STATEMENT TO THE SELECT COMMITTEE ON ENERGY INDEPENDENCE AND GLOBAL WARMING OF THE UNITED STATES HOUSE OF REPRESENTATIVES

Hearing on "Dangerous Climate Change"
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Judith A. Curry
Georgia Institute of Technology
curryja@eas.gatech.edu

I thank the Chairman and the Committee for the opportunity to offer testimony this morning on "Dangerous Climate Change." As a climate scientist, I have devoted 25 years to conducting research on a variety of topics including climate feedback processes in the Arctic, the exchange of energy between the ocean and the atmosphere, the role of clouds in the climate system, and most recently the impact of climate change on the characteristics of tropical cyclones.

The devastating 2004 and 2005 hurricane seasons, combined with the publication of two papers linking increased hurricane intensity to climate change (Emanuel 2005; Webster et al. 2005), for the first time made the public realize that one degree warming could potentially have dangerous consequences if this warming made future hurricanes like Katrina more likely. Hurricane-induced economic losses have increased steadily in the U.S. during the past 50 years, with estimated total losses averaging $36 billion per year during the last 5 years. During 2004 and 2005, nearly 2000 lost lives were attributed to landfalling hurricanes. To place the U.S. vulnerability in perspective, 50% of the U.S. population lives within 50 miles of a coastline. The physical infrastructure along the Gulf and Atlantic coasts represents an investment of over $3 trillion; over the next several decades this investment is expected to double.

The risk of increased hurricane activity is arguably the issue of greatest concern to the U.S. public associated with the near term impacts of global warming. Risk can be thought of as the product of consequences and likelihood: what can happen, and the odds of it happening. Managing the risks associated with increased hurricane activity requires an assessment of how our policy choices will affect those risks. Uncertainty is a critical factor in assessing the effectiveness of different policy strategies.

A summary of our current understanding of this issue and the levels of uncertainty is provided by the IPCC 4th Assessment Report Summary for Policy Makers (IPCC AR4 2007):

> "There is observational evidence for an increase of intense tropical cyclone activity in the North Atlantic since about 1970, correlated with increases of tropical sea surface temperatures. There are also suggestions of increased intense tropical cyclone activity in some other regions where concerns over data quality are greater. Multi-decadal variability and the quality of the tropical cyclone records prior to routine satellite observations in about 1970 complicate the detection of long-term trends in tropical cyclone activity. . . Based on a range of models, it is likely that future tropical cyclones (typhoons and hurricanes) will become more intense, with larger peak wind speeds and more heavy precipitation associated with ongoing increases of tropical SSTs. There is less confidence in projections of a global decrease in numbers of tropical cyclones. The

apparent increase in the proportion of very intense storms since 1970 in some regions is much larger than simulated by current models for that period."

My testimony seeks to clarify the nature of the risk associated with increased hurricane activity as a result of global warming. I will assess the current understanding of the impact of global warming on hurricanes, including the uncertainties, and the challenges to assessing what we can expect in terms of future hurricane activity if global temperatures continue to rise. I will present a general assessment of how certain policy strategies might affect the risks associated with increased hurricane activity as global temperatures continue to rise.

Observations of increased hurricane activity

During the 2005 hurricane season two papers were published, Emanuel (2005) and Webster et al. (2005), that demonstrated an increase in hurricane intensity associated with an increase in tropical sea surface temperature. Webster et al. (2005) examined the global hurricane activity since 1970 (the advent of reliable satellite data). The most striking finding from this study is that while the total number of hurricanes has not increased globally, the number and percentage of category 4 + 5 hurricanes has nearly doubled since 1970 (Figure 1). This increase in the percentage of category 4 + 5 hurricanes is associated with an increase in tropical sea surface temperatures (SST) of 0.5^{o}C (1^{o}F) in each of the ocean basins that spawn tropical cyclones. The surface temperature trends over the last century has been extensively studied as summarized in the IPCC AR4 (2007). The unanimous conclusion of climate model simulations is that the global surface temperature trend since 1970 (including the trend in tropical SSTs) cannot be reproduced in climate models without inclusion of anthropogenic greenhouse gases, and that most of this warming can be attributed to anthropogenic greenhouse gases. The climate model simulations are the basis for attributing the increase in tropical sea surface temperatures to anthropogenic greenhouse warming.

