atmosphere

MDPI

Article

Variability and Factors of Influence of Extreme Wet and Dry Events in Northern Mexico

Omar Llanes-Cárdenas [1], Alberto Gaxiola-Hernández [2], Rosa D. Estrella-Gastelum [1], Mariano Norzagaray-Campos [1,*], Enrique Troyo-Diéguez [3], Ernestina Pérez-González [1], Rosario Ruiz-Guerrero [4] and Manuel de J. Pellegrini Cervantes [2]

1 Instituto Politécnico Nacional, Centro Interdisciplinario de Investigación para el Desarrollo Integral Regional, Unidad Sinaloa (CIIDIR-IPN-Sinaloa), Boulevard Juan de Diós Bátiz Paredes # 250, Guasave, Sinaloa, Mexico C.P. 81101, Mexico; oma_llanes@hotmail.com (O.L.-C.); rossy_10_31@hotmail.com (R.D.E.-G.); ernestinaperezster@gmail.com (E.P.-G.)

2 Facultad de Ingeniería Mochis, Universidad Autónoma de Sinaloa. Fuente de Poseidón y calle Ángel Flores S/N, Los Mochis, Sinaloa C.P. 81223, Mexico; alberto.gaxiola@uas.edu.mx (A.G.-H.); manuel.pellegrini@uas.edu.mx (M.d.J.P.C.)

3 Centro de Investigaciones Biológicas del Noroeste (CIBNOR-La Paz), Av. Instituto Politécnico Nacional 195, Playa Palo de Santa Rita Sur, La Paz, B.C.S. México C.P. 23096, Mexico; etroyo04@cibnor.mx

4 Instituto Politécnico Nacional, Centro de Investigación e Innovación Tecnológica. Cerrada de Cecati S/N. Col. Santa Catarina Azcapotzalco, Ciudad de México 02250, Mexico; rosarior@hotmail.com

* Correspondence: mnorzacam@yahoo.com.mx; Tel.: +52-687-872-9625

Received: 15 January 2018; Accepted: 16 March 2018; Published: 23 March 2018

Abstract: The goal of this study was to generate a method to examine seasonal variability by climatic classification and Pacific seasonal factors to identify extreme wet and dry events in northern Mexico for the period 1952–2013. Using the standardized precipitation and evapotranspiration index (SPEI) on scales of three months (SPEI-3) and 24 months (SPEI-24), the variability of extreme wet and dry events were measured. The SPEI-3 and SPEI-24 anomalies were divided by the standard deviation (standardized Z anomalies). A Pearson correlation for SPEI-3, SPEI-24, Pacific decadal oscillation (PDO) and the oceanic El Niño index (ONI) was applied. Wet extreme events were recorded in 1954, 1968, 1976–1977, 1981, 1984, 1986 and 2003, of which the greatest magnitude was recorded in 1984 for the Sinaloa-very dry region. Extreme dry events were recorded in 1952–1953, 1990, 1997, 2003 and 2011–2013. The Z anomalies of the wet extreme events observed coincide with +PDO phase anomalies. In this study, the El Niño southern oscillation (ENSO) has little influence on wet and dry extreme events in northern Mexico. The negative phase anomalies of sea surface temperature (−SST) in the equatorial and eastern Pacific are indicators of extreme wet events. This study shows for the first time the influence of the PDO and the ONI on seasonal variability of extreme wet and dry events by climatic classification through the SPEI index in northern Mexico.

Keywords: SPEI-3; SPEI-24; extreme events

1. Introduction

In the coming decades, the effects of climate change will be reflected around the world in rainfall irregularity, increased maximum temperatures [1], and evapotranspiration, which could cause extreme wet [2] and dry [3] events.

According to [4], Mexico has historically been affected by a number of extreme events of both types as well as by fires associated with extreme dry events; most notably in the states of Chihuahua, Coahuila, Durango, Chiapas, Mexico City, Tabasco, Baja California Sur, Baja California, Sonora and Sinaloa [5–7]. In the northern states of Mexico (Chihuahua, Baja California, Durango, Baja California

Sur, Sinaloa and Sonora), summer precipitation (June–September) represents around 60% of total annual precipitation; however, in recent decades, significant meteorological irregularities have been recorded in various different climatic classifications [8–10] which predict that Mexico will become dryer as a consequence of global warming and that this drying may already be underway [11]. Of the meteorological indices in the literature, the standardized precipitation and evapotranspiration index (SPEI) is the most efficient for identifying extreme wet and dry events, due to the fact that it incorporates evapotranspiration, which can identify prolonged drought periods [12] and is indispensable in hydrological balance studies [13–15]. According to [16], the choice of time scale for the SPEI must be based specifically on the type of event to be identified or analyzed.

Given this, in this study for the identification of extreme wet events, the three-month scale (SPEI-3) was applied as it reflects short and medium term seasonal soil moisture conditions with higher resolution [17]. Specifically for the identification of extreme dry events, the 24-month scale (SPEI-24) was applied, since the bi-annual period is essential for capturing low frequency variability, avoiding the explicit annual cycle [13,14]. Two of the most important factors that induce extreme precipitation events globally [18–20] are the Pacific decadal oscillation (PDO) and the oceanic El Niño index (ONI) [13,21,22]. Northern Mexico is no exception, due to the fact that PDO and ONI are associated with precipitation variability in this region [9,23–26]. Extreme precipitation events in northern Mexico are also related to anomalies of the sea surface temperature (SST) in the equatorial and eastern Pacific Ocean [27]. Given the association between PDO and ONI, it can be inferred that sea surface temperature has a strong influence on the existence of dry and wet events in northern Mexico, and the goal of the present study was therefore to generate a method to examine seasonal variability by climatic classification and seasonal factors of the Pacific for extreme wet and dry events in northern Mexico for the period 1952–2013.

