

NOAA Technical Memorandum NWS TPC-1

THE DEADLIEST, COSTLIEST, AND MOST INTENSE

UNITED STATES HURRICANES OF THIS CENTURY

(AND OTHER FREQUENTLY REQUESTED HURRICANE FACTS)

Updated February 1997

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Tropical Prediction Center National Hurricane Center Miami, Florida February 1997

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National Oceanic & Atmospheric Administration US Dept of Commerce

Tropical Prediction Center National Hurricane Center Miami, Florida February 1997

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#### **PREFACE**

This version of the Deadliest, Costliest, and Most Intense United States Hurricanes of This Century is an update through the 1996 hurricane season of Hebert, Jarrell and Mayfield (1996). This update is largely to include the active 1996 season.

Information for Hawaii, Puerto Rico and the Virgin Islands, given in Table 15, was provided by Hans Rosendal and Raphael Mojica of the Weather Service Forecast Offices in Honolulu and San Juan, respectively.

Dr. Chris Landsea, of the Hurricane Research Division of the Atlantic Oceanographic and Meteorological Laboratory, in conducting research on hurricane damage and casualties, found documentation of damage and fatalities with a major hurricane striking the north-central coast of Texas in 1932. That particular hurricane was handled inconsistently in earlier printings of this report, and the current version will correct that oversight.

A chronological list of all hurricanes to strike the U.S. during this century through 1990 can be found in Jarrell, Hebert and Mayfield (1992). Another change to this report is to add Table 11 which extends that listing through 1996.

During 1995 the former National Meteorological Center, which included the National Hurricane Center, was re-organized into the National Centers for Environmental Prediction (NCEP). Under NCEP, the National Hurricane Center became the Tropical Prediction Center (TPC) to more accurately reflect the majority of its operational products being non-hurricane related, routine tropical forecasts. The name "National Hurricane Center" was retained to apply to the hurricane operations desk at TPC. We will follow the convention of using "NHC" to refer to the previous National Hurricane Center, "TPC" to refer to the current center and "TPC/NHC" to refer to the hurricane operations desk of TPC.

# THE DEADLIEST, COSTLIEST, AND MOST INTENSE UNITED STATES HURRICANES OF THIS CENTURY (AND OTHER FREQUENTLY REQUESTED HURRICANE FACTS)

by

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#### **ABSTRACT**

Lists of the thirty United States deadliest and costliest land falling hurricanes during this century have been compiled from all data sources available at the Tropical Prediction Center (TPC). Damages are given both before and after adjustment for inflation. In addition, all major¹ hurricanes which have made landfall in the United States during this century are listed. Some additional statistics on United States hurricanes of this and previous centuries and tropical cyclones in general are also presented.

#### 1. INTRODUCTION

Numerous requests are received at the Tropical Prediction Center for statistical information on deaths, damages, and severity of hurricanes which have affected the United States. Various reference materials give different estimates of these statistics so that decisions have to be constantly made as to which information should be given out by TPC as "official" from the National Hurricane Center. Requests to other Weather Service offices posed the same dilemma. These lists are published in the hope of presenting a single source of the best currently available estimates of deaths, damages, and intensity of major U.S. hurricanes which have made landfall in this century. In some instances, data in these lists present revised estimates. Such estimates, for individual hurricanes, are based on more complete information received after earlier published values, including the previous versions of this technical memorandum. There are other frequently asked questions about hurricanes. What is the average number of hurricanes per year? What year(s) had the most and least hurricanes? What hurricane had the longest life? When did the earliest and latest hurricane occur? What was the most intense Atlantic hurricane? What was the largest number of hurricanes in existence on the same day? When was the last time a major hurricane or any hurricane hit a given community directly? Answers to these and several other questions are provided in Section 3.

A major hurricane is a category 3, 4, or 5 on the Saffir/Simpson Hurricane Scale (see Table 1), and is comparable to a Great Hurricane in other publications.

<sup>&</sup>lt;sup>2</sup> A direct hit means experiencing the core of strong winds and high tides of a hurricane.

Table 1. Saffir/Simpson Hurricane Scale Ranges.

Scale Number		entral essure	Winds	Surge	
(Category)	(Millibars)	(Inches)	(Mph)	(Feet)	Damage
1	>979	>28.91	74-95	4 to 5	Minimal
2	965-979	28.50-28.91	96-110	6 to 8	Moderate
3	945-964	27.91-28.47	111-130	9 to 12	Extensive
4	920-944	27.17-27.88	131-155	13 to 18	Extreme
5	< 920	< 27.17	> 155	> 18	Catastrophic

#### 2. CRITERIA

The statistics in most of the tables and figures in this publication depend <u>directly</u> on the criteria used in preparing another study, Hurricane Experience Levels of Coastal County Populations-Texas to Maine (Jarrell, Hebert, and Mayfield, 1992). The <u>primary purpose</u> of that study was to demonstrate, county by county, the low hurricane experience level of a large majority of the population. Statistics show that the largest loss of life and, for the most part, property occur in locations experiencing the core of a category 3 or higher hurricane. Unless a given population has experienced this core, or direct hit, with its very strong winds and high tides, it would defeat the primary purpose of the study on hurricane experience levels to so categorize it.

Although the Saffir/Simpson category is defined by pressure, wind, and storm surge, in practice it is the maximum wind speed that determines the category. Operationally, the central pressure is used to make a first estimate of the wind. Thereafter, available surface wind reports and aircraft reconnaissance flight level winds (which must be reduced to the surface) are used to anchor the wind estimate. In post-analysis, the central pressure ranges of hurricanes on the Saffir/Simpson scale will usually agree fairly well with the wind ranges in that category.

On the other hand, the surge is strongly dependent on the slope of the continental shelf (shoaling factor). This can change the height of the surge by a factor of two for a given central pressure and/or maximum wind.

Heavy rainfall associated with a hurricane is not one of the criteria for categorizing it.

The <u>subjective</u> determination of which category number to assign to a hurricane, as well as its direct or indirect effect, is made on a <u>county by county basis</u> with the intent of the study on hurricane experience levels foremost in mind.

As with the assignment of scale numbers, a certain amount of subjectivity was inescapable at times in determining which counties received direct or indirect hits during the various hurricane situations. However, certain arbitrary guidelines for these classifications as used in Hurricane Experience Levels, etc., are indicated below:

<u>Direct Hit</u> - When the innermost core region or "eye" moved over a county, it was counted as a direct hit. Using "R" as the radius of maximum winds in a hurricane (the distance in miles from the storm's center to the circle of maximum winds around the center), all or parts of counties falling within approximately 2R to the right and R to the left of a storm's landfall point were considered to have received a direct hit. (This assumes an observer at sea looking toward the shore. If there was no landfall, the closest point of approach was used in place of the landfall point). On the average, this direct hit zone extended about 50 miles along the coastline ( $R \approx 15$  miles). Of course, some hurricanes were smaller than this and some, particularly at higher latitudes, were much larger. Cases were judged individually, and many borderline situations had to be resolved.

<u>Indirect Hit</u> - These were based primarily on a hurricane's strength and size, and on the configuration of the individual county coastline. Here again, much subjectivity was necessary in many cases which were complicated by storm paths and geography. Generally, those areas on either side of the direct hit zone which received at least wind gusts of hurricane force and/or tides of 4 to 5 feet or more above normal were considered to have had an indirect hit.

It is realized that the effect of an indirect hit by a large category 4 hurricane might be greater than that of a direct hit by a small category 1 affecting the same county. However, trying to account for these differences would hopelessly complicate the use of this system.

A study by Simpson and Lawrence (1971) gives climatological probabilities of the total number of storms and hurricanes to affect the U.S. coastline by fifty-mile wide coastal segments, as well as only hurricanes, and major (or great) hurricanes. While this 50 miles approximates that of the "core" used for direct hits, there are some differences. In the Simpson and Lawrence study, a storm/hurricane/ great hurricane was counted in the segment where it crossed the coast plus the next segment to the right. As indicated earlier, the "core" used in Jarrell, Hebert, and Mayfield (1992) can be smaller or larger than 50 miles, and could also affect one of the segments in Simpson and Lawrence to the left of a coastline crossing which that study would not count.

