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Statistical Aspects of ENSO Events (1950–1997) and the El Niño-Atlantic Intense Hurricane Activity Relationship

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STATISTICAL ASPECTS OF ENSO EVENTS (1950–1997) AND THE EL NIÑO-ATLANTIC INTENSE HURRICANE ACTIVITY RELATIONSHIP

1. INTRODUCTION

Although originally the term "El Niño" was used to describe the occasional warming of the Pacific Ocean waters off the west coast of South America near Peru and Ecuador (hence, it often was considered only of regional importance), the prevailing view now is that it refers exclusively to the extreme warming episodes (also called the "low and/or wet" phase, referring to the Southern Oscillation and level of precipitation, respectively, that generally predominates during the anomalous warming of sea surface temperature (SST)) of the globally effective, coupled ocean-atmospheric interaction known as "ENSO," or El Niño-Southern Oscillation.[1–24] Likewise, the term "La Niña" has come to signify the extreme cooling episodes of ENSO (also called the "high and/or dry" phase).[25–27] The appearance of the occasional strong/very strong El Niño (as in 1972–1973, 1982–1983, and now 1997–1998) has been found to greatly alter, or disrupt, the usual weather patterns at many places around the globe via the process called "teleconnection," thereby causing significant meteorological, ecological, and climatological change.[19, 28–57] Furthermore, ENSO has recently been linked to "global warming," although this inferred linkage is somewhat controversial.[58–71]

Previously, on the basis of the seasonal number of hurricane days for the years of 1900–1982, Gray[72] noted that in most El Niño years (as determined from the listing of El Niño events in Quinn et al.[73] and supplemented by the 1981–1982 event) hurricane activity was diminished in comparison to non-El Niño years, where he defined a hurricane day as, "any day when a tropical cyclone was considered to have a maximum sustained wind in excess of 34 m s^{-1}." Thus, he inferred an *anticorrelation* to exist between the seasonal number of hurricane days and El Niño years. The same was also true when he combined hurricanes and tropical storms (maximum sustained winds >22 m s^{-1}). In particular, Gray found the mean numbers of hurricane days in his 15 El Niño years to be 10.9 per season, as compared to 23.2 for the 68 non-El Niño years, the mean numbers of hurricanes per season during El Niño years to be 3.0, as compared to 5.4 for non-El Niño years, and the mean numbers of hurricanes and tropical storms per season during El Niño years to be 5.3, as compared to 9.0 for non-El Niño years. While he did not look, per se, at the collective class of "intense hurricanes" (i.e., those noted as category 3, 4, or 5 on the Saffir-Simpson hurricane damage potential scale),[74–77] he did note that of the 54 class 4–5 hurricanes striking the United States coast during the interval of 1900–1983, only 4 occurred during El Niño years. Thus, he concluded, "there can be little doubt that seasonal hurricane activity during the El Niño years of this century has been much suppressed compared with activity during non-El Niño years," and he attributed the reduction to enhanced westerly upper tropospheric wind patterns over the Caribbean basin and equatorial Atlantic.

Because the meaning of the term El Niño has changed through the years (leading to some confusion),[7,16] Trenberth[20] recently offered a purely quantitative definition of El Niño. Namely, he has suggested that, "... an El Niño can be said to occur if 5-mo running means of SST anomalies in the Niño 3.4 region (5° N–5° S, 120°–170° W) exceed 0.4 °C for 6 mo or more." On the basis of this definition, he was able to precisely determine (by month and year) the beginning and ending dates for 15 El Niño and 10 La Niña events during the interval of 1950–1997. Such a precise listing is certainly appealing from the statistical perspective, because it offers the opportunity to more carefully evaluate any suspected statistical associations, especially those that might be found to exist between the annual frequency of intense hurricanes and, specifically, each of the three descriptive conditions of ENSO—El Niño, La Niña, and the interludes between them. The purpose of this study, then, is first to examine the statistical aspects of ENSO (based on Trenberth's definition) and second to examine the statistics of intense hurricanes in relation to ENSO, including a determination of the importance of any inferred statistical association. Last, implications as they may relate to forecasting the 1998 and 1999 hurricane seasons will be discussed.

