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Have tropical storms and hurricanes of the Atlantic Ocean become more numerous over the past century, in response to what climate alarmists describe as unprecedented global warming?

In an early attempt to answer this question, Bove *et al.* (1998)[1] examined the characteristics of all recorded landfalling U.S. Gulf Coast hurricanes -- defined as those whose eyes made landfall between Cape Sable, Florida and Brownsville, Texas -- from 1896 to 1995. In doing so, they found that the first half of this period saw considerably more hurricanes than the last half: 11.8 per decade vs. 9.4 per decade, while the same was true for intense hurricanes of category 3 or more on the Saffir-Simpson storm scale: 4.8 vs. 3.6. In fact, the numbers of all hurricanes and the numbers of intense hurricanes both tended downward from 1966 to the end of the period investigated, with the decade 1986-1995 exhibiting the fewest intense hurricanes of the entire century. The three researchers concluded that "fears of increased hurricane activity in the Gulf of Mexico are premature."

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Noting that the 1995 Atlantic hurricane season was one of near-record tropical storm and hurricane activity, but that during the preceding four years (1991-94) such activity over the Atlantic basin was the lowest since the keeping of reliable records began in the mid-1940s, Landsea *et al.* (1998)[2] studied the meteorological characteristics of the two periods to determine what might have caused the remarkable upswing in storm activity in 1995. In doing so, they found that "perhaps the primary factor for the increased hurricane activity during 1995 can be attributed to a favorable large-scale pattern of extremely low vertical wind shear throughout the main development region." They also noted that "in addition to changes in the large-scale flow fields, the enhanced Atlantic hurricane activity has also been linked to below-normal sea level pressure, abnormally warm ocean waters, and very humid values of total precipitable water."

An additional factor that may have contributed to the enhanced activity of the 1995 Atlantic hurricane season was the westerly phase of the stratospheric quasi-biennial oscillation, which is known to enhance Atlantic basin storm activity. Possibly the most important factor of all,

[1] http://www.co2science.org/articles/V5/N17/C1.php.
[2] http://www.co2science.org/articles/V5/N20/C1.php.

however, was what Landsea *et al*. called the "dramatic transition from the prolonged late 1991-early 1995 warm episode (El Niño) to cold episode (La Niña) conditions," which contributed to what they described as "the dramatic reversal" of weather characteristics "which dominated during the [prior] four hurricane seasons."

"Some have asked," in the words of the four researchers, "whether the increase in hurricanes during 1995 is related to the global surface temperature increases that have been observed over the last century, some contribution of which is often ascribed to increases in anthropogenic 'greenhouse' gases." In reply, they stated that "such an interpretation is not warranted," because the various factors noted above seem sufficient to explain the observations. "Additionally," as they further wrote, "Atlantic hurricane activity has actually decreased significantly in both frequency of intense hurricanes and mean intensity of all named storms over the past few decades," and "this holds true even with the inclusion of 1995's Atlantic hurricane season."

Over the period 1944-1996, decreasing trends were found for

(1) the total number of hurricanes,

(2) the number of intense hurricanes,

(3) the annual number of hurricane days,

(4) the maximum attained wind speed of all hurricane storms averaged over the course of a year, and

(5) the highest wind speed associated with the strongest hurricane recorded in each year.

In a major synthesis of Atlantic basin hurricane indices published the following year, Landsea *et al*. (1999)[3] reported long-term variations in tropical cyclone activity for this region (North Atlantic Ocean, Gulf of Mexico, and Caribbean Sea). Over the period 1944-1996, decreasing trends were found for (1) the total number of hurricanes, (2) the number of intense hurricanes, (3) the annual number of hurricane days, (4) the maximum attained wind speed of all hurricane storms averaged over the course of a year, and (5) the highest wind speed associated with the strongest hurricane recorded in each year. In addition, they reported that the total number of Atlantic hurricanes making landfall in the United States had decreased over the 1899-1996 time period, and that *normalized* trends in hurricane damage in the United States between 1925 and 1996 revealed such damage to be decreasing at a rate of 728 million dollars per decade.