The foregoing two studies and their associated criteria are <u>climatological</u> with their primary purpose being for use in assessing risk based on <u>past</u> experience. On the other hand, the National Weather Service's Hurricane Probability Program has as its purpose the assessment of risk based on a <u>present</u> hurricane threat to the United States coastline. It does this by arbitrarily defining a "strike" as the center of a hurricane moving through a zone within approximately 50 nautical miles to the right or 75 nautical miles to the left of the site of interest (Sheets, 1984). The asymmetry is to allow for the strongest winds in a hurricane frequently being further to the right of the center than the left - a consideration reflected also in the earlier studies discussed. This 125 nautical mile diameter circle approximates the region of hurricane force winds for a "typical" hurricane. It will usually be larger than the "core", and is fixed, like the segments in Simpson and Lawrence. HURRICANE STRIKE PROBABILITIES HAVE NO RELATION TO HURRICANE INTENSITY. Users of these probabilities <u>must</u> take the intensity and expected arrival time of tropical storm and hurricane force winds into account when assessing risk. The reader is urged to refer to The National Weather Service Hurricane Probability Program (Sheets, 1984) for a more thorough explanation of forecast probabilities.

Statistics on total storm/hurricane activity in the North Atlantic Ocean (which includes the Gulf of Mexico and the Caribbean Sea) can be found in Neumann, et al. (1993). A detailed breakdown of hurricanes by category which have affected coastal counties of the Gulf of Mexico and North Atlantic Ocean both directly and indirectly can be found in Jarrell, Hebert, and Mayfield (1992), which has been updated where necessary for this technical memorandum. The best source of how a hurricane affected individual localities or states can be found in the annual articles on the hurricane season in the Monthly Weather Review (1996 for example) and Storm Data (1996 for example).

### 3. DISCUSSION Part I

- (1) What have been the deadliest hurricanes of this century in the United States? Table 2 lists the 30 deadliest hurricanes to strike the mainland U.S. in this century. Although technically incorrect, we have included 1900 in "this century". Three hurricanes prior to 1900, a tropical storm which affected southern California in 1939 and deadliest hurricanes affecting Puerto Rico and the Virgin Islands are listed as an addendum because of their large death tolls.
- What have been the costliest hurricanes of this century in the United States? Table 3 lists the 30 costliest hurricanes (including 4 tropical storms) to strike the mainland U.S. in this century. Figures are not adjusted for inflation. Table 3a re-orders some of these plus several other hurricanes (and 1 tropical storm) after adjusting to 1996 dollars<sup>3</sup>. Hawaiian, eastern Pacific, Puerto Rican and Virgin Island tropical cyclones are listed as addenda to Tables 3 and 3a.
- (3) What have been the most intense hurricanes to strike the United States during this century? Table 4 lists the 64 major hurricanes which have struck the mainland U.S. during this century. Hurricanes are ordered by the lowest estimated central pressure and/or highest category to affect the United States at time of landfall. Hawaiian, Puerto Rican and Virgin Island hurricanes are listed as an addenda to Table 4. Many of the island hurricanes are close passes, as opposed to landfalls as defined above.

A look at the lists of deadliest and costliest hurricanes of this century reveals several striking facts: (1) The twelve deadliest hurricanes were all the equivalent of a category 4 or higher, if the excessive forward speed is considered as raising the category of a hurricane by one. (2) Large death totals were primarily a result of the 15 to 20 feet or more rise of the ocean (storm surge) associated with many of these major hurricanes. All but five of the thirty deadliest hurricanes were major hurricanes. Three of these five were the inland flood-producing hurricanes Agnes and Diane and Tropical Storm Alberto. (3) A large portion of the damage in three of the fourteen costliest tropical cyclones (Table 3) resulted from inland flooding caused by torrential rainfall in. (4) Three-fifths of the deadliest hurricanes were the equivalent of a category four or higher, but only one-third of the costliest hurricanes (Table 3) met this criterion. (5) Only one of the deadliest hurricanes (plus one deadly tropical storm) has occurred during the past twenty five years in contrast to two-thirds of the costliest hurricanes (this drops to two-fifths after adjustment for inflation).

Addenda to tables 2, 3 and 4 include some noteworthy storms from pre-1900, the U.S. Pacific coast and the Hawaiian islands, as well as the U.S. Caribbean Islands. The rank is where they would fall if each alone were ranked within the main table.

Adjusted to 1996 dollars on basis of U.S. Department of Commerce Implicit Price Deflator for Construction. Available index numbers are rounded to the nearest tenth. This rounding can result in slight changes in the adjusted damage of one hurricane relative to others.

Table 2. The deadliest mainland United States hurricanes 1900-1996. (The top 30 are listed).

RANK	HURRICANE	YEAR	CATEGORY	DEATHS
1	TX (Galveston)	1900	4	8000
2	FL (SE/Lake Okeechobee)	1928	4	1836
3	FL (Keys)/S TX	1919	4	600
4	New England	1938	3 *	600
5	FL (Keys)	1935	5	408
6	AUDREY (SW LA/N TX)	1957	4	390
7	NE U.S.	1944	3 *	390
8	LA (Grand Isle)	1909	4	350
9	LA (New Orleans)	1915	4	275
10	TX (Galveston)	1915	4	275
11	CAMILLE (MS/SE LA/VA)	1969	5	256
12	FL (Miami)/MS/AL/Pensacola	1926	4	243
13	DIANE (NE U.S.)	1955	1	184
14	SEFL	1906	2	164
15	MS/AL/Pensacola	1906	3	134
16	AGNES (FL/NE U.S.)	1972	1	122
17	HAZEL (SC/NC)	1954	4 *	95
18	BETSY (SE FL/SE LA)	1965	3	75
19	CAROL (NE U.S.)	1954	3 *	60
20	SE FL/SE LA/MS	1947	4	51
21	DONNA (FL/Eastern U.S.)	1960	4	50
22	GA/SC/NC	1940	2	50
23	CARLA (N & Central TX)	1961	4	46
24	TX (Velasco)	1909	3	41
25	TX (Freeport)	1932	4	40
26	STX	1933	3	. 40
27	HILDA (Central LA)	1964	3	38
28	SW LA	1918	3	34
29	SW FL	1910	3	30
30	ALBERTO (NW FL,GA,AL)	1994	TS &	30
ADDE	NDUM (Pre-1900 or Not Atlantic	/Gulf Co	ast)	
2	LA	1893	Unk	2000
2-3	SC/GA	1893	Unk	1000-2000
3	GA/SC	1881	Unk	700
9	Puerto Rico	1928	4	312
13	USVI, Puerto Rico	1932	2	225
17	Donna (St. Thomas, VI) Southern California	1960	4 TS <sup>&amp;</sup>	107
24 24	Eloise(Puerto Rico)	1939 1975	TS &	45 44

- Moving more than 30 miles per hour
- Over 500 lost on ships at sea; 600-900 estimated deaths.
- © Some 344 of these lost on ships at sea.
- & Only of Tropical Storm intensity.
- Unk Intensity not sufficiently known to establish category

Table 3. The costliest mainland United States hurricanes, 1900-1996, (The top 30 are listed).

	HURRICANE		CATEGORY	DAMAGE (U.S.)
1	ANDREW (SE FL/SE LA)	1992	4	\$26,500,000,000
2	HUGO (SC)	1989	4	7,000,000,000
3	FRAN (NC)	1996	3	3,200,000,000
4	OPAL (NW FL/AL)	1995	3	3,000,000,000
5	FREDERIC (AL/MS)	1979	3	2,300,000,000
6	AGNES (FL/NE U.S.)	1972	1	2,100,000,000
7	ALICIA (N TX)	1983	3	2,000,000,000
8	BOB (NC, NE U.S)	1991	2	1,500,000,000
8	JUAN (LA)	1985	1	1,500,000,000
10	CAMILLE (MS/SE LA/VA)	1969	5	1,420,700,000
11	BETSY (SE FL/SE LA)	1965	3	1,420,500,000
12	ELENA (MS/AL/NW FL)	1985	3	1,250,000,000
13	GLORIA (Eastern U.S.)	1985	3 *	900,000,000
14	DIANE (NE U.S.)	1955	1	831,700,000
15	ALLISON (N TX)	1989	TS @	500,000,000
15	ALBERTO (NW FL,GA,AL)	1994	TS @	500,000,000
17	ELOISE (NW FL)	1975	3	490,000,000
18	CAROL (NE U.S.)	1954	3 *	461,000,000
19	CELIA (S TX)	1970	3	453,000,000
20	CARLA (N & Central TX)	1961	4	408,000,000
21	CLAUDETTE (N TX)	1979	TS @	400,000,000
21	GORDON (S & Cent FL,NC)	1994	TS @	400,000,000
23	DONNA (FL/Eastern U.S.)	1960	4	387,000,000
24	DAVID (FL/Eastern U.S.)	1979	2	320,000,000
25	New England	1938	3 *	306,000,000
26	KATE (FL Keys/NW FL)	1985	2	300,000,000
26	ALLEN (S TX)	1980	3	300,000,000
28	HAZEL (SC/NC)	1954	4 *	281,000,000
29	BERTHA (NC)	1996	2	270,000,000
30	DORA (NE FL)	1964	2	250,000,000
DDEN	DUM			
8	INIKI (Kauai, HI)	1992	Unk.	1,800,000,000
8	MARILYN (USVI, PR)	1995	2	1,500,000,000
13	HUGO (USVI, PR)	1989	4	1,000,000,000
15	HORTENSE (PR)	1996	1	500,000,000
24	OLIVIA (CA)	1982	T.D. &	325,000,000
25	IWA (Kauai, HI)	1982	Unk.	312,000,000
26	NORMAN (CA)	1978	T.D. &	300,000,000
Notes:				
*	Moving more than 30 miles pe	er hour.		
@	Only of Tropical Storm intensi			
&	Only a Tropical Depression			

Table 3a. The costliest mainland United States hurricanes, 1900-1996. (The top 30 are listed when adjusted\*\* to 1996 dollars.)

