EXTENDED RANGE FORECAST OF ATLANTIC SEASONAL HURRICANE ACTIVITY AND US LANDFALL STRIKE PROBABILITY FOR 2004

The recent upturn in Atlantic basin hurricane activity which began in 1995 is expected to continue in 2004. We anticipate an above-average number of Atlantic basin tropical cyclones and an above-average probability of U.S. hurricane landfall.

(as of 28 May 2004)

This forecast is based on new research by the authors,
along with current meteorological information through late May 2004

By

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Brad Bohlander and Thomas Milligan, Colorado State University Media Representatives (970-491-6432) are available to answer various questions about this forecast.

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ATLANTIC BASIN SEASONAL HURRICANE FORECAST FOR 2004

Forecast Parameter and 1950-2000 Climatology (in parentheses)	Issue Date 5 December	Issue Date 2 April	Issue Date 28 May
Named Storms (NS) (9.6)	13	14	14
Named Storm Days (NSD) (49.1)	55	60	60
Hurricanes (H)(5.9)	7	8	8
Hurricane Days (HD)(24.5)	30	35	35
Intense Hurricanes (IH) (2.3)	3	3	3
Intense Hurricane Days (IHD)(5.0)	6	8	8
Hurricane Destruction Potential (HDP) (72.7)	85	100	100
Net Tropical Cyclone Activity (NTC)(100%)	125	145	145

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

1) Entire U.S. coastline - 71% (average for last century is 52%)

2) U.S. East Coast Including the Florida Peninsula - 52% (average for last century is 31%)

3) Gulf Coast from the Florida Panhandle westward to Brownsville - 40% (average for last century is 30%)

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

DISTINCTION BETWEEN CSU SEASONAL HURRICANE FORECASTS AND THOSE ISSUED BY NOAA

Seasonal hurricane forecasts have been issued for 21 years by the tropical meteorology research group of Prof. William Gray of the Department of Atmospheric Science, Colorado State University (CSU). These forecasts are now issued in early December of the prior year, and in early April, June, August, September and October of the current year. The predictions have shown steady improvement through continuing research. These forecasts now include U.S. hurricane landfall probabilities for seasonal as well as individual monthly periods.

The National Oceanic and Atmospheric Administration (NOAA) has also recently begun to issue Atlantic basin seasonal hurricane forecasts. The NOAA forecasts are independent of our CSU forecasts although they utilize prior CSU research augmented by their own insights. The NOAA and the CSU forecasts will typically differ in some aspects and details. Chris Landsea and Eric Blake, former CSU project members presently employed by NOAA, have made important contributions to both forecasts.

Acknowledgment

We are grateful to AIG - Lexington Insurance Company (a member of the American International Group) for providing partial support for the research necessary to make these forecasts. The National Science Foundation has also contributed to the background research necessary to make these forecasts.

DEFINITIONS

ABSTRACT

Information obtained through May 2004 indicates that the 2004 Atlantic hurricane season will be an active one. We estimate that 2004 will have about 8 hurricanes (average is 5.9), 14 named storms (average is 9.6), 60 named storm days (average is 49), 35 hurricane days (average is 24.5), 3 intense (category 3-4-5) hurricanes (average is 2.3), 8 intense hurricane days (average is 5.0) and a Hurricane Destruction Potential (HDP) of 100 (average is 71). We expect Atlantic basin Net Tropical Cyclone (NTC) activity in 2004 to be about 145 percent of the long-term average. The probability of U.S. major hurricane landfall is estimated to be 40 percent above the long-period average. This late May forecast is based on a newly-devised extended range statistical forecast procedure which utilizes 52 years of past global reanalysis data. Analog predictors are also utilized. The influence of El Niño conditions in our hurricane forecast are implicit in our predictor fields, and therefore we do not utilize a specific ENSO forecast. As of late May, it appears that neutral or weak warm ENSO conditions are likely this summer and fall.

1 Introduction

This is the 21st year in which the first author has made forecasts of the coming season's Atlantic basin hurricane activity. 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 52 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. These evolving forecast techniques are based on a variety of climate-related global and regional predictors previously shown to be related to the forthcoming seasonal Atlantic tropical cyclone activity and landfall probability.

2 Earlier 1 June Statistical Hurricane Forecast Scheme

Our original early June seasonal hurricane forecast scheme was developed in the early 1990s and demonstrated significant hindcast skill for the period of 1950-1991 (Gray et al. 1994). This scheme included measurements of West African rainfall as an important forecast input.

