U. S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

NOAA Technical Memorandum NWS TM SR-58

ATLANTIC HURRICANE FREQUENCIES ALONG THE U. S. COASTLINE

SOUTHERN REGION HEADQUARTERS
SCIENTIFIC SERVICES DIVISION
FORT WORTH, TEXAS
June 1971

Atlantic Hurricane Frequencies Along the U.S. Coastline

by

R. H. Simpson and Miles B. Lawrence
NHC, Coral Gables, Florida

ABSTRACT

From a recently completed climatology of hurricanes at the National Hurricane Center covering a period of 85 years of record, the total number of incidents and the frequency of hurricanes and tropical storms for 50-mile segments of the U. S. Gulf of Mexico and Atlantic coastlines are presented.

INTRODUCTION

The migration of our population toward the seacoasts imposes an increasingly important requirement for intelligently assessing the risks involved on hurricane-prone coastlines of the U. S. This paper attempts to present the best available data on the occurrence of hurricanes in such a manner that these risk assessments will be easier to make. In connection with the development of the HURRAN technique by Hope and Neumann (1970) and the development of a hurricane climatology for $2\frac{1}{2}$ degree squares of latitude and longitude by Hope and Neumann (1969), the hurricane record of the last 85 years was carefully reviewed. The principal source of material for this study was the hurricane tracks and summary by Cry (1965). These data were stored on magnetic tape and now provide the basis for many climatological summaries and computations at the National Hurricane Center. From this tape, a compilation of tropical cyclone occurrences along the U.S. Gulf of Mexico and Atlantic coastlines has been prepared for coastal segments of 50 miles in length. The diagrams presented here summarize these data.

The frequency of hurricanes along our coastlines is such that no climatological summary can be considered a stable assessment of the risk of storm recurrence at any one locality. Nevertheless, it is important that the best possible information be available for various planning purposes, and this document is directed toward that end.

METHOD OF SUMMARIZATION

For planning purposes, especially for metropolitan areas and for the location of industrial sites, the summarization of hurricane events needs to be made for the smallest practicable coastal sectors for which the results may hold significance. In the present study, a review of all tropical cyclone events for the period of 1886 - 1970, indicates that a 50-mile coastal strip is the smallest segment for which a meaningful summary can be made for the purpose of examining hurricane events. In some areas, even this size segment involves a marginal number of storms. In summarizing the data, it was assumed that if a tropical cyclone of hurricane intensity crossed the coastline in one of the 50-mile sectors, it also affected the adjacent sector which lay in the right semicircle of the storm. For example, a hurricane which crossed the coastline in sector 2 (Fig. 1a) was counted not only for sector 2 but also for sector 3.

It should be mentioned that only storms entering a coastal area were considered; i.e., the method of tabulation made it unwieldy to include those storms that were passing off shore. This is significant only for the State of Florida where an intense storm crossing the peninsula could produce damaging winds along the coastal zone where this storm returns from land to sea. There have been a number of such cases over the years and, therefore, the data presented for peninsular Florida in this report may be regarded as somewhat conservative.

Tropical cyclones were divided into three categories. One includes all cyclones whose maximum (reported) sustained winds were 40 mph (gale force) or higher. The second includes all tropical cyclones with reported winds of 74 mph (hurricane force) or higher, and the third, those great hurricanes with sustained winds of 125 mph or more. The latter maximum wind threshold carries with it the likelihood of severe structural damage to residences and small industrial plants where building codes specifically designed to protect against a mature hurricane have not been enforced. The central pressure of approximately 950 mb, which normally accompanies this wind value, can be associated with storm surge heights as high as 12 to 15 feet where bottom depths and other coastal features favor this accumulation. Thus, due to both storm surge inundation and wind stresses on structures, storms in this category can be expected to bring major disasters to metropolitan areas with heavy damage to structures and high potential for loss of life.

The summary figures presented in the next section refer to the frequencies of tropical cyclones. These frequencies are expressed as probabilities in percentage units. These values are not, of course, probabilities in the strict mathematical sense, but are the arithmetic means of the 85 year sample of data.

