SUMMARY OF 1986 ATLANTIC TROPICAL CYCLONE ACTIVITY AND VERIFICATION OF AUTHOR'S SEASONAL FORECAST

By

William M. Gray

Department of Atmospheric Science

Colorado State University

Fort Collins, CO 80523

(As of 24 November 1986)

DEFINITIONS

El Nino - (EN) - a 12-18 month period in which anomalously warm sea surface temperatures occur in the eastern half of the equatorial Pacific. Moderate or strong El Nino events occur irregularly. Their average frequency is about once every 5-6 years or so.

QBO - Quasi-Biennial Oscillation. These letters refer to stratospheric (20 to 35 km altitude) equatorial east to west or west to east zonal winds which have a period of about 26 to 30 months or roughly 2 years. They typically blow for 12-16 months from the east and then reverse themselves and blow 12-16 months from the west and then back to the east again.

SLPA - Sea Level Pressure Anomaly. Caribbean and Gulf of Mexico Sea Level Pressure Anomaly in the spring and early summer has an inverse correlation with late summer and early autumn hurricane activity. The lower the pressure the more likely there will be hurricane activity.

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

Hurricane - A tropical cyclone with sustained low level winds of 74 miles per hour (32 meters/s) or greater.

Tropical Storm - a tropical cyclone with maximum sustained winds between 39 (17 m/s) and 73 (31 m/s) miles per hour.

Tropical Cyclone - a large-scale circular flow occurring within the tropics and subtropics which has its stronger winds at low levels. This includes tropical storms, hurricanes, and other weaker rotating vortices.

Hurricane Day - any part of a day in which a tropical cyclone is observed or estimated to have hurricane intensity winds.

Named Storm Day - any part of a day in which a tropical cyclone is observed or estimated to have tropical storm or hurricane intensity winds.

Millibar - (abbreviated mb). A measure of atmospheric pressure. Often used as a vertical height designator. 200 mb is at a level of about 12 kilometers, 30 mb at about 23 kilometers altitude. Monthly averages of surface pressure in the tropics show maximum seasonal summer variations of about $\pm$ 2 mb. These small pressure variations are associated with variations in seasonal hurricane activity. Average surface pressure is slightly over 1000 mb.

ZWA - Zonal Wind Anomaly. A measure of upper level (~ 200 mb or 12 km altitude) west to east wind strength. Positive values mean winds are stronger from the west or weaker from the east than normal.

ABSTRACT

This paper summarizes tropical cyclone activity which occurred in the Atlantic in 1986 and verifies the author's seasonal forecast of this activity that was issued in late May and updated in late July. This forecast was based on the author's previous research (Gray, 1983, 1984a, 1984b) which relates seasonal Atlantic hurricane activity to: 1) the El Nino (EN); 2) the Quasi-Biennial Oscillation (QBO) of equatorial 30 mb stratospheric wind; 3) the Caribbean Basin-Gulf of Mexico Sea-Level Pressure Anomaly (SLPA) in spring and early summary; and 4) lower latitude Caribbean Basin 200 mb zonal wind anomaly in June and July.

Information received by the author as of 29 May 1986 indicated that the 1986 hurricane season should have been a below average year with about 4 hurricanes (6 is average), 8 hurricanes and tropical storms (10 is average), 15 hurricane days (25 is average) and 35 tropical storm and hurricane days (45 is average).

Updated information received by the author as of late July reinforced this prediction of a below average hurricane season. June and July data indicated that the 1986 would be more suppressed than indicated by the late May forecast. The revised late July forecast called for the same number of hurricanes (4) but reduced the number of named storms from 8 to 7 and reduced the number of hurricane days to 10 and the number of named storm days was dropped to 25. This downward revision was made despite the occurrence of a hurricane and a tropical storm in June.

