# SUMMARY OF 2007 ATLANTIC TROPICAL CYCLONE ACTIVITY AND VERIFICATION OF AUTHOR'S SEASONAL AND MONTHLY FORECASTS

The 2007 Atlantic basin hurricane season had activity at near-average levels. This activity was less than predicted in our seasonal forecasts.

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with special assistance from William Thorson[3]

This forecast as well as past forecasts and verifications are available via the World Wide Web at http://hurricane.atmos.colostate.edu/Forecasts

Emily Wilmsen, Colorado State University Media Representative, (970-491-6432) is available to answer various questions about this verification.

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ATLANTIC BASIN SEASONAL HURRICANE FORECASTS FOR 2007

| Forecast Parameter and 1950-2000 Climatology (in parentheses) | 8 Dec 2006 | Update 3 April 2007 | Update 31 May 2007 | Update 3 Aug 2007 | Update 4 Sep 2007 | Update 2 Oct 2007 | Observed 2007 Total |
|---|---|---|---|---|---|---|---|
| Named Storms (NS) (9.6) | 14 | 17 | 17 | 15 | 15 | 17 | 14 |
| Named Storm Days (NSD) (49.1) | 70 | 85 | 85 | 75 | 71.75 | 53 | 33.50 |
| Hurricanes (H) (5.9) | 7 | 9 | 9 | 8 | 7 | 7 | 6 |
| Hurricane Days (HD) (24.5) | 35 | 40 | 40 | 35 | 35.50 | 20 | 11.25 |
| Intense Hurricanes (IH) (2.3) | 3 | 5 | 5 | 4 | 4 | 3 | 2 |
| Intense Hurricane Days (IHD) (5.0) | 8 | 11 | 11 | 10 | 12.25 | 8 | 5.75 |
| Accumulated Cyclone Energy (ACE) (96.2) | 130 | 170 | 170 | 150 | 148 | 100 | 68 |
| Net Tropical Cyclone Activity (NTC) (100%) | 140 | 185 | 185 | 160 | 162 | 127 | 94 |

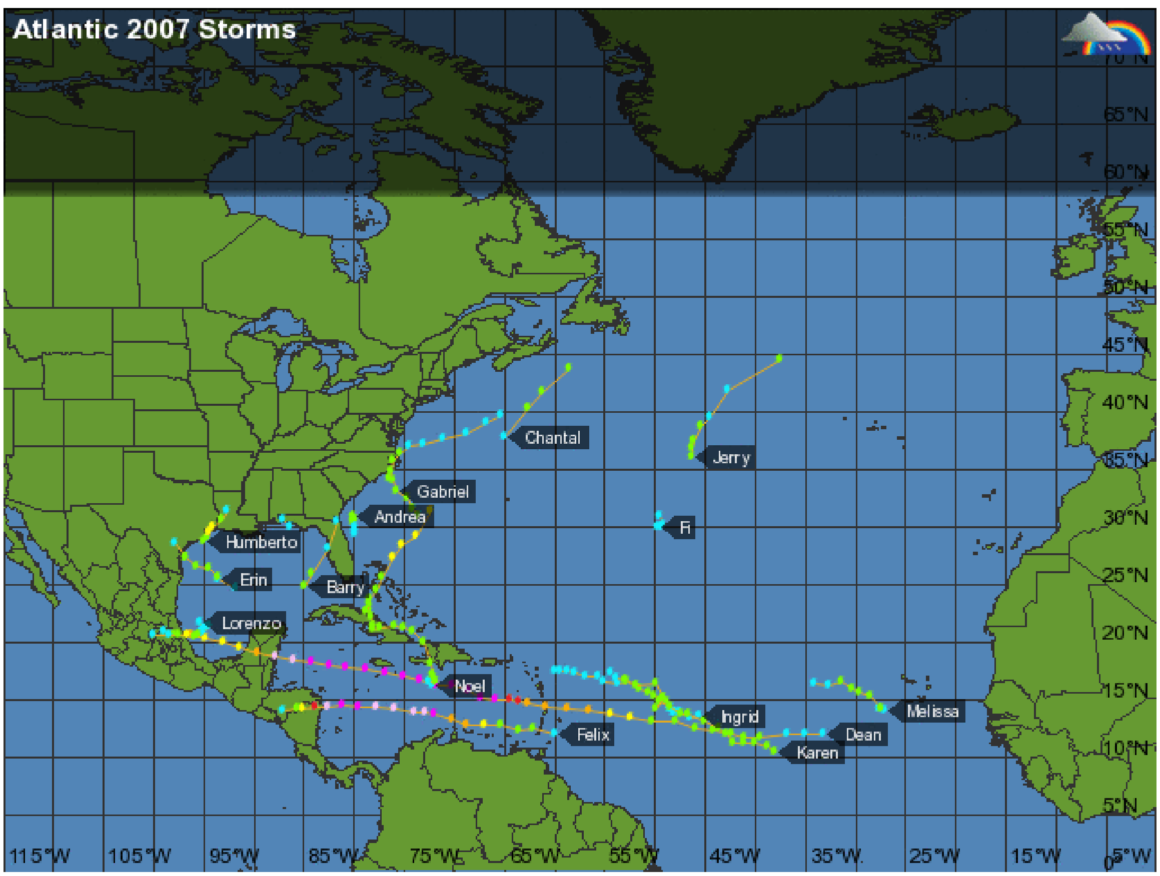


Figure courtesy of Weather Underground (http://www.weatherunderground.com)

ABSTRACT

This report summarizes tropical cyclone (TC) activity, which occurred in the Atlantic basin during 2007 and verifies the authors' seasonal and monthly forecasts of this activity. A forecast was initially issued for the 2007 season on 8 December 2006 with updates on 3 April, 31 May, 3 August, 4 September and 2 October of this year. The four seasonal forecasts issued in early December, early April, late May and early August also contained estimates of the probability of U.S. hurricane landfall during 2007. The 3 August forecast included forecasts of August-only, September-only and October-November tropical cyclone activity for 2007. Our 4 September forecast gave a seasonal summary to that date and included predictions of September-only and October-November activity. Our 2 October forecast gave a seasonal summary to that date and included an October-November forecast. Our 2007 seasonal hurricane forecast was not particularly successful. We anticipated an above-average season, and the season had activity at approximately average levels.

Our August-only forecast was quite successful. Our September and October-November forecasts were not successful. We predicted September and October-November to be active. September experienced activity at average levels, while below-average activity occurred in October-November. Our first forecast for the 2008 season will be issued on Friday, 7 December 2007.

“Meteorologists are known to be absolutely brilliant at after-the-fact explanation of weather phenomena … but please don't press us too hard on future events!!”

# DEFINITIONS

Accumulated Cyclone Energy – (ACE) A measure of a named storm's potential for wind and storm surge destruction defined as the sum of the square of a named storm's maximum wind speed (in $10^4$ $knots^2$) for each 6-hour period of its existence. The 1950-2000 average value of this parameter is 96.

Atlantic Basin – The area including the entire North Atlantic Ocean, the Caribbean Sea, and the Gulf of Mexico.

El Niño – (EN) A 12-18 month period during which anomalously warm sea surface temperatures occur in the eastern half of the equatorial Pacific. Moderate or strong El Niño events occur irregularly, about once every 3-7 years on average.

Hurricane – (H) A tropical cyclone with sustained low-level winds of 74 miles per hour (33 $ms^{-1}$ or 64 knots) or greater.

Hurricane Day – (HD) A measure of hurricane activity, one unit of which occurs as four 6-hour periods during which a tropical cyclone is observed or estimated to have hurricane intensity winds.

Intense Hurricane - (IH) A hurricane which reaches a sustained low-level wind of at least 111 mph (96 knots or 50 $ms^{-1}$) at some point in its lifetime. This constitutes a category 3 or higher on the Saffir/Simpson scale (also termed a "major" hurricane).

Intense Hurricane Day – (IHD) Four 6-hour periods during which a hurricane has an intensity of Saffir/Simpson category 3 or higher.

Named Storm – (NS) A hurricane, a tropical storm or a sub-tropical storm.

Named Storm Day – (NSD) As in HD but for four 6-hour periods during which a tropical cyclone is observed (or is estimated) to have attained tropical storm intensity winds.

NTC – Net Tropical Cyclone Activity –Average seasonal percentage mean of NS, NSD, H, HD, IH, IHD. Gives overall indication of Atlantic basin seasonal hurricane activity. The 1950-2000 average value of this parameter is 100.

QBO – Quasi-Biennial Oscillation – A stratospheric (16 to 35 km altitude) oscillation of equatorial east-west winds which vary with a period of about 26 to 30 months or roughly 2 years; typically blowing for 12-16 months from the east, then reversing and blowing 12-16 months from the west, then back to easterly again.

Saffir/Simpson (S-S) Category – A measurement scale ranging from 1 to 5 of hurricane wind and ocean surge intensity. One is a weak hurricane; whereas, five is the most intense hurricane.

SOI – Southern Oscillation Index – A normalized measure of the surface pressure difference between Tahiti and Darwin.

SST(s) – Sea Surface Temperature(s)

SSTA(s) – Sea Surface Temperature(s) Anomalies

Tropical Cyclone – (TC) A large-scale circular flow occurring within the tropics and subtropics which has its strongest winds at low levels; including hurricanes, tropical storms and other weaker rotating vortices.

Tropical Storm – (TS) A tropical cyclone with maximum sustained winds between 39 (18 $ms^{-1}$ or 34 knots) and 73 (32 $ms^{-1}$ or 63 knots) miles per hour.

ZWA – Zonal Wind Anomaly – A measure of the upper level (~200 mb) west to east wind strength. Positive anomaly values mean winds are stronger from the west or weaker from the east than normal.

1 knot = 1.15 miles per hour = 0.515 meters per second

## Notice of Author Changes

## By William Gray

The order of the authorship of these forecasts was reversed in 2006 from Gray and Klotzbach to Klotzbach and Gray. After 22 years (from 1984-2005) of making these forecasts, it is appropriate that I step back and have Phil Klotzbach assume the primary responsibility for our project's seasonal, monthly and landfall probability forecasts. Phil has been a member of my research project for the last seven years and was second author on these forecasts from 2001-2005. I have greatly profited and enjoyed our close personal and working relationships.

Phil is now devoting more time to the improvement of these forecasts than I am. I am now giving more of my efforts to the global warming issue and in synthesizing my projects' many years of hurricane and typhoon studies.

Phil Klotzbach is an outstanding young scientist with a superb academic record. I have been amazed at how far he has come in his knowledge of hurricane prediction since joining my project in 2000. I foresee an outstanding future for him in the hurricane field. I expect he will make many new forecast innovations and skill improvements in the coming years. He was recently awarded his Ph.D. degree.

## Acknowledgment

We are grateful to the National Science Foundation (NSF) and Lexington Insurance Company (a member of the American International Group (AIG)) for providing partial support for the research necessary to make these forecasts. We also thank the GeoGraphics Laboratory at Bridgewater State College (MA) for their assistance in developing the Landfalling Hurricane Probability Webpage (available online at http://www.e-transit.org/hurricane).

The second author gratefully acknowledges valuable input to his CSU research project over many years by former graduate students and now colleagues Chris Landsea, John Knaff and Eric Blake. We thank Jim Kossin and Dan Vimont for providing the prediction data for the Atlantic Meridional Mode. We thank Amato Evan for providing us with the African dust data. We also thank Professors Paul Mielke and Ken Berry of Colorado State University for much statistical analysis and advice over many years.

# 1 Introduction

A variety of atmosphere-ocean conditions interact with each other to cause year-to-year and month-to-month hurricane variability. The interactive physical linkages between these many physical parameters and hurricane variability are complicated and cannot be well elucidated to the satisfaction of the typical forecaster making short range (1-5 days) predictions where changes in the momentum fields are the crucial factors. Seasonal and monthly forecasts, unfortunately, must deal with the much more complicated interaction of the energy-moisture fields with the momentum fields.

We find that there is a rather high (50-60 percent) degree of year-to-year hurricane forecast potential if one combines 4-5 semi-independent atmospheric-oceanic parameters together. The best predictors (out of a group of 4-5) do not necessarily have the best individual correlations with hurricane activity. The best forecast parameters are those that explain the portion of the variance of seasonal hurricane activity that is not associated with the other variables. It is possible for an important hurricane forecast parameter to show little direct relationship to a predictand by itself but to have an important influence when included with a set of 4-5 other predictors.

In a five-predictor empirical forecast model, the contribution of each predictor to the net forecast skill can only be determined by the separate elimination of each parameter from the full five-predictor model while noting the hindcast skill degradation. When taken from the full set of predictors, one parameter may degrade the forecast skill by 25-30 percent, while another degrades the forecast skill by only 10-15 percent. An individual parameter that, through elimination from the forecast, degrades a forecast by as much as 25-30 percent may, in fact, by itself, show little direct correlation with the predictand. A direct correlation of a forecast parameter may not be the best measure of the importance of this predictor to the skill of a 4-5 parameter forecast model. This is the nature of the seasonal or climate forecast problem where one is dealing with a very complicated atmospheric-oceanic system that is highly non-linear. There is a maze of changing physical linkages between the many variables. These linkages can undergo unknown changes from weekly to decadal time scales. It is impossible to understand how all these processes interact with each other. Despite the complicated relationships that are involved, our statistical forecasts do show considerable hindcast skill.

# 2 Tropical Cyclone Activity for 2007

Figure 1 and Table 1 summarize the Atlantic basin tropical cyclone activity which occurred in 2007. A near-average season was experienced in 2007 for most tropical cyclone parameters. See page 4 for acronym definitions.

# 3 Individual 2007 Tropical Cyclone Characteristics

The following is a brief summary of each of the named tropical cyclones in the Atlantic basin for the 2007 season. See Fig. 1 for the tracks of these tropical cyclones, and see Table 1 for statistics of each of these tropical cyclones. Online entries from

Wikipedia (http://www.wikipedia.org) were very helpful in putting together these tropical cyclone summaries.

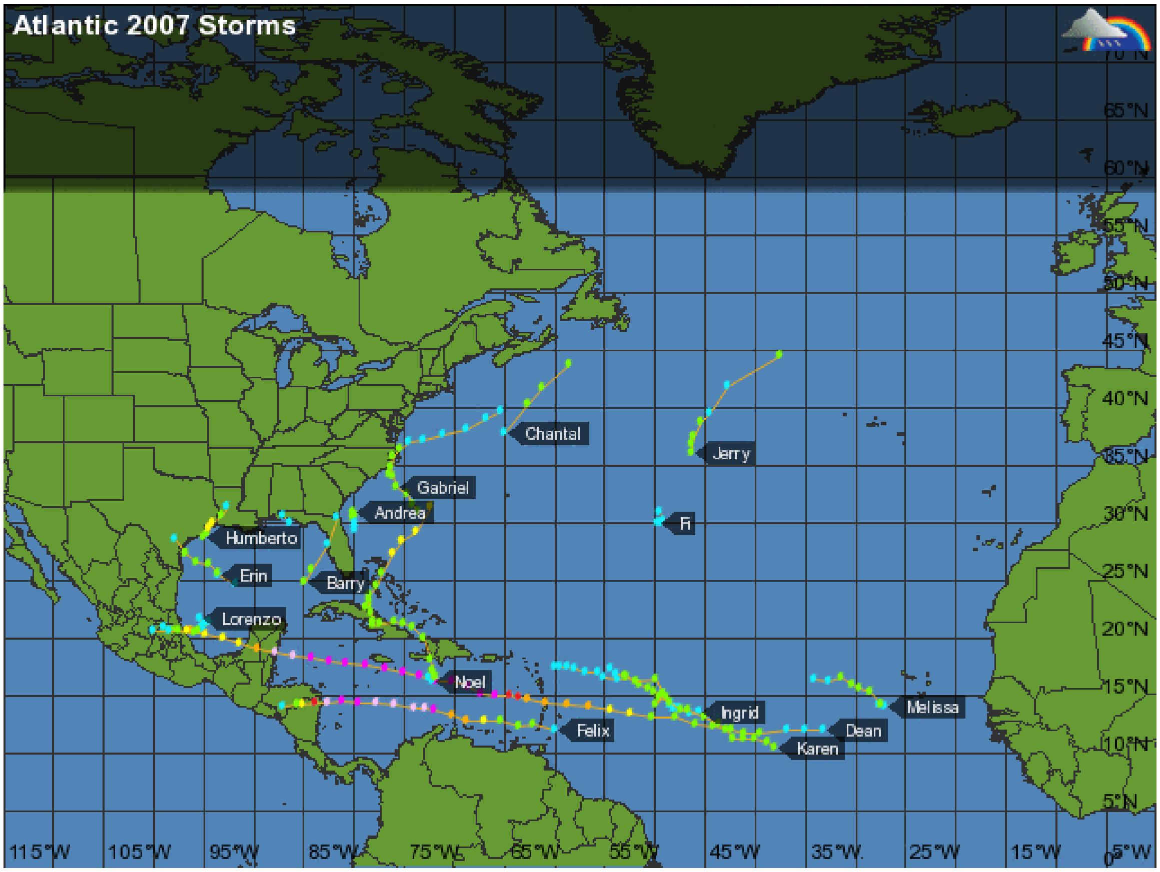


Figure 1: Tracks of 2007 Atlantic Basin tropical cyclones. Figure courtesy of Weather Underground (http://www.weatherunderground.com).

