UPDATED FORECAST OF ATLANTIC SEASONAL HURRICANE ACTIVITY FOR 1993

By

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(This update of the author's 24 November 1992 and 4 June 1993 seasonal forecasts of 1993 hurricane activity is based on new June–July meteorological conditions and recent studies by the author and his Colorado State University research colleagues.)

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DEFINITIONS

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

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) Four 6-hour periods during which a tropical cyclone is observed or estimated to have hurricane intensity winds.

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.

Named Storm - (NS) A hurricane or a tropical storm.

Named Storm Day - (NSD) Four 6-hour periods during which a tropical cyclone is observed or estimated to have attained tropical storm or 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 for each 6-hour period of its existence.

Intense Hurricane - (IH) A hurricane reaching at some point in its lifetime a sustained low level wind of at least 111 mph (96 kt or 50 ms^{-1}). This constitutes a category 3 or higher on the Saffir/Simpson scale (a "major" hurricane).

Intense Hurricane Day - (IHD) Four 6-hour periods during which a hurricane has intensity of Saffir/Simpson category 3 or higher.

Millibar - (mb) A measure of atmospheric pressure which is often used as a vertical height designator. Average surface values are about 1000 mb; the 200 mb level is about 12 kilometers and the 50 mb is about 20 kilometers altitude. Monthly averages of surface values in the tropics show maximum summertime variations of about $\pm$ 2 mb which are associated with variations in seasonal hurricane activity.

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 5-6 years or so on average.

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

SOI - Southern Oscillation Index - A normalized measure of the surface pressure difference between Tahiti and Darwin.

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 - A deviation of Caribbean and Gulf of Mexico sea level pressure from observed long term average conditions.

SST(s) - Sea Surface Temperature(s).

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 presents details of the author's updated forecast of tropical cyclone activity for the Atlantic Ocean region including the Caribbean Sea and the Gulf of Mexico during 1993. This updated forecast utilizes meteorological data for June and July and is based on the author and his research colleagues ongoing research activities which relates the amount of seasonal Atlantic tropical cyclone activity to five factors: Namely, 1) three measures of the Quasi-Biennial Oscillation of equatorial stratospheric zonal wind (QBO) at 50 mb (20 km) and 30 mb (23 km) and the absolute value of the shear between these levels; 2) the El Niño-Southern Oscillation (ENSO) conditions as specified by the Equatorial East Pacific Sea Surface Temperature Anomaly (SSTA) and the value of the Tahiti minus Darwin surface pressure; 3) Caribbean basin Sea-Level Pressure Anomalies (SLPA) and upper tropospheric 200 mb Zonal Wind Anomalies (ZWA); 4) two measures of West African Rainfall (AR) anomalies, one of June-July in the Western Sahel region, and the other the previous year August through November precipitation in the Gulf of Guinea region and 5) the surface west to east pressure and temperature gradients across the Western Sahel region of Africa during February through May.

Information received by the author through 4 August 1993 indicates that the 1993 hurricane season should, overall be about an average season when compared with hurricane activity of the last 43 years. Our statistical analysis indicates that this season should have about 6 hurricanes, 10 named storms of at least tropical storm intensity, about 25 hurricane days, a total of 50 named storm days and a Hurricane Destruction Potential of 55. Because the Western Sahel is expected to again have below average rainfall this year, it is anticipated that there will be only two intense or major hurricanes of Saffir/Simpson intensity category 3, 4 or 5 this season. This updated forecast is for slightly calmer conditions than were suggested in the 24 November 1992 and 4 June 1993 forecasts for 1993. A verification of this forecast will be issued in late November.

1 Introduction

The Atlantic basin (including the Atlantic Ocean, Caribbean Sea and Gulf of Mexico) experiences more seasonal variability of hurricane activity than occurs in any other global hurricane basin. The number of hurricanes per season in recent years can range as high as 12 (1969), 11 (1950), 9 (1955, 1980), or as low as 2 (1982) or 3 (1957, 1962, 1972, 1983, 1987). Until recently there has been no objective method for determining whether a forthcoming hurricane season was likely to be active, inactive, or near normal. Recent and ongoing research by the author and his colleagues (Gray, 1984a, 1984b, 1990; Landsea, 1991; Gray *et al.*, 1992 1993a,b) indicates that there are surprisingly skillful 3 to 11 month (in advance) predictive signals for Atlantic basin seasonal hurricane activity.

