SUMMARY OF 1997 ATLANTIC TROPICAL CYCLONE ACTIVITY AND VERIFICATION OF AUTHORS' SEASONAL PREDICTION

A year of below normal hurricane activity and a busted forecast. This was a consequence of an unprecedentedly strong El Niño event. The strength of the 1997 El Niño was not anticipated by any prediction models. It just overwhelmed a host of other positive hurricane enhancing factors.)

(as of 26 November 1997)

(A hurricane forecast for 1998 will be issued on 5 December 1997)

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[This summary is also available on the World Wide Web at the following URL: http://tropical.atmos.colostate.edu/forecasts/index.html] — also,

Ms. Carrie Schafer or Thomas Milligan, Media Representatives for Colorado State University, (970-491-6432) are available to answer questions concerning this forecast

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METEOROLOGISTS ARE USUALLY BRILLIANT AT AFTER-THE-FACT RECONSTRUCTION OF WHAT WENT WRONG WITH THEIR FORECASTS. THIS WILL HOPEFULLY LEAD TO IMPROVEMENT OF FUTURE FORECASTS.

DEFINITIONS

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

El Niño - (EN) A 12-18 month period during which anomalously warm sea surface temperatures occur in the eastern half of the equatorial Pacific. Moderate or strong El Niño events occur irregularly, about once every 3-7 years 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 for each named storm (see Appendix A for a listing of values for 1950-1995).

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) Anomaly(s).

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.

Delta PT - A parameter which measures anomalous east to west surface pressure (ΔP) and west to east surface temperature (ΔT) gradients across West Africa.

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

This paper summarizes the tropical cyclone (TC) activity which occurred in the Atlantic Basin during 1997 and verifies the authors' seasonal forecast of this activity which was initially issued on 6 December of last year, with updates on 4 April, 6 June and 6 August of this year. The 1997 hurricane season was characterized by reduced levels of tropical cyclone activity. There was a total of 7 named storms (average is 9.3) and 3 hurricanes (average is 5.8) which persisted for a total of only 10 days (average is 24). There was 1 major (intense) hurricanes of Saffir/Simpson category 3-4-5 (average is 2.3 intense hurricanes) with but 2 intense or major storm days (average is 4.7). The seasonal total of named storm days was 28 or only 60 percent of the long-term average. Net tropical cyclone (NTC) activity was 54 percent of the average years of 1950–1990. Despite having a reduced level of tropical cyclone activity the 1997 season was still more active in terms of NTC than 10 other of the last 30 hurricane seasons.

Our early 1997 forecasts called for a slightly above average hurricane season, our 6 August forecast was for an average season. This overforecast of activity was a result of our inability to anticipate that we would experience the most extreme El Niño event ever to be recorded during the period of June through October. This unprecedented El Niño dominated other normally hurricane-enhancing forecast signals, leading to a larger reduction in this year's hurricane activity than would have occurred if this El Niño had not been so intense. Had we only experienced a strong El Niño like 1972 and 1982 (as we anticipated in late July) it is likely that our forecasts would have benn close.

1 Introduction

The Atlantic basin (including the Atlantic Ocean, Caribbean Sea, and Gulf of Mexico) experiences more season-to-season hurricane variability than any of the other global tropical cyclone basin. The number of Atlantic Basin hurricanes per season in recent years has ranged as high as 12 (as in 1969), 11 (as in 1950 and 1995) and 9 (as in 1980, 1955), and as low as 2 (as in 1982) and 3 (1994, 1987, 1983, 1972, 1962, 1957). Until recent years there has been no objective methods for determining whether a forthcoming hurricane season was likely to be active, inactive, or near normal. Recent and ongoing research by the authors (see Gray, 1984a, 1984b, 1990; Landsea, 1991; Gray *et al.*, 1992, 1993a, 1994) indicates that there are surprisingly skillful 3-to-11 month (in advance) predictive signals for Atlantic basin seasonal hurricane activity. This research has led us to the issuance of extended-range forecasts of Atlantic Basin hurricane activity in early December with updates in early April, early June, and early August of each year.

2 Factors Known to be Associated With Atlantic Seasonal Hurricane Variability

Our various lead-time forecasts are based on the current values of indices derived from various global and regional scale predictive factors which the authors have previously shown to be statistically related to seasonal variations of Atlantic Basin hurricane activity. Figure 1 provides a summary of the locations of the various forecast parameters which go into our different lead time

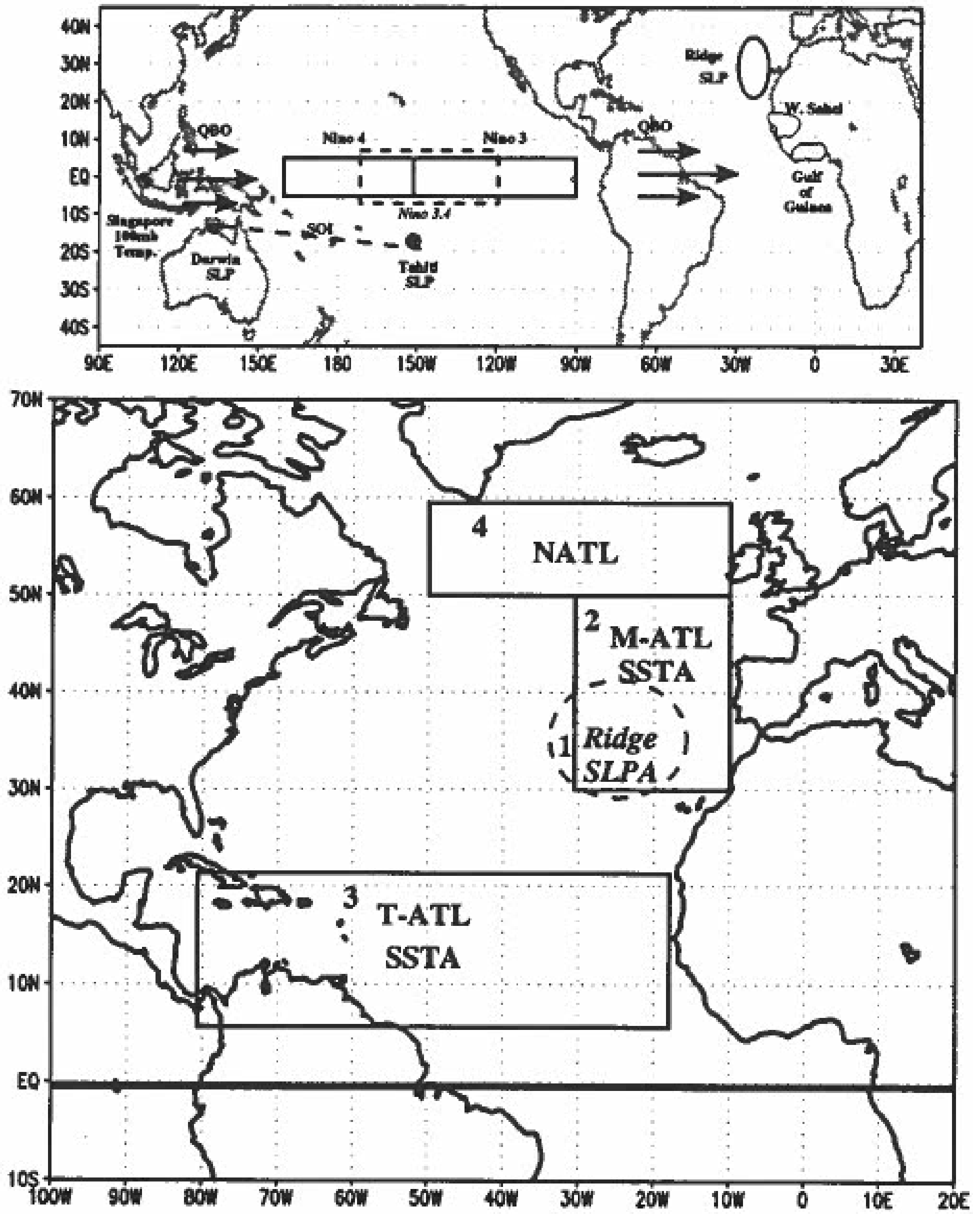

Figure 1: Source locations of meteorological parameters used in the seasonal forecasts. Symbols are defined on pages 3-5. The top diagram shows the locations of the global predictors. [Equatorial Pacific sea surface temperature anomaly indices (°C) for the areas indicated]. Note that Niño 3.4 is comprised of portions of Niño-4 and Niño-3. The bottom diagram shows the source locations for predictors in the Atlantic Ocean region.

forecasts. Our methodology statistically optimizes the predictive signals of these various forecast parameters. Predictors include:

(a) El Niño-Southern Oscillation (ENSO): ENSO is characterized by sea surface temperature anomalies in the eastern equatorial Pacific in the areas of Nino 1-2, 3, 3.4 and 4 (Fig. 1), the value of Tahiti minus Darwin surface pressure gradient, and the amount of equatorial deep convection near the Dateline. When present, it causes a disruption of the global circulation fields. (The effects of a moderate or strong El Niño event are, typically to reduce Atlantic basin hurricane activity). By contrast, in those seasons with cold sea surface temperatures, high values of Tahiti minus Darwin surface pressure occur (La Niña years), and reduced deep equatorial convection near the Dateline is present, there is typically an enhancement of Atlantic basin hurricane activity.