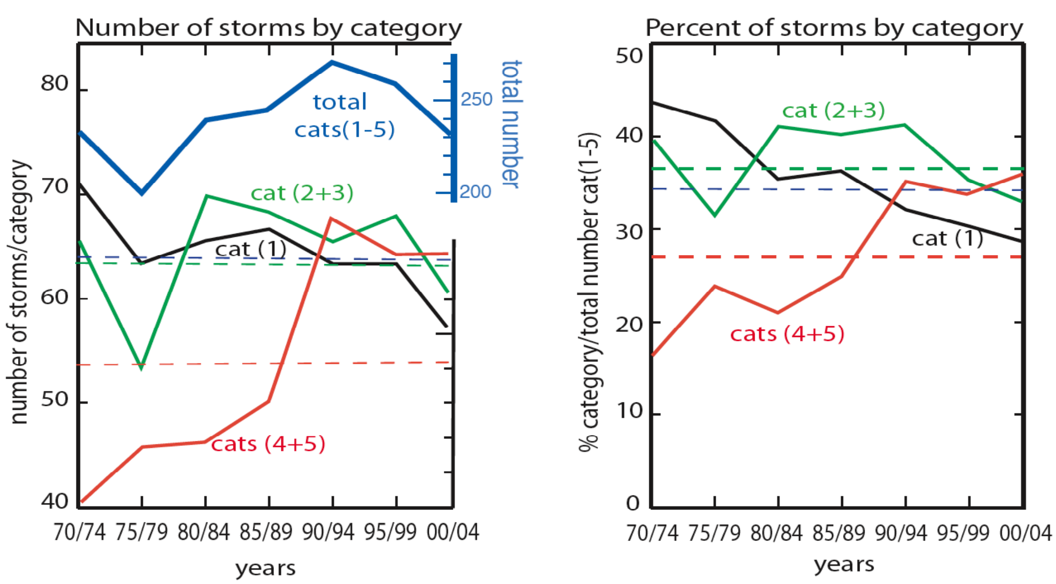


Figure 1: Intensity of global hurricanes according to the Saffir-Simpson scale (categories 1 to 5), in 5 year periods. (**A**) The total number of storms and (B) the percent of the total number of hurricanes in each category class. After Webster et al. (2005).

The quality of the hurricane intensity data used by Webster et al. has being questioned (Landsea, Kossin), particularly in the South Pacific and Indian Oceans. An additional issue of concern is that the magnitude of the intensity increase observed by Webster et al. substantially exceeds the intensity increase predicted by models and theory for a 1^oF increase in tropical sea surface temperature. The Webster et al. (2005) observations scale to a 6% increase in maximum wind speeds for a 1^oF SST increase. By contrast, high-resolution climate model simulations (Knutson and Tuleya 2004 and Oouchi et al. 2006) have found a 2% increase in intensity when scaled for a 1^oF SST increase, which is a factor of 3 times smaller than that determined from the observations. Two different theories of potential intensity indicate a 2.7 and 5.3% increase in hurricane intensity of a 1^oF SST increase. Although these estimates differ in magnitude, the observations, models and theory all agree that average hurricane intensity will increase with increasing sea surface temperature. The disagreement is over the magnitude of the increase.

The most reliable data on hurricane intensity is for the North Atlantic. The quality of the intensity data since 1983 is generally accepted (Kossin), and the data since 1970 is also expected to be reliable. Figure 2 shows histograms of the North Atlantic hurricane intensity during the periods 1970-1982, 1983-1994, 1995-2006. The most striking aspect of the histograms is the substantial increase of category 4 hurricanes during the period 1995-2006, consistent with the Webster et al. analysis. A key issue in the debate surrounding the intensity of the North Atlantic hurricanes is the intensity during the previous active period, ca. the 1950's. The intensity data during the period 1944-1970 is hotly debated over the issue of whether or not Landsea's adjustment to the intensity of major hurricanes (categories 3, 4, 5) prior to 1970 should be made. The debate surrounding Landsea's correction emerged after the publication of Emanuel (2005), with Landsea (2005) stating that his previously recommended Landsea (1993) correction should not be used. Whether or not Landsea's correction is applied makes a significant difference to our interpretation of whether the intensity distribution during the period 1995-2006 (arguably augmented by global warming) is different from the intensity distribution in the previous active period ca. the 1950's (associated with natural variability).

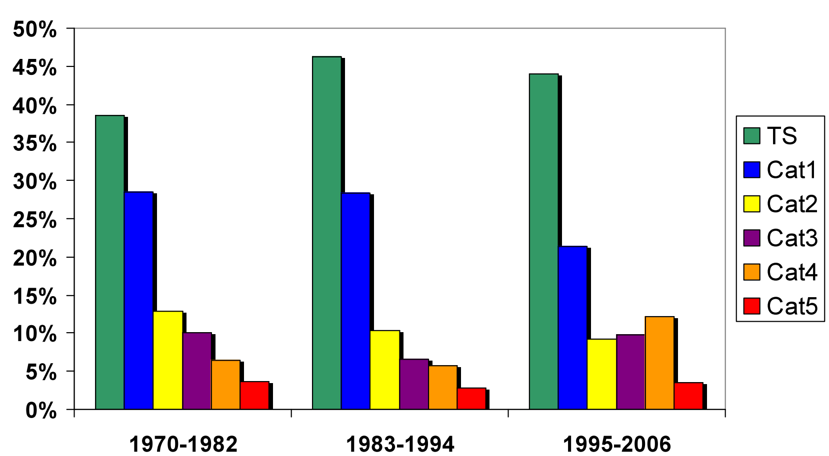


Figure 2. Histograms of the normalized distribution of hurricane intensities for 1970-1982, 1983-1994, and 1995-2006. Data are obtained from http://www.aoml.noaa.gov/hrd/hurdat/. Figure courtesy of M. Jelinek.

