EXTENDED RANGE FORECAST OF ATLANTIC SEASONAL HURRICANE ACTIVITY, INDIVIDUAL MONTHLY ACTIVITY, AND US LANDFALL STRIKE PROBABILITY FOR 2005

We foresee one of the most active hurricane seasons on record. An above-average probability of U.S. major hurricane landfall is anticipated. We have adjusted our forecast upward from our 31 May 2005 forecast.

(as of 5 August 2005)

This forecast is based on new research by the authors,
along with current meteorological information through late July 2005

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

Brad Bohlander, Colorado State University Media Representative, (970-491-6432) is available to answer various questions about this forecast.

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ATLANTIC BASIN SEASONAL HURRICANE FORECAST FOR 2005

Forecast Parameter and 1950–2000 Climatology (in parentheses)	Issue Date 3 December 2004	Issue Date 1 April 2005	Issue Date 31 May 2005	Observed Activity Through July 2005	Forecast After 1 Aug Activity	Total Seasonal Forecast
Named Storms (NS) (9.6)	11	13	15	7	13	20
Named Storm Days (NSD) (49.1)	55	65	75	28	67	95
Hurricanes (H)(5.9)	6	7	8	2	8	10
Hurricane Days (HD)(24.5)	25	35	45	11	44	55
Intense Hurricanes (IH) (2.3)	3	3	4	2	4	6
Intense Hurricane Days (IHD)(5.0)	6	7	11	6	12	18
Net Tropical Cyclone Activity (NTC)(100%)	115	135	170	68	167	235

POST-1 AUGUST PROBABILITIES FOR AT LEAST ONE MAJOR (CATEGORY 3-4-5) HURRICANE LANDFALL ON EACH OF THE FOLLOWING COASTAL AREAS:

1) Entire U.S. coastline – 77% (average for last century is 52%)

2) U.S. East Coast Including the Florida Peninsula – 58% (average for last century is 31%)

3) Gulf Coast from the Florida Panhandle westward to Brownsville – 44% (average for last century is 30%)

4) Expected above-average major hurricane landfall risk in the Caribbean and in the Bahamas

Acknowledgment

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DEFINITIONS

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.

Hurricane Destruction Potential - (HDP) A measure of a hurricane's potential for wind and storm surge destruction defined as the sum of the square of a hurricane's maximum wind speed (in 10^4 knots^2) for each 6-hour period of its existence.

Intense Hurricane - (IH) A hurricane which reaches a sustained low level wind of at least 111 mph (96 kt 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 intensity of Saffir/Simpson category 3 or higher.

MATL - Sea surface temperature anomaly in the Atlantic between 30-50°N, 10-30°W

Madden Julian Oscillation - (MJO) A broad area of equatorial convection that propagates eastward from the Indian Ocean. It is frequently associated with the development of El Niño events.

Named Storm - (NS) A hurricane or a 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.

NATL - Sea surface temperature anomaly in the Atlantic between 50-60°N, 10-50°W

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 (see Appendix B).

ONR - Previous year October-November SLPA of subtropical Ridge in eastern Atlantic between 20-30°W.

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 reverse 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.

SLPA - Sea Level Pressure Anomaly - The deviation of Caribbean and Gulf of Mexico sea level pressure from observed long term average conditions.

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.

TATL - Sea surface temperature anomaly in the Atlantic between 8-22°N, 10-50°W.

U - West to east zonal wind component.

V - South to north meridional wind component.

ZWA - Zonal Wind Anomaly - A measure of upper level ($\sim$ 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.

ABSTRACT

Information obtained through July 2005 indicates that the 2005 Atlantic hurricane season will be an extremely active one. We estimate that 2005 will have about 20 named storms (average is 9.6), 10 hurricanes (average is 5.9), 95 named storm days (average is 49.1), 55 hurricane days (average is 24.5), 6 intense (category 3-4-5) hurricanes (average is 2.3) and 18 intense hurricane days (average is 5.0). We expect Atlantic basin Net Tropical Cyclone (NTC) activity in 2005 to be about 235 percent of the long-term average. The probability of U.S. major hurricane landfall is estimated to be well above the long-period average. This year is expected to continue the past-decade trend of above-average hurricane seasons.

This early August forecast is based on our newly devised monthly forecasts for August, September and October which utilize 55 years of past global reanalysis data. Analog predictors are also utilized. We have increased our forecast from our 31 May prediction due to the seven named storms and the two major hurricanes that have already formed at low latitudes and the increase in favorability of several seasonal predictors over the past two months. This is the highest seasonal forecasts of hurricane activity we have ever made.

1 Introduction

Our Colorado State University research project has shown that a sizable portion of the year-to-year variability of Atlantic tropical cyclone (TC) activity can be hindcast with skill significantly exceeding climatology. These forecasts are based on a statistical methodology derived from 55 years of past global reanalysis data and a separate study of prior analog years which have had similar global atmosphere and ocean precursor circulation features to this year. Qualitative adjustments are added to accommodate additional processes which may not be explicitly represented by our statistical analyses. We believe that seasonal forecasts must be based on methods showing significant hindcast skill in application to long periods of prior data. It is only through hindcast skill that one can demonstrate that seasonal forecast skill is possible. This is a valid methodology provided the atmosphere continues to behave in the future as it has in the past. We have no reason for thinking that it will not.

