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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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 (IPCC AR4 2007a). 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 is 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 2007b):

> "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."

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. (for summaries see WMO 2007; Curry et al. 2006). 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°C (1°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 (2007b). 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.

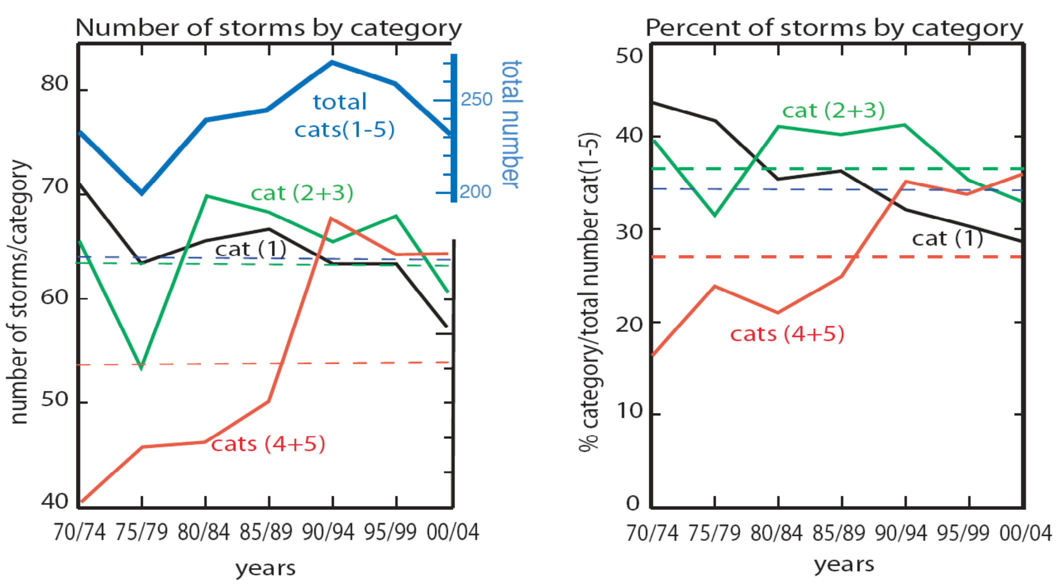

Figure 1: Intensity of global hurricanes according to the Saffir-Simpson scale (categories 1 to 5), in 5 year periods. (**A**) The total number of storms and (B) the percent of the total number of hurricanes in each category class. After Webster et al. (2005).

The quality of the hurricane intensity data used by Webster et al. has being questioned, particularly in the Pacific and Indian Oceans (e.g. WMO 2007). 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^{o}F increase in tropical sea surface temperature. The Webster et al. (2005) observations scale to a 6% increase in maximum wind speeds for a 1^{o}F SST increase. By contrast, high-resolution climate model simulations (Knutson and Tuleya 2004; Oouchi et al. 2006) have found a 2% increase in intensity when scaled for a 1^{o}F 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^{o}F 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. 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. Unfortunately, the intensity data prior the reconnaissance flights beginning in 1944 are deemed to be unreliable, and during the period 1944-1970 the quality of the data and the appropriate corrections to the data are hotly debated.

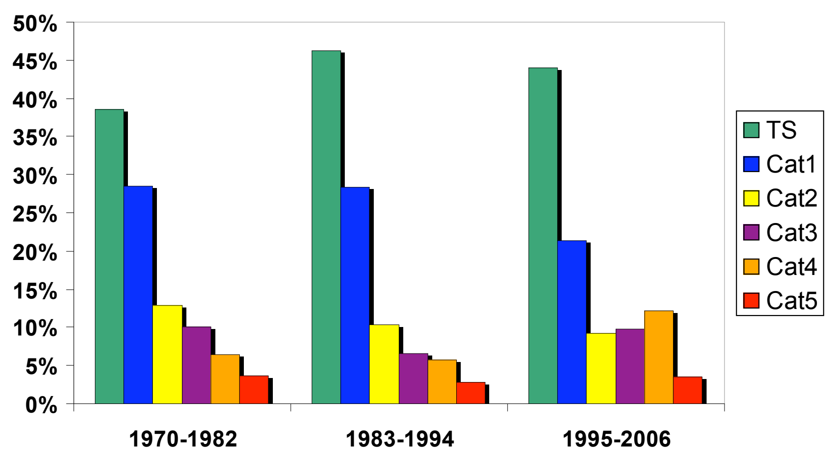

Figure 2. Histograms of the normalized distribution of hurricane intensities for 1970-1982, 1983-1994, and 1995-2006. Data are obtained from http://www.aoml.noaa.gov/hrd/hurdat/. Figure courtesy of M. Jelinek.

