UPDATED (as of 28 July 1987)

FORECAST OF ATLANTIC SEASONAL HURRICANE

ACTIVITY FOR 1987

By

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This updated forecast uses background material contained in the Colo. State Univ. Dept. of Atmospheric Science forecast report which was issued by the author on 28 May 1987. This report utilizes additional new June and July 1987 meteorological information and is issued to coincide with the start of the more active part of the hurricane season after 1 August.

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DEFINITIONS

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.

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. 1 mb = .0295 inches of mercury.

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 (16 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.

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 updated forecast of the amount of seasonal hurricane and tropical storm activity which can be expected to occur in the Atlantic basin, Caribbean, and Gulf of Mexico region in 1987. This updated forecast is issued just before the start of the most active part of the hurricane season. The author's previous forecast for 1987 was issued on 27 May 1987 (Gray, 1987) and called for 5 hurricanes (1 below the average of the 1947-86 seasons), 8 named tropical storms (2 below average), and 20 hurricane days (5 below average). This updated forecast is based on the author's earlier forecast and more recent June and July meteorological data. This revised forecast is considered to be more reliable than the forecast issued at the end of May.

Statistical information received by the author as of 28 July 1987 indicates that the hurricane and tropical storm activity for 1987 can be expected to be a somewhat more suppressed than that anticipated in late May. This revised forecast indicates a probability for 4 hurricanes (2 below average), 7 hurricanes and tropical storms (3 below average), and 15 hurricane days (10 below average).

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 the last few years 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, 1987; Gray et al., 1987) 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 rest of the 1987 season.

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

2. Atmospheric Precursor Factors Which are Associated With Variations in Atlantic Seasonal Hurricane Activity

Four atmospheric precursor factors have been found which are associated with later variations in Atlantic seasonal hurricane activity. These precursor factors are measured before the active portion of the hurricane season starts and are used as seasonal predictors. These 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 the 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 alterations 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 71 non El Nino years of this century. Figure 1 is a plot of the seasonal number of hurricane days for the years of 1900-1986 with strong and moderate El Nino years shown by the thick lines with a circle. It can be seen that in most years with strong or moderate El Ninos, hurricane activity as measured by the number of hurricane days is typically much less than in non-El Nino years. Of the 16 years of this century with the lowest number of hurricane days, 9 were strong or moderate El Nino years. Of the 22 years of this century with the largest number of hurricane days, not one was an El Nino year.

HURRICANE DAYS BY YEAR

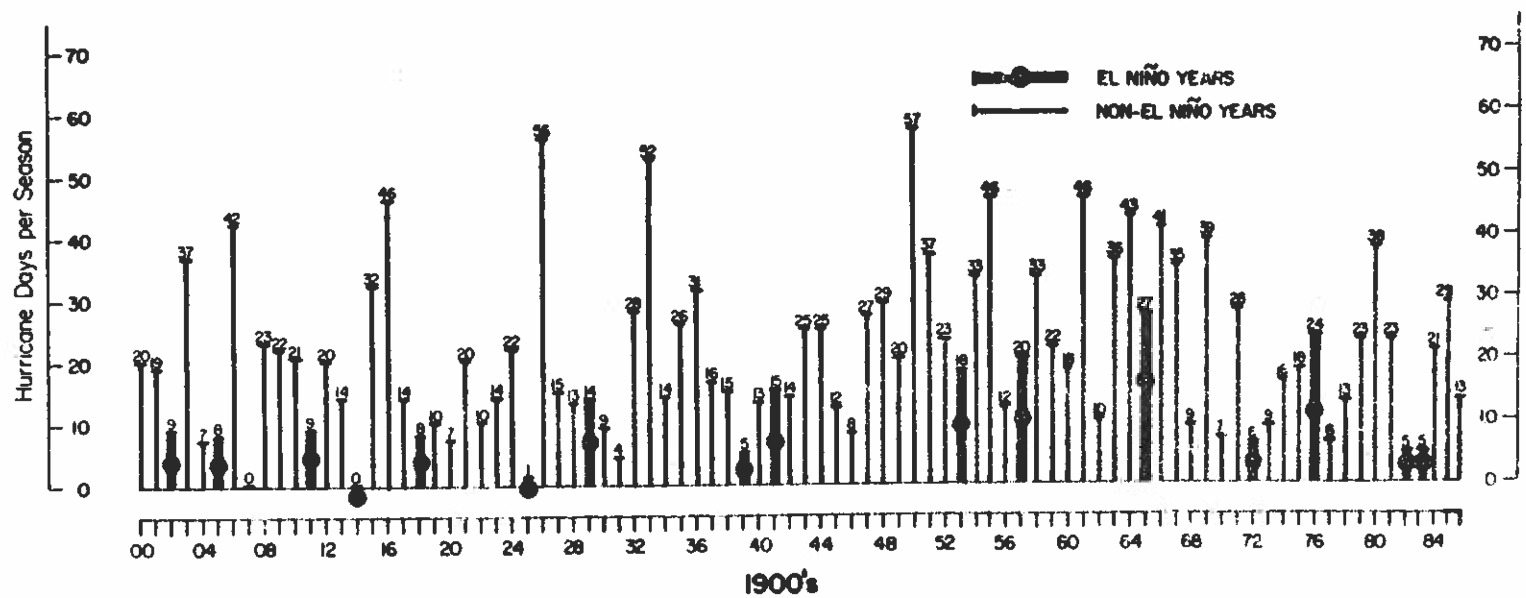

Fig. 1. Number of hurricane days (figure at top of lines) in El Nino/ non-El Nino years from 1900-1986.

