Hurricane Season Continues

The scientists and researchers from the previous chapter who question the role of man-made climate change in relationship to increased hurricane season intensity are in the minority. The changing scene is evident in NOAA's recent acknowledgement that there is not a consensus of NOAA scientists in agreement about hurricanes and climate change.

This chapter will talk about developments in the academic world that confirm that climate change is having an impact on hurricanes, detail some of the enormous implications of mega-hurricanes as relates to New Orleans post-Katrina, list some quotes, and highlight the tremendous number of records broken by our recently hyper-active hurricane climate in the Atlantic basin. The scientists being discussed will include Dr. James Hansen head of the NASA Goddard Institute for Space Studies, Dr. Kevin Trenberth, Head of the Climate Analysis Section at the National Center for Atmospheric Research, Research Meteorologist at NOAA's Geophysical Fluid Dynamics Laboratory, Judith Curry who is Chair of the School of Earth and Atmospheric Sciences at the Georgia Institute of Technology, Dr. Kerry Emanuel from the Massachusetts Institute of Technology, Dr. Peter Webster from the Georgia Institute of Technology, Dr. Thomas Knutson of the NOAA/Geophysical Fluid Dynamics Laboratory, Princeton, New Jersey and Dr. Robert E. Tuleya from the Center

for Coastal Physical Oceanography, Old Dominion University, Norfolk, Virginia.

The Academic Record

Kerry Emanuel: Index of Destructiveness[1, 2]

Emanuel has authored or co-authored over 100 peer reviewed papers and published two books. He is currently Professor of Atmospheric Science at the Massachusetts Institute of Technology. A September 16, 2005 paper in the journal Nature by Kerry Emanuel reveals that intense hurricanes have doubled since 1970 and describes why natural cycles are not solely responsible. In his paper, Emanuel developed an index of destructiveness for individual storms to prove this theory. His research has concluded that worldwide, the energy released by hurricanes has increased 70% in the past 30 to 50 years and that storms today have 15% stronger winds and 60% longer lifetimes. Emanuel also mentions that subsurface heating of ocean waters by global warming is helping to reduce the negative feedback from the mixing of ocean waters brought about by hurricanes. This means that, when a hurricane passes over a given portion of ocean, the strong winds mix the ocean waters, mixing the normally warmer surface waters with the less warm subsurface waters and cooling the area off. This reduces the fuel that a hurricane has to work with and therefore reduces its intensity. Warmer subsurface waters tend to reduce this cooling effect and therefore reduce the weakening effect on the hurricane.

Another thing that happens when there is less cooling due to the mixing of surface ocean waters from the strong winds of a hurricane is that, after the hurricane ocean waters are warmer. This allows for quicker redevelopment of new tropical systems that, because of the warmer water are more powerful than they would have been if the mixing had brought cooler water to the surface. Global warming has put more warmth into the ocean – not just on the surface, but mixed in to deeper levels.[3] Because there is more warmth in the engine, the hurricane gets more powerful.

P. J. Webster and Colleagues: More Frequent and Intense Hurricanes from Warmer Sea Surface Temperatures[4]

This paper was published in the journal Science in September 2005, and written by researchers from the School of Earth and Atmospheric Sciences, Georgia Institute of Technology and the National Center for Atmospheric Research. Their findings state: "We conclude that global data indicate a 30-year trend toward more frequent and intense hurricanes…" Webster's paper also identifies a "substantial change in the intensity distribution of hurricanes globally." His paper says that category 1, 2 and 3 storms have decreased in numbers and that category 4 and 5 storms have "almost doubled in number..." These findings are consistent in all of the ocean basins.

The paper finds a significant relationship between sea surface temperature increase and hurricane frequency and intensity in only the North Atlantic Basin that is significant at the 99% confidence level. What this means is that in the Atlantic there has been a real increase number of hurricanes and how long these hurricanes are lasting - basically, more, longer-lived hurricanes. The authors also accredit the relationship between increasing sea surface temperature and more and longer-lived hurricanes with global warming.

The paper concludes with a short discussion of the need for a longer record to be able to be able to determine a deeper understanding of the role of hurricanes in the general circulation of the atmosphere and ocean. This concept is also evident early on in the study. The paper says that it is "difficult to discern any trend relative to background SST (sea surface temperature) increases with statistical veracity. Factors other than SST have been cited for their role in regulating hurricane characteristics, including vertical shear and mid-tropospheric moisture." Vertical shear is what supplies the exhaust for a hurricane's heat engine. As heat is generated by the hurricane it is lifted and spun out of the top of the storm. If the upper level winds are too fast, the storm can be torn apart so vertical wind shear must not be too great. Mid-tropospheric moisture: This term includes two parts. The mid troposphere is basically the upper two thirds of the hurricane. Different levels of the atmosphere can contain differing amounts of moisture. For a hurricane to form or to reach intense proportions, there must be enough mid-level moisture. If it is to dry in the mid-levels the hurricane will not likely become

intense. What all of this hurricane formation information means is that global warming changes the basic way that our atmosphere behaves. [5]

Knutson and Tuleya - Implications of Increasing Strength of Hurricanes Due to Global Warming is Greater Than it Seems[6]

Knutson and Tuleya used computer models to find a significant tendency for more intense storms under high CO2 conditions for all ocean basins except the South Indian Ocean. This paper also found an increase in precipitation of 28% for high CO2 concentration storms. Revisions to the 1999 paper by Knutson and Tuleya in September 2004 in the Journal of Climate show greater increases in intensity due to global warming than the original study. Stronger winds and heavier precipitation are anticipated with tropical events because of the increase in temperatures from global warming. Knutson and Tuleya state that hurricanes maximum surface winds will increase by 6%, pressure will drop by 14% and precipitation will increase by 18% by the year 2080. They also imply that the probable maximum strength of tropical systems may have to be revised because of increased atmospheric and water temperatures. Their computer model observations of 1296 individual run, are based on a 1% increase per year in carbon dioxide. Implications of this study are increases in hurricane intensity equal to one-half of a step in the current 5-category rating system.

A paper by Patrick Michaels, Paul Knappenberger and Christoper Landsea make an argument that the carbon dioxide concentration used in the model is more than twice as much as it should be.[7] The authors also assert that carbon dioxide concentrations have been stable for 30 years. These assertions can be directly challenged with data from the Mauna Loa Observatory. The Mauna Loa Observatory in Hawaii is a part of the NOAA Global Monitoring Division's Earth Research Laboratory. The lab at "Mauna Loa has grown to become the premier long-term atmospheric monitoring facility on earth and is the site where the ever-increasing concentrations of global atmospheric carbon dioxide were determined." (NOAA) Table 1 clarifies the issue:

Table 1
Atmospheric Carbon Dioxide Summary of Increasing Trend Mauna Loa Observatory, Hawaii

Year	Carbon Dioxide Concentration 10-year average
1960	0.24%
1980	0.44%
2000	0.59%
2001 to 2005 annual average	0.72%

Data Source: Mauna Loa Observatory, Hawaii , NOAA Global Monitoring Division's Earth Research Laboratory

In fact, Figure 1 in Chapter 7 shows our old friend the hockey stick. Not only is the rate of carbon dioxide concentration increasing, the rate itself is increasing and is not stable at all as Michaels, Knappenberger and Landsea suggest. The last entry in Table 1 shows that over the last 5 years the rate has increased at an even faster rate to 0.72%. Knutson and Tuleya's carbon dioxide assumption of a 1% increase could actual be underestimated. At the rate we are currently progressing, increases could be well above 2% per year by as early as 2020.

