Hurricane Season and Climate Change

> "This hurricane season (2005) shattered records that have stood for decades—most named storms, most hurricanes and most category five storms. Arguably, it was the most devastating hurricane season the country has experienced in modern times..." (Navy Vice Admiral (Conrad C. Lautenbacher, Jr., Ph.D., Undersecretary of Commerce for Oceans and Atmosphere, National Oceanic and Atmospheric Administration (NOAA) Administrator)

For decades, scientists have been warning that an increase in global temperature will increase both the number and severity of tropical storm systems. And when it has finally occurred, NOAA's National Weather Service, announced that the increase in intensity of tropical storms was because of naturally occurring cycles and not man-made global warming. When the Atlantic basin has produced two season's worth of hurricanes in a single year, when the ferocity, severity and frequency of hurricanes surpassed everyone's - including scientist's - expectations, the United States National Weather Service can not comprehend the reality that climate change is here and that it is having an effect on this planet. Instead, they maintained their convictions that our

current increase in hurricane frequency and severity has nothing to do with global warming.

The debate on hurricanes and global warming continues with an increasing number of papers arguing that increases in hurricane strength and numbers are due to man-made warming *and* natural cycles, not natural cycles alone. NOAA has however, been a staunch consistent critic of these efforts. In an article on August the 2nd, 2005, in the NOAA Online Magazine, NOAA stated: "Any potentially weak signal associated with longer-term climate change appears to be a minor factor."[1] Max Mayfield, director of the Tropical Prediction Center at the National Hurricane Center in Miami, Florida confirmed NOAA's position on global warming and hurricanes with congressional testimony on September 20, 2005.

But the big news came on November 29, 2005 in another article in the NOAA Online Magazine. This time, in an article entitled, "*NOAA Attributes Recent Increase in Hurricane Activity to Naturally Occurring Multi-decadal Climate Variability"*, NOAA made their position clear by stating, "NOAA research shows that the tropical multi-decadal signal (natural hurricane intensity cycle) is causing the increased Atlantic hurricane activity since 1995, and is not related to greenhouse warming." In the November paper, NOAA also said: "There is consensus among NOAA hurricane researchers and forecasters that recent increases in hurricane activity are primarily the result of natural fluctuations in the tropical climate system known as the tropical multi-decadal signal."[2]

They just could not have been leading the country in a worse direction, but like many other leaders in this country at this time – they were. Their statements to the contrary of significant scientific position helped mislead the American public down the all to familiar path of climate change denial. This is a social misstep that is not easily undone. This is the 'National Weather Service' of the United States of America - the primary source of weather information for the greatest country on the planet. Playing the conservative side of the debate is one thing, but blatantly ignoring timely research is a different matter.

Fortunately, cooler heads prevailed. On February 20, 2006, NOAA revised their November 29 article, and formally revised their position on hurricane intensity, natural cycles and global warming. The revised position takes the form of an added editor's note to the November 29 article and reads as follows in the box:

NOAA Editor's Note

> **EDITOR'S NOTE:* *This consensus in this on-line magazine story represents the views of some NOAA hurricane researchers and forecasters, but does not necessarily represent the views of all NOAA scientists. It was not the intention of this article to discount the presence of a human-induced global warming element or to attempt to claim that such an element is not present. There is a robust, on-going discussion on hurricanes and climate change within NOAA and the scientific community.*

Unfortunately, A simple editor's note has extremely small impact compared to the significant influence pedaled by the media during the height of the tremendous 2005 hurricane season.

The Foretelling of Increased Hurricane Strength Due to Global Warming

Increases in Hurricane strength and numbers have been associated with increased ocean water temperatures and man-made global warming for decades.

- In 1955, a book entitled *The Hurricane Hunters*, by Ray Tannehill discussed how the slowly warming Earth, in the present century, is resulting in more hurricanes with greater intensity. Tannehill said that insurance companies had even taken the effects of increasing temperatures and hurricane intensities and numbers into account.[3]

- In 1969 Ooyama; in 1982 Tuleya and Kurihara and in 1994 Evans, et. al. published papers that modeled and discussed increasing tropical cyclone intensity with increasing sea surface temperature. The 1969 experiment by Ooyama even showed how a larger area of warm water could support larger hurricanes like the

larger size of Pacific Hurricanes compared to the smaller Atlantic hurricanes. [4]

- In 1987, Kerry Emanuel, in a paper in the Journal Nature, predicted that maximum hurricane intensity because of man-made warming of our planet would increase by 40% to 50%.[5]

- In 1993, a team of researchers led from the Royal Netherlands Meteorological Institute and the Hadley Center in Britain modeled tropical disturbances and found a 50% increase in the number of tropical disturbances and a 20% increase in their maximum strength.[6]

- In 1999, a pair of researchers named Knutson and Tuleya at Princeton's Geophysical Fluid Dynamics Laboratory found that man made increases in atmospheric carbon dioxide caused increases in storm winds of 5% to 11% and 28% increase in precipitation.[7]

We have known for decades that the tropical storm season starts when water temperatures reach 80 degrees. [8, 9, 10] NOAA has traditionally played a significant role in the academic research related to understanding climate factors involved in the formation of severe weather. NOAA along with an even larger portion of the scientific world, is trying to answer the question about hurricane intensity and climate change through traditional statistical analysis of our past climate. They are trying to see statistical trends in the recent past that show more, bigger, wetter, windier or longer hurricanes. There are a number of papers in the scientific literature that argue that there is no connection between a global warming and increases in hurricane strength and frequency. [11,12,13,] These papers all discuss past trends and their conclusions are based on past trends. The recent past however is not well represented in analysis of historic trends. There views of these scientists are now in the minority, and their biggest representative, NOAA, reversed their position on the subject in February 2006. But that has not reversed the impression that these influential resources have had on American leaders and the general population.

Hurricane Wilma, Category 5, October 21, 2005 11:46:20, NOAA Satellite and Information Service, Environmental Visualization Program

Natural Cycles - the Atlantic Multidecadal Oscillation

Our scientific record for hurricane behavior is grounded in well-recognized trends from the 20th century. The Atlantic multidecadal oscillation (AMO) is the most notable trend. This trend is reported to have a very definite affect on hurricane season intensity. Certainly the AMO is responsible for increases in tropical storms that can be seen when we look at the last couple of decades when the AMO was negative. Stanley Goldenberg describes this well-documented natural cycle in the Journal Science in July 2001.[11] Just as certainly, the 1º Fahrenheit average warming of our oceans confirmed

about the turn of the century is going to affect hurricane intensity because this warming increases the available fuel to the tropical storms.[14,15]

To say that global warming has no effect on hurricane season intensity is just not right. The effect is real based on our prior knowledge of the behavior of tropical systems in a warmer environment and this is something that even the contrarians do not deny. Just because the statistics are not accurate enough to show the connection is no reason to discredit the theory. It is a good theory, it has been around since the 1940s, and like gravity, it probably won't ever be replaced by a better one.

