FORECAST OF ATLANTIC SEASONAL HURRICANE ACTIVITY FOR 1991

By
*William M. Gray**

(This forecast is based on ongoing research by the author and his research colleagues at Colorado State University, together with current April–May 1991 meteorological information)

Department of Atmospheric Science
Colorado State University
Fort Collins, CO 80523

(As of 5 June 1991)

*Professor of Atmospheric Science

DEFINITIONS

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

Hurricane - A tropical cyclone with sustained low level winds of 74 miles per hour (33 ms^{-1} or 64 knots) or greater.

Hurricane Day - 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 - 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 - A hurricane or a tropical storm.

Named Storm Day - 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 - 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.

Intense Hurricane Day - 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.

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 (1 to 5) of a hurricane's wind and ocean surge intensity. One is the weakest hurricane, 5 the most intense hurricane.

SLPA - Sea Level Pressure Anomaly. Deviation of Caribbean and Gulf of Mexico sea level pressure from 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 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 forecast of tropical cyclone activity that might be expected in the Atlantic Ocean region including the Caribbean Sea and the Gulf of Mexico during 1991. This forecast is based on the author's and his project's ongoing research which relates the amount of seasonal Atlantic tropical cyclone activity to five factors: Namely, 1) the Quasi-Biennial Oscillation of equatorial stratospheric wind (QBO); 2) the El Niño (EN); 3) Gulf of Mexico and Caribbean Basin Sea-Level Pressure Anomalies (SLPA); 4) lower latitude Caribbean Basin 200 mb Zonal Wind Anomalies (ZWA) and 5) West African Rainfall (AR) anomalies.

Information received by the author through 5 June 1991 indicates that the 1991 hurricane season should be a below average season with about 4 hurricanes, 8 named storms of at least tropical storm intensity, about 15 hurricane days, a total of 35 named storm days and a Hurricane Destruction Potential of 40. It is also expected that there should be only one intense hurricane of Saffir/Simpson intensity category 3, 4 or 5 and 2 intense hurricane days. All of these parameter forecasts are for values which are below average. This assessment means that the 1991 Atlantic hurricane season will likely be substantially less active than have the hurricane seasons of the last three (1988–90) years, and more typical of the average hurricane season between 1970–87.

Reduced hurricane activity during this (1991) season is due to: 1) anticipated slightly negative influences of a stratospheric QBO; 2) the East Pacific Sea Surface Temperature (SST) anomaly patterns. It is anticipated that an El Niño event will begin to develop during the August to the October period. This should inhibit hurricane activity; 3) below average rainfall conditions are expected in the Sahel region of West Africa; and 4) higher than normal and suppressing SLPA and ZWA conditions are anticipated in the lower Caribbean Basin.

Thus, all five seasonal predictors are of the sign as to act to reduce hurricane activity for this season.

This forecast will be updated on 2 August, 1991 just before the start of the most active part of the Atlantic hurricane season. The updated 2 August forecast will make use of June and July data and should provide a more reliable forecast, particularly with regard to the African rainfall prospects of intense hurricane activity. The updated forecast will also have better verification on the anticipated El Niño event of this year.

This seasonal forecast has less skill for the Gulf of Mexico region where hurricane activity is more a result of meteorological conditions which are different than that which effects the rest of the Atlantic.

1 Introduction

The Atlantic basin (including the Atlantic Ocean, Caribbean Sea and Gulf of Mexico) experiences a larger seasonal variability of hurricane activity than any other global hurricane basin. The number of hurricanes per season can be as high as 12 (as in 1969), 11 (as in 1950, 1916), 10 (1933), 9 (as in 1980, 1955), or as low as zero (as in 1914, 1907), 1 (as in 1919, 1905), or 2 (as in 1982, 1931, 1930, 1922, 1917, 1904). 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) indicates that there is a surprising 3-5 month advance seasonal hurricane predictive signal available for the Atlantic basin from global and regional predictors. These predictor relationships are generally not operative in other global hurricane basins or in the middle latitudes.

2 Factors Known to be Associated With Atlantic Seasonal Hurricane Variability

The author's Atlantic seasonal hurricane forecast is based on the current values of indices derived from two global and three regional scale predictive factors which the author has previously shown to be statistically related to seasonal variations of hurricane activity. Current values of these predictive factors are available either by early June, the official start of the hurricane season, or by early August, the start of the most active portion of the hurricane season. The five predictive factors are:

a) The direction of the stratospheric Quasi-Biennial Oscillation (QBO) of east–west winds which circle the globe over the equator: On average, there is nearly twice as much Atlantic hurricane activity during seasons when equatorial winds at 30 mb and 50 mb (23 and 20 km altitude respectively) blow from a relatively westerly direction as compared to when they are from a relatively easterly direction. During the 1991 season, these QBO winds will be changing from a westerly to an easterly direction and are judged to pose a small inhibiting influence on the 1991 Atlantic hurricane activity.

