NOAA Technical Memorandum NWS TPC-1

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

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NWS NHC 20 The Miss/Hit Ratio - An Estimate of Reliability for Tropical Cyclone Track Predictions, Preston W. Leftwich, Jr. - April 1983

PREFACE

This version of the Deadliest, Costliest, and Most Intense United States Hurricanes of This Century is an update through the 1995 hurricane season of Hebert, Jarrell and Mayfield (1995). This update is largely to include the 1995 season and adds information on hurricanes affecting Puerto Rico and the U. S. Virgin Islands.

Information for Hawaii, Puerto Rico and the Virgin Islands, given in Table 14, was provided by Hans Rosendal and Raphael Mojica of the Weather Service Forecast Offices in Honolulu and San Juan, respectively.

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)

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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 major[1] 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 Information Center (another function of TPC). 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[2]? Answers to these and several other questions are provided in Section 3.

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[1] 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.

[2] 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 (Category)	Central Pressure (Millibars)	Central Pressure (Inches)	Winds (Mph)	Surge (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 directly on the criteria used in preparing another study, Hurricane Experience Levels of Coastal County Populations-Texas to Maine (Jarrell, Hebert, and Mayfield, 1992). The primary purpose 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 subjective determination of which category number to assign to a hurricane, as well as its direct or indirect effect, is made on a county by county basis 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:

> Direct Hit - 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.

Indirect Hit - 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 climatological with their primary purpose being for use in assessing risk based on past experience. On the other hand, the National Weather Service's Hurricane Probability Program has as its purpose the assessment of risk based on a present 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 must 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 (1995 for example) and Storm Data (1995 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.

(2) **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 1994 dollars[3]. 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 63 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 thirteen costliest tropical cyclones (Table 3) resulted from inland flooding caused by torrential rainfall in mountainous areas. (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) have occurred during the past twenty five years in contrast to three-fifths 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.

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[3] Adjusted to 1994 dollars on basis of U.S. Department of Commerce Implicit Price Deflator for Construction.

Table 2. The deadliest mainland United States hurricanes 1900-1995. (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	SE FL	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	S TX	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

ADDENDUM (Pre-1900 or Not Atlantic/Gulf Coast)

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)	1960	4	107
24	Southern California	1939	TS &	45
24	Eloise(Puerto Rico)	1975	TS &	44

\+ May actually have been as high as 10,000 to 12,000
* 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, 1900-1995, (The top 30 are listed).

RANK	HURRICANE	YEAR	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	OPAL (NW FL/AL)	1995	3	3,000,000,000 #
4	FREDERIC (AL/MS)	1979	3	2,300,000,000
5	AGNES (FL/NE U.S.)	1972	1	2,100,000,000
6	ALICIA (N TX)	1983	3	2,000,000,000
7	BOB (NC, NE U.S)	1991	2	1,500,000,000
7	JUAN (LA)	1985	1	1,500,000,000
9	CAMILLE (MS/SE LA/VA)	1969	5	1,420,700,000
10	BETSY (SE FL/SE LA)	1965	3	1,420,500,000
11	ELENA (MS/AL/NW FL)	1985	3	1,250,000,000
12	GLORIA (Eastern U.S.)	1985	3 *	900,000,000
13	DIANE (NE U.S.)	1955	1	831,700,000
14	ALLISON (N TX)	1989	TS @	500,000,000
14	ALBERTO (NW FL,GA,AL)	1994	TS @	500,000,000
16	ELOISE (NW FL)	1975	3	490,000,000
17	CAROL (NE U.S.)	1954	3 *	461,000,000
18	CELIA (S TX)	1970	3	453,000,000
19	CARLA (N & Central TX)	1961	4	408,000,000
20	CLAUDETTE (N TX)	1979	TS @	400,000,000
20	GORDON (S & Cent FL,NC)	1994	TS @	400,000,000
22	DONNA (FL/Eastern U.S.)	1960	4	387,000,000
23	DAVID (FL/Eastern U.S.)	1979	2	320,000,000
24	New England	1938	3 *	306,000,000
25	KATE (FL Keys/NW FL)	1985	2	300,000,000
25	ALLEN (S TX)	1980	3	300,000,000
27	HAZEL (SC/NC)	1954	4 *	281,000,000
28	DORA (NE FL)	1964	2	250,000,000
29	BEULAH (S TX)	1967	3	200,000,000
30	AUDREY (SW LA/N TX)	1957	4	150,000,000
ADDENDUM				
6	INIKI (Kauai, HI)	1992	Unk.	1,800,000,000
7	MARILYN (USVI, PR)	1995	2	1,500,000,000
12	HUGO (USVI, PR)	1989	4	1,000,000,000
22	OLIVIA (CA)	1982	T.D. &	325,000,000
23	IWA (Kauai, HI)	1982	Unk.	312,000,000
24	NORMAN (CA)	1978	T.D. &	300,000,000
29	KATHLEEN (CA & AZ)	1976	T.D. &	160,000,000

Notes:

* Moving more than 30 miles per hour.

@ Only of Tropical Storm intensity.

\# Current estimate subject to change, probably too high.

& Only a Tropical Depression

Table 3a. The costliest mainland United States hurricanes, 1900-1995.
(The top 30 are listed when adjusted** to 1994 dollars.)

RANK	HURRICANE	YEAR	Category	Damage (U.S.)**
1	ANDREW (SE FL/SE LA)	1992	4	28,620,000,000
2	HUGO (SC)	1989	4	7,910,000,000
3	AGNES (FL/NE U.S.)	1972	1	6,930,000,000
4	BETSY (SE FL/SE LA)	1965	3	6,875,220,000
5	CAMILLE (MS/SE LA/VA)	1969	5	5,640,179,000
6	DIANE (NE U.S.)	1955	1	4,516,131,000
7	FREDERIC (AL/MS)	1979	3	3,933,000,000
8	New England	1938	3 *	3,864,780,000
9	OPAL (NW FL/AL)	1995	3	2,880,000,000 #
10	ALICIA (N TX)	1983	3	2,760,000,000
11	CAROL (NE U.S.)	1954	3 *	2,549,330,000
12	CARLA (N & Central TX)	1961	4	2,072,640,000
13	DONNA(FL/Eastern U.S.)	1960	4	1,962,090,000
14	JUAN (LA)	1985	1	1,950,000,000
15	CELIA (S TX)	1970	3	1,694,220,000
16	BOB (NC, NE U.S)	1991	2	1,635,000,000
17	ELENA (MS/AL/NW FL)	1985	3	1,625,000,000
18	HAZEL (SC/NC)	1954	4 *	1,553,930,000
19	FL (Miami)/MS/AL/Pensacola	1926	4	1,414,560,000
20	N TX (Galveston)	1915	4	1,264,800,000 1
21	DORA (NE FL)	1964	2	1,245,000,000
22	ELOISE (NW FL)	1975	3	1,190,700,000
23	GLORIA (Eastern U.S.)	1985	3 *	1,170,000,000
24	NE U.S.	1944	3 *	994,000,000 +
25	BEULAH (S TX)	1967	3	900,000,000
26	N TX (Galveston)	1900	4	759,909,000 2
27	SE FL/SE LA/MS	1947	4	756,800,000
28	AUDREY (SW LA/N TX)	1957	4	748,500,000
29	CLAUDETTE(N TX)	1979	T.S. @	684,000,000
30	CLEO (SE FL)	1964	2	639,930,000

ADDENDUM

15	INIKI (Kauai, HI)	1992	Unk.	1,944,000,000
19	MARILYN (USVI,E. PR)	1995	2	1,440,000,000
24	HUGO (USVI, PR)	1989	4	1,130,000,000
24	SAN FELIPE (PR)	1928	4	1,071,000,000

notes

** Adjusted to 1994 dollars on basis of U.S. DOC Implicit Price Deflator for Construction. 1995 damages adjusted downward.

* Moving more than 30 miles per hour

\# Current estimate subject to change, probably too high.

