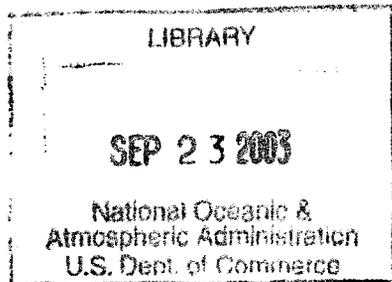


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OF PORTO RICO**

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ON THE FREQUENCY OF HURRICANES IN THE VICINITY OF PORTO RICO

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How often may we expect a hurricane in the vicinity of Porto Rico?

- (1) Of great intensity, such as the storm of August 8, 1899 (San Ciriaco)¹ or of September 13, 1928 (San Felipe)².
- (2) Of the second order of intensity, such as the storm of August 22, 1916 or of July 23, 1926.
- (3) Of a mild type, such as the storm of September 10, 1921 or of August 29, 1924.

On first thought an answer to these questions may seem to be simply a matter of searching the annals of Porto Rico and noting the frequency of occurrence of storms of great violence. The problem is not so simple however. References to storms in available historic records are often very fragmentary and very misleading. Estimates of loss of life and extent of property destroyed are contradictory, even in the case of storms of such recent occurrence as 1899 and 1928. Official records of wind velocity and of barometer readings are entirely lacking, prior to 1875.

Bulletin No. 32² of the United States Weather Bureau contains a list of forty-four hurricanes of more or less violence occurring in the vicinity of Porto Rico from 1515 to 1899. In most cases cited there is not sufficient evidence to classify the storm on a basis of intensity.

It is only since 1898, when the United States Weather Bureau established a series of storm warning stations in the West Indies, that we have sufficiently detailed information available about these storms to enable us to arrange them satisfactorily, in accordance with their extent and intensity.

Incomplete as the list of storms prior to 1898 is, we may safely use it to determine the distribution of storms through the year. Combining the two periods we find that hurricanes occurred in the

¹ The Saints Days upon which the storms passed over Porto Rico.

² Alexander, W. H.: Hurricanes. United States Weather Bureau. Bul. 32, 1902.

vicinity of Porto Rico during the period from 1515 to 1929 with the following monthly frequencies:

Storm Frequencies by Month

June	July	August	September	October
1	9	23	25	6

The only June hurricane recorded in a period of four hundred years in the vicinity of Porto Rico occurred in 1780, and the meagre description leaves us in doubt as to the character of the storm. Hence we may safely disregard June as a hurricane month. July, August, September and October constitute the hurricane season for Porto Rico. July and October storms are of infrequent occurrence. Since 1899 we have had but two July storms (1901 and 1906) and but one in October (1916). August and September storms were of nearly equal frequency, there being twenty-three and twenty-five, respectively, based upon the records for the entire period. The August and September storms as recorded in the recent period 1899-1929 show a greater divergence (six of the former and eleven of the latter, due undoubtedly to the fact that the earlier records probably do not include storms of a milder type.

Distribution by Centuries

1515-99	1600-99	1700-99	1800-99	1899-1929
10	1	12	21	20

The frequencies for the different centuries show too great a variation to permit us to place much reliance upon the accuracy or completeness of the records. The record for the seventeenth century is obviously incorrect with only one storm. The inclusion of minor disturbances in the list for later periods will explain the great increase in the number of storms recorded in the past thirty-one years.

A safer basis for determining the frequency of hurricanes is to examine closely the records since 1898. For this period we have accurate official accounts of weather conditions not only in Porto Rico but in many of the Islands of the Caribbean. While a period of thirty-one years is not as long as it should be for safety in discussing the question of the probability of occurrence of storms we may draw certain interesting conclusions even from this short period.

When it comes to the discussions of the relative violence of hurricanes it is necessary to confine our attention almost entirely to the period from 1899 to date.

CLASSIFICATION OF HURRICANES

Before attempting a classification of the storms of Porto Rico it may be well to refer to some of their characteristics. Consult also Figures I, II and III. Practically all storms affecting Porto Rico have their origin at a considerable distance to the east of the Windward Islands, probably not far from Cape Verde Islands, near the African coast; with rare exceptions they enter the Eastern Caribbean area fully developed. Their course varies generally between east-west and southeast-northwest.

Porto Rico is exposed only to the first or westward moving branch of the usual parabolic path of the storms. The rate of progress of the storm as a whole varies from ten to fifteen miles per hour, depending upon the rate of free movement of the Trade Winds which carry these storms in a westerly direction.