Many of the popular contrarians have had good press from the seemingly small amount of increase of surface winds estimated at 6%. What needs to be known, is that a 6% increase in maximum surface winds is bigger than it sounds. As wind speed increases, the force behind that wind increases even more quickly. Say the maximum wind force of a Cat 5 hurricane in the Atlantic basin is 175 mph and increase that by 6% to get 185 mph winds. A 175 mph wind generates 122.5 pounds per square foot of force whereas a 185 mph wind generates 136.5 pounds per square foot of force. This is a 12% increase in the *force* of the wind. So a 6% increase in wind speed is equal to a 12% increase in hurricane strength, or what really counts when houses are being blown away.

Kevin Trenberth: Statistics Can't Prove What Happens in the Future - Are we asking the right questions?[8]

Kevin Trenberth, Head of the Climate Analysis Section at the National Center for Atmospheric Research, published an article in the journal Science in June 2005 entitle, *Uncertainties in Hurricanes and Global Warming*, explores the uncertainties in long-term trends such as weather events. Trenberth makes the point that, "accepting the null hypothesis (the theory that global warming does not affect hurricanes) does not mean that there is no trend, only that it cannot be proven from the particular sample and that more data may be required." Hurricane frequency and intensity, like other weather phenomena, are highly variable. Statistics enable the proof of a highly variable assumption as long as there are enough data points. Generally, the more highly variable an assumption is, the greater number of data points that are required for its statistical proof. This is a statistical requirement and cannot be changed. Scientist even have a name for accepting a false hypothesis. It is called a Type II error.

We will not know for certain for any number of years into the future whether or not global warming is causing more intense hurricane seasons. Different scientists define concepts differently. The phrases in the first sentence of this paragraph; "know for certain", "is causing" and "more intense" can have different meanings based on their definition. Trenberth says that some studies and computer models have been able to identify trends, and also that some logical conclusions can be made from the realities of global warming (such as increased sea surface temperatures increasing evaporation, and that increased water vapor allows for more intense precipitation, etc.). Trenberth's concludes with a statement about which question may be the correct question to ask: "Trends in human-influenced environmental changes are now evident in hurricane regions. These changes are expected to affect hurricane intensity and rainfall, but the effect on hurricane numbers remains unclear. The key scientific question is not whether there is a trend in hurricane numbers and tracks, but rather how hurricanes are changing."

Bryden: Atlantic Ocean Currents Slowing Leaving More Warm Water in the Tropics[9]

A letter to Nature by Harry Bryden and colleagues from the National Oceanography Centre, Empress Dock, Southampton, United Kingdom, identifies new concerns for increasing intensification of tropical weather systems. The team has identified a decrease since 1992 of 18 - 27% in the transport of ocean waters across the 25 degree latitude line (Miami's latitude). This decrease consists of lesser northward moving warm surface waters and southward moving cold deep water. The paper quotes: "The Atlantic meridional overturning circulation (part of the great ocean current or thermohaline circulation) carries warm upper waters into far-northern latitudes and returns cold deep waters southward across the Equator. Its heat transport makes a substantial contribution to the moderate climate of maritime and continental Europe, and any slowdown in the overturning circulation would have profound implications for climate change." The decrease in northward transport of warm waters by the Gulf Stream means that more warm water is staying in the tropical Atlantic. The papers says that normal southward flows at depths between between 300 and 3300 feet deep (in what is known as the main thermocline, or layer of different temperature water) have increased by 77%, or almost twice the amount. This water is no longer flowing northward to warm northern Europe, Icleand and northern Russia. The amount of water is so large that scientists have a special unit of measure capable of describing its volume. The unit is called a sverdrup which is equal to 35.3 million cubic feet per second. The changes that started in the late 1990s now total 10 sverdrups in volume. That equals 353,000,000 cubic feet, or 2.64 billion gallons of water, *every second*.

This volume of water is approximately equal to 10 times the entire water output of every river on earth.

This 18 - 27% decrease in the northward transport of warm water is accomplished by much of that water recirculation in the main thermocline. The water flows northward to about 25 degrees latitude, sinks, and returns south on the mid level currents. With deeper warmer waters, there is a higher capacity to produce more, stronger tropical systems.

Hoyos, Cury, et. al., Deconvolution of the Factors Contributing to the Increase in Global Hurricane Intensity[10]

This study, presented in the journal Science in April 2006, uses advanced methods based on information theory to separate the trend in hurricane intensity from natural cycles. Information theory is the mathematical technical of analysis of data in a noisy background and is valuable in areas like cryptography where communications signals can be used that are embedded in the background noise. In this study, the team, including Judith Curry, Chair of the School of Earth and Atmospheric Sciences at the Georgia Institute of Technology, confirms that the increase in the numbers of category 4 and 5 hurricanes is due almost entirely to the increase in sea surface temperature. This reasoning is consistent with other researchers in the field who are trying to prove the positive link between the increasing number of and intensity of hurricanes and man-made global warming.

These authors say that the North Atlantic and the South Pacific show some slight associations of increased hurricane intensity with other atmospheric factors such as wind shear, but that the strongest association is with sea surface temperatures. In this study, natural cycles are considered to be the noise in the background and this theory is proven. The point is made that natural cycles influence short term variations in hurricane intensity but that the dominant factor in increasing hurricane intensity is sea surface temperature.

Donald Kennedy – The New Gag Rules: an Editorial in the Journal Science[11]

Editorials are not the greatest place to find scientific information. In this case however, an editorial in the journal Science is of special interest. The author of this editorial is Donald Kennedy, editor-in-chief at Science since 2000, president emeritus of Stanford University and former commissioner of the U.S. Food and Drug Administration with a PhD in biology from Harvard. Kennedy wants to draw attention to the significant gap between mainstream science and our nations top scientific institutions – NOAA and NASA.

