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THE DEADLIEST, COSTLIEST, AND MOST INTENSE UNITED STATES HURRICANES FROM 1900 TO 2000 (AND OTHER FREQUENTLY REQUESTED HURRICANE FACTS)

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PREFACE

This version of the Deadliest, Costliest, and Most Intense United States Hurricanes from 1900 to 2000 extends the work of Hebert et al. (1997) through the 2000 season. Its also includes an estimate of the monetary loss that historical hurricanes could exact on the current property-at-risk in the same location. Chris Landsea, of the NOAA Hurricane Research Division of the Atlantic Oceanographic and Meteorological Laboratory, has joined as a co-author to add this section. Ed Rappaport has also joined this effort, while Paul Hebert, in his retirement from NOAA, no longer contributes to this report. 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.

This update was begun under the leadership of Jerry Jarrell until his retirement in early 2000. He continued to participate in retirement.

During 1995, the 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), a name which more accurately reflects the broad scope of its responsibilities, and more formally publicizes that the majority of its operational products were for tropical weather events exclusive of hurricanes. The name "National Hurricane Center" was retained to apply to the hurricane operations desk at TPC. We will follow the convention where "NHC" refers to the previous National Hurricane Center, "TPC" refers to the current center and "TPC/NHC" refers to the hurricane operations desk of TPC.

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ABSTRACT

This technical memorandum lists the thirty deadliest and costliest hurricanes in the United States from 1900-2000. The compilation ranks damage, as expressed by monetary losses, in three ways: 1) contemporary estimates; 2) contemporary estimates adjusted by inflation to 2000 dollars; and 3) contemporary estimates adjusted for inflation and the growth of population and personal wealth [Pielke and Landsea, 1998]. In addition, the most intense (i.e., major[1]) hurricanes to make landfall in the United States during the period 1900-2000 are listed. Some additional statistics on United States hurricanes of this and previous centuries, and tropical cyclones in general, are also presented.

1. INTRODUCTION

The staff of the Tropical Prediction Center receives numerous requests for statistical information on deaths and damages, incurred during hurricanes affecting the United States. Information about the intensity of these hurricanes is also frequently of interest. Estimates of these measures vary in the literature. Our hope is to present the best compilation of currently available estimates. In some instances, data in our lists represent revised estimates based on more complete information received following earlier publications including previous versions of this technical memorandum.

There are other frequently asked questions about hurricanes, such as: What is the average number of hurricanes per year? What year(s) had the most and least hurricanes? What hurricane had the longest life? On what date 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 hurricane on the Saffir/Simpson Hurricane Scale (see Table 1), and is comparable to a Great Hurricane in some 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 [Simpson, R.H. (1974)].

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. BACKGROUND AND DEFINITIONS

Many of the statistics in this publication depend directly on the criteria used in preparing another study, "Hurricane Experience Levels of Coastal County Populations-Texas to Maine" [(Jarrell et al. (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 stronger hurricane.

The Saffir/Simpson category is defined by pressure, wind, and storm surge. In nature, however, there is not a one-to-one relationship between these elements. Therefore, in practice, the TPC uses the maximum wind speed to establish the category. Operationally, however, the central pressure is often used to make a first estimate of the wind. Thereafter, available surface wind reports, aircraft reconnaissance flight-level winds (from which surface wind speed can be estimated), and dropwindsonde data are used to anchor the wind estimate. In post-storm analysis, the central pressure ranges of hurricanes on the Saffir/Simpson Hurricane Scale will usually agree fairly well with the wind ranges in that category. On the other hand, the storm 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.

The process of assigning a category number to a hurricane is subjective, as is TPC's estimate of a cyclone's impact. It is made on a county by county basis. In this study, we applied the criteria for direct hit and indirect hit described in the work by Jarrell et al. (1992):

> 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 usually 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 average, this direct hit zone extended about 50 miles along the coastline (R≈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 - In general, areas on either side of the direct hit zone which received wind gusts of hurricane force and/or tides of at least 4 to 5 feet above normal were considered to have had an indirect hit. The evaluation subjectively incorporated a hurricane's strength and size, and the configuration of county coastlines.

The authors acknowledge that there are limitations to this technique. For example, the effect of an indirect hit by a large category 4 hurricane can be greater than that by a direct hit from a small category 1 hurricane.

Neumann et al. (1999) gives the variation in tropical cyclone frequency along the United States coastline for all tropical storms and hurricanes, hurricanes only, and major hurricanes (category 3 or greater). In that study, counts were made of the number of tropical cyclones or hurricanes whose center passed within 75 nautical miles of the coastal location. This counting method thus includes near-misses, as well as direct and indirect hits as defined above.

Statistics on tropical storm and hurricane activity in the North Atlantic Ocean (which includes the Gulf of Mexico and the Caribbean Sea) can be found in Neumann et al. (1999). A stratification of hurricanes by category which have affected coastal counties of the Gulf of Mexico and North Atlantic Ocean can be found in Jarrell et al. (1992). Additional information about the impact of hurricanes can be found in annual hurricane season articles in Monthly Weather Review and Storm Data .

3. DISCUSSION

Part I

The remainder of this memorandum provides answers to some of the most frequently asked questions about the characteristics and impacts of the tropical cyclones to affect the United States from 1900-2000.

(1) **What have been the deadliest hurricanes in the United States?** Table 2 lists the 30 deadliest tropical cyclones to strike the U.S. mainland 1900-2000. Three hurricanes prior to 1900, a tropical storm which affected southern California in 1939 and the deadliest Puerto Rico and Virgin Islands hurricanes are listed as an addendum.

(2) **What have been the costliest hurricanes in the United States?** Table 3 lists the 30 costliest tropical cyclones (includes 5 tropical storms) to strike the U.S. mainland 1900-2000. Figures are not adjusted for inflation. Table 3a re-orders some of these plus several other hurricanes after adjusting to 2000 dollars[3]. Hawaiian, eastern Pacific, Puerto Rican and Virgin Island tropical cyclones are listed as addenda to Tables 3 and 3a. Table 3a also lists the thirty costliest hurricanes 1900-2000 assuming that a hurricane having the same track, size and intensity as noted in the historical record would strike the area with today's population and property-at-risk (see Pielke and Landsea 1998.)

(3) **What have been the most intense hurricanes to strike the United States?** Table 4 lists the 65 major hurricanes which have struck the U.S. mainland 1900-2000. Hurricanes are ranked by estimated central pressure 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 1900-2000 reveals several striking facts: (1) Ten of the twelve deadliest hurricanes were the equivalent of a category 4 or higher. (2) Large death totals were primarily a result of the 15 to 20 feet or greater rise of the ocean (storm surge) associated with many of these major hurricanes. All but six of the thirty deadliest hurricanes were major hurricanes. Four of those six were the inland flood-producing hurricanes Agnes, Diane and Floyd and tropical storm Alberto. (3) A large portion of the damage in two of the eight costliest tropical cyclones (Table 3) resulted from inland flooding caused by torrential rain. (4) Half of the deadliest hurricanes were category four or higher, but only one-sixth of the costliest hurricanes (Table 3) met this criterion. (5) Only one of the deadliest hurricanes 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 and to one quarter after adjustment for inflation, population, and personal wealth).

Addenda to Tables 2, 3 and 4 include some noteworthy storms from before 1900, from the U.S. West coast and the Hawaiian islands, as well as in the U. S. Caribbean islands. The rank represents the position they would occupy if included in the main table.

[3] Adjusted to 2000 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 thirty deadliest mainland United States tropical cyclones 1900-2000

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	*FLOYD* (Mid Atlantic & NE U.S.)	1999	2	56
21	SE FL/SE LA/MS	1947	4	51
22	*DONNA* (FL/Eastern U.S.)	1960	4	50
22	GA/SC/NC	1940	2	50
24	*CARLA* (N & Central TX)	1961	4	46
25	TX (Velasco)	1909	3	41
26	TX (Freeport)	1932	4	40
26	S TX	1933	3	40
28	*HILDA* (Central LA)	1964	3	38
29	SW LA	1918	3	34
30	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	2	700
9	Puerto Rico	1928	4	312
13	USVI, Puerto Rico	1932	2	225
17	*DONNA* (St. Thomas, VI)	1960	4	107
25	Southern California	1939	TS &	45
25	*ELOISE* (Puerto Rico)	1975	TS &	44

\+ Could be 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 thirty costliest mainland United States tropical cyclones, 1900-2000.