The actual number of hurricanes which occurred in 1986 was 4 (as forecast); the number of hurricanes and tropical cyclones was 6 (1 below late July forecast); number of hurricane days was 13 (3 above late July forecast) and number of hurricane and tropical storms was 27 (2 above late July forecast). By all standards 1986 was a very suppressed tropical cyclone season, even more suppressed than the above numbers indicate. Activity during the four-month period of July through October was lower than that of any season since 1930. The most intense hurricane of 1986 had a higher central pressure than the central pressure of any season's maximum intensity hurricane since such measurements were begun to be taken by aircraft in the 1940's. Global and regional environmental factors such as stratospheric and upper tropospheric zonal winds and sea-level pressure were all unfavorable for hurricane activity.

TABLE OF CONTENTS

1. 1986 Atlantic Tropical Cyclone Activity

The 1986 Atlantic hurricane season officially ends on 30 November. There were four hurricanes (maximum sustained winds $\geq$ 74 mph) and 13 hurricane days during 1986. This is below the last 40 year seasonal average of 6 hurricanes and 25 hurricane days. Combined hurricane and tropical storm activity (tropical storms are tropical cyclones with maximum sustained surface winds between 39-73 mph) was also very much below average. This season had only 6 named tropical storms (10 is average) and 27 tropical storm and hurricane days (45 is average). But, seasonal activity for this year was lower than these numbers indicate. Nineteen eighty-six ranks as the most suppressed hurricane season in the last 56 years in which a significant El Nino event did not occur. As will be discussed, global and regional large-scale environmental conditions in 1986 were very unfavorable for tropical cyclone formation.

Table 1 and Fig. 1 gives a summary of all 1986 Atlantic season tropical cyclones. Note that two cyclones (Tropical Storm Andrew and Hurricane Bonnie) occurred in June. Between 28 June and November 19 there were only three named storms, one in August and two in September. This is the lowest number of named tropical cyclones to occur during this nearly 5-month period than in any season since 1930.

Also to be noted is the general lack of intensity of tropical cyclones during 1986. During the last 40 years in which tropical cyclone central pressure measurements from aircraft have been made, there has not been a year in which a seasonal's strongest hurricane had a minimum pressure as high as 979 millibars (mb) or (29.00 inches of mercury) as occurred for 1986's most intense tropical cyclone - Hurricane Earl.

TABLE 1

The 1986 Tropical Cyclone Season

Named Tropical Cyclones	Maximum Sustained Winds (knots)*	Minimum Sea Level Pressure (mb)	Dates	No. of Hurricane Days	No. of Hurricane and Trop. Storm Days
1. TS Andrew	45	999	6 June-8 June	0	3
2. HUR Bonnie	75	992	23 June-28 June	2	3
3. HUR Charley	70	987	13 Aug-20 Aug	2	6
4. HUR Earl	90	979	10 Sept-20 Sept	8	8
5. TS Danielle	50	1003	07 Sept-10 Sept	0	3
6. HUR Frances	75	1000	19 Nov-22 Nov	1	4
			TOTAL	13	27

* 1 knot equals 1.15 miles per hour.

A summary of Atlantic tropical cyclones which occurred during 1986 are as follows:

1) Tropical Storm Andrew formed 200 miles east of Jacksonville, FL. This early June storm was more of a sub-tropical type of formation. Andrew attained a maximum wind of only 45 knots and minimum pressure of 999 mb. It lasted for 3 days and just marginally affected the North Carolina coast.