This editorial was published in February 2006, just as the James Hansen story was boiling over (see the discussions on James Hansen and the politics of climate change in Chapter 4). The article draws attention to NOAA's official policy that climate change is not affecting the strength of tropical systems and that the Department of Commerce, NOAA's boss, "has ordered them [NOAA scientists] not to speak to reporters or present papers at meetings without departmental review and approval."[12] In the editorial, it is blatantly apparent that Kennedy wants to impress on his readers appropriate dismay over the great disparity of scientific viewpoints at these agencies today. The issue of hurricane intensity due to climate change is just a small part of the big picture. When politically persuasive forces are collaborating to present an inclined view of the science that goes on at NOAA and NASA, society loses on whole. These agencies should not be allowed to 'spin' their findings. Scientists should not be gagged, censored or edited by politicians and bureaucrats. Academia alone should be responsible for the science.

Gulfport, Mississippi, September 6, 2005: Damage from Hurricane Katrina.
Photo Credit: Federal Emergency Management Administration

Back to New Orleans

The significance of Hurricane Katrina was not in its enormous impact on a multi-state area the size of Great Britain. The significance of Katrina, and the growth in hurricane strength and frequency in the last decade lies in the consequences of climate change. Climate change will make this sort of record breaking super-disaster much more of a common thing than in the past.[13,14,15,16] Extreme events will include hotter, longer heat-waves, bigger, more widespread floods, colder, longer blizzards, and bigger, more intense and more frequent hurricanes. As our coastal populations increase, the effects of extreme tropical weather will also increase. It makes sense that there will be greater

impacts from weather events due to an increasing population as was discussed in the last chapter concerning normalized damages. The increasing number of and severity of weather events across the globe however will make the impacts of more and bigger weather events on our increasing population even more costly.

Seven months after Katrina made landfall, much of New Orleans was still significantly impaired from the storm. Approximately 400,000 people were still displaced, more than half of them from New Orleans. Restaurants and hotels could not open because there was not enough staff. Visitors to the area commented on the sea of blue roofs, referring to the tens of thousands of blue tarps that were used as temporary covering for damaged homes and businesses. The Mardi Gras parades drew only 300,00 visitors, instead of the annual 1 million before the storm. Airlines were flying only half as many flights in and out of the City than before the storm. Most of the hotels in the city were occupied, but displaced residents and cleanup workers occupied them. About one of third of the cities restaurants had reopened. The red cross was still serving 6,500 meals a day. Many of the Mardi Gras float themes echoed the hurricane: "Drove My Chevy to the Levee, but the Levee Was Gone" and "Rowed Hard and Put Up Wet." Many floats were skirted with blue tarp, and there was even a blue tarp beauty contest. Among the revelers was a group of women dressed in yellow hazmat suits calling themselves the FEMA Fatales. Many of the float riders were not in New Orleans anymore and could not afford to come home, much less to participate in a parade. Many will never return.

New Orleans Recovery as of February 2006

Seven months after the disaster began, New Orleans and much of the central Gulf Coast was still a disaster. The enormous impact of this event was even more astounding than the records set by the 2005 hurricane season. (Source: New Orleans Online http://www.neworleansonline.com/neworleans/business/factstats.html)

Population: Prior to Katrina, New Orleans had 484,000 residents, and the metro population was 1.3 million. The mayor's office was estimating the population was

increasing. They said that on January 17, 2006, more than 200,000 people had returned to Orleans Parish, with a total for the metropolitan area standing at 929,554.

Restaurants: The Louisiana Restaurant Association said that the current status of New Orleans restaurants was improving. 768 restaurants had reopened in Orleans Parish with 15,000 employees. At least 10,000 restaurant employees were still needed.

Hotels: Prior to Katrina, there were 265 hotels with 38,338 rooms available. After the storm there were 100 hotels and motels in operation with 27,000 rooms.

Flights: Louis Armstrong International Airport had 166 flights daily before the storm. As of February 3, air traffic had resumed to 74 flights daily,

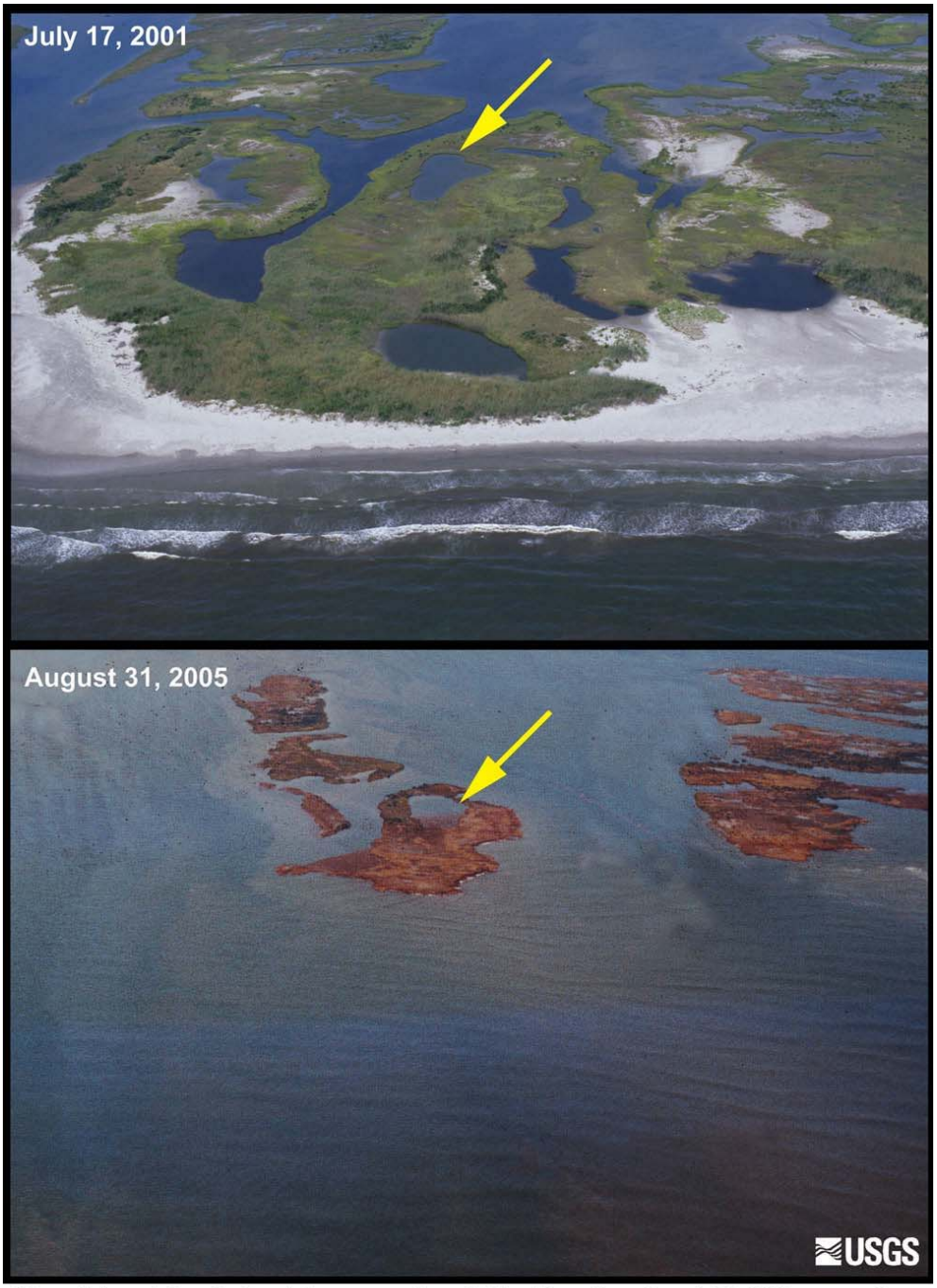
Public Transit: There were twenty-eight bus lines running providing 11,000 rides daily. The hard hit St. Charles Avenue streetcar line was in operation on Canal Street downtown. The St. Charles line will likely was not be operational again until Christmas, 2007, 16 months after the storm.

