ENSO and Precipitation Variability Over Mexico During the Last 90 Years

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Latin America has been shown to be susceptible to climatic anomalies during El Niño/Southern Oscillation (ENSO) events (*eg*, Aceituno 1988; Ropelewski and Halpert 1987; Kiladis and Diaz 1989). While these studies have emphasized ENSO-related rainfall and temperature anomalies over Central and South America, less work has been done on the climatic effects of ENSO over the Mexican region.

In this study we are investigating interannual and intraseasonal fluctuations in temperature and precipitation over the southwestern United States and Mexico since the turn of the century. We are particularly interested in the effects of ENSO on the interannual variability over this region. This report focuses on the association between ENSO and interannual variability of precipitation over Mexico.

Data and Methodology

We use a station network of records from the Global Historical Climatology Network, obtained from the National Climate Data Center in Asheville, North Carolina. These data are in monthly summary format and start in January 1900. Much of the temperature and precipitation data for Mexico obtained in this set was compiled and quality checked by Douglas (1982) from archived sources in Mexico.

The station data were interpolated to a regular latitude/longitude grid at 2.5-degree spacing (Figure 1). Climatic regions were determined based on an analysis of the seasonal cycle in precipitation over the study region (see Diaz and Brown, this volume). First an R-mode principal component analysis was performed using the 1900-1988 monthly mean precipitation at each gridpoint. Loadings from the first two eigenvectors of the monthly mean precipitation were then used as input into a K-means cluster analysis (Hartigan 1975) to group the gridpoints. In general, the amplitude and phase of the first two harmonics of the long-term mean seasonal cycle determine the first two eigenvectors, thus stations are grouped on the basis of similarity to their neighboring gridpoints. The climatic regions obtained are shown in Figure 1. It should be emphasized that these regions are not grouped on the basis of their coherent fluctuation over time, but only on the basis of similarity of their mean seasonal cycles.

In: K.T. Redmond and V.L. Tharp, Editors. 1993. Proceedings of the Ninth Annual Pacific Climate (PACLIM) Workshop, April 21-24, 1992. California Department of Water Resources, Interagency Ecological Studies Program, Technical Report 34.