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	*FLOYD* (Mid Atlantic & NE U.S.)	1999	2	4,500,000,000
4	*FRAN* (NC)	1996	3	3,200,000,000
5	*OPAL* (NW FL/AL)	1995	3	3,000,000,000
6	*GEORGES* (FL Keys, MS,AL)	1998	2	2,310,000,000
7	*FREDERIC (AL, MS)*	1979	3	2,300,000,000
8	*AGNES (FL/NE U.S.)*	1972	1	2,100,000,000
9	*ALICIA* (N TX)	1983	3	2,000,000,000
10	*BOB* (NC, NE U.S)	1991	2	1,500,000,000
10	*JUAN* (LA)	1985	1	1,500,000,000
12	*CAMILLE* (MS/SE LA/VA)	1969	5	1,420,700,000
13	*BETSY* (SE FL/SE LA)	1965	3	1,420,500,000
14	*ELENA* (MS/AL/NW FL)	1985	3	1,250,000,000
15	*GLORIA* (Eastern U.S.)	1985	3 *	900,000,000
16	*DIANE* (NE U.S.)	1955	1	831,700,000
17	*BONNIE* (NC,VA)	1998	2	720,000,000
18	*ERIN* (NW FL)	1995	2	700,000,000
19	*ALLISON* (N TX)	1989	TS @	500,000,000
19	*ALBERTO* (NW FL,GA,AL)	1994	TS @	500,000,000
19	*FRANCES* (TX)	1998	TS @	500,000,000
22	*ELOISE* (NW FL)	1975	3	490,000,000
23	*CAROL* (NE U.S.)	1954	3 *	461,000,000
24	*CELIA* (S TX)	1970	3	453,000,000
25	*CARLA* (N & Central TX)	1961	4	408,000,000
26	*CLAUDETTE* (N TX)	1979	TS @	400,000,000
26	*GORDON* (S & Cent FL,NC)	1994	TS @	400,000,000
28	*DONNA* (FL/Eastern U.S.)	1960	4	387,000,000
29	*DAVID* (FL/Eastern U.S.)	1979	2	320,000,000
30	New England	1938	3 *	306,000,000
ADDENDUM (Rank is independent of other events in group)				
4	*GEORGES* (USVI,PR)	1998	3	3,600,000,000
10	*INIKI* (Kauai, HI)	1992	Unk.	1,800,000,000
10	*MARILYN* (USVI, PR)	1995	2	1,500,000,000
15	*HUGO* (USVI, PR)	1989	4	1,000,000,000
19	*HORTENSE* (PR)	1996	1	500,000,000
29	*LENNY* (USVI, PR)	1999	4	330,000,000
29	*OLIVIA* (CA)	1982	T.D. &	325,000,000
30	*IWA* (Kauai, HI)	1982	Unk.	312,000,000

Notes:

* Moving more than 30 miles per hour

@ Only of Tropical Storm intensity

& Only a Tropical Depression

able 3a. The thirty costliest mainland United States tropical cyclones, 1900-2000.

Ranked Using 2000 Deflator**

RANK	HURRICANE	YEAR	Category	Damage (U.S.)**	
1	*ANDREW* (SE FL/SE LA)	1992	4	34,954,825,000	
2	*HUGO* (SC)	1989	4	9,739,820,675	
3	*AGNES* (FL/NE U.S.)	1972	1	8,602,500,000	
4	*BETSY* (SE FL/SE LA)	1965	3	8,516,866,023	
5	*CAMILLE* (MS/SE LA/VA)	1969	5	6,992,441,549	
6	*DIANE* (NE U.S.)	1955	1	5,540,676,187	
7	*FREDERIC* (AL/MS)	1979	3	4,965,327,332	
8	*FLOYD* (Mid Atlantic & NE U.S.)	1999	2	4,666,817,360	
9	New England	1938	3 *	4,748,580,000	
10	*FRAN* (NC)	1996	3	3,670,400,000	
11	*OPAL* (NW FL/AL)	1995	3	3,520,596,085	
12	*ALICIA* (N TX)	1983	3	3,421,660,182	
13	*CAROL* (NE U.S.)	1954	3 *	3,134,443,557	
14	*CARLA* (N & Central TX)	1961	4	2,550,580,095	
15	*GEORGES* (FL Keys,MS,AL)	1998	2	2,494,800,000	
16	*JUAN* (LA)	1985	1	2,418,795,844	
17	*DONNA* (FL/Eastern U.S.)	1960	4	2,407,888,443	
18	*CELIA* (S TX)	1970	3	2,015,663,203	
19	*ELENA* (MS/AL/NW FL)	1985	3	2,015,663,203	
20	*BOB* (NC, NE U.S)	1991	2	2,004,635,258	
21	*HAZEL* (SC/NC)	1954	4 *	1,910,582,732	
22	FL (Miami,Pensacola)/MS/AL	1926	4	1,738,042,353	
23	N TX (Galveston)	1915	4	1,544,253,659	1
24	*DORA* (NE FL)	1964	2	1,540,946,262	
25	*ELOISE* (NW FL)	1975	3	1,489,250,000	
26	*GLORIA* (Eastern U.S.)	1985	3 *	1,451,277,506	
27	NE U.S.	1944	3 *	1,221,342,593	
28	*BEULAH* (S TX)	1967	3	1,113,122,363	
29	SE FL/SE LA/MS	1947	4	930,099,359	
30	N TX (Galveston)	1900	4	928,160,793	2

ADDENDUM

10	*GEORGES (USVI,PR)*	1998	3	3,888,000,000	
18	*INIKI* (Kauai, HI)	1992	Unk.	2,190,600,000	
23	*MARILYN (USVI,E. PR)*	1995	2	1,624,110,320	
27	*HUGO (USVI,PR)*	1989	4	1,283,755,274	
28	San Felipe (PR)	1928	4	1,217,000,000	

Ranked Using 2000 Inflation, Population and Wealth Normalization[L]

RANK	HURRICANE	YEAR	Category	Damage (U.S.)[L]	
1	SE Florida/Alabama	1926	4	87,167,000,000	
2	ANDREW (SE FL/SE LA)	1992	4	39,696,000,000	
3	N Texas (Galveston)	1900	4	32,090,000,000	
4	N Texas (Galveston)	1915	4	27,190,000,000	1
5	SW Florida	1944	3	20,331,000,000	
6	New England	1938	3 *	20,046,000,000	
7	SE Florida/Lake Okeechobee	1928	4	16,631,000,000	
8	BETSY (SE FL/SE LA)	1965	3	14,990,000,000	
9	DONNA (FL/Eastern U.S.)	1960	4	14,526,000,000	
10	CAMILLE (MS/SE LA/VA)	1969	5	13,219,000,000	
11	*AGNES* (NW FL,NE U.S.)	1972	1	12,904,000,000	
12	*DIANE* (NE U.S.)	1955	1	12,335,000,000	
13	*HUGO* (SC)	1989	4	11,307,000,000	
14	*CAROL* (NE U.S.)	1954	3 *	10,929,000,000	
15	SE Florida/Louisiana/Alabama	1947	4	10,015,000,000	
16	*CARLA* (N & Central TX)	1961	4	8,522,000,000	
17	*HAZEL* (SC/NC)	1954	4 *	8,486,000,000	
18	NE U.S.	1944	3	7,790,000,000	
19	SE Florida	1945	3	7,611,000,000	
20	*FREDERIC* (AL/MS)	1979	3	7,587,000,000	
21	SE Florida	1949	3	7,038,000,000	
22	S Texas	1919	4	6,448,000,000	
23	*ALICIA* (N TX)	1983	3	4,890,000,000	
24	*FLOYD* (NC)	1999	2	4,680,000,000	
25	*CELIA* (S TX)	1970	3	4,024,000,000	
26	*DORA* (NE FL)	1964	2	3,747,000,000	
27	*FRAN* (NC)	1996	3	3,735,000,000	
28	*OPAL* (NW FL/AL)	1995	3	3,617,000,000	
29	*CLEO (SE FL)*	1964	2	2,936,000,000	
30	*JUAN (LA)*	1985	1	2,892,000,000	

notes

** 2000 $ based on U.S. DOC Implicit Price Deflator for Construction.

L 2000 Landsea normalization for population, wealth and inflation

* Moving more than 30 miles per hour

1 Damage estimate in 1915 reference is considered too high

2 Using 1915 cost adjustment base - none available prior to 1915

Table 4. The most intense mainland United States hurricanes, 1900-2000 (includes only major hurricanes at their most intense landfall).

RANK	HURRICANE	YEAR	CATEGORY (at landfall)	MINIMUM PRESSURE Millibars	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
33	*INIKI* (KAUAI, HI)	1992	UNK	950	27.91
43	*DOT* (KAUAI, HI)	1959	UNK	955	28.11
50	*DONNA* (St.Thomas, PR)	1960	4	958	28.29
64	*IWA* (KAUAI, HI)	1982	UNK	964	28.47
65	*GEORGES* (USVI & PR)	1998	3	968	28.59

RANK	HURRICANE	YEAR	CATEGORY (at landfall)	MINIMUM PRESSURE Millibars	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
37	*BRET* (S TX)	1999	3	951	28.08
39	FL (Tampa Bay)	1921	3	952	28.11
39	*CARMEN* (Central LA)	1974	3	952	28.11
41	*EDNA* (New England)	1954	3 *	954	28.17
41	SE FL	1949	3	954	28.17
41	*FRAN* (NC)	1996	3	954	28.17
44	*ELOISE* (NW FL)	1975	3	955	28.20
44	*KING* (SE FL)	1950	3	955	28.20
44	Central LA	1926	3	955	28.20
44	SW LA	1918	3	955	28.20
44	SW FL	1910	3	955	28.20
49	NC	1933	3	957	28.26
49	FL (Keys)	1909	3	957	28.26
51	*EASY* (NW FL)	1950	3	958	28.29
51	N TX	1941	3 '	958	28.29
51	NW FL	1917	3	958	28.29
51	N TX	1909	3	958	28.29
51	MS/AL	1906	3	958	28.29
56	*ELENA* (MS/AL/NW FL)	1985	3	959	28.32
57	*CAROL* (NE U.S.)	1954	3 *	960	28.35
57	*IONE* (NC)	1955	3	960	28.35
57	*EMILY* (NC)	1993	3	960	28.35
60	*ALICIA* (N TX)	1983	3	962	28.41
60	*CONNIE* (NC/VA)	1955	3	962	28.41
60	SW FL/NE FL	1944	3	962	28.41
60	Central LA	1934	3	962	28.41
64	SW FL/SE FL	1948	3	963	28.44
65	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 summarizes the direct hits on the U.S. mainland since 1900.