Local Businesses: The New Orleans Time Picaun says that, out of 81,000 local businesses in 10 parishes, 42,168 were currently open and another 20,268 were partially in operation.

Hospitals: There were 20 general major hospitals in operation in the metro area. As of February 2006, 12 were in operation.

More Recovery Information from the Katrina and Rita Disaster Zones:

- 85,000 households affected by both hurricanes had received temporary lodging through FEMA,
- $17.4 billion had been paid out to National Flood Insurance Program policyholders,



Chandeleur Islands, Louisiana, consist of 45 miles of surf and 30,000 acres of grass. Before Hurricane Katrina, they looked like the top picture. These photos were taken by the USGS, Hurricane and Extreme Storms Program.

Chandeleur Islands, Louisiana: Another location in the island chain. The grass is brown because of salt water submersion. Note the darker deeper waters indicating the deeper channels called cuts. They are made by the storm surge and can be over 20 feet deep. Photo: USGS, Hurricane and Extreme Storms Program

- 15,000 HUD-assisted or homeless families had receiving up to 18 months of housing assistance through the Katrina Disaster Housing Assistance Program (KDHAP), administered by the U.S. Department of Housing and Urban Development (HUD) and the U.S. Department of Homeland Security (DHS),

- In six months since Katrina struck, the U.S. Small Business Administration (SBA) had approved more than $5.2 billion in disaster loans to over 73,000 homeowners, renters and businesses in Louisiana, Mississippi, Alabama, Texas and Florida,

- 74 percent of the debris caused by the storms had been cleared by FEMA in Mississippi; 54 percent in Louisiana. A total of 78 million cubic yards of debris had been removed from the Coast. (The superdome has a capacity of 4.6 million cubic yards, so 78 million cubic yards would fill the superdome 17 times),

- Close to half (44 percent) of Louisiana's highways have been repaired.

Katrina was just one more major hurricane on the statistical trail to confirmation that climate change has affected hurricanes. No one can say, today at least, that Katrina was or was not caused by climate change. At this time it cannot be determined that her intensity, size or track were affected by climate change either. We may never know for sure about any individual storm. The chaotic and random way that the specific details of weather evolve cannot tell us much about individual events. But patterns can tell us about changes in the whole. More details of the puzzle will become clear as climate change progresses - details like the 2004 season with 4 major storm strikes to the Florida coast for the first time since 1886. These storms caused $45 Billion in damages, more that Andrew's adjusted $43 billion from 1992. The South Atlantic saw its first ever-recorded land falling hurricane in 2004. These puzzle details also include the 2003 season, where numerous hurricane records were also set in an above average season. A Cat 2 hurricane hit Halifax, Nova Scotia, in September 2003, the most intense since 1896. Many individual details tell a much different story than the details themselves.

Hurricanes and Global Warming News Conference

Center for Health and Global Environment, Harvard Medical School, October 21, 2004

Concerned scientists gathered at the Center for Health and Global Environment at Harvard Medical School after the tremendous hurricane season of 2004 to discuss the connection between hurricane activity, global warming and the future. Four speakers participated in this panel question and answer session:

> **Paul Epstein, M.D.**, Associate Director of the Center for Health and the Global Environment at Harvard Medical School
>
> **Jim McCarthy**, Professor of Biological Oceanography at Harvard University and the former co-chair of the impacts group of the Intergovernmental Panel on Climate Change
>
> **Matthias Weber**, Senior Vice President and chief property underwriter of the U.S. Direct Americas Division of Swiss Re
>
> **Kevin Trenberth**, Senior Scientist and head of the Climate Analysis Section of the National Center for Atmospheric Research in Boulder, Colorado, Convening Lead Author of the 2007 Intergovernmental Panel on Climate Change, IPCC report

The purpose of this news conference was to discuss the impacts of global warming on our climate. The conference came about because of the tremendous impact of the four hurricanes that hit Florida in the 2004 hurricane season, in combination with the response from NOAA that these hurricanes were a part of the natural cycle unrelated to global warming. Selected quotes are presented below:

(Jim McCarthy) **"The one aspect of this ongoing climate change that continues to receive less attention than it deserves is how**

the warmer world will lead to more extremes in weather and particularly these heavy precipitation events, extreme wind events, and more hot, dry periods as well." … "Warmer seas fuel the large storms forming over the Atlantic and Pacific, and greater evaporation generates heavy downpours. With warmer, saltier tropical seas, the IPCC has projected larger storms, heavier rainfalls and higher peak winds."

(Paul Epstein) **"In the past decade we've seen unprecedented set of events worldwide that have taken lives and left clusters of diseases - extremes of all types. So as we look at these hurricanes we have to see the context of more extreme events. Hurricane Mitch in '98 in Honduras, Mozambique floods in 2000, and then the pace quickens in 2003 with 21,000 to 35,000 deaths. Then this May we had 172 tornados in the U.S., five feet of rain in 36 hours - this is in Haiti, which later got hit again in September. So the context is that weather patterns are changing, the character of the system is changing. We're seeing this greater variance and variability. Variance from the scientific prospective is often a nuisance of the noise in the system. It is becoming a signal of how this system is behaving and it is not stable and we can project more of these kinds of extremes."**

(Matthias Weber) **"…it's the first time since 1886 that we had four hurricanes affecting a single state in one and the same season. Charley, Frances, Ivan, and Jeanne all hit the mainland or at least affected the state of Florida. Alone in the state of Florida more than 22% of all the homes were affected" …**

"A total of more than 2 million claims alone occurred in Florida. But if you had a comparison you probably remember Hurricane Andrew, which also hit mainland Florida in 1992. Hurricane Andrew created some 700,000 claims."

… "Japan has seen the most active hurricane or typhoon season … since 1970. Ten tropical cyclones or typhoons have (affected) Japan so far, resulting in a total insured loss of somewhere between 5 to 7 billion U.S."

