FORECAST OF ATLANTIC SEASONAL HURRICANE ACTIVITY FOR 1986

By

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(This forecast is based on past and current research by the author at Colorado State University together with new April-May 1986 meteorological information)

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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 73 miles per hour (32 meters/s) or greater.

Tropical Storm - a tropical cyclone with maximum sustained winds between 39 (17 m/s) and 72 (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.

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 ± 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 west to east wind strength. Positive values mean winds are stronger from the west or weaker from the east than normal.

OUTLINE

ABSTRACT

This paper discusses the author's forecast of the amount of tropical cyclone activity which might be expected to occur in the Atlantic Ocean region (including the Caribbean Sea and the Gulf of Mexico) in 1986. This forecast is based on the author's previous and current research (Gray, 1983, 1984a, 1984b, 1985) which relates seasonal amount of Atlantic tropical cyclone activity to four factors: 1) the El Nino (EN); 2) the Quasi-Biennial Oscillation of equatorial stratospheric wind (QBO); 3) Caribbean Basin and Gulf of Mexico Sea-Level Pressure Anomaly (SLPA); and 4) lower latitude Caribbean Basin 200 mb zonal wind anomaly in June and July.

Information received by the author up to 29 May 1986 indicates that the 1986 hurricane season can be expected to be a below average year with about 4 hurricanes (6 is average), 8 total name storms of both hurricanes and tropical storms intensity (10 is average), and about 15 hurricane days (25 is average). This forecast will be updated on 1 August before the start of the most active part of the hurricane season. The updated 1 August forecast which will make use of June and July data and should be more reliable.

This paper also gives a brief background description of the methodology of this objective forecast scheme and verification information on the author's forecasts for the 1984 and 1985 seasons.

1. Background

The Atlantic basin (including the Atlantic Ocean, Caribbean Sea and Gulf of Mexico) experiences a larger seasonal variability of tropical cyclone activity than any other global tropical cyclone 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 and very skillful 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 are four atmospheric parameters (out of a large number studied) which can be evaluated in spring and early summer and which are correlated with the following season's tropical cyclone activity. If these four predictors are used in combination, then it is possible to explain about half or more of the seasonal variability in Atlantic hurricane activity on a statistical multi-year basis.

This paper will briefly discuss the nature of these four seasonal hurricane predictors and what these predictors indicate for the level of hurricane and tropical storm activity for the coming 1986 season.

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

2. Atmospheric Predictors of Atlantic Hurricane Activity

The four predictors are the El Nino (EN), the Equatorial Stratospheric Quasi-Biennial-Oscillation (QBO) of east-west or zonal Wind, the Caribbean-Gulf of Mexico springtime and early summer Sea Level Pressure Anomaly (SLPA), and lower latitude Caribbean Basin springtime and early summer 200 mb zonal wind anomaly.

a. The El Nino

At irregular intervals of 3-8 years, sea surface temperatures over the central and eastern tropical Pacific Ocean rise to several degrees Celsius above average values, and remain so for 12-18 months. Associated with this phenomenon, named El Nino, are disruptions of worldwide weather patterns, particularly in the tropics and subtropics. One consequence of El Nino is reduced hurricane frequency in the Atlantic basin.

Strong or moderate El Nino events (as defined by Quinn et al., 1976) have occurred during 16 hurricane seasons of this century. One can compare the number of hurricanes, hurricane days, etc., occurring in each of these 16 El Nino years to the number of such events occurring during the other 69 strong or moderate non El Nino years of this century. Figure 1 is a plot of the seasonal number of hurricane days for the years of 1900-1985 with strong and moderate El Nino years shown by the thick circled lines. It can be seen that in most years with strong and moderate El Ninos that hurricane activity as measured by the number of hurricane days is typically much less than for non-El Nino years. Of the 16 years of this century with the lowest number of hurricane days, 9 are strong or moderate El Nino years. Of the 22 years of the century with the largest number of hurricane days, none were El Nino years.