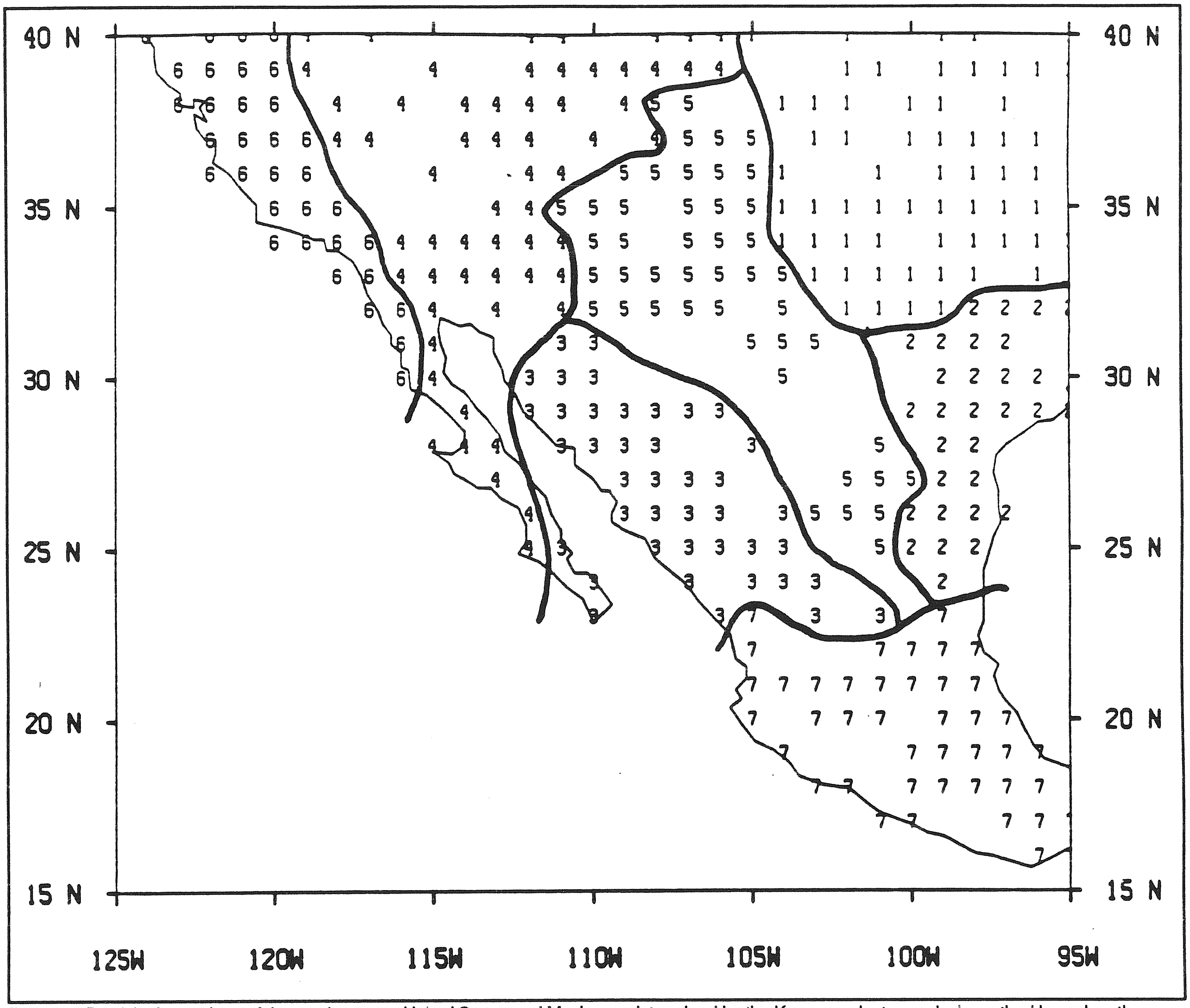

Figure 1. Precipitation regions of the southwestern United States and Mexico as determined by the K-means cluster analysis method based on the seasonal cycle of gridded precipitation data.

1 Southern Plains
2 Gulf Coastal
3 Sierra Madre
4 Sonora
5 Chihuahua
6 Pacific
7 Southern Mexico

Seven climate regions are defined using this technique. For example, the Pacific region (area 6) has a winter precipitation maximum and a summer minimum. The southern Mexico region (area 7) has a monsoon type climate, with maximum precipitation in May-September and a minimum in January. The Sierra Madre region (area 3) has a bimodal precipitation regime, with a main monsoonal maximum in July-August and a secondary maximum during December-January, when this region is affected by low latitude disturbances in the subtropical westerly flow from the Pacific. Precipitation over the southern Mexico and Sierra Madre divisions appears to be significantly modulated by ENSO conditions in the tropics and is the focus of this discussion.

Extreme ENSO years in Table 1 were taken from Kiladis and Diaz (1989) and are based on a combination of a sea surface temperature (SST) index and the Southern Oscillation Index (SOI). The SST index represents the integrated seasonal SST anomaly within 4 degrees of the equator from 160°W to the South American coast, based on COADS ship data. The SOI is the standard normalized Tahiti minus Darwin pressure index, which is a measure of the strength of the sea level pressure signal associated with ENSO (Ropelewski and Jones 1987). To qualify as an event, the SST anomaly had to be positive for at least three consecutive seasons, and be at least 0.5°C above the mean for at least one of these seasons, while the seasonal SOI had to remain below –1.0 for the same duration.

