Summary Report to the U.S. House of Representatives
Sub-Committee on Housing and Community Opportunity
(to be given on 28 June 2006 at 2:00 PM)

CLIMATE INFLUENCES ON U.S. LANDFALLING HURRICANES AND RECOMMENDATIONS FOR THE INSURANCE INDUSTRY

by

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Mr. Chairman and Members of the Committee, I am William M. Gray, a Professor Emeritus of Atmospheric Science at Colorado State University in Fort Collins, Colorado. I have been studying, teaching, and forecasting weather and climate for over 50 years (see my attached Vitae). My specialty has been tropical meteorology and tropical cyclones. I have made Atlantic basin seasonal hurricane forecasts for the last 23 years. I am pleased to present information to your sub-committee on the outlook for future US hurricane landfall frequency, economic loss, and insurance questions.

1. SUMMARY DISCUSSION

Trends in global oceanic and atmospheric observations during recent years indicate that we are in a multi-decadal period (since 1995) of increased Atlantic basin major hurricane activity. The latter include hurricanes of Saffir/Simpson intensity classes 3, 4, and 5 (or hurricanes with maximum sustained winds greater than 110 mph). Major hurricanes, when normalized by coastal population, wealth per capita, and inflation over the last century typically cause about 80-85 percent of the total US tropical cyclone destruction even though they only account for about one-fourth of the total number of named tropical cyclones (Pielke and Landsea, 1999). We are presently in a period of enhanced Atlantic basin major hurricane activity that is typical of what was experienced in the 1940s and 1950s when US coastal population and coastal property values were much lower than today. We were very fortunate during the very active 9 year period from 1995-2003. Of the 32 Atlantic basin major hurricanes, only 3 made US landfall (or less than 1 in 10). The long term average of US major hurricane landfall to total Atlantic basin major hurricanes is about one in three.

Most southeast coastal residents probably do not know how fortunate they have been in the prior 38-year period (1966-2003) leading up to 2004-2005. Only 17 major hurricanes (0.45/year) crossed the US coastline. In the prior 40-year period of 1926-1965, 36 major hurricanes (0.90/year or twice as many) made US landfall. It is understandable that current coastal residents were not prepared for the great upsurge in US landfalling major hurricanes in 2004-2005.

The recent US landfall of major hurricanes Dennis, Katrina, Rita and Wilma in 2005 and the four Florida landfalling hurricanes of 2004 (Charley, Frances, Ivan and Jeanne) has raised questions about the possible role that global warming and increased human induced greenhouse gas outputs may be playing in these two unusually destructive seasons.

The global warming arguments have recently received much attention in the media and by innumerable blog citations. The recent published papers claiming to show such a linkage (Emanuel 2005; Webster et al. 2005) have been cited frequently over the last 9 months. These papers should not be accepted. The observations that a number of my hurricane forecaster-research colleagues and I, have been gathering over many years, however, do not observationally or theoretically support the contention that hurricane activity globally or in the Atlantic has undergone anything but natural variability. The above papers have been discredited by many of us in the tropical cyclone research community. Despite the global warming of the sea surface of about 0.3^{o}C that has taken place over the last 3 decades, the global number of hurricanes and their intensity has not shown increases in recent years (Klotzbach 2006). The recent increase in Atlantic major hurricane activity reflect the natural multi-decadal alteration of the Atlantic Ocean thermohaline circulation (THC) which is not directly related to global temperature increase. Changes in ocean salinity are believed to be the driving mechanism for these Atlantic basin multi-decadal changes which have been termed the Atlantic Multi-Decadal Oscillation (AMO). The Atlantic has seen a very large increase in major hurricanes during the last 11 years (1995-2005), an average of 4.1 major hurricanes have occurred per year in comparison to the prior 25-year period (1970-1994) where an average of 1.5 major hurricanes per year occurred.

There have been similar periods in the past (1940s-1950s) when the Atlantic was just as active as in recent years. For instance, when we compare Atlantic basin major hurricanes of the last 11 years (45) with an earlier 11-year period of 1948-1958 (44) we see virtually no difference. If we compare the number of Atlantic basin major hurricanes during the last 20 years (1986-2005) with the 20 year period of 1950-1969, we find the earlier period had 11 more major hurricanes (67 vs. 56) in the Atlantic basin (Table 1). This active earlier period occurred despite the global mean sea-surface temperature (SSTAs) being cooler than the later period. Also, the technology available in the earlier period was less able to document cyclone intensity as well as recent-year observations. It is also likely that hurricane intensity in the earlier period (when the global SSTs were cooler) was, due to limited technology, somewhat under-estimated in comparison to the recent periods.

Table 1. Comparison of numbers of Atlantic basin major (Cat 3-4-5) hurricanes during two recent 11-and 20-year periods to major hurricane numbers in two earlier periods of similar length. Technology changes may have led to reports of higher numbers in the more recent periods.

1948-1958 *(11 years)* **44**	1995-2005 *(11 years)* **45**
1950-1969 *(20 years)* **67**	1986-2005 *(20 years)* **56**

2. MULTI-DECADAL VARIABILITY OF ATLANTIC BASIN MAJOR HURRICANE ACTIVITY

A surprising feature of Atlantic basin hurricane activity is the 20-30 year up-and-down variability in the frequency of major (Cat 3-4-5) hurricanes. Figure 1 illustrates these large swings. During the quarter-century periods of 1900-1925 and 1970-1994 there were only about one-third as many 6-hour periods per year of major hurricane activity as there were in the two periods of 1926-1969 and 1995-2005. We attribute these decadal period differences to the amount of North Atlantic Ocean water which sinks to deep levels off eastern Greenland and western Norway as illustrated in Figure 2. There are multi-decadal periods when there are enhanced amounts of North Atlantic Ocean subsidence (or deep-water formation) in which major hurricane activity is usually 2-3 times greater than when this North Atlantic subsidence (or strength of Thermohaline Circulation) is weaker than average. Figure 3 shows how this North Atlantic circulation can swing back and forth on time scales of 20-30 years. Figure 4 illustrates the large variability in major hurricane activity which occurred when the Thermohaline Circulation (THC) was stronger than average during 1950-1969 vs. when it was weaker than average during 1970-1994.

