Normalized Hurricane Damage in the United States: 1900–2005

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Abstract: After more than two decades of relatively little Atlantic hurricane activity, the past decade saw heightened hurricane activity and more than $150 billion in damage in 2004 and 2005. This paper normalizes mainland U.S. hurricane damage from 1900–2005 to 2005 values using two methodologies. A normalization provides an estimate of the damage that would occur if storms from the past made landfall under another year's societal conditions. Our methods use changes in inflation and wealth at the national level and changes in population and housing units at the coastal county level. Across both normalization methods, there is no remaining trend of increasing absolute damage in the data set, which follows the lack of trends in landfall frequency or intensity observed over the twentieth century. The 1970s and 1980s were notable because of the extremely low amounts of damage compared to other decades. The decade 1996–2005 has the second most damage among the past 11 decades, with only the decade 1926–1935 surpassing its costs. Over the 106 years of record, the average annual normalized damage in the continental United States is about $10 billion under both methods. The most damaging single storm is the 1926 Great Miami storm, with $140–157 billion of normalized damage: the most damaging years are 1926 and 2005. Of the total damage, about 85% is accounted for by the intense hurricanes (Saffir-Simpson Categories 3, 4, and 5), yet these have comprised only 24% of the U.S. landfalling tropical cyclones. Unless action is taken to address the growing concentration of people and properties in coastal areas where hurricanes strike, damage will increase, and by a great deal, as more and wealthier people increasingly inhabit these coastal locations.

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Introduction

In the aftermath of Hurricane Katrina's devastating economic and human toll along the U.S. Gulf Coast, renewed scientific and policy attention has focused on hurricanes and their impacts. This paper updates and extends work first presented by Pielke and Landsea (1998) and Collins and Lowe (2001) to provide longitudinally consistent estimates of the economic damage that past storms would have had under contemporary levels of population and development. The results presented here reinforce the conclusions of the earlier studies and illustrate clearly the effects of the tremendous pace of growth in societal vulnerability to hurricane impacts. Such growth in vulnerability is expected to continue for the foreseeable future, in the United States and around the world, and without effective disaster mitigation efforts, ever-escalating hurricane damage will be the inevitable result.

The paper is organized into four sections: The first describes the damage data that are used in the analysis and their origins and uncertainties; the second describes the two normalization methodologies; the third discusses the results of the normalizations; and the fourth discusses the significance of the findings and concludes the paper.

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Data

This study focuses on the total *economic* damage related to hurricane landfalls along the U.S. Gulf and Atlantic coasts from 1900 to 2005. Economic damage is defined as the direct losses associated with a hurricane's impact as determined in the weeks (and sometimes months) after the event (Changnon 1996; Downton et al. 2005). Indirect damage and longer-term macroeconomic effects are not considered in this analysis. Different methods exist for calculating a disaster's impacts, which lead to correspondingly different loss estimates for the same event. Our focus is on utilizing a consistent approach over time that allows for a meaningful normalization methodology and results that compare "apples to apples."

This paper builds upon work published originally by Pielke and Landsea (1998), which utilized historical economic damage compiled originally by Landsea (1991) from the *Monthly Weather Review* annual hurricane summaries and more recently the storm summary data archived on the National Hurricane Center (NHC) Web site (NHC 2006b). We use loss data from Pielke and Landsea (1998), extended by using NHC loss estimates for 1900–1924 and 1998–2005 contained in their storm summaries (NHC 2006a). The original loss data are reported in current-year dollars, meaning that damage estimates are presented in dollars of the year of hurricane landfall.

Although this study uses *economic* loss figures as opposed to *insured* losses, official estimates of economic damage have been in part dependent on insured figures since about 1987. Edward Rappaport, Deputy Director of the National Hurricane Center, said in an e-mail that since he came to the NHC in 1987, the center has in many cases worked from a doubling of insured loss estimates to arrive at their estimate of economic damage (E. Rapaport, personal communication, November 8, 2005). Although this practice could have started earlier than 1987, that year is the earliest reference we have for the practice. Our examination of the relationship of insured damages to official NHC totals since 1987 indicates that this practice is more of a guideline that is often modified on a storm-by-storm basis, rather than a formulaic application [see the comparison of insured and total losses reported in Pielke et al. (1999)]. It should be expected that the relationship of economic and insured damages would vary, depending on the extent of flooding (which is an excluded peril on many insurance policies) and damage to infrastructure and uninsured properties in each storm.

Because damage normalization is a function of the original damage estimate, systematic biases in damage collection would be problematic. We find no evidence of such biases in the NHC damage data set, with one exception. Before 1940, 32 storms made landfall with no reported damages in the official government damage data set, whereas only 8 such storms have occurred since 1940. Given current levels of coastal development, it is implausible that any hurricane could make landfall today and cause no damage. Hence, prior to 1940 there is an undercount of damaging storms. In principle, one could substitute estimates for the zero-loss storms, based for example, on the relationship between storm intensity and population of affected counties documented for comparable storms in the data set. Our results do not include such estimates [see Collins and Lowe (2001), which utilizes this approach].

The damage in the historical database includes seven storms with extensive inland flood damages (Agnes 1972; Alberto 1994; Diane 1955; Doria 1971; Eloise 1975; Floyd 1999; Frances 1998). Due to the practical difficulties of distinguishing flood from nonflood damages, we have included both in our analysis as reported by the U.S. Government. As a consequence, because the flooding from these storms includes a much wider area than just a few coastal counties affected at landfall, for these seven storms the population and housing unit multipliers were expanded to consider the entire state(s) affected by each storm. In each case this has the effect of maintaining or reducing the normalized adjustment, as population and housing growth have generally been more rapid along the desirable coastal counties than averaged for an entire state. In any case, the inclusion of flood damage associated with these seven storms is not a significant factor in interpreting the results of the analysis

There are of course uncertainties in damage estimates. Some insight on such uncertainties in disaster estimates is provided by Downton and Pielke (2005) and Downton et al. (2005), which discuss the collection of and errors in the U.S. National Weather Service's flood damage database, which is kept separately from the hurricane loss record. The historical record of flood damage is relevant because it is collected and reported in the same manner as is hurricane damage and by the same government agency. Downton and Pielke (2005) found that for the largest floods (i.e., inflation adjusted to >\$500 million in 1995 dollars), independent estimates (e.g., between states and the federal government over various time periods) of damage for the same event differed by as much as 40% for events greater than \$500 million in losses. However, Downton et al. (2005) suggested that the long-term record of flood damage is of sufficient quality to serve as the basis for long-term trend analysis as there was no evidence of systematic biases over time. Thus, we conclude that there are likely to be large uncertainties in the loss estimates for individual storms, but there is no evidence of a systematic bias in loss through the data set. This conclusion is reinforced by normalization results that are consistent with longitudinal geophysical data on hurricane frequency and intensity at landfall, which has no observed trends over time.

It is also important to mention the uncertainties in the normalized losses that arise from assumptions in the normalization schemes themselves. Both normalization methods described in this paper—Pielke/Landsea and Collins/Lowe—rely on national wealth data that have been collected systematically by the U.S. Government since 1925. We extrapolate this data set back to 1900 to generate estimates of wealth prior to 1925. Varying the assumptions underlying this extrapolation will have a large effect on pre-1925 normalized losses. For instance, assuming an annual average increase in pre-1925 wealth of 4% rather than 3% increases normalized loss estimates of the 1900 Galveston storm by more than 15%.

Similarly, the Collins/Lowe methodology requires an assumption-based extrapolation of county-level housing units prior to 1940. We therefore recommend that any analysis that uses the Pielke/Landsea normalized loss estimates prior to 1925 and the Collins/Lowe normalized loss estimates prior to 1940 recognize the larger uncertainties in the data at these earlier times compared to later periods, which benefit from original wealth and county unit housing data. Quantifying the uncertainty ranges around these normalized loss estimates would require further research that is beyond the scope of this paper. However, in all instances we sought to use conservative assumptions, i.e., those that would err on underestimating historical losses.

