RAINFALL FLUCTUATIONS AND TROPICAL STORM ACTIVITY IN MEXICO

With 2 figures and 6 tables

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Zusammenfassung: Niederschlagsschwankungen und Aktivität tropischer Stürme in Mexiko

In diesem Artikel wird eine mögliche Verbindung zwischen El Niño-Ereignissen und Trockenperioden in Mexiko untersucht. Die Arbeit basiert auf dem von QUINN a. NEAL (1992) veröffentlichten historischen Index von El Niño-Ereignissen und der von FLORESCANO (1980) veröffentlichten historischen Aufstellung von Trockenzeiten in Zentralmexiko seit der Kolonialzeit. Als Ergebnis ist festzuhalten, daß Trockenperioden zwar sehr häufig auftreten (in 233 von 452 aufgenommenen Jahren), aber nur 48 von insgesamt 113 Trockenjahren in Mexiko mit einem El Niño-Ereignis korrespondieren. Betrachtet man jedoch ausschließlich die Periode der letzten 165 Jahre, so ist ein signifikanter Zusammenhang zwischen Trockenzeiten in Mexiko und El Niño-Ereignissen festzuhalten. Die Analyse der Aktivität tropischer Stürme im Bereich des Golf von Mexiko zeigt indes, daß diese in El Niño-Jahren geringer als normal ist. Bei Untersuchung der Auftrittshäufigkeit sowie der Zugbahnen tropischer ostpazifischer Stürme an der mexikanischen Westküste ist hingegen keine erkennbare Veränderung nachzuweisen.

Kontinentübergreifend werden Untersuchungen von GRAY (1990) hinzugezogen, in denen die Ausprägung von Niederschlagsperioden in Westafrika im Zusammenhang mit Hurrikanen im US-amerikanischen Bereich betrachtet wird. In Übereinstimmung mit GRAY (1990) kann eine starke Verbindung zwischen feuchten und trockenen Perioden in Westafrika und Hurrikanen im Bereich des Golf von Mexiko, die ihren Ursprung im atlantisch-karibischen Becken haben, festgestellt werden.

1 Introduction

The climate of Mexico is influenced by the position and strength of the subtropical high pressure systems of the North Atlantic and North East Pacific oceans (near 30° latitude), as well as by the location of the intertropical convergence zone lying to the south of the country. While the moist trade winds prevail during the half year centred in summer, penetrations of polar continental air masses from North America dominate (associated with the subtropical jet stream) during the rest of the year. The effects of the intrusion of cold air are more evident in the highlands of North and Central Mexico, as well as on the coastal plains of the Gulf of Mexico and the Yucatan peninsula. In some areas the arrival of these weather systems is associated with substantial amounts of winter rains i. e. North West Mexico and the north-facing mountains in the isthmus of Tehuantepec. Climate fluctuation studies in Mexico, covering mainly the instrumented period (beginning from the last third of the XIX century), have been attempted in the past decades (WALLEN 1955; KLAUS a. JAUREGUI 1976; JAUREGUI 1979; BYRNE et al 1982).

In these studies the observed climate fluctuations in the various regions of Mexico have been linked to changes in the strength of the general circulation. In other works the main objective has been to assess the long-term variations of weather types (surface and upper air), as in those suggested by MOSIÑO (1963). The changes in the frequency of different types of the well-known polar outbreaks ("Nortes") in the cool season covering the first half of this century have been examined by KLAUS (1973) in relation to the resulting heat exchange. In a previous article (JAUREGUI 1971) an attempt was made to link the frequency of "Nortes" to variations in the strength of the Atlantic zonal index suggested by LAMB (1965). For a review of the subject see METCALFE (1987) and JAUREGUI (1994).

Another possible influence on rainfall fluctuations in Mexico is the near-global scale climatic disturbance associated with the El Niño phenomenon. This is a regional manifestation of the large-scale ocean-atmosphere circulation fluctuation (the Southern Oscillation) brought about by contrasts in sea surface temperature (SST)/pressure/wind along the equatorial Pacific (see QUINN 1987). WRIGHT (1987) has prepared global maps of annual (Apr/May) correlation patterns of pressure, temperature (SST) and precipitation with the annual mean Darwin Island pressure.