The combination of the weaker strength of THC and fortunate tracking of major hurricanes has led to a surprising multi-decadal variability to Peninsula Florida's landfalling hurricane activity. Note that Peninsula Florida went 38 years between 1966-2003 with only one major hurricane landfall event (Andrew 1992). Yet in the prior 33 year period (1933-1965) and the following two year period (2004-2005) –a total of 35 years, there were 14 major landfall events (Figure 5). It is no wonder that Florida residents were not mentally prepared for such a sudden onslaught of major hurricanes in 2004-2005.

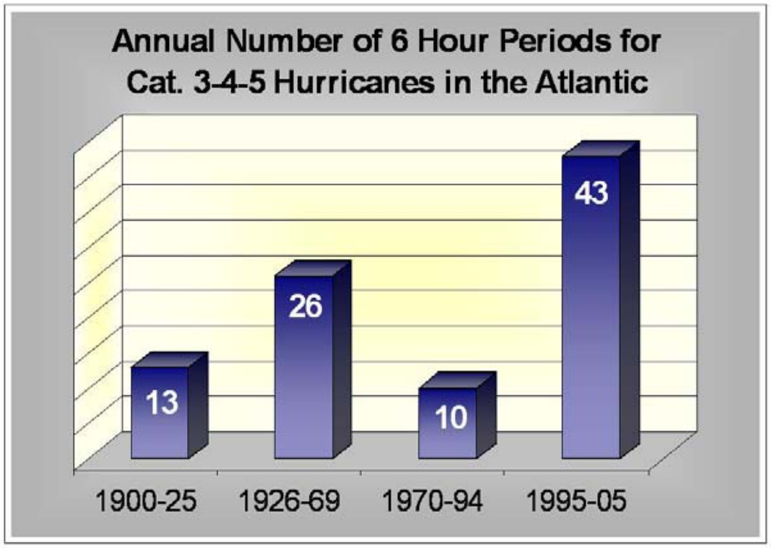

Figure 1. Multi-decadal comparison of number of Atlantic basin annual 6-hour reports of major (Cat 3-4-5) hurricane activity. The two earlier periods may be somewhat of an underestimate.

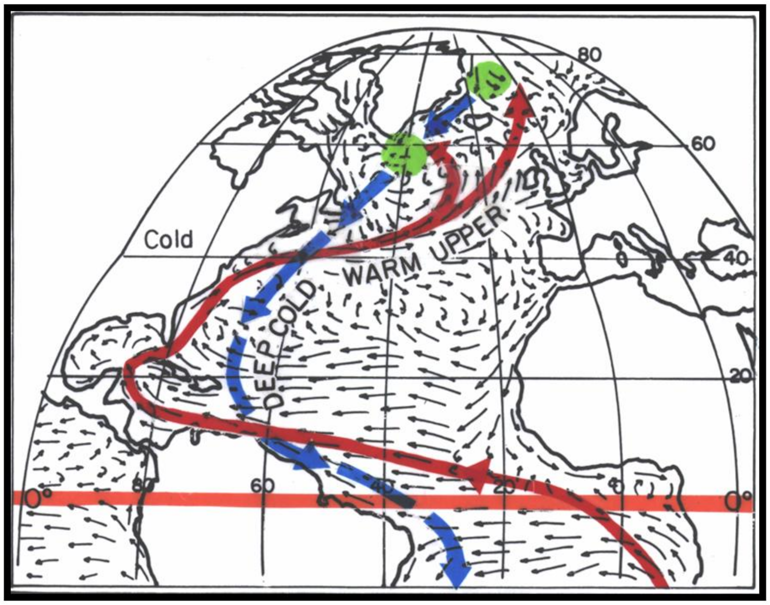

Figure 2. Idealized Atlantic Ocean circulation showing the upper ocean gulf stream (red) and the deep Atlantic return flow. Green circles portray typical area of upper to lower level ocean sinking.

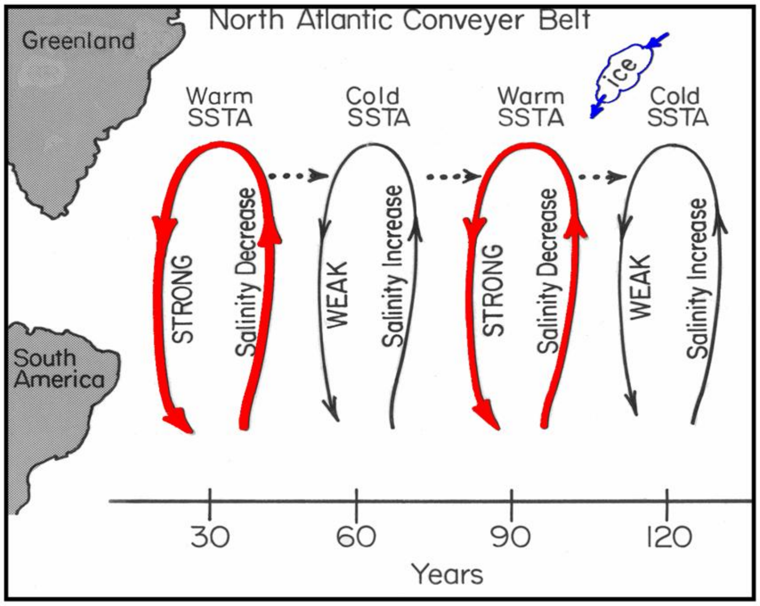

Figure 3. Idealized portrayal of how the Atlantic Thermohaline Circulation (THC) varies from strong to weak and back to strong again on multi-decadal periods due to salinity variations.

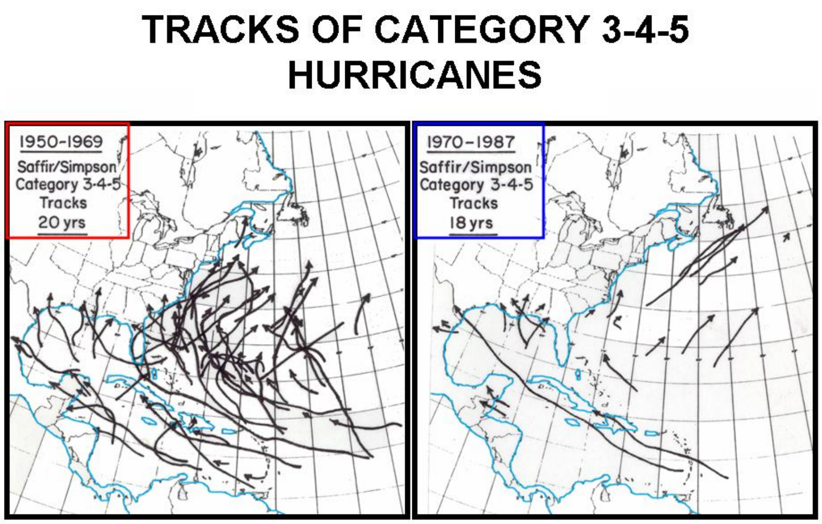

Figure 4. Illustrations of how different were the number of tracks of major hurricanes during the 20-year period of 1950-1969 when the Atlantic Ocean Thermohaline Circulation was strong (left) as compared to an 18-year period of 1970-1987 when the THC was weak (right).

