FORECAST OF ATLANTIC SEASONAL HURRICANE ACTIVITY FOR 1998

(A year expected to have near average hurricane activity)

(as of 5 June 1998)

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(This forecast is based on ongoing research by the authors, along with meteorological information through May 1998)

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

Thomas Milligan and David Weymiller, Colorado State University, Media Representatives (970-491-6432) are available to answer various questions about this forecast. A taped interview with William Gray can be obtained by calling 970-491-1525.

(A new forecast of the statistical probability of U.S. coastal landfall of intense (category 3-4-5) hurricanes for 1998 will be issued on the above Web Site on June 12, 1998).

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Summary of 5 June 1998 forecast of seasonal Atlantic hurricane activity.

Forecast Parameter	Forecast 1998 Seasonal Activity	Long-term (1950-1990) Average
Named Storms (NS)	10	9.3
Named Storm Days (NSD)	50	46.9
Hurricanes (H)	6	5.8
Hurricane Days (HD)	25	23.7
Intense Hurricanes (IH)	2	2.2
Intense Hurricane Days (IHD)	4	4.7
Hurricane Destruction Potential (HDP)	70	70.6
Net Tropical Cyclone Activity (NTC)	100%	100%
Maximum Potential Destruction (MPD)	65	61.7

Colorado State University Hurricane Forecast Team

John Knaff, Bill Thorson, Ken Berry, Bill Gray, Paul Mielke, Chris Landsea, John Sheaffer, Rick Taft and Todd Kimberlain (missing from photo).

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 or so 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 sub-tropical Atlantic between 30-50°N, 10-30°W

MPD - Maximum Potential Destruction - A measure of the net maximum destruction potential during the season compiled as the sum of the square of the maximum wind observed (in knots) for each named storm. Values expressed in 10^3kt.

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 5 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 Atlantic between 6-22°N, 18-80°W.

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 = .515 meters per second.

ABSTRACT

Information obtained through May 1998 indicates that the 1998 Atlantic hurricane season is likely to have about average activity. We project that total season activity will include 10 named storms (average is 9.3), 50 named storm days (average 47), 6 hurricanes (average 5.8), 25 hurricane days (average 24), 2 intense (category 3-4-5) hurricanes (average 2.2), 4 intense hurricane days (average is 4.7) and a hurricane destruction potential (HDP) of 70 (average 71). Whereas net 1998 tropical cyclone activity is expected to be about 100 percent of the long term average, this year's activity should be appreciably more than 1997 but less than the unusually active 1995 and 1996 seasons. Still, 1998 should be significantly more active than the average of the generally suppressed hurricane seasons during the last 25 years and especially in comparison to the particularly quiet seasons of 1991–1994. This early June updated forecast is very close to our early April 1998 forecast. An important element entering this updated forecast is the belief that the strongest El Niño on record will be mostly dissipated by the most active portion of the hurricane season from mid-August to late October. If this 1998 hurricane forecast is approximately correct, then the 4-year period of 1995-1998 will have been the most active consecutive four years of hurricane activity on record. This suggests that we are entering a new era of generally greater Atlantic basin hurricane activity. A final updated forecast for 1998 will be issued on 6 August 1998. A verification of this year's forecast will be made in late November 1998.

1. Introduction

Surprisingly strong long range predictive signals exist for Atlantic basin seasonal tropical cyclone activity. Our recent research indicates that a sizeable portion of the year-to-year variability of Atlantic tropical cyclone activity can be skillfully hindcast as early as late November of the prior year. This late fall forecast can then be updated with new information in early April, early June and early August. In this paper we present an early June update of the coming season's Atlantic basin tropical cyclone activity. This forecast is based on meteorological data available through the end of May 1998.

Forecasts equations were developed using 48 years (1950-1997) of historical data. We have studied these years of historical data to develop the best possible forecast from a variety of global wind, temperature, pressure, rainfall and ocean features. Figures 1 through 3 show the various factors which are used in our statistical models.

2. Prediction Methodology

We forecast nine measures of seasonal Atlantic basin tropical cyclone activity including the following seasonal numbers of Named Storms (NS), Named Storm Days (NSD), Hurricanes (H), Hurricane Days (HD), Intense Hurricanes (IH), Intense Hurricane Days (IHD), the Hurricane Destruction Potential (HDP), Net Tropical Cyclone activity (NTC), and the Maximum Potential Destruction (MPD). (Definitions for these indices are given on page 3). For each of these measures, we choose the best three to six predictors (i.e., those resulting in optimum prediction skill) from a group of 15 possible forecast parameters known to be related to tropical cyclone activity. The current set of potential predictors used to develop our early June forecast is shown in Table 1. The specific values of these parameters used in the early June forecast are shown in the right hand column.