In a similar study that included a slightly longer period of record (1935-1998), Parisi and Lund (2000)[4] conducted a number of statistical tests on all Atlantic Basin hurricanes that made landfall in the contiguous United States, finding that "a simple linear regression of the yearly number of landfalling hurricanes on the years of study produces a trend slope estimate of -0.011 ± 0.0086 storms per year." And to drive home the

[3] http://www.co2science.org/articles/V2/N20/C2.php.
[4] http://www.co2science.org/articles/V4/N4/C2.php.

significance of that result, they expressly called attention to the fact that "the estimated trend slope is negative," which means, of course, that -- if anything -- the yearly number of such storms is decreasing, which is just the opposite of what they described as the "frequent hypothesis ... that global warming is causing increased storm activity." Their statistical analysis, however, indicates that "the trend slope is not significantly different from zero."

Contemporaneously, Easterling *et al.* (2000)[5] noted that the mean temperature of the globe rose by about 0.6°C over the past century; and they thus looked for possible impacts of this phenomenon on extreme weather events, which if found to be increasing, as they describe it, "would add to the body of evidence that there is a discernable human affect on the climate." Their search, however, revealed few changes of significance, although they did determine that "the number of intense and landfalling Atlantic hurricanes has declined."

Three years later, Balling and Cerveny (2003)[6] wrote that "many numerical modeling papers have appeared showing that a warmer world with higher sea surface temperatures and elevated atmospheric moisture levels could increase the frequency, intensity, or duration of future tropical cyclones," but that empirical studies had failed to reveal any such relationships. They also noted that "some scientists have suggested that the buildup of greenhouse gases can ultimately alter other characteristics of tropical cyclones, ranging from timing of the active season to the location of the events," and that these relationships have not been thoroughly studied with historical real-world data. They proceeded to fill this void by conducting such a study for tropical storms in the Caribbean Sea, the Gulf of Mexico, and the western North Atlantic Ocean.

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More specifically, the two Arizona State University climatologists constructed a daily database of tropical storms that occurred within their study area over the period 1950-2002, generating "a variety of parameters dealing with duration, timing, and location of storm season," after which they tested for trends in these characteristics, attempting to explain the observed variances in the variables using regional, hemispheric and global temperatures. In doing so, they report they "found no trends related to timing and duration of the hurricane season and geographic position of storms in the Caribbean Sea, Gulf of Mexico and tropical sector of the western North Atlantic Ocean." Likewise, they said they "could find no significant trends in these variables and generally no association with them and the local ocean, hemispheric, and global temperatures."

[5] http://www.co2science.org/articles/V3/N9/C1.php.
[6] http://www.co2science.org/articles/V7/N6/C1.php.

In another study, Elsner *et al*. (2004)[7] conducted a *changepoint analysis* of time series of annual major North Atlantic hurricane counts and annual major U.S. hurricane counts for the 20th century, which technique, in their words, "quantitatively identifies temporal shifts in the mean value of the observations." This work revealed that "major North Atlantic hurricanes have become more frequent since 1995," but at "a level reminiscent of the 1940s and 1950s." In actuality, however, they had not quite reached that level, nor had they maintained it for as long a time. Their data indicate, for example, that the mean annual hurricane count for the 7-year period 1995-2001 was 3.86, while the mean count for the *14-year* period 1948-1961 was 4.14. They also reported that, "in general, twentieth-century U.S. hurricane activity shows no abrupt shifts," noting, however, that there was an exception over Florida, "where activity decreased during the early 1950s and again during the late 1960s." Last of all, they found that "El Niño events tend to suppress hurricane activity along the entire coast with the most pronounced effects over Florida."

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In contradiction of the climate-alarmist claim that global warming leads to more intense hurricane activity, the results of Elsner *et al*.'s study clearly suggest otherwise. Not only did North Atlantic hurricane activity *not* increase over the *entire 20th century*, during which period climate alarmists say the earth experienced a temperature increase that was *unprecedented over the past two millennia*, hurricane activity also did not increase in response to the more sporadic warming associated with periodic El Niño conditions. In fact, it *decreased*.