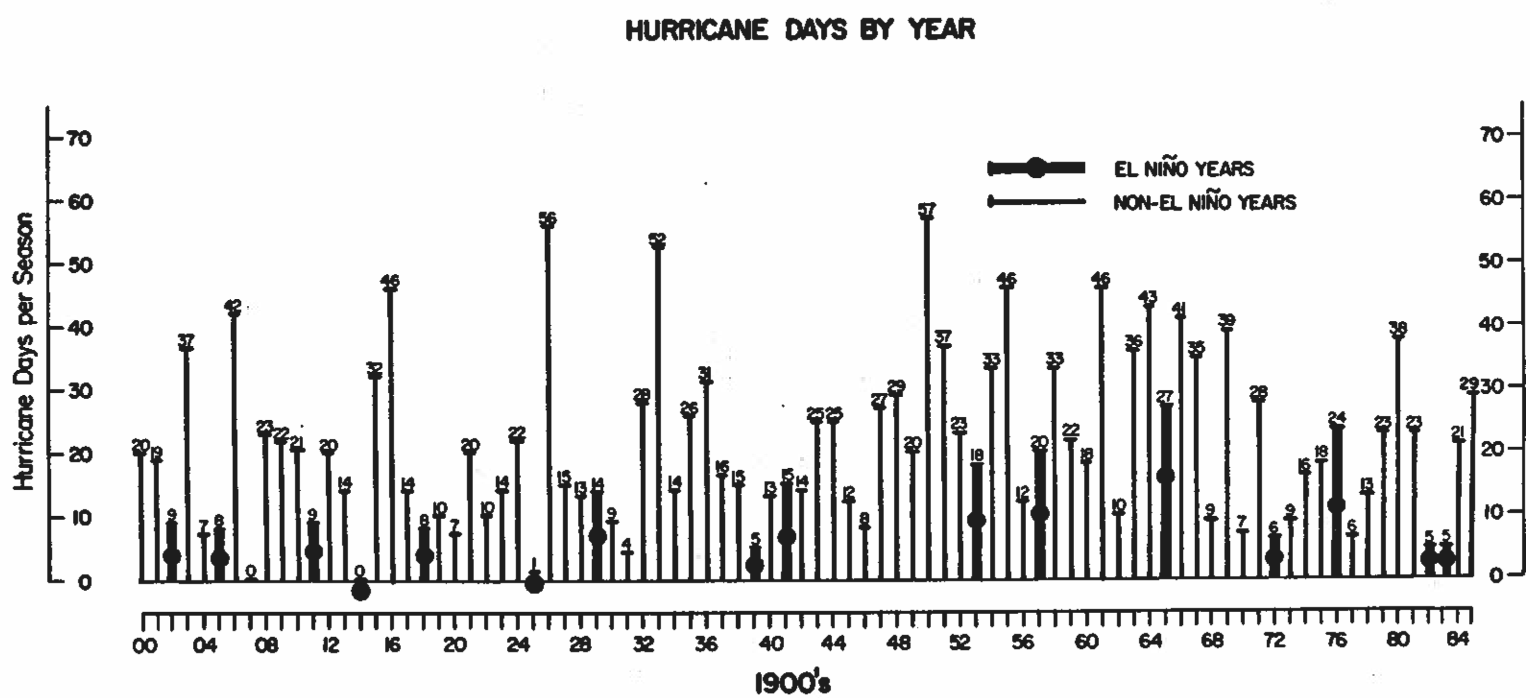

Fig. 1. Number of hurricane days (figure at top of lines) in El Nino/ non-El Nino years from 1900-1985.

This El Nino-Atlantic hurricane activity association is related to the anomalously strong westerly upper tropospheric (12 km height or 40,000 ft) wind patterns which become established over the Caribbean Sea and equatorial Atlantic Ocean during El Nino years. Such westerly wind patterns are known to inhibit hurricane activity.

Just a few months ago indications were that there was a strong possibility of an El Nino event for 1986. The US Climate Analysis Center (NOAA, Washington, DC) issued an El Nino alert on 13 March. A few numerical models and some other El Nino statistical forecast schemes indicated (in February and March) a high probability of an El Nino event for this year. But new data during April and May indicates that this possibility appears to be receding.

As of late May best estimates are that an El Nino event will not occur in 1986 or if one occurs it will be a less consequential weak or very weak event. A positive determination of an El Nino event will be able to be made with the update of this forecast on 1 August just before the start of the most active part of the hurricane season.

b. Quasi-Biennial Oscillation (QBO)

With the beginning of systematic wind measurements in the tropical stratosphere in the early 1950's, an unusual periodic reversal of equatorward winds at altitudes of 50-10 mb (20-35 km or 69,000-110,000 ft) from year to year was first detected.

These equatorial winds change from westerly to easterly and back again in just over two years or so. This wind reversal has been termed the Quasi-Biennial Oscillation (or QBO) by scientists who study it. This QBO stratospheric wind oscillation encompasses the globe and at individual stratospheric levels is present at all equatorial observing stations - see Fig. 2.

The direction of the stratospheric winds at 30 mb (23 km altitude) has a surprising correspondence with Atlantic hurricane activity. Hurricane activity as measured by the number of hurricane days is, in general, nearly twice as great when these stratospheric winds blow from a westerly direction in comparison to when they blow from an easterly direction. Figure 3 shows the number of hurricane days per year from 1949 through 1985 by east and west wind category. Notice how the west wind seasons (dashed line) usually have a higher number of hurricane days than east wind cases (solid line). Disregarding El Nino years (which due to their strong suppressing effect bias the data set) this ratio of seasonal hurricane days for west wind vs. east wind cases is 34:18. Though not yet understood, this association between stratospheric flow and hurricane activity is significant.