b) The presence or absence of a moderate or strong El Niño warm water event in the eastern tropical Pacific: Atlantic hurricane seasons during moderate or strong El Niño events average only about 40 percent as much hurricane activity as during non-El Niño seasons. This difference is 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. It is expected that a significant El Niño event will be under way by September or October of this year which should also pose an inhibiting influence on this season's hurricane activity.

c) 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 anomalies for April and May of this year indicate somewhat above normal values, likely posing a small negative factor for this season's hurricane activity.

d) Lower latitude Caribbean Basin upper tropospheric ($\sim$ 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 of seasonal hurricane activity and vice-versa.

e) African Rainfall (AR) is a new forecast parameter which we are now including in the forecast for the second time. Atlantic intense hurricane activity is much enhanced when the Sahel region of West Africa (shaded area in Fig. 1) has above average summer precipitation and much suppressed when precipitation in this region is below average. The striking differences in Atlantic intense hurricane activity between wet and dry rainfall years in West Africa are illustrated in Fig. 2. Recent analyses by Landsea (1991) show that nearly 60 percent of the year to year variance in the seasonal number of Atlantic intense hurricane days over the last 42 years can be explained by West Africa rainfall amounts prior to 1 August. Analyses of conditions through May 1991 indicate that Western Sahel precipitation will be below normal this year; this trend should lead to a significant reduction in this year's intense hurricane activity.

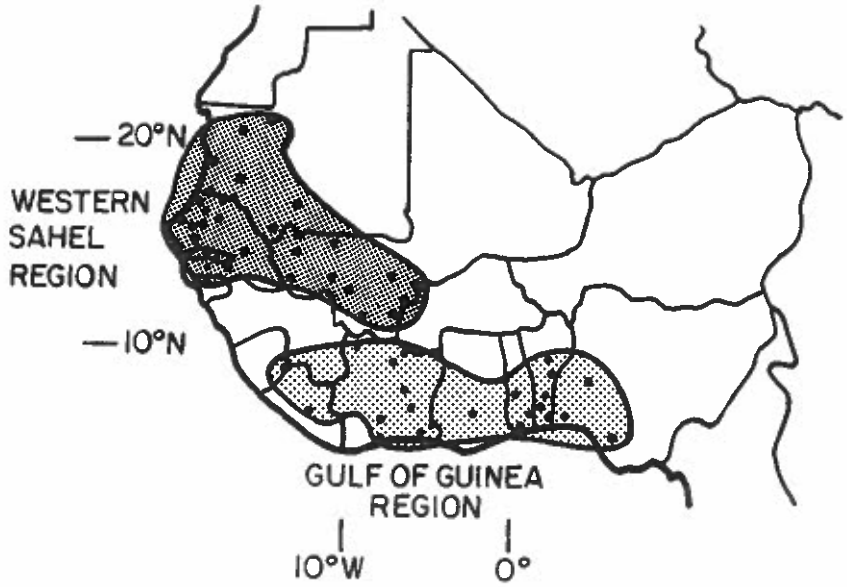

Figure 1: Locations of rainfall stations which make up the 38–station Western Sahel precipitation index and the 24 station Gulf of Guinea precipitation index. August to November rainfall within the Gulf of Guinea region provides a predictive signal for the following years seasonal Western Sahel rainfall and hurricane activity (from Landsea, 1991).