2. RESULTS AND DISCUSSION

2.1 Statistical Aspects of ENSO

Table 1 lists in staggered, sequential order the beginning and ending dates (month and year), as well as the duration (in months), for the extremes and interludes of ENSO during the interval of 1950–1997, adapted from Trenberth.[20] From this tabular listing, one easily determines that the population of La Niña events appears to have a mean duration of 13.3±3.1 mo at the 90-percent level of confidence (having a range of 7–22 mo), whereas the populations of interludes and El Niño events appear to have a mean duration of 10.2±4.3 mo (having a range of 1–59 mo) and 11.8±2.0 mo (having a range of 7–19 mo), respectively, at the 90-percent level of confidence. Of the 576 mo comprising the interval of 1950–1997, one finds that interludes were seen only about 45 percent of the time, while the extremes were seen about 55 percent of the time (previously noted by Trenberth[20]), El Niño and La Niña accounting for 32 percent and 23 percent, respectively.

Table 1. Begin and end dates for extremes of the ENSO cycle (1950–1997).[a]

La Niña (Cold)			Interlude			El Niño (Warm)		
Begin	End	Duration	Begin	End	Duration	Begin	End	Duration
			?	02–50	>2			
03–50	02–51	12						
			03–51	07–51	5			
						08–51	02–52	7
			03–52	02–53	12			
						03–53	11–53	9
			12–53	05–54	6			
06–54	03–56	22						
			04–56	04–56	1			
05–56	11–56	7						
			12–56	03–57	4			
						04–57	06–58	15
			07–58	05–63	59			
						06–63	02–64	9
			03–64	04–64	2			
05–64	01–65	9						
			02–65	04–65	3			
						05–65	06–66	14
			07–66	08–68	26			
						09–68	03–70	19
			04–70	06–70	3			
07–70	01–72	19						
			02–72	03–72	2			
						04–72	03–73	12
			04–73	05–73	2			
06–73	06–74	13						
			07–74	08–74	2			

Table 1. Begin and end dates for extremes of the ENSO cycle (1950–1997)[a] (Continued).

La Niña (Cold)			Interlude			El Niño (Warm)		
Begin	End	Duration	Begin	End	Duration	Begin	End	Duration
09–74	04–76	20						
			05–76	07–76	3			
						08–76	03–77	8
			04–77	06–77	3			
						07–77	01–78	7
			02–78	09–79	20			
						10–79	04–80	7
			05–80	03–82	23			
						04–82	07–83	16
			08–83	08–84	13			
09–84	06–85	10						
			07–85	07–86	13			
						08–86	02–88	19
			03–88	04–88	2			
05–88	06–89	14						
			07–89	02–91	20			
						03–91	07–92	17
			08–92	01–93	6			
						02–93	09–93	8
			10–93	05–94	8			
						06–94	03–95	10
			04–95	08–95	5			
09–95	03–96	7						
			04–96	03–97	2			
						04–97	?	>9
	$\bar{x}$	13.3			10.2			11.8
	sd:	5.4			12.5			4.5
	n:	10			25[b]			15[c]

[a]Adapted from Trenberth;[20] [b]Excludes indeterminate first entry; [c]Excludes indeterminate last entry.

Figure 1 displays histograms marking the frequency distributions for the *beginnings* and *endings* of the extremes and interludes of ENSO (from table 1) on the basis of "boreal seasons." Clearly, episodes of La Niña have begun in all seasons of the year, except boreal winter (December–February), and only once has one ended in boreal autumn (September–November). Episodes of El Niño have most often begun (81 percent) in boreal spring (March–May) and/or summer (June–August), and only rarely have they ended (13 percent) in boreal autumn. Interludes usually have begun (48 percent) in boreal spring and only once has one begun (4 percent) in boreal autumn, and they usually have ended in similar fashion. (The notion that ENSO extremes typically begin and end in boreal spring has previously been broached by a number of investigators, including, in part, Rasmusson and Carpenter,[5] Wright,[10] Wright et al.,[15] and Deser and Wallace.[27])