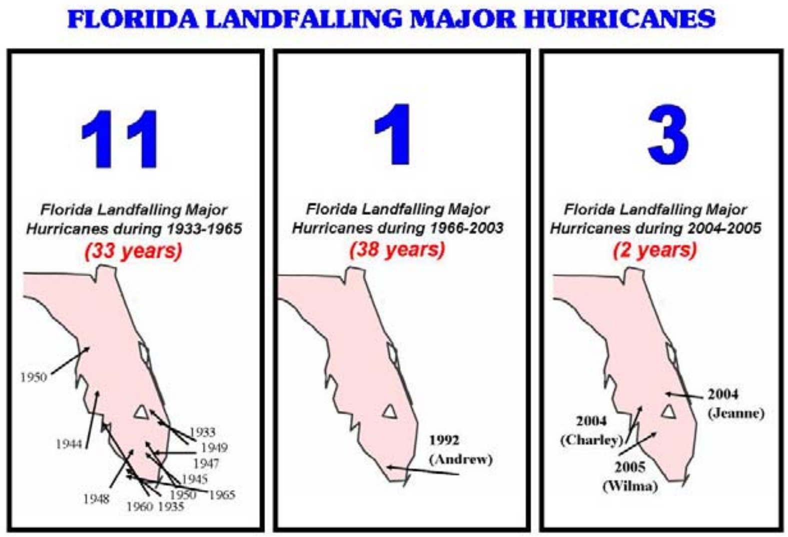

Figure 5. Portrayal of number of landfalling major hurricanes in Peninsula Florida by various periods. Note how fortunate Florida was during the 38-year period of 1966-2003.

There are no direct measurements of the strength of THC. It must be inferred from proxy measurements which are related to its strength. We infer the strength of the THC from a combination of North Atlantic sea surface temperature anomaly (SSTA) in the area between 50^oN-60^oN; 10^oW-60^oW minus the mean Atlantic sea surface pressure anomaly (SLPA) in the broad North Atlantic area of 0-50^oN; 10^oW-70^oW. Figure 6 portrays these areas. Figure 7 is a graph of the yearly combination of these two parameters (SSTA minus SLPA) for the 55 year period of 1950-2005. Note the higher than average values of this parameter between 1950-1967 and 1995-2005. Table 2 gives the average number of Atlantic basin major hurricanes during the two periods of high THC and the period of 1968-1994 when the THC was calculated to be weak. Note that the proxy derived strong vs. weak strength of the THC (given by SSTA minus SLPA) is related to an overall annual variation of Atlantic basin major hurricane activity of 2.32 and of major US East Coast landfall variation of 2.48.

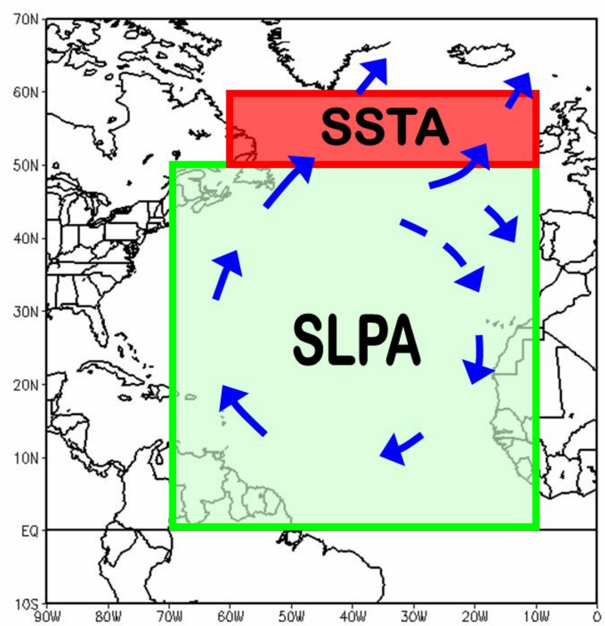

Figure 6. Area of parameters used as a proxy for the strength of the THC. Sea surface temperature anomaly (SSTA in red) and sea level pressure anomaly (SLPA in green).

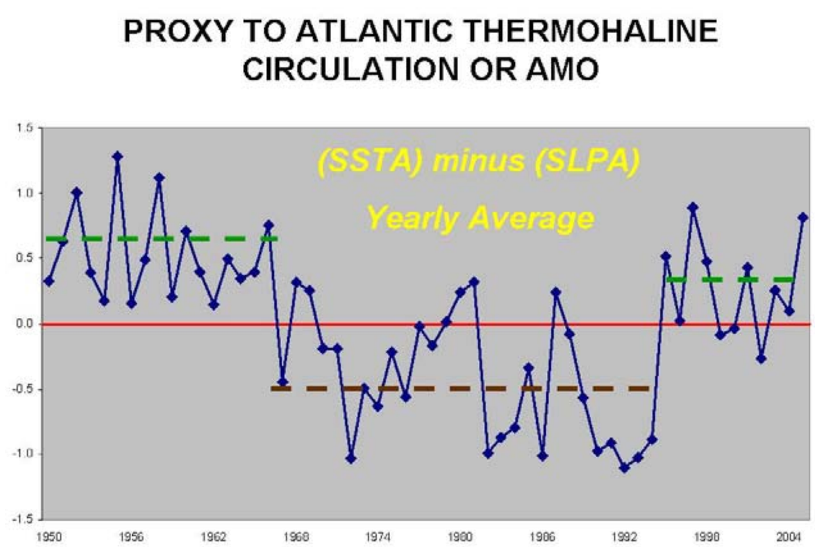

Figure 7. Graph of annual values of SSTA minus SLPA during the last 55 years. Above average values occur when the THC is stronger than average as in 1950-1967 and 1995-2005. During1968-1994 below average values occur when the THC was judged to be weaker than average.