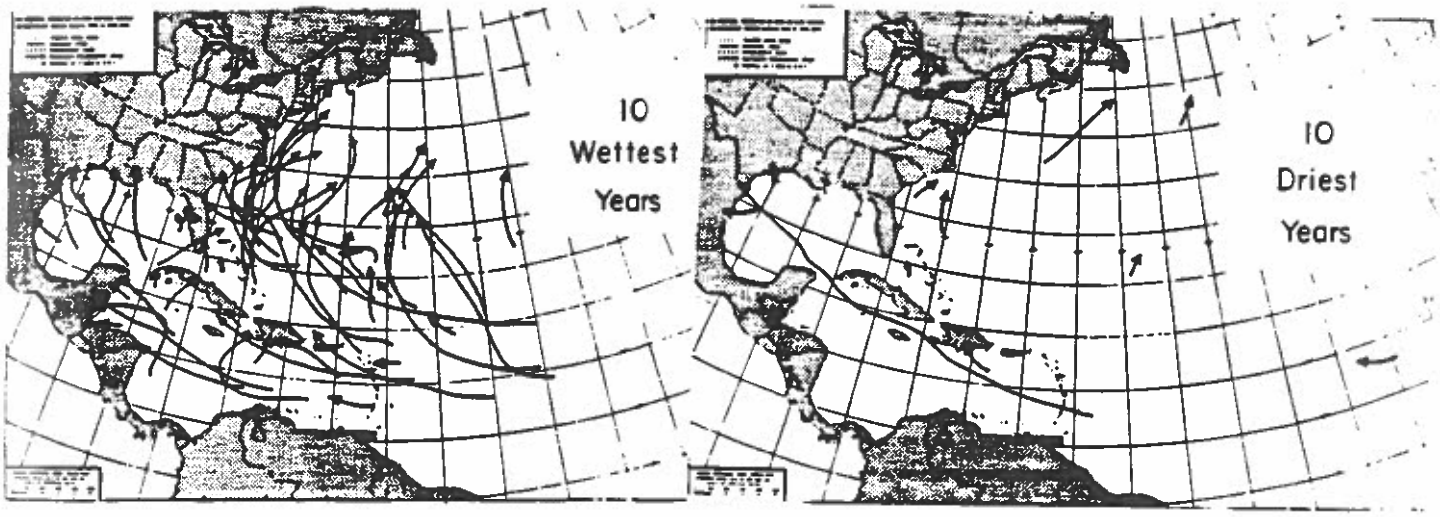

Figure 2: Comparison of intense hurricane storm tracks during the 10 wettest and 10 driest Western Sahel rainfall seasons during the 42–year (1949–90) period.

3 Current Characteristics and Further Discussion of the Five (EN, QBO, SLPA, ZWA, AR) Predictors for the 1991 Hurricane Season

a) QBO. Tables 1 and 2 show absolute and relative values of the current and extrapolated 30 mb (23 km) and 50 mb (20 km) stratospheric QBO zonal winds near 10°N for 1991 during the primary hurricane period of August through October. These estimates are based on a combination of current trends in the QBO winds plus the annual wind cycle variations at the low latitude stations of Curacoa (12°N), Trinidad (11°N), and Barbados (13°N). Note that during the primary August through October hurricane season, 30 mb winds are expected to be from a relative easterly direction and that 50 mb winds will be changing over to an easterly phase. This condition is less favorable for hurricane activity than in seasons of westerly phase, such as last year.

Table 1: April through October 1991 observed and extrapolated absolute value of stratospheric QBO zonal winds (U) in the critical latitude belts between 8-12°N, as obtained from lower Caribbean basin stations of Curacao (12°N), Barbados (13°N), and Trinidad (11°N). Values are in ms^{-1} (as supplied by James Angell and Colin McAdie).

	Observed			→ Extrapolated				
Level	March	April	May	Jun	Jul	Aug	Sept	Oct
30 mb (23 km)	+ 12	−3	−15	−21	−24	−28	−31	−27
50 mb (20 km)	+15	+10	+1	−5	−12	−14	−16	−16

Table 2: Same as Table 1 but for the relative or anomalous zonal wind where 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)	+ 17	+12	0	−4	−6	−10	−14	−15
50 mb (20 km)	+ 14	+12	+7	+5	+2	−1	−6	−9

b) El Niño. The Central and Eastern tropical Pacific are currently experiencing the beginning of an anomalous warming. It is likely that a significant El Niño event to develop before the end of the active part of the hurricane season. The Southern Oscillation has been negative for March, April and May 1991. May SSTA patterns indicate warming in all eastern and central Pacific sectors of +0.5–1.0°C. This growing warming event should be an inhibiting influence on this season's hurricane activity.

c) SLPA. Table 3 shows April–May 1991 Sea Level Pressure Anomaly (SLPA) values for the relevant tropical Atlantic stations. The April–May SLPA was above average (+0.5 mb) for this

special 5–station low latitude area. Pressure anomalies are based on deviations from the last 40–year average. The low latitude stations are more relevant to the forecast. Higher latitude Gulf of Mexico pressure anomalies are of lesser significance. The higher pressures of the low latitude stations of Table 3 are indicative of a weak reduction in this year's hurricane activity.

Table 3: Lower Caribbean Basin and Gulf of Mexico Sea-Level Pressure Anomalies (SLPA) for 1991 in mb (as kindly supplied by Colin McAdie of NHC).

Low Latitude	SLPA	Gulf of Mexico–Caribbean Basin	SLPA
San Juan	+0.5 (19.5°N, 66°W)	Brownsville	−1.5
Curacao	+0.4 (12°N, 69°W)	Merida (Mex.)	+0.1
Barbados	+0.3 (13.5°N, 60°W)	Miami	+0.7
Trinidad	+0.9 (11°N, 62°W)	San Juan	+0.5
Cayenne	+ 0.5 (5°N, 52.5°W)	Curacao	+0.4
		Barbados	+0.3
Average	+0.5	Average	+0.1

d) ZWA. Although not explicitly used for the 1 June forecast, the Lower Caribbean Basin 200 mb (12 km) zonal wind anomaly (ZWA) for April-May 1991 give some indications of future tropospheric wind shear conditions for the region. ZWA conditions also act as a monitor for the possible influence of a Pacific El Niño warm water event on Caribbean Basin upper tropospheric wind conditions. Data in Table 4 show that the upper tropospheric ZWAs for April and May are anomalously strong from the west. These ZWA values indicate that a possible El Niño may be in its initiating stages and/or that the intertropical convergence line in the Western Hemisphere is establishing itself further equatorward of its normal position. Either of these conditions are indicative of reduced Atlantic hurricane activity.