2 Factors Known to be Associated With Atlantic Seasonal Hurricane Variability

The author's early August Atlantic seasonal hurricane forecast is based on the current values of indices derived from two global and four regional scale predictive factors which the author and his colleagues have previously shown to be statistically related to seasonal variations of hurricane activity. The current values of these predictive factors are available by late November of the previous year, or by early June, at the official start of the hurricane season, or by early August, just before the start of the most active portion of the hurricane season. The predictive factors for early August are:

a) The direction of the east-west stratospheric Quasi-Biennial Oscillation (QBO) winds which circle the globe over the equator: On average, there is nearly twice as much intense Atlantic basin hurricane activity during seasons when equatorial winds at 30 mb and 50 mb (23 and 20 km altitude respectively) have a relatively westerly component as compared to periods when they have a relative easterly component. During the 1993 season, these QBO winds will be from a westerly direction. This is a factor which will act to enhance this year's hurricane activity.

b) The presence or absence of a moderate or strong El Niño (warm water) event in the eastern equatorial Pacific: Atlantic hurricane seasons during moderate or strong El Niño events average only about 40 percent as much hurricane activity as occurs during non-El Niño seasons. Years of cold water are observed to usually have above average amounts of hurricane activity. These seasonal hurricane activity differences are related to the stronger upper tropospheric (200 mb or 12 km) westerly winds which typically occur over the Caribbean basin and western Atlantic during El Niño seasons and the weaker westerly winds which occur during cold years. The recent moderately strong El Niño event of late 1991 to mid-1993 is now rapidly weakening and is expected to dissipate by early fall. This weakening warm event is not expected to cause a significant reduction or enhancement in this year's hurricane activity. El Niño strength can be assessed from the Sea Surface Temperature Anomaly (SSTA) in the Nino 3 area of the Pacific and from the normalized surface pressure difference between Tahiti and Darwin, or Southern Oscillation Index (SOI) (see Fig. 1).

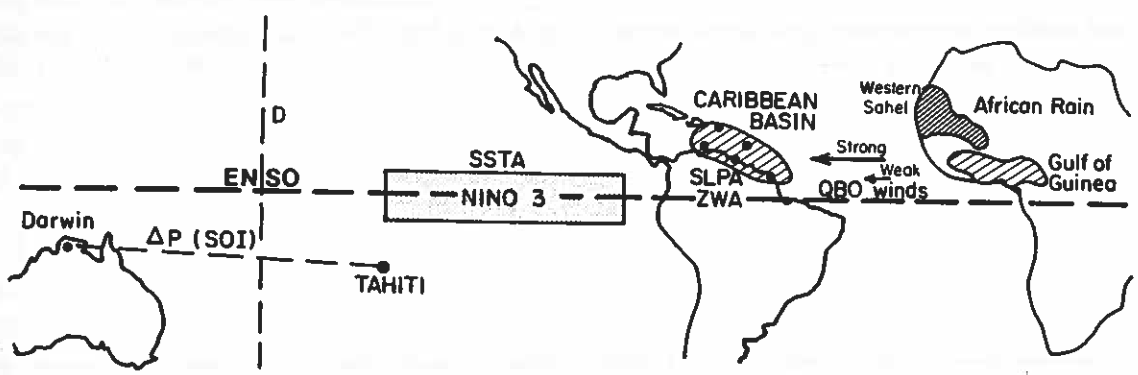

Figure 1: Locations of meteorological parameters used in early August Atlantic basin seasonal forecast.

c) African Rainfall (AR). Atlantic intense hurricane activity is typically enhanced in those seasons when the Western Sahel region of West Africa has had above average June-July rainfall and the Gulf of Guinea region (Fig. 2) has had above average late summer and fall precipitation during the previous year (i.e., in this case, during the fall of 1992). Hurricane activity is typically suppressed if the prior period rainfall in these two regions has been below average. Last year (1992) conditions in both of these regions were very dry and this trend has prevailed through July. However, drought conditions may not be as severe as previously anticipated. These rainfall conditions are expected to cause a moderate reduction in this year's hurricane activity, especially in intense hurricane activity.