Reanalysis data sets are available from the late 1940s and offer exciting and unique opportunities for the development of new and more skillful extended range empirical climate forecasts. Through extensive analyses of the recently available NOAA/NCEP reanalysis products, we have developed a new post-1 August seasonal forecast based on the sum of our individual August, September, and October forecasts.

2 Predictions of Individual Monthly Atlantic TC Activity for August, September, and October

A new aspect of our climate research is the development of TC activity predictions for individual months. There are often monthly periods within active and inactive Atlantic basin hurricane seasons which do not conform to the overall season. For example, 1961 was an active hurricane season (NTC of 222), but there was no TC activity during August; 1995 had 19 named storms, but only one named storm developed during a 30-day period during the peak of the hurricane season between 29 August and 27 September. By contrast, the inactive season of 1941 had only six named storms (average 9.3), but four of them developed during September. During the inactive 1968 hurricane season, three of the eight named storms formed in June (June average is 0.5).

We have conducted new research to see how well various sub-season or individual monthly trends of TC activity can be forecast. This effort has recently been documented in papers

Predictor Map

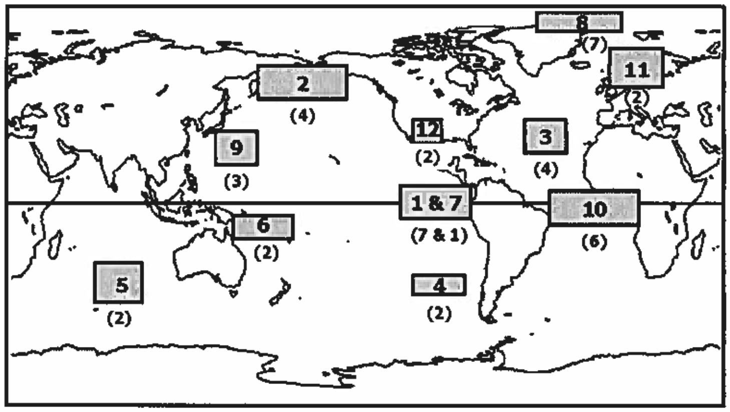

Figure 1: Global map showing locations of August-only TC predictors. Table 1 provides a listing and description of these predictors. The numbers in the boxes are keyed to descriptions in the bottom of Table 1. The numbers in parentheses beneath each box indicate how many individual parameters (NS, NSD, etc.) are obtained from each predictor.

by Blake and Gray (2004) for August and Klotzbach and Gray (2003) for September. These reports show that it is possible to develop skillful prediction schemes for August-only and September-only Atlantic basin tropical cyclone activity. We have also developed a separate October forecast scheme. On average, August, September, and October have about 26%, 48%, and 17% or 91% of the Atlantic basin's NTC activity. Initial August-only forecasts have now been made by Blake for the last five years (2000-2004), and the verification of these forecasts looks promising. The verification of the September-only and October-only forecasts also appears to show skill.

2.1 Independent August-Only Statistical Forecast

Figure 1 and Table 1 list the predictors used in the August-only hindcast (Blake and Gray 2004) for each of the seven different forecast parameters. The table also shows hindcast skill for the 51-year period 1950-2000, as well as the independent jackknife hindcast skill over this period. Table 2 gives the predictor values for August 2005. Table 3 gives our independent statistical prediction for August 2005. These predictors indicate above-average activity for August 2005. The most skillful August predictors, in general, call for a very active month, so we are calling for considerable activity during the month.

2.2 Independent September-Only Statistical Forecast

Figure 2 and Table 4 portray and list our 1 August predictors for September-only activity for this year. Table 5 gives the predictor values for September 2005. Table 6 gives our independent September statistical forecast and our adjusted final forecast.

Statistical data available through the end of July indicates that September 2005 will have about average activity. Our three most skillful predictors (Predictors 2, 3, and 8) all call for well above-average activity, and therefore, we believe that September will be quite active. An updated September-only statistical forecast will be issued on 3 September. This early September forecast will have the advantage of August data.

Table 1: Listing of predictors chosen for each forecast parameter and the total hindcast variance explained by these predictors for the August-only forecast. The name and atmospheric parameter utilized in each predictor is given below - where the number for each is keyed to Fig. 1.

Forecast Parameter	No. of Predictors	Predictors Chosen from Table	Variability Explained by Hindcast (R^2) (1949-1999)	Likely Independent Forecast Skill (Jackknife)
NS	5	3, 6, 7, 9, 11	.55	.41
NSD	5	1, 2, 3, 8, 10	.71	.61
H	4	1, 2, 8, 10	.57	.47
HD	5	3, 4, 8, 9, 10	.69	.59
IH	5	1, 3, 5, 8, 12	.68	.59
IHD	5	1, 4, 5, 6, 9	.78	.72
NTC	5	1, 2, 8, 10, 12	.74	.66

Table 2: August 2005 predictors.

