UPDATED FORECAST OF ATLANTIC SEASONAL HURRICANE ACTIVITY AND U.S. LANDFALL STRIKE PROBABILITY FOR 2003

The recent upturn in Atlantic basin hurricane activity which began in 1995 is expected to continue through 2003. We anticipate an above-average number of Atlantic basin tropical cyclones and an increased probability of U.S. hurricane landfall.

(as of 30 May 2003)

This forecast is based on new research by the authors,
along with current meteorological information through May 2003

By

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[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 2003

Forecast Parameter and 1950-2000 Climatology (in parentheses)	6 December 2002	Update 4 April 2003	Update 30 May 2003
Named Storms (NS) (9.6)	12	12	14
Named Storm Days (NSD) (49.1)	65	65	70
Hurricanes (H)(5.9)	8	8	8
Hurricane Days (HD)(24.5)	35	35	35
Intense Hurricanes (IH) (2.3)	3	3	3
Intense Hurricane Days (IHD)(5.0)	8	8	8
Hurricane Destruction Potential (HDP) (72.7)	100	100	100
Net Tropical Cyclone Activity (NTC)(100%)	140	140	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 - 69% (average for last century is 52%)

2) U.S. East Coast Including the Florida Peninsula - 49% (average for last century is 31%)

3) Gulf Coast from the Florida Panhandle westward to Brownsville - 39% (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 now been issued for 20 years by the tropical meteorology research group of Prof. William Gray of the Department of Atmospheric Science, Colorado State University (CSU). The forecasts, which are issued in December of the prior year, and in the early part of the months of April, June, August and September of the current year, have steadily improved through continuing research. These forecasts now include predictions of net Atlantic basin tropical cyclone activity and U.S. and Caribbean 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, are making important contributions to both forecasts.

Specific differences between the CSU and the NOAA forecasts include:

1. CSU's forecasts give specific numbers rather than the range of numbers that the NOAA forecast gives.

2. CSU's forecasts are more quantitative than NOAA's. NOAA has yet to show a quantitative basis for their forecast skill in long period hindcasting statistics.

3. CSU issues four updated forecasts a year, NOAA only issues one.

4. CSU issues quantitative U.S. hurricane landfall probability forecasts - NOAA does not.

5. CSU makes individual month forecasts (August, September, etc.) - NOAA does not. This year we will issue our first individual October forecast.

6. NOAA's forecasts make extensive use of CSU's prior early December and early April seasonal forecasts and of two of Gray's ex-students (Christopher Landsea and Eric Blake) as important sources to their mid-May and mid-August forecasts.

7. This is our 20th year of making and verifying these forecasts. We have a quantitative skill and verification that NOAA has not yet demonstrated over a significant number of years.

NOTE ON THE CONTINUATION AND IMPROVEMENT OF CSU FORECASTS

The federal agencies of NOAA, FEMA and ONR who are charged with funding this type of forecasting research have declined support. The majority of the financial backing of these CSU hurricane forecasts in recent years has come from the research foundations of the insurance groups of the United Services Automobile Association (USAA - $300K over four years and State Farm - $375K over three years). We will always be grateful for their support. These two insurance groups are not continuing their support. They have given more than their fair share of support for the insurance industry. We must find other funding to continue issuing hurricane forecasts and to undertake the background research necessary to sustain them. It is hoped that other private or government groups who would like to see our hurricane forecast continue provide us with financial help.

DEFINITIONS

ABSTRACT

Information obtained through May 2003 indicates that the 2003 Atlantic hurricane season will be an active one. We estimate that 2003 will have about 8 hurricanes (average is 5.9), 14 named storms (average is 9.6), 70 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 2003 to be about 145 percent of the long-term average. The probability of U.S. major hurricane landfall is estimated to be about 30 percent above the long-period average. We also foresee an above-average probability of Caribbean basin landfall. This 30 May forecast is based on a newly-developed statistical forecast scheme that shows itself to be significantly more skillful in hindcast tests than our older 1 June (1994) scheme. We also utilize an analog technique which selects prior years that have global conditions similar to this year. Our final forecast consists of a qualitative adjustment of these two separate methodologies. This late May updated forecast makes only a modest increase in the number of named storms and named storm days from our 6 December and 4 April forecasts. We are forecasting the same amount of hurricane activity as in our previously issued forecasts. We anticipate that the current near-neutral ENSO conditions will develop into La Niña (cold water) conditions by August-September and be an important enhancing influence on this year's hurricane activity.

