Hurricane Threat to Florida
Climate Change or Demographics?

by

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Great Miami Hurricane of 1926

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The ongoing controversy about hurricanes and global warming is a perfect example of the predicaments of consensus science. It also demonstrates that advocates who exploit the consensus argument against climate skeptics are more than happy to oppose the consensus - if it helps to further an alarmist agenda.

Dr. Benny Peiser

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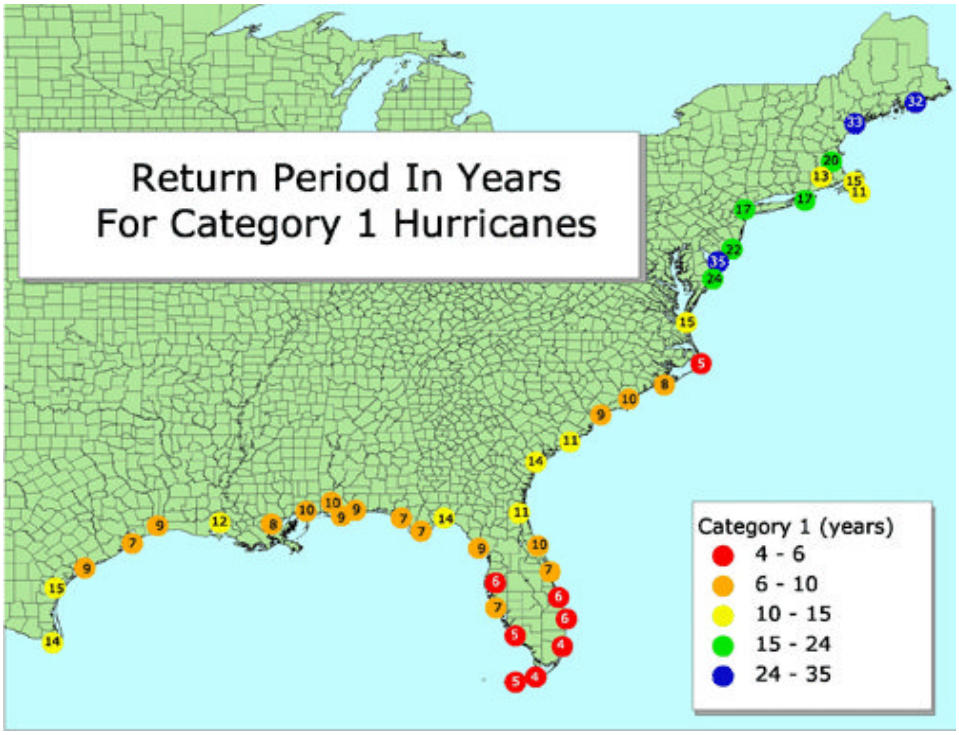
Background

Florida has the distinction of holding several not-so-enviable records when it comes to hurricane strength, frequency, and subsequent death and damages (Blake et al., 2007). The Florida Keys Hurricane of 1935 among of the most intense Atlantic hurricanes ever to strike land, passing over Florida's middle keys on September 2, 1935. It killed 408 Floridians. That storm was but one of Florida's five entries among the top-10 most intense storms ever to make landfall anywhere in the United States.

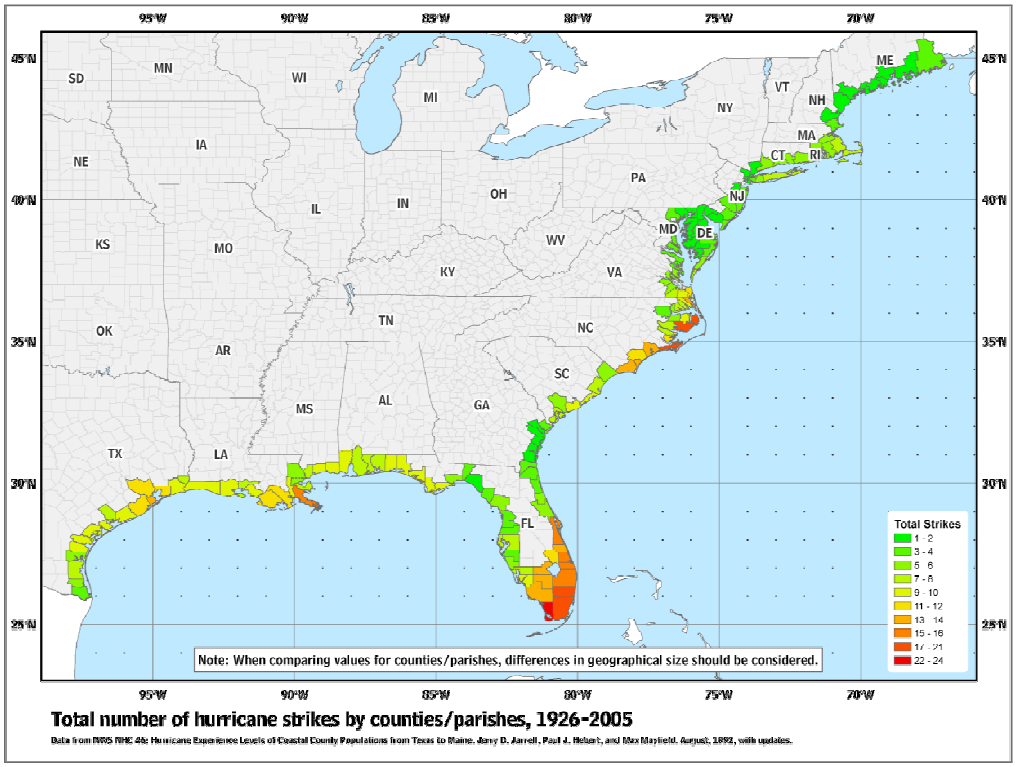
Number 3 in that list is 1992's Hurricane Andrew which also ranks 2nd on the list of all-time most damaging storms (behind Katrina)—causing just under 50 billion dollars in property damage. All of the top-5 costliest hurricanes

in U.S. history impacted Florida to some extent. Number 7 in the intensity list is the Lake Okeechobee Hurricane of 1928 which caused a 6 to 9 foot lake surge killing 1,836 people in Florida and ranking it second all-time in the list of deadliest U. S. hurricanes (behind only the Galveston Hurricane of 1900).

