RISING TEMPERATURES AND TROPICAL CYCLONES IN THE ATLANTIC BASIN

SPPI & CO2Science Original Paper ♦ December 5, 2012
Climate alarmists continue to claim that rising temperatures lead to ever more intense Atlantic Basin hurricanes. But are they correct? We here review the results of a number of studies that are germane to this question.

Setting the stage for our discussion, Free et al. (2004)¹ write that "increases in hurricane intensity are expected to result from increases in sea surface temperature and decreases in tropopause-level temperature accompanying greenhouse warming (Emanuel, 1987; Henderson-Sellers et al., 1998; Knutson et al., 1998)," but they say that "because the predicted increase in intensity for doubled CO₂ is only 5%-20%, changes over the past 50 years would likely be less than 2% -- too small to be detected easily." In addition, they say that "studies of observed frequencies and maximum intensities of tropical cyclones show no consistent upward trend (Landsea et al., 1996; Henderson-Sellers et al., 1998; Solow and Moore, 2002)." In fact, several studies have actually found yearly hurricane numbers to decline as temperatures rise (see the many papers reviewed and archived under the general heading of Hurricanes (Atlantic Ocean - Global Warming Effects: Frequency)²).

In an application of the old maxim, therefore, that "if at first you don't succeed, try, try again," Free et al. do just that, looking not for increases in actual hurricane intensity, but for increases in potential hurricane intensity, because, as they describe it, "changes in potential intensity (PI) can be estimated from thermodynamic principles as shown in Emanuel (1986, 1995) given a record of SSTs [sea surface temperatures] and profiles of atmospheric temperature and humidity." This they thus do, using radiosonde and SST data from 14 island radiosonde stations in the tropical Atlantic and Pacific Oceans, after which they compare their results with those of Bister and Emanuel (2002) at grid points near the selected stations. And when all is said and done, they report that their results "show no significant trend in potential intensity from 1980 to 1995 and no consistent trend from 1975 to 1995." What is more, they report that between 1975 and 1980, "while SSTs rose, PI decreased, illustrating the hazards of predicting changes in hurricane intensity from projected SST changes alone."

In the following year, some important new studies once again prompted the reissuing of the climate-alarmist claim that warming enhances tropical cyclone intensity (Emanuel, 2005; Webster et al., 2005); but a new review of the subject once again cast doubt on this contention.

¹ http://www.co2science.org/articles/V7/N31/C1.php.
² http://www.co2science.org/subject/h/subject_h.php.
In this publication, Pielke et al. (2005)\(^3\) began their discussion by noting that "globally there has been no increase in tropical cyclone frequency [italics added] over at least the past several decades," citing the studies of Lander and Guard (1998), Elsner and Kocher (2000) and Webster et al. (2005) in support of this statement. Furthermore, they noted that research on possible future changes in hurricane frequency due to global warming has produced studies that "give such contradictory results as to suggest that the state of understanding of tropical cyclogenesis provides too poor a foundation to base any projections about the future."

With respect to hurricane intensity, on the other hand, Pielke et al. noted that Emanuel (2005) claimed to have found "a very substantial upward trend in power dissipation (i.e., the sum over the life-time of the storm of the maximum wind speed cubed) in the North Atlantic and western North Pacific." However, they report that "other studies that have addressed tropical cyclone intensity variations (Landsea et al., 1999; Chan and Liu, 2004) show no significant secular trends during the decades of reliable records." In addition, they indicate that although early theoretical work by Emanuel (1987) "suggested an increase of about 10% in wind speed for a 2°C increase in tropical sea surface temperature," more recent work by Knutson and Tuleya (2004) points to only a 5% increase in hurricane windspeeds by 2080, and that Michaels et al. (2005) conclude that even this projection is likely twice as great as it should be.