Table 4: April-May 1991 lower Caribbean Basin 200 mb Zonal Wind Anomaly (ZWA) in ms^{-1} (as supplied by Colin McAdie of NHC).

Station	
Kingston (18°N, 77°W)	+3
Curacoa (12°N, 69°W)	+4
Barbados (13.5°N, 60°W)	+6
Trinidad (11°N, 62°W)	+4
Average	+4.2

e) West African Rainfall (AR). There is substantially more intense Atlantic hurricane activity when June through September West African rainfall is above average as compared to those seasons when it is below average. The long running West African drought of 1970-87 was associated with a great suppression of intense hurricane activity during that 18 year period. A temporary (two year) interuption of African drought conditions occurred in 1988–89 when there was also a substantial increase in intense hurricane activity with five Saffir/Simpson category 4-5 hurricanes. However, drought conditions return in 1990. The African rainfall assessment

for 1991 (as of the end of May) indicates that we may expect the Western Sahel region of West Africa to again experience significantly below normal precipitation this season. It is expected that precipitation amounts will be more in line with the greatly reduced precipitation years of 1970-87. West African rainfall is thus judged to be a strong inhibiting influence for Atlantic intense hurricane activity for 1991.

The expectation that 1991 will have below average precipitation year for the Sahel is based upon:

- (a) Low values (–0.70 standard deviations) of rainfall in the Gulf of Guinea region (Fig. 1) during August through November of last year (1990).
- (b) Anomalously warm surface land temperatures which developed over the Sahel region this spring.
- (c) Anticipated El Niño warm water event developing for this year (definitely not the cold conditions which occurred in 1988-89 when there was an interruption in the Sahel drought). This developing warm event is consistent with West African drought conditions for this year and a reduction in hurricane activity.
- (d) The present arrangement of global and Atlantic SSTA conditions which in past years have been associated with African drought conditions, such as positive South Atlantic SSTA and negative SSTA anomalies off of West Africa. The UK Meteorological Office (1991) is also forecasting drought conditions this year for the Sahel which are based on global SSTA patterns.

Interruption of Sahel Drought in 1988 and 1989. These two wet seasons represented a sharp increase in West African rainfall from conditions of the long running drought of 1970–87. More rainfall fell in the Western Sahel region during 1988–89 than during any two consecutive years since 1964–65. The 1988–89 rainfall was more typical of the yearly values during the 1950s and 1960s. And, no less than five category 4-5 hurricanes occurred in 1988–89 (Gilbert, Helene, Joan, Gabrielle, and Hugo) with a total of 18.75 intense hurricane days; well above the annual average of 2.1 intense hurricane days during 1970–87.

Following the 1989 hurricane season it seemed reasonable to surmise that the long running multi-decadal drought might be ending. If true, this would have far reaching implications for the potential of coastal hurricane destruction in the next few years. In retrospect however, it appears that this long running drought has not yet ended and that the two heavy rainfall years of 1988 and 1989 do not represent the end of the Sahelian drought. Very dry conditions returned again to the West Sahel in 1990 (see Fig. 3) and we anticipate general drought conditions again for 1991. We do not know when this now 21–year drought will end but, if past conditions are an indication of the future, it should likely run its course in the next few years.

Our recent research also indicates that the comparatively heavy West African rainfall of 1988–89 was likely a response to the unusually cold sea surface temperatures which developed throughout the eastern half of the equatorial Pacific Ocean during 1988–89. Similar cold water, or anti-El Niño conditions of this magnitude had not occurred for many years. Teleconnected effects of these cold sea temperatures acted to suppress deep convection in the eastern Pacific and inhibit the normal upper tropospheric westerly winds within the lower Caribbean Basin and their normal progression eastward into the tropical Atlantic. This reduction of upper tropospheric westerly winds over the tropical Atlantic allowed the establishment of stronger