Hurricane Rita, Category 5, September 21, 2005 18:03:24, NOAA Satellite and Information Service, Environmental Visualization program

There is another issue to be considered here that makes historic statistics meaningless in this situation. The Earth's climate system has changed. The argument that '*there is no statistical proof that warmer ocean temperatures caused by man can increase the intensity of hurricanes*' is out of place in this discussion. The computer modeling experiments are still valid because we can change the atmosphere and oceans to match our current climate. Historic statistics are based on our old climate. Our climate has changed. Ten years ago the trigger flipped. The AMO may have switched at the same time, but that does not really matter. Man-made global warming is affecting not only tropical storm formation, but it is affecting the entire Earth.

Today the predictions and the proof are widespread. This is a fundamental change in our climate that will likely continue to get worse. Global warming is responsible for more, bigger, and more intense hurricanes. NASA, The National Center for Atmospheric Research, The United Kingdom Meteorological Service, The Intergovernmental Panel on Climate Change, the Massachusetts Institute of Technology, Princeton University, Harvard University, the National Research Council, the PEW Climate Center, Lamont-Doherty Earth Observatory at Columbia University and The Georgia Institute of Technology, all agree. Climate scientist of the Union of Concerned Scientists, the National Climate Education Program, the National Center for Atmospheric Research and the National Science Foundation agree also. The list goes on. More study is needed to determine the actual extent to which global warming has affected hurricanes, and what we should anticipate in the future, but the facts are plain and demonstrated by this quote at the American Meteorological Society's 27th Conference on Hurricanes from Greg Holland, a division director at the National Center for Atmospheric Research in Boulder, Colorado:

> "The hurricanes we are seeing are indeed a direct result of climate change and it's no longer something we'll see in the future, it's happening now … The large bulk of the scientific community say what we are seeing now is linked directly to greenhouse gases."

Hurricane Katrina

Hurricane Katrina was the most costly hurricane ever, and was the third most intense. Many factors contributed to these costs. A major factor is the way our population is concentrated along coastal areas. This tendency, even though we are more prepared today than in the past, leads to higher costs because more people are affected.

Hurricane Katrina, Category 5, August 28, 2005 12:37:27, NOAA Satellite and Information Service, Environmental Visualization Program

This is one of the facts of global warming. As sea levels rise, as more tropical storms strike our coasts, there will be higher costs than in the past. It is not just hurricanes - it is droughts and blizzards, floods and snowstorms, heat waves, disease and sea level rise. We have just begun to see the impacts. As climate change progresses and global weather events get bigger, more frequent and more intense, so will the costs of climate change.

There were 18,000 water rescues in the first week after Hurricane Katrina. The storm total number of rescues by the Coast Guard was 33,000. By day ten, 63,000 troops were deployed to assist in rescue and recovery. 25,000 people who had evacuated themselves to the New Orleans Convention Center remained unnoticed by FEMA for three days. The area of total devastation covered 90,000 square miles – an area roughly the size of Great Britain. The storm destroyed or caused catastrophic damage to over 450,000 homes and businesses. And 28 days later, Hurricane Rita, following a similar storm track, became the second most intense hurricane ever recorded. In the 13 month period prior to Hurricane Katrina, there were 4 major storms that struck Florida costing $45 billion. Hurricane Katrina is expected to cost $200 billion. The most costly storms ever recorded prior to Andrew were Hugo, Agnes, Betsy and Camille, in 1989, 1972, 1965 and 1969 with costs of $12.2 billion, $11.3 billion, $10.8 billion and $8.9 billion. The cost of Andrew was more than the four costliest storms to date added together, and Katrina alone will be 5 times more costly than Andrew.

Hurricane Emily

NOAA's post season hurricane analysis showed that Hurricane Emily briefly became a Category 5 hurricane on July 16, 2005 in the Caribbean, with winds of 160 mph and a minimum pressure of 929 mb, about 100 miles southwest of Jamaica. Emily struck the Yucatan Peninsula as a Category 4 and intensified once more over the Gulf of Mexico to a Category 3 before striking land in northern Mexico as a Category 3 hurricane.

There were 6 deaths in the Caribbean. Remarkably, none occurred on the Yucatan Peninsula where nearly 100,000 people (mostly tourists) were evacuated. The level of damage from Emily was light, even though thousands of homes were reported destroyed.

This is one of those cases where better observation techniques could have shown a Category 5 storm when historic observation techniques would have missed this one. Nevertheless, this storm made it to Category 5. In the future, observations are likely to be better than they are today, so we march forward. [2]

Hurricane Emily, Category 5, July 16, 2005, NOAA Satellite and Information Service, Environmental Visualization program

Four Category 5 Storms

The previous record for recorded number of Category 5 storms was two, set in both 1960 and 1961. There have been 25 Category 5 storms recorded since reliable record keeping for hurricanes began in 1947. The 2005 hurricane season represents 19% increase in the number of Category 5 storms since 1945 in just a single year. Three of these storms; Wilma, Rita and Katrina were three of the top six most extreme minimum central pressure storms ever recorded. (Table 1) They were not just Category 5 hurricanes, but three of the six most powerful hurricanes ever recorded.

Just how rare of an event is it that four Category 5 storms happened in one year? Changes to monitoring techniques do allow for the questions to be asked. The answer is: four Category 5 hurricanes have never before occurred. We know that since 1947, our hurricane hunters have flown into virtually every tropical weather system in the

Atlantic basin, and all substantial ones, recording pressure as they went. They could have missed the quick jump and short stay at Cat 5 that occurred during Hurricane Emily, but not the others. We therefore have a pretty good record of hurricane pressures back to 1947.