Table 1: Observed 2007 Atlantic basin tropical cyclone activity.

| Highest Category | Name | Dates | Peak Sustained Winds (kts)/lowest SLP (mb) | NSD | HD | IHD | NTC |
|---|---|---|---|---|---|---|---|
| TS | Andrea | May 9-11 | 40 kt/1002 mb | 1.00 | | | 2.1 |
| TS | Barry | June 1-2 | 45 kt/997 mb | 0.75 | | | 2.0 |
| TS | Chantal | July 31-Aug. 1 | 45 kt/994 mb | 0.75 | | | 2.0 |
| IH-5 | Dean | Aug. 14-23 | 145 kt/918 mb | 8.50 | 6.50 | 3.75 | 31.6 |
| TS | Erin | Aug. 15-16 | 35 kt/1003 mb | 1.00 | | | 2.1 |
| IH-5 | Felix | Sep. 1-5 | 145 kt/929 mb | 4.00 | 3.00 | 2.00 | 21.9 |
| TS | Gabrielle | Sep. 8-10 | 45 kt/1004 mb | 2.25 | | | 2.5 |
| H-1 | Humberto | Sep. 12-13 | 75 kt/986 mb | 1.00 | 0.25 | | 5.1 |
| TS | Ingrid | Sep. 14-15 | 40 kt/1002 mb | 1.50 | | | 2.2 |
| TS | Jerry | Sep. 23-24 | 35 kt/1004 mb | 1.00 | | | 2.1 |
| H-1 | Karen | Sep. 25-29 | 65 kt/990 mb | 4.25 | 0.25 | | 6.2 |
| H-1 | Lorenzo | Sep. 27-28 | 70 kt/990 mb | 0.75 | 0.25 | | 5.0 |
| TS | Melissa | Sep. 29-30 | 40 kt/1003 mb | 1.25 | | | 2.2 |
| H-1 | Noel | Oct. 28-Nov.2 | 70 kt/981 mb | 5.25 | 1.00 | | 7.0 |
| Totals | 14 | | | 33.50 | 11.25 | 5.75 | 93.9 |

Sub-tropical Storm Andrea: Andrea formed from an area of low pressure off the southeast U.S. coast on May 9. Andrea exhibited a hybrid-type structure throughout its existence, and therefore it was classified as a sub-tropical cyclone. An upper-level trough caused Andrea to slowly drift southwestward. A combination of dry air and fairly strong northwesterly shear soon began to affect the tropical cyclone, and it was downgraded to a depression on May 10. The continued stable environment, dry air and shear inhibited sustained deep convection, and Andrea was downgraded to a remnant low early on May 11.

Tropical Storm Barry: Barry formed from an area of low pressure in the southeastern Gulf of Mexico on June 1. The system intensified briefly, but its intensification was limited due to strong southwesterly shear that stripped the system of its deep convection. An upper-level trough caused Barry to move towards the northeast. The system weakened as it approached the west coast of Florida, making landfall as a tropical depression near Tampa on June 2. It became extra-tropical later that day as it tracked northeast across Florida. Rainfall from Barry helped to alleviate drought conditions across portions of Florida.

Tropical Storm Chantal: Chantal formed from a non-tropical low while passing to the west of Bermuda on July 30. It intensified into a tropical storm on July 31 while traveling briskly northeastward across the open Atlantic. It reached its maximum intensity of 45 knots later on July 31 before beginning a transition to extra-tropical status later that day. It was classified as extra-tropical early on August 1. Heavy rains and strong winds from the extra-tropical remnants of Chantal caused some flooding in Newfoundland.

Intense Hurricane Dean: Dean formed from a tropical wave while located over the eastern tropical Atlantic on August 13. Moderate easterly wind shear inhibited the system's initial development as it tracked westward. An upper-level anti-cyclone began to build over the system, reducing levels of vertical wind shear, and the system was upgraded to a tropical storm on August 14. The deep-layer ridge to the north of Dean continued to keep Dean on a westward track as it began to intensify. A combination of low values of vertical wind shear and warm sea surface temperatures aided Dean's intensification into a hurricane on August 16. Some light westerly shear and dry air intrusion prevented rapid intensification of Dean as it passed near St. Lucia and Martinique. However, as it passed into the eastern Caribbean, the wind shear abated, and Dean rapidly intensified into a major hurricane. By August 18, Dean had become a Category 4 storm. Later on August 18, Dean underwent an eyewall replacement cycle, and it weakened slightly while passing south of Jamaica. The eyewall replacement cycle was completed by August 19, and Dean began to strengthen again. Hurricane hunter aircraft measured a central pressure of 918 mb and maximum flight level winds of 162 knots early on August 21, and Dean was then upgraded to a Category 5 hurricane with maximum sustained winds of 145 knots. Dean made landfall on the east coast of the Yucatan Peninsula as a Category 5 hurricane later on August 21. A 906 mb central pressure reading was recorded just prior to landfall, which is the ninth lowest pressure recorded for a tropical cyclone in the Atlantic basin. It is also the third lowest Atlantic basin landfalling central pressure trailing only the Florida Keys hurricane of 1935 and Hurricane Gilbert near Cancun, Mexico in 1988. Dean weakened to a Category 1 hurricane while traversing the Yucatan Peninsula. It emerged into the Bay of Campeche late on August 21. Dean re-intensified into a Category 2 storm over the Bay of Campeche before making its final landfall near Tecolutla, Mexico on August 22. It dissipated over the high terrain of Mexico early on August 23. 42 deaths have been attributed to Hurricane Dean, while total damage is estimated at nearly $4 billion dollars.

Tropical Storm Erin: Erin developed from an area of low pressure in the Gulf of Mexico on August 15. Erin was upgraded to a tropical storm later on August 15. A strong high pressure system to the northeast of Erin steered Erin west-northwestward. The system never got particularly well organized. It made landfall near Lamar, Texas as a weak tropical storm early on August 16 with 35-knot winds. The system dissipated over Texas later on August 16. Erin's remnants interacted with a low-level jet over the Great Plains and re-intensified to produce strong winds and heavy rain over portions of Texas, Oklahoma and Missouri. Eighteen deaths have been directly or indirectly attributed to Erin. Damage estimates for Erin were not available.

Intense Hurricane Felix: Felix formed on August 31 from a tropical wave while located about 200 miles east of the Windward Islands. An upper-level anticyclone kept Felix on a west-northwestward track throughout most of its lifetime. Felix intensified into a tropical storm on September 1. Felix was imbedded in a weak shear and warm sea surface temperature environment, and it intensified into a hurricane in just fifteen hours. It continued to intensify rapidly over the warm waters of the eastern Caribbean, becoming the second major hurricane of the season later on September 2. By late on September 2, Felix intensified into the second Category 5 hurricane of the year. Several hours later, the central pressure of Felix was estimated to have bottomed out at 929 mb. During this time, Felix's eye was estimated to have contracted to approximately 12 miles across. Felix weakened to a Category 4 hurricane on September 3, potentially due to an eyewall replacement cycle. Felix re-intensified to a Category 5 hurricane while nearing the coast of Nicaragua. It made landfall on September 4 near the Nicaragua/Honduras border as a Category 5 storm. The system dissipated rapidly over land, becoming a tropical storm early on September 5 and a remnant low later that day. At least 133 deaths have been reported due to Felix, while damage estimates remain unknown.

Tropical Storm Gabrielle: Gabrielle formed from an area of low pressure off the southeastern United States coast on September 8. It was initially classified as a sub-tropical storm due to its large radius of maximum winds, its convective structure and its interaction with an upper-level low to its west-southwest. By later on September 8, the system exhibited a weak warm core circulation, and it was classified as a tropical storm. It tracked northwestward around the western periphery of a ridge during the early part of its lifetime. The system intensified briefly; however, northerly shear prevented much deepening. Gabrielle began to turn more towards the north and then northeast as it traversed around the western end of the deep-layer ridge. Gabrielle made landfall near Cape Lookout National Seashore, North Carolina on September 9. Estimated maximum winds at landfall were near 50 knots. Gabrielle soon began to accelerate and turn more towards the northeast as it became embedded in the mid-latitude westerlies. The system was downgraded to a tropical depression on September 10, as strong shear stripped the system of its deep convection. It was downgraded to a remnant low on September 11. Damage in North Carolina was minor, and there were no reported fatalities.

Hurricane Humberto: Humberto formed from an area of low pressure in the western Gulf of Mexico on September 12. The system formed in a light shear environment with favorable upper-level outflow and warm sea surface temperatures. Humberto intensified into a tropical storm later on September 12. A mid-level high pressure system caused Humberto to track northward towards the Texas coast. Late on September 12, Humberto began to rapidly intensify, becoming a hurricane early on September 13. Humberto crossed the Texas coast near High Island later on September 13. The system rapidly weakened to a tropical depression after making landfall. Humberto was notable for its rapid intensification from a 30-knot tropical depression to a 75-knot hurricane. This intensification was accomplished over an 18-hour period, making it the fastest development in recorded history for the Atlantic basin. Although the exact causes of Humberto's rapid intensification are still being debated, it was likely due to a combination of warm sea surface temperatures, low values of vertical wind shear, favorable upper-level outflow patterns and the small size of the cyclone. One fatality has been attributed to Humberto, while damage estimates are estimated to be near $50 million dollars.

Tropical Storm Ingrid: Ingrid formed from a tropical wave on September 12 while located about 1100 miles east of the Lesser Antilles. A weak deep-layer ridge caused Ingrid to track westward during its initial stages, and some moderate northeasterly shear prevented its initial intensification. Ingrid overcame its initial problems with shear to become classified as a tropical storm on September 14. Ingrid became embedded in a weak steering environment and slowly drifted west-northwestward with little change in strength. Ingrid then intensified briefly as westerly shear temporarily slackened. Upper-level westerlies, associated with a strong upper-level low, soon began to impinge on the tropical cyclone, and it weakened back to a 35-knot tropical cyclone later on September 14. Ingrid was downgraded to a tropical depression on September 15 as strong westerly wind shear generated by the upper-level low continued to buffet the system. By September 17, the system was virtually void of deep convection, and it was downgraded to a remnant low.

Tropical Storm Jerry: Jerry formed from a non-tropical area of low pressure in the north central Atlantic on September 23. Since it was still interacting with an upper-level low, it was initially classified as a sub-tropical storm. Jerry tracked slowly northward and then began to accelerate towards the northeast as a digging mid-tropospheric trough intensifying off the east coast of Canada began to overtake the system. Jerry was classified as a tropical storm on September 24 due to the development of a warm core and a shrinking in the radius of maximum winds. Deep convection was mostly sheared away from Jerry later on September 24, and the system was downgraded to a tropical depression. Jerry was upgraded back to a tropical storm for its final advisory as it completed extra-tropical transition on September 25.

Hurricane Karen: Karen developed from a tropical wave while located about 1700 miles east of the Windward Islands on September 25. The system tracked west-northwestward underneath a mid-level ridge during its initial stages. Weak vertical wind shear allowed Karen to strengthen into a tropical storm later on September 25. Karen initially had a large and broad circulation that inhibited rapid intensification of the system. On September 26, Karen began to intensify and briefly reached hurricane intensity late in the day before weakening due to strong southwesterly vertical wind shear. Karen continued to track west-northwestward around the subtropical ridge while battling strong vertical wind shear. Karen weakened to a minimal tropical storm on September 28 and further weakened to a tropical depression on September 29. Shear prevailed over Karen, and it was downgraded to a remnant low late on September 29.

Hurricane Lorenzo: Lorenzo formed from an area of low pressure in the southeastern Gulf of Mexico on September 25. Lorenzo was embedded in a weak steering flow environment and slowly drifted westward over the next couple of days. Initially, an upper low near the Mexican coast imparted southwesterly shear over the system and inhibited development. Lorenzo was a very small system, and once shear relaxed, it rapidly intensified into a 50-knot tropical cyclone on September 27. It intensified further into a hurricane early on September 28. The system made landfall approximately 40 miles south of Tuxpan, Mexico later on September 28 as a 70-knot hurricane. It dissipated over the high terrain of Mexico later that day. Five fatalities have been attributed to Lorenzo. Damage estimates are not available.

Tropical Storm Melissa: Melissa formed from an easterly wave while located near the Cape Verde Islands on September 28. The storm tracked gradually towards the northwest while being steered by a narrow ridge. Westerly vertical wind shear inhibited initial intensification, although the system did manage to strengthen to a tropical storm on September 29. It reached its maximum intensity of 40 knots early on September 30.

Westerly shear was again on the increase soon after, and Melissa weakened later that day to a tropical depression. It degenerated further to a remnant low that evening.

Hurricane Noel: Noel formed from an area of low pressure in the Caribbean Sea on October 27. The system initially drifted slowly westward underneath an upper-level ridge. An upper-level low inhibited initial intensification. The circulation center developed closer to the center of the deep convection on October 28, and Noel was upgraded to a tropical storm later that day. The system intensified into a 50-knot tropical cyclone late on October 28. It then weakened as it tracked north-northwestward over Haiti. It then re-intensified into a 50-knot tropical cyclone as it tracked near the north coast of Cuba. Noel then began to drift westward over northern Cuba, weakening back to a minimal tropical cyclone on October 30. A mid-level trough began to turn Noel towards the northwest and then north, and the system moved back over warm waters near the Bahamas. Noel intensified somewhat on October 31, despite some southwesterly wind shear. The system intensified further on November 1, becoming a hurricane late in the day. A mid-latitude short-wave trough interacted with Noel, causing the system to accelerate northeastward. It maintained hurricane intensity until extra-tropical transition was complete late on November 2. The extra-tropical remnants of Noel brought heavy rains and strong winds to eastern New England and the Atlantic Provinces of Canada.

U.S. Landfall. Figure 2 shows the tracks of all tropical cyclones that made landfall in the United States in 2007. One tropical depression, two tropical storms and one hurricane made U.S. landfall this year: Tropical Depression Barry, Tropical Storms Erin and Gabrielle and Hurricane Humberto. Table 2 displays the estimated damage from these four storms. Barry and Gabrielle did minimal damage, while Humberto incurred approximately 500 million dollars in total damage in Texas. Damage from Erin is unavailable. This is the second year in a row that the United States has experienced fairly little damage from tropical cyclones.


Figure 2: Tropical cyclones making U.S. landfall (TD Barry, TS Erin, TS Gabrielle and Hurricane Humberto). A dashed line indicates tropical depression or storm strength, while a solid line indicates hurricane strength.

Table 2: United States damage estimates for the four tropical cyclones that made U.S. landfall in 2007 (in millions of dollars). We assume that total damage is twice that of insured damage.

| Storm Name | Insured Damage | Total Damage (Assumes Twice Insured Damage) |
|---|---|---|
| Barry | Minimal | Minimal |
| Erin | Unknown | Unknown |
| Gabrielle | Minimal | Minimal |
| Humberto | 25 | 50 |
| **Total** | **25** | **50** |

## 4 Special Characteristics of the 2007 Hurricane Season

The 2007 hurricane season had the following special characteristics:

- Another early-starting season. Andrea formed on May 9. The climatological average date for the first named storm formation in the Atlantic, based on 1944-2005 data, is July 10.

- Fourteen named storms formed during the 2007 season. Since 1995, 12 out of 13 seasons have had more than the 1950-2000 average of ten named storms.

- Six hurricanes formed during the 2007 season. This is very close to the long-term average (5.9 hurricanes per year).

- Two major hurricanes formed during the 2007 season. 1997 was the most recent year to have fewer than two major hurricanes form (1 – Erika).

- 33.50 named storm days occurred in 2007. This is the lowest value of named storm days since 1994, when only 27.75 named storm days occurred.

- 11.25 hurricane days occurred in 2007. This is the lowest value of hurricane days since 2002, when 10.75 hurricane days were observed.