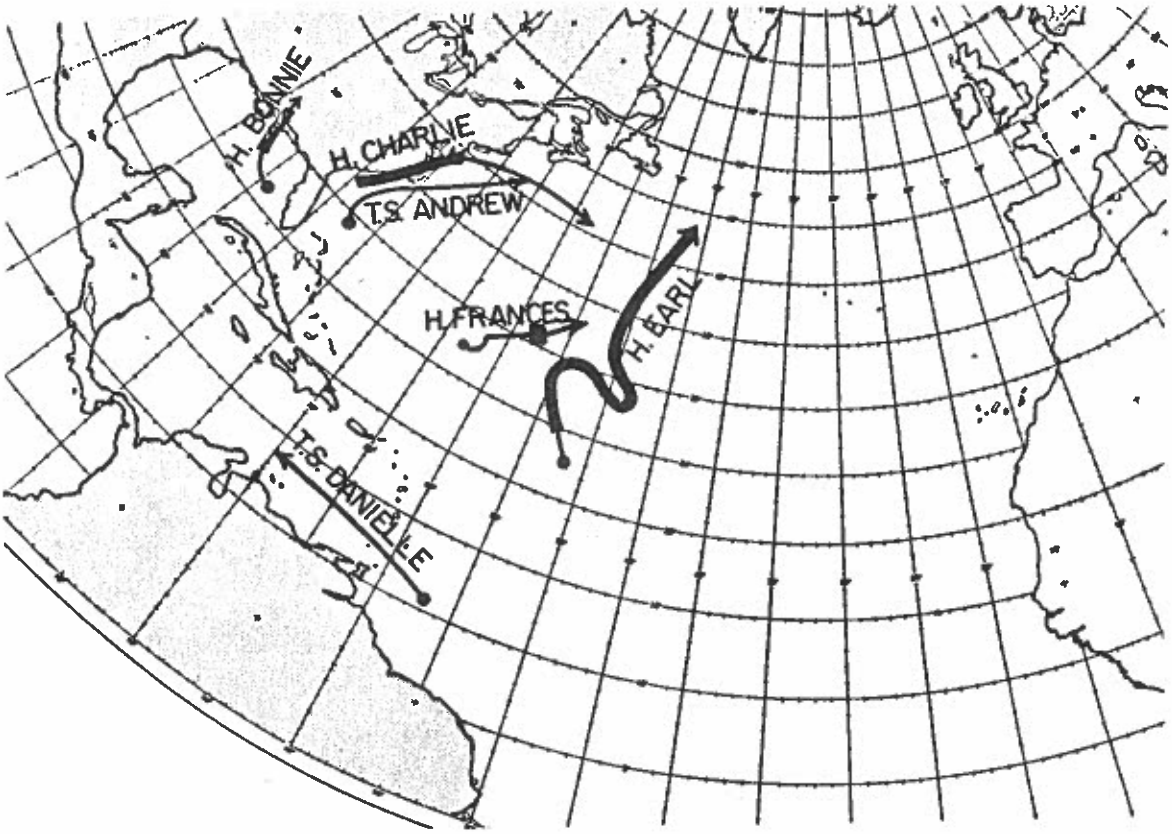

Fig. 1. Tracks of tropical cyclones for 1986. The thin line shows periods of tropical storm intensity, the thick lines are periods of hurricane intensity.

2) Hurricane Bonnie began to develop 200 miles south of New Orleans and moved northwestward across the east Texas coast as a minimal hurricane. Maximum winds were 75 knots and minimal sea-level pressure of 992 mb. Bonnie was a hurricane for only 24 hours.

3) Hurricane Charley formed from a broad rain area over Georgia which moved eastward over the Gulfstream and then developed. It moved north-northeastwards and crossed the eastern portions of North Carolina as a minimal hurricane. Maximum winds were 70 knots and minimum sea-level pressure 987 mb. Charley was of hurricane intensity for only 24 hours.

4) Hurricane Earl formed in the central Atlantic from a tropical

disturbance which could be traced from the African coast. It was the season's only real bonafide hurricane. It intensified about 900 miles southeast of Bermuda and was classified as a named storm for 8 days. Earl meandered about moving very slowly for the first week of its existence. It remained in the longitude belts of 45 to 55°W. Earl moved rapidly north-northeastward during the last two days of its existence. Although Earl was this season's most intense hurricane, it attained a maximum intensity of only 90 knots and had a minimum sea-level pressure of only 979 mb. It was distinguished by its very long distance from land and its comparatively long lifetime. It existed in hurricane intensity stage for nearly 8 days and as such accounted for nearly two-thirds of this season's hurricane days.

5) Tropical Storm Danielle formed from a disturbance which came off of the African coast. It first become a named storm 350 miles to the east-northeast of Trinidad. Danielle tracked west-northwestwards through the eastern Caribbean and then dissipated 3 days later in the central Caribbean due to the strong upper tropospheric wind shear. It attained a maximum wind of only 50 knots and a minimum sea-level pressure of 1003 mb.