Table 4a. Direct hits by mainland United States Hurricanes (1900-1999).

Category	Direct Hits
5	2
4	15
3	48
2	39
1	61
TOTAL	165
MAJOR	65

Major hurricanes are categories 3,4 & 5.

The data indicate that an average of 2 major hurricanes every 3 years made landfall somewhere along the U.S. Gulf or Atlantic coast. (When all categories were combined, about 5 hurricanes made landfall every 3 years.)

One of the greatest concerns of the National Weather Service's (NWS) hurricane preparedness officials is that the statistics in table 2 will mislead people into thinking that no more large loss of life will occur in a hurricane because of our advanced technology. Max Mayfield, spokesman for the NWS hurricane warning service and Director of TPC, as well as former NHC Directors, 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, maintained and executed.

The study by Jarrell et al. (1992) used 1990 census data to estimate 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, Opal, Fran and Bret have not lessened an ever growing concern brought by the continued increase in coastal populations.

Table 5, which lists hurricanes by decades since 1900, 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. But, 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, showed below average landfall frequencies. It could be noted that of the most recent four decades, only the 70's and 90's were significantly below normal.

On the average, a category 4 or stronger hurricane strikes the United States once every 6 years. Even though two category 4 hurricanes struck within three years, (Hugo in 1989 and Andrew in 1992), they represent the only category 4 hurricanes since 1969. Fewer hurricanes in a year do not necessarily mean a lesser threat of disaster, however. The 1919 hurricane, which is both the third deadliest and fourth most intense to strike the United States beginning 1900, 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.

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.

Table 5. Number of hurricanes by category to strike the mainland U.S. each decade. (Updated from Hebert et al., 1997)

	Category					ALL	Major
DECADE	1	2	3	4	5	1,2,3,4,5	3,4,5
1900-1909	5	4	4	2	0	15	6
1910-1919	9	3	5	3	0	20	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
1990-1999	3	6	4	1	0	14	5
2000-2009	0	0	0	0	0	0	0
1900-1999	61	39	48	15	2	165	65

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

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

Part II

This section answers some frequently asked questions about 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 during selected time periods. A total of ten tropical cyclones reaching storm strength with six of these becoming hurricanes appears to be the best averages to use based on the past 10 to 50 year time periods when adequate observing systems were in place.

Table 6. Average number of tropical cyclones which reached storm and hurricane strength for various periods. Updated from Neumann et al. (1999).

PERIOD	Number of years	Average number of Tropical Cyclones	Average number of Hurricanes
1886 - 2000	115	8.7	5.1
1951 - 2000	50	10.0	5.9
1961 - 2000	40	10.0	5.8
1971 - 2000	30	10.1	5.6
1981 - 2000	20	10.3	5.8
1986 - 2000	15	10.7	6.1
1991 - 2000	10	11.0	6.4

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 Atlantic hurricane basin. The only years after1900 when a hurricane failed to strike the U.S. mainland were 1902, 1905, 1907, 1914, 1922, 1927, 1930, 1931, 1937, 1951, 1958, 1962, 1973, 1978, 1981, 1982, 1990 ,1994 and 2000. Note that only twice has the U.S. mainland gone as long as two years without a hurricane. The most hurricanes to strike in one year were six in 1916 and 1985. There were five in 1933, and four in 1906, 1909, and 1964. Three hurricanes struck the U.S. in one year a total of sixteen times. Ten of these sixteen times occurred during the sixteen years from 1944 to 1959!

Table 7. Years maximum and minimum tropical cyclone and hurricane activity in the North Atlantic, Caribbean, and Gulf of Mexico 1871-2000. Updated from Neumann et al. (1999). Note, some activity undoubtely not observed in early years.

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		1998
16	1936	9	1955,1980,1996

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; excludes depressions.
2 Distinction of hurricanes recorded only after 1885.

(3) When did the earliest and latest hurricanes 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 United States since 1900 was Alma which struck northwest Florida on June 9, 1966. The latest hurricane to strike the United States 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 most days as a hurricane (20) and tropical cyclone (28) (includes depression stage). Many tropical cyclones remained at hurricane intensity for 12 hours or less.

(5) What were the strongest and weakest hurricanes? 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 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 United States. Numerous hurricanes have reached only the minimum wind speed near 74 miles per hour and several have struck the United States.

(6) How many hurricanes have there been in each month? Table 8, adapted from Neumann et al. (1999), shows the total and average number of tropical cyclones, and those which became hurricanes, by month, for the period 1944-2000. It also shows the monthly total and average number of hurricanes to strike the United States since 1900 (updated from Hebert et al., 1997).

Table 8. Tropical storms and hurricanes in the Atlantic, Caribbean and Gulf of Mexico by month of origin, [updated from Neumann et al. (1999)], and for hurricanes striking the U.S. mainland 1900-2000 [updated from Hebert et al. (1997)].

	1944-2000 TROPICAL STORMS AND HURRICANES		1944-2000 HURRICANES		1900-2000 U.S. HURRICANES	
MONTH	Total	Average	Total	Average	Total	Average
JANUARY-APRIL	3	0.1	0	0.0	0	0.00
MAY	8	0.1	2	*	0	0.00
JUNE	31	0.5	11	0.2	11	0.11
JULY	50	0.9	22	0.4	18	0.18
AUGUST	151	2.6	95	1.6	42	0.42
SEPTEMBER	198	3.5	129	2.3	65	0.64
OCTOBER	100	1.8	60	1.1	25	0.25
NOVEMBER	26	0.5	16	0.3	4	0.04
DECEMBER	4	0.1	2	*	0	0.00
YEAR	571	10.0	337	5.9	165	1.63

[1] Includes subtropical storms after 1967. See Neumann et al. (1999) for details.
* Less than 0.05.

(7) What was the largest number of hurricanes in the Atlantic Ocean at the same time? According to information on the current version of the master data file of Neumann et al. (1999), until September 25, 1998 there had not been four hurricanes in the North Atlantic at the same time in over 100 years. Hurricanes Georges, Ivan, Jeanne and Karl persisted into September 27th, 1998 as hurricanes. One hundred five years earlier, on August 22, 1893 four hurricanes co-existed, one of them killing an estimated 1,000-2,000 people in Georgia-South Carolina. On September 11, 1961, three hurricanes and possibly a fourth occurred simultaneously. The only other years after 1900 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 at the same time; however, while most of these ultimately achieved hurricane intensity, there were never more than two hurricanes at any one time.

(8) How many direct hits by hurricanes of various categories have affected each state? Table 9, updated from Hebert et al. (1997), shows the number of hurricanes affecting (direct hits) the United States and individual states. The table shows that, on the average, close to five hurricanes every three years (1.63 per year) strike the United States, while two major hurricanes cross the U.S. coast every three years (0.64 per year). Other noteworthy facts, updated from Hebert et al. (1997), are: 1.) Thirty-six percent of all U.S. hurricanes hit Florida; 2.) Seventy-six percent of category 4 or higher hurricanes have hit either Florida or Texas; 3.) Approximately half the hurricanes to strike the middle Gulf coast, southern Florida and New York were major hurricanes.

Table 9. Hurricane direct hits on the mainland U.S. coastline and for individual states 1900-2000 by Saffir/Simpson category. Updated from Hebert et al. (1997).

AREA	CATEGORY NUMBER 1	2	3	4	5	ALL	MAJOR HURRICANES
U.S. (Texas to Maine)	61	39	48	15	2	165	65
Texas	12	9	10	6	0	37	16
(North)	7	3	3	4	0	17	7
(Central)	2	2	1	1	0	6	2
(South)	3	4	6	1	0	14	7
Louisiana	9	5	8	3	1	26	12
Mississippi	1	2	5	0	1	9	6
Alabama	5	2	5	0	0	12	5
Florida	19	17	17	6	1	60	24
(Northwest)	10	8	7	0	0	25	7
(Northeast)	2	7	0	0	0	9	0
(Southwest)	7	3	6	2	1	19	9
(Southeast)	6	11	7	4	0	28	11
Georgia	1	4	0	0	0	5	0
South Carolina	6	4	2	2	0	14	4
North Carolina	10	6	10	1 *	0	27	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 *	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 U.S. mainland and individual states. For the United States, 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 U.S. mainland and individual states, 1900-2000, by Saffir/Simpson category. Updated from Hebert et al. (1997).

AREA	JUNE	JULY	AUG.	SEPT.	OCT.	ALL
U.S. (Texas to Maine)	2	3	16	36	8	65
Texas	1	1	8	6		16
(North)	1	1	3	2		7
(Central)			1	1		2
(South)			4	3		7
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.

10) How long has it been since a hurricane or a major hurricane hit a given community? A chronological list of all hurricanes to strike the United States 1900 through 1990 including month, states affected by category, and minimum sea level pressure at landfall can be found in Jarrell et al. (1992). Table 11 extends that listing through 2000. Table12 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 et al. (1992).

