EXTENDED RANGE FORECAST OF ATLANTIC SEASONAL HURRICANE ACTIVITY FOR 1993

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(This forecast is based on ongoing research by the author and his Colorado State University research colleagues, together with meteorological information through late November of 1992)

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ABSTRACT

This paper presents details of a 6–11 month extended range seasonal forecast of the tropical cyclone activity that might be expected to occur in the Atlantic Ocean basin during 1993. This forecast is based on new research by the author and his colleagues which allows an estimate of the amount of next season's Atlantic tropical cyclone activity to be made by late November of the prior year. The forecast scheme is based upon a 10-month extrapolation of the Quasi-Biennial Oscillation (QBO) of equatorial stratospheric zonal wind, two measures of West African rainfall through late November, and an extended range estimate of El Niño conditions for next year.

Information up to late November, 1992, indicates that the 1993 Atlantic hurricane activity will likely be somewhat above average with about 6 hurricanes, 11 named storms, 25 hurricane days, 3 intense hurricanes and a hurricane destruction potential of 75. The 1993 season should be more active than the two recent hurricane seasons of 1991 and 1992 and particular more active in the tropical regions where no hurricanes occurred the last two years. The 1993 season should be more similar to the hurricane seasons of 1988 and 1989 which produced hurricanes Gilbert and Hugo and three other Category 4 hurricanes. The probability of hurricane destruction along the US East Coast Peninsula Florida, and within the Caribbean basin for 1993 is projected to be somewhat above the last 40-year average.

It is expected that the long running West African drought will somewhat abate for next season and be less of an inhibiting influence on tropical cyclone activity than has occurred in recent years. This assessment is based on an anticipated cold ENSO event for next year in combination of stratospheric QBO winds being in a rainfall enhancing westerly phase.

DEFINITIONS AND ABBREVIATIONS

Named Storm (N) - A hurricane or tropical storm.

Named Storm Day (ND) - Four consecutive 6–hour periods during which a tropical cyclone is observed or estimated to have attained tropical storm or hurricane intensity winds.

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.

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

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

Hurricane Destruction Potential (HDP) - A measure of a hurricane's potential for wind and storm surge destruction. HDP is defined as the sum of the square of a hurricane's maximum wind speed for each 6-hour period of its existence. Value is summed for the season.

1 Introduction

A surprisingly strong long range predictive signal exists for Atlantic basin seasonal tropical cyclone activity. This predictive signal is related to two measures of West African rainfall in the prior year and to the phase of the stratospheric Quasi-Biennial Oscillation of zonal winds at 30 mb and 50 mb which can be extrapolated 10 months into the future with reasonable accuracy. These predictors, both of which are available by late November, can be utilized to make surprisingly skillful forecasts of Atlantic tropical cyclone activity in the following year.

Recent research by the author and research colleagues Chris Landsea, Paul Mielke and Ken Berry is showing that between 44 to 51 percent of season-to-season variability of seven indices of Atlantic seasonal tropical cyclone activity can be independently hindcast as early as late November of the previous year. The recent paper titled "Predicting Atlantic Seasonal Hurricane Activity 6-11 Months in Advance" (Gray *et al.*, 1992) explains this predictive scheme. This apparent forecast skill is based on lag associations for the period of 1950–1990.

a) QBO and Tropical Cyclone Lag Relationship

The easterly and westerly modes of stratospheric QBO zonal winds which circle the globe over the equatorial regions has a substantial influence on Atlantic tropical cyclone activity (Gray, 1984a; Shapiro, 1989). Nearly twice as much intense hurricane activity ($V_{max} \geq 50\ m/s$) occurs during seasons when the stratospheric QBO winds at the 50 mb (20 km) level are in a westerly as opposed to an easterly phase.

b) African Rainfall and Tropical Cyclone Lag Relationship

As discussed by Landsea (1991), Gray and Landsea (1992), and Landsea *et al.* 1992, there are surprising strong predictive signals from the use of mid-summer to fall West African rainfall amounts. These rainfall amounts are related to Atlantic hurricane activity in the following year. These include:

1) August–September Western Sahel Rainfall. During the last four decades, the Western Sahel (Fig. 1) has experienced a large year to year rainfall persistence. In general, wet years have been followed by wet years (e.g., in the 1950s and 1960s) while dry years typically followed dry years (e.g., in the 1970s and 1980s). This persistence provides a moderate amount of skill for forecasting next season's African rainfall and its associated Atlantic hurricane activity.