6) Hurricane Frances was a late November tropical cyclone which formed a few hundred miles to the southeast of Bermuda from a northwest moving tropical cloud cluster. This was the third marginal hurricane of the season. Frances existed in a hurricane stage for only 12 hours. Its maximum intensity was 75 knots and minimum sea-level pressure of only 1000 mb.

Discussion. This season's tropical cyclone activity was much lower than the number of hurricanes, named storms, and hurricane days

indicate. Three of the four hurricanes were just marginally intense enough to be classified as hurricanes. Each of these marginal hurricanes existed as a hurricane intensity system for only one day or less. The most intense hurricane of the season, Earl, as just discussed was also not a very strong hurricane.

The 1986 season continued the long period between 1980 and the present in which no hurricane has influenced the Caribbean. Tropical Storm Danielle was indicative of the unfavorable environmental conditions which existed in the low latitude western Atlantic and the Caribbean. Danielle dissipated in the central Caribbean. Named storm dissipation at low latitudes typically does not occur so often.

The major characteristics of the 1986 hurricane season was the unusually small amount of tropical cyclone activity during the three months of August through October which are climatologically the most active. Of the season's 6 named cyclones two occurred in June and one in November. A late November hurricane is a relatively rate event except for the last three seasons.

2. Known Factors Associated with Atlantic Seasonal Hurricane Variability

The author's Atlantic seasonal hurricane forecast is based on the characteristics of two global and two regional environmental factors which the author has previously shown to be statistically related to seasonal hurricane variations. These are:

a) The presence or absence of a moderate or strong El Nino warm water event in the eastern tropical Pacific off of Peru. Seasons during which an El Nino event is present are usually suppressed hurricane seasons.

b) The direction of the 30 mb (~ 23 km altitude) stratospheric or

QBO winds which circle the globe over the equator. On average, there is nearly twice as much hurricane activity in seasons when QBO winds are from the west as compared with seasons when they are from the east. In addition, if west QBO winds exist and west winds are also increasing during the hurricane season or if east QBO winds exist and east winds are increasing, then seasonal hurricane activity is (on average) even more enhanced or more suppressed.

c) The Caribbean Basin-Gulf of Mexico Sea Level Pressure Anomaly (SLPA). Other factors aside, the lower this pressure anomaly is the generally greater the Atlantic seasonal hurricane activity and vice-versa.

d) Lower latitude Caribbean Basin upper tropospheric (~ 200 mb or 12 km altitude) west to east or zonal wind anomaly (ZWA). The stronger the 200 mb zonal winds are from the west the generally greater the suppression of hurricane activity and vice-versa.

3. Characteristics of Known Seasonal Hurricane Associated Factors During 1986

a) El Nino. Measurements available in late May and late July indicated that 1986 would not be an El Nino year with tropical east-Pacific ocean warming. During most of this hurricane season this assessment appears to have held up. A typical El Nino warm water event has not been observed in the eastern Pacific through most of the hurricane season. There has, however, been a beginning eastern Pacific warming event which started in October. In addition, a significant ocean warming event did begin to occur in the tropical central Pacific in late August and September (Climate Diagnostics Bulletin - NOAA Climate Analysis Center, October, 1986). This mid-Pacific ocean warming

event has steadily increased and begun to spread to the eastern Pacific. As it is the eastern Pacific warm water events which most influence Atlantic hurricane activity, it is likely that this beginning warm water event in the central Pacific in late August and September (not a typical time for a warming event to start) and in the eastern Pacific in October has not been a major contributing influence on the suppression of this season's hurricane activity. But there may have been some contributing influence from this beginning warming event - particularly in that the lower latitude Caribbean Basin upper tropospheric winds have been observed to be so anomalously strong from the west, conditions which are associated with El Nino seasons. It is possible to have anomalously strong 200 mb zonal winds in non-El Nino years however. And, anomalously strong 200 mb zonal winds were present in the lower Caribbean Basin in June-July before this Pacific warming commenced.