Normalization Methodologies

Pielke and Landsea (1998) used a single approach to adjusting past storm damage for changing societal conditions. Here we present two different approaches to normalize damages, which result in broadly consistent results. The two approaches are (1) the methodology used by Pielke and Landsea (1998), adjusting for inflation, wealth, and population updated to 2005, called PL05; and (2) the methodology used by Collins and Lowe (2001), adjusting for inflation, wealth, and housing units updated to 2005, called CL05. Each approach is described in detail in the following two subsections.

Pielke and Landsea (1998) Updated to 2005 (PL05)

Pielke and Landsea (1998) estimated the damage that historical storms would have caused had they made landfall under contemporary levels of societal development by adjusting historical damages by three factors: inflation, wealth, and population. The factors are described below and illustrated with the example of Hurricane Frederic from 1979, which made landfall along the Gulf Coast.

Inflation

In order to adjust for changes in national inflation (i.e., the decrease in value of a currency over time), we use the implicit price deflator for gross domestic product (IPDGDP) for the years 1929–2005 from the Bureau of Economic Analysis (BEA 2006b). For inflation data for 1900–1928 the BEA recommends Johnston and Williamson (2006) as there are no official government inflation data during these years (V. Mannering, personal communication, January 19, 2006). From these data, the inflation adjustment is a ratio of the 2005 IPDGDP to that in the year in which the storm made landfall. For example, the 2005 IPDGDP was 112.737 and that for 1979 was 49.548. Thus, to convert damages expressed in 1979 dollars to 2005 dollars requires that 1979 damages be multiplied by $2.275 = 112.737/49.548$.

Wealth per Capita

The second adjustment to the economic loss data is to adjust for the growth in wealth; increasing "wealth" simply means that people have more "stuff" today as compared to the past and the real value of their "stuff" has in some cases increased. National wealth is captured by the estimate of current-cost net stock of fixed assets and consumer durable goods produced each year by the U.S. Department of Commerce's Bureau of Economic Analysis (BEA 2006a). Note that Pielke and Landsea (1998) used a different metric from the BEA: fixed reproducible tangible wealth. We use a slightly different metric here because of its greater longitudinal availability. Over the period that both metrics are available, they are correlated at 0.9916. Wealth from 1900–1924 was estimated to increase by 3% per year based on the lower of the average annual change in wealth from 1925–2005 (6%) and from 1925–1928 (3%). Because real GDP also increased by approximately 3% per year in 1900–1924, and wealth typically increases at a faster rate than GDP, our assumption for pre-1924 changes in wealth is exceedingly likely to be conservative (Johnston and Williamson 2006).

Because the wealth data are reported in billions of current-year dollars for the entire nation, we adjust these data for (1) inflation; and (2) population. We disaggregate wealth to a noninflated (real) per capita metric in order to allow us to distinguish the independent roles of inflation, wealth, and population in the normalization.

For example, wealth in 2005 was $40.99 trillion, and for 1979, $8.91 trillion. The ratio of 2005 to 1979 is 4.599. The inflation multiplier for 1979 was 2.275, so the inflation-corrected wealth adjustment (i.e., real wealth) for $1979 = 4.599/2.275 = 2.021$. Finally, the U.S. population in 1979 is estimated to be 224,212,417 people (based on a linear interpolation between 1970 and 1980). The U.S. population in 2005 was estimated to be 297,777,921 (using a linear extrapolation from 1990–2000). The U.S. population multiplier is thus the ratio of the 2005 estimate to the 1979 estimate, or 1.328, and the final wealth multiplier for 1979 is the real wealth multiplier of 2.021 divided by the U.S. population multiplier of 1.328, which equals 1.522. Therefore each person in the United States has (on average) 1.522 times more wealth in 2005 than did each person in 1979.

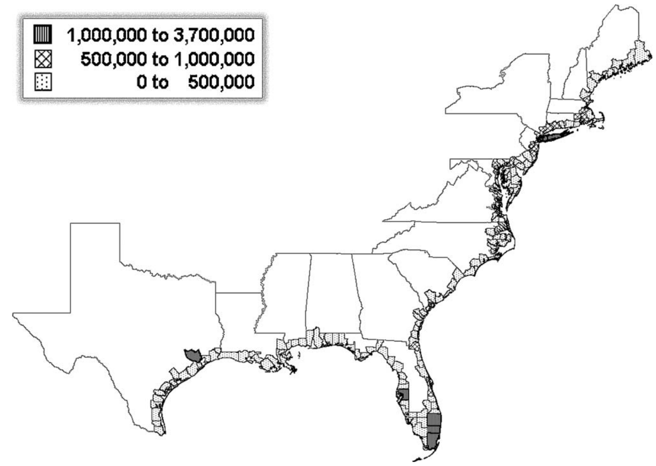

Fig. 1. 2005 Population by county. Galveston/Houston area of Texas, Tampa and Miami area of Florida, and Northeast coastline stand out as areas with high vulnerability due to exceedingly large populations.

Affected County Population

A third adjustment to the economic loss data is for population changes in the affected counties for each hurricane or tropical storm. The NOAA Coastal Services Center (2006) provides a detailed list of affected counties for each storm from 1900–2002, and using a similar approach we estimated the affected counties for storms of 2003–2005. County-level population data for 1900–2000 were obtained from the U.S. Department of Census [data for 1900–1990: U.S. Census (2000), and data from 2000: U.S. Census (2002)]. Census data are reported every 10 years, so linear interpretation between decades (extrapolation for 2001–2005) was used to generate a full population data set for each year in 1900–2005. Upon a suggestion in the reviews we examined whether a logarithmic interpolation would be more accurate, and we found no significant improvement in the results.

Fig. 1 maps coastal county population for 2005, while Fig. 2 shows coastal county population for 1930, 1960, 1990, and 2005. Table 1 contains the coastal counties used to generate Fig. 2. The NOAA Coastal Services Center defines 174 coastal counties from Texas to Maine, available by selecting each state from the drop-down menu on their home page and counting the listed counties. This analysis uses 177 counties with small adjustments in New York and Virginia. A reviewer notes correctly that intracounty demographic patterns would not be resolved by the county-based methodology used here.

From the county-level population data, a population multiplier was calculated based on the ratio of county population in 2005 to that of the year in which the storm originally made landfall. For example, the 1979 storm Frederic affected Baldwin and Mobile counties in Alabama and Jackson County in Mississippi. The sum of the population for these counties in 2005 is 711,434 compared to 551,862 in 1979. Thus the population adjustment for the 1979 storm Frederic is $711,434/551,862 = 1.289$.

Putting the Pieces Together: Normalization Example with PL05

Using base-year economic damage and the inflation, wealth, and population multipliers, we generate the 2005 normalized damage estimate as follows:

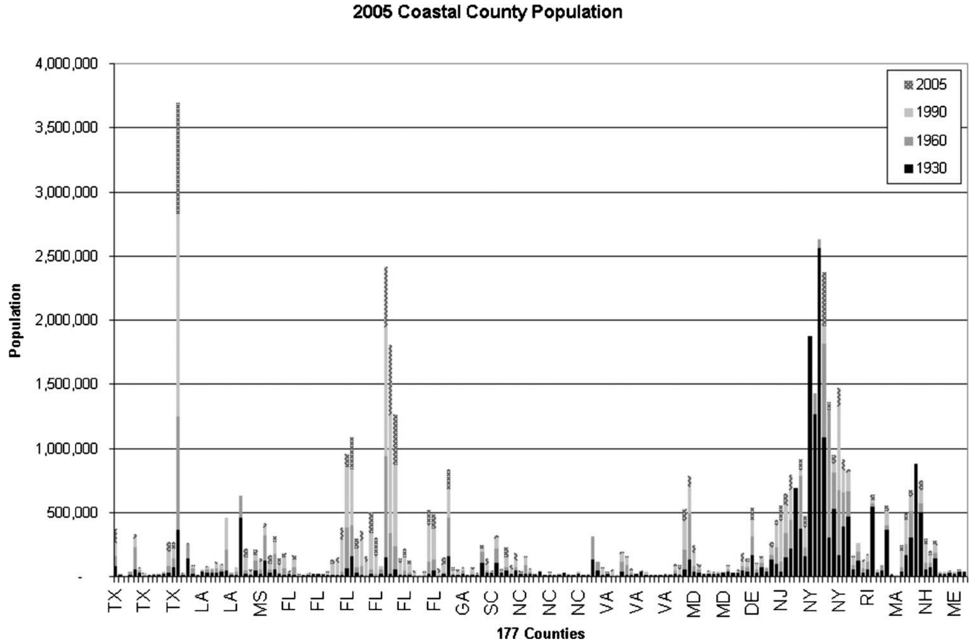

Fig. 2. Coastal county population 1930–2005. Coastal county population has grown rapidly since 1930, especially from the east coast of Florida through the Gulf Coast. The population of Harris County, Texas, has grown nearly three times since 1960, with the 2005 population of Harris County equaling the entire 1955 coastal county population from the Florida panhandle northward to South Carolina.