1 Introduction

This is the 20th 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 far exceeding climatology. This late May forecast is based on a new 52 year (1950-2001) hindcast scheme and an analog scheme that chooses prior years which had similar global atmospheric and oceanic conditions to May 2003. 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 atmosphere and ocean precursor signals that in previous years have been shown to be related to the forthcoming Atlantic basin hurricane activity and landfall probability.

2 Forecast Methodology

We believe that seasonal forecasts must be based on methods showing significant hindcast skill in application to long periods of prior years. Many atmosphere-ocean circulation and energy exchange processes are too complicated and too little understood to allow for skillful deterministic initial value seasonal and yearly prediction. It is only through hindcast studies 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. Unlike initial value deterministic prediction, it is not necessary to fully understand all relevant atmospheric and oceanic processes to issue a skillful statistical forecast. One can use prior empirical associations without understanding all the physical processes which are involved.

3 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 implied increase in 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.

3.1 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:

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

2. A 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.

Through extensive analyses of the recently available NOAA/NCEP reanalysis products, Phil

Klotzbach of our forecast team has recently developed a new set of 1 June extended range predictors which shows superior hindcast prediction skill over our previous 1 June forecast scheme. This new 1 June forecast scheme does not use West African rain as a predictor.

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.

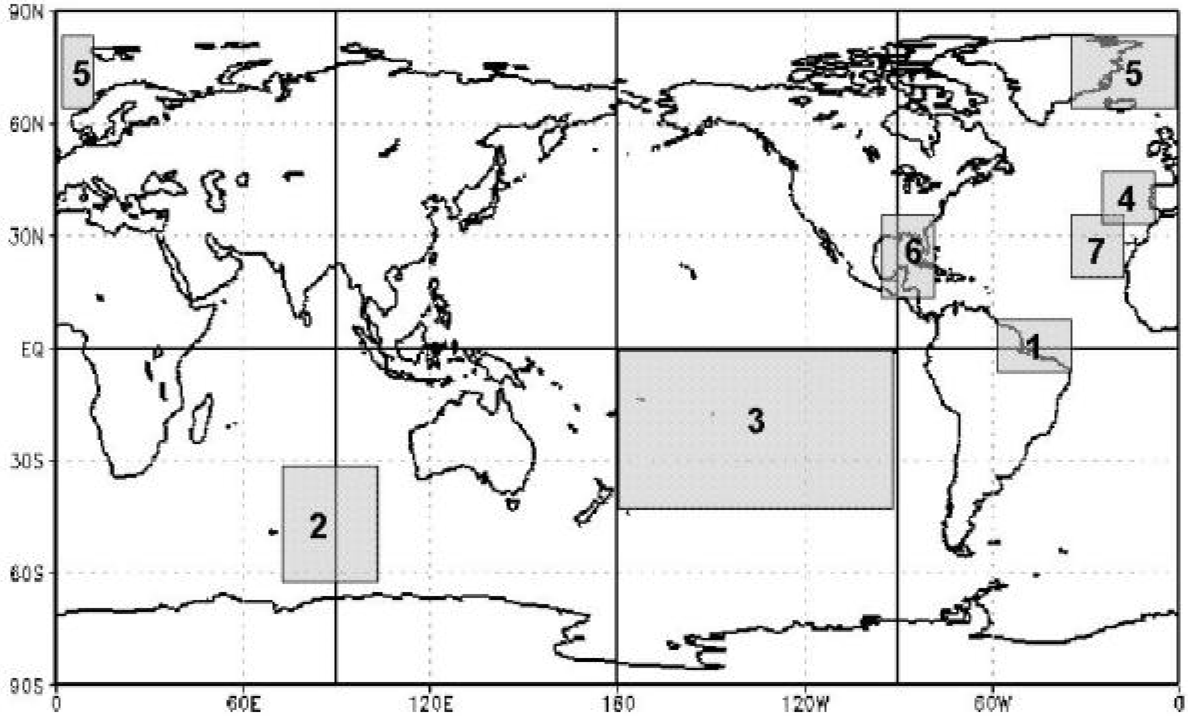


Figure 1: Location of predictors for our new 1 June forecast for the 2003 hurricane season.