1 Damage estimate was considered too high in 1915 reference.

\+ Probably higher

2 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, 1900-1995.

RANK	HURRICANE	YEAR	CATEGORY (at landfall)	MINIMUM PRESSURE Millibars	MINIMUM PRESSURE Inches
1	FL (Keys)	1935	5	892	26.35
2	CAMILLE (MS/SE LA/VA)	1969	5	909	26.84
3	ANDREW (SE FL/SE LA)	1992	4	922	27.23
4	FL (Keys)/S TX	1919	4	927	27.37
5	FL (Lake Okeechobee)	1928	4	929	27.43
6	DONNA (FL/Eastern U.S.)	1960	4	930	27.46
7	TX (Galveston)	1900	4	931	27.49
7	LA (Grand Isle)	1909	4	931	27.49
7	LA (New Orleans)	1915	4	931	27.49
7	CARLA (N & Central TX)	1961	4	931	27.49
11	HUGO (SC)	1989	4	934	27.58
12	FL (Miami)/MS/AL/Pensacola	1926	4	935	27.61
13	HAZEL (SC/NC)	1954	4 *	938	27.70
14	SE FL/SE LA/MS	1947	4	940	27.76
15	N TX	1932	4	941	27.79
16	GLORIA (Eastern U.S.)	1985	3 *&	942	27.82
16	OPAL (NW FL/AL)	1995	3 &	942	27.82
18	AUDREY (SW LA/N TX)	1957	4 #	945	27.91
18	TX (Galveston)	1915	4 #	945	27.91
18	CELIA (S TX)	1970	3	945	27.91
18	ALLEN (S TX)	1980	3	945	27.91
22	New England	1938	3 *	946	27.94
22	FREDERIC (AL/MS)	1979	3	946	27.94
24	NE U.S.	1944	3 *	947	27.97
24	SC/NC	1906	3	947	27.97
26	BETSY (SE FL/SE LA)	1965	3	948	27.99
26	SE FL/NW FL	1929	3	948	27.99
26	SE FL	1933	3	948	27.99
26	S TX	1916	3	948	27.99
26	MS/AL	1916	3	948	27.99
31	DIANA (NC)	1984	3 +	949	28.02
31	S TX	1933	3	949	28.02
	ADDENDUM				
4	DAVID (S of PR)	1979	4	924	27.29
7	San Felipe (PR)	1928	4	931	27.49
14	HUGO (USVI & PR)	1989	4	940	27.76
32	INIKI (KAUAI, HI)	1992	UNK	950	27.91
41	DOT (KAUAI, HI)	1959	UNK	955	28.11
49	DONNA (St.Thomas, PR)	1960	4	958	28.29
62	IWA (KAUAI, HI)	1982	UNK	964	28.47

RANK	HURRICANE	YEAR	CATEGORY (at landfall)	MINIMUM PRESSURE Millibars	MINIMUM PRESSURE Inches
33	BEULAH (S TX)	1967	3	950	28.05
33	HILDA (Central LA)	1964	3	950	28.05
33	GRACIE (SC)	1959	3	950	28.05
33	TX (Central)	1942	3	950	28.05
37	SE FL	1945	3	951	28.08
38	FL (Tampa Bay)	1921	3	952	28.11
38	CARMEN (Central LA)	1974	3	952	28.11
40	EDNA (New England)	1954	3 *	954	28.17
40	SE FL	1949	3	954	28.17
42	ELOISE (NW FL)	1975	3	955	28.20
42	KING (SE FL)	1950	3	955	28.20
42	Central LA	1926	3	955	28.20
42	SW LA	1918	3	955	28.20
42	SW FL	1910	3	955	28.20
47	NC	1933	3	957	28.26
47	FL (Keys)	1909	3	957	28.26
49	EASY (NW FL)	1950	3	958	28.29
49	N TX	1941	3	958	28.29
49	NW FL	1917	3	958	28.29
49	N TX	1909	3	958	28.29
49	MS/AL	1906	3	958	28.29
54	ELENA (MS/AL/NW FL)	1985	3	959	28.32
55	CAROL (NE U.S.)	1954	3 *	960	28.35
55	IONE (NC)	1955	3	960	28.35
55	EMILY (NC)	1993	3	960	28.35
58	ALICIA (N TX)	1983	3	962	28.41
58	CONNIE (NC/VA)	1955	3	962	28.41
58	SW FL/NE FL	1944	3	962	28.41
58	Central LA	1934	3	962	28.41
62	SW FL/SE FL	1948	3	963	28.44
63	NW FL	1936	3	964	28.47

Notes

- * Moving more than 30 miles per hour.
- & Highest category justified by winds.
- # Classified 4 because of estimated winds.
- + Cape Fear, NC area only; was a category 2 at final landfall.

Table 4a. Direct hits by mainland United States Hurricanes (1900-1995)

Category	Direct Hits
5	2
4	15
3	46
2	36
1	57
TOTAL	156
MAJOR	63

Major hurricanes are categories 3,4 & 5.

Table 4a summarizes the direct hits on the U. S. mainland this century. The implication of table 4a is that during the period 1900-1995, 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 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 never experienced a direct hit by a major hurricane. Many of those 45 million residents had moved to coastal sections during the past twenty-five years. Even the landfalls of Andrew, Hugo and Opal 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 near record 1995 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. The 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 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.

Table 5. Number of hurricanes by category to strike the mainland U.S. each decade. (Updated from Hebert et al. 1995)

	Category					ALL	Major
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
1990-1995	0	2	2	1	0	5	3
1900-1995	57	36	46	15	2	156	63

Note: Only the highest category to affect the U.S. has been used

Part II

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

(1) **What is the average 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.

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 - 1995	110	8.5	5.0
1946 - 1995	50	9.7	5.7
1956 - 1995	40	9.6	5.5
1966 - 1995	30	9.9	5.5
1976 - 1995	20	9.7	5.4
1981 - 1995	15	9.7	5.1
1986 - 1995	10	9.9	5.3

Includes subtropical storms after 1967

(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! A chronological list of all hurricanes to strike the U.S. during this century through 1991 including month, category by states affected, and minimum sea level pressure at landfall can be found in Jarrell, Hebert and Mayfield (1992).

Table 7. Years of maximum and minimum tropical cyclone and hurricane activity in the North Atlantic, Caribbean, and Gulf of Mexico 1871-1995 (updated from Neumann, et al., 1993)

MAXIMUM ACTIVITY

TROPICAL CYCLONES[1]		HURRICANES[2]	
Number	Years	Number	Years
21	1933	12	1969
19	1995	11	1916,1950,1995
18	1969	10	1887,1893,1933
17	1887	9	1955,1980
16	1936		

MINIMUM ACTIVITY

TROPICAL CYCLONES[1]		HURRICANES[2]	
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
1 Includes subtropical storms after 1967.
2 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.

(5) **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 strongest 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.

(6) **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 1886-1995. In addition, the monthly total and average number of hurricanes to strike the U.S. in this century (updated from Hebert, Jarrell and Mayfield, 1995) are given.

Table 8. Tropical storms and hurricanes in the Atlantic, Caribbean and Gulf of Mexico by month of origin, 1886-1995 (updated from Neumann et al. 1993), and for hurricanes striking the U.S. mainland (updated from Hebert, et al. 1995).

	TROPICAL CYCLONES[1]		HURRICANES		U.S. HURRICANES[2]	
MONTH	Total	Average	Total	Average	Total	Average
JANUARY-APRIL	4	*	1	*	0	0.00
MAY	14	0.1	3	*	0	0.00
JUNE	59	0.5	24	0.2	11	0.11
JULY	72	0.7	36	0.3	16	0.17
AUGUST	230	2.1	157	1.4	40	0.42
SEPTEMBER	316	2.9	199	1.8	61	0.64
OCTOBER	193	1.8	99	0.9	24	0.25
NOVEMBER	44	0.4	23	0.2	4	0.04
DECEMBER	6	0.1	3	*	0	0.00
YEAR	938	8.5	545	5.0	156	1.42

[1] Includes subtropical storms after 1967. See Neumann, et al. (1993) for details.
[2] For 1900-1995, (updated from Hebert, Jarrell and Mayfield, 1995)
* Less than 0.05.