El Niño-precipitation relationships have been examined for tropical and extratropical regions (ROPELEWSKI a. HALPERT 1986, 1989). Given the large latitudinal extent of the country in the tropics/subtropics CAVAZOS and HASTENRATH (1990), have explored the role of the Southern Oscillation for various rainfall regimes in Mexico. They found that during the dry season (November–April) the El Niño (low Southern Oscillation index) phenomenon is linked with increased precipitation in most of the country (with the exception of the Isthmus of Tehuantepec). On the other hand, during the rainy season precipitation is more abundant in the high Southern Oscillation (SO) phase, that is, in years without El Niño. Although not showing the highest values, large regions of Mexico appear to be correlated to the El Niño phenomenon in those maps. Using the Tacubaya (Mexico City) (May–Oct) rainfall series for the period 1921–85, MOSIÑO and MORALES (1988) have shown that drought conditions in Central Mexico are probably associated with strong El Niño, whereas moderate Niños favour abundant or normal rains in Central Mexico brought about by a concurrent increase in the number of Eastern Pacific tropical storms. Since, according to these authors, the rainfall in Tacubaya is highly correlated with precipitation in other places in the El Bajio region (Querétaro, Morelia, Guanajuato, San Luis, Aguascalientes), the results they present may be representative of a large portion of Central Mexico. Other regions of Mexico are likely to be related in a different way to moderate/strong El Niño events.

Examining the effect of El Niño on seasonal precipitation in Arizona ANDRADE and SELLERS (1988) show that strong El Niño's impact on that region close to north western Mexico is most pronounced in the normally dry spring and autumn seasons and suggest that precipitation on both seasons is enhanced by the presence of unusually warm waters off the California coast and the west coast of Mexico.

In this paper an attempt is made to explore the link between the El Niño phenomenon and its possible impact on seasonal rainfall anomalies (i. e. droughts) in some regions of Mexico during the historical time that covers the colonial period. The possible association between west African rainfall and the incidence of hurricanes that affect the Mexican coasts of the Gulf of Mexico is also examined.

2 The data

QUINN and NEAL (1992) have obtained the longest possible record of El Niño events from existing historical records. The list of moderate (M), severe (S) and very severe (VS) El Niño events covers the period 1524–1987. Historical records of deficient rainfall periods (i. e. droughts) in Colonial Mexico since the XVIth Century have been published by FLORESCANO (1980). They contain information on the impact of climate on crops and society in certain regions of Mexico. During the XVI and XVII centuries information on droughts were limited to earlier settlements in Central and Southern Mexico. Tropical storm and hurricane trajectories for the period 1961–90 were taken from the Monthly Weather Review.

3 Method

Given the above mentioned historical series, it was considered worthwhile to explore the possible link between deficient rainfall in some parts of Mexico and the El Niño phenomenon through several centuries. As would be expected, some difficulties arise in attempting to look for a teleconnection between the two events. Information on the extent and intensity of drought conditions in colonial times in Mexico is not always geographically well delimited. Moreover, FLORESCANO's (1980) definition of persistent rainfall deficiency was necessarily based on its impact on society (i. e. the price of maize, social unrest, cattle mortality, crop failure) as listed in historical records. QUINN and NEAL's historical record of El Niño, based mainly on the impact of torrential down pours in the normally arid coastal low lands of northern Peru, is perhaps by the nature of its various impacts (i. e. flood soil erosion, red tide, mass mortality of guano birds) a more reliable record. Taking into consideration these limitations, a comparison was made between the two historical series. On the other hand, in order to establish a possible association, records of wet and dry periods in West Africa from 1947 to 1987, taken from GRAY (1990), are compared with the frequency of tropical cyclones (all intensities) that affected Mexican coasts of the Gulf of Mexico and the Caribbean during the same period.

