FORECAST OF ATLANTIC SEASONAL HURRICANE ACTIVITY FOR 1995

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(This forecast is based on ongoing research by the authors at Colorado State University, together with recent April–May 1995 meteorological information)

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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 (in 10^4 knots^2)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.

Net Tropical Cyclone Activity (NTC) - Average seasonal percentage sum of NS, NSD, H, HD, IH, IHD. Gives overall indication of Atlantic basin seasonal hurricane activity.

1 knot = 1.15 miles per hour = .515 meters per second.

ABSTRACT

This paper presents details of the authors' forecast for the amount of tropical cyclone activity expected to occur in the Atlantic Ocean region including the Caribbean Sea and the Gulf of Mexico during 1995. This forecast is based on the authors' ongoing research relating the amount of seasonal Atlantic tropical cyclone activity to five basic physical parameters. These are: 1) the Quasi-Biennial Oscillation (QBO) of equatorial stratospheric winds; 2) the El Niño-Southern Oscillation (ENSO); 3) West African Rainfall (AR) anomalies during the previous year, 4) anomalous west to east gradients of surface pressure and surface temperature (ΔPT) in West Africa during February through May, and 5) Caribbean Basin Sea Level Pressure and Upper Level Zonal Wind Anomalies (SLPA and ZWA, respectively).

Information received by the authors up to 6 June 1995 indicates that the overall 1995 hurricane season should be an above average season with about 8 hurricanes (average is 5.7), 12 named storms (average is 9.3) of at least tropical storm intensity, a total of about 35 hurricane days (average is 23), 65 named storm days (average is 46) and total Hurricane Destruction Potential (HDP) of 110 (average is 68). It is also expected that there should be 3 intense or major hurricanes of Saffir/Simpson intensity category 3, 4 or 5 this season (average is 2.1) and about 6 major hurricane days (average is 4.5). These parameters represent an overall measure of total hurricane and tropical cyclone activity which is about 140 percent of the last 45-year average. The amount of hurricane activity in this forecast has been increased somewhat from that in the first author's 30 November 1994 forecast and is above the 13 April 1995 assessment given at the Atlantic City National Hurricane Conference. This early June enhancement of the hurricane forecast is due to the dissipation of the long running El Niño event and the observed return of cold water conditions in the equatorial East Pacific, to new estimates of African Western Sahel rainfall (+0.27 S.D.), and to warm eastern Atlantic sea surface temperature conditions which have become established the last two months. This is favorable for hurricane activity.

This forecast will again be updated on 4 August 1995, at the beginning of what is climatologically the most active part of the hurricane season. The updated August forecast will make use of June and July data and should provide a more reliable forecast, particularly with regard to the African rainfall as it relates to prospects for intense hurricane activity during the most active part of the season. The updated August forecast will also provide a much better gage on the extent of expected development of a (cold water) La Niña event in the equatorial east Pacific.

1 Introduction

The Atlantic basin, including the Atlantic Ocean, Caribbean Sea and Gulf of Mexico, experiences more season-to-season variability of hurricane activity than any other global hurricane basin. The number of hurricanes per season in recent years has ranged as high as 12 (as in 1969), 11 (as in 1950) and 9 (as in 1980, 1955), and as low as 2 (as in 1982) and 3 (1994, 1987, 1983, 1972, 1962, 1957). 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 colleagues (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.

2 Factors Known to be Associated With Atlantic Seasonal Hurricane Variability

This early June Atlantic seasonal hurricane forecast is based on the current values of indices derived from various global and regional scale predictive factors which the author and his colleagues have previously shown to be statistically related to seasonal variations of hurricane activity. Successive sets of values for these predictive factors are obtained by late November of the previous year, by early June of the concurrent year, the official start of the hurricane season and by early August (at the start of the most active portion of the hurricane season). These predictive factors include the following:

(a) The stratospheric Quasi-Biennial Oscillation (QBO) influence. The QBO refers to variable east–west oscillating stratospheric winds which circle the globe near the equator. On average, there is nearly twice as much intense Atlantic basin hurricane activity during seasons when equatorial stratospheric winds at 30 mb and 50 mb (23 and 20 km altitude, respectively) are more westerly as compared to when they are more easterly directed. During the 1995 season, these QBO winds will be from an westerly direction and are expected to be an enhancing influence for this season's hurricane activity.

(b) El Niño-Southern Oscillation (ENSO) influence: ENSO characterizes the presence of either warm or cold sea surface temperature anomalies in the eastern equatorial Pacific. The effects of a moderate or strong El Niño (warm water) event in the eastern equatorial Pacific act to reduce Atlantic basin hurricane activity. By contrast, seasons with cold sea surface temperatures, or La Niña years, have enhanced hurricane activity. These differences are related to alterations of upper tropospheric (200 mb or 12 km) westerly winds over the Caribbean Basin and western Atlantic. These westerly winds are enhanced during El Niño seasons. This condition creates strong vertical wind shear over the Atlantic which inhibits hurricane activity. During La Niña (or cold) years, these westerly winds and the associated vertical wind shear are reduced and hurricane activity is typically greater. It is expected that the unusually long lasting 1991-94 El Niño has finally run its course and cold water conditions are settling in. This, in turn, should be a factor enhancing this year's Atlantic basin hurricane activity. New April-May data indicates that distinctly cold conditions are developing for this year.

(c) African Rainfall (AR) influence: The incidence of intense Atlantic hurricane activity is typically enhanced during those seasons when the Western Sahel and Gulf of Guinea regions of West Africa (shaded area in Fig. 1) had above average late summer and fall precipitation during the previous year (in this case during the fall of 1994). Hurricane activity is typically suppressed if the prior fall rainfall in these two regions was below average. Rainfall amounts in the Western Sahel in August-September 1994 was +0.08 S.D.; Gulf of Guinea rainfall was +0.24 S.D. during August through November 1994. From these slightly wetter than average rainfall amounts we anticipate that Western Sahel rainfall will be slightly above normal in 1995 and distinctly above the very low rainfall which has occurred in the recent years of 1990-1993 and also greater than the drought years of the 1970s and 1980s. This Western Sahel rainfall forecast is based upon our early June forecast (Landsea et al., 1993) of rainfall.

