UPDATED FORECAST OF ATLANTIC SEASONAL HURRICANE ACTIVITY FOR 1991

By
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(This update of the author's 5 June forecast is based on new June–July meteorological conditions and upon ongoing research by the author and his research colleagues at Colorado State University.)

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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 updated 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 updated forecast includes the more recent June and July meteorological data and 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 up to 2 August 1991 indicates that the 1991 hurricane season should be a below average season with about 3 hurricanes, 7 named storms of at least tropical storm intensity, about 10 hurricane days, a total of 30 named storm days and a Hurricane Destruction Potential of 25. It is also expected that there should be no intense hurricanes of Saffir/Simpson intensity category 3, 4 or 5 this season. All of these parameter forecasts are for values which are much 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.

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

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

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 more from an easterly direction and are judged to pose an inhibiting influence on 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 the current weak El Niño conditions will intensify during the coming August to October period. This should be 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 through July of this year indicate above normal values. This is judged to be a small negative influence on this season's hurricane activity.

d) 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 of seasonal hurricane activity and negative anomalies an enhancement. Very strong 200 mb zonal wind anomalies have been present during April through July of this year. This should also be a suppressing influence on this season's hurricane activity.

e) African Rainfall (AR) is a new forecast parameter which we are now including in the forecast for the second year. 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 variations in West Africa rainfall amounts prior to 1 August. Analyses of conditions through July 1991 indicate that Western Sahel precipitation will be very much below normal this year; one of the driest of the last 43 years. This should cause a significant reduction in this year's intense hurricane activity. For this reason we are forecasting no intense hurricane activity for this season.

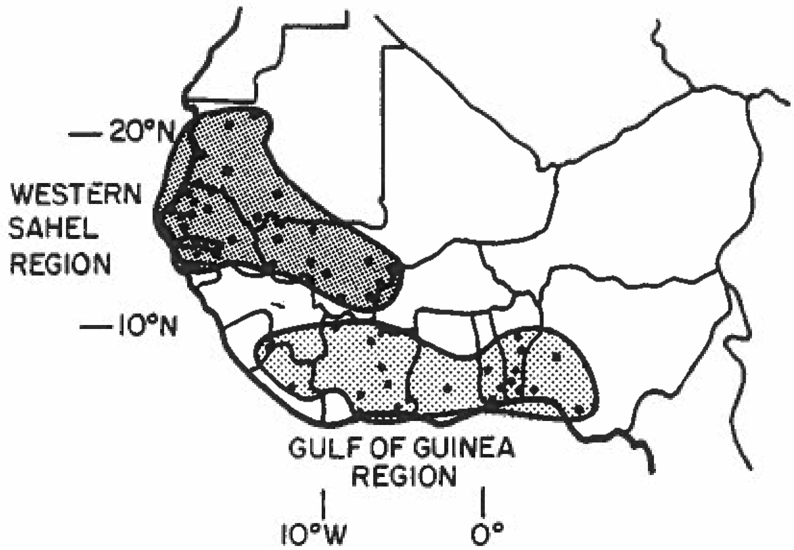

Figure 1: Locations of rainfall stations which make up the 38–station Western Sahel precipitation index and the 24 station Gulf of Guinea precipitation index. August to November rainfall within the Gulf of Guinea region provides a predictive signal for the following years seasonal Western Sahel rainfall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