When considering what would have happened had historical hurricanes struck today (given the current population demographics), it is estimated that the Great Miami Hurricane of 1926, whose eye passed directly over Miami as a category 4 hurricane, would have caused nearly $160 billion in damages—more than Katrina and Andrew combined. Additionally, the state of Florida suffers from the lowest return period and highest frequency of hurricane strikes.



Average return frequency (in years) of hurricane landfalls in Florida (source: National Hurricane Center)



Total number of hurricane landfalls, 1926-2005 (source: National Hurricane Center)

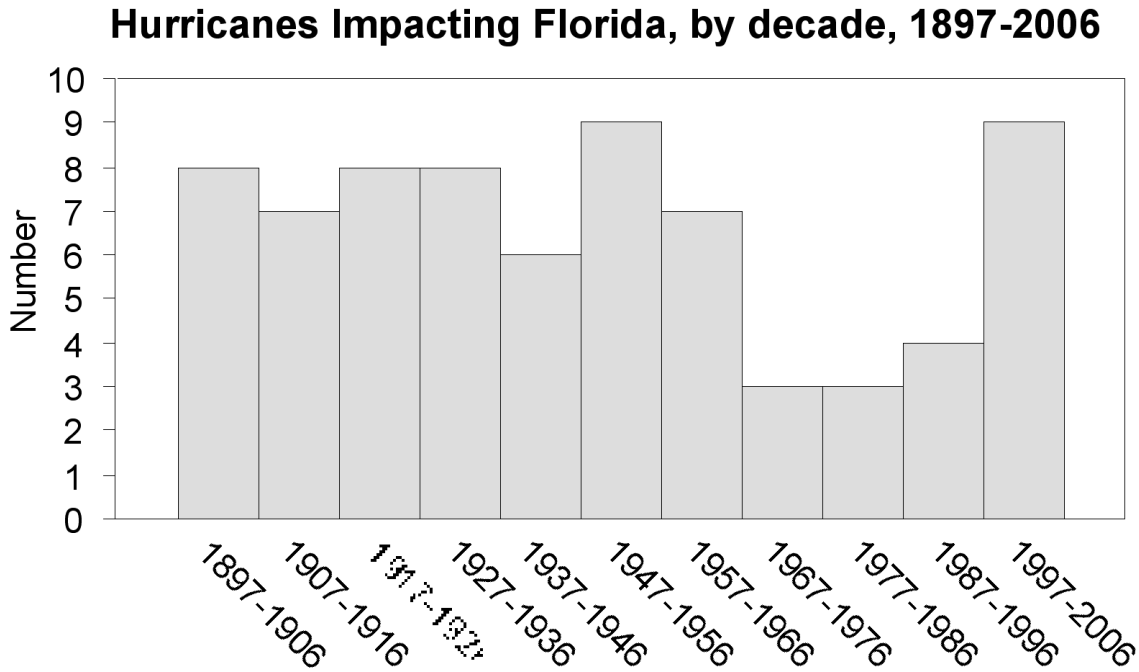
Therefore, the question of whether or not human-induced changes in the earth's greenhouse effect may impact current or future hurricane patterns is probably nowhere more important than it is in Florida. Florida's 17.3 million coastal residents account for half of the vulnerable coastal population from Texas through North Carolina. So clearly, Floridians have a lot at stake when hurricane season approaches each year.

Far and away the most important determinant in future vulnerability is not changes to climate or hurricanes themselves, but changes to the population and wealth structure of Florida's coastal communities.

The best available scientific evidence suggests that natural variations, on time scales ranging from years to decades, dominate any small impacts that a warming climate may have on the frequency and intensity of Atlantic tropical cyclones. Far and away the most important determinant in future vulnerability is not changes to climate or hurricanes themselves, but changes to the population and wealth structure of Florida's coastal communities, many of which rank among the fastest growing localities in America, having increased five-fold since the mid-20th century (U.S. Census Bureau, 2006).

Observed Trends

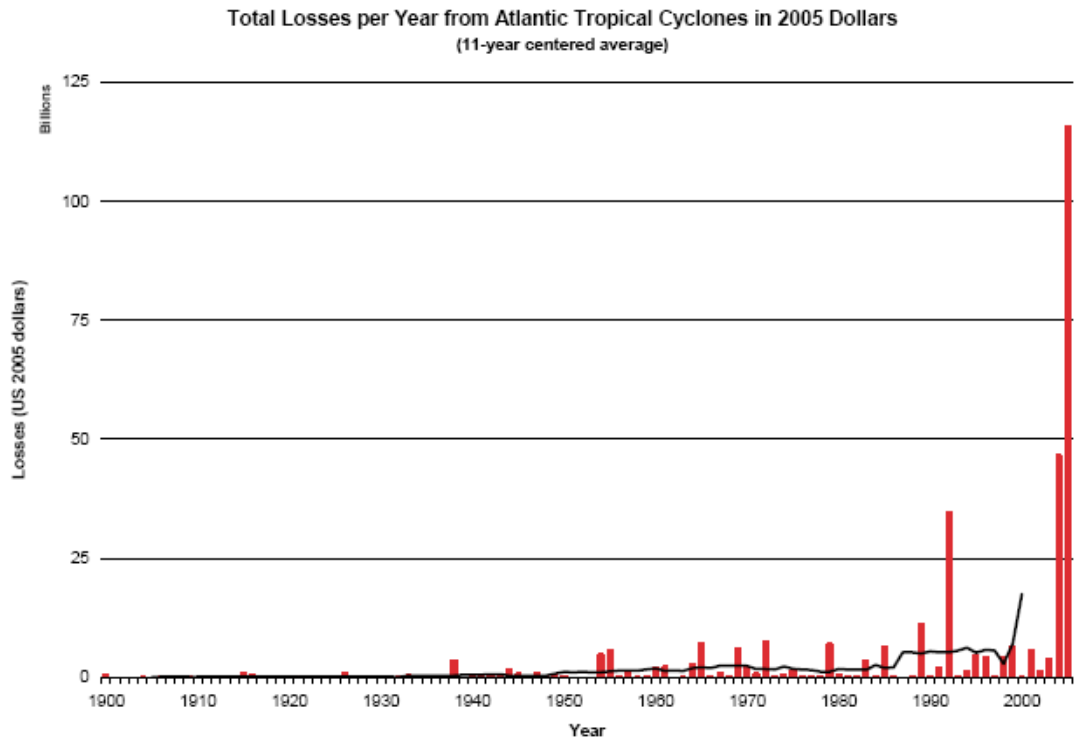
Since 1995 there has been an increase in the frequency of tropical storms and hurricanes in the Atlantic basin. While some scientists have attempted to link this increase to anthropogenic global warming, others have pointed out that Atlantic hurricanes exhibit long-term cycles, and that this latest upswing is simply a return to conditions that characterized earlier decades in the 20th century. Along the Florida coast, according to records from the National Hurricane Center (http://www.aoml.noaa.gov/hrd/tcfaq/E23.html), the number of total hurricanes strikes exhibits decadal variations, but no real long-term trends. The number of hurricanes impacting Florida during the last 10-year period, 1997-2006, was similar to periods in the first half of the 20th century. Since the current period follows a 3 decade-long period of relative quiet, it has seemed exceptionally active. However, it has *not* been so in the greater historical perspective.