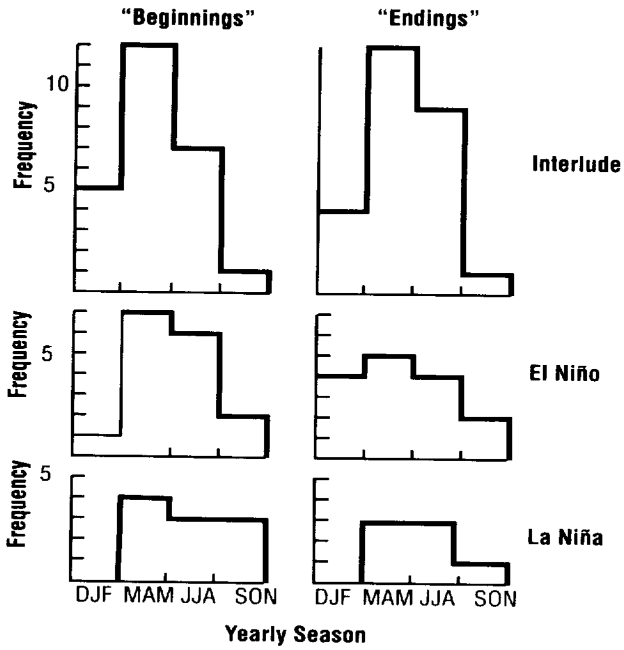

Figure 1. Frequency distributions for the "beginnings" and "endings" of the extremes and interludes of ENSO on the basis of boreal seasons.

Figure 2 depicts *recurrence* rates for the extremes and interludes of ENSO (also from table 1). Episodes of La Niña are observed to recur (elapsed time in months from onset to onset) about every 51 mo (median), having a distribution that looks rather flat and ranges between 15 and 120 mo, although, possibly, one can speculate that it could be bimodal in nature, ranging between 15 and 51 mo and between 74 and 120 mo. Episodes of El Niño are observed to recur about every 34 mo (median), also having a distribution that looks rather flat and ranges from 11 to 74 mo, although, as before (for La Niña), one can speculate that it could be bimodal in nature, ranging between 11 and 34 mo and between 40 and 55 mo, where the one instance of a recurrence of 74 mo is regarded as being highly unusual, owing to the 59-mo interlude that was observed in mid-1958 through mid-1963, when neither El Niño nor La Niña occurred. Finally, interludes are observed to recur about every 18.5 mo (median), ranging between 8 and 68 mo, with half recurring every 10–19 mo and three-fourths recurring every 10–29 mo. For each case, runs testing[78] shows that the recurrence rate is randomly distributed at the 95-percent level of confidence. (Plainly, the sample size is too small to differentiate a *bimodal* versus a *normal* distribution for both El Niño and La Niña events).

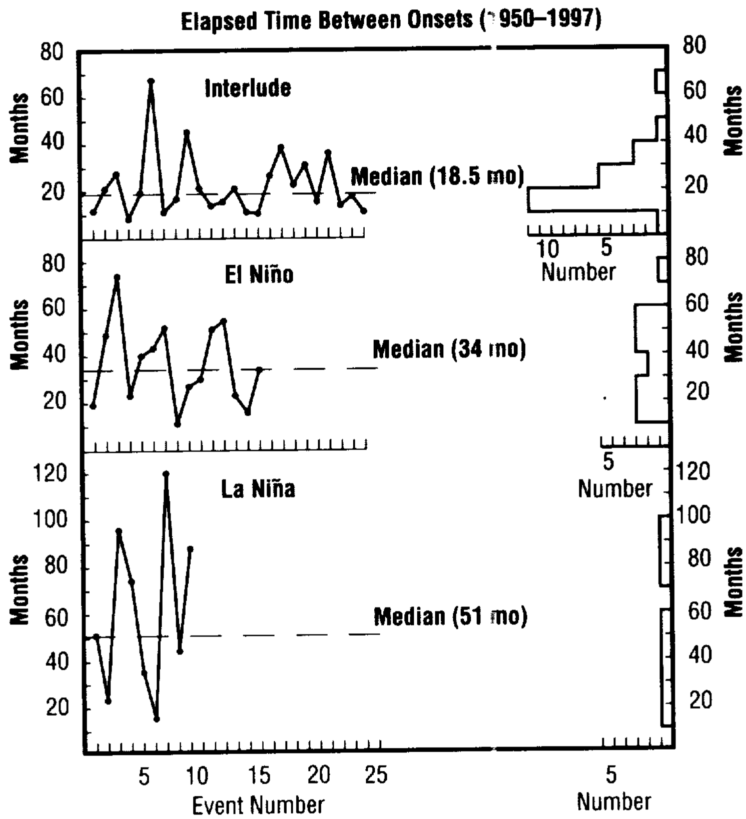

Figure 2. Recurrence rates (i.e., elapsed time in months between onsets) and frequency distributions of the extremes and interludes of ENSO.