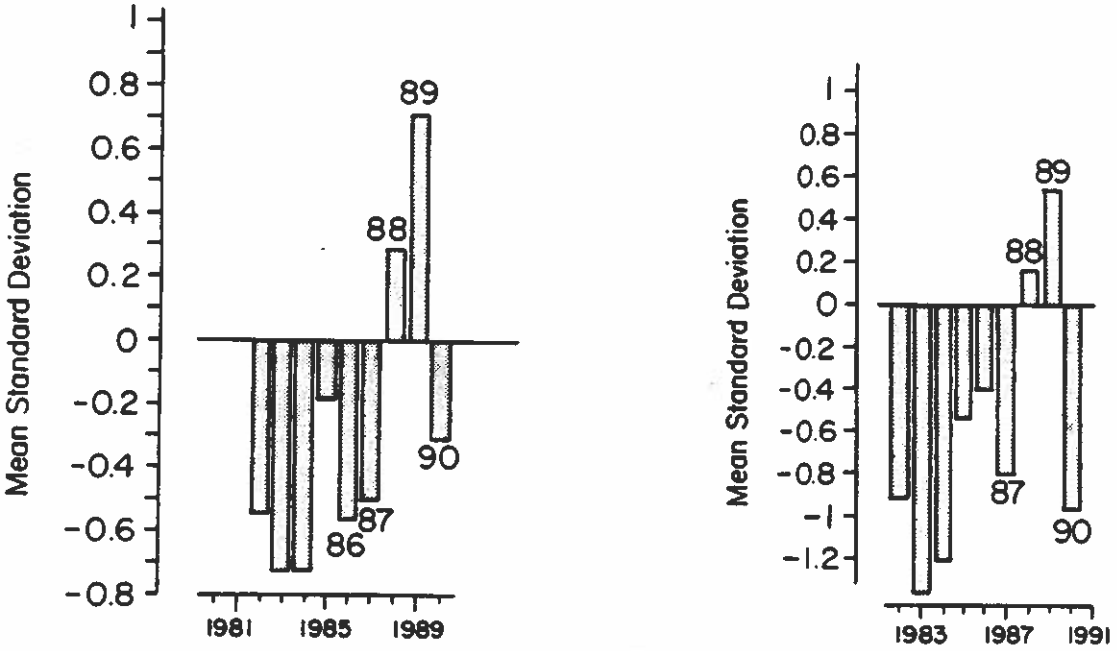

Figure 3: (Left diagram) Variations in recent years of the standard deviation of "early season" rainfall (prior to 1 August) and June through September rainfall (right diagram). Note the break in drought conditions during 1988 and 1989; early season rainfall in 1989 was especially heavy.

upper tropospheric easterlies over West Africa with a general enhancement of the West African monsoon rainfall. A conceptual illustration of this association is shown in Fig. 4.

4 Author's 1990 Forecast

The author's Atlantic seasonal forecast scheme is of the following form:

$$\begin{array}{lcl} & & \textit{Adjustment Terms} \\ (\textit{Predicted Amt.} & & \\ \textit{of Hurricane} & = & \textit{Ave. Season} + (QBO + EN + SLPA + ZWA + AR) \\ \textit{Activity} & & \\ \text{Per Season }) & & \end{array}$$

where

QBO = 30 mb and 50 mb Quasi-Biennial Oscillation equatorial zonal wind corrections, positive for west phase, negative for east phase.

EN = El Niño influence; warm East Pacific water reduces hurricane activity, cold water enhances it.

SLPA = Average SLPA for April-May from selected Caribbean-Gulf of Mexico stations. Reduce or enhance if SLPA is significantly above or below average.