Since the observed shift of Atlantic Ocean SST patterns in 1995 [and the implied increase in the strength of the Atlantic Thermohaline Circulation (THC)], our original 1 June forecast scheme (1994) has consistently underpredicted Atlantic basin hurricane activity. Our earlier 1 June statistical scheme used West African rainfall data as an important predictor. We do not understand why, but the previously observed (1950-1994) strong association between West Africa rainfall and Atlantic hurricanes has not been reliable since 1994. We have lost confidence in the previous 1 June statistical forecast scheme compared to our newly developed one. We have thus decided to discontinue our earlier 1 June forecast scheme.

2.1 Newly Developed 1 June Forecast Scheme

The last few years have seen tremendous growth in the accessibility of global atmospheric and oceanic data on the Internet. An example of this accessibility is the NOAA/NCEP reanalysis data sets which archives historical atmospheric and ocean surface data and makes this data easily available. Most of these 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. For example:

- Our new scheme has been developed on 11 more years of hindcast data (1950-2001).

- Our new scheme has been able to use the recently developed NOAA/NCEP reanalysis data that was not available to us at the time we developed our earlier scheme. The reanalysis has allowed us to more readily search for new forecast parameters that were previously not available.

The pool of seven predictors for this new extended range forecast is given and defined in Table 1. The location of each of these new predictors is shown in Fig. 1. Strong statistical relationships can be extracted via combinations of these predictive parameters (which are available by the end of May), and quite skillful Atlantic basin hurricane forecasts for the following summer and fall can be made if the atmosphere and ocean continue to behave in the future as they have during the hindcast period of 1950-2001.

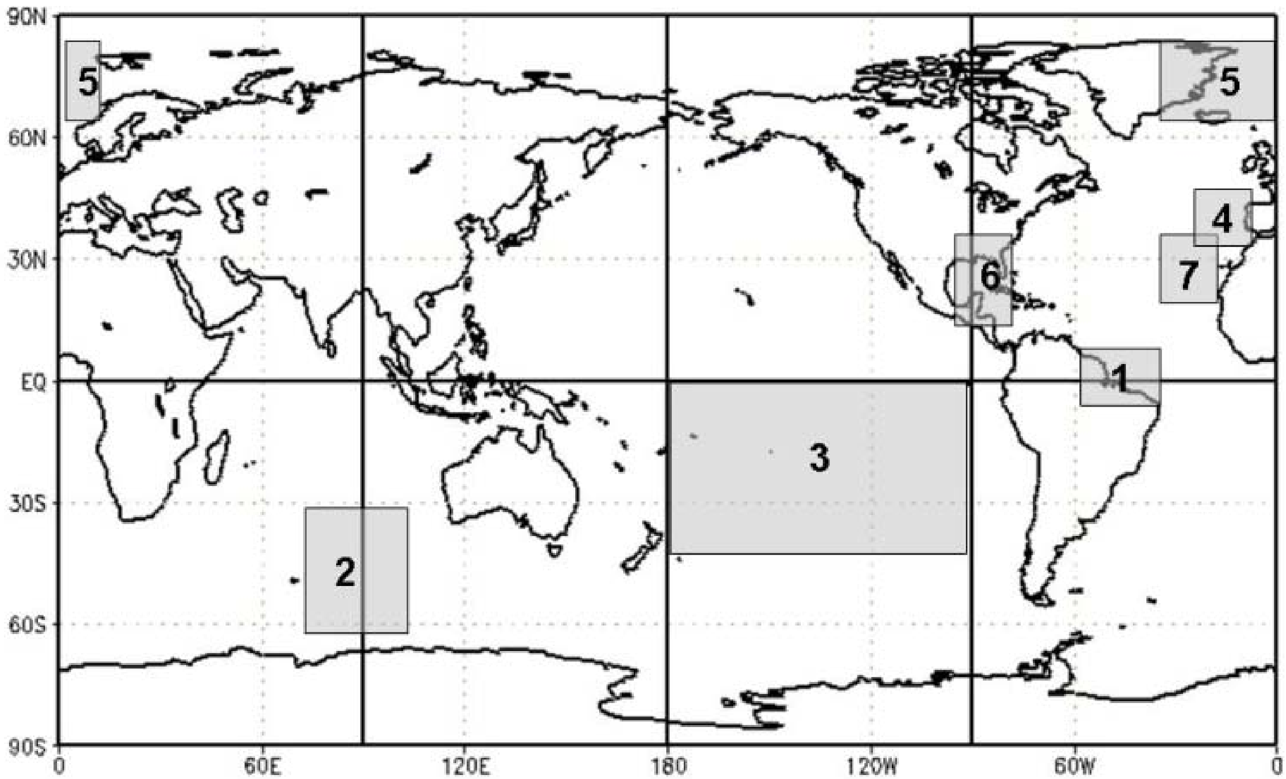

Figure 1: Location of predictors for our new 1 June forecast for the 2004 hurricane season.

