SUMMARY OF 1993 ATLANTIC TROPICAL CYCLONE ACTIVITY AND VERIFICATION OF AUTHOR'S FORECAST

(A year of unanticipated light hurricane activity and a poor forecast: the expected dissipation of the El Niño did not take place and Caribbean basin surface pressure became quite high)

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BABE RUTH'S career home run record of 714 lasted a long time --- 38 years --- before Hank Aaron broke it. Ruth held another, less enviable, record for more than three decades. He struck out 1,330 times in his career.

The Babe shrugged off his propensity for whiffing. "I hit 'em big or I miss 'em big," he said.

The close connection between strikeouts and home runs has a long history."

Bruce Dunlavy
Baseball Digest
(November 1993, p.60)

ABSTRACT

This paper summarized the tropical cyclone (TC) activity which occurred in the Atlantic Basin during 1993, and verifies the author's seasonal forecasts of this activity which were issued on 24 November of last year and updated on 5 June and 4 August of this year.

The 1993 hurricane season was relatively inactive with eight named storms (average 9.3) and four hurricanes (average 5.7). There was only one major (or intense) Saffir/Simpson category 3-4-5 hurricane (average is 2.2) and this storm (Emily) was only of marginal category 3 intensity for slightly less than one day. The seasonal total of hurricane days was only 10 (average is 23) and the seasonal total of named storm days was just 30 (average is 46). Only two systems (tropical cyclone Arlene in south Texas and Hurricane Emily near Cape Hatteras) affected the US mainland.

The author had forecast a substantially more active hurricane season. This forecast failure was primarily the result of the misjudgment of the remarkably persistent El Niño conditions which occurred this year and of the high Caribbean basin surface pressure which became established in August. The Caribbean pressure changes are believed to be unrelated to the El Niño and are a result of the intertropical convergence line being shifted southward over the South American continent. Additional unfavorable hurricane conditions included a continuing West Sahel drought. It is quite unusual for an El Niño to last through three consecutive seasons as the current El Niño event has. Actually, warm water has persisted in the equatorial Pacific through the last four hurricane seasons. The El Niño is the most dominant of the climate influences affecting Atlantic hurricane activity, tending to strongly suppress the activity. The long lasting (1991-1993) El Niño conditions had finally started weakening in June and July and this weakening was expected to continue. But, beginning in late August, a surprisingly resurgence of warming SST conditions occurred in the eastern Pacific. This warming lead to a stronger upper tropospheric trough over the western Atlantic and Caribbean sea, and with it, enhanced vertical wind shear. All tropical cyclone activity ended after the 21st of September, a date which is normally only 60 percent of the way through the Atlantic season.

1. 1993 Summary of Atlantic Tropical Cyclone Activity

The 1993 Atlantic hurricane season officially ends on 30 November. There were four hurricanes (maximum sustained wind >73 mph) and 10 hurricane days during the 1993 season. Total named storms (or the sum of the number of hurricanes and tropical storms) was eight and there were but 30 named storm days. There was only one major or intense hurricane this season and all designated tropical cyclone parameters were below the long period average. Figure 1 and Table 1 give the tracks and statistical summaries respectively for all 1993 Atlantic named storms. Table 2 contrasts the tropical cyclone statistics, for this season, with recent past seasons and with climatology. During the last three years hurricane seasons, only one hurricane has formed equatorwards of 25°N. This was Hurricane Gert which this year became a hurricane near 21°N in the western Gulf of Mexico and maintained hurricane intensity for only one day. In the last 25 years only eight other hurricane seasons have had less activity than 1993; these were 1968, 1972, 1973, 1977, 1982, 1983, 1986, 1987.

The one intense (Saffir/Simpson Category 3-4-5) hurricane that developed this year (Emily) intensified at high latitude (> 30°N). This lack of low latitude hurricane activity was a consequence of the combined effects of the teleconnected influence of the persistent warm ENSO