Table 2. Comparison of Atlantic basin major hurricane activity during the two periods when the THC was judged to be strong and in the period between when it was judged to be weak.

Period	**THC Strength**	**Atlantic basin annual average of major hurricanes**	**US annual average of major hurricane landfall**	**US East Coast landfall**
1950-1967 *18 years*	**Strong**	3.44	0.89	.67
1968-1994 *27 years*	Weak	1.59	0.56	.22
1995-2005 *11 years*	**Strong**	4.09	1.00	.36
Ratio of Strong/Weak THC years		2.32	1.66	2.48

Figure 8 illustrates the amount of Atlantic basin major hurricane activity during the 25-year period during 1945-1969 when the globe was undergoing a general cooling and the THC circulation was judged to be strong versus the 25-year period of 1970-1994 when the THC circulation was weak but global warming was occurring. Note how Atlantic basin major hurricane activity was much greater (about 2 ½ times more) during a period of global cooling and that significantly less Atlantic basin major hurricane activity was occurring during a 25-year period when the globe was undergoing warming. This data indicates that the THC trumps any global temperature changes that may be occurring.

Figure 9 illustrates the annual average differences in Atlantic major hurricane activity within the overall global warming period between 1970-2005. Note that when the THC was generally weak as during the global warming period 1970-1994 the annual average of major hurricane activity was much less than it has been during the last 11-year period 1995-2005 when the THC has been strong. This illustrates again that the THC is a dominant player in Atlantic major hurricanes. Figure 10 shows a longer time-series of the THC circulation going back over 140 years. Not the multi-decadal periods of back and forth swing of the North Atlantic temperature anomaly. There have been nearly twice as many Atlantic basin major hurricanes during the warm versus compared to the cooler periods.

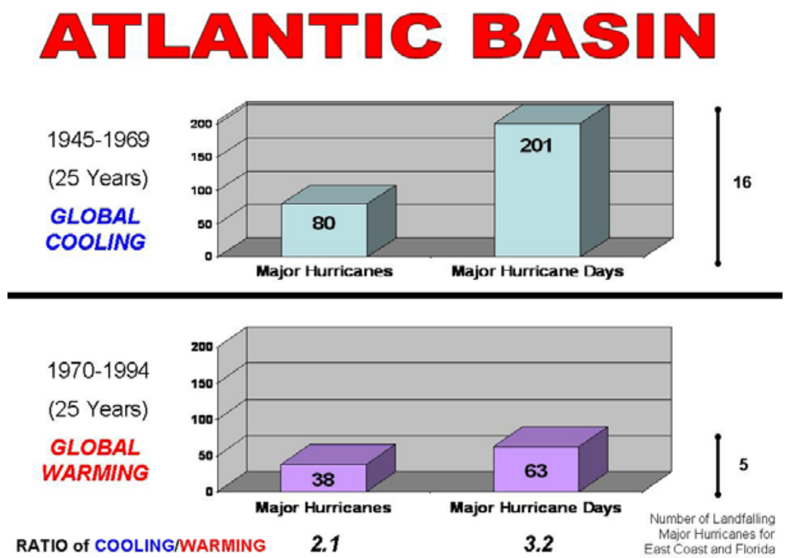

Figure 8. Comparison of Atlantic basin hurricane activity during two 25-year periods during which the globe was cooling (top – more hurricane activity) and in a similar 25-year period when global warming was occurring (bottom – less hurricane activity). Numbers to the right (16 and 5) give the number of US landfall major hurricanes during the eastern US during each time period.

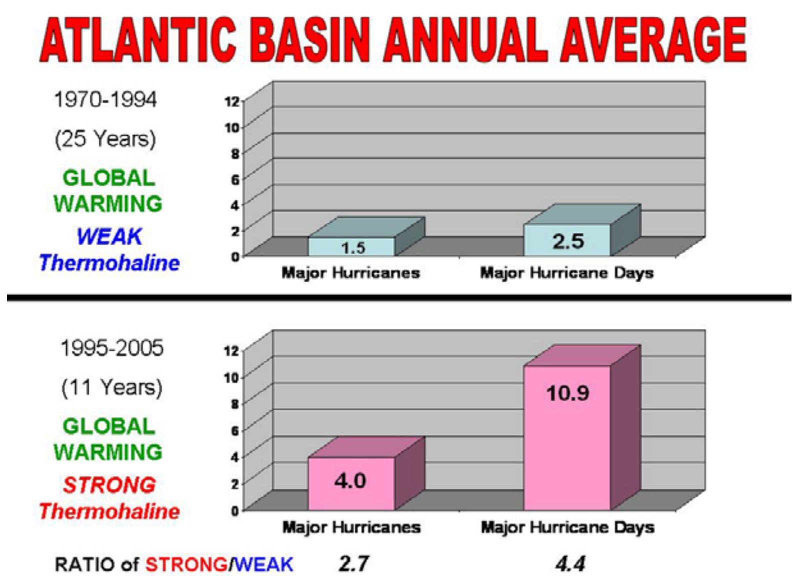

Figure 9. Comparison of Atlantic basin major hurricane activity during two periods when global warming was occurring. The top gives the annual major hurricane activity when the THC was weak and the bottom during the last 11 years when THC was strong.