4 Results

Table 1 shows El Niño events (moderate (M), strong (S) and very strong (VS) as listed by QUINN and NEAL (1992) that were coincident with drought conditions in Mexico for the period 1535–1987. The time of occurrence and the character of the drought and its impact are also described in this Table. As may be seen in Table 1 in some cases the rains were scarce during the normally dry spring, or were delayed until July, or rainfall was deficient during a considerable portion of the rainy season. This result is in contrast with MOSIÑO and MORALES' (1987) finding, who concluded that Niños of moderate strength (M) are likely to be related to abundant or normal rains in Central Mexico. This discrepancy may be attributed to the fact that the above-mentioned authors based their correlation analysis only on the precipitation series of Mexico City's observatory (Tacubaya). Dur-

Tabelle 1: El Niño moderate (M), severe (S) and very severe (VS) intensity events (after Quinn a. Neal *1992) and simultaneously observed droughts in Mexico for period 1835–1987*

Mittlere (M), starke (S) und sehr starke (VS) El Niño-Ereignisse (nach Quinn a. Neal 1992) und gleichzeitig beobachtete Trockenzeiten in Mexiko für die Periode 1835–1987

Year	Intensity	Affected region[1)]	Period of reported drought	Drought character	Drought Impact
1535	M +	SEM	May–Jun	drought and locust	loss of crops, hunger, migration
1544	M +	n/s	2 dry months, frost in previous year	scarcity of wheat and corn	hunger
1551–52	S	SEM	6 months		hunger
1589–91	M/S	CM	June	early rains followed by drought	n/s
1618–19	S	CM	July	frequent droughts	crop failure
1624	S +	MB	June	intense drought heat wave	scarcity of grains
1641	S	MB	May–Oct	no spring rains, extreme drought	high prices for grains
1684	M +	EB	n/s	drought	n/s
1692	S	CM	June	n/s	scarcity of water, crop failure, social unrest
1701	S +	CM	June	drought	procession to pray for rains
1707–9	M/S	EB	n/s	drought	n/s
1720	VS	EB	June	drought	cattle loss
1746–47	S +	EB	n/s	drought	cattle loss
1755–56	M	MB	June	water scarcity, heat wave	crop damage
1768	M	EB	n/s	drought	crop decrease, scarcity of grains
1775	S	NEM	July	drought	sheep mortality
1778–79	M +	CM	June	drought	high price for maize
1803–4	S +	CM and Oax.	August	scarcity of rains	cattle loss
1806–7	M	NEM and Yuc.	n/s	scarcity of rains	crop failure, scarcity of grain
1850	M	Durango	n/s	prolonged period of rain scarcity	crop losses
1854	M	CM	n/s	7 year period of rainfall deficiency 1848–1854	n/s
1867–68	M +	NEM, MB Oax., Ver.	May–Jul	generalized severe drought heat waves	crop failure, high price of grains
1877–78	VS	NEM, EB, Ver., MB	n/s	rainfall deficiency	crop failure, scarcity of grains

Year	Intensity	Affected region[1)]	Period of reported drought	Drought character	Drought Impact
1880	M	NWM, EB	Jan-May	extreme drought	n/s
1884	S +	NEM		no rain	scarcity of water, crop failure
1887-89	M/M +	NEM, SEM, CM, NWM	July-Oct	resistant drought since 1886	cattle loss, high price of grains
1891	VS	MC, EB	March-Aug	scarcity of rains	crop failure, high price of grains
1899-1900	S	NEM, SEM, CM	March-Sept	lack of water, deficient rains	crop failure
1902	M +	EB	Apr-May, Jun-Aug	no rain in 3 weeks, scarcity of rains	poor crops
1904-05	M -	CM, NEM Oaxaca	July, Aug-Oct	no rain in 20 days, water scarcity	cattle loss for lack of water
1907	M	NEM, CM	Jan-Sept	no rain since last year, the most persistent drought in years	scarcity of crops, cattle loss, high price of maize
1910	M +	NEM	Sept. until May following year	8 month drought	crop failure
1917	S	NEM, EB, NWM, Jal.	Jun-Dec	persistent drought	scarcity of crops
1923	M	CM, NWM, NEM, EB, Oaxaca	Jun-Aug	lack of rains	poor crops, crop failure in previous years, limited water supply
1925-26	VS	EB, NM, MB, NEM, NWM Veracruz	May-June-July	prolonged intense drought, heat waves	cattle loss, crop failure, unemployment in the fields
1930-31	M	NEM	May	lack of rains	unemployment for lack of water
1932	S	NEM, MC	June	severe drought	crop failure, high price of grains
1939	M +	CM, NEM	Apr-Aug	drought delayed rains	cattle loss for lack of water, limited water supply
1940-41	S	Jalisco, NEM	Apr	intense drought	dry streams
1943	M +	NEM, SEM, NWM, MC	May, Aug	generalized drought	partial loss of crops, cattle loss
1951	M -	NM, NEM	spring	intense drought	limited water supply
1953	M +	NEM, NM	June	drought	loss of cotton crops in NEM
1957-58	S	NM, Oaxaca NEM	spring, Sept	intense drought	unemployment in the fields, partial loss of crops