The period from 1920 through 1960 is an example of a natural positive cycle of increased hurricane intensity that is described by Goldenberg in his 2001 Nature article. We therefore know the potential for maximum storm intensities that we should be expecting now because we are in another positive hurricane intensity cycle. What we must concentrate on is determining if the numbers of hurricanes and their apparent increasing intensities are reflecting the natural cycles, or changes in climate due to global warming, or both. If you answered both, you will most likely be correct.

Table 1
HURRICANE INTENSITY RECORD 1851 to 2005

No.	Name	Year	Pressure
1	Wilma	2005	882
2	Gilbert	1988	888
3	"Labor Day"	1935	892
4	Rita	2005	895
5	Allen	1980	899
6	Katrina	2005	902
7	Camille	1969	905
8	Mitch	1998	905
9	Ivan	2004	910
10	Janet	1955	914

Reference: NOAA Technical Memorandum NWS NHC 22 , A Tropical Cyclone Data Tape for the North Atlantic Basin, 1886-1983, (updated to 2004, by the author to 2005).

Global Warming *and* Natural Cycles

Four important papers in 2005 and 2006 have found that global warming is in fact responsible for an increase in the intensity of hurricanes. These papers generally don't contradict the theory of natural climate cycles influencing hurricane intensity, so the combination of global warming *and* natural cycles is responsible for increasing the number of and intensity of tropical systems even more than the peak from the last natural intensity cycle. This is why we are seeing all of the hurricane records being broken. The Earth's climate has changed.

The purpose of this book is to present all of the science. Whether this science says that global warming is real, or that natural cycles are real, if the research is good enough to be published in a scholarly journal, then that information will be presented. Only recently have a significant number of papers been published that discuss the positive influence of our changing climate on tropical storms. This is the way that science changes - one paper at a time. Scholars are a stubborn bunch, and this is good thing. If it were not for the tenacity of scientists, any old theory could become accepted as the truth and then, well, it could be explained like this: Remember the video clips of all the different flying machine contraptions that were invented early in the 20th century? -the ones that always ended with an inventor's face buried in the dirt, with some sort of crash or flaming contraption? Where would our air transportation industry be today without thorough design and testing of those theories? Our climate theories are proved or disproved the same way. New theories arise as knowledge increases. We know more now than we did then.

Hurricane Hunting – The Reliable Hurricane Record

Atlantic basin aircraft weather reconnaissance became widespread due to World War II in 1944. The first flight into a hurricane actually took place on a dare. During the middle of WWII, at an Air Force base in Bryan, Texas, A pilot trainer flying a Texan AT-6 flew into the eye of a Category 2 hurricane approaching the Texas coast. The flight was successful, so the pilot returned to the hurricane with the base meteorologist, who took notes, and the 53rd Squadron Hurricane Hunters were born.

The B-17 Flying Fortress and the WB-25 Mitchell were the most common planes used by the Army's Hurricane Reconnaissance Unit. In 1945 these planes were stationed

Eyewall of Hurricane Katrina: National Oceanic and Atmospheric Administration, Department of Commerce

around the globe so that they could visually seek out and report on tropical storms on their daily reconnaissance flights. The U.S. Weather Bureau (National Weather Service) began an around-the-clock hurricane warning service for the 1947 hurricane season and hurricane naming began. In the mid 1950s, coastal radar and aircraft reconnaissance for research purposes came into use. In the mid 1960s satellite observation of weather systems was begun. The use of hurricane data for meaningful study has been documented by two significant sources as well. An atlas of hurricane information by Nuemann and colleagues and a paper by Landsea, both from 1993 recommend using data after 1944 for statistical research.[16,17]

New techniques for extending the reliable records are being pursued which include the study sediment deposits in barrier islands, coral growth rings, and tree rings. Hurricanes leave their traces on the environment. Every time a big hurricane crosses a barrier island, the sand deposition on the backside of the dunes changes patterns. It becomes much more grainy as the much more powerful storm systems washes the beach into the interior. Coral grows in layers somewhat like a tree or stalactites. Every year a new layer forms as the seasons and growth patterns repeat themselves. Oxygen ratios in seawater are different in hurricanes vs. plain seawater, so when a hurricane crosses a coral reef it is recorded in the growth rings of the coral. Similarly in trees, hurricane damage has a significant effect on tree growth and the formation of annual growth rings.

More study is required before the scientific research is proven reliable. More time is also required. Data for statistical analysis of hurricane seasons do not just happen overnight. When data is accumulated as slowly as in the annual characteristics of hurricane seasons, decades to perhaps centuries are required for proper analysis. So, what if we are on the brink of a rapid or abrupt climate change? Can we afford to wait until history has accumulated enough information so that scientists can say that there is a trend that supports the increase of hurricane intensity due to man caused global warming?

Many different lines of scientific research can help us to intelligently decide whether or not global warming is and will continue to affect hurricanes, and whether or not hurricanes will continue to become more numerous and more intense. A simple look at the number of storms in each hurricane season back to 1947 helps illustrate how our climate is changing.

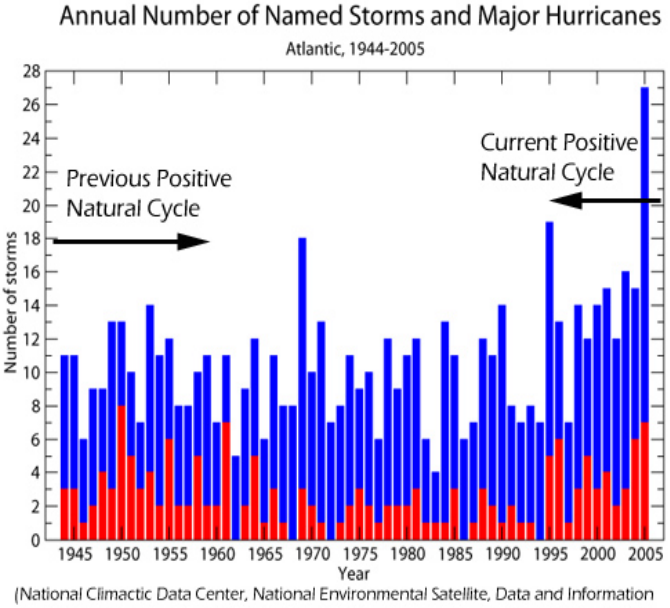
Basics: Increasing Number of Hurricanes

As of the writing of this book, one of the most pervasive theories across academia is that global warming has not increased the number of hurricanes. The reasoning is that statistics do not support an increase over historic numbers of tropical systems. Statistics require many years of data to be proven true. While statistics may not be able

to prove anything yet, that will likely not be the case in the near future. The graph in Figure 2 shows total number of named storms per year in blue and number of major hurricanes in red.