2) August–November Gulf of Guinea Rainfall. Landsea (1991) and Gray and Landsea (1992) have documented an even stronger rainfall - intense hurricane lag relationship for August through November rainfall along the Gulf of Guinea (see Fig. 1). Intense hurricane activity in seasons following the 10 wettest August–November Gulf of Guinea years has four times the amount of activity that occurred during those hurricane seasons following the 10 driest Gulf of Guinea years. This suggests a very strong rainfall modulation.

2 Basis for Extended Range Forecasts

This extended range forecast scheme is based on an optimized combination of these two lag rainfall relationships plus a 10-month extrapolation (November to September) of the absolute value of the QBO zonal winds at 30 mb (U_{30}) and at 50 mb (U_{50}) and the resulting wind shear between these levels at 10° North latitude. Hence, there are five forecast predictors: extrapolated QBO U_{30}, U_{50}, $|U_{30} - U_{50}|$ and August–September Western Sahel rainfall (R_s) and August–November Gulf of Guinea (R_G) rainfall. These five forecast parameters specify next year's expected number of named storms (N), named storm days (ND), hurricanes (H), hurricane days (HD), intense hurricanes (IH), intense hurricane days (IHD), and Hurricane Destruction Potential (HDP).

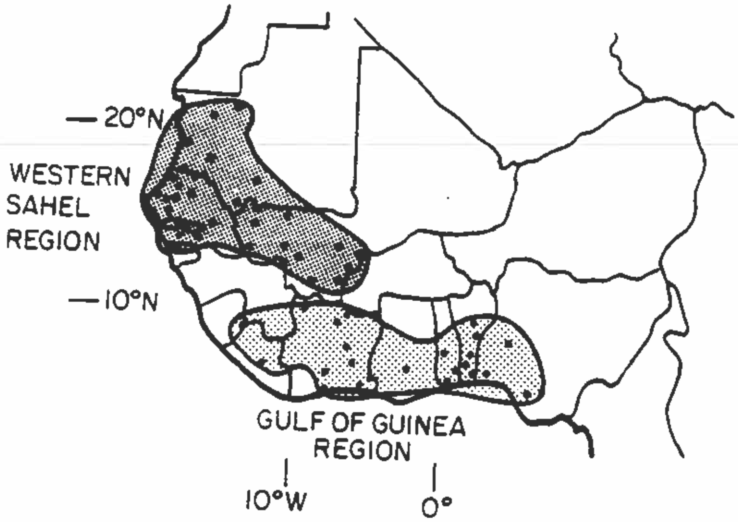

Figure 1: Locations of rainfall stations which make up the 38-station Western Sahel precipitation index and the 24-station Gulf of Guinea precipitation index. August to November rainfall within the Gulf of Guinea region provides a predictive signal for the following year's seasonal Western Sahel rainfall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

3 Statistical Analysis

Extensive statistical analyses have been made of these five late November predictors and of the seven following season predictants for the 41-year period of 1950–1990 by Professors Paul Mielke and Ken Berry of the CSU Statistics Department. Their analysis attempts to develop optimized regression equations for the most skillful extended range hindcasts.

The statistical methodology for these analyses consists of four distinct, but interrelated steps: (1) Least-absolute deviation regression provides prediction values for each of the n years. (2) A cross-validation (jackknife) procedure ensures that the prediction for any year is independent of the observations for that year. (3) The predicted values and observed values for all n years are compared by calculating a measure of agreement. (4) The probability of the measure of agreement is obtained under the null hypothesis (Gray *et al.*, 1992).