A number of statistical forecasts are made for each activity parameter. Table 2 lists the seasonal hurricane indices that we predict, the number of forecast parameters we use in each forecast and which forecast parameters these are. Our hindcast skill (between 50-60 percent) for the 48-year period of 1950-97 is shown in the right column. These prediction equations are

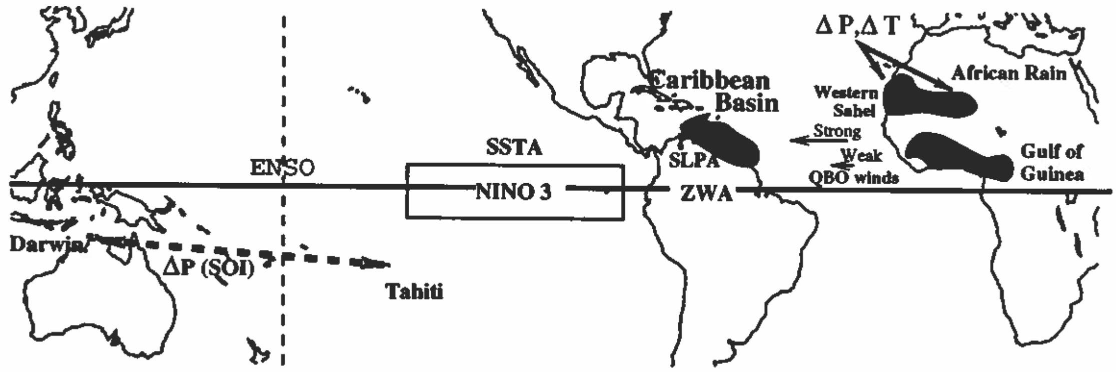

Figure 1: Meteorological parameters used in a prior version of our old early June (Gray et al. 1994a) seasonal forecast.

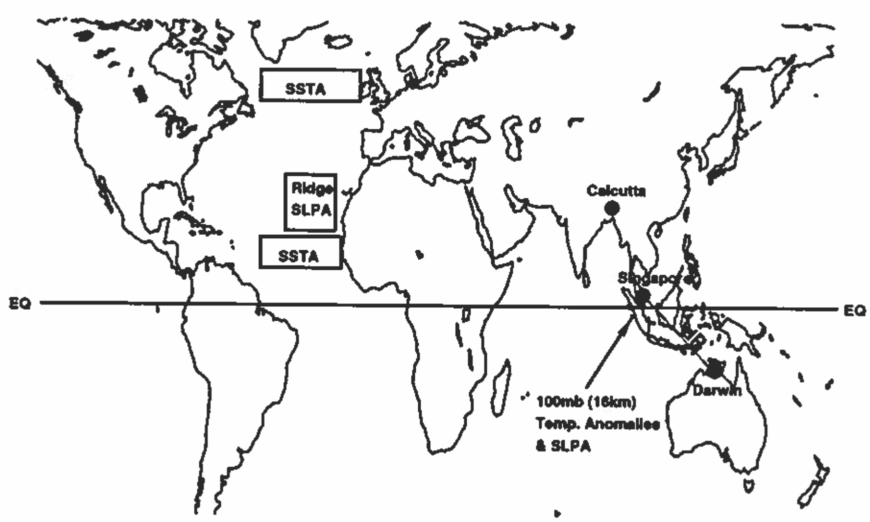

Figure 2: Additional (new) predictors which have recently been noted to be related to the upcoming Atlantic hurricane activity.

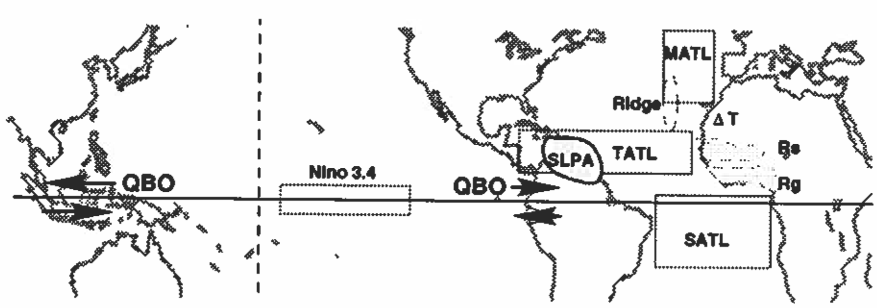

Figure 3: Some additional meteorological parameters that are now used in our new formulation of the June forecast.

Table 1: Pool of predictive parameters and their estimated values for the early June 1998 prediction. This is based on meteorological data through May 1998. See Figs. 1 and 2 for the locations of these predictors.

Predictive Parameter	
1 = QBO 50 mb 4-month extrapolation of zonal wind at 12°N to Sept. 1998	–14 ms^{-1}
2 = QBO 30 mb 4-month extrapolation of zonal wind at 12°N to Sept. 1998	–31 ms^{-1}
3 = QBO absolute value of shear between 50 and 30 mb at 12°N to Sept. 1998	17 ms^{-1}
4 = Rgc AN Gulf of Guinea rainfall anomaly (Aug-Nov of 1997)	–0.43 SD
5 = Rws West Sahel rainfall anomaly (June-Sept 1997)	–0.73 SD
6 = Temp East-West Sahel temperature gradient(Feb-May 1998)	+0.7 SD
7 = SLPA April-May Caribbean basin sea level pressure anomaly	0.0 mb
8 = ZWA April-May Caribbean basin zonal wind anomaly	+1.0 m/s
9 = R-ON: Azores surface pressure ridge strength in Oct-Nov 1997	–1.37 SD
10 = R-M: Mar Azores surface pressure ridge strength in Mar 1998	–0.91 SD
11 = SST3.4 Nino 3.4 SSTA in April-May 1998	+0.94°C
12 = D-SST3.4: Nino 3.4 SSTA for April-May minus Feb-Mar 1998	–1.56°C
13 = TATL Tropical Atlantic SSTA anomaly (10-22°N,18-50°W) (Apr-May)	+0.47°C
14 = NATL North Atlantic SSTA anomaly (50-60°N,10-50°W) (Apr-May)	+0.28°C
15 = SATL Mid Atlantic SSTA anomaly (5-18°S,50°W-10°E) (Apr-May)	+0.62°C

established for our variable parameter forecast model. This represents our best statistical forecast where, so as to minimize the skill degradation of these equations when making independent forecasts via statistical "overfitting", we include the least number of predictors for the highest amount of hindcast variance. We stop adding predictors when the hindcast improvement of the next best predictor adds less than a 0.025 improvement to the total variance explained. These equations are also constrained to have regression coefficients whose sign match those when analyzed in isolation.