The increase in global hurricane intensity since 1970 has been associated directly with a global increase in tropical sea surface temperature. 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^{o}C (or 1^{o}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^{o}C (80^{o}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.

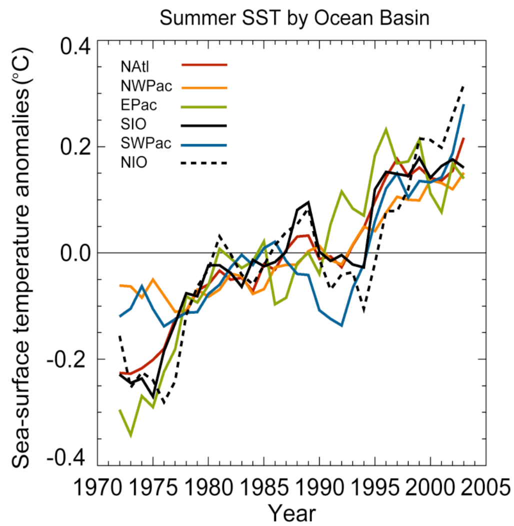

Figure 3. Evolution of the sea surface temperature anomalies relative to the 1970-2004 period for the North Atlantic, Western Pacific, East Pacific, South Indian Ocean, Southwest Pacific and North Indian Ocean Basins (Curry et al., 2006).

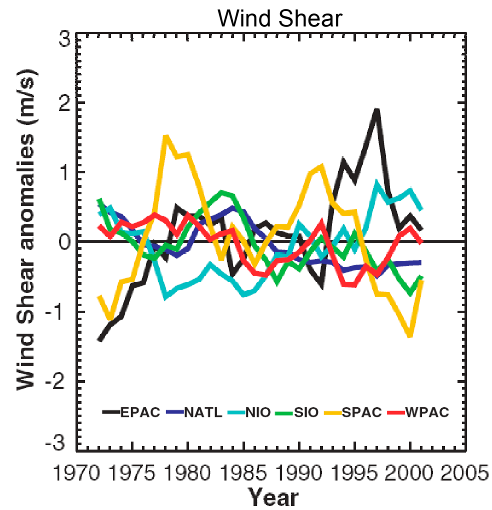

Figure 4. Evolution of the wind shear anomalies relative to the 1970-2004 period for the North Atlantic, Western Pacific, East Pacific, South Indian Ocean, Southwest Pacific and North Indian Ocean Basins (Hoyos et al., 2006).

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^{o}C (82.4^{o}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 low latitudes of the east Atlantic. 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.

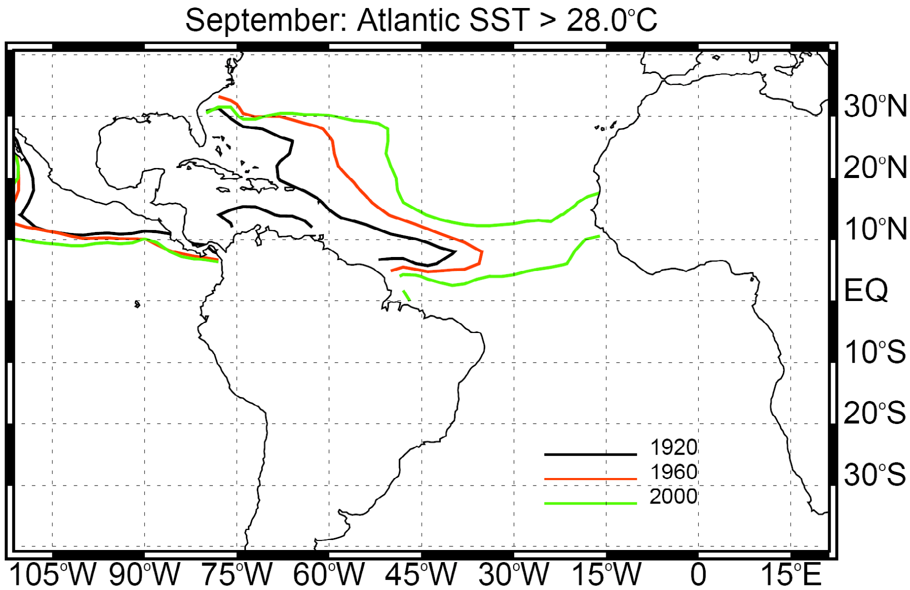

Figure 5. Map of the 28°C (82.4°F) isotherms during September in the North Atlantic for 1920, 1960, and 2000, showing the increased area and eastward extension of the warm pool. Figure courtesy of C. Hoyos and P. Webster