Table 1
LIST OF YEAR ZEROS OF WARM AND COLD EVENTS
(From Kiladis and Diaz 1989)

Warm Events		Cold Events	
1902	1953	1903	1942
1904	1957	1906	1949
1911	1963	1908	1954
1913	1965	1916	1964
1918	1969	1920	1970
1923	1972	1924	1973
1925	1976	1928	1975
1930	1982	1931	1988
1932	1986	1938	
1939	1991		
1951			

The warm event (El Niño) years shown in Table 1 are called year zero of the events, and are defined, as in Rasmusson and Carpenter (1982), as the year when the SOI changes sign from positive to negative, and when central and eastern equatorial Pacific SST anomalies become strongly positive. Cold event (La Niña) year zeros are defined as having the opposite characteristics. Thus we have included only the first year of multiyear events and ignored successive years, regardless of their magnitudes. Year+1 refers to the year following the start of the event, when remote ENSO teleconnections tend to be maximized.

Results

Figure 2 shows a superposed epoch analysis of year 0 through year+1 warm and cold event precipitation anomalies for the Sierra Madre region. These two time series were obtained by averaging the integrated Sierra Madre monthly precipitation anomalies (in millimeters) for all warm event years and then for all cold event years separately, then smoothing the respective composite series with a 3-month running mean (see Bradley *et al* 1987). The plot shows that summer monsoon precipitation over the western plateau of Mexico is not strongly affected by ENSO, but that, on average, late fall and early winter precipitation is above normal during

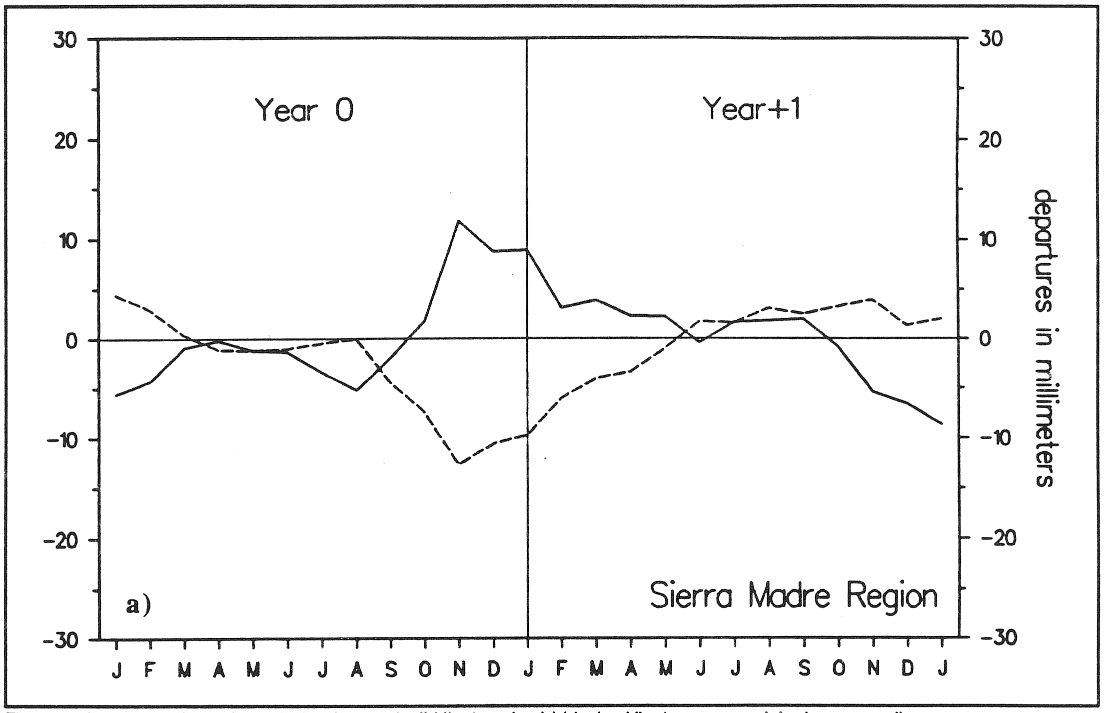

Figure 2. Superposed epoch analysis of warm (solid line) and cold (dashed line) event precipitation anomalies in the Sierra Madre region.