b) QBO Wind Direction. Figure 2 shows QBO zonal wind speeds during the last three hurricane seasons. It can be seen that during the 1986 hurricane season that 30 mb QBO winds were from the east and were increasing with time from the east. This is as predicted. Information on the QBO going back to 1950 indicates that easterly QBO winds and increasing easterly QBO winds are often associated with suppressed hurricane seasons. This is considered to be an important contributing influence in explaining why 1986 was such an inactive hurricane year.

c) Sea-Level Pressure Anomaly (SLPA). Table 2 gives information on SLPA during the 1986 season. From June through October SLPA was unusually high. Pressure data available to the author over the last 40 years indicates that there has never been a previous season in which Caribbean-Gulf of Mexico surface pressure was so high during the period

of June through October or August through October. Note that every station has had positive pressure anomaly in all months from June through October. High SLPA is considered to be another important contributing influence as to why 1986 was such a suppressed hurricane season. As SLPA is largely unrelated to the QBO and the EL Nino (Gray, 1984a), SLPA may be considered to be a separate and largely independent contributing factor to hurricane suppression.

d) Upper Tropospheric Zonal Wind Anomaly (ZWA). Table 3 shows lower Caribbean Basin 200 mb west to east zonal wind anomaly for the period of June-July through October. Note that 200 mb winds were 3-5 m/s (or 6-10 knots) anomalously strong from the west in all 5 months. These are large wind anomalies. Wind information available to the author since the mid-1950's indicate that there has never before been a

TABLE 2

1986 Sea Level Pressure Anomaly (SLPA) for Six Key Caribbean Basin-Gulf of Mexico Stations Plus Trinidad (in mb). (1 mb = .0295 inches of mercury)

	April-May	June-July	Aug	Sept	Oct
Brownville	-0.1	+1.3	+0.3	+1.2	+0.6
Merida	-0.5	+1.3	+0.6	+2.2	+1.0
Miami	-0.2	+1.2	+1.2	+3.4	+2.6
San Juan	-1.4	+0.9	+0.4	+1.2	+1.3
Curacao	-1.0	+1.1	+0.5	+1.3	+1.5
Barbados	0.0	+1.3	+0.3	+1.0	+1.1
6-Station Mean	-0.5	+1.2	+0.6	+1.7	+1.4
Trinidad	-0.1	+1.3	+0.7	+0.7	+1.0