Predictors	2005 Observed Values	Effect on 2005 Hurricane Season
Galapagos July 200 mb v, sign of correlation (-)	-1.0 SD	**Enhance**
Bering Sea July SLP, sign of correlation (-)	+0.6 SD	Suppress
Atlantic Ocean July SLP, sign of correlation (-)	-0.6 SD	**Enhance**
SE Pacific July 200 mb u, sign of correlation (-)	-0.9 SD	**Enhance**
S. Indian Ocean July 500 mb ht, sign of correlation (-)	-0.2 SD	**Enhance**
Coral Sea July 200 mb u, sign of correlation (+)	-0.1 SD	Suppress
Galapagos July 200 mb u, sign of correlation (-)	-0.7 SD	**Enhance**
North Greenland June 200 mb u, sign of correlation (+)	-0.1 SD	Suppress
Northwest Pacific June SLP, sign of correlation (+)	-0.1 SD	Suppress
S. Atlantic Ocean April SLP, sign of correlation (-)	+0.8 SD	Suppress
Scandinavia February SLP, sign of correlation (-)	+0.8 SD	Suppress
SW USA January SLP, sign of correlation (-)	+0.4 SD	Suppress

Table 3: Independent August-only prediction of 2005 hurricane activity based on Blake and Gray (2004). August climatology is shown in parentheses.

	Statistical Model	Qualitative Adjustment
NS	3.2 (2.8)	5
NSD	12.1 (11.8)	20
H	1.3 (1.6)	3
HD	6.7 (5.7)	10
IH	0.9 (0.6)	1
IHD	2.8 (1.2)	3
NTC	33.7 (26.1)	50

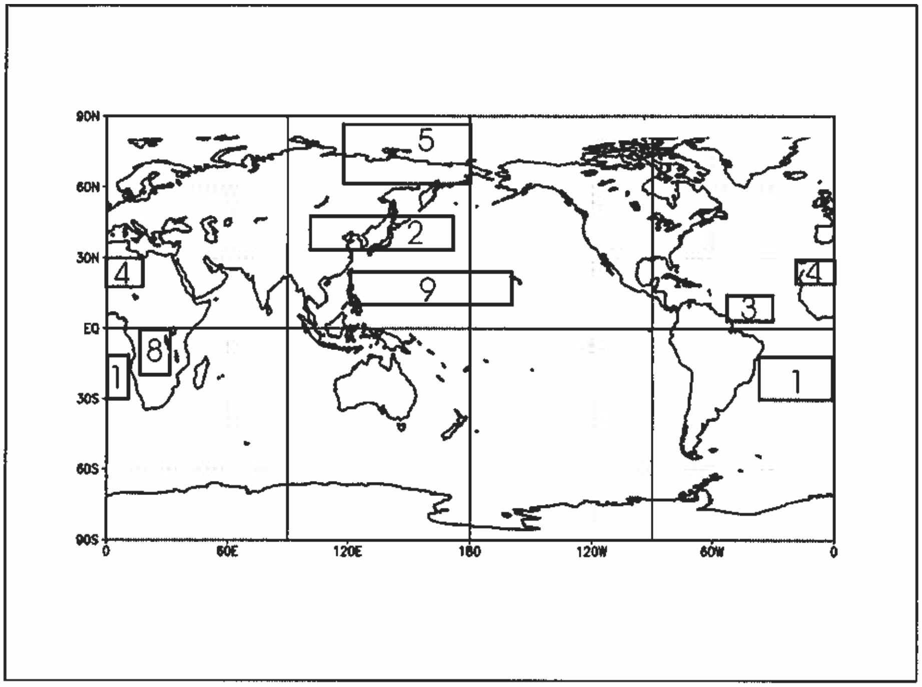

Figure 2: Predictors selected for the end of July forecast of September tropical cyclone activity. The numbers in each area are keyed to the description given in Table 4.

Table 4: Predictors selected for the end of July forecast of September-only tropical cyclone activity. The sign of the predictor associated with increased tropical cyclone activity is in parentheses. Note that predictors 6 and 7 are not used since they require August data.

Name of Predictor	Location	Equations Used
1) April 1000 mb U (-)	(12.5-30°S, 40°W-10°E)	IH
2) July 200 mb Geo Ht. (+)	(32-42°N, 100-160°E)	NS, NSD, H, HD, IH, NTC
3) July 1000 mb U (+)	(5-15°N, 30-50°W)	NS, NSD, H, HD, IH, IHD, NTC
4) Feb. 1000 mb U (-)	(20-30°N, 15°W-15°E)	NSD, HD, IHD, NTC
5) April 200 mb U (-)	(67.5-85°N, 110-180°E)	NS, NSD, HD, IH, IHD, NTC
8) May 200 mb V (+)	(0-20°S, 15-30°E)	NSD, H, HD
9) Jan-Feb 200 mb U (-)	(15-25°N, 120°E-160°W)	IH, IHD, NTC

Table 5: September 2005 predictor values – the sign of the predictor associated with increased tropical cyclone activity is in parentheses.

Predictor	2005 Observed Values	Effect on 2005 Hurricane Season
1) April 1000 mb U (12.5-30°S, 40°W-10°E) (–):	–0.1 SD	**Enhance**
2) July 200 mb Geopotential Height (32-42°N, 100-160°E) (+):	+0.6 SD	**Enhance**
3) July 1000 mb U (5-15°N, 30-50°W) (+):	+0.9 SD	**Enhance**
4) February 1000 mb U (20-30°N, 15°W-15°E) (–):	+1.3 SD	Suppress
5) April 200 mb U (67.5-85°N, 110-180°E) (–):	–0.1 SD	**Enhance**
8) May 200 mb V (0-20°S, 15-30°E) (+):	+1.2 SD	**Enhance**
9) January-February 200 mb U (15-25°N, 120°E-160°W) (–):	+1.2 SD	Suppress

Table 6: Independent 2005 September forecast based on data through July 2005.