The forecast equations take the following form:

$$(Seasonal\ Forecast) = \beta_o + \beta_1[a_1 U_{50} + a_2 U_{30} + a_3|U_{50} - U_{30}|] + \beta_2[a_4 R_s + a_5 R_G] \quad (1)$$

where the β's and a's are arbitrarily determined constants. Table 1 lists these coefficients for each forecast parameter.

Table 2 shows the 41-year jackknife measure of agreement coefficient (ρ), hence the percentage of variance explained by the Lease Absolute Deviation (Or LAD analysis) scheme. The probability (P) of no statistical relationship is also given and the amount of variance explained had an ordinary least–squares (OLS) type of analysis been performed. Note that LAD analysis demonstrates a significant forecast skill (or explanation of variance) of between 45–50 percent. OLS analysis for the intense cyclone activity exceeds 50 percent of explained variance.

4 1993 Forecast

Meteorological information as of late November, 1992, yields the following values for the five predictors:

Table 1: Regression weights, from a non-jackknife solution for prediction equations.

Predictants	Term Coefficient			QBO Wind			Rainfall	
	β_0	β_1	β_2	a_1	a_2	a_3	a_4	a_5
(N)	11.732	0.135	0.701	1.000	0.252	−0.640	1.000	2.498
(ND)	64.072	1.031	7.149	1.000	−0.320	−3.384	1.000	2.302
(H)	7.560	0.049	0.759	1.000	−0.320	−3.384	1.000	2.302
(HD)	33.303	0.215	6.645	1.000	1.781	−1.370	1.000	2.144
(IH)	3.571	0.042	0.717	1.000	0.103	−1.415	1.000	2.455
(IHD)	7.605	0.124	2.006	1.000	−0.080	−1.410	1.000	2.292
(HDP)	95.326	0.686	24.747	1.000	1.066	−1.346	1.000	1.700

Table 2: Agreement coefficient (ρ) or amount of variance explained from a cross-validation or jackknife solution and the probability of no statistical relationship, and the amount of variance explained by a Ordinary Least Squares (OLR) type of analysis.

	ρ	P	r^2
Named Storms	0.440	0.22×10^{-5}	0.395
Named Storm Days	0.514	0.89×10^{-7}	0.488
Hurricanes	0.447	0.15×10^{-5}	0.466
Hurricane Days	0.491	0.46×10^{-6}	0.511
Intense Hurricanes	0.498	0.95×10^{-7}	0.581
Intense Hurricane Days	0.451	0.27×10^{-6}	0.517
Hurricane Destruction Potential	0.447	0.11×10^{-5}	0.527

1. 10 month extrapolated 50 mb September QBO zonal wind near 10°N (U_{50}) = –1 m/s.

2. 10 month extrapolated (Nov. 1992 to Sept. 1993) 30 mb September QBO zonal wind near 10°N (U_{30}) = –4 m/s.

3. 10 month extrapolated 50 mb minus 30 mb September QBO zonal wind shear $|U_{50} - U_{30}|$ = 3 m/s.

4. Measured S. D. of 1992 August–September Western Sahel rainfall σ_{RS} = –0.60.

5. Measured S. D. of previous year August–November Gulf of Guinea rainfall σ_{RG} = –0.60.

Substituting these values into the general forecast Eq. (1) with the appropriate forecast parameter coefficients from Table 1 renders the 1993 forecast statistics as shown in Column A of Table 3. Column B gives the author's qualitative adjustment of the statistical forecast information and my actual 1993 forecast. This adjustment includes an additional estimate of El Niño conditions for next year. This estimate is based on more recent project research which has not yet been included in this original forecast development. This ENSO estimate should add some improvement to the statistical forecast.

Although August and September precipitation in the Western Sahel has been dry (–0.60 S.D.) and August through November precipitation in the Gulf of Guinea region also quite dry (– 0.60 S.D.) I do not believe that these low rainfall amounts are indicative of next year's Western Sahel rainfall amounts. Next season will see the stratospheric QBO in its westerly phase and it is likely a cold ENSO or La Niña conditions will also be in place. In recent years we have seen large warm and cold swings of the ENSO. New research is relating the timing of these ENSO swing's to the stratospheric QBO and to the season of the year. In this coming spring and summer the QBO and other conditions will be favorable for a swing to cold ENSO conditions. This combination of westerly QBO and cold ENSO will likely bring about an amelioration of Western Sahel rainfall conditions as occurred in the recent years of 1988, 1985, 1978, 1975, and 1971.