The Island lies between latitudes 18 and 19 N. and between longitudes 66 and 67 W. and hence is in the center of the hurricane belt with its width of forty miles exposed to the westward moving storms. The area of great devastation within a hurricane seldom extends beyond a distance of fifty miles from the center of the storm. In any well developed storm, winds of seventy-five miles per hour or more occur near the center. Beyond a radius of fifty miles however, the winds rapidly decrease in force. The rainfall attending these storms may extend to 150 to 200 miles from the center.

As we are considering the frequency and intensity of hurricanes in the vicinity of Porto Rico only, the classification is based upon the extent of the Island covered by the central area of hurricane winds.

Class A. Storms in which the entire Island is swept by winds exceeding seventy-five miles an hour.

Class B. Storms in which hurricane winds occur over a portion of the Island only.

Class C. When the winds do not reach full hurricane force over any portion of the Island.

All storms considered are assumed to be real hurricanes but classification into groups A, B and C depends on the distance of the center of the storm from Porto Rico. In storms of Class A the

center passed directly over Porto Rico attended by hurricane winds over the entire Island. In Class B the center was not more than fifty miles distant, while in Class C the center was more than fifty miles distant. Hence the importance of anticipating the exact distance of the centre from any portion of the Island, on the approach of a hurricane.

With this statement of the basis of hurricane classification we may examine the list of storms recorded in the vicinity of Porto Rico since the historic storm of August 8, 1899:

List of Hurricanes in the Vicinity of Porto Rico (1899-1929)

TABLE I

Year	Date	Class
1899.....	August 8 (San Ciriaco).....	A
1900.....	September 9th.....	C
1900.....	September 1st.....	C
1901.....	July 7th.....	C
1906.....	September 3rd.....	C
1908.....	September 10th.....	C
1908.....	September 27th.....	C
1909.....	August 22nd.....	B
1910.....	September 6th.....	B
1915.....	August 11th.....	B
1915.....	August 22nd.....	B
1916.....	August 29th.....	C
1916.....	October 10th.....	B
1917.....	September 21st.....	C
1919.....	September 3rd.....	C
1921.....	September 10th.....	C
1922.....	September 17th.....	C
1924.....	August 29th.....	C
1928.....	July 23rd.....	B
1928.....	September 13, (San Felipe).....	A

On examination of the official records we may place the storms of this period in the following groups:

Class	Number of storms	Percentage	Dates
A.....	2	10	August 8, 1899 (San Ciriaco) September 13, 1928 (San Felipe)
B.....	6	30	July 1898; August 1909, 1915, 1916; September 1910, October 1916 (2 storms)
C.....	12	60	July 1901; August 1916, 1924; September 1900, 1901 1906, 1908, 1917, 1920, 1922, 1923

The total number of storms recorded in Porto Rico for the thirty-one years from 1899 to date is twenty. As already shown in the list of storms prior to 1899 the hurricane months are July, August, September and October. Class A shows only two hurricanes in thirty-one years with an interval of thirty years; Class B shows six, with an average interval of five years, and Class C shows twelve, with an average interval of two and a half years. The distribution of the

storms through the period is not at all even, however, as there are two periods of four consecutive years and six periods of one year without a storm of any class. There was but one storm in the month of October and only two in the month of July, confirming the common impression that the months of August and September constitute the real hurricane season in the vicinity of Porto Rico. Six storms are credited to August and eleven to September, but nine of the eleven September storms were of the mild type, or Class C.

As storms of Class A were of such infrequent occurrence from 1899 to 1929 an effort was made to extend the period for this class backward to the beginning of the nineteenth century. This may safely be done as storms of such violence would certainly be noted in any local chronicle of hurricanes. In looking over Alexander's list of hurricanes from 1800 to 1899 we find only two additional storms which seem to merit a place with San Ciriaco and San Felipe II, namely Santa Ana (July 26, 1825) and San Narciso (October 29, 1867). Incidentally, San Narciso is the only storm recorded after the middle of October in a period of over four hundred years. Los Angeles (August 2, 1837), Santa Elena (August 18, 1851) and San Felipe I (September 13, 1876) which are frequently quoted as historic storms seem rather to have been of Class B, so far as extent of damage in Porto Rico is concerned. The addition of these two storms of the nineteenth century will give us four storms of Class A in a period of one hundred and thirty years, with an average interval of thirty-one years.