Statistical Forecast	Adjusted Forecast	September Climatology
NS: 4.0	NS: 5.0	NS: 3.4
NSD: 25.9	NSD: 31.0	NSD: 21.7
H: 3.5	H: 4.0	H: 2.4
HD: 13.0	HD: 22.0	HD: 12.3
IH: 1.4	IH: 2.0	IH: 1.3
IHD: 1.1	IHD: 6.0	IHD: 3.0
NTC: 48.7	NTC: 80.0	NTC: 48

2.3 Independent October-only Statistical Forecast

Through examination of the NCEP/NCAR reanalysis, we have discovered four predictors that in combination explain about 50 percent of the October cross-validated variance in Net Tropical Cyclone activity for the hindcast period of 1950-2001. We are currently unable to find combinations of predictors that explain large amounts of variance for the individual tropical cyclone parameters (i.e., named storms, hurricane days, etc.). Therefore, our October forecast consists of predicting NTC and consequently increasing or decreasing October's values for the other parameters accordingly. For example, if October NTC was 150 percent of normal and a typical October had two named storms, we would forecast three named storms for October. The predictors utilized in our initial October prediction are displayed graphically in Figure 3, and their 2005 values are displayed in Table 7. Three of the four predictors are above-average for storms. Therefore, we are calling for a very active October with an NTC of about 200 percent of the climatological average. In round numbers, we are forecasting 3 named storms, 2 hurricanes, 1 intense hurricane and an NTC of 35 for October. Table 8 displays our initial statistical forecast and our adjusted forecast for October tropical cyclone activity. Additional updates for the October-only forecast will be issued in early September and in early October.

Table 7: Predictors selected for the 1 August forecast of October tropical cyclone activity. The sign of the predictor associated with increased tropical cyclone activity is in parentheses.

Predictor	2005 Observed Values	Effect on 2005 Hurricane Season
1) June-July SLP (10-25°N, 10-40°W) (–):	-0.1 SD	**Enhance**
2) July 200 mb Geopotential Height (20-35°N,5-45°W) (+):	+1.0 SD	**Enhance**
3) July 200 mb U (35-47.5°S,160°E-160°W) (+):	+0.8 SD	**Enhance**
4) Previous November SLP (45-65°N, 115-145°W) (–):	+0.7 SD	Suppress

2.4 Monthly Prediction Summary

Table 9 summarizes our individual monthly predictions and our monthly adjustments to these predictions. Based on jackknifed hindcast data from 1950-2000, the sum of the August, September, and October forecasts explains 79% of the variance in seasonal TC activity.

OCTOBER PREDICTORS

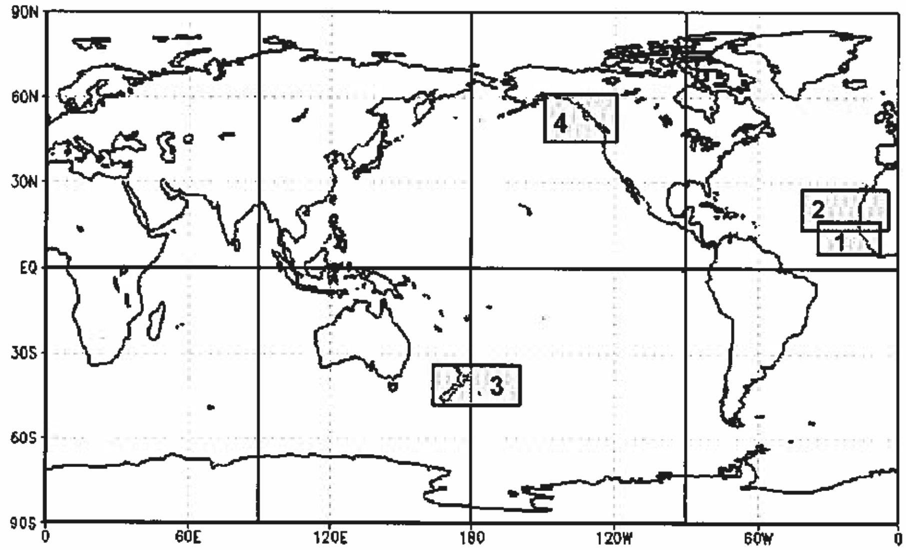

Figure 3: Location of 1 August predictors for October tropical cyclone activity.

Table 8: Independent 2005 October-only forecast based on data through July 2005.

Statistical Forecast	Adjusted Forecast	October Climatology
NS: 2.1	NS: 3.0	NS: 1.7
NSD: 11.0	NSD: 13.0	NSD: 9.0
H: 1.3	H: 2.0	H: 1.1
HD: 5.4	HD: 7.0	HD: 4.4
IH: 0.4	IH: 1.0	IH: 0.3
IHD: 1.0	IHD: 2.0	IHD: 0.8
NTC: 21	NTC: 35	NTC: 18

Table 9: August, September and October 2005 individual statistical model predictions and qualitative adjustments. The monthly climatology is given in parentheses.