1	ANDREW (SE FL/SE LA)	1992	Category 4	Damage (U.S.)** 30,475,000,000
2	HUGO (SC)	1989	4	8,491,561,181
3	AGNES (FL/NE U.S.)	1972	1	7,500,000,000
4	BETSY (SE FL/SE LA)	1965	3	7,425,340,909
5	CAMILLE (MS/SE LA/VA)	1969	5	6,096,287,313
6	DIANE (NE U.S.)	1955	1	4,830,580,808
7	FREDERIC (AL/MS)	1979	3	4,328,968,903
8	New England	1938	3 *	4,140,000,000
9	FRAN (NC)	1996	3	3,200,000,000
10	OPAL (NW FL/AL)	1995	3	3,069,395,018
11	ALICIA (N TX)	1983	3	2,983,138,781
12	CAROL (NE Ú.S.)	1954	3 *	2,732,731,959
13	CARLA (N & Central TX)	1961	4	2,223,696,682
14	JUAN (LA)	1985	1	2,108,801,956
15	DONNA(FL/Eastern U.S.)	1960	4	2,099,292,453
16	CELIA (S TX)	1970	3	1,834,330,986
17	ELENA (MS/AL/NW FL)	1985	3	1,757,334,963
18	BOB (NC, NE U.S)	1991	2	1,747,720,365
19	HAZEL (SC/NC)	1954	4 *	1,665,721,649
20	FL (Miami)/MS/AL/Pensacola	1926	4	1,515,294,118
21	N TX (Galveston)	1915	4	1,346,341,463
22	DORA (NE FL)	1964	2	1,343,457,944
23	ELOISE (NW FL)	1975	3	1,298,387,097
24	GLORIA (Eastern U.S.)	1985	3 *	1,265,281,174
25	NE U.S.	1944	3 *	1,064,814,815
26	BEULAH (S TX)	1967	3	970,464,135
27	SE FL/SE LA/MS	1947	4	810,897,436
28	N TX (Galveston)	1900	4	809,207,317
29	AUDREY (SW LA/N TX)	1957	4	802,325,581
30	CLAUDETTE(N TX)	1979	T.S. @	752,864,157
ADDE	NDUM			
16	INIKI (Kauai, HI)	1992	Unk.	2,070,000,000
20	MARILYN (USVI,E. PR)	1995	2	1,534,697,509
25	HUGO (USVI, PR)	1989	4	1,213,080,169
25	SAN FELIPE (PR)	1928	4	1,150,000,000

#### notes

- Adjusted to 1996 dollars on basis of U.S. DOC Implicit Price Deflator for Construction.
- Moving more than 30 miles per hour
- Damage estimate was considered too high in 1915 reference.
- Probably higher
- Using 1915 cost adjustment base none available prior to 1915
- Only of Tropical Storm intensity, included because of high damage.

Table 4. The most intense mainland United States hurricanes, 1900-1996.

(מו ומו וו	(at landfall) Millibars Inches	1		2	KANK HUKKICANE	YEAR	(at landfall)	Millibars	(at landfall) Millibars Inches
2		20.35	33	Г	BEULAH (STX)	1967	3	950	28.05
2		26.84	33		HILDA (Central LA)	1964	က	950	28.05
4		27.23	33		GRACIE (SC)	1959	ဗ	950	28.05
4		27.37	33		TX (Central)	1942	က	950	28.05
4		27.43	37		7	1945	က	951	28.08
4	_	27.46	38	_	FL (Tampa Bay)	1921	က	952	28.11
4 .		27.49	38	_	CARMEN (Central LA)	1974	က	952	28.11
20.0		27.49	9 :		EDNA (New England)	1954	· e	954	28.17
4.		27.49	40		7	1949	က	954	28.17
9 0	931 27	27.49	40		FRAN (NC)	1996	က	954	28.17
4 -		27.58	43	_	ELOISE (NW FL)	1975	က	955	28.20
4 <b>.</b>	72 658	19.72	43		KING (SE FL)	1950	က	955	28.20
		27.75	3 5		Central	1926	ლ (	955	28.20
4		27.72	4. 4.		SWE	1918	m c	955	28.20
, c		27.82	48		<u>.</u>	1033	2 6	22	28.20
3 %		27.82	48	_	FI (Keys)	1000	י כ	937	20.20
* 4		27.91	20 20		EASY (NW FL)	1950	o «	92/ 058	28.20
* 4		27.91	20		( ×	1941	) (°	920	20.29
3 945		27.91	20		<u>1</u>	1917	o m	928	28.29
8°		27.91	20		×	1909	က	958	28.29
3 946		27.94	20	_	/AL	1906	က	958	28.29
3 946		27.94	22		ELENA (MS/AL/NW FL)	1985	ຕ່	626	28.32
מ מ	047 27	.97	ខ ខ		CAROL (NE U.S.)	1954	ന	096	28.35
. "		27 00	8 4		ONE (NC)	1955	က၊	096	28.35
		27.00	8 6			1993	m :	960	28.35
		27 99	200		ACICIA (N IX)	1983	ကဖ	362	28.41
		27.99	25 62	S ≥	SW FI /NF FI	1044	n 6	796	28.41
3 948		27.99	29	Cen	Central LA	1934	o «	206	20.41
3 + 949		28.02	63	SW	SW FL/SE FL	1948	) r	206	20.41
3 949		28.02	4	NW FL		1936	) m	66.0	28.47
		-						5	76.07
4 924		27.29							
4 931	3	27.49	Notes	ď					
4 940		27.76			Moving more than 30 miles and paint				
UNK 950		27.91	•8	High	Highest Category institled by winds	winds.			
		28.11	*		Classified 4 because of estimated winds	willds.			
4		28.29	+	Cap	Cape Fear. NC area only: was a category 2 at final landfall	as a catego	o. Pv 2 af final land	lfall	
	958 28		,			90000	) - at 1111 land		

Table 4a summarizes the direct hits on the U. S. mainland this century. The implication of Table 4a is that during the period 1900-1996, an average of 2 major hurricanes every 3 years made landfall somewhere along the U.S. Gulf or Atlantic coast. (All categories combined average about 5 hurricanes every 3 years for the same period.)

One of the greatest concerns of the National Weather Service's (NWS) hurricane preparedness officials is that the statistics in tables 2-4 will mislead people

Table 4a. Direct hits by mainland United States Hurricanes (1900-1996)

	Category	Direct Hits	
•	5	2	
	4	15	
	3	47	
	2	37	
	1	57	
•	TOTAL	158	À.
	MAJOR	64	
Major hu	rricanes are	e categories	3,4 & 5.

into thinking that no more large loss of life will occur in a hurricane because of our advanced technology. Dr. Robert Burpee, spokesman for the NWS hurricane warning service and Director of TPC, as well as former NHC Directors, Dr. Robert Sheets and Dr. Neil Frank, have repeatedly emphasized the great danger of a catastrophic loss of life in a future hurricane if proper preparedness plans for vulnerable areas are not formulated and maintained.

The study by Jarrell, Hebert and Mayfield (1992), using 1990 census data, showed that 85% of U.S. coastal residents from Texas to Maine had <u>never</u> experienced a direct hit by a major hurricane. Many of those <u>45 million residents</u> had moved to coastal sections during the past twenty-five years. <u>Even the landfalls of Andrew, Hugo, Opal and Fran</u> have not lessened an ever growing concern brought by the continued increase in coastal populations.