We have also studied a scheme which uses various fixed number of predictors. Table 3 lists the predictors used. This procedure investigates how hindcast variance (not necessarily true skill) increases as a fixed number of predictors are increased from 4 to 6 to 8. Although independent forecast skill (i.e., "true skill") typically degrades in approximate proportion to the increased number of predictors, it is of interest to determine the degree of hindcast improvement which occurs with added predictors. Individual year forecast skill degradation from application of hindcast statistics can never be accurately specified. Consequently, as the latter are purely random effects, the hazards of overfitting become obvious.

Additional forecast parameters representing conditions in the Atlantic and Pacific Ocean basins and in the Asia-Australia regions (Figs. 1 and 2) are also consulted for further qualitative interpolation and possible influence on our final "adjusted" forecast.

Table 4 lists hindcast prediction skills for our various statistical models including the variable number of predictor schemes along with fixed sets of 4, 6 and 8 predictors. Probability dictates that, on average, a net degradation of this hindcast skill of between 10-20 percent of total in variability will likely occur. The amount of degradation (if any) for an individual year forecast is a random process. In some years, when conditions include strong trends that are similar to past

Table 2: Listing of predictors chosen for each parameter forecast and the total hindcast variance explained by these predictors for the enclosed updated 1 June forecast.

Forecast Parameter	No. of Predictors	Predictors Chosen from Table 1	Variability Explained by Hindcast (1950-1997)	Likely Independent Forecast Skill
NS	3	1, 3, 9	.498	.322
NSD	6	3, 4, 5, 7, 9, 10	.562	.405
H	6	3, 4, 5, 7, 10, 11	.532	.361
HD	6	2, 4, 5, 6, 9, 14	.544	.379
IH	5	1, 4, 6, 9, 10	.557	.402
IHD	3	4, 6, 11	.443	.230
HDP	5	1, 4, 5, 6, 10	.532	.366
NTC	5	1, 4, 5, 6, 10	.554	.398
MPD	4	3, 4, 9, 14	.591	.453

Table 3: Hindcast (i.e., regression testing on data for past years) statistical predictor skill (measure of agreement or variance explained) of our separate hindcasts for the period of 1950-1997 for 4, 6 and 8 predictor numbers.

	Best Four Predictors	Hindcast Skill
NS	U50, AbsShe, R-ON, SATL	.538
NSD	AbsShe, Rgc, R-ON, NATL	.502
H	AbsShe, Rgc, R-ON, R-M	.480
HD	AbsShe, Rgc, R-ON, NATL	.482
IH	U50, Rgc, Del-T, R-M	.519
IHD	Rgc, Del-T, SST3.4, SATL	.466
HDP	U50, Rgc, Rws, Del-T	.481
NTC	AbsShe, Rgc, SST3.4, NATL	.516
MPD	AbsShe, Rgc, R-ON, NATL	.591
	Best Six Predictors	**Hindcast Skill**
NS	U50, AbsShe, Rgc, Del-T, R-ON, SATL	.586
NSD	AbsShe, Rgc, Rws, SLPA, R-ON, R-M	.562
H	AbsShe, Rgc, Rws, SLPA,R-ON, SST3.4	.532
HD	U30, Rgc, Rws, Del-T, R-ON, NATL	.544
IH	U50, U30, Rgc, Del-T, R-ON, R-M	.571
IHD	Rgc, Del-T, R-ON, SST3.4, NATL, SATL	.487
HDP	U30, Rgc, Del-T, R-ON, TATL, NATL	.549
NTC	U30, Rgc, Del-T, R-ON, TATL, NATL	.577
MPD	U50, U30, Rgc, Rws, R-ON, R-M	.635
	Best Eight Predictors	**Hindcast Skill**
NS	U50, AbsShe, Rgc, Del-T, R-ON, TATL, NATL, SATL	.606
NSD	AbsShe, Rgc, Rws, Del-T, SLPA, R-ON, R-M, SST3.4	.591
H	U50, AbsShe, Rgc, Rws, Del-T, SLPA, R-ON, SST3.4	.553
HD	U30, AbsShe, Rgc, Del-T, ZWA, R-ON, SST3.4, NATL	.568
IH	U50, U30, Rgc, Del-T, R-ON, R-M, TATL, SATL	.602
IHD	U50, AbsShe, Rgc, Rws, Del-T, R-ON, Del-SST3.4, SATL	.516
HDP	U50, U30, Rgc, Rws, Del-T, R-ON, R-M, Del-SST3.4	.584
NTC	U50, U30, Rgc, Del-T, R-ON, SST3.4, Del-SST3.4, NATL	.606
MPD	U50, U30, Rgc, Rws, Del-T, R-ON, R-M, Del-SST3.4	.652

years, forecasts will do quite well, perhaps better than the skill of the hindcast scheme. In other years, a given forecast can perform quite poorly. This is because our 48-year (1950-1997) base of predictors likely does not contain realizations of the full range of independent possibilities. Our 1997 forecast is a good example. No year in our 1950 through 1996 developmental data sets had ever experienced an El Niño event anywhere nearly as intense (by a factor of 2) as the 1997-98 El Niño event.