A method of estimating the mathematical probabilities is to assume that the statistical properties of the data sample represent the properties of the entire population of events (i.e., all coastline crossings). These statistical properties will then determine a particular distribution of events. In the present case, the Poisson distribution is appropriate, as demostrated by Hope and Neumann (1968), and also by Thom (1960).

Table 1 shows the relation between the observed frequency of occurrences of coastline crossings and the probability of occurrences of at least one storm crossing in a year as computed from the Poisson distribution.

TABLE I

Observed Frequency of Occurrence Versus Poisson Probability

Observed Average Number of Storm Crossings Per Year	Poisson Probability of At Least One Storm Crossing Per Year
.00	.00
.01	.01
.02	.02
.03	.03
.04	.04
.05	.05

Table I (cont'd)

Observed Average Number of Storm Crossings Per Year	Poisson Probability of At Least One Storm Crossing Per Year
.06	.06
.07	.07
.08	.08
.09	.09
.10	.10
.11	.10
.12	.11
.13	.12
.14	.13
.15	.14
.16	.15
.17	.16
.18	.16
.19	.17
.20	.18
.21	.19

It is seen from Table 1 that the difference between the observed averages and the Poisson probabilities is small, being no more than two percentage points, and this only at the high end of the range. Also, the Poisson probabilities, where different, are always a reduction from the observed frequencies. This is explained by the fact that the Poisson distribution accounts for the possibility of more than one storm crossing during a single year.

In view of the above, it seemed advisable to present the data and figures of this study in terms of the raw data; that is, the observed frequencies of occurrence, leaving the particular statistical application up to the potential user of these data.

SUMMARY

Figure 1a shows the locations of the coastline segments. With just a few exceptions (segment no. 12 for example), the coastal strips approximate 50 nautical miles in length. A list of the exact positions of the endpoints of the segments that were used in the computations are given in an Appendix to this report. Figure 1a indicates the dates of the earliest

