# EXTENDED RANGE FORECAST OF ATLANTIC SEASONAL HURRICANE ACTIVITY FOR 1998

(A year of slightly below average hurricane activity is expected)

(This forecast is based on ongoing research by the authors along with meteorological information through November of 1997)

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[This summary is also available on the World Wide Web at the following URL:
http://tropical.atmos.colostate.edu/forecasts/index.html ] — also,

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## DEFINITIONS

Atlantic Basin - The area including the entire North Atlantic Ocean, the Caribbean Sea, and the Gulf of Mexico.

El Niño - (EN) A 12-18 month period during which anomalously warm sea surface temperatures occur in the eastern half of the equatorial Pacific. Moderate or strong El Niño events occur irregularly, about once every 3-7 years or so on average.

Hurricane - (H) A tropical cyclone with sustained low level winds of 74 miles per hour (33 $ms^{-1}$ or 64 knots) or greater.

Hurricane Day - (HD) A measure of hurricane activity, one unit of which occurs as four 6-hour periods during which a tropical cyclone is observed or estimated to have hurricane intensity winds.

Hurricane Destruction Potential - (HDP) A measure of a hurricane's potential for wind and storm surge destruction defined as the sum of the square of a hurricane's maximum wind speed (in $10^4$ knots$^2$)for each 6-hour period of its existence.

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

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

MATL - Sea surface temperature anomaly in the sub-tropical Atlantic between 30-50°N, 10-30°W

MPD - Maximum Potential Destruction - A measure of the net maximum destruction potential during the season compiled as the sum of the square of the maximum wind observed for each named storm (see Appendix A for a listing of values for 1950-1995).

Named Storm - (NS) A hurricane or a tropical storm.

Named Storm Day - (NSD) As in HD but for four 6-hour periods during which a tropical cyclone is observed (or is estimated) to have attained tropical storm intensity winds.

NATL - Sea surface temperature anomaly in the Atlantic between 50-60°N, 10-50°W

NTC - Net Tropical Cyclone Activity - Average seasonal percentage mean of NS, NSD, H, HD, IH, IHD. Gives overall indication of Atlantic basin seasonal hurricane activity (see Appendix B).

ONR - previous year October-November SLPA of subtropical Ridge in eastern Atlantic between 20-30°W.

QBO - Quasi-Biennial Oscillation - A stratospheric (16 to 35 km altitude) oscillation of equatorial east-west winds which vary with a period of about 26 to 30 months or roughly 2 years; typically blowing for 12-16 months from the east, then reverse and blowing 12-16 months from the west, then back to easterly again.

Saffir/Simpson (S-S) Category - A measurement scale ranging from 1 to 5 of hurricane wind and ocean surge intensity. One is a weak hurricane whereas 5 is the most intense hurricane.

SLPA - Sea Level Pressure Anomaly - The deviation of Caribbean and Gulf of Mexico sea level pressure from observed long term average conditions.

SOI - Southern Oscillation Index - A normalized measure of the surface pressure difference between Tahiti and Darwin.

SST(s) - Sea Surface Temperature(s).

SSTA(s) - Sea Surface Temperature(s) Anomalies.

Tropical Cyclone - (TC) A large-scale circular flow occurring within the tropics and subtropics which has its strongest winds at low levels; including hurricanes, tropical storms, and other weaker rotating vortices.

Tropical Storm - (TS) A tropical cyclone with maximum sustained winds between 39 (18 $ms^{-1}$ or 34 knots) and 73 (32 $ms^{-1}$ or 63 knots) miles per hour.

Delta PT - A parameter which measures anomalous east to west surface pressure ($\Delta P$) and west to east surface temperature ($\Delta T$) gradients across West Africa.

TATL - Sea surface temperature anomaly in Atlantic between 6-22°N, 18-80°W.

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

1 knot = 1.15 miles per hour = .515 meters per second.

ABSTRACT

This paper presents details of a 6–11 month extended range seasonal forecast of the tropical cyclone activity likely to occur in the Atlantic Ocean basin during 1998. This forecast is based on the results of two statistical forecast schemes developed by the authors plus our qualitative adjustments to these statistical results which are based upon supplementary global atmosphere and ocean information. These schemes allow estimates of seasonal Atlantic tropical cyclone activity to be made in early December of the prior year. Our ever evolving forecast techniques are based on a variety of global and regional predictors shown in the past to be related to forthcoming seasonal Atlantic tropical cyclone activity.

Information obtained through November 1997 indicates that 1998 Atlantic hurricane activity is likely to be slightly below the average for the 1950–1990 period with 5 hurricanes (average 5.7), 9 named storms (average 9.3), 40 named storm days (average 47), 20 hurricane days (average 24), 2 intense (category 3-4-5) hurricanes (average 2.2), 3 intense hurricane days (average is 4.7) and a hurricane destruction potential (HDP) of 50 (average 71). Collectively, net tropical cyclone activity is expected to be about 90 percent of the long term average. The 1998 season should be considerably more active than the 1997 season, but much less active than the recent very busy 1995 and 1996 seasons.