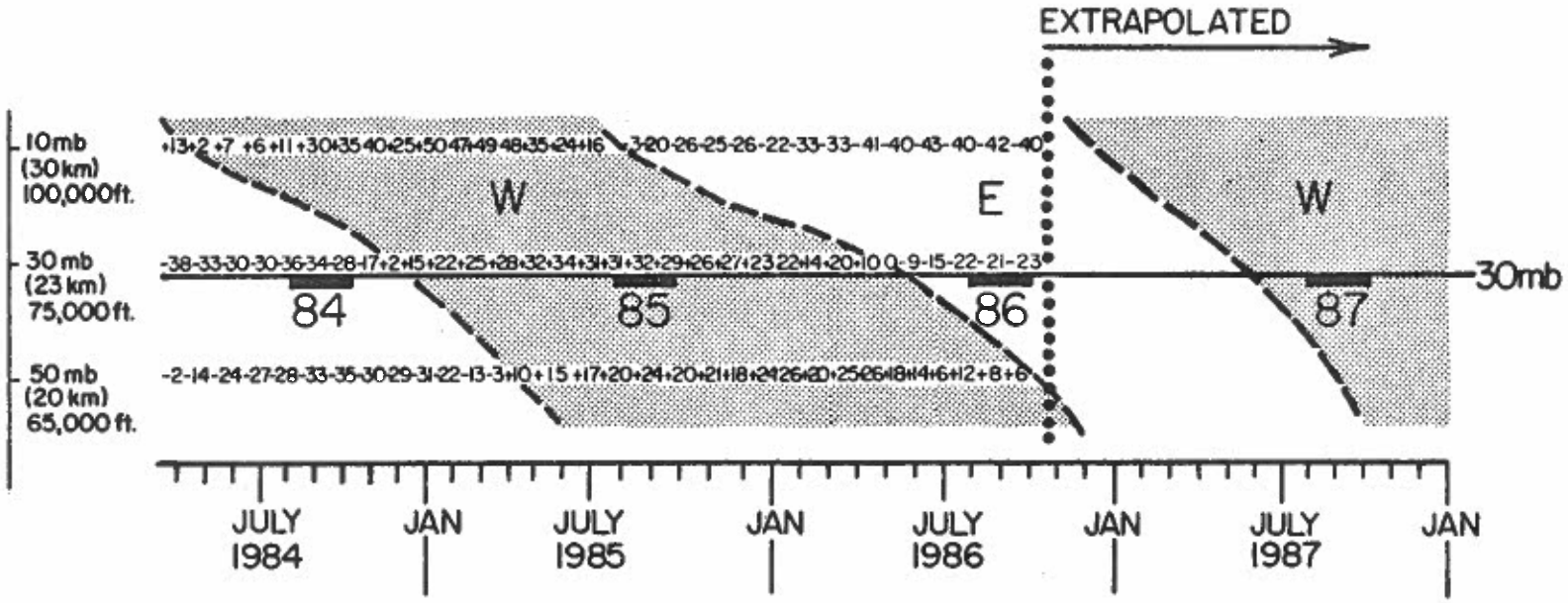

Fig. 2. Vertical cross-section of recent stratosphere monthly average QBO zonal wind (in knots). This figure represents an average of the Balboa, C.Z. (9^{o}N) and Ascension (8^{o}S) rawinsondes. The annual cycle has been removed from each sounding before averaging. Winds from a westerly direction have been shaded. Information beyond October 1986 has been extrapolated. Thick horizontal lines show the active portion of each hurricane season for 1984-1987.

non-El Nino year in which lower latitude Caribbean Basin 200 mb ZWA has been as large in all months as in 1986. This is also considered to have been an important contributing factor to the strong suppression of 1986 Atlantic hurricane activity.

Summary. It is no surprise that 1986 was one of the most suppressed hurricane seasons since 1930. Of the four known global and regional factors which can be statistically related to seasonal hurricane activity three (QBO, SLPA and ZWA) showed strong suppressing influences on seasonal hurricane activity. The fourth factor, the El Nino, although probably not a major suppressing factor, may have also played some smaller role in the suppression of late season hurricane activity.

TABLE 3

Lower Caribbean Basin 200 mb Upper Tropospheric Zonal Wind Anomaly (ZWA) in m/s.

	June-July	Aug	Sept	Oct
Balboa (9°N)	+3	+4	+3	+5
San Andres (12 1/2°N)	+3	+5	+3	+4
Curacao (12°N)	+4	+5	+5	+6
Barbados (13 1/2°N)	+2	+3	Miss	+7
Trinidad (11°N)	+3	+1	+3	+6
Average	+3.0	+3.6	+3.5	+5.6
Kingston, Ja.(18°N)	+7	+5	+7	+3

4. Specifics of 1986 Seasonal Prediction and Verification

Table 4 gives the author's numerical estimates of each term of his three prediction equations for the 1986 season as issued on 29 May 1986. Number of hurricanes, number of hurricanes and tropical storms, and number of hurricane days were forecast to be 4, 8, and 15, respectively.

TABLE 4

1986 PREDICTED SEASONAL HURRICANE ACTIVITY (ON 29 MAY 1986)

(PREDICTED NO. OF HURRICANES PER SEASON)

$= 6 + (QBO_1 + QBO_2) + EN + SLPA + ZWA$

$= 6 + (-1) + (-1) + (0) + (0) + (0) = 4$, 2 Below Average

(PREDICTED NO. OF HURRICANES AND TROPICAL STORMS PER SEASON)

$= 10 + QBO + EN + SLPA + ZWA$

$= 10 + (-1.5) + (-0.7) + (0) + (0) = 8$, 2 Below Average

(PREDICTED NO. OF HURRICANE DAYS PER SEASON)

$= 25 + 5\ [(QBO_1 + QBO_2) + EN + SLPA + ZWA]$

$= 25 + (-5) + (-5) + (0) + (0) + (0) = 15$, 10 Below Average

If 1986 followed the average ratio of name storm days to hurricane days then one should expect about 35 named storm days.