Perhaps of greatest significance of all to the issue of future hurricanes and the destruction they may cause is the nature and degree of human occupation of exposed coastal areas. By 2050, for example, Pielke et al. report that "for every additional dollar in damage that the Intergovernmental Panel on Climate Change expects to result from the effects of global warming on tropical cyclones, we should expect between $22 and $60 of increase in damage due to population growth and wealth," citing the findings of Pielke et al. (2000). Based on this evidence, they thus state, without equivocation, that "the primary factors that govern the magnitude and patterns of future damages and casualties are how society develops and prepares for storms rather than any presently conceivable future changes in the frequency and intensity of the storms."

In concluding their review, Pielke et al. note that many climate alarmists continue to claim a significant hurricane-global warming connection for the purpose of advocating massive

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\(^3\) http://www.co2science.org/articles/V9/N21/EDIT.php.
anthropogenic CO$_2$ emissions reductions that "simply will not be effective with respect to addressing future hurricane impacts," additionally noting that "there are much, much better ways to deal with the threat of hurricanes than with energy policies (e.g., Pielke and Pielke, 1997)."

In a subsequent analysis of Emanuel's (2005) and Webster et al.'s (2005) claims that "rising sea surface temperatures (SSTs) in the North Atlantic hurricane formation region are linked to recent increases in hurricane intensity, and that the trend of rising SSTs during the past 3 to 4 decades bears a strong resemblance to that projected to occur from increasing greenhouse gas concentrations," Michaels et al. (2006)$^4$ used weekly-averaged 1° latitude by 1° longitude SST data together with hurricane track data of the National Hurricane Center that provide hurricane-center locations (latitude and longitude in tenths of a degree) and maximum 1-minute surface wind speeds (both at six-hour intervals) for all tropical storms and hurricanes in the Atlantic basin that occurred between 1982 (when the SST data set begins) through 2005. And plotting maximum cyclone wind speed against the maximum SST that occurred prior to (or concurrent with) the maximum wind speed of each of the 270 Atlantic tropical cyclones of their study period, they found that for each 1°C increase in SST between 21.5°C and 28.25°C, the maximum wind speed attained by Atlantic basin cyclones rises, in the mean, by 2.8 m/s, and that thereafter, as SSTs rise still further, the first category-3-or-greater storms begin to appear. However, they report "there is no significant relationship between SST and maximum winds at SST exceeding 28.25°C."

From these observations, Michaels et al. conclude that "while crossing the 28.25°C threshold is a virtual necessity for attaining category 3 or higher winds, SST greater than 28.25°C does not act to further increase the intensity of tropical cyclones." Hence, it would appear that the comparison of SSTs actually encountered by individual storms performed by Michaels et al. -- as opposed to the comparisons of Emanuel (2005) and Webster et al. (2005), which utilized basin-wide averaged monthly or seasonal SSTs -- refutes the idea that anthropogenic activity has detectably influenced the severity of Atlantic basin hurricanes over the past quarter-century.

Simultaneously, Balling and Cerveny (2006)$^5$ examined temporal patterns in the frequency of intense tropical cyclones (TCs), the rates of rapid intensification of TCs, and the average rate of

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$^4$ http://www.co2science.org/articles/V9/N22/C1.php.

intensification of hurricanes in the North Atlantic Basin, including the tropical and subtropical North Atlantic, Caribbean Sea and Gulf of Mexico, where they say there was "a highly statistically significant warming of 0.12°C decade\(^1\) over the period 1970-2003 ... based on linear regression analysis and confirmed by a variety of other popular trend identification techniques." In doing so, they found "no increase in a variety of TC intensification indices," and that "TC intensification and/or hurricane intensification rates ... are not explained by current month or antecedent sea surface temperatures (despite observed surface warming over the study period)." Hence, they concluded that "while some researchers have hypothesized that increases in long-term sea surface temperature may lead to marked increases in TC storm intensity, our findings demonstrate that various indicators of TC intensification show no significant trend over the recent three decades."

