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INTERANNUAL VARIABILITY OF NEAR-COASTAL EASTERN PACIFIC TROPICAL CYCLONES

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1. INTRODUCTION

Pacific tropical cyclones are a significant factor in the summer precipitation regime across southwestern North America. The necessary climatic ingredients for such storms: warm ocean temperatures, modest shear, and incipient disturbances to facilitate cyclogenesis are generally present in the northeastern tropical Pacific during the warm season. Consideration of tropical cyclone activity should therefore be part of more general efforts to improve seasonal prediction of summer rainfall in the North American monsoon region.

In this paper we describe the interannual variability of tropical storm counts in the eastern North Pacific Ocean. Although individual storms are inherently unpredictable months in advance, it is possible that the aggregate monthly/seasonal storm activity may be predictable. Slow fluctuations of the ocean provide the physical basis for such potential predictability, so we examine the statistics of tropical storm counts for possible modulation by ENSO and decadal oceanic modes of variability.

2. EASTERN PACIFIC OCEAN TROPICAL STORM AND TEMPERATURE DATA

Lewis (2003) reconstructed the tracks of tropical storms, including disturbances of depression and cyclone strength, in the northeastern Pacific Ocean since 1921. His census was based on examination of individual storm track data from a variety of U.S. and Mexican data sources. The present study is based on the subset of storms that tracked near the west coast of North America, defined as the region east of 110°W and north of 15°N. The number of such storms each month during the May-November storm season is used as an index of tropical storm activity. The seasonal and interannual variability of this index is the focus of this study.

Monthly near-coastal storm counts are compared with the monthly Niño3 SST index, obtained from the NOAA Climate Prediction Center. Niño3 is the monthly mean near-equatorial SST averaged between 5°S-5°N latitude and 150°W-90°W longitude. Niño3 was chosen to represent ENSO variability for this study, rather than other ENSO indices based on equatorial regions farther west, because describes SST index directly south of the Mexican coast affected by near-coastal storms.

Previous analyses of ENSO and rainfall variability (e.g. Englehart and Douglas 2001; Gutzler 2004) have found that statistics of interannual variability change before and after 1977, when Pacific Ocean temperatures and circulation underwent a pronounced shift (Mantua et al. 1997). We therefore examine relationships between SST and tropical storm counts for separate periods before and after 1977.

After examining the relationship between SST and near-coastal tropical storms, we consider the interannual covariability of storm counts and continental rainfall variability. The dynamics of tropical storms are very different from monsoon dynamics, so attempts to understand (and predict) seasonal anomalies in summer rainfall must distinguish precipitation generated by "monsoonal" processes from precipitation produced by tropical storms. Englehart and Douglas (2001) estimated the fraction of total summertime rainfall in Mexico attributable to tropical cyclones. To complement their results, we will examine the covariability of seasonal near-coastal tropical storm counts with the seasonal rainfall in monsoonal regions defined by Gutzler (2004). These regions were derived from an EOF analysis of summertime interannual rainfall variability across southwest North America.

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3. INTERANNUAL VARIABILITY OF NEAR-COASTAL TROPICAL PACIFIC STORMS

The seven-month tropical storm season begins in May each year, with a broad average seasonal maximum of near-coastal storms from July-September followed by a rapid dropoff (Serra 1971; Lewis 2003). The annual average number of near-coastal storms is 8.8, and the annual count of storms ranged from 4 to 12 during the 45-year period of record (Fig. 1). A very slight annual average decrease (from 8.9 to 8.5 storms/year, a difference of marginal statistical significance) is associated with the 1977 PDO shift.