The anomalies have been smoothed by applying a 3-month running mean to the original monthly mean data. Warm and cold event years were taken from Table 1.

warm events and below normal during cold events. This signal reflects a strengthening of the subtropical westerly circulation tied to anomalously strong warm event convection in the equatorial Pacific. Not surprisingly, this particular signal is shared by the Sonora, Chihuahua, and Gulf coast divisions (not shown), which are also under the influence of a strengthened subtropical jet during warm events and a weakened jet during cold events. Although the 1991-92 warm event winter season was not included in the composite, this was an excellent example of this signal, with extremely high precipitation in the northern desert of Mexico, the southwestern United States, and Texas.

The magnitude of monthly anomalies for the Sierra Madre barely exceeds 10 mm per month at most, which is not a large amount of precipitation, but this region is normally quite dry during November through March, averaging less than 25 mm per month. Thus the ENSO signal can account for a substantial portion of the variance in precipitation during winter and, in fact, is responsible for many of the extreme precipitation events during this time of year. This is illustrated in Figure 3a, where individual November-March precipitation departures from the mean are plotted from 1900 through 1988. The winter Sierra Madre precipitation has a consistent ENSO signal, such that nearly all warm events are associated with above-normal precipitation and, without exception, cold events are characterized by below-normal precipitation. What's more, many of the extremely wet winters in the Sierra Madre occurred in association with warm events.

