EARLY APRIL FORECAST OF ATLANTIC BASIN SEASONAL HURRICANE ACTIVITY FOR 1998

(A year of expected average hurricane activity)

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(This forecast is based on ongoing research by the authors, together with meteorological information available through March 1998)

[This forecast with figures and tables is available on the World Wide Web at: http://tropical.atmos.colostate.edu/forecasts/index.html] - also

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DEFINITIONS

Atlantic Basin - The area including the entire North Atlantic Ocean, the Caribbean Sea, and the Gulf of Mexico.

El Niño - (EN) A 12-18 month period during which anomalously warm sea surface temperatures occur in the eastern half of the equatorial Pacific. Moderate or strong El Niño events occur irregularly, about once every 3-7 years 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

Current trends in the relevant global climate conditions lack any dominating feature likely to cause either a highly active or inactive Atlantic hurricane season this summer. Rather, information obtained through March 1998 indicates that the upcoming 1998 Atlantic hurricane season is likely to experience about average hurricane activity. We project that total season activity will include 10 named storms (average is 9.3), 50 named storm days (average is 47), 6 hurricanes (average is 5.8), 20 hurricane days (average is 24), 2 intense (category 3-4-5) hurricanes (average is 2.3), 4 intense hurricane days (average is 4.7) and a hurricane destruction potential (HDP) of 65 (average is 71). Whereas net 1998 tropical cyclone activity is expected to be about 95 percent of the long term average, conditions this year should be distinctively more active than 1997 but less active than the very busy hurricane seasons of 1995 and 1996. This early April prediction indicates a greater possibility of a slightly more active season than did our early December (1997) forecast of 1998 hurricane activity. An important element entering this April forecast update is more evidence that the very strong 1997-1998 El Niño will be largely dissipated by the start of the (climatologically) active part of the hurricane season (i.e., mid-August). Additional later forecasts updates for 1998 will be issued on 5 June and 6 August 1998. A post-season review and critique of this forecast will be made in late November 1998. These forecasts, as well as those for past seasons, are also available on the World Wide Web at the access location given on the cover page.

1. Introduction

Surprisingly strong long range predictive signals exist for seasonal tropical cyclone activity in the Atlantic basin. Our ongoing research indicates that a sizeable portion of the year-to-year variability of nine indices of Atlantic tropical cyclone activity can be forecast with useful skill as early as late November of the prior year. Each year this late fall forecast is then updated in early April, early June and early August. This paper presents the early April update of our Atlantic 1998 forecast which contain meteorological data available through the end of March 1998.

Our seasonal hurricane forecasts are based on the premise that the behavior of the atmosphere during the coming year will, in general, follow that of similar years of the past. In other words, we assume that those global environmental conditions which preceded active (or inactive) hurricane seasons in the past will be similarly related to future active (or inactive) hurricane seasons. Allowing that seasonal variations of the global atmosphere and ocean tend to occur as a coherent, structured process, past observations provide insight as to how the atmosphere-ocean-land system will likely operate in future months and seasons. As we study new data and ideas, our forecast methodology continues to evolve while our overall forecast skill improves with time.

Forecasts are developed using 48 years (1950-1997) of historical data. We examine this historical data in order to develop the best possible forecast equations from a variety of global wind, temperature, pressure, and rainfall features. Figures 1 and 2 show the various factors which are used either for our statistical models or provide additional considerations for determining our final "adjusted" forecast.