Table 1. Coastal Counties Used in This Study

State	Number of counties—NOAA	Number of counties—P&L[a]
Maine	8	8
New Hampshire	1	1
Massachusetts	8	8
Rhode Island	5	5
Connecticut	4	4
New York	7	8[a]
New Jersey	10	10
Delaware	3	3
Maryland	14	14
Virginia	15	17[b]
North Carolina	17	17
South Carolina	5	5
Georgia	6	6
Florida	38	38
Alabama	2	2
Mississippi	3	3
Louisiana	11	11
Texas	17	17
	174	177

Note: The 177 coastal counties used to generate Fig. 1. Some small differences exist between our list and that NOAA list due to data availability and the use of near-ocean bays and inlets for coastlines.

[a]In New York, Richmond county was added.

[b]In Virginia, Hampton City, Newport News City, Norfolk City, Portsmouth City, and Williamsburg City were added. Chesapeake (no data until 1961), Virginia Beach (no data until 1951), and Surry were removed.

$$D_{2005} = D_y \times I_y \times \mathrm{RWPC}_y \times P_{2005/y} \quad (1)$$

where D_{2005}=normalized damages in 2005 dollars; D_y=reported damages in current-year dollars; I_y=inflation adjustment; RWPC_y=real wealth per capita adjustment; and $P_{2005/y}$=coastal county population adjustment.

As an example, here is how damage from Hurricane Frederic is calculated: D_y=\$2,300,000,000; I_y=2.275; $RWPC_y$ =1.522; and $P_{2005/y}$=1.289. 2005 normalized loss =\$2,300,000,000(×)2.275(×)1.522(×)1.289=\$10,267,559,526 (this is the actual normalized damage result for Frederic calculated using nonrounded multipliers).

Frederic caused \$2.3 billion in total damage when it made landfall in 1979. If this same storm were to occur in 2005, it would cause an estimated \$10.3 billion dollars in total damage, under the PL05 approach to normalization.

Collins and Lowe (2001) Updated to 2005 (CL05)

Several studies suggested that a normalization methodology based on inflation, wealth, and population could underestimate the magnitude of contemporary losses because in many exposed coastal locations the amount of property at risk to damage has increased at a rate that exceeds local population growth (e.g., Collins and Lowe 2001; Pielke et al. 1999). The Collins and Lowe (2001) normalization methodology differs from PL05 in its use of coastal county housing units rather than population. The original Collins and Lowe (2001) methodology also differed in two respects from the method used here: normalized damages were based on estimates of insured losses rather than total economic losses, and losses were allocated to a county based on the damage indices derived from the ToPCat hurricane model rather than applying the damage evenly over all affected counties. These changes were made so that losses could more easily be compared to the Pielke and Landsea (1998) methodology estimates. The calculation of CL05 involves the same inflation multiplier as PL05. The wealth

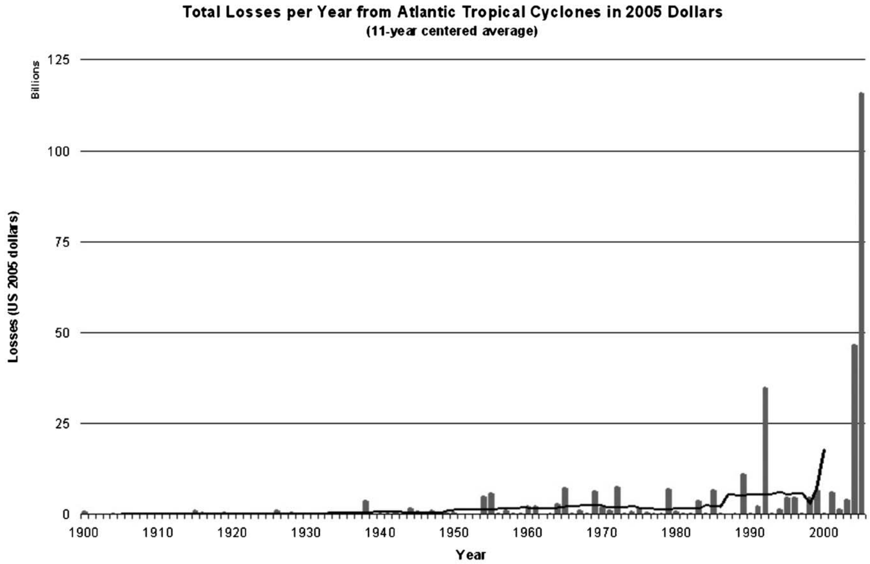

Fig. 3. U.S. Gulf and Atlantic hurricane damage 1900–2005 adjusted for inflation. Total United States tropical cyclone losses adjusted only for inflation to 2005 dollars. Upward trend in damages is clearly evident, but this is misleading since increased wealth, population, and housing units are not taken into account.

multiplier is different, however, as it corrects for national changes in housing units—rather than population—to determine a change in wealth per housing unit.

For example, wealth in 2005 was \$40.99 trillion and \$8.912 trillion in 1979; the ratio of 2005 to 1979 is 4.599. The inflation multiplier for 1979 was 2.275, so the inflation-corrected wealth adjustment for $1979 = 4.599/2.275 = 2.021$, exactly as in PL05. The number of U.S. housing units in 1979 is estimated to be 86,438,040 (based on a linear interpolation of 68,679,030 units in 1970 and 88,411,263 in 1980). U.S. housing units in 2005 were estimated to be 122,725,123 (using a linear extrapolation from 1990–2000). The U.S housing unit multiplier is thus the ratio of the 2005 estimate to the 1979 estimate, or 1.420. Thus, the final wealth multiplier for 1979 is the real wealth multiplier of 2.021 divided by the U.S. housing unit multiplier of 1.420, which equals 1.424. Therefore each housing unit in the United States contains (on average) 1.424 times more wealth in 2005 than did each housing unit in 1979.

The final multiplier in CL05 is county housing units, and as with other U.S. Census information, housing unit data are provided by decade, and linear interpolation (extrapolation) provides the data for all years 1940–2005. Specifically, Joel Gratz updated a spreadsheet of housing unit data compiled by D. Collins for Collins and Lowe (2001) based on U.S. Census (2006). At the time of our research the census only had this information by county by decade in nondigital media (Bureau of the Census 1990). Housing units for 1900–1939 were estimated based on extrapolating back in time the county-level relationship of population and housing units from 1940–2005.

From the county-level housing unit data, a housing unit multiplier was calculated based on the ratio of county housing units in 2005 to that of the year in which the storm originally made landfall. For example, the 1979 storm Frederic affected Baldwin and Mobile counties in Alabama and Jackson County in Mississippi. The sum of the housing units for these counties in 2005 is 312,749 compared to 201,946 in 1979. Thus the population adjustment for the 1979 storm Frederic is $312,749/201,946 = 1.549$.