Year	Intensity	Affected region[1)]	Period of reported drought	Drought character	Drought Impact
1969	M-	NM, CM, MC	Jun-Jul-Aug	prolonged intense drought	cattle loss, crop failure
1972-73	S	NM, EB, NEM	Jul-Oct	drought, heat waves	unemployment, crop loss, infant mortality due to heat wave
1976	M	NM	Apr-Oct	prolonged drought, frosts	limited water supply in Durango, crop failure
1982-83	VS	NEM, CM, Jalisco	n/s	drought	n/s
1987	M	NEM, MB, EB, NWM	n/s	drought	n/s

[1)] Affected region: MC - Most of the country; EB - El Bajio region (central highlands); MB - The Mexico Basin; NEM - North Eastern Mexico; CM - Central Mexico; SEM - South East Mexico; NM - Northern Mexico; NWM - North West Mexico; n/s - not specified

ing this period of 452 years drought conditions were observed in Mexico in 233 years (almost half the time span). Only in 48 years were the droughts observed in Mexico synchronous with an El Niño event (from 113 occurrences), while 59 droughts occurred one or two years before or after El Niño. Taken altogether, 107 droughts in Mexico could possibly be associated with a low index phase of the Sourthern Oscillation. The above results do not provide a clear evidence of a link between the two phenomena.

4.1 Long-term variation

Table 2 illustrates the number of droughts in Mexico by centuries that were coincident with El Niño events. It is interesting to note that from the XVII century on, droughts that were synchronous with El Niño have more than doubled their numbers. The increase could be attributed to improvement in reporting drought in the various regions of Mexico in the last two centuries.

It is worth noting from Table 2 that El Niño events of moderate (M) strength have been most frequently linked to drought conditions in Mexico (followed by the strong (S) El Niño since the eighteenth century. During the present century the number of El Niño (all strengths) coincident with droughts has almost doubled with respect to those observed in the XIX century. This was in spite of the fact that only 87 years of the present century are considered. Again this could be attributed to improvement in information on drought events in Mexico. In view of the results of Table 2, a shorter and more recent period comprising the years from 1822 to 1987 (165 years) was considered. This was in order to eliminate possible uncertainties in the drought historical record of previous centuries.

The number of droughts coincident with El Niño and those separated one, two and three years apart from an El Niño year were calculated. The result is shown in Table 3. It may be readily seen that instead of an even distribution, as would be expected, the highest frequency of droughts (29) occurs in El Niño years, decreasing almost symmetrically when 1 to 3 years before or after the El Niño event are considered. The Chi-square test reveals that the distribution of droughts observed in Mexico during 1822-1987, as shown in Table 3, was affected by the El Niño events at the 0.001 level of significance. Moreover, when applying the t-student test the observed maximum frequency of droughts in an El Niño year is also found to be significant at 0.001. The above results suggest that for the period under consideration drought conditions in regions of Mexico seem to be linked significantly to the El Niño phenomenon.