# 1 Introduction

Surprising long-range predictive signals exist for Atlantic basin seasonal tropical cyclone activity. Our research has shown that a sizeable portion of the season-to-season variability of nine indices of Atlantic tropical cyclone activity can be skillfully hindcast (ie., successfully forecast in experiments with past data) by early December of the prior year. We now have two separate prediction schemes for estimating hurricane activity in the following year. Sets of separate forecasts are developed from 41 years (1950-1990) and from 46 years (1950-1995) of past data respectively. Our extended-range predictive signals include two measures of Western Sahel rainfall during the prior year, the phase of the stratospheric Quasi-Biennial Oscillation of zonal winds at 30 mb and 50 mb (which can be readily extrapolated ten months into the future) and extended range estimates of El Niño-Southern Oscillation (ENSO) variability and Western Sahel rainfall anomalies for the following summer, the October-November strength (pressure) of the Azores high pressure and the configuration of the broad scale Atlantic sea surface temperature anomaly patterns (see Fig. 3). A brief summary of these predictor indices and their specific implications for 1998 are as follows:

a) QBO–Tropical Cyclone Lag Relationship

The easterly and westerly modes of stratospheric QBO zonal winds which encircle the globe over the equatorial regions have a substantial influence on Atlantic tropical cyclone activity (Gray, 1984a; Shapiro, 1989). Typically, there is 50 to 75 percent more hurricane activity (depending on the specific activity index considered) during those seasons when stratospheric QBO winds between 30 mb and 50 mb are anomalously westerly and, consequently, when the vertical wind shear (ie., the variation of wind speed with height) between these two levels is small. Conversely, seasonal hurricane activity is typically reduced when the stratospheric QBO is in an easterly phase and the wind shear between 30 and 50 mb is large. We project that 30- and 50-mb winds in 1998 will be

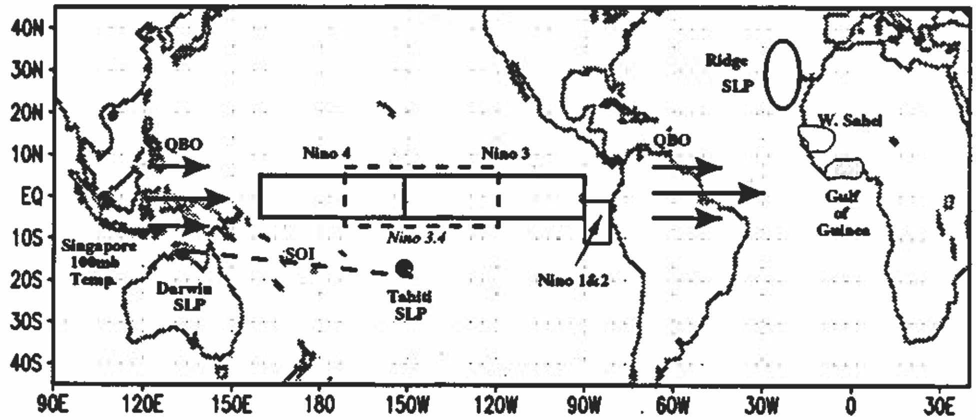


Figure 1: African rainfall regions used in our extended-range forecasts.

from a relatively easterly direction next year with large wind shear between these two levels. This should be an inhibiting influence on next year's hurricane activity, especially major hurricanes.

b) African Rainfall-Tropical Cyclone Lag Relationship

As discussed by Landsea (1991), Gray and Landsea (1992) and Gray et al. (1992), surprising strong predictive signals for seasonal hurricane activity can be obtained from West African rainfall data during the mid-summer to fall of the prior year. These rainfall-linked signals include:

(1) August–September Western Sahel Rainfall. The Western Sahel area (see Fig. 2) has experienced large year to year persistence of rainfall trends. Wet years tend to be followed by wet years (e.g., in the 1950s and 1960s) while dry years are typically followed by dry years (e.g., in the 1970s, 1980s and 1990s). Since the rainfall in this region is positively related to Atlantic hurricane activity, persistence alone tends to provide a moderate amount of skill for forecasting next season's African rainfall as well as the associated Atlantic hurricane activity. This year's rainfall for the West Sahel (Fig. 2) during August-September 1997 was –0.73 SD below average. We believe that a portion of this decrease was due to the 1997 El Niño which was the strongest on record. It has been documented that western Sahel rainfall is reduced in El Niño years.