Table 4: 1 June statistical forecasts which have a variable number of predictors with variable predictors (column 1) along with 4, 6 and 8 fixed predictors forecast (columns 2, 3, and 4). Column 5 is our final adjusted early June forecast of 1998 hurricane activity. Column 6 gives climatology.

Full Forecast Parameter	(1) Variable Predictor	(2) Fixed predictors 4 Predictors	(3) 6 Predictors	(4) 8 Predictors	(5) Adjusted Actual Fcst	(6) 1950-1990 Climatology
Named Storms (NS)	10.0	12.3	11.7	13.6	10	9.3
Named Storm Days (NSD)	53.7	53.6	53.7	38.0	50	46.9
Hurricanes (H)	3.4	5.9	3.4	4.0	6	5.8
Hurricane Days (HD)	26.8	24.7	26.8	26.2	25	23.7
Intense Hurricanes (IH)	2.8	2.5	2.4	1.8	2	2.2
Intense Hurricane Days (IHD)	4.5	4.5	6.9	7.2	4	4.7
Hurricane Destruction Potential (HDP)	79.0	58.4	57.9	62.6	70	70.6
Net Tropical Cyclone Activity (NTC)	109.5%	71.4%	98.9%	97.3%	100%	100%
Maximum Potential Destruction (MPD)	63.1	63.1	62.8	65.3	65	61.7

In Table 4, columns 1-4 lists all of our statistical forecasts, column 5 contains our best qualitative adjusted "final" forecasts and column 6 provides the climatological mean for each parameter for 1950-1990. We have made a small upward adjustment of our early December and early April forecasts to express the expectation of an average hurricane season.

We consider the variable predictor scheme shown in column 1 of Table 4 to be our best forecast. Table 5 shows the statistical spread of our prediction. Table 2 also presents the hindcast skill and the expected likely skill with independent data.

3. Discussion

Presently, the forecast signals for 1998 are becoming more positive than negative. Only the stratospheric QBO and the 1997 West African rainfall signals are negative. And, we attribute a sizeable portion of the below average Guinea Coast and western Sahel precipitation to last year's strongest ever observed El Niño. Of the 15 potential predictors listed in Table 1, only six indicate a below average activity, whereas the other nine factors indicate above average or average activity for 1998. Additional climate conditions favorable for 1998 hurricane activity in the Atlantic basin which are not believed to be fully reflected in our objective 1 June predictions include the following:

1. Negative Atlantic subtropical ridge (or Azores high) anomalies of −1.37 SD in October-November 1997 and −0.91 March 1998. The weaker than normal Atlantic wind gyre resulting from these pressure decreases acts to reduce the amount of ocean upwelling

Table 5: Statistical spread of variable parameter forecast. The lowest and highest 25 percent are obtained from the variable statistical scheme applied to our adjusted forecast.

Forecast Parameter	Lowest 25%	Adjusted Forecast	Highest 25%
NS	8.9	10	11.2
NSD	46.1	50	54.1
H	4.9	6	7.9
HD	18.9	25	27.8
IH	1.5	2	2.4
IHD	2.3	4	6.1
HDP	51.5	70	86.7
NTC	76.7%	100%	110.7%
MPD	50.6	63.1	69.3

along Western Africa and South America, implying warmer (SST) waters and lower sea level pressure in the tropical Atlantic during the summer.

2. Broadscale North Atlantic SSTA patterns are warm for the fourth consecutive year, implying that a multidecadal shift in North Atlantic SSTs has occurred which we believe is related to changes in the Atlantic Ocean thermohaline ("conveyor") circulation. Persistence of warm SST (anomaly) conditions over the North Atlantic west of the UK during 1997 and for the January–May 1998 period indicates the persistence of a stronger than normal Atlantic Ocean thermohaline circulation. Such ocean circulation changes are typically associated with increased intense hurricane activity.

3. More evidence (and hence, greater confidence) that the strongest El Niño on record will be largely dissipated by August 1998 with somewhat cooler conditions becoming established by September and October. Below average (cold) water should continue to expand the cool upwelling area along the eastern Pacific equator during the next 1-2 months. East Pacific subtropical highs in both sides of the equator should become stronger and stronger trade winds established. Both of these influences should lead to a termination of the present El Niño during the next few months.

   Knaff and Landsea (1997) have recently developed a new extended-range ENSO prediction scheme based on an optimum combination of climatology and persistence. Their SST forecast of June-July-August and September-October-November 1998 for Nino 3.4 SST anomaly indicates values are –0.2°C and –1.1°C, respectively. Hence, we believe that the current ENSO will continue to cool rapidly during the next 3-4 months such that cool eastern Pacific SSTA conditions will be in place by late summer and early fall. Such a rapid winter to summer reversal is typical of very strong El Niños.

