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 2 April 2004)

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

By
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with assistance from William Thorson[3]

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

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 2003	Issue Date 2 April 2004
Named Storms (NS) (9.6)	13	14
Named Storm Days (NSD) (49.1)	55	60
Hurricanes (H)(5.9)	7	8
Hurricane Days (HD)(24.5)	30	35
Intense Hurricanes (IH) (2.3)	3	3
Intense Hurricane Days (IHD)(5.0)	6	8
Hurricane Destruction Potential (HDP) (72.7)	85	100
Net Tropical Cyclone Activity (NTC)(100%)	125	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

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

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 March 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 early April 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. Our predictors indicate that weak cool ENSO conditions are likely this summer and fall. Having a perfect ENSO forecast, however, explains only 15-20 percent of Atlantic seasonal hurricane variability. There are other global parameters that are associated with both ENSO and hurricane variability. These give a more skillful prediction of Atlantic hurricane activity than does ENSO by itself.

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 April Forecast Methodology

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. Our initial early April seasonal hurricane forecast scheme demonstrated hindcast skill for the period of 1950–1995. Our new, recently developed early April forecast scheme uses more hindcast years (1950–2001) and shows improved hindcast skill and better physical insights into why such precursor relationships have an extended period memory.

Through extensive analyses of NOAA-NCEP reanalysis products, second author Phil Klotzbach has recently developed a new set of 1 April extended range predictors which shows superior hindcast prediction skill over our previous 1 April forecast scheme. The location of each of these new predictors is shown in Fig. 1. The pool of six predictors for this new extended range forecast is given in Table 1. Strong statistical relationships can be extracted via combinations of these predictors (which are available by the end of March) and the amount of Atlantic basin hurricane activity occurring later in the year.

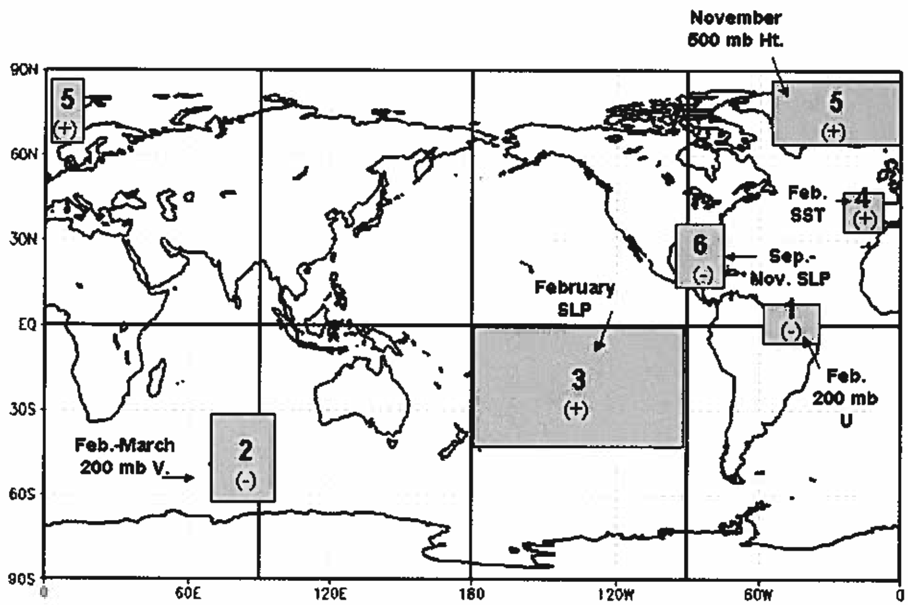

Figure 1: Location of predictors for our early April forecast for the 2004 hurricane season. A plus (+) means that positive values of the parameter indicate increased hurricane activity this year, and a minus (–) means that positive values of the parameter indicate decreased hurricane activity this year.

Table 1: Listing of April 2004 predictors for this year's hurricane activity. A plus (+) means that positive values of the parameter indicate increased hurricane activity this year, and a minus (–) means that positive values of the parameter indicate decreased hurricane activity this year.

	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

2.1 Physical Associations among Predictors Listed in Table 1

Brief descriptions of our early April predictors follow:

Predictor 1. February 200 MB U in Equatorial East Brazil (-)

(5°S-10°N, 35-55°W)

Easterly upper-level zonal wind anomalies off the northeast coast of South America imply that the upward branch of the Walker Circulation associated with ENSO remains in the western Pacific and that cool ENSO or La Niña conditions are likely to be present in the eastern equatorial Pacific for the next 4-6 months. El Niño conditions shift the upward portion of the Walker Circulation to the eastern Pacific and cause 200 mb westerly wind anomalies over the tropical Atlantic. These anomalies inhibit Atlantic hurricane activity.