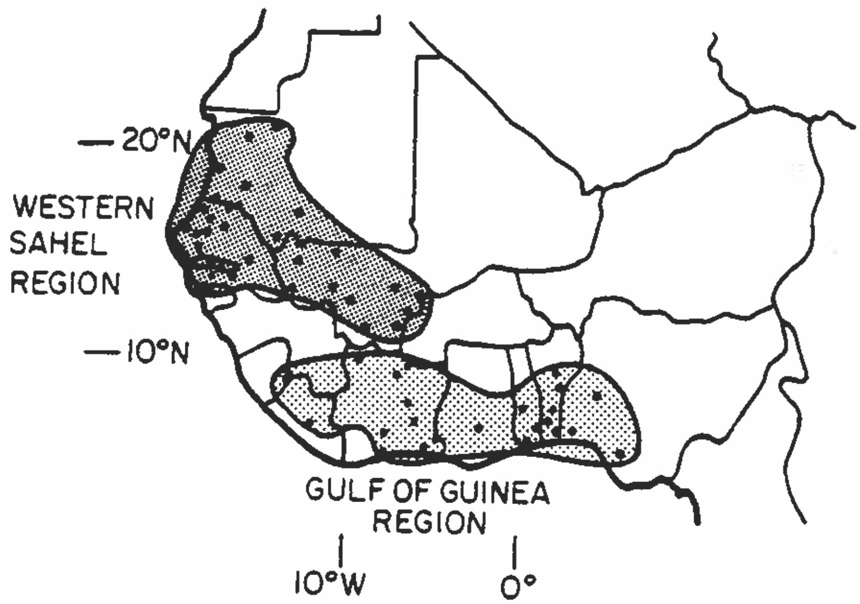

Figure 1: Locations of rainfall stations which make up the 38–station Western Sahel precipitation index and the 24-station Gulf of Guinea precipitation index. August to November rainfall within the Gulf of Guinea region provides a predictive signal for the following years hurricane activity as does prior year August-September rainfall in the Western Sahel (see Landsea, 1991; and Gray *et al.*, 1992).

(d) West Africa west-to-east surface pressure and surface temperature gradients (Δ PT) influence. Recent project research has shown that anomalous west-to-east surface pressure and surface temperature gradients across West Africa during February through May are strongly correlated with the hurricane activity which follows later in the year (see Gray *et al.*, 1994). We find that Atlantic hurricane activity is enhanced when the February to May east (Region B—see Fig. 2) minus west (Region A) pressure gradient is higher than normal and/or when the east minus west temperature gradient anomaly is below average. These pressure and temperature gradients during February through May 1995 indicate an about average West African monsoon and an about average amount of seasonal hurricane activity.

(e) Caribbean Basin Sea Level Pressure Anomaly (SLPA) and upper tropospheric (12 km) Zonal Wind Anomaly (ZWA) influence. April and May values of SLPA and ZWA have a modest predictive potential for hurricane activity during the following season. Negative anomalies (low pressure and easterly anomalies) imply enhanced seasonal hurricane activity while positive values imply suppressed hurricane activity. April-May 1994 values of SLPA and ZWA were both slightly below average, indicating a slight enhancing influence on this season's hurricane activity. Figure 3 provides a summary of the locations of the various forecast parameters which go into the early June forecast.

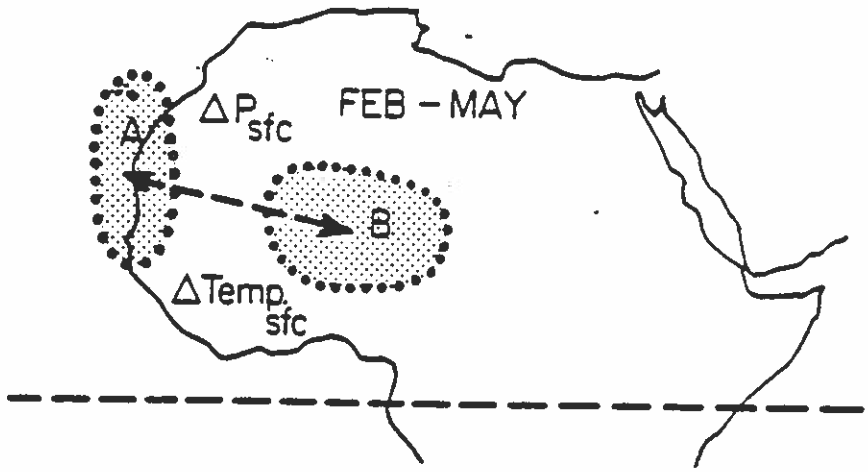

Figure 2: Map showing of the two West African regions—west (Area A) and east (Area B)—from which multi-station surface pressure and temperature values are computed to form combined west-to-east pressure and temperature gradients or Δ PT parameter. (Gray et al. 1994).

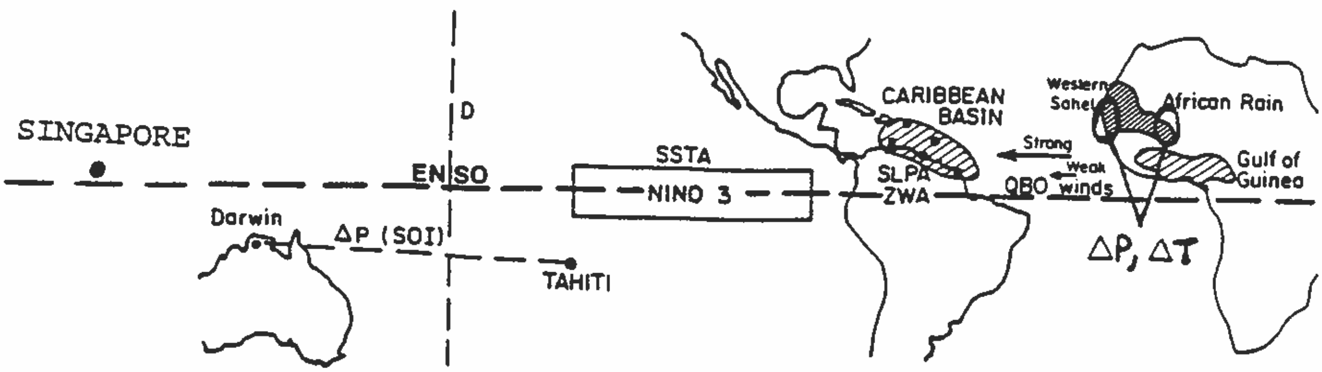

Figure 3: Locations of meteorological parameters used in the early June Atlantic basin seasonal forecast.