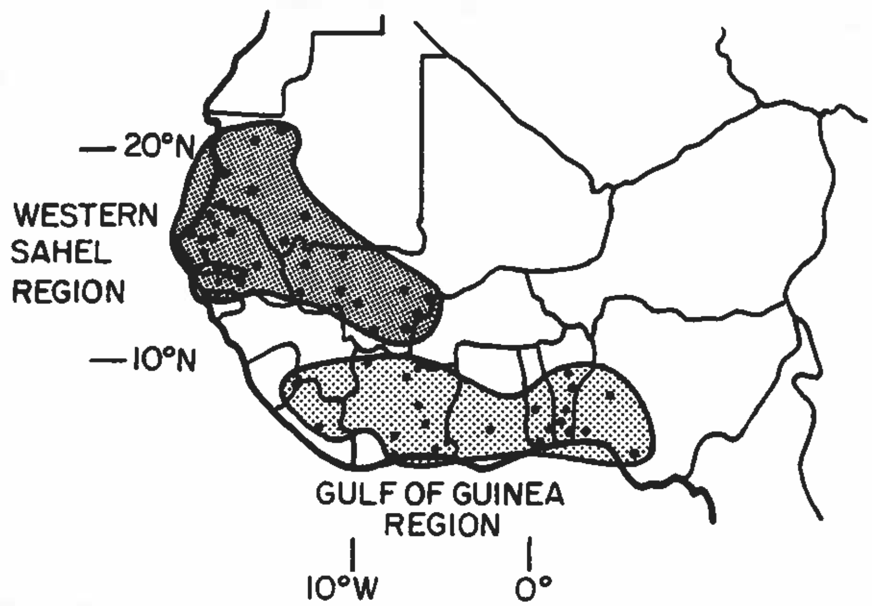

Figure 2: Locations of rainfall stations which make up the 38–station Western Sahel precipitation index and the 24-station Gulf of Guinea precipitation index. August to November rainfall within the Gulf of Guinea region provides a predictive signal for the following year's hurricane activity while June to July rainfall in the Western Sahel provides a predictive signal for the upcoming Atlantic hurricane season (see Landsea, 1991; and Gray *et al.*, 1992, 1993a,b).

d) Sea Level Pressure Anomaly (SLPA) in the eastern Caribbean basin. Other factors aside, negative pressure anomalies in the eastern Caribbean basin in late spring and early summer are typically associated with active hurricane seasons and vice-versa. Pressure anomaly values for June and July of this year have been near normal (+ 0.1 mb) and are judged to be a neutral influence on this season's hurricane activity.

e) Lower latitude Caribbean basin upper tropospheric (~ 200 mb or 12 km altitude) west to east or zonal wind anomalies (ZWA): Stronger 200 mb zonal wind anomalies are associated with a suppression and negative anomalies with an enhancement of seasonal hurricane activity. June-July ZWA values have been weakly positive (+0.6 m/s). This is judged to be a neutral influence on this season's hurricane activity. These weak zonal winds are an indication that the current weakening El Niño will likely not exert a significant inhibiting influence on this year's activity. A number of meteorologists thought that the March through May ENSO warming event would produce an inhibiting influence on this year's hurricane activity. This is not likely to occur.

f) Western Sahel west to east surface pressure and temperature gradients (or Delta PT). Recent research is showing that west to east surface pressure and surface temperature gradients across the Western Sahel region of Africa from February through May are well correlated with the hurricane activity which follows later in the year. We find that Atlantic hurricane activity is enhanced when the surface pressure difference between the east minus the west is greater than normal and/or when the east minus west temperature difference is below average. These pressure and temperature gradients between February and May of this year have been configured so as to indicate below average hurricane conditions for this season.

3 Current Characteristics and Discussion of the Five Primary (QBO, ENSO, AR, SLPA-ZWA and Δ PT) Early August Predictors of 1993 Seasonal Hurricane Activity

3.1 QBO

Tables 1 and 2 show the absolute and relative values of the current and extrapolated 30 mb (23 km) and 50 mb (20 km) stratospheric QBO zonal winds near 11 to 13°N for 1993 during the primary hurricane period of August through October. These estimates are based on a combination of the current trends in the QBO winds combined with the annual wind cycle variations for low latitude stations at Curacao (12°N), Trinidad (11°N), and Barbados (13°N). Note that during the primary August through October hurricane season, 30 mb and 50 mb zonal winds will be relatively westerly. Hence, stratospheric QBO wind conditions this year should enhance hurricane activity.

Table 1: April through October 1993 observed and extrapolated absolute 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} (supplied by James Angell and Colin McAdie).