The results obtained in one of the most important agricultural regions in Mexico, which also has the largest number of Ramsar wetlands in the country, can serve to give an insight into future wet and dry events, which could put at risk the sustainability of food, the environment and life for the region's inhabitants [28–30]. This study also determines for the first time the influence of the PDO and the ONI on seasonal variability of extreme wet and dry events by climatic classification through the SPEI index in northern Mexico.

2. Experiments

2.1. Study Area

Table 1 and Figure 1 show the annual average temperature (AAT) and annual average precipitation (AAP), and the study area, respectively, which consists of six states located in northern Mexico (Chihuahua, Baja California, Durango, Sinaloa, Sonora and Baja California Sur). Historically, northern Mexico experienced extreme meteorological droughts in the periods 1953–1957, 1972–1979, 1985–1988, 1996–2002 and 2003 [5,12,31], which put the food sovereignty of the most important agricultural region of Mexico at risk.

Table 1. Annual average temperature (AAT, °C) and annual average precipitation (AAP, mm) in northern Mexico by state. Source: Authors, from (INEGI, (2011) [30]).

State	AAT (°C)	AAP (mm)
Chihuahua	17.0	500
Baja California	18.5	200
Durango	17.0	500
Sinaloa	25.0	790
Sonora	22.0	450
Baja California Sur	20.0	200

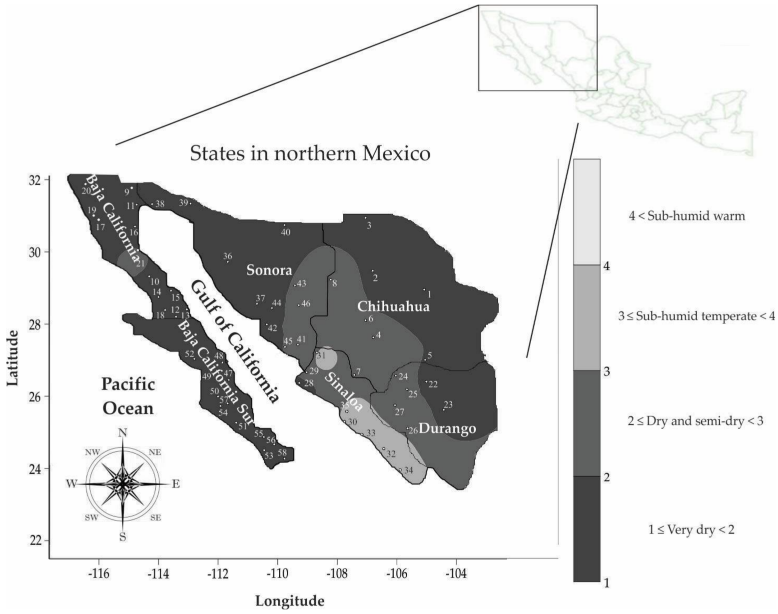

Figure 1. Location, climate classification and weather stations in six states in northern Mexico (Chihuahua, Baja California, Durango, Sinaloa, Sonora and Baja California Sur). Source: Authors, following the Climate Computing (CLICOM, 2018) database and climatic classification of INEGI (2018) (http://www.cuentame.inegi.org.mx/monografias/).

2.2. Climatic Classifications

Fifty-eight weather stations were identified from [32]. Applying the climatic classification from [33], four types of climate were identified in northern Mexico: very dry, dry and semi-dry, sub-humid temperate, and sub-humid warm (Table 2).

Table 2. Climatic classification and location of weather stations in six states in northern Mexico. Source: Authors, following CLICOM (2018) and INEGI (2018) databases.

State	Number on Map	Weather Stations	Climatic Classification
Chihuahua	1, 2 and 3	Maijona, Presa Chihuahua and Samalayuca	Very dry
	4, 5 and 6	El Sitio, Escalon and San Lorenzo	Dry and semi-dry
	7 and 8	Ciudad Guerrero and Babicora	Sub-humid temperate
Baja California	9, 10, 11, 12, 13, 14, 15 and 16	Bataques, Chapala Ensenada, Delta, El Arco, El Barril, Nuevo Rosarito, Punta Prieta and San Felipe	Very dry
	17, 18, 19 and 20	Ejido Ignacio L.R., Rancho Alegre, Santo Tomás and Valle de las Palmas	Dry and semi-dry
	21	San Agustín	Sub-humid temperate
Durango	22 and 23	Cinco de Mayo and Cuencame	Very dry
	24 and 25	Canutillo and El Palmito II	Dry and semi-dry
	26 and 27	La Ciudad and Santiago Papasquiaro	Sub-humid temperate
Sinaloa	28, 29 and 30	Topolobampo, El Fuerte and Quila	Very dry
	31, 32, 33, 34 and 35	Choix, El Palmito, Ixpalino, La Concha and Sanalona	Sub-humid warm
Sonora	36, 37, 38 and 39	Felix Gomez, Punta de agua, Riito and Sonoyta	Very dry
	40, 41, 42, 43 and 44	Col. Morelos, Minas Nuevas, Psa. A. Obregón de Oviachiac, Sahuaripa, San Javier and Tesia	Dry and semi-dry
	46	Yecora	Sub-humid temperate
Baja California Sur	47, 48, 49, 50, 51, 52, 53 and 54	Buena Vista, El Rosarito, La Purísima, Las Cruces, Penjamo, San José de Gracia, Todos Santos and V. Constitución a Km 211	Very dry
	55, 56, 57 and 58	Los Divisaderos, San Bartolo, San Javier and San Felipe	Dry and semi-dry

2.3. Standardized Precipitation Evapotranspiration Index on a 3-Month Scale (SPEI-3) and on a 24-Month Scale (SPEI-24)

The SPEI-3 and SPEI-24 were obtained from database [34]. The SPEI-3 and SPEI-24 data were calculated by [14] and used by [14,35]. The SPEI data in this study was used to detect wet and dry extreme events in the period 1952–2013. Thus, SPEI-3 and SPEI-24 capture the difference between precipitation and evapotranspiration on time scales of three and 24 months, respectively [14]. The average of the SPEI-3 and SPEI-24 were calculated for all weather types of the weather stations. For Table 3, a wet event was defined to be when SPEI-3 > 0 and a dry event when SPEI-24 < 0. A wet extreme event was considered to occur when SPEI-3 > 2.0 and a dry extreme event was considered to occur when SPEI-24 < −2.0 [36–38].