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 is 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 also 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 American that are typical of La Niña and hurricane-enhancing conditions. Cool sea surface temperatures are associated with these higher surface pressures that 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, 10-30°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, the subtropical high near the Azores is weaker than normal and consequently trade wind strength across the Atlantic is also reduced. Weaker trade winds induce less upwelling which keeps the tropical Atlantic warmer than normal. This pattern tends to persist throughout the spring and summer implying a warmer tropical Atlantic during the hurricane season which is an enhancing factor for developing tropical waves.

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

(67.5-85°N, 50°W-10°E)

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 the following summer. Both of the latter are also hurricane-enhancing factors.

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

(15-35°N, 75-95°W)

Low pressure in this area during September-November of the previous year correlates quite strongly with the positive phase of the PNA. According to Horel and Wallace (1981), the PNA is positive during the final year of most warm ENSO events. Therefore, a change to neutral or cool ENSO conditions are to be expected the following year. This feature is also strongly correlated 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 pressures in the tropical Atlantic provide more favorable conditions for TC activity. In addition, easterly anomalies at 200 mb throughout the tropical Atlantic are typical during the following year's August-September period with low SLP values.

2.2 Hindcast Skill

Table 2 shows the degree of hindcast variance explained by our 1 April forecast scheme based upon our 52 year developmental dataset (1950-2001). To reduce overfitting, we use no more than five predictors. Note that there is substantial skill for predictions of NTC and HDP.

The 1 April forecast picks the best combination of five predictors from a pool of six predictors or until the hindcast variance explained increases less than three percent through the addition of another predictor.

Table 2: Variance explained based upon 52 years (1950-2001) of hindcasting.

Variables Selected	Variance (r^2) Explained	Jackknife Skill (Year of Forecast Not in the Developmental Data Set)
NS- 1 2 4 5	0.454	0.338
NSD- 1 2 4 5	0.594	0.496
H- 2 3 5 6	0.529	0.414
HD- 1 2 5 6	0.650	0.566
IH- 2 3 4 5	0.610	0.527
IHD- 1 2 4 5 6	0.548	0.460
HDP- 1 2 4 5 6	0.707	0.630
NTC- 1 2 4 5 6	0.707	0.637

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 March 2004 conditions. Table 3 lists our analog selections.

Analog Years. We have found four prior hurricane seasons since 1949 which appear to be similar to current March 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 cool 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 March 2004 and what we anticipate for the summer/fall 2004 period. These best analog years are 1958, 1961, 1980 and 2001 (Table 3). 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 3: Best analog years for 2004 with the associated hurricane activity listed for each year.

	NS	NSD	H	HD	IH	IHD	HDP	NTC
1958	10	56	7	30	4	8.25	94	133
1961	11	71	8	48	6	20.75	170	211
1980	11	60	9	38	2	7.25	126	129
2001	15	63	9	27	4	5.00	65	137
Mean	11.8	62.5	8.3	35.8	4.0	10.3	114	153
2004 Forecast	14	60	8	35	3	8	100	145

4 Comparison of Forecast Techniques

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

Table 4: Comparison of our statistical and analog forecast techniques along with our final adjusted forecast and the 1950-2000 climatology.

Forecast Parameter	(1) Statistical Forecast	(2) Analog Forecast.	(3) 2 April 2004 Final Fcst	(4) 1950-2000 Climatology
Named Storms (NS)	11.7	11.8	14	9.6
Named Storm Days (NSD)	67.2	62.5	60	49.1
Hurricanes (H)	6.4	8.3	8	5.9
Hurricane Days (HD)	31.9	35.8	35	24.5
Intense Hurricanes (IH)	3.0	4.0	3	2.3
Intense Hurricane Days (IHD)	9.2	10.3	8	5.0
Hurricane Destruction Potential (HDP)	111	114	100	72.7
Net Tropical Cyclone Activity (NTC)	143	153	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.

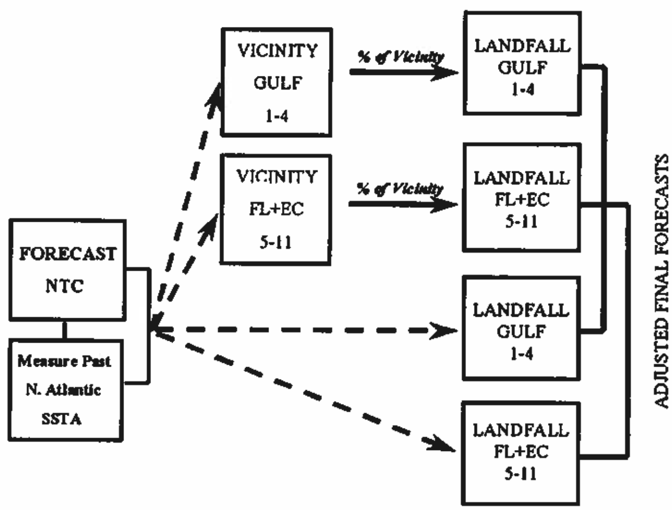

Figure 2: Flow diagram illustrating how forecasts of U.S. hurricane landfall probabilities are made. Forecast NTC values and an observed measure of recent North Atlantic (50-60°N, 10-50°W) SSTA* are used to develop regression equations for U.S. hurricane landfall. Separate equations are derived for the 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 5) 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* 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 (March 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 5, 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 5: 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 6 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.