Klotzbach and Gray (2006)\(^6\) note that still other papers question the validity of the findings of Emanuel (2005) and Webster et al. (2005) "due to potential bias-correction errors in the earlier part of the data record for the Atlantic basin (Landsea, 2005)," and that "while major hurricane activity in the Atlantic has shown a large increase since 1995, global [italics added] tropical-cyclone activity, as measured by the accumulated cyclone energy index, has decreased slightly during the past 16 years (Klotzbach, 2006)." And as a result of these and other data and reasoning described in their paper, they "attribute the heightened Atlantic major hurricane activity of the 2004 season as well as the increased Atlantic major hurricane activity of the previous nine years to be a consequence of multidecadal fluctuations in the strength of the Atlantic multidecadal mode and strength of the Atlantic Ocean thermohaline circulation." In this regard, for example, they say "historical records indicate that positive and negative phases of the Atlantic multidecadal mode and thermohaline circulation last about 25-30 years (typical period ~50-60 years; Gray et al., 1997; Latif et al., 2004)," and that "since we have been in this new active thermohaline circulation period for about 11 years, we can likely expect that most of the next 15-20 hurricane seasons will also be active, particularly with regard to increased major hurricane activity," demonstrating that the science of this subject is far from "settled," in contrast to what the world's climate alarmists typically contend.

Also referencing the debate over the impact of global warming on hurricane intensity, Vecchi and Soden (2007a)\(^7\) explored 21st-century projected changes in vertical wind shear (VS) over the tropical Atlantic and its ties to the Pacific Walker circulation via a suite of coupled ocean-

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\(^6\) http://www.co2science.org/articles/V10/N12/C1.php.

\(^7\) http://www.co2science.org/articles/V10/N28/C2.php.
atmosphere models forced by emissions scenario A1B (atmospheric CO\textsubscript{2} stabilization at 720 ppm by 2100) of the Intergovernmental Panel on Climate Change's 4th Assessment Report, where VS is defined as the magnitude of the vector difference between monthly mean winds at 850 and 200 hPa, and where changes are computed between the two 20-year periods 2001-2020 and 2081-2100. The 18-model mean result indicated a prominent increase in VS over the topical Atlantic and East Pacific (10°N-25°N); and noting that "the relative amplitude of the shear increase in these models is comparable to or larger than model-projected changes in other large-scale parameters related to tropical cyclone activity," the two researchers went on to state that the projected changes "would not suggest a strong anthropogenic increase in tropical Atlantic or Pacific hurricane activity during the 21st Century," and that "in addition to impacting cyclogenesis, the increase in SER [shear enhancement region] shear could act to inhibit the intensification of tropical cyclones as they traverse from the MDR [main development region] to the Caribbean and North America." Consequently, and in addition to the growing body of \textit{empirical} evidence that indicates global warming has little to no impact on the intensity of hurricanes (Donnelly and Woodruff, 2007; Nyberg \textit{et al.}, 2007), there is now considerable up-to-date \textit{model}-based evidence for the same conclusion.

In a second closely related paper, \textit{Vecchi and Soden (2007b)}\textsuperscript{8} used both climate models and observational reconstructions "to explore the relationship between changes in sea surface temperature and tropical cyclone 'potential intensity' -- a measure that provides an upper bound on cyclone intensity and can also reflect the likelihood of cyclone development." In doing so, they found, as they describe it, that "changes in local sea surface temperature are inadequate for characterizing even the sign [italics added] of changes in potential intensity." Instead, they report that "long-term changes in potential intensity are closely related to the regional structure of warming," such that "regions that warm more than the tropical average are characterized by increased potential intensity, and vice versa." Using this relationship to reconstruct changes in potential intensity over the 20th century, based on observational reconstructions of sea surface temperature, they further found that "even though tropical Atlantic sea surface temperatures are currently at a historical high, Atlantic potential intensity probably peaked in the 1930s and 1950s," noting that "recent values are near the historical average." Consequently, the ultimate conclusion of the two scientists was that the response of tropical cyclone activity to natural climate variations "may be larger than the response to the more uniform patterns of greenhouse-gas-induced warming," which further suggests, in our estimation, that climate-alarmist attempts to blame any recent \textit{imagined} increases -- or any near-future \textit{real} increases --

\textsuperscript{8} http://www.co2science.org/articles/V11/N7/C1.php.
in either cyclone numbers or intensities on CO₂-induced global warming would be totally unjustified, based on our present state of knowledge.