- 5.75 intense hurricane days occurred in 2007. Despite low values of named storm days and hurricane days, intense hurricane days were at above-average levels.

- The season accrued an ACE of 68. This is the lowest value for the ACE index since 2002, when a value of 65 was observed.

- Hurricane Dean became a Category 5 hurricane in August. Hurricane Katrina became a Category 5 hurricane in August 2005. The most recent year with a Category 5 hurricane in August prior to 2005 was Hurricane Andrew in 1992.

- September 2007's NTC value was 47. This is the first September with NTC below the climatological average of 48 since 1997, when only 28 NTC units were accrued.

- Only 3.75 hurricane days occurred in September 2007. This is the fewest hurricane days observed in September since 1994 when no hurricane days were observed.

- Eight named storms formed in September. This ties the record, set in 2002, for most named storm formations during the month of September.

- Only one named storm formed during October. This marks the second year in a row with fewer than two named storm formations (the climatological average) during October.

- The season accumulated 94 NTC units. This marks the second year in a row with below-normal NTC. The most recent year with a below-normal NTC prior to 2006 was 2002.

- Three named storms (Erin, Gabrielle and Humberto) made United States landfall in 2007. This year ties2006 for the fewest number of named storms to make landfall in the United States since 2001.

- Hurricane Humberto became the first hurricane to make landfall in Texas since Hurricane Claudette in 2003.

- Although fourteen named storms formed in 2007, they lasted for a cumulative total of only 33.50 named storm days, or approximately 2.4 named storm days per named storm. This is the lowest ratio of named storm days per named storm since 1977 (2.3 named storm days per storm).

# 5 Verification of Individual 2007 Lead Time Forecasts

Table 3 is a comparison of our 2007 forecasts for six different lead times along with this year's observations. Our seasonal forecasts for 2007 were a disappointment. We expected an active season, and the season had activity at near-average levels. The attribution of the near-average season that occurred in 2007 is quite difficult, especially considering that a La Niña episode developed during this year's hurricane season.

Table 3: Verification of our 2007 seasonal hurricane predictions.

| Forecast Parameter and 1950-2000 Climatology (in parentheses) | 8 Dec 2006 | Update 3 April 2007 | Update 31 May 2007 | Update 3 Aug 2007 | Update 4 Sep 2007 | Update 2 Oct 2007 | Observed 2007 Total |
|---|---|---|---|---|---|---|---|
| Named Storms (NS) (9.6) | 14 | 17 | 17 | 15 | 15 | 17 | 14 |
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| Hurricanes (H) (5.9) | 7 | 9 | 9 | 8 | 7 | 7 | 6 |
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| Intense Hurricane Days (IHD) (5.0) | 8 | 11 | 11 | 10 | 12.25 | 8 | 5.75 |
| Accumulated Cyclone Energy (ACE) (96.2) | 130 | 170 | 170 | 150 | 148 | 100 | 68 |
| Net Tropical Cyclone Activity (NTC) (100%) | 140 | 185 | 185 | 160 | 162 | 127 | 94 |

## 5.1 Preface: Aggregate Verification of our Last Nine Yearly Forecasts

A way to consider the skill of our forecasts is to evaluate whether the forecast for each parameter successfully forecast above- or below-average activity. Table 4 displays how frequently our forecasts have been on the right side of climatology for the past nine years. In general, our forecasts are successful at forecasting whether the season will be more or less active than normal by as early as December of the previous year with improving skill as the hurricane season approaches.

Table 4: The number of years that our tropical cyclone forecasts issued at various lead times have correctly predicted above- or below-average activity for each predictand over the past nine years (1999-2007).

| Tropical Cyclone Parameter | Early December | Early April | Early June | Early August |
|---|---|---|---|---|
| **NS** | 7/9 | 8/9 | 8/9 | 7/9 |
| **NSD** | 7/9 | 8/9 | 8/9 | 7/9 |
| **H** | 6/9 | 7/9 | 7/9 | 7/9 |
| **HD** | 5/9 | 6/9 | 6/9 | 7/9 |
| **IH** | 5/9 | 5/9 | 7/9 | 7/9 |
| **IHD** | 6/9 | 6/9 | 8/9 | 8/9 |
| **NTC** | 5/9 | 6/9 | 6/9 | 7/9 |
| **Total** | **41/63 (65%)** | **46/63 (73%)** | **50/63 (79%)** | **50/63 (79%)** |

Of course, there are significant amounts of unexplained variance in a number of the individual parameter forecasts. Even though the skill for some of these parameter forecasts is somewhat low, especially for the early December lead time, there is a great curiosity in having some objective measure as to how active the coming hurricane season is likely to be. Therefore, even a forecast that is only modestly skillful is likely of interest. Complete verifications of all seasonal and monthly forecasts are available online at http://tropical.atmos.colostate.edu/Includes/Documents/Publications/forecast_verifications.xls. Verifications are currently available for 1984-2006. Verifications for 2007 will be completed when the National Hurricane Center completes their best track analysis of all of the 2007 Atlantic basin tropical cyclones.

## 5.1 Predictions of Individual Monthly TC Activity

A new aspect of our climate research is the development of TC activity predictions for individual months. On average, August, September and October have about 26%, 48%, and 17% or 91% of the total Atlantic basin NTC activity. August-only monthly forecasts have now been made for the past eight seasons, and September-only forecasts have been made for the last six seasons. This is the fifth year that we have issued an October forecast. This is the second year that we have issued a combined October-November outlook.

There are often monthly periods within active and inactive hurricane seasons which do not conform to the overall season. To this end, we have recently developed new schemes to forecast August-only, September-only and October-November Atlantic basin TC activity. These efforts have been documented by Blake and Gray (2004) for the

August-only forecast and Klotzbach and Gray (2003) for the September-only forecast – see citations and additional reading section.

Quite skillful August-only, September-only and October-November prediction schemes have been developed based on 51 years (1950-2000) of hindcast testing using a statistically independent jackknife approach. Predictors are derived from prior months, usually June and July (NCEP global reanalysis) data for all three (August-only, September-only and October-November) monthly forecasts and include August's data for the early September forecast of September-only and October-November forecasts. We include data through September for our final October-November forecast issued in early October. Table 5 gives an outline and timetable of the different forecasts and verifications that we issue in early August, early September and early October.

Table 5: Timetable of the issuing of our monthly forecasts (in early August, in early September, and early October), the times of their verification, and the dates of seasonal updates. Note that we make three separate October-November forecasts; two separate September-only forecasts, and one separate August-only forecast. Seasonal updates are issued in early September and early October.

| Times of Forecast and Verification | Based on Data Through | | **Forecasts** | | |
|---|---|---|---|---|---|
| Early August | July | August Forecast | September Forecast | October-November Forecast | Full Season Forecast |
| Early September | August | August Verification | September Forecast | October-November Forecast | Remainder of Season Forecast |
| Early October | September | | September Verification | October-November Forecast | Remainder of Season Forecast |

## 5.2 August-only 2007 Forecast

Our August 2007 forecast was successful (see Table 6). We predicted a slightly above-average month (based on the Net Tropical Cyclone activity parameter), and this forecast verified quite well. August 2007 was notable for long-lived major hurricane Dean which devastated portions of Nicaragua and Honduras. We have now correctly predicted above- or below-average activity (based on NTC) in six out of eight years that August-only forecasts have been issued (see Table 7).

Table 6: Forecast and verification of August-only hurricane activity made in early August.

| Tropical Cyclone Parameters and 1950-2000 August Average (in parentheses) | August 2007 Forecast | August 2007 Verification |
|---|---|---|
| Named Storms (NS) (2.8) | 3 | 2 |
| Named Storm Days (NSD) (11.8) | 14 | 9.75 |
| Hurricanes (H) (1.6) | 2 | 1 |
| Hurricane Days (HD) (5.7) | 6 | 6.50 |
| Intense Hurricanes (IH) (0.6) | 1 | 1 |
| Intense Hurricane Days (IHD) (1.2) | 1.5 | 3.75 |
| Net Tropical Cyclone Activity (NTC) (26.4) | 32 | 34 |

Table 7: Predicted, observed, and climatological NTC for our eight August-only forecasts of 2000-2007. Years where we have correctly predicted an above- or below-average August are in bold-faced type.

| Year | Observed NTC | Predicted NTC | Climatological NTC |
|---|---|---|---|
| **2000** | **42** | **33** | **26** |
| **2001** | **9** | **22** | **26** |
| **2002** | **7** | **18** | **26** |
| 2003 | 26 | 22 | 26 |
| **2004** | **89** | **35** | **26** |
| **2005** | **41** | **50** | **26** |
| 2006 | 12 | 50 | 26 |
| **2007** | **34** | **32** | **26** |

August 2007 had a slightly below-average number of named storm and hurricane formations. However, the one hurricane that did form (Dean) reached Category 5 status and lasted for 3.75 days as a major hurricane. This is the most days that a single major hurricane has accrued during the month of August since 2004 (Frances). When investigating an aggregate measure such as NTC, August 2007 had slightly above-average activity.

From a large-scale perspective, atmospheric and oceanic conditions provided a mixed bag for the tropical Atlantic during August. Sea level pressures were quite low (Figure 3). Typically, low sea level pressures lead to active Atlantic basin hurricane seasons through an implied increase in instability and weaker-than-normal trades. August sea level pressures across the tropical Atlantic were estimated to be at their fifth lowest values since 1948. The only lower years were 1955, 1995, 1950 and 1958, respectively. All four of those years were very active hurricane seasons.

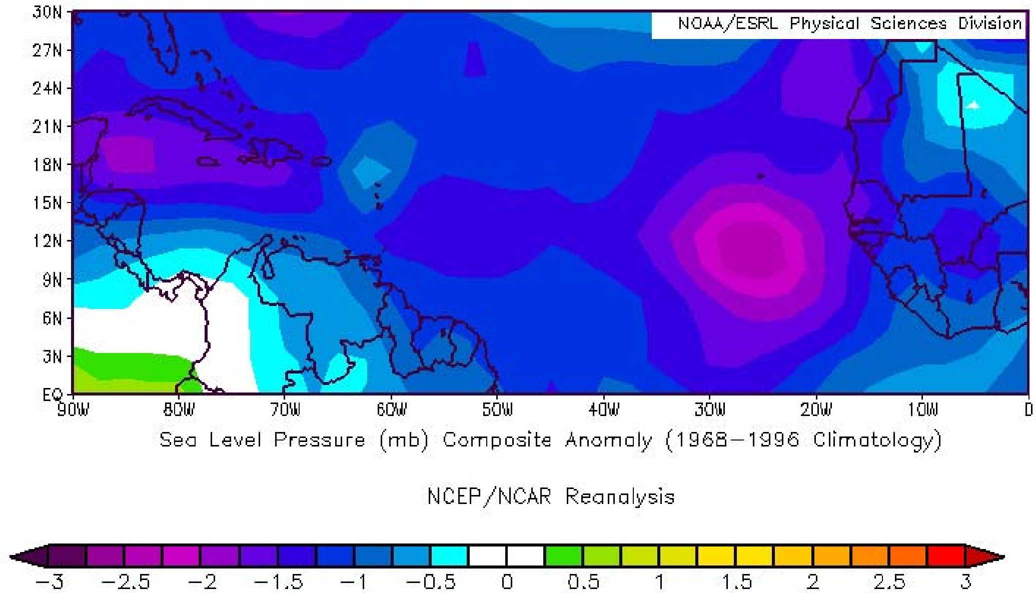


Figure 3: Tropical Atlantic sea level pressure anomalies during August 2007.

Vertical wind shear values across the tropical Atlantic were slightly above average during August. Low-level trade winds were weaker than normal, while upper-level westerlies were stronger than normal. Low- and mid-level moisture values were also near their long-period averages. Atlantic sea surface temperature values remained near average during August. Figure 4 displays the SST anomaly pattern that was observed across the tropical Atlantic in August. Additional discussion of August 2007 follows in Section 8.

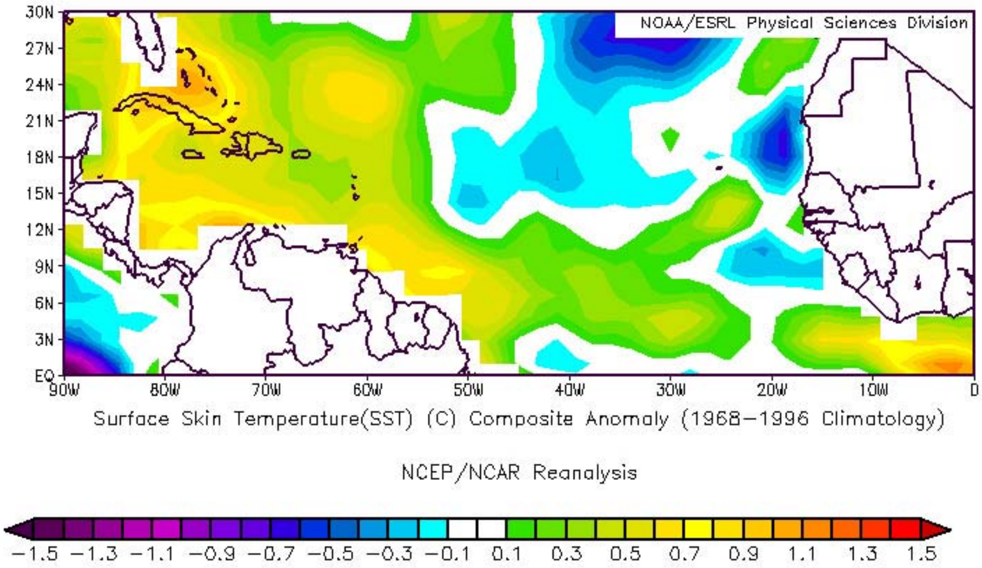


Figure 4: Tropical Atlantic sea surface temperature anomalies during August

## 5.3 September-only 2007 Forecast

Our September 2007 forecasts did not verify particularly well (Table 8). The month witnessed the formation of eight named storms, tying a record for most named storm formations during the month (set in 2002). However, most of these tropical cyclones were quite short-lived and not particularly intense. September had about average activity when evaluated by the NTC metric.

Table 8: Independent September-only forecasts for 2007 including the 3 August forecast for September and the 4 September forecast for September. Observed activity is in the far right-hand column.

| Tropical Cyclone Parameters and 1950-2000 September Average (in parentheses) | 3 Aug. Forecast | 4 Sep. Forecast | Observed Sep. 2007 Activity |
|---|---|---|---|
| Named Storms (NS) (3.4) | 5 | 5 | 8 |
| Named Storm Days (NSD) (21.7) | 35 | 35 | 16.25 |
| Hurricanes (H) (2.4) | 4 | 4 | 4 |
| Hurricane Days (HD) (12.3) | 20 | 20 | 3.50 |
| Intense Hurricanes (IH) (1.3) | 2 | 2 | 1 |
| Intense Hurricane Days (IHD) (3.0) | 6.5 | 6.5 | 2 |
| Net Tropical Cyclone Activity (NTC) (48%) | 80 | 80 | 47 |

Figure 5 displays the difference between Atlantic basin sea surface temperatures in September 2007 and Atlantic basin sea surface temperatures from September 1995-2006. Tropical Atlantic SSTs were approximately 0.3-0.5°C cooler during this September than they were during the previous twelve-year average. The last twelve years were much warmer than the long-period (1950-2000) average, and September 2007's tropical Atlantic SSTs were close to the long-period average. Of particular interest is the strong cold SST anomaly just west of the Iberian Peninsula and Morocco. Cold SST anomalies in this area are known to be associated with reduced hurricane activity.

Figure 6 displays 200-850 mb vertical wind shear anomalies during the month of September. Vertical wind shear during September tended to be near average in the tropical Atlantic and above average in the Caribbean.

Based on NTC, September tropical cyclone activity was near its long-term average values. Since both SSTs and vertical wind shear values were also near their long-period average values, it is not a complete surprise that September activity was about average.

We do not consider our September forecast to have been particularly successful. We expected a very active month, and only average activity was observed. A more in-depth discussion of September 2007 follows in Section 8.