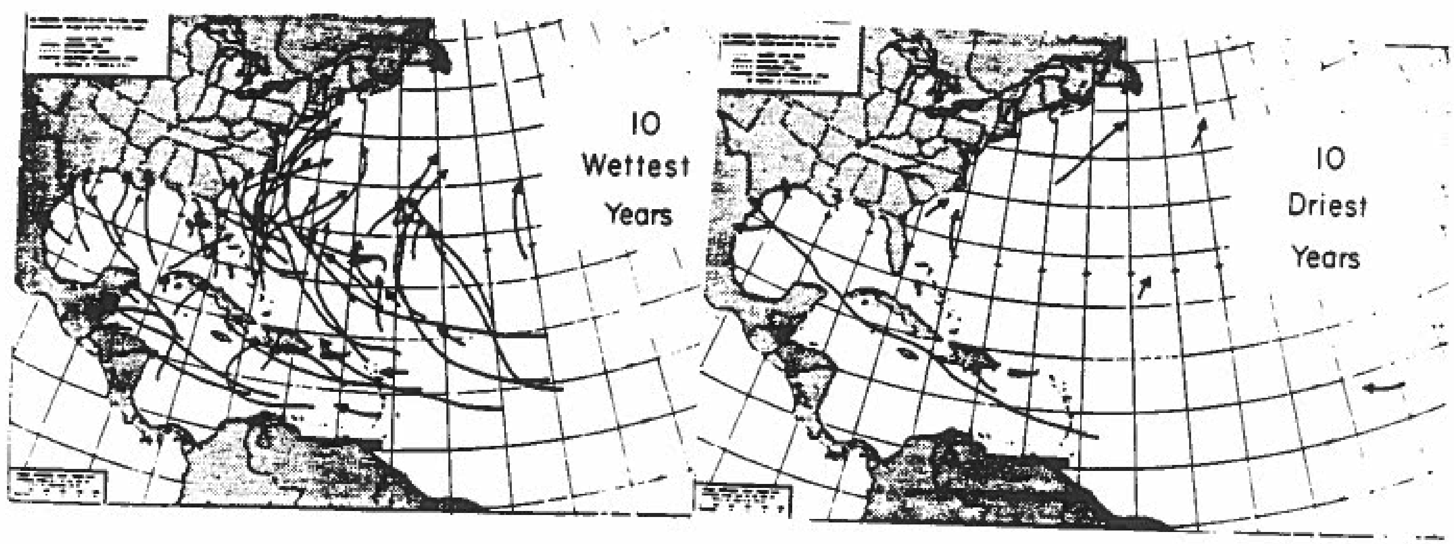

Figure 2: Comparison of intense hurricane storm tracks during the 10 wettest and 10 driest Western Sahel rainfall seasons during the 42–year (1949–90) period.

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 for 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 Curacao (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 in the early stages of an easterly phase. These condition favors a reduction in hurricane activity.

Table 1: April through October 1991 observed and extrapolated absolute value of stratospheric QBO zonal winds (U) in the critical latitude belt between 8-12°N, as obtained from lower Caribbean basin stations of Curacao (12°N), Barbados (13°N), and Trinidad (11°N) and other tropical stations. 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	-25	-28	-31	-27
50 mb (20 km)	+15	+10	+1	-7	-17	-17	-18	-18

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	-7	-10	-14	-15
50 mb (20 km)	+ 14	+12	+7	+3	-2	-4	-8	-11

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 since March 1991. Although July SSTA patterns have weakened from June values, they still indicate a warming in the eastern and central Pacific. It is expected that this warming will resume its strengthening in August through October. This expected growing warming event should be an inhibiting influence on this season's hurricane activity through the strong 200 mb zonal winds which typically develop over the Caribbean Basin and tropical Atlantic in these seasons.

c) SLPA. Table 3 shows April–July 1991 Sea Level Pressure Anomaly (SLPA) values for the relevant tropical Atlantic stations. The April through July SLPA have been above average in the 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 also indicative of a 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) and from our CSU analysis.

Low Latitude SLPA	Apr-May	Jun-Jul	Gulf of SLPA Mexico-Caribbean Basin	Apr-May	Jun-Jul
San Juan (19.5°N, 66°W)	+0.5	+0.1	Brownsville	-1.5	+0.2
Curacao (12°N, 69°W)	+0.4	+1.0	Merida (Mex.)	+0.1	+1.1
Barbados (13.5°N, 60°W)	+0.3	+0.1	Miami	+0.7	+0.3
Trinidad (11°N, 62°W)	+0.9	+0.6	San Juan	+0.5	+0.1
Cayenne (5°N, 52.5°W)	+0.5	0	Curacao	+0.4	+1.0
			Barbados	+0.3	+0.1
Average	+0.5	+0.4	Average	+0.1	+0.5

d) ZWA. The June–July Lower Caribbean Basin 200 mb (12 km) zonal wind anomaly (ZWA) usually give good indications of future tropospheric wind shear conditions for this region during the later active part of the hurricane season. 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 June and July are moderately strong from the west. These ZWA values indicate that a progressively intensifying El Niño may be in progress 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 seasonal 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) and from our CSU analysis.

Station	April-May	June-July
Kingston (18°N, 77°W)	+3	+4
Curacao (12°N, 69°W)	+4	+5
Barbados (13.5°N, 60°W)	+6	+3
Trinidad (11°N, 62°W)	+4	+5
Average	+4	+4

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) interruption of African drought conditions occurred in 1988–89 and there was a directly related increase in intense hurricane activity with five Saffir/Simpson category 4-5 hurricanes in those two seasons. However, drought conditions returned in 1990 and will likely continue through the rest of this year. Information received as of the end of July indicates that we should expect the Western Sahel region of West Africa to again experience significantly below normal precipitation. It is expected that precipitation amounts this summer will be one of the lowest of the last 43 years. West African rainfall conditions for this year are thus judged to be a very strong inhibiting influence on Atlantic intense hurricane activity. No intense or category 3-4-5 hurricane activity is forecast for this year.