Two years later, things got a bit more interesting. "The 2005 hurricane season," in the words of Virmani and Weisberg (2006)[8], "saw an unprecedented number of named tropical storms since records began in 1851." Moreover, they said it followed "on the heels of the unusual 2004 hurricane season when, in addition to the first South Atlantic hurricane, a record-breaking number of major hurricanes made landfall in the United States, also causing destruction on the Caribbean islands in their path." The question they thus posed for themselves was whether these things occurred in response to recent global warming or if they bore sufficient similarities with hurricane seasons of years past to preclude such an attribution.

In probing this question the two researchers determined that "latent heat loss from the tropical Atlantic and Caribbean was less in late spring and early summer 2005 than preceding years due to anomalously weak trade winds associated with weaker sea level pressure," which phenomenon "resulted in anomalously high sea surface temperatures" that "contributed to earlier and more intense hurricanes in 2005." However, they went on to note that "these conditions in the Atlantic and Caribbean during 2004 and 2005 were not unprecedented and were equally favorable during the active hurricane seasons of 1958, 1969, 1980, 1995 and 1998." In addition, they said there was "not a clear link between the Atlantic Multidecadal

[7] http://www.co2science.org/articles/V7/N33/C1.php.
[8] http://www.co2science.org/articles/V9/N21/C1.php.

Oscillation or the long term trend [of temperature] and individual active hurricane years, confirming the importance of other factors in hurricane formation." Hence, it would appear that the 2005 hurricane season was not as unique as many people have made it out to be, and that there is no compelling reason to ascribe whatever degree of uniqueness it may have possessed to recent global warming.

By the time three more years had elapsed, however, Mann and Emanuel (2006) had used quantitative records stretching back to the mid-nineteenth century to develop a positive correlation between sea surface temperatures and Atlantic basin tropical cyclone frequency for the period 1871-2005, while Holland and Webster (2007) had analyzed Atlantic tropical cyclone frequency back to 1855 and found a doubling of the number of tropical cyclones over the past 100 years; and both of these papers linked these changes to anthropogenic greenhouse warming. In a compelling rebuttal of these conclusions, however, Landsea (2007)[9] cited a number of possible biases that may exist in the cyclone frequency trends derived in the two studies, concluding that "improved monitoring in recent years is responsible for most, if not all, of the observed trend in increasing frequency of tropical cyclones."

More recently, Parisi and Lund (2008)[10] calculated return periods of Atlantic-basin U.S. landfalling hurricanes based on "historical data from the 1900 to 2006 period via extreme value methods and Poisson regression techniques" for each of the categories (1-5) of the Saffir-Simpson Hurricane Scale. This work revealed that return periods (in years) for these hurricanes were, in ascending Saffir-Simpson Scale category order: (1) 0.9, (2) 1.3, (3) 2.0, (4) 4.7, and (5) 23.1. In addition, the two researchers reported that corresponding non-encounter probabilities in any one hurricane season were calculated to be (1) 0.17, (2) 0.37, (3) 0.55, (4) 0.78, and (5) 0.95; and they stated that the *hypothesis* that U.S. hurricane strike frequencies are "increasing in time" -- which is often stated as fact by climate alarmists -- is "statistically rejected."

The hypothesis that U.S. hurricane strike frequencies are "increasing in time" – which is often stated as fact by climate alarmists – is "statistically rejected."

