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Original paper

Variability of extreme precipitation in coastal river basins of the southern mexican Pacific region

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Resumen

Se realizó un estudio sobre eventos extremos de sequía y humedad (± 1 desviación estándar), así como eventos de precipitación diaria mayores al percentil 95 (P95), asociados a tormentas tropicales y otros eventos, en tres cuencas hidrológicas costeras del sur de Oaxaca (Río Verde, Río Tehuantepec y la costa del sur de Oaxaca). El estudio está basado en registros de precipitación diaria de 47 estaciones bajo control de calidad durante el periodo de 1961-1990, con datos de tormentas tropicales para el Pacífico Oriental Tropical. El objetivo de este estudio fue evaluar eventos extremos (húmedos y secos), las tendencias de la contribución anual de la precipitación derivada del P95 y la relación de la precipitación de verano con El Niño-Oscilación del Sur y la Oscilación Decadal del Pacífico. Se realizó una regionalización basada en un análisis de componentes principales lo cual dió por resultado cuatro regiones de precipitación. Una correlación negativa significativa (al 95 % de confianza) fue encontrada sólo con el índice ONI en la región 3, la más cercana al Golfo de Tehuantepec. Los años húmedos ligados a eventos del P95 asociados con tormentas tropicales, fueron relacionados con anomalías negativas $(\geq -0.6°C)$ similares a condiciones de La Niña débil y neutrales. Mientras que los años secos fueron relacionados con anomalías positivas similares a condiciones neutrales $(\leq -0.5°C)$. La mayor contribución de precipitación del P95, asociada con tormentas tropicales, fue observada en la región 3. Sólo se encontró una tendencia positiva de esta contribución en la región 1: el bajo Río Verde.

Palabras clave: eventos de lluvia extrema, MSD, años secos, ciclones tropicales, ENSO, PDO.

Abstract

Extreme wet and dry years (± 1 standard deviation, respectively), as well as the top 95 percentile (P95) of daily precipitation events, derived from tropical cyclone (TC) and non-tropical cyclone (NTC) rainfall, were analyzed in coastal river basins in Southern Oaxaca, Mexico (Río Verde, Río Tehuantepec, and the Southern Coast). The study is based on daily precipitation records from 47 quality-controlled stations for the 1961 to 1990 period and TC data for the Eastern Tropical Pacific (EPAC). The aim of this study was to evaluate extreme (dry and wet) trends in the annual contribution of daily P95 precipitation events and to determine the relationship of summer precipitation with El Niño Southern Oscillation (ENSO) and the Pacifical Decadal Oscillation (PDO). A regionalization based on a rotated principal component analysis (PCA) was used to produce four precipitation regions in the coastal river basins. A significant negative correlation (significance at the 95% level) was only found with ONI in rainfall Region 3, nearest to the Gulf of Tehuantepec. Wet years, mainly linked to TC-derived P95 precipitation events, were associated with SST anomalies $(\geq -0.6°C)$ similar to weak La Niña and Neutral cool conditions, while dry years were associated with SST positive anomalies similar to Neutral warm conditions $(\leq -0.5°C)$. The largest contribution of extreme P95 precipitation derived from TCs to the annual precipitation was observed in Region 3. A significant upward trend in the contribution of TC-derived precipitation to the annual precipitation was found only in Region 1, low Río Verde.

Key words: extreme rainfall events, MSD, dry years, tropical cyclones, ENSO, PDO.

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Introduction

Precipitation variability in the southern Mexican state of Oaxaca (Figure 1) has played a decisive role in the agriculture sector with social (Endfield *et al.*, 2004) and economic (Dilley, 1997; Endfield *et al.*, 2004) impacts, mainly during extreme events such as those associated with El Niño conditions or with the passage of tropical cyclones (TCs). Agriculture accounts for about 30% of the economic activity in Oaxaca and takes place mainly in the valleys, in the southern coastal plains, and the northeastern part of the state, with corn being one of the main crops (INEGI, 2012). Most maize in Oaxaca is planted during May and June to coincide with the onset of the rainy season (Dilley, 1997). Stress has been observed in maize growth (Dilley, 1997) coincident with the mid-summer drought (a relative minimum of precipitation between July and August known as "Canicula"; Mosiño and García, 1966; Magaña *et al.*, 1999; Curtis, 2004; Magaña and Caetano, 2005). For the 1978 to 1990 period the total August precipitation in the Oaxaca Valley predicted the yields on rain-fed maize (Dilley, 1997). During the August precipitation variability during this period was sensitive to interannual variations of the Southern Oscillation Index (SOI) and a synoptic index of summer 850 hPa-level temperatures (Dilley, 1997).