Table 5 which lists hurricanes by decades in this century shows that during the twenty year period 1960-1979 both the number and intensity of landfalling U.S. hurricanes decreased sharply! Based on 1900-1959 statistics, the expected number of hurricanes and major hurricanes during the period 1960-1979 was 36 and 15, respectively. In fact, only 27 or 75% of the expected number of hurricanes struck the U.S. with only 10 major hurricanes or 67% of that expected number. The decade of the eighties showed little change to this trend. Even the decade of the nineties, to date, shows below average landfall frequencies. If the 1995-96 pace of storm frequencies continues, a reversal in the recent trend may be upon us.

On the average a category 4 or greater hurricane strikes the U.S. once every 6 years. Even with two category 4 hurricanes in three years, Hugo in 1989 and Andrew in 1992, these are the only category 4 hurricanes since 1969. Fewer hurricanes do not necessarily mean a lesser threat of disaster, however. The 1919 hurricane which is both the third deadliest and fourth most intense of this century to strike the U.S. occurred in a year which had a total of only three storms/hurricanes. Records for the most intense U.S. hurricane in 1935 and the costliest, Andrew in 1992, occurred in years which had only six tropical storms or hurricanes.

The conclusions are obvious. A large death toll in a U.S. hurricane is still possible. decreased death totals in recent years may be as much a result of lack of major hurricanes striking the most vulnerable areas as they are of any fail-proof forecasting, warning, and observing systems. Continued coastal growth and inflation will almost certainly result in every future major landfalling hurricane (and even weaker hurricanes and tropical storms) replacing one of the

Table 5. Number of hurricanes by category to strike the mainland U.S. each decade. (Updated from Hebert et al. 1996)

		<u>C</u>	atego	гу		ALL	<u>Major</u>
DECADE	1	2	3	4	5	1,2,3,4,5	3,4,5
1900-1909	5	5	4	2	0	16	6
1910-1919	8	3	5	3	0	19	8
1920-1929	6	4	3	2	0	15	5
1930-1939	4	5	6	1	1	17	8
1940-1949	7	8	7	1	0	23	8
1950-1959	8	1	7	2	0	18	9
1960-1969	4	5	3	2	1	15	6
1970-1979	6	2	4	0	0	12	4
1980-1989	9	1	5	1	0	16	6
1990-1996	0	3	3	1	0	7	4
1900-1996	57	37	47	15	2	158	64
Note: Only t	he hi	ghest	categ	ory to	affect	the U.S. has	been used

current costliest hurricanes. If warnings are heeded and preparedness plans developed, the death toll can be reduced, but, in the absence of a change of attitude or laws restricting building near the ocean, large property losses are inevitable.

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In addition to information about U.S. hurricanes, this section also includes statistics on total tropical storm and hurricane activity.

## number of hurricanes per year?

Table 6 gives the average number of tropical cyclones which reached storm strength and hurricane strength for various time periods. A total of ten tropical cyclones reaching storm strength with five or six of these becoming hurricanes appears to be the best averages to use based on the past 10 to 50 year time periods.

#### (2) What year(s) have had the most and least hurricanes?

Table 7 shows the years of maximum and minimum tropical cyclone and hurricane activity for the entire Atlantic Ocean. The only years when a hurricane failed to strike the U.S. coast were 1902, 1905, 1907, 1914, 1922, 1927, 1930, 1931, 1937, 1951, 1958, 1962, 1973, 1978, 1981, 1982, 1990 and 1994. Note that only twice has the U.S. gone as long as two years without a hurricane. The most hurricanes to strike the U.S. in one year were six in 1916 and 1985. There were five in 1933, and four in 1906, 1909, and 1964. Three hurricanes have struck the U.S. in one year a total of fifteen times. Ten of these fifteen times occurred during the sixteen years from 1944 to 1959!

What is the average Table 6. Average number of tropical cyclones which reached storm and hurricane strength for various periods. Updated from Neumann, et al. (1993).

PERIOD	Number of years	Average number of Tropical Cyclones	Average number of Hurricanes
1886 - 1996	111	8.6	5.0
1947 - 1996	50	9.9	5.9
1957 - 1996	40	9.7	5.6
1967 - 1996	30	9.9	5.6
1977 - 1996	20	9.8	5.5
1982 - 1996	15	9.7	5.3
1987 - 1996	10	10.6	5.8

Table 7. Years of maximum and minimum tropical cyclone and hurricane activity in the North Atlantic, Caribbean, and Gulf of Mexico 1871-1996 (updated from Neumann, et al., 1993)

TROPICAL	CYCLONES <sup>1</sup>	HU	RRICANES <sup>2</sup>
Number	Years	Number	Years
21	1933	42	1969
19	1995	11	1916, 1950, 1995
18	1969	10	1887, 1893, 1933
17	1887	9	1955, 1980, 1996
16	1936		

TROPICA	L CYCLONES <sup>1</sup>	HU	RRICANES <sup>2</sup>
Number	Years	Number	Years
1	1890, 1914	0	1907,1914
2	1925, 1930	1	1890, 1905, 1919
			1925
		2	1895, 1897, 1904
			1917, 1922, 1930
			1931,1982

#### Notes

- Includes subtropical storms after 1967.
- Distinction of hurricanes recorded only after 1885.

- (3) When did the earliest and latest hurricane occur? The hurricane season is defined as June 1 through November 30. An early hurricane can be defined as occurring in the three months prior to the start of the season, and a late hurricane can be defined as occurring in the three months after the season. With these criteria the earliest observed hurricane in the Atlantic was on March 7, 1908, while the latest observed hurricane was on December 31, 1954, the second "Alice" of that year which persisted as a hurricane until January 5, 1955. The earliest hurricane to strike the U.S. in this century was Alma which struck northwest Florida on June 9, 1966. The latest hurricane to strike the U.S. was late on November 30, 1925 near Tampa, Florida.
- (4) What were the longest-lived and shortest-lived hurricanes? Ginger in 1971 holds the record for both the most number of days as a hurricane (20) and tropical cyclone (28). There have been many tropical cyclones which attained hurricane intensity for periods of 12 hours or less.
- What were the strongest and weakest Atlantic hurricanes? To strike the United States? In terms of central pressure (and probably winds), the strongest observed hurricane in the Atlantic basin was Gilbert in 1988 with a pressure of 888 millibars while located in the northwest Caribbean. The 1935 Labor Day hurricane in the Florida Keys with a pressure of 892 millibars was the most intense hurricane to strike the U.S. Numerous hurricanes have reached only the minimum wind speed near 74 miles per hour and struck the U.S.
- How many hurricanes have there been in each month? Table 8 adapted from Neumann, et al. (1993) shows the total and average number of tropical cyclones and those which became hurricanes by months for the period 1886-1996. In addition, the monthly total and average number of hurricanes to strike the U.S. in this century (updated from Hebert, Jarrell and Mayfield, 1996) are given.

Table 8. Tropical storms and hurricanes in the Atlantic, Caribbean and Gulf of Mexico by month of origin, 1886-1996 (updated from Neumann et al. 1993), and for hurricanes striking the U.S. mainland (updated from Hebert, et al. 1996).

	TROPICAL	CYCLONES1	HURR	ICANES	U.S. HUR	RRICANES <sup>2</sup>
MONTH	Total	Average	Total	Average	Total	Average
JANUARY-APRIL	. 4	*	1	*	0	0.00
MAY	14	0.1	3	*	0	0.00
JUNE	60	0.5	24	0.2	11	0.11
JULY	74	0.7	38	0.3	17	0.18
AUGUST	234	2.1	160	1.5	40	0.42
SEPTEMBER	318	2.9	201	1.8	62	0.65
OCTOBER	196	1.8	100	0.9	24	0.25
NOVEMBER	45	0.4	24	0.2	4	0.04
DECEMBER	6	0.1	3	*	0	0.00
YEAR	951	8.6	554	5.0	158	1.44

Includes subtropical storms after 1967. See Neumann, et al. (1993) for details.

<sup>&</sup>lt;sup>2</sup> For 1900-1996, (updated from Hebert, Jarrell and Mayfield, 1996)

<sup>\*</sup> Less than 0.05.