Table 11. Chronological list of all hurricanes which affected the U.S. 1991-1999, including category by state. This is a continuation of a comparable table covering the years 1900-1990 given in Jarrell et al. (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(SE) 4, (SW) 3, LA 3	4	922	*ANDREW*
1993	Aug.	NC 3	3	960	*EMILY*
1995	Aug.	FL(SE) 1, (NW) 2	2	973	*ERIN*
1995	Oct.	FL(NW) 3	3	942	*OPAL*
1996	July	NC 2	2	974	*BERTHA*
1996	Sept.	NC 3	3	954	*FRAN*
1997	July	LA, AL 1	1	984	*DANNY*
1998	Aug.	NC 2	2	964	*BONNIE*
1998	Sept.	FL(NW) 1	1	987	*EARL*
1998	Sept.	FL(SW), (Keys), MS 2	2	964	*GEORGES*
1999	Aug.	TX (S) 3	3	951	*BRET*
1999	Sep.	NC 2	2	956	*FLOYD*
1999	Oct.	FL (SW, SE), NC 1	1	987	*IRENE*

There many illustrative examples of the uncertainty of when a hurricane might strike a given locality. After a period of nearly 70 years without a direct hit, Pensacola, Florida was hit directly by hurricane Erin and indirectly by major hurricane Opal during a two month period in 1995.

Miami, which expects a major hurricane every nine years, on average, was struck by a major hurricane in 1992 for the first time since 1950. Tampa hasn't experienced a major hurricane since 1921 years. Many locations along the Gulf and Atlantic coasts have not experienced a major hurricane during the period 1900-2000 (see Table 12).

(11) What is the total United States damage (before and after adjustment for inflation) and death toll for each year since 1900? 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 converted to 2000 dollars by the factors used in Table 3a.

Table 12. Last direct or indirect hit by any hurricane or a major hurricane at certain populated coastal communities. Category in parenthesis. Updated from Jarrell et al. (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	1998(2) Georges	
	Pascagoula	1985(3) Elena	1998(2) Georges	
Alabama	Mobile	1985(3) Elena	1998(2) Georges	
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)	1999(1) Irene	
	Miami	1992(4) Andrew	1999(1) Irene	
	Fort Lauderdale	1950(3) King	1999(1) Irene	1992(4) Andrew
	West Palm Beach	1949(3)	1999(1) Irene	
	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	1996(3) Fran	1999(2) Floyd	1999(2) Dennis
	Morehead City	1996(3) Fran	1999(2) Floyd	
	Cape Hatteras	1993(3) Emily	1993(3) Emily	1999(1) Dennis
Virginia	Virginia Beach	1944(3*)	1999(2) Floyd	
	Norfolk	<1900	1955(1) Connie	1999(1) Floyd
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. Hampshire	Portsmouth	<1900	1985(2*) Gloria	
Maine	Portland	<1900	1985(1*) Gloria	
	Eastport	<1900	1969(1) Gerda	1985(1*) Gloria

Notes: * Moving over 30 mph

Table 13. Estimated annual deaths and damages (unadjusted and adjusted for inflation[1] and normalized[L] for inflation, growth in personal wealth and population) in the mainland United States from landfalling Atlantic of Gulf tropical cyclones 1900-2000

Year	Deaths	DAMAGE ($Millions) Unadjusted	Adjusted[1]	Normalized[L]
1900	8,000 *	30	965 [2]	32,090
1901	10	1	32 [2]	773
1902	0	Minor	Minor	0
1903	15	1	32 [2]	8,317
1904	5	2	64 [2]	1006
1905	0	Minor	Minor	0
1906	298	3 *	97 [2]	4,906
1907	0	Minor	Minor	0
1908	0	Minor	Minor	0
1909	406	8	257 [2]	3,523
1910	30	1	32 [2]	1,360
1911	17	1 *	32 [2]	260
1912	1	Minor	Minor	0
1913	5	3	97 [2]	786
1914	0	Minor	Minor	0
1915	550	63	2,027 [3]	28,503
1916	107	33	888	4,340
1917	5	Minor	Minor	0
1918	34	5	87	441
1919	287 *	22	341	6,448
1920	2	3	37	439
1921	6	3	46	3,918
1922	0	Minor	Minor	0
1923	0	Minor	Minor	0
1924	2	Minor	Minor	0
1925	6	Minor	Minor	0
1926	289	112	1,738	89,676
1927	0	Minor	Minor	0
1928	1,836	25	388	16,632
1929	3	1	14	162
1930	0	Minor	Minor	0
1931	0	Minor	Minor	0
1932	40	8	132	2,187
1933	63	47	861	4,182
1934	17	5	83	442
1935	414	12	200	3,820
1936	9	2	34	125
1937	0	Minor	Minor	0
1938	600	306	4,749	20,057
1939	3	Minor	Minor	0
1940	51	5	80	617
1941	10	8	120	1,205
1942	8	27	353	1,408
1943	16	17	208	1,822
1944	64 *	165	2,015	28,322
1945	7	80	951	8,512
1946	0	5	50	2,703
1947	53	136	1,150	12,990
1948	3	18	139	2,037
1949	4	59	455	7,443
1950	19	36	273	3,383
1951	0	2	13	219
1952	3	3	20	76
1953	2	6	41	34
1954	193	756	5,140	21,121
1955	218	985	6,562	15,906
1956	19	27	170	422
1957	400	152	933	2,946
1958	2	11	67	268
1959	24	23	143	538
1960	65	396	2,464	14,717
1961	46	414	2,588	8,635
1962	3	2	12	51
1963	10	12	73	179
1964	49	515	3,174	8,499
1965	75	1,445	8,664	15,308
1966	54	15	86	199
1967	18	200	1,113	2,471
1968	9	10	53	386
1969	256	1,421	8,994	13,219
1970	11	454	2,109	4,024
1971	8	213	927	1,461
1972	122	2,100	8,603	12,923
1973	5	18	68	114
1974	1	150	498	863
1975	21	490	1,489	2,117
1976	9	100	290	370
1977	0	10	27	39
1978	36	20	48	92
1979	22	3,045	6,574	10,414
1980	2	300	584	1,043
1981	0	25	45	94
1982	0	Minor	Minor	0
1983	22	2,000	3,422	4,890
1984	4	66	109	157
1985	30	4,000	6,450	7,921
1986	9	17	26	35
1987	0	8	12	16
1988	6	59	86	106
1989	56	7,670	10,672	12,422
1990	13	57	77	89
1991	16	1,500	2,005	2,085
1992	24	26,500	34,955	39,896
1993	4	57	72	77
1994	38	973	1,187	1,238
1995	29	3,723	4,369	4,493
1996	36	3,600	4,129	4,201
1997	4	100	111	112
1998	23	3,699	3,995	4,001
1999	62	5,532	5,737	5,753
2000	6	27	27	27

* 1900 could have been as high as 10,000 to 12,000, other years means "more than".

[1] Adjusted to 2000 dollars based on U.S. Department of Commerce Implicit Price Deflator for Construction.

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

[3] Considered too high in 1915 reference.

* Figures do not agree with Table 2 because deaths at sea are not included here.

[L] Normalization reflects inflation, changes in personal wealth and coastal county population to 2000 (Pielke and Landsea 1998).

Table 13a. As in Table 13, but for the thirty deadliest and costliest years from 1900-2000.

	Ranked on Deaths			Ranked on Unadjusted Damage			Ranked on Adjusted[1] Damage			Ranked by Normalized[L] Damage	
	Year	Deaths		Year	($ Millions)		Year	($ Millions)		Year	($ Millions)
1	1900	8,000 [+]	1	1992	26,500	1	1992	34,955	1	1926	89,676
2	1928	1,836	2	1989	7,670	2	1989	10,672	2	1992	39,896
3	1938	600	3	1999	5,532	3	1965	8,664	3	1900	32,090
4	1915	550	4	1985	4,000	4	1972	8,603	4	1915	28,503
5	1935	414	5	1995	3,723	5	1969	6,994	5	1944	28,322
6	1909	406	6	1998	3,699	6	1979	6,574	6	1954	21,121
7	1957	400	7	1996	3,600	7	1955	6,562	7	1938	20,057
8	1906	298	8	1979	3,045	8	1985	6,450	8	1928	16,632
9	1919	287 [s]	9	1972	2,100	9	1999	5,737	9	1955	15,906
10	1926	269	10	1983	2,000	10	1954	5,140	10	1965	15,308
11	1969	256	11	1991	1,500	11	1938	4,749	11	1960	14,717
12	1955	218	12	1965	1,445	12	1995	4,369	12	1969	13,219
13	1954	193	13	1969	1,421	13	1996	4,129	13	1947	12,990
14	1972	122	14	1955	985	14	1998	3,995	14	1972	12,923
15	1916	107	15	1994	973	15	1983	3,422	15	1989	12,422
16	1965	75	16	1954	756	16	1964	3,174	16	1979	10,414
17	1960	65	17	1964	515	17	1961	2,588	17	1961	8,635
18	1944	64 [s]	18	1975	490	18	1960	2,464	18	1945	8,512
19	1933	63	19	1970	454	19	1970	2,109	19	1964	8,499
20	1999	62	20	1961	414	20	1915	2,027 [3]	20	1903	8,317
21	1989	56	21	1960	396	21	1944	2,015	21	1985	7,921
22	1966	54	22	1938	306	22	1991	2,005	22	1949	7,443
23	1947	53	23	1980	300	23	1926	1,738	23	1919	6,448
24	1940	51	24	1971	213	24	1975	1,489	24	1999	5,753
25	1964	49	25	1967	200	25	1994	1,187	25	1906	4,906
26	1961	46	26	1944	165	26	1947	1,150	26	1983	4,890
27	1932	40	27	1957	152	27	1967	1,113	27	1995	4,493
28	1994	38	28	1974	150	28	1900	965 [2]	28	1916	4,340
29	1978	36	29	1947	136	29	1945	951	29	1996	4,201
30	1996	36	30	1926	112	30	1957	933	30	1933	4,182

[+] Could have been as high as 10,000 to 12,000.