(b) The stratospheric Quasi-Biennial Oscillation (QBO). The QBO refers to the variable east–west oscillating stratospheric winds which encircle the globe near the equator. On average, there is nearly twice as much intense (category 3-4-5) Atlantic basin hurricane activity during those seasons when equatorial stratospheric winds at 30 mb and 50 mb (23 and 20 km altitude, respectively) blow from a westerly as compared to an easterly direction.

(c) African Rainfall (AR): The incidence of intense Atlantic hurricane activity is enhanced during those prior years or season when June-September Western Sahel rainfall and previous year August-November Gulf of Guinea region have above average precipitation. Hurricane activity is typically suppressed if the rainfall of the prior year or season in these two regions is below average.

(d) Previous Year October-November and March northeast Atlantic Subtropical Ridge Strength (ONR). When this pressure ridge is anomalously weak during the previous autumn and spring periods, the eastern Atlantic trade winds are weaker. This condition (weak ridge) is related to a decrease in mid-latitude cold water advection and upwelling off the northwest African coast as well as decreased evaporative cooling rates in this area of the Atlantic. A weak ridge leads to warmer sea surface temperatures which carry over into the following summer period and lead to more season hurricane activity. Weaker hurricane activity occurs when the October-November and spring pressure ridge is anomalously high.

(e) Atlantic Sea Surface Temperature Anomalies (SSTA) in the three regions (MATL; 30-50°N, 10-30°N and TATL; 6-22°N, 18-82°W) during April through June and NATL; 50-60°N, 10-50°W and TATL during January through March: See Fig. 1 (bottom) for the location of these areas. Higher SSTAs enhance deep oceanic convection and, other factors aside, provide conditions more conducive for tropical cyclone activity.

(f) Caribbean Basin Sea Level Pressure Anomaly (SLPA) and upper tropospheric (12 km) Zonal Wind Anomaly (ZWA): Spring and early summer SLPA and ZWA have a moderate predictive potential for hurricane activity occurring during the following August through October months. Negative anomalies (i.e., low pressure and easterly zonal wind anomalies) imply enhanced seasonal hurricane activity while positive values imply suppressed hurricane activity.

(g) Influence of West Africa west-to-east surface pressure and temperature gradients (Δ PT): Anomalous west-to-east surface pressure and temperature gradients across West Africa from February through May are typically correlated with the hurricane activity which follows later in the year. Our varying lead-time forecast schemes are created by maximizing the pre-season forecast skill from a variety of the above predictors in combination from the period 1950–1995.

3 Statistical Summary of 1997 Atlantic Tropical Cyclone Activity

The 1997 Atlantic hurricane season officially ends on 30 November. There were three hurricanes and 10 hurricane days during the 1997 season. The total named storms (or, the number of hurricanes plus tropical storms) was seven, yielding 28 named storm days. Moreover, there was one major (or intense) hurricanes this season. All designated tropical cyclone activity parameters were below the long term average. Figure 2 and Table 1 show the tracks and give statistical summaries, respectively, for the 1997 season. Table 2 also characterizes 1997 seasonal tropical cyclone activity in terms of percentages of the 1950-1990 climatology.

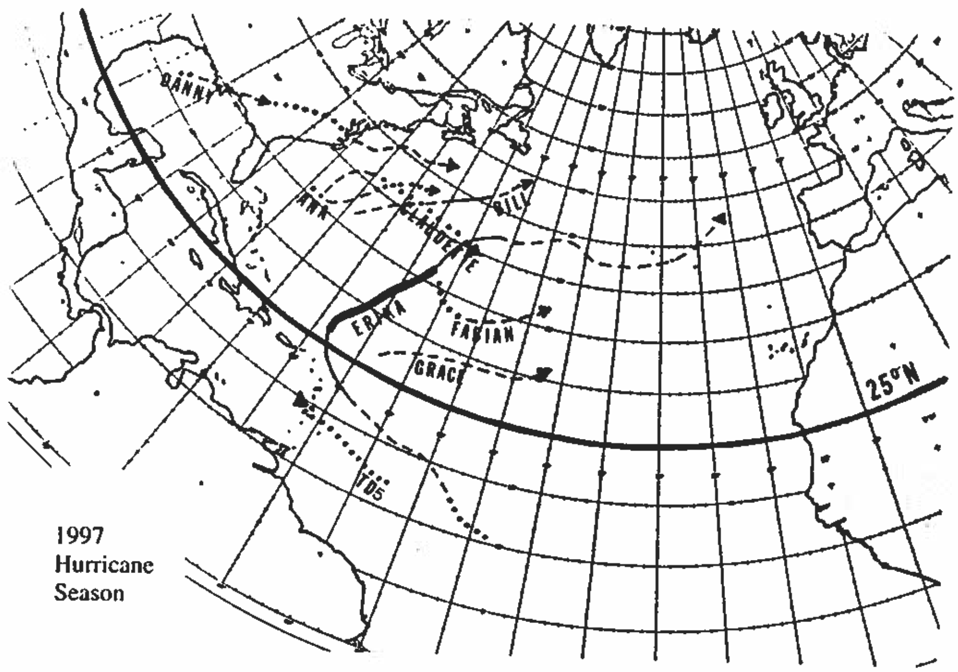

Figure 2: Tracks of the seven 1997 named tropical cyclones. Dashed lines indicate the tropical storm intensity stage, thin solid lines indicate the Saffir/Simpson hurricane category 1-2 stage, and the thick lines show the intense (or major) hurricane category 3-4-5 hurricane stage. Note dots indicate depression stage.

By all measures, the 1997 season was an inactive one but not so inactive as 10 other of the past 30 hurricane seasons. Ranking season by the measure of Net Tropical Cyclone (NTC)[5] the hurricane seasons of 1968, 1972, 1973, 1977, 1982, 1983, 1986, 1987, 1993 and 1994 were less active than 1997 despite the extreme 1997 El Niño. The modest level of activity that did occur was a result of a number of counteracting, favorable, hurricane-enhancing factors such as a westerly QBO, warm Atlantic SST anomalies and low values for the western Atlantic Sea Level Pressure Anomaly (SLPA).

UNIQUE CHARACTERISTICS OF THE 1997 HURRICANE SEASON

[5]Average of the percentage of the long term mean of the six seasonal number of Named Storms (NS), Named Storm Days (NSD), Hurricanes (H), Hurricane Days (HD), Intense (category 3-4-5) Hurricanes (IH), and Intense Hurricane Days (IHD).

Table 1: Summary of information for named tropical cyclones occurring during the 1997 Atlantic tropical cyclone season. Information on Tropical Storm (TS), Hurricanes (H) and Intense Hurricanes (IH) with highest Saffir/Simpson category is shown. Information was supplied, courtesy of the National Hurricane Center.

	Named Storm	Peak Category	Dates of > = TD	Peak Sustained Wind (in kts)	NSD	HD	IHD	HDP
1.	Ana	TS	Jun 30-Jul 4	40	2.50	0	0	0
2.	Bill	H-1	Jul 11-13	65	1.8	0.50	0	1.3
3.	Claudette	TS	Jul 13-16	40	2.8	0	0	0
4.	Danna	H-1	Jul 16-26	70	4.8	1.8	0	3.2
5.	Erika	IH-3	Sep 3-15	110	12.2	7.2	2.2	21.6
6.	Fabian	TS	Oct 5-8	35	2.8	0	0	0
7.	Grace	TS	Oct 16-17	40	1.50	0	0	0
	Totals				28.4	9.5	2.2	26.1

Table 2: Summary of the 1997 seasonal hurricane in comparison with long-term average conditions.

Forecast Parameter	1950–1990 Mean	1997	1997 in % of 1950-1990 Ave.
Named Storms (NS)	9.3	7	75
Named Storm Days (NSD)	46.6	28	60
Hurricanes (H)	5.8	3	52
Hurricane Days (HD)	23.9	10	42
Intense Hurricanes (IH)	2.3	1	43
Intense Hurricane Days (IHD)	4.7	2.2	47
Hurricane Destruction Potential (HDP)	71.2	26	37
Maximum Potential Destruction (MPD)	66.0	26	39
Net Tropical Cyclone Activity (NTC)	100	54	54

1. An early start. Four of the seven named storms (Ana, Bill, Claudette and Danny) occurred before 18 July. Only 1959 (5), 1966 (5) and 1995 (5) had more named storms by the first of August. There has never been a year since 1929 when only one named storm formed in August and September. There were no named storms in August for the first time since 1961 and only one hurricane (intense or category 3-4-5 Erika) in September, and two tropical storms in October (Fabian and Grace).