Our current AMO started in the mid 1990s. The last AMO cycle was 1920 through the 1960s. Our current AMO started in 1995.[11] , The graph shows 16 years of the previous positive cycle in natural hurricane intensity and 10 years of the current positive cycle. During the negative cycle between 1960 and 1995 appears to be a slightly fewer number of hurricanes, especially major hurricanes. It is also obvious that there are more hurricanes from 1995 to 2005. If our current AMO were similar to the previous AMO, why are there more storms now than then?

Figure 1

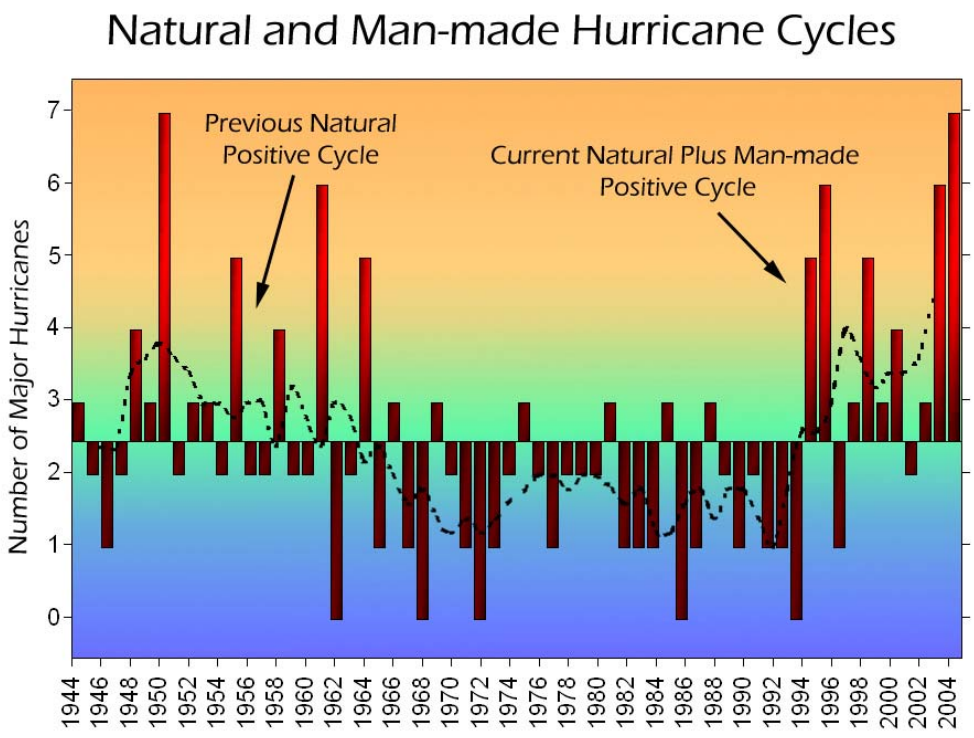


(National Climactic Data Center, National Environmental Satellite, Data and Information Service, National Oceanic and Atmospheric Administration, 2005.)

This is not a statistical analysis it is a simple observation. This is what is called a WYSIWYG demonstration (pronounced wis-ee-wig or What You See Is What You Get). There are many more storms in the current positive cycle than the previous, and probably even more major storms in the current cycle, although that assumption is not as obvious as the total number of storms. This graph is based on a few more years (back to1944) than the reliable record, which only helps to confirm that there have been more storms recently than the past positive cycle.

Figure 2 shows only major hurricanes. This is the first graph in the Goldenberg paper from 2001 that discusses why hurricane intensities and numbers are not being influenced by global warming.[11] The author has extended the data to include the 2005 season. In this graph it is blatantly obvious that something out of the ordinary is going on. The current natural positive intensity cycle is so much bigger than the previous cycle that there really can be no doubt about the recent studies theorizing that global warming is increasing the intensity of hurricane season. There is one more thing that needs to be said about data and statistics. If the last 5 years of data are left off of this graph, is it any wonder that Goldenberg and his colleagues understood that there were no connections between global warming and Hurricanes?

Figure 2



Original Data Source: Goldenberg et. al., The Recent Increase in Atlantic Hurricane Activity: Causes and Implications, Science, July 2001. Dashed line is 5-year running average

Another way of identifying when a drastic change has taken place in a long term predictable pattern could be to take a close look at the accuracy of long-term predictions. Dr. William Gray of has just this sort of record that is highlighted in the next section.

Dr. William Gray – A Lifetime of Hurricane Forecasting

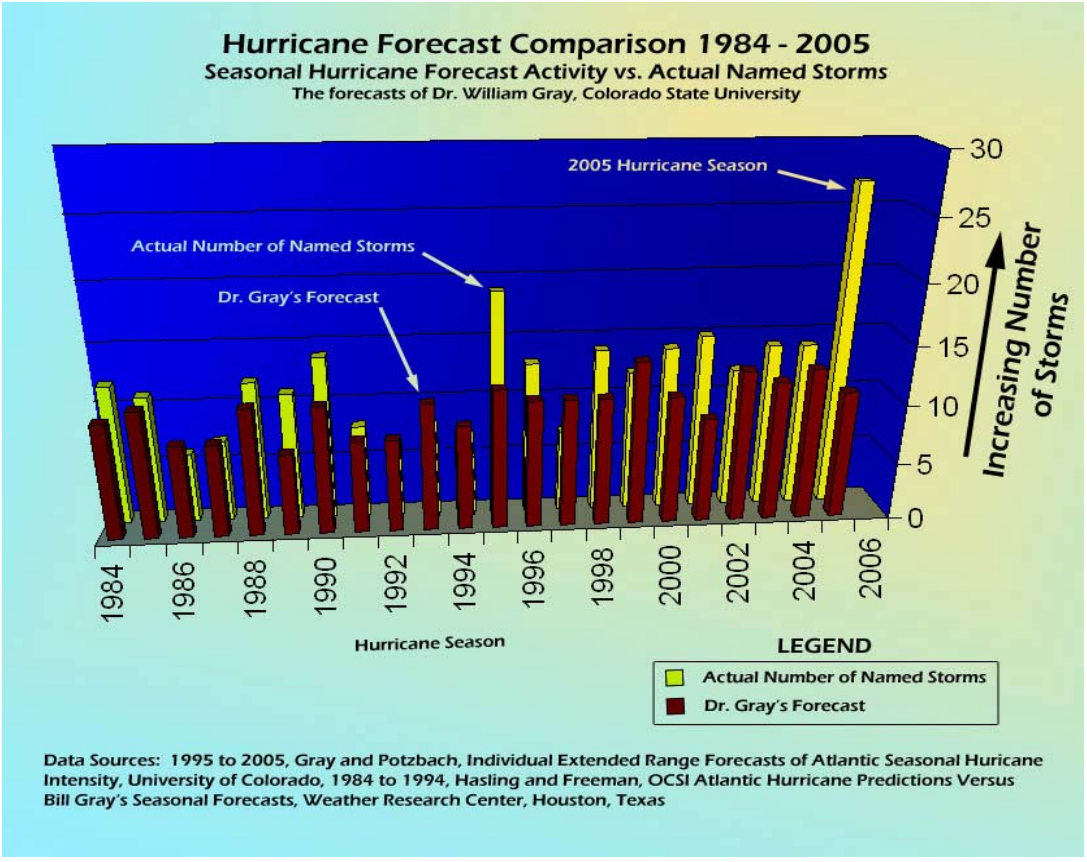
William Gray, Professor Emeritus, is a National Science Foundation sponsored tropical cyclone research scientist for the Department of Atmospheric Science at the University of Colorado. He pioneered long-range hurricane forecasting using global teleconnections with his first forecast in 1984. He has the longest existing track record of Atlantic Basin hurricane forecasting and is more often quoted for his forecast than the National Weather Service.