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 typically become established over the Caribbean Sea and equatorial Atlantic Ocean during El Nino years. Such westerly wind patterns are known to inhibit hurricane activity.

b. Quasi-Biennial Oscillation (QBO)

With the beginning of systematic wind measurements in the tropical stratosphere in the early 1950's, an unusually long periodic reversal of equatorward winds at altitudes of 70-10 mb (18-35 km or 60,000-110,000 ft) was first detected.

These equatorial winds change from westerly to easterly and back again to westerly with a period of about two and one-half years. This wind reversal has been termed the Quasi-Biennial Oscillation (or QBO) by scientists who first studied 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 levels of 70 to 30 mb 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 relative westerly direction in comparison to when they blow from a relative easterly direction. Figure 3 shows the number of hurricane days per year from 1949 through 1986 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

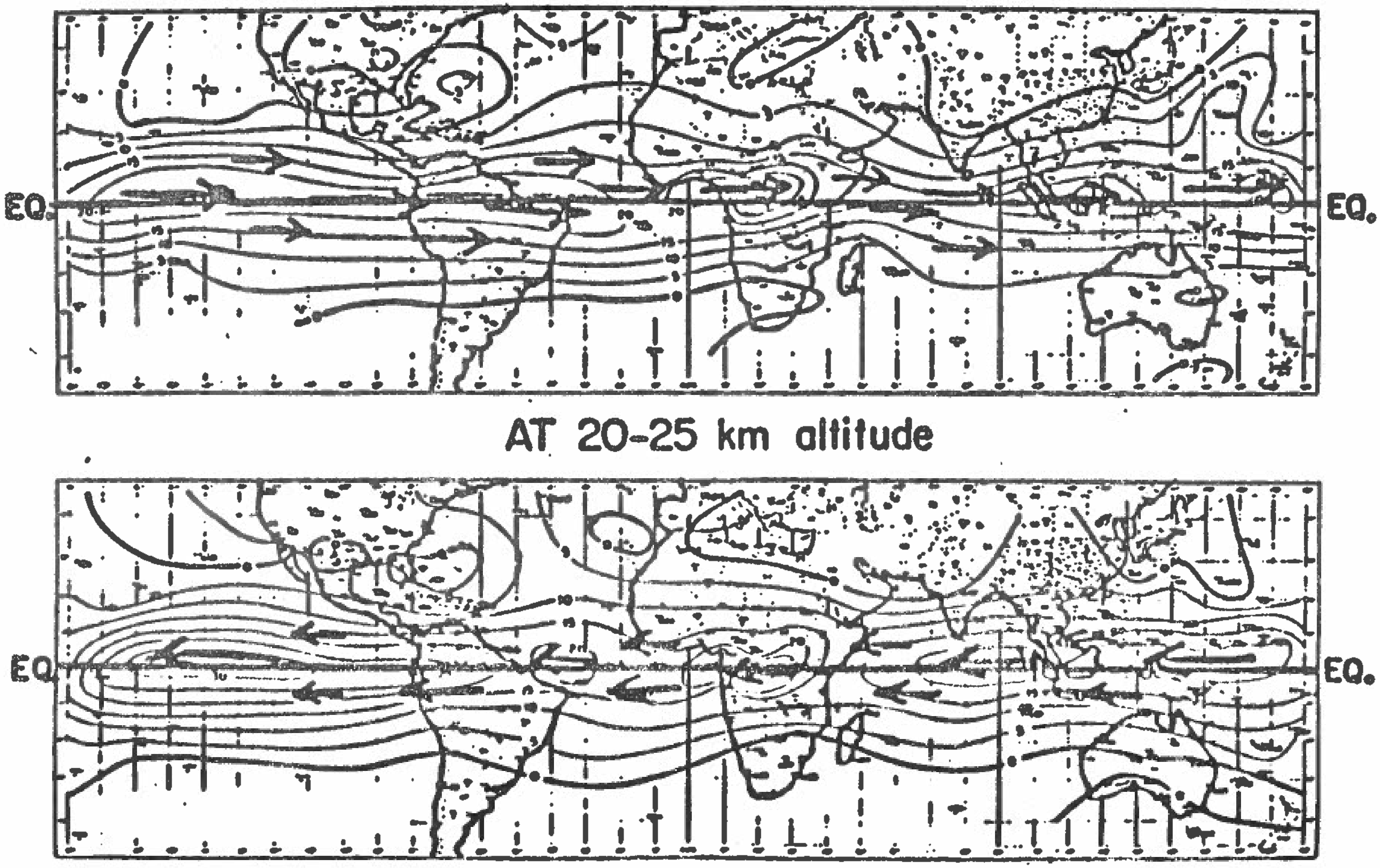

Fig. 2. Illustration of typical zonal wind conditions in the 20 to 25 km altitude layer in the tropics when QBO winds are from the west (top diagram) vs. those conditions when they blow from the east (bottom diagram). The climatological annual wind cycle has been removed from all wind values. (Adapted from Newell et al., 1974).

bias the data set) the ratio of seasonal hurricane days for west wind vs. east wind cases is 33.0 to 17.8. Because these winds change so slowly over such a long period, it is possible to anticipate their direction for several months into the future.