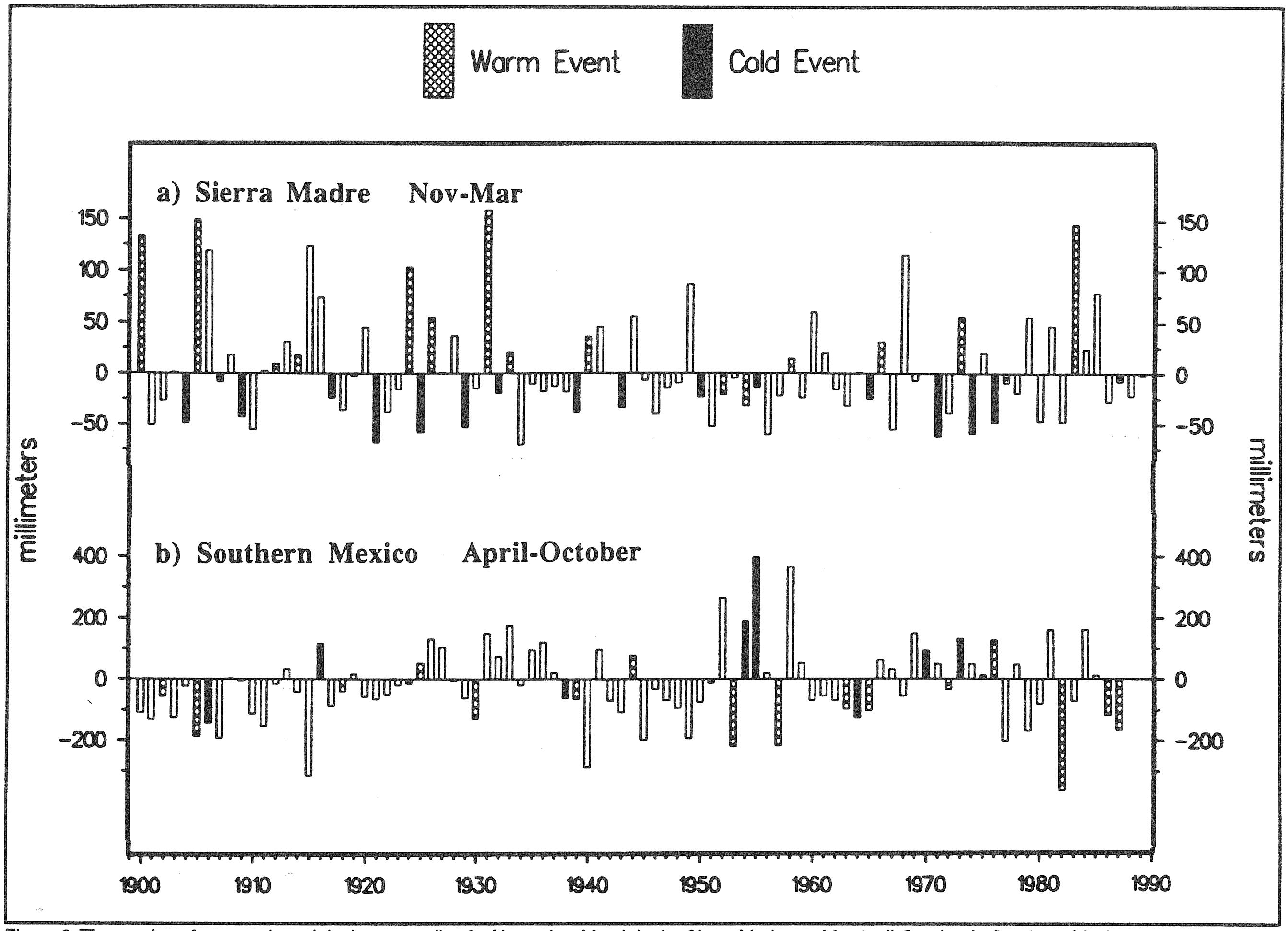

Figure 3. Time series of seasonal precipitation anomalies for November-March in the Sierra Madre and for April-October in Southern Mexico. Departures are in millimeters/season.
The years in (a) are plotted according to the year zeros listed in Table 1 and refer to the year in which November falls. Warm and cold years in (b) are listed in Table 2.

Similar plots (not shown) were constructed for the southern Mexico region, using the warm and cold event years from Table 1. These plots showed that warm events were, on average, drier than normal and cold events were wetter than normal over southern Mexico; however, the consistency of the signal between events was less impressive than that for the Sierra Madre. We believe the source of this unreliability between ENSO and precipitation over southern Mexico is due to the irregular timing of ENSO onset between events during year 0. Because warm and cold event onset can often occur late in the calendar year (see Fu *et al* 1986), many year 0 designations in Table 1 likely were not necessarily associated with anomalously high SST and convection in the eastern Pacific.

With this in mind, we decided to look at monsoon precipitation during periods of anomalous SST over the central and eastern equatorial Pacific, regardless of whether a year was classified as a warm or cold event as defined by the criteria above. June through August seasons when the integrated SST index described above was greater than 0.8°C or less than −0.8°C were chosen for this analysis. These years are given in Table 2.

Table 2
MONSOON SEASONS OF EXTREME SEA SURFACE TEMPERATURE IN THE EASTERN EQUATORIAL PACIFIC

Integrated June-August SST anomaly from 160°W-90°W greater than 0.8°C or less than −0.8°C.

Warm SST		Cold SST	
1902	1957	1906	1955
1905	1963	1909	1964
1918	1965	1916	1970
1925	1972	1924	1973
1930	1976	1938	1975
1939	1982	1954	1988
1944	1986		
1951	1987		
1953			

Figure 4 shows a superposed epoch plot for April-October southern Mexico precipitation, using the above- and below-normal SST years from Table 2. These show clearly the tendency for precipitation to be deficient during periods of high SST from about April through October of year 0, followed by slightly above-average precipitation until February. Cold SST events show nearly opposite characteristics for a similar period.

The consistency of the southern Mexican precipitation signal to Pacific SST is shown in Figure 3b, where high monsoon season SST is coded as "warm event" and low SST as "cold event". Of 17 warm SST years, 14 had below-normal precipitation, while 8 of 12 cold SST years had above-normal precipitation — anomalies consistent with the composite signal in Figure 4.