Also in the year 2007, and at the same time that Vecchi and Soden were conducting their studies of the subject, Latif et al. (2007) were hard at work analyzing the 1851-2005 history of Accumulated Cyclone Energy or ACE Index for the Atlantic basin, which parameter, in their words, "takes into account the number, strength and duration of all tropical storms in a season," after which they "analyzed the results of an atmospheric general circulation model forced by the history of observed global monthly sea surface temperatures for the period 1870-2003."

With respect to the first part of their study, they report that "the ACE Index shows pronounced multidecadal variability, with enhanced tropical storm activity during the 1890s, 1950s and at present, and mostly reduced activity in between, but no sustained long-term trend [italics added]," while with respect to the second part of their study, they report that "a clear warming trend is seen in the tropical North Atlantic sea surface temperature," but that this warming trend "does not seem to influence the tropical storm activity" [italics added again].

This state of affairs seemed puzzling at first, because a warming of the tropical North Atlantic is known to reduce vertical wind shear there and thus promote the development of tropical storms. However, Latif et al.'s modeling work revealed that a warming of the tropical Pacific enhances the vertical wind shear over the Atlantic, as does a warming of the tropical Indian Ocean. Consequently, they learned, as they describe it, that "the response of the vertical wind shear over the tropical Atlantic to a warming of all three tropical oceans, as observed during the last decades, will depend on the warming of the Indo-Pacific relative to that of the tropical North Atlantic," and "apparently," as they continue, "the warming trends of the three tropical oceans cancel with respect to their effects on the vertical wind shear over the tropical North Atlantic, so that the tropical cyclone activity [has] remained rather stable and mostly within the range of the natural multidecadal variability."

Nevertheless, a striking exception to this general state of affairs occurred in 2005, when the researchers report that "the tropical North Atlantic warmed more rapidly than the Indo-Pacific," which reduced vertical wind shear over the North Atlantic, producing the most intense Atlantic hurricane season of the historical record. In contrast, they say that the summer and fall of 2006 were "characterized by El Niño conditions in the Indo-Pacific, leading to a rather small temperature difference between the tropical North Atlantic and the tropical Indian and Pacific Oceans," and they say that "this explains the weak tropical storm activity [of that year]."

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9 http://www.co2science.org/articles/V10/N31/EDIT.php.
Clearly, the temperature/hurricane connection is nowhere near as "one-dimensional" as Al Gore and others make it out to be. Warming alone does not imply that hurricanes are getting stronger. Rather, as Latif et al. describe it, "the future evolution of Atlantic tropical storm activity will critically depend on the warming of the tropical North Atlantic relative to that in the Indo-Pacific region [italics added]." and in this context they note that "changes in the meridional overturning circulation and their effect on tropical Atlantic sea surface temperatures have to be considered," and that "changes in ENSO statistics in the tropical Pacific may become important." Consequently, it is anyone's guess as to what would actually occur in the real world if the earth were to experience additional substantial warming. However, since the global temperature rise of the 20th-century -- which climate alarmists contend was unprecedented over the past two millennia -- did not lead to a sustained long-term increase in hurricane intensity, there is little reason to believe that any further warming would do so.

In one more concurrent study, Scileppi and Donnelly (2007)\(^\text{10}\) note that "when a hurricane makes landfall, waves and storm surge can overtop coastal barriers, depositing sandy overwash fans on backbarrier salt marshes and tidal flats," and that long-term records of hurricane activity are thus formed "as organic-rich sediments accumulate over storm-induced deposits, preserving coarse overwash layers." Based on this knowledge, they refined and lengthened the hurricane record of the New York City area by first calibrating the sedimentary record of surrounding backbarrier environments to documented hurricanes -- including those of 1893, 1821, 1788 and 1693 -- and then extracting several thousand additional years of hurricane history from this important sedimentary archive.