Recent research by the author is showing that this association is related to a combination of the lower 60 to 80 mb (~ 18 to 20 km altitude) stratospheric zonal wind speeds which occur in QBO west as opposed to QBO east wind situations and to the vertical shear of stratospheric zonal wind between the lower (~70 mb) to middle stratosphere levels (~30 mb). New hurricane analysis shows that the hurricane's inner core circulation often extends well into the lower stratosphere. When lower stratospheric zonal winds at levels of 80 to 60 mb are weaker than normal from the east (as occurs in QBO relative west wind situations) then seasonal Atlantic tropical disturbances and hurricane activity is typically more active. Conversely, stronger than normal zonal stratospheric winds from the east (as occurs in QBO relative east wind situations) is typically associated with reduced Atlantic seasonal hurricane activity.

There is less lower tropospheric wind (or ventilation) across Atlantic tropical disturbance in QBO relative west wind situations. Weaker lower stratospheric winds (and thus weaker lower stratospheric ventilation and weaker stratospheric vertical wind shear) is more conducive to hurricane formation and more intense inner-core hurricane wind strength.

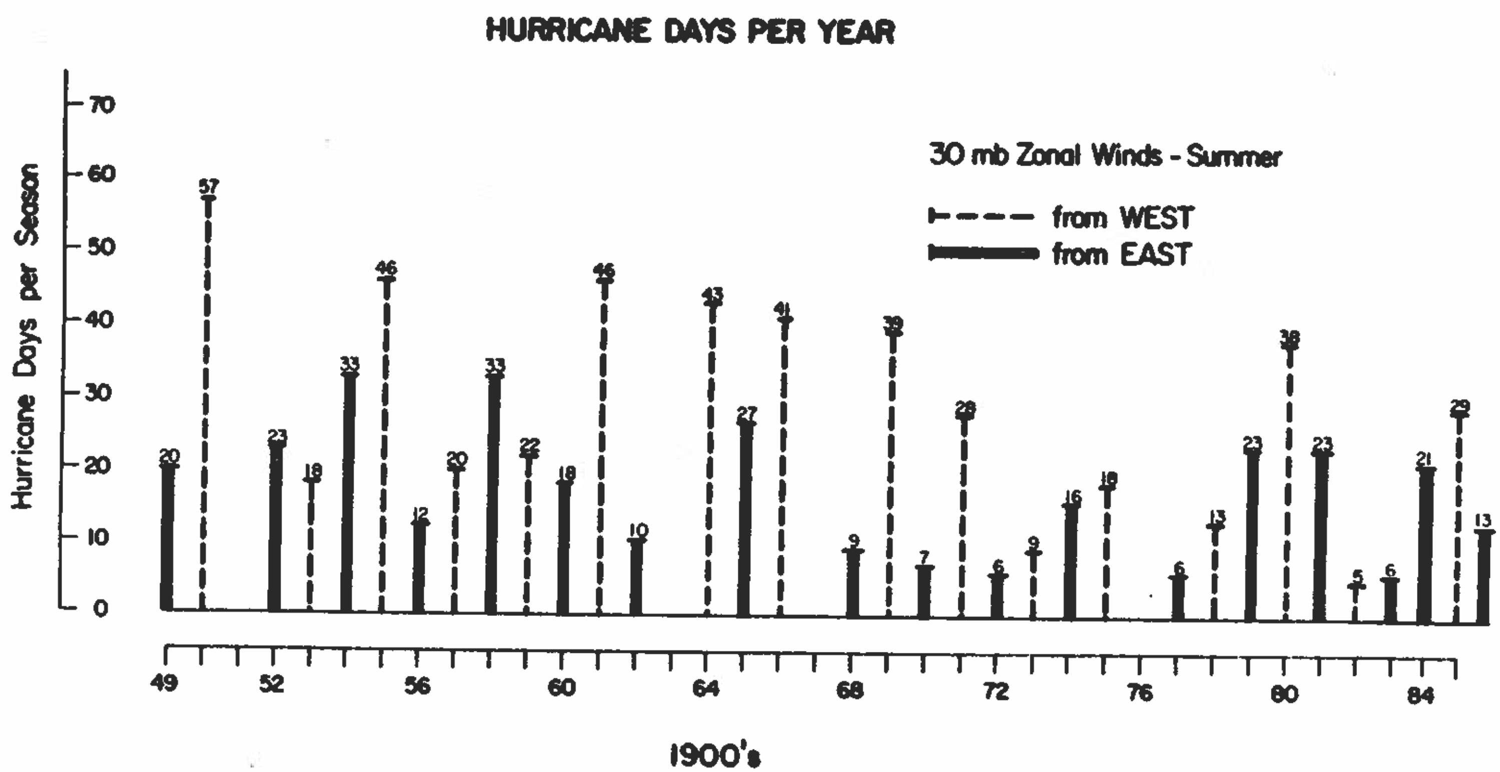

Fig. 3. Relationship between 30 mb stratospheric wind direction and seasonal number of hurricane days from 1949-1986. Years with no observation are those in which the 30 mb zonal wind is changing direction or is very weak.

c. Caribbean Sea Level Pressure Anomaly (SLPA)

Although the influence of the QBO and El Nino events on hurricane frequency are of primary importance, the influences of springtime and early summer regional Sea Level Pressure Anomaly (SLPA) also exhibits a well 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 sea-level pressure anomaly is lower than average and fewer storms occur when sea-level pressure is higher than average.

d. 200 mb Zonal Wind Anomaly (ZWA)

A study of hurricane frequency over the last 35 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^{o}N), San Andres (12.5^{o}N), Curacao (12^{o}N), Trinidad (10.5^{o}N) and Barbados (13^{o}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. April-May winds are not related. Due to a suspected 40-60 day oscillation in the 200 mb wind reports, it is desirable (as with the surface pressure data) to average zonal wind data over at least a two month period and not make judgements based on individual monthly information.