Our seasonal forecast scheme has the following general form:

$$\begin{pmatrix}\textit{Predicted Amount} \\ \textit{of TC Activity} \\ \textit{Per Season}\end{pmatrix} = Ave.\ Season + \overbrace{(QBO + EN + AR + PT + SLPA + ZWA)}^{\textit{Adjustment Terms}} \quad (1)$$

where

QBO = 30 mb and 50 mb Quasi-Biennial Oscillation zonal wind influence. (Increased hurricane activity for westerly (or positive) zonal wind anomalies; reduced hurricane activity for easterly or negative zonal wind anomalies.)

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

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

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

SLPA = Average Caribbean Sea Level Pressure Anomaly (SLPA) for Spring and early Summer. (Reduce hurricane activity if SLPA is significantly above average; add activity if SLPA is significantly below average.)

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

3 Discussion of the Current Characteristics of the Five Primary Early June Predictors (QBO, ENSO, AR, Δ PT, and SLPA-ZWA) as Regards the Amount of Anticipated 1995 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 1995 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 that 30 mb and 50 mb zonal winds will be from a relative westerly direction. This should be an enhancing influence for this year's hurricane activity.

Table 1: March through October 1995 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} (data supplied by James Angell and Colin McAdie).

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

3.2 ENSO

The long running 4-year El Niño event of 1991-94 has finally dissipated. April-May 1995 SSTA conditions in Nino 1-2 were cool, –1.0°C below average, and Nino-3 for May has also gone

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)	+10	+11	+14	+13	+12	+11	+10	+8
50 mb (20 km)	+3	+5	+8	+10	+11	+10	+9	+8

cold and is −0.4°C. The authors anticipate a continuing weak cooling trend to occur during the next three months with the establishment of the Asian summer monsoon. A change over to warm conditions later in the summer, as has occurred the last three summers, is not expected for this year. Anticipated August through October ENSO conditions dictate a significant increase in this year's hurricane activity over what has occurred during he last four seasons.

ENSO is the most important global scale environmental influence affecting Atlantic seasonal hurricane activity. Hurricane activity during the last four seasons has been much suppressed because of the persistent up-and-down warm water conditions which have been present in Nino-3 and Nino-4 (see Fig. 4) regions of the equatorial Pacific and the continuous drought conditions which have been present in the Western Sahel region of Africa (except for last year). Sea surface temperature anomaly (SSTA) conditions (in °C) in Nino-1-2, 3, and 4 since January 1995 have been as follows:

	Jan	Feb	Mar	Apr	May
Nino-1-2	0.9	0.6	−0.2	−1.0	−1.0
Nino-3	1.0	0.7	0.2	−0.2	−0.4
Nino-4	1.1	1.0	0.8	0.5	0.5

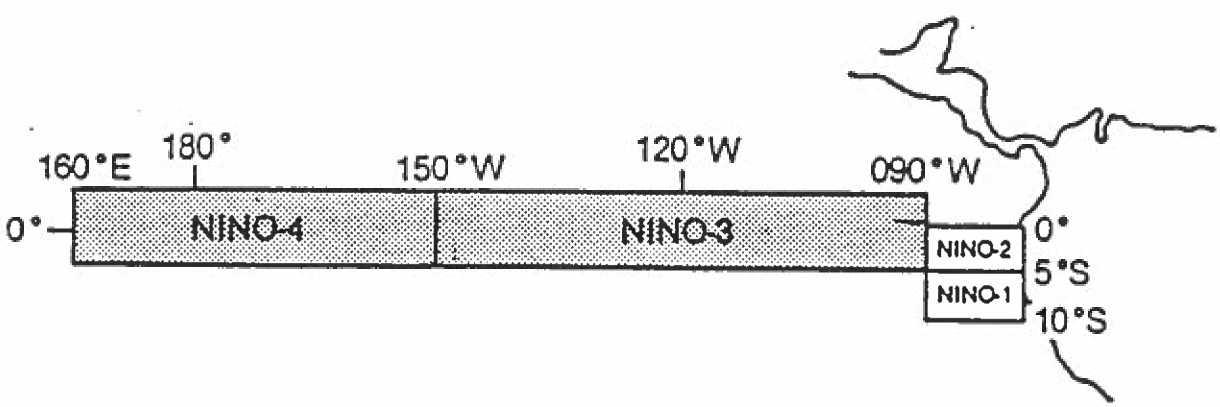

Figure 4: Equatorial Pacific sea surface temperature anomaly indices (°C) for the areas indicated.

Note the rapid cooling that has occurred since January and February. ENSO conditions through May 1995 are distinctly different from conditions through May of the last four years. May SSTA conditions during 1991 through 1994 in Nino-1-2 areas were 0.5, 2.3, 1.2 and −0.5°C, respectively, quite different than the present May 1995 value of −1.0°C. May Nino-3 SSTA conditions during 1991 through 1994 were 1.0, 1.6, 1.7 and 0.4, much warmer than the present year value of −0.4°C. It appears that for the first year since 1990 ENSO will not be an important inhibiting influence for Atlantic basin hurricane activity; in fact, it is expected to be an enhancing influence.

3.3 West African Rainfall (AR)

Substantially more intense 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 has been associated with a great suppression of intense (or major) hurricane activity during that 18 year period. A temporary (two year) interruption of African drought conditions occurred in 1988–89, concurrent with a substantial increase in intense hurricane activity, including five Saffir/Simpson category 4-5 hurricanes. However, drought conditions have returned again during 1990-1993. But these drought conditions were broken for 1994. The forecast by Landsea, et al. (1995) (as of the end of May) for June through September rainfall is that drought conditions will not occur this year. We forecast Western Sahel rainfall of +0.27 S.D., which is in the high end of the "Near average" quintile (with choices of quintiles "very dry", "dry", "near average", "wet", and "very wet" composed of 20 percent of all cases each). The Sahel rainfall quintiles are as follows:

Wettest 1/5: +0.65 S.D. ↑
Wet 1/5: +0.28 to +0.64 S.D.
Neutral 1/5: −0.27 to +0.27 S.D.
Dry 1/5: −0.75 to −0.28 S.D.
Driest 1/5: −0.76 S.D. ↓

This Sahel rainfall forecast is based on most of the same factors as the current seasonal hurricane forecast and indicates that Western Sahel rainfall conditions will be distinctly above the rainfall conditions of the 1990-1993 period. We are in disagreement with the 1995 experimental West African rainfall forecast which was issued by the UK Meteorological Office (1995) using data through April, which is forecasting "Dry" to "Very Dry" conditions.

Western Sahel rainfall is judged not to be an inhibiting influence on Atlantic intense hurricane activity during 1995 in comparison to what it has been for most of the last 25 years. See the attached forecast of Western Sahel rainfall by Landsea, et al. (1995).