(7) **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, (1995), 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 per year). Other noteworthy facts, updated from Hebert, Jarrell and Mayfield, (1995), 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 or Texas; 3.) Approximately half the 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 1900-1995 by Saffir/Simpson category (updated from Hebert, et al. 1995).

AREA	CATEGORY NUMBER 1	2	3	4	5	ALL	MAJOR HURRICANES
U.S. (Texas to Maine)	58	35	46	15	2	156	63
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
Mississippi	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	3	9	1 *	0	23	10
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 *	0	0	0	2 *	0
Maine	5 *	0	0	0	0	5	0

Notes:

* 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 major 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 not 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, 1900-1995, by Saffir/Simpson category. (Updated from Hebert, et al. 1995)

AREA	JUNE	JULY	AUG.	SEPT.	OCT.	ALL
U.S. (Texas to Maine)	2	3	15	35	8	63
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	7	1	10
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.

(10) **How long has it been since a major hurricane directly hit a given community? Any hurricane? Indirectly?** Table 11 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 11 for the remaining coastal communities, the reader is referred to Jarrell, Hebert and Mayfield (1992).

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 11).

(11) **What is the total United States damage (before and after adjustment for inflation) and death toll for each year of this century?** Table 12 summarizes this information. Tables 12a ranks the 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 1994 dollars by the same factors as used in Table 3a.

Table 11. Last direct or indirect hit by any or a major hurricane at certain populated coastal communities. Category in parenthesis (Updated from Jarrell, Hebert and Mayfield, 1992)

State	City	Direct Hits Last Major	Direct Hits Last Any	Indirect Hits Last any
Texas	Brownsville	1980(3) Allen	1980(3) Allen	
	Corpus Christi	1970(3) Celia	1971(1) Fern	1980(3) Allen
	Port Aransas	1970(3) Celia	1971(1) Fern	1980(3) Allen
	Matagorda	1961(4) Carla	1971(1) Fern	1983(3) Alicia
	Freeport	1983(3) Alicia	1983(3) Alicia	
	Galveston	1983(3) Alicia	1989(1) Jerry	
	Houston	1941(3)	1989(1) Jerry	
	Beaumont	<1900	1986(1) Bonnie	
Louisiana	Cameron	1957(4) Audrey	1985(1) Danny	1985(1) Juan
	Morgan City	1992(3) Andrew	1992(3) Andrew	
	Houma	1974(3) Carmen	1985(1) Juan	1992(3) Andrew
	New Orleans	1965(3) Betsy	1965(3) Betsy	1969(5) Camille
Mississippi	Bay St. Louis	1985(3) Elena	1985(3) Elena	
	Biloxi	1985(3) Elena	1985(3) Elena	
	Pascagoula	1985(3) Elena	1985(3) Elena	
Alabama	Mobile	1985(3) Elena	1985(3) Elena	
Florida	Pensacola	1926(3)	1995(1) Erin	1995(3) Opal
	Panama City	1995(3) Opal	1995(3) Opal	
	Apalachicola	1985(3) Elena	1985(2) Kate	1995(3) Opal
	Homosassa	1950(3) Easy	1968(2) Gladys	
	St. Petersburg	1921(3)	1946(1)	1968(2) Gladys
	Tampa	1921(3)	1946(1)	1968(2) Gladys
	Sarasota	1944(3)	1946(1)	1966(2) Alma
	Fort Myers	1960(3) Donna	1960(3) Donna	1966(2) Alma
	Naples	1960(4) Donna	1964(2) Isbell	1992(3) Andrew
	Key West	1948(3)	1987(1) Floyd	
	Miami	1992(4) Andrew	1992(4) Andrew	
	Fort Lauderdale	1950(3) King	1964(2) Cleo	1992(4) Andrew
	West Palm Beach	1949(3)	1979(2) David	
	Stuart	1949(3)	1979(2) David	
	Fort Pierce	1933(3)	1979(2) David	
	Vero Beach	<1900	1995(1) Erin	

Notes: <1900 means before 1900

State	City	Direct Hits Last Major	Direct Hits Last Any	Indirect Hits Last any
Florida	Cocoa	<1900	1995(1) Erin	
	Daytona Bch	<1900	1960(2) Donna	1979(2) David
	St. Augustine	<1900	1964(2) Dora	
	Jacksonville	<1900	1964(2) Dora	
	Fernandina Bch	<1900	1928(2)	1964(2) Dora
Georgia	Brunswick	<1900	1928(1)	
	Savannah	<1900	1979(2) David	
S. Carolina	Hilton Head	1959(3) Gracie	1979(2) David	1985(1) Bob
	Charleston	1989(4) Hugo	1989(4) Hugo	
	Myrtle Beach	1954(4*) Hazel	1954(4*) Hazel	1989(4) Hugo
N. Carolina	Wilmington	1960(3*) Donna	1984(2) & Diana	
	Morehead City	1960(3*) Donna	1960(3*) Donna	1985(3*) Gloria
	Cape Hatteras	1993(3) Emily	1993(3) Emily	
Virginia	Virginia Beach	1944(3*)	1986(1) Charley	
	Norfolk	<1900	1955(1) Connie	1985(3*) Gloria
Maryland	Ocean City	<1900	<1900	1985(3*) Gloria
	Baltimore	<1900	<1900	1954(2*) Hazel
Delaware	Rehoboth Bch	<1900	<1900	1985(3*) Gloria
	Wilmington	<1900	<1900	1954(2*) Hazel
New Jersey	Cape May	<1900	1903(1)	1985(3*) Gloria
	Atlantic City	<1900	1903(1)	1985(3*) Gloria
New York	New York City	<1900	1903(1)	1976(1) Belle
	Westhampton	1985(3*) Gloria	1985(3*) Gloria	
Connecticut	New London	1938(3*)	1991(2*) Bob	
	New Haven	1938(3*)	1985(2*) Gloria	
	Bridgeport	1954(3*) Carol	1985(2*) Gloria	
Rhode Island	Providence	1954(3*) Carol	1991(2*) Bob	
Mass.	Cape Cod	1954(3*) Edna	1991(2*) Bob	
	Boston	<1900	1960(1*) Donna	1991(1*) Bob
N. Hampshir	Portsmouth	<1900	1985(2*) Gloria	
Maine	Portland	<1900	1985(1*) Gloria	
	Eastport	<1900	1969(1) Gerda	1985(1*) Gloria

Notes: & Cape fear only, * Moving over 30 mph

Table 12. Estimated annual deaths and damages (unadjusted and adjusted[1]) in the mainland United States from landfalling Atlantic or Gulf hurricanes 1900-1995.