Tabelle 2: Number of droughts in Mexico by century that were synchronous with an El Niño event; period 1535-1987

Nach Jahrhunderten geordnete Anzahl der Trockenzeiten in Mexiko, die mit einem El-Niño-Ereignis zusammenfallen; Periode 1535-1987

Intensity	1535-1599	1600-1699	1700-1799	1800-1899	1900-1987
M, M+	2	1	4	5	13
S, S+	2	4	3	3	4
VS	0	0	1	2	2
Total sum	4	5	8	10	19

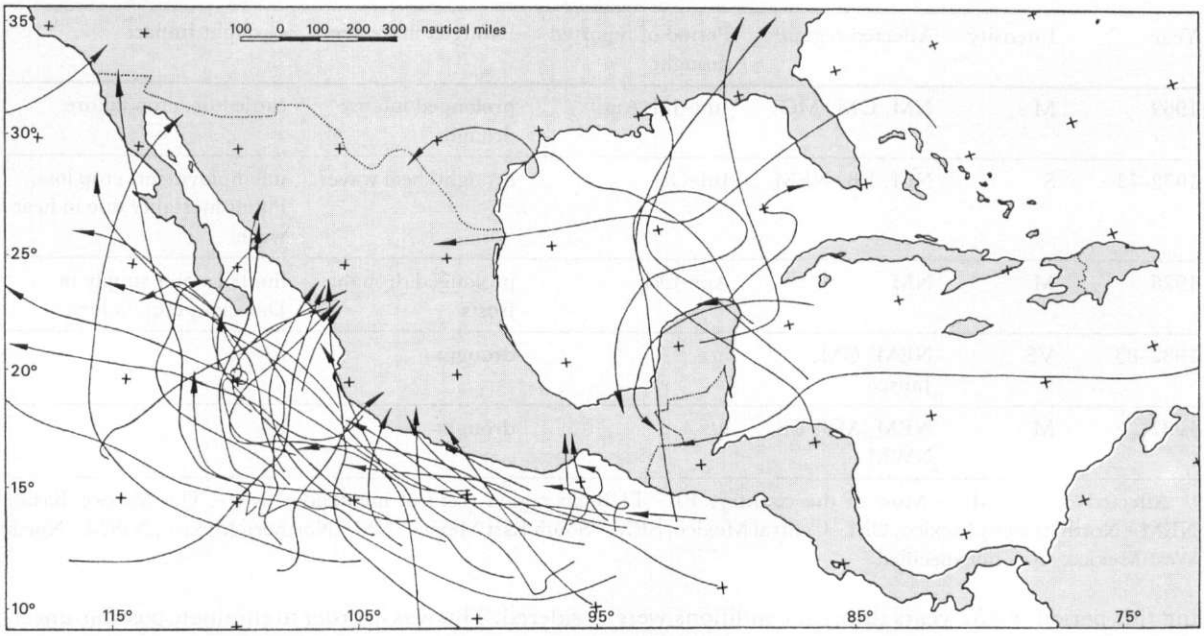

Fig. 1. Trajectories of Tropical Storms and Hurricanes that affected Mexico during El Niño years; period 1961–1990

Zugbahnen tropischer Stürme und Hurrikane, die sich auf Mexiko in El Niño-Jahren ausgewirkt haben; Periode 1961–1990

Tabelle 3: Frequency of droughts that occurred in Mexico during (0), before (–) and after (+) one, two and three years of an El Niño event for period 1822–1987

Häufigkeiten von Trockenzeiten, die in Mexiko während (0), vor (–) und nach (+) ein, zwei und drei Jahren eines El Niño-Ereignisses auftraten, für die Periode 1922–1987

	–3	–2	–1	0	+1	+2	+3	sum
Number of events	3	7	13	29	12	6	2	72
Frequency (%)	4	10	18	40	17	8	3	

4.2 The El Niño phenomenon and tropical storm activity in Mexico

Examining relationships between precipitation and the high index phase of the Southern Oscillation (SO) for 19 regions of the globe, Ropelweski and Halpert (1989) found that in years without El Niño precipitation was less than median in northern Mexico (for the dry season), whereas on the other hand, Gray (1984) found a slightly greater activity than normal for Atlantic tropical storms during non-El Niño (high SO index) years.

Gray (1984) suggests that the sea-surface temperature (SST) warming events associated with El Niño reduce hurricane activity in the western Atlantic during the season following the onset of the El Niño event. After the second summer following the El Niño hurricane activity returns to normal according to this author. The enhanced convection in the Eastern Pacific warm waters during an ENSO event seems to be associated with strong upper tropospheric westerlies over the Caribbean and equatorial Atlantic. Gray (1984) believes that this condition is probably the major cause for the reduction in hurricane activity in that region.

