

NOAA Technical Memorandum NWS TPC-1

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

by

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Updated October 2001

**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.

**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., major1 ) 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<sup>2</sup>? Answers to these and several other questions are provided in Section 3.

<sup>1</sup> 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.

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

## 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<sup>3</sup>. 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.

Table 4a summarizes the direct hits on the U.S. mainland since 1900.

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.

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.

**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 after 1900 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!

**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. **(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).
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.
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.
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. Table 12 summarizes the occurrence of the last major hurricane or of any hurricane to directly hit the more populated coastal communities from Brownsville, Texas to Eastport, Maine. In addition, if a hurricane indirectly affected a community after the last direct hit, it is listed in the last column of the table. In order to obtain the same type of information listed in Table 12 for the remaining coastal communities, the reader is again referred to Jarrell et al. (1992).

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.

**12. Are there hurricane cycles ? Choose decade :**

(1901-1910), (1911-1920), (1921-1930), (1931-1940), (1941-1950), (1951-1960), (1961-1970), (1971-1980), (1981-1990), (1991-2000)

Figures 1 through 10 show the landfalling portion of the tracks of major hurricanes that have struck the United States 1901-1999 (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.**

## **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.

**Acknowledgments:** Paul Hebert, J.G. Taylor and R.A. Case, co-authors of previous version of this paper, are recognized for their enduring contributions to this work. Joan David drafted the figures.

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