2.2 Statistical Aspects of the Annual Frequency of Intense Hurricanes in Relation to Extremes and Interludes of ENSO—The El Niño-Atlantic Intense Hurricane Activity Relationship

Figure 3 provides a lucid visual representation of the appearances of El Niño (dark bars), La Niña (gray bars), and the interludes for the years of 1950–1997, in particular, in relation to each year's hurricane season (June–November), thereby allowing each yearly hurricane season to be specifically classified (i.e., a yearly hurricane season is termed "El Niño-related" when an El Niño either is observed to have had its onset/demise within the season or to span the entire season; it is termed "La Niña-related" when a La Niña either is observed to have had its onset/demise within the season or to span the entire season; and it is termed "interlude-related" when it cannot be classified as being either El Niño- or La Niña-related). Such a classification reveals that of the 48 hurricane seasons spanning 1950–1997, 20 are El Niño-related, 13 are La Niña-related, and 15 are interlude-related, or, as noted below, they can be grouped more simply as 20 El Niño-related and 28 non-El Niño-related seasons.

To the right of the chart is a listing of the annual frequency of intense hurricanes (N(IH)) and the annual mean temperature (T(°C)) at Armagh Observatory (Northern Ireland) which has been shown to be a useful proxy for climatic change.[79–82] For the class of 20 El Niño-related seasons, it has a mean annual