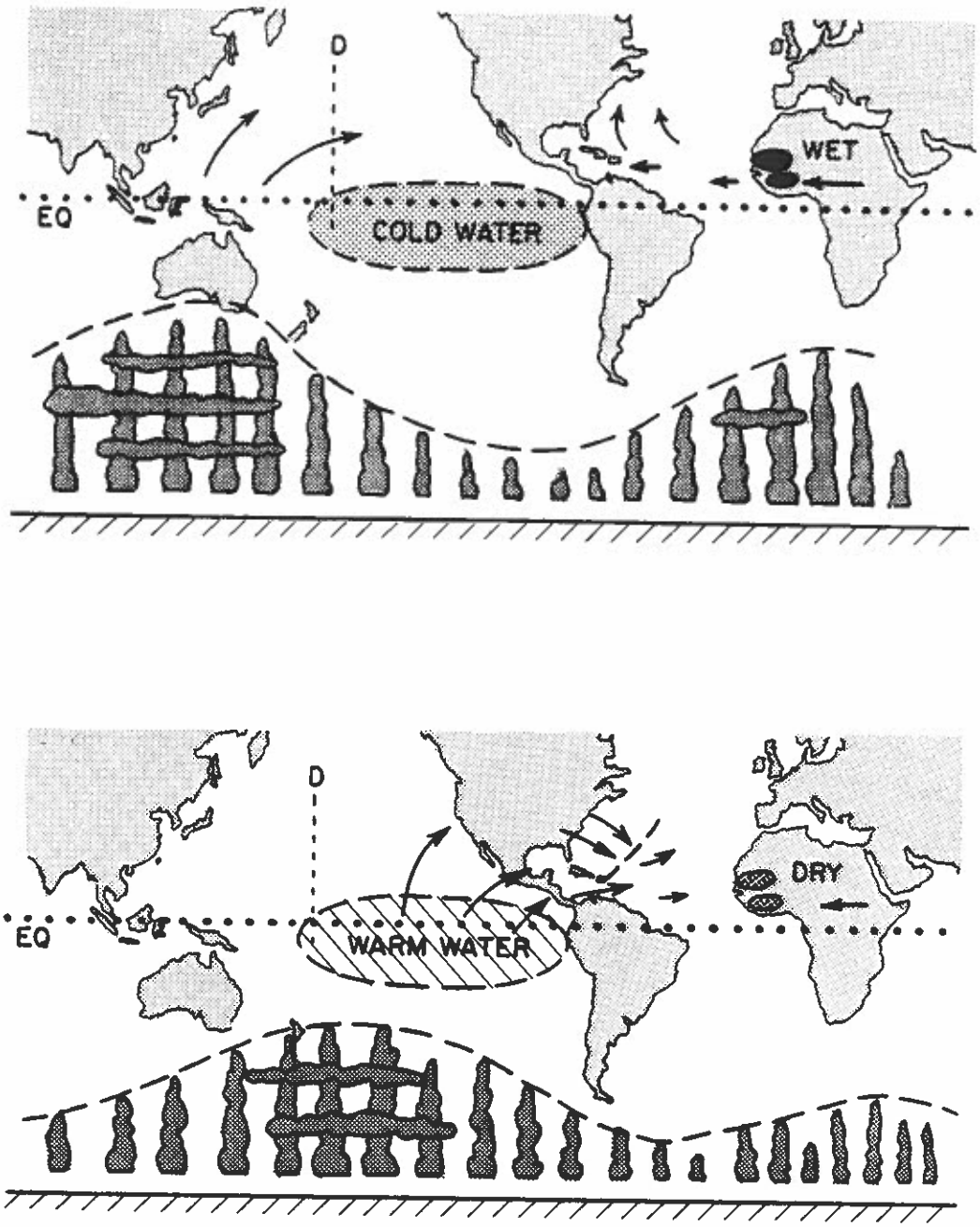

Figure 4: Idealized rendering of the associations between anomalous SST values in the eastern equatorial Pacific and anomalous westerly winds in the upper troposphere over the western tropical Atlantic, as well as the broad features of anomalous equatorial convection around the globe. Cold SST values (top panel) are linked to diminished westerlies and hence enhanced hurricane activity and vice versa for elevated (El Niño) SST values (bottom panel).

ZWA = Zonal Wind Anomaly at 200 mb (12 km) for five low latitude upper air stations in the Caribbean. Hurricane activity is typically inversely correlated with this parameter.

AR = African rainfall: Heavy summertime West African rainfall is associated with an increase of both the number and the intensity of Atlantic hurricanes; reduced rainfall with a decrease in hurricane number and intensity.

A synthesis of the five forecast factors, as discussed in section 3, leads to the author's 1991 seasonal forecasts for the number of hurricanes, named storms, hurricane days, named storm days, Hurricane Destruction Potential (HDP), major hurricanes, and major hurricane days for the coming 1991 hurricane season (see Table 5).

TABLE 5
1991 Predicted Seasonal Hurricane Activity

(No. of Hurricanes per Season)	=	(Ave. Season) + QBO + EN + SLPA + ZWA + AR	
		5.9 + (0) + (−0.5) + (0.5) + (N/A) + (−1)	≈ 4
(No. of Hurricanes and Tropical Storms)	=	(Ave. Season) + QBO + EN + SLPA + ZWA + AR	
		(9.8) + (0) + (0.5) + (0.5) + (N/A) +(−1)	≈ 8
(No. of Hurricane Days)	=	(Ave. Season) + 5 (QBO + EN + SLPA + ZWA + AR)	
		25 + 5[+ 0 + (−0.5) + (−0.5) + (N/A) + (−1)]	≈ 15
(No. of Named Storm Days)	=	2.3 x (No. of Hurricane Days)	≈ 35
(Hurricane Destruction Potential - HDP)[1]	=	(Ave. Season) + 15 (QBO + EN + SLPA + ZWA + AR)	
		75 + 15[0 + −0.5 + −0.5 + (N/A) + −1.3]	≈ 40
(No. of Major [2] Hurricanes)	=	2.5 + 0.7 (QBO + EN + AR)	
		0.7[(0) + (−0.5) + (-1.6)]	≈ 1
(Major Hurricane Days [3])		(No. of Major Hurricanes) x (2)	= 2

[1]The wind and storm surge destruction of a hurricane is better represented by the square of the storm's maximum winds than by the maximum wind itself. This potential for damage from hurricane winds and storm surge might be termed Hurricane Destruction Potential (HDP). We define Hurricane Destruction Potential (HDP) as the sum or $\Sigma(V_{max})^2$ for V_{max} equal or greater 64 knots (74 mph) for each 6-hour period for all hurricanes that are in existence during a full season. Units are $10^4 knots^2$.