Table 1: List of our new 1 June 2004 predictors and their anomalous values for this year's hurricane activity. A plus (+) means that positive values of the parameter are associated with increased hurricane activity, and a minus (-) indicates that negative values of the parameter are associated with increased hurricane activity. Five of the seven values indicate increased hurricane activity for this year.

Predictor	Values for 2004 Forecast
(1) - February 200 MB U (5°S-10°N, 35-55°W) (-)	-0.5 SD
(2) - February-March 200 MB V (35-62.5°S, 70-95°E) (-)	+0.3 SD
(3) - February SLP (0-45°S, 90-180°W) (+)	-0.4 SD
(4) - February SST (35-50°N, 10-30°W) (+)	+1.8 SD
(5) - Previous November 500 MB Ht. (67.5-85°N, 50°W-10°E) (+)	+0.7 SD
(6) - Previous September-November SLP (15-35°N, 75-95°W) (-)	-0.8 SD
(7) - May SSTA (20-40°N, 15-30°W) (+)	+0.5 SD

Table 2 shows our statistical forecast for the 2004 hurricane season and the comparison of this forecast with climatology (average season between 1950-2000). All our forecast parameters are currently expected to be above average.

Table 2: New late May statistical forecast for 2004.

Predictands and Climatology	Statistical Forecast Numbers
Named Storms (NS) - 9.6	11.7
Named Storm Days (NSD) - 49.1	67.2
Hurricanes (H) - 5.9	6.4
Hurricane Days (HD) - 24.5	31.9
Intense Hurricanes (IH) - 2.3	2.5
Intense Hurricane Days (IHD) - 5.0	5.2
Hurricane Destruction Potential (HDP) - 72.7	99
Net Tropical Cyclone Activity (NTC) - 100	107

2.2 Physical Associations of Predictors With Hurricane Activity

Brief descriptions of our new late May predictors follow:

Predictor 1. February 200 MB U in the Central Tropical Atlantic (-)

(5˙S-10˙N, 35-55˙W)

Easterly upper-level zonal wind anomalies off the northeast coast of South America imply that the upward circulation associated with the Walker Circulation of a warm ENSO event has shifted westward and that cool La Niña conditions are likely to be present for the next 4-6 months. El Niño conditions shift the upward portion of the Walker Circulation eastward and cause 200 mb westerly anomalies in this area. Such 200 mb westerly wind anomalies are associated with increased upper-level divergence in the East Pacific which occurs with warm ENSO conditions.

Predictor 2. February-March 200 MB V in the Southern Indian Ocean (-)

(35-62.5˙S, 70-95˙E)

Anomalous winds from the north at 200 mb in the southern Indian Ocean are associated with a northeastward shift of the South Indian Convergence Zone (SICZ) (Cook 2000), a more longitudinally concentrated upward branch of the Hadley Cell near Indonesia, and warm sea surface temperatures throughout most of the Indian Ocean. This implies that warm ENSO conditions have likely been prevalent throughout the past several months due to the lag teleconnected effect of a warm Indian Ocean with a warm eastern Pacific Ocean. Strong lag correlations ($r > 0.4$) with this predictor indicate that a change in phase of ENSO from warm to cool is likely during the summer.

Predictor 3. February SLP in the Southeast Pacific (+)

(0-45˙S, 90-180˙W)

High sea level pressure in the eastern Pacific south of the equator indicates a positive Southern Oscillation Index (SOI) and stronger-than-normal trade winds across the Pacific. Increased trades drive enhanced upwelling off the west coast of South America which is typical of La Niña and hurricane-enhancing conditions. Cool sea surface temperatures associated with this higher pressure tend to persist throughout the spring and summer, thereby reducing vertical wind shear over the tropical Atlantic and providing more favorable conditions for tropical cyclone development.

Predictor 4. February SST off the Northwestern European Coast (+)

(35-50°N, 30-50°W)

Warm sea surface temperatures off the northwest coast of Europe correlate quite strongly with warm sea surface temperatures across the entire North Atlantic Ocean. A warm North Atlantic Ocean indicates that the thermohaline circulation is likely stronger than normal, and the Azores subtropical high and trade wind strength across the Atlantic are weaker than normal. Weaker trade winds induce less upwelling which keeps the tropical Atlantic warmer than normal. This pattern tends to persist throughout the spring and summer and implies a warmer tropical Atlantic during the following hurricane season.