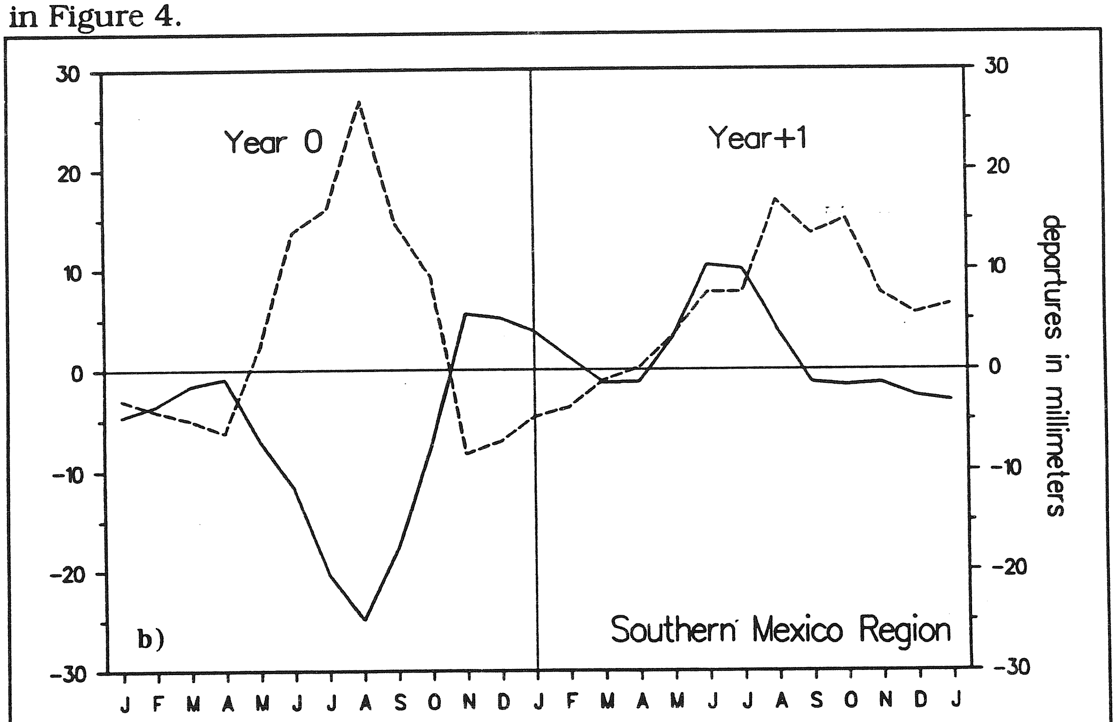

Figure 4. Superposed epoch analysis of warm (solid line) and cold (dashed line) event precipitation anomalies in the Southern Mexico region.
The anomalies have been smoothed by applying a 3-month running mean to the original monthly mean data. Warm and cold event years were taken from Table 2.

Summary

Both warm and cold ENSO events have a detectable influence on precipitation over Mexico, although the effect varies for different parts of the country. In the "composite" warm event, the Sierra Madre (and, as it turns out, the whole of north-central Mexico) receives higher-than-normal amounts of precipitation during winter, a signal that is in phase with that over the southeastern United States. This is related to a more active subtropical flow, induced by anomalously strong equatorial convection over the eastern Pacific. During June through August periods of anomalously high SST in the eastern equatorial Pacific, a condition presumably related to active convection in that region, the monsoon rainfall over southern Mexico tends to be weaker than normal. This is likely related to the southward displacement of ITCZ convection over the warmer-than-normal ocean to the south and west of Mexico (*eg*, Douglas 1982). Cold events tend to be characterized by opposite patterns. These signals are fairly robust in that anomalies during most individual events share the same sign as the composite events.

It should be emphasized that, as opposed to the Sierra Madre region, the anomaly amounts over southern Mexico are not large with respect to the total climatological precipitation over this region. On average during April through October, the warm SST years had 88 mm less precipitation than the mean, while cold SST years averaged only 73 mm above the mean, compared to a mean seasonal precipitation of 1175 mm. Thus, while the signal is consistent and individual years can have significant departures related to SST (*eg*, 1953, 1957, 1982 warm years; 1954, 1955 cold years), the net effect of ENSO on monsoon precipitation and agriculture over southern Mexico would appear to be negligible in most cases, with only the most extreme events (such as 1982-83) having a more significant impact.

Acknowledgments

This work is funded by NOAA's Climate and Global Change Program. We thank Jon Eischeid for graphics and data support.

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