Table 1: List of our new 1 June 2003 predictor set and their anomaly 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.

	2003 Observed Values
(1) - February 200 mb U Anomaly (5˙S-10˙N, 35-55˙W) (-)	+0.6 SD
(2) - February-March 200 MB V Anomaly (35-62.5˙S, 70-95˙E (-)	+0.5 SD
(3) - February SLPA (0-45˙S, 90-180˙W) (+)	+0.2 SD
(4) - February SSTA (35-50˙N, 10-30˙E) (+)	+0.7 SD

(5) - Previous November 500 mb Height Anomaly (67.5-85°N, 10°E-50°W) (+)	+1.7 SD
(6) - Previous September-November SLP Anomaly (15-35°N, 75-95°W) (-)	-1.5 SD
(7) - May SSTA (20-40°N, 15-30°W) (+)	+0.5 SD

Table 2 shows our statistical forecast for the 2003 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 1 June statistical forecast for 2003.

Predictands and Climatology	**Statistical Forecast Numbers**
Named Storms (NS) - 9.2	11.2
Named Storm Days (NSD) - 49.1	55.1
Hurricanes (H) - 5.9	7.9
Hurricane Days (HD) - 24.5	32.2
Intense Hurricanes (IH) - 2.3	3.3
Intense Hurricane Days (IHD) - 5.0	6.2
Hurricane Destruction Potential (HDP) - 72.7	97
Net Tropical Cyclone Activity (NTC) - 100	133

3.2 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 northerly flow 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 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. Lag correlations with this predictor indicate that a change in phase of ENSO from warm to cool is likely during the coming summer if northerly 200 mb wind anomalies are observed in February-March.

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 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.

3.3 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, we use no more than four predictors for most parameters.

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

Variables Selected and Number of Predictors (in parentheses)	**Variance (r^2) Explained**	**Jackknife Skill (Year of Forecast Not in the 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 optimized for 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 increased 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.

Hindcast Skill of Outliers. Another way to consider the forecast skill is to examine years from 1950-2001 that had the largest observed deviations from climatology. That is, how well did this forecast scheme do in detecting years that had NTC values of greater than 130 or less than 70? As one can see from Table 4, in years where the observed NTC was over 130 units, the cross-validated statistical hindcast scheme predicted an NTC greater than the climatological mean of 100 in 11 out of 12 years. In a similar comparison, when seasonal NTC was observed to be less than 70 units, the cross-validated statistical hindcast scheme predicted an NTC less than the climatological mean of 100 in 15 out of 16 years. When combining these two instances, the statistical hindcast was better than climatology in 26 out of 28 years indicating that in years with large deviations from climatology, this hindcast scheme has shown itself to be quite skillful.

Table 4: Hindcast skill of the new 1 June statistical scheme in detecting years with significant deviations from climatology.

Observed Value	**Hindcast Beats Climatology**	**Hindcast Loses to Climatology**
< 70	15	1
> 130	11	1
Total Successes	26	2

Another way of evaluating the success of the statistical technique is to examine years where hindcast values were anticipated to be significantly different from climatology. In years where the hindcast NTC was over 140 units (Table 5), the hindcast NTC was closer to the observed value than to the climatological value of 100 units in 9 out of 11 years. For years where the hindcast was under 65 units, the observed NTC was closer to a climatological forecast in 8 out of 11 years. These examples serve as further evidence of the utility of this hindcast scheme.

Table 5: Skill of the new 1 June statistical scheme in detecting years that deviated significantly from climatology.

Hindcast Value	**Observed Value**	**Climatological Forecast of 100 NTC**
< 65	9	2
> 140	8	3
Total Successes	17	5

4 Analog-Based Predictors for 2003 Hurricane Activity

Certain years in the historical record have global oceanic and atmospheric precursor conditions which are similar to the year being forecast. These years provide clues as to likely activity in the forthcoming hurricane season. For this late May forecast, we find atmospheric and oceanic conditions for prior years which are similar to 2003 conditions. Table 6 lists our analog selections.

Table 6: Best analog years for 2003 with the associated hurricane activity listed for each year.