In El Nino years, 200 mb ZWA at these lower Caribbean stations

stations are almost always very strongly positive. A forecast alteration of hurricane activity due to positive or negative ZWA is thus redundant with the El Nino signal. In those seasons when an El Nino is present one should not use the 200 mb ZWA as a forecast parameter in combination with the El Nino.

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 the El Nino, the QBO, and the combination of SLPA-ZWA. This is 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 (~ 14-17 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 anomaly (SLPA) and 200 mb zonal winds (ZWA) for the four pre-hurricane months of April through July are readily available.

Figure 4 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.

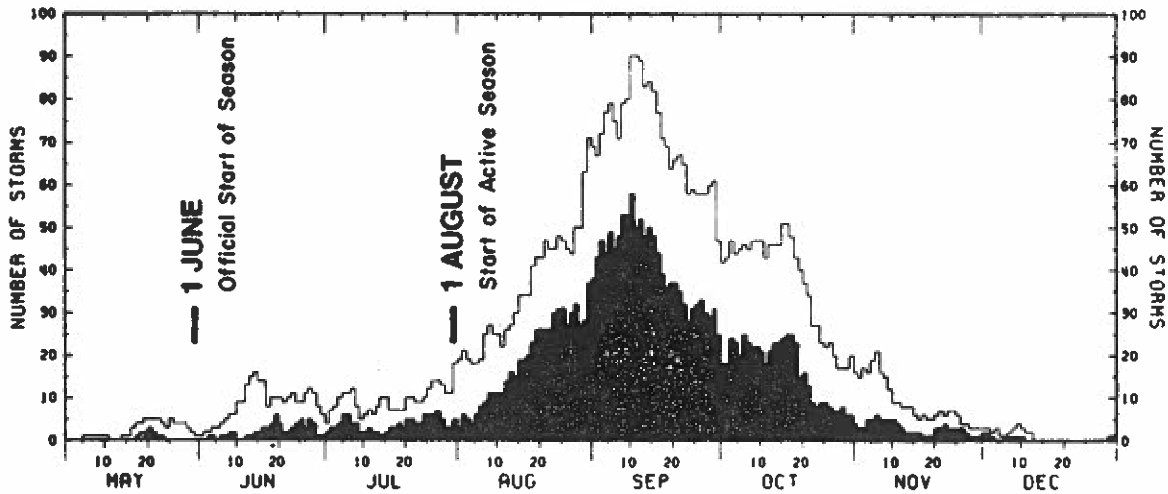

Fig. 4. Number of tropical storms and hurricanes (open curve) and hurricanes (solid curve) observed on each day, May 1, 1886 through December 31, 1980 (from Neumann, <u>et al</u>., 1981).

Seasonal hurricane activity forecast equations have been developed from 37 years of dependent data as discussed in the author and his colleagues' previous papers (Gray, 1984b; Gray <u>et al</u>., 1987). Recent research has led to some small modification of these formulas. These cited papers have shown the prediction of the number of hurricanes per year, the number of hurricanes and tropical storms per season, and the number of hurricane days per season can be made from a combination of the previously discussed QBO, EN, SLPA and ZWA factors.

3. Assessment of Conditions as of Late July

The following discussion gives an assessment of the four predictive terms (QBO, EN, SLPA, and ZWA) of the author's seasonal hurricane forecast scheme for 1987. This assessment is made from meteorological information as available to the author up to 27 July 1987.

a. Likely Quasi-Biennial Oscillation (QBO) Influence on 1987 Seasonal Hurriicane Activity

New second half of July low latitude stratospheric zonal wind information from the Caribbean Basin stations of (Barbados (13°N), Trinidad (10.5°N), Curacoa (12°N), San Andres (12.5°N), Cayenne (5°N), and Bogata (4.5°N)) has caused the author to alter his original assessment made in late May that the 1987 hurricane season will be one of neutral QBO hurricane correction. Although it appears that the author's late May prediction of 30 mb (or 23 km or 75,000 ft altitude) QBO zonal winds (with the annual cycle removed) being in a transitional phase from easterly to westerly wind during the middle of the 1987 season will be valid, new late July data indicates that 50 mb (~ 20 km) and 70 mb (~ 18 km) stratospheric winds will continue to be stronger than normal from the east throughout the entire 1987 hurricane season. Note in Fig. 5 how 30 mb relative QBO winds are extrapolated to be in an east to west transitional phase during the height of the 1987 hurricane season but that 50 mb relative winds will remain out of the east. QBO relative winds at 70 mb should also be from the east.

These stronger than normal easterly winds at 50 and 70 mb levels are an inhibiting influence on hurricane activity. One should thus expect a modest reduction of hurricane activity from this lower stratospheric QBO influence.