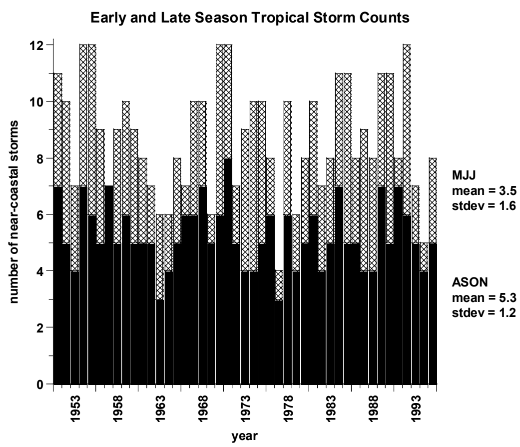

Fig. 1. Time series of near-coastal tropical storm counts along the Pacific coast of North America. The hatched bars represent the Early phase of the season, defined here as May-Jul (denoted MJJ). Solid bars represent the Late phase of the storm season, defined here as Aug-Nov (denoted ASON). Note that the interannual variability of MJJ storm counts is greater than the variability of ASON storm counts, despite the larger mean number of storms in the Late phase.

The interannual variability of storm counts is not evenly distributed over the May-November season. Storm counts are more variable from year to year during the early months of the season (Fig. 1). Splitting the storm season into an Early phase (May-Jul, MJJ) and a Late phase (Aug-Nov, ASON), Fig. 1 shows that the standard deviation of annual storm counts is considerably larger in the Early phase, despite the smaller mean number of near-coastal storms during this phase compared to the later phase. There is no significant intra-annual lag correlation between the number of near-coastal storms in MJJ and ASON each year, so the storm count in the Early phase provides no indication (hence no statistical predictability) of the storm count in the later months, during the peak of the tropical storm season.

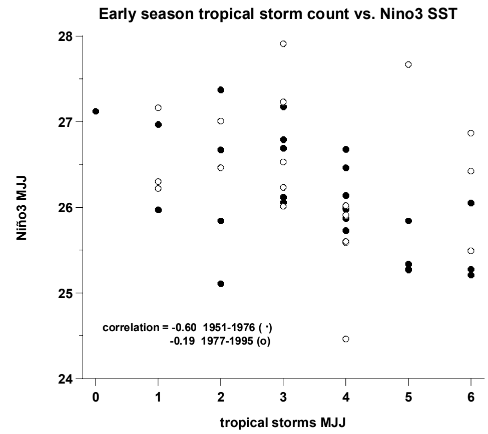

Fig. 2. Scatter plot of the annual numbers of near-coastal tropical storms in MJJ vs. contemporaneous Niño3 SST. Data points for 1951-1976 years are solid circles; open circles are for years between 1977 and 1995, after the PDO shift to warmer temperatures in the tropical Pacific. Correlation for the entire period of record is -0.50; correlation based on just the 1951-1977 period is -0.60.

Interannual variability of near-coastal storm counts is significantly negatively correlated with Niño3 SST in the Early season, when interannual variability of storm counts is largest. Over the entire 45-year period of record the correlation between Niño3 and storm count in MJJ is -0.50, easily significant assuming one dof/year. Most of this relationship comes from the pre-1977 part of the record (Fig. 2), when equatorial SST was significantly colder. Correlations between Niño3 and ASON storm counts are not significant over the entire period of record, a result not sensitive to PDO phase. Thus neither ENSO phase nor Early season storm count provides a basis for a simple statistical prediction of late summer/autumn anomalies of the near-coastal tropical storm count.

Interannual variability of tropical storm counts was correlated with each of the coherent regions of continental rainfall identified by Gutzler (2004), for both the "Early" warm season (mid-May through June) and the "Late" season (July-mid September) identified in that paper. For comparison these two halves of the warm season were compared with May-June (MJ) and July-Sept

(JAS) near-coastal tropical storm counts. The principal relationship emerging from this analysis involved rainfall in a region of west-central Mexico including the states of Nayarit, Jalisco, and southern Sinaloa. This region emerged in separate EOF analyses as mode 1 in the Early season, and mode 2 in the Late season.