Also in 2008, Chylek and Lesins[11] applied "simple statistical methods to the NOAA HURDAT record of storm activity in the North Atlantic basin between 1851 and 2007 to investigate a possible linear trend, periodicity and other features of interest." Using a hurricane activity index that integrates over hurricane numbers, durations, and strengths, the two researchers report discovering "a quasi-periodic behavior with a period around 60 years superimposed upon a linearly increasing background." However, they note that "the linearly increasing background is significantly reduced or removed when various corrections were applied for hurricane undercounting in the early portion of the record." Further noting that "the last minimum in hurricane activity occurred around 1980," Chylek and Lesins state that comparing the two 28-year-long periods on either side of this date, they found "a modest increase of

[9] http://www.co2science.org/articles/V10/N30/C1.php.
[10] http://www.co2science.org/articles/V11/N30/C2.php.
[11] http://www.co2science.org/articles/V12/N2/C1.php.

minor hurricanes, no change in the number of major hurricanes, and a decrease in cases of rapid hurricane intensification." Given such findings, they conclude that "if there is an increase in hurricane activity connected to a greenhouse gas induced global warming, it is currently obscured by the 60-year quasi-periodic cycle."

In another paper demonstrating the influence of natural cycles on hurricane frequency, Klotzbach and Gray (2008)[12] employed *sea surface temperature* (SST) data for the *far* North Atlantic (50-60°N, 50-10°W) and *sea level pressure* (SLP) data for the North Atlantic (0-50°N, 70-10°W) to construct an index of the *Atlantic Multidecadal Oscillation* (AMO), which they defined as the difference between the standardized SST and SLP anomalies (SST-SLP) for the hurricane season of June-November, and which they evaluated for the period 1878-2006, after which they compared their results (to which they applied a 1-2-3-2-1 filter) with a number of hurricane properties.

Klotzbach and Gray's analysis revealed the existence of three positive and two negative AMO phases over the period of their study, as may be seen in the figure below.

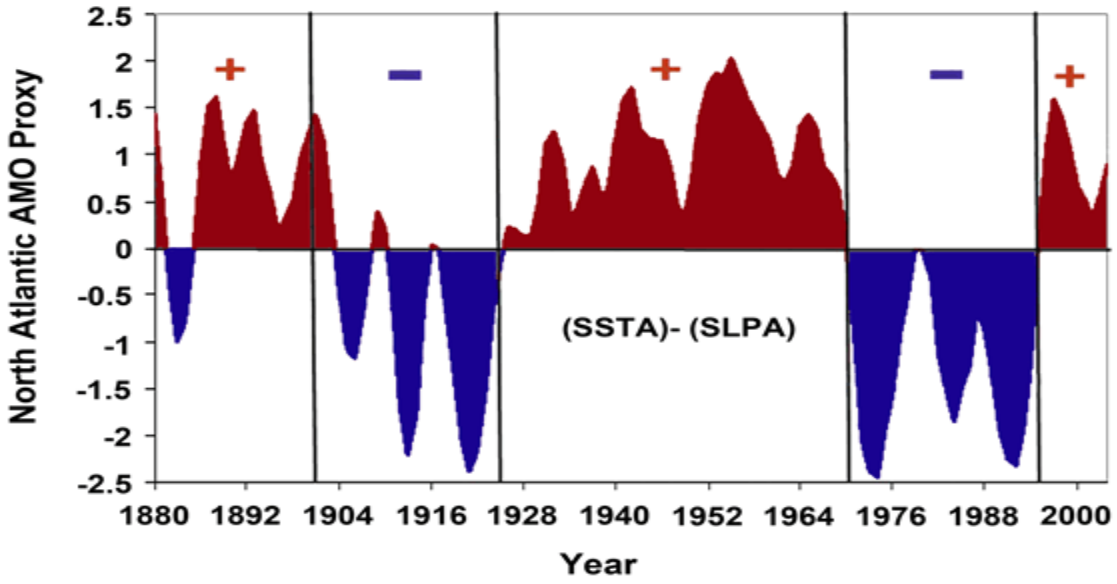

Figure 1. North Atlantic AMO Index. Adapted from Klotzbach and Gray (2008).