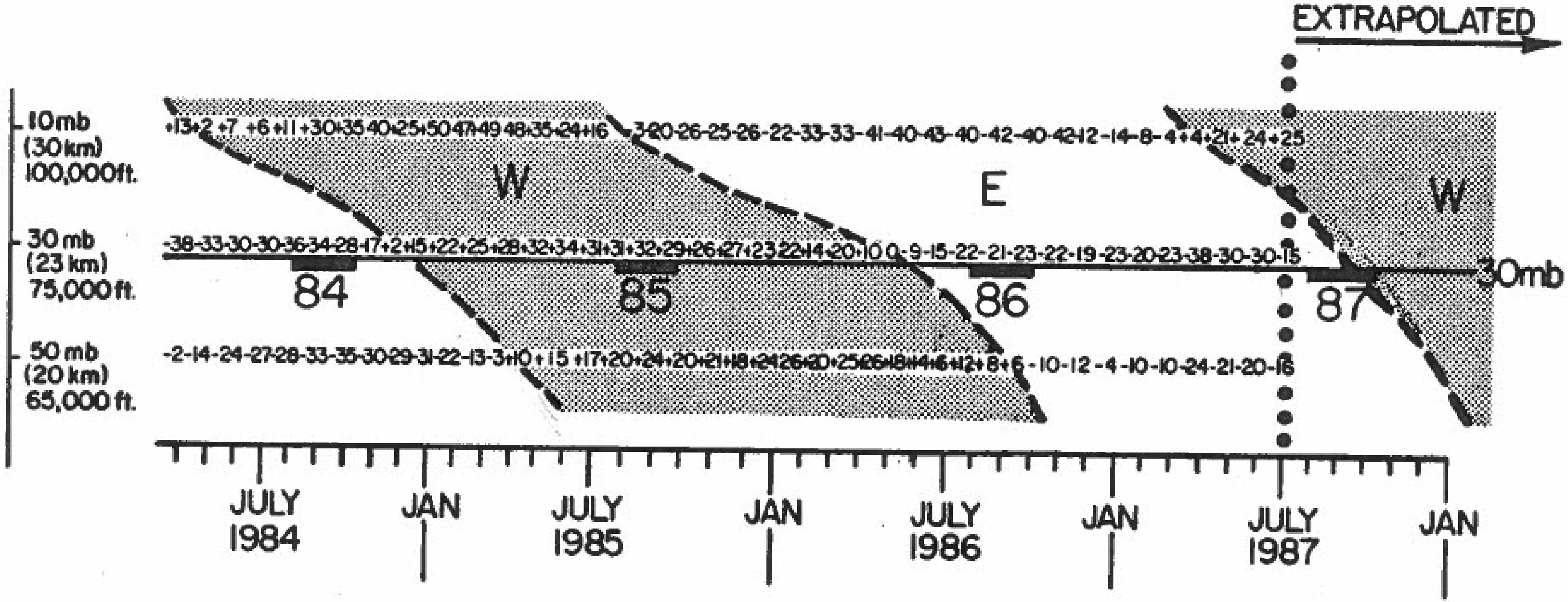

Fig. 5. Vertical cross-section of recent stratosphere monthly average QBO west to east or zonal wind (in knots). This figure represents an average of the Balboa, C.Z. (9°N) (in June); Curacao (12°N) - Trinidad (10.5°N) - in July) and the Ascension (8°S) rawinsondes. Data is not available in July from Balboa. The climatological annual cycle has been removed from each sounding before averaging. Winds from a westerly direction have been shaded. Information beyond July 1987 has been extrapolated. Thick horizontal lines show the active portion of each hurricane season from 1984 to 1987.

Recent research by the author is showing that in addition to the association of 30 mb QBO winds with seasonal Atlantic hurricane activity that there is also a strong association of hurricane activity with the lower stratospheric 5-13^{o}N latitude Caribbean Basin August-September 70 mb and 50 mb zonal winds. This downward alteration of the author's hurricane activity forecast from the late May value is due to this new late July stratospheric wind information and also from new research insights derived in the last couple of months.

Recent research is showing that seasonal hurricane activity has a surprisingly high negative correlation with the sum of the lower latitude Caribbean Basin (latitude ~ 8-13^{o}N) September 70 mb plus 50 mb zonal wind minus the vertical shear of zonal wind (without respect to sign) between 50 and 30 mb.

Predicted values of [70 mb + 50 mb − |30 mb − 50 mb shear|] for September 1987 indicate a value of about -75 (in knots). Those seasons in which the September value of $[U_{70mb} + U_{50mb} - |\text{Shear 30 to 50 mb}|]$ is as negative or more negative than this have typically been seasons of below average Atlantic hurricane activity.

Table 1 shows 2nd half of July 70 mb through 10 mb average zonal winds for the stations of Barbados, Trinidad, Curacoa, and San Andres and the prediction of average zonal wind values from these stations for the month of September. Note that 50 mb and 70 mb zonal wind in the low latitude Caribbean Basin in September are forecast to be rather strongly from the east and that moderately high 50 to 30 mb wind shear should be expected.

This information indicates that one should expect a reduction of Atlantic seasonal hurricane activity from average due to this QBO influence by about one hurricane, one named storm, and 5 hurricane days.

TABLE 1

2nd half of July observed and forecast September 1987 stratospheric zonal winds for the average of the four stations of Barbados (13°N); Trinidad (10.5°N); Curacoa (12°N), and San Andres (12.5°N). Zonal wind values are given in actual measured values and as deviations from the long term average from that period. Negative values indicate east winds or with the deviational values relative easterly winds. Positive values westerly winds. Speeds are in knots. Data kindly supplied to the author by Keith Johnson of the NOAA-CAC, Washington, DC.