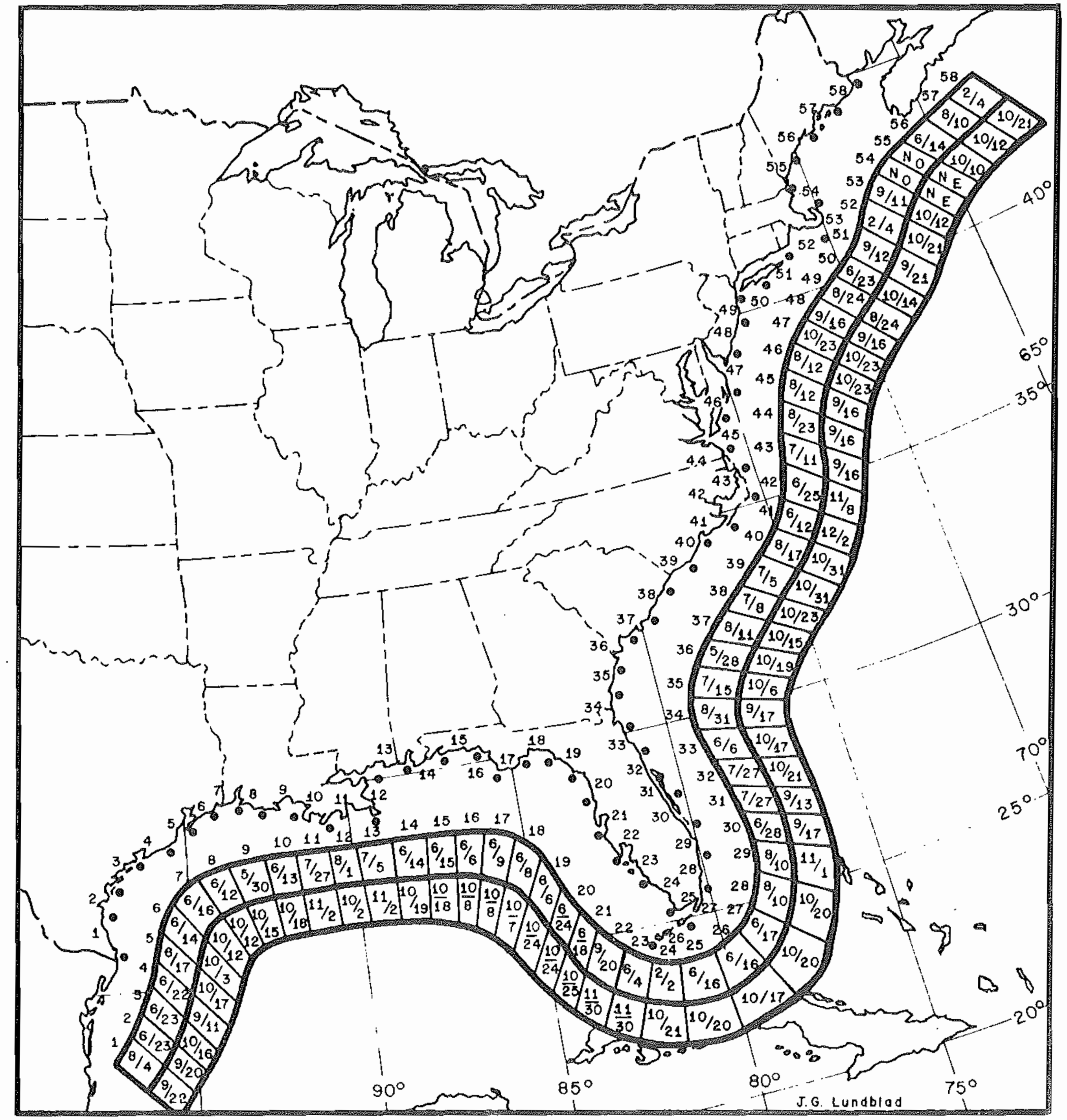


Fig. 1a. Earliest and latest tropical cyclone occurrences for the period 1886-1970. Numbers within boxes are the month and date of earliest and latest landfalls for the indicated coastal segment.