	Observed					Extrapolated		
Level	March	April	May	Jun	Jul	Aug	Sept	Oct
30 mb (23 km)	+10	+7	0	–9	–10	–6	–5	–5
50 mb (20 km)	+8	+7	+5	–4	–8	–4	–2	–2

Table 2: As in Table 1 but for the "relative" (or anomalous) zonal wind values wherein the annual wind cycle has been removed. Values are in ms^{-1}.

	Observed					Extrapolated		
Level	March	April	May	Jun	Jul	Aug	Sept	Oct
30 mb (23 km)	+15	+15	+14	+9	+9	+8	+5	+2
50 mb (20 km)	+8	+8	+11	+7	+8	+9	+8	+5

3.2 ENSO

The Central and Eastern tropical Pacific have experienced a large oscillation of the warm El Niño event which has been present for the last two years. This event weakened greatly during the second half of 1992 but strengthened again during March through May of this year. April and May 1993 data show quite warm water temperatures and low values for the Southern Oscillation. It is unusual for an El Niño event to act in this way and for warm water conditions to persist for three consecutive years. The resurgence of the warm event in March through May surprised most El Niño watchers who had been anticipating a change to cooler conditions by spring 1993.

Most changes in ENSO conditions occur between late spring and summer, during the establishment and maintenance of the Asian summer monsoon. In early June, the author anticipated a strong cooling trend in ENSO during the months of June, July, and August. Westerly QBO conditions, lack of a West Pacific Ocean warm pool buildup, and other current conditions favored such a rapid depletion of the El Niño during these months and rapid retreat of those springtime warm El Niño conditions has taken place during the months of June and July. It is anticipated that this cooling tendency will continue during the rest of the hurricane season. Only slight eastern Pacific warm water conditions are expected to be present during the height of the hurricane season which spans the period of mid-August to mid-October. Stronger trade winds have been established in the eastern and central Pacific and the Southern Oscillation is beginning to increase. It is anticipated that the current warm water El Niño will not cause a significant inhibiting influence on this year's hurricane activity. Table 3 shows how NINO-3 SSTA conditions have altered since January.

Table 3: 1993 NINO-3 sea surface temperature anomaly in $°C$.

Jan	Feb	Mar	Apr	May	Jun	Jul
0.1	0.3	0.8	1.2	1.7	0.8	0.3

3.3 West African Rainfall (AR)

Substantially more intense (Category 3-4-5) Atlantic hurricane activity occurs when June through September West Sahel rainfall is above average as compared to those seasons when rainfall is below average (Gray, 1990; Landsea and Gray, 1992). The long running Sahel drought of 1970-87 was associated with a great suppression of intense hurricane activity during that 18 year period. A temporary (two year) interruption of African drought conditions occurred in 1988–89 and there was also a substantial increase in intense hurricane activity, including five Saffir/Simpson category 4-5 hurricanes. However, drought conditions returned again in 1990-1992. The assessment for 1993 (as of the end of July) is that we will again see below average Western Sahel rainfall this year. June and July rainfall has been below average (–0.70 S.D.). This is consistent with the low values of the Western Sahel August-September precipitation last year (–0.95 S.D.) and the very low values of Gulf of Guinea region (Fig. 1) rainfall during August through November of last year (–0.90 S.D.). Other factors indicating drought conditions are:

- (a) The Landsea *et al.* (1993a,b) early June forecast of −1.20 S.D. of West African June to September rainfall conditions for this year. This forecast is based on most of the same factors as the current seasonal hurricane forecast and indicates quite dry conditions for this summer.

- (b) The present arrangement of global and Atlantic SSTA conditions which in past years have been associated with African drought conditions. These SSTA conditions include Northern versus Southern Hemisphere SSTA conditions, southwest Atlantic SSTA and SSTA anomalies in the eastern equatorial Pacific. The UK Meteorological Office (1993) is also forecasting dry to very dry conditions this year for the Sahel. The Meteorological Office's most recent forecasts are based on global SSTA patterns through June.

The author believes these earlier forecasts of very dry Western Sahel conditions are too extreme. Westerly QBO conditions and the lack of a warm ENSO should favor somewhat more West African rainfall. We anticipate that Western Sahel rainfall during August and September will be about what June and July values have been, about -0.7 S.D. This is expected to cause a moderate, but not extreme, inhibiting influence on this season's hurricane activity.