	August Model Prediction	August Adjustment to	September Model Prediction	September Adjustment to	October Model Prediction	October Adjustment to	3 Month Sum Statistics	3 Month Sum of Adjusted Monthly Fcsts.
NS	3.2 (2.8)	5	4.0 (3.4)	5	2.1 (1.7)	3	9.3	13
NSD	12.1 (11.8)	20	25.9 (21.7)	31	11.0 (9.0)	13	49.0	64
H	1.3 (1.6)	3	3.5 (2.4)	4	1.3 (1.1)	2	6.1	9
HD	6.7 (5.7)	10	13.0 (12.3)	22	5.4 (4.4)	7	25.1	39
IH	0.9 (0.6)	1	1.4 (1.3)	2	0.4 (0.3)	1	2.7	4
IHD	2.8 (1.2)	3	1.1 (3.0)	6	1.0 (0.8)	2	4.9	11
NTC	33.7 (26.1)	50	48.7 (48.0)	80	21.0 (18)	35	103.4	165

3 Seasonal Analogs for 2005

Table 10 lists our best seasonal analogs for 2005. We selected years with a warm tropical Atlantic, neutral ENSO conditions, and, in general, active early seasons. Our seasonal analogs continue to point toward a very active season.

Table 10: Best analog years for 2005 with the associated hurricane activity listed for each year.

Year	NS	NSD	H	HD	IH	IHD	NTC
1886	12	84	10	49.5	4	4.5	155
1933	21	136	10	50.5	5	10.5	216
1966	11	64	7	42	3	7	134
1995	19	121	11	62	5	11.5	222
1996	13	78	9	45	6	13	192
2003	16	75	7	33	3	16.75	173
2004	14	90.25	9	45.5	6	22.25	229
Mean	15.1	92.6	9.0	46.8	4.6	12.2	188.8
Pre-1 August Observed Activity	7	28	2	11	2	6	68
Post-1 August Forecast	13	67	8	44	4	12	167
Entire 2005 Season Forecast	20	95	10	55	6	18	235

4 Forecast Adjustments

Table 11 provides a comparison of all of our forecast techniques along with the final full season adjusted forecast. Given the current (July) global conditions and other information we have, we anticipate comparable activity to what is indicated by the sum of our three adjusted individual monthly predictions.

5 Comparison of Forecast Techniques

Table 11 provides a comparison of our statistical and analog forecast techniques along with the final adjusted forecast and climatology. Column 1 gives activity prior to 1 August. Column 2 gives the 3-month sum of our monthly forecasts. Column 3 is our adjusted final after 1 August forecast, Column 4 is our analog scheme, column 5 is the total season adjusted forecast and column 6 is the 1950-2000 climatology.

The reader will note that we have raised our forecast from our earlier forecasts. Atlantic SST conditions are close to being the highest on record. Also, we have already witnessed two major hurricanes forming in the deep tropics which is very favorable for an extremely active season.

We believe that the current active period is quite similar to the 1930s, where we had many active hurricane seasons, even though other features typically associated with active seasons in the 1950s and 1960s were not present. The 1930s were also a period of strong global warming similar to the global warming of the last decade. From the limited data available during the 1930s and 1940s, we deduce that the Atlantic was quite warm, similar

Table 11: Comparison of our post-1 August 2005 statistical and analog forecast techniques along with our final adjusted forecast and the 1950-2000 climatology.

Forecast Parameter	(1) Pre- 1 Aug Activity	(2) Sum of 3 Individual Adjusted Monthly Forecasts	(3) After 1 Aug Adjusted Final Fcst	(4) Total Season Analog Forecast	(5) Total Season Adjusted Forecast	(6) 1950-2000 Climatology
NS	7	13	13	15.1	20	9.6
NSD	28	64	67	92.6	95	49.1
H	2	9	8	9.0	10	5.9
HD	11	39	44	46.8	55	24.5
IH	2	4	4	4.6	6	2.3
IHD	6	11	12	12.2	18	5.0
NTC	68	165	167	188.8	235	100

to conditions that we are presently experiencing. However, other features, such as strong easterly anomalies at upper levels in the tropical Atlantic which were present in the 1950s and 1960s, do not appear to have been present in the earlier period of the 1930s. We have seen a slight increase in tropical Atlantic easterly anomalies since 1995 but have yet to see the easterlies that were present in the earlier decades of the 1950s and 1960s. In addition, the westerlies in the Southern Hemisphere have not yet weakened, even though, a weaker midlatitude circulation in the Southern Hemisphere is typically associated with active Atlantic hurricane seasons.

6 Post-1 August Landfall Probabilities for 2005

A significant focus of our recent research involves efforts to develop forecasts of the probability of hurricane landfall along the U.S. coastline. Whereas individual hurricane landfall events cannot be accurately forecast months in advance, the total seasonal probability of landfall can be forecast with statistical skill. With the observation that, statistically, landfall is a function of varying climate conditions, a probability specification has been developed through statistical analyses of all U.S. hurricane and named storm landfall events during the last century (1900–1999). Specific landfall probabilities can be given for all cyclone intensity classes for a set of distinct U.S. coastal regions.