As a result of these efforts, the two researchers determined that "alternating periods of quiescent conditions and frequent hurricane landfall are recorded in the sedimentary record and likely indicate that climate conditions may have modulated hurricane activity on millennial timescales." Of special interest in this regard, as they describe it, is the fact that "several major hurricanes occur in the western Long Island record during the latter part of the Little Ice Age (~1550-1850 AD) when sea surface temperatures were generally colder than present," but that "no major hurricanes have impacted this area since 1893," when the earth experienced the warming that took it from the Little Ice Age to the Current Warm Period.

Noting that Emanuel (2005) and Webster et al. (2005) had produced analyses that suggest that "cooler climate conditions in the past may have resulted in fewer strong hurricanes," but that their own findings suggest just the opposite, Scileppe and Donnelly concluded that "other climate phenomena, such as atmospheric circulation, may have been favorable for intense hurricane development despite lower sea surface temperatures" prior to the development of

\(^{10}\) http://www.co2science.org/articles/V10/N40/C1.php.
the Current Warm Period. Perhaps, therefore, we have much-maligned global warming to thank for the complete absence of major hurricanes in the vicinity of New York City over the past 115 years.

Still more papers investigating hurricane intensity were published the following year. Briggs (2008)\textsuperscript{11}, for example, developed Bayesian statistical models for the number of tropical cyclones, the rate at which these cyclones became hurricanes, and the rate at which the hurricanes became category 4+ storms in the North Atlantic, based on data from 1966 to 2006; and this work led him to conclude that there is "no evidence that the distributional mean of individual storm intensity, measured by storm days, track length, or individual storm power dissipation index, has changed (increased or decreased) through time."

Chylek and Lesins (2008)\textsuperscript{12} 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." Noting that "the last minimum in hurricane activity occurred around 1980," the two researchers state that comparing the two 28-year-long periods on either side of this date, they find "a modest increase of minor hurricanes, no change in the number of major hurricanes, and a decrease in cases of rapid hurricane intensification." Hence, they conclude that "if there is an increase in hurricane activity connected to a greenhouse gas induced global warming, it is currently obscured ..."

Writing as background for their work, Vecchi et al. (2008)\textsuperscript{13} say that "a key question in the study of near-term climate change is whether there is a causal connection between warming tropical sea surface temperatures (SSTs) and Atlantic hurricane activity." Thus begins their contribution to this subject as they go on to explain in more detail about the two schools of thought relative to this topic; one posits that the intensity of Atlantic Basin hurricanes is directly related to the absolute SST of the basin's main development region, which would be expected to rise in response to global warming, while the other posits that Atlantic hurricane intensity is directly related to the SST of the Atlantic basin's main development region relative to the SSTs of the other tropical ocean basins, which factor could either rise or fall to a modest degree in response to global warming -- and possibly even cycle between the two modes.

Against this backdrop and based on pertinent data obtained between 1946 and 2007, Vecchi et al. proceeded to plot Atlantic hurricane power dissipation index (PDI) anomalies calculated from both the absolute SST values of the Atlantic Basin and the relative SST values derived from all tropical ocean basins as a function time, extending them throughout most of the current

\textsuperscript{11}http://www.co2science.org/articles/V11/N21/C1.php.
\textsuperscript{12}http://www.co2science.org/articles/V12/N2/C1.php.
\textsuperscript{13}http://www.co2science.org/articles/V12/N4/C1.php.
A future where relative SST controls Atlantic hurricane activity is a future similar to the recent past, with periods of higher and lower hurricane activity relative to present-day conditions due to natural climate variability, but with little long-term trend.

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The projections derived from the absolute and relative SST parameters "do not diverge completely until the mid-2020s." Consequently, if the absolute SST ultimately proves to be the proper forcing factor, the scare stories of Al Gore and James Hansen relative to this topic would have some validity. But if the relative SST proves to be the controlling factor, the researchers say that "an attribution of the recent increase in hurricane activity to human activities is not appropriate, because the recent changes in relative SST in the Atlantic are not yet distinct from natural climate variability." As for which of these two alternate futures awaits us, perusal of the prior studies reviewed in this treatise may help provide at least a tentative conclusion.