2. Prediction Methodology

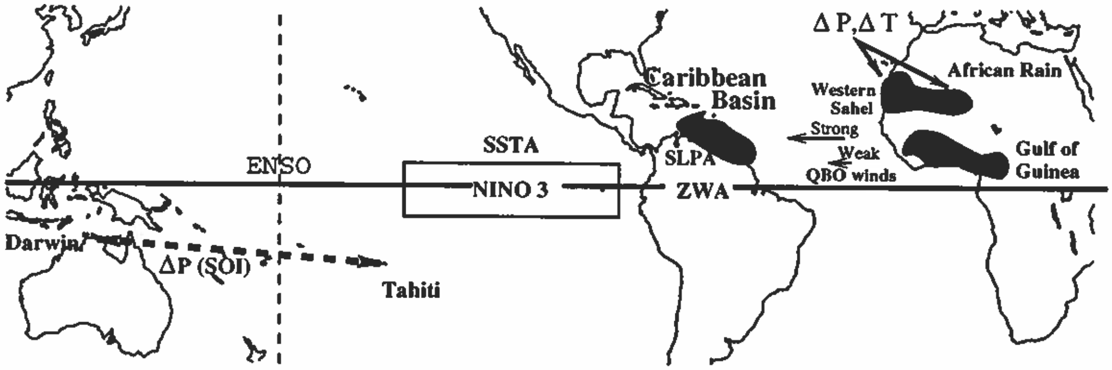

Figure 1: Meteorological parameters used in our late November, early April, early June and early August forecasts.

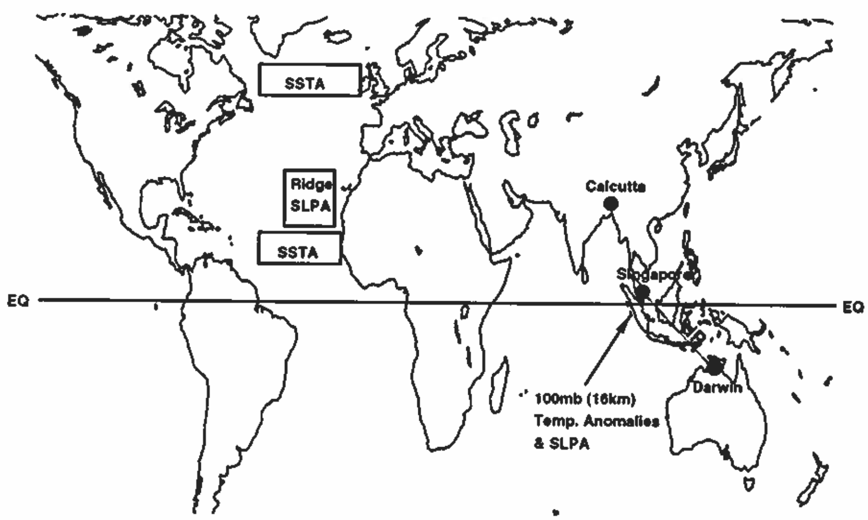

Figure 2: Other new predictors which have recently been found to be related to the upcoming Atlantic hurricane activity.

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 2). 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 13 possible forecast parameters known to be related to tropical cyclone activity. The current set of potential predictors used to develop our early April forecast is shown in Table 1. The specific values of these parameters used in this year's April forecast are shown in the right hand column.

We make a number of statistical forecasts which are summarized in Table 2. Column 1 of Table 2 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.

We have also studied a scheme which uses various fixed number of predictors. This procedure investigates how hindcast variance (not necessarily true skill) increases as a fixed number of predictors are increased from 4 to 6. 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 2 lists hindcast prediction skills for our various statistical models including the variable number of predictor schemes along with fixed sets of 4 and 6 predictors. Probability dictates that, on average, a net degradation of this hindcast skill of between 5-15 percent of total in variance 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 years, forecasts will do quite well while in other years, a given forecast can perform quite poorly. This is because our 48-year (1950-1997) base of predictors likely does not explain 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 – the most intense event ever measured.

3. Early April Forecast

Table 3 lists our April statistical forecast prediction for the 1998 hurricane season along with what we consider our current best qualitatively adjusted forecast.

Table 1: Pool of predictors and their values as of 1 April which are used to develop the 1998 prediction based on meteorological data available through March 1998. See Figs. 1 and 2 for the locations of these predictors.

For 1 April Prediction (see Figs. 1 and 2 for location)	Specific 1 April Fcst Parameters
1) U50 (Mar extrapolated to Sep)	–14 m/s
2) U30 (Mar extrapolated to Sep)	–31 m/s
3) AbsShe - absolute shear (Mar extrapolated to Sep)	17 m/s
4) Balboa - U50 (June-Aug, 1997)	- 4 m/s
5) Rain GG- Aug-Nov Guinea Coast Rain	-0.43 SD
6) Rain WS- Jun-Sep West Sahel Rain	-0.73 SD
7) R-ON - Ridge SLPA (Oct to Nov)	- 1.37 SD
8) R-M - Ridge SLPA (Mar)	-.91 SD
9) NATL (Jan to Mar) SSTA	+0.26°C
10) TATL (Jan to Mar) SSTA	+0.67°C
11) Nino 3.4 Mar SSTA	+1.47°C
12) Nino 3.4 (Mar minus Feb) SSTA	-0.67°C
13) Nino 4 (Jan, Feb, Mar minus Oct, Nov, Dec) SSTA	-0.26°C