4. Middle latitude Atlantic wind patterns during the winter of 1997-1998 have been more typical of the blocking conditions which were more prevalent during the late 1940s through the late 1960s, a time when the far North Atlantic also had similar warm SSTA conditions and Atlantic intense hurricane activity was more prevalent.

5. Lower than normal summertime tropical West Atlantic SLPA are typically related to increased hurricane activity (Shapiro 1982, Gray 1984, Knaff 1997). An early April 1998

forecast by Knaff (1998) calls for negative SLPA in the Caribbean and western tropical Atlantic for this coming summer. Table 6 provides details of these SLPA forecasts which are based on anomaly information concerning the March Atlantic subtropical ridge, January through March SSTs in the North Atlantic (50-60°N, 10-50°W), and January through March Niño 3.4 (5°N–5°S, 120°W–170°W) SST anomalies. Using these factors in separate regression equations leads Knaff to a forecast reduced Caribbean-western tropical Atlantic SLPA for the months of June-July, August-September, June-August and June through September, respectively. Lower pressures should enhance hurricane activity. A similar SLPA forecast for early June is not possible.

Table 6: April 1,1998 multi-month independent statistical prediction of Caribbean basin and Western tropical Atlantic Sea Level Pressure Anomaly (SLPA) for this summer (Knaff 1998). Separate regression analyses are made for each category. SLPA predictions are given in terms of mb.

	June-July	August-September	June through September
SLPA	–0.84	–0.35	–0.84

4. Current El Niño Influences on the 1998 Hurricane Season and Analog Years to 1998

Hurricane seasons in years of dissipating El Niños can be either active or inactive. For instance, the hurricane seasons of 1919, 1931, 1970, 1973, 1983, and 1992 (following El Niño years of 1918, 1930, 1969, 1972, 1982, and 1991) were generally inactive whereas 1906, 1915, 1926, 1958, 1966, and 1995 (following the El Niño years of 1905, 1914, 1925, 1957, 1965, and 1994) were quite active. Table 7 lists these years.

Table 7: Analog and non-analog years for dissipating El Niños.

Analog Years	Non-analog Years
1905-1906	1918-1919
1914-1915	1930-1931
1925-1926	1969-1970
1957-1958	1972-1973
1965-1966	1982-1983
1994-1995	1991-1992
Likely 1997-98	

We believe that the 1998 hurricane season will be more typical of the active hurricane years associated with dissipating El Niños. Atlantic basin ocean and atmospheric circulation conditions, as manifested by Atlantic subtropical ridge pressure anomalies, Atlantic SSTA, Atlantic SLPA, and Western Sahel rainfall are different for these two classes of ENSO weakening years; 1998 Atlantic basin weather conditions being more typical of an active period. Hence, we view the 1998 hurricane season to be more typical of those more active hurricane seasons of 1906, 1915, 1926, 1958, 1966, 1995 when El Niño condition were weakening following prior year El Niños. These years are to be contrasted with the years not similar to 1998 of weakening El Niño years of 1919, 1931, 1973, 1983, 1987, 1992. Table 8 shows the differences in seasonal activity in active (analog years) versus inactive (non-analog) El Niño second years.

Table 8: Average hurricane activity for analog versus non-analog years fading El Niño years.

	NS	H	IH	NTC
Analog Years	11.1	7.8	4.2	173
Non-analog Years	6.5	3.2	1.2	52
Ratio	1.7	2.4	3.5	3.3

The best signal preseason analog year to 1998 is 1958. This was a year of an easterly QBO, a fading El Niño in an era of a strong thermohaline circulation with warm Atlantic SSTs, and weak Azores high conditions during October-November of the previous year and March of the current year. This was an active year with a NTC of 139. The next best analog years for the largest number of parameters are 1981 (NTC of 113 percent) and 1987 (NTC of 47 percent). A weaker analog that marginally matches 1998's conditions was 1969 (NTC of 155 percent). Note that the analogues provide a wide range of possible activity for 1998.

Table 9: Comparison of Atlantic basin 1 June forecast parameters for similar versus non-similar years following an El Niño.

	(1) NATL SSTA	(2) TATL SSTA	(3) W. ATL SLPA	(4) MAR Ridge	(5) O-N Ridge	(6) W. Sahel Rain
Similar Years	+.30°C	+.08°C	-.69	+.15	-.50	+.93 SD
Non-similar years	-.21°C	-.25°C	+.11	+.51	-.04	-.64 SD
Difference	+.51°C	+.33°C	-.80	-.36	-.46	+1.57 SD
Observed or Fcst for 1998 – more typical of similar years	+.26°C	+.67°C	-.84 mb fcst.	-.91 SD	-1.37 SD	-.25 SD fcst.

The inference for an average 1998 hurricane season is a consequence of several early year (1998) Atlantic basin and circulation trends including:

1. (inferred) stronger Atlantic Ocean thermohaline circulation
2. a weaker Atlantic wind gyre as indicated by a weaker subtropical ridge (Azores high),
3. forecast below average SLPA conditions in the tropical Atlantic
4. observed above average north and tropical Atlantic SST anomalies, and
5. a forecast of the absence of drought conditions for the Western Sahel (see Landsea et al. 1998).