Our last winter forecast of Western Sahel rainfall (based on data through November 1994) also indicated near average to above average rainfall conditions for this year. This forecast of non-drought conditions for the Western Sahel indicates an enhanced probability of Atlantic basin intense hurricane activity.

3.4 West Africa Δ P and Δ T

The anomalous west-to-east surface pressure and temperature gradients which become established across West Africa during February through May are good indicators of the hurricane activity to be expected during the late summer-fall period. Figure 2 showed the west-and-east areas of Africa from which these surface pressure and temperature gradients are taken. Hurricane activity is greatest when the east (Region B) minus west (Region A) pressure gradient deviations are most positive and/or when the west-minus-east temperature gradients are positive.

Given the typical inverse relationship between land surface temperature and surface pressure, positive west-to-east pressure gradients are typically associated with positive east-to-west temperature gradients and vice versa. A positive value of west to east Δ P and east to west Δ T would act to enhance southerly winds and thus bring about a comparatively moist low level flow over West Africa. More Sahel rainfall and more Atlantic intense hurricane activity would result. When west to east ΔP and east to west Δ T are negative, West Africa tends to have anomalously northerly and dry winds; this is conducive to dry Western Sahel rainfall conditions and fewer Atlantic intense seasonal hurricanes. February through May 1995 west to east Δ P was −1.0 and Δ T was +0.75 S.D. Taken together these values are indicative of an approximate neutral influence on this season's hurricane activity in comparison to average activity of the last 45 years.

3.5 SLPA and ZWA

Two Caribbean parameters which contribute to the early June forecast are Caribbean Basin Sea Level Pressure Anomalies (SLPA) and 200 mb (12 km) Zonal Wind Anomalies (ZWA). The April-May 1995 five-station tropical (Trinidad, Barbados, Curacao, San Juan and Cayenne) SLPA's were slightly below average (−0.2 mb) and the five-station April-May (Trinidad, Curacao, Barbados, Kingston and Balboa) ZWA values are slightly negative with −1.5 m/s. These two April-May measurements indicate a neutral to slight enhancing influence on this year's hurricane activity.

4 1 June Forecast Scheme

Our early June forecast takes the following form:

Hurricane Activity =

$$\begin{aligned}\beta_0 &+ \beta_1(a_1U_{50} + a_2U_{30} + a_3|U_{50} - U_{30}|)\\ &+ \beta_2(a_4R_s + a_5R_g + a_6\Delta_x\mathrm{P} + a_7\Delta_x\mathrm{T})\\ &+ \beta_3(a_8\mathrm{SLPA} + a_9\mathrm{ZWA} + a_{10}\mathrm{SST} + a_{11}\Delta_t\mathrm{SST} + a_{12}\mathrm{SOI} + a_{13}\Delta_t\mathrm{SOI})\end{aligned} \quad (1)$$

where

β's and α's are empirically derived coefficients for prior years of data
U_{50}, U_{30} are extrapolated September QBO zonal winds at 30 and 50 mb at 10°N
$|U_{50} - U_{30}|$ absolute value of the extrapolated vertical wind shear between 50 and 30 mb
R_s is the western Sahel precipitation in the previous August and September
R_g is the previous year August to November precipitation in the Gulf of Guinea region
ΔP is West African anomalous east-west pressure gradient deviation in February through May
ΔT is West African anomalous west-east temperature deviation in February through May
SLPA is the April-May Sea Level Pressure Anomaly in the lower Caribbean basin
ZWA is the April-May Zonal Wind Anomaly in the Caribbean basin
SOI is the April-May normalized Tahiti minus Darwin Sea Level Pressure differences
SSTA is the April-May Sea Surface Temperature Anomaly in Nino 3
ΔSOI is the recent months change in SOI from January-February to April-May
ΔSSTA is the recent months change in SSTA from January-February to April-May.

Figure 3 illustrates the source areas from which the data for these predictors are obtained.

Based on data through the end of May 1995, the 1 June predictors for Equation (1) have the values as listed in Table 3. Substitution of these variables into equation (1) with the coefficients listed in Appendix B gives 1995 seasonal hurricane activity forecast summarized in Table 4. The right column of Table 5 shows the authors' qualitative adjustment of the statistical forecast leading to the actual forecast for this season. We are being conservative. Observe that our prediction equations indicate an extremely active hurricane season for this year. We have added a downward adjustment to many of the values here shown. Last year our adjustment to our forecast equation actually gave a poorer forecast.

Table 5 expresses each parameter in this adjusted forecast as a percentage of the last 45-year average. Note that all forecast parameters are well above the long period average. Table 6 compares this early June forecast to the first author's late November 1994 forecast (Gray, 1994) of last year. The November 1994 forecast anticipated cold ENSO conditions to be in place during the height of the 1995 hurricane season. As of early June, this late November, 1994 assessment appears to be on target. Table 7 gives a comparison of this year's seasonal activity forecast with the amount of hurricane activity which has occurred during past years.

Note that the 1995 season is expected to be much more active than have the last four hurricane seasons and more active than most of the hurricane seasons since the late 1960's.

Table 3: Predictors for the early June 1995 forecast which are substituted into Equation (1).

QBO Predictors	U_{30}	-5 m/s	4-month
	U_{50}	-1 m/s	extrapolation to Sept. 1995
	$\|U_{50} - U_{30}\|$	4 m/s	
	R_s	+0.08 S.D.	Aug.-Sept. 1994
	R_g	+0.24 S.D.	Aug.-Nov. 1994
West African Predictors	ΔP	-1.0 S.D.	
	ΔT	+0.75 S.D.	Feb. through May 1995
Caribbean and ENSO Predictors	SLPA	-0.20 mb	April-May 1995 value
	ZWA	-1.5 m/s	April-May 1995 value
	SOI	-10.0 10^{-1}S.D.	April-May 1995 value
	SSTA	-35 x 10^{-2} °C	April-May 1995 value
	ΔSOI	-3.5 x 10^{-1} S.D.	(Apr-May) - (Jan-Feb) 1995
	ΔSSTA	-120 x 10^{-2} °C	(Apr-May) - (Jan-Feb) 1995

Table 4: The 1995 seasonal forecasts obtained by substitution of the parameter values in Table 5 into Equation (1). The author's qualitative adjustments and actual forecast are shown on the right column.