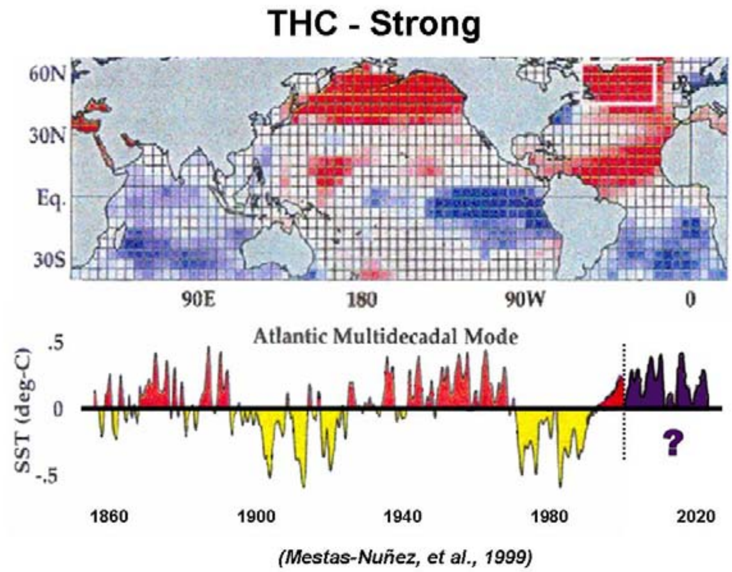

Figure 10. Ilustration of the relative changes in Atlantic thermohaline circulation (THC) over the last 145 years and extrapolation to 2020 (bottom). Red color indicates when THC was stronger than average, yellow color when it was weaker than average. The top diagram shows the typical global sea surface temperature (SST) condition which is associated with a strong THC. Red gives positive SST anomalies, blue are negative SST conditions. The opposite SST conditions occur when the THC is weaker than normal. Note the 3 distinctive multi-decadal periods when the THC is above average and the two periods when it was below average.

3. DETERMINATION OF HURRICANE INTENSITY

There always has been, and there probably always will be, problems in assigning an accurate and representative maximum surface wind to a hurricane. As technology advances and the methods of determining a hurricane's maximum winds become more accurate, different values of maximum winds (generally higher) will be assigned to hurricanes than would have been possible in previous years. Advancement in technology is, in general, telling us that hurricanes are somewhat stronger than we have previously thought.

With the availability of new aircraft-deployed inertial dropwindsondes and the new step-frequency surface wind measurement instruments on the reconnaissance aircraft, it is being established that a portion of Atlantic hurricane surface winds are stronger than they were previously thought to be when surface winds were estimated from downward extrapolation of upper-level aircraft measurements. Although most of the comparative differences in the 45 Atlantic basin major hurricanes of the last 11 years (1995-2005) vs. the 15 major hurricanes of the prior 11 years (1984-1994) is thought to represent real variability, a small part of this difference may be due to the assignment of a Category 3 status to a few hurricanes which in earlier years might have received a weaker designation.

4. PERSPECTIVE ON THE LAST TWO HURRICANE SEASONS

We should interpret the last two years of unusually large numbers of US landfalling hurricanes as natural (but very low probability). During 1966-2003, US hurricane landfall numbers were substantially below the long-term average. In the last two seasons, they have been above the long-term average. This is how nature often works. We should not try to read more into these years than this. Although the 2004 and 2005 hurricane seasons have had an unusually high number of major landfall events, the overall Atlantic basin hurricane activity has not been much more active than it was in seven of the recent hurricane seasons since 1995 (1995, 1996, 1998, 1999, 2000, 2001, 2003). What has made the 2004-2005 seasons so unusually destructive is the high percentage of major hurricanes that moved over the US coastline. These landfall events were not primarily a function of the overall Atlantic basin net major hurricane numbers, but rather of the favorable broad-scale Atlantic upper-air steering currents which were present the last two seasons. It was the favorable Atlantic basin steering currents (produced by middle troposphere high pressure or ridge conditions over the Northeast US) which caused so many of the major hurricanes which formed the last two years to move further westward than normal and come ashore.

It is rare to have two consecutive years with such high numbers of landfalling major hurricanes. The historical records and the laws of statistics indicate that the probability of seeing another two consecutive hurricane season like 2004-2005 is very low. Even though we expect to see the current active period of Atlantic major hurricane activity continue for another 15-20 years, it is statistically unlikely that any future two consecutive year periods will have as many major US hurricane landfall events as were seen in 2004-2005 period. It is possible; however, that US hurricane destruction could be as high as ~ $100 billion if a major hurricane were to make landfall in a few highly populated metropolitan areas such as Galveston-Houston, New Orleans, Tampa, the gold coast of SE Florida and/or Long Island-NY City.

The large increase in hurricane-spawned destruction of the last two seasons has not surprised us as it likely has surprised many others. We have been anticipating a great upsurge in hurricane destruction for many years. The following are a few quotes from our previous Colorado State University forecast papers:

April 1989: “Because of the rapid growth in U.S. coastal population and property investment in recent years… it would appear that major increases in hurricane-spawned coastal destruction are inevitably to come.”

August 1996: "There has been a significant lull in the incident of intense category 3-4-5 hurricanes striking the U.S. East Coast, Florida and Caribbean basin (except for 1995) during the last 25 years. We see this trend as a natural consequence of the slowdown in the Atlantic Ocean Thermohaline Conveyor Belt circulation which appears to be associated with a long list of concurrent global circulation changes during the last quarter century... Both historical and geological (proxy) records indicate that this lull in major hurricane activity will not continue indefinitely; the return of increased major landfalling hurricane activity should be expected within the next decade or so… Increased intense hurricane activity striking U.S. coastal area is an assured threat to the U.S., much more so than earthquakes, greenhouse gas warming and other environmental problems which are receiving comparatively much greater attention."

June 1997: "Recent data and historical and geological (proxy) records indicate that this extended lull in major hurricane activity is unlikely to continue. A new era of major hurricane activity appears to have begun with the unusually active 1995 and 1996 seasons… As a consequence of the exploding U.S. and Caribbean coastal populations during the last 25-30 years, we will begin to see a large upturn in hurricane-spawned destruction – likely higher than anything previously experienced."

April 2001: "It is highly likely that climatology will eventually right itself, and we must therefore expect a great increase in landfalling major hurricanes in the coming decades. With exploding southeast coastal populations, we must also prepare for levels of hurricane damage never before experienced."

August 2001: "We owe our good fortune to a persistent upper-air trough which has been located along the U.S. East Coast during a high percentage of the time during the last six hurricane seasons. This fortunate trend has caused a large portion of otherwise northwest moving major hurricanes to be recurved to the north before they reached the U.S. coastline. However, our good luck cannot be expected to continue forever."

May 2002: "If the future is like the past, it is highly likely that very active hurricane seasons will again emerge during the next few years, and the prospects for very large U.S. and Caribbean increases in hurricane damage over the next few decades remains high. We should indeed see future hurricane damage much greater than anything in the past as future storms begin to impact the very greatly increased coastal population and property values."

May 2003: "Regardless of whether a major hurricane makes landfall this year, it is inevitable that we will see hurricane-spawned destruction in coming years on a scale many, many times greater than what we have seen in the past."

