

A Critique of Pielke et al.'s paper entitled
"Normalized Hurricane Damage in the United States: 1900-2005"
http://sciencepolicy.colorado.edu/publications/special/nhd_paper.pdf

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In a series of papers beginning in 1998, Pielke and collaborators have conducted an analysis that attempts to provide estimates of damage that past landfalling U.S. hurricanes would have had under contemporary conditions of population and development. Pielke accounts for this by taking into account changes in population and the number of housing units, inflation, and changes in wealth.

Analyzing the data record for the period 1900-2005, Pielke et al. conclude that there is no trend in normalized hurricane damage, consistent with the lack of trend in number of U.S. landfalls over the period. The most damaging storm in the record was the Great Miami Hurricane of 1926, with an adjusted level of damage of \$157B. The results of this research have been used to support statements by Pielke that there has been no influence of global warming on U.S. hurricane damage.

Pielke's conclusion that there is no increase in normalized damage from hurricanes since 1900 hinges on erroneous analysis of two hurricanes in the 1920's, the Great Miami Hurricane (1926) and the Lake Okeechobee Hurricane (1928).

The first problem with Pielke's analysis is that it requires account for inflation, so that damage, say in 1926 dollars, can be converted into equivalent 2006 dollars. The Bureau of Economic Analysis does not attempt a price deflation factor prior to 1929, with good reason. 1929 was the year of the big stock market crash, and property was almost certainly grossly overvalued. It is arguably impossible to credibly account for inflation prior to 1929.

The second problem with the analysis is that the paper does not account for major engineering improvements that rendered these regions in Florida less susceptible to damage. After the 1926 Great Miami Hurricane, the first building codes in the U.S. were implemented in Miami. Until Hurricane Andrew (1992) there had not been a significant revision to hurricane relevant building codes since the mid-1970s. New building codes were adopted in 1994 for South Florida that required new homes to be built with opening protection (windows and doors) to minimize the impact of windborne debris, pressure and water. A new statewide building code was implemented in 2002. In 2005, a team of researchers led by Kurt Gurley at the University of Florida completed an extensive study of how homes built before and after Florida's latest building code held up against Hurricanes Charley, Frances, Jeanne and Ivan (2004).

<http://www.napa.ufl.edu/2005news/newcode.htm>. The study concluded that homes built under the Florida Building Code that became effective in 2002 sustained less damage on average than those built between 1994 and 2001 under the Standard Building Code. Homes completed before 1994, meanwhile, fared worse. However, the 2004 storms did expose some problems and the building codes continue to be evaluated and modified. The relatively small amount of damage to south Florida particularly during the devastating 2004 and 2005 hurricane seasons is a tribute to the efficacy of these building codes.

After the 1928 Lake Okeechobee Hurricane, a system of dikes was implemented to prevent flooding from lake storm surges. In the 1920's a 6 ft mud dike circled Lake Okeechobee. The

storm surge from the Lake Okeechobee hurricane breached the mud dike, flooding a substantial region of south Florida. In 1937, the Okeechobee Waterway was completed which included the Herbert Hoover Dike surrounding the lake. The 1947 Ft. Lauderdale Hurricane, with an even larger storm surge, nearly went over the dike, which motivated the dike to be expanded again in the 1960's, to its current 20 ft height. There have been no subsequent major adverse effects from hurricanes in the communities surrounding Lake Okeechobee, although \$6M was spent in repairs after Hurricane Jeanne in 2004.

Implicit in the Pielke et al. analysis is the assumption that a hurricane of the same intensity and size striking the same location should cause similar (normalized) damage. It is instructive to compare Hurricane Andrew (1992) with the Great Miami Hurricane (1926), and the Fort Lauderdale Hurricane (1947) with the Lake Okeechobee Hurricane (1928). The later comparable hurricanes followed a similar path and had an intensity at least as large as the earlier hurricanes. Here is a table comparing the damage from the earlier vs the later hurricanes:

| | Great Miami | Andrew | Okeechobee | Lauderdale |
|--------------|-------------|--------|------------|------------|
| Year | 1926 | 1992 | 1928 | 1947 |
| Landfall Cat | 4 | 5 | 4 | 4 |
| Storm surge | 15 ft | 17 ft | 17 ft | 20 ft |
| Damage | \$100M | \$26B | \$25M | \$110M |
| Dam. 06 \$ | \$159B | \$58B | \$34B | \$17B |

It is very difficult to explain why the Great Miami hurricane (weaker and with a smaller storm surge) caused three times more (normalized) damage than did Andrew. Similarly, Lake Okeechobee had twice as much (normalized) damage as the Fort Lauderdale hurricane, even though the Fort Lauderdale Hurricane had a greater lake storm surge. The missing “normalization factor” in the south Florida hurricane cases is changes to the building codes and the dikes in Lake Okeechobee.