2. All but one of the seven named storms in 1997 formed poleward of 25°N. This trend is characteristic of a year with a strong El Niño when deep tropical cyclone development (latitude < 25°N is suppressed. When this happens, subtropical (25 – 40°N) development is typically enhanced as occurred this year. Given the usual strength of this year's El Niño it is surprising that it was possible for even one intense hurricane (Erika) to develop at low latitudes (Kimberlain et al. 1988).

a) The Extremely Strong 1997 El Niño

Eastern equatorial Pacific sea surface temperature (SST) anomaly conditions (in °C) in Niño-1-2, 3, 3.4 and 4 (see Fig. 1 for locations) are shown in Table 3. Unusually warm water developed rapidly with the highest SST anomaly conditions ever recorded for the June to October period. In addition, the Tahiti minus Darwin surface pressure difference or SOI was quite low and Outgoing Longwave Radiation (OLR) values near the Dateline were much reduced, indicating the presence of usually large amounts of deep convection. This magnitude of El Niño conditions is judged to be an overwhelming factor in causing the large suppression of this year's Atlantic hurricane activity and the reason for our overforecast.

Table 3: April through October 1997 Niño area sea surface temperature anomalies in °C.

	June–October	August–October
Niño-1-2	4.08	4.15
Niño-3	2.95	3.30
Niño-3.4	2.21	2.51
Niño-4	0.96	0.97

b) Stratospheric QBO Winds

Tables 4 and 5 show both the absolute and relative (i.e., anomaly) values of 30 mb (23 km) and 50 mb (20 km) stratospheric QBO zonal winds near 12°N during the period of March through October 1997. During the height of the 1997 hurricane season, QBO winds were from a relatively westerly direction. These QBO wind conditions likely were an enhancing influence for the hurricane activity that did occur.

c) Sea-Level Pressure Anomaly (SLPA)

Table 6 gives information on regional Caribbean basin and Gulf of Mexico SLPA during the 1997 season. Note that, except for August, the western Atlantic did not have high values of SLPA as is typical during suppressed hurricane years and we did not anticipate positive pressure anomaly to develop this year. Knaff's (1997) Atlantic SLPA forecast scheme for 1997 was correct in predicting slightly below average pressure conditions.

d) Zonal Wind Anomalies (ZWA)

Table 4: Observed March through October 1997 observed values of stratospheric QBO zonal winds (U) in the (critical) latitude belts between 11-13°N, as obtained from Caribbean stations at Curacao (12°N), Barbados (13°N), and Trinidad (11°N). Values are in ms^{-1} (as supplied by James Angell and Colin McAdie).

	Observed							
Level	March	April	May	Jun	Jul	Aug	Sept	Oct
30 mb (23 km)	+3	+2	–3	–5	–5	–5	–4	–1
50 mb (20 km)	–4	–2	0	+4	+6	+2	+1	+3

Table 5: As in Table 4, but for the 1997 "relative" (or anomalous) zonal wind values wherein the annual wind cycle has been removed. Values are in ms^{-1}.

	Observed							
Level	March	April	May	Jun	Jul	Aug	Sept	Oct
30 mb (23 km)	+8	+9	+11	+12	+13	+13	+12	+12
50 mb (20 km)	–4	–2	0	+4	+6	+11	+11	+12

Table 6: Lower Caribbean basin SLPA for 1997 in mb (for San Juan, Barbados, Trinidad, Curacao and Cayenne) - top row and for the Caribbean-Gulf of Mexico. Brownsville, Miami, Merida (Mexico), San Juan, Curacao and Barbados - bottom row (as kindly supplied by Colin McAdie of NHC in combination with our CSU analysis). Values in millibars (mb).

	Apr	May	Jun	Jul	Aug	Sep	Oct
5-station Lower Caribbean Ave. SLPA	+1.2	+1.2	–0.5	+0.4	+1.8	–0.1	–0.5
6-station Caribbean plus Gulf of Mexico Ave. SLPA	–0.1	+1.5	–0.5	+0.4	+1.5	–0.1	–0.4

Table 7 shows that the upper tropospheric (12 km or 200 mb) Zonal Wind Anomalies (ZWA) were strongly positive (westerly) in all months. These large positive ZWA values were fundamental in explaining why the 1997 season was so inactive. The strong westerly winds sheared off the tops of the easterly waves moving westward from Africa and prevented the organization of all but one of these easterly waves. Such positive ZWA values are typical of El Niño years.

Table 7: 1997 Caribbean basin 200 mb (12 km) Zonal Wind Anomaly (ZWA) in ms^{-1} (as supplied by Colin McAdie of NHC and in combination with CSU data) for the four stations including Kingston (18°N), Curacao (12°N), Barbados (13.5°N), and Trinidad (11°N).

	April	May	June	July	August	September	October
Average ZWA	+0.2	+1.8	–1.5	+4.5	+3.6	+3.7	+3.5

e) African Western Sahel Rainfall in 1997

The Western Sahel region of Africa was quite dry this year, much drier than we had expected. Information received from 17 of our best stations in the Western Sahel (Fig. 1) indicate the June through September rainfall was –0.91 Standard Deviation below average, or the 6th driest year of the last 46 years. This was unexpected and likely a result of the anomalously high surface pressure which developed off of West Africa and the associaed presence of an El Niño. Analysis has shown that Western Sahel rainfall is typically suppressed in past El Niño years.

4 Verification of Individual Lead Time Forecasts

Table 8 compares our various lead time forecasts for 1997 with their verification, while Table 9 provides a more detailed verification of our after 1 August forecast. As is evident, all our forecasts overestimated the seasonal amounts of 1997 hurricane activity. Given the strength of this year's El Niño, we are, afterward, not surprised by the weak season that developed. Our forecasts are based upon past data. The years used to develop our forecast schemes did not include the unprecedented El Niño conditions experienced this year. We feel confident that future forecasts will not suffer as they did this year.

5 Reasons for Large Overforecast of 1997 Hurricane Activity

We did not expect such an inactive 1997 hurricane season. Our overforecast is due to the extreme El Niño event (the strongest on record for the time of year) that neither we nor anyone else had anticipated. Figure 3 compares the 1997 El Niño's June through October SST anomalies with the three strongest El Niño period onsets since 1950. Note how much stronger the 1997 El Niño was. Figure 4 compares the March to October changes in Nino 1-2 and Nino 3 SST anomaly in comparison with other El Niño onset years since 1950. Note the much greater strength of the 1997 event. Table 10 compares the 1997 June through October strength with previous strong El Niños during June through October. El Niños are listed in decreasing intensity by SST anomaly within the Nino 3 region. Data goes back to 1870 and is obtained from two sources, that between 1950–1997 coming from Smith et al. (1996) analysis and data for the period of 1870-1986 from Wright (1989). Wright's data provides an estimate of eastern equatorial Pacific SST anomalies in a

Table 8: Verification of our 1997 total seasonal hurricane predictions.

Forecast Parameter	1950-1990 Mean	6 Dec 1996 Fcst.	Apr 4 1997 Fcst.	Jun 6 1997 Fcst.	Aug 5 1997 Fcst.	1997 Observed Activity
Named Storms (NS)	9.3	11	11	11	11	7
Named Storm Days (NSD)	46.9	55	55	55	45	28
Hurricanes (H)	5.8	7	7	7	6	3
Hurricane Days (HD)	23.7	25	25	25	20	10
Intense Hurricanes (IH)	2.2	3	3	3	2	1
Intense Hurricane Days (IHD)	4.7	5	5	5	4	2.2
Hurricane Destruction Potential (HDP)	70.6	75	75	75	60	26
Maximum Potential Destruction (MPD)	66.0	70	70	70	60	26
Net Tropical Cyclone Activity (NTC)	100%	110%	110%	110%	100%	54%

Table 9: Verification of 6 August 1997 forecast for hurricane activity after 1 August.

Forecast Parameter	Climatology After 1 Aug	Forecast 1996 Activity After 1 Aug	1997 After 1 Aug Verification
Named Storms (NS)	7.8	7	3
Named Storm Days (NSD)	41	35	17
Hurricanes (H)	5.1	4	1
Hurricane Days (HD)	21.4	18	7
Intense Hurricanes (IH)	2.0	2	1
Intense Hurricane Days (IHD)	4.4	3	2
Hurricane Destruction Potential (HDP)	64.4	56	22
Maximum Potential Destruction (MPD)	57.1	51	15
Net Tropical Cyclone Activity (NTC)	86%	82%	34.5%

region of the Pacific roughly representative of Nino 3. Comparing Smith et al. (1996) and Wright's (1989) data for the overlapping periods of 1950–1984 it is possible to make a systematic correction to normalize the Wright values to those of Smith et al. (1996). Using this adjusted information as a measure of the El Niño's strength we are able to compare El Niños strength during June through October for the last 125 years. Note that the 1997 June through October El Niño was stronger than all other previous El Niños since 1870 by a factor of nearly 2 to 3.