	OBSERVED		FORECAST	
LEVEL	15-27 July 1987	Deviation from long term July Caribbean Basin Average	Sept. Average	Deviation from long-period Sept. Caribbean Basin Average
10 mb (30 km)	-35	+11	+5	+41
20 mb (26 km)	-24	+17	0	+34
30 mb (23 km)	-42	-5	-13	+7
50 mb (20 km)	-50	-20	-32	-12
70 mb (18 km)	-33	-11	-24	-12

b. Likely El Nino Influences on 1987 Atlantic Seasonal Hurricane Activity

A weak to moderately intense Pacific El Nino event began last autumn and has continued. Figure 6 shows that eastern and central Pacific tropical sea surface temperature (SST) anomalies (°C) for the first 15 days of July 1987 were above normal by 1-2°C over a very broad region. These SST anomalies are expected to persist for a few more months.

The current El Nino event started much later in the year (early autumn, 1986) than the typical El Nino event. It reached a peak this

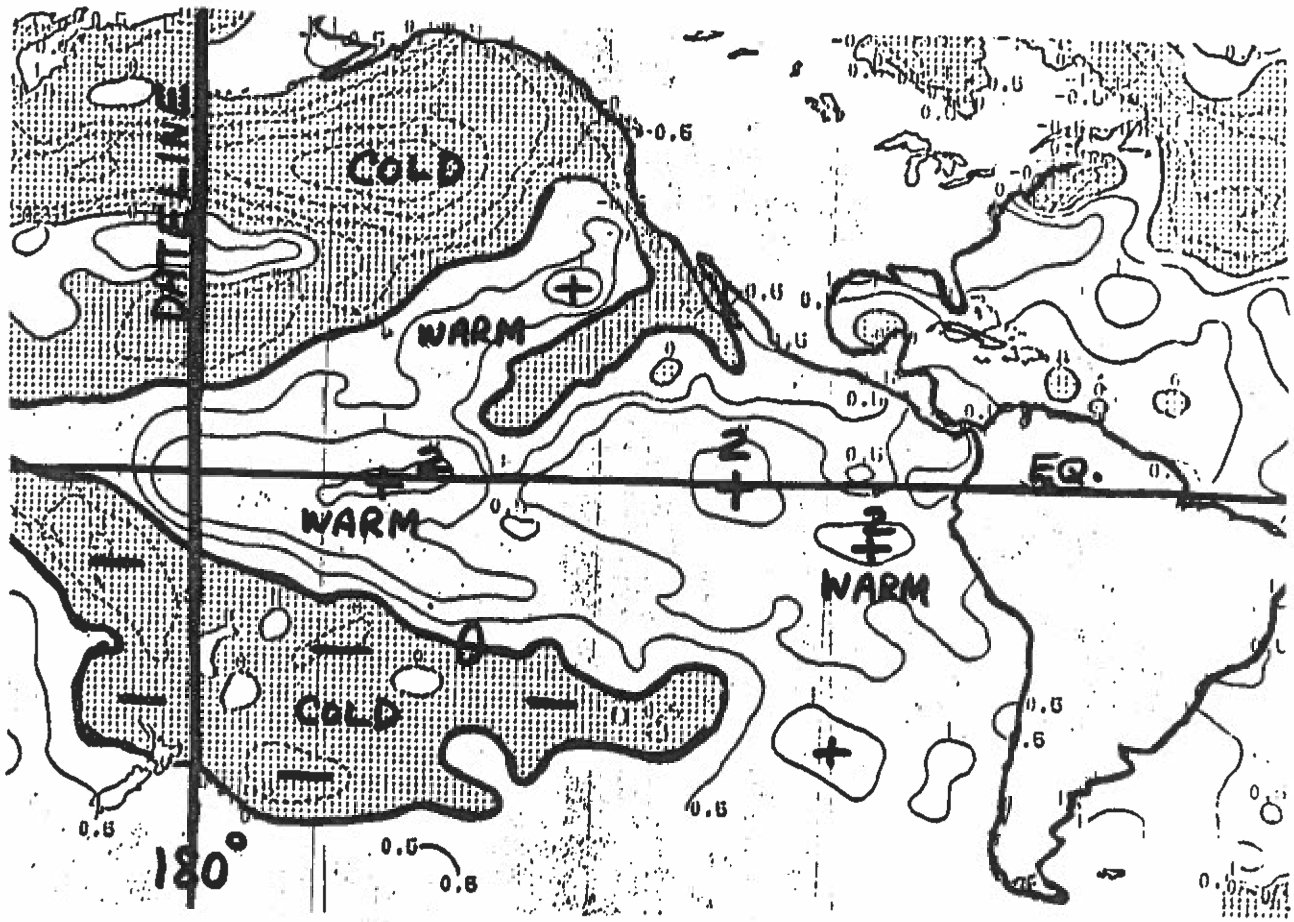

Fig. 6. 1-16 July 1987 Sea Surface Temperature Anomaly (SST) in °C. Dotted areas show cold anomaly (-), unshaded areas positive anomaly (+) - from NOAA blended SST anomaly analyses.

winter (February-March, 1987) and has been slowly but steadily weakening with time. Although the ocean surface temperatures off of Peru have cooled considerably from the values in February and March, sizeable areas of positive SST anomalies remain in the central Pacific. Also the Southern Oscillation Index (SOI) of the sea-level pressure difference between Tahiti and Darwin, Australia has remained very low. The SOI for June was -2.8 mb which is the lowest value of the SOI for this current El Nino event. El Nino and low values of the SOI are typically rather well related to each other.

El Nino specialists are uncertain as to how many more months this present moderate to weak El Nino warming event will last. It now appears likely that this warming event will persist through most of the 1987 hurricane season.