5. HURRICANE INTENSITY AS RELATED TO INCREASES IN GLOBAL MEAN SEA SURFACE TEMPERATURE (SST)

There is no physical basis for assuming that global Atlantic hurricane intensity or frequency is necessarily related to global mean surface temperature changes of less than ± 0.5^{o}C. As the ocean surface warms, so too do global upper air temperatures to maintain conditionally unstable lapse-rates and global rainfall rates at their required values. Seasonal and monthly variations of sea surface temperature (SST) within individual storm basins show only very low correlations with monthly, seasonal, and yearly variations of hurricane activity. Other factors such as tropospheric vertical wind shear, surface pressure, low level vorticity, mid-level moisture, etc. play more dominant roles in explaining hurricane variability than do sea surface temperature. Although there has been a general global warming over the last 30 years, SST increases in the individual tropical cyclone basins have been smaller than the overall global temperature increase (about half) and, according to the observations; have not brought about any significant increases in global major tropical cyclones. No credible observational evidence is available or likely will be available in the next few decades which will be able to directly associate global surface temperature change to changes in global hurricane frequency and intensity.

Although there has been a general warming of the globe in recent decades, observations do not show increases in global tropical cyclone activity. The new analysis of Klotzbach (2006) shows no increase in global TC frequency and intensity over the last 20 years when global mean temperatures have been rising (Figures 11 and 12), and global satellite technology has advanced to the stage where reliable non-Atlantic intensity estimates can be made. Klotzbach also shows that except for the Atlantic and the Northeast Pacific, there is no significant correlation between SST and hurricane intensity in the four TC basins of the Northwestern Pacific, the North Indian, the South Indian and the South Pacific.

One of the most misunderstood topics in tropical meteorology is the association of sea surface temperatures (SSTs) and tropical cyclone frequency and intensity. Although local areas of warmer SST, such as along the Atlantic Gulf Stream and over the Gulf of Mexico loop current may act to enhance individual hurricane intensification, one should not conclude that these observations that a direct SST-hurricane intensity relationship exists that would also be applicable to a global warming scenario.

Such local patches of warm SST can increase local convective buoyancy (where upper-tropospheric temperature-moisture contents remain the same) and allow for the potential for greater deep cumulus convection and hurricane intensity increases. Such changes in convective buoyancy should not be expected to occur in a slow multi-decadal global warming scenario, however. Here the whole troposphere warms in unison with the surface temperatures, global rainfall rates are not significantly altered, and tropical cyclone basin convective buoyancy patterns do not change. There is thus no reason to expect that convective buoyancy (a required component for increased hurricane intensity) will become significantly greater in a global environment where mean SSTs are a little warmer than current global temperatures.

In distinguishing between active and inactive Atlantic basin hurricane seasons, the author and his colleagues have found that seasonal changes in SST explain just a small portion (about 10%) of the variance of seasonal and monthly hurricane activity. Other factors such as tropospheric vertical wind-shear, low-level horizontal wind-shear, middle level moisture, strength of the Atlantic equatorial trough, etc. play much more important roles in explaining Atlantic seasonal and monthly hurricane variability. This has also been found and discussed by Shapiro and Goldenberg (1998). Hurricane intensity is also a function of eye-wall size, depth of ocean mixed layer, cyclone motion, and other factors not necessarily related to global sea surface temperature.

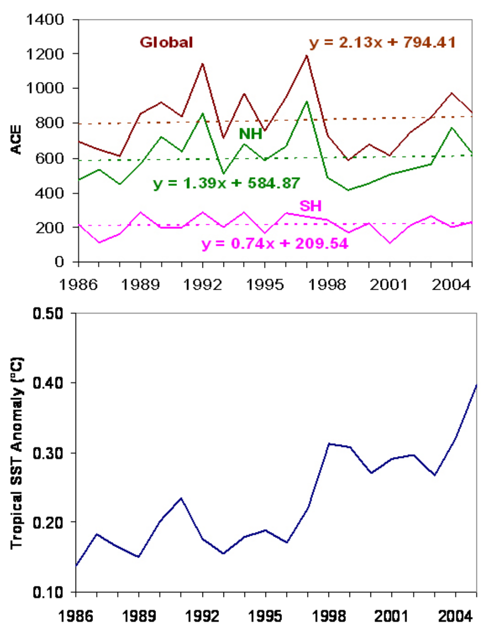

Figure 11. Accumulated Cyclone Energy (ACE) index values for 1986-2005 for the Northern Hemisphere (NH) green line, the Southern Hemisphere (SH) pink line, and the globe (brown line) (from Klotzbach, 2006). Linear trends have been fitted to the three curves. Five-year running mean tropical NCEP Reanalysis SST anomalies (23.5^{o}N-23.5^{o}S, all longitudes) blue lines are also plotted. The base period for tropical SSTs is 1951-1980. ACE is the sum of the square of each cyclone's maximum wind at each 6-hour measuring period.

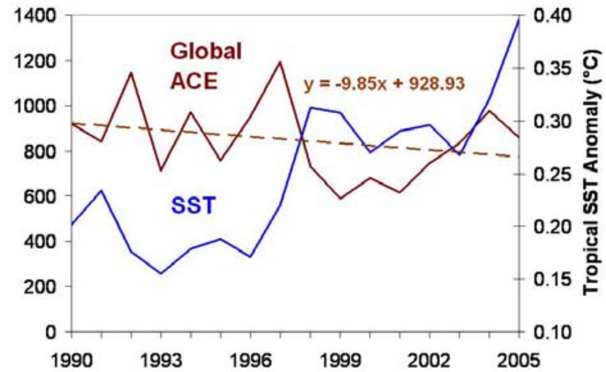

Figure 12. Global Accumulated Cyclone Energy (ACE) index values for 1990-2005 (brown line). A linear trend has been fitted to global ACE. Five-year running mean tropical NCEP Reanalysis SST anomalies (23.5°N-23.5°S, all longitudes) blue lines are also plotted. The base period for tropical SSTs is 1951-1980 (from Klotzbach, 2006).

Although the climatology of Atlantic major (Cat 3-4-5) hurricane activity sharply peaks around 10 September (Landsea, 1993), Atlantic SST variations do not peak around this period. They are no higher around 10 September than they are a month earlier or a month later when major hurricane frequency is typically much less frequent. Such strong Atlantic peaking of major hurricane activity without a similar peaking in SST shows that SST by itself is not a dominant factor.