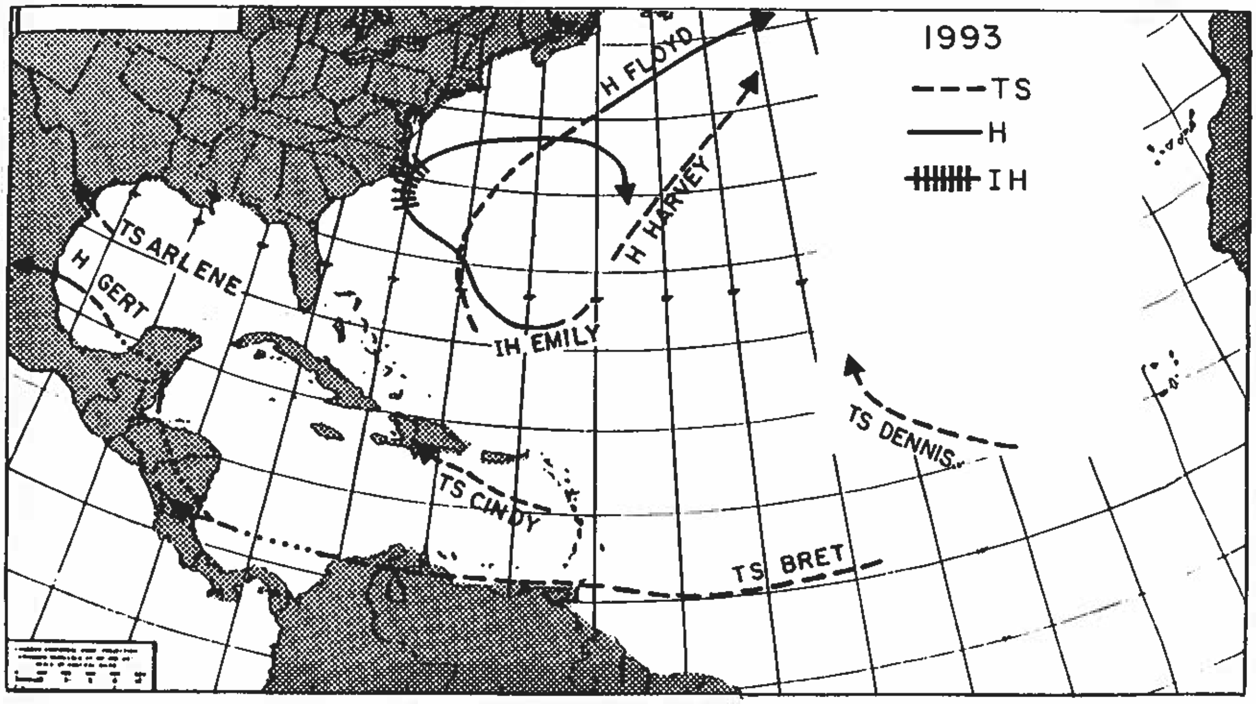

Figure 1: Tracks of Atlantic named storms for 1993. Dashed lines indicate periods of tropical storm intensity (maximum sustained winds with 39-73 mph), solid lines show the periods of hurricane intensity (maximum sustained winds greater than 73 mph) and railroad track lines indicate periods of intense (Category 3-4-5) hurricane activity.

Table 1: Summary of information on named tropical cyclones occurring during the 1993 Atlantic tropical cyclone season. Hurricane (H) and Tropical Storm (TS) information was supplied by courtesy of the National Hurricane Center.

NAME and CATEGORY	DATES	TS DAYS	HUR. DAYS	INT. HUR. DAYS	HDP	MIN. CENTRAL PRESS. (mb)	MAX. WIND (kts)	MAX. S/S (Cat.)
1. TS Arlene	June 18-21	1.00	–	–	–	1000	35	–
2. TS Bret	Aug. 4-10	5.25	–	–	–	1002	40	–
3. TS Cindy	Aug. 14-16	2.25	–	–	–	1007	40	–
4. TS Dennis	Aug. 23-28	3.00	–	–	–	1000	45	–
5. IH Emily	Aug. 23-Sept. 5	10.25	7.25	0.75	19.0	960	100	3
6. H Floyd	Sept. 7-10	3.00	1.00	–	1.7	990	65	1
7. H Gert	Sept. 14-21	3.50	1.00	–	2.2	970	85	2
8. H Harvey	Sept. 18-21	1.50	0.25	–	0.4	990	65	1
TOTAL (rounded off)		30	10	0.75	23			
8 Named Storms; 4 Hurricanes; 1 Intense Hurricane								

Table 2: Comparison of 1993 hurricane activity forecast with previous years' activity.

	1993	As % of last 43 year Average	Last three seasons 1992	1991	1990	Long Term 1950-93 Ave.
Named Storms (NS)	8	86	6	8	14	9.3
Named Storm Days (NSD)	30	65	38	22	68	46.1
Hurricanes (H)	4	70	4	4	8	5.7
Hurricane Days (HD)	10	44	16	8	27	23.0
Intense Hurricanes (Cat. 3-4-5) (IH)	1	46	1	2	1	2.2
Intense Hurricane Days (IHD)	0.75	17	3.25	1.25	1	4.5
Hur. Dest. Pot. (HDP)	23	34	51	23	57	68.1
Net Tropical Cyclone Activity (NTC)	55	55	62	59	104	100

event, anomalously high values of Caribbean basin surface pressure and Caribbean basin 200 mb westerly wind anomalies. Unfavorable (for tropical cyclone activity) springtime West African west-to-east gradients of surface pressure and surface temperature, as well as continuing West Africa drought conditions were also contributing factors to this season's relative inactivity. Hence, as discussed below in sections 4 and 5, five of six basic climate factors known to govern the incidence of TCs had an inhibiting influence upon this season's hurricane activity.

Expressing Seasonal Tropical Cyclone Activity in Terms of One Number: The Concept of Net Tropical Cyclone Activity. Measures of seasonal tropical cyclone activity include the seasonal total number of named storms (NS), hurricanes (H), intense (or major) hurricanes (IH), named storm days (NSD), hurricane days (HD), intense hurricane days (IHD), and hurricane destruction potential (HDP). Definitions of these hurricane indices are given at the beginning of this report. More detailed information is contained in Gray et al. (1992, 1993a) and in Landsea (1993).

It is desirable to define a single number which provides a simple but comprehensive expression of net season tropical cyclone activity in terms of a percentage difference from a long term mean. To this end, we propose a new parameter of seasonal activity termed the "Net Tropical Cyclone activity" (NTC) which is defined as:

$$NTC = (\%NS + \%H + \%IH + \%NSD + \%HD + \%IHD)/6$$

where each season's percentage departure values from the long term mean are used as the six measures of seasonal activity. The NTC value is useful as a seasonal tropical cyclone measure because it combines most of the other tropical cyclone parameters of interest into a single measure of activity. There are many seasons in which a single parameter, say for example, the number of hurricanes, is not well representative of the actual character of the overall tropical cyclone activity for that year. We propose the use of this single (NTC) index as a measure of tropical cyclone activity. This single index has the highest forecast skill. Table 3 lists the values of NTC for 1950-1993.