The increase in global hurricane intensity since 1970 has been associated directly with a global increase in tropical sea surface temperature (Webster et al. 2005; Hoyos et al. 2006). Figure 3 shows the variation of tropical sea surface temperature (SST) in each of the ocean regions where tropical cyclone storms form. It is seen that in each of these regions that the sea surface temperature has increased by approximately 0.5°C (or 1°F) since 1970. The causal link between SST and hurricane intensity was established over 50 years ago, when it was observed that tropical cyclones do not form unless the underlying SST exceeds 26.5°C (80°F) and that warm temperatures in the upper ocean are needed to supply the energy to support development of hurricane winds. The role of SST in determining hurricane intensity is generally understood and is supported by case studies of individual storms and by the theory of potential intensity. By contrast, no trend is seen in wind shear (Figure 4). Wind shear is the change of wind speed and direction with height in the atmosphere; small wind shear is conducive to tropical cyclone formation. While wind shear is an important determinant of the intensity of individual storms and even in the population of storms in an individual season, there is no trend in wind shear that can explain the observed increase in global hurricane intensity since 1970. Wind shear in the North Atlantic (dark blue curve) has shown some decrease during this period, contributing to the recent intensity increase in the North Atlantic.

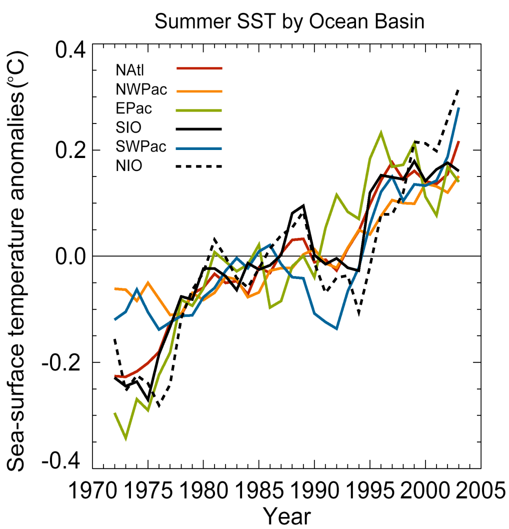


Figure 3. Evolution of the sea surface temperature anomalies relative to the 1970-2004 period for the North Atlantic, Western Pacific, East Pacific, South Indian Ocean, Southwest Pacific and North Indian Ocean Basins (Curry et al., 2006).

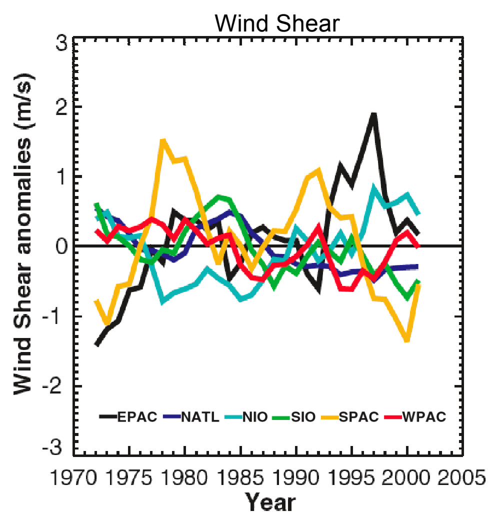


Figure 4. Evolution of the wind shear anomalies relative to the 1970-2004 period for the North Atlantic, Western Pacific, East Pacific, South Indian Ocean, Southwest Pacific and North Indian Ocean Basins (Hoyos et al., 2006).

In the North Atlantic, not only has the average sea surface temperature increased, but the area of the warm pool is expanding. Figure 5 shows the area in the North Atlantic with sea surface temperatures exceeding 28°C (82.4°F) during 1920, 1960, and 2000. The curve for 2000 shows that the warm pool has extended eastward to the coast of Africa. The expanding warm pool has resulted in the increased frequency of formation of tropical cyclones in the east Atlantic (ref Holland HELP). Further, the expanding warm pool has changed the temperature gradients in the North Atlantic, influencing atmospheric circulations and hence the wind shear and the currents that steer hurricanes. Hence, changes in wind shear are partially being influenced by changes in the patterns of sea surface temperature.