3.4 SLPA and ZWA

Two parameters which are very important for the early August forecast are Caribbean Basin Sea Level Pressure Anomalies and 200 mb (12 km) Zonal Wind Anomalies. The June-July 1993 four-station tropical (Trinidad, Barbados, San Juan and Cayenne) SLPA's were near neutral (+0.1 mb) and a five-station June-July (Balboa, Kingston, Trinidad, Curacao, and Barbados) ZWA values averaged out to be slightly positive (+0.6 m/s). These are close to average conditions and suggest neither an enhancement or suppression of this season's hurricane activity. They also suggest that the current weakening El Niño event is not causing strong upper level winds in the Caribbean or tropical Atlantic. Table 4 shows these SLPA values for the period April through July.

Table 4: Lower Caribbean basin Sea Level Pressure Anomalies (SLPA) for 1993 in mb (for San Juan, Barbados, Trinidad, and Cayenne) and Zonal Wind Anomaly (ZWA) in m/s for Kingston, Balboa, Curacao, Barbados, and Trinidad (as supplied by Colin McAdie of NHC and from our CSU analysis).

	April	May	June	July
SLPA	-0.63	-1.21	+0.20	+0.03
ZWA	+2.6	-1.9	+1.2	0.0

3.5 Δ PT

February through May 1993 West African east-west surface pressure and surface temperature gradient (Δ PT) were both negative in comparison with the prior 43-year average. This influence is indicative of a weakening of the West African monsoon and this is a suppressing influence on this season's hurricane activity.

4 Seasonal Predictants

The tropical cyclone predictants include the seasonal total numbers 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 predictants are contained in Gray *et al.* (1992, 1993a) and in Landsea (1993). Also included is 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 for 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, the number of hurricanes is not representative of the entire tropical cyclone activity for that year. For instance, the 1977 season had 5 H but was otherwise an inactive year; only 7 HD, 1 IH, and 1 IHD. By contrast, 1988 which also had 5 H, but was an active year in terms of the other seasonal parameters which included 24 HD, 3 IH and 8 IHD. These are examples of years having one identical parameter yet much different levels of other activity. To overcome these difficulties we propose the use of a single (NTC) index which is a combination of six measures of tropical cyclone activity. This single index also has quite high forecast skill. Table 5 shows what the values of NTC have been between 1950-1992.

Table 5: Listing of Seasonal Net Tropical Cyclone activity (NTC) values between 1950-1992.

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

5 Statistical Forecast for 1993

The author and his research colleagues Chris Landsea, Paul Mielke and Ken Berry have recently developed a quantitative forecast scheme specifically for the prediction of Atlantic seasonal hurricane activity from early August (see paper by Gray, Landsea, Mielke, and Berry, 1993). These collaborative research activities have yielded new quantitative prediction equations which better refine and maximize our early August predictions. This prediction equation is of the form

$$\tilde{y} = b_o + b_1 \left[a_1 U_{50} + a_2 U_{30} + a_3 |U_{50} - U_{30}|\right]$$

$$+ b_2 \left[a_4 R_S + a_5 R_G\right]$$

$$+ b_3 \left[a_6(SOI) + a_7(SSTA) + a_8(SLPA) + a_9(ZWA)\right] \quad (1)$$

where

$\tilde{y}$ is the predictant (NS, NSD, H, etc.),
a's and b's are empirically derived coefficients,
U_{50}, U_{30} are extrapolated September QBO zonal winds at 30 and 50 mb at 10°N (Table 1),
$|U_{50} - U_{30}|$ absolute value of the extrapolated vertical wind shear between 50 and 30 mb,
R_S is the Western Sahel June–July precipitation,
R_G is the previous year August to November precipitation in the Gulf of Guinea region,
SLPA is the Sea Level Pressure Anomaly in the lower Caribbean basin in June–July,
ZWA is the Zonal Wind Anomaly in the Caribbean basin in June–July.
SSTA is the Sea Surface Temperature Anomaly in Nino 3 in June and July,
SOI is the normalized Tahiti minus Darwin Sea Level Pressure differences for June–July,

The a and b coefficients vary for each forecast parameter and are given in Table 6.

Figure 1 shows the regions from where the data for these predictors was obtained.