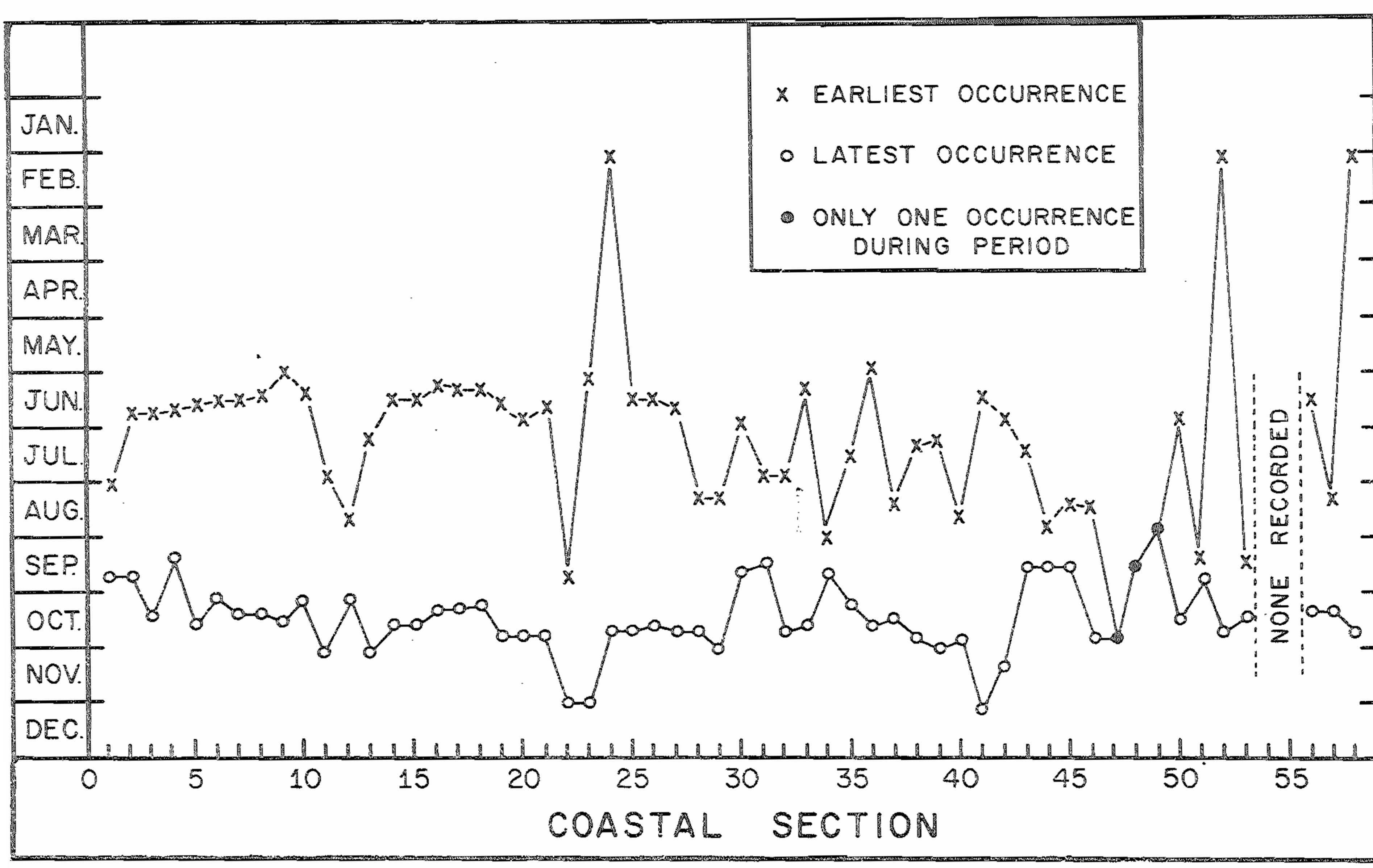


Fig. 1b. Earliest and latest tropical cyclone occurrences for the period 1886-1970. Numbers along the abscissa are the coastal segment identifiers.

and latest tropical cyclone landfalls in each sector. The same information is presented graphically in Figure 1b.

Here it is seen that there are three coastal areas where storms occurred in February; these are segment numbers 24, 52 and 58. In fact, all three of these events were the result of a single tropical storm in 1952 that moved from the western Caribbean across southern Florida and then along the Atlantic Seaboard to New England. Although this storm has been identified as an early occurrence on Figures 1a and 1b, it was actually a highly anomalous, off-season storm, and should not be seriously considered when assessing risks.