The general formula for the CL05 normalized losses is

$$D_{2005} = D_y \times I_y \times \mathrm{RWPHU}_y \times HU_{2005/y} \qquad (2)$$

where D_{2005}=normalized damages in 2005 dollars; D_y=reported damages in current-year dollars; I_y=inflation adjustment; RWPHU_y=real wealth per housing unit adjustment; and $HU_{2005/y}$=coastal county housing unit adjustment.

As an example, here is how damage from Hurricane Frederic is calculated: $D_y = \$2,300,000,000$; $I_y = 2.275$; $\mathrm{RWPHU}_y = 1.424$; and $HU_{2005/y} = 1.549$, or $\$2,300,000,000(\times)2.275(\times)1.423(\times)1.549 = \$11,537,923,783$ (this is the actual normalized damage result for Frederic calculated using nonrounded multipliers).

Frederic caused \$2.3 billion in total damage when it made landfall in 1979. If this same storm were to have occurred in 2005, it would have caused an estimated \$11.5 billion in total damage under the CL05 approach to normalization.

Discussion of Results of Normalization

Fig. 3 shows U.S. hurricane damages from 1900–2005 adjusted only for inflation, showing a clear increase in losses. The dark line represents an 11-year centered moving average. Figs. 4(a–c) show the summarized and individual results for the two different approaches to normalization for the complete data set. The results of PL05 and CL05 tend to be very similar, with larger differences further back in time.

Further details can be seen in the tables. Table 2 shows the top 50 damaging events, ranked by PL05, along with the corresponding ranking of CL05. Under both approaches, the 1926 Great Miami hurricane is estimated to result in the largest losses at \$140 billion–\$157 billion. Hurricane Katrina is second under both normalization schemes. The years 2004 and 2005 stand out as particularly extreme, with 7 of the top 30 most damaging (normalized) storms over 106 years. No other 2-year period has more than 3 top 30 storms (1944–1945). Of particular note is the rapid increase in estimated damage for historical storms as compared to Pielke and Landsea, who, for instance, estimated that the 1926

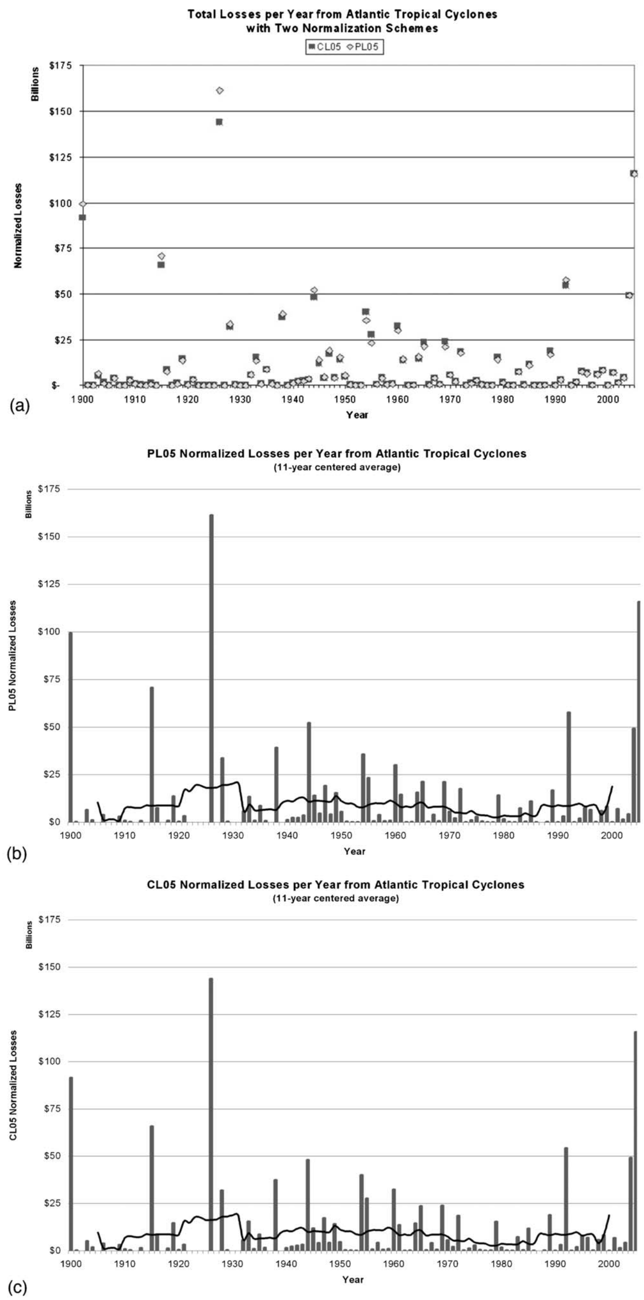

Fig. 4. U.S. Gulf and Atlantic damage, 1900–2005, normalized: (a) total U.S. tropical cyclone losses normalized with both schemes; (b) only the PL05 methodology; and (c) only the CL05 methodology. Both schemes present very similar results though PL05 focuses on population change, whereas CL05 focuses on changes in housing units. Although the 2004 and 2005 seasons produced high losses, these years are not unprecedented when considering normalized losses since 1900.

Great Miami hurricane would have resulted in $72.3 billion in 1995 (in 1995 dollars). Normalized to 2005, the estimate jumps to $157 billion, which is consistent with independent analyses that have found in some locations that losses are doubling every 10 years (e.g., ABI 2005). According to one current report ("Sound" 2006)

> . . . analyses by ISO's catastrophe modeling subsidiary, AIR Worldwide, indicate that catastrophe losses should be expected to double roughly every 10 years because of increases in construction costs, increases in the number of structures and changes in their characteristics. AIR's research shows that, because of exposure growth, the one in one-hundred-year industry loss grew from $60 billion in 1995 to $110 billion in 2005, and it will likely grow to over $200 billion during the next 10 years.

Note that the numbers above are estimates of insured damages, as opposed to total economic damages.

Table 3 shows normalized damages for each of the three approaches by month over 1900–2005. While PL05 and CL05 differ by about 2% over the entire period, the monthly distribution of damages is almost identical in both cases, with August and September accounting for approximately 85% of normalized damages. September alone accounts for greater than 50% of normalized damages. October has approximately 10% of normalized damages, and the other months much smaller amounts. Of note, June has 40% more normalized damages than does July. This somewhat surprising result is primarily due to Agnes (June 1972), which was mainly a flood event, being by far the largest normalized storm in these months.

Table 4 shows normalized damages by decade for both approaches. The decade 1996–2005 has the second-highest normalized damage compared to any other such period. While 1996–2005 is similar to 1926–1935, the table also underscores how anomalously benign the 1970s and 1980s were in comparison to the rest of the record, with about 5% of the data set total damages in each decade. Decadal totals are dominated by the effects of a single or several individual storms. For instance, 70% of the 1926–1935 damage total comes from the 1926 Miami hurricane, and about 40% of the 1996–2005 total comes from Katrina.

Table 5 shows damage for each approach to normalization by Saffir-Simpson category at the time of hurricane landfall. The normalizations each indicate that storms of Category 3 or stronger are responsible for more than 85% of the total normalized damages. PL05 and CL05 indicate a similar distribution and magnitude of normalized damages by category, but with only three Category 5 landfalls, little can be said with specificity about the relative effects of a Category 5 impact beyond the observation that its impacts in any situation will be huge. Table 6 shows damage by different populations inhabiting the coastal counties directly affected by the storm and illustrates the large sensitivity of damage to population of the affected area.

Lack of Trends in the Data

Pielke and Landsea (1998) found no trends in normalized losses, a finding subsequently replicated by Katz (2002). Recent analyses of longitudinal geophysical data find that there are no trends on hurricane frequency and intensity at U.S. landfall (Landsea 2005, 2007; Emanuel 2005). Because the normalization methodology is subject to assumptions, differences in which can lead to significant changes in results, there is general agreement that normalized data are in general not the best first place to look for changes in underlying geophysical variables, and such changes are best explored using the geophysical data directly (Höppe and Pielke 2006). However, when climate trends or variability have sufficiently large effects on losses, they can be detected in damage data (e.g., Pielke and Landsea 1999).