[1] Adjusted to 2000 dollars based on U.S. Department of Commerce Implicit Price Deflator for Construction.

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

[3] Considered too high in 1915 reference.

[s] Figures do not agree with Table 2 because deaths at sea are not included here.

[L] Landsea normalization reflects inflation, changes in personal wealth and coastal county population to 2000 (Pielke and Landsea 1998).

12) Are there hurricane cycles? Figures 1 through 10 show the landfalling portion of the tracks of major hurricanes that have struck the United States 1900-1999 (there were no major hurricane strikes on the United States in 2000). The reader might note the tendency for the major hurricane landfalls to cluster in certain areas during certain decades. Another interesting point is the 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 1901 indicates that the major hurricanes tended to be in the western Gulf Coast states at the beginning of the 20th 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.

(13) What are the death and damage statistics for Hawaii, Puerto Rico and the U.S. Virgin Islands? Table 14 lists some of the deadliest, costliest and most intense tropical cyclones to affect the islands. The Saffir/Simpson hurricane 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. In both island areas, some minimum pressure values appear inconsistent with the given wind values. This is largely attributable to the given minimum and maximum winds not necessarily being the extremes in the hurricane.

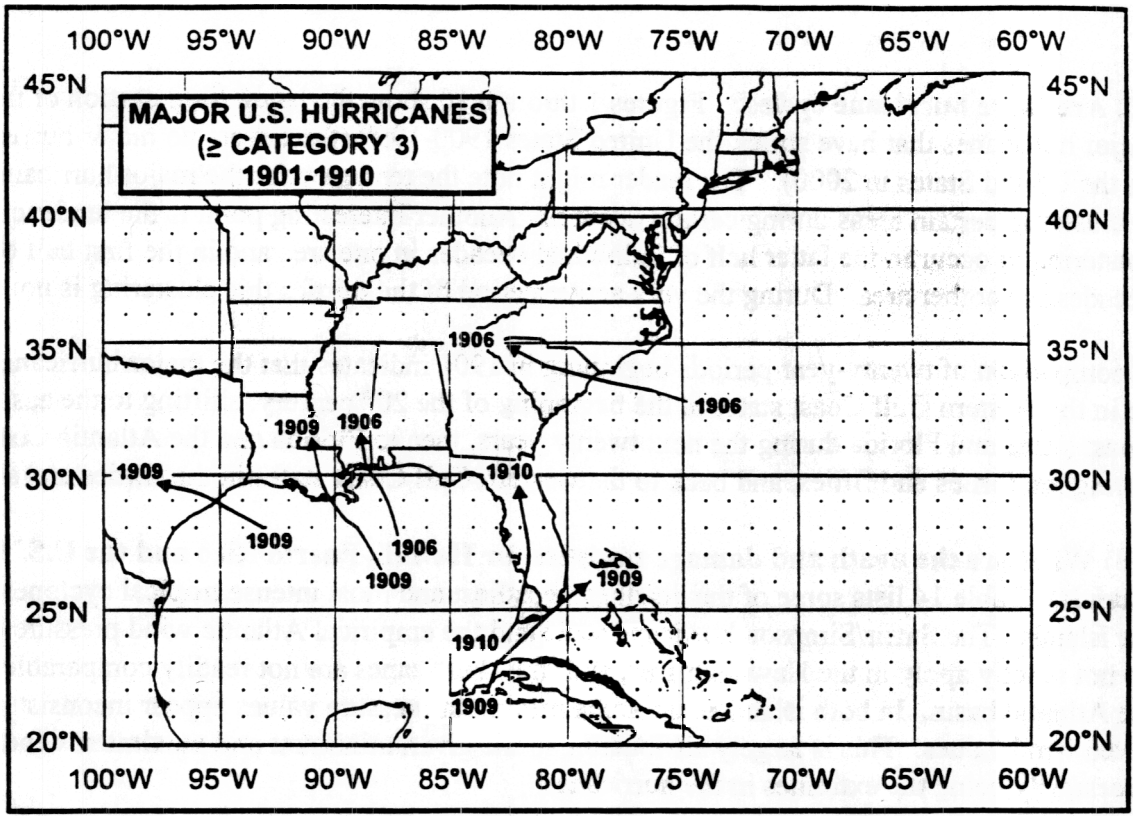

Figure 1. Landfalling United States major hurricanes (stronger than or equal to a category 3) during the period 1901-1910.

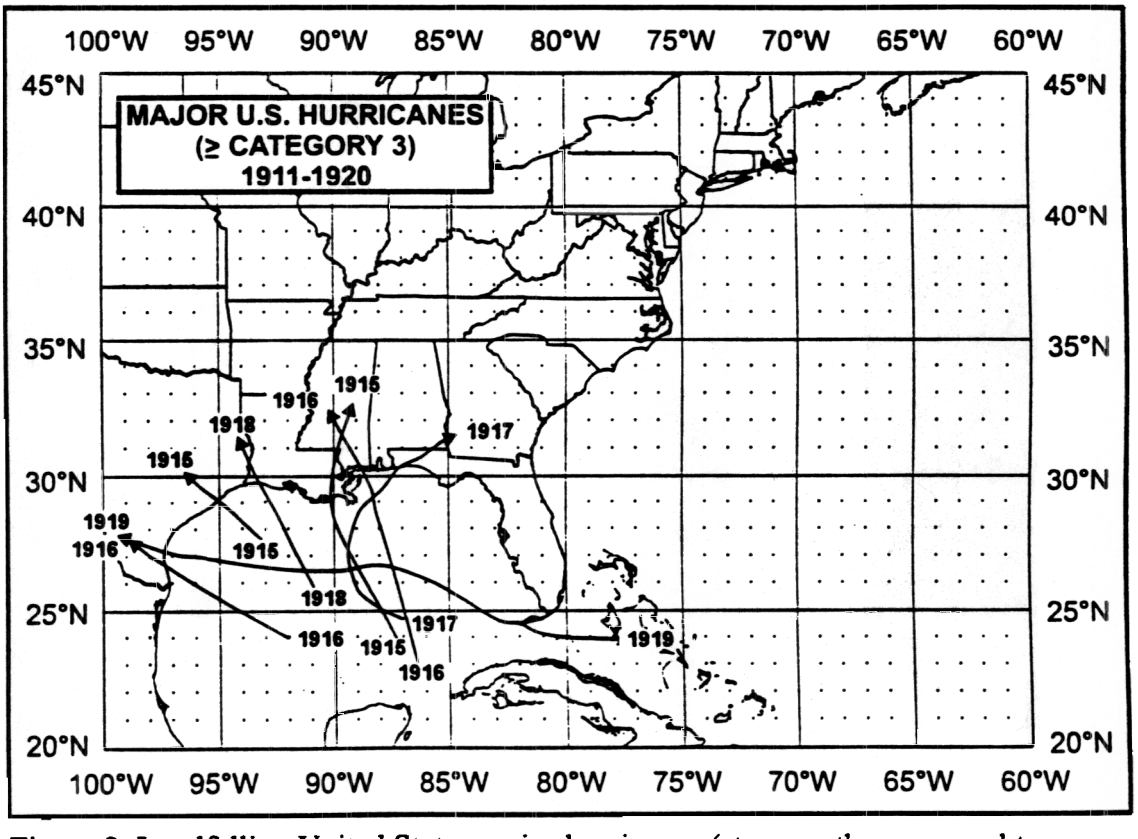

Figure 2. Landfalling United States major hurricanes (stronger than or equal to a category 3) during the period 1911-1920.