(2) August–November Rainfall in the Gulf of Guinea. Landsea (1991) and Gray and Landsea (1992) have documented a strong African rainfall - intense hurricane lag relationship using August through November rainfall along the Gulf of Guinea (see Fig. 2). Intense hurricane activity during seasons following the ten wettest August–November Gulf of Guinea years is many times greater than that which occurred during those hurricane seasons following the ten driest August-November periods in the Gulf of Guinea. (This association suggests the existence of a very strong relationship between hurricane activity and the August to November rainfall during the prior year.) The 1997 August-November Gulf of Guinea rainfall was below average (–0.43 SD). As was the case in the Sahel, we believe that much of this decrease is due to the anomalously strong El Niño of this year and not so much an indication that next year's hurricane activity will be greatly reduced. This below average rainfall would likely be better representative of a reduced influence of next year's hurricane activity if the 1997 El Niño had not been present or not been so intense.

c) The El Niño-Southern Oscillation (ENSO) relationship

ENSO is one of the principal global scale environmental factors affecting Atlantic seasonal

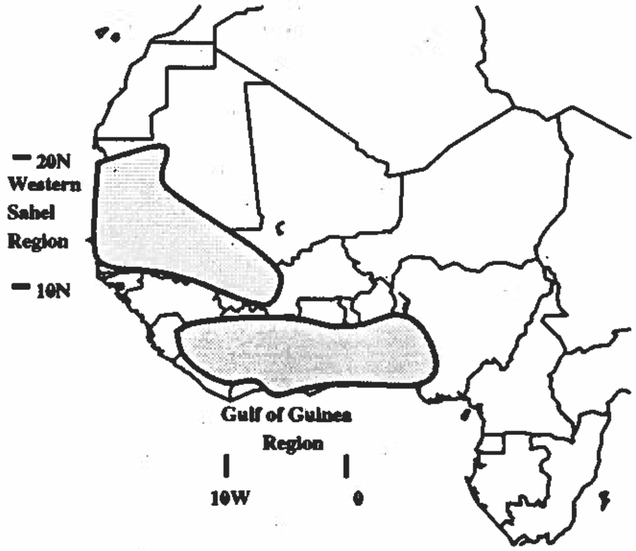


Figure 2: Locations of meteorological parameters used in 1 December Atlantic basin seasonal forecast.

hurricane activity. Hurricane activity is usually quite suppressed (eg., 1997) during those seasons when anomalously warm water temperatures are present in the equatorial eastern and central Pacific. Conversely, activity is usually enhanced during seasons with cold (or La Niña) water conditions. We expect current conditions to rapidly cool during the spring of 1998 resulting in near average to cool conditions during the key months of August through October. Our estimate of next year's ENSO conditions are discussed in a separate section to follow.

d) Strength of the October–November Atlantic Subtropical Ridge (Azores High) Between 20-30°W

High surface pressure associated with this atmospheric ridge feature are positively related to stronger east Atlantic trade winds which enhance upwelling of cold water off the northwest African coast when surface pressures associated with the Azores high are anomalously high. Colder sea surface temperatures are created due to this enhanced ocean upwelling. These, in turn, can cause higher surface pressures to develop in the spring which creates a self-enhancing (positive feedback) response. The long-term memory and feedback in this association make it a useful parameter for predicting next year's seasonal hurricane activity. Higher than normal surface pressure goes with reduced hurricane activity and lower-than-normal pressure with enhanced activity. The ridge strength during this October-November (1997) was significantly below (–1.37 SD) the average value. Consequently, this should be an enhancing influence on 1998 hurricane activity.

e) Other Potential Long Range Predictors

Our analyses have revealed additional global parameters which add value to our extended range forecast. These include:

- The configuration of SST anomaly patterns over much of the low and high latitude Atlantic: warm SST anomaly patterns in these regions during the summer and fall are usually associated with an enhancement of next summer's hurricane activity, similarly cold SST anomaly patterns with a reduction of next year's hurricane activity. This summer and fall's SST anomaly patterns have all been anomalously warm in the Atlantic. This should be an enhancing influence on next summer's hurricane activity

- Middle latitude circulation patterns during the September through November period: when middle latitude westerly oceanic wind patterns are more zonal, and both the Aleutian low and the Icelandic low are stronger (eg., blocking action in Atlantic is reduced) then hurricane activity during the following summer is typically reduced. When the opposite conditions exist (that is, when westerly circulation and the Aleutian low pressure is weaker and more blocking action is present in the North Atlantic, the next year's hurricane activity is typically enhanced.