	NS	NSD	H	HD	IH	IHD	HDP	NTC
1952	7	40	6	23	3	4.00	70	93
1954	11	52	8	32	2	8.50	91	123
1964	12	71	6	43	5	9.75	139	160
1966	11	62	7	42	3	7	121	140
1998	14	88	10	49	3	9.50	149	168
Mean	11.0	62.6	7.4	37.8	3.2	8.0	114	137
2003 Forecast	14	70	8	35	3	8	100	145

Analog Years. We have found five pre-hurricane seasons since 1949 which appear to have similar February through May conditions as has occurred during 2003. Specifically, we expect the North Atlantic (50-60°N, 10-50°W) warm SST anomalies to remain warm for the 2003 hurricane season. This is indicative of a stronger than average Atlantic THC. This assumption carries the implication that the recent global atmosphere and ocean circulation regimes which have been present in all but two of the last eight years will continue to be present in 2003. In addition, we look for years that had warm ENSO conditions the previous fall and winter with cooling sea surface temperatures in the eastern and central Pacific observed during the summer of the year being selected.

There were five hurricane seasons since 1949 with characteristics similar to what we have observed through May 2003 and what we anticipate will occur in the late summer/fall period of 2003. These closest analog years to 2003 are 1952, 1954, 1964, 1966 and 1998 (Table 6). We expect that the 2003 seasonal hurricane conditions will be similar to the average hurricane activity which occurred in these years. All five of these years had above average hurricane activity. Based on these analog years, we expect 2003 to be an active hurricane season but slightly less than the average of six of the last eight years (1995-1996; 1998-2001) (see Table 7). We anticipate 2003 to be considerably more active than the average season during the inactive 1970-1994 period or during the two recent El Niño years (1997 and 2002).

Table 7: Hurricane activity during six of the last eight hurricane seasons without El Niño conditions.

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
TOTAL	87	496	55	256	26	59.00	1064
Six-year Ave.							
1995-96,98-01	14.5	83	9.2	43	4.33	9.83	177
2003 Fcst.	14	70	8	35	3	8	145

5 Atlantic Basin Hurricane Activity as Related to the Basic Bi-Modal Functioning of the Ocean-Atmosphere

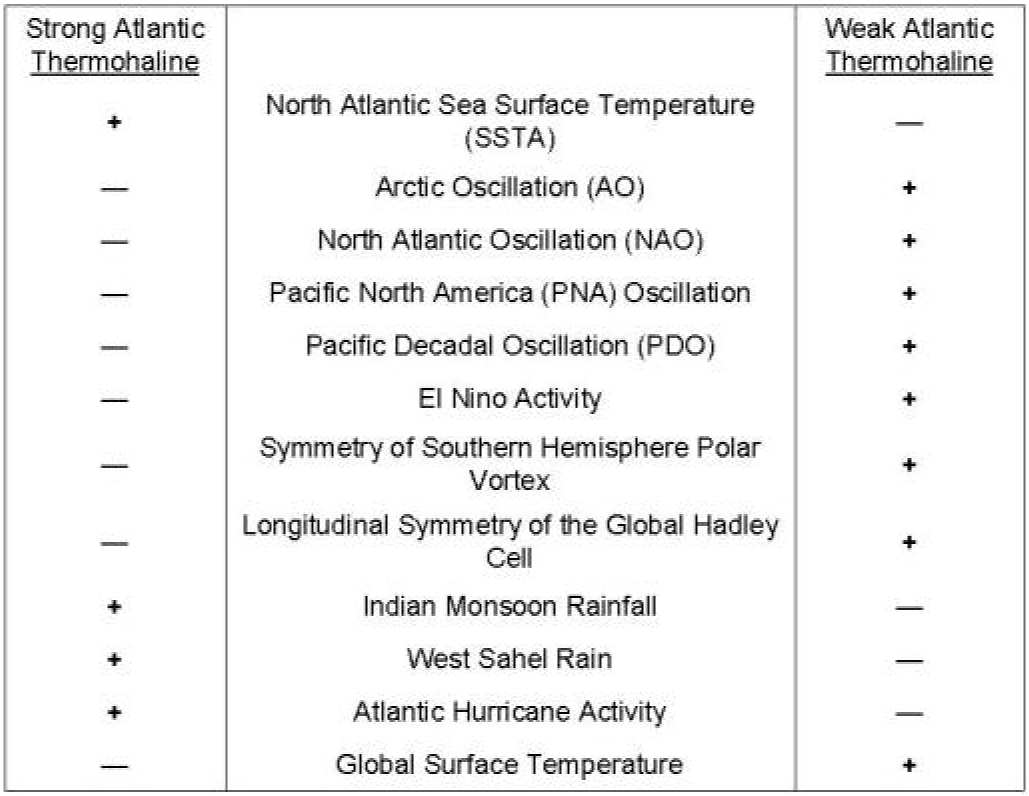
The ocean-atmosphere global circulation has been observed to deviate from its long-term climatological average in two basic but opposite modes. These modes involve the temperature gradient between the tropics and poles. Tropical-polar temperature gradients are observed to vary inversely with the strength of the Atlantic Thermohaline Circulation (ATC).