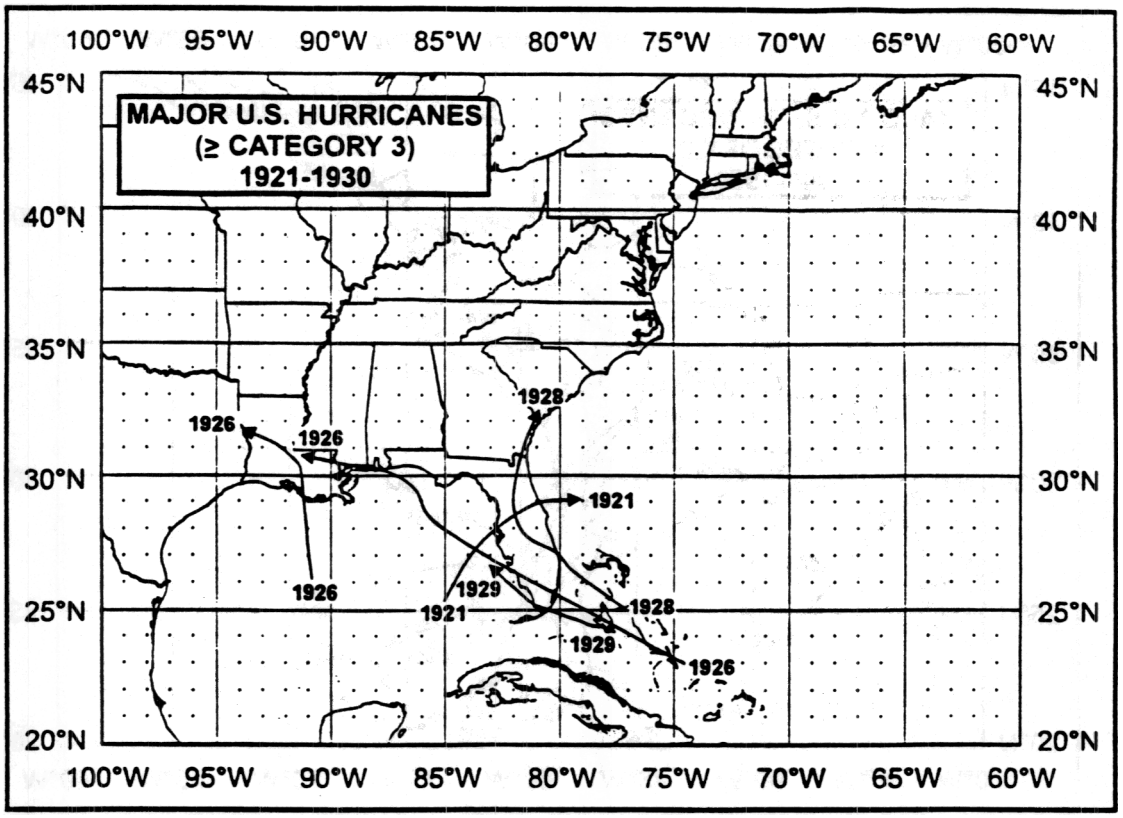

Figure 3. Landfalling United States major hurricanes (stronger than or equal to a category 3) during the period 1921-1930.

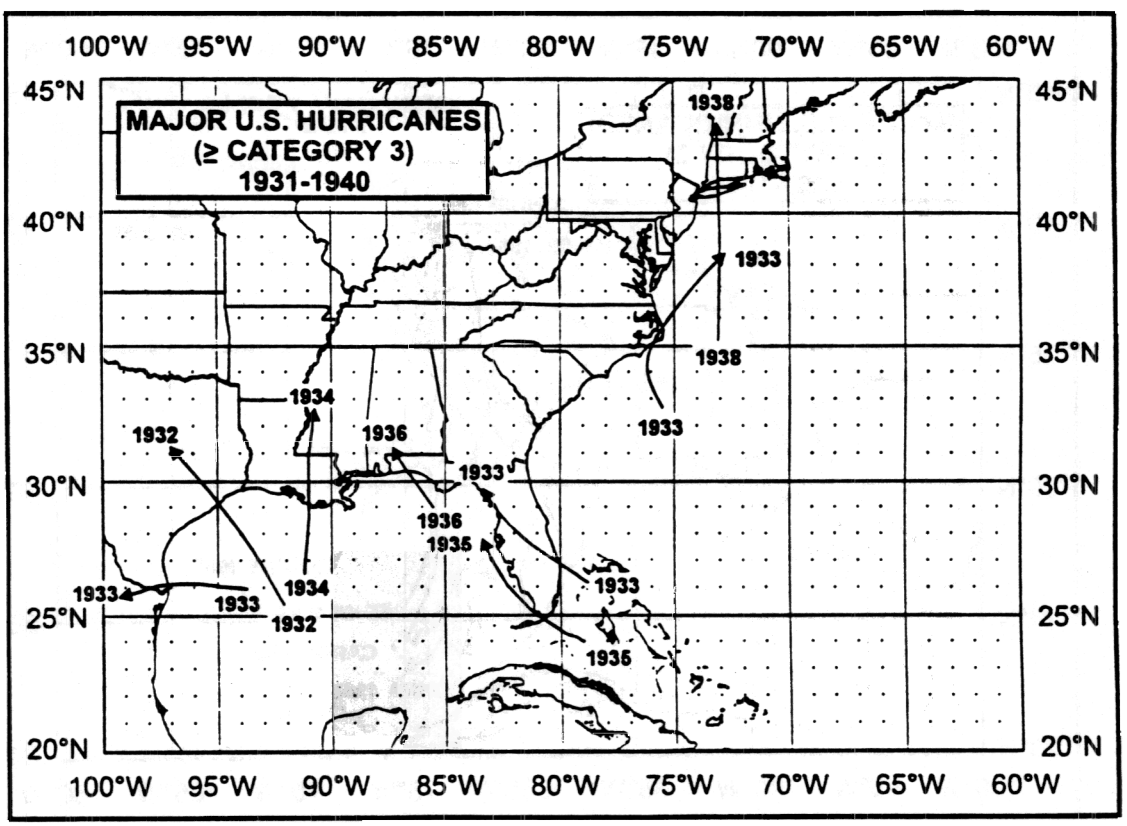

Figure 4. Landfalling United States major hurricanes (stronger than or equal to a category 3) during the period 1931-1940.

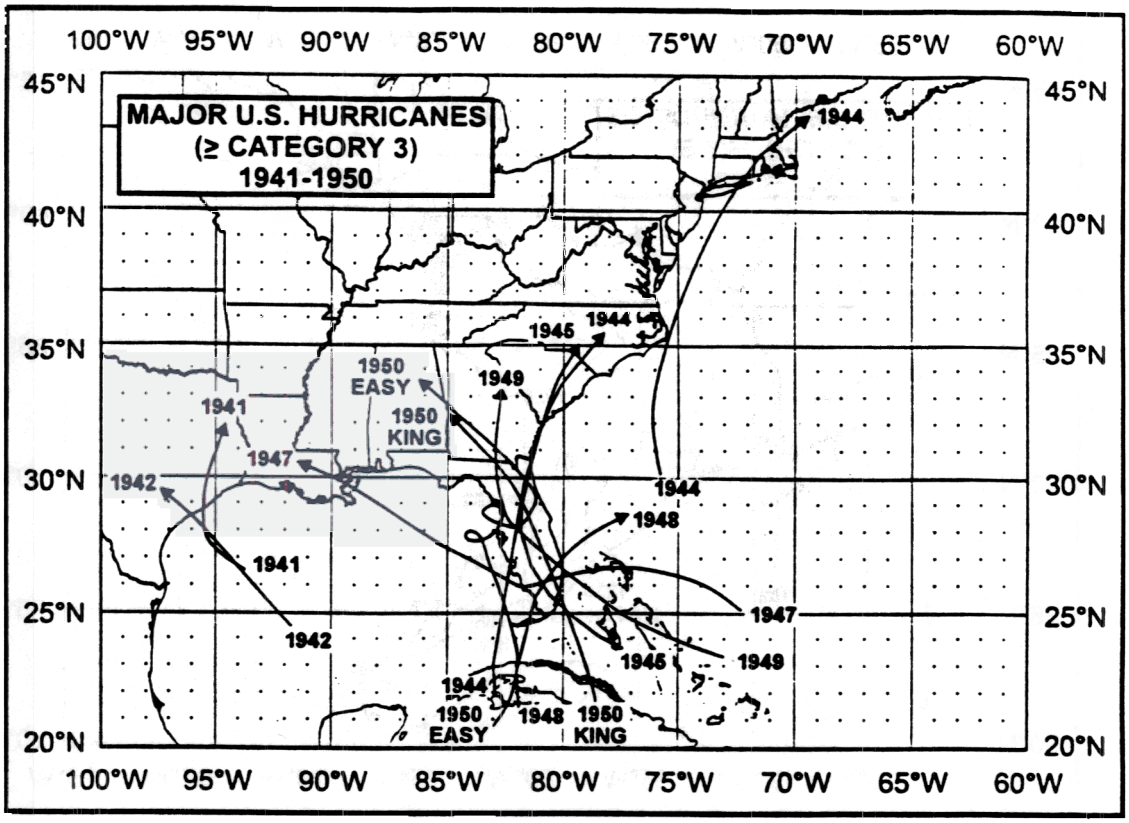

Figure 5. Landfalling United States major hurricanes (stronger than or equal to a category 3) during the period 1941-1950.