# 2 8-11 Month Extended Range Prediction Schemes

## 2.1 Outline of Basic (Gray et al. 1992) Scheme

Our original extended range forecast scheme had the following form:

$$(Seasonal\ Forecast) = \beta_o(1 + a_1 U_{50} + a_2 U_{30} + a_3|U_{50} - U_{30}|$$

$$+ a_4 R_s + a_5 R_G \quad (1)$$

where

| | |
|---|---|
| 1. $U_{50}$ | = 10 month extrapolated 50 mb QBO zonal wind near 10°N for September 1998 |
| 2. $U_{30}$ | = 10 month extrapolated 30 mb QBO zonal wind near 10°N for September 1998 |
| 3. $\|U_{50} - U_{30}\|$ | = 10 month extrapolated 50 mb minus 30 mb QBO absolute value of zonal wind for September 1998 shear |
| 4. $R_s$ | = Measured standard deviation of previous year August-September 1997 Western Sahel rainfall |
| 5. $R_G$ | = Measured standard deviation of previous year August-November 1997 Gulf of Guinea rainfall |

The $\beta_o$ and "a" coefficients are determined to maximize the hindcast predictive signals. Different $\beta_o$ and "a" coefficients are determined for each predictor. These equations were developed on data from the 41 years of 1950-1990. They explain about 40-50 percent of the variance of each of the nine forecast parameters in non-independent hindcasts.

Values of the forecast parameters used for prediction of the next year's 1998 Atlantic hurricane activity are given in Table 1. Substitution of the forecast predictors in Table 1 into Eq. 1 yields the forecast for the amount of next year's Atlantic basin seasonal hurricane activity shown in Table 2. Again, this forecast indicates much below average hurricane activity during 1998. Table 2 also gives the hindcast and expected forecast skill associated with each prediction. This older and simpler forecast scheme incorporates none of the positive physical associations discussed previously and thus gives a forecast of next year's hurricane activity that we are certain is too low.

Table 1: Values of the five (input) parameters for 1998 forecast are as follows:

1. $U_{50} = -14$ m/s
2. $U_{30} = -31$ m/s
3. $|U_{50} - U_{30}| = 17$ m/s
4. Sahel ($R_s$) = –0.73 S.D.
5. Gulf of Guinea ($R_G$) = –0.43 S.D.

Table 2: Statistical prediction for the 1998 season as obtained with Eq. 1 and the final amount of non-degraded variance explained in the 41-year hindcast developmental data set (1950–1990). The third column gives the expected forecast skill when this forecast scheme is applied to future observations which may not be fully representative of the hindcast data set.

| Forecast Parameter | Gray et al. (1992) Statistical Forecast for 1998 | Amount of Hindcast Variance Explained | Expected Independent Forecast Skill |
|---|---|---|---|
| Named Storms (NS) | 5.90 | .44 | .17 |
| Named Storm Days (NSD) | 16.45 | .51 | .30 |
| Hurricanes (H) | 3.08 | .45 | .18 |
| Hurricane Days (HD) | 1.16 | .49 | .26 |
| Intense Hurricanes (IH) | 0.73 | .47 | .22 |
| Intense Hurricane Days (IHD) | 0.34 | .45 | .19 |
| Hurricane Destruction Potential (HDP) | 10.49 | .44 | .18 |
| Net Tropical Cyclone Activity (NTC) | 33.36 | .53 | .33 |

## 2.2 New (and Improved) Extended Range Forecast Scheme

A new version of our extended range forecasting scheme differs from the original scheme in that it involves an updated pool of predictors to which we apply a "leaps-and-bounds" regression method. This procedure iteratively chooses the best two predictors, the best three predictors, etc. to as many as ten predictors. Variability explained by the resulting forecast equations typically increases as we add predictors, but at an ever-decreasing rate of improvement. Given the limited pool of hindcast years (46) from which to develop our scheme (1950-1995), a degrading of true skill occurs when the scheme is applied to independent data if too many predictors are used (i.e., overfitting). Consequently, we optimally limit the number of predictors, to between three and seven.

Table 3 shows the pool of ten potential predictors and their numerical values for this year's forecast. Table 4 shows the predictors chosen for each of our nine hurricane forecast activity parameters. Table 5 shows the predictions for the 1998 hurricane season with this newer forecast scheme, along with the amount of non-degraded variance explained within the 46-year developmental data sets. We judge this newer scheme to give better estimates of next year's activity. It also indicates a below average 1998 hurricane season but not as inactive as our earlier scheme. This newer (methodology) forecast may also underestimates 1998 activity as it does not incorporate our belief that the current ENSO conditions will rapidly fade, likely becoming cooler than normal during the heart of the 1998 hurricane season. This is the primary reasons for our upward adjustment.