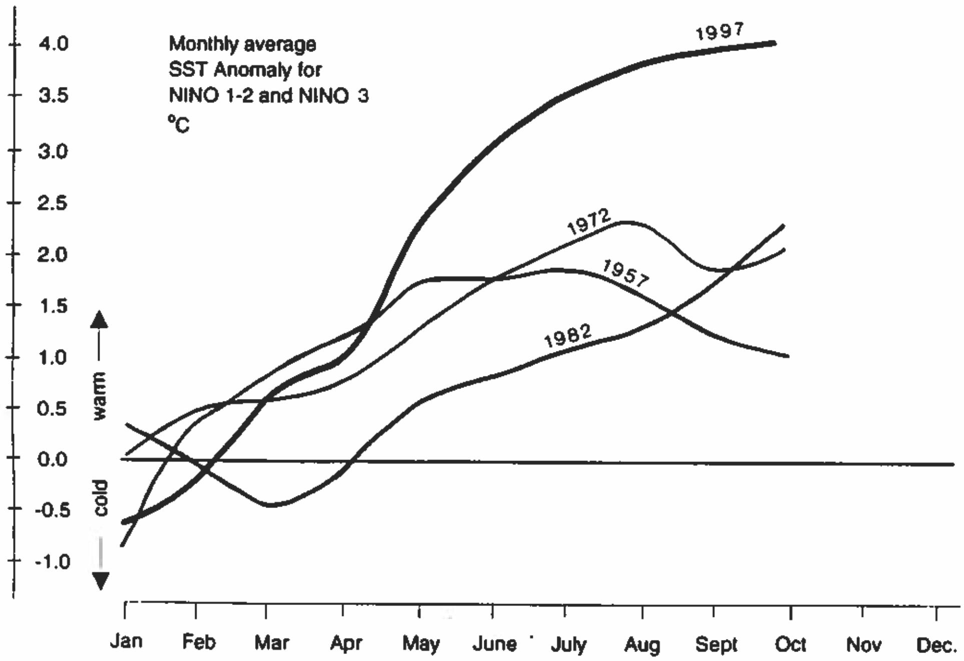

Figure 3: Contrast of the magnitude of the extreme 1997 El Niño with this year's unprecedentedly strong El Niños of 1957, 1972, 1982 for the period of January through October. Note: the 1982–83 season peaked during the spring of 1983.

Given the unexpected magnitude of the 1997 El Niño, it is surprising that there was as much hurricane activity as there was. The activity that did occur was a result of a number of hurricane enhancing climate and circulation factors which acted to reduce some of the 1997 El Niño's suppressing influences.

It is possible to make an estimate of the likely hurricane suppressing influence of this year's extreme El Niño event by analyzing the typical difference between the hurricane activity of warm and cold ENSO years and assuming that these typical ENSO hurricane modifications applied to this year.

Table 11 gives differences in average hurricane activity between the period of 1950–1996 when Nino 1-2 and Nino 3 mean SST anomalies were the warmest (14) and when they were the coldest (14). This gives a general quantitative estimate of the typical ENSO influences on seasonal hurricane behavior. Using this information we can then factor out much of the El Niño influence upon this year tropical cyclone activity.

It would be expected that most of the individual year positive and negative non-ENSO influences would be largely averaged out in a 14-year average. Table 11 illustrates the large average differences in hurricane activity between warm and cold ENSO years. The ratio of average cold to average warm year activity varies for 1.40 for named storms, 1.79 for hurricane days and 2.94 for intense

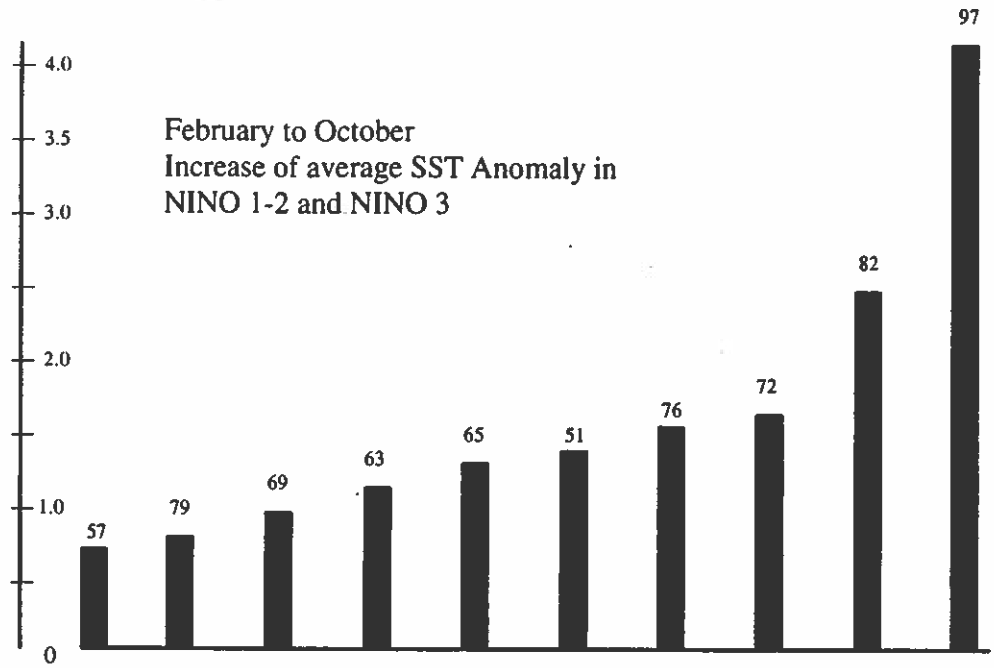

Figure 4: Range of all onset El Niños between 1950–1997 by their February to October warming. Years are given above each column. 1997 far outranks all other years.

Table 10: Ranking of June through October 12 highest El Niño magnitudes as defined by Nino 3 SST anomaly in °C.

Year	SSTA
1997	2.95
1972	1.79
1987	1.74
1982	1.66
1902	1.46
1877	1.39
1965	1.37
1940	1.21
1957	1.11
1914	1.11
1896	1.09

(category 3-4-5) hurricane days.

Note that there is a wide spread of hurricane activity between individual years within each 14 year cold and warm grouping. This is due to the influence of multiple non-ENSO parameters which also effect hurricane activity such as the QBO, Atlantic SSTA/SLPA, West African rain, etc.

Using this methodology, we can estimate the amount of hurricane activity that should have occurred in 1997 had all other non-ENSO seasonal influences been neutral. Figures 5 and 6 illustrate how this would be done for named storms (NS) and Net Tropical Cyclone (NTC) activity. A straight line is extended between the points of the two averages of hurricane activity and the differences in the strengths of the two average ENSOs. Note that hurricane activity was greater for both parameters (+2.8 for NS and +54 for NTC) than would be expected with such an extreme El Niño. Similar calculations were also made for NSD, H, HD, IH, IHD and HDP. These estimates give an indication as to what the 1997 hurricane activity would have been had there been no other net positive hurricane influences present (column 1 of Table 12). Note that the overall non-ENSO influences were distinctly positive for 1997.