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 1950 is unreliable, a credible dataset on the number of the number of tropical cyclones (hurricanes plus tropical storms) in the North Atlantic 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. 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.

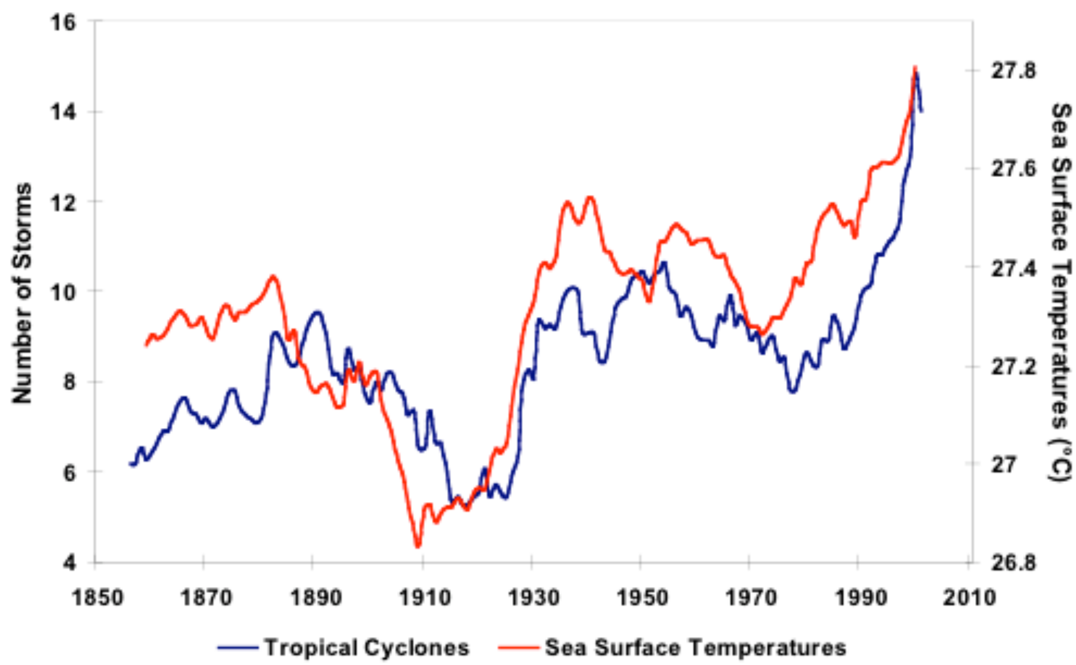

Figure 6: Number of total named storms in the North Atlantic and the average sea surface temperature in the main development region, filtered by an 11-year running mean. Data are obtained from http://www.aoml.noaa.gov/hrd/hurdat/. Figure courtesy of M. Jelinek.

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 NOAA 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. Separation of the AMO signal from the global warming signal has been the subject of recent debate. Assuming that the next peak of the AMO can be anticipated ca. 2020. The strength of the tropical cyclone activity during the period 1995-2005, which is at least a decade away from the expected peak of the current AMO cycle and already 50% greater than the previous peak period ca. 1950, suggests that the AMO alone cannot explain the elevated tropical cyclone activity observed during the last decade. The best available evidence supports the assertion that greenhouse warming is contributing to the increase in hurricane activity in the North Atlantic.