Table 2: Hindcast (i.e., regression testing on data for past years) statistical predictor skill (measure of agreement or r^2) of our separate hindcasts for the period of 1950-1997. Column (a) gives our best prediction with minimum number of predictors shown in parenthesis. Columns (b), (c) and (d) give our hindcast skill with the best 4, 6, and 8 predictors.

		Fixed Number of predictors		
	Variable Predictors	4	6	8
	(a)	(b)	(c)	(d)
N	.531 (4)	.531	.569	.591
NSD	.541 (5)	.489	.559	.583
H	.459 (4)	.459	.506	.526
HD	.505 (5)	.460	.517	.549
IH	.510 (4)	.520	.552	.572
IHD	.362 (3)	.378	.465	.491
HDP	.504 (5)	.455	.518	.542
NTC	.566 (6)	.490	.573	.599
MPD	.613 (5)	.573	.630	.644

Columns 1-3 lists all of our statistical forecasts, column 4 contains our best qualitative adjusted "final" forecasts, and column 5 provides the climatological mean for each parameter for 1950-1990. We have made a small upward adjustment of our early December forecast. An average hurricane season is expected.

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

Full Forecast Parameter	(1) Variable Predictor	(2) Fixed predictors 4 Predictors	(3) Fixed predictors 6 Predictors	(4) Adjusted Actual Fcst	(5) 1950-1990 Climatology
Named Storms (NS)	8.71 (4)	8.71	9.63	10	9.3
Named Storm Days (NSD)	49.95 (5)	49.16	46.40	50	46.6
Hurricanes (H)	6.10 (4)	6.10	4.66	6	5.8
Hurricane Days (HD)	21.14 (5)	19.53	14.16	20	23.9
Intense Hurricanes (IH)	2.88 (4)	2.74	2.70	2	2.3
Intense Hurricane Days (IHD)	3.61 (3)	3.13	0.39	4	4.7
Hurricane Destruction Potential (HDP)	64.22 (5)	40.99	62.91	65	71.2
Net Tropical Cyclone Activity (NTC)	86.78 (6)	66.63	54.05	95	100
Maximum Potential Destruction (MPD)	63.98 (5)	68.81	62.63	65	66

We consider the variable predictor scheme to be our best forecast. Table 4 shows the statistical spread of our predictors as well as our hindcast skill and expected likely skill with independent data.

Table 4: Statistical spread of parameter forecast and comparison of hindcast and likely independent forecast skill.

Fcst Parameter	No. of Prediction	Lowest 25% Below	Fore-cast	Highest 25% Above	Hindcast Skill	Likely Independent Forecast Skill
NS	(4)	8.19	8.71	10.19	.531	.369
NSD	(5)	44.28	49.95	54.65	.541	.379
H	(4)	4.89	6.10	6.79	.459	.254
HD	(5)	14.45	21.14	25.21	.505	.324
IH	(4)	2.30	2.88	3.36	.510	.337
IHD	(3)	2.12	3.61	5.48	.362	.204
HDP	(5)	35.48	64.22	75.11	.504	.323
NTC	(6)	66.59	86.78	99.79	.566	.411
MPD	(5)	56.77	63.98	71.42	.613	.478

Discussion

Forecast signals for 1998 contain a mix of positive and negative influences. Of the 13 potential predictors listed in Table 1, six (those associated with the QBO and last year's West African rainfall) indicate below average activity, whereas the other seven factors indicate above average activity for 1998. Additional climate factors favorable for 1998 hurricane activity in the Atlantic basin which are not believed to be fully reflected in our objective April predictions include:

1. A large weakening of the Atlantic subtropical ridge or Azores high 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 along Western Africa and South America and leads in warmer waters and lower sea level pressure in the tropical Atlantic this coming summer.