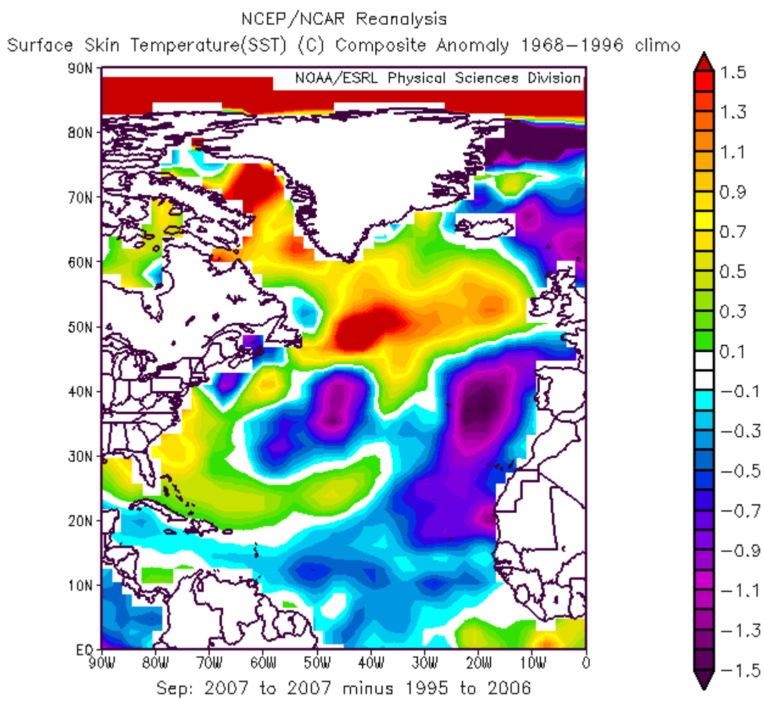


Figure 5: September 2007 Atlantic basin sea surface temperatures differenced from September 1995-2006 Atlantic basin sea surface temperatures.

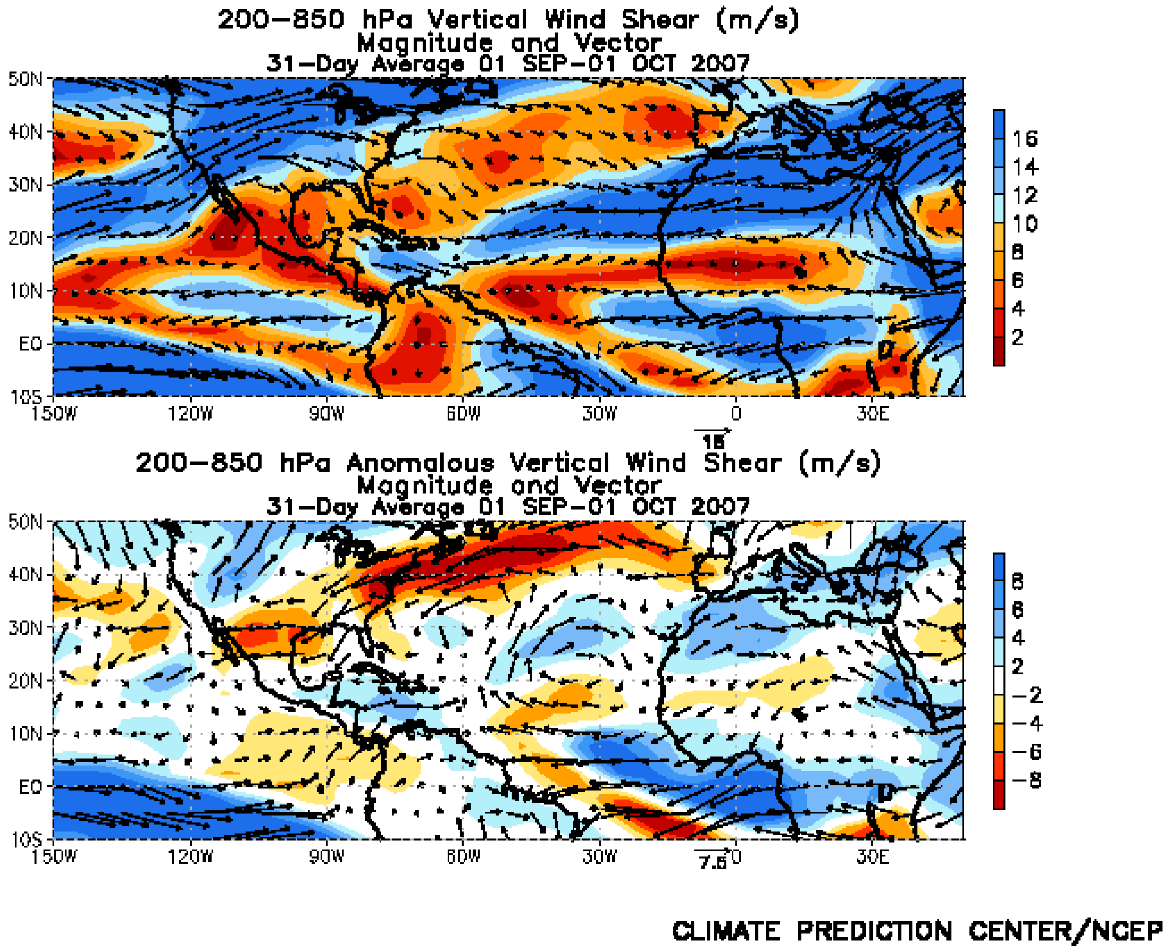


Figure 6: September observed vertical wind shear values and anomalies. Vertical wind shear values were generally near average across the tropical Atlantic and above average in the Caribbean.

## 5.5 October-November 2007 Forecast

The failure of the October-November forecast is very difficult to explain. In general, conditions were quite favorable for tropical cyclone development, and yet, only one hurricane formed (Noel). Table 9 displays our predictions for October-November 2007 issued in early August, early September, and early October, along with observations for the October-November 2007 period.

According to the genesis parameter generated by the Cooperative Institute for Research in the Atmosphere (CIRA), the likelihood of genesis in the Caribbean was well above average for most of the month (Figure 7). Tropical cyclone formations during the month of October tend to cluster in the Caribbean and the western Atlantic. A more in-depth discussion as to what conditions were present in the Atlantic during October-November will be conducted in Section 8.

Table 9: Independent October-November forecasts for 2007 including the 3 August forecast for October-November, the 4 September forecast for October-November and the 2 October forecast for October-November. Observed activity is in the far right-hand column.

| TC Parameters and 1950-2000 October-November Climatology (in parentheses) | 3 August Forecast | 4 September Forecast | 2 October Forecast | Observed Oct-Nov 2007 Activity |
|---|---|---|---|---|
| NS (2.2) | 5 | 5 | 4 | 1 |
| NSD (11.5) | 24.75 | 24.75 | 24.75 | 5.25 |
| H (1.4) | 2 | 2 | 2 | 1 |
| HD (5.2) | 9 | 9 | 10 | 1 |
| IH (0.4) | 1 | 1 | 1 | 0 |
| IHD (0.9) | 2 | 2 | 2.25 | 0 |
| NTC (22%) | 42 | 42 | 43 | 7 |

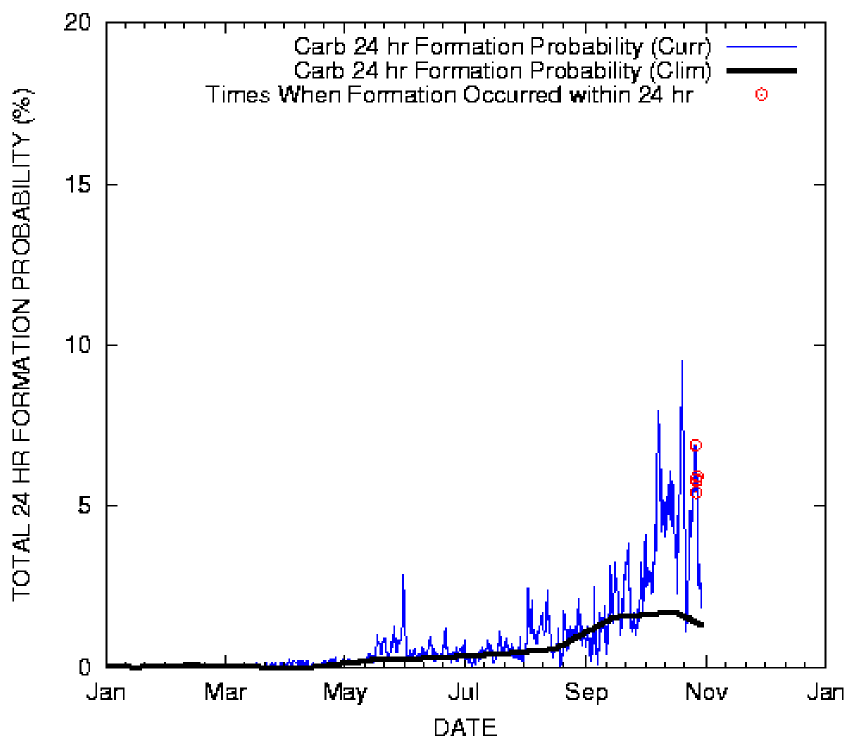


Figure 7: Tropical cyclone genesis parameter for the Caribbean. Note the positive anomaly values that were present for most of the month of October. Figure courtesy of the Cooperative Institute for Research in the Atmosphere (CIRA) from the Tropical Cyclone Formation Probability Product (DeMaria et al. 2001).

## 6 Verification of 2007 U.S. Landfall Probabilities

A new initiative in our research involves efforts to develop forecasts of the seasonal probability of hurricane landfall along the U.S. coastline. Whereas individual hurricane landfall events cannot be accurately forecast, the net seasonal probability of landfall (relative to climatology) can be forecast with statistical skill. With the premise that landfall is a function of varying climate conditions, a probability specification has been accomplished through a statistical analysis of all U.S. hurricane and named storm landfalls during a 100-year period (1900-1999). Specific landfall probabilities can be given for all tropical cyclone intensity classes for a set of distinct U.S. coastal regions. Net landfall probability is statistically related to the overall Atlantic basin Net Tropical Cyclone (NTC) activity and to climate trends linked to multi-decadal variations of the Atlantic Ocean thermohaline circulation (as measured by North Atlantic SSTA). Table 10 gives verifications of our landfall probability estimates for 2007.

Landfall probabilities for the 2007 hurricane season were estimated to be well above their climatological averages due to our prediction for an active season. Two tropical storms and one hurricane made landfall this year (Tropical Storm Erin, Tropical Storm Gabrielle and Hurricane Humberto). On average, the United States experiences approximately 3.6 named storm, 1.9 hurricane, and 0.7 major hurricane landfalls per year.

Landfall probabilities include specific forecasts of the probability of landfalling tropical storms (TS) and hurricanes of category 1-2 and 3-4-5 intensity for each of 11 units of the U.S. coastline (Figure 8). These 11 units are further subdivided into 55 subregions based on coastal population density, and these subregions are further subdivided into 205 coastal and near-coastal counties. The climatological and current-year probabilities are now available online via the United States Landfalling Hurricane Probability Webpage at http://www.e-transit.org/hurricane. Since the website went live on June 1, 2004, the webpage has received over half-a-million hits. Work is underway to improve the webpage interface and add additional functionality. More information will be available in the next couple of months.

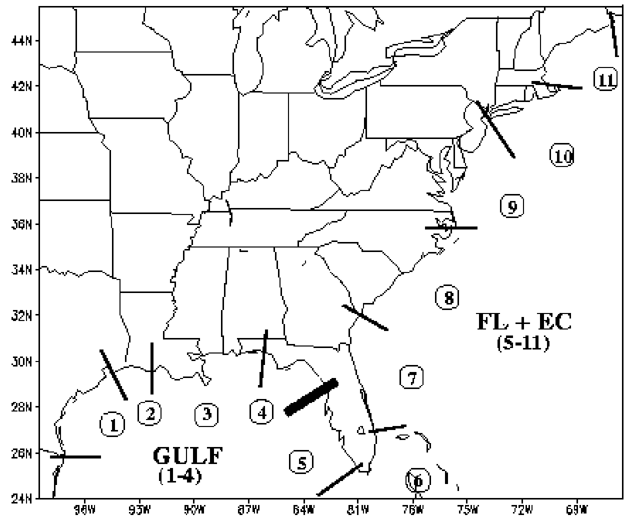


Figure 8: Location of the 11 coastal regions for which separate hurricane landfall probability estimates are made.

Table 10: Estimated forecast probability (percent) of one or more U.S. landfalling tropical storms (TS), category 1-2 hurricanes, and category 3-4-5 hurricanes, total hurricanes and named storms along the entire U.S. coastline, along the Gulf Coast (Regions 1-4), and along the Florida Peninsula and the East Coast (Regions 5-11) for 2007 at various lead times. The mean annual percentage of one or more landfalling systems during the 20th century is given in parentheses in the 3 August forecast column. Table (a) is for the entire United States, Table (b) is for the U.S. Gulf Coast, and Table (c) is for the Florida Peninsula and the East Coast.

**(a) The entire U.S. (Regions 1-11)**

| | Forecast Date | | | | |
|---|---|---|---|---|---|
| | 8 Dec. | 3 Apr. | 31 May | 3 Aug. | Observed Number |
| TS | 89% | 95% | 95% | 92% (80%) | 2 |
| HUR (Cat 1-2) | 79% | 88% | 88% | 83% (68%) | 1 |
| HUR (Cat 3-4-5) | 64% | 74% | 74% | 68% (52%) | 0 |
| All HUR | 93% | 97% | 97% | 95% (84%) | 1 |
| Named Storms | 99% | 99% | 99% | 99% (97%) | 3 |

**(b) The Gulf Coast (Regions 1-4)**

| | Forecast Date | | | | |
|---|---|---|---|---|---|
| | 8 Dec. | 3 Apr. | 31 May | 3 Aug. | Observed Number |
| TS | 71% | 80% | 80% | 75% (59%) | 1 |
| HUR (Cat 1-2) | 54% | 64% | 64% | 58% (42%) | 1 |
| HUR (Cat 3-4-5) | 40% | 49% | 49% | 43% (30%) | 0 |
| All HUR | 72% | 81% | 81% | 76% (61%) | 1 |
| Named Storms | 92% | 96% | 96% | 94% (83%) | 2 |

**(c) Florida Peninsula Plus the East Coast (Regions 5-11)**

| | Forecast Date | | | | |
|---|---|---|---|---|---|
| | 8 Dec. | 3 Apr. | 31 May | 3 Aug. | Observed Number |
| TS | 62% | 73% | 73% | 67% (51%) | 1 |
| HUR (Cat 1-2) | 56% | 66% | 66% | 60% (45%) | 0 |
| HUR (Cat 3-4-5) | 40% | 50% | 50% | 44% (31%) | 0 |
| All HUR | 72% | 83% | 83% | 78% (62%) | 0 |
| Named Storms | 92% | 95% | 95% | 93% (81%) | 1 |

# 7 Summary of 2007 Atmospheric/Oceanic Conditions

In this section, we go into detail discussing large-scale conditions that were present in the atmosphere and in the ocean during the 2007 Atlantic basin hurricane season.

## 7.1 ENSO

One of the most notable large-scale features during the 2007 Atlantic basin hurricane season was the rapid transition from neutral to La Niña conditions in the tropical Pacific that occurred during the summer and fall. At the start of the hurricane season, neutral ENSO conditions were observed with anomalously cool SSTs in the eastern Pacific and average SSTs in the central Pacific. However, over the next few months, SSTs cooled rapidly in the central Pacific, with La Niña conditions becoming established by the end of the summer. These conditions have continued to intensify through the early portion of this fall, and currently, a moderate La Niña is underway. Table 11 shows the changes in the 4 Nino regions between May and September, while Figure 9 displays this transition to La Niña conditions.

Typically, La Niña conditions enhance Atlantic basin hurricane activity by reducing levels of vertical wind shear throughout the Caribbean and the tropical Atlantic. This was one of the primary reasons why we predicted a well above-average hurricane season in our early April, late May and early August predictions.