Table 3. Categorization of wet and dry events according to standardized precipitation and evapotranspiration index (SPEI)-3 and SPEI-24 for northern Mexico. Source: Méndez and Magaña (2009) [31].

SPEI-3 and SPEI-24 (Dimensionless)	Category
>2.0	Extremely wet
1.5 to 1.99	Severely wet
1.0 to 1.49	Moderately wet
0.5 to 0.99	Wet
0.0 to 0.49	Slightly wet
−0.49 to 0.0	Slightly dry
−0.99 to −0.50	Dry
−1.49 to −1.0	Moderately dry
−1.99 to −1.5	Severely dry
<−2.0	Extremely dry

2.4. Oceanic Factors: Pacific Decadal Oscillation (PDO) and Oceanic El Niño Index (ONI)

The PDO is defined as anomalies of the SST in the North Pacific Ocean (20° N–65° N, 100° W–0° W). Anomalies with positive phase (+PDO) are associated with El Niño events [39], which represent an increase in wet extreme events in northern Mexico. Anomalies with negative phase are associated with La Niña events, which represent an increase in dry extreme events in northern Mexico. The ONI is the standard used by the National Oceanic and Atmospheric Administration (NOAA) to identify El Niño (anomalies with positive phase) and La Niña events (anomalies with negative phase) in the tropical Pacific Ocean, which are associated with extreme wet and dry events, respectively, in northern Mexico. The ONI is calculated by the ERSST v.4 program using the three-month moving average of SST anomalies for the El Niño 3.4 region (5° N to 5° S and 120° W to 170° W) [40]. El Niño events are classified as weak (anomaly of 0.5 to 0.9 °C), moderate (1.0 to 1.4 °C) or strong (>1.4 °C). La Niña events are classified as weak (anomaly of −0.5 to −0.9 °C), moderate (−1.0 to −1.4 °C) or strong (<−1.4 °C). Monthly series of the PDO and ONI were obtained from the NOAA for the period 1952–2013 at the websites [41,42] (https://www.ncdc.noaa.gov/teleconnections/pdo/ and http://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_v5.php, respectively).

2.5. Regional Z Anomalies of the SPEI-3 and SPEI-24

Regional Z anomalies of the SPEI-3 and SPEI-24 were calculated for each climate classification in the period 1952–2013, following [35,36], in order to analyze the correlation between these two SPEI indexes for the states of northern Mexico.

2.6. Correlation Analysis

To measure the relationship between regional SPEI-3 and SPEI-24 values and the PDO and ONI factors, a Pearson correlation (rP) was applied, due to its high effectiveness and ease of interpretation [40,43]. The correlation coefficients were compared using the two-tailed Pearson critical correlation index (Prcrit = 0.25, n = 62), equivalent to a confidence level of 95% (α = 0.05).

2.7. Anomalies of Equatorial and Eastern Pacific Sea Surface Termperature (SST)

Extreme dry and wet events in northern Mexico were related with sea surface temperature (SST) phase anomalies in the equatorial and eastern Pacific. Seasonal anomalies of the SST for the years with extreme wet (positive anomalies of SST) and dry (negative anomalies of SST) events were used to show SST conditions in the years with extreme precipitation in northern Mexico. The SST anomalies were obtained from the website [44] https://www.esrl.noaa.gov/psd/data/composites/day/. The anomaly data from the map were digitalized to enable the average of wet and dry extreme events to be calculated.

3. Results

3.1. SPEI-3: Wet Events by Climate Region

Table 4 and Figure 2 show the values of the SPEI-3 by climate region divided by range from minimum to maximum events and by classification of range in the states of northern Mexico, where the events with the highest extreme rainfall associated with tropical cyclones in the eastern Pacific Ocean occurred in the periods 1984 and 2003.

Table 4. Variation, extreme events and classification of SPEI-3 by climate region in northern Mexico. Source: Authors, following SPEI database (http://sac.csic.es/spei/, 2018) and INEGI climatic classification (http://www.cuentame.inegi.org.mx/monografias/).

State	Climate Region	SPEI-3 (Dimensionless)	
		Range	Classification of Range
Chihuahua	Very dry	[0.01–2.02]	Slightly wet to extremely wet
	Dry and semi-dry	[0.01–2.20]	Slightly wet to extremely wet
	Sub-humid temperate	[0.01–1.83]	Slightly wet to severely wet
Baja California	Very dry	[0.01–2.11]	Slightly wet to extremely wet
	Dry and semi-dry	[0.03–2.06]	Slightly wet to extremely wet
	Sub-humid temperate	[0.01–2.75]	Slightly wet to extremely wet
Durango	Very dry	[0.01–2.66]	Slightly wet to extremely wet
	Dry and semi-dry	[0.01–1.81]	Slightly wet to severely wet
	Sub-humid temperate	[0.01–2.33]	Slightly wet to extremely wet
Sinaloa	Very dry	[0.01–3.11]	Slightly wet to extremely wet
	Dry and semi-dry	[0.02–2.42]	Slightly wet to extremely wet
	Sub-humid warm	[0.01–1.80]	Slightly wet to severely wet
Sonora	Very dry	[0.01–1.98]	Slightly wet to severely wet
	Dry and semi-dry	[0.02–1.88]	Slightly wet to severely wet
	Sub-humid temperate	[0.01–2.29]	Slightly wet to extremely wet
Baja California Sur	Very dry	[0.01–1.87]	Slightly wet to severely wet
	Dry and semi-dry	[0.01–2.02]	Slightly wet to extremely wet

In Table 4 and Figure 2, the most intense extreme wet events for the Baja California sub-humid temperate climate were recorded in the period 2003 with a magnitude of SPEI-3 = 2.75.