2. Projected equatorial Atlantic SST anomalies in the Gulf of Guinea area south of the West Africa bulge are forecast (IRI, 1998) to become cold while the tropical Atlantic west of Africa (i.e., off the coast of Mauritania and Senegal) is presently warm and is projected to remain warm. If these SSTA patterns do occur (as we expect them to), this should be an enhancing influence for both West African rainfall and associated intense hurricane activity this season. We now expect rainfall conditions for the Western Sahel region this summer to be somewhat above average and higher than those anticipated in our early December 1997 forecast (Landsea et al. 1997).

3. Broad scale North Atlantic SSTA patterns are warm for the fourth consecutive year, implying 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–March 1998 period indicates a persistence of a stronger than normal Atlantic Ocean thermohaline circulation. Such ocean circulation changes are typically associated with increased intense or major hurricane activity.

4. More evidence (and hence, greater confidence) that the strongest El Niño on record will be largely dissipated by August 1998. Anomalously cold Pacific equatorial sub-surface ocean water is presently moving upward and eastward. Below average (cold) water should begin upwelling along the eastern Pacific equator in the next 2-3 months. East Pacific subtropical highs in both the Northern and Southern Hemisphere are now becoming stronger and trade winds should soon be established. Both of these influences should lead to a speedy termination of the present El Niño by this summer.

5. Middle latitude Atlantic wind patterns during the winter of 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.

6. Lower than normal 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 5 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.

Table 5: 1 April 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

In summary, data through the end of March indicate that 1998 will experience hurricane activity above that to be expected for an easterly stratospheric QBO year and in a year when a strong El Niño is still present near the start of the season.

4. Current El Niño Influences on the 1998 Hurricane Season

A difficult aspect of our 1998 forecast is predicting the rate of dissipation of the current El Niño and determining if there are going to be an El Niño induced residual influences on this year's hurricane season. This assessment involves prediction of both the El Niño dissipation rate through summer 1998, as well as gauging delayed El Niño induced negative residual influences. Hurricane seasons in years of fading 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 quite inactive while those years of 1906, 1915, 1926, 1958, 1966, and 1995 (following the El Niño years of 1905, 1914, 1925, 1957, 1965, and 1994) were quite active. Table 6 lists these years.

Table 6: 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 presently believe that the 1998 hurricane season will be more typical of the active hurricane years associated with fading El Niños. Atlantic basin ocean and atmospheric circulation conditions as manifested by the Atlantic subtropical ridge pressure, 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.

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 –0.03°C and –0.06°C, respectively. Hence, we believe that the current ENSO will cool rapidly over the next 3-4 months and 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. Figure 3 indicates how we project the current El Niño to fade out.

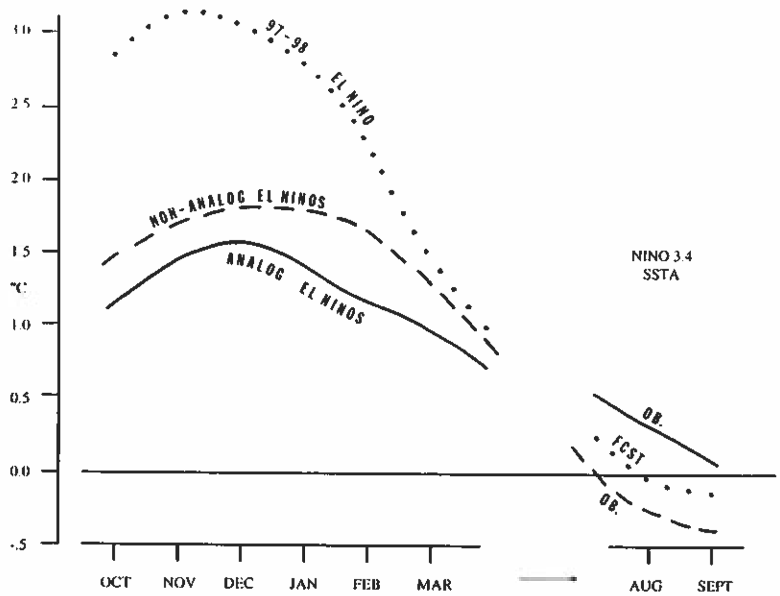

Figure 3: Portrayal of Nino-3.4 SST anomaly and how El Niños fade away during the six analog years and the six non-analog years in comparison with the 1997-1998 event. Most warming is gone by the main portion of the hurricane season.