Table 11: May anomalies, September anomalies, and the difference between September and May anomalies for the four Nino regions.

| Region | May Anomaly (ºC) | September Anomaly (ºC) | September-May Anomaly (ºC) |
|---|---|---|---|
| Nino 1+2 | -1.6 | -1.9 | -0.3 |
| Nino 3 | -0.7 | -1.3 | -0.6 |
| Nino 3.4 | -0.2 | -0.8 | -0.6 |
| Nino 4 | +0.2 | -0.4 | -0.6 |

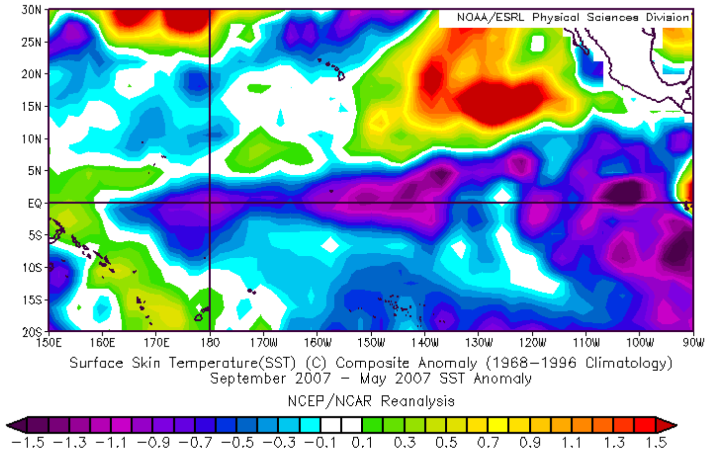


Figure 9: September 2007 SST anomalies – May 2007 SST anomalies in the tropical Pacific.

## 7.2 Tropical Atlantic SST

The tropical Atlantic was somewhat cooler during the hurricane season of 2007 than it has been over the past few years. Figure 10 displays the difference between August-September 2007 SST anomalies compared with August-September 1995-2006 SST anomalies. SSTs were approximately 0.2 – 0.5°C cooler across the eastern and central tropical Atlantic then they had been over the average of the past twelve years. However, as mentioned briefly earlier, SSTs in the tropical Atlantic were well above the long-period (1950-2000) average during the past twelve years. This year's tropical Atlantic SSTs were near the 1950-2000 average values. We consider the cooling of the tropical Atlantic SSTs to be one of the factors that likely reduced activity across the Atlantic basin this year. Despite cooling waters in the tropical Atlantic, far North Atlantic sea surface temperatures are still well above their long-period average values, indicative of a continued strong thermohaline circulation.

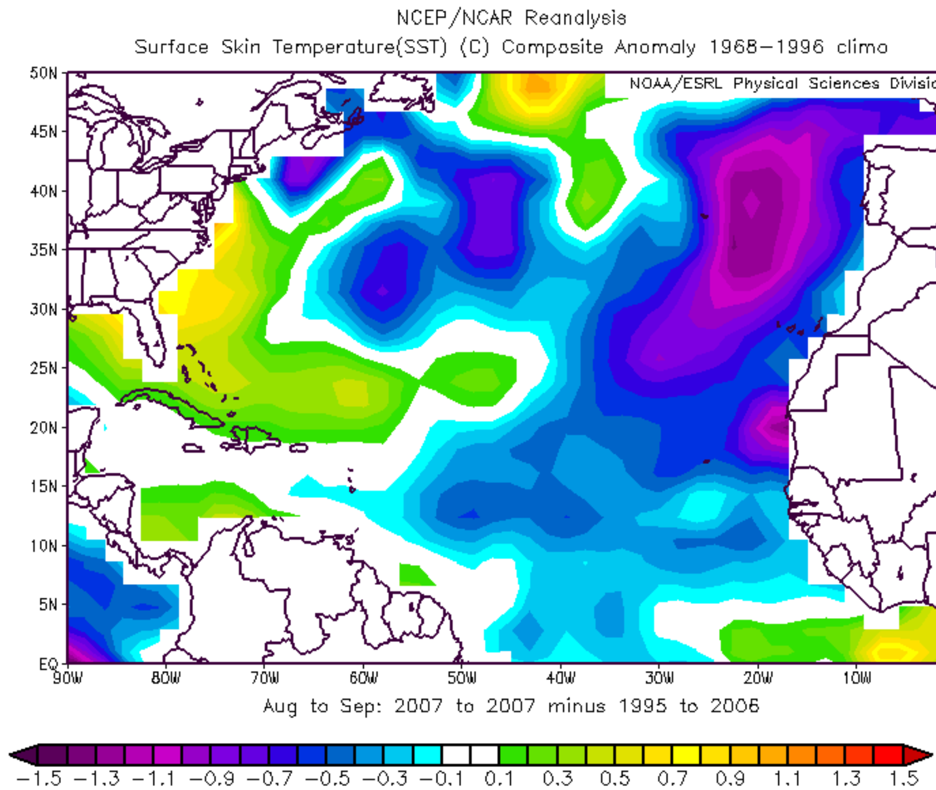


Figure 10: August-September 2007 Atlantic basin sea surface temperatures minus August-September (1995-2006) sea surface temperatures.

### 7.2a Why did Tropical Atlantic SSTs cool?

An important question then becomes: why did tropical Atlantic SSTs cool? The most dramatic anomalous cooling took place during the time period from April 2007 – September 2007 (Figure 11). The tropical Atlantic anomalously cooled by approximately 0.5°C during this time period. Trade winds were somewhat weaker-than-average during this same time period. Typically, weak trade winds lead to a warming tropical Atlantic due to less evaporation and upwelling. Therefore, one must look elsewhere for an explanation of the cooling tropical Atlantic SSTs.

The answer appears to lie with dust across the tropical Atlantic. According to data compiled by Amato Evan at the Cooperative Institute for Meteorological Satellite Studies (CIMSS), dustiness across the Main Development Region (MDR), defined as 10-20°N, 15-65°W in his analysis, was at its highest levels since 1999 (Figure 12). Higher-than-normal levels of dust reflect incoming solar radiation back to space, thereby preventing this radiation from reaching the surface and warming the ocean. Dust levels were especially high in June and July. Evan et al. (2007, paper submitted to Geochem. Geophys. Geosyst.) have shown that anomalous dust early in the tropical cyclone season can have a considerable effect on tropical Atlantic SSTs throughout the summer and fall due to radiative feedback processes. Figure 13 shows the strong negative correlations that arise between June-July dust in the MDR and MDR sea surface temperatures 1-4 months later (during the heart of the hurricane season).

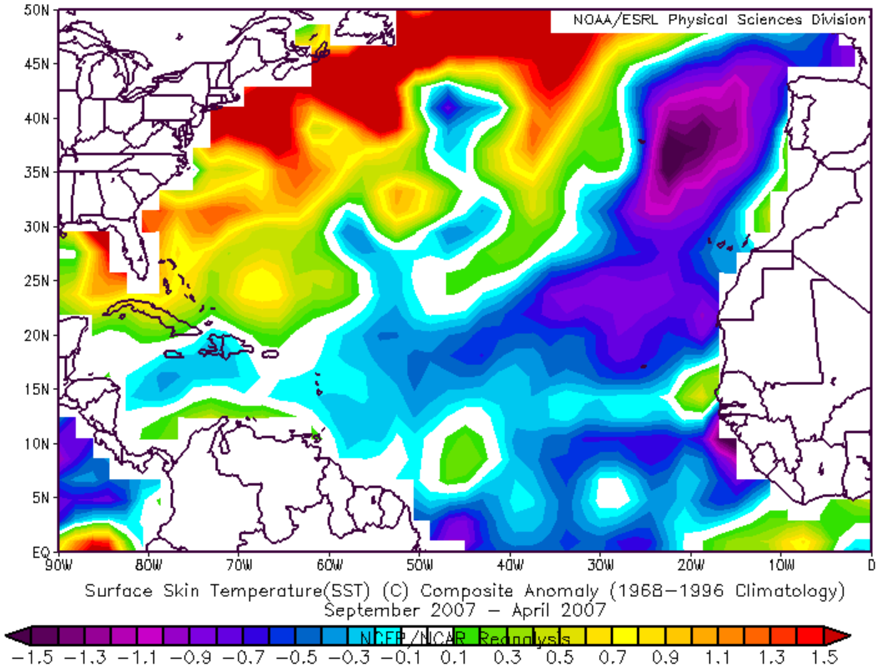


Figure 11: September 2007 Atlantic SST anomalies – April 2007 Atlantic SST anomalies. Note the anomalous cooling across the tropical Atlantic between these two months.

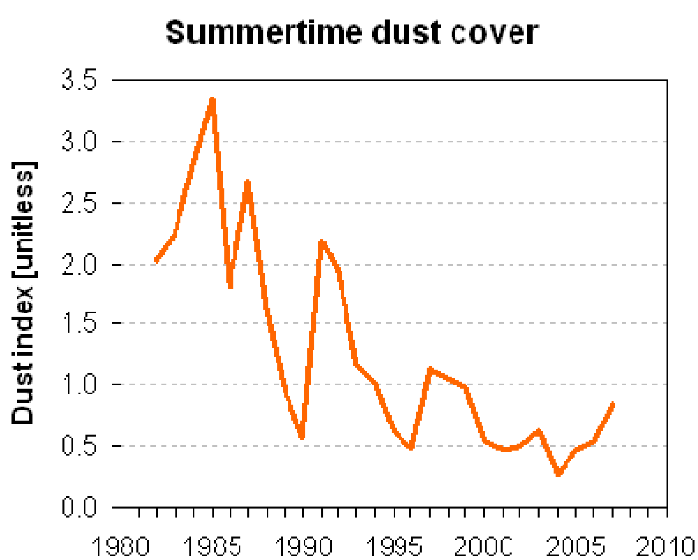


Figure 12: Summertime (MJJAS) dust cover across the MDR. Figure courtesy of Amato Evan at CIMSS.

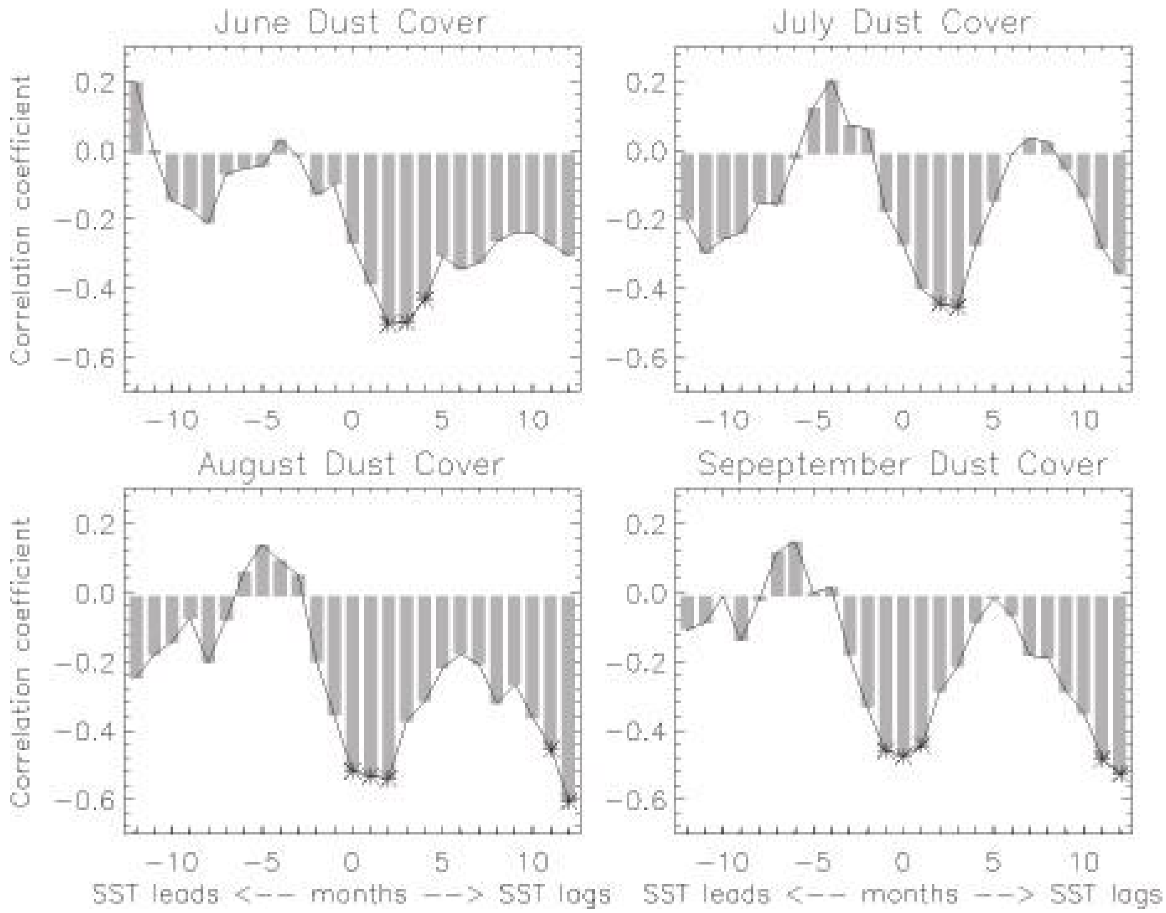


Figure 13: Correlations between MDR dust and MDR sea surface temperatures. Note that the most significant correlations lie where MDR SSTs lag MDR June-July dust by 1-4 months. Figure courtesy of Amato Evan at CIMSS.

### 7.3 Tropical Atlantic SLP

Tropical Atlantic sea level pressure values are another important parameter to consider when evaluating likely tropical cyclone activity in the Atlantic basin. Lower-than-normal sea level pressures across the tropical Atlantic imply increased instability, increased low-level moisture, and conditions that are generally favorable for tropical cyclone development and intensification. Figure 14 displays August-September 2007 Atlantic basin sea level pressures minus August-September (1995-2006) sea level pressures. Sea level pressures were somewhat lower than the previous twelve-year average in the eastern tropical Atlantic and slightly higher than normal than the previous twelve-year average in the western tropical Atlantic. Since the average hurricane season of the past twelve years was quite active, we do not believe that the observed sea level pressure pattern significantly inhibited the 2007 hurricane season.

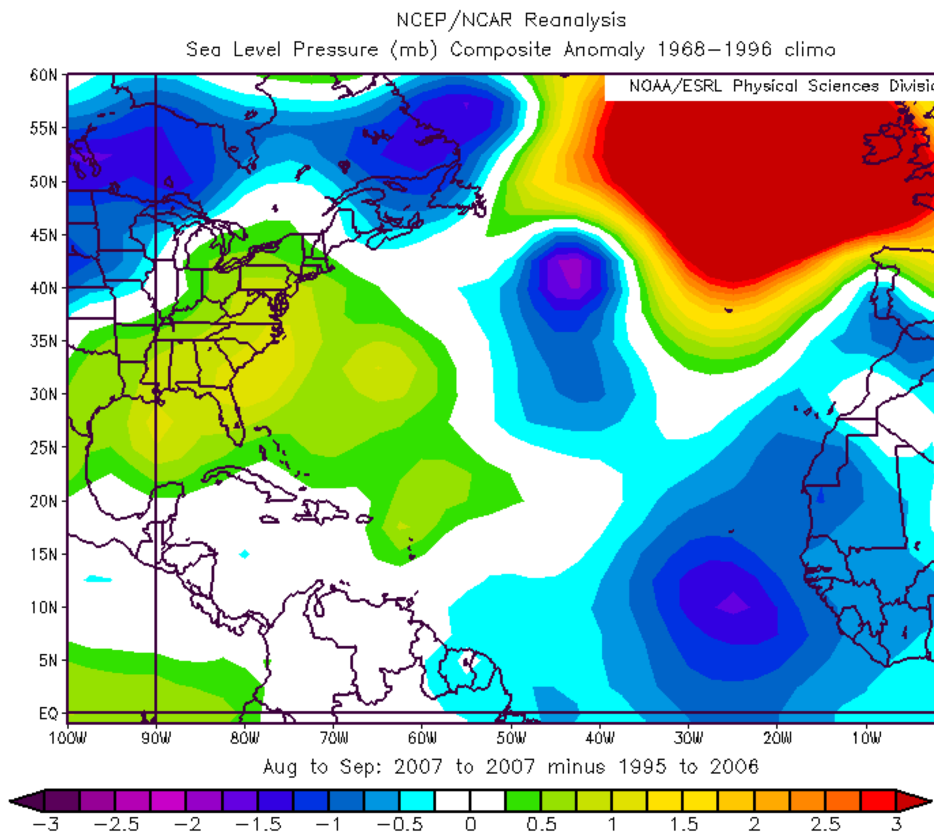


Figure 14: August-September 2007 Atlantic sea level pressure – August-September (1995-2006) Atlantic sea level pressure. Sea level pressures were somewhat lower than the previous twelve-year average in the eastern tropical Atlantic and slightly higher than the previous twelve-year average in the western tropical Atlantic.