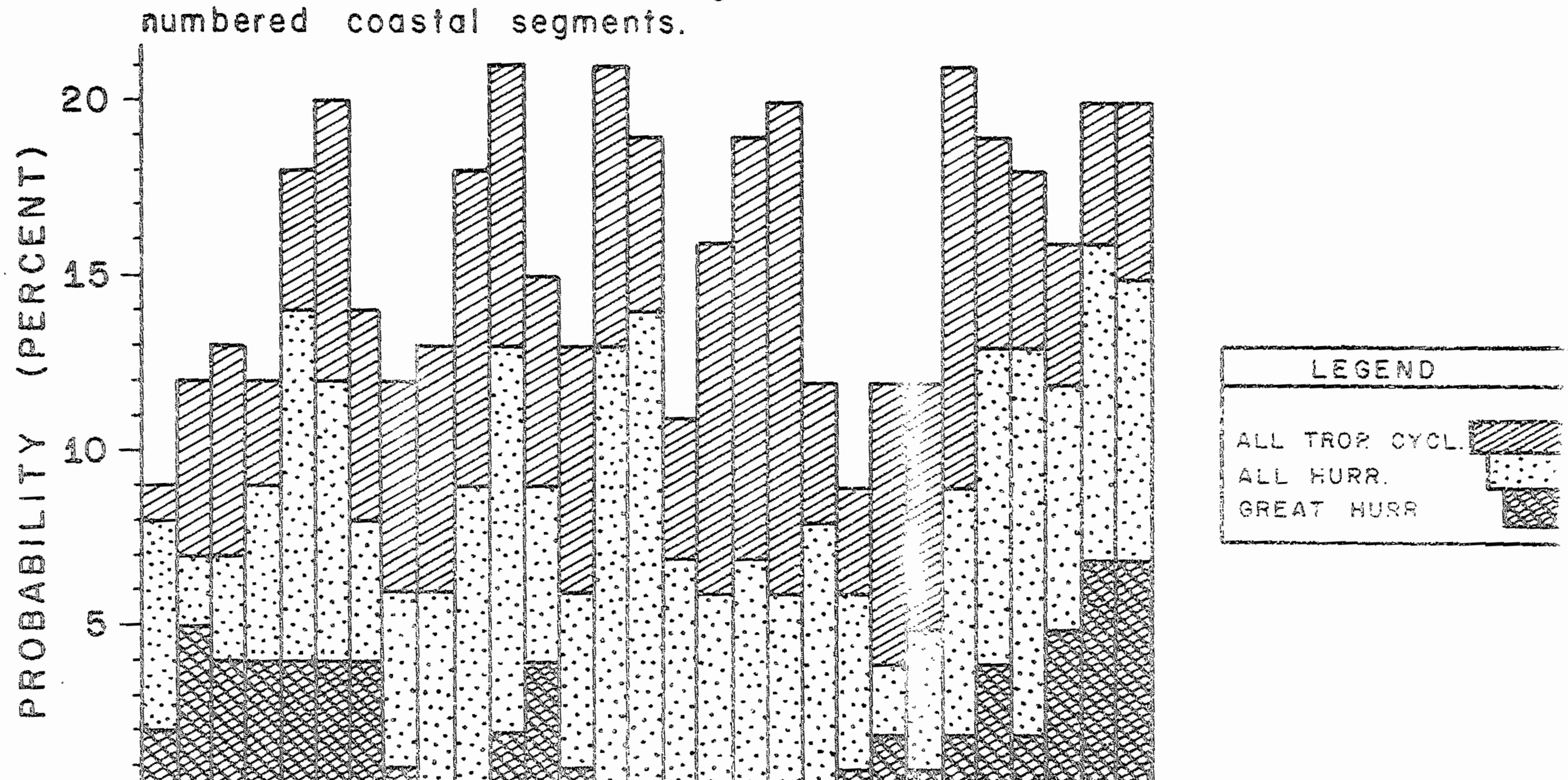
Otherwise, it is noted that in general the Gulf of Mexico coastline is more vulnerable than the Atlantic coast to early-season cyclones. This, of course, is to be expected since the primary early-season hurricane genesis regions are the western Caribbean and the Gulf of Mexico.

The location of the latest occurrences of late-season storms is shared by southwest Florida and the Cape Hatteras area. Other than this, late storms appear to be fairly well distributed along the Gulf of Mexico and Atlantic coastlines.

Figures 2a and 2b show the frequency of occurrence of tropical cyclones for each of the three categories for each coastal sector. The numbers are in percentage units and are the arithmetic average of actual storm occurrences over the period of record. As discussed in the preceeding section, these values may be regarded as an estimate of the probability of a cyclone landfall.

One obvious feature of Figures 2a and 2b is the concentration of high likelihood of great hurricane landfalls along the Gold Coast of southeastern Florida as well as along most of the Texas coast.