Number of hurricane impacting Florida, by decade, 1897-2006.

Neither has there been any long-term trend towards greater damages from hurricanes—not when changes in inflation and population demographics are correctly considered.

Researchers led by Dr. Roger Pielke Jr. (2007) examined the historical damage amounts from tropical cyclones in the United States from 1900 to 2005. When adjusting reported damage estimates for inflation, they found a trend towards increased amounts of loss, peaking in the years 2004 and 2005. Katrina was the record holder, causing 81 billion dollars in property damages.



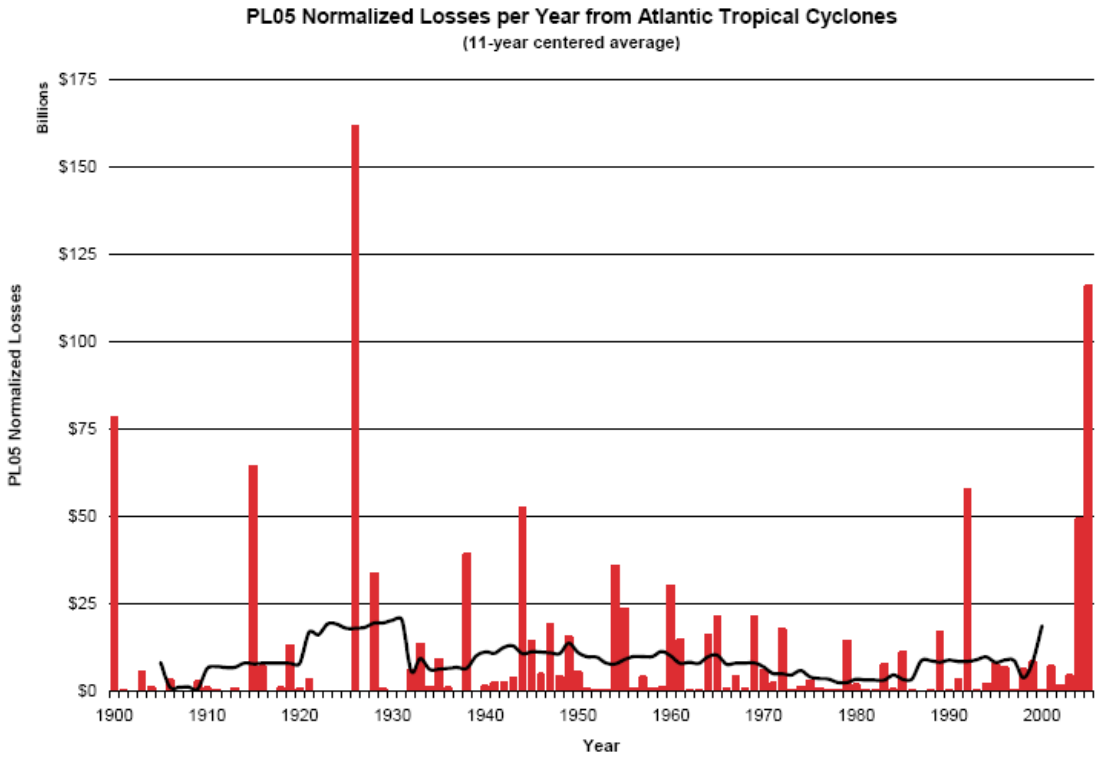
U.S. tropical cyclone damage (in 2005 dollars) when adjusted for inflation, 1900-2005 (from Pielke Jr., et al., 2007)

However, many changes have occurred in hurricane prone areas since 1900 besides inflation. These changes include a coastal population that is growing in size as well as wealth. When the Pielke Jr. team made adjustments considering all three factors, they found no long-term change in damage amounts. Rather, the loss estimates in 2004 and 2005, while high, were not historically highest. The record


Miami 1926

holder, for what would have been the most damaging storm in history had it hit in 2005 was the Great Miami hurricane of 1926, which they estimated would have caused *157 billion dollars* worth of damage.

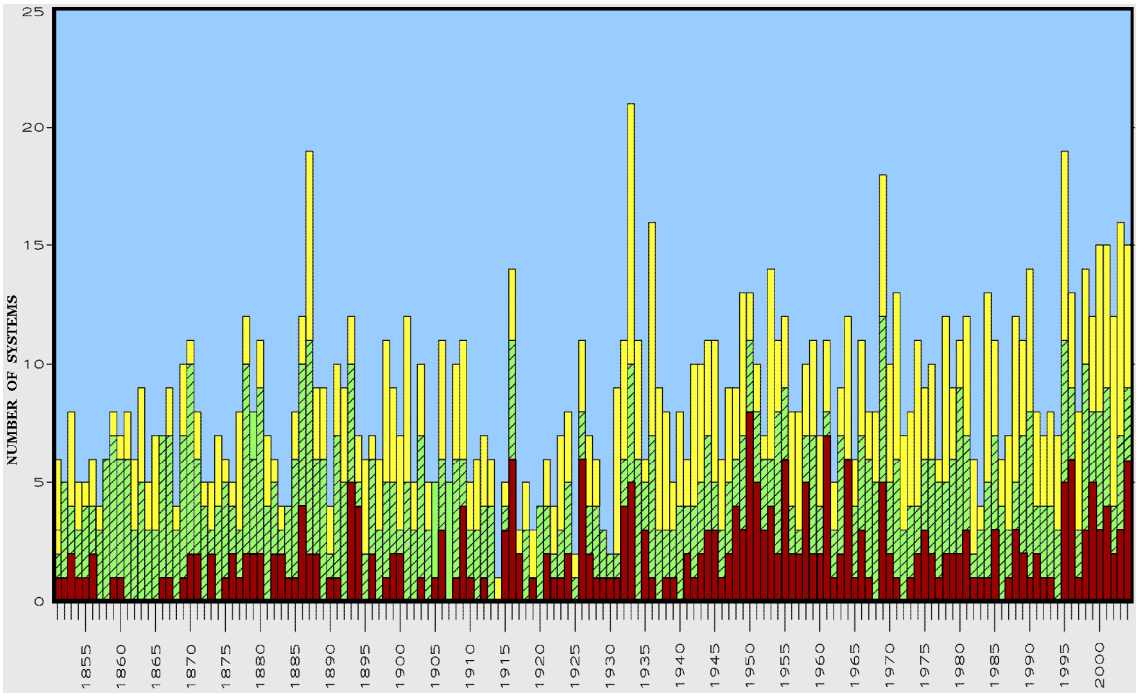
After the Great Miami hurricane of 1026 and Katrina (which fell to second place), the remaining "top-ten" storms (in descending order) occurred in 1900 (Galveston 1), 1915 (Galveston 2), 1992 (Andrew), 1983 (New England), 1944 (unnamed), 1928 (Lake Okeechobee 4), 1960 (Donna/Florida), and 1969 (Camille/Mississippi). There is no obvious bias towards recent years. In fact, the combination of the 1926 and 1928 hurricanes places the damages in 1926-35 nearly 15% higher than 1996-2005, the last decade Pielke Jr. and colleagues studied.