Table 5 shows these same numerical estimtates as given by the author on his updated forecast as of 28 July 1986.

TABLE 5

$$\left(\begin{array}{l}\text{PREDICTED NO.}\\ \text{OF HURRICANES}\\ \text{PER SEASON}\end{array}\right) = 6 + (QBO_1 + QBO_2) + EN + SLPA + ZWA$$

$$= 6 + (-1) + (-1) + (0) + (-1) + (-1) = 2\ (4)$$ (2 Below Average)

The qualitative part of this forecast scheme (see Gray, 1984b) specifies that when this value is less than 4 in a non-El Nino year the value should be raised to a value of 4.

$$\left(\begin{array}{l}\text{PREDICTED NO. OF}\\ \text{HURRICANES AND}\\ \text{TROPICAL STORMS}\\ \text{PER SEASON}\end{array}\right) = 10 + QBO + EN + SLPA + ZWA$$

$$= 10 + (-1.6) + (0.7) + (-1) + (-1) = 7$$ (3 Below Average)

$$\left(\begin{array}{l}\text{PREDICTED NO. OF}\\ \text{HURRICANE DAYS}\\ \text{PER SEASON}\end{array}\right) = 25 + 5\ (QBO_1 + QBO_2) + EN + SLPA + ZWA$$

$$= 25 + (-5) + (-5) + (0) + (-5) + (-5) = 5\ (10)$$ (15 Below Average)

The qualitative part of this forecast scheme specifies that if the above formula gives a value less than 10, then the value should be raised to 10.

The forecast of named storm days was reduced to 25.

In that 1 hurricane and 1 tropical cyclone had already occurred in June this 28 July forecast allowed for only 3 additional hurricanes, 5 additional named storms, and 8 additional hurricane days for the remainder and most active part of the season.

Table 6 gives a summary of the author's end of May seasonal forecast and the end of July updated forecast and the seasonal verification.

TABLE 6

Forecast and Verification of 1986 Seasonal TC Forecast

	Original Forecast as of 29 May 1986	Revised Forecast as of 28 July 1986	Observed Verification as of 1 Nov. 1986
No. of Hurricanes (Average Season 6)	4	4	4
No. of Named Storms (Hurricanes and Tropical Storms) (Average Season 10)	8	7	6
No. of Hurricane Days (Average Season 25)	15	10	13
No. of Hurricane and Tropical Storm Days (Average Season 45)	35	25	27

Tables 7 and 8 give the author's forecasts and verifications for the 1984 and 1985 seasons. These seasonal forecasts for 1984-1986 are a significant improvement over climatology, the previous only objective seasonal predictors that were available.

TABLE 7

Prediction vs. Observed Tropical Cyclone Activity for 1984

	Predicted 24 May and in 30 July Update	Observed
No. of Hurricanes	7	5
No. of Hurricane Days	30	21
No. of Hurricane and Tropical Storms	10	12
No. of Hurricane and Tropical Storm Days	45 (implied from hurricane forecast)	61

TABLE 8

Prediction vs. Observed Tropical Cyclone Activity for 1985

	Prediction as of 28 May 1985	Updated Prediction of 27 July 1985	Observed
No. of Hurricanes	8	7	7
No. of Hurricane Days	35	30	29
No. of Hurricane and Tropical Storms	11	10	11
No. of Hurricane and Tropical Storm Days	55 (implied from hurricane forecast)	50	60

5. Outlook for 1987

Statistical odds favor a more active 1987 season particularly if the tropical Pacific Ocean warming event now occurring does not materialize into a major multi-year El Nino event like the very special 1982-1983 El Nino warming event was. This new El Nino needs to be carefully watched.

Stratospheric QBO winds in 1987 will be less unfavorable for hurricane activity than they were this year. QBO winds will likely not, however, have fully switched around to the west by the start of next year's season.