Dr. William Gray strongly believes that natural cycles justify the recent increases in hurricanes.[11] His rebuttal to the 2005 paper in the journal Science by Webster and colleagues and the 2005 paper in the journal Nature by Kerry Emanuel makes numerous observations as to the accuracy of the two papers.[18] Kerry Emanuel addresses these comments in his January 2006 rebuttal response.[19] Emanuel's actions reflect adjustment of his paper to fit comments by Gray, or justification as to why Gray's comments are not applicable. These issues do not seem to change the outcome of Emanuel's assumptions but do bring an important climate change concept into focus. Statistical observations on our past climate may not be so valid for our present or future climate. The point, once again, is that it is the big picture that counts.

Important scientific conclusions sometimes rely solely on statistical observation of the past. These observations are often quite correct however; it would in no way be appropriate to say that only Gray is correct, or that Webster and Emanuel are wrong. Only the future will tell us that. Like global warming science - it took many, many years before the general concepts of the science were accepted as reality. Many of the details are still in dispute.

Many different aspects of the 2005 hurricane season were not only out of the ordinary, but have never before happened in the historic record. The science of hurricane forecasting is said to still be in its infancy. In the last 30 years NOAA has decreased its error in its three-day hurricane forecasts from 520 miles to 140 miles. Hurricane intensity forecasting however, is far less accurate. Max Mayfield, the director of NOAA's National Hurricane Center is quoted here at the Senate Disaster Prevention and Prediction Hearing in September 2005 "Predicting hurricane Intensity remains a challenge. …While we accurately predicted the intensity (Hurricane Katrina) at landfall, there is still more work to be done in improving intensity prediction, especially for rapidly intensifying or rapidly weakening storms." [20, 21]

Figure 3



Dr. Gray's 2005 hurricane forecast started off in December 2004 with 11 hurricanes. The April update was for 13 storms, the May update was for 15 storms, and the August through October updates were all for 20 storms. The season ended with 28 storms.

What happened? Dr. Gray's forecast for the previous 22 years were much closer than this, as is normal with his forecasts. The largest error he had during this period was 67% in 2001, followed by 58% in 1995 and 57% in 1989. His average error prior to 2005 was 24%. His error in 2005 was 155%. This was more than twice the size or 231% percent bigger than his biggest error in the last 22 years or 6 times the size of his average error. That is a big difference. Need something to compare that to? Say you get three speeding tickets in 22 years. Yeah, well it happens. Four or five years go by without another speeding ticket then BAM, you get 4 speeding tickets in one year. What happened? Did you buy a new car? A really fast new car? Did you start drinking? Could our climate have suddenly started reacting viciously to global warming?

The Statistics of Reality - Or How to Tell That Your Climate Has Changed In 1000 Words or Less

Dr. Gray's 231% forecasting error for the 2005 hurricane season was over six times the size of his average error. That kind of huge error just does not happen unless something fundamental has changed within the system. It hardly matters what is being discussed. In statistics this kind of thing is called an outlier.

A few things should be explained concerning statistics about now. Statistical science, as defined by Meriam-Webster is: a branch of mathematics dealing with the collection, analysis, interpretation, and presentation of masses of numerical data. Statistics is the study of groups of like things and their relationships with one-another and the rest of the world. When something is different from something else, statistically it can be classified, quantified and otherwise dissected and demystified in many different ways. In order to be able to use statistics there has to be a bunch of events, objects or "things"

to study. The value of statistics is in being able to look at a bunch of similar but really variable things and say something true about those things. Say you have a bunch of marbles. There are cat eyes, solids, shooters, boulders, aggies, steelies and marbles in every color of the rainbow including many different swirled patterns of one or more colors each - lots of different kinds of marbles. One day out on the schoolyard you picked up a round rock by accident and put it in your marble bag. When you returned home and decided to statistically analyze all of your marbles, you first poured them out on the floor and then began to sort them into different groups. A group for shooters, one for cat eyes, one for blue ones, one for red ones, one for clearies and so on. When you came to the rock, you threw it out the back door. The 2005 hurricane season was like that. It doesn't belong with the rest of the marbles.

When statistician divide up their marbles they throw out the rocks too. They are called outliers. You can't use outliers in your statistical analysis because they don't belong with the group. If you are on the carpet at the house analyzing your marbles and all of a sudden you come upon a frog, it is not part of the group and you throw it out the back door. The rock in the bag of marbles is the outlier, just like the frog. Statistically, scientists are a little more sophisticated. In general, anything that is not included in four standard deviations is considered an outlier and is thrown out the back door. The 2005 Hurricane Season had a standard deviation of 4.95. Four standard deviations in layman's terms represents 99.99% of the items being analyzed, in this case, marbles. So if you had 1,000 marbles in a sack, and only one of them was a rock, you would have a 1000 to 1 chance of blindly reaching in that bag and pulling out the marble. That 1 in 1000 chance is four standard deviations of marbles. Another way of looking at an outlier is to think of a 100-year storm. Most people reading this book have heard of a 100-year storm. This is the great snowstorm or the great flood that only happens once in a hundred years or, more precisely, has a 1 in 100 chance of happening in any given year. Outliers represent storms bigger than 1,000-year storms. So the 2005 Hurricane season forecast is a rock that needs to be thrown out the back door. Or not? Is it a hurricane season that is less likely to happen than a 1,000-year storm, or does Ockham's Razor apply? Friar William of Ockham was a 14th century English philosopher who popularized the philosophy that the solution to a problem is often the one with the least complicated answer. The simplest answer is usually correct.