[2]Hurricanes of Saffir/Simpson category 3, 4, or 5.

[3]Number of days which hurricane have an intensity of category 3-4-5.

Table 6 provides a comparison of this season's Atlantic hurricane forecast with the observed hurricane activity of recent years. Note that the 1991 season is expected to be significantly less active than the last three hurricane seasons of 1988–89–90; it is expected that the 1991 hurricane season will be more typical of the average hurricane season during 1970–87.

Table 6: Comparison of 1991 Hurricane Activity Forecast With Activity in Previous Years.

	5 June Forecast 1991	Observed 1990	1989	1988	Average Season 1970-87	Average Season 1950-69	42–Year Ave.
Hurricanes	4	8	7	5	4.9	6.5	5.9
Named Storms	8	14	11	12	8.3	9.8	9.9
Hurricane Days	15	28	32	24	15.5	30.7	23.8
Named Storm Days	35	68	66	47	37.3	53.4	47.2
Hurr. Dest. Pot. (HDP)	40	57	108	81	42.7	100.0	74.5
Major Hurricanes (Cat. 3-4-5)	1	1	2	3	1.6	3.4	2.5
Major Hurricane Days	2	1	10.75	8	2.1	8.8	5.5

Table 7 gives verification data for the author's previous seven 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. 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 West Africa prior to 1990, this rainfall was not explicitly included in the author's forecast scheme. This rainfall is now included and its influences are becoming better understood.

5 Early August Update of Seasonal Forecast

This forecast will be updated on 2 August and will make use of June–July meteorological parameters and should be more accurate. In particular we will have June–July Western African rainfall information which is a very good predictor of total West African rainfall.

6 Forecast for the Gulf of Mexico

New analyses are showing that Gulf of Mexico hurricane activity is less closely related to the seasonal prediction factors for hurricane activity variations in the Atlantic basin as a whole. The Gulf of Mexico is removed from the tropical belt and is further downwind from Africa. Only a small percentage of hurricanes track into the Gulf of Mexico from the open Atlantic. Hurricanes occur earlier in the season in the Gulf and the hurricane season therein typically terminates earlier. Intense hurricanes (category 3-4-5) Alicia (1983), Allen (1980), Celia (1970), and Elena (1985) all made landfall along the Gulf Coast in deficient West African rainfall years. This is atypical of the rest of the Atlantic basin. Thus, a below average season for the Atlantic Basin as a whole does not necessarily imply that hurricane activity within the Gulf will be below average.

Table 7: Verification of the author's previous seasonal predictions of Atlantic tropical cyclone activity for 1984-1989.

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	27.5
No. of Named Storm Days	55	50	68
Hurr. Destruction Potential(HDP)	90	75	57
Major Hurricanes (Caregory 3-4-5)	3	2	1
Major Hurricane Days	Not fcst.	5	2

It is thus not possible to issue as skillful a seasonal forecast for the upper Gulf of Mexico region (see Fig. 5) as compared with the rest of the Atlantic basin. Gulf Coast residents should take note of this.