As storms of Class C are on the whole beneficial, owing to the value of the rains which they bring and the comparatively small property losses, we may disregard this class as a source of personal danger, eliminating the element of fear from sixty per cent of the total number of Porto Rican hurricanes.

Storms of Class B are likewise attended by beneficial rains; but such benefits may or may not be overshadowed by heavy local property losses.

Storms of Class A are a calamity and are responsible for the universal dread which seems to be inseparably connected with the word hurricane throughout the world. Hurricanes of the severest type, if their centers are more than fifty miles distant, are more likely to be beneficial than harmful, as winds exceeding seventy-five miles an hour seldom extend beyond this distance from the center.

Reviewing the statistics in the above tables and including Class A

hurricanes of the nineteenth century, we have the following hurricane frequencies for Porto Rico and vicinity:

Class	Number of storms	Period of years
A.....	4	130
B.....	6	31
C.....	12	31

While we may not be justified in concluding that these frequencies and proportions will hold good in the future we may say that the probabilities are in favor of the occurrence of one storm of Class A, six storms of Class B and twelve storms of Class C in the next generation. Even this broad statement may have some practical value in estimating probable losses to property and crops and in determining insurance rates.

FIG. 1.—PATH OF THE HURRICANE OF SEPTEMBER 13, 1928.



The progressive movement in the vicinity of Porto Rico was westnorthwest at the rate of about 300 miles per day, or approximately 13 miles per hour. The 24-hour progressive movement of the storm is shown by the figures 13 A to 16 A near the small circles which show the area swept by winds of hurricane force. The entire body of the storm is carried along in the general westward drift of the Trade Wind belt which, in the vicinity of Porto Rico has a width of about 1,000 miles and a depth of three to four miles.