		DAMAGE ($Millions)				DAMAGE ($Millions)	
YEAR	DEATHS	Unadjusted	Adjusted[1]	YEAR	DEATHS	Unadjusted	Adjusted[1]
1900	8000 [5]	30	790 [2]	1948	3	18	113
1901	10	1	26 [2]	1949	4	59	370
1902	0	Minor	Minor	1950	19	36	222
1903	15	1	26 [2]	1951	0	2	11
1904	5	2	53 [2]	1952	3	3	16
1905	0	Minor	Minor	1953	2	6	33
1906	298	3 [5]	79 [2]	1954	193	756	4180
1907	0	0	0	1955	218	985	5348
1908	0	0	0	1956	19	27	139
1909	406	8	211 [2]	1957	400	152	758
1910	30	1	26 [2]	1958	2	11	55
1911	17	1 [5]	26 [2]	1959	24	23	116
1912	1	Minor	Minor	1960	65	396	2006
1913	5	3	79 [2]	1961	46	414	2102
1914	0	0	0	1962	3	2	10
1915	550	63	1660 [3]	1963	10	12	59
1916	107	33	723	1964	49	515	2564
1917	5	Minor	Minor	1965	75	1445	6996
1918	34	5	71	1966	54	15	70
1919	287 [5]	22	278	1967	18	200	900
1920	2	3	30	1968	9	10	43
1921	6	3	38	1969	256	1421	5647
1922	0	0	0	1970	11	454	1699
1923	0	Minor	Minor	1971	8	213	747
1924	2	Minor	Minor	1972	122	2100	6924
1925	6	Minor	Minor	1973	5	3	9
1926	269	112	1415	1974	1	150	396
1927	0	0	0	1975	21	490	1191
1928	1836	25	315	1976	9	100	233
1929	3	1	12	1977	0	10	22
1930	0	Minor	Minor	1978	36	20	38
1931	0	0	0	1979	22	3045	5210
1932	0	0	0	1980	2	300	463
1933	63	47	701	1981	0	25	36
1934	17	5	68	1982	0	Minor	Minor
1935	414	12	163	1983	22	2000	2751
1936	9	2	28	1984	4	66	88
1937	0	Minor	Minor	1985	30	4000	5197
1938	600	306	3864	1986	9	17	21
1939	3	Minor	Minor	1987	0	8	10
1940	51	5	66	1988	6	9	11
1941	10	8	98	1989	56	7670	8640
1942	8	27	286	1990	13	57	63
1943	16	17	169	1991	16	1500	1637
1944	64 [5]	165	1641	1992	24	26500	28687
1945	7	80	773	1993	4	57	59
1946	0	5	41	1994	38	973	973
1947	53	136	935	1995	29	3723 [4]	3582 [4]

[1] Adjusted to 1994 dollars based on U.S. Department of Commerce Implicit Price Deflator for Construction. 1995 damages adjusted downward.

[2] Using 1915 cost adjustment - none available prior to 1915.

[3] Considered too high in 1915 reference.

[4] Current estimate - subject to change.

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

Table 12a. Same information as in table 12, but only the top 30 years are ranked in colums by deaths, by unadjusted damages, and by adjusted[1] damages.

Ranked on Deaths			Ranked on Unadjusted Damage			Ranked on Adjusted[1] Damage		
1	1900	8000 +	1	1992	26500	1	1992	28620
2	1928	1836	2	1989	7670	2	1989	8667
3	1938	600	3	1985	4000	3	1965	6994
4	1915	550	4	1995	3723	4	1972	6930
5	1935	414	5	1979	3045	5	1969	5641
6	1909	406	6	1972	2100	6	1955	5349
7	1957	400	7	1983	2000	7	1979	5207
8	1906	298	8	1991	1500	8	1985	5200
9	1919	287 s	9	1965	1445	9	1954	4181
10	1926	269	10	1969	1421	10	1938	3865
11	1969	256	11	1955	985	11	1995	3582
12	1955	218	12	1994	973	12	1983	2760
13	1954	193	13	1954	756	13	1964	2565
14	1972	122	14	1964	515	14	1961	2103
15	1916	107	15	1975	490	15	1960	2008
16	1965	75	16	1970	454	16	1970	1698
17	1960	65	17	1961	414	17	1915	1660 [2]
18	1944	64 s	18	1960	396	18	1944	1640
19	1933	63	19	1938	306	19	1991	1635
20	1989	56	20	1980	300	20	1926	1415
21	1966	54	21	1971	213	21	1975	1191
22	1947	53	22	1967	200	22	1994	973
23	1940	51	23	1944	165	23	1947	936
24	1964	49	24	1957	152	24	1967	900
25	1961	46	25	1974	150	25	1900	790 [3]
26	1994	38	26	1947	136	26	1945	773
27	1978	36	27	1926	112	27	1957	758
28	1918	34	28	1976	100	28	1971	748
29	1910	30	29	1945	80	29	1916	723
30	1985	30	30	1984	66	30	1933	701

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

1 Adjusted to 1994 dollars based on U.S. Department of Commerce Implicit Price Deflator for Construction. 1995 adjusted downward.

2 Considered too high in 1915 reference.

3 Using 1915 cost adjustment - none available prior to 1915.

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

(12) **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?

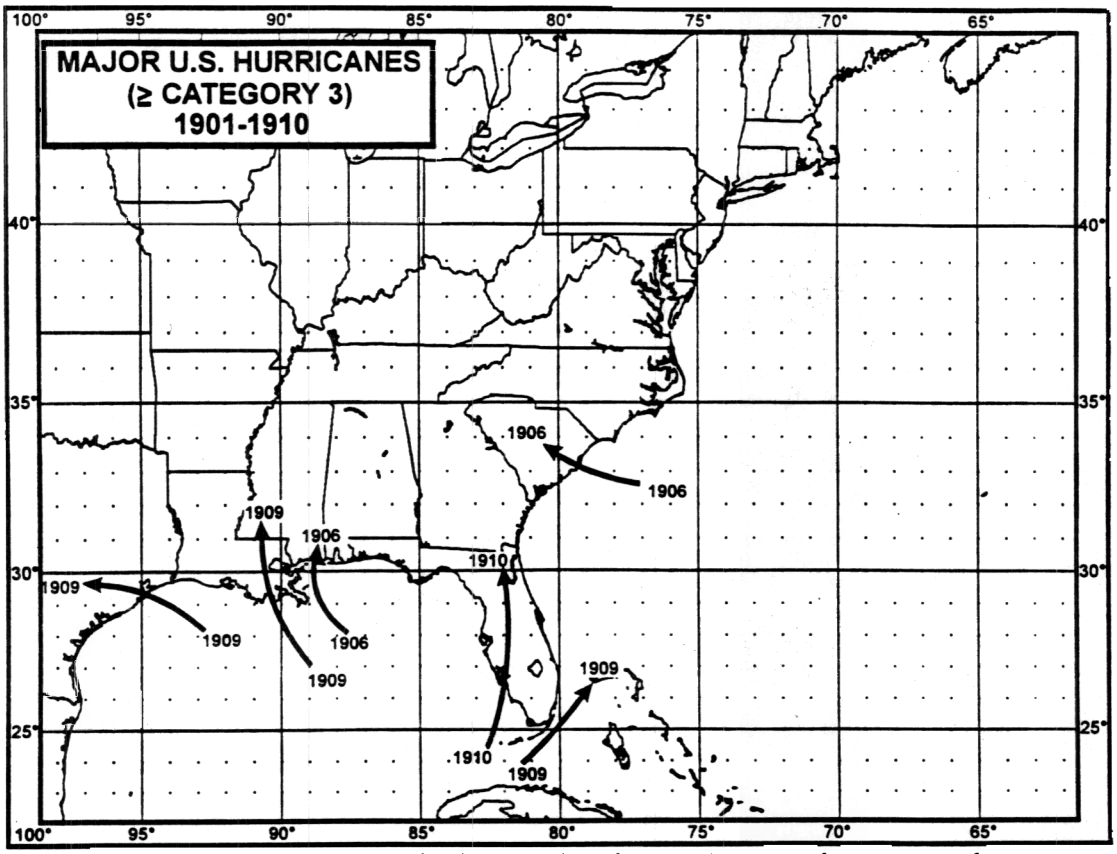

Figure 1. Major landfalling United States hurricanes (greater than or equal to a category 3) during the period 1901-1910.