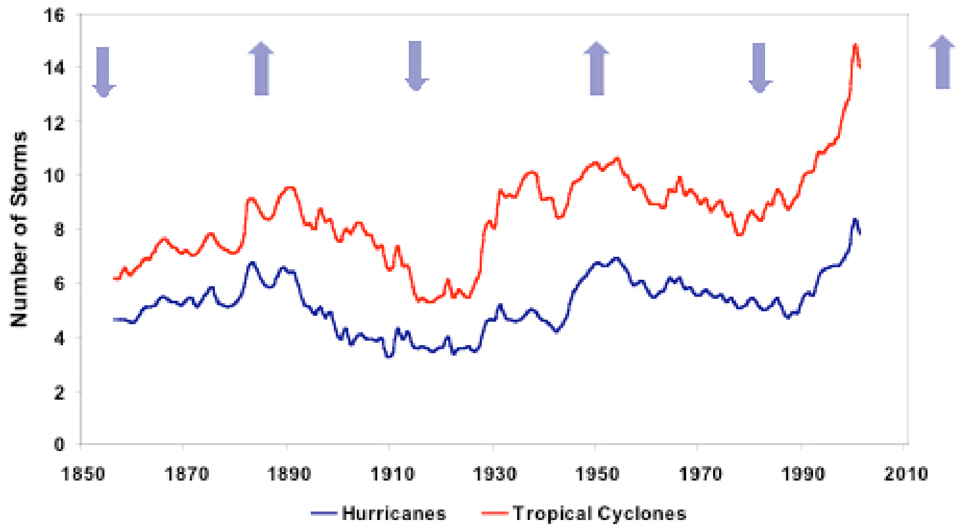

Figure 7: Number of tropical cyclones and hurricanes in the North Atlantic since 1851, filtered by an 11-year running mean. The up/down arrows indicate the positive/negative phases of the Atlantic Multidecadal Oscillation. Data are obtained from http://www.aoml.noaa.gov/hrd/hurdat/. Figure courtesy of 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 is plausible that we will see an increase in the coming decades exceeding anything in the historical data record.

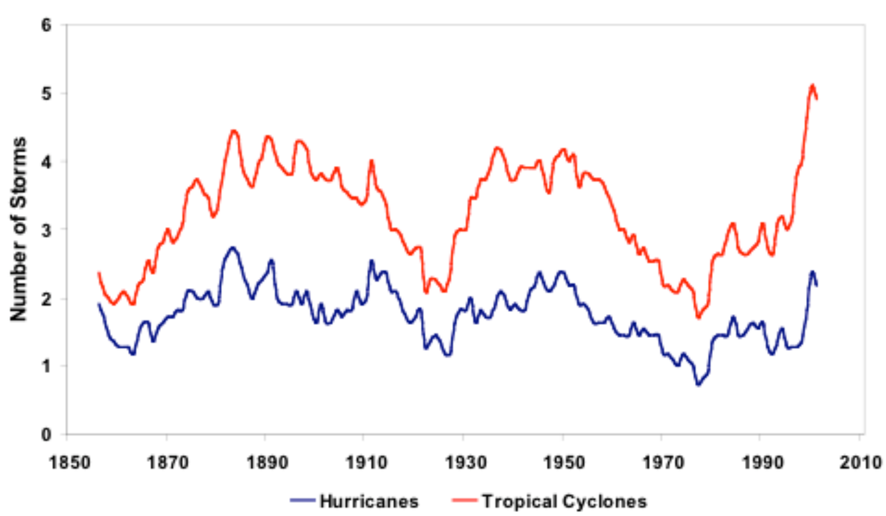

Figure 8: Number of tropical cyclones and hurricanes that have made landfall on the continental U.S. since 1851, filtered by an 11-year running mean. Data are obtained from http://www.aoml.noaa.gov/hrd/hurdat/. Figure courtesy of M. Jelinek.

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 a fraction of the total North Atlantic storms. Storm tracks may take the storms north over the open 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 versus global warming on the long-term variations in tropical cyclone tracks. 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.