Fig. II. SEA LEVEL CROSS SECTION OF A TYPICAL HURRICANE OF CLASS A. IN THE VICINITY OF PORTO RICO

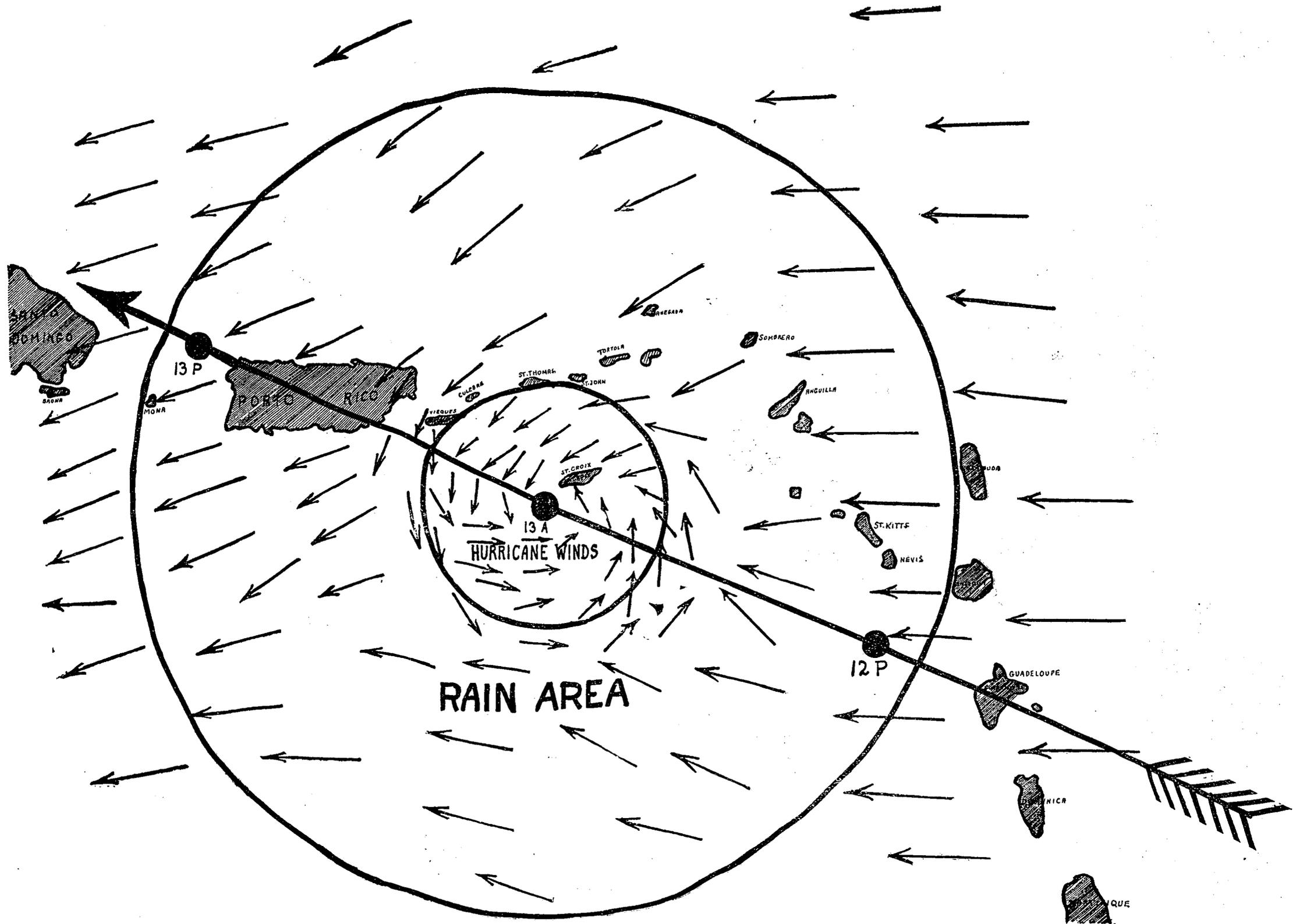
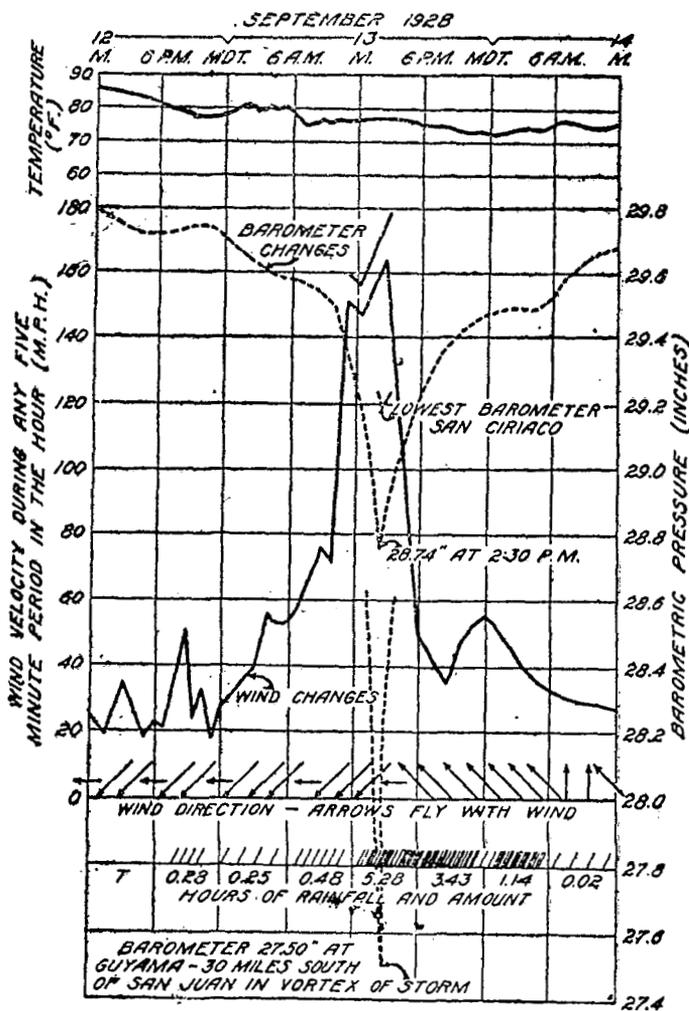


FIG. III.—HOURLY VARIATIONS OF WEATHER CONDITIONS AS THE STORM OF SEPTEMBER 13, 1928, PASSED OVER SAN JUAN, PORTO RICO.



The rapid fall in the barometer and increase in wind velocity to hurricane force began about 9 a. m. Hurricane winds prevailed for a period of 7 to 8 hours; the distance of San Juan from the center of the storm between 2 p. m. and 3 p. m. was approximately 25 miles. The estimated extreme velocity of the wind for one minute was 180 miles. The barometer fell to 28.74" at 2.30 p. m. at San Juan; in the vortex of the storm the pressure was 27.50" at Guayama and 27.35" at Yabucoa. The heaviest rainfall occurred as the vortex was passing to the south of San Juan, the total precipitation being about ten inches.