Nevertheless, the modelers are not quite ready to throw in the towel, as evidenced from a recent report from Bender et al. (2010). In their analysis, they "explored the influence of future global warming on Atlantic hurricanes with a downscaling strategy by using an operational hurricane-prediction model that produces a realistic distribution of intense hurricane activity for present-day conditions," working with 18 models from the World Climate Research Program's Coupled Model Intercomparison Project 3, while employing the Intergovernmental Panel on Climate Change's A1B emissions scenario. So what did they find?

The result of this exercise was, in their words, "an increase in the number of the most intense storms for the warmer climate compared with the control climate." More specifically, Bender et al.'s modeling work predicted that for "category 4 and 5 hurricanes with maximum winds greater than 60 m/s, the total number increased sharply from 24 to 46," and that "hurricanes with winds greater than 65 m/s increased from 6 to 21." However, they report there were reductions in the total number of hurricanes of all categories, which seems a bit contradictory.

In further discussing their findings, the researchers comment on the wide range of variability in what the various models predicted. They note, for example, that an increase in hurricane-caused "damage potential" of +30% was projected for the 18-model ensemble, while a range of -50% to +70% was found for four models for which they did more detailed work. And this extreme range of variability also reduces confidence in their mean result.

On another point, however, Bender et al.'s findings fly in the face of those who have tried to link the occurrence of strong hurricanes of the recent past with what they have claimed was unnatural and unprecedented CO₂-induced global warming (e.g. Al Gore and James Hansen). Quite to the contrary, and although the new model results suggest that "a significant anthropogenic increase in the frequency of very intense Atlantic hurricanes may emerge from the background climate variability," the researchers say that this development would likely not occur until "the latter half of the 21st century."

As is nearly always the case in climate modeling work, Kerr (2010) reports -- in a commentary on Bender et al.'s study -- that the researchers "are looking for yet more computer power and higher resolution to boost the realism of simulations." And if such occurs, and "if the models continue to converge as realism increases," Kerr writes that "the monster storms that seemed to be already upon us would be removed to decades hence."

But who really knows, when one is working with much-less-than-perfect models of a complex planetary climate/weather system? As Kerr reports, even the researchers themselves "caution" that their findings are still "far from the last word" on the subject. And so they are, especially in light of the many real-world observations (as well as certain modeling work) discussed above, which suggest that the supposedly unprecedented global warming of the past century or more has not led to an increase in the intensity of Atlantic hurricanes.

In one final study, following up on an earlier paper (Chenoweth and Divine, 2008) in which they "presented a 318-year record of tropical cyclone activity in the Lesser Antilles and determined that there [was] no statistically significant change in the frequency of tropical cyclones (tropical storms and hurricanes) as well as tropical depressions over the entire length of the record," Chenoweth and Divine (2012)¹⁵ conducted a new analysis in which they examined the records employed in their earlier paper in somewhat more detail, determining "the maximum estimated wind speed for each tropical cyclone for each hurricane season to produce a seasonal value of the total cyclone energy of each storm along various transects that pass through the 61.5°W meridian." And somewhat analogous to accumulated cyclone energy (ACE), they calculated Lesser Antilles Cyclone Energy (LACE) along a fixed spatial domain (10-25°N, 61.5°W) at any time a tropical cyclone passed through it, after which they performed spectral and wavelet analysis on the LACE time series and tested it for statistical significance of trends. In discussing their findings, Chenoweth and Divine report that their record of tropical cyclone activity "reveals no trends in LACE in the best-sampled regions for the past 320 years," and that "even in the incompletely sampled region north of the Lesser Antilles there is no trend in either numbers or LACE." In addition, they indicate that LACE along the 61.5°W meridian is "highly

correlated” with Atlantic-Basin-wide ACE, suggesting their findings may well extend beyond their region of study.

REFERENCES


Cover photo of Hurricane Andrew in the Atlantic Ocean provided by Microsoft.