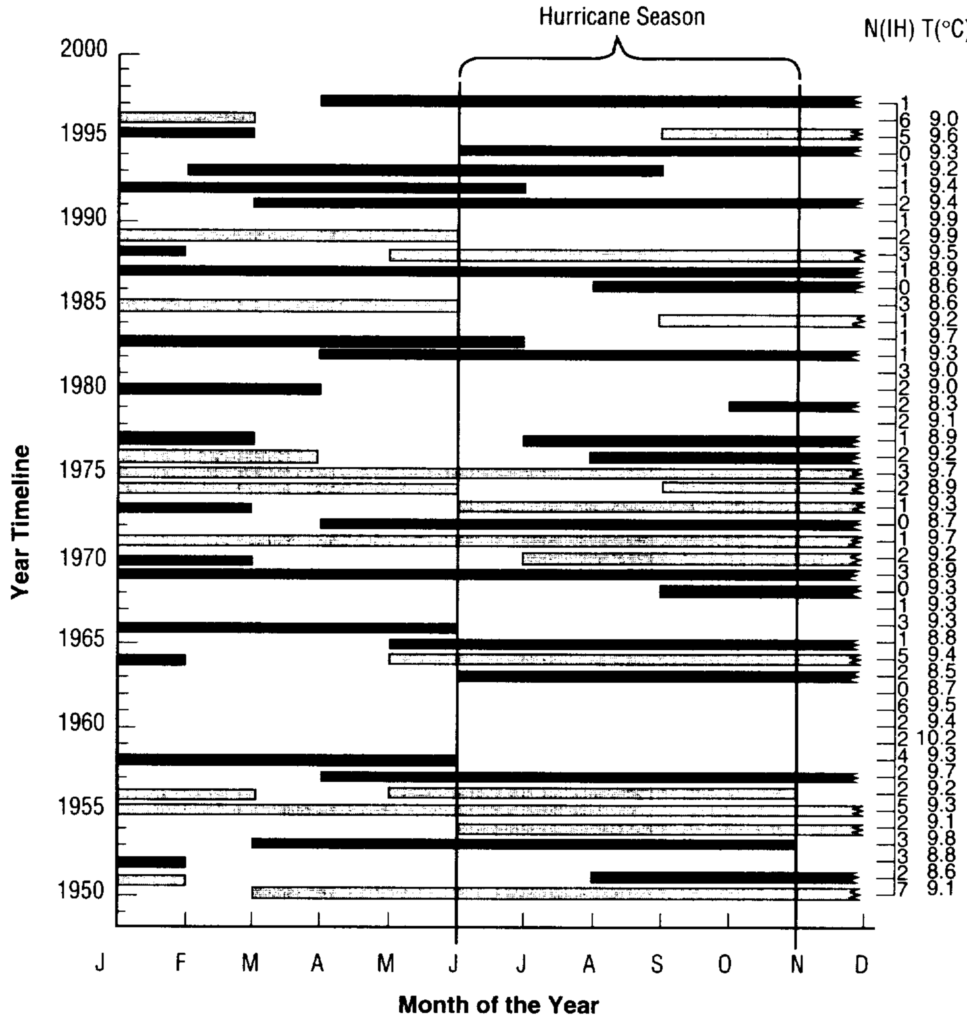

Figure 3. Visual display of the appearances of the extremes and interludes of ENSO during the interval of 1950–1997, relative to the yearly hurricane season. Also given (to the right) are the annual frequency of intense hurricanes and the annual mean temperature at Armagh Observatory (Northern Ireland).

frequency of intense hurricanes of 1.3. Because, statistically speaking, the difference in mean annual frequency of intense hurricanes for the other two classes, being 3.0 (for La Niña-related) and 2.7 (for interlude-related), is not statistically important, one can combine them together into a single class called, hereafter, "non-El Niño-related" seasons. For the class of 28 non-El Niño-related seasons, it has a mean annual frequency of intense hurricanes of 2.8. Statistical testing shows that the difference in the two means representative of the two classes of El Niño-related and non-El Niño-related seasons is statistically important at the 99.8-percent level of confidence. Thus, during any given hurricane season, one should expect fewer intense hurricanes when the season is El Niño-related and more when the season is non-El Niño-related. Furthermore, perhaps rather interestingly, the mean annual temperature at Armagh Observatory is slightly cooler during years that are El Niño-related as compared to those that are non-El Niño-related, 9.08 °C and 9.29 °C, respectively, where the difference is of marginal statistical significance. (This latter finding may prove useful as a discriminator for determining whether a season is El Niño-related or not, or for determining the long-term behavior of intense hurricane activity.)

2.3 Implications for the 1998 and 1999 Hurricane Seasons

Historically, the frequency of tropical storms and hurricanes has been greatest during the months of June–November; hence, this interval is conventionally called the "hurricane season." For example,[83, 84] of the 511 tropical storms and hurricanes that occurred during 1886–1989, only 7 occurred during the months of December–May, accounting for only about 1 percent of the total. The months of August and September are the peak months, accounting for 334 of the tropical storms and hurricanes (65 percent). Because El Niño has a disrupting effect on wind circulation over much of the tropical Atlantic Ocean (in particular, by enhancing the vertical wind shear[85]), one infers that conditions for the formation of tropical storms and hurricanes during a particular season will be less favorable when El Niño is in vogue and more favorable when El Niño is not in vogue (previously noted by Gray[72]). Consequently, one expects fewer tropical storms and hurricanes during an El Niño-related season than during a non-El Niño-related season.