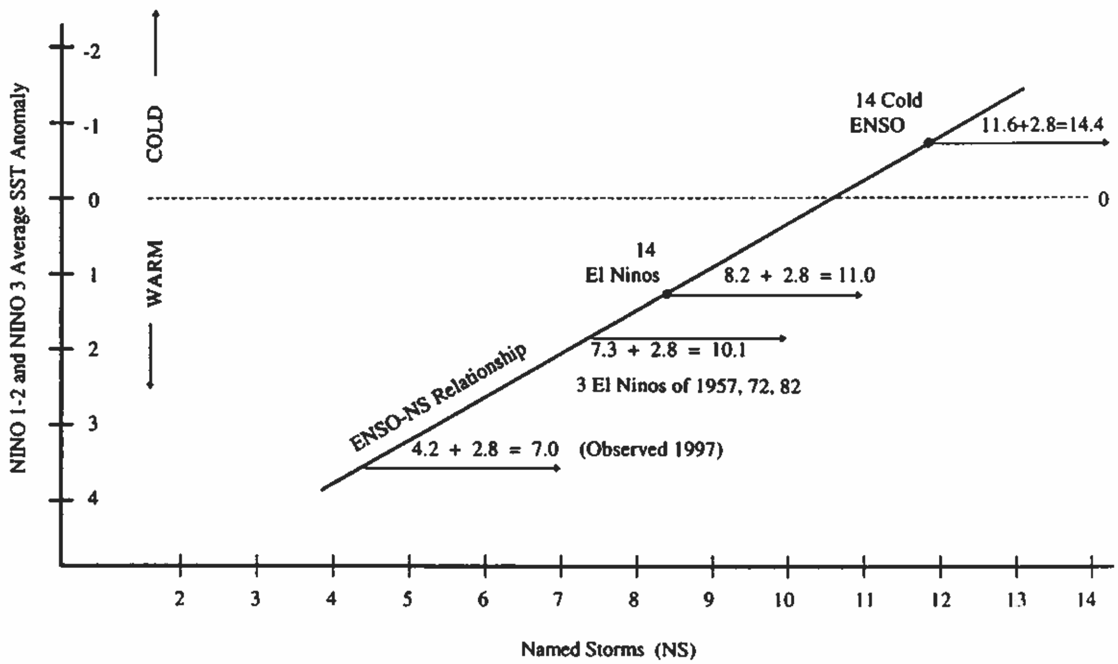

Figure 5: Estimated ENSO influences on named storms. Assuming no other factors we would have expected that this year's El Niño would have reduced the named storm number to about 4.2. We speculate that favorable non-ENSO influence raised this number to the 7 that were observed.

Column (2) of Table 12 shows the actual amount of 1997 hurricane activity which occurred. Column (3) of this table shows the estimated extra hurricane activity which occurred above that to be expected from the 1997 El Niño influence itself. All deviations are positive. Thus, we had more hurricane activity in 1997 than one should have expected given the nature of this year's El Niño conditions.

If we assume that column (3) of Table 12 represent all non-ENSO influences on this year's hurricane activity then we might ask the question as to what would have been the level of this year's hurricane activity had we experienced only a strong El Niño event such as occurred in 1957, 1972 and 1982.

Table 11: Comparison of seasonal Atlantic hurricane activity during 14 warm versus 14 cold ENSO years. The average of NINO 1-2 and 3 SST differences are shown in the right column.

Warm ENSO Years	NS	NSD	H	HD	IH	IHD	HDP	NTC	Mean SSTA of NINO 1-2 and 3 (in °C)
1951	10	58	8	36	2	5	113	120	1.39
1953	14	65	6	18	3	5.5	59	120	.82
1957	8	38	3	21	2	5.25	67	85	1.47
1963	9	52	7	37	2	5.5	103	115	.70
1965	6	40	4	27	1	6.25	73	85	1.42
1969	17	83	12	40	3	2.75	110	155	.84
1972	4	21	3	6	0	0	14	28	2.02
1976	8	45	6	26	2	1	65	84	1.26
1979	8	44	5	22	2	5.75	73	95	.68
1982	5	16	2	6	1	1.25	18	37	1.47
1983	4	14	3	4	1	0.25	8	32	2.18
1987	7	37	3	5	1	0.5	11	47	1.47
1991	8	22	4	8	2	1.25	22	59	.49
1993	8	30	4	10	1	0.75	23	53	.40
Average	8.29	40.4	5	19	1.64	2.93	54.2	79.6	+1.1
Cold ENSO Years	NS	NSD	H	HD	IH	IHD	HDP	NTC	Mean SSTA of NINO 1-2 and 3 (in °C)
1950	13	98	11	60	7	15.5	200	240	-.44
1954	11	52	8	32	2	8.5	91	128	-1.09
1955	12	83	9	47	5	13.75	158	196	-1.01
1961	11	71	6	43	5	9.75	139	167	-.52
1964	12	71	6	43	5	9.75	139	167	-.90
1970	10	23	5	7	2	1	18	64	-1.10
1971	13	63	6	29	1	1	65	94	-.55
1973	7	33	4	10	1	0.25	21	51	-.99
1975	8	43	6	21	3	2.25	53	92	-.92
1985	11	51	7	21	3	4	61	110	-.79
1988	12	47	5	21	3	9.25	81	123	-1.44
1989	11	66	7	32	2	9.75	108	135	-.27
1995	19	121	11	62	5	11.5	172	231	-.37
1996	13	74	9	44	6	14	131	200	-.62
Average	11.64	64	7.29	34.1	3.64	8.66	104.9	146.5	-1.0
Cold-Warm Year	3.35	23.6	2.29	15.1	2.03	5.73	50.7	66.9	
Ratio Cold/Warm Years	1.40	1.58	1.46	1.79	2.22	2.96	1.94	1.84	

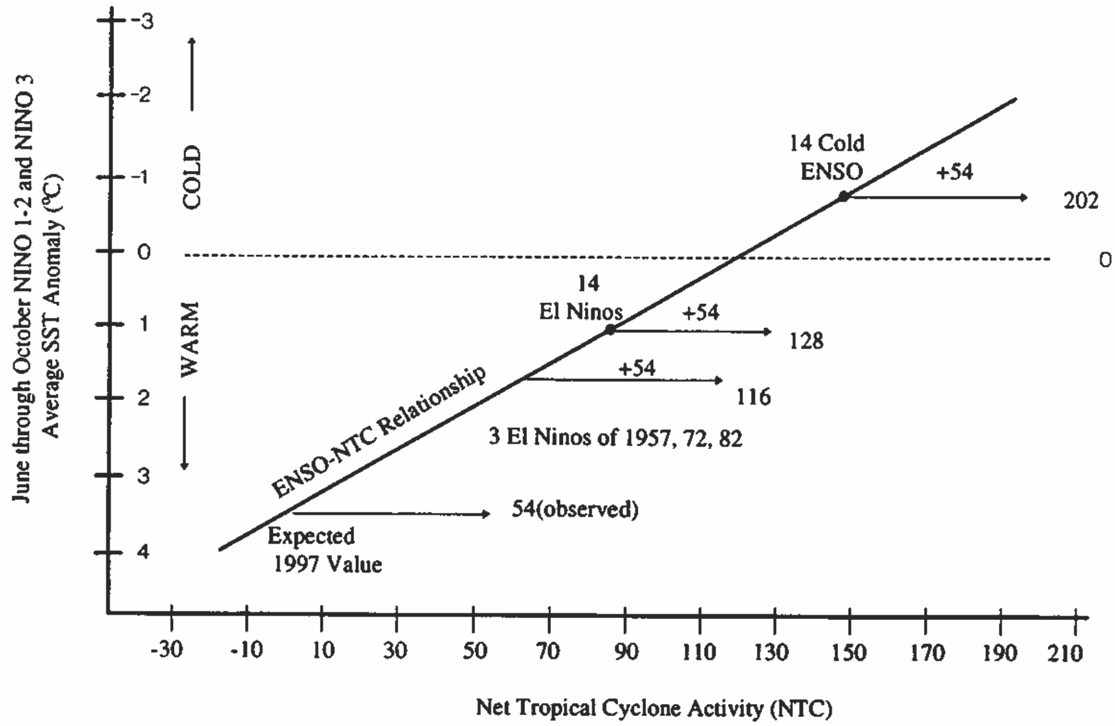

Figure 6: Same as Fig. 5 but for NTC activity. We would have expected a value of zero NTC for 1997 if there were no other favorable climate factors.

Table 12: Estimate of 1997 hurricane activity with and without favorable non-El Niño factors and observed hurricane 1997 seasonal activity.

	(1) Estimated 1997 Hurr. Activity which would have resulted from the Extreme 1997 El Niño if no other favorable non-El Niño Factors were present	(2) 1997 Observed Activity	(3) Estimated Increase in 1997 Hurricane Activity due to Favorable Non-El Niño Factors such as West QBO, Warm Atlantic SST Anomalies, etc.
Named Storms (NS)	4.2	7	+2.8
Named Storm Days (NSD)	13	28	+15
Hurricanes (H)	2.2	3.0	+0.8
Hurricane Days (HD)	3	10	+7
Intense Hurricanes (IH)	0 (−1.7 from graph)	1	+2.7
Intense Hurricane Days (IHD)	0 (−3.3 from graph)	2.2	+5.5
Hurr. Dest. Pot. (HDP)	2	25	+23
Net Tropical Cyclone Activity (NTC)	0	54	+54

Column (1) of Table 13 gives the expected hurricane activity which would have been likely in 1997 if this year's El Niño had only been as intense as the average of the three strong El Niños of 1957, 1972, and 1982 and no other non-El Niño 1997 influence also present. Comparing column (1) of Table 12 with column (1) of Table 13, it is seen that the 1997 El Niño caused a significant reduction in the 1997 hurricane activity which would likely not have taken place had the El Niño of this year been only as intense as the average strong El Niño. Were the 1997 El Niño to have been only as strong as the average of the 1957, 1972 and 1982 events and the same favorable 1997 non-ENSO conditions present as this year (column 2 of Table 12), then we would likely have had the amount of hurricane activity as indicated in column (3) of Table 13. Comparing this scenario with our four 1997 forecasts (columns 4 and 5 of Table 13) it is seen that the expected 1997 hurricane activity forecast would have been quite close to our forecasts, i.e., compare columns (4) and (5) with column (3). For instance, this adjusted forecast of NTC gives a value of 116 with the 1997 El Niño being only as intense as the average of the 1957–72–82 events. This 116 NTC value is quite close to our NTC forecasts of 110 and 100.

