for the Poisson distribution is as follows:

$$EP = (e^{-p}) (p^{x}) / x!$$

Where: EP = Expected Probability

p = Annual average number of tropical cyclones that have occurred in the past 100 years

x = Number of storms expected in the upcoming year based on the Poisson formula

x! = Factorial. If x = 3, then x! = 3*2*1 = 6

If x = 4, then x! = 4*3*2*1 = 24

e = 2.71828

For example, the Poisson-derived Expected Probability (EP) of exactly one named storm passing within 50 miles of Barbados where 26 named storms were associated with this criteria over the past 100 years (p = 0.26) is calculated as follows:

$EP = (e^{-p}) (p^{x}) / x!$ (Poisson formula)

$p = 0.26; x = 1$

$EP = (e^{-0.26})*(0.26^{1})/1!; 1! = 1$

$EP = 0.77*0.26$

$EP = 0.20$ or 20%

Therefore, the probability of exactly one named storm tracking within 50 miles of Barbados in an average year is 20%.

Likewise, for the probability of exactly two named storms tracking 50 miles of Barbados, the calculation would be made as follows:

$EP = (e^{-p}) (p^{x}) / x!$ (Poisson formula)

$p = 0.26; x = 2$

$EP = (e^{-0.26})*(0.26^{2})/2!; 2! = 2$

$EP = 0.77*0.07/2$

$EP = 0.03$ or 3%

Therefore, the probability of exactly two storms tracking within 50 miles of Barbados in an average year is 3%.

Similar calculations can be made for other numbers of tropical cyclones (i.e., 0, 3, 4, etc.) tracking within 50 miles of Barbados.

**B. Calculating 50-Year Probabilities**

Fifty-year probabilities of major hurricanes tracking within 50 miles of each island or landmass have been provided because most structures are built to last at least 50 years, and construction decisions on the cost of hurricane-protecting building materials should be based on the longer period. All other fifty-year probabilities (e.g., named storm and hurricane) are near 100% for most islands and landmasses, so they have not been included.

The 50-year probability is calculated by taking the individual year climatological probability into account and then using a binomial distribution. For Grenada, the 50-year probability of a major hurricane tracking within 50 miles of the island based on 20$^{th}$ century data (individual year probability is 2%) is calculated as follows (using decimals for all calculations, i.e. 2% = 0.02):

$$\text{50-Year Prob.} = 1 - (1 - \text{One-Year Prob.})^{50}$$
$$= 1 - (1 - 0.02)^{50}$$
$$= 1 - (0.98)^{50}$$
$$= 1 - 0.37$$
$$\text{50-Year Prob.} = 0.63 \text{ or } 63\%$$

Therefore, one would expect a 63% chance of a major hurricane being within 50 miles of Grenada over a 50-year period.

The probability of a tropical cyclone impact grows considerably as the number of years increases. The example below shows the growth of individual-year probabilities when 1, 5, 10, 25, 50 and 100-year periods are considered for near-climatological conditions.  For ease of comparison, probabilities of a major hurricane within 50 miles of Grenada will be calculated.

1-Year Prob. = 1 - (1 - 0.02)$^{1}$ = 0.02 or 2%
5-Year Prob. = 1 - (1 - 0.02)$^{5}$ = 0.10 or 10%
10-Year Prob. = 1 - (1 - 0.02)$^{10}$ = 0.18 or 18%
25-Year Prob. = 1 - (1 - 0.02)$^{25}$ = 0.40 or 40%
50-Year Prob. = 1 - (1 - 0.02)$^{50}$ = 0.63 or 63%
100-Year Prob. = 1 - (1 - 0.02)$^{100}$ = 0.87 or 87%

## 3. Current-Year Probabilities

Current-year probabilities were calculated by simply multiplying climatological probabilities by the predicted Net Tropical Cyclone Activity value divided by 100.  We have shown in several papers that from a long-term perspective, more active tropical cyclone seasons have more United States landfalls.  Also, more active Atlantic basin hurricane seasons tend to have more activity in the Caribbean.

If the predicted NTC value for a given year was 130 (seasonal forecast is to have 130% of tropical cyclone activity compared to the average season), all values would be multiplied by 1.3.   Storm number values were multiplied by the NTC factor, and then these revised values were fit to the Poisson distribution.

## 4. Conclusions

To our knowledge, this is the first website available that provides probabilities of storms tracking within 50 and 100 miles of Caribbean islands and Central American landmasses and adjusts them based on the current global climate features and their projected effects on the upcoming hurricane season.

These webpages allow residents living in these areas to learn of the probabilities of being impacted by a tropical cyclone in any particular year.  This information should be valuable for residents, emergency managers, local governments, insurance companies, business groups and others.