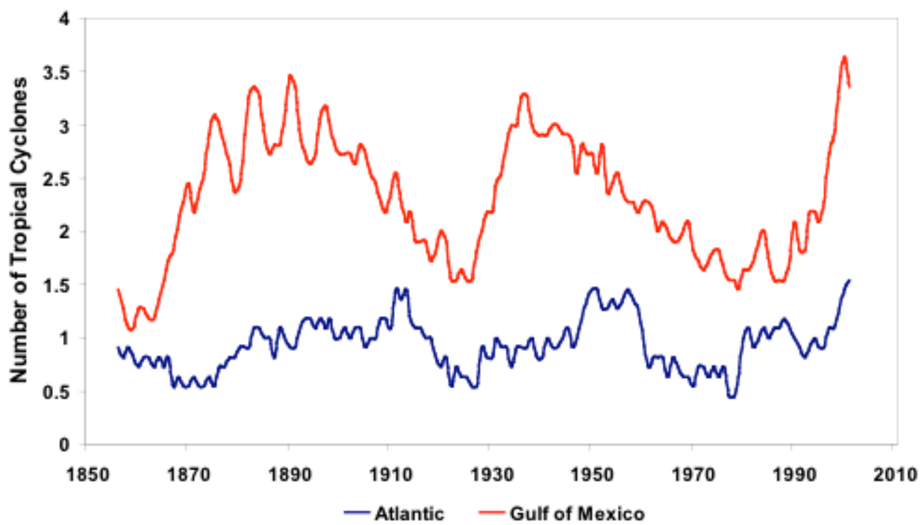

Figure 9: Number of tropical cyclones and hurricanes that have made landfall on the U.S. Atlantic coast and the Gulf coast since 1851, filtered by an 11-year running mean. Data are obtained from http://www.aoml.noaa.gov/hrd/hurdat/. Figure courtesy of M. Jelinek.

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) conducted a ten year simulation of the current climate at 20 km resolution 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. A recent high-resolution simulation (40 km resolution) by Bengtsson et al. (2007) also found a global decrease in the number of tropical cyclones, but not in the North Atlantic. Significantly they also found that the number of major hurricanes (categories 3, 4, 5) increased by 30% in the 21st century. While the Oouchi et al. and Bengtsson et al. simulations represent a considerable advance over previous simulations, significant uncertainties remain, especially with the treatment of convective clouds and the exchange of heat and moisture between the ocean and the lower atmosphere.

To infer what the hurricane activity might look like in the coming decades, a simple statistical model is formulated that accounts for both global warming and natural variability to estimate the average conditions in the year 2025, 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 1^{o}F 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 slightly 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 versus 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 annual number for the past decade of 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 average annual numbers of tropical cyclones in 2025 ranging from 15 to 20, the range accounting for the uncertainties in the impacts of both global warming and the AMO. Interannual influences, such as the El Nino-La Nina cycle will lead to some years being substantially lower, but others substantially higher, and future years similar to or exceeding 2005 must be expected. Thus, 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 is estimated to vary with the cube of wind speed (Iman et al. 2005), so the 30% increase in major hurricanes projected by Bengtsson et al (2007) would be expected to lead to a more than doubling of the damage. Storm surge increases with increasing size and intensity of the hurricane. Climate models indicate that we can expect increased rainfall from hurricanes as a result of global warming. 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 inland damage from an intense Gulf landfalling was Ivan, which caused much of its $13 billion damage inland. Ivan caused 100-year floods in the Chattahoochee River near Atlanta and many other rivers and streams and record flooding in the Delaware. Ivan also spawned an estimated 117 tornadoes including 26 in the DC and Maryland area (Franklin et al 2006).

What can we expect to happen after 2025? Once the AMO begins descending from its peak 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 using 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.

Policy responses

Based upon the arguments presented here, there is certainly a risk of further elevated hurricane activity with increased global warming, although the magnitude of this risk is uncertain. How should policy 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; however the risk of elevated hurricane activity arguably represents the most devastating short-term impact of global warming, at least for the U.S.

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; over a 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, industry 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 can be found at http://wind.mit.edu/~emanuel/Hurricane_threat.htm and is reproduced in its entirety in Attachment I to this testimony. Recently a group of concerned scientists wrote a letter to the Honorable Bart Gordon, Chairman of the House Science and Technology Committee, on the need for the Federal Government to undertake prompt action to institute a comprehensive interagency research program aimed at reducing the impacts of hurricanes for the U.S.A and our neighbors (this letter is appended to the testimony as Attachment II).

Summary. As the climate continues to warm, models and observations agree that it is likely that global hurricane intensity will increase and that the number of North Atlantic hurricanes will increase, although the magnitude of the increase is uncertain. The increasing hurricane activity coupled with existing (and increasing) coastal vulnerabilities indicates an urgent need for adaptation in vulnerable coastal regions, particularly in the North Atlantic where the combination of global warming with the active mode of the Atlantic Multidecadal Oscillation indicates substantially elevated hurricane activity in the next few decades. Reducing carbon dioxide emissions will help avoid the longer term risks associated with sea level rise and storm surge expected from increasingly intense hurricanes.