Figure 4 shows the QBO equatorial stratospheric winds up through April of this year and the extrapolated values for the coming hurricane season. Note that in the coming 1986 hurricane season these winds will be from the east and they should be increasing their speed from the east. Because these winds change so slowly and over such a long period it is possible to anticipate their direction for several months into the future.

Note also in this figure that 1987 will likely have QBO winds from the west.

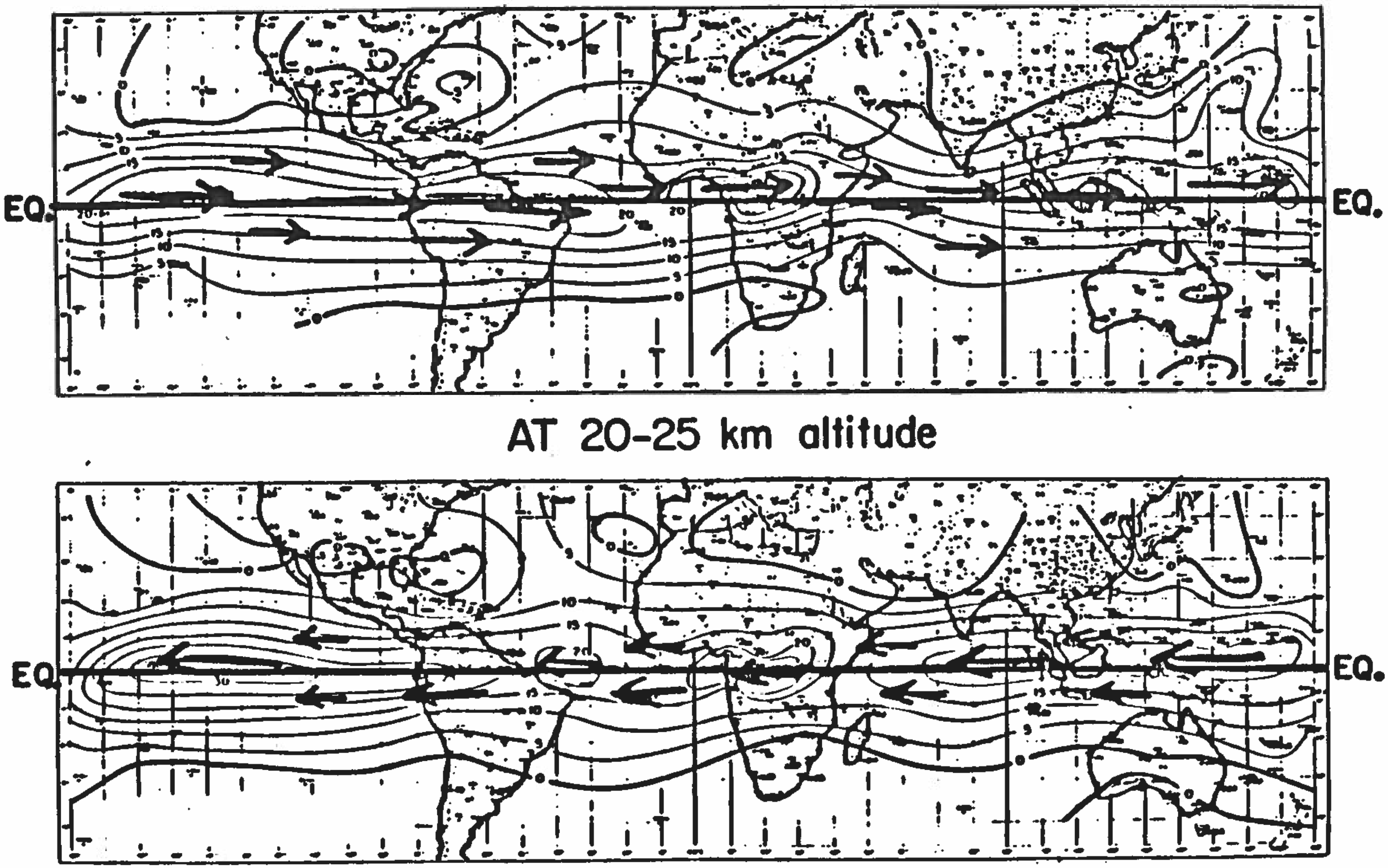

Fig. 2. Illustration of typical zonal wind conditions in the 20 to 25 km altitude layer in the tropics when QBO winds are from the west (top diagram) vs. those conditions when they blow from the east (bottom diagram).