It should also be noted that there can be quite strong high latitude tropical cyclones existing over ocean surface water temperature 3-5°C cooler than SST conditions in the tropics. In these cases, low-level temperatures are 3-5°C colder, but the potential buoyancy can be maintained by similar upper-level cooling brought about by upper-level cold air advection. Thus, it should not be expected that if the earth were to continue to warm as it has for the last 30 years that global tropical cyclone activity would necessarily be more frequent and/or more intense.

6. THE GROSS EXAGGERATION OF HUMAN INDUCED GLOBAL WARMING

Over the last 20 years, I have been dismayed over the bogus science and media hype associated with the nuclear winter and the human-induced global warming hypotheses. My innate sense of how the atmosphere-ocean functions does not allow me to accept either of these scenarios or the new scenario that a portion of the US hurricane destruction over the last two years is a result of human influences on global temperature. Observations and theory do not support these ideas.

Few people know enough about how the atmosphere and oceans function to be able to judge the validity of these claims. Warming advocates and the media have adroitly exploited this general lack of knowledge on how the global climate system functions to justify themselves and their organization's agendas. I do not believe most of the statements concerning human-induced global warming that have previously been made by former Vice-President Al Gore in his new book and his new film on this topic. The scientific questions are far from being settled. Most of my meteorology and climate colleagues are quite skeptical of the human-induced scenarios which have been so confidently advanced by the warming advocates. The global average temperature changes we have seen over the last century and the last 30-years are, in my view, and the view of most of my colleagues (whose opinions I value), of natural origin.

There are many other physical processes which can cause global warming besides an increase in human-induced greenhouse gases. It is nature that we have to worry about, not human-induced influences. My great skepticism of both human and natural global warming influences on the alteration of Atlantic basin hurricane activity is shared by most of us who have spent our careers studying hurricanes. This includes most of the hurricane forecasters and researcher of NOAA and most of the retired former National Hurricane directors, such as Neil Frank, Robert Sheets and Jerry Jarrell, and nearly all of my long-period hurricane research colleagues. I find that, in general, it is those meteorologists or climatologists who have had limited operational or research backgrounds who are most prone to claim a human-induced component to the 2004-2005 increase in US hurricane damage. Most of those who claim such a global warming – hurricane intensity association have a vested interest in having this idea accepted so they can request research funds to study the relationship in greater detail.

7. WHAT OTHERS SAY

I fully subscribe to the view expressed by Max Mayfield, Director of the NOAA National Hurricane Center when he stated (20 September 2005) before the Senate Committee of Commerce, Science and Transportation Sub-Committee:

> "We believe this heightened period of hurricane activity will continue due to multi-decadal variance, as tropical cyclone activity in the Atlantic is cyclical. The 1940s through the 1960s experienced an above average number of hurricanes, while the 1970s into the mid-1990s averaged fewer hurricanes. The current period of heightened activity could last another 10-20 years. The increased activity since 1995 is due to natural fluctuations/cycles of hurricane activity, driven by the Atlantic Ocean itself along with the atmosphere above it and not enhanced substantially by global warming. The natural cycles are quite large with an average of 3-4 major hurricanes a year in active periods and only about 1-2 major

> hurricanes annually during quiet periods, with each period lasting 25-40 years".

I also fully subscribe to the views expressed in the new paper titled "Hurricanes and Global Warming" which will soon be published in the **Bulletin of the American Meteorological Society (June 2006)**. This paper is authored by:

- *Roger Pielke*, Jr., Director, Center for Science and Technology, U. of Colorado;
- *Christopher Landsea*, Dir. of Research, NOAA Nat. Hurricane Center, Miami, FL;
- *Max Mayfield*, Director, National Hurricane Center, Miami, FL;
- *James Laver*, Director, NOAA National Climate Center, Washington, DC; and
- *Richard Pasch*, Hurricane Specialist, NOAA Nat. Hurricane Center, Miami, FL

and makes the following statements:

> "Since 1995 there has been an increase in frequency and in particular the intensity of hurricanes in the Atlantic. But the changes of the past decade are not so large as to clearly indicate that anything is going on other than the multi-decadal variability that has been well documented since at least 1900 (Gray et al. 1997; Landsea et al. 1999; Goldenberg et al. 2001)"......

and

> "Globally there has been no increase in tropical cyclone frequency over at least the past several decades (Lander and Guard 1998, Elsner and Kocher 2000). In addition to a lack of theory for future changes in storm frequencies, the few global modeling results are contradictory (Henderson-Sellers et al. 1998; IPCC 2001)"

8. INSURANCE DISCUSSION

The great natural attraction and the desire of people to live along US coastal locations vulnerable to hurricanes will continue to increase. This is understandable. The statistical probability of a hurricane making landfall at any one location along the southeast US coastline in any year or decade is very low. Most coastal locations will experience decades of enjoyable coastal living without any hurricane problems. But they must realize that living in vulnerable coastal areas has its occasional drawbacks. They must pay for the added insurance protection for their location and/or be willing and sufficiently wealthy to absorb large property losses should a hurricane make landfall.

9. ASSUMPTIONS

Our country needs a vibrant insurance industry that is willing to sell hurricane coverage to any person or group who desires it. But insurance companies have to show profits to attract needed investment. Investment in the insurance industry will surely follow insurance profits. This can only be accomplished if insurance rates are allowed to float to levels which make them actuarially sound with regard to our country's long-term hurricane risk. Due to the new era for increased US major hurricane landfall which our country is in, hurricane risk over the next 15-20 years will be much higher than it has been over the last 40 years where we have witnessed a natural downturn in US landfalling US major (Cat 3-4-5) hurricane activity. The large downturn in US hurricane damage of the 34-year period between 1966-2003 was not at all representative of the last 2 years and will likely not be representative of what we are likely to see over the next 15-20 years. Hurricane landfall conditions and risk has undergone large changes in recent years. The best available evidence indicates that annual US hurricane damage is going to undergo a large increase over the next 15-20 years in comparison with the prior 38-year period of 1966-2003. This expected increase should be considered a natural phenomenon of the Atlantic basin ocean circulation. It should not be associated with global warming or increases in human-induced greenhouse gases.