(Kevin Trenberth) **"What we can say is that the high sea surface temperatures of water vapor make for more intense storms (hurricanes) and so this is consistent with the evidence that we're seeing. This is the main link with global warming that we can establish at the current time." … "I think the evidence is mounting as Jim McCarthy suggested, and I refer to the hurricane off of the coast of Brazil. You heard also from Matthias that there is unprecedented activity out in parts of the Pacific, the far western Pacific, and now we have a series of seasons, very vigorous [hurricane] seasons ever since 1995. Let's see, I think seven of those—seven of the last ten years—has been above normal in terms of hurricanes. So this kind of evidence is pointing more in the direction that these extremes are occurring and are having a real impact on society."**

(The following is a question from: Chris Joyce, National Public Radio)

"...I'm just wondering, why have you all come together at this particular moment to talk about this? Obviously something occurred to you that you felt the need to come together and remind the world about what is happening with global warming and I wonder what those reasons might be."

(Jim McCarthy) **" I think that several of us who have spent the last several years looking at these larger pictures were surprised by some of the statements appearing in the press. Again, as I suggested earlier, in cases attributed to people who either are not, have not been involved or have shown interest in these larger studies, but who have also at times even said that they don't, for example, believe that the Arctic is losing ice today. These statements were very local in perspective and didn't have the benefit of the larger picture that so much occupies our lives both as researchers in this field and as teachers, and as we begin talking with other people through groups like the Center for Health and the Global Environment at Harvard Medical School, people like Kevin, others, it appeared that within our community there was a lot of surprise that this possible relationship that we're discussing seemed to have been buried by a number of stories in the press."**

(Kevin Trenberth) **“There are several factors that go into making hurricanes. They're really a collective of thunderstorms and they need a disturbance that hangs together. And we are not able to say what global warming is likely to do to that, and so there could be a trade off between individual thunderstorms versus actual hurricanes. It also requires—this actually requires a favorable atmospheric circulation. This relates to things like whether the wind will blow it apart or wind shear will cause it to collapse before the hurricane actually forms. And we can't say anything really about the tracks which make the hurricanes hit the U.S. or miss the U.S.—whether they [make] landfall or not. What we can say is that the high sea surface temperatures of water vapor make for more intense storms and so this is consistent with**

the evidence that we're seeing. And so this is the main link with global warming that we can establish at the current time."

More Quotes:

A post by the Chief Scientist of the Environmental Defense Dr. Bill Chameides (formerly the Environmental Defense Fund)

A Wake Up Call

"While it is not possible to determine to what extent global warming may have contributed to the destruction wrought by a single storm such as Katrina, the evidence is mounting that tropical storms have already become more destructive as a result of global warming, and that global warming will be an increasingly significant factor exacerbating the destruction caused by hurricanes in the coming decades."

(Dr. Bill Chameides, Chief Scientist, Environmental Defense Fund, Member of the U.S. National Academy of Sciences, and has been named a National Associate of the National Academies. He is also an American Geophysical Union Fellow, and has received the American Geophysical Union's Macelwane Award. Dr. Chameides has served as editor of the Journal of Geophysical Research and is the author or co-author of more than 120 scientific publications and five books. He received his doctorate from Yale University, 09/27/2005)

You Can't Blame Global Warming for Katrina, Yet - by staff writer for Science Magazine, Richard Kerr in September 2005 (20):

> **"Were New Orleans and coastal Mississippi victims of global warming? Greenhouse alarmists and the tabloids say yes, but until recently, most scientists would have answered no way. There was no evidence that global warming has had any effect on the planet's most powerful storms--dubbed hurricanes, typhoons, or cyclones depending on the ocean that spawns them. ... Now, however, a connection is emerging between warming oceans and severe tropical cyclones."**

Claims that recent hurricane intensification is due to natural cycles are irrational - James Hansen, Director of the NASA Goddard Institute for Space Science

> **"Our climate simulations provided to IPCC, driven by known climate forcings, predominately increasing greenhouse gases, yield a warming of 0.35°C (0.6°F) in the tropical Atlantic region of hurricane formation in 1995-2005 relative to the preceding 25 years. ... The observed warming in that region was 0.45°C (0.8°F). So the categorical contention that recent hurricane intensification is due to a natural cycle of Atlantic Ocean temperature in the region of hurricane formation, and has nothing to do with global warming, is irrational. How could a hurricane distinguish between a natural and greenhouse gas warming? It is not impossible, but it would require an explanation that has not been proffered. I conclude that greenhouse gases are probably responsible for a substantial fraction of the ocean warming that fuels stronger hurricanes."**

(Hansen, James, Presentation to the American Geophysical Union, in San Francisco, California, December 6, 2005. The original quote did not italicize the last sentence.)

The Intergovernmental Panel on Climate Change (IPCC), in their 2001 report says:

"There is evidence that the peak intensity of tropical storm systems may increase by 5% to 10% and precipitation rates may increase by 20% to 30%."

The Records

National Hurricane Center Information

Warmer oceans grow bigger hurricanes. The Atlantic Multidecadal Oscillation also increases the number of hurricanes. Add these two facts together and what is created is unprecedented tropical cyclone seasons. The number of hurricanes in the 2005 hurricane season in itself was sure to have been a record, but the sheer magnitude of the hurricane records set in 2005 makes it difficult to compare the 2005 season to any other. The National Hurricane Service ended its 2005 hurricanes season of tropical storm advisories with the following statement in January 2006:

"I SUPPOSE IT IS ONLY FITTING THAT THE RECORD-BREAKING 2005 ATLANTIC HURRICANE SEASON ENDS WITH A RECORD BREAKING STORM. TODAY, ZETA SURPASSED 1954 ALICE #2 AS THE LONGEST-LIVED TROPICAL CYCLONE TO FORM IN DECEMBER AND CROSS OVER INTO THE NEXT YEAR. ZETA WAS ALSO THE LONGEST-LIVED JANUARY TROPICAL CYCLONE. IN ADDITION, ZETA RESULTED IN THE 2005 SEASON HAVING THE LARGEST ACCUMULATED CYCLONE ENERGY (ACE) SURPASSING THE 1950 SEASON. SO, UNTIL THE 2006 SEASON BEGINS..."

In April 2006 NOAA announced that they had added another storm to the 2006 season. The storm occurred in July, and was never a hurricane; however, had it been identified earlier it would been named Tammy. Which means that Hurricane Wilma would then have been named hurricane Alpha, and because the name Wilma was retired, the hurricane center would have to have retired a letter of the Greek alphabet. There are no replacement names set up for retiring Greek letter names, probably because we had never had a hurricane with a Greek letter name, and the contingent was just not planned for. This would have been quite an enigma in the records.