The two normalized data sets reported here show no trends either in the absolute data or under a logarithmic transformation: the variance explained by a best-fit linear trend line=0.0004 and

Table 2. Top 50 Damaging Storms[a]

Rank	Hurricane	Year	State	Category	PL05 damage (US$ billions)	CL05 damage (US$ billions)		AIR top 10 events (US$ billions)	
1	Great Miami (6)	1926	FL-FL,AL	4-3	157.0	(1)	139.5	(1)	160.0
2	Katrina	2005	LA,MS	3	81.0	(2)	81.0	(3)	82.0
3	Galveston (1)	1900	TX	4	78.0	(3)	71.9	(6)	66.0
4	Galveston (2)	1915	TX	4	61.7	(4)	57.1	—	—
5	Andrew	1992	FL-LA	5-3	57.7	(5)	54.3	(2)	84.0
6	New England (4)	1938	CT,MA,NY,RI	3	39.2	(6)	37.3	(4)	70.0
7	11	1944	FL	3	38.7	(7)	35.6	—	—
8	Lake Okeechobee (4)	1928	FL	4	33.6	(9)	31.8	(6)	66.0
9	Donna	1960	FL-NC,NY	4-3	29.6	(8)	31.9	(8)	52.0
10	Camille	1969	LA,MS	5	21.2	(10)	24.0	—	—
11	Betsy	1965	FL-LA	3-3	20.7	(12)	23.0	(5)	68.0
12	Wilma	2005	FL	3	20.6	(13)	20.6	—	—
13	Agnes	1972	FL-CT,NY	1-1	17.5	(14)	18.4	—	—
14	Diane	1955	NC	1	17.2	(15)	17.8	—	—
15	4	1947	FL-LA,MS	4-3	16.8	(20)	14.8	(9)	48.0
16	Hazel	1954	NC,SC	4	16.5	(11)	23.2	—	—
17	Charley	2004	FL	4	16.3	(17)	16.3	—	—
18	Carol	1954	CT,NY,RI	3	16.1	(19)	15.1	—	—
19	Ivan	2004	FL	3	15.5	(18)	15.5	—	—
20	Hugo	1989	SC	4	15.3	(16)	17.5	—	—
21	2	1949	FL	3	14.7	(22)	13.5	—	—
22	Carla	1961	TX	4	14.2	(23)	13.5	—	—
23	7	1944	CT,NC,NY,RI,VA	3	13.2	(24)	12.1	—	—
24	2	1919	FL-TX	4-4	12.9	(21)	13.8	—	—
25	9	1945	FL	3	12.3	(26)	10.1	(10)	40.0
26	Frederic	1979	AL,MS	3	10.3	(25)	11.5	—	—
27	Rita	2005	TX	3	10.0	(27)	10.0	—	—
28	Frances	2004	FL	2	9.7	(29)	9.6	—	—
29	8	1933	VA	2	8.2	(28)	9.8	—	—
30	Dora	1964	FL	2	7.7	(33)	6.6	—	—
31	Jeanne	2004	FL	3	7.5	(30)	7.5	—	—
32	Alicia	1983	TX	3	7.5	(31)	7.2	—	—
33	Floyd	1999	NC	2	6.7	(32)	6.8	—	—
34	Allison	2001	TX	TS	6.6	(34)	6.4	—	—
35	6	1935	FL	2	6.4	(41)	5.6	—	—
36	Opal	1995	FL	3	6.1	(35)	6.3	—	—
37	Freeport (2)	1932	TX	4	5.9	(39)	5.7	—	—
38	Fran	1996	NC	3	5.8	(37)	6.2	—	—
39	Celia	1970	TX	3	5.6	(40)	5.7	—	—
40	1	1916	AL,MS	3	5.3	(36)	6.3	—	—
41	3	1903	FL	1	5.2	(44)	4.2	—	—
42	Cleo	1964	FL	2	5.2	(42)	4.7	—	—
43	King	1950	FL	3	4.4	(51)	3.7	—	—
44	Beulah	1967	TX	3	4.0	(46)	4.0	—	—
45	Isabel	2003	NC	2	4.0	(47)	4.0	—	—
46	Juan	1985	LA	1	3.9	(43)	4.2	—	—
47	Georges	1998	FL-AL,MS	2-2	3.8	(54)	3.6	—	—
48	Audrey	1957	LA,TX	4	3.8	(45)	4.1	—	—
49	Ione	1955	NC	3	3.7	(38)	6.0	—	—
50	1	1926	FL	2	3.7	(53)	3.6	—	—

Note: Storms with the highest normalized damages based on the PL05 methodology. The CL05 normalized damage figures are also included, with the ranking for this dataset in parentheses. The private catastrophe modeling company AIR-Worldwide provided an estimate of the top 10 insured losses normalized to 2005. These values were doubled to approximate the total economic loss.

[a]AIR data from 9/12/2006 press release (AIR Worldwide 2006). According to AIR, “Modeled loss to property, contents and direct business interruption and additional living expenses for residential, mobile home, commercial, and auto exposures as of December 31, 2005. Losses include demand surge.”

Table 3. Normalized Damage by Month

Month	Total damage ($ millions)	Total damage (%)
(a) PL05 normalization		
May	76	0.0
June	30,301	2.8
July	21,002	1.9
August	339,931	31.1
September	581,479	53.2
October	107,452	9.8
November	12,020	1.1
Total	1,092,261	100
(b) CL05 normalization		
May	109	0.0
June	31,475	2.9
July	21,768	2.0
August	337,196	31.4
September	560,566	52.3
October	110,985	10.3
November	10,627	1.0
Total	1,072,726	100

Note: Normalized losses for both schemes summed by month of tropical cyclone landfall. About 85% of all normalized damage occurs during the months of August and September.

0.0003, respectively, for PL05, and 0.0014 and 0.00006, respectively, for CL05. The lack of trend in twentieth century normalized hurricane losses is consistent with what one would expect to find given the lack of trends in hurricane frequency or intensity at landfall. This finding should add some confidence that, at least to a first degree, the normalization approach has successfully adjusted for changing societal conditions. Given the lack of trends in hurricanes themselves, any trend observed in the normalized losses would necessarily reflect some bias in the adjustment process, such as failing to recognize changes in adaptive capacity or misspecifying wealth. That we do not have a resulting bias suggests that any factors not included in the normalization methods do not have a resulting net large significance.

Note on Demand Surge and Loss Mitigation

The normalization methodologies do not explicitly reflect two important factors driving losses: demand surge and loss mitigation. Adjustments for these factors are beyond the scope of this paper, but it is important for those using this study to consider their potential effect.

Demand surge refers to the increase in costs that often occurs after very large events due to shortages of labor and materials required for reconstruction. The actual effect of demand surge is the result of a complex interaction of local and national economic

Table 4. Normalized Damage by Decade

Year range	Count > $1 billion	Count > $5 billion	Count > $10 billion	Average damage per year ($ million)	Total damage ($ million)	Percent total damage
(a) PL05 normalization						
1900–1905	2	2	1	14,040	84,240	7.7
1906–1915	6	1	1	7,146	71,460	6.5
1916–1925	4	2	1	2,403	24,030	2.2
1926–1935	10	6	2	22,417	224,174	20.5
1936–1945	8	4	4	11,561	115,608	10.6
1946–1955	15	5	5	10,826	108,261	9.9
1956–1965	9	5	3	8,752	87,520	8.0
1966–1975	6	3	2	5,554	55,537	5.1
1976–1985	9	2	1	3,543	35,426	3.2
1986–1995	7	3	2	8,741	87,415	8.0
1996–2005	17	10	4	19,859	198,591	18.2
Total	93	43	26		1,092,261	100
Average count/year	0.88	0.41	0.25			
(b) CL05 normalization						
1900–1905	3	1	1			7.3
1906–1915	7	1	1	6,775	67,749	6.3
1916–1925	5	2	1	2,638	26,378	2.5
1926–1935	10	6	3	20,690	206,903	19.3
1936–1945	10	4	4	10,833	108,329	10.1
1946–1955	13	6	5	11,255	112,551	10.5
1956–1965	9	4	3	9,100	90,995	8.5
1966–1975	7	3	2	5,947	59,475	5.5
1976–1985	9	2	1	3,734	37,335	3.5
1986–1995	7	3	2	8,652	86,524	8.1
1996–2005	18	10	4	19,868	198,682	18.5
Total	98	42	27		1,072,726	100
Average count/year	0.92	0.40	0.25			

Note: Normalized losses for both schemes summed by (partial) decade of tropical cyclone landfall. The highest loss decade occurred between 1926–1935, with 1996–2005 as the second highest decade. The count of events exceeding certain loss thresholds is also shown.