An important related consideration is whether the lower latitude Caribbean Basin is presently experiencing stronger than normal 200 mb (12 km) zonal west winds as typically occurs in El Nino seasons. It is of interest to note that the Caribbean basin is indeed experiencing the expected stronger than normal 200 mb westerly winds (see Table 3 on following pages). June-July 200 mb zonal wind anomalies are quite high - higher in fact than one would expect from the current only weak-to-moderately intense El Nino. These current Caribbean Basin positive 200 mb zonal wind anomalies help substantiate the likely teleconnection influence of the current Pacific El Nino event with the tropical Atlantic circulation patterns and suggest that hurricane activity due to this influence should be expected to be reduced from average conditions.

Consequently, the author is reducing his seasonal forecast of tropical cyclone activity by one hurricane, one named storm, and 5 hurricane days because of this El Nino event. Where this El Nino event observed or expected to be of moderate or strong intensity this forecast downward correction would be for -2 to -4 hurricanes and -10 to -20 hurricane days.

c. Likely Caribbean Basin Sea-Level Pressure Anomaly (SLPA) Influences on 1987 Seasonal Hurricane Activity

Table 2 gives information on the April-May and the 1 June to 27 July 1987 Caribbean-Gulf of Mexico SLPA in mb. SLPA is derived from six key stations in this region. A seventh SLPA for Trinidad (10.5^{o}N), is also shown. Values are averaged over two months to eliminate a suspected 40-60 day oscillation in surface pressure. Such an oscillation reduces the validity of a single month's pressure values. The average of these stations was negative (by -0.2 mb) in April-May but is about zero for the period 1 June to 27 July. June-July values of SLPA correlate better with hurricane activity than do April-May values. The combination of April-May and June-July values are slightly superior to June-July values by themselves. April through July anomaly is near zero. These sea level pressure anomalies by themselves (other factors remaining constant) indicate that there should likely be no appreciable alteration in the 1987 seasonal hurricane activity from considerations of surface pressure. The author has decided to make no SLPA correction.

This near zero surface pressure correction assessment may not, however, be the best evaluation of the situation as regards to the possibility of lower latitude Atlantic hurricane activity. It is

TABLE 2

APRIL-MAY AND JUNE-JULY 1987 AVERAGE CARIBBEAN-GULF OF MEXICO SEA-LEVEL PRESSURE ANOMALY (SLPA) - IN MB (FROM DATA SUPPLIED BY A. PIKE OF NHC)

	APRIL-MAY	1 JUNE-27 JULY
BROWNSVILLE	+2.0	+0.4
MERIDA (MEX.)	+1.1	+0.6
MIAMI	-0.1	+0.7
SAN JUAN	-2.1	-0.6
CURACAO	-1.4	-0.6
BARBADOS	-1.1	-0.5
MEAN	-0.2	0.0
TRINIDAD	-0.4	-0.1

important to note that the SLPA at the four eastern Caribbean stations of San Juan (18^{o}N), Curacoa (12^{o}N), Barbados (13^{o}N) and Trinidad (10.5^{o}N) has been lower than normal for the entire April through 27 July period. And 1-27 July average SLPA from these four stations was -0.9 mb. This is a quite low SLPA and considerably below the SLPA measured for these same stations and same period for last year. Last year's July SLPAs at these 4 low latitude stations averaged +1.2 - a 2.1 mb higher value than this year's measurements. June SLPA at these four stations averaged +0.5 mb.

Other factors remaining the same, these eastern Caribbean Basin negative SLPAs would indicate a higher potential than normal for low latitude hurricane activity. Recent research is substantiating the importance of June-July eastern Caribbean Basin SLPA as an indicator of low latitude hurricane activity.

These negative eastern Caribbean SLPAs are being strongly opposed by the positive 200 mb zonal wind anomalies which are occurring in this region, however. If these positive 200 mb zonal wind anomalies hold during the active portion of the season (as forecast) then these negative SLPAs will likely not have much of an influence on the coming seasons hurricane activity. They should be closely monitored, however.

d. 200 mb Zonal Wind Anomaly (ZWA) in 1987 and Association with the El Nino

As discussed in section 2.d Atlantic seasonal hurricane activity is also related to June and July upper tropospheric 200 mb zonal or west to east wind anomalies at the low latitude Caribbean Basin stations of Balboa, C.Z. (9^{o}N), San Andres (12.5^{o}N), Curacao (12^{o}N), Trinidad (10.5^{o}N) and Barbados (13^{o}N).

Table 3 shows 200 mb zonal or west-to-east wind anomaly for these 5 key low latitude Caribbean Basin upper air stations for the period 1 June to 27 July 1986. Values for Kingston are also shown. Note that positive west wind anomalies are present at all stations. These positive wind anomalies are quite high and rather typical of a prominent or strong El Nino event. If an El Nino event were not present, these wind anomalies would imply a likely reduction of Atlantic hurricane activity for the coming 1987 season. In that a known El Nino event is already in process it is likely that these enhanced 200 mb westerly winds are occurring in response to this event.

A ZWA correction for these stronger than normal 200 mb westerlies and also a correction for the current El Nino event would be redundant. Only one of these two corrections should be made in an El Nino year. In that the author is making a correction for the current El Nino event in progress a correction for these positive ZWA values is thus not applicable (NA) and will not be made. The observation of these winds is, as previously discussed, quite important, however, for substantiating the likely teleconnection influence of the current Pacific El Nino event on the Atlantic upper tropospheric wind patterns.