Forecast Parameter	Table 3 Values in Eq. 1	Qualitative Adjustment and Actual Forecast
Named Storms (N)	12.6	12
Named Storm Days (NS)	77.9	65
Hurricanes (H)	10.4	8
Hurricane Days (HD)	49.5	35
Intense Hurricanes (IH)	2.3	3
Intense Hurricane Days (IHD)	5.7	6
Hurricane Destruction Potential (HDP)	135.4	110
Net Tropical Cyclone Activity (NTC)*	153.5%	140%
Western Sahel rainfall forecast	+0.27 S.D.	+0.27 S.D.

*See Appendix A for definition

5 Analog Years

There have been four past years when a majority of the early June forecast parameters were similar to those of this year. Those were 1966, 1971, 1975 and 1980. This forecast parameters and their 4-year average compared with the early June 1995 parameters are shown in Table 8.

Table 9 shows the early June hindcasts with the use of Equation 1 (top) with the end of season verification (bottom). Note how the 4-year average hindcast and the average verification are very similar. The hurricane activity in these four analog years was considerably above

Table 5: 1995 Atlantic basin seasonal forecast values and the percent of the long term (1950-1994) average.

	%
Named Storms (N)	129
Named Storm Days (NS)	141
Hurricanes (H)	140
Hurricane Days (HD)	152
Intense Hurricanes (IH)	136
Intense Hurricane Days (IHD)	133
Hurricane Destruction Potential (HDP)	162
Net Tropical Cyclone Activity (NTC)	140

Table 6: Comparison of current, early June 1995, seasonal predictions with the 1995 seasonal predictions made in late November 1994.

Forecast Parameter	30 Nov. 1994 Fcst	Qualitative Adjustment 13 April 1995	Current 1995 Early June Fcst	Changes in 7 June 95 Fcst from 30 Nov. 1994 Fcst
Named Storms (N)	12	10	12	0
Named Storm Days (NS)	65	50	65	0
Hurricanes (H)	8	6	8	0
Hurricane Days (HD)	35	25	35	0
Intense Hurricanes (IH)	3	2	3	0
Intense Hurricane Days (IHD)	8	5	6	-2
Hurricane Destruction Potential (HDP)	100	75	110	+10
Net Tropical Cyclone Activity (NTC)	140%	100%	140%	0

Table 7: Comparison of early June 1995 seasonal prediction with activity in previous years.

	7 June Forecast 1995	Observed 1994	1993	1992	Average Season 1970-87	Average Season 1950-69	45-Year Ave. (1950-94)
Hurricanes	8	3	4	4	4.9	6.5	5.7
Named Storms	12	7	8	6	8.3	9.8	9.3
Hurricane Days	35	7	10	16	15.5	30.7	23.0
Named Storm Days	65	28	30	38	37.3	53.4	46.1
Hurr. Dest. Pot. (HDP)	110	15	23	51	42.7	100.0	68.1
Intense Hurricanes (Cat. 3-4-5)	3	0	1	1	1.6	3.4	2.1
Intense Hurricane Days	6	0	0.75	3.25	2.1	8.8	4.5
Net Tropical Cyclone Activity (NTC)	140%	37%	55%	62%	73%	123%	100%

Table 8: Values of the early June forecast parameters in the five analogous years similar 1995 and mean value comparison with early June 1995 values.

Year	U_{50}	U_{30}	$U_{50} - U_{30}$	R_s	R_g	Δ_z P	Δ_z T	SLPA	ZWA	SSTA	ΔSSTA	SOI	ΔSOI
1966	−7	−1	6	.78	−.16	0.56	1.34	0.0	0.5	3	−100	−6.9	1.8
1971	−3	−3	0	−.44	−.21	−1.16	−1.77	0.2	0.5	−61	−63	14.4	5.6
1975	−7	−1	6	−.02	−.06	−1.14	−.09	0.4	1.3	−57	−2	9.3	9.9
1980	−5	−2	3	−.90	.57	−.88	−.43	0.1	0.2	46	−13	−7.2	−8.7
Mean	−5	−2	4	−.14	.30	−0.64	−0.24	0.2	0.6	−18	−44	2.4	2.1
1995 Fcst Parameter	−1	−5	4	.08	.24	−1.00	0.75	−0.2	−1.5	−35	−120	−10.0	−3.5

average for the 25 years of 1970 through 1994. The early June forecast parameter information for this year is considered to be indicative of a slightly higher level of hurricane activity than that of the average of the 4-year analog years.

Table 9: Comparison of analog year hurricane statistics of early June hindcast (top table) with actual seasonal verification (below).

Early June Hindcast

Year	NS	NSD	H	HD	IH	IHD	HDP	NTC
1966	10.5	60.0	6.7	29.0	3.0	7.0	121	140
1971	11.6	51.8	9.2	29.0	1.2	1.3	65.0	95
1975	10.6	43.1	6.0	22.2	1.8	1.7	64.6	92
1980	11.0	60.0	8.7	37.5	2.0	5.5	95.3	125
4-Year Mean	10.9	53.7	7.6	31.9	2.0	3.9	86.5	113

End of Season Verification

Year	NS	NSD	H	HD	IH	IHD	HDP	NTC
1966	11	62	7	42	3	7	121	140
1971	13	63	6	29	1	1	65	95
1975	8	43	6	20	3	3	54.6	92
1980	11	60	9	38	2	2	126	135
4-Year Mean	10.8	57.0	7.0	32.3	2.2	3.3	91.5	115
Mean Observed Minus Mean Fcst Difference	−0.1	3.3	−0.6	0.4	0.2	−0.6	5.0	2

6 Great Suppression of 1991-1994 Hurricane Activity - Especially for Latitudes South of 25°N

There has been an unusually strong suppression of hurricane activity during the last four years (1991-94). Figure 5 illustrates the 1991-94 averages for the eight seasonal forecast parameters, expressed as percentages of the long term 1950-1994 climatology. Overall, hurricane activity during the last four years has averaged only about half of the long-term mean.