For Durango-very dry, the most intense extreme wet events were recorded in the years 1976 and 1984 with a magnitude of SPEI-3 from 2.26 to 2.66. The wet events for Chihuahua, Baja California and Durango were classified from slightly wet to extremely wet (Table 4 and Figure 2). The number of events for month for Chihuahua were: slightly wet = 139, wet = 124, moderately wet = 73, severely wet = 30 and extremely wet = 4; for Baja California: slightly wet = 144, wet = 132, moderately wet = 59, severely wet = 18 and extremely wet = 17 and for Durango: slightly wet = 145, wet = 122, moderately wet = 64, severely wet = 31 and extremely wet = 8.

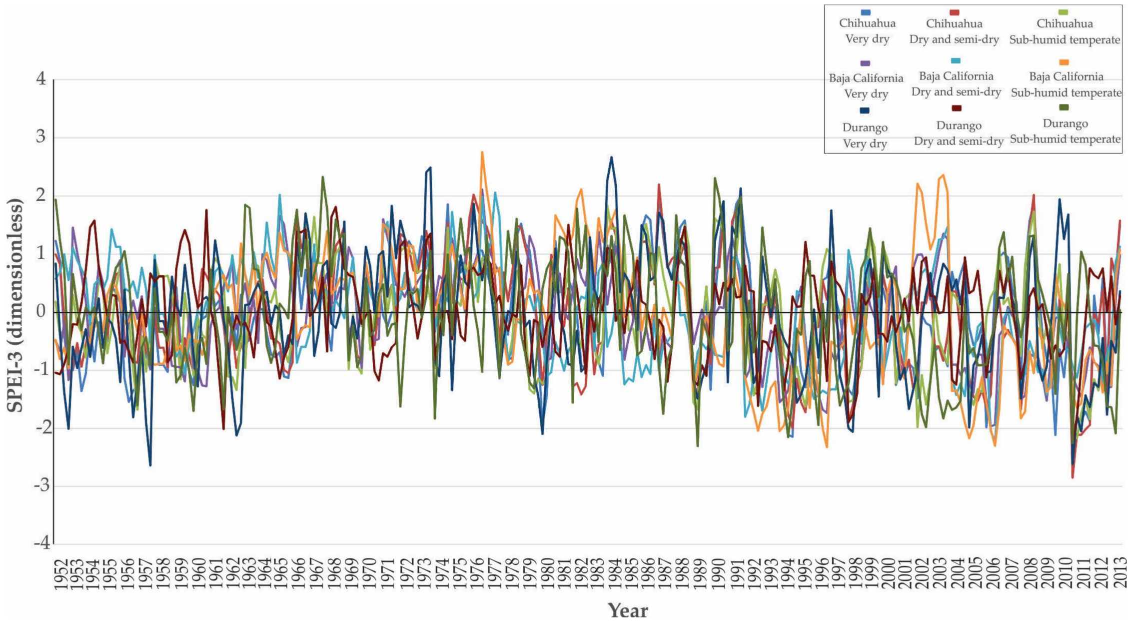

Figure 2. Seasonal variation of SPEI-3 by climate region in states in northern Mexico (Chihuahua, Baja California and Durango) in the period 1952–2013 (dimensionless). Source: Authors, following SPEI database (http://sac.csic.es/spei/) and INEGI climatic classification (http://www.cuentame.inegi.org.mx/monografias/).

The results of the SPEI-3 for Sinaloa-very dry and dry and semi-dry (Figure 3) showed magnitudes of SPEI-3 ranging from 2.14 to 3.11. In general, the SPEI-3 for Sinaloa, Sonora and Baja California Sur ranged from mildly wet to extremely wet (Table 4 and Figure 3).

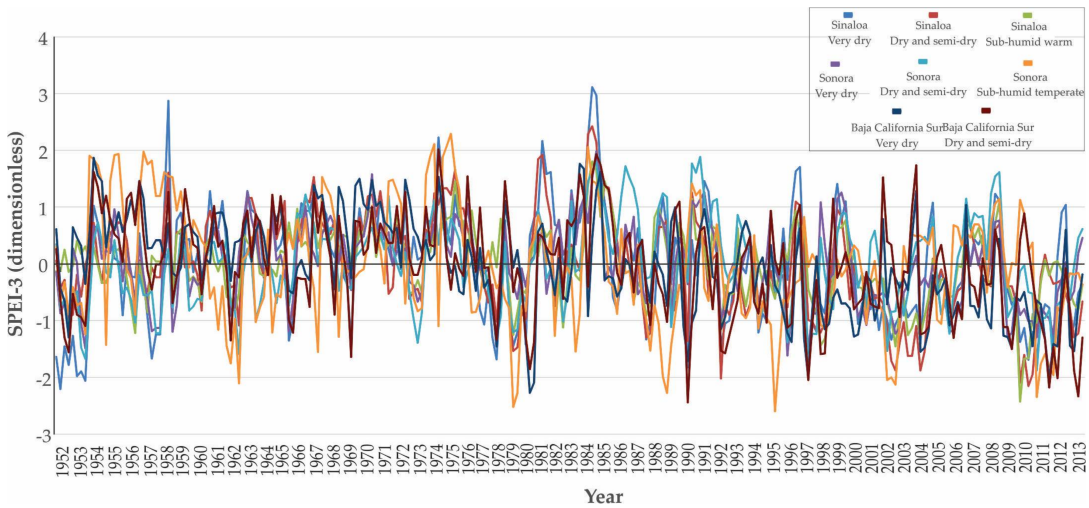

Figure 3. Seasonal variation of SPEI-3 by climate region in states in northern Mexico (Sinaloa, Sonora and Baja California Sur) in the period 1952–2013 (dimensionless). Source: Authors, following SPEI database (http://sac.csic.es/spei/) and INEGI climatic classification (http://www.cuentame.inegi.org.mx/monografias/).