Figure 4 provides a flow diagram showing how these forecasts are made. Net landfall probability is shown linked to the overall Atlantic basin NTC (see Table 12) and to climate trends linked to multi-decadal variations of the Atlantic Ocean thermohaline circulation as inferred from recent past years of North Atlantic SSTA*.

Higher values of SSTA* (see prior forecast for definition) generally indicate greater Atlantic hurricane activity, especially for intense or major hurricanes. Atlantic basin NTC can be skillfully hindcast, and the strength of the Atlantic Ocean thermohaline circulation can be inferred as SSTA* from North Atlantic SST anomalies in the current and prior years. These relationships are then utilized to make probability estimates for U.S. landfall. The current (July 2005) value of SSTA* is 62. Hence, in combination with a post-1 August prediction of NTC of 167 for 2005, a combination of NTC + SSTA* of (167 + 62) yields a value of 229.

As shown in Table 12, NTC is a combined measure of the year-to-year mean of six indices of hurricane activity, each expressed as a percentage difference from the long-term average. Although many active Atlantic hurricane seasons feature no landfalling hurricanes, and some inactive years experience one or more landfalling hurricanes, it is found that, on average, the more active the overall Atlantic basin hurricane season is, the greater the probability of U.S. hurricane landfall. For example, landfall observations during the last 100 years show that a greater number of intense (Saffir-Simpson category 3-4-5) hurricanes strike Florida and the

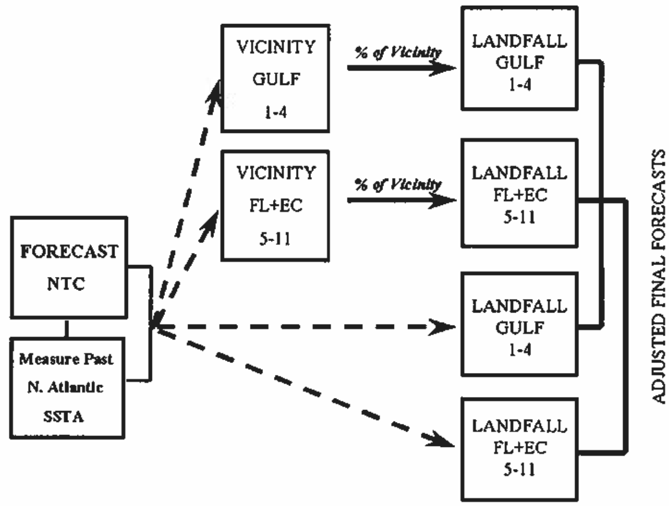

Figure 4: Flow diagram illustrating how forecasts of U.S. hurricane landfall probabilities are made. Forecast NTC values and an observed measure of recent North Atlantic (50-60°N, 10-50°W) SSTA* are used to develop regression equations for U.S. hurricane landfall. Separate equations are derived for the Gulf and for Florida and the East Coast (FL+EC).

U.S. East Coast during years of (1) increased NTC and (2) above-average North Atlantic SSTA* conditions.

Table 12: NTC activity in any year consists of the seasonal total of the following six parameters expressed in terms of their long-term averages. A season with 10 NS, 50 NSD, 6 H, 25 HD, 3 IH, and 5 IHD, would then be the sum of the following ratios: 10/9.6 = 104, 50/49.1 = 102, 6/5.9 = 102, 25/24.5 = 102, 3/2.3 = 130, 5/5.0 = 100, divided by six, yielding an NTC of 107.

	1950-2000 Average	
1)	Named Storms (NS)	9.6
2)	Named Storm Days (NSD)	49.1
3)	Hurricanes (H)	5.9
4)	Hurricane Days (HD)	24.5
5)	Intense Hurricanes (IH)	2.3
6)	Intense Hurricane Days (IHD)	5.0

Table 13 lists strike probabilities for different TC categories for the entire U.S. coastline, the Gulf Coast, and Florida and the East Coast for 2005. The mean annual probability of one or more landfalling systems is given in parentheses. Note that post-1 August Atlantic basin NTC activity in 2005 is expected to be greater than the long-term average (167 versus 100), and North Atlantic SSTA* values are measured to be above average (62 units). U.S. hurricane landfall probability is thus expected to be well above average owing to both a higher NTC and above-average North Atlantic SSTAs. During periods of positive North Atlantic SSTA*, a higher percentage of Atlantic basin major hurricanes cross the Florida and eastern U.S. coastline for a given level of NTC.

Table 13: Estimate of 2005 post-1 August probability (expressed in percent) of one or more U.S. landfalling tropical storms (TS), category 1-2 hurricanes (HUR), category 3-4-5 hurricanes, total hurricanes and named storms along the entire U.S. coastline, along the Gulf Coast (region 1-4), and along Florida and the East Coast (Regions 5-11) for 2005. The long-term mean annual probability of one or more landfalling systems during the last 100 years is given in parentheses.