U.S. tropical cyclone damage (in 2005 dollars) when adjusted for inflation, population growth and wealth, 1900-2005 (from Pielke Jr., et al., 2007)

This new result by the Pielke Jr. team, that there has not been any long-term increase in tropical cyclone damage in the United States, is consistent with other science concerning the history of

Atlantic hurricanes. One of Pielke Jr.'s co-authors, Dr. Chris Landsea, from the National Hurricane Center, has also found no trends in hurricane frequency or intensity when they strike the U.S. While there has been an increase in the number of strong storms in the past decade, there were also a similar number of major hurricanes in the 1940s and 1950s, long before such activity could be attributed to global warming.



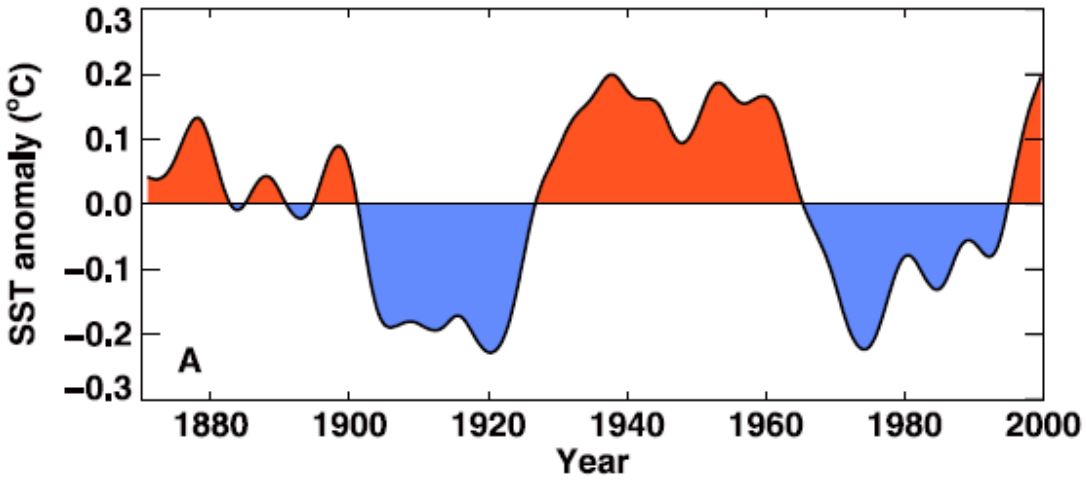
Annual number of hurricane and major hurricanes observed in the Atlantic basin, 1886-2004. Bars depict number of named systems (open/yellow), hurricanes (hatched/green), and category 3 or greater (solid/red) (source: National Hurricane Center).

As Pielke writes, "The lack of trend in twentieth century hurricane losses is consistent with what one would expect to find given the lack of trends in hurricane frequency or intensity at landfall."

While there has been an increase in the number of strong storms in the past decade, there were also a similar number of major hurricanes in the 1940s and 1950s, long before such activity could be attributed to global warming.

Natural cycles dominate the observed record of Atlantic tropical cyclones, dating back into the 18th and 19th centuries. The Figure below depicts the total number of hurricanes, and major hurricanes (category 3 or greater storms) observed in the Atlantic basin since 1930. Multidecadal oscillations are obvious in this record—hurricane activity was quiet in the 1910s and 1920s, elevated in the 1950 and 1960s, quiet in the 1970s and 1980s, and has picked up again since 1995.

The timing of these oscillations match well with the oscillations of a phenomenon known as the Atlantic Multidecadal Oscillation (AMO), which reflects changes in large-scale patterns of sea surface temperatures in the Atlantic Ocean. Much research has shown a connection between the AMO and Atlantic hurricane activity (Knight et al., 2006, Zhang and Delworth, 2006; Gray, 2007) despite some claims to the contrary (Mann and Emanuel, 2006). And from patterns in paleoclimate datasets coupled with model simulations, the AMO can be simulated back for more than *1,400 years* (Knight et al., 2005).



The observed historical time series of the Atlantic Multidecadal Oscillation (AMO) (from Knight et al., 2005).

Further, not only is there evidence that the AMO has been operating for at least many centuries (prior to any possible human influence on the climate), but there is also growing evidence that there have been active and inactive periods in the Atlantic hurricane frequency and strength extending many centuries into the past (as far backward as the various paleodatasets will allow).

For instance, research by Miller et al. (2006) using oxygen isotope information stored in tree-rings in the southeastern United States, finds distinct periods of activity/inactivity in a record dating back 220 years. In research that examined sediment records deposited from beach over wash in a lagoon in Puerto Rico, scientists Donnelly and Woodruff (2007) have identified patterns of Atlantic tropical cyclone activity extending back 5,000 years.