3.2. SPEI-24: Dry Events by Climate Region

The results of the SPEI-24 for Chihuahua-very dry, dry and semi-dry, and sub-humid temperate and Durango-very dry and sub-humid temperate (Table 5 and Figure 4) showed that the periods of most intense drought were 1952, 1954, 1989, 1997 and 2012–2013, with a SPEI-24 that ranged from −2.93 to −2.00 (Table 5 and Figure 4). In Table 5, the SPEI-24 by climate region was divided by range from minimum to maximum events and classification of range in states in northern Mexico.

Table 5. Variation, extreme events and classification of SPEI-24 by climate region in northern Mexico. Source: Authors, following SPEI database (http://sac.csic.es/spei/, 2018) and INEGI climatic classification (http://www.cuentame.inegi.org.mx/monografias/).

State	Climate Region	SPEI-24 (Dimensionless)	
		Range	Classification of Range
Chihuahua	Very dry	[−2.40–−0.02]	Slightly dry to extremely dry
	Dry and semi-dry	[−2.19–−0.01]	Slightly dry to extremely dry
	Sub-humid temperate	[−2.93–−0.01]	Slightly dry to extremely dry
Baja California	Very dry	[−2.31–−0.01]	Slightly dry to extremely dry
	Dry and semi-dry	[−2.58–−0.01]	Slightly dry to extremely dry
	Sub-humid temperate	[−2.19–−0.01]	Slightly dry to extremely dry
Durango	Very dry	[−2.48–−0.01]	Slightly dry to extremely dry
	Dry and semi-dry	[−1.81–−0.01]	Slightly dry to severely dry
	Sub-humid temperate	[−2.36–−0.01]	Slightly dry to extremely dry
Sinaloa	Very dry	[−2.70–−0.02]	Slightly dry to extremely dry
	Dry and semi-dry	[−2.05–−0.01]	Slightly dry to extremely dry
	Sub-humid warm	[−1.69–−0.01]	Slightly dry to severely dry
Sonora	Very dry	[−1.5–−0.01]	Slightly dry to severely dry
	Dry and semi-dry	[−1.84–−0.01]	Slightly dry to severely dry
	Sub-humid temperate	[−2.56–−0.01]	Slightly dry to extremely dry
Baja California Sur	Very dry	[−2.20–−0.02]	Slightly dry to extremely dry
	Dry and semi-dry	[−2.50–−0.01]	Slightly dry to extremely dry

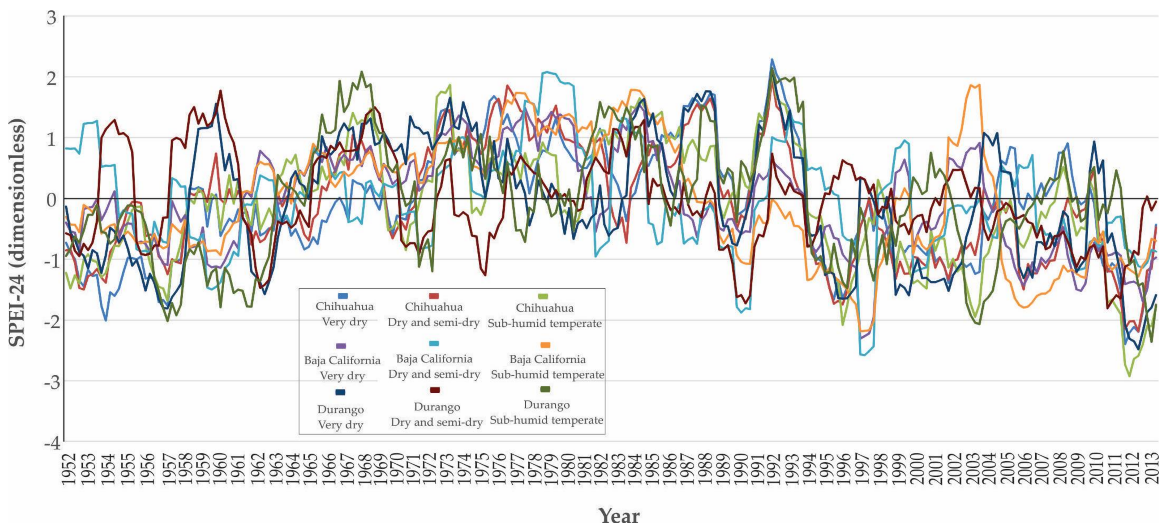

Figure 4. Seasonal variation of SPEI-24 by climate region in states in northern Mexico (Chihuahua, Baja California and Durango) in the period 1952–2013 (dimensionless). Source: Authors, following SPEI database (http://sac.csic.es/spei/) and INEGI climatic classification (http://www.cuentame.inegi.org.mx/monografias/).

The results of the SPEI-24 for Chihuahua-very dry and Baja California-very dry, dry and semi-dry and sub-humid temperate showed that the periods of most intense drought were 1954, 1997 and 2012, with SPEI-24 ranging from −2.58 to −2.00 (Figure 4).