- What was the largest number of hurricanes in existence in the Atlantic Ocean at the same time? According to information on the current version of the master data file of Neumann, et al (1993), there have never been four hurricanes in existence in the North Atlantic at the same time in this century. On August 22, 1893 four hurricanes co-existed, one of them being the hurricane which killed an estimated 2,000 people in Georgia-South Carolina several days later. On September 11, 1961 three hurricanes and possibly a fourth existed. The only other years in this century with three hurricanes on the map at the same time were 1950 and 1967. In 1971 from September 10 to 12, there were five tropical cyclones in existence at once; however while four of these ultimately achieved hurricane intensity, never more than two were hurricanes at any one time.
- (8) How many direct hits by hurricanes of various categories have affected each state? Table 9, updated from Hebert, Jarrell and Mayfield, (1996), shows the number of hurricanes (direct hits) affecting the U.S. and individual states. The table shows that on the average close to three hurricanes every two years (1.5 per year) strike the U.S., while two major hurricanes cross the U.S.

coast somewhere every three years (0.67)year). per noteworthy Other facts, updated from Hebert, Jarrell and Mayfield, (1996), are: 1.) Thirty-seven percent of all U.S. hurricanes hit Florida: 2.) Seventy-one percent of category 4 or higher hurricanes have hit either Florida Texas; 3.) Approximately half hurricanes to strike along the middle Gulf coast, southern Florida. New York and southern New England are major ones.

Table 9. Hurricane direct hits on the mainland U.S. coastline and for individual states 1900-1996 by Saffir/Simpson category (updated from Hebert, et al. 1996).

										HUR	RI	CANI	E S
8 (440 A)		С	ATE	G	ORY	N	UME	BER		ALL		MAJ	OF
AREA	1		2		3		4		5				
U.S. (Texas to Maine)	58		36		47		15		2	158		6 4	
Texas	12		9		9		6		0	36		15	
(North)	7		3		3		4		0	17		7	
(Central)	2		2		1		1		0	6		2	
(South)	3		4		5		1		0	13		6	
Louisiana	8		5		8		3		1	25		12	
M ississippi	1		1		5		0		1	8		6	
Alabama	4		1		5		0		0	10		5	
Florida	17		16		17		6		1	57		24	
(Northwest)	9		8		7		0		0	. 24		7	
(Northeast)	2		7		0		0		0	9		0	
(Southwest)	6		3		6		2		1	18		9	
(Southeast)	5		10		7		4		0	26		11	
Georgia	1		4		0		0		0	5		0	
South Carolina	6		4		2		2		0	14		4	
North Carolina	10		4		10		1	•	0	25		11	
Virginia	2		1		1	•	0		0	4		1	*
Maryland	0		1	•	0		0		0	1	•	0	
Delaware	0		0		0		0		0	0		0	
New Jersey	1		0		0		0		0	1	•	0	
New York	3		1	•	5	•	0		0	9		5	*
Connecticut	2		3		3		0		0	8		3	
Rhode Island	0		2	•	3	*	0		0	5	•	3	
Massachusetts	2		2	•	2	•	0		0	6		2	*
New Hampshire	1	•	1	٠	0		0		0	2	*	0	
Maine	5		0		0		0		0	5		0	

Indicates all hurricanes in this group were moving faster than 30 mph. State totals will not equal U.S. totals, and Texas or Florida totals will not necessarily equal sum of sectional totals.

(9) When are the <u>major</u> hurricanes likely to strike given areas? Table 10 shows the incidence of major hurricanes by months for the mainland U.S. and individual states. For the United States as a whole, September has had more major hurricanes than all other months combined. However, four of the most devastating hurricanes did <u>not</u> occur in September--ANDREW (August 1992), CAMILLE (August 1969), AUDREY (June 1957), and HAZEL (October 1954). Only in Texas and Louisiana are major hurricanes in August and September almost an equal threat. Most major October hurricanes occur in southern Florida.

Table 10. Incidence of major hurricane direct hits on the mainland U.S. and individual states, 1900-1996, by Saffir/Simpson category. (Updated from Hebert, et al. 1996)

AREA	JUNE	JULY	AUG.	SEPT.	OCT.	ALL
U.S. (Texas to Maine)	2	3	15	36	8	64
Texas	1	1	7	6		15
(North)	1	1	3	2		7
(Central)			1	1		2
(South)			3	3		6
Louisiana	2		4	5	1	12
Mississippi		1	1	4		6
Alabama		1		4		5
Florida		1	2	15	6	24
(Northwest)		1		5	1	7
(Northeast)						0
(Southwest)			1	5	3	9
(Southeast)			2	7	2	11
Georgia						0
South Carolina				3	1	4
North Carolina			2	8	1	11
Virginia				1		1
Maryland						0
Delaware						0
New Jersey						0
New York			1	4		5
Connecticut			1	2		3
Rhode Island			1	2		3
Massachusetts				2		2
New Hampshire						0
Maine						0

Note: State totals do not equal U.S. totals and Texas or Florida totals do not necessarily equal the sum of sectional entries.

How long has it been since a major hurricane directly hit a given community? Any hurricane? Indirectly? A chronological list of all hurricanes to strike the U.S. during this century through 1990 including month, states affected by category, and minimum sea level pressure at landfall can be found in Jarrell, Hebert and Mayfield (1992). Table 11 extends that listing through 1996. Table 12 summarizes the occurrence of the last major hurricane or of any hurricane to directly hit the more populated coastal communities from Brownsville, Texas to Eastport, Maine. In addition, if a hurricane indirectly affected a community after the last direct hit, it is listed in the last column of the table. In order to obtain the same type of information listed in Table 12 for the remaining coastal communities, the reader is again referred to Jarrell, Hebert and Mayfield (1992).

Table 11. Chronological list of all hurricanes which affected the U.S. 1991-1996, including category by state. This is a continuation of a comparable table covering the years 1900-1990 given in Jarrell, Hebert and Mayfield (1992).

Year	Month	States Affected & Category by States	Highest Category U.S.	Minimum Sea Level Pressure (Mb.)	Name
1991	Aug.	NY,MA,RI 2	2	964	Bob
1992	Aug.	FL 4SE, 3SW, LA 3	4	922	Andrew
1993	Aug.	NC 3	3	960	Emily
1995	Aug.	FL, 1SE, 2NW	2	973	Erin
1995	Oct.	FL, 3NW	3	942	Opal
1996	July	NC 2	2	974	Bertha
1996	Sept.	NC 3	3	954	Fran

There are many illustrative examples of the uncertainty of when a hurricane might strike a given locality. Pensacola, Florida, in 1995 experienced a direct hit by hurricanes Erin and an indirect hit from major hurricane Opal within two months after a period of nearly 70 years without a direct hit. Miami, which expects a major hurricane every 25 years, on average, was struck by a major hurricane in 1992 for the first time since 1950. Tampa, hasn't experienced a major hurricane for 75 years. Many locations along the Gulf and Atlantic coasts have never experienced a major hurricane in this century (see Table 12).

What is the total United States damage (before and after adjustment for inflation) and death toll for each year of this century? Table 13 summarizes this information. Table 13a ranks the top 30 years by deaths, by unadjusted damage and by adjusted damage. In most years the death and damage totals are the result of a single, major hurricane. Gentry (1966) gives damages adjusted to 1957-59 costs as a base for the period 1915-1965. For the most part, death and damage totals for the period 1915-1965 were taken from Gentry's paper, and for the remaining years from the Monthly Weather Review. Adjusted damages were calculated to 1996 dollars by the same factors as used in Table 3a.