Table 5. Damage by Saffir/Simpson Category

Category of storm	Count	Total damage ($ million)	Mean damage ($ million)	Median damage ($ million)	Potential damage[a]	Percent of total damage	Percent total for each storm
(a) PL05 normalization							
Tropical/subtropical	157	21,843	139	—	0.0	2.0	0.01
1	46	55,172	1,199	158	1.0	5.1	0.11
2	36	80,619	2,239	984	6.2	7.4	0.21
3	58	405,987	7,000	2,828	17.9	37.2	0.64
4	15	449,375	29,958	15,322	97.0	41.1	2.74
5	3	79,266	26,422	21,225	134.4	7.3	2.42
Total	315	1,092,261					
(b) CL05 normalization							
Tropical/subtropical	157	21,267	135	—	0.0	2.0	0.01
1	46	57,602	1,252	167	1.0	5.4	0.12
2	36	80,574	2,238	1,152	6.9	7.5	0.21
3	58	407,088	7,019	3,029	18.2	37.9	0.65
4	15	426,792	28,453	16,297	97.9	39.8	2.65
5	3	79,404	26,468	23,958	143.9	7.4	2.47
Total	315	1,072,726					

Note: The major hurricanes (CAT 3,4,5) account for only 24% of landfalls but 85% of normalized damage.

[a]The potential damage is the ratio of the median damage for a Category X to the median damage for a Category One.

Table 6. Damage by 2005 Population

Category of storm	Mean damage ($ million)	<1 million people		1–3 million people		>3 million people	
		PL05 average damage ($ million) by 2005 population value					
Tropical/subtropical	140	170	(45)	90	(7)	1,930	(7)
1	1,200	340	(35)	1,400	(5)	6,030	(6)
2	2,200	1,400	(21)	3,000	(9)	4,300	(6)
3	7,000	5,800	(38)	5,600	(11)	13,800	(9)
4	30,000	11,900	(8)	18,000	(2)	63,600	(5)
5	26,400	11,700	(2)	55,800	(1)	—	(0)
		CL05 average damage ($ million) by 2005 population value					
Tropical/subtropical	140	180	(45)	90	(7)	1,800	(7)
1	1,300	400	(35)	1,200	(5)	6,300	(6)
2	2,200	1,500	(21)	2,800	(9)	4,000	(6)
3	7,000	6,000	(38)	5,800	(11)	13,000	(9)
4	28,500	13,300	(8)	17,200	(2)	57,100	(5)
5	26,500	13,500	(2)	52,300	(1)	—	(0)

Note: Although only 14 major hurricanes have made landfall in an area with greater than 1 million people, this table illustrates the pronounced increase in vulnerability from a larger population. The average damage of a Category Four hurricane increases 3.5 times when making landfall in an area with >3 million people compared to 1–3 million people (parentheses denote number of storms in that cell).

conditions that is not uniform between events. For example, demand surge will be greater in periods of strong economic activity and low unemployment due to the lack of slack resources. Local economic conditions will also have an effect, as will the proximity of losses in time and space (the demand surge in the 2004 Florida hurricanes was greater than would have been the case had the four major loss events occurred in different years).

The normalization methodologies used in this paper assume that demand surge is uniform over time. To the degree that past losses were relatively smaller in the context of the economy of the time than they would be today, the methodology may understate the size of the loss in current dollars and vice versa. A good example of this might be the Miami hurricane of 1926, which was a smaller proportion of the national economy than a similar event would be in 2005. Certainly, an event larger than $100 billion today would lead to significant shortages in the affected areas and result in inflationary pressures. Thus, our historical estimates may be considered conservative.

Another important factor is mitigation and the implementation of stronger building codes. There is considerable evidence that strong building codes can significantly reduce losses; for example, data presented to the Florida Legislature during a debate over building codes in 2001 indicated that strong codes could reduce losses by over 40% (IntraRisk 2002). As strong codes have only been implemented in recent years (and in some cases vary significantly on a county-by-county basis), their effect on overall losses is unlikely to be large, but in future years efforts to improve building practices and encourage retrofit of existing structures could have a large impact on losses.

Conclusions

Our analysis of normalized damage associated with U.S. mainland hurricane landfalls 1900–2005 underscores the results of previous research and highlights the tremendous importance of societal factors in shaping trends in damage related to hurricanes. As people continue to flock to the nation's coasts and bring with them ever more personal wealth, losses will continue to increase. A simple extrapolation of the current trend of doubling losses every 10 years suggests that a storm like the 1926 Great Miami hurricane could result in perhaps $500 billion in damage as soon as the 2020s. Efforts to mitigate hurricane losses do have significant potential to affect the future growth in losses such that future storms cause less damage than a simple extrapolation may imply.

A detailed analysis of the relationship of climatic factors in the loss record in the context of societal trends, in the face of uncertainty in both, is the subject of a follow-up paper. However, it should be clear from the normalized estimates that while 2004 and 2005 were exceptional from the standpoint of the number of very damaging storms, there is no long-term trend of increasing damage over the time period covered by this analysis. Even Hurricane Katrina is not outside the range of normalized estimates for past storms. The analysis here should provide a cautionary warning for hurricane policy makers. Potential damage from storms is growing at a rate that may place severe burdens on society. Avoiding huge losses will require either a change in the rate of population growth in coastal areas, major improvements in construction standards, or other mitigation actions. Unless such action is taken to address the growing concentration of people and properties in coastal areas where hurricanes strike, damage will increase, and by a great deal, as more and wealthier people increasingly inhabit these coastal locations.