5. Prospects for a Long Term Increase of Atlantic Hurricane Activity Associated With Major Reconfiguration of Atlantic Basin SSTs

Our data sets show that a multi-decadal lapse of intense hurricane activity began during the early 1970s and extended to 1994. We believe that this trend was associated with concurrent slowing of the North Atlantic thermohaline circulation during this period, resulting in North Atlantic SSTs cooling and South Atlantic SSTs warming during these decades. Presuming that this SST anomaly pattern is now in fact dissipating, we anticipate forthcoming concurrent multi-decadal increased West African Sahel rainfall, decreased summertime upper tropospheric westerly winds over the tropical Atlantic and, regarding the issue at hand, a multi-decadal period of increased Atlantic Basin intense hurricane activity.

High salinity increases sea water density allowing it to sink to great depths, and thereby in the North Atlantic, causing increased equatorward flow of deep ocean water. This southward deep water flow causes a compensating northward flow of warm replacement water near the ocean's surface. The resulting net north and south transports of (surface) warm and (deep) cold water is called the "Atlantic Ocean Conveyor." A strong conveyor circulation transports more heat to high latitudes, increasing North Atlantic surface water temperatures. Salinity values in the North Atlantic have been steadily rising during the last 15 years. There are also recent reports of decreased southward ice flow through the Fram Strait between Greenland and Spitzbergen. This trend reduces the introduction of fresh water leading to an increase in upper level salinity values in these high latitude ocean areas. Related observations also report increased salinity in other areas of the tropical Atlantic and North Atlantic. Collectively, these processes all suggest that surface salinity increases now being measured in the North Atlantic appear to be the prelude to a stronger Atlantic Ocean thermohaline circulation.

It has been nearly three decades since the SST anomaly patterns of the Atlantic Ocean have shown as strong a north to south SST difference as is recently being observed. Figure 4 shows average SST anomaly changes between the three-year periods 1992-93-94 and 1995-96-97. We expect that increased Atlantic SST pattern will continue to contribute to increased incidence of major hurricanes in coming years, more like the conditions observed during the mid 1940s to mid-1960s. Specifically, this trend should manifest itself primarily in the form of more hurricanes forming at low latitudes. The climatology of this basin would then favor more intense hurricanes, especially those of the classic Cape Verde type.

6. Forthcoming Forecast Updates

This 5 June 1998 forecast will be updated again on

- Thursday 6 August 1998, just prior to the most active portion of the hurricane season.

The early August forecast will utilize data which are closer in time to the peak of the hurricane season and therefore, should be somewhat more reliable than this and our earlier forecasts. Verification of all our forecasts will be issued in late November 1998.

7. Theory Behind Forecasts and Cautionary Note

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 predict specifically where within the Atlantic basin storms will strike. Regardless of whether 1998 is an above or below average hurricane season, the probability always exists that one or more hurricanes may strike along the US or Caribbean Basin coastline and do much damage.

8. Anticipated Hurricane Activity for Next Year (1999)

The ensemble of slowly evolving climatic conditions suggest that an active hurricane season is likely during the summer of 1999. This speculation is based on expectations that (1) the current El Niño will be fully dissipated and cool SST anomaly conditions will be present

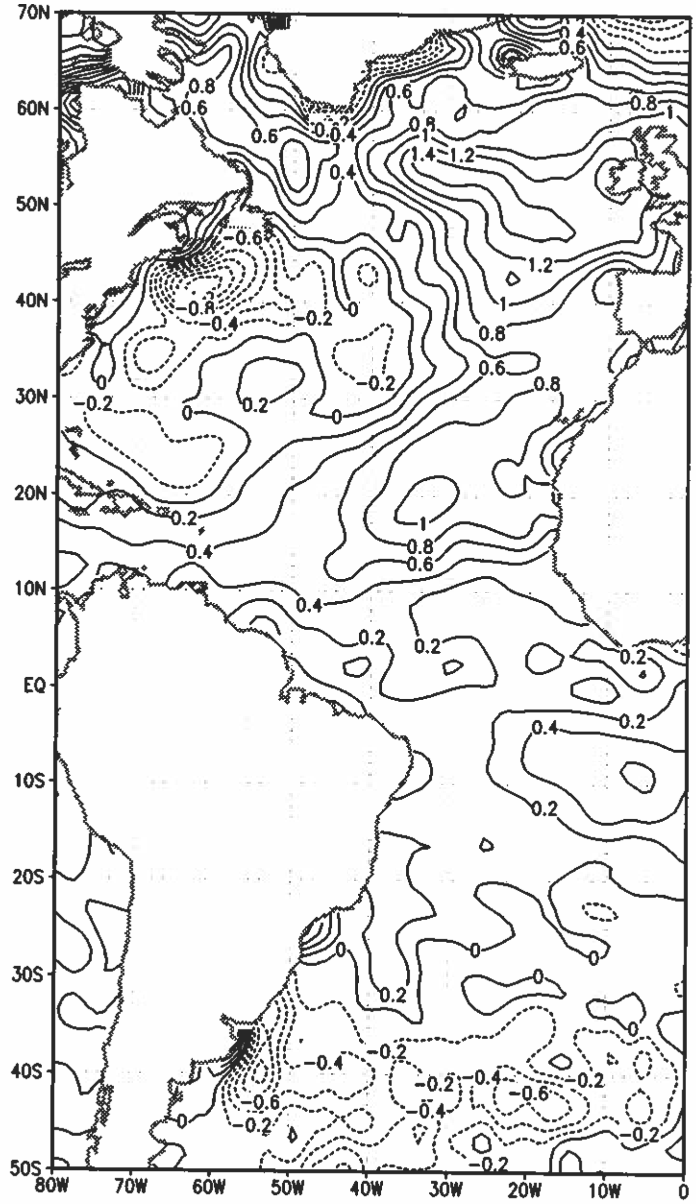

Figure 4: Analysis of SST difference for August through October of 1995-96-97 minus August through October 1992-93-94. Values are in °C.

during 1999 in the Eastern Equatorial Pacific, (2) relatively warm tropical North Atlantic SST anomaly conditions and a strong thermohaline circulation will persist and (3) stratospheric QBO conditions during 1999 are projected to be from the more favorable westerly direction.