Table 3: Listing of Seasonal Net Tropical Cyclone activity (NTC) values between 1950-1993.

Year	NTC (%)	Year	NTC (%)	Year	NTC (%)
1950	243	1964	168	1978	86
1951	121	1965	86	1979	96
1952	97	1966	140	1980	135
1953	121	1967	97	1981	114
1954	127	1968	41	1982	37
1955	198	1969	157	1983	32
1956	69	1970	65	1984	77
1957	86	1971	95	1985	110
1958	140	1972	28	1986	38
1959	99	1973	52	1987	48
1960	101	1974	76	1988	121
1961	222	1975	92	1989	140
1962	33	1976	85	1990	104
1963	116	1977	46	1991	59
				1992	62
				1993	55

2. Brief Summary of Characteristics for Individual 1993 Named Storms

1. Tropical Storm Arlene formed off the south Texas coast on the 18th of June and moved northwestward crossing the Texas coast just south of Corpus Christi. Arlene was a minimal tropical storm for only one day. It had maximum sustained winds of only 35 knots and minimum central pressure of 1000 mb. Arlene caused some heavy flooding in east Texas.

2. Tropical Storm Bret developed in early August at low latitudes to the east of the Antilles. It moved steadily westward for a week along the 10-11° latitude line before entering and dissipating in Central America. Although it never obtained maximum winds greater than 50 knots or central pressure lower than 1002 mb, Bret caused extensive flooding damage to Venezuela, Columbia and Central America.

3. Tropical Storm Cindy formed in the northeastern Caribbean during the middle of August. Like Arlene and Bret, it was only a minimal tropical storm with maximum sustained

winds of only 35 knots and minimum central pressure of but 1007 mb. It dissipated over Hispaniola.

4. Tropical Storm Dennis formed in the central Atlantic in late August. It slowly moved northwest for three days and then dissipated. It had maximum sustained winds were 45 knots and minimum sea level pressure of 1000 mb.
5. Intense (or Major) Hurricane Emily was the only intense hurricane of the 1993 season. It formed south of Bermuda and gradually intensified as it moved northwestward towards Cape Hatteras. It recurved near Cape Hatteras and then moved east northeastward and slowly dissipated south of Newfoundland. Emily had maximum winds of 100 kts (115 mph) and a minimum central pressure of 960 mb. Emily did damage to many homes on the outer banks of North Carolina.
6. Hurricane Floyd initially developed as it was moving on a northward track to the southwest of Bermuda. It gradually intensified to minimal hurricane strength of 65 knots (75 mph) southeast of the Maritime Provinces and became extratropical to the east of Newfoundland. Floyd was classified as a hurricane for only one day. Minimum pressure at hurricane stage was estimated to be 990 mb.
7. Hurricane Gert first formed as a named storm in the southwest Caribbean. It then moved inland before emerging over water in the southern Gulf of Mexico. Once over the Gulf it moved westward and rapidly intensified. It reached 85 knots maximum winds (minimal category 2) at landfall near Vera Cruz state. Gert caused much flood damage in Central America and eastern Mexico.
8. Hurricane Harvey was a minimal hurricane for only 6 hours and a named storm for only 1 1/2 days. It formed a few hundred miles east of Bermuda on the 20th of September. It had a track to the northeast. It was absorbed in a frontal system to the southeast of Newfoundland. Harvey's dissipation on the 21st of September represented an early end of this year's hurricane season.

It is notable that all 1993 hurricane activity occurred prior to the 21st of September, a date which, on average, is only 60 percent of the way through the hurricane season. The 1993 season was weaker than is indicated by the number of named storm and hurricanes. Specifically: none of the four 1993tropical storms (Arlene, Bret, Cindy, Dennis) attained central pressures lower than 1000 mb; hurricanes Floyd and Harvey were quite minimal and short lived; hurricane Gert was a hurricane for only one day; the one intense hurricane which did develop (Emily), was only marginally so (100 kts, 960 mb minimum pressure) and Emily held its category 3 intensity for only three-quarters of one day. For the third straight year, the amount of hurricane activity equatorwards of 25°N was greatly suppressed. Gert (existing for one day near 21°N) is the only hurricane to occur equatorwards of 25°N since the 1990 season. It is unusual to have three consecutive years with such a dearth of low latitude hurricane activity.

3. Verification of Author's 1993 Forecast

Table 4 lists statistical information for the author's 1993 seasonal forecast. All parameters were overforecasted. Notably, the number of named storm days, hurricane days, and HDP were all badly overcast. As is discussed throughout this report, these errors were largely the result of the totally unanticipated August reintensification of the El Niño plus the unexpected strong rise in August-October Caribbean basin surface pressure.

Table 4: Verification of 1993 hurricane activity forecast from various dates of forecast.