Coastal Region	TS	Category 1-2 HUR	Category 3-4-5 HUR	All HUR	Named Storms
Entire U.S. (Regions 1-11)	89% (80)	85% (68)	77% (52)	97% (84)	99% (97)
Gulf Coast (Regions 1-4)	71% (59)	58% (42)	44% (30)	76% (61)	93% (83)
Florida plus East Coast (5-11)	61% (51)	64% (45)	58% (31)	85% (62)	94% (81)

7 United States Landfalling Hurricane Webpage Application

Over the past four years, we have been compiling and synthesizing our landfalling hurricane data and have developed a webpage application with extensive landfall probabilities for the Gulf and East Coasts of the United States. In partnership with the GeoGraphics Laboratory at Bridgewater State College, a web application has been created that displays landfall probabilities for eleven regions, 55 subregions and all 205 U.S. coastal and near-coastal counties from Brownsville, Texas to Eastport, Maine. Individual probabilities of sustained winds of tropical storm force (40-75 mph), hurricane force ($\geq$ 75 mph) and intense or major hurricane force ($\geq$ 115 mph) are also given. These probabilities are based on the current forecast of NTC activity and on current values of SSTA*. Probabilities of winds in the vicinity of a subregion and county as well as 50-year probabilities for winds of tropical storm force, hurricane force, and intense hurricane force are also provided. These probabilities have recently been updated with data from the latter part of the 19th century with the release of the first part of the HURDAT reanalysis (Landsea et al. 2005). Table 14 summarizes the data currently available on the webpage.

Table 14: Data currently available on our CSU landfalling hurricane probability webpage.

	Annual Landfall Probability	Annual Vicinity Probability	50-Year Probability
NS	X	X	X
H	X	X	X
IH	X	X	X

Figures 5 and 6 display example screens of data that is available on this website. The user can select tracks of all intense hurricanes that have made landfall in a given area over the last 100 years. This webpage is currently available at http://www.e-transit.org/hurricane. One can also reach this webpage from a link off the CSU Tropical Meteorology Project homepage http://hurricane.atmos.colostate.edu.

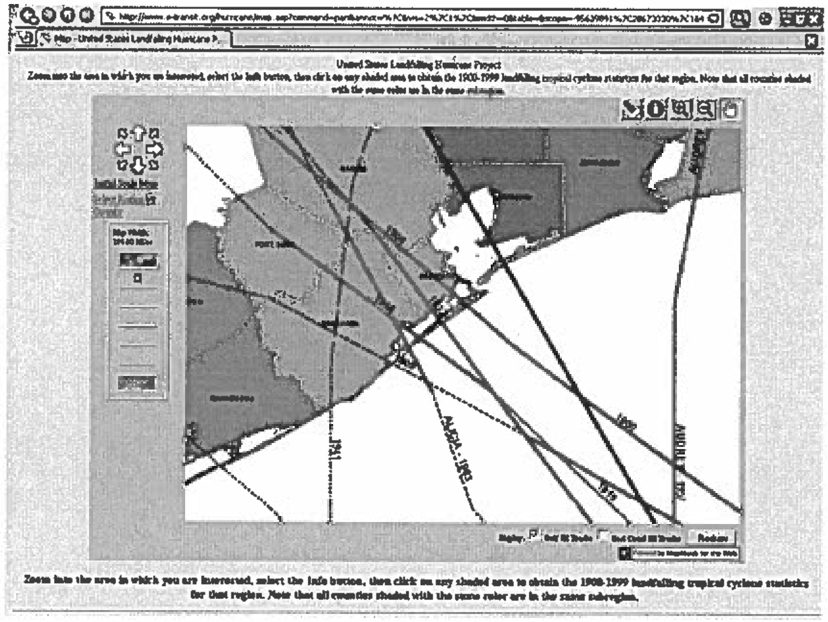

Figure 5: View of landfalling hurricane webpage centered on Subregion 1E - the Houston/Galveston metropolitan area.

County (High) Information	
Name	Miami-Dade FL
Region	6
Region - Coastline Distance	463
Region - 2000 Population	5,213,884
Region - Named Storms (1900-1999)	47
Region - Prob. 1 or More NS	54.4% (37.5%)
Region - Prob. 2 or More NS	11.8% (8.1%)
Region - Hurricanes (1900-1999)	34
Region - Prob. 1 or More H	41.8% (28.8%)
Region - Prob. 2 or More H	6.7% (4.6%)
Region - Intense Hurricanes (1900-1999)	16
Region - Prob. 1 or More IH	21.4% (14.8%)
Region - Prob. 2 or More IH	1.7% (1.2%)
Region - Prob. TS Force	44.3% (30.5%)
Region - 50 Year TS Prob.	100.0%
Region - NS Vicinity Prob.	98.1% (93.6%)
Region - Prob. H Force	13.5% (9.3%)
Region - 50 Year H Prob.	99.3%
Region - H Vicinity Prob.	70.4% (56.9%)
Region - Prob. IH Force	4.3% (3.0%)
Region - 50 Year IH Prob.	78.1%
Region - IH Vicinity Prob.	32.3% (23.6%)

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

Figure 6: Example of data available from the United States landfalling hurricane webpage.

8 The 1995-2004 Upswing in Atlantic Hurricanes and Global Warming

Many individuals have queried whether the unprecedented landfall of four destructive hurricanes in a seven-week period during August-September 2004 is related in any way to human-induced climate changes. There is no evidence that this is the case. If global warming were the cause of the increase in United States hurricane landfalls in 2004 and the overall increase in Atlantic basin major hurricane activity of the past ten years (1995-2004), one would expect to see an increase in tropical cyclone activity in the other storm basins as well (ie., West Pacific, East Pacific, Indian Ocean, etc.). This has not occurred. When tropical cyclones worldwide are summed, there has actually been a slight decrease since 1995. In addition, it has been well-documented that the measured global warming during the 25-year period of 1970-1994 was accompanied by a downturn in Atlantic basin hurricane activity over what was experienced during the 1930s through the 1960s.