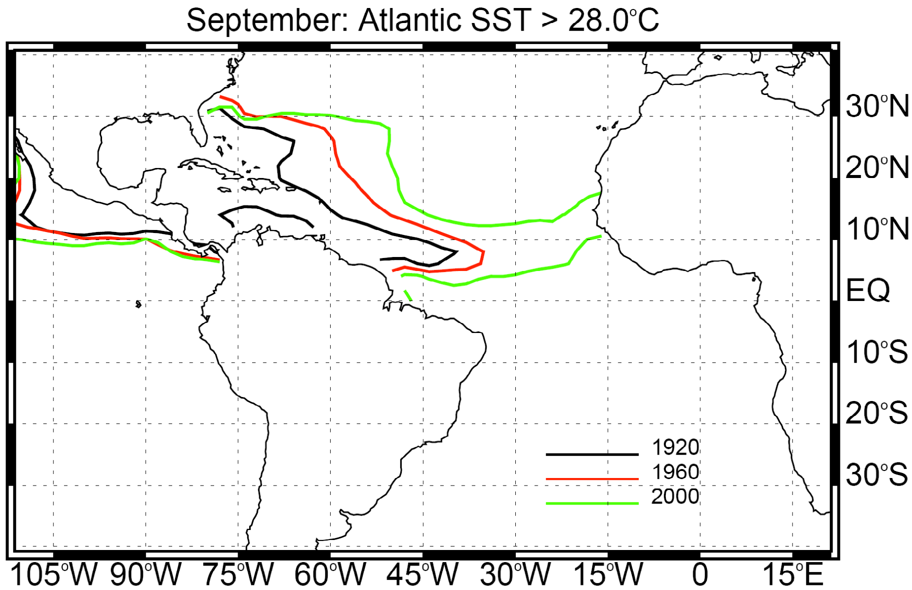


Figure 5. Map of the 28°C (82.4°F) isotherms during September in the North Atlantic for 1920, 1960, and 2000, showing the increased area and eastward extension of the warm pool. Figure courtesy of C. Hoyos and P. Webster

To look for signals of global warming in the hurricane database relative to natural variability, it is desirable to go back further in time. While the intensity data prior to 1970 is unreliable even in the North Atlantic, a credible dataset on the number of the number of tropical cyclones (hurricanes plus tropical storms) exists back to 1851. Figure 6 shows the time series in the North Atlantic of the number of tropical cyclones where the data has been smoothed (11 year running mean) to eliminate the year-to-year variability and so to highlight the decadal and longer-term variability. A nominal 70-year cycle is evident from peaks ca. 1880 and 1950 and minima ca. 1915 and 1985. However, the most striking aspect of the time series is the overall increasing trend since 1970 and the high level of activity since 1995. Note, Figure 1 showed that the number of hurricanes has not increased globally since 1970; it is only in the North Atlantic that the numbers of tropical cyclones and hurricanes are increasing. How credible is this dataset, particularly during the early part of the period? There is almost certainly some undercounting of tropical storms prior to 1944, and particularly prior to 1900. Several estimates of undercounting have been made for the period prior to 1944, ranging from 1 to 2.5 storms (ref Neumann, Knutson). A further confounding factor is that some storms may have been counted twice, particularly prior to 1900. In any event, the inaccuracies in the tropical cyclone data set appear to be relatively small (with the effects of undercounting and double counting partially canceling), and we can state with confidence that the number of North Atlantic tropical cyclones in the last decade is unprecedented in the historical record. Also shown in Figure 6 is the time series of the average SST in the main development region of the tropical north Atlantic. Comparison of time series of SST and the number of topical cyclones shows generally coherent variations on the longer time scales. In particular, the period 1910-1920 with low storm activity is associated with anomalously cool sea surface temperatures, and the largest number of tropical cyclones is seen during the past decade, when SST values have been the warmest. The data set indicates that a 0.5°C (1°F) temperature increase has been associated with on average an additional 5 tropical storms.

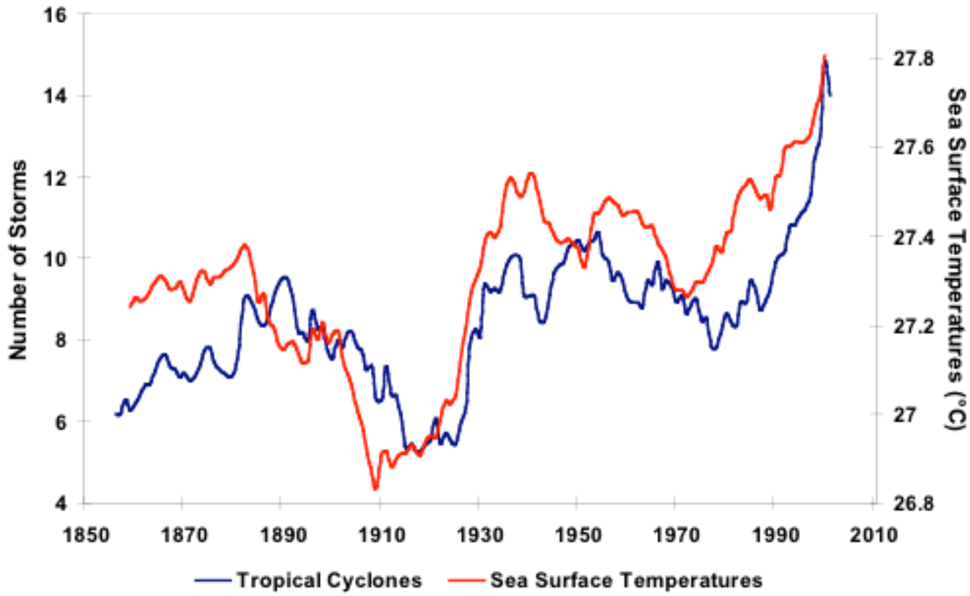
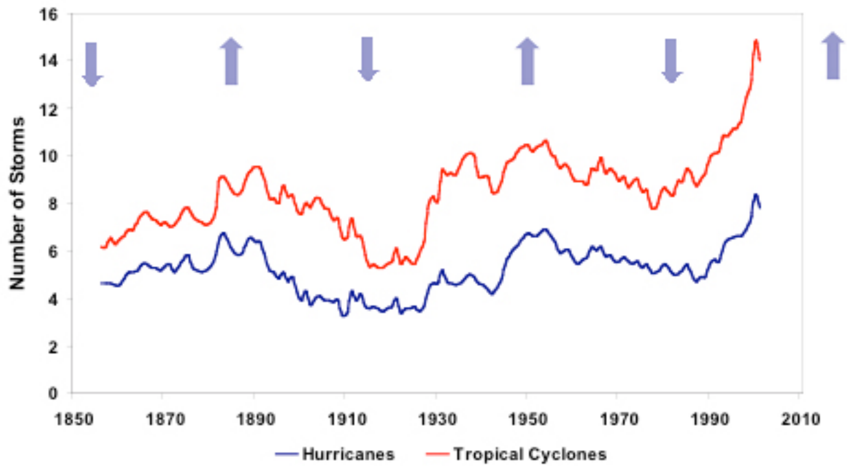