This assessment is based upon the following observations:

- (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). This was the seventh driest of the last 43 years.

- (b) The low values (–0.79 standard deviation) of the Western Sahel June–July rainfall of this year. June–July rainfall values have also been one of the driest of the last 43 years. tem (c) The early season or prior to 1 August West African rainfall which combines Gulf of Guinea and Western Sahel is –0.76 standard deviation. This is the lowest "early season" rainfall value of the last 43 years. Note in Table 5 the number of intense hurricane days which have occurred in those seasons when "early season" or prior to 1 August rainfall was more than 0.5 S. D. below average. These 9 years had an annual average less than 10% of the annual average of the last 42 years.

- (d) 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 ENSO event is consistent with a reduction in Western Sahel rainfall.

- (e) The present arrangement of global and Atlantic SSTA conditions which in past years have been associated with African drought conditions, such as positive Southern Hemisphere 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.

Table 5: Number of intense hurricane (or Saffir/Simpson category 3-4-5) days which have occurred in those 9 of the last 42 years when the "early season" (of prior 1 August) West African rainfall has been 0.50 or greater standard deviations (S.D.) below normal. Early season rainfall is a combination of August through November Gulf of Guinea rainfall (Fig. 1) weighted 0.3 and Western Sahel June–July rainfall weighted 0.7). The 42 average number of intense hurricane days is 5.70.

Year	S. D. of Rainfall	No. of Intense Hurricane Days
1991	–0.79	?
1983	–0.78	0.25
1984	–0.77	0.75
1977	–0.73	1.00
1982	–0.71	1.25
1972	–0.66	0.00
1973	–0.62	0.25
1986	–0.59	0.00
1987	–0.56	0.50
1976	–0.50	1.00

4 Author's 1991 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.

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 updated seasonal forecast 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 6).

TABLE 6
1991 Predicted Seasonal Hurricane Activity

$$\begin{pmatrix}\text{No. of}\\ \text{Hurricanes}\\ \text{per Season}\end{pmatrix} = (\text{Ave. Season}) + QBO + EN + SLPA + ZWA + AR$$

$$5.9 + (-0.5) + (-0.5) + (-0.3) + (-0.3) + (-1) \approx 3$$

$$\begin{pmatrix}\text{No. of}\\ \text{Hurricanes and}\\ \text{Tropical Storms}\end{pmatrix} = (\text{Ave. Season}) + QBO + EN + SLPA + ZWA + AR$$

$$(9.8) + (-0.5) + (0.5) + (-0.3) + (-0.3) + (-1) \approx 7$$

$$\begin{pmatrix}\text{No. of}\\ \text{Hurricane Days}\end{pmatrix} = (\text{Ave. Season}) + 5\ (QBO + EN + SLPA + ZWA + AR\ )$$

$$25 + 5[(-0.5) + (-0.5) + (-0.3) + (-0.3) + (-1.4)] \approx 10$$

$$\begin{pmatrix}\text{No. of}\\ \text{Named Storm Days}\end{pmatrix} = 2.5 \text{ x } (\text{No. of Hurricane Days}) \approx 30$$

$$\begin{pmatrix}\text{Hurricane Destruction}\\ \text{Potential - HDP}\end{pmatrix}^1 = (\text{Ave. Season}) + 15\ (QBO + EN + SLPA + ZWA + AR)$$

$$75 + 15[-0.5 + -0.5 + -0.3 + (-0.3) + -1.7] \approx 25$$

$$\left(\text{No. of Major}^{\,2} \text{ Hurricanes}\right) = 2.5 + 0.7\ (QBO + EN + AR\ )$$

$$0.7[(-0.5) + (-0.5) + (-2.2)] \approx 0$$

$$\left(\text{Major Hurricane Days}\right)^3 \quad (\text{No. of Major Hurricanes}) \text{ x } (2) = 0$$

Table 7 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 very reduced hurricane seasons of 1968, 1972, 1977, 1982, 1983, 1986 and 1987.

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[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 7: Comparison of 1991 Hurricane Activity Forecast With Activity in Previous Years.