Table 12. Last direct or indirect hit by any or a major hunicane at certain populated coastal communities. Category in parenthesis (Updated from Jarrell, Hebert and Mayfield, 1992)

			111	of the			2	Cross Lists		Indimod Life
			DIEGINS .			i				I MIEGINIS
State	Q <del>.</del>	Last Major	Last Any	Last any	State	City	Last Major	Last Any	Arry	Last any
Texas	Brownsville	1980(3) Allen	1980(3) Allen		Florida	Cocoa	<1900	1995(1)	Erin	
	Corpus Christi	1970(3) Celia	1971(1) Fem	1980(3) Allen		Daytona Boh	<1900	1960(2)	Donna	1979(2) David
	Port Aransas	1970(3) Celia	1971(1) Fern	1980(3) Allen		St. Augustine	<1900	1964(2)	Dora	
	Matagorda	1961(4) Carla	1971(1) Fem	1983(3) Alicia		Jacksonville	<1900	1964(2)	Dora	
	Freeport	1983(3) Alicia	1983(3) Alicia		3.65	Fernandina Bdh	<1900	1928(2)		1964(2) Dora
	Galveston	1983(3) Alicia	1989(1) Jerry		Georgia	Brunswick	<1900	1928(1)		31
	Houston	1941(3)	1989(1) Jerry			Savannah	<1900	1979(2)	David	
	Beaumont	<1900	1986(1) Bornie		S. Carolina	Hilton Head	1959(3) Gradie	1979(2)	David	1985(1) Bob
Louisiana	Cameron	1957(4) Audrey		1985(1) Juan	a state	Charleston	1989(4) Hugo	1989(4)	Hugo	
	Morgan City	1992(3) Andrew			SE NOTE .	Myrtle Beach	1954(4*) Hazel	1954(4*)	Hazel	1989(4) Hugo
	Houma	1974(3) Carmen	14	1992(3) Andrew	N. Carolina	Wilmington		1996(3)	Fran	
	New Orleans	1965(3) Betsy	1965(3) Betsy	1969(5) Camille	W. N.	Morehead City		1996(3)	Fran	
Mssissippi	Bay St. Louis	1985(3) Bena	1985(3) Bena			Cape Hatteras	1993(3) Emily	1993(3)	Emily	
	Biloxi	1985(3) Bena	1985(3) Bena		Virginia	Virginia Beach	1944(3*)	1986(1)	Charley	
	Pascagoula	1985(3) Bena	1985(3) Bena			Norfolk	<1900	1966(1)	Connie	1985(3") Gloria
Alabama	Mobile	1985(3) Bena	1985(3) Bena		Maryland	Ocean City	<1900	<1900		1985(3*) Gloria
Florida	Pensacola	1926(3)	1995(1) Erin	1995(3) Opal	W 200	Baltimore	<1900	<1900		1954(2") Hazel
	Panama City	1995(3) Opal	1995(3) Opal		Delaware	Rehaboth Bah	<1900	<1900		1985(3") Gloria
	Apalachicola	1985(3) Bena	1985(2) Kate	1995(3) Opal	and the	Wilmington	<1900	<1900		1954(2") Hazel
	Homosassa	1950(3) Easy	1968(2) Gladys		New Jersey	Cape May	<1900	1903(1)		1985(3*) Gloria
	St. Petersburg	1921(3)	1946(1)	1968(2) Gladys		Atlantic City	<1900	1903(1)		1985(3*) Gloria
	Tampa	1921(3)	1946(1)	1968(2) Gladys	New York	New York City	<1900	1903(1)		1976(1) Belle
	Sarasota	1944(3)	1946(1)	1966(2) Alma		Westhampton	1985(3*) Gloria	1985(3*)	Goria	
	Fort Myers	1960(3) Donna		1966(2) Alma	Connecticut	NewLondon	1938(3*)	1991(2*)	Bob	
	Naples	1960(4) Donna	à.	1992(3) Andrew		NewHaven	1938(3*)	1985(2")	Goria	
	Key West	1948(3)	1987(1) Floyd		in sta	Bridgeport	1954(3°) Carol	1985(2*)	Goria	
	Mami	1992(4) Andrew			Rhode Island	Providence	1954(3°) Carol	1991(2*)	Bob	
	Fort Lauderdale	1950(3) King	1964(2) Cleo	1992(4) Andrew	Mass.	Cape Cod	1954(3*) Edna	1991(2*)	Bob	
	West Palm Beach	1949(3)	1979(2) David			Boston	<1900	1960(1*)	Donna	1991(1*) Bob
	Stuart	1949(3)	1979(2) David	,	N Hampshire Portsmouth	Portsmouth	<1900	1985(2")	Goria	
	Fort Pierce	1933(3)	1979(2) David		Maine	Portland	<1900	1985(1*)	Goria	
	Vero Beach	<1900	1995(1) Erin			Eastport	<1900	1969(1)	Gerda	1985(1*) Gloria
Notes:	<1900 means before 1900	re 1900			Notes:	* Moving over 30 mph	hợm C			

Table 13. Estimated annual deaths and damages (unadjusted and adjusted 1) in the mainland United States from landfalling Atlantic or Gulf hurricanes 1900-1996.

YEAR	DEATHS	DAMAGE ( Unadjusted	Adjusted <sup>1</sup>	741	YEAR	DEATHS	DAMAGE (S Unadjusted	Adjusted
1900	8000 +	30	841 2	704	1949	4	59	397
1901	10	1	28 <sup>2</sup>	100	1950	19	36	238
1902	0	Minor	Minor		1951	0	2	12
1903	15	1	28 2		1952	3	3	17
1904	5	2	56 <sup>2</sup>		1953	2	6	36
1905	0	Minor	Minor	Care L. But	1954	193	756	
1906	298	3	84 2		1954	218	985	4481
1907	0	0	0		1955	19		5721
1907	0	0	0		1. (2) (2) (3)	400	27	149
1908	406	8	224 2		1957	2	152	813
		1			1958		11	59
1910	30	1	28 <sup>2</sup> 28 <sup>2</sup>		1959	24	23	125
1911	17	14-0-0			1960	6.5	396	2148
1912	1	Minor	Minor		1961	46	414	2256
1913	5	3	84 2	- 111	1962	3	2	10
1914	0	0	0		1963	10	12	63
1915	550	63	1767 <sup>3</sup>		1964	49	5 1 5	2768
1916	107	33	774		1965	75	1445	7553
1917	5	Minor	Minor	Ant 1	1966	54	15	7 5
1918	34	5	76		1967	18	200	970
1919	287 5	22	298		1968	9	10	46
1920	2	3	32		1969	256	1421	6098
1921	6	3	40	77 W	1970	11	454	1838
1922	0	0	0		1971	8	213	808
1923	0	Minor	Minor		1972	122	2100	7500
1924	2	Minor	Minor		1973	5	3	10
1925	6	Minor	Minor		1974	1	150	435
1926	269	112	1515		1975	21	490	1298
1927	0	0	0		1976	9	100	253
1928	1836	25	338		1977	0	10	23
1929	3	1	13	10.4	1978	36	20	42
1930	0	Minor	Minor		1979	22	3045	5731
1931	0	0	0		1980	2	300	509
1932	40	8	115		1981	0	25	39
1933	63	47	751		1982	0	Minor	Minor
1934	17	5	73		1983	22	2000	2983
1935	414	12	175	一十五人	1984	4	66	95
1936	9	2	30		1985	30	4000	5623
1937	0	Minor	Minor	- Held	1986	9	17	23
1938	600	306	4140	15	1987	0	8	10
1939	3	Minor	Minor	5,110	1988	6	9	11
1940	5 1	5	70		1989	56	7670	9304
1941	10	8	105	THE PERSON NAMED IN	1990	13	57	67
1942	8	27	307	14. 19	1991	16	1500	1748
1943	16	17	181	11 11 11 11	1992	24	26500	30475
1944	64 s	165	1757	or all	1993	4	57	63
1945	7	80	829		1994	38	973	1035
1946	0	5	44		1995	29	3723	3809
1947	53	136	1003		1996	36	3600	3600
1948	3	18	121	7,50	1000	30	3000	3000

Adjusted to 1996 dollars based on U.S. Department of Commerce Implicit Price Deflator for Construction.

Using 1915 cost adjustment - none available prior to 1915.

Considered too high in 1915 reference.

Figures do not agree with table 2 because these figures are for landfalling hurricanes and do not include non-coastal deaths at sea.

Table 13a. Same information as in table 13, but only the top 30 years are ranked in colums by deaths, by unadjusted damages, and by adjusted damages.

	Ranke	d on			Ranke	ed on			Ranke		
	Deat			Un	adjusted	d Damage		A	djusted <sup>1</sup>	Damage	9
1	1900	8000 +		1	1992	26500	12	1	1992	30475	
2	1928	1836		2	1989	7670	1 21	2	1989	9304	
3	1938	600		3	1985	4000		3	1965	7553	
4	1915	550		4	1995	3723		4	1972	7500	
5	1935	414		5	1996	3600		5	1969	6098	
6	1909	406		6	1979	3045		6	1979	5731	
7	1957	400		7	1972	2100		7	1955	5721	
8	1906	298		8	1983	2000		8	1985	5623	
9	1919	287 <sup>s</sup>		9	1991	1500		9	1954	4481	
10	1926	269		10	1965	1445		10	1938	4140	
11	1969	256		11	1969	1421	m - 1 1 1	11	1995	3809	
12	1955	218		12	1955	985		12	1996	3600	
13	1954	193		13	1994	973	A STATE OF THE STA	13	1983	2983	
14	1972	122		14	1954	756		14	1964	2768	
15	1916	107		15	1964	515		15	1961	2256	
16	1965	75		16	1975	490		16	1960	2148	
17	1960	65		17	1970	454		17	1970	1838	
18	1944	64 <sup>s</sup>		18	1961	414		18	1915	1767	
19	1933	63		19	1960	396		19	1944	1757	
20	1989	56		20	1938	306		20	1991	1748	
21	1966	54		21	1980	300		21	1926	1515	
22	1947	53		22	1971	213		22	1975	1298	
23	1940	51		23	1967	200		23	1994	1035	
24	1964	49	1	24	1944	165		24	1947	1003	
25	1961	46		25	1957	152		25	1967	970	
26	1932	40		26	1974	150	8	26	1900	841	
27	1994	38		27	1947	136		27	1945	829	
28	1978	36		28	1926	112	30	28	1957	813	
29	1918	34		29	1976	100		29	1971	808	
30	1910	30		30	1945	80		30	1916	774	

May actually have been as high as 10,000 to 12,000.