In comparing annually-averaged results for tropical cyclone characteristics between the positive and negative AMO phases indicated in the above graph, it can be calculated from the tropical cyclone data of the authors that the positive AMO phase-to-negative AMO phase *ratios* of hurricane numbers, hurricane days, major hurricane numbers and major hurricane days were 1.53, 1.89, 2.00 and 2.46, respectively, over the entire period studied, while for the 20 most positive and 20 most negative AMO years the same ratios, in the same order, were 1.73, 2.41, 2.80 and 4.94. Such calculations demonstrate that the state of the North Atlantic AMO is tremendously important to hurricane genesis and development; and this striking natural variability makes it extremely difficult to determine if there is any long-term trend in the tropical cyclone data that might possibly be due to 20th-century global warming.

[12] http://www.co2science.org/articles/V12/N2/C2.php.

Moving forward one year, Zeng *et al*. (2009)[13] "synthesized field measurements, satellite image analyses, and empirical models to evaluate forest and carbon cycle impacts for historical tropical cyclones from 1851 to 2000 over the continental U.S." Results indicated there was greater forest impacts and biomass loss between 1851 and 1900 from hurricane activity than during the 20th century. On average, for example, the authors found that "147 million trees were affected each year between 1851 and 1900," which led to "a 79-Tg annual biomass loss." Average annual forest impact and biomass loss between 1900 and 2000, on the other hand, "were 72 million trees and 39 Tg, which were only half of the impacts before 1900," which results they say are in "accordance with historical records showing that Atlantic tropical cyclones were more active during the period from 1870 to 1900." In addition, they note that the amount of carbon released from the downed and damaged trees "reached a maximum value in 1896, after which it continuously decreased until 1978," whereupon it leveled off for the remaining two decades of the 20th century.

Lastly, and looking to the future, Villarini *et al*. (2011) used the statistical model developed by Villarini *et al*. (2010), in which "the frequency of North Atlantic tropical storms is modeled by a conditional Poisson distribution with a rate of occurrence parameter that is a function of tropical Atlantic and mean tropical sea surface temperatures (SSTs)," in order to (1) examine "the impact of different climate models and climate change scenarios on North Atlantic and U.S. landfalling tropical storm activity," and (2) reconcile "differing model projections of changes in the frequency of North Atlantic tropical storms in a warmer climate."

In light of all the multi-decadal to century-scale analyses referenced … it does not appear that tropical storm and hurricane frequencies of the Atlantic Ocean have changed … Nor does it appear they will be influenced any by global warming if it is to occur in the future.

The five researchers report, first of all, that their results "do not support the notion of large increases in tropical storm frequency in the North Atlantic basin over the twenty-first century in response to increasing greenhouse gases." Second, they report that "the disagreement among published results concerning increasing or decreasing North Atlantic tropical storm trends in a warmer climate can be largely explained (close to half of the variance) in terms of the different SST projections (Atlantic minus tropical mean) of the different climate model projections." Third, they say that "for the SRES A1B scenario and 24 climate models, over the twenty-first century there is a large spread among projected trends in tropical storm activity in the North Atlantic basin, with a mean of -0.83 tropical storm per century and a standard deviation of 2.48 tropical storms per century." And finally, with respect to U.S. land-falling tropical storms, they say that "results based on 7 climate models point to a statistically significant increasing trend, while 6 point to a decreasing trend," which suggests that the models don't really know what will happen over the course of the current century.

[13] http://www.co2science.org/articles/V12/N32/C1.php.

And thus it is that Villarini *et al*. (2011) conclude, among several other things, that "there is a considerable level of uncertainty in climate change projections that will remain effectively 'irreducible,' as no current prospects exist for skillful century-scale predictions of unforced climate variability."

In light of all the multi-decadal to century-scale analyses referenced above, it does not appear that tropical storm and hurricane frequencies of the Atlantic Ocean have changed in response to what climate alarmists describe as unprecedented CO_2-induced global warming of the past century. Nor does it appear they will be influenced any by global warming if it is to occur in the future.

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Cover photo of the surf at Satellite Beach, FL, as Hurricane Irene passes through the Bahamas, posted by obxncweather on wunderground.com.