	1993 Fcst made on 24 Nov 1991	1993 Fcst as of 5 June	1993 Fcst as of 4 Aug	1993 Verification
Named Storms (NS)	11	11	10	8
Named Storm Days (NSD)	55	55	50	30
Hurricanes (H)	6	7	6	4
Hurricane Days (HD)	25	25	25	10
Intense Hurricanes (IH)	3	2	2	1
Intense Hurricane Days (IHD)	7	3	2	0.75
Hurricane Destruction Potential (HDP)	75	65	55	23
Net Tropical Cyclone Activity (NTC)	NOT MADE	95	85	55

4. Factors Known to be Associated With Atlantic Seasonal Hurricane Variability

This forecast was based on past research by the author and colleagues (Gray, 1984a, 1984b); Gray (1990); Landsea and Gray (1992); Landsea et al. (1992); Gray et al. (1992, 1993a,b)) which relates seasonal Atlantic hurricane activity to six climate indices including: (a) the El Niño (EN); (b) the Quasi-Biennial Oscillation (QBO) of equatorial 30 mb and 50 mb stratospheric winds; (c) Caribbean Basin-Gulf of Mexico Sea-Level Pressure Anomaly (SLPA) in spring and early summer; (d) lower latitude Caribbean Basin 200 mb (12 km altitude) zonal wind anomaly in early summer, (e) Western Sahel rainfall and, (f) a parameter expressing the trend in west to east surface pressure and surface temperature gradients in February through May in West Africa. Figure 2 shows the geographical distribution of these forecasts. These six factors have all been shown to be strongly related to seasonal variations in Atlantic tropical cyclone activity.

The author's seasonal forecast scheme has the following form:

$$\begin{array}{l} \\ (Predicted\ Amount \\ of\ TC\ Activity \\ Per\ Season) \end{array} = \begin{array}{c} Adjustment\ Terms \\ Ave.\ Season + (EN + QBO + SLPA + ZWA + AR + PT) \end{array}$$

where

EN = El Niño influence. (Warm East Pacific water reduces hurricane activity, cold water enhances it.)

QBO = 30 mb and 50 mb Quasi-Biennial Oscillation zonal wind anomaly correction. (Increased hurricane activity for westerly or positive phase, reduced hurricane activity for easterly or negative zonal wind.)

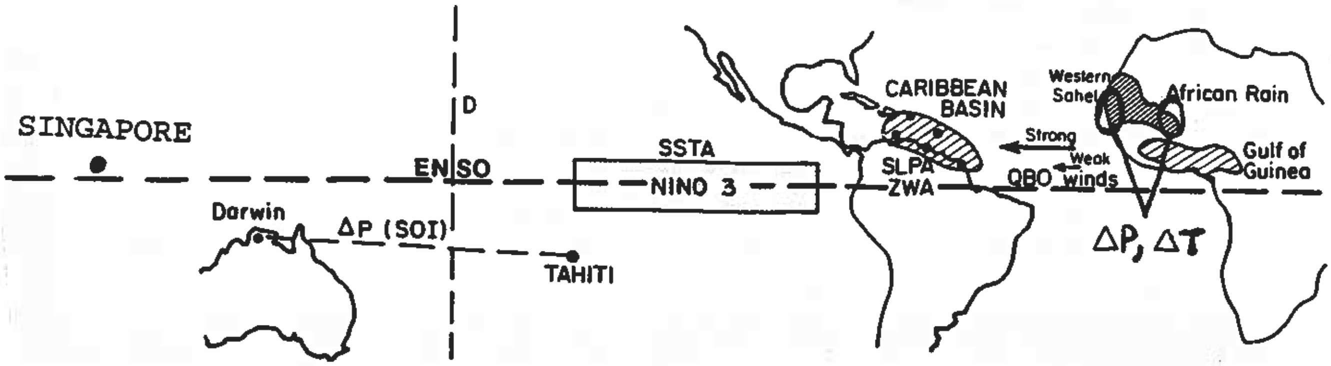

Figure 2: Locations of meteorological parameters used in early August Atlantic basin seasonal forecast.

SLPA = Average Caribbean SLPA for Spring and early Summer. (Reduce hurricane activity if SLPA is significantly above average, add activity if significantly below average.)

ZWA = Zonal Wind Anomaly at 200 mb (12 km) for five low latitude upper air Caribbean stations. (Reduce hurricane activity if positive, increase hurricane activity if negative.)

AR = Western Sahel rainfall. (Increase activity if wet, reduce it if dry.)

PT = West Africa west-to-east gradients of surface pressure and surface temperature during February through May. (High values of pressure gradient and lower values of temperature gradient indicate more hurricane activity.)

a. *Specific 1993 Values for Characteristics of Seasonal Hurricane Predictors*

a) El Niño

An El Niño formed in the tropical Pacific 1991 and El Niño-like conditions have persisted through the 1993 hurricane season. For the third straight year these El Niño conditions exerted an inhibiting influence on Atlantic seasonal hurricane activity. It is unusual to have an El Niño last through three years. This has not happened since the three year event of 1939–40–41. The 1990 year also had warm NINO-3 and NINO-4 (Fig. 3, Table 9) Sea Surface Temperature Anomaly (SSTA) conditions. Hence, ENSO conditions have been on the warm side for four consecutive years. The only other occurrences of continuous warm ENSO-like conditions for four consecutive years during the last 150 years were the two periods of 1899–1902 and 1911–1914.