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Post-Season Reviews of All Prior Seasonal Forecasts

The first author has now issued seasonal hurricane forecasts for 14 consecutive years (1984–1997). In most of these prior forecasts, predictions have been superior to climatology (i.e., long-term averages), particularly for named storms. Whereas the forecasts for 1989 (underestimated), 1993 (overestimated), 1996 (underestimated), and 1997 (overestimated) were quite poor, they were also quite instructive in that each of these failures has led to important new insight and forecast model improvements. Figures 6 and 7 offer a comparison of our 1 August forecasts of named storms and hurricanes versus climatology and actual year-by-year variability.

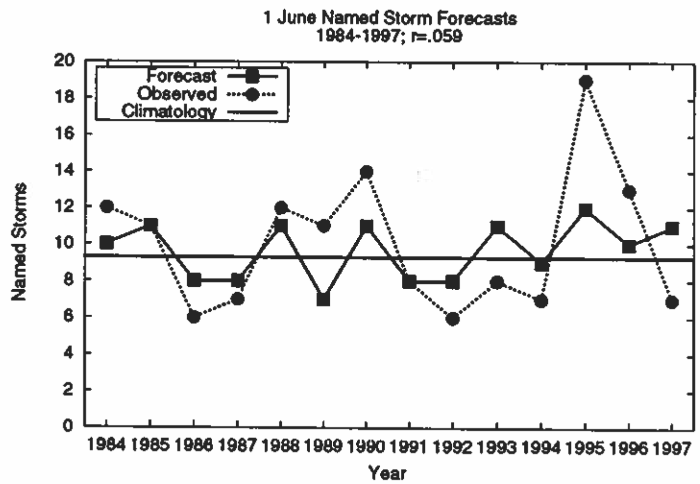

Figure 5: 1 June prediction of total named storms versus the number of actually observed versus long-term climatological mean (r = 0.59) for period 1984–1997.

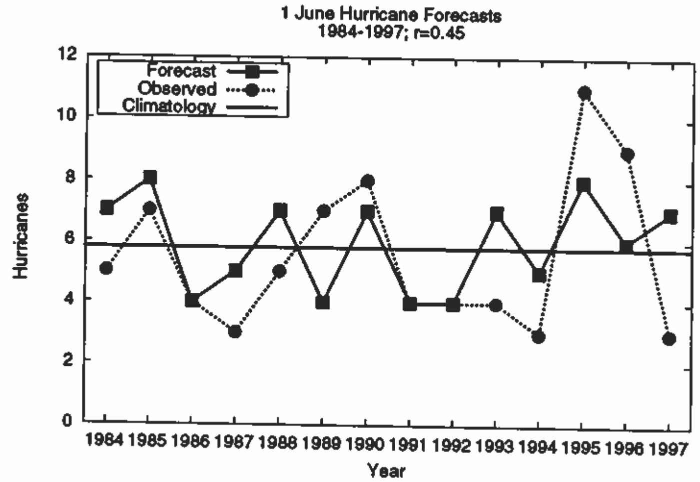

Figure 6: 1 June prediction of total hurricanes versus the number of actually observed versus climatological long-term mean (r = 0.45).

Table 10: APPENDIX A –Listing of Seasonal Net Tropical Cyclone activity (NTC) and Maximum Potential Destruction (MPD) values between 1950-1997.

Year	NTC (%)	MPD	Year	NTC (%)	MPD	Year	NTC (%)	MPD
1950	237	130	1965	85	38	1980	134	86
1951	119	80	1966	138	65	1981	112	70
1952	96	59	1967	96	54	1982	36	29
1953	119	81	1968	40	28	1983	31	22
1954	128	66	1969	154	120	1984	77	53
1955	195	103	1970	63	57	1985	109	73
1956	68	46	1971	94	72	1986	38	29
1957	84	46	1972	28	22	1987	47	28
1958	137	82	1973	51	39	1988	122	82
1959	97	59	1974	75	50	1989	135	78
1960	96	53	1975	91	65	1990	101	65
1961	218	106	1976	83	51	1991	59	43
1962	33	30	1977	46	44	1992	66	48
1963	115	61	1978	85	60	1993	53	33
1964	165	88	1979	94	59	1994	36	31
						1995	229	108
						1996	198	92
						1997	54	27

Table 11: Verification of the authors' previous seasonal predictions of Atlantic tropical cyclone activity for 1984-1996.