> A) Weak Atlantic Thermohaline Circulation:
>
> The temperature gradient from the tropics to the polar regions becomes greater than average. The tropics are warmer than normal, and the poles are colder than normal. It is during these periods that mid-latitude westerly winds are anomalously strong, and the AO and NAO are positive. The Eastern Hemisphere warms relative to the Western Hemisphere, and the temperature of the globe becomes slightly warmer than normal. El Niño activity is more frequent. A weaker ATC results in less ocean energy being advected to the high latitudes in the Atlantic. This causes more energy to be concentrated in the tropics. This is the general condition we have been in for the quarter century periods between 1900-1925 and 1970-1994. It is at these times that Atlantic basin hurricane activity (particularly major or intense hurricane activity) is reduced.
>
> B) Strong Atlantic Thermohaline Circulation:
>
> The opposite of the above conditions occurs when the ATC is stronger than average. A stronger thermohaline circulation causes more ocean energy to be advected out of the tropics into the far North Atlantic. This reduces the tropical to polar atmospheric and oceanic temperature gradient and results in the earth's surface becoming slightly cooler than average. Although the small area of the Arctic is anomalously warm, the much larger area of the tropics, in net, loses more energy than the Arctic gains. The net effect is a slight cooling of the globe. It is during these times that Atlantic basin hurricane activity (particulary major or intense hurricane activity) becomes enhanced.

The atmosphere and the ocean are observed to swing back-and-forth between these two basic modes of circulation on yearly to multi-decadal time scales. We believe that the primary driver for these back-and-forth swings in the global circulation is the varying strength of the ATC. We hypothesize that the ATC variations on multi-decadal time scales are primarily driven by fluctuations in Atlantic subtropical salinity content. Salinity will gradually build up when the ATC is weaker than average and will gradually be reduced when the ATC is stronger than average. Thus, the variation of salinity in the Atlantic subtropics is believed to be the primary driver for climate changes on multi-decadal time scales that have been well documented in ice core and ocean floor core measurements.

There is an inverse relationship between the strength of the ATC and the sign of the rate of change of Atlantic sub-tropical salinity. These salinity changes bring about the observed long period back-and-forth swings of the ATC and the accompanying lag response in the alteration of the functioning of the whole global ocean-atmosphere system. When the ATC is weaker than average, less salt is being advected to the Arctic region for subsidence. This causes a gradual buildup of oceanic salt content underneath the sub-tropical Atlantic anticyclones. The opposite occurs when the ATC is strong.

General global parameter changes occurring with these two basic global modes of atmosphere-ocean circulation are shown in Figure 2.



Strong Atlantic Thermohaline		Weak Atlantic Thermohaline
+	North Atlantic Sea Surface Temperature (SSTA)	—
—	Arctic Oscillation (AO)	+
—	North Atlantic Oscillation (NAO)	+
—	Pacific North America (PNA) Oscillation	+
—	Pacific Decadal Oscillation (PDO)	+
—	El Nino Activity	+
—	Symmetry of Southern Hemisphere Polar Vortex	+
—	Longitudinal Symmetry of the Global Hadley Cell	+
+	Indian Monsoon Rainfall	—
+	West Sahel Rain	—
+	Atlantic Hurricane Activity	—
—	Global Surface Temperature	+

Figure 2: Features typically associated with a strong (left) and weak (right) thermohaline circulation, respectively. A plus (+) indicates that this parameter is typically stronger than average, and a minus (-) indicates that this parameter is typically weaker than average.