Based on cross-validated (or jackknife) hindcasts for the 42 seasons of 1950-1991 we find that we can explain a substantial amount of the variance in individual season forecasts (Gray *et al.*, 1993a). Although these 9 variables are not independent, when taken together, each variable contributes to the forecast skill.

Based on data through the end of July, 1993, we find that the 1 August predictors of Equation (1) to have the values listed in Table 7. Substitution of these variables into equation (1) gives 1993 seasonal hurricane activity forecast as indicated in column A of Table 8. Our present forecast equation (1) contains information only on current and past ENSO conditions, not future conditions. Because of the recent unusual and likely temporary enhancement of the ENSO in March through June, the author does not believe June-July ENSO conditions are representative of the ENSO conditions to be expected between the height of the hurricane season from mid-August through mid-October. I believe that cooler or more neutral ENSO conditions should be present.

Table 6: Constants and coefficients for 1 August statistical forecasts (from Gray *et al.* 1993a,b). Asterisk refers to the removal of a small bias in intense hurricane (cat. 3-4-5) maximum winds in the years of 1950-1969 (see Landsea, 1993).

	a_1	a_2	a_3	a_4	a_5	a_6	a_7	a_8	a_9
NS	1.000	0.711	−0.082	1.000	−1.260	1.000	0.106	−0.275	0.046
NSD	1.000	0.560	−0.358	1.000	1.109	1.000	0.096	−0.864	−1.489
H	1.000	1.928	0.284	1.000	17.876	1.000	−1.172	−1.966	−0.025
HD	1.000	0.894	0.266	1.000	0.613	1.000	0.182	−0.050	−0.075
IH*	1.000	2.448	−0.876	1.000	0.689	1.000	0.166	0.476	1.462
IHD*	1.000	0.195	0.929	1.000	0.222	1.000	0.286	3.045	1.270
HDP*	1.000	0.550	0.649	1.000	0.186	1.000	0.497	1.978	3.327
NTC*	1.000	1.056	1.013	1.000	1.815	1.000	1.709	13.791	21.775

	$\hat{\beta}_0$	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_3$
NS	11.228	0.100	−0.757	−0.931
NSD	68.890	1.029	5.106	−5.309
H	7.410	0.046	0.050	0.239
HD	33.509	0.493	4.503	−4.318
IH*	3.000	0.013	0.745	−0.290
IHD*	4.806	0.109	4.933	−0.569
HDP*	85.835	1.615	30.989	−4.038
NTC*	122.819	1.481	11.310	−0.619

Table 7: The nine predictor variables for the 1993 early August forecast are as follows.

U_{50}	=	−5 m/s
U_{30}	=	−2 m/s
$\lvert U_{50} - U_{30}\rvert$	=	3 m/s
R_s	=	−0.7 S.D.
R_g	=	−0.9 S.D.
SLPA	=	+0.1 mb
ZWA	=	+0.6 m/s
SSTA	=	+0.55°C
SOI	=	−0.9 S.D.

Table 8: The 1993 seasonal forecasts obtained by substitution of the parameters in Table 4 into Equation (1). The author's qualitative adjustment and actual forecast is given in Column B.

Forecast Parameter	A Table 5 Values in Eq. 1	B Qualitative Adjustment and Actual Forecast
Named Storms (N)	9.8	10
Named Storm Days (NS)	52.1	50
Hurricanes (H)	6.5	6
Hurricane Days (HD)	23.9	25
Intense Hurricanes (IH)	1.7	2
Intense Hurricane Days (IHD)	1.1	2
Hurricane Destruction Potential (HDP)	50.4	55
Net Tropical Cyclone Activity (NTC)	72%	85%

The right column of Table 8 shows the author's qualitative adjustment of the statistical forecast and the actual forecast for this season. Table 9 compares this early August forecast to the author's late November forecast (Gray, 1992) and early June forecast. Note that the forecast has been revised downward from the late November and early June forecast. This table also compares each parameter of this season's forecast as a percentage of the last 43-year average. Table 10 shows a comparison of this year's August forecast with the amount of hurricane activity of past years.

Table 9: Comparison of current early August 1993 seasonal predictions with the seasonal predictions made in late November 1992 and prediction made in early June and the percent of normal.