It may be seen from Figure 1 that during El Niño years few tropical storms and hurricanes affected the western portions of the Gulf of Mexico, as opposed to years without El Niño, which were characterized by larger numbers of such storms penetrating deep into the Gulf as illustrated by Figure 2. Comparing hurricane tracks in Figures 1 and 2, no apparent change in the number or in the trajectories is evident for Eastern pacific tropical storms and hurricanes that affect Mexico in years with El Niño with respect to years without El Niño.

It may be appreciated from Table 4 that, while the average number of tropical storms/hurricanes during El Niño years in the Atlantic is 71% of those observed during non-El Niño years, the corresponding proportion for the eastern North Pacific is 93%. This means that the effect of El Niño seems to influence tropical storm activity on both oceans, although this effect is apparently less marked in the Pacific. How-

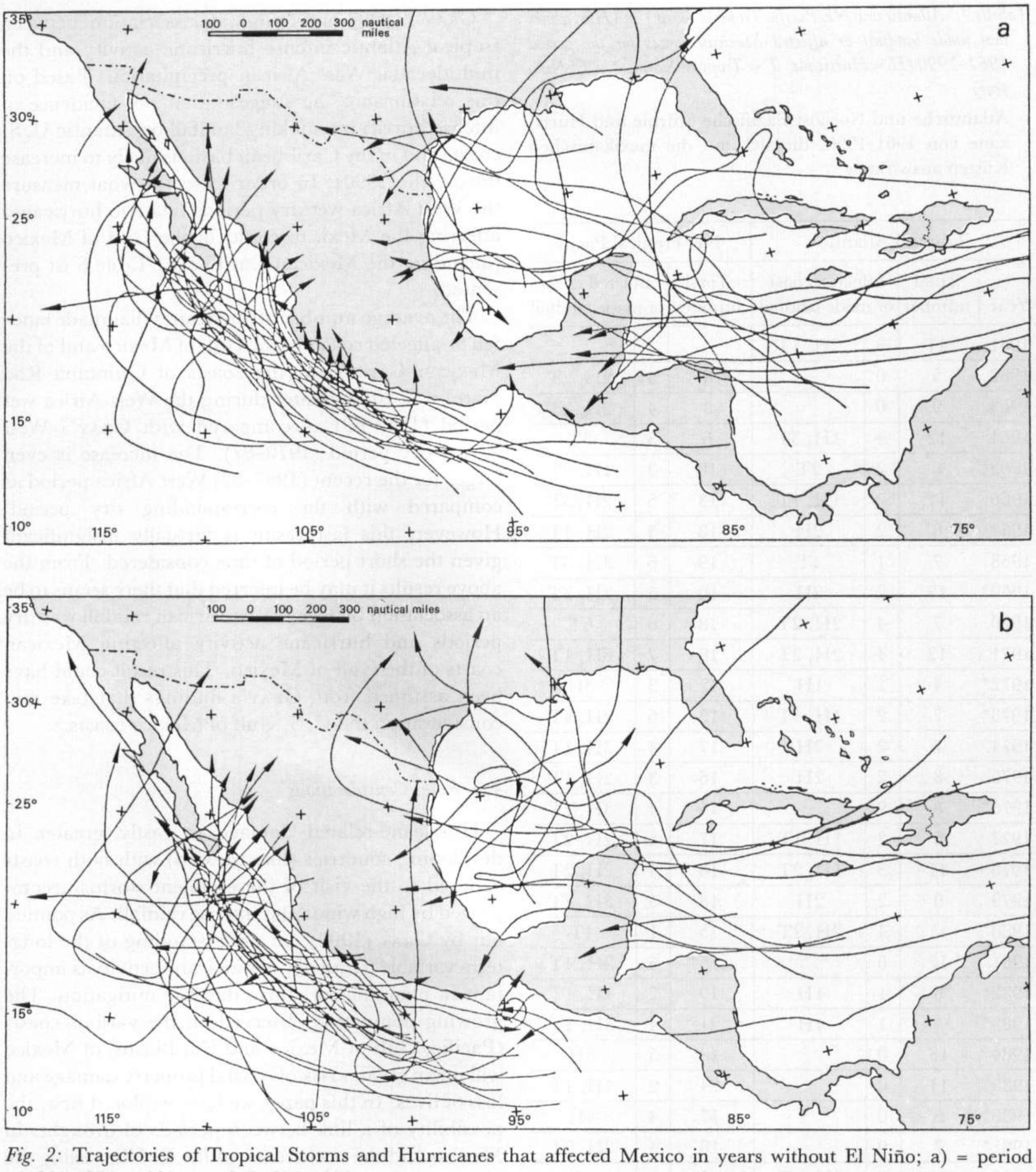

Fig. 2: Trajectories of Tropical Storms and Hurricanes that affected Mexico in years without El Niño; a) = period 1961–1974 and b) = period 1975–1990

Zugbahnen tropischer Stürme und Hurrikane, die sich auf Mexiko in Nicht-El Niño-Jahren ausgewirkt haben

ever, when we consider only those storms that made landfall or affected (to less than 100 nm) Mexican coasts, the reduction in the number of storms during El Niño years is more marked (to 42%) in the Atlantic and (to 36%) in the Pacific as compared with activity during non-El Niño years.

When only the frequency of hurricanes is considered in the statistics the reduction of these intense storms in El Niño years is 62% on the Gulf of Mexico, while, as illustrated in Table 5, on the average no apparent change in the number of hurricanes that affect the Pacific coasts of Mexico is evident.