Figure 6: Number of total named storms in the North Atlantic and the average sea surface temperature in the main development region, filtered by an 11-year running mean. Data are obtained from http://www.aoml.noaa.gov/hrd/hurdat/. Figure courtesy of M. Jelinek.

A number of natural internal oscillations of the atmosphere/ocean system have a large impact on SST and tropical cyclone activity (e.g. El Nino, North Atlantic Oscillation), and some scientists have argued the increase in tropical cyclone activity can be explained by such natural variability. In particular, there have been repeated assertions from the National Hurricane Center that the recent elevated hurricane activity is associated with natural variability, particularly the Atlantic Multidecadal Oscillation (AMO). Figure 7 shows the time series of the number of tropical cyclones and hurricanes since 1851, with arrows indicating the phases of the AMO. This figure suggests that the AMO (nominally a ~70 year cycle), does have an influence on North Atlantic hurricane activity. However, recent examination of the data by Mann and Emanuel (2006) suggest that the impact of the AMO on tropical sea surface temperature and hurricane activity has been overestimated owing to the convolution of the AMO with the global forcing (natural plus anthropogenic). Analyses that rely solely on SST to identify the AMO may have aliased the phase and amplitude of the AMO signal. The next peak of the AMO is anticipated ca. 2020. The strength of the tropical cyclone activity during the period 1995-2005 (50% greater than the previous peak period ca. 1950), which is at least a decade away from the expected peak of the current AMO cycle, suggests that the AMO alone cannot explain the elevated tropical cyclone activity observed in the North Atlantic during the last decade. The best available evidence supports the assertion that greenhouse warming is contributing to the increase in hurricane activity.



an 11-year running mean. Data are obtained from http://www.aoml.noaa.gov/hrd/hurdat/. Figure courtesy of M. Jelinek.

Examination of U.S. landfalling data (Figure 8) shows a strong signal of a 70-year cycle (nominally the AMO). Unlike Figure 7 which showed a showed an overall increase in the total number of North Atlantic tropical cyclones, no increase in the number of U.S. landfalling cyclones is seen. However there is a hint of an increase since the most recent number of landfalling tropical cyclone slightly exceeds the peak values observed ca. 1950 and 1880; since the next peak of the AMO is anticipated ca. 2020, it seems likely that we will see an increase in the coming decades exceeding anything in the historical data record.

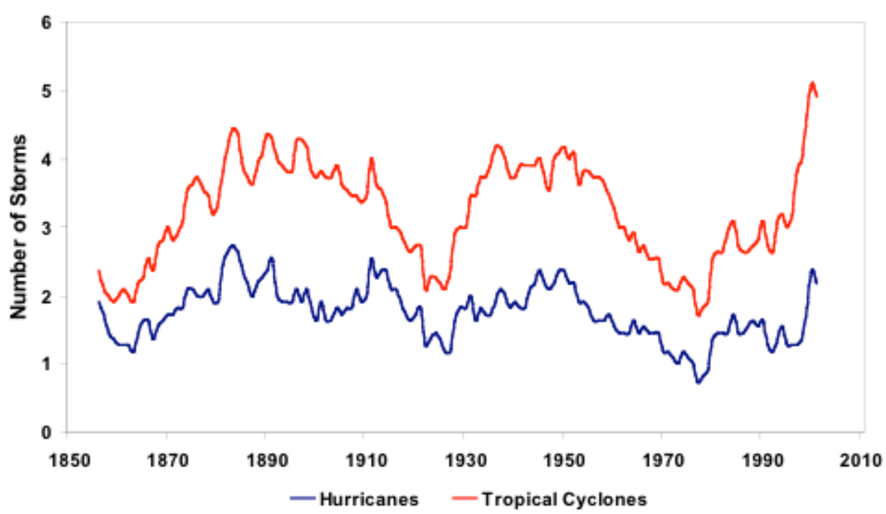


Figure 8: Number of tropical cyclones and hurricanes that have made landfall on the continental U.S. since 1851, filtered by an 11-year running mean. Data are obtained from http://www.aoml.noaa.gov/hrd/hurdat/. Figure courtesy of M. Jelinek.