Predictor 5. November 500 mb Geopotential Height in the far North Atlantic (+)

(67.5-85°N, 10°E-50°W)

Positive values of this predictor correlate very strongly (r = -0.7) with negative values of the Arctic Oscillation (AO) and the North Atlantic Oscillation (NAO). Negative AO and NAO values imply more ridging in the central Atlantic and a likely warm north Atlantic Ocean (50-60°N, 10-50°W). Also, on decadal timescales, weaker zonal winds in the subpolar areas are indicative of a relatively strong thermohaline circulation which is favorable for hurricane activity. Positive values of this November index are negatively correlated with both 200 mb zonal winds and trade winds the following September in the tropical Atlantic. The associated reduced tropospheric vertical wind shear enhances conditions for TC development. Other features that are directly correlated with this predictor are low sea-level pressure in the Caribbean and a warm North and tropical Atlantic. Both of the latter are also hurricane-enhancing factors.

Predictor 6. September-November SLP in the Gulf-SE USA (-)

(15-35°N, 75-95°W)

Low pressure in this area during September-November correlates quite strongly with a current positive phase of the PNA. As was stated earlier, the PNA is usually positive in the final year of an El Niño event, and therefore cooler ENSO conditions are likely the following year (Horel and Wallace 1981). This feature is strongly negatively correlated (r £#0.5) with the following year's August-September sea level pressure in the tropical and subtropical Atlantic. August-September SLP in the tropical Atlantic is one of the most important predictors for seasonal activity, that is, lower-than-normal sea level pressure is favorable for more TC activity. Easterly anomalies at 200 mb are also typical during the following year's August-October period with low values of this predictor.

Predictor 7. May SST off the Northwest Coast of Africa (+)

(20-40°N, 15-30°W)

Warm sea surface temperatures in this area indicate that the Atlantic subtropical ridge is weaker than normal, and therefore trade winds across the Atlantic are also weaker than normal. These anomalies in May correlate strongly with a generally warm Atlantic Ocean as well as with low sea level pressure throughout the tropical Atlantic during the heart of the hurricane season from August-October. Weaker trade winds and easterly anomalies at upper levels during the summer throughout the tropical Atlantic are also associated with this feature.

2.3 Hindcast Skill of New 1 June Scheme

Table 3 shows the degree of hindcast variance explained by our new 1 June forecast scheme based on a 52-year developmental data set (1950-2001). To reduce overfitting, we use no more than five predictors.

Table 3: Variance explained based upon 52 years (1950-2001) of hindcasting.

Variables Selected	Variance	Jackknife Skill
and Number of Predictors	Explained	(Year of Forecast Not in the
(in parentheses)	(r^2)	Developmental Data Set)
NS- 1 2 4 5 (4)	0.454	0.338
NSD- 1 2 4 5 (4)	0.594	0.496
H- 2 3 5 6 (4)	0.529	0.414
HD- 1 2 5 6 (4)	0.650	0.566
IH- 2 3 5 7 (4)	0.621	0.539
IHD- 2 3 7 (3)	0.592	0.520
HDP- 1 2 5 6 7 (5)	0.718	0.642
NTC- 2 3 5 7 (4)	0.694	0.618

To minimize the skill degradation (i.e., limit statistical ``overfitting") of these equations when making independent forecasts, we optimize the least number of predictors for the highest amount of hindcast skill. The 1 June forecast picks the best combination of five predictors from the pool of seven predictors or until the hindcast variance explained increases less than three percent through the addition of another predictor. Note that the amount of jackknife hindcast variance explained for HDP and NTC activity is over 60 percent.

3 Analog-Based Predictors for 2004 Hurricane Activity

Certain years in the historical record have global oceanic and atmospheric trends which are substantially similar to 2004. These years also provide useful clues as to likely trends in activity that the forthcoming 2004 hurricane season may bring. For this 1 April forecast, we project atmospheric and oceanic conditions for August through October 2004 and determine which of the prior years in our database have distinct trends in key environmental conditions which are similar to current May 2004 conditions. Table 4 lists our analog selections.

Analog Years. We have found four prior hurricane seasons since 1949 which appear to be similar to current May 2004 conditions and projected 2004 August-October conditions. Specifically, we expect the North Atlantic (50-60˙N, 10-50˙ W) warm SST anomalies to remain warm for the 2004 hurricane season due to predominately negative values of the AO and NAO indices throughout the winter months. A warm north Atlantic is indicative of a strong Atlantic thermohaline circulation. The tropical equatorial Quasi-Biennial Oscillation (QBO) is projected to be from a westerly direction. This is typically an enhancing factor for hurricane activity. We assume that the recent global atmosphere and ocean circulation regimes which have been present in all but two of the last nine years will continue to be present in 2004. In addition, we look for years that had slightly warm ENSO conditions the previous fall and winter with neutral or slightly warm ENSO conditions in the eastern and central Pacific observed during the summer of the year being selected.