Consistent with this ENSO warming event has been the persistent positive 200 mb zonal wind anomalies (ZWA) which have been observed throughout the Caribbean basin (see Table 8) and tropical Atlantic. These winds acted as a suppressing influence for this season's low latitude tropical cyclone activity through the influences of their inhibiting vertical wind shear on African spawned easterly waves. Figure 4 shows how the strength of El Niño increased from late July to early September.

b) Stratospheric QBO Winds

Tables 5 and 6 show both the absolute and relative (anomaly) values for 30 mb (23 km) and 50 mb (20 km) stratospheric QBO zonal winds near 12°N during the 1993 Spring and again during the primary hurricane period spanning August through October. Note that during the August through October portion of the hurricane season that 30 mb zonal winds experienced a shift to easterly phase conditions. This shift occurred earlier than expected and was likely a contributing factor to the August-September resurgence of the warm El Niño. Wind at 50

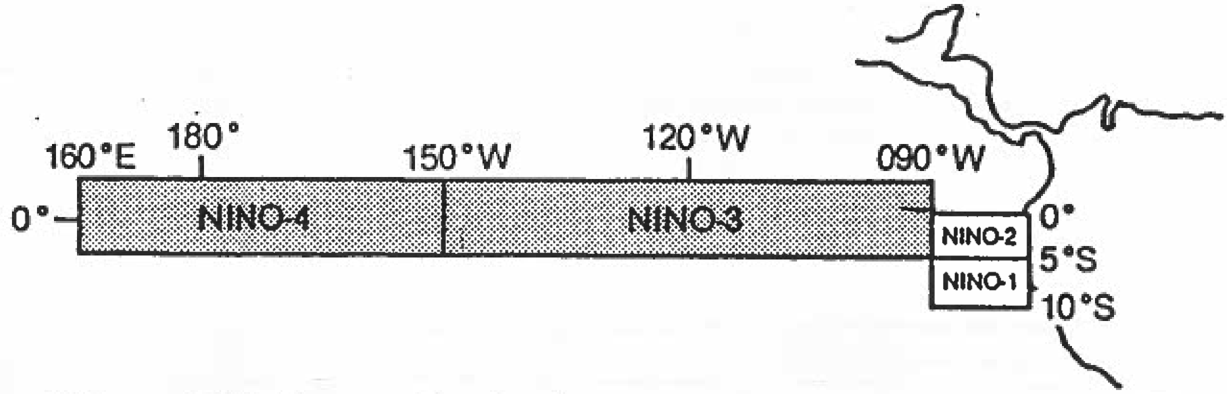

Figure 3: Equatorial Pacific areas where NINO-4 and NINO-3 sea surface water temperatures are measured.

mb, as anticipated, held persistently from a westerly phase direction. This created a rather large vertical wind shears between 50-30 mb. QBO conditions during 1993 were thus not the enhancing component originally envisaged.

Table 5: April through October 1993 absolute values of stratospheric QBO zonal winds (U) in the (critical) latitude belt between 11-13°N, as obtained from lower Caribbean basin stations Curacao (12°N), Barbados (13°N), and Trinidad (11°N). Values are in ms^{-1} (as supplied by James Angell and Colin McAdie).

Observed Actual Winds

Level	March	April	May	Jun	Jul	Aug	Sept	Oct
30 mb (23 km)	+10	+7	0	-9	-14	-19	-16	-16
50 mb (20 km)	+8	+7	+5	-4	-8	-11	-8	-3

Table 6: As in Table 5 but for the "relative" (or anomalous) zonal wind values where the annual wind cycle has been removed. Values are in ms^{-1}.

Observed Anomaly Values

Level	March	April	May	Jun	Jul	Aug	Sept	Oct
30 mb (23 km)	+15	+15	+14	+9	+4	+1	0	-4
50 mb (20 km)	+8	+8	+11	+7	+8	+7	+8	+4

C) Sea-Level Pressure Anomaly (SLPA)

Table 7 gives information on Caribbean basin and Gulf of Mexico region SLPA during the 1993 season. Note that all stations had quite high SLPA during the months of August through October. Springtime and early summer SLPA was generally low and not a reliable predictive signal for the high values which developed for August through October. The higher surface pressure anomalies which did develop are consistent with the very low amount of tropical cyclone activity which occurred this year.

d) Zonal Wind Anomaly (ZWA)