*Tabelle 4: Atlantic and NE Pacific Tropical Storms and Hurricanes that made landfall or affected Mexican coasts for the period 1961–1990 (H = Hurricane, T = Tropical Storm, * = El Niño year)*

Atlantische und Nordost-Pazifische Stürme und Hurrikane von 1961–1990, die sich auf die mexikanischen Küsten auswirkten

	Tropical Atlantic			NE Tropical Pacific		
Year	Total number	affected coast or made landfall		Total number	affected coast or made landfall	
1961	11	3	2H, 1T			
1962	5	0		8	4	2H, 2T
1963	9	0		8	4	2H, 2T
1964	12	4	1H, 3T	6	3	3T
1965*	6	2	2T	10	3	1H, 2T
1966	11	2	1H, 1T	13	5	2H, 3T
1967	8	2	2H	18	3	2H, 1T
1968	7	1	1T	19	6	3H, 3T
1969*	13	2	2H	10	5	2H, 3T
1970	7	4	2H, 2T	18	6	6T
1971	12	4	2H, 2T	18	7	6H, 1T
1972*	4	1	1H	12	3	3H
1973*	7	2	1H, 1T	12	6	2H, 4T
1974	7	2	2H	17	4	3H, 1T
1975	8	2	2H	16	3	2H, 1T
1976*	8	9		14	4	3H, 1T
1977	6	2	1H, 1T	17	4	2H, 2T
1978	11	3	1H, 2T	18	4	2H, 2T
1979	9	2	2H	13	5	3H, 2T
1980	11	4	2H, 2T	15	1	1T
1981	12	0		15	6	2H, 4T
1982*	6	1	1H	19	2	1H, 1T
1983*	4	1	1H	21	4	3H, 1T
1984	13	0		18	5	5H
1985	11	0		24	2	1H, 1T
1986	6	0		17	4	4H
1987*	7	0		18	4	2H, 2T
1988	12	5	4H, 1T	13	4	4T
1989	11	2	2H	17	4	3H, 1T
1990	14	1	1H	20	2	2T
1)	213	43	28H, 16T	328	86	44H, 42T
2)	55	18	6H, 3T	116	31	17H, 14T
3)	9.7	2.0	1.3H, 0.7T	15.62	4.1	2.1H,2T
4)	6.9	2.3	0.8H, 0.4T	14.5	3.9	2.1H, 1.8T

1) total non-El Niño; 2) total El Niño

3) Average/yr non El Niño year; 4) Average/yr El Niño year

GRAY (1990) has found an association between tropical Atlantic intense hurricane activity and the multidecadal West African precipitation. Based on this relationship, he suggests that the incidence of intense hurricanes making landfall on Atlantic U. S. coasts and in the Caribbean basin is likely to increase during the 1990s. In order to see in what measure the West Africa wet/dry periods relate to hurricanes affecting the Mexican coasts of the Gulf of Mexico (including the Mexican Caribbean) Table 6 ist presented.