"The 2005 Hurricane season set a massive number of records. While this list is not meant to be all-inclusive, it gives some perspective on the tremendous amount of activity seen in the 2005 hurricane season. Since the previous most active season of 1933, we have come a long way in the technology we use to sense tropical cyclones. It is entirely possible that some of these records set in the 2005 season occurred previously or were exceeded by tropical cyclones in prior seasons." (NOAA website quote)

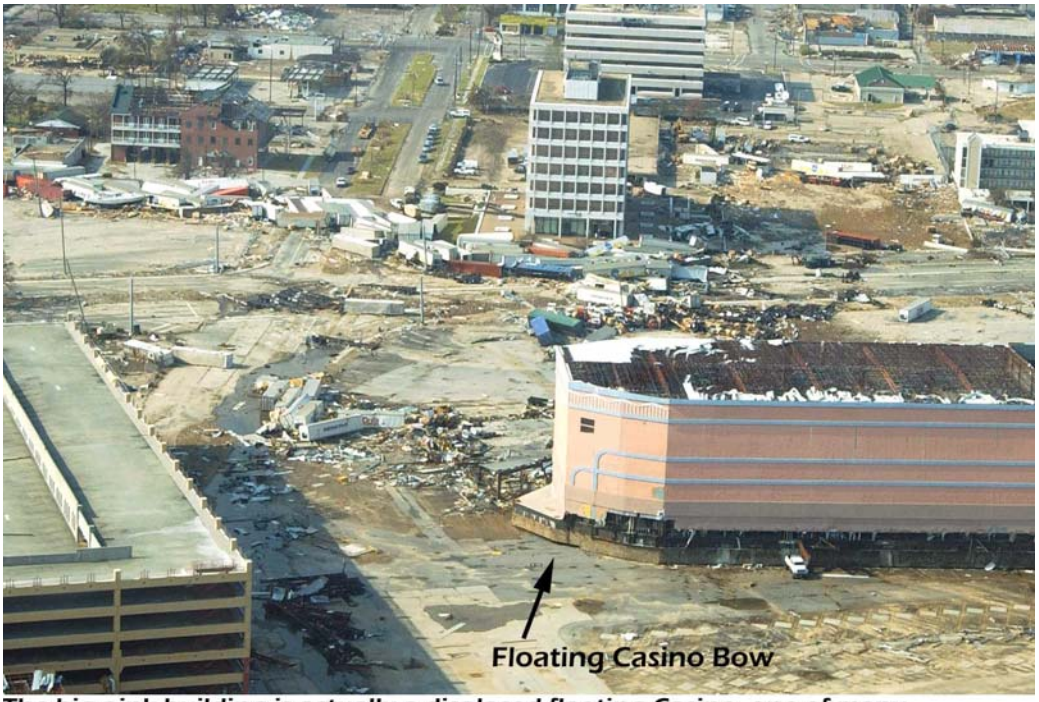
Pass Christian, Lousiana: Devestation from storm surge similar to this affects 90 miles of coastline. Photo: USGS Hurricane Katrina Impact Studies, Post-Storm Quick Response Photos

Some of these records are obviously being beaten due to new observation techniques. Some of the records have been left off because of redundancy, like the many number of records dealing with tropical depressions in a season. Many other records, with obscure meaning because they had to be created because of all the records being set, have been left off of the list as well. An example of this kind of record would be the first occurrence of each of the storms #22 through #28. And five more example of records that did not make the list: there are five different records set for the smallest hurricane eye, all by Wilma. They were: Category 2 at 8 nautical miles (nm), Category 3 at 5nm, Category 4 at 2nm, Category 5 at 2nm and smallest hurricane eye of any hurricane ever recorded at 2nm.

99 Hurricane Records - 2005 Season

1. 28 Named Storms (previous record: 21 in 1933)
2. 15 Hurricanes (previous record: 12 in 1969)
3. Four major hurricanes hitting the U.S. (previous record: three in 2004)
4. Four Category 5 Hurricanes Wilma, Katrina, Rita and Emily (previous record: two in 1960 and 1961)
5. Katrina was the deadliest U.S. hurricane since 1928: Katrina had at least 1,300 deaths.
6. Earliest Category 5 Hurricane in the Atlantic Basin: Emily reached Cat 5 status on July 16 which significantly beats the previous record holder of 25 years, hurricane Allen which first reached Cat 5 status on August 5, 1980.
7. Seven Tropical Storms before August 1 (previous record: five in 1997).
8. Most damaging hurricane ever. Hurricane Katrina's total economic damages (preliminary and conservative) exceeded $148 billion dollars. Old record belonged to Hurricane Andrew (1992) of $43 billion normalized to 2005, or the Great Miami Hurricane of 1926 normalized to 2005 at $102 billion.
9. Most damage ever done in the Atlantic basin in July by hurricanes.
10. Katrina's pressure at landfall was 918mb. This is the third lowest pressure recorded at landfall. Only the Labor Day 1935 storm (892mb) and Camille, 1969 (909mb) had lower pressures.

11. Highest storm surge from an Atlantic Basin hurricane of 28-30 feet from Katrina. The previous record was for Camille (1969) when 24.6 feet was recorded.
12. Strongest hurricane in the in the Atlantic Basin was Wilma at 882 millibars (mb). The previous record was Gilbert at 888 mb.
13. Strongest Accumulated Cyclone Energy Index (ACE) ever recorded at 250. Previous record was 243 in 1950.



The big pink building is actually a displaced flaoting Casino, one of many destroyed in Gulfport, Mississippi during Katrina. It has floated on the storm surge a quarter mile from its original mooring. Photo USGS Hurricane Katrina Impact Studies, Post-Storm Quick Response Photos

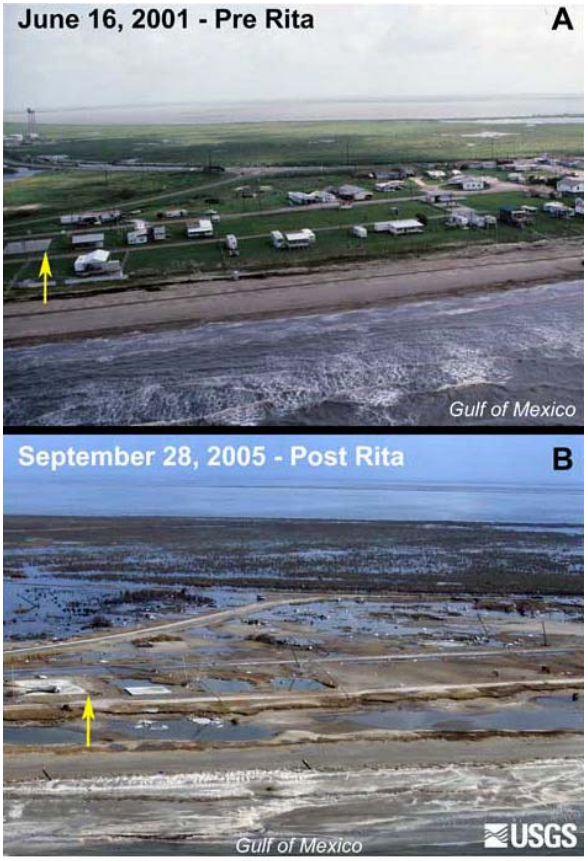
14. The earliest Category 5 storm, Emily formed on July 16 with 155 mph top sustained winds. The previous record: was Dennis (150 mph) in 2005; and hurricane #1 (140 mph) in 1926.
15. Rita had the largest peacetime evacuation (more than 3 Million People Evacuated) for a tropical system in United States history.