HURRICANE DAYS PER YEAR

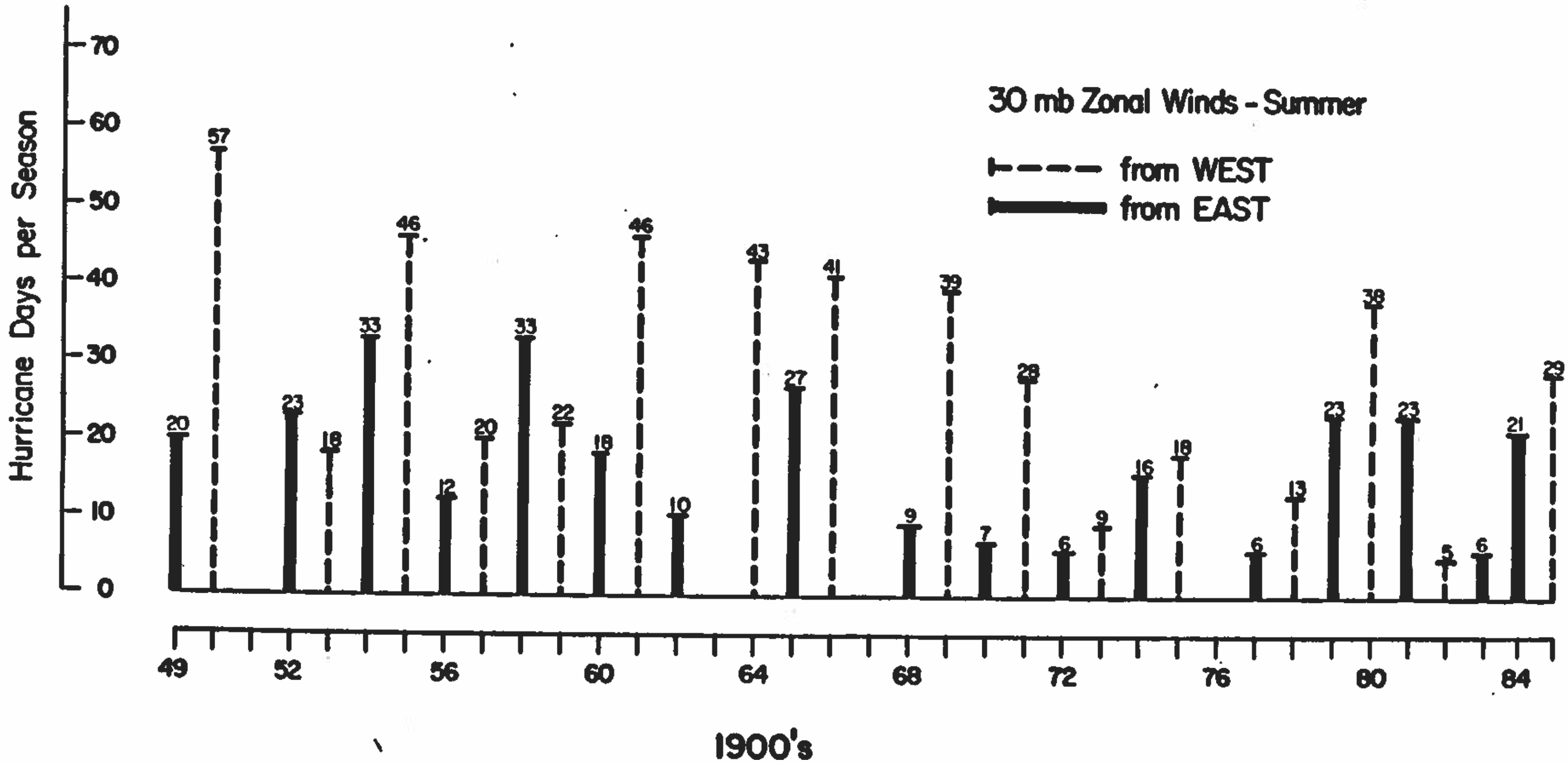

Fig. 3. Relationship between 30 mb stratospheric wind direction and seasonal number of hurricane days from 1949-1985. Years with no observation are those in which the 30 mb zonal wind is changing direction or is very weak.