Adjusted to 1996 dollars based on U.S. Department of Commerce Implicit Price Deflator for Construction.

<sup>&</sup>lt;sup>2</sup> Considered too high in 1915 reference.

<sup>&</sup>lt;sup>3</sup> Using 1915 cost adjustment - none available prior to 1915.

Figures do not agree with Table 2 because these figures are for landfalling hurricanes and do not include non-coastal deaths at sea.

Are there hurricane cycles? Figures 1 through 10 show the landfalling portion of the tracks of major hurricanes which have struck any portion of the United States during this century. The reader might note the tendency of the major hurricanes to cluster in certain areas during certain decades. Another interesting point is the general tendency for this clustering to occur in the latter half of individual decades in one area and in the first half of individual decades in another area. During the very active period of the thirties this clustering is not apparent.

A comparison of twenty-year periods beginning in 1900 indicates that the major hurricanes tended to be in the western Gulf Coast states at the beginning of the century, shifting to the eastern Gulf Coast states and Florida during the next twenty years, then to Florida and the Atlantic Coast states during the forties and fifties, and back to the western Gulf Coast states in the sixties and seventies. Do figures 9 and 10 indicate a shift to the eastern Gulf Coast states, Florida, and the Atlantic Coast states in the eighties and nineties?

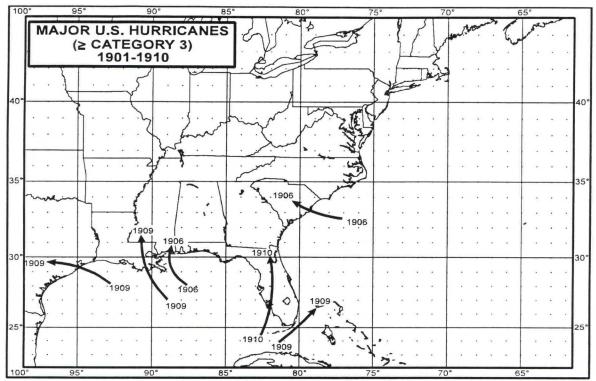


Figure 1. Major landfalling United States hurricanes (greater than or equal to a category 3) during the period 1901-1910.

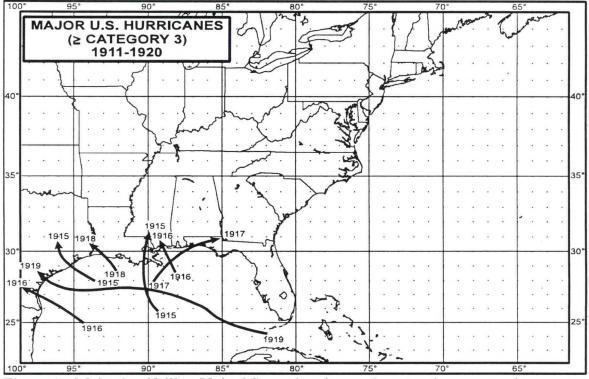


Figure 2. Major landfalling United States hurricanes (greater than or equal to a category 3) during the period 1911-1920.

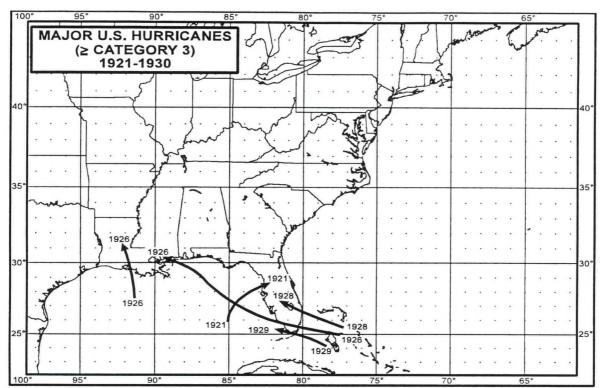


Figure 3. Major landfalling United States hurricanes (greater than or equal to a category 3) during the period 1921-1930.

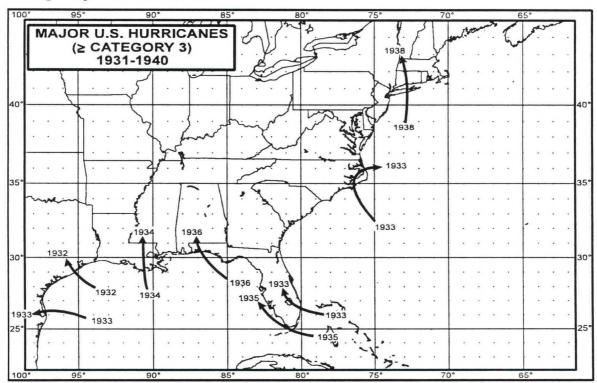


Figure 4. Major landfalling United States hurricanes (greater than or equal to a category 3) during the period 1931-1940.

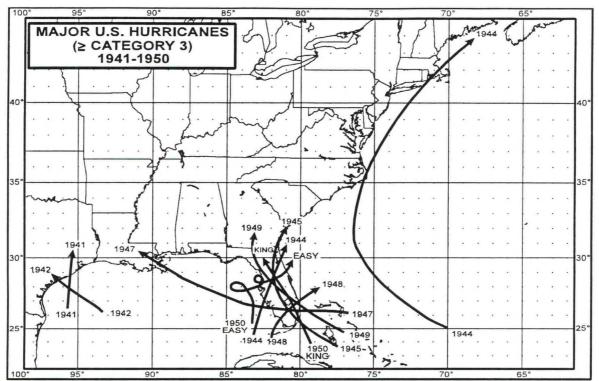


Figure 5. Major landfalling United States hurricanes (greater than or equal to a category 3) during the period 1941-1950.

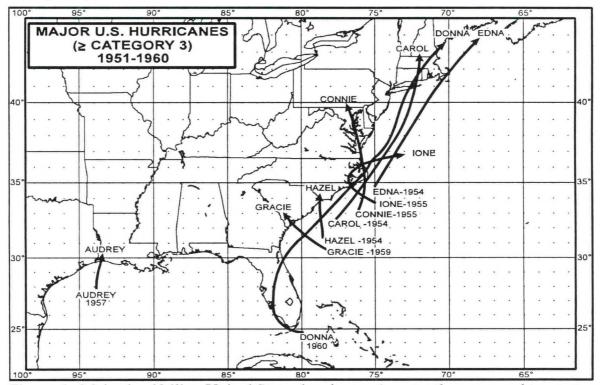


Figure 6. Major landfalling United States hurricanes (greater than or equal to a category 3) during the period 1951-1960.

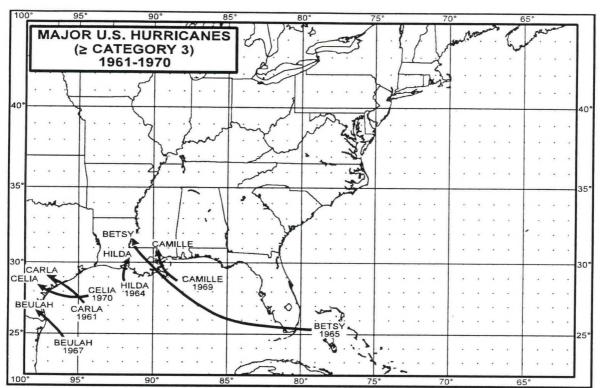


Figure 7. Major landfalling United States hurricanes (greater than or equal to a category 3) during the period 1961-1970.