There were four hurricane seasons since 1949 with characteristics similar to what we observe in May 2004 and what we anticipate for the summer/fall 2004 period. These best analog years are 1953, 1969, 2001 and 2003 (Table 4). Thus, based on this analysis, we expect 2004 to be an active hurricane season and in line with the average of seven of the last nine years (1995, 1996; 1998-2001; 2003). We anticipate 2004 to be considerably more active than the average season during the inactive 1970-1994 period.

Table 4: Best analog years for 2004 with the associated hurricane activity listed for each year.

	NS	NSD	H	HD	IH	IHD	HDP	NTC
1953	14	65	6	18	3	5.5	59	116
1969	17	83	12	40	3	2.75	110	150
2001	15	63	9	27	4	5.00	65	137
2003	16	75	7	33	3	16.75	131	173
Mean	15.5	71.5	8.5	29.5	3.3	7.5	91	144
2004 Forecast	**14**	**60**	**8**	**35**	**3**	**8**	**100**	**145**

4 Comparison of Forecast Techniques

Table 5 provides a comparison of our statistical and analog forecast techniques along with the final adjusted forecast and climatology. Column 1 is our 1 June statistical scheme, column 2 is our analog scheme, column 3 is our adjusted final forecast, and column 4 is the 1950-2000 climatology.

Table 5: Comparison of our 2004 statistical and analog forecast techniques along with our final adjusted forecast and the 1950-2000 climatology.

	(1)	(2)	(3)	(4)
Forecast	Statistical	Analog	28 May 2004	1950-2000
Parameter	Forecast	Forecast.	Final Fcst	Climatology
Named Storms (NS)	11.7	15.5	14	9.6
Named Storm Days (NSD)	67.2	71.5	60	49.1
Hurricanes (H)	6.4	8.5	8	5.9
Hurricane Days (HD)	31.9	29.5	35	24.5
Intense Hurricanes (IH)	2.5	3.3	3	2.3
Intense Hurricane Days (IHD)	5.2	7.5	8	5.0
Hurricane Destruction				
Potential (HDP)	99	91	100	72.7
Net Tropical Cyclone Activity				
(NTC)	107	144	145	100

5 Landfall Probabilities for 2004

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 100 years (1900-1999). Specific landfall probabilities can be given for all cyclone intensity classes for a set of distinct U.S. coastal regions.

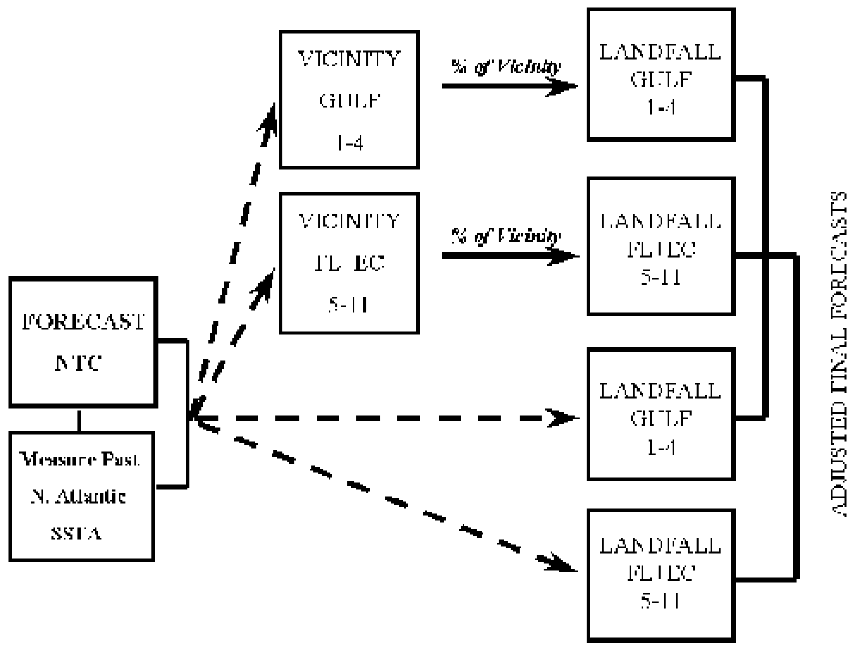

Figure 2: Flow diagram illustrating how forecasts of U.S. hurricane landfall probabilities are made. Forecast NTC values and an observed measure of recent North Atlantic (50-60°N, 10-50°W) SSTA* are used to develop regression equations for U.S. hurricane landfall. Separate equations are derived for the Gulf and for Florida and the East Coast (FL+EC).