On a pure statistical basis it is not to be expected that Caribbean Basin-Gulf of Mexico surface pressure anomaly will be as high in 1987 as it was in 1986. Likewise, lower Caribbean Basin 200 mb ZWA wind are not expected to be as strong from the west in 1987 as they were in 1986. From the vantage point of late November the author's best estimate (or speculation!) is that 1987 will likely have about an average amount of hurricane activity.

6. Summary Discussion

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 11 per season (as in 1950, 1916), 10 (1969, 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 indicating whether a coming hurricane season was going to be an active

one or not. Recent and ongoing research by the author (Gray, 1983, 1984a, 1984b, 1985) indicates that there is a surprising 3-5 month atmospheric predictive signal available in the Atlantic basin from global and regional predictors which are not operative in the other global hurricane basins.

Five years ago the author would never have imagined that such a strong seasonal predictive signal existed for such a variable and convective-scale event as the hurricane. This extended range seasonal predictive signal for Atlantic hurricane activity appears stronger and more significant than any other now known extended range meteorological predictive signal. New statistical studies by the author and two of his CSU research colleagues are showing that it is possible to independently predict approximately half of the Atlantic seasonal variance. With more research this predictive signal may be improved upon and perhaps extended to allow seasonal prediction not just of hurricane number but also perhaps some objective estimates of seasonal hurricane intensity.

This paper has been prepared for the professional meteorologist, the news media and any interested layman.

7. Acknowledgements

The author is grateful to the following individuals for the information furnished him and/or beneficial discussions on: 1) the characteristics of the stratospheric QBO from James Angell (NOAA); 2) on the El Nino from Vernon Kousky and Eugene Rasmusson (NOAA Climate Analysis Center). The author also thanks Arthur Pike and Robert Merrill of NOAA and Lexion Avila of the University of Miami for supplying him with Caribbean Basin meteorological data. He has benefited from statistical analysis and discussions with Professors Paul W. Mielke and

Kenneth J. Berry of Colorado State University statistics department. He also acknowledges beneficial discussions with Roger Edson formerly of Colorado State University.

The author would also like to acknowledge the very beneficial encouragement he has received for this type of forecasting research application from Neil Frank, Director of the National Hurricane Center (NHC) and other forecasters at the center. Also the meteorological data that has been supplied to him by the NHC.

This research has been funded by the National Science Foundation.

8. References

Gray, W. M., 1983: Atlantic seasonal hurricane frequency, Part I and II. Dept. of Atmos. Sci. Paper No. 370, Colo. State Univ., Ft. Collins, CO, 100 pp.

Gray, W. M., 1984a: Atlantic seasonal hurricane frequency: Part I: El Nino 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., 1986a: Forecast of Atlantic seasonal hurricane activity for 1985. Colo. State Univ., Dept. of Atmospheric Science Paper issued on 29 May 1986, Fort Collins, CO, 34 pp. (Available upon request from the author's office).

Gray, W. M., 1986b: Updated (as of 27 July 1985) Forecast of Atlantic seasonal hurricane activity for 1986. Colo. State Univ., Dept. of Atmospheric Science Paper issued on 28 July 1986, Fort Collins, CO, 16 pp. (Available upon request from the author' office).

Neumann, C., G. Cry, E. Caso and B. Jarvinen, 1981: Tropical Cyclones of the North Atlantic Ocean, 1871-1977. National Climatic Center, Asheville, NC, 170 pp. (Available from the Superintendent of Documents, US Government Printing Office, Washington, DC, 20402, Stock Number 003-017-00425-2.)

Quinn, W. H., D. O. Zopf, K. S. Short and R. T. W. Kuo Yang, 1978: Historical trends and statistics of the Southern Oscillation, El Nino, and Indonesian droughts. Fish. Bull., 76, 663-678.

Shapiro, L., 1982: Hurricane climatic fluctuations, Part II: Relation to large-scale circulation. Mon. Wea. Rev., 110, 1014-1023.

Author - The author of this paper is a Professor in the Dept. of Atmospheric Science at Colorado State University.