Appendix

Hurricane	Year	State	Category	PL05 damage (U.S. $ billions)		CL05 damage (U.S. $ billions)		AIR top 10 events (U.S. $ billions)	
Galveston (1)	1900	TX	4	78.0	(3)	71.9	(3)	66.0	(6)
4	1901	LA,MS	1	0.2	(140)	0.2	(136)	—	—
3	1903	FL	1	5.2	(41)	4.2	(44)	—	—
2	1904	SC	1	0.9	(92)	1.5	(76)	-	-
5	1906	AL,MS	2	1.8	(70)	2.0	(67)	-	-
8	1906	FL	3	1.4	(77)	1.2	(85)	-	-
Valasco (4)	1909	TX	3	1.1	(82)	1.1	(88)	-	-
Grand Isle (8)	1909	LA,MS	3	1.1	(84)	1.1	(87)	-	-
10	1909	FL	3	0.3	(123)	0.4	(115)	-	-
4	1910	FL	2	0.7	(96)	0.7	(100)	-	-
2	1911	GA,SC	2	0.2	(134)	0.3	(129)	-	-
2	1913	NC	1	0.6	(100)	1.3	(80)	-	-
Galveston (2)	1915	TX	4	61.7	(4)	57.1	(4)	-	-
New Orleans (5)	1915	LA	4	2.5	(60)	2.5	(63)	-	-
1	1916	AL,MS	3	5.3	(40)	6.3	(36)	-	-
4	1916	TX	3	1.6	(74)	1.7	(73)	-	-
1	1918	LA	3	0.8	(94)	1.2	(84)	-	-
2	1919	FL-TX	4-4	12.9	(24)	13.8	(21)	-	-
2	1920	LA	2	0.3	(116)	0.4	(114)	-	-
Tampa Bay (6)	1921	FL	3	3.1	(56)	3.1	(58)	-	-
1	1926	FL	2	3.7	(50)	3.6	(53)	-	-
3	1926	LA	3	0.6	(101)	0.7	(98)	-	-
Great Miami (6)	1926	FL-FL,AL	4-3	157.0	(1)	139.5	(1)	160.0	(1)
Lake Okeechobee (4)	1928	FL	4	33.6	(8)	31.8	(9)	66.0	(6)
1	1929	TX	1	0.1	(161)	0.1	(159)	-	-
2	1929	FL	3	0.3	(121)	0.3	(127)	-	-
Freeport (2)	1932	TX	4	5.9	(37)	5.7	(39)	-	-
8	1933	VA	2	8.2	(29)	9.8	(28)	-	-
11	1933	TX	3	3.5	(54)	3.8	(49)	-	-
12	1933	FL	3	1.5	(76)	1.4	(78)	-	-
13	1933	NC	3	0.2	(132)	0.5	(109)	-	-
1	1934	SC	TS	0.0	(171)	0.1	(165)	-	-
2	1934	LA	3	0.4	(109)	0.5	(106)	-	-
3	1934	TX	2	0.4	(111)	0.4	(112)	-	-
Labor Day (2)	1935	FL	5	2.3	(63)	3.1	(57)	-	-
6	1935	FL	2	6.4	(35)	5.6	(41)	-	-
3	1936	TX	1	0.1	(151)	0.1	(149)	-	-
5	1936	FL	3	0.1	(156)	0.1	(155)	-	-
13	1936	NC	2	0.6	(104)	1.3	(81)	-	-
2	1938	LA	1	0.0	(189)	0.0	(188)	-	-

New England (4)	1938	CT,MA,NY,RI	3	39.2	(6)	37.3	(6)	70	(4)
2	1940	LA,TX	2	0.2	(136)	0.2	(137)	-	-
3	1940	GA,SC	2	1.0	(90)	1.2	(82)	-	-
2	1941	TX	3	2.0	(68)	1.8	(69)	-	-
5	1941	FL	2	0.4	(110)	0.4	(117)	-	-
1	1942	TX	1	0.1	(146)	0.1	(152)	-	-
2	1942	TX	3	2.2	(66)	2.6	(61)	-	-
1	1943	TX	2	3.6	(53)	3.3	(55)	-	-
3	1944	NC	1	0.2	(128)	0.4	(116)	-	-
7	1944	CT,NC,NY,RI,VA	3	13.2	(23)	12.1	(24)	-	-
11	1944	FL	3	38.7	(7)	35.6	(7)	-	-
5	1945	TX	2	1.6	(71)	1.7	(71)	-	-
9	1945	FL	3	12.3	(25)	10.1	(26)	40.0	(10)
5	1946	FL	1	1.0	(87)	1.0	(94)	-	-
6	1946	FL	TS	3.7	(51)	3.1	(56)	-	-
3	1947	TX	1	0.1	(158)	0.1	(162)	-	-
4	1947	FL-LA,MS	4-3	16.8	(15)	14.8	(20)	48.0	(9)
6	1947	FL	TS	0.1	(170)	0.0	(173)	-	-
7	1947	FL,GA	TS	0.3	(120)	0.3	(119)	-	-
8	1947	FL-GA,SC	2-2	1.8	(69)	2.0	(68)	-	-
5	1948	LA	1	0.0	(176)	0.0	(177)	-	-
7	1948	FL	3	3.3	(55)	3.6	(52)	-	-
8	1948	FL	2	0.7	(98)	0.6	(105)	-	-
2	1949	FL	3	14.7	(21)	13.5	(22)	-	-
10	1949	TX	2	0.7	(97)	0.6	(102)	-	-
Easy	1950	FL	3	1.1	(83)	1.0	(95)	-	-
King	1950	FL	3	4.4	(43)	3.7	(51)	-	-
How	1951	FL	TS	0.4	(114)	0.3	(120)	-	-
Able	1952	SC	1	0.1	(154)	0.2	(143)	-	-
Barbara	1953	NC	1	0.0	(174)	0.1	(167)	-	-
Florence	1953	FL	1	0.0	(193)	0.0	(192)	-	-
Carol	1954	CT,NY,RI	3	16.1	(18)	15.1	(19)	-	-
Edna	1954	MA	3	3.0	(58)	1.7	(72)	-	-
Hazel	1954	NC,SC	4	16.5	(16)	23.2	(11)	-	-
Connie	1955	NC	3	2.3	(62)	3.8	(48)	-	-
Diane	1955	NC	1	17.2	(14)	17.8	(15)	-	-
Ione	1955	NC	3	3.7	(49)	6.0	(38)	-	-
Flossy	1956	LA	2	0.6	(103)	0.7	(99)	-	-
Audrey	1957	LA,TX	4	3.8	(48)	4.1	(45)	-	-
Esther	1957	LA	TS	0.1	(164)	0.1	(161)	-	-
Helene	1958	NC	3	0.5	(106)	0.6	(101)	-	-
Arlene	1959	LA	TS	0.0	(184)	0.0	(183)	-	-
Debra	1959	TX	1	0.3	(118)	0.3	(124)	-	-
Gracie	1959	SC	3	0.4	(113)	0.5	(108)	-	-
Unnamed	1959	FL	TS	0.1	(147)	0.1	(151)	-	-
Brenda	1960	SC	TS	0.2	(135)	0.3	(126)	-	-
Donna	1960	FL-NC,NY	4-3	29.6	(9)	31.9	(8)	52	(8)
Ethel	1960	MS	1	0.0	(183)	0.0	(182)	-	-
Unnamed	1960	TX	TS	0.1	(149)	0.1	(150)	-	-
Carla	1961	TX	4	14.2	(22)	13.5	(23)	-	-
Esther	1961	MA	TS	0.3	(125)	0.2	(138)	-	-
Alma	1962	NC	TS	0.1	(163)	0.1	(163)	-	-
Daisy	1962	ME	TS	0.0	(191)	0.0	(189)	-	-
Cindy	1963	TX	1	0.2	(127)	0.2	(131)	-	-
Abby	1964	TX	TS	0.0	(188)	0.0	(190)	-	-