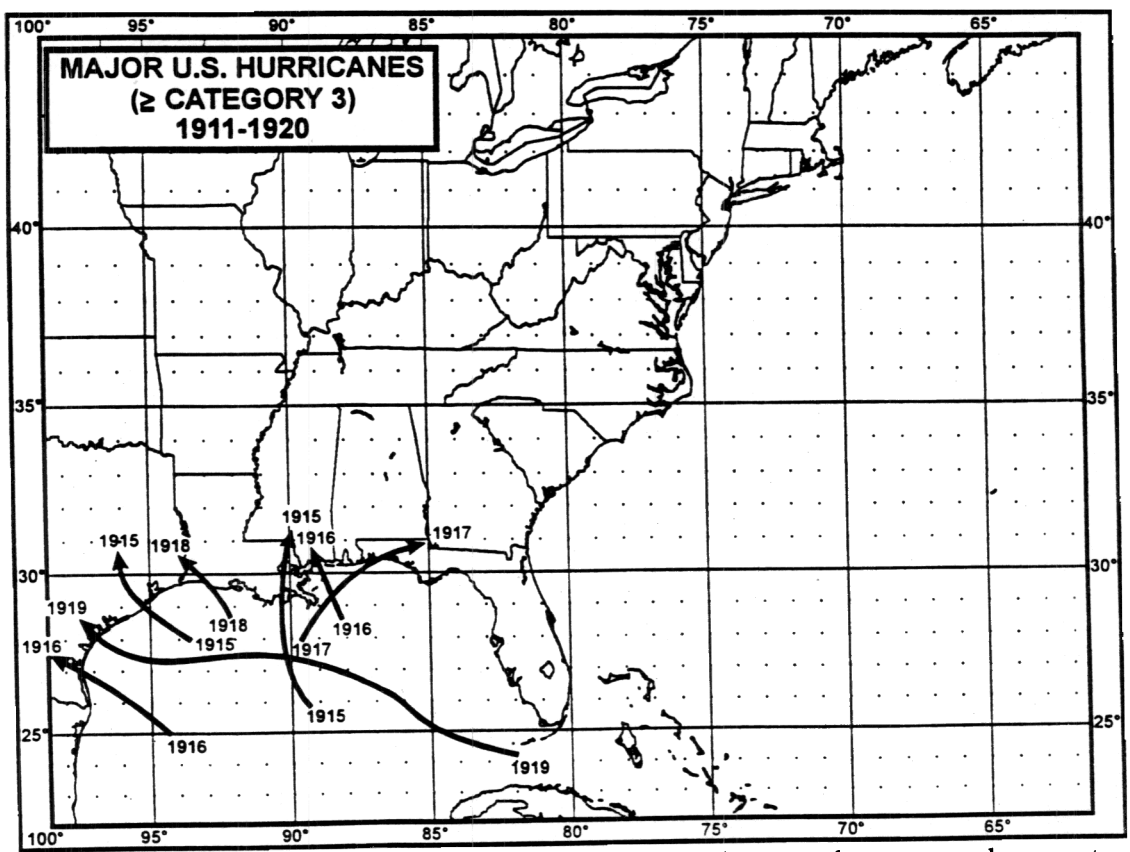

Figure 2. Major landfalling United States hurricanes (greater than or equal to a category 3) during the period 1911-1920.

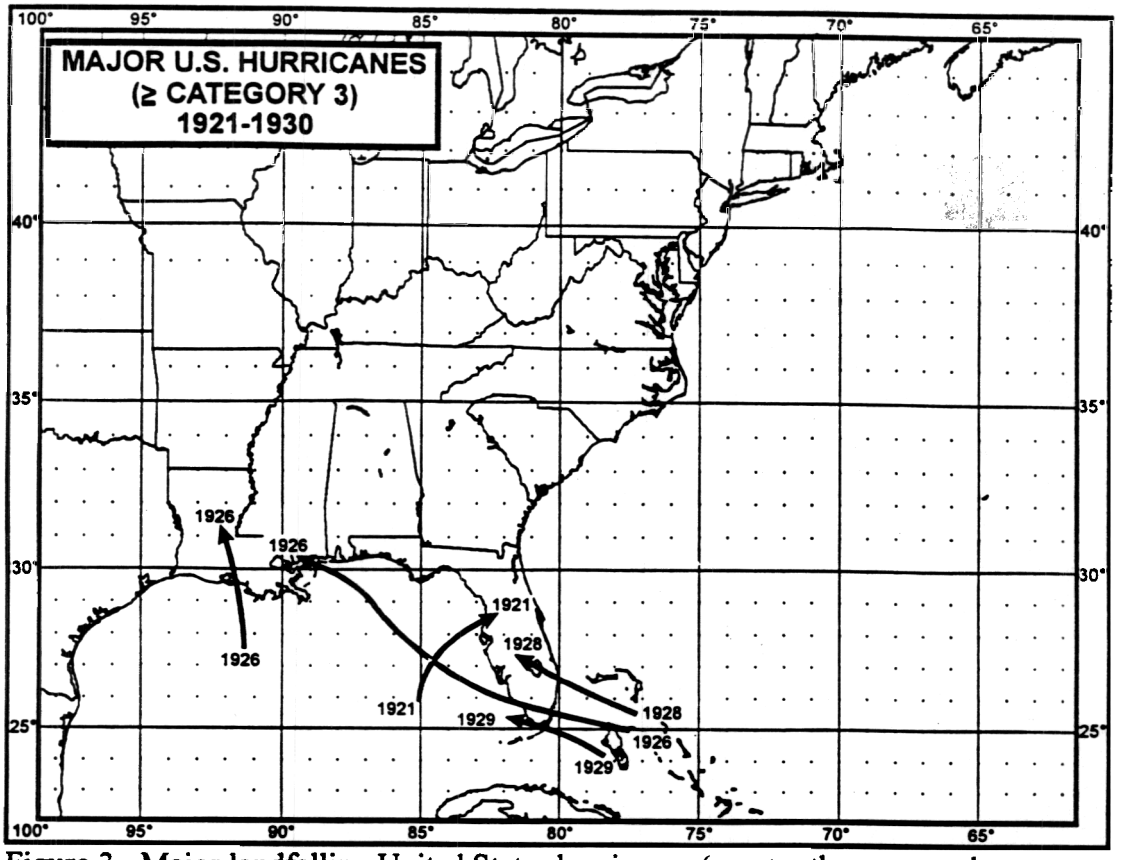

Figure 3. Major landfalling United States hurricanes (greater than or equal to a category 3) during the period 1921-1930.

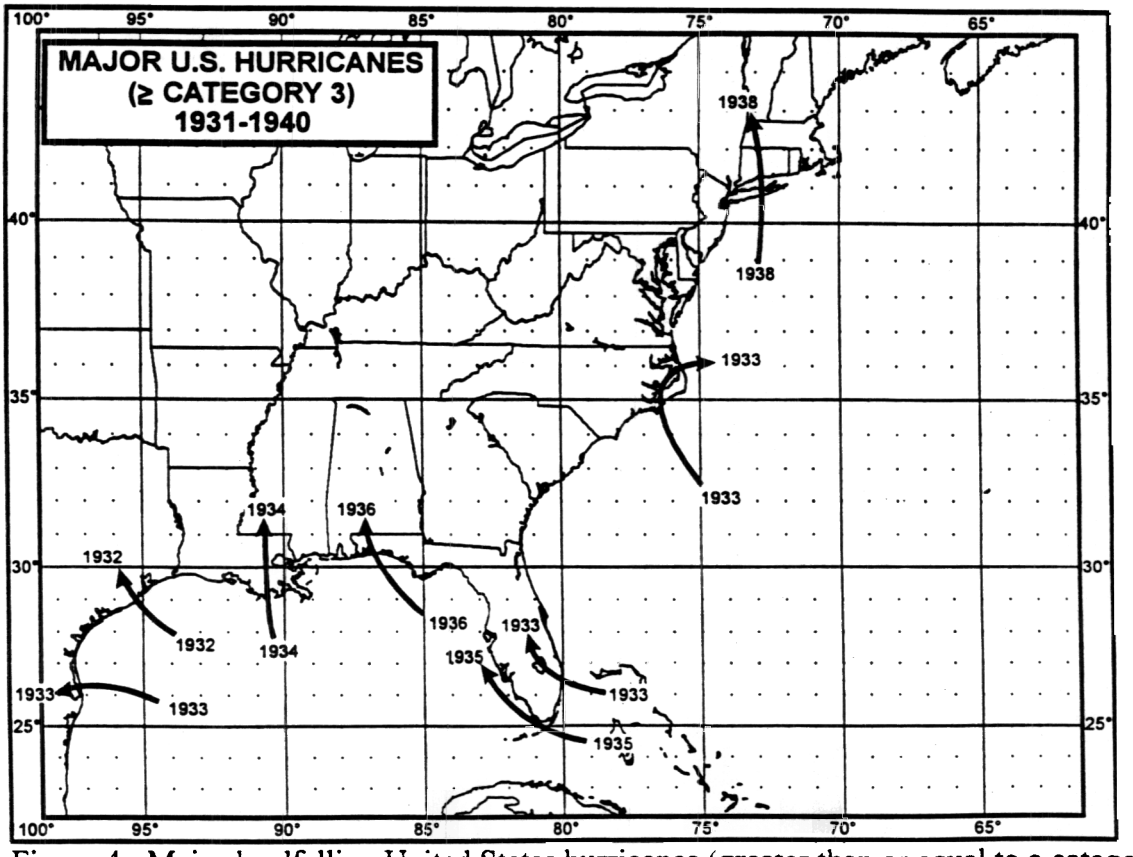

Figure 4. Major landfalling United States hurricanes (greater than or equal to a category 3) during the period 1931-1940.