## 7.4 Tropical Atlantic Vertical Wind Shear

Tropical Atlantic vertical wind shear is a critical component in determining the level of tropical cyclone activity experienced in the Atlantic basin. Excessive levels of vertical wind shear inhibit tropical cyclone development and intensification by tilting the vortex and reducing the ability of the system to develop a warm core. As mentioned before, typically, with La Niña conditions present, vertical wind shear across the tropical Atlantic and especially across the Caribbean is reduced considerably. This typical reduction in vertical wind shear was not particularly evident during the middle portion of this year's hurricane season. Figure 15 displays 200-850 mb vertical shear across the tropical Atlantic during September. The top panel represents observed values of shear, while the bottom panel represents shear anomalies. Shear was generally near average across the tropical Atlantic east of the Leeward Islands, which is the typical formation zone for intense tropical cyclone activity during September. Hurricane Felix did form and intensify in this area during September; however, all other storms that formed in the tropical Atlantic after Felix were short-lived. We go into detail in Section 8 describing why we think September witnessed only average tropical cyclone activity.

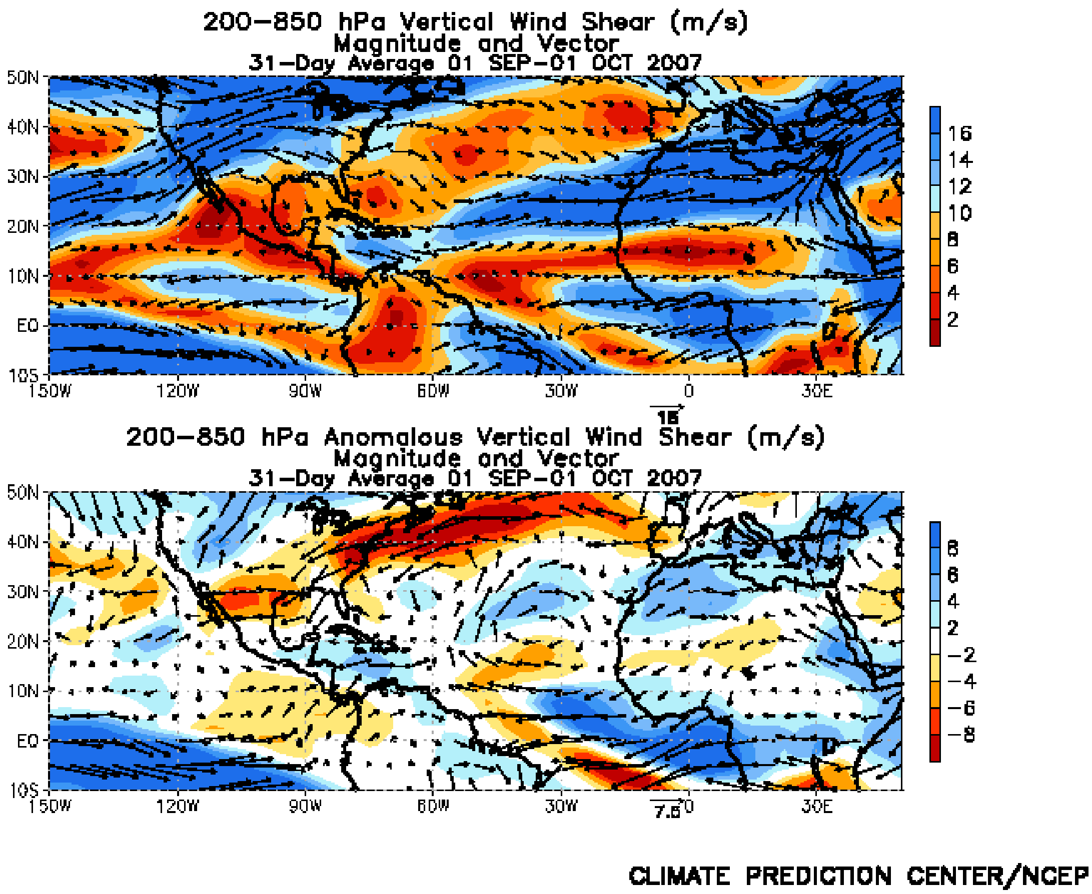


Figure 15: September 200-850 mb vertical wind shear (top panel) observed values and (bottom panel) anomalies. Figure courtesy of the Climate Prediction Center.

Although values of vertical wind shear in September were fairly close to their long-term average values, vertical wind shear in October was somewhat below average across the Caribbean (Figure 16). This is what is typically expected with La Niña conditions. The typical area for storm formations in October is the central and western Caribbean, and with the wind shear patterns that were observed, it was to be expected that an active October was in store. However, only one tropical cyclone formed during the month. We analyze October conditions in more detail in Section 8.

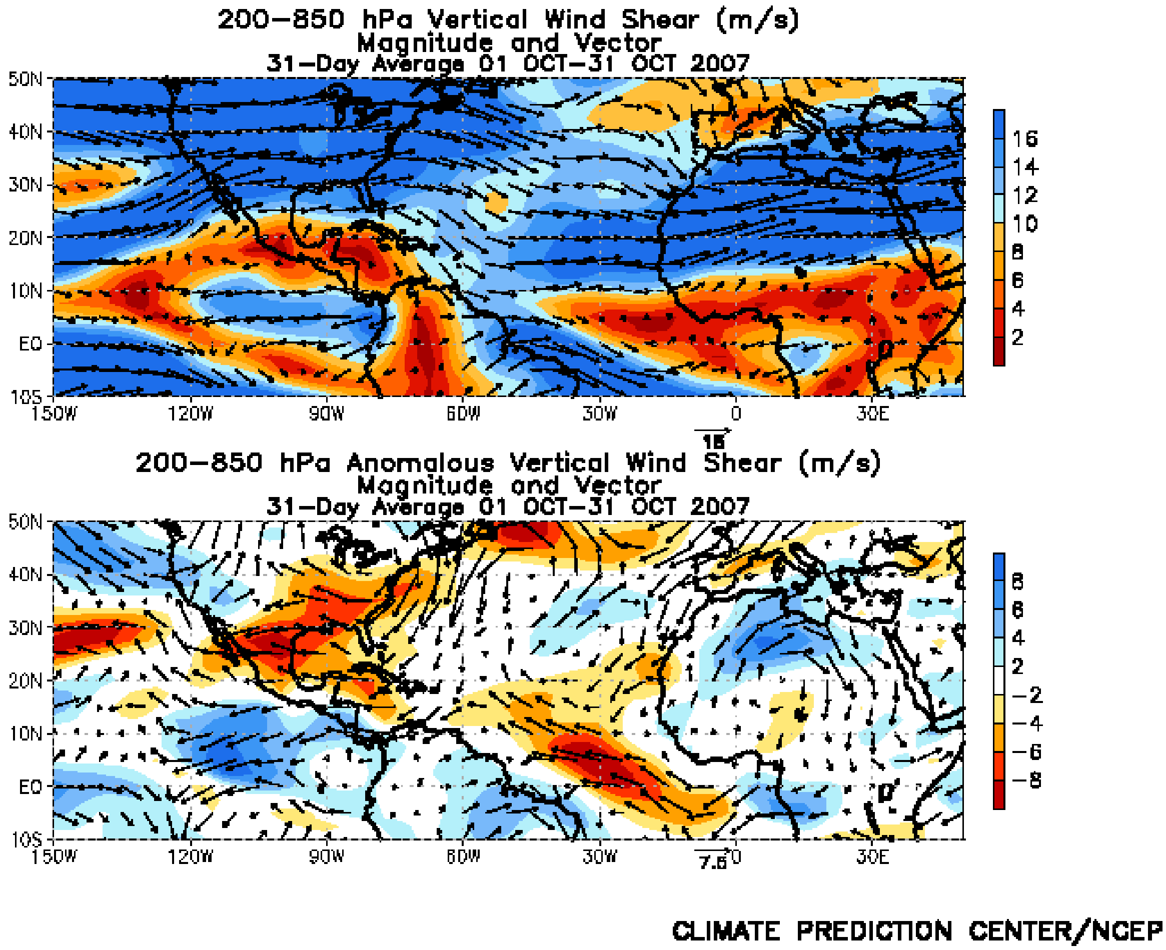


Figure 16: October 200-850 mb vertical wind shear (top panel) observed values and (bottom panel) anomalies. Figure courtesy of the Climate Prediction Center.

# 8 Discussion of Individual Portions of the 2007 Atlantic Basin Hurricane Season

## 8.1 Introduction

The 2007 Atlantic basin hurricane season ended up with about average activity when compared with the 1950-2000 average. A total of fourteen named storms, six hurricanes and two major hurricanes developed in 2007. This represents the fourth year since the return of the active phase (in 1995) of the AMO that has witnessed near- or below-average activity. However, the other three years (1997, 2002, and 2006) had El Niño conditions during the heart of the hurricane season. Conversely, La Niña conditions developed during this year's hurricane season. The reasons for this year's average season and our over-forecast are challenging to explain. No individual parameter stood out as a large inhibiting factor this year (see Section 7).

The 2007 hurricane season started out reasonably active with approximately 120% of normal activity witnessed through September 10. Two Category 5 hurricanes had already been observed by the early part of September. Since, on average, La Niña conditions enhance the second half of the hurricane season more than the first half of the hurricane season, due to its association with reduced vertical wind shear, we expected a very active hurricane season. We thought that our forecast was on track through the middle part of the hurricane season.

However, the second half of the 2007 hurricane season has been very quiet. In the next few sub-sections, we investigate sub-periods of the 2007 hurricane season and try to provide some reasons why the second half of the hurricane season was so quiet.

## 8.2 June-July Discussion

June-July 2007 had about average activity with two named storms forming during the two-month period (Barry and Chantal). The level of activity witnessed in 2007 was near the long-period average from 1950-2000 (approximately 1.5 named storm formations and 0.6 hurricane formations). We did not see any activity in the deep tropics during June and July 2007.

The start of the Atlantic basin hurricane season in the deep tropics is usually restricted by thermodynamic factors (i.e., sea surface temperatures, mid-level moisture, upper-level temperatures, etc.) (DeMaria et al. 2001). Generally, thermodynamic conditions in the tropical Atlantic do not become favorable for hurricane activity until August. SSTs were not favorable for deep tropical formation during June-July 2007. Figure 17 shows Atlantic basin sea surface temperatures in June-July of 2007 differenced from Atlantic basin sea surface temperatures in June-July of 1995-2006. SSTs were slightly cooler across the tropical Atlantic in June-July 2007 then they were during the average of the previous twelve years.

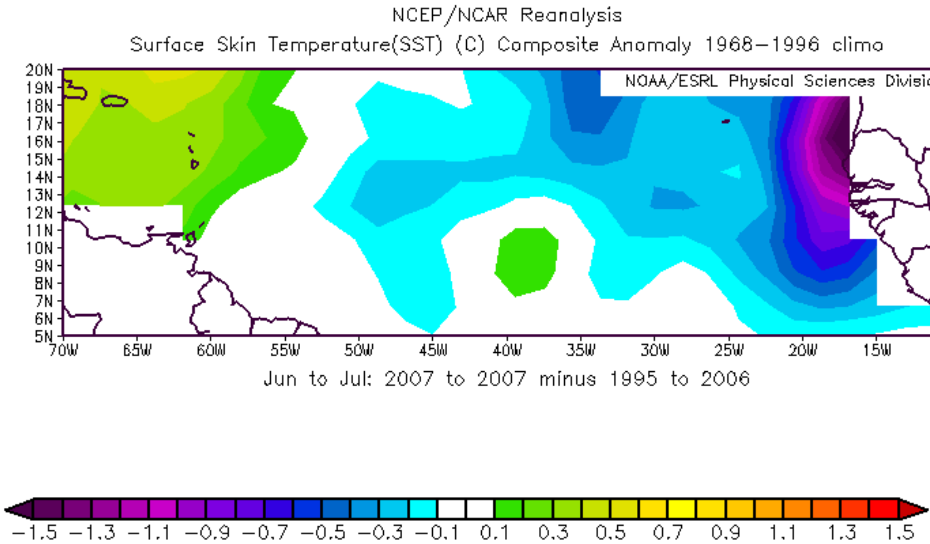


Figure 17: June-July sea surface temperatures in the tropical Atlantic in 2007 minus June-July sea surface temperatures in the tropical Atlantic from 1995-2006.

## 8.3 August Discussion

Our August forecast verified quite well. We expected activity at slightly above-average levels, and this is exactly what occurred. Hurricane Dean wrought considerable devastation across the Caribbean and especially in Honduras and Nicaragua as it intensified to Category 5 status while tracking through the Caribbean. Most atmospheric/oceanic parameters that we evaluate had near-average or slightly favorable values in August 2007. As shown earlier, tropical Atlantic sea level pressure values were very low throughout the month, while vertical wind shear values were approximately average. August 2007 played out in a way similar to the way that we thought it would.

## 8.4 September Discussion

Our September forecast did not verify particularly well. We expected a very active month, and only average activity occurred. As was shown earlier, vertical wind shear values and SSTs were near their long-period averages. Certainly, the problem with September 2007 was not in getting storms to form. A total of eight named storms formed during the month, which tied the record for most named storm formations set in 2002.

Interestingly enough, similar to 2002, only approximately average activity occurred when evaluated by the NTC metric.

The problem in September 2007 appeared to be interactions with the mid-latitudes. Several storms that formed in the tropical Atlantic were rapidly sheared apart by upper-level lows. The primary examples of this were Ingrid, Karen and Melissa. These three storms formed in the tropical Atlantic east of the Windward Islands, in an area where storms typically intensify into hurricanes. Figure 18 displays the upper-level geopotential height pattern across the Atlantic in September 2007 differenced from the upper-level geopotential height pattern across the Atlantic in September (1995-2006). Note the lower-than-normal heights across the west-central Atlantic indicative of strong upper-level lows in this area. Strong upper-level lows were located to the northwest of Ingrid, Karen and Melissa. Strong upper-level lows positioned to the northwest of a tropical cyclone are detrimental to storm intensification by increasing upper-level westerly winds and inhibiting upper-level outflow.

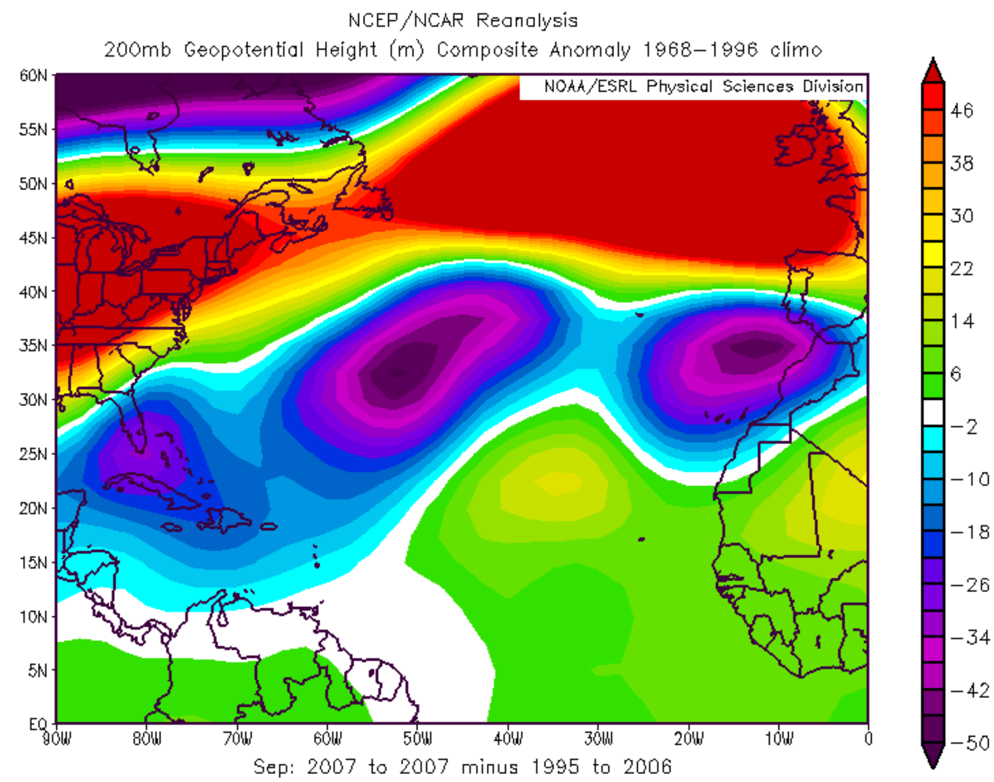


Figure 18: 200 mb geopotential heights in September 2007 minus 200 mb geopotential heights in September of 1995-2006.

Strong intensification of several of the other tropical cyclones that formed in September 2007 was prevented due to their development close to land. For example, both Hurricanes Humberto and Lorenzo began intensifying rapidly as they approached land.  If either of these systems had remained over water for another 24 hours, they had the potential to reach major hurricane intensity.