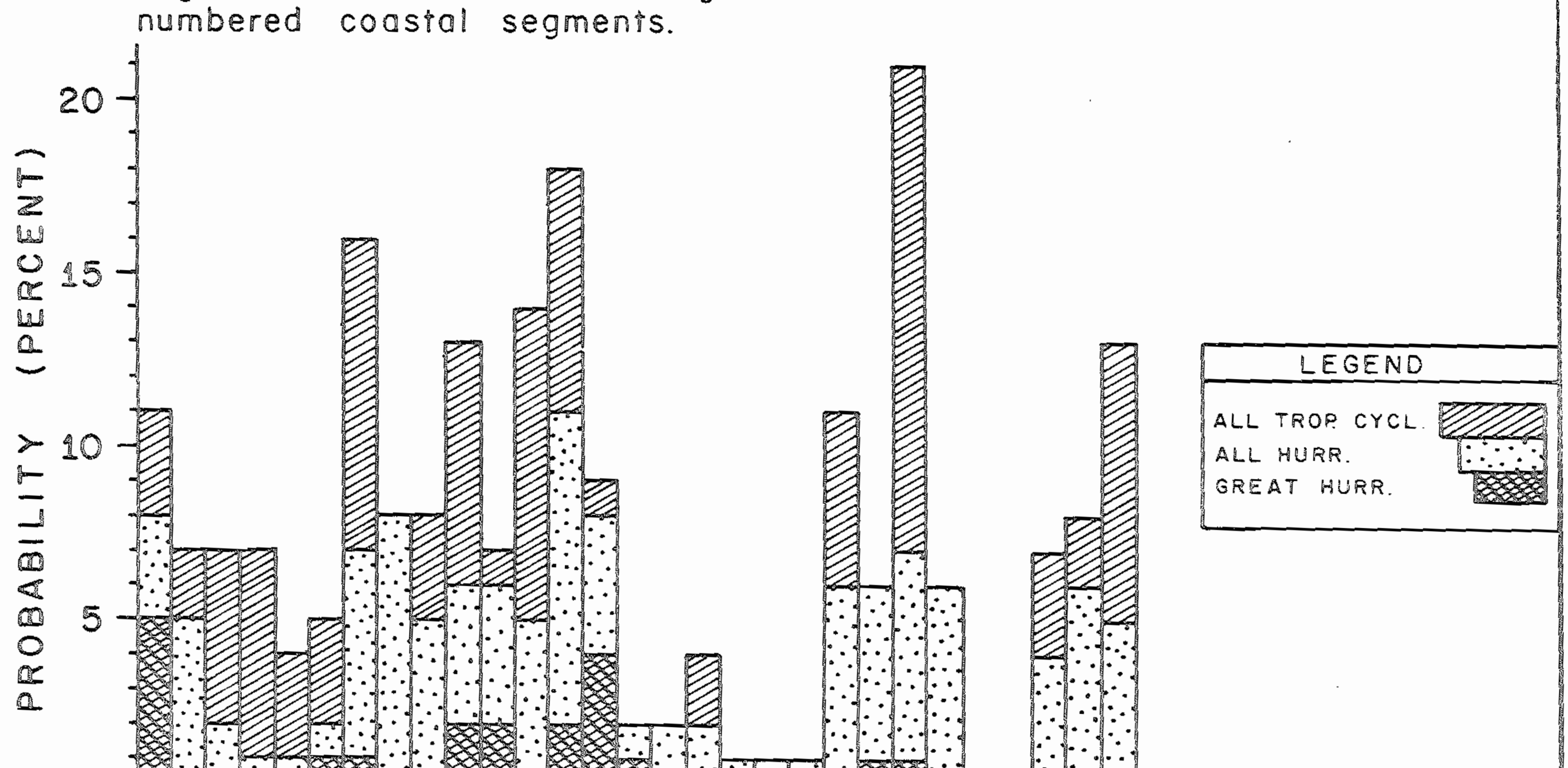
This histogram and table shows the probability (percentage) that a tropical storm, hurricane, or great hurricane will occur in any one year in a 50 mile segment of the coastline. Figure 1 identifies the numbered coastal segments.



COASTAL SECTOR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
ALL TROPICAL CYCLONES	9	12	13	12	18	20	14	12	13	18	21	15	13	21	19	11	16	19	20	12	9	12	12	21	19	18	16	20	20
ALL HURRICANES	8	7	7	9	14	12	8	6	6	9	13	9	6	13	14	7	6	7	6	8	6	4	5	9	13	13	12	16	15
GREAT HURRICANES	2	5	4	4	4	4	4	1	-	-	2	4	1	-	-	-	-	-	-	-	1	2	1	2	4	2	5	7	7

Fig. 2a. Frequency of tropical cyclones along the U.S. Gulf of Mexico coastline.