There are two basic reasons for qualitatively adjusting of our 1998 forecast upward. They

Table 3: Predictor values for 1998 forecast.

| Predictor No. | Predictor | Predictor Values for 1998 Fcst |
|---|---|---|
| | Pool of 10 Potential Predictors | |
| 1 = | $U_{50}$ | –14 m/s |
| 2 = | $U_{30}$ | –31 m/s |
| 3 = | $\|U_{50} - U_{30}\|$ | 17 m/s |
| 4 = | Guinea Rain (Aug-Nov) | –0.43 SD |
| 5 = | West Sahel rain (Aug-Sept) | –0.73 SD |
| 6 = | Atlantic Ridge | –1.37 SD |
| 7 = | Darwin (May-Jul) | + 1.63 mb |
| 8 = | Nino-4 Trend (Aug-Oct)-(May-Jul) | 0.03°$C$ |
| 9 = | SOI (Aug-Oct) | –1.8 SD |
| 10 = | SOI Trend (Aug-Oct)-(May-Jul) | –0.2 SD |

Table 4: Most skillful predictor values for 1998 forecast.

| Number | Top predictors chosen for each forecast variable | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Predictors | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| NS (3) | | 2 | | 4 | | 6 | | | | |
| NSD (6) | 1 | 2 | | 4 | 5 | 6 | | | | 10 |
| H (5) | 1 | | 3 | 4 | 5 | 6 | | | | |
| HD (5) | 1 | 2 | | 4 | 5 | 6 | | | | |
| IH (4) | 1 | | 3 | 4 | | 6 | | | | |
| IHD (3) | | | 3 | 4 | 5 | | | | | |
| HDP (5) | 1 | 2 | | 4 | 5 | 6 | | | | |
| NTC (4) | | | 3 | 4 | 5 | 6 | | | | |
| MPD (4) | 1 | | 3 | 4 | 5 | 6 | | 8 | 9 | |

Table 5: Newer extended range forecast scheme for 1998 hurricane activity with the amount of non-degraded forecast variance explained. Developmental data is for the years of 1950-1995. The third column gives the expected forecast skill when this forecast scheme is applied to future observations which may not be fully representative of the hindcast data set.

| Forecast Parameter | Best Forecast Forecast | Amount of non-degraded Variance Explained | Expected Independent Forecast Skill |
|---|---|---|---|
| NS | 9.36 | .519 | .332 |
| NSD | 35.13 | .547 | .374 |
| H | 4.57 | .494 | .297 |
| HD | 15.88 | .536 | .358 |
| IH | 1.67 | .436 | .196 |
| IHD | 0.91 | .417 | .160 |
| HDP | 43.59 | .492 | .294 |
| NTC | 78.32 | .528 | .350 |
| MPD | 46.96 | .660 | .523 |

involve: (a) our assessment that the current extreme El Niño event will be dissipated by the beginning of the active portion of next year's hurricane season. (b) Atlantic surface temperature changes: An ongoing major rearrangement of the Atlantic Ocean SST features has taken place since late 1994. This has brought global circulation changes which are broadscale and substantial in comparison with the typical year-to-year variations taking place prior to 1994. These changes include general warming of the North, Eastern and tropical Atlantic. Figure 3 shows Aug-Oct 1997 SST anomalies.

Real Forecast Skill. Application of both forecast schemes to independent data (i.e., the future) will usually entail a forecast skill degradation such that the amount of real forecast skill will be degraded from that specified in our experimental hindcast examples. Our hurricane forecast for 1997 was a classic example. In our developmental data set we never had any El Niño event as strong as the one that occurred this year. Nevertheless, on average this degradation should be on the order of 15-25 percent from the hindcast skill shown. In some years it will be larger, in other years there will be no degradation and yet in other years an improvement might occur. It is impossible to judge the degree of statistical degradation in any individual forecast year. It is, however, possible to say that our confidence in next year's forecast, because of the current ENSO conditions and other contradictory factors, is somewhat less than in a year when most factors point the same direction.

Table 6 provides a comparison of the forecasts from both hurricane prediction schemes and our qualitative upward adjustment to the actual 1998 seasonal forecast. Columns two and four give 25 and 75% probability limits on our recent forecast. The fifth column shows our 1998 forecast. Column six gives 1950-1990 climatology. Column 7 gives the 1998 forecast activity expressed as percent of the 1950-1990 average season. Net tropical cyclone activity is expected to be about 90 percent of the average of the 1950-1990 hurricane seasons.