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 the El Niños of 1905, 1914, 1925, 1957, 1965 and 1994. These are the best "analog" years to 1998. These years are to be contrasted with the non-analog years to 1998 of weakening El Niño years of 1919, 1931, 1973, 1983, 1987, 1992, following the El Niño years of 1918, 1930, 1972, 1982, 1986, and 1991. Table 7 shows the differences in seasonal activity in active (analog years) versus inactive (non-analog) years. Observations support 1998 being an analog year. This inference is a consequence of several early year 1998 Atlantic basin and circulation trends including:

1. inferred stronger Atlantic Ocean thermohaline circulation
2. the weaker Atlantic wind gyre as indicated by a weaker subtropical ridge (Azores high),
3. expected below average SLPA conditions in the tropical Atlantic

4. observed above average north and tropical Atlantic SST anomalies, and
5. anticipated above average Western Sahel rainfall conditions.

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	

Table 8 lists contrasting information for Atlantic basin circulation features associated with analog years which had retreating El Niños versus those retreating El Niño years when Atlantic basin conditions were different than 1998, the "non-analog" 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

Table 9: Comparison of Atlantic basin 1 April forecast parameters for analog versus non-analog years.

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

Given the hurricane enhancing warm Atlantic SST and low Azores subtropical ridge conditions, we expect that the negative influences of the likely easterly QBO to be more than canceled out and that a near average 1998 hurricane season will ensue.

5. Likely Cause of Unusually Strong 1997-1998 El Niño

Our 1997 hurricane underestimation was due to our inability to anticipate the coming strength of the strongest El Niño on record. The West Pacific equatorial warm water pool was stronger than we realized. Figure 4 shows that the weak El Niño warming events of 1991 through 1994 probably did not significantly deplete the warm pool. Since the last major El Niño of 1986-87, the warm water pool was very large. This "poised for release" warm water pool was then set off by a number of 40-50 day oscillation westerly wind events and from the development of a number of long lasting tropical cyclones which also caused equatorial wind to also be from the west. This was a very unusual combination of events.

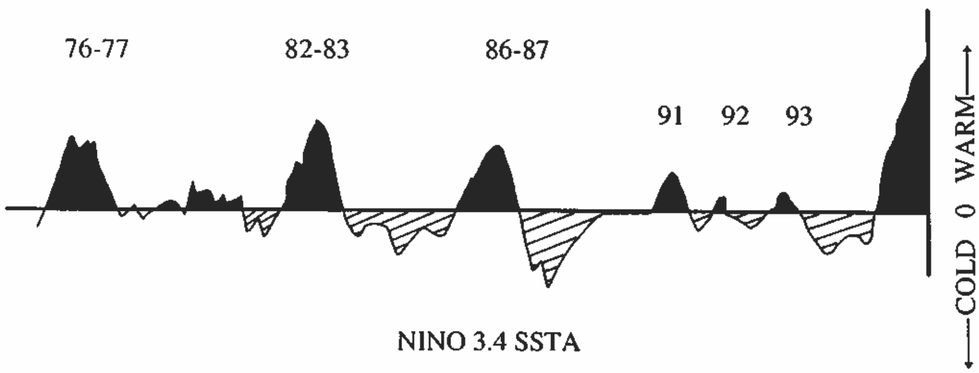

Figure 4: Portrayal of Nino-3.4 SST anomalies from 1975 on a trended upward warming curve. Note that the strong 1997 event was the first major El Niño since 1986-1987.

6. Prospects for a Long Term Increased 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 late 1960s and extended to 1994. We believe that this trend was associated with the concurrent slowing of the North Atlantic thermohaline circulation during this period which resulted in North Atlantic SSTs cooling and South Atlantic SSTs warming during these decades. Presuming that the opposite ocean circulation trends are now in fact developing, 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. Increased salinity increases sea water density allowing it to sink to great depths, 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 and recent deep water observations in the North Atlantic reveal that fairly stagnant water has been present for a decade or more. There are 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 5 shows average SST anomaly changes between the three-year periods 1992-93-94 and 1995-96-97. Some notable broad area changes include 1.4 to 0.6°C in the north-east and tropical Atlantic regions, respectively. We expect that as occurred during 1995 and 1996, this developing 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.