Overall, Sinaloa, Sonora and Baja California Sur were classified from slightly dry to extremely dry (Table 5 and Figure 5). The results of the SPEI-24 for Sinaloa-very dry, Sonora sub-humid temperate and Baja California Sur very dry and dry and semi-dry showed that the periods of most intense drought were 1952–1954, 1989, 2003 and 2012–2013, with SPEI-24 ranging from −2.70 to −2.01 (Figure 5).

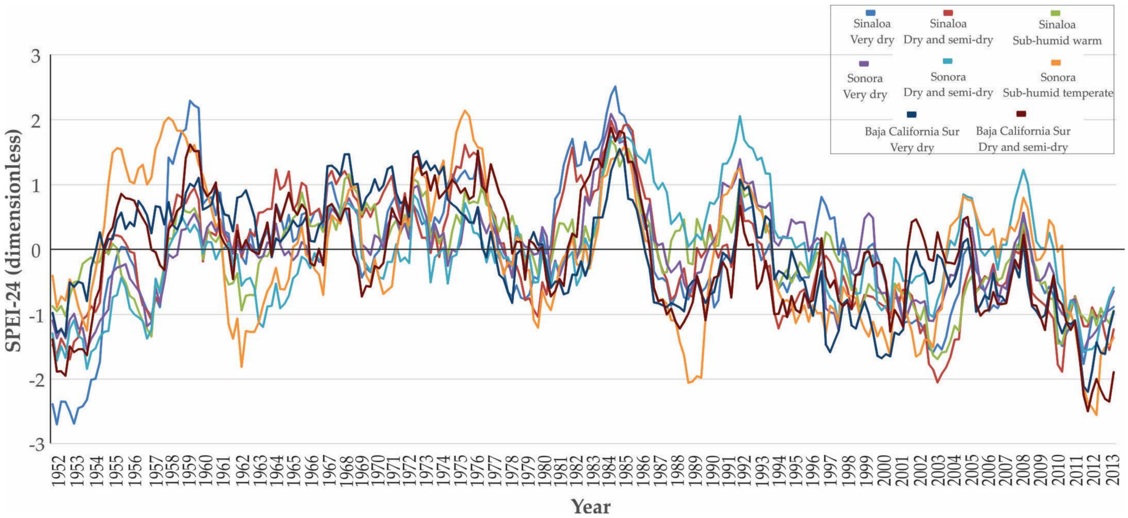

Figure 5. Seasonal variation of SPEI-24 by climate region in states in northern Mexico (Sinaloa, Sonora and Baja California Sur) in the period 1952–2013 (dimensionless). Source: Authors, following SPEI database (http://sac.csic.es/spei/) and INEGI climatic classification (http://www.cuentame.inegi.org.mx/monografias/).

3.3. Z Standardized Anomalies of SPEI-3 and SPEI-24

In Figure 6a–d, the regional variability of SPEI-3 and SPEI-24 for northern Mexico is shown. In Figure 6e, the variability of PDO and ONI is shown, and in Figure 6f, the average annual variability of SPEI-3, SPEI-24 and ONI is shown. In Figure 6a,b, it can be observed that wet extreme events were recorded in 1954, 1968, 1976–1977, 1981, 1984, 1986 and 2003, and that the highest intensity was recorded in 1984 for Sinaloa-very dry with SPEI-3 = 3.15.

In Figure 6c,d, the extreme dry events recorded in 1952–1953, 1990, 1997, 2003 and 2011–2013 can be observed; the greatest magnitude was recorded in 1997 for Baja California-very dry, dry and semi-dry and sub-humid temperate with an SPEI-24 that ranged from −2.02 to −2.58. As shown in Figure 6e, the PDO anomalies for 1952 and 2011–2013 had a −PDO phase that ranged from −0.89 to −1.63. In Figure 6e and for ONI, it can also be observed that 1968, 1976–1977, 1986 and 2003 registered +ONI phase anomalies (ONI < 0.50; absence of El Niño) and in 2011 and 2013 −ONI phase anomalies were seen (ONI > −0.50; absence of La Niña).

3.4. Correlation Analysis

SPEI-3 had a significant negative correlation with PDO and ONI for Baja California-dry and semi-dry, rP = −0.330; and with ONI for Sinaloa-very dry, rP = −0.253 (Table 6). As seen in Table 6, ONI anomalies are more important than PDO anomalies for the occurrence of extreme wet summers in Durango-sub-humid temperate, Sinaloa-dry and semi-dry and Sonora-dry and semi-dry.

The SPEI-24 correlated significantly and positively with the PDO for the very dry and sub-humid temperate climatic classifications of Chihuahua (Pr = 0.320 and Pr = 0.283, respectively) and dry and semi-dry of Sonora (Pr = 0.348). As seen in Table 7, only the PDO showed significant magnitudes of correlation in Chihuhua-very dry and sub-humid temperate and Sonora-dry and semi-dry.