So clearly, there is strong evidence for natural oscillations in the frequency and intensity of tropical cyclone activity in the Atlantic basin. Hurricane researchers have known this fact for many years and they fully expected the coming of the active period that began in 1995. Further, they recognize that the heighten activity levels are likely here to stay awhile, as the oscillations usually last several decades. Back in 2002, leading hurricane researchers Dr. William Gray and Dr. Christopher Landsea authored an article for the Miami Herald in which they specifically warned Florida's residents of bad things to come:

> "The combined effect in the next few decades of more land falling major hurricanes in Florida with very large and increasing coastal populations with much more property at risk leads to a recipe for disaster. Projections of major hurricane strikes and population/wealth changes over the next twenty to thirty years lead to some amazing conclusions. We anticipate that the rate of economic loss in the state of Florida due to hurricane landfalls will be about SIX TO EIGHT TIMES the rate that occurred during the 1970s, 1980s and 1990s. Anyone living in or doing business in the state of Florida needs to heed these warnings of probable impacts in the future and to best plan for them." [emphasis in original]

(The full, rather ominous article by Gray and Landsea, written for the 10th anniversary of Hurricane Andrew's landfall, is reprinted in Appendix I.)

Future Trends

The question of whether human-induced climate changes will impact future patterns of tropical cyclone frequency and/or intensity in the Atlantic basin is currently one of the most active research topics in climate science. And simply put, there is no general consensus on the matter.

As we head into the future, it is believe by some that human activity will contribute to an overall climate warming.

A warming climate – natural or not – is reasonably expected to lead to higher sea surface temperatures in the tropical Atlantic spawning grounds of hurricanes. And sea surface temperatures play an important role in the processes of formation and intensification of tropical cyclones. Therefore, some researchers (e.g., Knutson and Tuleya, 2004; Emanuel, 2005; Webster et al. 2005) suggest that hurricanes will become stronger in a warmer world. However, at the same time, some of the climate changes that are projected to occur as the levels of atmospheric carbon dioxide continue to grow into the future, are also ones that act to *hinder* tropical cyclone formation and development.

This includes projections of increased vertical wind shear (Vecchi and Soden, 2007) and increasing atmospheric stability (Knutson and Tuleya, 2004). Thus, when *all* of the projected changes are incorporated into climate models, the models generally predict only small increases in intensity (maximum winds increase by just 6%) over the course of the next coming century (Knutson and Tuleya, 2004), and *decreases* in frequency of storms (Bengtsson et al., 2006). And the small intensity increases projected by some are produced by a suspect climate model driven by scenarios of future carbon dioxide increases that are much greater than current trends suggest that they will be (Michaels et al., 2006). Thus, even the small projected intensity increases are likely overestimates.

Other claims are being made that the current period of elevated hurricane activity is the result of human-induced climate changes which have led to a long-term increase in the number and intensity of hurricanes during recent decades (e.g., Hoyos et al., 2006; Webster et al., 2005; Emanuel, 2005) as well as over the longer term (Holland and Webster, 2007).

However, a host of factors combine to argue against those who have claimed to have detected anthropogenic-induced trends: analytical errors (Landsea, 2005), the lack of strike (Landsea, 2005) and damage (Pielke Jr., 2005; Pielke Jr. et al., 2007) trends in the United States, changes in observational technology (Landsea et al., 2006; Landsea, 2007), and other issues (Klotzbach,

2006; Landsea, 2007) coupled with climate models simulations that project only minor intensity increases and frequency decreases that are not anticipated to be detectable towards the end of the 21st century.

Certainly, there is neither strong current evidence nor any strong future projections that support the idea that the frequency and/or intensity of Atlantic basin tropical cyclones—which included all the storms that potentially impact Florida—have increased or will increase in the future in any detectable manner as a result of the human enhancement of the earth's natural greenhouse effect and any accompanying climate changes.

Summary

Despite the lack of any trends in hurricane landfalls along the U.S. and Florida coast, or damage to U.S. coastlines when population demographics are taken into account, the impact from a single storm can be enormous as residents of Florida know all too well. The massive population and infrastructure build-up of the coastline has vastly raised the potential damage that a storm can inflict. Recently, a collection of some of the world's leading hurricane researchers issued the following statement that reflecting the current scientific thinking on hurricanes and their potential impact (http://wind.mit.edu/~emanuel/Hurricane_threat.htm) in coming years:

> As the Atlantic hurricane season gets underway, the possible influence of climate change on hurricane activity is receiving renewed attention. While the debate on this issue is of considerable scientific and societal interest and concern, it should in no event detract from the main hurricane problem facing the United States: the ever-growing concentration of population and wealth in vulnerable coastal regions. These demographic trends are setting us up for rapidly increasing human and economic losses from hurricane disasters, especially in this era of heightened activity. Scores of scientists and engineers had warned of the threat to New Orleans long before climate change was seriously considered, and a Katrina-like storm or worse was (and is) inevitable even in a stable climate.
>
> Rapidly escalating hurricane damage in recent decades owes much to government policies that serve to subsidize risk. State regulation of insurance is captive to political pressures that hold down premiums in risky coastal areas at the expense of higher premiums in less risky places. Federal flood insurance programs likewise undercharge property owners in vulnerable areas. Federal disaster

policies, while providing obvious humanitarian benefits, also serve to promote risky behavior in the long run.

We are optimistic that continued research will eventually resolve much of the current controversy over the effect of climate change on hurricanes. But the more urgent problem of our lemming-like march to the sea requires immediate and sustained attention. We call upon leaders of government and industry to undertake a comprehensive evaluation of building and insurance practices, land use, and disaster relief policies that currently serve to promote an ever-increasing vulnerability to hurricanes.

Finally, it is stunningly dishonest to insinuate, let alone believe, that man-made CO_2 mitigation policies could cage the destructiveness of nature, particularly in hurricane-prone Florida.

http://www.tommymarkham.com/Hurricane/damagepage1.htm

Estimated 200 mph and record-breaking low pressure put the 1935 hurricane at the top of the list. The wreckage of an 11-car passenger train is shown in the Florida Keys on Labor Day 1935 after the train was derailed by the unnamed hurricane that claimed the lives of 423 people. (AP Photo/File / September 2, 1935)

The 1935 storm left the Long Key Fishing Camp in Layton in ruins. Originally featuring an office, recreation room, a hotel upstairs and 17 cottages, it was demolished by the 180-plus mile-per-hour winds. (Florida Photographic Collection, State Archives)

Impacts of climate-mitigation measures in Florida

Globally, in 2003, humankind emitted 25,780 million metric tons of carbon dioxide ($mmtCO_2$: EIA, 2007a), of which the state of Florida accounted for 243.9 $mmtCO_2$, or only 0.95% (EIA, 2007b). Further, this proportion of manmade CO_2 emissions from Florida will decrease over the 21st century as the rapid demand for power in developing countries such as China and India quickly outpaces the growth of Florida's CO_2 emissions (EIA, 2007b).