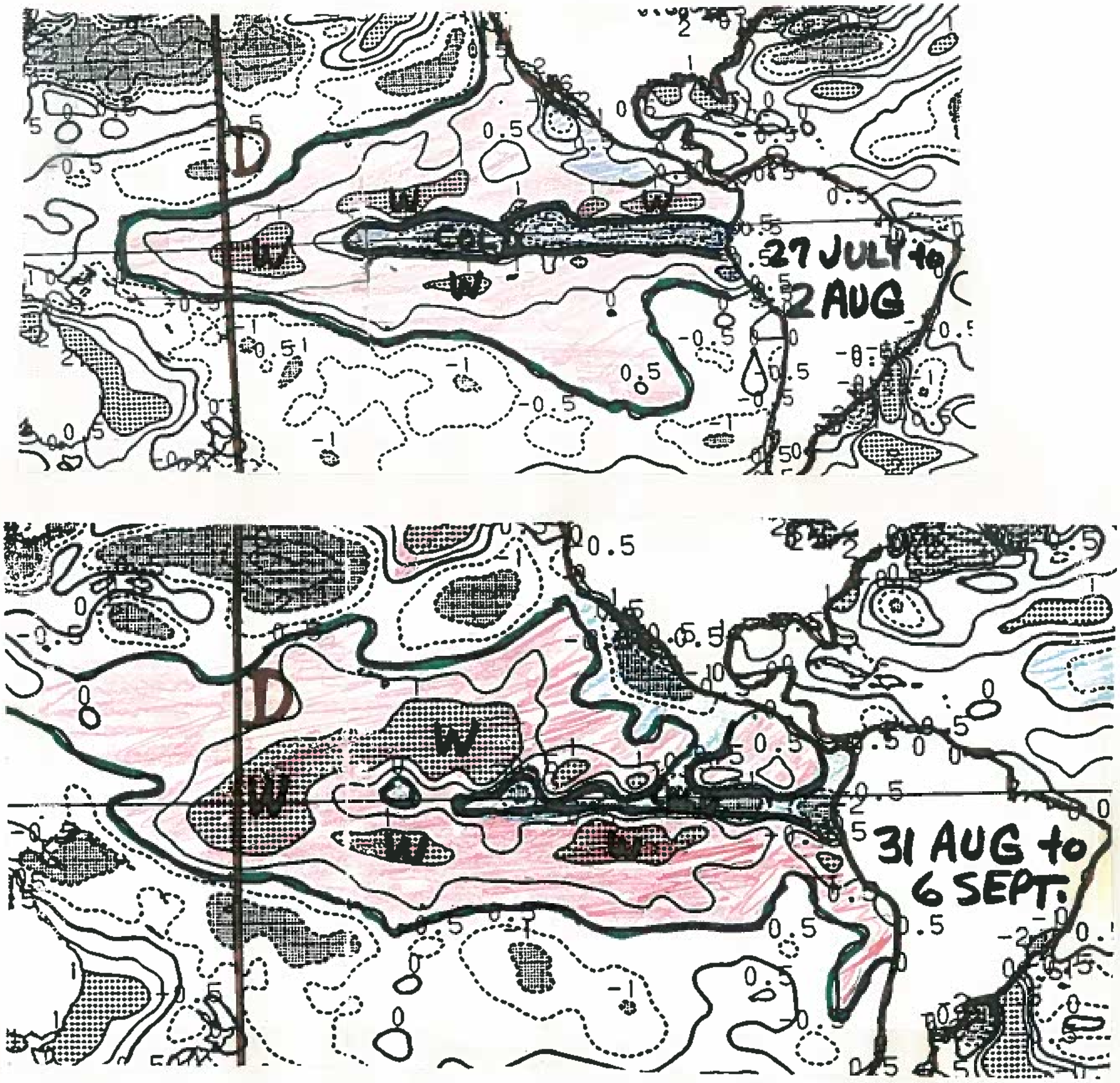

Figure 4: Weekly average Sea Surface Temperature Anomaly (SSTA) maps for 27 July to 2 August (top map) and for 31 August to 6 September 1993 (bottom map). Note the general increase in warm water throughout the tropical East Pacific.

Table 7: Lower Caribbean basin SLPA for 1993 in mb (for the tropical stations of San Juan, Barbados, Trinidad, Curacao and Cayenne) top row and for the Gulf of Mexico. Caribbean basin stations of Brownsville, Texas, Miami, Merida (Mexico), San Juan, Curacao and Barbados - bottom row (as kindly supplied by Colin McAdie of NHC in combination with CSU analysis).

	April-May	June-July	August	September	October	Aug-Oct Ave.
Caribbean Ave. SLPA	–0.9	+0.3	+1.1	+0.6	+1.3	+1.0
Carib. - G. of Mex. Ave. SLPA	–1.0	+0.3	+1.2	+1.2	+0.8	+1.1

Table 8 shows that the upper tropospheric Zonal Wind Anomalies (ZWA) were generally positive throughout the June through October period. These positive upper tropospheric zonal wind anomalies brought about a general increase of tropospheric vertical wind shear in the low latitude Atlantic. This was an important factor for inhibiting this years low latitude tropical cyclone activity.

Table 8: 1993 Caribbean basin 200 mb (12 km) Zonal Wind Anomaly (ZWA) in ms^{-1} (as supplied by Colin McAdie of NHC analyses in combination with CSU data) for the four stations of Kingston (18°N), Curacao (12°N), Barbados (13.5°N), and Trinidad (11°N).

	April-May	June-July	August	September	October	Aug-Oct Ave.
Average ZWA	+2.6	+0.3	+3.3	–0.6	+1.8	+1.5

The combined high Caribbean basin SLPA and positive 200 mb ZWA tend to occur when the Intertropical Convergence Zone (ITCZ) in the Western Atlantic and Caribbean is displaced somewhat south from its normal position.

e) African Rainfall (AR)

African Rainfall (AR) is an important seasonal hurricane forecast parameter. In the last few years we have found (Gray, 1990; Landsea, 1991; Landsea and Gray, 1992; Landsea et al., 1992) that Atlantic intense hurricane activity is much enhanced when the Western Sahel region of West Africa (see Fig. 2) has above average precipitation; conversely, this intense TC activity is much reduced during drought conditions. Intense hurricane activity shows special sensitivity to Western Sahel rainfall conditions. The rainfall which fell in the 38-station Western Sahel region between June and September, 1993, was –0.50 S. D. below average and thereby, was an inhibiting influence on this season's hurricane activity and an indication that the long running drought has persisted.

f) West-to-East Gradient of Surface Pressure and Surface Temperature (PT) in West Africa

We find that the west to east gradients of surface pressure and surface temperature which become established over West Africa during February through May are good indicators of the forth coming seasonal hurricane activity. This is a new forecast parameter that was used for the second time this year. Pressure and temperature gradients during February-May 1993 indicated a below average hurricane season for this year.