Cleo	1964	FL	2	5.2	(42)	4.7	(42)	-	-
Dora	1964	FL	2	7.7	(30)	6.6	(33)	-	-
Hilda	1964	LA	3	2.2	(67)	2.6	(62)	-	-
Isabel	1964	FL	2	0.6	(99)	0.6	(103)	-	-
Betsy	1965	FL-LA	3-3	20.7	(11)	23.0	(12)	68	(5)
Debbie	1965	MS	TS	0.6	(105)	0.6	(104)	-	-
Alma	1966	FL	2	0.2	(129)	0.3	(128)	-	-
Inez	1966	FL	1	0.1	(159)	0.1	(153)	-	-
Beulah	1967	TX	3	4.0	(44)	4.0	(46)	-	-
Abby	1968	FL	TS	0.0	(182)	0.0	(184)	-	-
Candy	1968	TX	TS	0.0	(181)	0.0	(178)	-	-
Gladys	1968	FL	2	0.6	(102)	0.5	(110)	-	-
Camille	1969	LA,MS	5	21.2	(10)	24.0	(10)	-	-
Celia	1970	TX	3	5.6	(39)	5.7	(40)	-	-
Doria	1971	NC	TS	1.3	(79)	1.3	(79)	-	-
Edith	1971	LA	2	0.3	(124)	0.3	(125)	-	-
Fern	1971	TX	1	0.3	(115)	0.3	(118)	-	-
Ginger	1971	NC	1	0.2	(141)	0.2	(134)	-	-
Agnes	1972	FL-CT,NY	1-1	17.5	(13)	18.4	(14)	-	-
Carrie	1972	MA	TS	0.0	(177)	0.0	(180)	-	-
Delia	1973	TX	TS	0.1	(145)	0.2	(146)	-	-
Carmen	1974	LA	3	1.0	(91)	1.1	(89)	-	-
Sub-trop	1974	FL	TS	0.1	(157)	0.1	(158)	-	-
Eloise	1975	FL	3	2.8	(59)	2.8	(60)	-	-
Belle	1976	NY	1	0.5	(108)	0.5	(111)	-	-
Babe	1977	LA	1	0.1	(168)	0.1	(170)	-	-
Amelia	1978	TX	TS	0.1	(144)	0.2	(144)	-	-
Bob	1979	LA	1	0.1	(167)	0.1	(169)	-	-
Claudette	1979	LA,TX	TS	1.5	(75)	1.6	(75)	-	-
David	1979	FL,GA,SC	2	2.3	(64)	2.2	(66)	-	-
Elena	1979	TX	TS	0.0	(179)	0.0	(176)	-	-
Frederic	1979	AL,MS	3	10.3	(26)	11.5	(25)	-	-
Allen	1980	TX	3	1.6	(72)	1.7	(70)	-	-
Dennis	1981	FL	TS	0.2	(137)	0.2	(142)	-	-
Chris	1982	LA,TX	TS	0.0	(198)	0.0	(196)	-	-
Sub-trop	1982	FL	STS	0.0	(178)	0.0	(181)	-	-
Alicia	1983	TX	3	7.5	(32)	7.2	(31)	-	-
Diana	1984	NC	3	0.3	(122)	0.3	(122)	-	-
Isidore	1984	FL	TS	0.0	(201)	0.0	(202)	-	-
Bob	1985	SC	1	0.1	(155)	0.1	(157)	-	-
Danny	1985	LA	1	0.1	(150)	0.1	(147)	-	-
Elena	1985	AL,FL,MS	3	3.6	(52)	3.8	(50)	-	-
Gloria	1985	NC,NY	3	2.4	(61)	2.4	(64)	-	-
Juan	1985	LA	1	3.9	(46)	4.2	(43)	-	-
Kate	1985	FL	2	1.0	(88)	1.1	(90)	-	-
Bonnie	1986	TX	1	0.0	(199)	0.0	(199)	-	-
Charley	1986	NC,VA	1	0.0	(172)	0.0	(172)	-	-
Floyd	1987	FL	1	0.0	(205)	0.0	(205)	-	-
Unnamed	1987	TX	TS	0.0	(190)	0.0	(191)	-	-
Beryl	1988	LA	TS	0.0	(197)	0.0	(198)	-	-
Chris	1988	GA,SC	TS	0.0	(204)	0.0	(204)	-	-
Florence	1988	LA	1	0.0	(202)	0.0	(200)	-	-
Gilbert	1988	TX	TS	0.2	(142)	0.2	(141)	-	-
Keith	1988	FL	TS	0.0	(194)	0.0	(194)	-	-
Allison	1989	TX	TS	1.0	(86)	1.0	(92)	-	-

Chantal	1989	TX	1	0.2	(130)	0.2	(133)	-	-
Hugo	1989	SC	4	15.3	(20)	17.5	(16)	-	-
Jerry	1989	TX	1	0.2	(138)	0.2	(140)	-	-
Marco	1990	FL	TS	0.1	(152)	0.1	(156)	-	-
Bob	1991	CT,MA,NY,RI	2	3.0	(57)	3.1	(59)	-	-
Andrew	1992	FL-LA	5-3	57.7	(5)	54.3	(5)	84.0	(2)
Arlene	1993	TX	TS	0.0	(173)	0.0	(174)	-	-
Emily	1993	NC	3	0.1	(160)	0.1	(166)	-	-
Alberto	1994	FL	TS	1.0	(89)	1.0	(93)	-	-
Beryl	1994	FL	TS	0.1	(143)	0.2	(145)	-	-
Gordon	1994	FL	TS	0.8	(95)	0.8	(97)	-	-
Allison	1995	FL	TS	0.0	(203)	0.0	(203)	-	-
Dean	1995	TX	TS	0.0	(206)	0.0	(206)	-	-
Erin	1995	FL-FL	2-1	1.4	(78)	1.4	(77)	-	-
Jerry	1995	FL	TS	0.1	(169)	0.0	(171)	-	-
Opal	1995	FL	3	6.1	(36)	6.3	(35)	-	-
Bertha	1996	NC	2	0.5	(107)	0.5	(107)	-	-
Fran	1996	NC	3	5.8	(38)	6.2	(37)	-	-
Josephine	1996	FL	TS	0.2	(131)	0.2	(132)	-	-
Danny	1997	AL,LA	1	0.2	(139)	0.2	(139)	-	-
Bonnie	1998	NC	2	1.2	(81)	1.2	(83)	-	-
Charley	1998	TX	TS	0.1	(162)	0.1	(164)	-	-
Earl	1998	FL	1	0.1	(153)	0.1	(154)	-	-
Frances	1998	TX	TS	0.8	(93)	0.8	(96)	-	-
Georges	1998	FL-AL,MS	2-2	3.8	(47)	3.6	(54)	-	-
Mitch	1998	FL	TS	0.1	(166)	0.1	(168)	-	-
Bret	1999	TX	3	0.1	(165)	0.1	(160)	-	-
Dennis	1999	NC	TS	0.2	(126)	0.2	(130)	-	-
Floyd	1999	NC	2	6.7	(33)	6.8	(32)	-	-
Harvey	1999	FL	TS	0.0	(186)	0.0	(186)	-	-
Irene	1999	FL	1	1.2	(80)	1.2	(86)	-	-
Gordon	2000	FL	TS	0.0	(192)	0.0	(193)	-	-
Helene	2000	FL	TS	0.0	(187)	0.0	(187)	-	-
Allison	2001	TX	TS	6.6	(34)	6.4	(34)	-	-
Barry	2001	FL	TS	0.0	(175)	0.0	(175)	-	-
Gabrielle	2001	FL	TS	0.3	(119)	0.3	(123)	-	-
Fay	2002	TX	TS	0.0	(196)	0.0	(197)	-	-
Gustav	2002	NC	TS	0.0	(207)	0.0	(207)	-	-
Hanna	2002	MS	TS	0.0	(185)	0.0	(185)	-	-
Isidore	2002	LA	TS	0.4	(112)	0.4	(113)	-	-
Kyle	2002	SC	TS	0.0	(195)	0.0	(195)	-	-
Lili	2002	LA	1	1.1	(85)	1.1	(91)	-	-
Bill	2003	LA	TS	0.0	(180)	0.0	(179)	-	-
Claudette	2003	TX	1	0.2	(133)	0.2	(135)	-	-
Isabel	2003	NC	2	4.0	(45)	4.0	(47)	-	-
Alex	2004	NC	1	0.0	(200)	0.0	(201)	-	-
Charley	2004	FL	4	16.3	(17)	16.3	(17)	-	-
Frances	2004	FL	2	9.7	(28)	9.6	(29)	-	-
Gaston	2004	SC	1	0.1	(148)	0.1	(148)	-	-
Ivan	2004	FL	3	15.5	(19)	15.5	(18)	-	-
Jeanne	2004	FL	3	7.5	(31)	7.5	(30)	-	-
Cindy	2005	LA	1	0.3	(117)	0.3	(121)	-	-
Dennis	2005	FL	3	2.2	(65)	2.2	(65)	-	-
Katrina	2005	LA,MS	3	81.0	(2)	81.0	(2)	82.0	(3)
Ophelia	2005	NC	1	1.6	(73)	1.6	(74)	-	-
Rita	2005	TX	3	10.0	(27)	10.0	(27)	-	-
Wilma	2005	FL	3	20.6	(12)	20.6	(13)	-	-

[a] Multiple landfall events contain dashes (–) denoting separate states and categories per landfall.
[b] Storms occurring prior to 1950 were not given official names. These storms' official numbers are noted in parentheses following their nicknames.

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