In April 1997, an extremely strong El Niño (called, the strongest of the 20th century)[55, 71, 86, 87] began and it continued to be evident, at least, through March 1998 (when the original version of this manuscript was written), inferring that its duration would exceed 12 mo. Initially, the event was anticipated to persist, perhaps, through June–August 1998 (Trenberth, private communication). However, during the spring months its strength greatly waned, so that, technically speaking, the event appeared to be over as of the end of May 1998 (Trenberth, private communication). While apparently true, its remnants were found to still be exerting an influence on the meteorology of the Atlantic basin, at least, through mid-July 1998, providing conditions that proved to be unfavorable for the development of intense hurricanes (these conditions have since lessened and, in fact, are now favorable for the development of intense hurricanes; through September 1998, two intense hurricanes have been observed in the Atlantic basin—"Bonnie" and "Georges," a category 3 and 4 hurricane, respectively, and "Jeanne," presently a category 2 hurricane, is slowly intensifying and may soon become a category 3 or greater storm). Its duration, presuming the official end date to be May 1998, measures 14 mo, a length that is longer than most for the interval of 1950–1997, but shorter than the record events of September 1968–March 1970 and August 1986–February 1988 (duration=19 mo). Compared to the two previous strong El Niño events, April 1972–March 1973 and April 1982–July 1983, the 1997–1998 event persisted 2 mo longer than the 1972–1973 event (duration=12 mo) and 2 mo shorter than the 1982–1983 event (duration=16 mo). From table 1 and figure 1, it is important to recall that El Niño events rarely have ended, and interludes rarely have begun, in boreal autumn, with only 2 of the 15 previous El Niño events and only 1 of the previous 25 interludes having done so. Therefore, statistically speaking, the 1997–1998 El Niño, should have been expected to end either before September 1998 or not until after November 1998. Likewise, from table 1 and figure 2, one recognizes that since the last interlude had its onset in April 1996 and 19 of 25 (76 percent) have had a recurrence rate of 8–28 mo, statistically speaking, a new interlude should have been anticipated to begin before August 1998. Hence, the quick demise of the 1997–1998 El Niño in the spring/summer of 1998 seemed inevitable and probably should have been anticipated well beforehand. However, because of the proximity of the anticipated end of the 1997–1998 event to a timeframe near to just after the start of the 1998 hurricane season, one faced a clear dilemma regarding the classification of the 1998 hurricane season; i.e., should it be classified as an El Niño-related season or not? Accepting the official end date to be May 1998, the answer now is obvious: It must be classified as a non-El Niño-related season.

Figure 4 contrasts the observed distributions of annual frequency of intense hurricanes for the two classes of El Niño-related seasons (left panel) and non-El Niño-related seasons (right panel). Had the 1998 hurricane season been classified as an El Niño-related season, past experience strongly dictated that the annual frequency of intense hurricanes for the 1998 season would be ≤3 (100 percent) and, probably, ≤2 (90 percent). However, now that it is apparent that the 1998 hurricane season is classifiable as non-El Niño-related, the annual frequency of intense hurricanes for the 1998 season probably should be ≥2 (79 percent) and, possibly, ≥4, especially, if the long-term downward trend in annual frequency of intense hurricanes from a more active state, prior to the mid-1960's, to a less active state, from the mid-1960's, has ended.[76, 88–98] (It is noteworthy that, presuming a Poisson distribution for intense hurricanes, one having a *mean* of 2.22 events per season—from the actual data of 120 events during the interval of 1944–1997, the probability of having 2±1 events per season is easily computed to be 70.7 percent, where 2 events per season represents the *mode* and *median* values of the observed distribution. For the two cases of 0 events per season and ≥4 events per season, the probability is computed to be, respectively, 10.9 and 18.5 percent.)

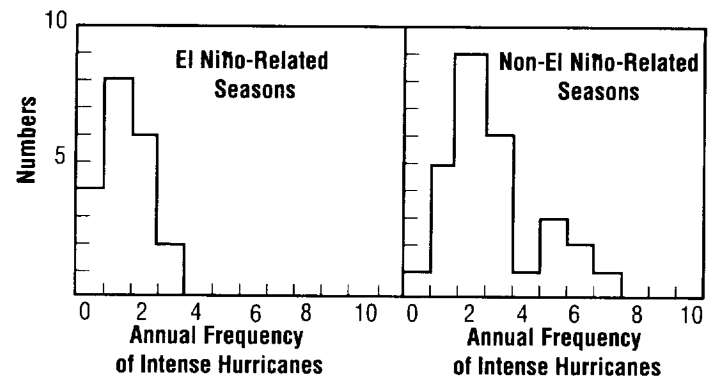

Figure 4. Frequency distributions of annual frequency of intense hurricanes for the two classes of hurricane-related seasons: El Niño-related seasons (left panel) and non-El Niño-relatedseasons (right panel).

Because more than 90 percent of all seasonal Atlantic tropical cyclone activity typically occurs after the first of August,[99–101] the quick transition from El Niño-dominated to non-El Niño-dominated weather patterns that occurred in late spring/early summer may portend an overly active hurricane season for 1998, especially during August–October when intense hurricanes are typically the most likely to be seen. The demise of the 1997–1998 El Niño and the beginning of an interlude in June certainly indicates that the 1998 season is non-El Niño-related; however, the possibility clearly exists that it could also be classified as La Niña-related. While interludes have spanned 1–59 mo in duration, the most frequently occurring durations are 2–3 mo (36 percent), with 60 percent having durations ≤6 mo. Hence the onset for the anticipated La Niña should be before December 1998 and, perhaps, as early as August–September 1998.