What accounts for the fact that we are seeing an increase in the total number of North Atlantic tropical storms, but little or no increase in the number of U.S. landfalling storms? U.S. landfalling storms on average account for 30-60% (HOLLAND CHECK) of the total North Atlantic storms. Storm tracks may take the storms north in the Atlantic Ocean where they never strike land, or south where they may strike the Caribbean Islands or Central America. Unfortunately, prior to the satellite era, storm tracks are relatively unreliable, so it is difficult to sort out the influence of the AMO vs global warming on the long-term variations in tropical cyclone tracks. The expanding North Atlantic warm pool (Figure 5) has been associated with an increased number of storms that track northward in the mid Atlantic PETER GREG CHECK. Some insight into variation in the tropical cyclone tracks can be gleaned from examining the time variations in the locations of the storms that strike the U.S. Figure 9 shows that the number of storms striking the Atlantic shows relatively little variation, whereas the number of storms striking the Gulf Coast shows a strong recent increase that is partly explained by the signal from the 70 year AMO cycle.

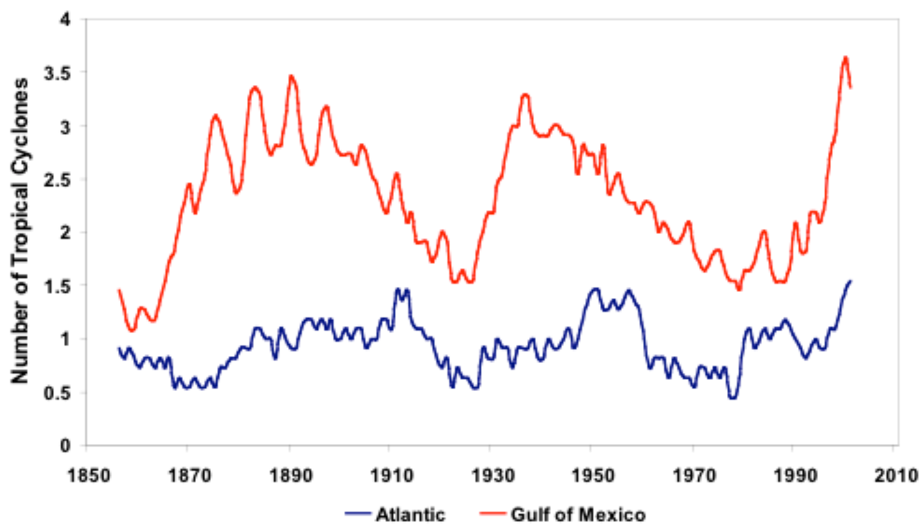


Figure 9: Number of tropical cyclones and hurricanes that have made landfall on the U.S. Atlantic coast and the Gulf coast since 1851, filtered by an 11-year running mean. Data are obtained from http://www.aoml.noaa.gov/hrd/hurdat/. Figure courtesy of M. Jelinek.

In summary, the Atlantic Multidecadal Oscillation appears to influence the number of North Atlantic tropical cyclones through wind shear and SST, and also the tropical cyclone tracks. However, the recent increase in the number of North Atlantic tropical cyclones, which is strongly correlated with sea surface temperature on multidecadal time scales, is unprecedented in the historical record. The intensity of the North Atlantic hurricanes has increased since 1970, this increase reflected most markedly by a doubling of the proportion of category 4 storms. Attribution of the increased hurricane intensity to global warming is complicated by the signal from the AMO and uncertainties in hurricane intensity prior to 1970, although an increase in intensity with increasing SST is expected from both theory and models.

Projections of future hurricane activity

Climate model projections of future hurricane activity in a warmer climate are hampered by the coarse resolution of the models that cannot adequately resolve the individual storms. Hence most climate model estimates of future hurricane activity rely on some sort of statistical relationship with the atmospheric circulation characteristics to infer hurricane activity. The most credible climate model projections of hurricane activity are made using high resolutions simulations. Using the Japanese Earth Simulator computer, Oouchi et al. (2006) have conducted the highest resolution global climate model simulations to date, consisting of a ten year simulation of the current climate and a ten year simulation of a climate that is about 2.5^{o}C (5^{o}F) warmer. Oouchi et al. found that while the number of tropical cyclones decreased globally, the number increased in the North Atlantic by 30%. The simulated increase in intensity was 10%, in general agreement with previous high-resolution simulations using regional models. While the Oouchi et al. simulations represent a considerable advance over previous simulations, significant uncertainties are associated with the treatment of convective clouds and the exchange of heat and moisture between the ocean and the lower atmosphere.