Table 13: Estimated 1997 hurricane activity that would have occurred if the extreme June through October El Niño event of 1997 had been only as intense during June–October as the average of the three strong El Niños of 1957, 1972 and 1982 with comparison of 1997 forecasts.

Hurr. Parameter	(1) Estimated 1997 Hurr. Activity if extreme 1997 El Niño had instead been the average intensity of the 1957, 1972, and 1982 strong events and other influences were negligible	(2) Estimated increase in 1997 Activity due to favorable non-El Niño Conditions	(3) Estimated 1997 Hurricane Activity if the 1997 extreme El Niño event had instead been only as intense as the average of the three strong El Niño of 1957, 1972, 1982	(4) Seasonal Forecast of 6 Dec 1996, 4 Apr 1997, and 6 June 1997	(5) Seasonal Forecast of 6 Aug 1997
NS	7.3	+2.8	10.1	11	11
NSD	36	+15	51	55	45
H	4.4	+0.8	5.2	7	6
HD	16	+7	23	25	20
IH	1.3	+2.7	4.0	3	2
IHD	1.7	+5.5	7.2	5	3
HDP	45	+23	68	75	60
NTC	62	+54	116	110	100

Table 14 further explores the likely amount of hurricane activity we would have had in 1997 if the current El Niño had been only as strong as the average of the 14 warmest ENSO years between 1950–1996 and the same 1997 favorable non-ENSO factors were present. Above average hurricane conditions would have resulted with a NTC of 128. Column (2) of Table 13 estimates the amount of hurricane activity that would have likely occurred had neutral or zero ENSO conditions occurred, and the same favorable non-ENSO conditions present. This gives an NTC of 174. Column (3) of this table shows the amount of likely 1997 hurricane activity that would have occurred if we had had an ENSO event as cold as the average of the 14 coldest ENSO events between 1950–1996. Non-ENSO conditions were favorable enough this year such that had a quite modest cold ENSO event occurred, then we would have likely experienced seasonal hurricane amounts equal to that of the 1995 and 1996 seasons when NTC activity measured 243 and 200, the highest two consecutive hurricane years on record.

Table 14: Estimated 1997 hurricane activity that would have occurred if the extreme 1997 June through October El Niño had instead been of the following magnitudes and with the addition of the favorable 1997 non-ENSO influences.

Seasonal Hurr. Parameter	(1) This year's El Niño only as strong as the average of the 14 warmest El Niños of the 1950-1996 period	(2) Neutral ENSO Conditions Neither Warm Nor Cold	(3) This year's ENSO event as cold as the average of the 14 Coldest La Niñas of the 1950-1996 period
Named Storms (NS)	11	13	14.4
Named Storm Days (NSD)	56	70	78
Hurricanes (H)	5.8	7.2	8.1
Hurricane Days (HD)	26	33	41
Intense Hurricanes (IH)	3.3	4.4	5.3
Intense Hurricane Days (IHD)	8.4	10.2	13.7
Hurr. Dest. Pot. (HDP)	79	103	127
Net Tropical Cyclone Activity (NTC)	128	174	202

There is no way that we (or anybody else) could have anticipated that we would have experienced the strongest El Niño event during June through October 1997 that has ever been recorded (by a factor of nearly two). All El Niño forecasts for 1997 grossly underestimated the strength of this surprising and extreme warming event. And some ENSO forecasts for 1997 anticipated cool east Pacific water temperatures.

Verifying Aspects of our 1997 Seasonal Forecast

1. We estimated more subtropical cyclones and fewer tropical systems for this year. This verified. Six of this year's seven named storms which developed were formed at latitudes poleward of 25°N.

2. We predicted warm SST anomalies in the north and equatorial Atlantic. This verified.

3. We predicted that hurricane activity this year would be sufficient to cause the consecutive three-year period of 1995, 1996 and 1997 to be the most active consecutive three-year period on record. In terms of NTC activity there have not been any three consecutive year periods in past data with as high an average NTC. This verified.

4. We predicted that Caribbean and West Atlantic SLPA would be slightly below average. This verified except for the month of August.

6 Why the 1997 El Niño was so Strong and so Underforecast

This is a question that will be debated for many years. It is likely that the 1997 El Niño was unusually strong because of the Western Pacific Ocean warm pool of deep water that had built up to a very high level over the last three years. The potential strength of this warm pool was not given sufficient consideration. There was also a weakness in the southeast Pacific anticyclone which often precedes El Niños and other factors that, in hindsight, could have specified the possibility of an unusually strong El Niño for this year.

Trigger Mechanism. We now view the El Niño onset this year as being a combination of a very strong warm pool buildup, and the unexpected development of three strong Madden–Julian Oscillations (MJO) which occurred in December, March and then May. Strong and prolonged (long-lived) 30–50 day wave oscillations were the likely impetus for the release of the West Pacific warm pool. Apparently, the West Pacific warm pool was fully replenished and poised to reinitiate El Niño conditions again, despite the longevity of the 1991–94 warm ENSO event. These MJO events enhance central Pacific equatorial westerly winds which, in turn, forced the release the warm pool by propagating ocean energy eastward through Kelvin wave action. These strong MJOs were enhanced by the timely formation and favorable positioning of western Pacific tropical cyclones. There were opposite hemispheric cyclone pairs. And of special note was the Southern Hemisphere tropical cyclone Justin. This lasted in a near stationary position for over three weeks during March, the time of maximum eastward Kelvin wave propagation.

7 Reason for Invalid Statistical Forecasts for 1997

Our statistical hurricane forecasts have been based on the assumption that those precursor global general circulation and climate features which have, in the past, been associated with increased or decreased amounts of seasonal hurricane activity will be representative of future high and low amounts of hurricane activity. To this end we have developed our seasonal forecasts schemes on past data from 1950. There has been enough variety of general circulation and seasonal hurricane variations during the past 47 year period (1950-1996) to expect that our statistical forecast schemes would have encompassed most of the different climate features which are associated with Atlantic hurricane variability. In hindcasting tests of these past data sets we have been able to explain about 45-65 percent of the seasonal hurricane variability at lead times ranging from two to nine months. This methodology works quite well when the developmental data sets from which the forecast statistics are developed contain the extremes of all climate-global circulation features which can occur in the future. Our forecasts are based on this assumption.

Our 1997 statistical hurricane forecasts are shown in Table 16. We used these statistical forecasts as an important guide for our actual forecast. But this assumption on the applicability of prior down in 1997. We experienced the most intense El Nino for the June-October period on record. Nothing in our developmental data set contained such an intense El Nino. We had assumed that the developing strong El Nino onset years of 1957, 1972 and 1982 would be representative of our most severe El Niño event. Instead we had an El Niño which was twice as strong as any one in our developmental data sets.

We do not expect another El Niño of this strength anytime in the near future. We feel confident that future forecasts will not encounter the unusual difficulties of this season.

8 Recent Hurricane Enhancing Atlantic Surface Temperature Rearrangements

A major rearrangement of the Atlantic Ocean SST features began in late 1994 and continued through October 1997. Figure 7 shows Atlantic mean 1997 August-September-October SST anomaly conditions; the northerly and tropical Atlantic had warm water anomaly conditions. These

Table 15: Summary of our best statistical forecasts for 1997 from different time periods.

Forecast Parameter	From 1 Dec 96	From 1 Apr 97	From 1 Jun 97	From 1 Aug 97	Observed
NS	10.19	10.50	10.66	11.81	7
NSD	50.19	47.69	43.59	63.04	28
H	6.29	7.04	647	7.37	3
HD	23.56	19.95	34.00	30.93	10
IH	1.87	2.40	5.97	3.09	1
IHD	3.77	4.87	8.78	8.22	2
HDP	60.39	60.43	116.34	90.82	25
NTC	91.13	92.00	128.74	150.89	54
MPD		60.09	68.68	62.38	27

SST changes were likely important in keeping the intense El Niño from causing a complete shut down of this year's Atlantic hurricane season. We hypothesize that the strong broadscale SST changes are due to a major shift in the strength of the Atlantic Ocean thermohaline or "conveyor belt" circulation. This interpretation is consistent with changes in a number of other global circulation features that have occurred during the last three years. We appear to be experiencing a shift towards a stronger Atlantic Ocean thermohaline circulation, and likely will experience greater amounts of hurricane activity in the coming decades than occurred in the 1970s, 1980s and early 1990s.