Our late November forecast (Gray *et al.*, 1992) scheme does not explicitly include forecast information on ENSO or of the special influence of the mutually enhancing effect of a combined cold ENSO and westerly phase QBO. I thus believe that our extended range forecast underestimates the amount of tropical cyclone activity which might be expected to occur next year, particularly so with major or intense hurricane activity. I have accordingly adjusted the figures upward as indicated in Table 3.

It is expected that the 1993 hurricane season will be somewhat above normal with typical tropical cyclone parameters about 100 to 120 percent of the last 42 year average. This will be a change from the generally inactive conditions (except for Hurricane Andrew) of the last two seasons of 1991 and 1992. Next year should be more typical of the more active recent hurricane seasons of 1988 and 1989.

5 Discussion

Why issue such an extended range seasonal hurricane forecast? Answer: because statistical analysis shows that over a number of years, it is possible to improve on climatology based forecasts by an appreciable amount. If there is a significant degree of forecast skill then it should be made available to the broad spectrum of parties who have an interest in the variations of Atlantic tropical cyclones.

It is remarkable that Atlantic seasonal hurricane activity, manifesting itself in many sporadic mesoscale events, would show such a strong and such a long period lag response to forcing functions far removed in space and time. We know of no other climate signals showing this degree of extended range skill. This is further evidence for the primary role of global and regional circulation patterns on seasonal hurricane frequency and intensity. Previously, we had viewed hurricanes and the weaker weather systems which spawned them, more as the product of

Table 3: Raw Atlantic Basin statistical seasonal forecast for 1993 (column A) and author's adjusted forecast (column B) and comparison (in percent) of adjusted forecast for 1993 with the last 42-year average (column C).

Forecast Parameter	A Late November Statistical Prediction For 1993	B Author's 1993 Forecast after Quantitative Adjustment for Expected ENSO-QBO Activity Enhancement	C 1993 Forecast as a Percent of the last 42 Year Ave.
Named Storms (N)	9.7	11	111
Named Storm Days (NS)	45.8	55	117
Hurricanes (H)	5.6	6	102
Hurricane Days (HD)	18.1	25	105
Intense Hurricanes (IH)	1.8	3	120
Intense Hurricane Days (IHD)	3.1	7	127
Hurricane Destruction Potential (HDP)	48.8	75	101

rapidly varying local circulation characteristics which had a large random component and which were impossible to predict a few days in advance, let alone 10 months in advance. Although this view is still true for individual hurricane systems, it is not for the seasonal aggregate of systems. The climate signal has a strong influence in determining the seasonal number of short lived and transitory events (i.e., hurricanes) which may be activated.

6 Last Year's Forecast Verification

Our first 6 to 11 month extended range Atlantic basin seasonal hurricane activity forecast was made on 26 November, 1991, for the 1992 hurricane season. The following table shows its verification. Note how well this first extended range forecast worked out.

Forecast Parameter	Prediction of 26 Nov 1991	1992 Verification
No. of Hurricanes	4	4
No. of Named Storms	8	6
No. of Hurricane Days	15	15.75
No. of Named Storm Days	35	38.25
Hurr. Destruction Potential (HDP)	35	50.7
Major Hurricanes (Category 3-4-5)	1	1
Major Hurr. Days	2.0	3.25

7 Cautionary Note

It is important that the reader realize that this seasonal forecast is a statistical one which will fail in some years. Even though a remarkable degree of 45–50% of independent hindcast skill has been obtained from analysis of the last 41-years of data, there still remains 50–55% of the variance which is not explained. 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 1993 should prove to be an active hurricane season, there are no assurances that hurricanes will strike along the US or Caribbean coastlines and do much damage although the probability of this is somewhat higher than the last 40 year average.

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