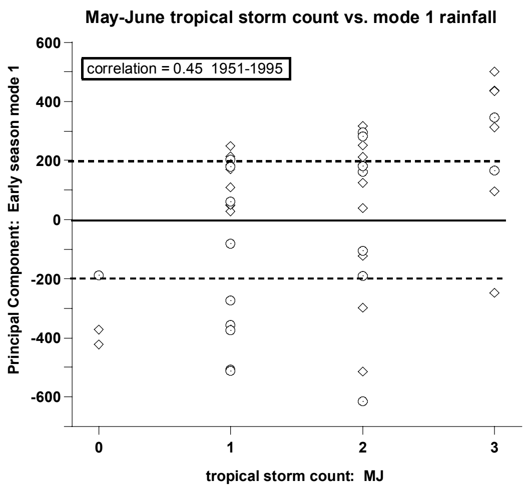

Fig. 3. Scatter plot of the annual numbers of near-coastal storms in May-June vs. principal component of rainfall in coastal states of western Mexico (derived from of an EOF analysis of interannual variability of southwest North American rainfall from May 15-Jul 3, the "Early" monsoon season defined by Gutzler 2004). Data points for 1951-1976 years are diamonds; open circles are for years between 1977 and 1995. Correlation for the entire period of record is 0.45; this value does not change significantly in association with the 1977 PDO shift.

In the early season, the linear correlation coefficient between mode 1 rainfall and MJ storm count was about 0.45 for the entire period of record, or for either pre- or post-1977 epochs. A scatter plot of the MJ storm count vs. the Early season principal component of mode 1 shows that much of this correlation is associated with years of either the lowest or high MJ storm counts (Fig. 3). Each of the three years with no storms in May or June corresponded to rainfall well below average in the mode 1 region. At the other extreme, eight of the nine MJ seasons with three tropical storms corresponded to above average rainfall in the mode 1 region. However, 1 or 2 storms occurred during most MJ seasons and these years exhibited little correspondence between storm counts and rainfall anomalies across west-central Mexico, including several years with less Early season rainfall than any of the three years with no near-coastal storms in May or June.

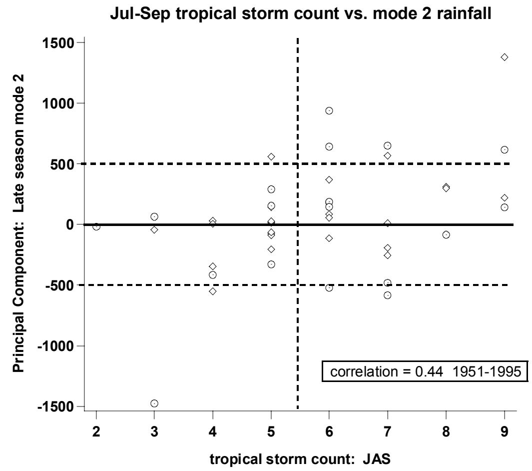

Fig. 4. Scatter plot of the annual numbers of near-coastal storms in Jul-Sep vs. principal component of rainfall in coastal states of western Mexico (as in Fig. 3, but for the "Late" monsoon season defined by Gutzler 2004). Data points for 1951-1976 years are diamonds; open circles are for years between 1977 and 1995. Correlation for the entire period of record is 0.44; this value does not change significantly in association with the 1977 PDO shift.

A very similar positive linear correlation (0.44) exists between JAS storm counts and the Late season rainfall of mode 2, corresponding to nearly the same region as mode 1 of the Early season (Fig. 4). The scatter plot for this relationship shows that much of the correlation is associated with high seasonal storm counts and positive rainfall anomalies: 5 of 6 years with 8 or 9 near-coastal storms exhibited above average rainfall, and 6 of the 7 highest-rainfall years (principal component > 500) were years with 5 or more storms in JAS.

4. SUMMARY

Interannual fluctuations of tropical storms affecting the west coast of North America are modulated by the ENSO cycle and by Pacific decadal variability, particularly during the early months of the tropical storm season. More tropical storms affect the Pacific coast in May-July during La Niña years (when equatorial Pacific Ocean temperature is anomalously cold) than during El Niño years. The difference between La Niña and El Niño years was especially pronounced during the mid-20th Century epoch when cold equatorial ocean temperatures were enhanced, associated with Pacific decadal variability. The results potentially provide a basis for probabilistic seasonal prediction of the propensity for landfalling tropical storms on the west coast of Mexico.

5. REFERENCES

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