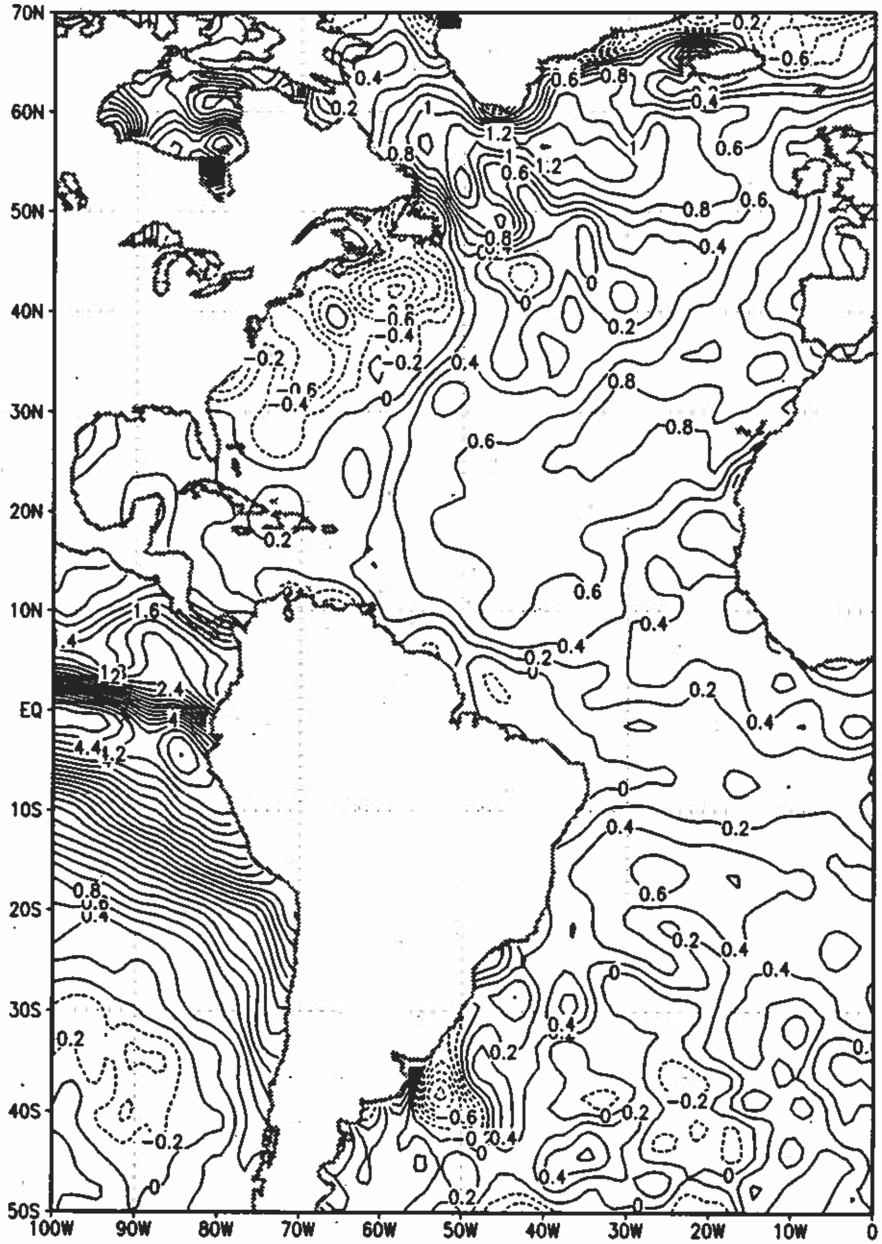


Figure 3: Sea surface temperature (SST) anomaly during the August through October 1997 period. Values are in °C. Note the North Atlantic warming.

Table 6: Comparison of our two objective forecast schemes with our qualitative upward adjustment due to changing atmosphere-ocean conditions not explicitly in our forecasts.

| Forecast Parameter | (1) Older 1 Dec Fcst Scheme | (2) Lowest 25% Below | (3) Newer 1 Dec Fcst Scheme | (4) Highest 25% Above | (5) Qualitatively Adjusted 1998 Fcst | (6) 1950–1990 Average | (7) Percent of 1950–1990 Period |
|---|---|---|---|---|---|---|---|
| NS | 5.9 | 8.18 | 9.36 | 11.04 | 9 | 9.3 | 97 |
| NSD | 16.45 | 31.73 | 35.13 | 46.37 | 40 | 46.6 | 86 |
| H | 3.08 | 4.00 | 4.57 | 5.66 | 5 | 5.8 | 86 |
| HD | 1.16 | 11.27 | 15.88 | 19.58 | 20 | 23.9 | 83 |
| IH | 0.73 | 1.05 | 1.67 | 2.34 | 2 | 2.3 | 87 |
| IHD | 0.34 | –0.40 | 0.91 | 3.24 | 3 | 4.7 | 64 |
| HDP | 10.49 | 28.67 | 43.59 | 67.80 | 50 | 71.2 | 70 |
| NTC | 33.36 | 65.03 | 78.32 | 97.03 | 90 | 100 | 90 |
| MPD | — | 43.49 | 46.96 | 52.89 | 55 | 66.0 | 83 |

# 3 Likely El Niño Influence on 1998 Hurricane Season

The most difficult aspect of our 1998 forecast is predicting the rate of dissipation of the current most intense summer-fall El Niño on record. Will there be residual influences on next year's hurricane season or will the present El Niño be fully dissipated by next year? This assessment involves prediction of both the El Niño dissipation rate through next summer and also gauging the residual influences from this year's El Niño on next year's hurricane activity.