TABLE 3

200 MB (OR 12 KM HEIGHT) ZONAL WIND ANOMALY (IN KNOTS) FOR 1987 FOR 5 KEY LOW-LATITUDE CARIBBEAN BASIN UPPER AIR STATIONS AND KINGSTON, JAMAICA FOR THE PERIOD OF 1 JUNE THROUGH 27 JULY 1987 AS KINDLY SUPPLIED THE AUTHOR BY ARTHUR PIKE OF NHC, MIAMI.

Balboa, C.Z. (9^{o}N)	+7 (many missing obs.)
San Andres (12.5^{o}N)	+7
Curacao (12^{o}N)	+10
Trinidad (10.5^{o}N)	+10
Barbados (13^{o}N)	+7
Average	+8.2
Kingston (13^{o}N)	+19

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4. Seasonal Prediction for 1987

Table 4 gives the author's updated forecast of each term of his three prediction equations (1-3) for number of hurricanes, number of named storms, and number of hurricane days for the 1987 season. As discussed, since this is an El Nino year, the ZWA term is not used (non-applicable - N/A) in this season's forecast. Equations give correction factors to the average hurricane activity as observed over the last 40 years. Number of hurricanes, number of hurricanes and tropical storms, and number of hurricane days are forecast to be 4, 7, and 15 respectively. This is 2 hurricanes, 3 named storms, and 10 hurricane days below the averages of the last 40 years and 1 hurricane, 1 named storm, and 5 hurricane days less than the author's forecast issued in late May.

The forecast for 1987 is thus for a below average hurricane season based on hurricane statistics of the last 40 years. If 1987 follows the average ratio of name storm days to hurricane days then one should expect about 30 named storm days.

Hurricane activity in 1987 should however be more active than last year which was a very inactive hurricane year. This year should also be more active than the recent hurricane seasons of 1982 and 1983. By the standard of the generally below average hurricane activity of 1970-1986 (Gray, 1987), 1987 is forecast to be a slightly below average hurricane season.

The fact that no named cyclones have occurred in the Atlantic in June and July has no influence on this forecast. June and July hurricane activity is not corrected with August through October hurricane activity.

TABLE 4

1987 UPDATED PREDICTED SEASONAL HURRICANE ACTIVITY

(PREDICTED NO. OF HURRICANES PER SEASON)	=	6 +	QBO*	+	EN	+	SLPA	+	ZWA	
	=		(-1)	+	(-1)	+	(0)	+	N/A	= 4
(PREDICTED NO. OF HURRICANES AND TROPICAL STORMS PER SEASON)	=	9 +	QBO*	+	EN	+	SLPA	+	ZWA	
	=	+	(-1)	+	(-1)	+	(0)	+	N/A	= 7
(PREDICTED NO. OF HURRICANE DAYS PER SEASON)	=	25 + 5	[QBO*	+	EN	+	SLPA	+	ZWA]	
	=		(-5)	+	(-5)	+	(0)	+	N/A	= 15

* New Research has lead the author to slightly alter his previous forecast equations with regard to the QBO correction factor (Gray, 1984b). Rather than make two QBO corrections (QBO_1 and QBO_2), only one correction is being made. This new QBO correction factor combines QBO information at the three stratospheric levels of 70, 50 and 30 mbs and will be fully discussed in a forthcoming Colo. State Univ. research paper.

Hurricane activity since 1970 has been reduced over that of average hurricane activity of the 23-year period of 1947-1969. This is especially the case with regards to low latitude and intense hurricanes which are spawned from tropical disturbances originating from west Africa.

This reduction of low latitude Atlantic hurricane activity since 1970 is well associated with the multi-decade African Sahel drought conditions of the 1970's and 1980's and the higher summertime-autumn

Caribbean basin surface pressures and 200 mb (12 km) westerly zonal winds which have occurred during the last 17 years in comparison with the period of 1947-1969. It is impossible to tell how many more years these generally suppressed Atlantic hurricane conditions will last. Evidence to date indicates that these generally suppressed hurricane conditions of the last 17 seasons should continue for at least another season.

Not only has the general number of hurricanes over the last 17 seasons been lower but also the number of intense hurricanes has been much reduced. The most intense hurricanes typically occur in seasons of above average number of hurricanes. On this basis one might expect that those hurricanes which do occur during 1987 should, on average, be somewhat less intense than some of the hurricanes which develop during a more active hurricane season.

5. 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 hurricane variability are more dominant. It is impossible to determine beforehand in which years the author's forecast scheme will work best or worst.

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 hurricane 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, of course, for you, 1987 will seem to be a very active hurricane season.

6. Verification of Author's 1984, 1985, and 1986 Seasonal Forecasts

Tables 5-7 give verification information on the author's 1984 through 1986 seasonal predictions. In 1984 hurricane activity was over predicted but the total of hurricane and tropical storm activity underpredicted. The 1985 and 1986 forecasts were closely verified.

TABLE 5

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 6

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

TABLE 7

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 9)	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

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8. Bibliography

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., 1987: Cyclical trends in hurricane destruction potential and discussion of factors which will be used in the 1987 seasonal forecast. Paper presented at the 9th National Hurricane Conference, Orlando, Florida, 3 April 1987, 29 pp.

Gray, W. M., 1987: Forecast of Atlantic seasonal hurricane activity for 1987. Colo. State Univ., Fort Collins, Colo., May 28, 1987, 28 pp.

Gray, W. M., P. Mielke, and K. Berry, 1987: Statistical analysis of Gray's Atlantic seasonal hurricane forecast scheme. Paper presented at the 17th AMS Conference on Hurricanes and Tropical Meteorology, April 7-10, Miami, FL, 4 pp.

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.

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