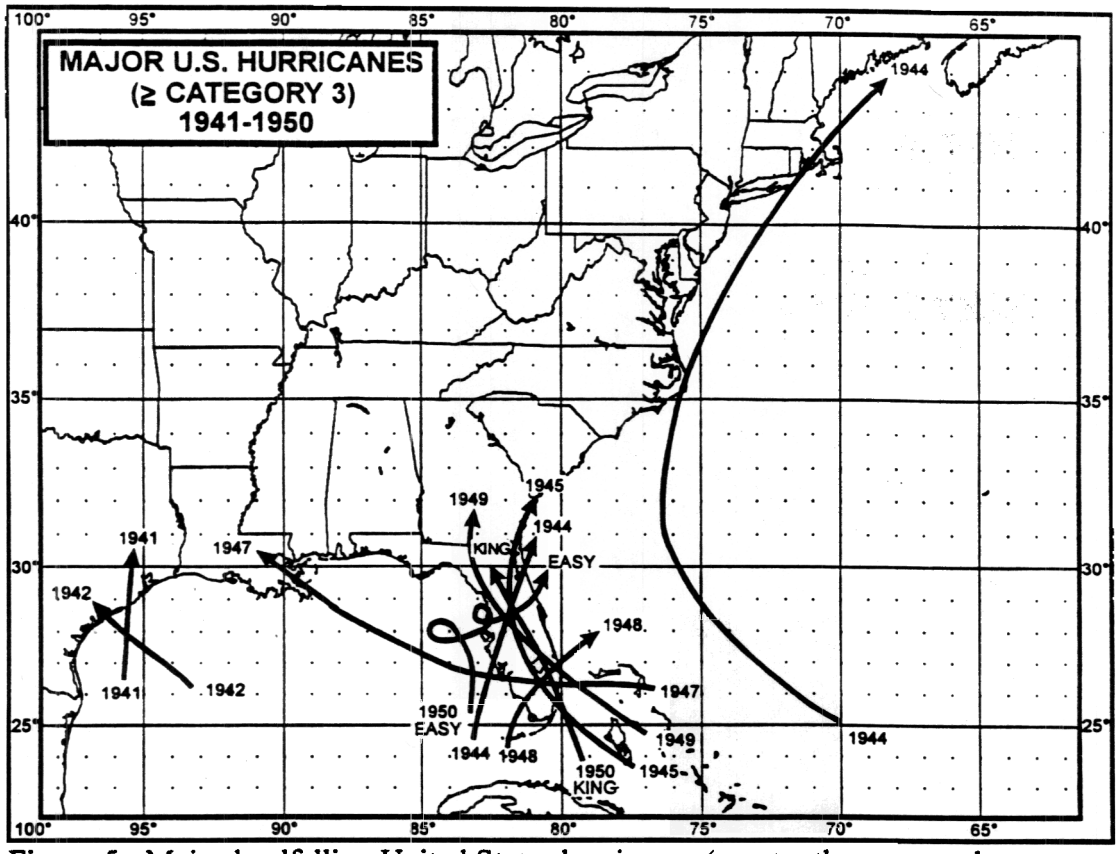

Figure 5. Major landfalling United States hurricanes (greater than or equal to a category 3) during the period 1941-1950.

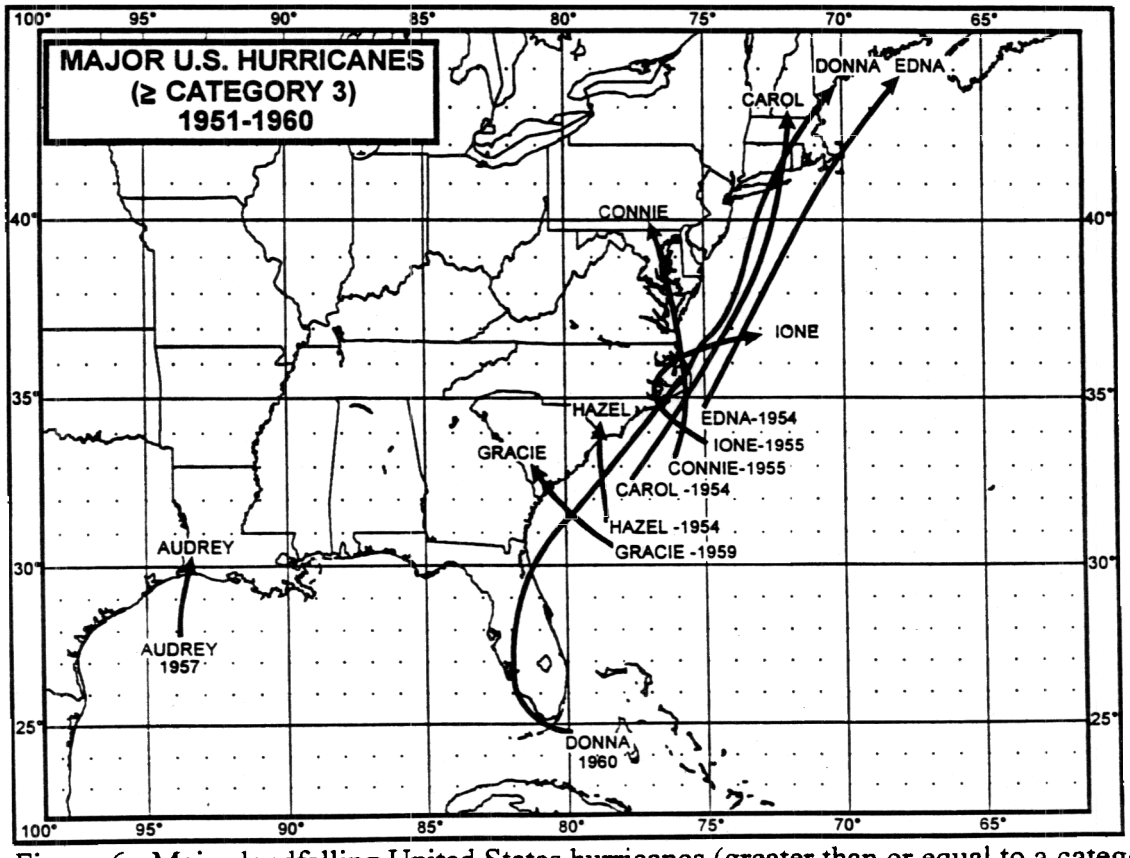

Figure 6. Major landfalling United States hurricanes (greater than or equal to a category 3) during the period 1951-1960.