But still, one season does not a changed climate make. The 2004 season was one for the record books as well. Florida had 4 major hurricanes in a row in 2004. They all made the top 20 list of damages with a total of $45 billion. In 1992, Hurricane Andrew's damages in southern Florida, the most ever experienced by any Atlantic basin hurricane, were $26.5 billion. This kind of damage is also on the edge of the statistical group of marbles. Is the simplest answer to this riddle - that the climate has changed? Have Dr. Gray's forecasting techniques become inaccurate in our new climate?

Today's Outlier May Not Be So Far-out In 10 Years

Hurricane seasons in 2006, 2007 and 2008 could see forecasting errors that are much higher than the other 22 years of Dr. Gray's record. After several years the average may climb significantly so that the 2005 season error

HELP! HELP! Grand Isle Louisiana after hurricane Katrina, August 31, 2005, NOAA Satellite and Information Service, Environmental Visualization program

is no longer in the outlier range anymore. The rock in the marble bag would then statistically change into a marble and be allowed to be included in the statistical analysis. Stranger things have happened! Hurricane forecasting is likely to adapt to new challenges though, so the errors should get smaller. If our hurricane seasons continue to include more storms than the number of marbles in most marble bags, after

5 or 10 years the 2005 season will begin to look like much more of a normal occurrence and therefore will deserve no special attention. That would be statistics in action.

In the same breath, if the 2005 hurricane season was a 1,000-year hurricane season, then it will quickly be put in its place by successive normal or "normally distributed" (as the statisticians say) hurricane seasons.

Back to the big picture – there are many ways to use statistics to draw conclusions. One of them is to use past data on hurricane damage and economic impact to compare our current hurricane seasons to ones from the past.

Increasing Tropical Damages from a Changing Climate

It will be years before the total economic damages from Hurricane Katrina are known. Were the incredible costs of Katrina's damages associated with global warming induced hurricane strengthening? The difficulty in answering this question comes from comparing the older costs of hurricane damage to damages from more recent storms.

In years gone by, there were fewer people along our coastlines and inflation had not increased the cost of everything. This makes comparing the costs of damages a little tricky. Cost of living adjustments are used only for adjusting dollars to inflation rates over time, so how does one estimate the damages from, lets say Galveston – in the 1900 storm (Category 4) to a similar storm striking Galveston today? That comparison just can't be made because the population of Galveston County today is 6 or 7 times what it was in 1900. In considering this dilemma, a pair of researchers named Pielke and Landsea has developed a way to compare hurricane damages estimates of not only inflation, but also changes in population and wealth in an area over time. This allows for a much better comparison of storms from historic times to more recent storms that are likely influenced by climate change.

Pielke and Landsea's paper is called, *Evaluation of Catastrophe Models Using a Normalized Historical Record*, was published in the Journal of Insurance Regulation in 1999 and revised in 2004. This study looks at the significant storms impacting the U.S. back to the turn of the century and updates, or 'normalizes', their damages estimates using normalization techniques to adjust for inflation, population and changes in wealth to 2004 dollars. Inflation and population growth are easy to visualize, but what does "changes in wealth," mean? Changes in wealth are the what happens to the value something, say land, in an area as it changes over time. For example: Most of the beachfront in the Panhandle of Florida today has a value many times more than that property would have been worth based on inflation alone because the value of that property has increased as the demand for beachfront property has increased. The paper also considers the total damage estimate of a storm to be two times the insurance losses, which is a catastrophe milepost of sorts and has been a common assumption of disaster cost estimation for some time.[22]

Before we can compare normalized economic damages we must first determine an approximate cost for the Katrina catastrophe. The final economic impact of this storm colasal storm is not known as of this writing so we will have to evaluate its costs on our own. The following assumptions from the Insurance Information Institute (March 2006) were used:

- Katrina's insured losses to data $38.1 billion,
- Commercial insured losses $12 billion,
- Nation Flood Insurance Program has paid $24.1 billion.

Total insured losses: $74.2 billion
Total economic losses (2 times total insured loss) = $148.4 billion

On top of these losses are lawsuit filings from Louisiana, Mississippi and Alabama concerning lawsuits with insurance companies for residential commercial and environmental damage. The lawsuits cover:

- floodwaters from breached levees,
- "Act of God" interpretation of insurance issues from flooding vs. storm surge,
- environmental damage from oil spills and,

- environmental damage due to hurricane exaggerated land subsidence from oil pumping.

In March 2006 the Insurance Information Institute said that "claims associated with the flooding caused by the 2005 hurricanes were much higher than normal, averaging $101,018 per claim in Louisiana and $135,000 per claim in Mississippi, in part because many homes were swept away completely or remained waterlogged for weeks, resulting in structural damage." In addition are issues that concern:

- the flooding claims in Mississippi alone, where the insurance industry has decided that flooding from storm surge is not hurricane related affects 160,000 homes and other structures and is estimated to be $18 billion,
- a tripling of the cost of rebuilding the New Orleans levees to $10 billion, announced by the Bush Administration in March 2006,
- in April 2005, about 22 percent of the oil production in the Gulf of Mexico was still offline at 240,000 barrels per day,
- the total loss of oil production in the Gulf because of the 2005 Hurricane season in the seven months since Katrina and Rita as per the US Department of the Interior Mineral Management Service has been 144 million barrels, at $65 per barrel is about $10 billion,
- gas production losses in the Gulf are 711 billion cubic feet, at $14 per 1,000 cubic feet another $10 billion
- the Gulf normally produces 547 million barrels of oil per year,
- the Louisiana State University Agriculture Report says that farm damages in Louisiana will reach $1.6 billion,
- the Louisiana Department of Wildlife and Fisheries gives a preliminary estimate of approximately $1.3 billion in lost sales to the fishery,
- the Red Cross estimated that 492,576 structures were either destroyed (352,930) or sustained major damage (139,646),
- as of April 2005, ten percent of insurance claims of $74 billion are still to be settled, totaling 20% when doubled to account for total economic losses which is about another $15 billion,
- the total additional economic loss of the above for Katrina is about another $66 billion or $132 billion doubled for total economic impact,
- the Insurer Swiss Re, in their publication Sigma No. 2/2006 showed both Wilma and Rita as having a total economic damages of $20 billion each. Hurricane Wilma was the Category 5 storm that set the lowest all-time Atlantic low pressure record at 888mb.