9 The Extreme 1997 El Niño and Man-Induced Greenhouse Gas Increases

Undoubtedly, some people will want to interpret the warmest-on-record El Niño event of 1997 as a partial response to man-induced greenhouse gas buildup. We do not subscribe to this view. Rather, it is likely that this year's extreme El Niño occurred as the result of a peculiar juxtaposition of favorable El Niño enhancing mechanisms. Intense El Niños rivaling the 1997 event have probably occurred in prior periods before records were adequate to measure their intensity. We expect the current El Niño to be gone by the next hurricane season.

10 Forthcoming Early December Forecasts for 1998 Hurricane Activity and West African Sahel Rainfall

We will be issuing seasonal forecasts for 1998 Atlantic basin hurricane activity, West African rainfall, and the El Niño-Southern Oscillation (ENSO) on 5 December 1997. These forecasts will be based on data available to us through November 1997. These forecasts will be disseminated on the World Wide Web and sent to those on our mailing list.

11 Acknowledgements

This research, analysis and forecast have been supported by research grants from the National Science Foundation (NSF). The authors are indebted to a number of meteorological experts who

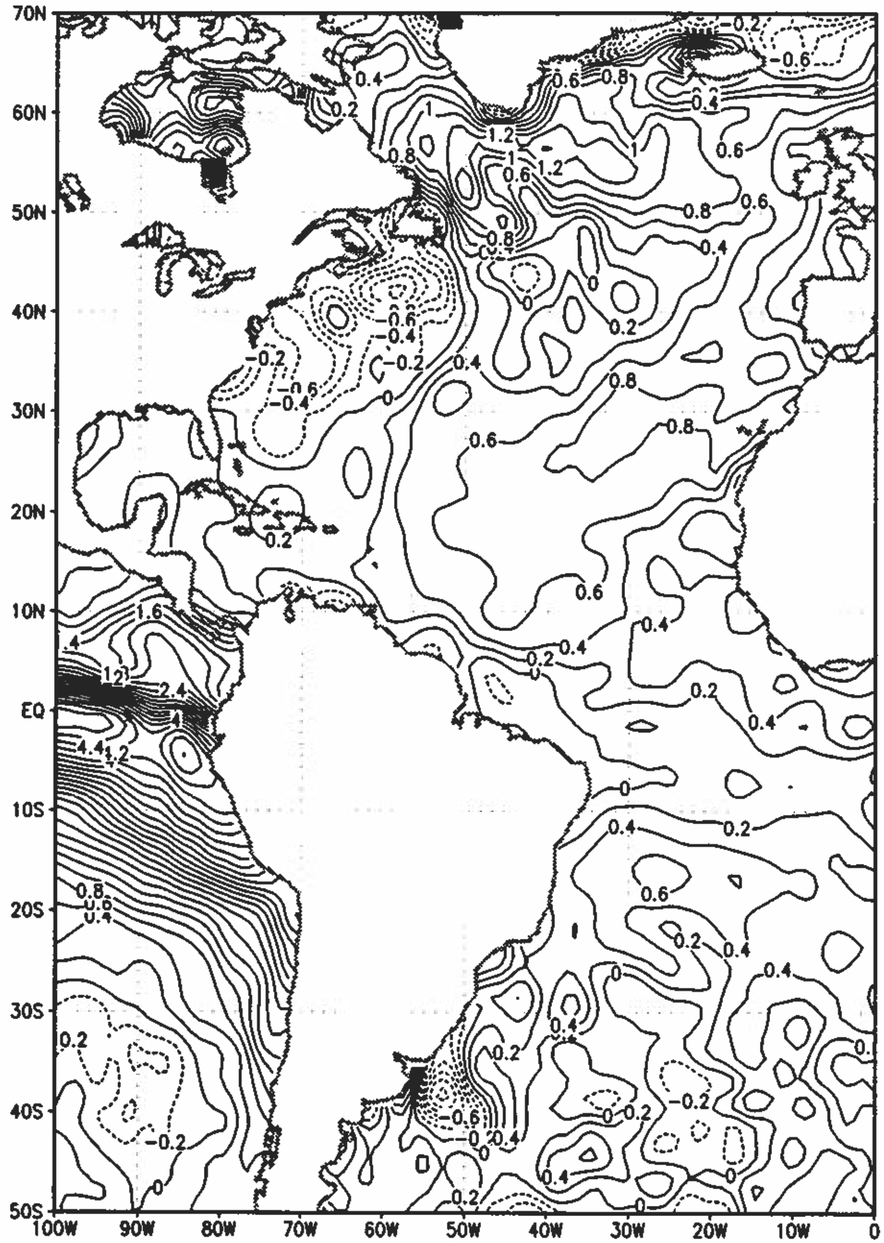

Figure 7: Sea surface temperature (SST) anomaly during the August through October 1997 period. Values in °C. Note the North Atlantic warming.

have furnished us with the data necessary to make this forecast or who have given us valuable assessments of the current state of global atmospheric and oceanic conditions. We are particularly grateful to John Sheaffer and Todd Kimberlain of CSU for very valuable climate discussion and input data. We are grateful to Colin McAdie who has furnished much data necessary to make this forecast and to Vern Kousky, Gerry Bell, James Angell, Stan Goldenberg, Richard Larsen, Arthur Douglas and Dave Masonis for helpful discussions. The authors have also profited from indepth interchange with their project colleagues Ray Zehr and Clara Deser. William Thorson and Richard Taft have provided valuable data development and computer assistance. We wish to thank Tom Ross of NCDC and Wassila Thiao of the African Desk of CPC who provided us with West African and other meteorological information. Douglas LeCompte of USDA has provided us with African rainfall summaries. Barbara Brumit and Amie Hedstrom have provided manuscript and data reduction assistance. We have profited over the years from many indepth discussions with most of the current NHC hurricane forecasters. These include Lixion Avila, Miles Lawrence, Max Mayfield, Richard Pasch, Edward Rappaport and Jack Beven. The first author would further like to acknowledge the encouragement he has received over recent years for this type of forecasting research applications from Neil Frank, Robert Sheets, Robert Burpee former directors of the National Hurricane Center (NHC) and from acting NHC director Jerry Jarrell.

12 Additional Reading

Goldenberg, S. B. and L. J. Shapiro, 1996: Physical mechanisms for the association of El Niño and West African rainfall with Atlantic major hurricane activity. *J. Climate*, 1169-1187.

Gray, W. M., 1984a: Atlantic seasonal hurricane frequency: Part I: El Niño and 30 mb quasi-biennial oscillation influences. *Mon. Wea. Rev.*, 112, 1649-1668.

Gray, W. M., 1984b: Atlantic seasonal hurricane frequency: Part II: Forecasting its variability. *Mon. Wea. Rev.*, 112, 1669-1683.

Gray, W. M., 1990: Strong association between West African rainfall and US landfall of intense hurricanes. *Science*, 249, 1251–1256.

Gray, W. M., C. W. Landsea, P. W. Mielke, Jr., and K. J. Berry, 1992: Predicting Atlantic seasonal hurricane activity 6–11 months in advance. *Wea. Forecasting*, 7, 440-455.

Gray, W. M., C. W. Landsea, P. W. Mielke, Jr., and K. J. Berry, 1993: Predicting Atlantic basin seasonal tropical cyclone activity by 1 August. *Wea. Forecasting*, 8, 73-86.

Gray, W. M., C. W. Landsea, P. W. Mielke, Jr., and K. J. Berry, 1994a: Predicting Atlantic basin seasonal tropical cyclone activity by 1 June. *Wea. Forecasting*, 9, 103-115.

Gray, W. M., J. D. Sheaffer and C. W. Landsea, 1996: Climate trends associated with multi-decadal variability of intense Atlantic hurricane activity. Chapter 2 in "Hurricanes, Climatic Change and Socioeconomic Impacts: A Current Perspective", H. F. Diaz and R. S. Pulwarty, Eds., Westview Press, 49 pp.

Kimberlain, T. B., J. B. Elsner and N. E. LaSeur, 1998: Baroclinically-inhibited hurricanes of North Atlantic basin, 1950–1996. To be submitted.

Knaff, J. A., 1997: Implications of summertime sea level pressure anomalies. *J. Climate*, 10, 789-804.

Knaff, J. A., 1998: Predicting summertime Caribbean sea level pressure. *Weather and Forecasting*, 13 (in press).

Landsea, C. W., 1991: West African monsoonal rainfall and intense hurricane associations. Dept. of Atmos. Sci. Paper, Colo. State Univ., Ft. Collins, CO, 272 pp.