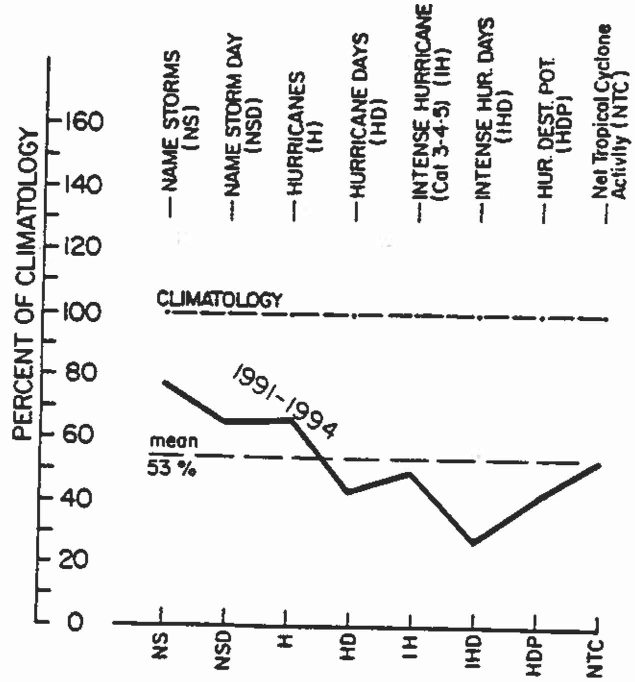

Figure 5: Comparison of mean hurricane parameters for the four years of 1991-94 with 1950-94 climatology.

The large decrease in hurricane activity during these four years has occurred exclusively in lower latitudes, south of 25°N. By contrast the higher latitude (> 25°N) hurricane activity has increased slightly from the long term average. This is a typical feature wherein an out-of-phase relationship occurs between hurricane formation activity in the lower (5-25°N) versus higher latitudes (25-40°N). Figure 6 gives percentage comparisons of the number of named storms, hurricanes, and intense category 3-4-5 hurricanes which formed both North and South of 25°N during this four year period. The net downturn in named storm and hurricane activity has been exclusively a function of the greater suppression of activity in the lower latitudes. Note that no category 3-4-5 hurricanes formed equatorwards of 25°N when climatology would have specified six. Only two hurricanes formed equatorwards of 25°N when climatology would have specified 10. This strong low latitude downturn is related to continuous El Niño-like conditions, strong African drought conditions in three of the last four years and higher than average values of West Atlantic and Caribbean basin surface pressure in all four years. These three climate parameters have a greater influence on the modulation of lower than higher latitude hurricane activity.

US Eastcoast and Florida Hurricane Landfall. Hurricane Andrew and Bob have been the only US landfalling hurricanes of the last five years (Emily, 1993 only skimmed the outer banks as a minimal category 3 hurricane). All of these cyclones did not become of hurricane intensity until they were poleward of 25°N. It is unusual to go five consecutive years without any low latitude origin hurricanes threatening upon the US coastline. These inhibiting influences are not expected to be present during the 1995 hurricane season, however.

Gulf of Mexico. During the last five years (1990-94), there was only one hurricane (Andrew, 1992) to make landfall on the US Gulf Coast. This is much below the long term average. This reduction of hurricane activity in the Gulf was primarily a response to the long lasting El Niño event of 1991-94. Historical records show that Gulf hurricane activity is usually suppressed during El Niño years and enhanced during La Niña (cold SST) years. The probability of hurricane activity within the Gulf of Mexico will be higher during 1995 than it has been

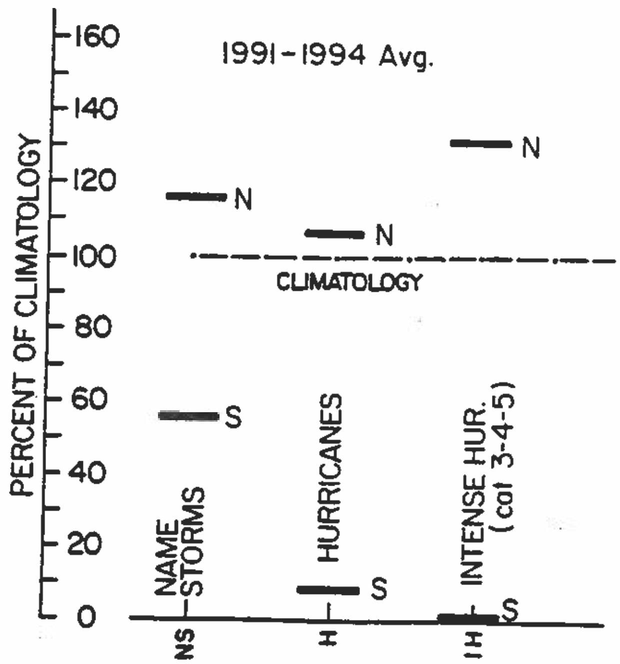

Figure 6: Comparison of the average number of named storms, hurricanes and intense (category 3-4-5) hurricanes forming north (N) of 25°N latitude and south (S) of 25°N latitude during the four seasons 1991-1994 in comparison with what is expected from the 1950-93 climatology. There was more activity than climatology in the north and far fewer formation events in the south than expected from climatology.

since 1989.

Caribbean Basin. There has been no hurricane activity at all within the Caribbean during the last five years. This is a consequence of the long lasting El Niño event of 1991-94, Western Sahel drought conditions during 1990-93 and higher than average Caribbean basin surface pressures during the last five years. These inhibiting influences are not expected to be present during the 1995 season. Consequently, the probability of Caribbean basin hurricane activity will be greater this year than any of the last five years.

7 Forecast Skill

This early June forecast scheme is presently being reworked. We hope to have a more skillful forecast scheme available by the time of the 1996 forecast. In extended analysis of hindcast skill for the period of 1950-1991 we estimate that we can independently explain between 40 and 55 percent of the variance of hurricane activity. Our highest skill of nearly 55 percent variation comes in the parameters of HD, HDP and NTC. Our skill with non-independent data explains 55-70 percent of the seasonal variance.

8 Discussion

It is well known that Atlantic Basin seasonal hurricane activity is quite variable. Past records indicate that it is typical to have a number of suppressed or somewhat below normal years in a row which are then followed by a year of greatly increased hurricane activity. It appears that 1995 will be one of those seasons wherein a large upsurge in hurricane activity occurs.

The El Niño, stratospheric QBO, West African rainfall, and Atlantic sea surface temperature anomalies are all coming together to promote the large-scale wind and thermal-moisture conditions which are associated with an active season. The first author now regrets his qualitative downward adjustment of the forecast in early April. The sea surface temperature pattern in both the Atlantic and Pacific have been more favorable for hurricane activity in the last two months.

Figures 7 and 8 illustrate how the late May SSTA patterns have changed between 1993 and 1995. Note how cold SSTA conditions have now returned to the equatorial East Pacific and how much of the eastern and tropical Atlantic conditions have gotten much warmer as compared to two years ago. Such SSTA changes are conducive to an active hurricane season.