Figure 2 provides a flow diagram showing how these forecasts are made. Net landfall probability is shown linked to the overall Atlantic basin Net Tropical Cyclone activity (NTC; see Table 6) 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* in the region of 50-60°N, 10-50°W.

Higher values of SSTA* 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 (May 2004) value of SSTA* is 44. Hence, in combination with a prediction of NTC of 145 for 2004, a combination of NTC + SSTA* of (145 + 44) yields a value of 189.

As shown in Table 6, 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. Whereas many active Atlantic hurricane seasons feature no landfalling hurricanes, some inactive years have experienced one or more landfalling hurricanes. Long-term statistics show 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 the Florida and U.S. East Coast during years of (1) increased NTC and (2) above-average North Atlantic SSTA* conditions.

Table 6: 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 7 lists strike probabilities for different TC categories for the entire U.S. coastline, the Gulf Coast and Florida, and the East Coast for 2004. The mean annual probability of one or more landfalling systems is given in parentheses. Note that Atlantic basin NTC activity in 2004 is expected to be greater than the long-term average (145), and North Atlantic SSTA* values are measured to be above average (44 units). U.S. hurricane landfall probability is thus expected to be 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 7: Estimated 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 the Florida and the East coastline (Regions 5-11) for 2004. 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)	87% (80)	81% (68)	71% (52)	95% (84)	99% (97)
Gulf Coast (Regions 1-4)	68% (59)	53% (42)	40% (30)	72% (61)	91% (83)
Florida plus East Coast (5-11)	58% (51)	59% (45)	52% (31)	80% (62)	92% (81)

6 United States Landfalling Hurricane Webpage Application

Over the past four years, we have been compiling and synthesizing our landfalling hurricane data and have been developing a webpage application with extensive landfalling 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 205 individual counties of the United States coast extending from Brownsville, Texas to Eastport, Maine. Individual probabilities of sustained winds of tropical storm force (40-75 mph), hurricane force (A 75 mph) and intense or major hurricane force (A 115 mph) are also given. These probabilities are based on the current forecast of NTC activity and on current values of SSTA*.