During the past 5 years, global emissions of CO_2 from human activity have increased at an average rate of 3.5%/yr (EIA, 2007a), meaning that the *annual increase* of anthropogenic *global* CO_2 emissions is more than *three times greater* than Florida's *total* emissions. Even a complete cessation of *all* CO_2 emissions in Florida will be undetectable globally. *A fortiori,* regulations prescribing a *reduction*, rather than a complete cessation, of Florida's CO_2 emissions will have absolutely no effect on global climate.

Wigley (1998) examined the climate impact of adherence to the emissions controls agreed under the Kyoto Protocol by participating nations, and found that, if all developed countries meet their commitments in 2010 and maintain them through 2100, with a mid-range sensitivity of surface temperature to changes in CO_2, the amount of warming "saved" by the Kyoto Protocol would be 0.07°C by 2050 and 0.15°C by 2100. The global sea level rise "saved" would be 2.6 cm, or one inch. A complete cessation of CO_2 emissions in Florida is only a tiny fraction of the worldwide reductions assumed in Dr. Wigley's global analysis, so its impact on future trends in global temperature and sea level will be only a minuscule fraction of the negligible effects calculated by Dr. Wigley.

We now apply Dr. Wigley's results to CO_2 emissions in Florida, assuming that the ratio of U.S. CO_2 emissions to those of the developed countries which have agreed to limits under the Kyoto Protocol remains constant at 39% (25% of global emissions) throughout the 21st century. We also assume that developing countries such as China and India continue to emit at an increasing rate. Consequently, the annual proportion of global CO_2 emissions from human activity that is contributed by human activity in the United States will decline. Finally, we assume that the *proportion* of total U.S. CO_2 emissions in Florida – now 4.2% – remains constant throughout the 21st century. With these assumptions, we generate the following table derived from Wigley's (1998) mid-range emissions scenario (which itself is based upon the IPCC's scenario "IS92a"):

Table 1
Projected annual CO_2 emissions ($mmtCO_2$)

Year	Global emissions: *Wigley, 1998*	Developed countries: *Wigley, 1998*	U.S. (39% of developed countries)	Florida (4.2% of U.S.)
2000	26,609	14,934	5,795	243
2025	41,276	18,308	7,103	298
2050	50,809	18,308	7,103	298
2100	75,376	21,534	8,355	351

Note: *Developed countries' emissions, according to Wigley's assumptions, do not change between 2025 and 2050: neither does total U.S or Florida emissions.*

In Table 2, we compare the total CO_2 emissions saving that would result if Florida's CO_2 emissions were completely halted by 2025 with the emissions savings assumed by Wigley (1998) if all nations met their Kyoto commitments by 2010, and then held their emissions constant throughout the rest of the century. This scenario is "Kyoto Const."

Table 2
Projected annual CO_2 emissions savings ($mmtCO_2$)

Year	Florida	Kyoto Const.
2000	0	0
2025	298	4,697
2050	298	4,697
2100	351	7,924

Table 3 shows the proportion of the total emissions reductions in Wigley's (1998) case that would be contributed by a complete halt of all Florida's CO_2 emissions (calculated as column 2 in Table 2 divided by column 3 in Table 2).

Table 3
Florida's percentage of emissions savings

Year	Florida
2000	0.0%
2025	6.3%
2050	6.3%
2100	4.4%

Using the percentages in Table 3, and assuming that temperature change scales in proportion to CO_2 emissions, we calculate the global temperature savings that will result from the complete cessation of anthropogenic CO_2 emissions in Florida:

Table 4
Projected global temperature savings (°C)

Year	Kyoto Const	Florida
2000	0	0
2025	0.03	0.002
2050	0.07	0.004
2100	0.15	0.007

Accordingly, a cessation of all of Florida's CO_2 emissions would result in a climatically-irrelevant global temperature reduction by the year 2100 of less than one *hundredths* of a degree Celsius. Results for sea-level rise are also negligible:

Table 5
Projected global sea-level rise savings (cm)

Year	Kyoto Const	Florida
2000	0	0
2025	0.2	0.01
2050	0.9	0.06
2100	2.6	0.11

A complete cessation of all anthropogenic emissions from Florida will result in a global sea-level rise savings by the year 2100 of an estimated 0.11 cm, or less than five *hundredths* of an inch. Again, this value is irrelevant in every way.

Even if the entire United States were to close down its economy completely and revert to the Stone Age, without even the ability to light fires, the *growth* in emissions from China and India would replace our *entire* emissions in little more than a decade. In this context, any cuts in emissions from Florida would be extravagantly pointless.

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Appendix I

Note, this article of Florida's coming hurricane calamities was written in 2002, prior to the destructive 2004 and 2005 hurricane seasons in Florida by leading hurricane researchers Dr. William Gray and Dr. Christopher Landsea.
(http://www.aoml.noaa.gov/hrd/Landsea/herald/)

Florida's Coming Hurricane Calamities

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Miami Herald, 23 July 2002

Hurricanes have always been synonymous with Florida, back to the time of Juan Ponce de Leon's explorations here. While historical records are incomplete before 1900, Florida is clearly the epicenter for hurricane strikes in the United States. Florida experienced 62 hurricanes in the 20th Century, with 23 of these reaching "major" hurricane status - Saffir-Simpson Category 3, 4 or 5 with sustained winds of at least 111 mph at the coast. These numbers dwarf the 37 hurricanes, of which 16 reached major hurricane status, that the second most active state - Texas - has experienced. Major hurricanes - like the "Lake Okeechobee Hurricane" of 1928, the "Labor Day Hurricane" of 1935, Hurricane Donna of 1960 and Hurricane Andrew of 1992 - are the ones of most concern since these cause over 80% of the storm-caused destruction even though they only account for about one-fifth of all landfalling tropical storms and hurricanes. With the ten year anniversary of Hurricane Andrew now upon us, one could (and should) ask what might be in store in coming years for the United States' most vulnerable hurricane state.