Precipitation in the early part of the rainy season (May–June) results from the northwards movement of the Inter-Tropical Convergence Zone (ITCZ) and easterly winds that bring moisture from the Gulf of Mexico; the latter part of the rainy season (July–September) is governed by the Mexican monsoon and increased TC frequency in the Gulf of Mexico and the Pacific, which are strongest during August (Dilley, 1997). This particular contribution for TCs over the annual precipitation has not been studied for the coast of Oaxaca. Between 1993 and 2007, one third of the major hurricanes in the Eastern Tropical Pacific (EPAC) had tracks that remained close to the Mexican west coast, with the highest peak intensity near Southern Mexico (Sánchez *et al.*, 2009). The ecological (Villegas-Romero *et al.*, 2009, Villegas-Romero *et al.*, 2004), social and economic impacts of TCs on the coast of Oaxaca are well documented by Bitrán (2002). Hurricane Pauline (in 1997) alone caused economic losses of around 450 million USD in Acapulco, in the neighbor state of Guerrero (Bitrán, 2002). Several parts of the basins in the southern coast of Oaxaca, such as Barra Coyula, Río Colotepec and Río Grande basins were also affected by this extreme event (CONABIO, 2012a).

A study regarding global trends shows an increase in daily extreme precipitation in Southern Mexico over the past half century; one of the main problems in analyzing extreme climate events is the lack of high-quality, long-term climate data with adequate time resolution (Easterling *et al.*, 2000). Most studies of extremes have focused on Northwestern and Central Mexico (e.g., Magaña *et al.*, 2003; Cavazos *et al.*, 2008; Arriaga-Ramírez and Cavazos, 2010; Méndez and Magaña, 2010), while only a few studies have analyzed extreme events in Southern Mexico (Dilley, 1996; Peralta-Hernández, 2009). Peralta *et al.* (2009) in a regional study of Southern Mexico analyzed 23 extreme rainfall indices; they found an increase in extreme daily precipitation events over the 1960-2004 period, with a step-like jump in the early 1970's. The variability of extreme events was significantly related to ENSO (El Niño Southern Oscillation) and the PDO (Pacific Decadal Oscillation), with most daily heavy rainfall events occurring during La Niña and the positive phase of the PDO (Peralta *et al.*, 2009). In contrast, according to Pavía *et al.* (2006) El Niño events favor seasonal wet conditions in Southern Mexico, but during summers of a cold phase of the PDO.

Another study of the Oaxaca Valley associated droughts and reduced corn production to El Niño conditions (Dilley, 1997). ENSO warm events were associated with dry conditions in the valley owing to a southward displacement of the ITCZ during the low phase of the Southern Oscillation and diminished storm frequency in the Gulf of Mexico (Dilley, 1996). In other parts of the west coast of Mexico, this association of El Niño with dry conditions has also been found to occur during the warm phase of PDO in the Gulf of California continental watershed (Brito-Castillo *et al.*, 2003). On the other hand, a reduced number of TCs making landfall during El Niño years was also observed during 1961-1990 (Jauregui, 1995). According to these previous studies, a wet or dry summer depends on the phase of PDO and the ENSO condition. The current study focuses more on the positive and negative PDO phases and regions from the coast, to the Oaxaca Valley, and through the mountains of Oaxaca State. Study of the climate variability in this region is important due to its localization just in the north limit of the ITCZ, south of the North American monsoon and near the warm pool in the Gulf of Tehuantepec. In the case of extreme daily precipitation associated with TCs there are no studies in Oaxaca, while these events have been associated with weak La Niña to Neutral conditions in the monsoon region (Cavazos *et al.*, 2008).

The present study aims to understand the variability of extreme annual, seasonal and daily precipitation events in Southern Oaxaca (shown in Fig. 1), and their relationship to interannual