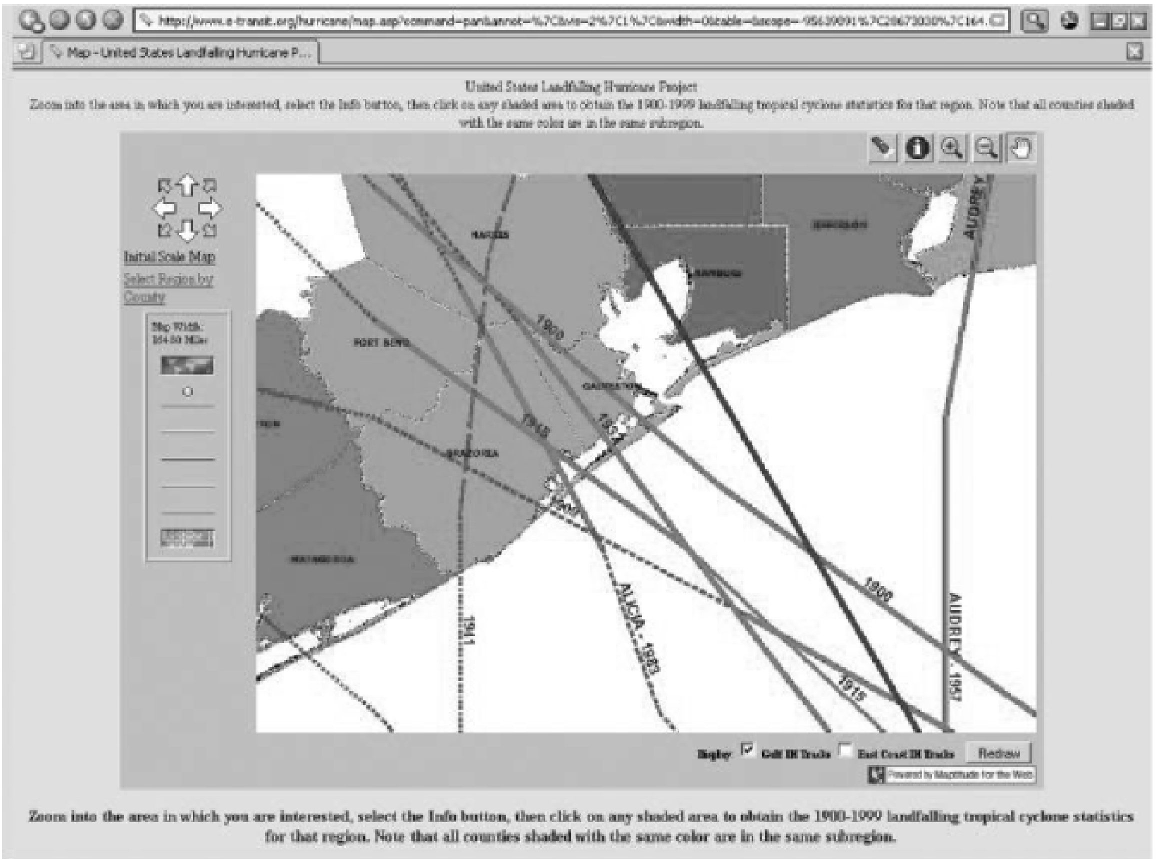

Figure 3: View of landfalling hurricane webpage centered on Subregion 1E - the Houston/Galveston metropolitan area.

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

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

Figure 4: Example of data available from the United States landfalling hurricane webpage.

Figures 3 and 4 display example screens of data that is to be made 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. We plan to make this webpage available in early June at http://www.e-transit.org/hurricane. One will also be able to reach this webpage from a link off the CSU Tropical Meteorology Project homepage http://tropical.atmos.colostate.edu.

7 Increased Level of Atlantic Basin Hurricane Activity During Seven of the Last Nine Years - But Decreased U.S. Major Hurricane Landfall

7.1 Increased Activity Since 1995

A major reconfiguration of the distribution of Atlantic SST anomalies began in mid-1995 and has largely persisted through the present. North Atlantic SSTs have become about 0.4 to 0.6°C warmer than normal since 1995 and tropical Atlantic August-October upper tropospheric 200 mb winds have increased from the east, bringing about a significant decrease in tropospheric vertical wind shear. There have been large changes in SSTA and 200 mb zonal wind anomaly (ZWA) during 1995-2003 as compared to conditions from the prior 25-year period of 1970-1994. These changes are well associated with the large increase in major hurricane activity in the Atlantic basin during seven of the last nine years. As noted several times before, we hypothesize that these strong broadscale SST changes are associated with basic changes in the strength of the Atlantic Ocean thermohaline circulation (ATC). This interpretation is consistent with changes in a long list of global atmospheric circulation features during the last nine years which conform to a prominent shift into hurricane-enhancing Atlantic circulation patterns, particularly the enhancement of major hurricane activity. Historical and geographic evidence going back thousands of years indicates that shifts in the Atlantic multi-decadal thermohaline circulation tend to occur on periods of 25-50 years. If the recent nine-year shift follows prior occurrences, it is likely that enhanced intense Atlantic basin hurricane activity will persist through the early decades of the 21st century in contrast with the diminished activity that persisted from 1970-1994.

Despite El Niño-linked reductions of Atlantic basin hurricane activity during 1997 and 2002, the last nine years (1995-2003) constitute the most active nine consecutive years on record. Table 8 provides a summary of the total number of named storms (101), named storm days (567), hurricanes (62), hurricane days (288), major hurricanes (29), major hurricane days (76) and Net Tropical Cyclone activity (1232) that have occurred during the recent active seven of the last nine-year period of 1995-1996, 1998-2001, and 2003. The seven-year annual average of NS, NSD, H, HD, IH, IHD and NTC during these years has been 143, 206, 151, 254, 261, 362 and 234 percent, respectively above the averages of the prior 25-year period of 1970-1994. These trends toward increased hurricane activity give strong support to the suggestion that we have indeed entered a new era of enhanced major hurricane activity.

Table 8: Comparison of recent seven of the last nine years (1995-1996, 1998-2001, 2003) hurricane activity with climatology and with the prior quarter century period of 1970-1994.

Year	Named Storms (NS)	Named Storm Days (NSD)	Hurricanes (H)	Hurricane Days (HD)	Cat 3-4-5 Hurricanes (IH)	Cat 3-4-5 Hurricane Days (IHD)	Net Tropical Cyclone Activity (NTC)
1995	19	121	11	60	5	11.50	229
1996	13	78	9	45	6	13.00	198
1998	14	80	10	49	3	9.25	168
1999	12	77	8	43	5	15.00	193
2000	14	77	8	32	3	5.25	134
2001	15	63	9	27	4	5.00	142
2003	16	71	7	32	3	17.00	168
TOTAL	103	567	62	288	29	75.25	1230
Seven-year Ave. 1995-96,98-01, 03	14.5	81	8.9	41	4.14	10.86	176
Ratio 7 active yr/climatology in percent	149	165	151	167	180	215	176
Ratio 7 active yrs/1970-94 in percent	143	206	151	254	261	362	234