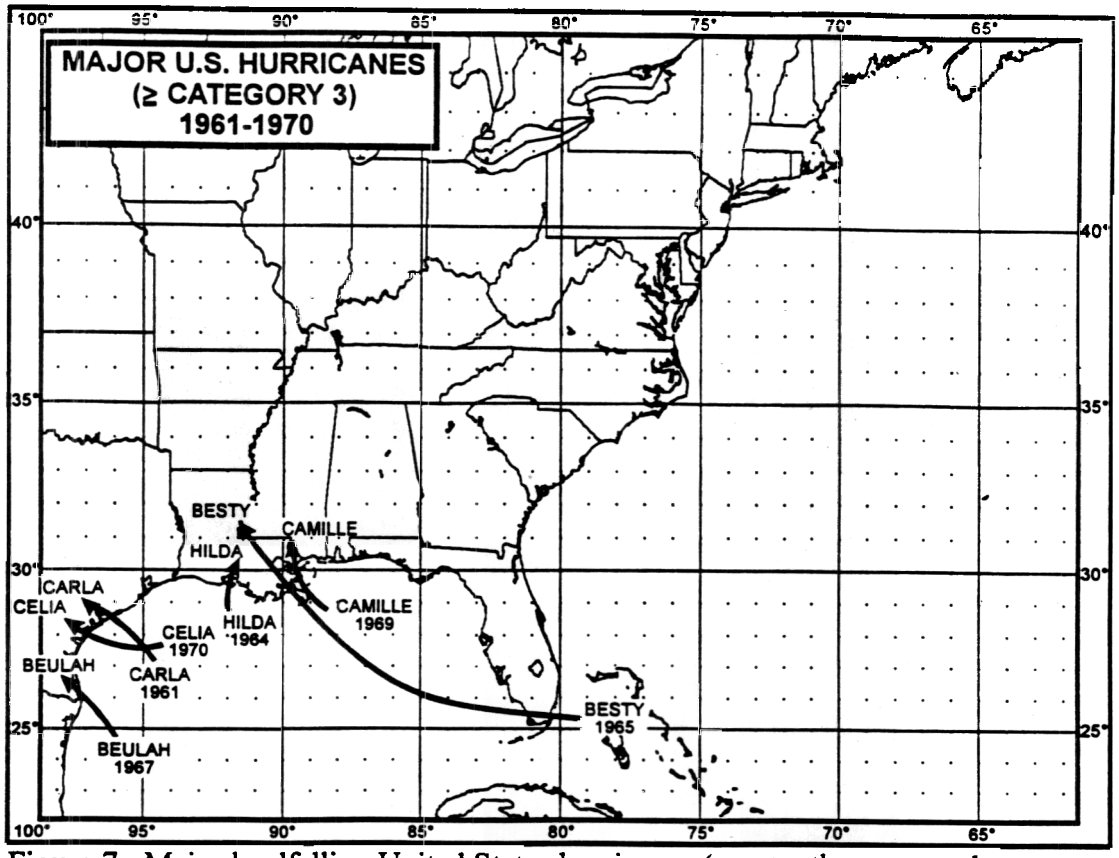

Figure 7. Major landfalling United States hurricanes (greater than or equal to a category 3) during the period 1961-1970.

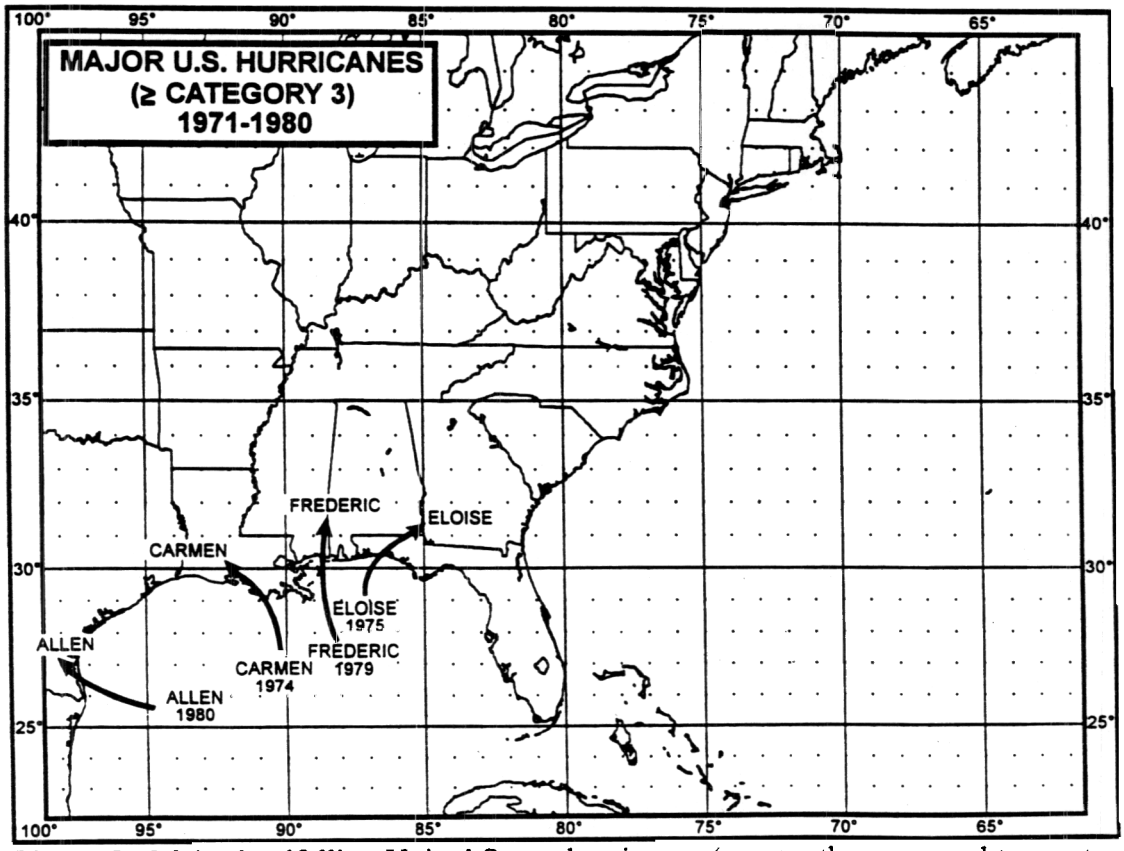

Figure 8. Major landfalling United States hurricanes (greater than or equal to a category 3) during the period 1971-1980.