The majority of the forecast parameters listed in Table 1 are global responses related to the bimodal functioning of the ocean-atmosphere system. The basic mode of stronger ATC and reduced tropical to polar temperature gradient that we have, on average, been in since 1995 is the mode that causes an enhancement of Atlantic basin hurricane activity. The very high amount of Atlantic basin hurricane activity that has been experienced the last eight years (1995-2002) are consistent with a stronger ATC circulation and reduced tropical to high latitude temperature gradients.

6 Summary Comparison of Forecasts

Table 8 provides a comparison of all of our forecast techniques along with the final adjusted forecast and climatology. Column (1) gives our new 1 June statistical scheme, column (2) is our analog scheme, and column (3) is our qualitatively adjusted final forecast, Column (4) is the 1950-2000 seasonal climatology, and column (5) is the 2003 forecast as a percentage of the average season.

Table 8: Comparison of all our forecast techniques along with our final adjusted forecast.

Full Forecast Parameter	**(1) New 1 June Scheme**	**(2) Analog Scheme**	**(3) 30 May Adjusted**	**(4) Averaage Season 1950-2000**	**(5) 2003 Fcst. as % of Ave.**
Named Storms (NS)	11.2	11.0	14	9.6	146
Named Storm Days (NSD)	55.1	62.6	70	49.1	143
Hurricanes (H)	7.9	7.4	8	5.9	136
Hurricane Days (HD)	32.2	37.8	35	24.5	143
Intense Hurricanes (IH)	3.3	3.2	3	2.3	130
Intense Hurricane Days (IHD)	6.2	7.8	8	5.0	160
Hurricane Destruction Potential (HDP)	97	114	100	72.7	138
Net Tropical Cyclone Activity (NTC) constructed from first six parameters	133	137	145	100	145

7 Discussion

Our analysis through May and of the prior 52 years indicates that we should have an above-average Atlantic basin hurricane season for 2003. We expect the current neutral ENSO conditions to be replaced by cold water (La Niña conditions) in the eastern tropical Pacific by the beginning of the active part (mid-August onward) of the 2003 season. We expect the atmosphere and oceans to return to the typical conditions that were experienced in the six non-El Niño years (1995-1996 and 1998-2001) when hurricane activity was significantly above average. We foresee 2003 as being typical of these years and in those seasons where the tropical-polar temperature gradient is weaker than average and tropical tropospheric vertical wind shears are reduced.

8 Landfall Probabilities for 2003

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.