Table 12 compares activity that occurred in September 2007 with activity in September 2006, September 2005, September 2004 and the 1950-2000 September average.   September 2007 had the most named storm formations of any of the past four Septembers, while it had the lowest values for most other tropical cyclone parameters.

Table 12:  Atlantic basin tropical cyclone activity in September 2007 compared with September 2006, September 2005, September 2004 and the 1950-2000 September average.

| TC Parameter | September 2007 | September 2006 | September 2005 | September 2004 | Average September 1950-2000 |
|---|---|---|---|---|---|
| Named Storms | 8 | 4 | 5 | 4 | 3.4 |
| Named Storm Days | 16.25 | 30.50 | 35.75 | 52.25 | 21.7 |
| Hurricanes | 4 | 4 | 5 | 3 | 2.4 |
| Hurricane Days | 3.50 | 18.25 | 16.75 | 29.75 | 12.3 |
| Intense Hurricanes | 1 | 2 | 2 | 3 | 1.3 |
| Intense Hurricane Days | 2 | 3 | 3.5 | 16.75 | 3.0 |
| Net Tropical Cyclone Activity | 47 | 66 | 73 | 131 | 48 |

It is interesting to note, for example, that September 2007 had twice as many named storm formations as did September 2004.  However, September 2004 had more than three times the number of named storm days and nearly three times the level of Net Tropical Cyclone (NTC) activity that 2007 had.  The average named storm in September 2004 lasted approximately 13 times longer than did the average named storm in September 2007.

### 8.5 October-November Discussion

Approximately six times more tropical cyclone activity occurs in an average season in October than in November, so this discussion will focus on October.  It is very difficult to explain what happened in October 2007.  In general, La Niña conditions lead to very active Octobers, and a moderate La Niña was underway during this October. Table 13 displays the observed October NTC in La Niña years (defined as observed October Nino 3.4 < -0.5°C) in the active AMO years (defined as 1950-1969, 1995-2007). All La Niña years prior to 2007 had above-average October values of NTC (1950-2000 average October NTC value is 18).  Obviously, NTC in October 2007 was well below the long-term average with only an NTC of 3 being observed during the month.  But, clearly based upon all other La Niña Octobers prior to this October in an active AMO era, precedent dictated forecasting an active month.

Table 13: Observed October Net Tropical Cyclone activity values in La Niña years during active AMO phases.

| Year | October NTC | October Nino 3.4 (°C) |
|---|---|---|
| 1950 | 67 | -0.6 |
| 1954 | 52 | -0.8 |
| 1955 | 19 | -1.8 |
| 1961 | 53 | -0.6 |
| 1964 | 39 | -0.8 |
| 1967 | 21 | -0.5 |
| 1995 | 52 | -0.9 |
| 1998 | 38 | -1.3 |
| 1999 | 20 | -1.0 |
| 2000 | 27 | -0.6 |
| **Average** | **39** | **-0.9** |
| **2007** | **3** | **-1.4** |

We are still struggling to understand why October was not more active. As noted earlier in the verification, vertical wind shear levels were well below their long-period averages across the Caribbean during the month. Typically, October storms develop and intensify in the Caribbean (Figure 19), and conditions were quite favorable for development in the Caribbean during October.

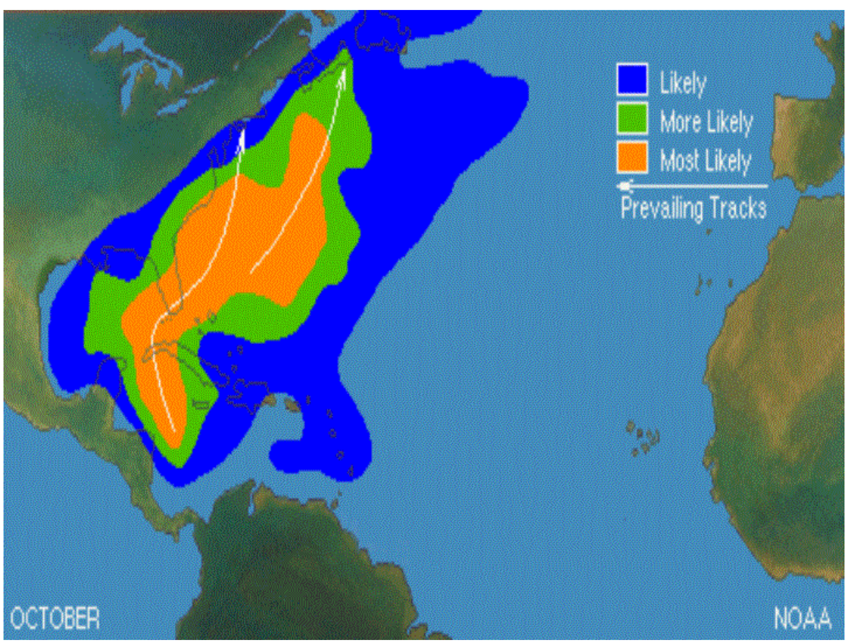


Figure 19: Typical tracks of October Atlantic basin tropical cyclones. Note that the most typical formation area for storms in October is the western Caribbean. Figure courtesy of the National Oceanic and Atmospheric Administration (NOAA).

Deep convection was also plentiful across the Caribbean throughout October. Brightness temperature values were cooler than normal throughout the month, indicating enhanced levels of intense thunderstorm activity (Figure 20).

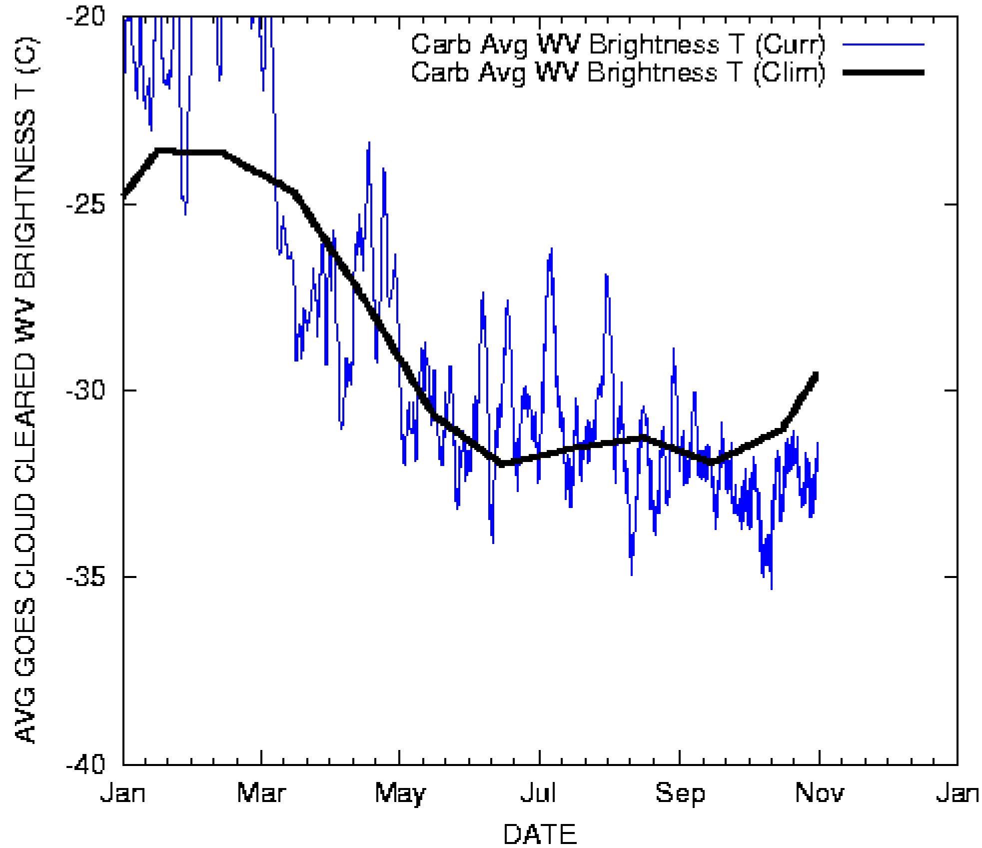


Figure 20: Caribbean brightness temperatures from January-October. Note that average brightness temperatures were much cooler than normal in October 2007, indicating enhanced levels of deep convection.

Since unfavorable conditions for genesis do not seem to have been the inhibiting factor for the lack of activity in October 2007, we believe that it may be due to the size of the disturbances that formed, along with the proximity of land to where vorticity was most pronounced. A large cyclonic circulation was evident over most of the western Caribbean during the first half of October. This system drifted over land as it was beginning to get organized. Another large disturbance located over the Bahamas in early October had large amounts of deep convection and favorable upper-level winds for several days. However, this system was never able to concentrate its large-scale vorticity. Another small area of low pressure had a very organized low-level circulation but little deep convection as it tracked across the northern Gulf of Mexico. Convection finally began to fire as the system reached the coastline.

The pronounced upper-level low near the islands in September persisted through October and may have also played a role in reducing October's hurricane activity. More discussion on October 2007 follows in Section 9.

The October over-forecast illustrates that there are certainly challenges left to be solved when it comes to predicting hurricane activity. Statistical genesis forecasts indicated well above-average chances of formation in October, and many of the dynamical models spun up several tropical cyclones during the month. The 2007 hurricane season illustrates that there are still many lessons to be learned about tropical cyclone genesis and intensification.

The average November witnesses a total of 0.5 named storms, 0.3 hurricanes and 0.1 major hurricanes. The first two days of November witnessed the intensification of Noel into a hurricane followed by its extra-tropical transition. After Noel became an extra-tropical cyclone, no other tropical cyclone activity was recorded during the month.

## 8.6 Track Differences

As evident from Figure 1, both major hurricanes in 2007 developed in the tropical Atlantic and had long westward tracks, staying south of the United States. Both Dean and Felix formed and remained at low latitudes throughout their life span. All tropical cyclones that formed south of 20°N (except for Noel) remained south of 20°N until they either made landfall or dissipated. The 2006 hurricane season was notable for its re-curvature, while 2007 was notable for its straight-moving systems. Figure 21 displays the difference in the 500 mb height pattern that was present from August 1 – September 10, 2007 from the 500 mb height pattern that was present from August 1 – September 10, 2006. The anomalous high heights (ridging) over the southeastern United States helped force both Dean and Felix to track westward across the Caribbean into Central America.

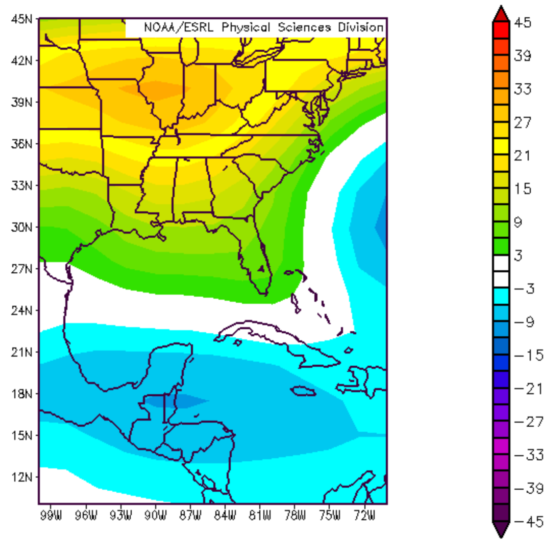


Figure 21: 500 mb geopotential height difference between August 1 – September 10, 2007 and August 1 – September 10, 2006.

As noted previously, there tended to be an anomalous upper-level low across the central Atlantic during most of September and October. This upper low tended to re-curve storms towards the north and sheared them apart before they left the tropics.

## 9 Comparison of the last four hurricane seasons of 2004, 2005, 2006 and 2007

The last four hurricane seasons have been notable for:

1. Large numbers of Atlantic basin storms and heightened levels of United States damage in 2004 and 2005 (~ $150 billion in US damage).
2. Near-normal Atlantic basin storm counts and minimal levels of United States damage in 2006 and 2007 (~ $0.5 billion in US damage).

The character of the hurricane activity in 2004 and 2005 seasons was dissimilar. Nearly all TC activity during the 2004 season was concentrated in the two months of August and September. No previous hurricane season has had so much activity concentrated in August-September. By contrast, 2005, the most active hurricane season on record, had elevated levels of activity from June through December. There had never been a previous season with as much TC activity before August as the season of 2005. Yet, even though well above the long-period average, August-September NTC in 2005 was only half of the August-September NTC in 2004.

In addition to the fact that both 2006 and 2007 rendered little damage in the United States, both the 2006 and 2007 seasons had similar levels of total Atlantic basin activity. Both seasons had two major hurricanes. 2006 had five hurricanes, while 2007 witnessed six hurricanes. The 2006 and 2007 hurricane seasons were similar to 2004 in that nearly all activity was concentrated in August and September. However, NTC in 2006 and 2007 in the two months of August-September was only about a third of that experienced in August-September 2004. Table 14 lists the amount of Net Tropical Cyclone (NTC) activity by month from June-October for the last four years. Nearly all TC activity in the three seasons of 2004, 2006, and 2007 occurred during the months of August and September. Even though 2006 and 2007 had very similar amounts of August-September NTC activity (77 for 2006 and 81 for 2007), ENSO conditions for these two seasons was very different. An El Niño was present during these months in 2006, while a La Niña event was present in 2007. We seldom see similar amounts of hurricane activity in two seasons with such large differences in ENSO conditions. There were compensating negative factors in the Atlantic which prevented the 2007 season from being as active as we expected it to be given the fact that we had a moderately strong La Niña this year.

Table 14 – The last four years of Net Tropical Cyclone (NTC) activity by month from June-October.

| Year | June-July | August | September | October | Seasonal Total |
|---|---|---|---|---|---|
| 2004 | 0 | 89 | 131 | 9 | 229 |
| 2005 | 75 | 41 | 73 | 66 | 277 |
| 2006 | 5 | 12 | 66 | 2 | 85 |
| 2007 | 6 | 34 | 47 | 3 | 94 |
| Avg. | 6 | 26 | 48 | 18 | 100 |

To understand the activity variations in these last four seasons we must answer the following questions.

1. Why did October 2007 have low NTC activity when a La Niña event was present? As Table 13 showed, all previous La Niña Octobers had above-average NTC activity in October.

2. Besides 2007, why did the seasons of 2004 and 2006 also have such small amounts of October activity in comparison to the extremely active October in 2005?

3. Why was July 2005 so much more active than July 2004, 2006 or 2007?

4. Why were the four months of July-August-September-October 2005 the most active four consecutive months on record?

5. Why was August-September 2004 the most active two-month period on record?

6. Why were 2006 and 2007 so similar in overall TC activity when ENSO conditions in these two years were so different?

Although it was impossible for us to have well predicted each of these individual seasons and individual monthly variations in NTC it is possible in post analysis to suggest likely physical causes for these differences. The following is our current best suggested explanation for the six questions listed above.

### 9.1 Why did October 2007 have low NTC activity when a La Niña was present?

The 2007 October period did not have the usual teleconnection patterns from the eastern Pacific which occur in most La Niña years. A nearly stationary strong baroclinic trough extended from the middle latitudes at 50°W into the deep tropics near central Venezuela. This trough increased low latitude wind shear to its east, preventing systems from the east penetrating through it. The 2007 October monthly hemispheric westerly wind pattern showed a five wave stationary pattern. This near stationary wave pattern produced a strong trough and broadly unfavorable cyclonic conditions at upper tropospheric levels throughout the whole western Atlantic. Low latitude tropical systems moving through this trough encountered strong upper level northeasterly winds on the back side of the trough. These northeasterly winds inhibited cyclone formation and/or maintenance by disrupting upper-level outflow. Southern upper level winds to the west of a system are important ingredient in aiding upper-level outflow. This strong and deep baroclinic trough thus led to broad-scale upper tropospheric cyclonic conditions which are known to be unfavorable for tropical cyclone formation. In addition, 200 mb zonal wind conditions within the western Atlantic were stronger out of the west than in the typical La Niña year.

### 9.2 Why was October 2005 so active when the three Octobers of 2004, 2006 and 2007 were so inactive?

The 200 mb westerlies and the 200 mb minus 850 mb zonal wind shear across the Caribbean and the tropical Atlantic in October 2005 were weaker than in the three other years. Caribbean low level winds were significantly stronger from the west – giving favorable higher low-level vorticity during October 2005 than occurred during October 2004, 2006 and 2007. Upper level anticyclonic vorticity in October 2005 was also more favorable than in the three other years. In addition, October tropical Atlantic SSTs were higher in 2005 than they were in 2004, 2006 or 2007.