This histogram and table shows the probability (percentage) that a tropical storm, hurricane, or great hurricane will occur in any one year in a 50 mile segment of the coastline. Figure 1 identifies the numbered coastal segments.



COASTAL SECTOR	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58
ALL TROPICAL CYCLONES	11	7	7	7	4	5	16	8	8	13	7	14	18	9	2	2	4	1	1	1	11	6	21	6	–	–	7	8	13
ALL HURRICANES	8	5	2	1	1	2	7	8	5	6	6	5	11	8	2	2	2	1	–	1	6	6	7	6	–	–	4	6	5
GREAT HURRICANES	5	–	–	–	–	1	1	–	–	2	2	–	2	4	1	–	–	–	–	–	–	1	1	–	–	–	–	–	–

Fig. 2b. Frequency of tropical cyclones along the U. S. Atlantic coastline

Fig.3 Number of TROPICAL CYCLONES reaching U.S. mainland 1886–1970

Sector	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
All Tropical Cyclones	8	10	11	10	15	17	12	10	11	15	18	13	11	18	16	9	14	16	17	10	8	10	10	18	16	15	14	17	17
All Hurricanes	7	6	6	8	12	10	7	5	5	8	11	8	5	11	12	6	5	6	5	7	5	3	4	8	11	11	10	14	13
Great Hurricanes	2	4	3	3	3	3	3	1	-	-	2	3	1	-	-	-	-	-	-	-	1	2	1	2	3	2	4	6	6

Sector	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58
All Tropical Cyclones	9	6	6	6	3	4	14	7	7	11	6	12	15	8	2	2	3	1	1	1	9	5	18	5	-	-	6	7	11
All Hurricanes	7	4	2	1	1	2	6	7	4	5	5	4	9	7	2	2	2	1	-	1	5	5	6	5	-	-	3	5	4
Great Hurricanes	4	-	-	-	-	1	1	-	-	2	2	-	2	3	1	-	-	-	-	-	-	1	1	-	-	-	-	-	-

Fig. 4 Number of years between TROPICAL CYCLONE occurrences Average for the period 1886–1970

Sector	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
All Tropical Cyclones	10	8	7	8	5	5	7	8	7	5	4	6	7	4	5	9	6	5	5	8	10	8	8	4	5	5	6	5	5
All Hurricanes	12	14	14	10	7	8	12	17	17	10	7	10	17	7	7	14	17	14	17	12	17	28	21	10	7	7	8	6	6
Great Hurricanes	42	21	28	28	28	28	28	85	-	-	42	28	85	-	-	-	-	-	-	-	85	42	85	42	28	42	21	14	14

Sector	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58
All Tropical Cyclones	9	14	14	14	28	21	6	12	12	7	14	7	5	10	42	42	28	85	85	85	9	17	4	17	-	-	14	12	7
All Hurricanes	12	21	42	85	85	42	14	12	21	17	17	21	9	12	42	42	42	85	-	85	17	17	14	17	-	-	28	17	21
Great Hurricanes	21	-	-	-	-	85	85	-	-	42	42	-	42	28	85	-	-	-	-	-	-	85	85	-	-	-	-	-	-

All TROPICAL CYCLONES (40MPH or higher) All HURRICANES (74MPH or higher)
GREAT HURRICANES (125MPH or higher)

Figure 3 summarizes the actual count of the tropical cyclone landfalls which affected each coastal sector. Finally, Figure 4 lists the average number of years between tropical cyclone occurrences.

It is beyond the scope of this report to discuss any further the many details of the data contained herein. Certainly, some of the smaller-scale details must be considered cautiously in light of the nature of the data. However, it is hoped that this paper will serve as a useful starting point for the application of tropical cyclone summary data.