	2 Aug Updated Forecast	5 June Forecast 1991	Observed 1990	Observed 1989	Observed 1988	Average Season 1970-87	Average Season 1950-69	42-Year Ave.
Hurricanes	3	4	8	7	5	4.9	6.5	5.9
Named Storms	7	8	14	11	12	8.3	9.8	9.9
Hurricane Days	10	15	28	32	24	15.5	30.7	23.8
Named Storm Days	30	35	68	66	47	37.3	53.4	47.2
Hurr. Dest. Pot.[1] (HDP)	25	40	57	108	81	42.7	100.0	74.5
Major Hurricanes (Cat. 3-4-5)	0	1	1	2	3	1.6	3.4	2.5
Major Hurricane Days	0	2	1	10.75	8	2.1	8.8	5.5

5 New Alternate Statistical Forecast for 1991

New research with CSU statistics professors Paul Mielke and Kenneth Berry is attempting to better refine and maximize the type of predictive equations shown in Table 6. Mielke and Berry find that the best early August predictive equations take the form of

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

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

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

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

$|U_{50} - U_{30}|$ absolute value of the extrapolated vertical wind shear between 50 and 30 mb.

R_s is the Western Sahel (Fig. 1) June–July precipitation.

R_G is the previous year August through November precipitation in the Gulf of Guinea region.

SLPA is the Sea Level Pressure Anomaly in the lower Caribbean basin in June–July.

SOI is the Tahiti minus Darwin Sea Level Pressure differences for June–July.

SSTA is the Sea Surface Temperature Anomaly in Nino 3 in June and July.

ZWA is the Zonal Wind Anomaly in the Caribbean basin in June–July.

a and b coefficients vary for each forecast parameter. The nine variables for the early August 1991 forecast are as follows.

$$U_{50} = 18m/s,\ U_{30} = 31m/s,\ |U_{50} - U_{30}| = 13m/s$$

$$R_s = -0.79S.D., R_G = 0.70S.D.$$

$$SLPA = 0.4mb, SOI = -0.7mb$$

$$SSTA = 1.15°C, ZWA = 4.0m/s$$

Although we are still experimenting to determine the best early August statistical prediction, the initial coefficients we have used are able to independently (jackknife method) explain between 47–59 percent of the season-to-season variability of the seven forecast parameters over the last 42 years. We are confident that with more experimentation will be able to improve this already high measure of agreement.

Applying this new statistical prediction scheme to 1991 June–July meteorological data gives a 1991 seasonal forecast of 6 name storms, 20 name storm days, and 3 hurricanes, and a forecast of no intense hurricane activity for 1991. These new statistical predictions are in close agreement with our more qualitative estimates shown in Table 6. These new calculations add confidence to Table 6 predictions.

6 Seasonal Forecast for 1992

New research (Gray et al., 1991) is indicating that it is possible to make quite surprisingly skillful 6 to 11 month Atlantic seasonal hurricane forecasts by early December of prior year. A seasonal forecast of hurricane activity for 1992 will be issued by early December of this year at the time of the verification of this year's forecast.

7 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 not located in the deep tropics 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.

8 Verification of Previous Forecasts

Table 8 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 the usually heavy rainfall which fell in West Africa this season. Prior to 1990 West African rainfall was not explicitly included in the author's forecast scheme.

Table 8: 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 (Category 3-4-5)	3	2	1
Major Hurricane Days	Not fcst.	5	2

9 US Hurricane Spawned Destruction

Recent studies (Gray and Landsea, 1991) on US hurricane spawned destruction over the last 42 years indicate that three-quarters of all hurricane spawned destruction occurs with intense hurricanes of Saffir/Simpson category 3-4-5 ($V_{max} > 115mph$). Intense hurricane landfall in the Florida Peninsula and along the US East Coast is well associated with Western Sahel rainfall. For instance, 90 percent of all Peninsula Florida and US East Coast hurricane spawned damage over the last 42 years has occurred in the top third of West African rainfall years. The probability of hurricane spawned destruction is a great deal higher when the Western Sahel region of Africa experience above average rainfall and much reduced when rainfall is below average. This assessment also applies to hurricane spawned destruction in the Caribbean basin but not along the US Gulf Coast from the Florida Panhandle westward. Gulf Coast hurricane destruction has a much weaker association with West African rainfall.

The very low amounts of Western Sahel rainfall that are anticipated for this year indicate that the probability of major hurricane spawned destruction along the Florida Peninsula, the US East Coast and within the Caribbean is much below the long term average probability.

10 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 very low hurricane season, there are no assurances that a few hurricanes will not strike along the US or Caribbean coastline and do much damage.

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