6 United States Landfalling Hurricane Webpage Application

Over the past year, we have been compiling and synthesizing our landfalling hurricane data and have been developing a webpage application with extensive landfalling probabilities

Table 6: 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)

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 and 96 subregions of the United States coast extending from Brownsville, Texas to Eastport, Maine. Individual state probabilities are also given. These probabilities are based on the current forecast of NTC activity and on current values of SSTA*.

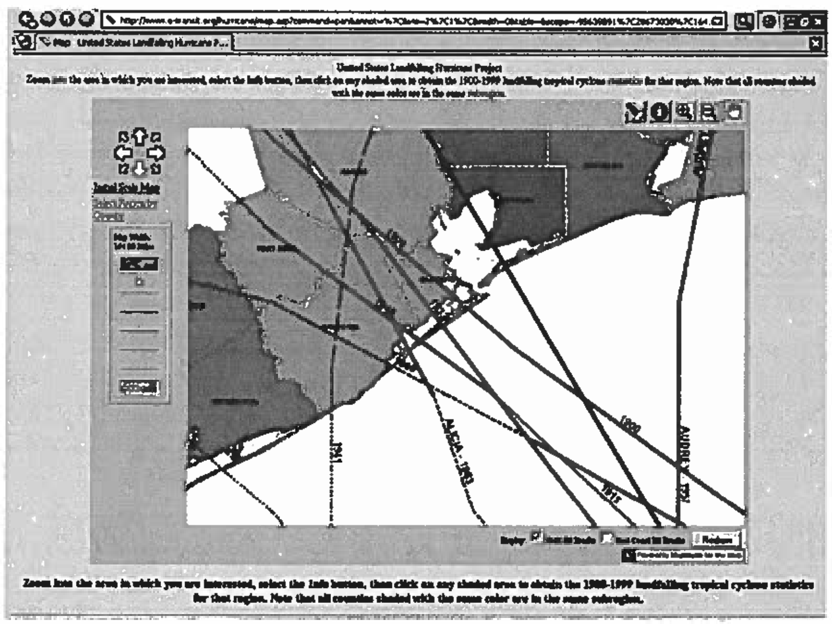

Figure 3: View of landfalling hurricane webpage centered on Subregion 1E - the Houston/Galveston metropolitan area.

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. Also, one can view a spreadsheet file that displays all the landfalling storms for the region that the user has selected. 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).

County Name Information	
County	BRAZORIA
Region_Name	Region 1
Region_2000_Population	5899658
Region_Coastal_Length (km)	530
Named Storms (1900-1999)	57
Hurricanes (1900-1999)	35
Intense Hurricanes (1900-1999)	15
2004 Region Prob. (NS)	56% (45%)
2004 Region Prob. (H)	38% (30%)
2004 Region Prob. (IH)	19% (15%)
IH Return Period	6.700
Subregion	1e
Subregion_2000_Population	4246955
Subregion_Coastal_Length (km)	97
2004 Subregion Prob. (NS)	10.8% (8.7%)
2004 Subregion Prob. (H)	7.2% (5.8%)
2004 Subregion Prob. (IH)	3.6% (2.9%)
Region File	http://www.e-transit.org/hurricane/Region_1.xls

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

7 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/index.html]

8 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.

9 Forthcoming Update Forecasts of 2003 Hurricane Activity

We will be issuing seasonal updates of our 2004 Atlantic basin hurricane activity forecast on Friday 28 May (to coincide with the official start of the 2004 hurricane season on 1 June), 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 forecasts will be issued in late 2004. All of these forecasts will be available at our web address given on the front cover (http://tropical.atmos.colostate.edu/forecasts/index.html).

10 Acknowledgments

The first author gratefully acknowledges past valuable input to our project research by former graduate students and colleagues Chris Landsea, John Knaff and Eric Blake. A number of other meteorologists have furnished us with data and given valuable assessments of the current state of global atmospheric and oceanic conditions. This includes Arthur Douglas, Richard Larsen, Todd Kimberlain, Ray Zehr and Mark DeMaria. In addition, Barbara Brumit and Amie Hedstrom have provided excellent manuscript, graphical, and data analysis assistance over a number of years. We have profited over the years from many in-depth discussions with most of the current NHC hurricane forecasters. The first author would further like to acknowledge the encouragement he has received for this type of forecasting research application from Neil Frank, Robert Sheets, Robert Burpee, Jerry Jarrell, former directors of the National Hurricane Center (NHC), and from the current director, Max Mayfield. We also thank Bill Bailey of the Insurance Information Institute for his sage advice and encouragement.

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11 Citations and Additional Reading

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12 Verification of Previous Forecasts

Table 7: 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

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	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