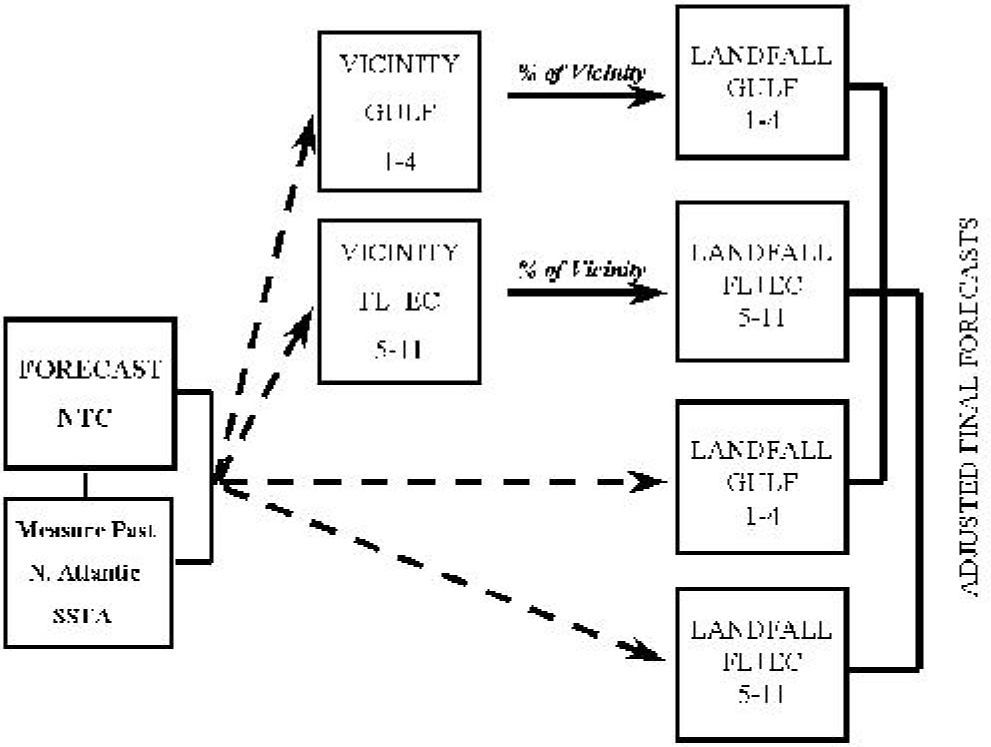


Figure 3: Flow diagram illustrating how forecasts of U.S. hurricane landfall probabilities are made. Forecast NTC values and an observed measure of recent North Atlantic (50-60°N, 10-50°W) SSTA* are used to develop regression equations for U.S. hurricane landfall. Separate equations are derived for the Gulf and for Florida and the East Coast (FL+EC).

Figure 3 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 8) and to climate trends linked to multi-decadal variations of the Atlantic Ocean thermohaline circulation which we infer from recent past years of North Atlantic sea surface temperature anomalies (SSTA*). SSTA* is expressed in units of hundredth (10^{02}) of a °C for the ocean location of (50-60°N, 10-50°W) over the last six years with primary weight given to the most recent year.

Greater values of SSTA* indicate a stronger thermohaline circulation and higher amounts of 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 from SSTA*, which is a measure of North Atlantic SST anomalies over the past few years. The current (May 2003) value of SSTA* is 30, or 0.30°C. Hence, in combination with a prediction of NTC of 145 for 2003, the combination of NTC + SSTA* of (145 + 30) yields a value of 175. If NTC + SSTA* were averaged over 50 to 100 years, its value would be 100. Regression equations have been developed to relate the seasonal value of NTC+SSTA* to U.S. landfall probability during the last 100 years.

As shown in Table 9, 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 9: 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 10 lists strike probabilities for different TC categories for the entire U.S. coastline, the Gulf Coast, for Florida and the East Coast for 2003. The mean annual probability of one or more landfalling systems is given in parentheses. Note that Atlantic basin NTC activity in 2003 is expected to be greater than the long-term average (145), and North Atlantic SSTA* values are measured to be above normal (30 units or 0.30°C). 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 10: 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. coast, along the Gulf Coast (region 1-4), and along the Florida and East Coast (Regions 5-11) for 2003. 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)	86% (80)	79% (68)	69% (52)	94% (84)	99% (97)
Gulf Coast (Regions 1-4)	67% (59)	52% (42)	39% (30)	70% (61)	90% (83)
Florida plus East Coast (5-11)	57% (51)	57% (45)	49% (31)	78% (62)	91% (81)

9 The 1995-2002 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 2002 verification report for more discussion on this subject.

[http://tropical.atmos.colostate.edu/forecasts/index.html]

10 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 2003 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.

11 Forthcoming Update Forecasts of 2003 Hurricane Activity

We will be issuing a further seasonal update of our 2003 Atlantic basin hurricane activity forecast on Wednesday 6 August. This forecast will also include separate individual monthly forecasts for August-only, September-only and October-only activity. Individual monthly forecasts for September-only and October-only activity will be issued on Wednesday 3 September and for October-only on Thursday 2 October. All these forecasts will be available at our web address given on the front cover (http://tropical.atmos.colostate.edu/forecasts/index.html).

12 Acknowledgments

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13 Citations and Additional Reading

14 Verification of Previous Forecasts

Table 11: Summary verifications of the authors' four previous years of seasonal forecasts of Atlantic TC activity between 1999-2002. Verification of our earlier year forecast for the years 1984-1998 are given in our late November seasonal verifications in years before 2002 (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

Footnotes:

[1] Professor of Atmospheric Science

[2] Research Associate

[3] Dr. Landsea, a former project member, is an employee of the NOAA Atlantic Oceanographic and Meteorological Laboratory. As part of his research to improve NOAA's climate forecasting ability, he collaborates with researchers at Colorado State University on our CSU seasonal hurricane forecasts (see page 3).

[4] Research Associate

[5] Research Associate

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