ACKNOWLEDGEMENTS

The authors are indebted to Mr. Robert L. Carrodus of the National Hurricane Research Laboratory who prepared the figures, and to Mr. Charles J. Neumann, Spaceflight Meteorology Group, Miami, Florida, who assisted with the programming for the numerical computations.

APPENDIX

Coastline Segment Locations

The following latitude/longitude combinations comprise a list of the left endpoints of the coastline segments as referenced from an off-shore viewing position and as illustrated in Fig. 1a. The right end-point of any segment is the left endpoint of the next higher-numbered segment. There are two exceptions: segment no. 25 in extreme southern Florida; and segment no. 58, the northernmost segment. The right end-points for the exceptions are indicated in the listings below.

Also, the cities identified below are only for the reader's convenience as points of reference.

Coastline Segment Locations

Coastline Segment No.	Left Endpoint		
	Lat.	Long.	
1	25.95	97.15	(Brownsville)
2	26.75	97.35	
3	27.57	97.22	
4	28.23	96.62	
5	28.67	95.80	
6	29.13	95.02	(Galveston)
7	29.60	94.25	
8	29.77	93.30	
9	29.52	92.37	
10	29.32	91.43	
11	29.07	90.52	(New Orleans)
12	28.98	89.15	
13	30.20	88.93	
14	30.22	87.97	
15	30.35	87.02	

Coastline Segment No.	Left Endpoint		
	Lat.	Long.	
16	30.28	86.05	(Panama City)
17	29.68	85.38	
18	29.88	84.43	
19	29.70	83.50	
20	29.08	82.88	
21	28.23	82.87	(Tampa)
22	27.42	82.68	
23	26.67	82.25	
24	25.97	81.77	
25	25.12	81.13	---- Right Endpoint: Lat. 25.32, Long. 80.25
26	24.53	81.82	(Key West)
27	24.77	80.93	
28	25.32	80.25	
29	26.13	80.03	
30	27.00	80.05	
31	27.73	80.38	(Vero Beach)
32	28.55	80.55	
33	29.27	81.02	
34	30.05	81.33	(Jacksonville)
35	30.90	81.42	
36	31.68	81.12	(Savannah)
37	32.33	80.48	
38	32.83	79.70	
39	33.48	79.08	
40	33.77	78.15	(Wilmington, N.C.)
41	34.43	77.53	
42	34.60	76.53	
43	35.23	75.53	
44	36.05	75.67	(Norfolk)
45	36.85	75.97	
46	37.63	75.60	
47	38.35	75.07	
48	39.15	74.70	
49	39.83	74.08	
50	40.58	73.63	
51	40.80	72.57	
52	41.15	71.55	(Nantucket)
53	41.25	69.95	
54	42.08	69.90	
55	42.72	70.62	
56	43.52	70.32	(Portland)
57	43.91	69.32	
58	44.25	68.25	---- Right Endpoint: Lat. 44.80, Long. 66.90

REFERENCES

Cry, George W., 1965: "Tropical Cyclones of the North Atlantic Ocean: Tracks and Frequencies of Hurricanes and Tropical Storms, 1871-1963", Technical Paper No. 55, U. S. Weather Bureau, Washington, D. C., 148 pp.

Hope, John R., and Neumann, Charles J., 1968: "Probability of Tropical Cyclone Induced Winds at Cape Kennedy", ESSA Technical Memorandum WBTM SOS - 1, U. S. Department of Commerce, Washington, D.C., 67 pp.

----, and ----, 1969: " Climatology of Atlantic Tropical Cyclones by Two and One-Half Degree Latitude - Longitude Boxes", Technical Memorandum WBTM - SR - 44, U.S. Weather Bureau, Southern Region Headquarters, Fort Worth, Texas, 50 pp.

----, and ----, 1970: "An Operational Technique for Relating the Movement of Existing Tropical Cyclones to Past Tracks", Monthly Weather Review, Vol. 98, No. 12, pp 925 - 933.

Thom, H. C. S., 1960: "The Distribution of Annual Tropical Cyclone Frequency", Journal of Geophysical Research, Vol. 65, pp 213-222.