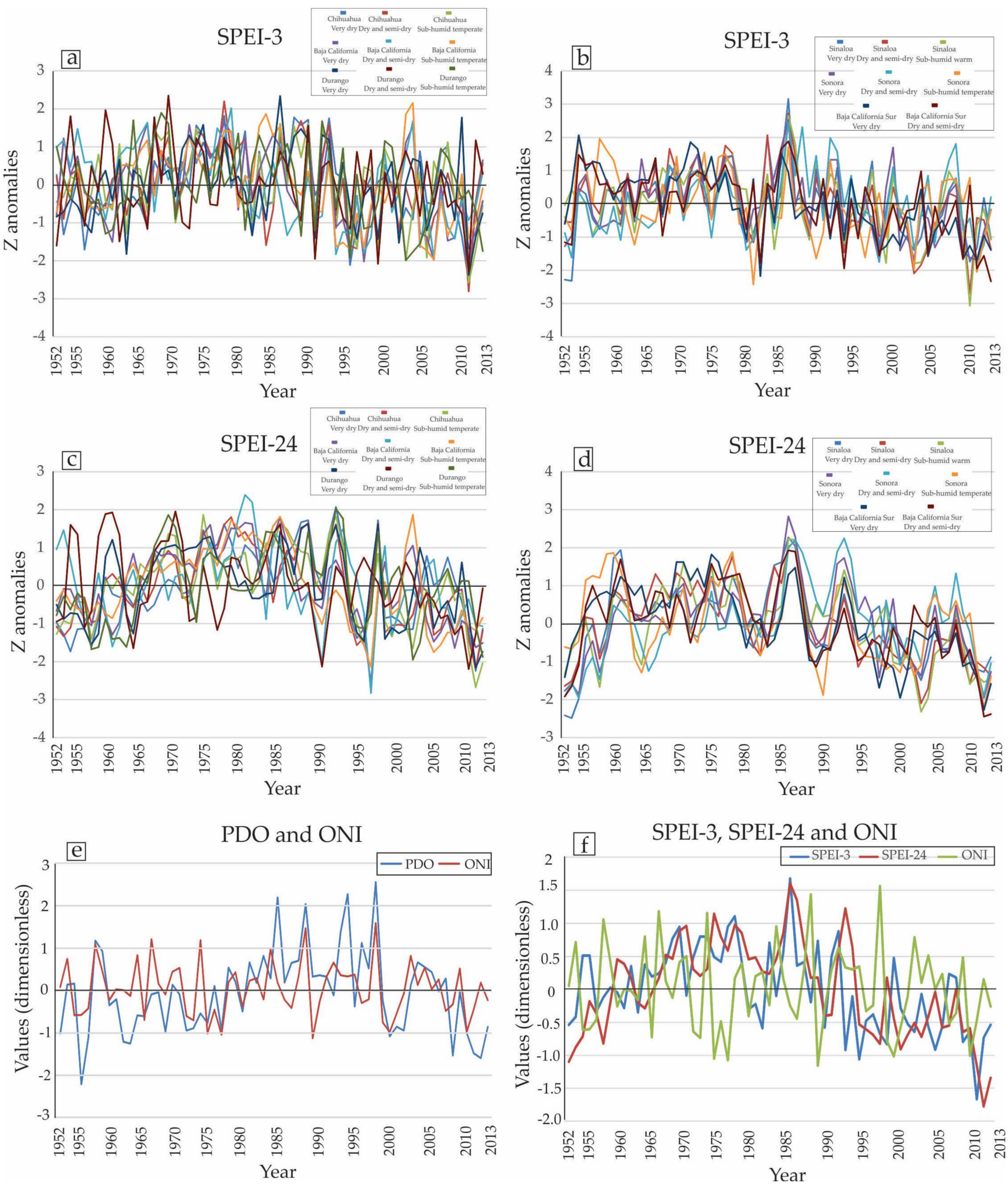

Figure 6. (**a**,**b**) Standardized Z anomalies of SPEI-3 (dimensionless); (**c**,**d**) standardized Z anomalies of SPEI-24 (dimensionless); (**e**) values of pacific decadal oscillation (PDO) and oceanic El Niño index (ONI) (dimensionless); and (**f**) average annual variability of SPEI-3, SPEI-24 and ONI (dimensionless) for the period 1952–2013. Source: Authors, following the database: http://sac.csic.es/spei/, https://www.ncdc.noaa.gov/teleconnections/pdo/ and http://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_v5.php and INEGI climatic classification (http://www.cuentame.inegi.org.mx/monografias/).

Table 6. Correlation analysis for standardized precipitation evapotranspiration index on a three-month scale (SPEI-3), Pacific decadal oscillation (PDO) and oceanic El Niño index (ONI) in the period 1952–2013 in northern Mexico. Source: Authors, following INEGI climatic classification (http://www.cuentame.inegi.org.mx/monografias/) and databases: http://sac.csic.es/spei/, https://www.ncdc.noaa.gov/teleconnections/pdo/ and http://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_v5.php.

State	Climate Region	PDO	ONI
Chihuahua	Very dry	0.153	0.002
	Dry and semi-dry	0.062	0.006
	Sub-humid temperate	0.065	−0.017
Baja California	Very dry	−0.022	−0.062
	Dry and semi-dry	**−0.330**	−0.102
	Sub-humid temperate	−0.052	0.006
Durango	Very dry	0.163	−0.058
	Dry and semi-dry	0.183	0.104
	Sub-humid temperate	−0.149	−0.210
Sinaloa	Very dry	−0.021	**−0.253**
	Dry and semi-dry	−0.129	−0.226
	Sub-humid warm	−0.053	−0.142
Sonora	Very dry	−0.051	−0.198
	Dry and semi-dry	0.047	−0.206
	Sub-humid temperate	−0.003	−0.010
Baja California Sur	Very dry	−0.034	−0.055
	Dry and semi-dry	0.016	−0.175

Bold and boxed = Significant correlation.

Table 7. Correlation analysis for SPEI-24, PDO and ONI in the period 1952–2013 in northern Mexico. Source: Authors, following INEGI climatic classification, 2018 (http://www.cuentame.inegi.org.mx/monografias/) and the databases (http://sac.csic.es/spei/, https://www.ncdc.noaa.gov/teleconnections/pdo/ and http://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_v5.php).

State	Climate Region	PDO	ONI
Chihuahua	Very dry	**0.320**	−0.015
	Dry and semi-dry	0.237	0.000
	Sub-humid temperate	**0.283**	0.035
Baja California	Very dry	0.088	−0.085
	Dry and semi-dry	0.112	−0.120
	Sub-humid temperate	0.112	0.004
Durango	Very dry	0.214	−0.048
	Dry and semi-dry	0.213	−0.004
	Sub-humid temperate	0.148	−0.160
Sinaloa	Very dry	0.166	0.013
	Dry and semi-dry	0.071	0.020
	Sub-humid warm	0.183	−0.069
Sonora	Very dry	0.226	−0.022
	Dry and semi-dry	**0.348**	0.019
	Sub-humid temperate	0.095	−0.002
Baja California Sur	Very dry	0.038	−0.007
	Dry and semi-dry	0.112	0.011

Bold and boxed = Significant correlation.