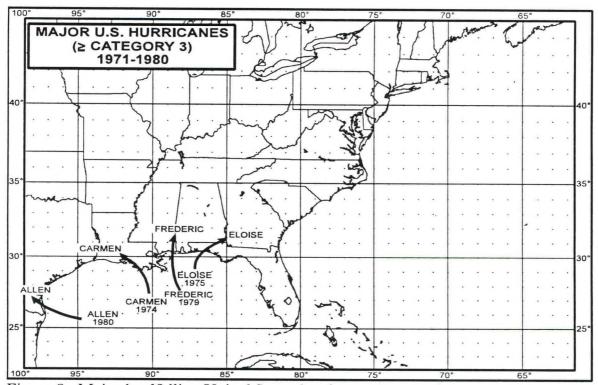


Figure 8. Major landfalling United States hurricanes (greater than or equal to a category 3) during the period 1971-1980.

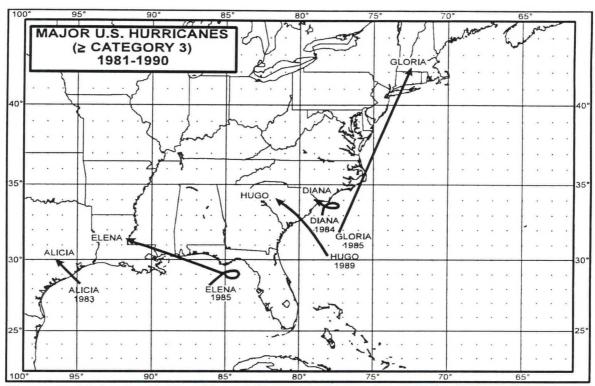


Figure 9. Major landfalling United States hurricanes (greater than or equal to a category 3) during the period 1981-1990.

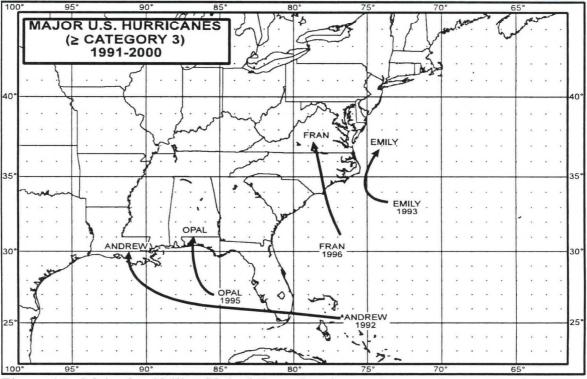


Figure 10. Major landfalling United States hurricanes (greater than or equal to a category 3) during the period 1991-2000.

(13) Are there hurricane cycles evident in certain years regardless of category or geographical area? Table 14 gives a tabulation of hurricanes of all categories to affect the U.S. by individual years within each decade.

Table 14. Major and all category landfalling hurricanes in the mainland United States by individual years.

				Mai	or Hu	rrican	98				
Decade	00	01	02	03	04	05	06	07	08	09	Total
1900-09	1						2			3	6
1910-19	1					2	2	1	1	1	8
1920-29		1					2		1	1	5
1930-39			1	3	1	1	1		1		8
1940-49		1	1		2	1		1	1	1	8
1950-59	2				3	2		1		1	9
1960-69	1	1			1	1		1		1	6
1970-79	1				1	1				1	4
1980-89	1			1	1	2				1	6
TOTAL	7	3	2	4	9	10	7	4	4	10	60
1990-99			1	1		1	1				4
				٨п	Llurei	canes					
Decade	00	01	02	03	04			07	00	001	
1900-09	1	2	02	2		05	06	07	08	09	Total
1910-19	2	2	2	2	1	2	4		1	4	15
1920-29	2	2	2	1	2	3	6	1	1	1	20
1930-39	2	2	2	5			3		2	2	15
1940-49	2	2	2	1	2	2	3	2	2	1	. 17
1950-59	3	2	1	3			1	3	3	3	23
1960-69	2	1	1		3	3	1	1		3	18
1970-79	1	1 3	4	1	4	1	2	1	1	2	15
1980-89	1	3	1	4	1	1	1	1		3	12
TOTAL	14	12	8	1	1	6	2	1	1	3	16
1990-99	14			16	17	20	23	8	11	22	151
1330-39		1	1	1		2	2				7

Figures 1 through 10 certainly support the existence of a cyclical nature of major hurricanes affecting given regions. Table 14 is also suggestive of preferred periods. However, it is left to the reader to decide what weight should be given to these statistics.

Table 15. Deadliest, Costliest Hurricanes of the Twentieth Century to affect Hawaii, Puerto Rico and the U.S. Virgin Islands.

		Island or	Damage (\$000)			Max Wind	Min P
Name	Date	CPA	Unadjusted	Adjusted	Deaths	(Mph)	(Mb)
Mokapu Cyclone	Aug 19,1938	25 mi NE Oahu	Unk	Unk	Chk	Unk	Sur
ΤΞΞ	Aug 15,1950	100 mi NE Hawaii	Cuk	Cnk	Unk	Unk	Unk
Nina	Dec 02,1957	100 mi SW Kauai	200	1,070	4	06	965
Dot	Aug 06,1959	Kauai	000'9	32,547	0	115	955
lwa	Nov 23,1982	25 mi NW Kauai	312,000	473,976	-	06	964
Iniki	Sep 11,1992	Kauai	1,800,000	2,070,000	4	130	950
San Hipolito	Aug 22,1916	Puerto Rico	1,000	23,469	-	86	988
San Liborio	Jul 23,1926	SW Puerto Rico	2,000	67,647	25	81	~985
San Felipe	Sep 13,1928	Puerto Rico	85,000	1,150,000	312	161	0
San Nicolas	Sep 10,1931	1 Puerto Rico	200	2,875	2	121	0
San Ciprian	Sep 26,1932	1 USVI, PR	30,000	431,250	225	86	948
San Mateo	Sep 21,1949	St. Croix	Chr	Urk	Unk	81	~985
Santa Clara (Betsy)	Aug 12,1956	Puerto Rico	40,000	220,096	16	92	991
Donna	Sep 05,1960	PR & St. Thomas	Unk	Crk	107	132	958
Eloise (T.S.)	Sep 15,1975	Puerto Rico	Unk	Unk	44	40	1007
David	Aug 30,1979	2 S. of Puerto Rico	Unk	Crk	Unk	173	924
Frederic (T.S.)	Sep 04,1979	Puerto Rico	125,000	235,270	7	58	1000
Hugo	Sep 18,1989	USVI, PR	1,000,000	1,213,080	5	138	940
Marilyn	Sep 16,1995	USVI, E. PR	1,500,000	1,534,698	80	109	952
Hortense	Sep 10,1996	SW Puerto Rico	200,000	200,000	18	81	686

Effects continued into the following day. \* Damage and Casualties from David and Frederic are combined.

Table 15 lists important hurricanes of Hawaii, Puerto Rico, and the U. S. Virgin Islands during the twentieth century. The Saffir/Simpson scale and the empirical Atlantic wind pressure relationship do not strictly apply in the Hawaiian area, and thus hurricanes are not readily comparable to those of the Atlantic basin. Additionally some of the hurricanes passing Kauai were moving fast and this translation speed probably adds to the maximum wind. In both island areas, some minimum pressure values appear inconsistent with the given wind values. This is largely attributable to the given minimum pressure and maximum winds not necessarily being the extremes in the hurricane.

#### **SUMMARY**

In virtually every coastal city of any size from Texas to Maine, the present Tropical Prediction Center Director, Dr. Robert Burpee, or former National Hurricane Center Directors, Dr. Robert Sheets and Dr. Neil Frank, have stated that the United States is building toward a hurricane disaster. The population growth versus low hurricane experience levels indicated in Hebert, Taylor, and Case (1984), together with updated statistics presented by Jarrell, Hebert and Mayfield (1992) form the basis for their statements. Stated simply, the areas of the United States where 9 out of 10 persons have lost their lives by drowning from the storm surge during hurricanes (along the immediate Gulf of Mexico and Atlantic shorelines) are the very areas where the most dramatic increases in population have occurred in recent years. This situation, in combination with continued building on low coastal elevations, will lead to serious problems for many areas in future hurricanes. Since it is likely that people will always live along the immediate shoreline, a pleasant way of life, the solution to the problem lies in education and preparedness.

The message to coastal residents is this: Become familiar with what hurricanes can do, and when a hurricane threatens your area, increase your chances of survival by moving away from the water until the hurricane has passed! Unless this message is clearly understood by coastal residents through a thorough and continuing preparedness effort, disastrous loss of life is inevitable in the future.

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