Owing to the severe problems in attempting to infer inflation prior to 1929, I would argue that this type of analysis should not attempt to include years prior to 1930. Owing to the massive engineering improvements following both the Great Miami and Lake Okeechobee hurricanes, the damage caused by these hurricanes cannot be compared with the hurricanes particularly in the last decade. Hence it appears that this is not an “apples to apples” comparison, but rather an apples to sausage comparison.

How does the neglect of hurricanes prior to 1930 influence Pielke's analysis? Here is a reproduction of the adjusted damage by decade from Pielke's paper:

| YEAR | Adjusted damage (\$B) |
|-----------|-----------------------|
| 1900-1905 | 84 |
| 1906-1915 | 71 |
| 1916-1925 | 24 |
| 1926-1935 | 224 |
| 1936-1945 | 116 |
| 1946-1955 | 108 |
| 1956-1965 | 88 |
| 1966-1975 | 56 |
| 1976-1985 | 35 |
| 1986-1995 | 87 |

If you omit the data prior to the 1930's, and look for the decade early in the period with the largest total damage, it turns out to be 1936-1945, encompassing both the New England Hurricane (1938) and a major hurricane that struck Florida in 1944. The period post 1929 with the greatest amount damage is 1996-2005, which is 84% greater than the period 1936-1945. Such a conclusion is counter to Pielke's conclusion that found no trend in damage.

There is considerable debate about the role of the Atlantic Multidecadal Oscillation in influencing Atlantic tropical sea surface temperatures and hence the number and intensity of North Atlantic tropical cyclones. However, the number of landfalling tropical cyclones, which shows no increase on the time scale of a century (in contrast to the total number of tropical cyclones), is apparently influenced by the AMO through its impact on the atmospheric circulation patterns and hence the tracks of the storms. The period in the 1930's is a good analogue for the recent active period, 1995-2006: both are in the ascending portion of the warm phase of the AMO. In the presence of the AMO, it makes sense to start any trend at a comparable point in the AMO cycle; hence the obvious place to begin a trend line that extends to 2006 is arguably in the 1930's. Comparing the 30's and 40's to the recent decade is arguably neutral to the AMO and any increase in tropical cyclone activity between these two periods can arguably be attributed to global warming.

One could conclude from this comparison that damage in the recent active decade has nearly doubled relative to the analogue active period ca. 1940. However, we are comparing apples to cabbages at this point, not quite the apples to apples comparison that is sought. The damages in the earlier part of the record can't be strictly compared to the more recent damage owing to continued changes in building codes, engineering improvements, and improvements in hurricane forecasts/warning and emergency management. All of these factors have almost certainly contributed to reduced damage over time for a given storm intensity/size. It would be interesting to evaluate additional pairs of comparable hurricanes from the early vs the later portion of the data record to assess the impact of these changes on damage and loss of life.

Can such a damage analysis be used to infer anything about the characteristics of the landfalling tropical cyclones and how these characteristics have changed? The greatest amount of damage is expected to be associated with the most intense storms of the largest horizontal extent. Unfortunately, the hurricane intensity data in the North Atlantic is uncertain prior to 1970, and there is no existing climatology of hurricane horizontal extent.

Pielke et al.'s take home point about the increasing vulnerability of coastal regions owing to increasing population and wealth is but part of the story. Particularly in Florida, improvements to building codes and other engineering improvements have substantially reduced Florida's vulnerability. Adaptation measures do work in terms of reducing damage from hurricanes. The use of this analysis to infer anything about whether or not global warming is causing an increase in hurricane damage reflects flawed reasoning.

In summary, Pielke's analysis has been used to refute the existence of any influence of global warming on damage from hurricanes, stating that all of the increase in damage can. This critique of Pielke's analysis and the argument for starting the data record in the 1930's does result in a substantial trend in the damage amount. The potential attribution of this increase in damage to global warming would require interpretation of the damage in the context of more accurate hurricane intensity data and data on the size of the hurricanes.

Note in postscript:

There is currently great concern over the condition of the Lake Okeechobee dike. A recent technical evaluation by the South Florida Water Management District http://www.palmbeachpost.com/storm/content/storm/reports/2006/lakeo_dike.html found that "...the current condition of Herbert Hoover Dike poses a grave and imminent danger to the people and environment of South Florida...it needs to be fixed now and it needs to be fixed right. We firmly believe that the region's future depends on it . . . releasing the waters of Lake Okeechobee would submerge vast areas in the subsidence basin to the south and east, threaten water supplies throughout the urban corridor, and potentially allow saltwater intrusion into coastal groundwater... Uncontrolled discharges would further damage tidal estuaries and could harm Big Cypress and the Everglades, perhaps irreversibly."