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 specifically predict where within the Atlantic basin storms will strike. Regardless of whether 1998 should prove to be an above or a below average hurricane season or not, 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 we will likely have an active hurricane season 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 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.

9. Acknowledgements

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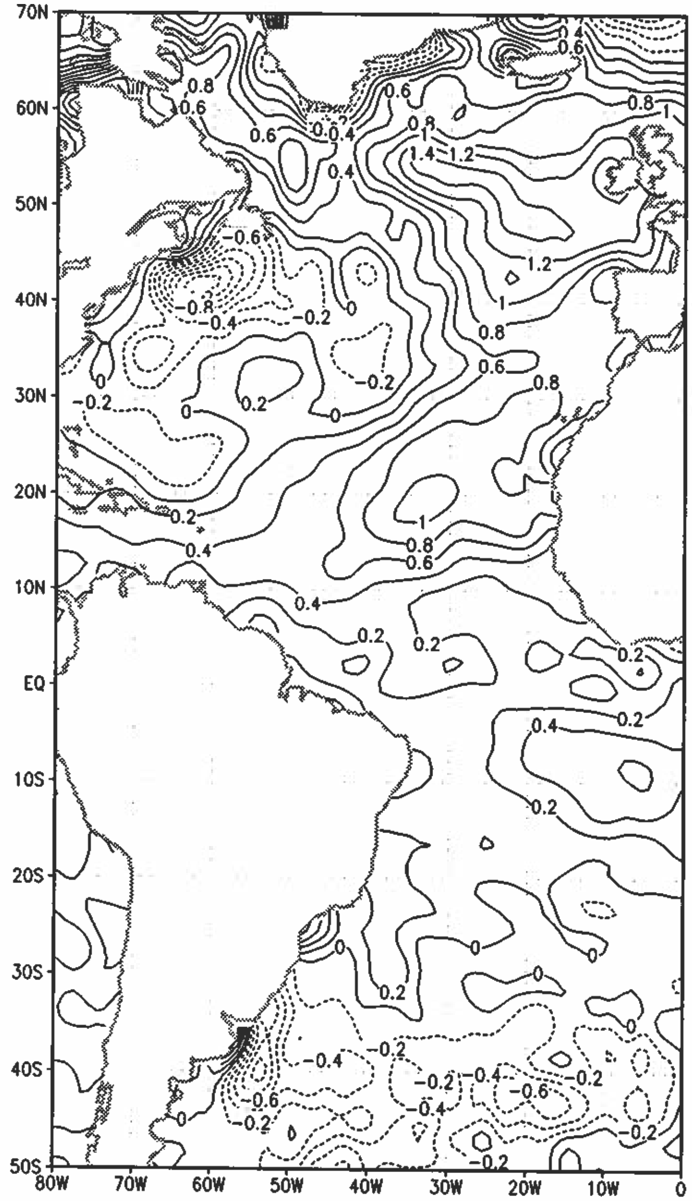

Figure 5: Portrayal of SST difference of August through October of 1995-96-97 minus the same months for 1992-93-94. Values are in °C.

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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.