We attribute the heightened Atlantic major hurricane activity between 1995-2004 to be a consequence of the multidecadal fluctuations in the Atlantic Ocean thermohaline circulation (THC) as we have been discussing in our Atlantic basin seasonal hurricane forecasts for several years. Major hurricane activity in the Atlantic has been shown to undergo marked multidecadal fluctuations that are directly related to North Atlantic sea surface temperature anomalies. When the Atlantic Ocean thermohaline circulation is running strong, the central Atlantic equatorial trough (ITCZ) becomes stronger. The stronger the Atlantic equatorial trough becomes, the more favorable are conditions for the development of major hurricanes in the central Atlantic. Since 1995, the THC has been flowing more strongly, and there has been a concomitant increase in major hurricanes in the tropical Atlantic.

9 Forecast Theory and Cautionary Note

Our forecasts are based on the premise that those global oceanic and atmospheric conditions which precede comparatively active or inactive hurricane seasons in the past provide meaningful information about similar trends in future seasons. It is important that the reader appreciate that these seasonal forecasts are based on statistical schemes which, owing to their intrinsically probabilistic nature, will fail in some years. Moreover, these forecasts do not specifically predict where within the Atlantic basin these storms will strike. The probability of landfall for any one location along the coast is very low and reflects the fact that, in any one season, most US coastal areas will not feel the effects of a hurricane no matter how active the individual season is. However, it must also be emphasized that a low landfall probability does not insure that hurricanes will not come ashore. Regardless of how active the 2005 hurricane season is, a finite probability always exists that one or more hurricanes may strike along the US coastline or the Caribbean Basin and do much damage.

10 Forthcoming Update Forecasts of 2005 Hurricane Activity

We will be issuing seasonal updates of our 2005 Atlantic basin hurricane activity forecast on Friday 2 September and Monday 3 October 2005. These 2 September and 3 October forecasts will include separate forecasts of September-only and October-only Atlantic basin tropical cyclone activity. A verification and discussion of all 2005 forecasts will be issued in late November 2005. Our first seasonal hurricane forecast for the 2006 hurricane season will be issued in early December 2005. All these forecasts will be available at our web address given on the front cover
(http://hurricane.atmos.colostate.edu/Forecasts).

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13 Verification of Previous Forecasts

Table 15: Summary verification of the authors' six previous years of seasonal forecasts for Atlantic TC activity between 1999-2004. Verification of our earlier year forecasts for the years 1984-1998 are given in our late November seasonal verifications (on this Web location).

1999	5 Dec 1998	Update 7 April	Update 4 June	Update 6 August	Obs.
No. of Hurricanes	9	9	9	9	8
No. of Named Storms	14	14	14	14	12
No. of Hurricane Days	40	40	40	40	43
No. of Named Storm Days	65	65	75	75	77
Hurr. Destruction Potential(HDP)	130	130	130	130	145
Major Hurricanes (Cat. 3-4-5)	4	4	4	4	5
Major Hurr. Days	10	10	10	10	15
Net Trop. Cyclone (NTC) Activity	160	160	160	160	193

2000	8 Dec 1999	Update 7 April	Update 7 June	Update 4 August	Obs.
No. of Hurricanes	7	7	8	7	8
No. of Named Storms	11	11	12	11	14
No. of Hurricane Days	25	25	35	30	32
No. of Named Storm Days	55	55	65	55	66
Hurr. Destruction Potential (HDP)	85	85	100	90	85
Major Hurricanes (Cat. 3-4-5)	3	3	4	3	3
Major Hurr. Days	6	6	8	6	5.25
Net Trop. Cyclone (NTC) Activity	125	125	160	130	134

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	27
No. of Named Storm Days	45	50	60	60	63
Hurr. Destruction Potential (HDP)	65	65	75	75	71
Major Hurricanes (Cat. 3-4-5)	2	2	3	3	4
Major Hurr. Days	4	4	5	5	5
Net Trop. Cyclone (NTC) Activity	90	100	120	120	142

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 (HDP)	90	85	75	35	25	31
Major Hurricanes (Cat. 3-4-5)	4	3	2	1	1	2
Major Hurr. Days	7	6	5	2	2	2.5
Net Trop. Cyclone (NTC) Activity	140	125	100	60	45	80

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	14
No. of Hurricane Days	35	35	35	25	25	35	32
No. of Named Storm Days	65	65	70	60	55	70	71
Hurr. Destruction Potential (HDP)	100	100	100	80	80	125	129
Major Hurricanes (Cat. 3-4-5)	3	3	3	3	3	2	3
Major Hurr. Days	8	8	8	5	9	15	17
Net Trop. Cyclone (NTC) Activity	140	140	145	120	130	155	168

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
Major Hurricanes (Cat. 3-4-5)	3	3	3	3	5	6	6
Major Hurr. Days	6	8	8	6	15	23	22
Net Trop. Cyclone (NTC) Activity	125	145	145	125	185	240	229