1984	Prediction of 24 May and 30 July Update		Observed
No. of Hurricanes	7		5
No. of Named Storms	10		12
No. of Hurricane Days	30		18
No. of Named Storm Days	45		51
1985	**Prediction of 28 May**	**Updated Prediction of 27 July**	**Observed**
No. of Hurricanes	8	7	7
No. of Named Storms	11	10	11
No. of Hurricane Days	35	30	21
No. of Named Storm Days	55	50	51
1986	**Prediction of 29 May**	**Updated Prediction of 28 July**	**Observed**
No. of Hurricanes	4	4	4
No. of Named Storms	8	7	6
No. of Hurricane Days	15	10	11
No. of Named Storm Days	35	25	23
1987	**Prediction of 26 May**	**Updated Prediction of 28 July**	**Observed**
No. of Hurricanes	5	4	3
No. of Named Storms	8	7	7
No. of Hurricane Days	20	15	5
No. of Named Storm Days	40	35	37
1988	**Prediction of 26 May and 28 July Update**		**Observed**
No. of Hurricanes	7		5
No. of Named Storms	11		12
No. of Hurricane Days	30		21
No. of Named Storm Days	50		47
Hurr. Destruction Potential(HDP)	75		81
1989	**Prediction of 26 May**	**Updated Prediction of 27 July**	**Observed**
No. of Hurricanes	4	4	7
No. of Named Storms	7	9	11
No. of Hurricane Days	15	15	32
No. of Named Storm Days	30	35	66
Hurr. Destruction Potential(HDP)	40	40	108
1990	**Prediction of 5 June**	**Updated Prediction of 3 August**	**Observed**
No. of Hurricanes	7	6	8
No. of Named Storms	11	11	14
No. of Hurricane Days	30	25	27
No. of Named Storm Days	55	50	66
Hurr. Destruction Potential(HDP)	90	75	57
Major Hurricanes (Cat. 3-4-5)	3	2	1
Major Hurr. Days	Not Fcst.	5	1.00

1991	Prediction of 5 June	Updated Prediction of 2 August	Observed
No. of Hurricanes	4	3	4
No. of Named Storms	8	7	8
No. of Hurricane Days	15	10	8
No. of Named Storm Days	35	30	22
Hurr. Destruction Potential(HDP)	40	25	22
Major Hurricanes (Cat. 3-4-5)	1	0	2
Major Hurr. Days	2	0	1.25

1992	Prediction of 26 Nov 1991	Updated Prediction of 5 June	Updated Prediction of 5 August	Observed
No. of Hurricanes	4	4	4	4
No. of Named Storms	8	8	8	6
No. of Hurricane Days	15	15	15	16
No. of Named Storm Days	35	35	35	39
Hurr. Destruction Potential(HDP)	35	35	35	51
Major Hurricanes (Cat. 3-4-5)	1	1	1	1
Major Hurr. Days	2	2	2	3.25

1993	Prediction of 24 Nov 1992	Updated Prediction of 4 June	Updated Prediction of 5 August	Observed
No. of Hurricanes	6	7	6	4
No. of Named Storms	11	11	10	8
No. of Hurricane Days	25	25	25	10
No. of Named Storm Days	55	55	50	30
Hurr. Destruction Potential(HDP)	75	65	55	23
Major Hurricanes (Cat. 3-4-5)	3	2	2	1
Major Hurr. Days	7	3	2	0.75

1994	Prediction of 19 Nov 1993	Updated Prediction of 5 June	Updated Prediction of 4 August	Observed
No. of Hurricanes	6	5	4	3
No. of Named Storms	10	9	7	7
No. of Hurricane Days	25	15	12	7
No. of Named Storm Days	60	35	30	28
Hurr. Destruction Potential(HDP)	85	40	35	15
Major Hurricanes (Cat. 3-4-5)	2	1	1	0
Major Hurr. Days	7	1	1	0
Net Trop. Cyclone Activity	110	70	55	36

1995	Prediction of 30 Nov 1994	14 April Qualit. Adjust.	Updated Prediction of 7 June	Updated Prediction 4 August	Obs.
No. of Hurricanes	8	6	8	9	11
No. of Named Storms	12	10	12	16	19
No. of Hurricane Days	35	25	35	30	62
No. of Named Storm Days	65	50	65	65	121
Hurr. Destruction Potential(HDP)	100	75	110	90	173
Major Hurricanes (Cat. 3-4-5)	3	2	3	3	5
Major Hurr. Days	8	5	6	5	11.5
Net Trop. Cyclone Activity	140	100	140	130	229

1996	Prediction of 30 Nov 1995	Updated 14 April	Updated Prediction of 7 June	Updated Prediction 4 August	Obs.
No. of Hurricanes	5	7	6	7	9
No. of Named Storms	8	11	10	11	13
No. of Hurricane Days	20	25	20	25	45
No. of Named Storm Days	40	55	45	50	78
Hurr. Destruction Potential(HDP)	50	75	60	70	135
Major Hurricanes (Cat. 3-4-5)	2	2	2	3	6
Major Hurr. Days	5	5	5	4	13
Net Trop. Cyclone Activity	85	105	95	105	198

1997	Prediction of 30 Nov 1996	Updated 14 April	Updated Prediction of 6 June	Updated Prediction 5 August	Obs.
No. of Hurricanes	7	7	7	6	3
No. of Named Storms	11	11	11	11	7
No. of Hurricane Days	25	25	25	20	10
No. of Named Storm Days	55	55	55	45	28
Hurr. Destruction Potential(HDP)	75	75	75	60	26
Major Hurricanes (Cat. 3-4-5)	3	3	3	2	1
Major Hurr. Days	5	5	5	4	2.2
Net Trop. Cyclone Activity	110	110	110	100	54