When all of these additional issues are finally taken into consideration, the total economic losses from Katrina will likely be in considerably in excess over $200 billion.

As it is right now, in April of 2006, with Katrina at $148 billion, the 2005 hurricanes season has preliminary total economic damages of $188 billion.

2005 Hurricane Season
Total Preliminary Economic Damages
$188 Billion

Normalized Damages - Comparing Today to Yesterday

The authors of *The Deadliest, Costliest and Most Intense Hurricanes, 1854 to 2004* (Pielke and Landsea) took the value of damages from each storm and forwarded those damage costs to 2004 population, inflation and property value status. For example: The 1900 storm in Galveston, Texas was arguably one of the most devastating hurricanes of all time. In 1900 Galveston County had a population of 44,000. The 1900 storm destroyed 3,600 homes and businesses, killed 7,000 people and caused an estimated $30 million in total economic damages in 1900 dollars. Adjusted for inflation to the year 2004 the damages become $1.2 billion. Now, adjust this amount to include the approximate number of homes and businesses that have been constructed in this area since 1900 (Galveston County population in 2000 was 250,000) and apply equal amounts of hurricane wind and storm surge to all of these buildings and the results are what are called 'normalized' damages. The 1900 storm, normalized to 2004 is a $37.5 billion dollar catastrophic disaster.

Table 2 (next page), Normalized Hurricane Damages 1900 to 2005 is adapted from Pielke and Landsea (1998) and Blake (2005). This table shows the conservative $148 billion in damages for Katrina. The next most costly storm is the Great Miami hurricane at $102 billion and Andrew is next at $43 billion. Remember, these damages are normalized to 2004 and are not the typical damage reports heard on the news that only take into consideration inflation. Andrews damage cost in 1992 when it was the most costly hurricane ever recorded was $26.5 billion.

Table 2
NORMALIZED HURRICANE DAMAGE RECORD 1900 - 2005

No.	Storm Name	Year	Cat	Damage
1	Katrina (Louisiana, Mississippi and Alabama)	2005	3	$148,000
2	Great Miami Hurricane	1926	4	$101,973
3	Andrew (SE Florida)	1992	5	$43,152
4	Galveston	1900	4	$37,541
5	Galveston*	1915	5	$31,808
6	SW Florida	1944	3	$23,784
7	New England	1938	3	$23,451
8	Rita (Louisiana, Texas)	2005	3	$20,000
9	Wilma (S Florida)	2005	3	$20,000
10	Florida, Lake Okeechobee	1928	4	$19,456
11	Betsy (SE Florida, Louisiana)	1965	3	$17,536
12	Donna (Florida, Eastern US)	1960	4	$16,993
13	Camille (Mississippi, Louisiana, Virginia)	1969	5	$15,464
14	Agnes (NW Florida, NE US)	1972	1	$15,096
15	Charley (SW Florida)	2004	4	$15,000
16	Rita (E Louisiana and N Texas)	2005	3	$15,000
17	Diane (NE US)	1955	1	$14,430
18	Ivan (NW Florida)	2004	3	$14,200
19	Hugo (South Carolina)	1989	4	$13,228
20	Carol (NE US)	1954	3	$12,785
21	SE Florida, Louisiana, Alabama	1947	4	$11,716
22	Carla (N & central Texas coast)	1961	4	$9,970
23	Hazel (N and S Carolina)	1954	4	$9,297
24	NE U.S.	1944	3	$9,113
25	SE Florida	1945	3	$8,904
26	Francis (SE Florida)	2004	2	$8,900
27	Frederic (Alabama, Mississippi)	1979	3	$8,876
28	SE Florida	1949	3	$8,233
29	S Texas	1919	4	$7,543
30	Jeanne (SE Florida)	2004	3	$6,900
31	Allison (Texas , Louisiana)	2001	TS	$6,254
32	Alicia (N Texas)	1983	3	$5,721
33	Floyd (North Carolina)	1999	2	$5,475
34	Celia (S Texas)	1970	3	$4,708

Original Source: Pielke and Landsea, Normalized hurricane damage in the United States 1925 to 1995, Weather and Forecasting Volume 19, 1998. and NOAA Technical Memorandum NWS-TPC-4, Blake et. al, The deadliest, costliest, most Intense hurricanes 1854 to 2004, 2005. * Blake (2005) says this damage estimate is high.

The Great Miami Hurricane struck a direct hit to Miami as a Category 4 storm and went on to a second landfall at Category 3 in Alabama and Mississippi. So why did a $102 billion dollar storm go unreported during the 2004 and 2005 hurricanes seasons, not to mention the last 14 years that Andrew has ranked number 1 in hurricane damages? The answer is mostly because even the best records are based on inflated dollars., even though this is a less realistic way of keeping track. Pileka and Landsea originally published their paper in 1998 – another reason why Andrew was considered to be the second most costly hurricane, and the last reason is that, even though normalization is a better tool for comparison, representing a more realistic damage amount for any given historic storm, it is only a tool and has not become accepted as a common way to view reality. (NOAA's most easily accessible historic hurricane cost information is not even inflated to current dollars.)

Reliability of the data needs a short discussion here. When aircraft started regular hurricane reconnaissance in World War II the accuracy of the strength of hurricanes over water

became significantly higher.[16, 17] When we are discussing landfalling hurricanes, reliability issues are less questionable than when studying hurricanes at sea before airplane reconnaissance. Dr. Landsea, confirms that the reliability of records for landfalling storms in the U.S. is good back to the turn of the century.[32] There is however, one storm in this record that is suspect. Marked with an asterisk, Blake made a special note on the 1915 Galveston Hurricane. The note says "Damage estimate in 1915 reference is considered too high."