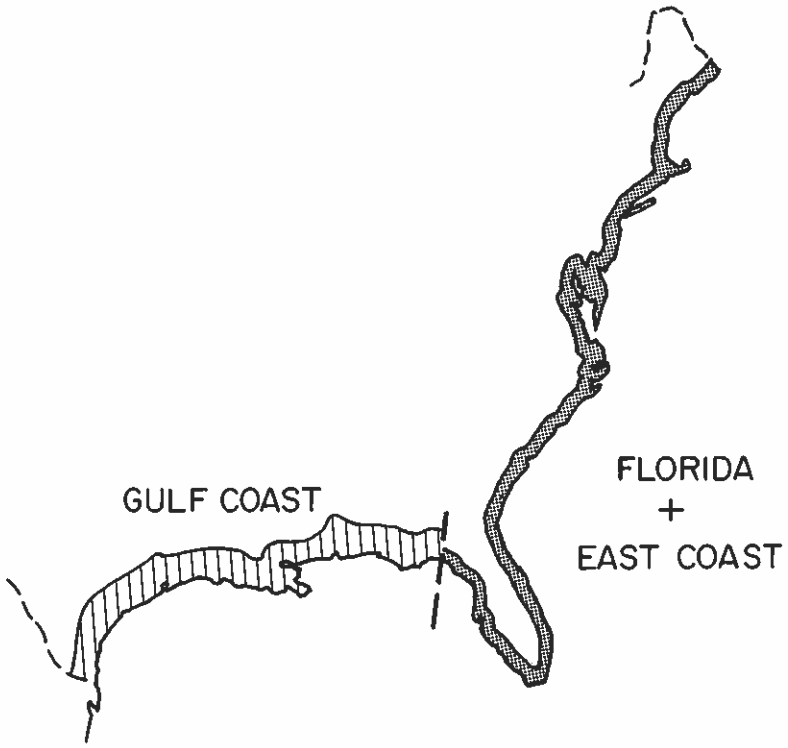

Figure 5: Illustration of the two basic US coastal regions which have different seasonal predictability responses to West African precipitation. There is smaller statistical skill for seasonal prediction along the Gulf Coast including the Florida Panhandle but good statistical skill for Peninsula Florida, the US East coast, within the Caribbean basin and in the open Atlantic.

7 Outlook for 1992

There is a good possibility that next years' Atlantic basin hurricane activity will also be below average. This assessment is based on considerations relating to the three primary forecast factors (El Niño, QBO, African rain) all of which indicate a below average season.

1) There is a high probability that a moderate or strong El Niño event or the influences of such an event will still be in progress during the 1992 season. This should be an inhibiting influence on Atlantic basin 1992 hurricane activity.

2) It appears that the stratospheric QBO will still be in an easterly (inhibiting) phase during the main part of next years' hurricane season.

3) Unless this year's observations indicate otherwise, one should expect a continuation of the long running West African drought into 1992. Continued drought conditions would also be a strong influence to reduce intense hurricane activity.

Thus all three basic predictors indicate the likelihood of a below average hurricane season also for next year.

8 Cautionary Note

It is important that the reader realize that the author's seasonal forecast is a statistical scheme which will likely fail in some years. This forecast also does not specifically predict which portion of the hurricane season will be most active or where within the Atlantic basin storms will strike. Even if 1991 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.

9 References

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

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

Gray, W. M., 1990: Likely increase in intense landfalling hurricanes in the coming decades. Background information of talk by William M. Gray to the 12th Annual National Hurricane Conference, 20 April, 33 pp.

Gray, W. M. and C. W. Landsea, 1991: Predicting US hurricane and spawned destruction from West African rainfall. Background information of talk by Wiliam M. Gray to the 13th Annual National Hurrricane Conference, Miami, FL, April, 40 pp.

Landsea, C. W., 1991: West African monsoonal rainfall and intense hurricane associations. Forthcoming Dept. of Atmos. Sci. Paper, Colo. State Univ., Ft. Collins, CO, 270 pp.

Neumann, C. J., B. R. Jarvinen, A. C. Pike and J. D. Elms, 1987: Tropical cyclones of the North Atlantic Ocean 1871–1986. Historical climatology Series 6-2, NOAA National Climate Data Center, Asheville, NC, 186 pp.

UK Meteorological Service, 1991: Summary of experimental forecast of 1991 rainfall in the Sahel of Africa. May, 1991, 2pp.

Acknowledgements

The author is indebted to many meteorological experts who have furnished him with the data necessary to make this forecast or who have given him their assessments of the current state of global atmospheric and oceanic conditions. I am especially appreciative of the expert assistance of Chris Landsea who is currently performing research on the associations of West African rainfall and intense hurricane activity.

The author is most thankful to Colin McAdie who has furnished a great deal of tropical data and to Vern Kousky who has provided data and very helpful discussion. I thank James

Angell for stratospheric QBO data and beneficial discussions. The author has also profited from indepth interchange with his project colleagues John Sheaffer, Ray Zehr and John Knaff. I have also appreciated the statistical advice and the many calculations on this topic that have been made by CSU Professors Paul Mielke and Kenneth Berry. William Thorson and Richard Taft has provided valuable computer assistance. Barbara Brumit and Laneigh Walters have provided manuscript and data reduction assistance.

I would also like to acknowledge the very helpful discussions I have had concerning the El Niño with Nevelle Nicholls, Eugene Rasmussen and Mark Cane. I also appreciate receiving the valuable opinions of David Rowell, John Owen, and Neil Ward of the UK Meteorological Office on their forecasts of this summer's Sahel precipitation. I thank Sharon Nicholson for her information on long period African rainfall. I have also profited from discussion with Lixion Avila and Max Mayfield of the NHC and with Douglas LeCompte. I would further like to acknowledge the encouragement I have received over recent years for this type of forecasting research application from Neil Frank and Robert Sheets, former and current directors of the National Hurricane Center (NHC) and the other forecasters at the National Hurricane Center.

This research analysis and forecast has been supported by the National Science Foundation.