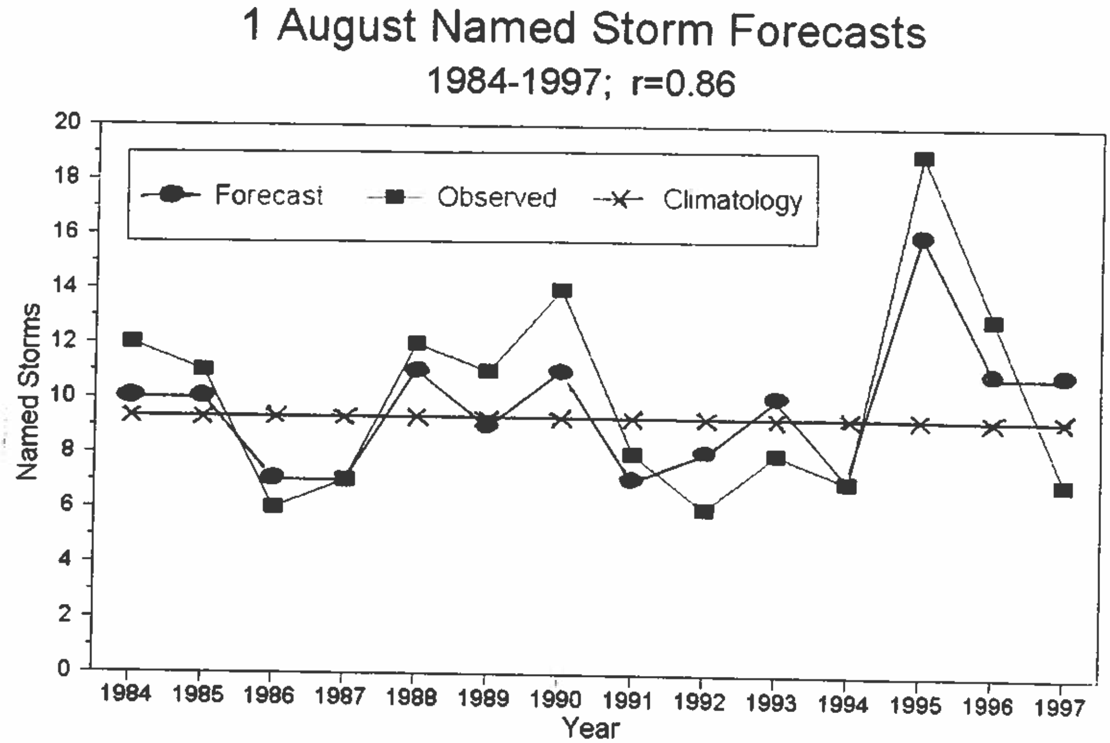

Figure 6: 1 August prediction of total named storms versus the number of actually observed versus long-term climatological mean (r = 0.86) for period 1984–1997.

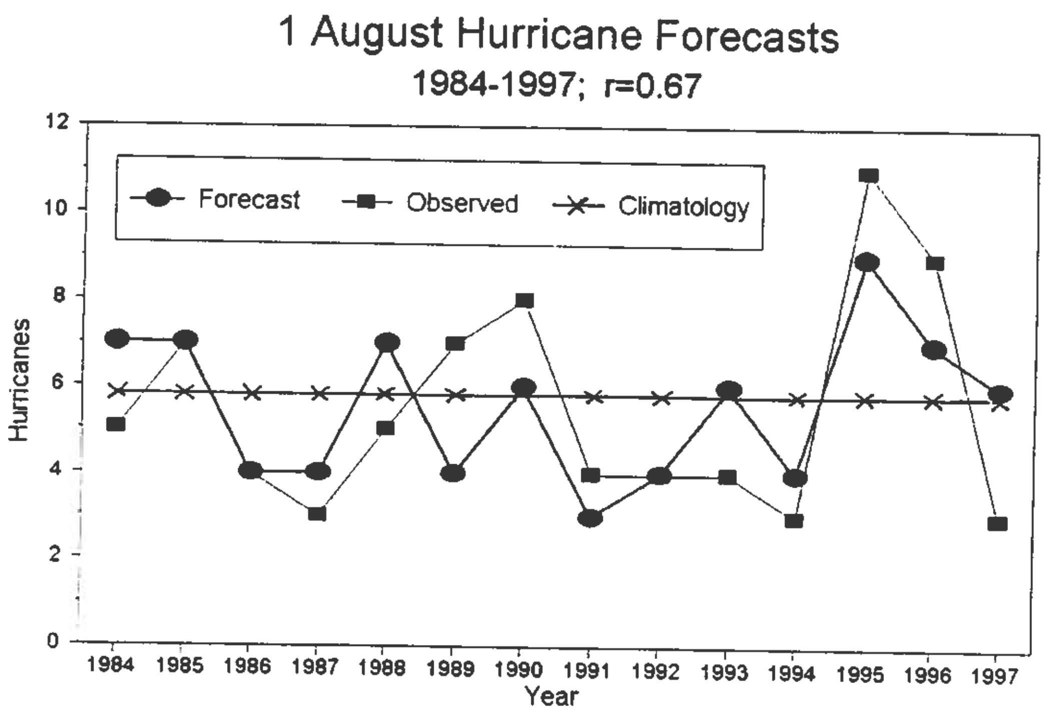

Figure 7: 1 August prediction of total hurricanes versus the number of actually observed versus climatological long-term mean (r = 0.67).

Table 10: 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