16. Wilma set the record for lowest pressure ever measured in the Atlantic Basin. The 882mb pressure in Wilma broke the old record of 888mb measured in Gilbert in 1988.
17. Fastest intensification ever by an Atlantic hurricane: Wilma. Wilma's pressure dropped 97 millibars (mb) in 24 hours Previous record: Gilbert (1988) dropped 72 mb in 24 hours.

Broad Avenue at Beach Boulevard, Long Beach, Mississippi (Gulfport). Photo: USGS Hurricane Katrina Impact Studies, Post-Storm Quick Response Photos

18. Wilma's pressure fell 54 mb over six hours, beating Hurricane Beulah's drop of 38 mb in six hours in 1967.
19. Wilma's 12 hour pressure fall of 83 mb beat the old 12 hour pressure fall record of 48 mb set by Hurricane Allen in 1980.
20. Wilma came in second for the fastest deepening tropical cyclone ever globally. Typhoon Forrest in the Western Pacific deepened 100mb in 24 hours.
21. Wilma had the greatest change in wind speed ever recorded in any tropical system. In 24 hours winds increased 95 knots. (65 knots to 160 knots).
22. Wilma had the smallest eye diameter ever measured in a hurricane, two nautical miles.
23. Wilma had the coldest cloud tops ever recorded at -87C/-125F

24. Wilma - Most Intense Atlantic hurricane in October.
25. Wilma was the most Intense Category 4 storm with a central pressure of 894 mb with 155mph winds.
26. Wilma was the costliest hurricane in Mexican history.
27. Wilma had the greatest 24-hour rainfall total in Mexico at 62.05 inches.
28. Dennis deserves its own record as the most intense Cat 4 hurricane on record with a minimum pressure of 930 mb on July 10. A title that it held until Emily's record of 929 mb a few days on July 16.
29. Dennis was the earliest Category 4 storm ever forming on July 7th.
30. Emily was the earliest Category 5 storm ever recorded on July 16th.
31. Emily was the first July Category 5 hurricane.
32. Emily eclipsed the record previously set by Dennis for lowest pressure recorded for a hurricane before August when its central pressure reached 929mb.
33. Vince was the first tropical cyclone in recorded history to make landfall on the Iberian peninsula (Spain/Portugal or mainland Europe).
34. Vince was the furthest north and east that a storm has ever developed in the Atlantic basin.
35. Beta was the latest major hurricane to ever form.



Holley Beach, Louisiana: Before and after Hurricane Rita. The yellow arrow points to the foundation of the same home in each photo. Everything in town was washed away, including the water tower in the upper left corner. Photo: USGS

36. Delta was the first tropical cyclone on record to affect the Canary Islands.
37. Delta was the second furthest east a tropical cyclone has existed. In October Vince became the furthest east.
38. First time ever that 2 tropical storms hit land in the eastern hemisphere (Delta and Vince).
39. Delta was the first tropical cyclone of any sort to hit Africa.
40. Epsilon had the coldest temperature for a tropical storm to Form (22 degrees C)
41. Epsilon was the longest-lasting hurricane in December at 5.25 days. The old record was hurricane Lili in 1984 and an unnamed hurricane of 1887 with just over 4 days each.
42. Hurricane Epsilon became the longest lasting Atlantic hurricane on record for the month of December (5 days).

Plaquemines Parish, Louisiana. State Highway 23 was closed for quite some time while these two ships were removed. Photo: FEMA

Gulfport, Mississippi: A small part of the Deep South Motel, the blue-green roofed building in the top photo, is the only structure to remain standing in this area. The red arrows point to the same place in each image. Photo: USGS Hurricane Katrina Impact Studies, Post-Storm Quick Response Photos.

43. Zeta was the latest tropical storm to form in the Atlantic basin. It formed on noon of December 30, 2005. Hurricane Alice formed at 1 am on December 30th 1954.
44. Tropical Storm Zeta beat Alice #2 (1954) as the longest-lived tropical cyclone to survive from December into January at 6.75 days.
45. First season that the Greek Alphabet had to be used.
46. Most hurricanes to affect the U.S. in a single season at 9. The old record was 8 in 1933.
47. 124.25 named storm days were recorded in the 2005 season. This breaks the record of 120.5 named storm days set back in 1995.
48. The July record of four named storms was broken with five named storms, two hurricanes and three tropical storms.
49. Two major hurricanes formed in July, tying the previous record set in 1916.
50. July also set records for 25.25 named storm days.
51. Five hurricanes formed in September. This ties the record for most hurricanes in September set in 1955, 1969, 1981, 1998, and 2000.
52. Six named storms formed in October. This ties the record for most named storms in October set in 1950.
53. In October, two intense hurricanes formed. This ties the record for most intense hurricanes set in 1950, 1961, 1964, and 1995.
54. Most storms to form in November at three, the old record was 2 set most recently in 2001.

55. Three tropical storms formed in November (Gamma, Delta, and Epsilon). This breaks the record of two storms set most recently in 2001.
56. Most Named Storm Days after November 30th with 15.75. The old record was 7 in 2003.
57. Latest end to a hurricane season: January 6. The previous record: January 5, for the 1954-55 hurricane season
58. January 2006 had the greatest number of named storm days ever recorded in January (six).
59.
60. Most storm names retired in a single year Katrina, Dennis, Rita, Stan

Gulfside, Beach Boulevard, Waveland Mississippi. Photo: USGS Hurricane Katrina Impact Studies, Post-Storm Quick Response Photos

and Wilma. The previous record was 4 names in 1955, 1995 and, 2004.
61. Katrina - 1st time a Major US City was Rendered "Uninhabitable" (New Orleans).
62. First season with 4 months having the most hurricanes days in that particular month (July, September, October, December).
63. Earliest 4th storm of the season.
64. Earliest 5th storm of the season.