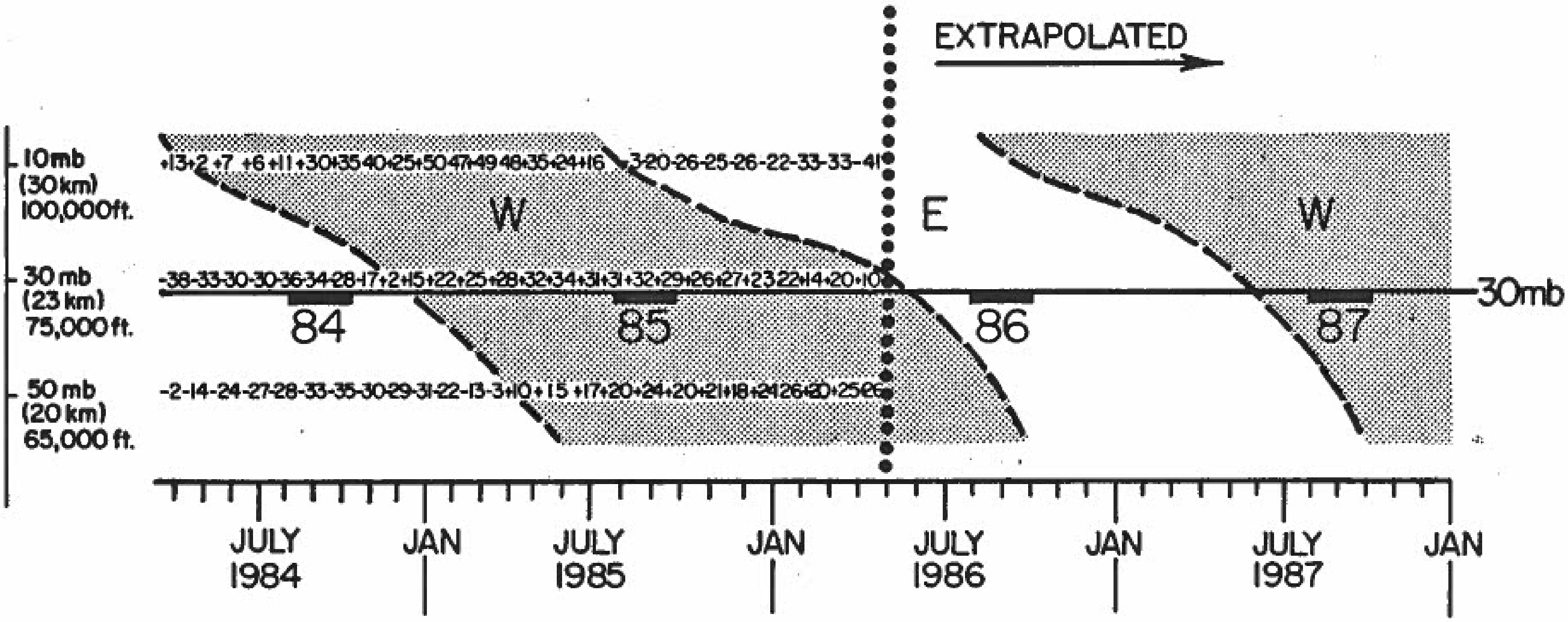

Fig. 4. Vertical cross-section of recent stratosphere monthly average QBO west to east or zonal wind (in knots). This figure represents an average of the Balboa, C.Z. (9^oN) and Ascension (8^oS) rawinsondes. The climatological annual cycle has been removed from each sounding before averaging. Winds from a westerly direction have been shaded. Information beyond April 1986 has been extrapolated. Thick horizontal lines show the active portion of each hurricane season from 1984 to 1987.

c. Caribbean Sea Level Pressure Anomaly (SLPA)

Although the influence of QBO and El Nino events on hurricane frequency are of primary importance, the influences of sringtime and early summer regional Sea Level Pressure Anomaly (SLPA) also exhibits a detectable and significant association with seasonal hurricane activity. SLPA acts to influence seasonal cyclone frequency by about one cyclone for every 0.4 mb of mean pre-season pressure anomaly. More hurricanes occur when pre-season springtime Caribbean pressure anomaly is lower and fewer storms occur when pressure is higher than average. Lower pressure is typically associated with higher sea surface temperature and vice versa. As discussed by Shapiro (1982) one can account for much of the seasonal variation of sea surface temperature through the pressure measurement.

d. 200 mb Zonal Wind Anomaly (ZWA)

A study of hurricane frequency over the last 25 years shows that Atlantic hurricane activity in non-El Nino years is also associated with late spring and early summer upper tropospheric west to east zonal wind velocities at the low latitude Caribbean Sea stations of Balboa, C.Z. (9°N), San Andres (12.5°N), Curacao (12°N), Trinidad (10.5°N) and Barbados (13°N). Stronger than average 200 mb (12 km or 40,000 ft level) winds from the west are associated with fewer hurricanes. By contrast, hurricane activity is more prevalent when early summer 200 mb winds at these stations are weaker than average from the west or stronger than average from the east. It is only the June-July winds which are related to cyclone activity. The April-May winds are not. These winds are not used for the 1 June forecast but assist with the 1 August updated forecast.