### 9.3 Why was July 2005 so extremely active when the July periods of 2004, 2006 and 2007 were not?

July 2005 saw the formation of two major hurricanes and three other tropical cyclones. Since reliable records began in the mid 1940s, no other July has seen this amount of activity. Sea surface temperatures (SST) in the tropical Atlantic in July 2005 were higher than in any year since 1950. In addition to SST, a number of other factors led to July 2005 being the most active July on record. Both low level cyclonic vorticity and upper level anti-cyclonic vorticity in the western half of the Atlantic basin were the highest on record according to the NOAA/NCEP reanalysis data records which extend back to 1948.

### 9.4 Why were the four months of July-August-September-October 2005 the most active four consecutive months on record?

The above-discussed factors which made July and October 2005 so active were also generally applicable to the months of August and September. It is unusual to have such favorable conditions for tropical cyclone development and intensification extending for four consecutive months.

### 9.5 Why was August-September 2004 the most active two-month tropical cyclone period on record?

The eastern Atlantic SST pattern off of the African coast during August-September was observed to be the highest on record. Extremely favorable lower and upper tropospheric wind patterns also existed in the western half of the tropical Atlantic. These favorable August-September West Atlantic conditions even exceeded those of 2005 for this two month period. As previously discussed (Klotzbach and Gray 2006), the eastern Atlantic monsoon trough in August-September 2004 was unusually strong, leading to the generation of many tropical disturbances. The positioning of a mid-latitude ridge over southeastern Canada assured that most of the storms that formed in August-September of 2004 in the central Atlantic would have long westward tracks. These long tracks led to the great buildup of NTC values in these months.

### 9.6 Why were 2006 and 2007 so similar in overall TC activity when ENSO conditions in these two years were so different?

This was due to the fact that, despite La Niña conditions in the Pacific, conditions in the Atlantic in 2007 were more unfavorable than the observed Atlantic conditions during the El Nino year of 2006. The unfavorable 2007 Atlantic conditions tended to cancel out the positive influence of the La Niña in 2007. The SST conditions of the eastern tropical Atlantic were significantly colder than in 2006. Despite general La Niña conditions in 2007, the central Atlantic showed stronger upper-level westerly winds and more upper-level cyclonic vorticity in 2007 compared to 2006.

## 10 Was Global Warming Responsible for the Large Upswing in 2004-2005 US Hurricane Landfalls?

The U.S. landfall of major hurricanes Dennis, Katrina, Rita and Wilma in 2005 and the four Florida landfalling hurricanes of 2004 (Charley, Frances, Ivan and Jeanne) raised questions about the possible role that global warming played in these two unusually destructive seasons.

The global warming arguments have been given much attention by many media references to recent papers claiming to show such a linkage. Despite the global warming of the sea surface that has taken place over the last 3 decades, the global numbers of hurricanes and their intensity have not shown increases in recent years except for the Atlantic (Klotzbach 2006).

The Atlantic has seen a very large increase in major hurricanes during the 13-year period of 1995-2007 (average 3.8 per year) in comparison to the prior 25-year period of 1970-1994 (average 1.5 per year). This large increase in Atlantic major hurricanes is primarily a result of the multi-decadal increase in the Atlantic Ocean thermohaline circulation (THC) that is not directly related to global temperature increase. Changes in ocean salinity are believed to be the driving mechanism. These multi-decadal changes have also been termed the Atlantic Multidecadal Oscillation (AMO).

There have been similar past periods (1940s-1950s) when the Atlantic was just as active as in recent years. For instance, when we compare Atlantic basin hurricane numbers over the 15-year period from 1990-2004 with an earlier 15-year period (1950-1964), we see no difference in hurricane frequency or intensity even though the global surface temperatures were cooler and there was a general global cooling during 1950-1964 as compared with global warming during 1990-2004.

Although global surface temperatures have increased over the last century and over the last 30 years, there is no reliable data available to indicate increased hurricane frequency or intensity in any of the globe's seven tropical cyclone basins besides the Atlantic. Meteorologists who study tropical cyclones have no valid physical theory as to why hurricane frequency or intensity would necessarily be altered significantly by small amounts ($< \pm 1^{o}$C) of global mean temperature change.

In a global warming or global cooling world, the atmosphere's upper air temperatures will warm or cool in unison with the sea surface temperatures. Vertical lapse rates will not be significantly altered. We have no plausible physical reasons for believing that Atlantic hurricane frequency or intensity will change significantly if global ocean temperatures continue to rise. For instance, in the quarter-century period from 1945-1969 when the globe was undergoing a weak cooling trend, the Atlantic basin experienced 80 major (Cat 3-4-5) hurricanes and 201 major hurricane days. By contrast, in a similar 25-year period from 1970-1994 when the globe was undergoing a general warming trend, there were only 38 major hurricanes (48% as many) and 63 major hurricane days (31% as many). Atlantic sea-surface temperatures and hurricane activity do not necessarily follow global mean temperature trends.

The most reliable long-period hurricane records we have are the measurements of US landfalling tropical cyclones since 1900 (Table 15). Although global mean ocean and Atlantic surface temperatures have increased by about 0.4$^{o}$C between these two 50-year periods (1900-1949 compared with 1956-2005), the frequency of US landfall numbers actually shows a slight downward trend for the later period. If we chose to make a similar comparison between US landfall from the earlier 30-year period of 1900-1929 when global mean surface temperatures were estimated to be about 0.5°C colder than they were during the 30-year period from 1976-2005, we find exactly the same US hurricane landfall numbers (54 to 54) and major hurricane landfall numbers (21 to 21).

We should not read too much into the two hurricane seasons of 2004-2005. The activity of these two years was unusual but well within natural bounds of hurricane variation. In addition, following the two very active seasons of 2004 and 2005, both 2006 and 2007 had slightly below-average and average activity, respectively, and only one Category 1 hurricane made United States landfall.

Between 1966 and 2003, US major hurricane landfall numbers were below the long-term average. Of the 79 major hurricanes that formed in the Atlantic basin from 1966-2003, only 19 (24 percent) made US landfall. During the two seasons of 2004-2005, seven of 13 (54 percent) came ashore. Zero of the four major hurricanes that formed in 2006 and 2007 made US landfall. This is how nature sometimes works.

What made the 2004-2005 seasons so unusually destructive was not the high frequency of major hurricanes but the high percentage of major hurricanes that were steered over the US coastline. The major US hurricane landfall events of 2004-2005 were primarily a result of the favorable upper-air steering currents present during these two years.

Table 15: U.S. landfalling tropical cyclones by intensity during two 50-year periods.

| ***YEARS*** | ***Named Storms*** | ***Hurricanes*** | ***Intense Hurricanes (Cat 3-4-5)*** | ***Global Temperature Increase*** |
|---|---|---|---|---|
| 1900-1949 (50 years) | 189 | 101 | 39 | +0.4°C |
| 1956-2005 (50 years) | 165 | 83 | 34 | |

Although 2005 had a record number of tropical cyclones (28 named storms, 15 hurricanes and 7 major hurricanes), this should not be taken as an indication of something beyond natural processes. There have been several other years with comparable hurricane activity to 2005. For instance, 1933 had 21 named storms in a year when there was no satellite or aircraft data. Records of 1933 show all 21 named storm had tracks west of 60°W where surface observations were more plentiful. If we eliminate all the named storms of 2005 whose tracks were entirely east of 60°W and therefore may have been missed given the technology available in 1933, we reduce the 2005 named storms by seven (to 21) – about the same number as was observed to occur in 1933.

Utilizing the National Hurricanes Center's best track database of hurricane records back to 1875, six previous seasons had more hurricane days than the 2005 season. These years were 1878, 1893, 1926, 1933, 1950 and 1995. Also, five prior seasons (1893, 1926, 1950, 1961 and 2004) had more major hurricane days. Finally, five previous seasons (1893, 1926, 1950, 1961 and 2004) had greater Hurricane Destruction Potential (HDP) values than 2005. HDP is the sum of the squares of all hurricane-force maximum winds and provides a cumulative measure of the net wind force generated by a season's hurricanes. Although the 2005 hurricane season was certainly one of the most active on record, it is not as much of an outlier as many have indicated.

Despite a slightly below-average season in 2006 and average activity in 2007, we believe that the Atlantic basin is currently in an active hurricane cycle associated with a strong thermohaline circulation and an active phase of the Atlantic Multidecadal Oscillation (AMO). This active cycle is expected to continue for another decade or two at which time we should enter a quieter Atlantic major hurricane period like we experienced during the quarter-century periods of 1970-1994 and 1901-1925. Atlantic hurricanes go through multi-decadal cycles. Cycles in Atlantic major hurricanes have been observationally traced back to the mid-19th century, and changes in the AMO have been inferred from Greenland paleo ice-core temperature measurements going back thousand of years.

## 11 Forecasts of 2008 Hurricane Activity

We will be issuing our first forecast for the 2008 hurricane season on Friday, 7 December 2007. This 7 December forecast will include the dates of all of our updated 2008 forecasts. All of these forecasts will be made available online at: http://hurricane.atmos.colostate.edu/Forecasts.

## 12 Acknowledgments

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## 14 Verification of Previous Forecasts

Table 16: Verification of the authors' early August forecasts of Atlantic named storms and hurricanes between 1984-2007. Observations only include storms that formed after 1 August. Note that these early August forecasts have either exactly verified or forecasted the correct deviation from climatology in 22 of 24 years for named storms and 18 of 24 years for hurricanes. If we predict an above- or below-average season, it tends to be above or below average, even if our exact forecast numbers do not verify.

| Year | Predicted NS | Observed NS | Predicted H | Observed H |
|---|---|---|---|---|
| 1984 | 10 | 12 | 7 | 5 |
| 1985 | 10 | 9 | 7 | 6 |
| 1986 | 7 | 4 | 4 | 3 |
| 1987 | 7 | 7 | 4 | 3 |
| 1988 | 11 | 12 | 7 | 5 |
| 1989 | 9 | 8 | 4 | 7 |
| 1990 | 11 | 12 | 6 | 7 |
| 1991 | 7 | 7 | 3 | 4 |
| 1992 | 8 | 6 | 4 | 4 |
| 1993 | 10 | 7 | 6 | 4 |
| 1994 | 7 | 6 | 4 | 3 |
| 1995 | 16 | 14 | 9 | 10 |
| 1996 | 11 | 10 | 7 | 7 |
| 1997 | 11 | 3 | 6 | 1 |
| 1998 | 10 | 13 | 6 | 10 |
| 1999 | 14 | 11 | 9 | 8 |
| 2000 | 11 | 14 | 7 | 8 |
| 2001 | 12 | 14 | 7 | 9 |
| 2002 | 9 | 11 | 4 | 4 |
| 2003 | 14 | 12 | 8 | 5 |
| 2004 | 13 | 14 | 7 | 9 |
| 2005 | 13 | 20 | 8 | 12 |
| 2006 | 13 | 7 | 7 | 5 |
| 2007 | 13 | 12 | 8 | 6 |
| Average | **10.7** | **10.2** | **6.2** | **6.0** |
| 1984-2007 Correlation | | **0.61** | | **0.59** |

Table 17: Summary verification of the authors' six previous years of seasonal forecasts for Atlantic TC activity between 2001-2006.

| 2001 | 7 Dec. 2000 | Update 6 April | Update 7 June | Update 7 August | Obs. |
|---|---|---|---|---|---|
| No. of Hurricanes | 5 | 6 | 7 | 7 | 9 |
| No. of Named Storms | 9 | 10 | 12 | 12 | 15 |
| No. of Hurricane Days | 20 | 25 | 30 | 30 | 26 |
| No. of Named Storm Days | 45 | 50 | 60 | 60 | 64 |
| Hurr. Destruction Potential | 65 | 65 | 75 | 75 | 71 |
| Intense Hurricanes | 2 | 2 | 3 | 3 | 4 |
| Intense Hurricane Days | 4 | 4 | 5 | 5 | 4.25 |
| Net Tropical Cyclone Activity | 90 | 100 | 120 | 120 | 134 |

| 2002 | 7 Dec. 2001 | Update 5 April | Update 31 May | Update 7 August | Update 2 Sept. | Obs. |
|---|---|---|---|---|---|---|
| No. of Hurricanes | 8 | 7 | 6 | 4 | 3 | 4 |
| No. of Named Storms | 13 | 12 | 11 | 9 | 8 | 12 |
| No. of Hurricane Days | 35 | 30 | 25 | 12 | 10 | 11 |
| No. of Named Storm Days | 70 | 65 | 55 | 35 | 25 | 54 |
| Hurr. Destruction Potential | 90 | 85 | 75 | 35 | 25 | 31 |
| Intense Hurricanes | 4 | 3 | 2 | 1 | 1 | 2 |
| Intense Hurricane Days | 7 | 6 | 5 | 2 | 2 | 3 |
| Net Tropical Cyclone Activity | 140 | 125 | 100 | 60 | 45 | 82 |

| 2003 | 6 Dec. 2002 | Update 4 April | Update 30 May | Update 6 August | Update 3 Sept. | Update 2 Oct. | Obs. |
|---|---|---|---|---|---|---|---|
| No. of Hurricanes | 8 | 8 | 8 | 8 | 7 | 8 | 7 |
| No. of Named Storms | 12 | 12 | 14 | 14 | 14 | 14 | 16 |
| No. of Hurricane Days | 35 | 35 | 35 | 25 | 25 | 35 | 32 |
| No. of Named Storm Days | 65 | 65 | 70 | 60 | 55 | 70 | 79 |
| Intense Hurricanes | 3 | 3 | 3 | 3 | 3 | 2 | 3 |
| Intense Hurricane Days | 8 | 8 | 8 | 5 | 9 | 15 | 16.75 |
| Net Tropical Cyclone Activity | 140 | 140 | 145 | 120 | 130 | 155 | 174 |

| 2004 | 5 Dec. 2003 | Update 2 April | Update 28 May | Update 6 August | Update 3 Sept. | Update 1 Oct. | Obs. |
|---|---|---|---|---|---|---|---|
| No. of Hurricanes | 7 | 8 | 8 | 7 | 8 | 9 | 9 |
| No. of Named Storms | 13 | 14 | 14 | 13 | 16 | 15 | 14 |
| No. of Hurricane Days | 30 | 35 | 35 | 30 | 40 | 52 | 46 |
| No. of Named Storm Days | 55 | 60 | 60 | 55 | 70 | 96 | 90 |
| Intense Hurricanes | 3 | 3 | 3 | 3 | 5 | 6 | 6 |
| Intense Hurricane Days | 6 | 8 | 8 | 6 | 15 | 23 | 22.25 |
| Net Tropical Cyclone Activity | 125 | 145 | 145 | 125 | 185 | 240 | 229 |

| 2005 | 3 Dec. 2004 | Update 1 April | Update 31 May | Update 5 August | Update 2 Sept. | Update 3 Oct. | Obs. |
|---|---|---|---|---|---|---|---|
| No. of Hurricanes | 6 | 7 | 8 | 10 | 10 | 11 | 15 |
| No. of Named Storms | 11 | 13 | 15 | 20 | 20 | 20 | 27 |
| No. of Hurricane Days | 25 | 35 | 45 | 55 | 45 | 40 | 50 |
| No. of Named Storm Days | 55 | 65 | 75 | 95 | 95 | 100 | 129 |
| Intense Hurricanes | 3 | 3 | 4 | 6 | 6 | 6 | 7 |
| Intense Hurricane Days | 6 | 7 | 11 | 18 | 15 | 13 | 17.75 |
| Net Tropical Cyclone Activity | 115 | 135 | 170 | 235 | 220 | 215 | 277 |

| 2006 | 6 Dec. 2005 | Update 4 April | Update 31 May | Update 3 August | Update 1 Sept. | Update 3 Oct. | Obs. |
|---|---|---|---|---|---|---|---|
| No. of Hurricanes | 9 | 9 | 9 | 7 | 5 | 6 | 5 |
| No. of Named Storms | 17 | 17 | 17 | 15 | 13 | 11 | 10 |
| No. of Hurricane Days | 45 | 45 | 45 | 35 | 13 | 23 | 21 |
| No. of Named Storm Days | 85 | 85 | 85 | 75 | 50 | 58 | 53 |
| Intense Hurricanes | 5 | 5 | 5 | 3 | 2 | 2 | 2 |
| Intense Hurricane Days | 13 | 13 | 13 | 8 | 4 | 3 | 2 |
| Net Tropical Cyclone Activity | 195 | 195 | 195 | 140 | 90 | 95 | 85 |