The average number of hurricanes that made landfall or affected coasts of the Gulf of Mexico and of the Mexican Caribbean (the coasts of Quintana Roo State) was 20% greater during the West Africa wet period (1947–69) as compared with GRAY's West Africa dry period (1970–87). The increase is even larger for the recent (1987–88) West Africa period as compared with the corresponding dry period. However, this last result is virtually insignificant given the short period of time considered. From the above results it may be inferred that there seems to be an association between West African rainfall wet/dry periods and hurricane activity affecting Mexican coasts of the Gulf of Mexico. This result could have been assumed from GRAY's findings that take into consideration the U. S. Gulf of Mexico coasts.

4.3 Final Considerations

Hurricane-related damage is vastly greater in developing countries (like Mexico) with both coasts exposed to the visit of these violent storms accompanied by high winds and intense rainfall. As pointed out by GRAY (1990), an understanding of the long-term variable frequency of hurricane activity is important in planning for storm damage mitigation. The growing population observed on the various coasts (Pacific, Gulf of Mexico and Caribbean) of Mexico will mean greater risk of coastal property damage and loss of lives. In this paper we have explored first, the possibility of a link between periods of droughts in Mexico and the occurrence of the El Niño using the historical proxy data series covering the historical period and second, the influence of the El Niño phenomenon on hurricane activity affecting Mexican coasts. Analysis of long-term (period 1822–1897) historical series of droughts in Mexico and El Niño shows a significant link between deficient rainfall conditions in Mexico and the El Niño phenomenon. Moreover, it is clear from the above results that tropical storm activity affecting Mexican coasts is weaker than normal in years with El Niño. Clearly

Tabelle 5: Frequency of Hurricanes that made landfall or affected coasts in Mexico for El Niño years and for non-El Niño years in the period 1961–1990

Häufigkeiten von Hurrikanen, die sich von 1961–1990 auf die mexikanischen Küsten auswirkten

	Non El Niño			El Niño			Ratio
	Total	Number of years	Avg./yr (1)	Total	Number of years	Avg./yr (2)	(2)/(1)
Gulf of Mexico and Caribbean	28	22	1.3	6	8	0.8	0.62
NE Pacific	44	21	2.1	17	8	2.1	1.0

Tabelle 6: Summary of statistics of annual incidence of hurricanes that made landfall or affected Mexican coasts on the Gulf of Mexico Caribbean for GRAY's (1990) West African wet/dry periods

Zusammenfassung der Statistiken jährlicher Hurrikanvorkommen, die die mexikanischen Küsten im Bereich des Golf von Mexiko betrafen für GRAYS (1990) westafrikanische feucht/trocken-Perioden

	1947–69 wet years in W. Africa (1)	1970–87 dry years in W. Africa (2)	1988–89 wet years in W. Africa (3)	wet/dry (1)/(2)	wet/dry (3)/(2)
Total Number of hurricanes Atlantic basin	146	86	12		
Average number per year	6.3	4.8	6.0	1.3	1.2
Total number that made landfall/affected Mexican coasts	30	19	6		
Average number/yr	1.3	1.1	3.0	1.2	2.7

other factors affect rainfall conditions in Mexico, such as basic changes in the large-scale global circulation patterns as have been reviewed by Jauregui (1995).

GRAY (1990) suggests that the annual frequency of intense Atlantic hurricanes (categories 3, 4, 5 as defined by the Saffir-Simpson intensity scale) is associated with rainfall patterns in West Africa. He has observed that seasonal frequency and lengths of tracks of intense category hurricanes was substantially greater during the period 1947–1969 when West African precipitation was above normal by comparison with that of the 18-year period of 1970–1987, when drought conditions prevailed in the Western Sahel. The apparent recent breaking of the 18-year Sahel drought during 1988–1989 suggests that the incidence of intense hurricanes making landfall in the U. S. coast and the Caribbean basin (including the Gulf of Mexico) is likely to increase during the 1990s according to GRAY. If GRAY's findings prove to be true, long-track intense hurricanes making a landfall on Mexican coasts of the Gulf of Mexico are also likely to be more frequent in the coming non-El Niño years.

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