Knaff and Landsea (1997) have recently developed a new extended-range ENSO prediction scheme based on climatology and persistence. Their SST anomaly forecast of June-July-August and September-October-November 1998 for Nino 3.4 SST anomaly values are –0.54°C and –0.75°C, respectively.

Eight other ENSO forecasts for the summer of 1998 are listed in the "NOAA/CPC Experimental Long-lead Forecast Bulletin (courtesy of Tony Barnston)". Most of these forecasts are also calling for neutral or cool Nino 3 or Nino 3.4 SST anomalies conditions for next summer. The Scrippts and Max-Plank Institute model predicts strong cooling conditions to set in by the early summer 1998. Arthur Douglas (Creighton University - private communication December, 1997) also sees an early end to this El Niño by late spring. We also believe that the current ENSO will rather rapidly rebound to cool conditions by next August. Such a rapid next year reversal is typical of very strong El Niños and would be quite consistent with recent global observations of Professor Douglas and the authors of:

1. Warm Atlantic SST anomalies; the combination of warm Atlantic SSTAs and very warm El Niños is historically unstable. One pattern will have to shortly change and it should be the El Niño dissipating.

2. Northern Hemisphere middle and high-latitude summer and fall circulation patterns are inconsistent with the maintenance of a strong El Niño.

3. Fall 1997 global 700 mb patterns are not typical of a lingering multi-year El Niño; rather, they

are more characteristic of years preceding El Niño dissipation, as occurred with the strong ENSO cooling changes between, 1963 to 1964, 1969 to 1970, 1972 to 1973 and 1987 to 1988.

4. New MJO activity in the tropical western Indian Ocean is expected to propagate eastward and reestablish deep convection over Indonesia.

5. Increased high pressure in the Southeast Pacific and increasing east Pacific trade winds have begun.

6. Eastward movement of intense equatorial convection from near the Dateline should begin to establish weaker deep convection over the Dateline area - typical of El Niño weakening.

The foregoing weather events are now being observed and are typical of a forthcoming demise of an El Niño. A carry over of this event to next hurricane season, as occurred in 1982-83, 1986-87, 1991-94 Ninos is not expected. Thus, the unusually strong suppressing influences of this year's El Niño are not expected to be present by next summer. Given the hurricane enhancing Atlantic SST and low Azores ridge conditions, we expect the negative influences of an easterly QBO and dry 1997 West African rainfall conditions to be largely canceled out; only a slightly below average 1998 hurricane season is thus expected.

# 4 Speculation Concerning The Likely Coming New Era of Atlantic Hurricane Activity Associated With Major Reconfiguration of Atlantic Basin SSTs

There are recent reports of decreased ice flow through the Fram Strait (the North Atlantic passage between Greenland and Spitzbergen). This trend reduces the introduction of fresh water leading to an increase in upper level salinity values in the high latitude areas of the North Atlantic. Related observations also report increased salinity in other areas of the tropical Atlantic and North Atlantic. Salinity increases water density and creates water which is able to sink to great depth, thereby causing increased equatorward flow of deep water. This causes a compensating northward flow of warm replacement water near the ocean surface. The resulting net transports of warm and cold water is called the "Atlantic Ocean Conveyor." A strong conveyor circulation increases North Atlantic water temperatures and thus transports more heat to high latitudes. Salinity values in the North Atlantic have been steadily rising during the last 15 years and recent deep water observations in the North Atlantic reveal that fairly stagnant water has been present for a decade or more. Collectively, these processes all suggest that surface salinity increases now being measured in the North Atlantic appear to be leading to a stronger Atlantic Ocean thermohaline circulation.

It has been nearly three decades since the SST anomaly patterns of the Atlantic Ocean has had as strong a north to south SST difference as is now observed. Figure 4 portrays average SST anomaly changes between the three-year periods 1992-93-94 and 1995-96-97. Some notable broad area changes include 1.4 to 0.6°C in the north and tropical Atlantic, respectively. We expect that this developing Atlantic SST pattern will lead to increased incidence of major hurricanes in coming years, more like the conditions observed during the mid 1940s to mid-1960s. Specifically, this trend should manifest itself primarily in the form of more hurricanes forming at low latitudes and especially more intense low latitude hurricanes.