Last August, we were co-authors on a research paper led by our colleague Mr. Stan Goldenberg in the journal _Science_ that came to two big conclusions about major hurricanes. The first is that major hurricanes tend to occur in cycles of active and quiet periods that last between about 25 to 40 years each. This switching between active and quiet eras is due to a natural fluctuation of the water temperatures and atmospheric conditions governed by the Atlantic Ocean itself. The second finding was that as of about 1995, the major hurricanes of the Atlantic basin had made a return after a 25 year lull and were likely to continue to be more numerous for about two to three more decades. Such a result has large repercussions to the general public, business owners, emergency managers and government officials not only in the United States, but also to our neighbors in the Caribbean and Central America. The natural question is how does this change to active conditions manifest itself in Florida?

Unfortunately, the answer is not good news. Florida shows a dramatic change in major hurricane strikes due to this multi-decade flip-flop in activity (Figure 1). In the 53 years of busy hurricane conditions in the 20th Century, Florida experienced 16 major hurricane strikes compared with just 7 major hurricanes in the 47 years of light hurricane activity. This works out to about three major hurricanes making landfall in Florida per decade in the active era versus one and a half major hurricane per decade in the quiet era - a doubling in the major hurricane landfalls expected.While these changes are for all of Florida's coastline, these active versus quiet differences are most pronounced in southern Florida, from Tampa-St. Petersburg to the Keys to Miami-Ft. Lauderdale to Cape Canaveral.

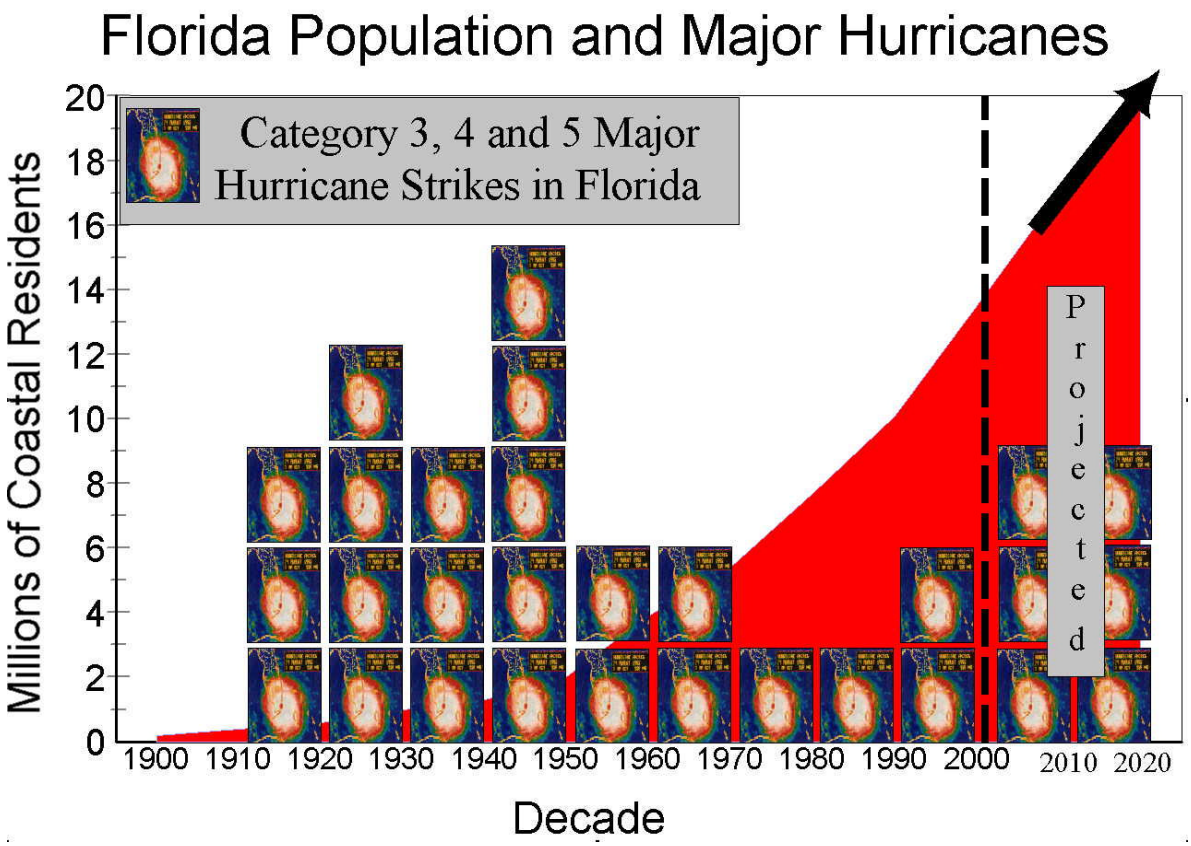
If all else remains the same, a temporary increase in major hurricanes making landfall in Florida might not be too disruptive to the environment since presumably the ecology of the region had adapted to this natural swing that has been going on at least hundreds, if not thousands of years. However, in ever-changing Florida, nothing remains the same when it comes to people. The population in Florida has dramatically increased: coastal county residents numbered only about 200,000 in 1900; about a million in 1930; and over 13 million today. In addition to these huge increases in numbers of people, we are also quite a bit wealthier as a whole today. U.S. residents are twice as wealthy per capita now (twice as many possessions essentially) as we were 40 years ago. These factors of population and wealth account for why hurricanes today are much more destructive in terms of human impact than they used to be.

The combined effect in the next few decades of more landfalling major hurricanes in Florida with very large and increasing coastal populations with much more property at risk leads to a recipe for disaster. Projections of major hurricane strikes and population/wealth changes over the next twenty to thirty years lead to some amazing conclusions. We anticipate that the rate of economic loss in the state of Florida due to hurricane landfalls will be about SIX TO EIGHT TIMES the rate that occurred during the 1970s, 1980s and 1990s. Anyone living in or doing business in the state of Florida needs to heed these warnings of probable impacts in the future and to best plan for them.

In addition to impacts financially, concerns loom about the possibility of a large number of fatalities from a major hurricane making landfall. If an incomplete evacuation occurs due to either an unanticipated rapid intensification of a hurricane at landfall or due to apathetic residents choosing foolishly not to evacuate until too late on congested roadways, then hundreds or even thousands of Florida residents could drown in a hurricane's storm surge. Clearly, a doubling in the number of landfalling major hurricanes in Florida means that residents must listen to the advisories of the National Hurricane Center and take action when appropriate, as suggested by local emergency management officials.