It is not surprising that the 1993 hurricane season was so inactive. Of the six basic climate predictors, five were unfavorable for hurricane activity. And even the QBO which was expected to be a strong positive influence turned out to be less favorable.

In retrospect, nature behaved correctly; the small amount of tropical cyclone activity was well represented in the many inhibiting climate predictive signals. The failure was due to the forecaster (myself) not being able to properly anticipate the resurgence of the El Niño in August or the movement of the Atlantic Inter-Tropical Convergence Zone (ITCZ) to a more southerly latitude resulting in much higher surface pressure. Springtime and early summer Caribbean sea level pressures were not representative of the surface pressures of August through October. In addition, West African rainfall and east-west surface pressure and surface temperature gradients were not favorable.

5. Discussion

a. *Persistence of the El Niño*

El Niño events typically last only one or two years and it is very usual that El Niño-like warm water conditions would exist in the eastern and central Pacific for four consecutive years. The longer that an El Niño event persists, the greater the likelihood of its immimant dissipation. It was therefore quite reasonable to anticipate that three consecutive years (1990-1992) of warm water conditions would be followed by a trend to colder water. I now recognize that there are rare and very exceptional ENSO periods wherein warm events persist longer than the typical 1-2 year period. Table 9 gives monthly sea surface temperature anomaly (SSTA) values for the years of 1990-1993 in the NINO-3 and NINO-4 regions of the equatorial Pacific (see Fig. 3). Note that warm water conditions have been present in nearly every month. These four consecutive years of warm water conditions, along with reduced amounts of West African rainfall, have contributed to a great reduction in intense or major hurricane activity during these years. Only five intense hurricanes and 6.5 intense hurricane days have occurred during the last four years when simple climatology would specify 11 intense hurricanes and 19 intense hurricane days. And, all five of the intense hurricanes of 1990-1993 became intense poleward of 25°N. It is quite unusual for the low latitude tropics to be almost devoid of intense hurricanes during four consecutive years. This trend is directly linked to the long running El Niño conditions in combination with West Africa drought conditions.

Table 9: Sea surface temperature anomalies (°C) in the equatorial Pacific regions of NINO3 and NINO4 during the years of 1990-1993.

NINO3 (5°N to 5°S, 90-150°W)

Year	J	F	M	A	M	J	J	A	S	O	N	D
1990	0.4	0.3	0.5	0.6	0.3	0.0	0.1	0.2	0.2	0.0	0.2	0.4
1991	0.4	0.2	0.3	0.4	1.0	1.3	1.0	0.5	0.6	0.8	1.1	1.2
1992	1.5	1.4	1.3	1.4	1.6	0.7	0.1	−0.2	0.1	−0.1	0.0	0.0
1993	0.1	0.3	0.8	1.2	1.7	0.8	0.3	0.0	0.3	0.5		

NINO4 (5°N to 5°S, 150°E to 150°W)

Year	J	F	M	A	M	J	J	A	S	O	N	D
1990	0.7	0.6	0.6	0.6	0.4	0.4	0.6	0.7	0.8	0.8	0.8	1.0
1991	0.8	0.7	0.5	0.8	0.9	0.8	0.9	0.9	0.8	1.2	1.1	1.2
1992	0.7	0.9	1.0	0.9	0.8	0.9	0.9	0.7	0.7	0.6	0.5	0.7
1993	0.5	0.4	0.5	0.5	0.6	0.6	0.8	0.6	0.9	0.5		

Even after three consecutive years of warm conditions, it is still (occasionally) possible to have warm conditions carry on into a fourth year. The historical records back to the 1850s (eg., Wright, 1989) indicate, however, that there is no precedent for warm water conditions to persist into a fifth consecutive year. The statistical odds thus appear to be well stacked against continued warm conditions for next year. No realizations of these three-to-four consecutive years of warm water was (previously) in our seasonal forecast development data set of 1950-1992. The generally reliable forecast rule that two consecutive years of El Niño conditions will be followed in the next year by a cold or at least neutral event was not valid for 1993.

b. *Other Considerations Contributing to Overforecasts of 1993 Activity*

Other influences contributed to this season's failure include the following:

- the spring and early summer Caribbean basin sea level pressure anomaly (SLPA) which was not representative of the SLPA during the August to October period. In most seasons, August-October SLPA follows the trend in the April-July values. This year saw the opposite relationship.
- stratospheric QBO easterly winds descended from 10 to 30 mb more rapidly than either climatology would dictate or that I forecast. It is known that the period of the QBO can deviate from the climatological period. In the present case, a shortened period led to the establishment of easterly phase QBO winds at 30 mb in September and October while strong westerly phase winds remained at 50 mb. The resulting strong 50 mb to 30 mb wind shear during August through October was 8–13 m/s rather than the 2–4 m/s wind shear which was predicted. Thus, the climatological predictor (ie., the QBO) which was expected to be most favorable for enhanced hurricane activity this year was much less so.