Interestingly, because it is now believed that the 1998 season is classifiable as non-El Niño-related, the subsequent 1999 season may be slightly easier to forecast than the 1998 season, especially, if a long-lasting La Niña begins in late 1998. Recall (from table 1) that the 10 previous La Niña events have had durations that span 7–22 mo, averaging about 13 mo in length. Presuming the onset of the anticipated La Niña to be September 1998, it follows that the event should persist until at least April 1999 (if one assumes a 7-mo duration for the La Niña, the *shortest* duration that has been seen since 1950) and, quite possibly, beyond April 1999. Presuming an *average* duration suggests that the end of the anticipated La Niña would not occur until the fall of 1999 (about September 1999) which, if true, would essentially quell any likelihood that the 1999 season would be El Niño-related. Hence, the next hurricane season seems highly likely to be classified as non-El Niño-related, as well, leading to the possibility that the 1998 and 1999 seasons will see a sharp *increase* in hurricane activity in the Atlantic basin, as compared to the 1997 season when only one intense hurricane was observed. Such behavior would be highly reminiscent of the 1995 and 1996 seasons which were markedly stronger than immediately preceding seasons.[102] Based on the recurrence rate (fig. 2), one really does not expect another onset of El Niño until, probably, after about March 2000 (i.e., April 1997+34 mo), although, conceivably, it could come earlier if, for example, another anomalous El Niño-related period, like the one of 1991–1995, happens to recur (see table 1 and fig. 3).

Concerning this latter remark, it is important to note (from table 1 and fig. 3) that the number of El-Niño-related seasons per decade has increased. For example, during the 1950's 3 of the 10 seasons were El Niño-related, while during the 1960's, 1970's, and 1980's, 4 of the 10 seasons were El Niño-related, and now, during the 1990's, at least 5 are El Niño-related. Additionally, the number of El Niño-related months per decade has sharply increased; i.e., in the 1950's, 31 mo were El Niño-related, while in the 1960's and 1980's, 39 mo were El Niño-related (only 33 mo in the 1970's) and, thus far, in the 1990's 49 mo have been El Niño-related. Perhaps, somehow, these findings are related to "global warming." If true, then El Niño may be expected to occur more frequently and the number of yearly intense hurricanes may be expected to remain below normal.

Conflicting with this notion, however, is the observation that La Niña- and interlude-related years have, in the past, been associated with slightly *warmer* annual mean temperatures at Armagh Observatory in Northern Ireland, a viable proxy for monitoring global change, and the trend now is towards *warmer* temperatures.[66–81] Also, it appears that the return to the more active state (in terms of the frequency of intense hurricanes) may already have taken place,[76, 88, 93] this being especially true if the inferred correlation between annual frequency of intense hurricanes and temperature proves to be legitimate. Hence, instead of an anticipated lull in annual frequency of intense hurricanes, one probably should expect an *increase* in the number of intense hurricanes and, perhaps, fewer El Niño-related seasons (as well as a *lessening* in the drought-like conditions in the African Sahel).[76, 88, 90, 103–105] It is also important to note that other intervals of anomalous El Niño activity have been seen in the past. For example, Quinn et al.[14] previously have emphasized that the frequency of El Niño was considerably higher (with some eight events of near moderate to very strong intensity occurring in the brief span of just 20 yr) during the interval of 1812–1832, a timespan that has been linked with cooler temperatures (i.e., the "Dalton minimum," or "Little Maunder minimum" as it is sometimes called).[82, 106] Thus, the strongly advocated linkage between the increased frequency of El Niño and climatic change (i.e., global warming), perhaps, is unwarranted, since the increased frequency of El Niño in the 1990's may merely be the manifestation of a natural climatic fluctuation.