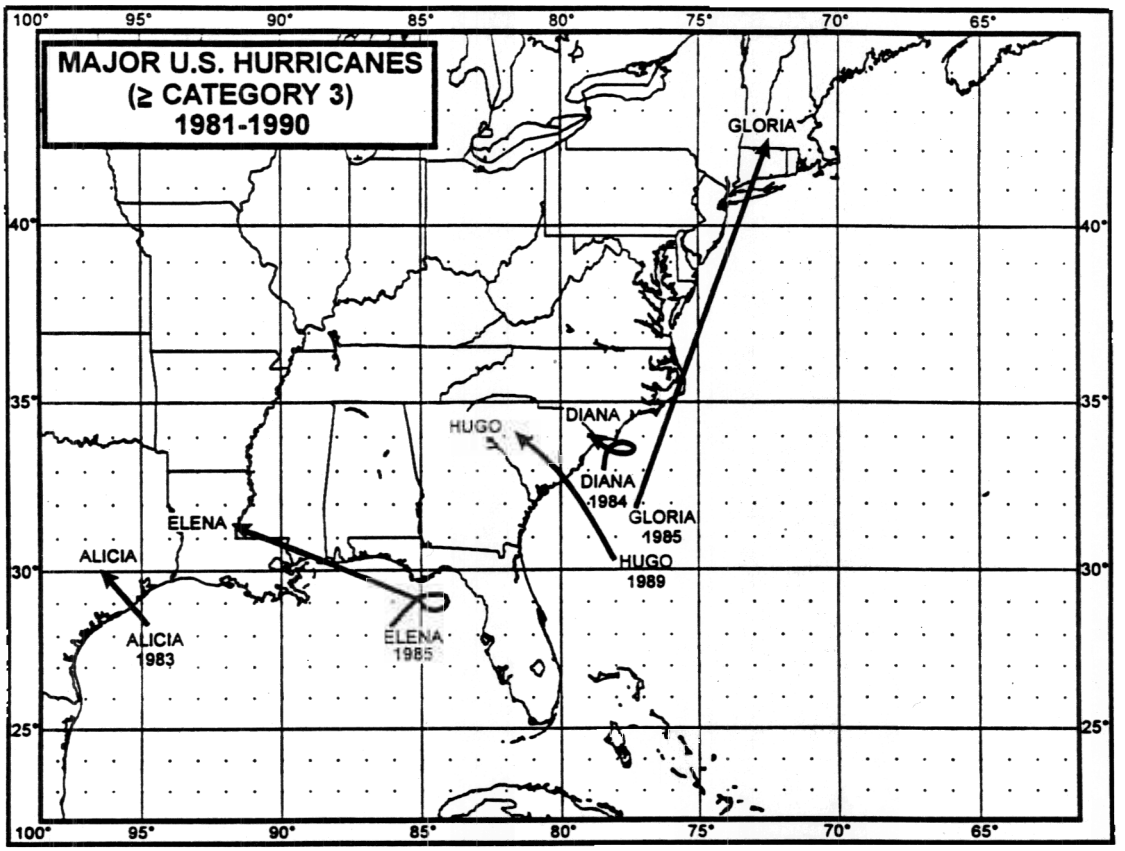

Figure 9. Major landfalling United States hurricanes (greater than or equal to a category 3) during the period 1981-1990.

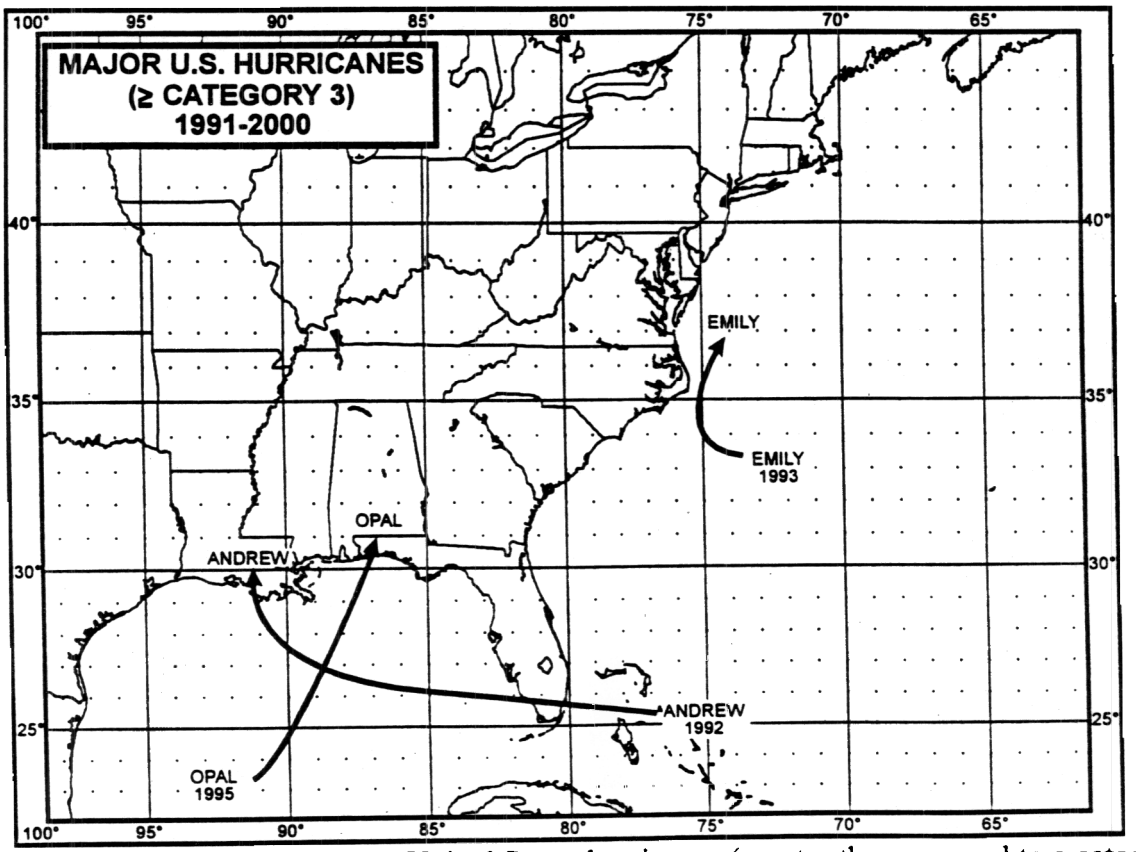

Figure 10. Major landfalling United States hurricanes (greater than or equal to a category 3) during the period 1991-2000.

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

Figures 1 through 10 certainly support the existence of a cyclical nature of major hurricanes affecting given regions. Table 13 is also suggestive of preferred periods. However, it is left to the reader to decide what weight should be given to these statistics.

Table 13. Major and all category landfalling hurricanes in the mainland United States by individual years.

Major Hurricanes

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					3

All Hurricanes

Decade	00	01	02	03	04	05	06	07	08	09	Total
1900-09	1	2		2	1		4		1	4	15
1910-19	2	2	2	2		3	6	1	1	1	20
1920-29	2	2		1	2	1	3		2	2	15
1930-39			2	5	2	2	3		2	1	17
1940-49	2	2	2	1	3	3	1	3	3	3	23
1950-59	3		1	3	3	3	1	1		3	18
1960-69	2	1		1	4	1	2	1	1	2	15
1970-79	1	3	1		1	1	1	1		3	12
1980-89	1			1	1	6	2	1	1	3	16
TOTAL	14	12	8	16	17	20	23	8	11	22	151
1990-99		1	1	1		2					5

Table 14. Deadliest, Costliest Hurricanes of theTwentieth Century to affect Hawaii, Puerto Rico and the U.S. Virgin Islands.

Name	Date	Island or CPA	Damage ($000) Unadjusted	Damage ($000) Adjusted	Deaths	Max Wind (Mph)	Min P (Mb)
Mokapu Cyclone	Aug 19,1938	25 mi NE Oahu	Unk	Unk	Unk	Unk	Unk
Hiki	Aug 15,1950	100 mi NE Hawaii	Unk	Unk	Unk	Unk	Unk
Nina	Dec 02,1957	100 mi SW Kauai	200	998	4	90	965
Dot	Aug 06,1959	Kauai	6,000	30,300	0	115	955
Iwa	Nov 23,1982	25 mi NW Kauai	312,000	433,680	1	90	964
Iniki	Sep 11,199	Kaua	1,800,00	1,944,000	4	130	950
San Hipolito	Aug 22,1916	Puerto Ric	1,000	21,900	1	98	988
San Liborio	Jul 23,1926 [1]	SW Puerto Rico	5,000	63,150	25	81	~985
San Felipe	Sep 13,1928	Puerto Rico	85,000	1,071,000	312	161	931
San Nicolas	Sep 10,1931 [1]	Puerto Rico	200	2,674	2	121	988
San Ciprian	Sep 26,1932 [1]	USVI, PR	30,000	401,100	225	98	948
San Mateo	Sep 21,1949	St. Croix	Unk.	Unk	Unk	81	~985
Santa Clara (Betsy)	Aug 12,1956	Puerto Rico	40,000	205,600	16	92	991
Donna	Sep 05,1960 [1]	PR & St. Thomas	Unk	Unk	107	132	958
Eloise (T.S.)	Sep 15,1975 [1]	Puerto Rico	Unk	Unk	44	40	1007
David	Aug 30,1979 [2]	S. of Puerto Rico	Unk	Unk	Unk	173	924
Frederic (T.S.)	Sep 04,1979 [2]	Puerto Rico	125,000	213,750	7	58	1000
Hugo	Sep 18,1989	USVI, PR	1,000,000	1,130,000	5	138	940
Marilyn	Sep 16,1995	USVI, E. PR	1,500,000	1,440,000	8	109	952

[1] Effects continued into the following day. [2] Damage and Casualties from David and Frederic are combined.

Table 14 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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