It is important that the insurance industry not embrace the human-induced global warming rationale for increased hurricane destruction that has been advanced by those attempting to profit from this scare. There is no way such hypothesized human intervention of hurricane activity could be incorporated into insurance actuarially rate structures, even if it were true. Nature is difficult enough to deal with without having to factor in the false speculations of credentialed scientists who have little knowledge of hurricane-climate relationships, but strong desires to profit from the general ignorance on this topic.

The problems arising from insurance companies pulling out of coastal markets – such as South Florida, can only be solved by the development of a new national insurance regulation standard. It is assumed that the goal of both the general public and the insurance industry is to arrange that future insurance hurricane financial losses be made as actuarially realistic as possible and that the rate structure be able to cover most of the catastrophic hurricane events. The attempt should be to reduce, as much as possible, the need for federal government economic assistance in rebuilding. Coastal residents should assume as much as possible the economic consequence of their choosing to live along hurricane-vulnerable coastlines.

> It is recognized, however, that a few rare catastrophic hurricane events (such as Katrina) will be beyond the ability of the insurance industry to handle – and that some federal government intervention for rebuilding will be necessary.

To accomplish such a desired actuarially sound US insurance industry for hurricane loss it is inevitable that insurance rates will have to substantially rise to meet the increased natural vulnerability of our southeastern coastlines. It is recognized that these rate increases may be beyond the ability of many less affluent coastal residents to pay. It should be expected that economic pressures will, over time, gradually force many less affluent US coastal residents to move to less vulnerable locations.

Catastrophic hurricane damage (>$50 billion in current dollars) occurs when a major hurricane goes into a heavily populated area. Over the last century, these normalized event losses occurred about once per decade. As coastal populations and property increase, we should expect catastrophic hurricane damage to become more frequent, perhaps one event about every 5-8 years. It is also possible (but statistically, a very low probability) to have two or more US landfall catastrophic events in one year. Although the US experienced seven major hurricane landfall events (Charley, Frances, Ivan, Jeanne, Katrina, Rita and Wilma) during 2004-2005, it is only Katrina that can be defined as a catastrophic event.

It is inevitable that hurricane-spawned destruction will sharply rise in the coming years due to increased coastal population and property values. It is possible, however, that per-capita insurance rates will not have to rise as much as might be envisioned if the majority of the new and older coastal residents take out coverage. An ever increasing home owner and business owner insurance coverage base should help alleviate a portion of the required increased insurance needs and aid in keeping per-capita coverage at a manageable level.

10. RECOMMENDATIONS FOR THE INSURANCE INDUSTRY ADJUSTING TO THE INEVITABLE INCREASE IN US HURRICANE DESTRUCTION

1. Insurance companies need to be allowed to set aside a portion of their yearly profits as tax-free investment to cover inevitable future catastrophic losses.

2. Insurance coverage rates should not be regulated by individual state government commissions. Rates should be allowed to float in conformity to the last century US hurricane landfall frequency/intensity statistics and current coastal population and property values. Fifty year probability values by US coastal region – down to the county level (205) are available on our website (http://www.e-transit.org/hurricane/welcome.html) see Figure 13. These probabilities are based on 100 years (20th century) of US tropical storm and hurricane landfall statistics. We believe these 50-year landfall probabilities can be used to estimate relative US landfall frequency/intensity. Hurricanes do not know state boundaries. Insurance

rates should be nationally based on the last 100 years of US landfall hurricane frequency and intensity.

3. Wind engineers have verified that homes and business structures can be built to withstand all but the strongest hurricane wind speeds with a small percentage added to building costs. Also, retrofitting of most homes and businesses to withstand hurricane-force winds is quite feasible. There needs to be a national building and retrofitting code established for hurricane vulnerable coastal structures, and these codes need to be enforced. There are, however, diminishing return limits for some home and business construction for hurricane wind mitigation. It may not be cost-efficient to attempt to build structures to withstand Category 4-5 hurricane winds in areas of low major hurricane landfall probability.

County (High) Information	
Name	Miami-Dade FL
Region	6
Region - Coastline Distance	483
Region - 2000 Population	5,213,884
Region - Named Storms (1900-1999)	47
Region - Prob. 1 or More NS	54.4% (37.5%)
Region - Prob. 2 or More NS	11.8% (8.1%)
Region - Hurricanes (1900-1999)	34
Region - Prob. 1 or More H	41.8% (28.8%)
Region - Prob. 2 or More H	6.7% (4.6%)
Region - Intense Hurricanes (1900-1999)	16
Region - Prob. 1 or More IH	21.4% (14.8%)
Region - Prob. 2 or More IH	1.7% (1.2%)
Region - Prob. TS Force	44.3% (30.5%)
Region - 50 Year TS Prob.	100.0%
Region - NS Vicinity Prob.	98.1% (93.6%)
Region - Prob. H Force	13.5% (9.3%)
Region - 50 Year H Prob.	99.3%
Region - H Vicinity Prob.	70.4% (56.9%)
Region - Prob. IH Force	4.3% (3.0%)
Region - 50 Year IH Prob.	78.1%
Region - IH Vicinity Prob.	32.3% (23.6%)

Subregion:1	6b
Subregion - Coastline Distance (km)	89
Subregion - 2000 Population	2,253,362
Subregion - Prob. TS Force	8.2% (5.6%)
Subregion - Prob. TS Vicinity	52.0% (39.7%)
Subregion - 50 Year TS Prob.	94.5%
Subregion - Prob. H Force	2.5% (1.7%)
Subregion - Prob. H Vicinity	20.1% (14.3%)
Subregion - 50 Year H Prob.	58.0%
Subregion - Prob. IH Force	0.8% (0.6%)
Subregion - Prob. IH Vicinity	6.9% (4.8%)
Subregion - 50 Year IH Prob.	24.1%
County - Coastline Distance (km)	89
County - Inland Border Width (km)	--
County - 2000 Population	2,253,362
County - Prob. TS Force	8.2% (5.6%)
County - Prob. TS Vicinity	52.0% (39.7%)
County - 50 Year TS Prob.	94.5%
County - Prob. H Force	2.5% (1.7%)
County - Prob. H Vicinity	20.1% (14.3%)
County - 50 Year H Prob.	58.0%
County - Prob. IH Force	0.8% (0.6%)
County - Prob. IH Vicinity	6.9% (4.8%)
County - 50 Year IH Prob.	24.1%

Figure 13. Example of the type of tropical cyclone landfall probability information which is available on our Colorado State University website (http://www.e-transit.org/hurricane/welcome.html).

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