Table 2 can now be seen as the tool that it is. It transports the past to the present and allows for a much more accurately based comparison of the effects of individual storms. What we see is not surprising. Well, the $102 billion dollar Great Miami Hurricane of 1926 is surprising, but that storm was a Cat 4 and it bullseyed Miami. When the population changes of our coastal communities are taken into consideration, the surprise is not justified. At the end of World War II in 1945, Texas had a coastal population of 1.25 million, Florida's population was 2.25 million and the heavily populated area of the east coast of Virginia, Maryland, New Jersey and Delaware had a population of about 4 million.[33] In the period from 1980 to 2003 the northeastern coastal population of the U.S. increased from 43 million to 52 million. Gulf Coast states have seen an increase of from 10 to 19 million and the southeast U.S. population, including Atlantic Florida, has increased from 6 to 14 million.[23]

One third of the top 34 most catastrophic hurricanes recorded since 1900, or 10 out of 34, have happened in the last 7 years. Twenty nine percent of the most catastrophic storms have occurred in 7 percent of the time. Even more impressive is the amount of damages totaled up in the last 7 hurricanes seasons. An amazing 52% of all damages from major hurricanes – those are normalized damages – for the last one hundred and six years has occurred since 1998. More than half of the damages have occurred in only seven percent of the time.

1999 to 2005 damage total (to date)	**$245 billion**
1900 to 1998 damage total	**$471 billion**

More than half of all of the damages from all of the major hurricanes in the last 106 years has occurred in the last 7 years.

What in the world is going on here? Has this ever happened before? Can this be realistic?

Let's look at the Great Miami Hurricane and the active hurricane period associated with the 1920s. This is the period with the next highest damages within the record. Starting with the second Galveston Hurricane in 1915, including a South Texas hurricane in 1919 and the Okeechobee and Great Miami Hurricanes in 1926 and 1928, the total economic damages for this peak of activity are $161 billion. The period from 1992 to 2005, for eight hurricanes named Andrew through Wilma, there were $288 billion in damages. The latest peak in hurricane damages is 79% bigger than the previous peak. That is almost a doubling of damages. These natural cycles supposed to be the similar to one another. Why would this cycle be so much bigger than the last unless something had changed – like the climate? Considering that significant amounts of the damage estimate from the Katrina and Rita storms are still not known, the current peak in activity will, in all likelihood, be double that seen from 1915 to 1928.

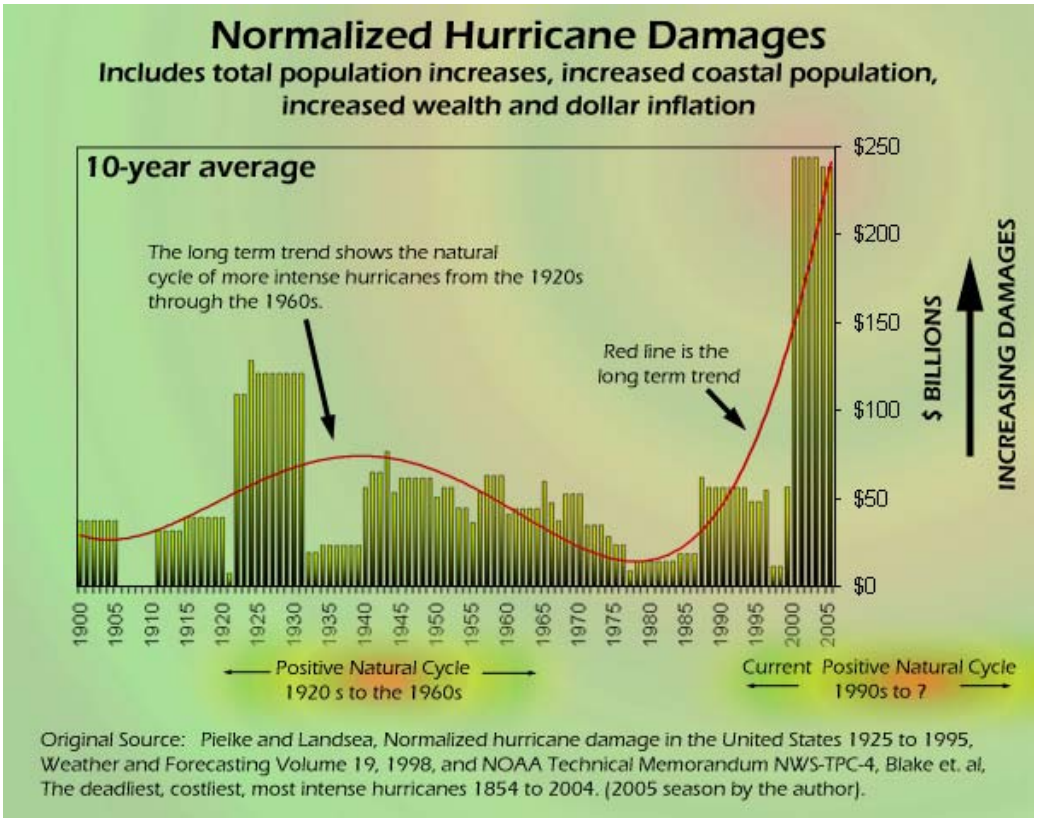
1915 to 1928 peak	**$161 billion**
1992 to 2005 peak	**$288 billion**

When the final damages are known for 2005, recent impacts are likely to be twice that of the most intense hurricane peak of the entire last century.

This is a marbles to marbles comparison. Normalized damage comparisons are becoming more common as the methods are refined. The 2004 paper on normalization by Blake, et. al. was a product of NOAA, and is available on their Hurricane Prediction website.

The last thing to see about normalized damages is how the natural cycles are represented over time in graph form. This graph (Figure 4) shows particularly well the impacts of climate change on hurricane damages. This graph uses a 10-year average to emphasize the natural cycles. A 10-year average is method used to more accurately see the effects of longer-term trends. Instead of graphing a single years worth of damages at each date on the graph, a ten-year total (five years before and five years after) are plotted at each date. This is called a running average.

Figure 4



Also notice that the hockey stick shape is back. The trend line today (the business end of the hockey stick) is in a new cycle that is much bigger than the previous cycle. This shape, in statistical analysis, is an indication that something very different is happening in a group, something that is not normal, or not a part of the past trend. Today it is showing us that climate change is happening and it has changed the way our climate behaves. We have accurately and realistically looked into the past and been able to draw conclusions based on a scene that was written for today's date.

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