e. Internal Correlation of EN, QBO, and SLPA Predictors

To try to better delineate the relationships between these combinations of predictors and seasonal hurricane activity a multiple linear regression analysis was made. It was found that a very low internal correlation exists between each of these predictors. This is very fortunate and is the basis of the forecast scheme to follow. These low internal correlations of predictors allow for a significant forecast improvement when all these predictors are used in combination.

f. The Rationale for Developing an Atlantic Seasonal Hurricane Activity Forecast

A forecast scheme using this QBO, EN, SLPA and ZWA information is based on the premise that:

1) the sign (east or west) of the QBO wind direction changes on such a long period (~ 12-15 months) and in such a uniform manner, that this wind direction can be extrapolated for 3 to 6 months into the future.

2) the oceanography-meteorological community is able to detect the presence and approximate intensity of an El Nino event by 1 June or 1 August at the latest.

3) information on the Caribbean Basin-Gulf of Mexico sea level pressure and 200 mb zonal winds for the four pre-hurricane months of April through July are readily available.

Figure 5 shows the average distribution of hurricane and tropical storm activity by calendar date for a 95 year period. Note that although the official start of the hurricane season is 1 June, the active part of the hurricane season does not begin in earnest until after the 1st of August.

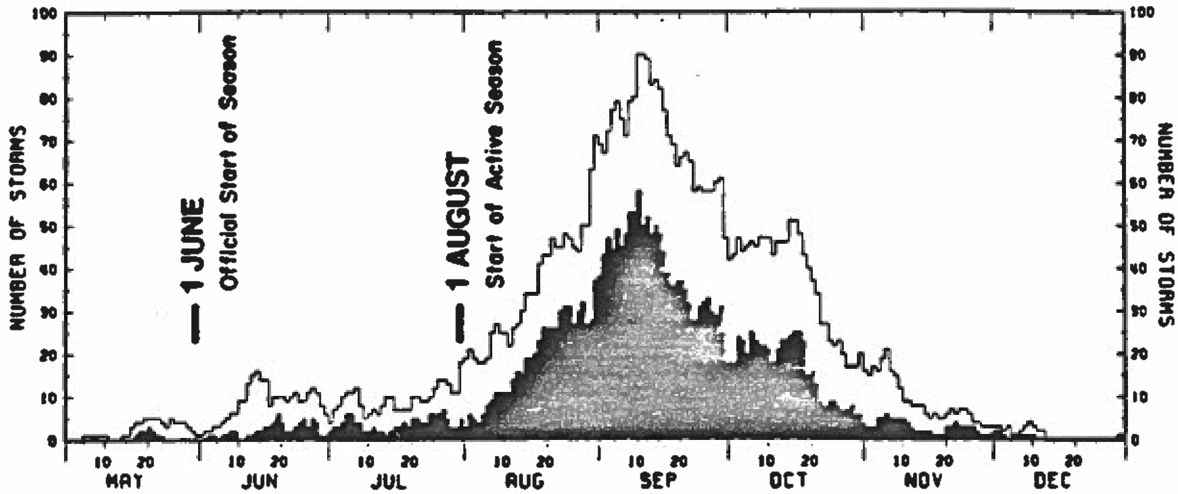

Fig. 5. Number of tropical storms and hurricanes (open curve) and hurricanes (solid curve) observed on each day, May 1, 1886 through December 31, 1980 (from Neumann, _et al_., 1981).

3. Seasonal Hurricane Activity Forecast Methodology

Seasonal hurricane activity forecast equations have been developed from 33 years of dependent data as discussed in the author's previous paper (Gray, 1984b). Recent research has led to some small modification of these formulas. The following equations show how the prediction of the number of hurricanes per year, the number of hurricanes and tropical storms per year, and the number of hurricane days per year are made from QBO, EN, SLPA and ZWA information.

a. Number of Hurricanes

Equation (1) gives a simple formula to predict the seasonal number of hurricanes:

$$\begin{pmatrix}\text{Predicted No.}\\ \text{of Hurricanes}\\ \text{per season}\end{pmatrix} = 6 + (QBO_1 + QBO_2) + EN + SLPA + ZWA \qquad (1)$$

where

QBO_1 = 30 mb equatorial wind direction correction factor – if westerly add one, if easterly subtract one. Set to zero if zonal wind direction during the season is in a change over phase from east to west or west to east.

QBO_2 = correction factor for change in 30 mb equatorial zonal winds (u) during the hurricane season – if uniformally increasing westerly (positive $\partial u/\partial t$) then add one, if uniformally decreasing westerly (negative $\partial u/\partial t$) then subtract one. Set to zero if there is a change of sign of $\partial u/\partial t$ during the season.