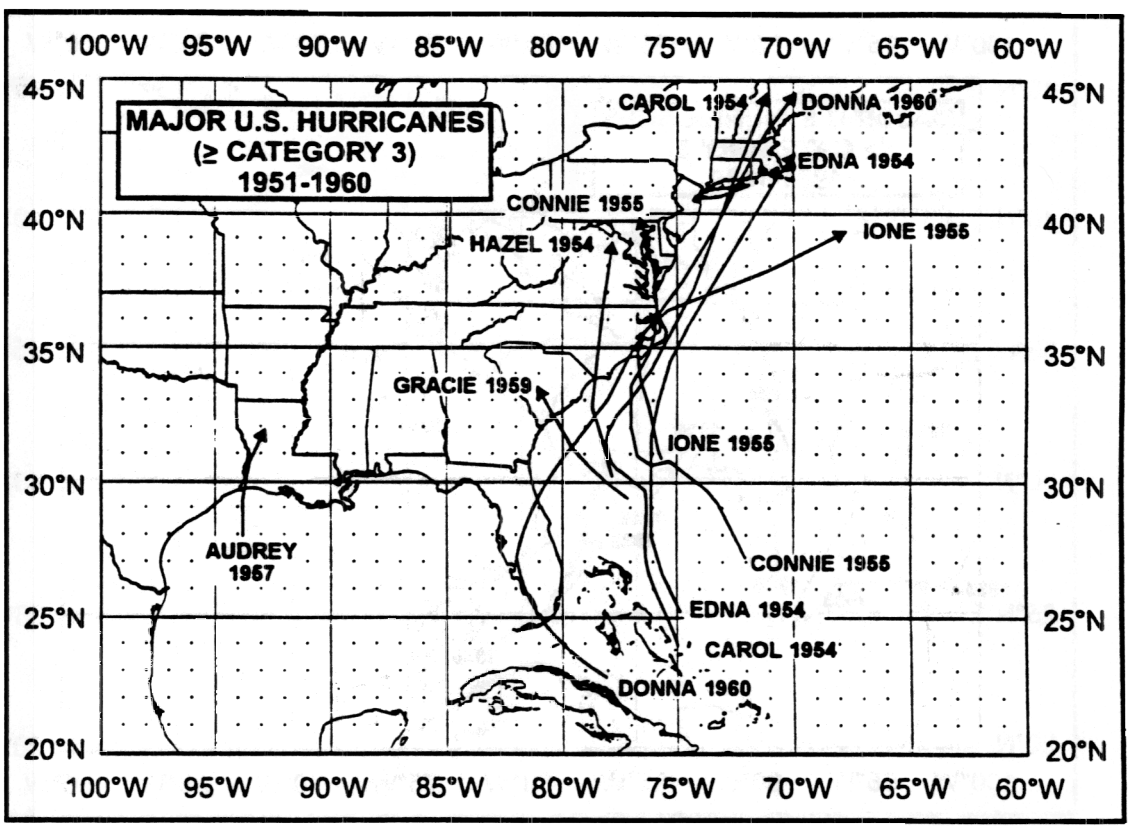

Figure 6. Landfalling United States major hurricanes (stronger than or equal to a category 3) during the period 1951-1960.

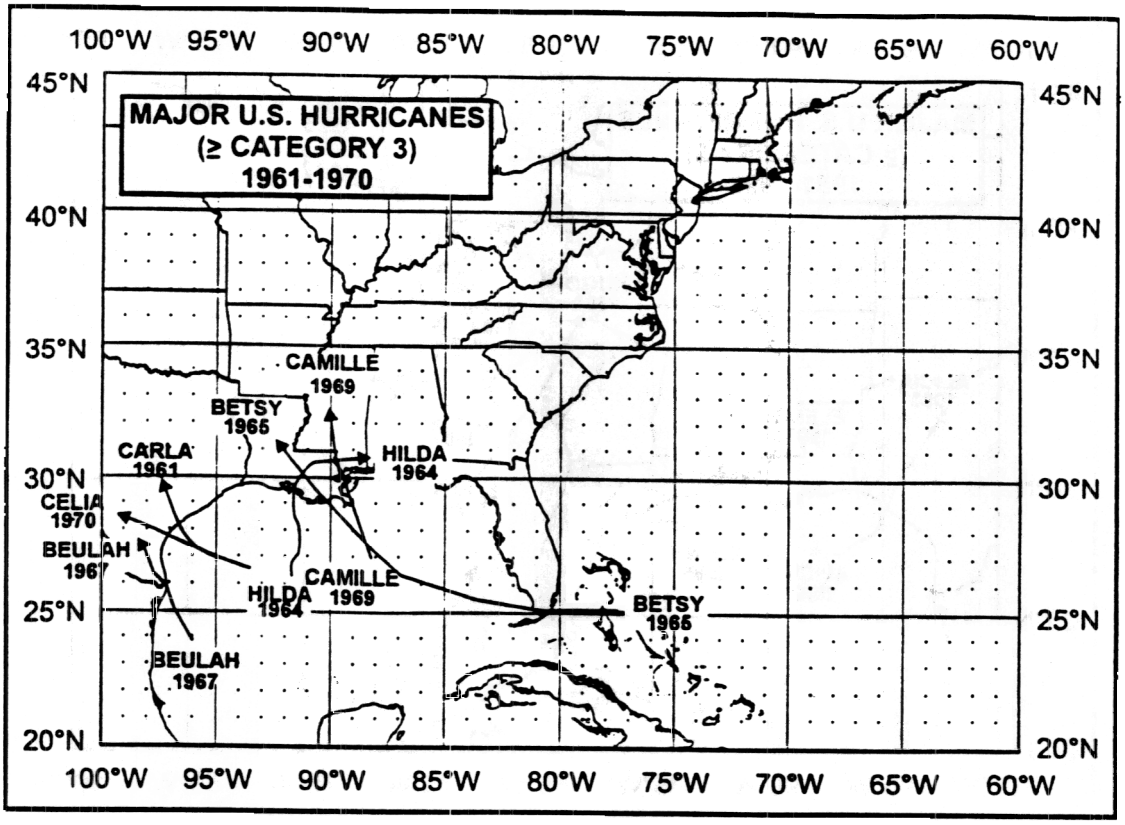

Figure 7. Landfalling United States major hurricanes (stronger than or equal to a category 3) during the period 1961-1970.

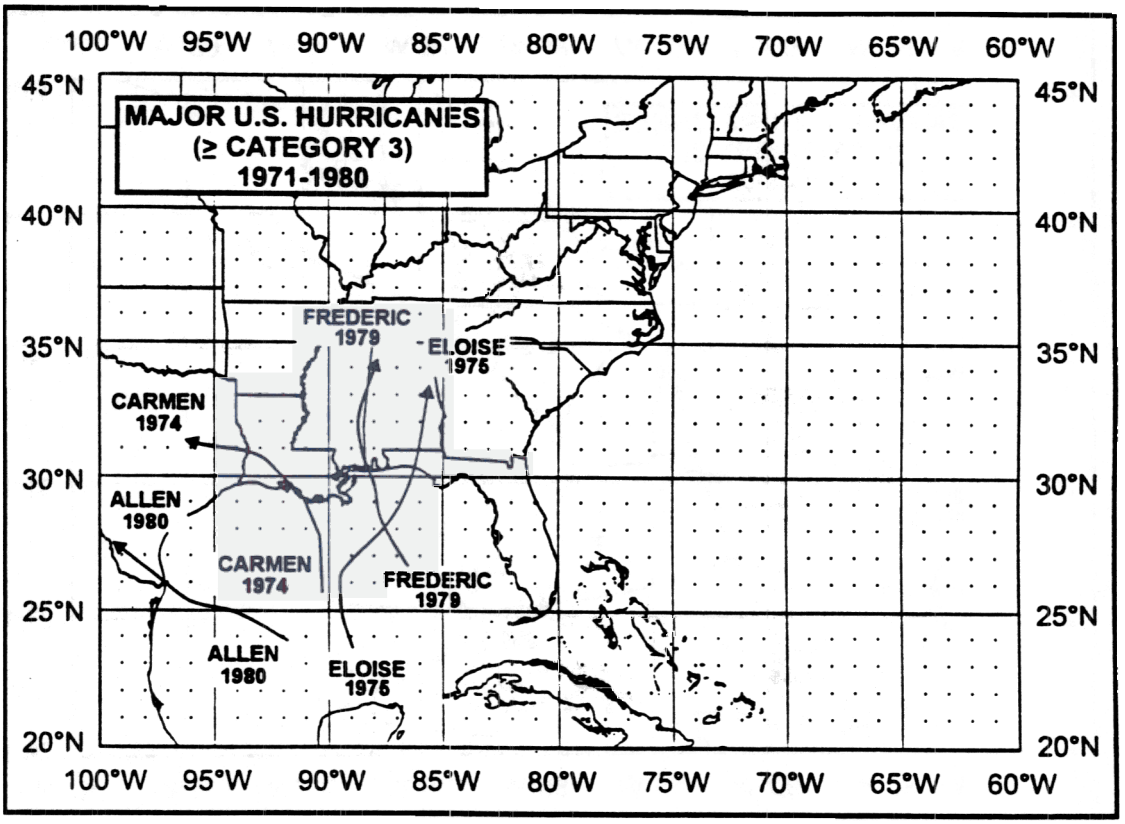

Figure 8. Landfalling United States major hurricanes (stronger than or equal to a category 3) during the period 1971-1980.