In the North Atlantic, any projection of future hurricane activity should account for both global warming and natural variability. Towards inferring what the hurricane activity might look like in the coming decades, a simple statistical model is formulated to estimate the average conditions in the year 2025 (such that high frequency fluctuations from short-term oscillations such as El Nino are ignored), using results from both the observational record and climate model simulations. In the year 2025, we assume that the tropical sea surface temperatures have increased by owing to greenhouse warming. Figure 6 suggests that an increase of 1^{o}F is associated with an increase of 5 tropical cyclones, while the increased number of North Atlantic tropical cyclones projected by Oouchi et al.'s high-resolution climate model simulation is less than 1 when scaled for an increase of 1^{o}F. Hence, we bound the range of the expected increase in tropical cyclones for a 1^{o}F temperature increase by 1-5 storms. Further, we assume that 2025 is near the peak of the AMO cycle. Different interpretations of the relative importance of the AMO vs global forcing of the surface temperature yield estimates of the magnitude of the impact of the AMO on the total number of tropical cyclones per year range from 0 (no effect) to 4 (the AMO explains the entire magnitude of the trough to peak variability in Figure 7); since we are halfway up the positive phase of the AMO, we infer a maximum additional contribution of 1 cyclone from the AMO by 2025.

Based upon these assumptions of variability of the total number of North Atlantic tropical cyclones, consider the following simple statistical model for the projection of the average number of North Atlantic tropical cyclones in 2025. The average number for the past decade of total North Atlantic tropical cyclones is 14 (Figure 7). We assume that the effects of greenhouse warming and the AMO are separable and additive. Adding the range of contributions from global warming plus the AMO to the base value of 14 tropical cyclones yields a range of projected tropical cyclones from 15 to 20, the range accounting for the uncertainties in the impacts of both global warming and the AMO. The combination of global warming and the elevated activity associated with the active phase of the AMO can be expected to result a level of tropical cyclone activity that is unprecedented in the historical record. In terms of the intensity of the storms, an increase in the number of category 4 and 5 hurricanes is expected, ranging from 3-4 per year.

What are the implications of the projected basin wide increase in total North Atlantic tropical cyclones for U.S. landfalls? We have seen from Figures 8 and 9 that the active phase of the AMO is associated with an increase in the proportion of U.S. landfalls, particularly those that strike the Gulf coast. As both the frequency and intensity of the hurricanes increases, we can expect increased damage from winds, storm surges, flooding, and tornadoes. Wind damage goes at cube of wind speed (need an interesting statement). Local vulnerability to storm sturge has been assessed by FEMA, with regions at particular risk including xxxx REF. The increased frequency of Gulf landfalls combined with increased intensity increases the risk for inland flooding and tornadoes. The largest rainfall and tornadic activity are associated with the forward right quadrant of the storm, and hence an intense hurricane that makes landfall in the Gulf will be associated with intense rainfall and tornadic activity in the northeast part of the storm as the storm moves northward. A recent example of what an intense gulf landfall can do was ivan, which spawned xxxx tornadoes, flooding etc. HELP

What can we expect to happen after 2025? Once the AMO begins its descending mode ca. 2020, continued warming makes it doubtful that we will ever again see the low levels of hurricane activity of the 1980's and we can expect a leveling off rather than significant decrease in activity until the next ascending phase of the AMO. Continued warming is likely to influence the AMO, and hence projections of the combined effects of global warming and the AMO beyond the next peak of the AMO are probably unjustified by the simple statistical model.

Theory and climate models provide only a rough guide to the longer-term future of hurricane activity. Theory and models both agree that with continued warming of the tropical oceans, we can expect continued increase in hurricane intensity. Projections regarding the number of tropical cyclones are less certain. There is some evidence supporting a decrease in the number of tropical cyclones outside the North Atlantic; it is only in the North Atlantic where the numbers are expected to increase. Our understanding is not sufficient to indicate whether the numbers in the North Atlantic will continue to increase, or whether they will saturate out at some point and what that point might be.

On longer time scales (order of a century), sea level rise will compound the impact of increased hurricane activity owing to increased storm surge vulnerability. By 2100, a sea level rise of 1 to 2 feet is plausible, and these figures do not account for any potential catastrophic melting of Greenland and Antarctica. Hurricane prone regions in the U.S. at greatest risk from storm surge enhancement associated with greenhouse warming are New Orleans, South Florida, and portions of the mid-Atlantic coast. Looking globally, Bangladesh is particularly vulnerable to the combination of increased hurricane activity and sea level rise; several hundred million people live in the southern part of the country where the elevation is only a few feet above sea level, and three tropical cyclones during the 20th century each killed over 100,000 people. The vulnerability of the developing world to increased hurricane activity and sea level rise raises not only the obvious humanitarian and economic issues, but potential regional instabilities associated with mass migrations raise serious international security issues.