EN = El Nino influence. If present subtract two for a moderate El Nino event, four for a strong El Nino event. Add one in non-El Nino years if QBO winds are from the west otherwise set to zero.

SLPA = average SLPA for April-May, from the Caribbean Gulf of Mexico stations. Add one or two if SLPA is < -0.4 mb or < -0.8 mb respectively. Subtract one or two if SLPA is 0.4–0.8 mb or > 0.8 mb respectively. Make no correction for SLPA between −0.4 and 0.4 mb.

ZWA = Zonal Wind Anomaly at 200 mb (12 km) for five low latitude upper air Caribbean stations. Valid for June and July wind data only in non-El Nino years. Used only to update the 1 August forecast. Not used for the 1 June forecast. Forecast an additional hurricane if the mean June-July zonal wind anomaly for these 5 stations is less than −1 m/s. Decrease the hurricane forecast by one if June-July zonal wind anomaly is greater than +1. Make zero if anomaly is $\leq + 1$ m/s.

b. Number of Hurricanes and Tropical Storms

Equation (2), similar to Eq. 1 gives the formula for the prediction of the number of hurricanes and tropical storms:

$$\begin{pmatrix}\text{Predicted No. of} \\ \text{Hurricanes and} \\ \text{Tropical Storms} \\ \text{per season}\end{pmatrix} = 10 + QBO + EN + SLPA + ZWA \qquad (2)$$

where

QBO = 30 mb equatorial wind direction correction factor - if westerly add 1.5, if easterly subtract 1.5. In El Nino years add 2 for west winds and subtract 2 for east winds. Set to zero if zonal wind direction is in a change over phase from east to west or west to east during the season. Make no correction for the change in QBO wind speed during the season.

EN = El Nino influence. If present subtract two for a moderate El Nino event, four for a strong El Nino event, otherwise add 0.7. If some indication of a weak or very weak El Nino event is present then subtract 0.5.

SLPA = Same as for hurricane forecast.

ZWA = Same as for hurricane forecast.

c. Number of Hurricane Days

Equation (3) gives a prediction of the number of hurricane days per season,

$$\begin{pmatrix}\text{Predicted No. of} \\ \text{Hurricane Days} \\ \text{per season}\end{pmatrix} = 25 + 5\ [(QBO_1 + QBO_2)+EN+SLPA+ZWA)] \qquad (3)$$

where the meaning of the symbols are similar to Eq. 1 but each unit of correction factor will be multiplied by 5 instead of 1 as with the two previous determinations, thus

QBO_1 = QBO correction factor due to 30 mb wind direction - if westerly add one, if easterly subtract one. Set to zero if wind direction is in a change over phase from east to west or west to east during the season.

QBO_2 = QBO correction factor due to uniform change in 30 mb zonal wind (u) speed during the hurricane season - if increasing westerly (positive $\partial u/\partial t$) then add one, if decreasing westerly (negative $\partial u/\partial t$) then subtract one. Set to zero if there is a change of sign of $\partial u/\partial t$ during the season.

EN = If El Nino year then subtract two for moderate El Nino or four for a strong El Nino. Add one in all non-El Nino years.

SLPA = Same as for hurricane forecast.

ZWA = Zonal Wind Anomaly at 200 mb (12 km) for five low latitude upper air Caribbean stations. Valid for June and July wind data only in non-El Nino years. Used only to update the 1 August forecast. Not used for the 1 June forecast. Value +1 if mean June-July zonal wind anomaly for these 5 stations is less than -1 m/s. Value -1 if the same 5 station anomaly is greater than 1 m/s. Make zero if anomaly is $\leq$ + 1 m/s.

4. Seasonal Forecast for 1986

a. QBO

Stratospheric winds are forecast to be from the east and to be increasing from the east during the 1986 hurricane season. This means that (other factors remaining normal) that 1986 should have less hurricanes than average.

b. El Nino

Meteorologists who study the El Nino believe at this time (late May) that 1986 will not experience a significant El Nino event.

c. Sea Level Pressure Anomaly (SLPA)

Table 1 gives information on 1 April-27 May, 1986 mean Caribbean-Gulf of Mexico SLPA in millibars (mb). Data is derived from six key stations (see Table 1) of this region. The average of these stations is negative (-0.40 mb) but not negative enough (<0.4 mb) that a forecast correction for pressure will be made. The low pressure anomaly readings from San Juan and Curacao appear not to be representative of the other 4 key stations or of Trinidad (10.5°N). A pressure correction will thus not be made.