It is important to keep in mind that the early season hurricane activity has no bearing on the entire season. Early June Hurricane Allison means nothing with regards to the hurricane activity to follow later in the season. The number of named storms (hurricanes) occurring in June and July correlates at an insignificant $r = +0.13$ ($+0.02$) versus the whole season activity. Actually, there is a slight negative association of early season storms (hurricanes) versus late season – August through November – $r = -0.28$ (-0.35). Thus, early season activity, be it very active or quite calm, has little or no bearing on the season as a whole.

9 Schedule of Updated Seasonal Hurricane Forecasts of 1995

An updated forecast, to be made at the start of the most active part of the hurricane season, will be issued on Friday August 4, 1995. A verification report on the 1995 hurricane season and a forecast for the 1996 hurricane season will be issued in late November of this year. In addition, seasonal forecasts for 1996 ENSO conditions and 1996 Sahel rainfall will also be issued at that time.

10 Cautionary Note

It is important that the reader realize that this seasonal forecast is based on 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 1995 should prove to be an active hurricane season, there are no assurances that hurricanes will necessarily strike along the US or Caribbean Basin coastline and do much damage. Or, if 1995 should prove to be an inactive season there is no assurance that no storms will come ashore.

11 Likely Increase of Landfalling Major Hurricanes in Coming Decades

There has been a great lull in the incidence of intense (category 3-4-5) landfalling hurricanes on US East Coast, Florida and Caribbean Basin during the last 25 years. We see this as a natural consequence of the slowdown in the Atlantic Ocean (thermohaline) Conveyor Belt circulation which has set off a variety of global circulation and rainfall pattern changes such as the Sahel drought, increased El Nino activity, Pacific and Atlantic middle latitude zonal wind increases, etc.

Historical and geological records indicate that this lull in major landfalling hurricane activity will not continue indefinitely. A return of increased major landfalling hurricane activity should be expected within the next decade or two. 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. More research on the causes and the likely timing of this change-over to increased intense hurricane activity is desperately needed. This is a more assured and immediate threat to the US than that of greenhouse gas warming and other environmental problems which are receiving much greater attention in comparison to the hurricane threat.

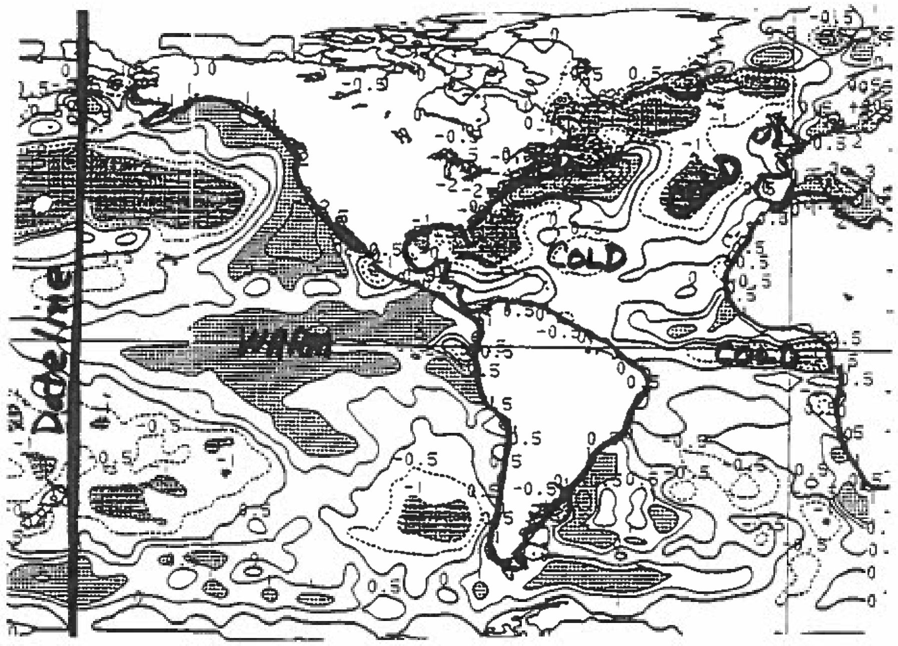

Figure 7: Sea surface temperature anomalies (SSTA) condition during late May 1993.

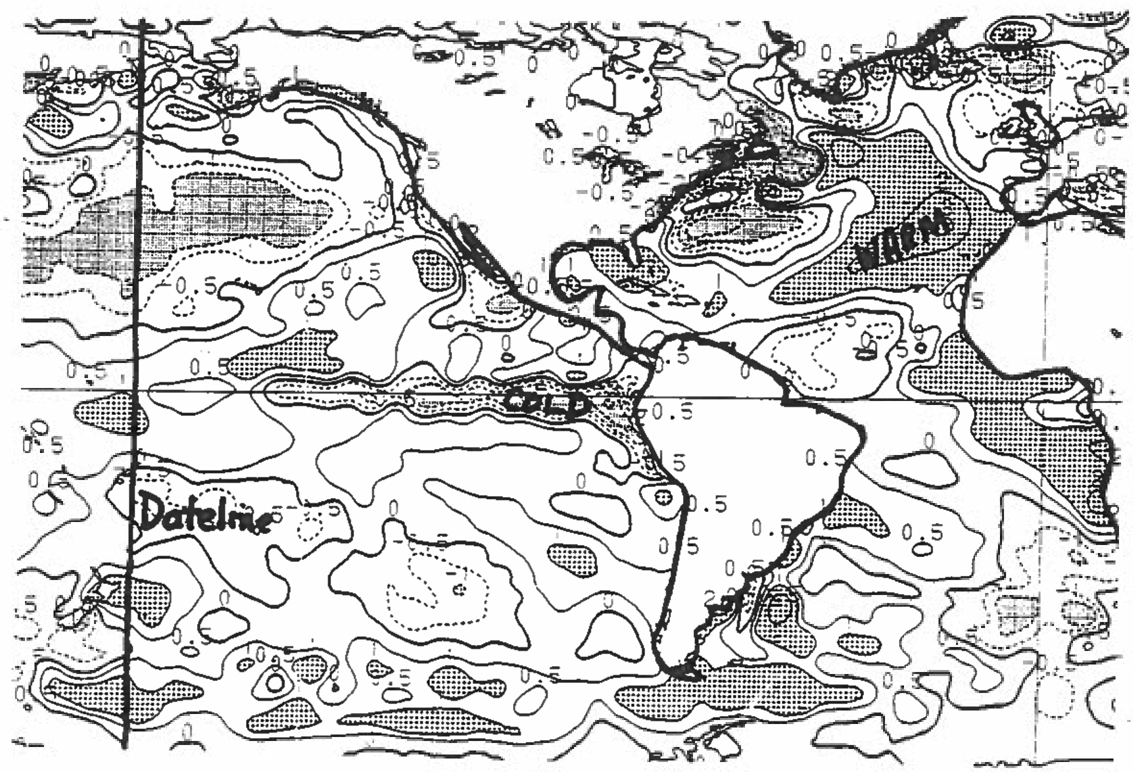

Figure 8: Sea surface temperature anomalies (SSTA) condition during late May 1995.