Yet another factor in this year's poor forecast involves the inappropriate qualitative alteration of our own recently developed statistical forecast values. Our objective forecasts proved to be superior to the adjusted forecasts, particularly for the parameters most in error. These include hurricanes days (HD), intense hurricanes (IH), intense hurricane days (IHD) and net tropical cyclone activity (NTC). Tables 10 and 11 show comparisons of the author's actual forecasts versus the objective statistical forecasts. The statistical forecasts were particularly superior for intense activity and the various total "day" activity numbers. A good comparison is that for Net Tropical Cyclone activity (NTC). Although overpredicting the actual NTC, our statistical forecasts were superior to climatology (100%). The statistical predictions called for below average amounts of NTC activity of 82 percent (24 November 1992), 73 percent (5 June 1993), and 72 percent (4 August 1993). The actual (observed) value was 55 percent. Statistical prediction was better than actual predictions which were 125%, 95%, and 85% respectively.

The author and his research colleagues are not at all deterred by this year's forecast failure. We have not had many forecast failures in the past; this was a special year and we will profit from this failure. As the poor 1989 forecast lead us to new insights on the importance of West African rainfall and east-west gradients of surface pressure and surface temperature, this year's poor forecast is stimulating us into new studies of the El Niño-Southern Oscillation (ENSO). The author and his research colleagues J. Sheaffer, P. Mielke, K. Berry and J. Knaff have recently developed a new extended range ENSO prediction scheme (Gray et al., 1993c). We have also begun carefully studying multi-year ENSO warming from data of the past 140 years (Wright, 1989).

Presently we have no way to foresee the flip-flop of April-July to August-October Caribbean sea level pressure anomaly which occurred this year. More study will be directed to this topic. In most years, April-July SLPA gives a good estimate of August-October values but this was not the case this year. We also had no way of anticipating the shortened QBO period for this year.

The failure of this year's forecast may not be so surprising. In my 5 June forecast I said

> "This is the 10th season that the author has made an Atlantic Basin seasonal hurricane forecast and one of the most difficult forecasts. This is due to the uncertainty concerning the resurgence of warm El Niño conditions in April and May."

Table 10: Actual forecasts for 1993 and their verification.

Forecast Parameter and its last 43 year average in parenthesis	Forecast 24 Nov. 1992	4 June 1993	5 Aug. 1993	Observed 1993 Verification
Name Storms (NS) (9.3)	11	11	10	8
Name Storm Days (NSD) (46.1)	55	55	50	30
Hurricanes (H) (5.7)	6	7	6	4
Hurricane Days (HD) (23)	25	25	25	10
Intense Hurricanes (IH) Cat. 3-4-5 (2.2)	3	2	2	1
Intense Hurricane Days (IHD)(4.5)	7	3	2	0.75
Hur. Destruction Potential (HDP) (68.1)	75	65	55	23
Net Tropical Cyclone Activity (NTC) (100%)	125%	95%	85%	55%

Table 11: Statistical forecast model results for 1993 from Gray, Landsea, Mielke, and Berry (1992, 1993a,b).

Forecast Parameter and its last 43 yr. ave.	Forecast 24 Nov. 1992	4 June 1993	5 Aug. 1993 (older value)	Observed 1993 Verification
Name Storms (NS) (9.3)	9.7	11.7	9.8	8
Name Storm Days (NSD) (46.1)	45.8	53.6	52.1	30
Hurricanes (H) (5.7)	5.6	9.0	6.5	4
Hurricane Days (HD) (23)	18.1	12.5	23.9	10
Intense Hurricanes (IH) Cat. 3-4-5 (2.2)	1.8	-0.3	1.7	1
Intense Hurricane Days (IHD) (4.5)	3.1	-2.1	1.1	0.75
Hur. Destruction Potential (HDP) (68.1)	48.8	21.8	50.4	23
Net Tropical Cyclone Activity (NTC) (100%)	82%	73%	72%	55%

The author and most El Niño researchers did not anticipate this recent warming. I did not believe that these warm sea surface temperature conditions would persist through the height of the hurricane season from mid-August through mid-October, however. My June forecast predicted a rather rapid and progressive ENSO cooling in the next 3-4 months.

Such a cooling did not take place.

I have consistently stated in my forecasts that:

> "It is important that the reader realize that these seasonal forecasts or statistical in nature and will fail in some years."

This was one of these years.

6. Summary Verification of Ten Previous Seasonal Forecasts and General Potential for Seasonal Prediction

The author has now issued seasonal forecasts of Atlantic hurricane activity for 10 years. A summary of these forecast verifications is given in Table 12. The author's forecasts have evolved during these ten years. We now have a superior forecast scheme to that applied in the first six years. If applied in hindcasts over the ten-year period, or over a longer 42-year period, our current forecast scheme is superior to climatology, the only other method with which to forecast activity for a forthcoming hurricane season. Regardless of how one might rate these seasonal forecasts over the last ten years, we are confident that future forecasts will stand the test of time and will demonstrate an ever improving skill.

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Table 12: Verification of the author's previous seasonal predictions of Atlantic tropical cyclone activity for 1984-1992.

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	10
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	24
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 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	68
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 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	23
Major Hurricanes (Cat. 3-4-5)	1	0	2
Major Hurr. Days	2	0	1.25

1992	Prediction of 26 Nov 1991	Prediction 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	38
Hurr. Destruction Potential(HDP)	35	35	35	51
Major Hurricanes (Cat. 3-4-5)	1	1	1	1
Major Hurr. Days	2.0	2.0	2.0	3.25

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