TABLE 1

PRE-1986 HURRICANE SEASON
SEA LEVEL PRESSURE ANOMALY (SLPA) - IN MB
(from data kindly supplied by Arthur Pike, Lexion Avila, and Robert Merrill of NHC)

	1 April-27 May 1986
BROWNSVILLE	-0.2
MERIDA	-0.1
MIAMI	+0.1
SAN JUAN	-1.3*
CURACAO	-0.9*
BARBADOS	0.0
MEAN	-0.40
TRINIDAD	-0.2

* Appear unrepresentatively low in comparison with 5 other station readings.

d. Estimation of Correction Terms for Equations (1) to (3) for the Coming 1986 Tropical Cyclone Season

1) (QBO) - stratospheric equatorial winds will be from the east. Correction is -1.

2) $(QBO)_2$ - 30 mb stratospheric winds should be increasing with time from the east during the 1986 hurricane season. Correction is thus -1.

3) EN - no moderate or strong El Nino event is expected this year. With QBO winds from the east the EN correction is 0 for the number of hurricanes, -0.5 for the number of hurricanes and tropical storms, and 0 for the number of hurricane days.

4) SLPA - mean values not greater than ±0.4 mb. No correction is made.

5) ZWA - value not applicable for 1 June forecast. Information from June-July data will be applied for the updated 1 August forecast.

5. Seasonal Prediction for 1986

Table 2 gives the author's numerical estimates of each term of the three prediction equations (1-3) for the 1986 season. Number of hurricanes, number of hurricanes and tropical storms, and number of hurricane days are forecast to be 4 (2 below average), 8 (2 below average), and 15 (10 below average) respectively. The 1986 hurricane season is thus predicted to be a season of below average hurricane activity.

TABLE 2

1986 PREDICTED SEASONAL HURRICANE ACTIVITY

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

$$= 6 + (-1) + (-1) + (0) + (0) + (0) = 4$$, <u>2 Below Average</u>

$$\begin{pmatrix}\text{PREDICTED NO. OF}\\ \text{HURRICANES AND}\\ \text{TROPICAL STORMS}\\ \text{PER SEASON}\end{pmatrix} = 10 + QBO + EN + SLPA + ZWA$$

$$= 10 + (-1.5) + (-0.7) + (0) + (0) = 8$$, <u>2 Below Average</u>

$$\begin{pmatrix}\text{PREDICTED NO. OF}\\ \text{HURRICANE DAYS}\\ \text{PER SEASON}\end{pmatrix} = 25 + 5\ [(QBO_1 + QBO_2) + EN + SLPA + ZWA]$$

$$= 25 + (-5) + (-5) + (0) + (0) + (0) = 15$$, <u>10 Below Average</u>

If 1986 follows the average ratio of name storm days to hurricane days then one should expect about 35 named storm days. An update to this forecast will be made on 1 August.

6. Cautionary Note

It is important that the reader realize that the author's forecast scheme, although showing quite promising statistical skill in the typically meteorological sense, can only predict about 50% of the total variability in Atlantic Seasonal hurricane activity. This forecast scheme will likely fail in some years when the other unknown factors (besides the QBO, EN, SLPA and ZWA) which cause storm variability are more dominant, or, if the QBO or EN conditions should be misforecast. It is impossible to determine beforehand in which years the author's forecast scheme will work best or worst.

This forecast scheme cannot be judged in its verification in any one or a few seasons. The author is very confident that this forecast scheme has definite skill over a longer time period of 10-12 seasons. It should only be evaluated on this longer time scale.

This forecast scheme also does not specifically predict which portion of the hurricane season will be most active or where within the Atlantic basin the storms will strike. For instance, 1981 was a moderately active season (7 hurricanes, 12 hurricanes and tropical cyclones) but only two of the weaker systems affected the US). By contrast 1985 had a similar amount of overall hurricane activity as 1981 did, but 1985 had 6 hurricanes and 8 named storms to effect the US coastline. 1983 was one of the most inactive seasons on record but Hurricane Alicia caused over a billion dollars of damage to the Houston area. If there is only one Atlantic hurricane this year, but it happens to go over your house or business, then for you, 1986 will seem to be a very active hurricane season indeed!

7. Verification of Author's 1984 and 1985 Seasonal Forecasts

Tables 3 and 4 give verification information on the author's 1984 and 1985 seasonal predictions. In 1984 hurricane activity was over predicted but the total of hurricane and tropical storm activity underpredicted. The 1985 forecast was closely verified.

TABLE 3

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 4

Prediction vs. Observed Tropical Cyclone Activity for 1985

	Prediction as of 28 May	Updated Prediction of 27 July	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

8. Acknowledgements

The author is grateful to the following meteorologists for the information furnished to 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), and James O'Brien of Florida State University. 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 springtime sea level pressure and upper air wind information. He has also benefited from discussions with Roger Edson of Colorado State University.

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