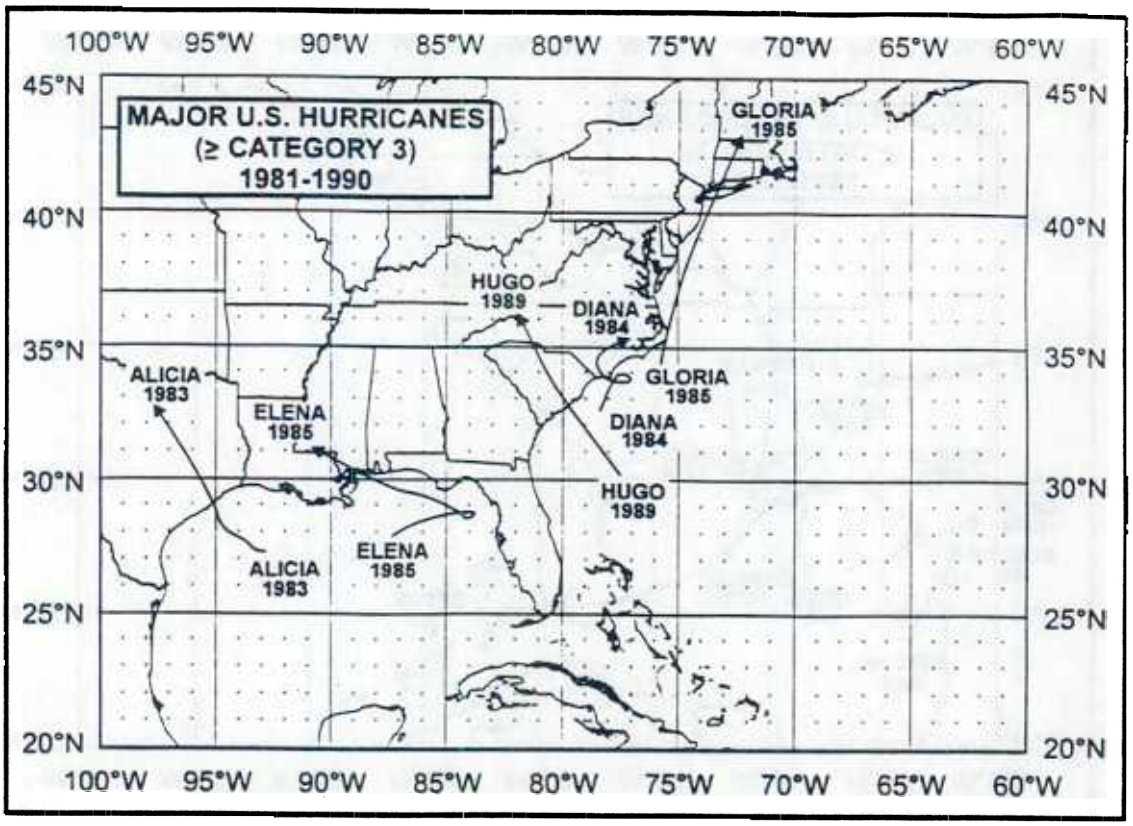

Figure 9. Landfalling United States major hurricanes (stronger than or equal to a category 3) during the period 1981-1990.

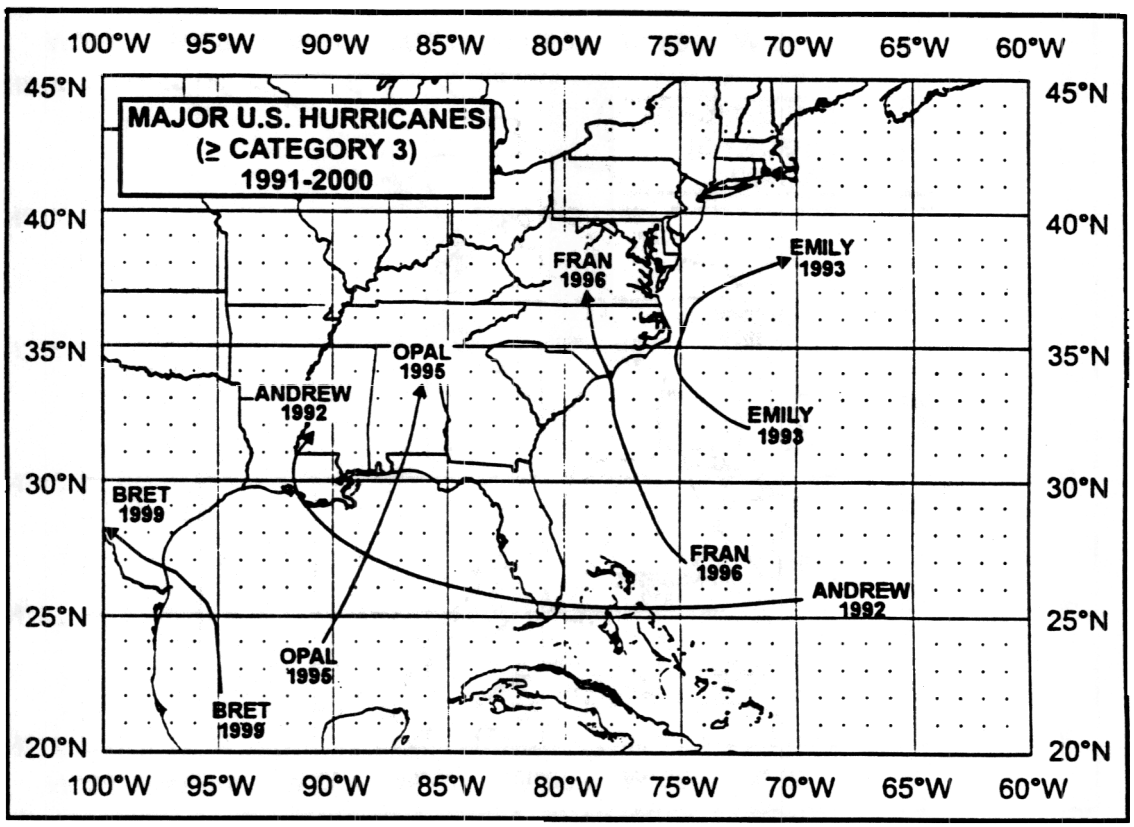

Figure 10. Landfalling United States major hurricanes (stronger than or equal to a category 3) during the period 1991-2000.

Table 14. Deadliest and costliest tropical cyclones from 1900- 2000 to affect Hawaii, Puerto Rico and the U.S. Virgin Islands.

Name	Date	Island or CPA	Damage ($000) Unadjusted	Adjusted for Inflation	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	1,227	4	90	965
Dot	Aug 06,1959	Kauai	6,000	37,332	0	115	955
Iwa	Nov 23,1982	25 mi NW Kauai	312,000	543,651	1	90	964
Iniki	Sep 11,199	Kauai	1,800,00(	2,374,29(	4	130	950
San Hipolito	Aug 22,1916	Puerto Rico	1,000	26,919	1	98	988
San Liborio	Jul 23,1926	[1] SW Puerto Rico	5,000	77,591	25	81	~985
San Felipe	Sep 13,1928	Puerto Rico	85,000	1,319,050	312	161	Unk
San Nicolas	Sep 10,1931	[1] Puerto Rico	200	3,298	2	121	Unk
San Ciprian	Sep 26,1932	[1] USVI, PR	30,000	494,644	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	252,450	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	269,855	7	58	1000
Hugo	Sep 18,1989	USVI, PR	1,000,000	1,391,403	5	138	940
Marilyn	Sep 16,1995	USVI, E. PR	1,500,000	1,760,298	8	109	952
Hortense	Sep 10,1996	SW Puerto Rico	500,000	573,500	18	81	989
Georges	Sep 21,1998	USVI & PR	1,800,000	1,945,900	0	115	968
Lenny	Nov 17,1999	USVI & PR	330,000	342,233	0	155	933

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

SUMMARY

In virtually every coastal city of any size from Texas to Maine, the present Tropical Prediction Center Director, Max Mayfield, or former National Hurricane Center Directors, have stated that the United States is building toward its next hurricane disaster. The population growth and low hurricane experience levels indicated in Hebert et al. (1984), together with updated statistics presented by Jarrell et al. (1992), form the basis for their statements. The areas along the United States Gulf and Atlantic coasts where most of this country's hurricane related fatalities have occurred are also now experiencing the country's most significant growth in population. This situation, in combination with continued building along the coast, will lead to serious problems for many areas in hurricanes. Because it is likely that people will always be attracted to live along the shoreline, a solution to the problem lies in education, preparedness and mitigation.

The message to coastal residents is: 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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REFERENCES

Gentry, R.C., 1966: Nature and Scope of Hurricane Damage, American Society for Oceanography Hurricane Symposium, Publication Number One, 344p.

Hebert, P.J., J.G. Taylor, and R.A. Case, 1984: Hurricane Experience Levels of Coastal County Populations -Texas to Maine, NOAA, Technical Memorandum NWS-NHC-24, 127pp.

Hebert, P.J., J.D. Jarrell, and B.M. Mayfield, 1997: The Deadliest, Costliest and Most Intense United States Hurricanes of this Century (and Other Frequently Requested Hurricane Facts), NOAA. Technical Memorandum NWS-TPC-1, 30 pp.

Jarrell, J.D., P.J. Hebert, and B.M. Mayfield, 1992: Hurricane Experience Levels of Coastal County Populations-Texas to Maine, NOAA, Technical Memorandum NWS-NHC-46, 152 pp.

Neumann, C.J., B.R. Jarvinen, C.J. McAdie, and G.R. Hammer, 1999:Tropical Cyclones of the North Atlantic Ocean, 1871-1998, NOAA, Historical Climatogy Series 6-2.

Pielke, Jr., R.A., and C.W. Landsea, 1998: Normalized U.S. Hurricane Damage. 1925-1995, Weather and Forecasting, 13, 621-631.

Simpson, R.H., 1974: The Hurricane Disaster Potential Scale. Weatherwise. 27,169,186.

U.S. Weather Bureau: Climatological Data and Storm Data, various volumes, various periods, National and State Summaries (National Weather Service 1971-1998).

U.S. Weather Bureau: Monthly Weather Review, 1872-1970 (National Weather Service 1971-1973, and American Meteorological Society 1974-2001).