Plaquemines Parish, Louisiana. Hurricane Katrian aftermath. Photo: USGS

65. Earliest 6th storm of the season.
66. Earliest 7th storm of the season.
67. Earliest 8th storm of the season.
68. through 77. Earliest 9th through 21st storms of the season.
78. Two-Year Consecutive total of Category 5 hurricanes at 5, beats 1960-61 at 4.
79. Two-Year Consecutive Total of Tropical Storms: 42 (previous record: 32 most recently in 1995-96)

New Orleans, April 9, 2006: FEMA Debris Specialist for Private Property Debris Removal, Philip Jones. Recovery continues in the 9th Ward. Photo: FEMA

80. Two-Year Consecutive Total of Hurricanes: 25 (previous record: 21 in 1886-87)
81. Two-Year Consecutive Total of Major Hurricanes: 13 (ties record in 1950-51)
82. Two-Year Consecutive Major Hurricane Landfalls: 7 (previous record: 5 in 1954-55)
83. Two -Year Consecutive Florida Major Hurricane Landfalls: 5 (previous record: three in 1949-50)
84. Three-Year Consecutive Total of Tropical Storms: 58 (previous record: 43 most recently in 2002-04)
85. Three-Year Consecutive Total of Hurricanes: 31 (previous record: 27 in 1886-88)

86. Three-Year Consecutive Total of Major Hurricanes: 16 (ties record in 1949-51 and 1950-52)

Pass Christian, Mississippi. This is all that is left of the Pass Christian Middle school. Photo: FEMA

87. Most storms in one season to drop below 1000 mb at 22.\
88. Most storms in one season to drop below 980 mb at 13.
89. Most storms in one season to drop below 950 mb at 7.
90. Most storms in one season to drop below 930 mb at 5.
91. Most storms in one season to drop below 900 mb at 2.
92. Most storms under 950 mb to hit the US in one season at 4.
93. Most storms under 940 mb to hit the US in one season at 2.
94. The 2005 season had the highest combined maximum wind speed of 2410 mph
95. 2005 had the most storms to hit the United States with a pressure less than 950mb at 4, and less than 940mb at 2.
96. The 2005 season had the most tropical depressions to have a central pressure below 1010mb.

97. The 2005 season had the shortest duration of "Longest Quiet Period" in any season of 4.5 days.
98. Most Hurricanes to have top winds of 175mph+ included Katrina, Rita and Wilma.
99. Deadliest Hurricane season ever recorded. To compare the 1780 season with 3,000 lost, or the 1928 season with 1,400, or the 1900 season with 7,000 to 8,000 is not fair. If hurricanes Katrina and Rita had hit the coasts of Louisiana and Texas with current populations of between 1 and 2 million, without evacuation, the loss of life would have been substantially more than 10s of thousands. The population of Galveston in 1900 was about 40,000. Somewhere near 20% of the entire population of Galveston perished in this storm. If only the New Orleans metropolitan area population of 500,000 had been struck by a similar storm today without warning (like the 1900 Galveston storm) and 20% of the population perished, 100,000 people would have died. Katrina was by far the worst disaster that a hurricane has ever experienced in the United States.

2004 Season Hurricane Records

The 2004 Season was by no means a normal season. Four storms hit Florida, causing $45 billion in damages, beating the previous record of total damages in one season set in 1992 by Hurricane Andrew of $43 billion. The last time four storms hit one state was in Texas in 1886. It was the first time since 1906 that two storms, Bonnie and Charlie, hit the same state in a 24-hour period. Other noteworthy records include:

- Hurricane Ivan set the record for the sixth most intense hurricane ever with a minimum central pressure of 910 mb.

- Ivan was the first major hurricane on record to form as far south as 10° N latitude.

- Ivan set the all time record for the highest ACE value of 69.9 $x10^4$ knots, and became the sixth most powerful hurricane ever recorded in the Atlantic Basin.

State Highway 23, Plaquemines Parish, Louisiana. A common method of protection boats during a hurricane is to tie up together. Apparently, this group of boats escaped its mooring and ended up on this bridge. Photo: FEMA

- Ivan set the record for the greatest consecutive amount of time to have wind speeds in excess of 138 mph for any ocean basin.

- Alex became the second storm ever to reach major hurricane status (Category 3) north of 38º North Latitude, the only other storm to do this was Ellen in 1973.

- An estimated one in five homes in Florida were damaged by hurricanes during August and September 2004.

- Hurricane Francis made landfall near Sewell's Point, Florida on September 5, as major Category 2 hurricane causing $8 billion in damages. Hurricane Jeanne came ashore 3 weeks later as a Category 3 and caused $6 billion in damages. This is the first time that two major hurricanes have ever impact a single area in such a short span of time.

- On March 27, Hurricane Catarina made landfall on the coast of Brazil. This was the first time a landfalling hurricane in the South Atlantic had ever been recorded in the satellite era. It made landfall in the Brazillian State of Catarina causing 3 deaths and $350 million in damages. The photo of this classically shaped cyclone shows a rotation that is opposite of that found north of the equator. This is a classic example of the coreolis affect spinning in the opposite direction when comparing one hemisphere to the other.

Hurricane Catarina - on March 27, 2004 became the first tropical cyclone to ever make landfall in the South Atlantic. Photo: NOAA Satellite and Information Service, Environmental Visualization Program

- Five hurricanes made landfall in the US tying 1933 for second place. Six hurricanes impacted the United States in both 1916 and 1985. (Hurricane Alex

also impacted North Carolina when the eye came within 20 miles of the Outer Banks without officially making landfall.)

- 3,000 people were killed in flooding from tropical storm Jeanne in Haiti.

- A total of eight tropical systems reached storm strength in August. This breaks the previous record of seven set in 1933 and 1995.

- The 2004 season, oddly enough, had the fifth latest start ever to a hurricane season. The first storm of the season was named Alex on August 1. The last time a season had started this late was 1952.

- Tropical storm Earl died out in the Caribbean and crossed over into the Pacific to re-intensify into Hurricane Frank.

- Three major hurricanes struck the US, tying that record.

- This season spawned the most tornadoes for a single hurricane not once, but twice. Hurricane Frances had 123 and Ivan had 117. The previous record was held by Hurricane Beulah, which struck the Texas Coast in 1967 with 115 tornadoes.

- Four hurricane names were retired in 2004, tying 1955 and 1995.

- Ten tropical cyclones struck Japan in 2004. This tied the record for number of cyclones in one year.

2003 Season Hurricane Records

Tropical activity during the 2003 season was above normal, with 14 named storms, 7 hurricanes and 3 major hurricanes. Hurricane Isabel, in September 2003, a Category 2 hurricane impacted a large swath of the East Coast. Five billion dollars in damages and 55 deaths were attributed to Isabel. Hurricane Juan became the worst hurricane to hit Nova Scotia since 1893. Juan had 100 mph winds and was responsible for 3 deaths in Halifax. 300,000 were without power, some for up to two weeks. More records from the 2003 season are below:

Hurricane Anna became the first Atlantic tropical storm on record to or during April. The Atlantic Basin's earliest ever recorded hurricane was on March 7, 1908.

- Anna, had the distinction of being the first Atlantic tropical storm on record to form in the month of April the season's earliest Atlantic hurricane ever recorded was on March 7th, 1908.
- The 2003 season tied with 2003 when a tropical storm formed in 7 months out of the 9 month season.
- Most storms in December: Tied with 1887.
- Most named storm days after November 30th with 15.75. The old record was 7 in 2003.
- 2003 had the longest Hurricane Season recorded since 1952.
- On December 4, 2003, tropical storm Odette formed in the Caribbean. This was the first tropical storm ever to have formed in the Caribbean in December.

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