Changes in the North Atlantic. We may be seeing the early stages of the beginning speed-up of the Atlantic thermohaline (Conveyor Belt) circulation from its three decades long slow down. Aagaard (1995) has recently reported on a large decrease in ice flow through the Fram Strait (the North Atlantic passage between Greenland and Spitzbergen). This decreased ice flow reduces the introduction of fresh water and low salinity values into the North Atlantic. This ice flow reduction is leading to salinity increases in the North Atlantic. Other researchers have also recently reported recent salinity increases in the North Atlantic. Saline water weighs more than fresh water and is able to sink to readily to the bottom of the North Atlantic.

These salinity increases that are now being measured in the North Atlantic may result in a speed-up of the Atlantic Ocean thermohaline circulation in the next few years. If this does occur, then we should see a general increase in West African Sahel rainfall, a decrease in Atlantic summertime upper tropospheric westerly winds and an increase of Atlantic basin intense hurricane activity. These new regional Atlantic measurements may be an ominous sign of future increases in US and Caribbean basin landfalling hurricane activity. The quarter century lull which we have enjoyed cannot be expected to continue indefinitely into the future.

12 Verification of Past Seasonal Forecasts

The first author has now issued seasonal hurricane forecasts for the last eleven years. In most of the prior forecasts, predictions have been superior to climatology, which was previously the only way to estimate future hurricane activity (see Table 10). The seven late May and early June seasonal forecasts for 1985, 1986, 1987, 1988, 1991, 1992 and 1994 were more accurate than climatology. The forecasts for 1984 and 1990 were only marginally successful and the two seasonal forecasts for 1989 and 1993 were failures. The 1989 forecast was a failure because of processes associated with the excessive amounts of rainfall which fell in the Western Sahel that year. Prior to 1990, our seasonal forecast did not include African rainfall as a predictor. We have corrected this important omission and forecasts since 1990 have incorporated Western Sahel rainfall estimates. The failure of the 1993 seasonal forecast is attributed to our failure to anticipate the resurgence and continuation of El Niño conditions through the whole of the 1993 hurricane season. In particular, the first author failed to anticipate the re-emergence of stronger El Niño conditions after the middle of August 1993. It is very unusual to have an El Niño last as long as the recent 1991-94 event has. This failure motivated us to develop a new extended range ENSO prediction scheme (Gray et al., 1994).

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Jerry Jarrell, Deputy NHC director. We look forward to a beneficial association with the new director, Robert Burpee.

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Table 10: Verification of the author's previous seasonal predictions of Atlantic tropical cyclone activity for 1984-1994.

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 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	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

Table 10: Continued.

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	23
Major Hurricanes (Cat. 3-4-5)		1	0	2
Major Hurr. Days		2	0	1.25
1992	**Prediction of 26 Nov 1991**	**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	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
1993	**Prediction of 24 Nov 1992**	**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**	**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	37

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APPENDIX A

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, 1994) and in Landsea (1993). In view of this complexity, 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 of six of the percentage departure values from the long term means are used as measures of seasonal activity. The NTC value is useful as a measure of seasonal tropical cyclone activity because it combines most of the other tropical cyclone parameters of interest into a single index. There are many seasons during 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. This single index has the highest forecast skill. Table 11 lists the values of NTC for 1950-1994.

Note that the last four hurricane seasons have had net seasonal hurricane activity averaging only 53 percent of the 1950-1994 average, when the seasonal hurricane activities in the previous three seasons of 1988-1990 averaged 122 percent or over twice as much.

Table 11: Listing of Seasonal Net Tropical Cyclone activity (NTC) values between 1950-1994.

Year	NTC (%)	Year	NTC (%)	Year	NTC (%)
1950	243	1965	86	1980	135
1951	121	1966	140	1981	114
1952	97	1967	97	1982	37
1953	121	1968	41	1983	32
1954	127	1969	157	1984	77
1955	198	1970	65	1985	110
1956	69	1971	95	1986	38
1957	86	1972	28	1987	48
1958	140	1973	52	1988	121
1959	99	1974	76	1989	140
1960	101	1975	92	1990	104
1961	222	1976	85	1991	59
1962	33	1977	46	1992	62
1963	116	1978	86	1993	55
1964	168	1979	96	1994	37

APPENDIX B

Weights of β_i and a_i coefficients used in Eq. (1).

	β_0	β_1	β_2	β_3
NS	12.3781	.1651	.6312	-.2714
NSD	68.8556	1.0409	.7985	-19.5133
H	9.7544	.1389	.5074	-2.5884
HD	41.2690	.6513	3.8807	-13.1287
IH	2.5199	.0252	-.4059	.0187
IHD	6.3386	.1527	-1.6019	-1.0636
HDP	112.9477	1.5122	8.5714	-34.8274
NTC	146.7669	2.0802	-2.2472	-17.0237

	NS	NSD	H	HD	IH	IHD	HDP	NTC
QBO								
a_1	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
a_2	-.0714	-.0729	-.3662	-.3971	.4160	-.2182	-.3153	-.1021
a_3	-.9199	-1.2538	-2.1072	-2.0173	.2899	-.7551	-1.8143	-1.1884
a_4	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
a_5	2.4308	8.4673	.5335	.5796	-2.4883	-1.0317	1.3122	-7.7489
a_6	-.0478	1.0972	-1.3485	-.4836	-2.4395	-1.6112	.2809	-5.4734
a_7	-.6367	7.2463	.8690	1.4982	-.6668	-.9943	2.7448	-9.3565
a_8	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
a_9	-.1987	-.0294	.0667	-.0667	5.8344	-.6537	-.0889	-.0824
a_{10}	.0713	.0054	-.0012	-.0055	-.6297	.0103	-.0016	.0098
a_{11}	-.0430	.0002	.0016	.0113	.0171	.0167	.0088	.0024
a_{12}	.7902	-.0037	-.0521	-.1327	-1.4853	-.1748	-.1166	-.0687
a_{13}	-.4711	.0437	.0631	.1258	.1546	.2521	.1199	.1416