3. SUMMARY

This investigation corroborates and extends the original findings of Gray[72] that the appearances of El Niño events inhibit the production of Atlantic basin tropical cyclones, in particular, the collective class of intense hurricanes, the most destructive of all hurricanes. When El Niño is present, the number of seasonal intense hurricanes is greatly depressed—always ≤3 per hurricane season, having a *mean* and *mode* of 1.3 and 1, respectively, per hurricane season—whereas, when El Niño is not in vogue, the number usually is higher—typically, ≥2, having a *mean* and *mode* of 2.8 and 2, respectively, per hurricane season and a range of 0–7—the difference in means being statistically important at the 99.8-percent level of confidence. Consequently, an accurate prediction for the number of intense hurricanes in the Atlantic basin during any given season requires precise knowledge about whether or not an El Niño is in progress during the hurricane season. For the 1998 season, because the strongest El Niño of the century (beginning in April 1997) now appears to be over (ending in May 1998) prior to the start of the 1998 hurricane season, it must be classified as non-El Niño-related. Hence ≥2 intense hurricanes probably should be expected (in fact, 2 have already been seen thus far during the 1998 hurricane season). Presuming a Poisson distribution, the probability of having 2±1 events during the current season is 70.7 percent, while it is about 18.5 percent for ≥4 events and only 10.9 percent for no occurrences. Likewise, for the 1999 season, because a La Niña appears imminent for late 1998 (Trenberth, private communication), presuming it to have an average duration of 13 mo implies that the 1999 season probably will also be classified as a non-El Niño-related season (actually, a La Niña-related season). Statistically speaking, another El Niño is not really expected until after the start of the next millennium. Hence both the 1998 and 1999 seasons appear very likely to be more active (a la 1995 and 1996) than what was seen in 1997 which, if it turns out to be true, provides additional evidence for the more active/less active states of Atlantic basin intense hurricane activity and for the return of the more active state of hurricane activity to already have taken place during the present epoch. (In a companion study,[107] the author shows that on the basis of 4- and 10-yr moving averages the long-term trends of the annual frequency of intense hurricanes and Armagh temperatures are statistically related at >>99.9-percent level of confidence, when temperature leads by 6 yr, having a correlation coefficient equal to about 0.90. Because the long-term leading trend of temperature is now *upwards* towards warmer temperatures, beginning about the mid-1980's, the long-term trend of the annual frequency of intense hurricanes should now also be *upwards*, indicative of the more active state, beginning near 1990, being modulated, of course, by the appearances of El Niño.)

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13. ABSTRACT *(Maximum 200 words)*

On the basis of Kevin Trenberth's quantitative definition for marking the occurrence of an El Niño (or La Niña), one can precisely identify by month and year the starts and ends of some 15 El Niño and 10 La Niña events during the interval of 1950–1997, an interval corresponding to the most reliable for cataloguing intense hurricane activity in the Atlantic basin (i.e., those of category 3–5 on the Saffir-Simpson hurricane scale). The main purpose of this investigation is primarily two-fold: First, the statistical aspects of these identified extremes and the intervening periods between them (called "interludes") are examined and, second, the statistics of the seasonal frequency of intense hurricanes in comparison to the extremes and interludes are determined.

This study clearly demonstrates that of the last 48 hurricane seasons, 20 (42 percent) can be described as being "El Niño-related" (i.e., an El Niño was in progress during all, or part, of the yearly hurricane season—June–November), 13 (27 percent) as "La Niña-related" (i.e., a La Niña was in progress during all, or part, of the yearly hurricane season), and 15 (31 percent) as "interlude-related" (i.e., neither an El Niño nor a La Niña was in progress during any portion of the yearly hurricane season). Combining the latter two subgroups into a single grouping called "non-El Niño-related" seasons, one finds that they have had a mean frequency of intense hurricanes measuring 2.3 events per season, while the El Niño-related seasons have had a mean frequency of intense hurricanes measuring 1.3 events per season, where the observed difference in the means is inferred to be statistically important at the 99.8-percent level of confidence. Therefore, as previously shown by William Gray and colleagues more than a decade ago using a different data set, there undeniably exists an El Niño-Atlantic hurricane activity relationship, one which also extends to the class of intense hurricanes. During the interval of 1950–1997, fewer intense hurricanes occurred during El Niño-related seasons (always ≤3 and usually ≤2, this latter value having been true for 18 of the 20 El Niño-related seasons), while more usually occurred during non-El Niño-related seasons (typically ≥2, having been true for 22 of the 28 non-El Niño-related seasons). Implications for the 1998 and 1999 hurricane seasons are discussed.

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