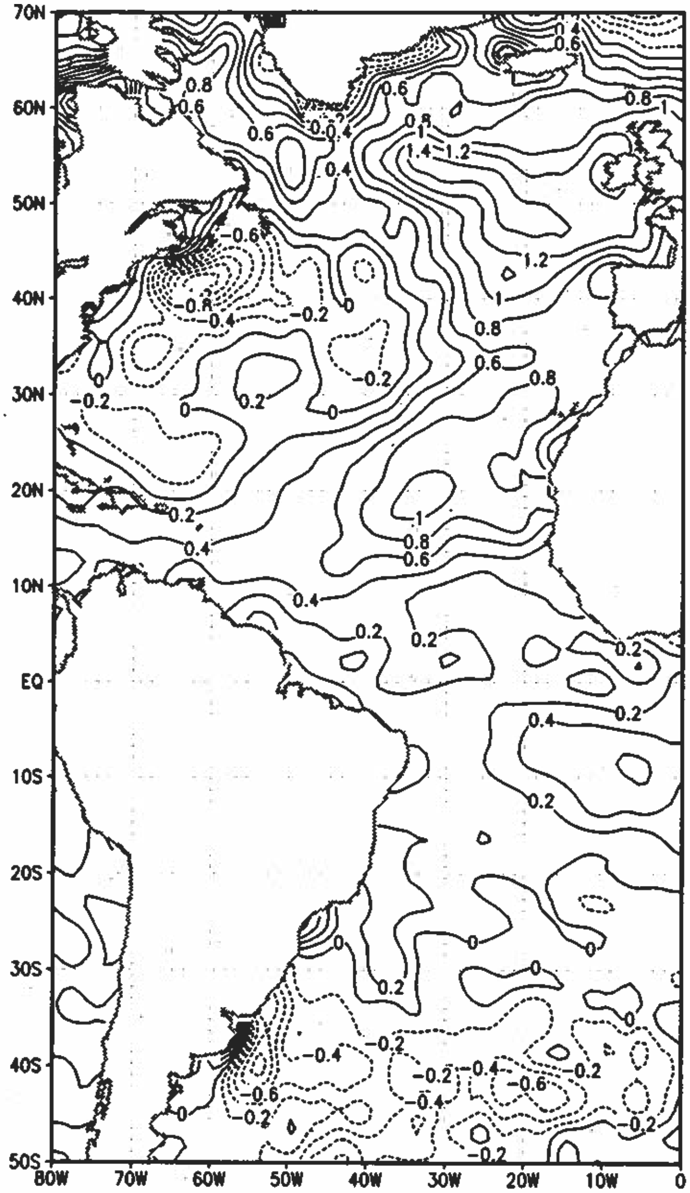


Figure 4: Portrayal of SST difference of August through October of 1995-96-97 minus the same months for 1992-93-94. Values are in °C.

Our data sets show that a multi-decadal lapse of intense hurricane activity began during the late 1960s, extending to 1994. We believe that this trend was associated with the concurrent slowing of the North Atlantic thermohaline circulation during this period which resulted in North Atlantic SSTs cooling and South Atlantic SSTs warming during these decades. Presuming that the opposite ocean circulation trends are now developing, we anticipate forthcoming concurrent multi-decadal increased West African Sahel rainfall, decreased Atlantic summertime upper tropospheric westerly winds over the tropical Atlantic and, regarding the issue at hand, multi-decadal increased Atlantic Basin intense hurricane activity. Hence, the new North Atlantic SST patterns may be an ominous sign of increased US and Caribbean Basin intense hurricane frequency and landfall.

## 5 Theory Behind Forecasts and Cautionary Note

Our forecasts are based on the premise that the atmosphere will behave in 1998 as it has in the past; that is, those global environmental conditions which proceed comparatively active or inactive hurricane seasons in the past are assumed to provide meaningful information about the future. The atmosphere operates as a single entity and hence, each separate forecast enhances our physical interpretation of the complete atmosphere-ocean-land system.

It is important that the reader appreciate that these seasonal forecasts are based on statistical schemes which, owing to their intrinsically probabilistic nature, will fail in some years. Moreover, these forecasts do not specifically predict where within the Atlantic basin storms will strike. Regardless of whether 1998 should prove to be an above or a below average hurricane season or not, the probability always exists that one or more hurricanes may strike along the US or Caribbean Basin coastline and do much damage.

## 6 Schedule of Seasonal Hurricane Forecast Updates for 1998

This early December 1997 forecast will be updated on 7 April 1998, 5 June 1998 and 6 August 1998. This allows us to make pre-season forecast adjustments as new information becomes available. Seasonal verification of the 1998 forecasts will be issued in the last week of November 1998. In addition, new seasonal forecasts for the 1999 hurricane season will be issued in early December, 1998.

## 7 Acknowledgements

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## Verification of All Past Seasonal Forecasts

The first author has now issued seasonal hurricane forecasts for 14 consecutive years (1984–1997). In most of these prior forecasts, predictions have been superior to climatology (i.e., long-term averages), particularly for named storms. Whereas the forecasts for 1989 (underestimated), 1993 (overestimated), 1996 (underestimated), and 1997 (overestimated) were quite poor, they were also quite instructive in that each of these failures has led to important new insight and forecast model improvements.