The bottom line is that Florida is the proverbial "sitting duck" in the Atlantic major hurricane "firing range". This is even more the case when the Atlantic Ocean has altered to a more active era during the next twenty to thirty years, with a doubling of landfalling major hurricanes in Florida causing much more damage we have seen in recent years. While Hurricane Andrew was a devastating hurricane for Florida ten years ago, it is far from the worse case scenario in causing major destruction and fatalities. If the 1926 Great Miami Hurricane - nearly as intense as Andrew, but double or triple its size - were to hit today's south Florida, there would likely be on the order of $70-80 BILLION in damages in Miami-Dade and Broward counties. By far the biggest decade during the last active era was the 1940s, when five major hurricanes made

landfall in Florida. This contrasts dramatically with the very low activity of the 1970s, 1980s and 1990s. The question is - are we ready for a repeat of these past busy periods in Florida today? (Figure 1). It is the purpose of this note to alert Floridians of these concerns for the future, so that individuals, families, businesses, communities and the state can best get ready for increased numbers of major hurricane strikes. As the sage old saying goes, we should hope for the best, but prepare for the worst.



Appendix II

Great Miami Hurricane 1926

http://www.nhc.noaa.gov/HAW2/english/history.shtml#okee

The "Great Miami" Hurricane was first spotted as a tropical wave located 1,000 miles east of the Lesser Antilles on September 11th. The system moved quickly westward and intensified to hurricane strength as it moved to the north of Puerto Rico on the 15th. Winds were reported to be nearly 150 mph as the hurricane passed over the Turks Islands on the 16th and through the Bahamas on the 17th. Little in the way of meteorological information on the approaching hurricane was available to the Weather Bureau in Miami. As a result, hurricane warnings were not issued until midnight on September 18th, which gave the booming population of South Florida little notice of the impending disaster.

The Category 4 hurricane's eye moved directly over Miami Beach and downtown Miami during the morning hours of the 18th. This cyclone produced the highest sustained winds ever recorded in the United States at the time, and the barometric pressure fell to 27.61 inches as the eye passed over Miami. A storm surge of nearly 15 feet was reported in Coconut Grove. Many casualties resulted as people ventured outdoors during the half-hour lull in the storm as the eye passed overhead. Most residents, having not experienced a hurricane, believed that the storm had passed during the lull. They were suddenly trapped and exposed to the eastern half of the hurricane shortly thereafter. Every building in the downtown district of Miami was damaged or destroyed. The town of Moore Haven on the south side of Lake Okeechobee was completely flooded by lake surge from the hurricane. Hundreds of people in Moore Haven alone were killed by this surge, which left behind floodwaters in the town for weeks afterward.

The hurricane continued northwestward across the Gulf of Mexico and approached Pensacola on September 20th. The storm nearly stalled to the south of Pensacola later that day and buffeted the central Gulf Coast with 24 hours of heavy rainfall, hurricane force winds, and storm surge. The hurricane weakened as it moved inland over Louisiana later on the 21st. Nearly every pier, warehouse, and vessel on Pensacola Bay was destroyed.

The great hurricane of 1926 ended the economic boom in South Florida and would be a $90 billion disaster had it occurred in recent times. With a highly transient population across southeastern Florida during the 1920s, the death toll is uncertain since more than 800 people were missing in the aftermath of the cyclone. A Red Cross report lists 373 deaths and 6,381 injuries as a result of the hurricane.

Appendix III

http://www.nhc.noaa.gov/HAW2/english/history.shtml#okee

San Felipe-Okeechobee Hurricane 1928

This classic Cape Verde hurricane was first detected over the tropical Atlantic on September 10, although it likely formed several days earlier. It moved westward through the Leeward Islands on the 12th. It then turned west-northwestward, scoring a direct hit on Puerto Rico on the 13th (the feast of San Felipe) as a Category 4 hurricane. The hurricane continued west-northwestward through the Bahamas and made landfall near Palm Beach, Florida on September 16. It turned north-northeastward over the Florida Peninsula on the 17th, a motion which brought the remains of the storm to eastern North Carolina on the 19th. It then turned northward and merged with a non-tropical low over the eastern Great Lakes on September 20.

No reliable wind readings are available from near the landfall area in Florida. However, Palm Beach reported a minimum pressure of 27.43 in, making this the fourth strongest hurricane of record to hit the United States. In Puerto Rico, San Juan reported 144 mph sustained winds, while Guayama reported a pressure of 27.65 inches. Additionally, a ship just south of St. Croix, United States Virgin Islands (USVI) reported a pressure of 27.50 inches, while Guadeloupe in the Leeward Islands reported a pressure of 27.76 inches.

This hurricane caused heavy casualties and extensive destruction along its path from the Leeward Islands to Florida. The worst tragedy occurred at inland Lake Okeechobee in Florida, where the hurricane caused a lake surge of 6 to 9 ft that inundated the surrounding area. 1,836 people died in Florida, mainly due to the lake surge. An additional 312 people died in Puerto Rico, and 18 more were reported dead in the Bahamas. Damage to property was estimated at $50,000,000 in Puerto Rico and $25,000,000 in Florida.

Appendix IV

Florida Keys Labor Day Hurricane 1935

http://www.nhc.noaa.gov/HAW2/english/history.shtml#okee

This system was first detected east of the central Bahamas on August 29. Moving westward, it passed near Andros Island on September 1, at which time it reached hurricane strength and turned west-northwestward. Phenomenal strengthening then occurred, and when the storm reached the middle Florida Keys on September 2, it was a Category 5 hurricane. After roaring through the Keys, the hurricane turned gradually northward almost parallel to the Florida west coast until it again made landfall near Cedar Key as a Category 2 hurricane on the 4th. A northeastward motion took the storm across the southeastern United States to the Atlantic coast near Norfolk, Virginia on September 6. It continued into the Atlantic, becoming extratropical on the 7th and last being detected on the 10th.

No wind measurements are available from the core of this small, but vicious hurricane. However, a pressure of 26.35 inches measured at Long Key, Florida makes this the most intense hurricane of record to hit the United States and the second most intense hurricane of record in the Atlantic basin (surpassed only by the 26.22 inches observed in Hurricane Gilbert in 1988).

The combination of winds and tides were responsible for 408 deaths in the Florida Keys, primarily among World War I veterans working in the area. Damage in the United States was estimated at $6 million.

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