Landsea, C. W., 1993: A climatology of intense (or major) Atlantic hurricanes. *Mon. Wea. Rev.*, 121, 1703-1713.

Landsea, C. W. and W. M. Gray, 1992: The strong association between Western Sahel monsoon rainfall and intense Atlantic hurricanes. *J. Climate*, 5, 435–453.

Landsea, C. W., W. M. Gray, P. W. Mielke, Jr., and K. J. Berry, 1992: Long-term variations of Western Sahelian monsoon rainfall and intense U.S. landfalling hurricanes. *J. Climate*, 5, 1528–1534.

Landsea, C. W., W. M. Gray, K. J. Berry and P. W. Mielke, Jr., 1997: Revised Atlantic basin seasonal tropical cyclone prediction methods for 1 June and 1 August forecast dates. To be submitted to *Wea. Forecasting.*

Landsea, C. W., W. M. Gray, K. J. Berry and P. W. Mielke, Jr., 1996: June to September rainfall in the African Sahel: A seasonal forecast for 1996. 4 pp.

Landsea, C.W., N. Nicholls, W.M. Gray, and L.A. Avila, 1996: Downward trends in the frequency of intense Atlantic hurricanes during the past five decades. *Geo. Res. Letters*, **23**, 1697-1700.

Mielke, P. W., K. J. Berry, C. W. Landsea and W. M. Gray, 1996: Artificial skill and validation in meteorological forecasting. *Wea. Forecasting*, 11, 153-169.

Mielke, P. W., K. J. Berry, C. W. Landsea and W. M. Gray, 1997: A single-sample estimate of shrinkage in meteorological forecasting. Submitted to *Wea. Forecasting.*

Sheaffer, J. D., 1995: Associations between anomalous lower stratospheric thickness and upper ocean heat content in the West Pacific warm pool. Presentation at the 21st AMS Conference on Hurricanes and Tropical Meteorology, Miami, FL, April 22-28.

Sheaffer, J. D. and W. M. Gray, 1994: Associations between Singapore 100 mb temperatures and the intensity of subsequent El Niño events. Proceedings, 18th Climate Diagnostics Workshop, 1-5 November, 1993, Boulder, CO.

Smith, T. M., et al., 1996: Reconstruction of historical sea surface temperatures using empirical orthogonal functions. *J. Climate*, 9, 1403-1420.

UK Meteorological Office, 1996: Preliminary experimental forecast of 1996 seasonal rainfall in the Sahel and other regions of tropical North Africa (issued 14 May and mid-July, 1996).

Wright, P. B., 1984: Relationship between indices of the southern oscillation. *Mon. Wea. Rev.*, 112, 1913-1919.

Wright, P.B., 1989: Homogenized long-period southern oscillation indicies. *Int. J. Climatology*, 9, 33-54.

APPENDIX A: Verification of All Past Seasonal Forecasts

The first author has now issued seasonal hurricane forecasts for 13 consecutive years (1984–1996). In most of these prior forecasts, predictions have been superior to climatology (i.e., long-term averages), particularly for named storms. Figures 8 and 9 offer a comparison of our 1 August forecasts of named storms and hurricanes versus climatology and actual year-by-year variability.

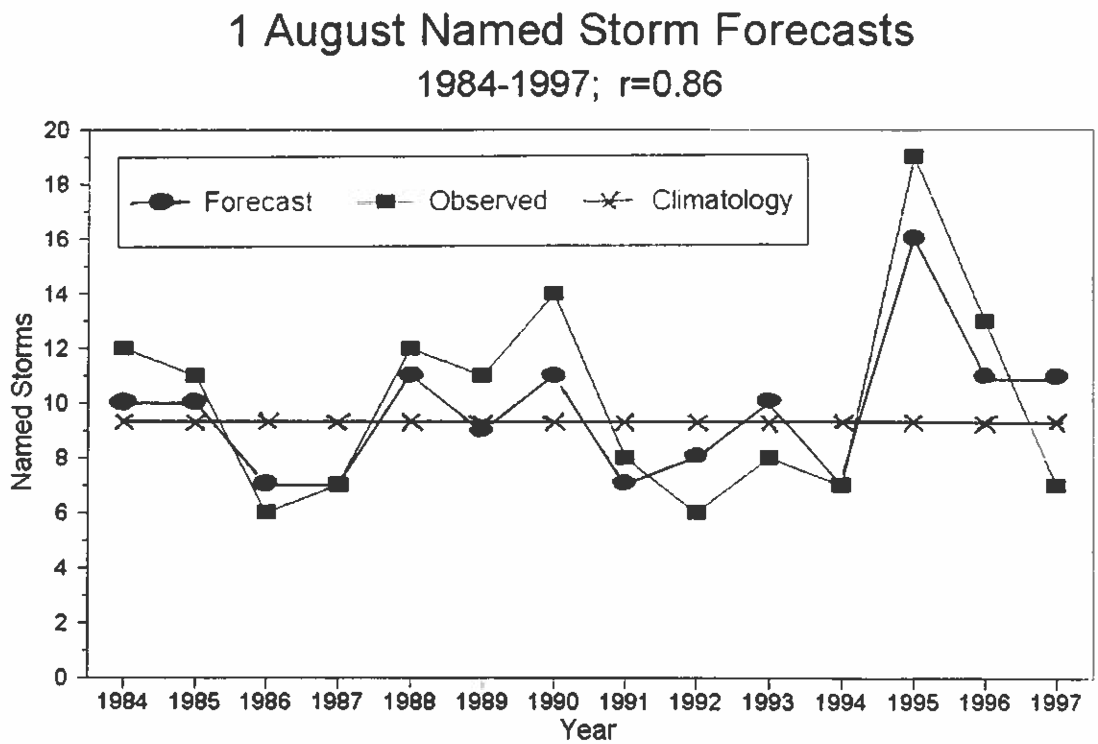

Figure 8: 1 August prediction of total named storms versus the number of actually observed versus long-term climatological mean (r = 0.86) for period 1984–1997.

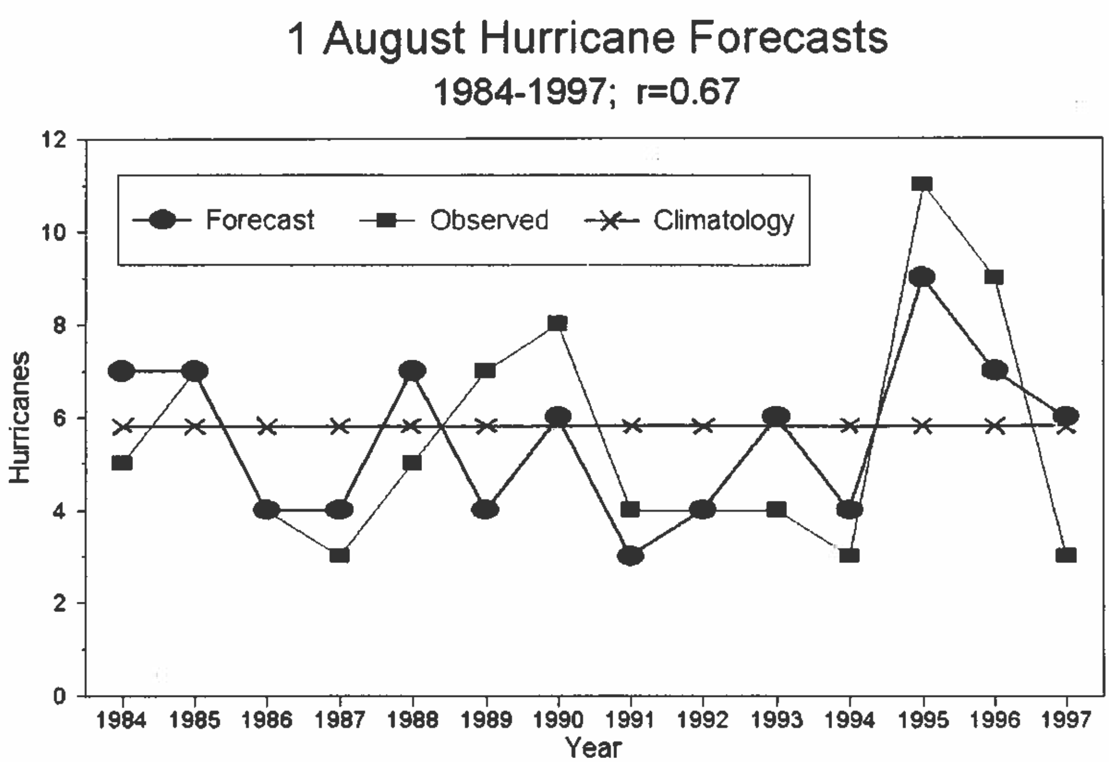

Figure 9: 1 August prediction of total hurricanes versus the number of actually observed versus climatological long-term mean (r = 0.67).

Table 16: 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