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Attachment I

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
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Attachment II

February 26, 2007

The Honorable Bart Gordon
Chairman Committee on Science and Technology
U.S. House of Representatives
Washington, D.C. 20515

Dear Mr. Chairman:

We, the under listed group of concerned scientists, believe the Federal Government should undertake prompt action to institute a comprehensive interagency research program aimed at reducing the impacts of hurricanes for the U.S.A and our neighbors. We hope that your Committee might be persuaded to take the lead on legislation authorizing the establishment of such a program.

The severe hurricane impacts on Florida in 2004, along with the record number and intensities of hurricanes with severe impacts around the Gulf of Mexico and the devastating flooding of New Orleans in 2005, have provided a "wake-up" call that cannot be neglected. A 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 US 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].

These separate investigations are entirely consistent in advising that we have a major and worsening situation that requires urgent action in the following priority areas:

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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

- **0 to 5 Day Hurricane Forecast Improvements**
  - In particular, skill in forecasting hurricane intensity in terms of expected wind speed and the extent of damaging winds and flood rains is at an unacceptably low level;
  - Understanding the important processes and development of new hurricane forecasting tools will require development of innovative oceanic and atmospheric observing systems combined with the next generation of research and operational hurricane forecast models to enable observations and prediction of the critical internal hurricane processes.

- **Long Range Projections of hurricane activity from Weeks to Decades**
  - Climate projections out to 20, 40 and 60 years of the expected variations in the number of Atlantic hurricanes, their intensities and geographical regions affected are critical to sound planning and engineering design, yet these are presently largely unknown;
  - Developing a capacity to predict these longer-term variations and trends requires improved understanding of the complex interactions between hurricanes and the global climate, together with a commitment to development of the next generation of regional climate models.

- **Impacts Projections**
  - Hurricane damage arises from the effects of high winds, ocean waves, coastal storm surge, rainfall and associated flooding, land slippage and environmental deterioration;
  - Reducing these impacts will require multidisciplinary collaborations amongst physical scientists, engineers, social scientists, ecologists and community leaders.

Further details on these priorities are provided in the original documents as referenced on the previous page.

We were encouraged by, and supportive of the efforts by Senators Martinez and Nelson who introduced legislation in the last Congress (S. 2004) that proposed the authorization of a national initiative to address these priority areas. We hope that your Committee will consider enactment of legislation along the lines of the legislation introduced last year as part of the agenda for the 110th Congress.

Considerable planning discussions within the scientific community have convinced us that a visionary and comprehensive national hurricane initiative is required. To be successful this program needs to be sustained for at least a decade to ensure that the critical combination of fundamental research and system development can be accomplished. Further, several federal agencies and laboratories and the academic community should be involved in the initiative in a highly collaborative and cooperative manner to ensure the needed depth and diversity of multi-disciplinary expertise and institutional capabilities and to address the many dimensions of federal and state responsibility related to hurricanes.

We stand ready to assist your Committee and the Congress to address the Nation's need for improved understanding and prediction of hurricanes and their impacts.

Sincerely,

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Biosketch

Dr. Judith Curry is Professor and Chair of the School of Earth and Atmospheric Sciences at the Georgia Institute of Technology. Dr. Curry received a Ph.D. in atmospheric science from the University of Chicago in 1982. Prior to joining the faculty at Georgia Tech, she has held faculty positions at the University of Colorado, Penn State University and Purdue University. Dr. Curry's research interests span a variety of topics in climate; current interests include air/sea interactions, climate feedback processes associated with clouds and sea ice, and applications of satellite data to interpreting recent variations in the climate data record. Most recently she has been investigating the variability of hurricanes on global scales, in the North Atlantic, and landfalling hurricanes striking the U.S. and Latin America. Dr. Curry has recently served on the National Academies Climate Research Committee and the Space Studies Board, and the NOAA Climate Working Group. Dr. Curry is coauthor of the book *Thermodynamics of Atmospheres and Oceans* and is editor for the *Encyclopedia of Atmospheric Sciences*. She has published over 140 refereed journal articles. Dr. Curry is a Fellow of the American Meteorological Society and the American Geophysical Union, and her research has been recognized by receiving the Henry Houghton Award from the American Meteorological Society.