Towards increasing our confidence in projections of future risk

The research on the potential impacts of climate change on hurricane activity has increased dramatically in volume over the past two years in response to the high-impact tropical cyclone events around the globe and particularly in the U.S. This recent research is leading to major advances in understanding of the relationships between tropical cyclones and the large scale atmospheric state or "climate" as well as advances in the understanding of the observational record of tropical cyclones. It is becoming increasingly apparent that understanding the relationship between climate change and hurricane activity requires the combined expertise of scientists in climate dynamics, oceanography, tropical meteorology, and paleoclimatology, as well as operational hurricane forecasters. Further, addressing the impacts of the problem requires expertise from engineering, ecology, and social, behavioural and economic sciences.

We are on the threshold of major advances in modelling etc

With regards to observations, the problem is not just with the historical data base, but our observing capacity is degrading (tropical analyst situation, degrading satellites), need for UAVs, satellites, etc.

The combination of sustained development in vulnerable coastal areas and high levels of hurricane activity has brought us to a critical stage where major action is required to address critical gaps in our capacity to handle growing hurricane impacts that pose both immediate and very real long-term threats to the safety of U.S. citizens and their property, and to local and regional economic activity. These gaps have been identified by several distinguished scientific entities, including:

- The National Science Board, who has recommended that the relevant Federal agencies commit to a major hurricane research program to reduce the impacts of hurricanes and encompassing all aspects of the problem: physical sciences, engineering, social, behavioral, economic and ecological[1];
- The NOAA Science Advisory Board, who established an expert Hurricane Intensity Research Working Group that recommended specific action on hurricane intensity and rainfall prediction[2];
- The American Geophysical Union, who convened a meeting of scientific experts to produce a white paper recommending action across all science-engineering and community levels[3]; and,
- A group of leading hurricane experts have convened several workshops to develop priorities and strategies for addressing the most critical hurricane issues[4].

Policy responses

Based upon the arguments presented here, there is certainly a risk of elevated hurricane activity with increased global warming, although the magnitude of this risk is presently uncertain. How should policy makers and other decision makers react to this risk in the face of the scientific uncertainties? The uncertainties in the hurricane data are sufficient that hurricanes cannot be used as any kind of "smoking gun" for global warming; rather the risk of elevated hurricane activity arguably represents the most devastating short-term impact of global warming, at least for the U.S.

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[1] **Hurricane Warning: The Critical Need for a National Hurricane Research Initiative** www.nsf.gov/nsb/committees/hurricane/pre_publication.pdf
[2] **HIRWG Final Report** www.sab.noaa.gov/Reports/HIRWG_final73.pdf
[3] **Hurricanes and the U.S. Gulf Coast: Science and Sustainable Rebuilding** www.agu.org/report/hurricanes/
[4] **HiFi Science Strategy** www.nova.edu/ocean/hifi/hifi_science_strategy.pdf

The combination of the coastal demographics with the increased hurricane activity will continue to escalate the socioeconomic impact of hurricanes. Any conceivable policy for reducing CO_2 emissions or sequestering CO_2 is unlikely to have a noticeable impact on sea surface temperatures and hurricane characteristics over the next few decades; rather, any such mitigation strategies would only have the potential to impact the longer term effects of global warming including sea level rise. Looking globally, Bangladesh is particularly vulnerable to the combination of increased hurricane activity and sea level rise; several hundred million people live in the southern part of the country where the elevation is only a few feet above sea level, and three tropical cyclones during the 20th century each killed over 100,000 people. The vulnerability of the developing world to increased hurricane activity and sea level rise raises not only the obvious humanitarian and economic issues, but potential regional instabilities associated with mass migrations raise serious national security issues.

To address the short-term (decadal) impacts of elevated hurricane activity, the increasing concentration of population and wealth in vulnerable coastal regions must be confronted. Rapidly escalating hurricane damage in recent decades owes much to government policies that serve to subsidize risk and hence promote risky behavior. Decreasing our vulnerability to damage from hurricanes will require a comprehensive evaluation of coastal engineering, building construction practices, insurance, land use, emergency management, and disaster relief policies in vulnerable regions. Political will at levels from local to the federal government is needed to develop the appropriate policy and technological options that are practically feasible, cost effective, and politically viable. Adaptation strategies will vary regionally, based upon the local geographic risks and nature of the economic dependence on coastal development and activities; Florida's economic and geographic vulnerabilities are different from those of North Carolina and Louisiana.

The urgent need for adaptation strategies to deal with increased hurricane activity was emphasized in a statement made last year by 10 scientists involved in both sides of the sometimes acrimonious debate over hurricanes and global warming. The statement is reproduced here in its entirety: http://wind.mit.edu/~emanuel/Hurricane_threat.htm

Statement on the U.S. Hurricane Problem
July 25th 2006

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 practices, and insurance, land use, and disaster relief policies that currently serve to promote an ever-increasing vulnerability to hurricanes.

Kerry Emanuel
Richard Anthes
Judith Curry
James Elsner
Greg Holland
Phil Klotzbach
Tom Knutson
Chris Landsea
Max Mayfield
Peter Webster