Forecast Parameter	Late Nov. 1992 Fcst.	Early June Fcst.	Current Early August Fcst.	As percent of long term mean
Named Storms (N)	11	11	10	109
Named Storm Days (NS)	55	55	50	108
Hurricanes (H)	6	7	6	105
Hurricane Days (HD)	25	25	25	107
Intense Hurricanes (IH)	3	2	2	93
Intense Hurricane Days (IHD)	7	3	2	43
Hurricane Destruction Potential (HDP)	75	65	55	80
Net Tropical Cyclone Activity (NTC)	-	95%	85%	85%

Table 10: Comparison of early August 1993 seasonal prediction with activity in previous years.

	5 August Forecast 1993	Observed 1992	1991	Average Season 1970-87	Average Season 1950-69	43-Year Ave.
Hurricanes	6	4	4	4.9	6.5	5.7
Named Storms	10	6	8	8.3	9.8	9.2
Hurricane Days	25	16	8	15.5	30.7	23.3
Named Storm Days	50	38	22	37.3	53.4	46.1
Hurr. Dest. Pot. (HDP)	55	51	23	42.7	100.0	69.0
Intense Hurricanes (Cat. 3-4-5)	2	1	2	1.6	3.4	2.1
Intense Hurricane Days	2	3.25	1.25	2.1	8.8	4.7
Net Tropical Cyclone Activity (NTC)	85%	62%	59%	73%	123%	100%

6 Summary Discussion

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 through June. The author and most El Niño researchers did not anticipate this recent warming. As discussed earlier in the 4 June forecast, the author did not believe that these warm springtime SST conditions would persist through the height of the 1993 hurricane season from mid-August through mid-October. But this was difficult to ascertain in early June. A rather rapid and progressive cooling was anticipated.

The reader should note that this forecast rests on a number of other parameters in addition to the ENSO. Name storm and hurricane numbers are expected to be near normal for this season. African rainfall and surface pressure and temperature gradient conditions are indicative of somewhat suppressed intense (or major category 3-4-5) hurricane activity, for this year. The 1993 season should definitely have more name storms and hurricanes than have the last two seasons of 1991 and 1992.

7 Verification of Previous Forecasts

Table 11 gives verification data for the author's previous nine years of seasonal forecasts. The late July forecasts have been superior to the early June forecasts and the forecasts of named storm activity have been the most skillful. Last year's forecast went very well. Except for 1989, these forecasts are an improvement over climatology - the only objective seasonal prediction that had previously been available. The lack of accuracy for the 1989 forecast is attributed to heavy rainfall which fell in the West Sahel. Prior to 1990 this rainfall was not explicitly included in the author's forecast scheme. This rainfall is now included and its influence is becoming better understood.

8 Forecast for 1994

A forecast for seasonal hurricane activity of 1994 will be issued in late November, 1993, at the time of verification of this year's forecast.

Table 11: 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
Intense Hurricanes (Cat. 3-4-5)		3	2	2
Intense Hurr. Days		Not fcst.	5	2
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
Intense Hurricanes (Cat. 3-4-5)		1	0	2
Intense Hurr. Days		2	0	1
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
Intense Hurricanes (Cat. 3-4-5)	1	1	1	1
Intense Hurr. Days	2	2	2	3

9 Cautionary Note

It is important that the reader realize that this seasonal forecast is a statistical scheme which will fail in some years. This forecast also does not specifically predict where within the Atlantic basin storms will strike. Even if 1993 should prove to be a below average hurricane season, there are no assurances that several hurricanes will not strike along the US or Caribbean Basin coastline and do much damage. Or, if 1993 should prove to be a very active hurricane season there is no assurance that any storms will come ashore.

10 Likely Increase in Landfalling Major Hurricanes in Coming Decades

There has been a great lull in US East Coast, Florida and Caribbean Basin major (category 3-4-5) landfalling hurricanes over the last 25 years. We see this as a natural consequence of the slowdown in the Atlantic Ocean thermohaline Conveyor Belt circulation and its closely related consequences for Sahel drought, increased El Nino activity and other global scale circulation changes which have occurred over the last 25 years.

Historical and geological records indicate that this lull in major landfalling hurricane activity should not be expected to indefinitely continue. A return of increased major landfalling hurricane activity is to be expected in the next few decades. When this happens, (because of the large coastal development during the last 25-30 years), the US will see hurricane destruction as never before experienced (Gray and Landsea, 1992). Research on the causes and the likely time frame for this change-over is desperately needed. This is a real and likely more of an immediate natural threat for US than that of earthquakes, tornados or greenhouse gas warming.

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