7.2 Theory for the Recent Increase in Major Hurricane Activity

The oceanic and atmospheric temperature change in the northwest Atlantic around Greenland and Iceland has been observed to undergo significant monthly to multi-decadal and longer time scale changes. We hypothesize that these changes in North Atlantic SSTAs are to a substantial degree a result of variations in the Atlantic Thermohaline Circulation (ATC). These ATC changes are believed to be caused by a combination of variations in North Atlantic upper ocean salinity, southward polar ice flow and the general circulation of the atmosphere. It is observed that when North Atlantic SSTAs are positive (and the ATC is thus diagnosed to be strong) we also simultaneously observe Atlantic basin conditions where:

1. the equator to 70˙N Atlantic Ocean average SSTAs are positive,
2. Atlantic SLPA from the equator to 50˙N are lower than average, and the Atlantic atmospheric and ocean gyres are consequently weaker than average,
3. the NAO and AO circulations are weaker,
4. South Atlantic (equator to 30˙S) SSTAs are typically negative,
5. summertime rainfall in Africa is enhanced,
6. major hurricane activity in the Atlantic is enhanced.

The opposite conditions occur when the North Atlantic SSTA are observed to be negative, and we diagnose that the Atlantic ATC is weaker than average. It is likely that the salt content of the North Atlantic plays a dominant role in these ATC changes.

7.3 Downturn in U.S. Major Hurricane Landfall Despite Atlantic Basin Major Hurricane Increase

During the 104 years between 1900 and 2003, 114 category 1-2 hurricanes and 73 category 3-4-5 hurricanes made landfall along the U.S. coast. However, the annual incidence of landfall in Florida and the East Coast was nearly twice as great during the first 67 years (1900-1966) as it was during the recent 38-year period (1966-2003). Given the much greater incidence of major U.S. hurricanes in terms of landfall numbers during the earlier portions of the last century, our luck at having fewer intense hurricane landfalls than specified by the long period climatology has now extended for over three decades.

Good fortune has been manifest during recent years as a persistent upper-air trough located along the U.S. East Coast much of the time during hurricane season. The presence of this upper-level trough caused a large portion of otherwise northwest moving major hurricanes to recurve to the north before they reached the U.S. coastline.

For the Florida Peninsula and the U.S. East Coast, these same considerations are even more skewed. During the 39 years since 1965, only 8 landfalling major hurricanes (an average of 0.2 per year) have struck the Florida Peninsula and U.S. East Coast. However, between 1900-1965 there were 29 major landfall events along this same coastline with a mean incidence of 0.44 per year. Hence, the first six decades of the 20th century along the Florida Peninsula and East Coast had twice the number of major hurricanes make landfall per year than has occurred during the last three and a half decades. It cannot be presumed that this recent downturn in U.S. major hurricane landfall events along the Florida Peninsula and East Coast will continue. Climatology will eventually right itself, and we must expect a great increase in landfalling major hurricanes in the coming decades.

8 The 1995-2003 Upswing in Atlantic Hurricanes and Global Warming

Various groups and individuals have suggested that the recent large upswing in Atlantic hurricane activity (since 1995) may be in some way related to the effects of increased man-made greenhouse gases such as carbon dioxide (CO_2). There is no reasonable scientific way that such an interpretation of this recent upward shift in Atlantic hurricane activity can be made. Please see our recent 21 November 2003 verification report for more discussion on this subject http://tropical.atmos.colostate.edu/Forecasts/2003/nov2003

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 2004 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 Updated Forecasts of 2004 Hurricane Activity

We will be issuing seasonal updates of our 2004 Atlantic basin hurricane activity forecast on Friday 6 August, Friday 3 September and Friday 1 October 2004. The 6 August, 3 September and 1 October forecasts will include separate forecasts for 2004 August-only, September-only activity and October-only Atlantic basin TC activity. A verification and discussion of all 2004 hurricane activity and forecasts will be issued in late November 2004. All of these forecasts will be available at our web address given on the front cover http://tropical.atmos.colostate.edu/Forecasts

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12 Citations and Additional Reading

13 Verification of Previous Forecasts

Table 9: Summary verifications of the authors' five previous years of seasonal forecasts of Atlantic TC activity between 1999-2003.

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

		Update	**Update**	**Update**	

2000	8 Dec 1999	7 April	7 June	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	2 Oct.	Obs.
No. of Hurricanes	8	8	8	8	7	8	7
No. of Named Storms	12	12	14	14	14	14	17
No. of Hurricane Days	35	35	35	25	25	35	33
No. of Named Storm Days	65	65	70	60	55	70	75
Hurr. Destruction Potential(HDP)	100	100	100	80	80	125	131

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	173

Footnotes:

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