3.5. Anomalies of Sea Surface Temperature (SST) of the Equatorial and Eastern Pacific

Figure 7a shows seasonal average anomalies of the SST for the years with extreme wet events (1954, 1968, 1976–1977, 1981, 1984, 1986 and 2003) in northern Mexico. Figure 7b shows seasonal average anomalies of the SST for the years with extreme dry events (1952–1953, 1990, 1997, 2003 and 2011–2013), where +SST phases are observed in the equatorial and eastern Pacific (from 0.3 to 0.7 °C year^{-1}). In Figure 7a it can be seen that the presence of −SST phase anomalies in the equatorial and eastern Pacific (from −1.1 to −0.1 °C year^{-1}) are an important factor for the occurrence of extreme precipitation in the north of Mexico. The presence of +SST phase anomalies (Figure 7b) is an indicator of extreme dry events in northern Mexico.

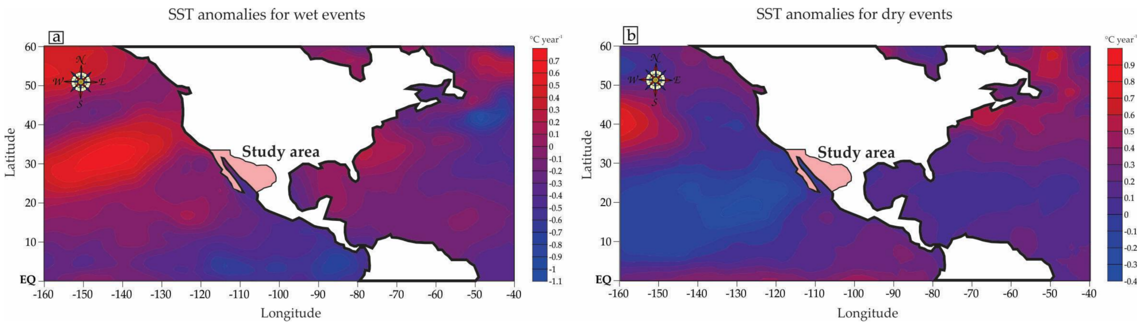

Figure 7. Seasonal average anomalies of the sea surface temperature (SST) for: (**a**) wet extreme years (°C year^{-1}) and (**b**) dry extreme years (°C year^{-1}). Source: Authors, following database (https://www.esrl.noaa.gov/psd/data/composites/day/).

4. Discussion

The results shown in Table 4 are similar to those of [9,21], who report that the events with the highest extreme rainfall associated with tropical cyclones in the eastern Pacific Ocean occurred in the periods 1982–1984 and the late 1990s. The findings of this study are also similar to the timing of the wet events for northern Mexico noted by [9], who indicate that 1984 was one of the wettest years in the period 1961–2000, which was caused by excess water and deficient or excess evapotranspiration [45]. As shown in Table 4, the results for the Baja California sub-humid temperate climate are similar to those of [46], who report that the most intense extreme wet events were recorded in the period 2003–2005, with a magnitude of standardized precipitation index on a three-month scale (SPI-3) ranging from 4.07 to 2.51.

The literature results for Durango reported magnitudes of SPI-3 = 4.07 for 1984 [46] and an SPI-3 = 2.47 for 1992 [47]; our results for Durango-very dry show an average of SPEI-3 = 2.46 for 1976 and 1984, which is consistent with the wet extreme events registered for northern Mexico according to the criteria of [31]. In the case of Chihuahua, in the literature (graphics) they registered magnitudes of SPI-3 = 2.8 and SPI-3 = 3.05 for 1984 at the Batopilas and Bocatoma weather stations [48], respectively, which is in agreement with this study; in Figure 2 they showed an SPEI-3 = 20.02 and SPEI-3 = 2.20 in Chihuahua with a climate classification of very dry and dry and semi-dry, respectively. For Sinaloa, it was reported in the literature [49] that 1984 was the year with the highest precipitation in the period 1960–2010, which is in agreement with the results of this study because the highest wet extreme events occurred in Sinaloa-very dry and dry and semi-dry in 1984, with magnitudes of SPEI-3 = 3.11 and SPEI-3 = 2.42, respectively.

The results shown in Figure 3 also agree with one of the few studies found in the bibliography; [48], who note that an extreme wet event with SPEI-3 = 2.2 was recorded in 1984 in the northern basin of Sinaloa (Figure 3). The results for Sonora-sub-humid temperate and Baja California Sur-dry and semi-dry, with magnitudes of SPEI-3 from 1.93 to 2.06 for 1984, are similar to [46], who report that the wettest period was 1982–1984, with SPI-3 values from 4.07 to 2.90. The results of this study are consistent with those of [45], who state that 2011 was the driest year in northern Mexico, caused by a precipitation deficit and evapotranspiration [13]. In this study, the results of the SPEI-24 for Chihuahua-very dry, dry and semi-dry, and sub-humid temperate and Durango-very dry and sub-humid temperate (Table 5 and Figure 4) are similar to those of [46], who report that in the period of most intense drought (2010–2013), SPI-24 ranged from −0.45 to −2.89 (Table 5). The results of this study are also similar to those of [31], who report a drought event for Chihuahua (from 1953 to 1957) with SPI-24 magnitudes ranging from −0.5 to −2.2 (Table 5 and Figure 4). In this study, for Baja California-very dry, dry and semi-dry and sub-humid temperate, the SPEI-24 results also coincide with [31], who state that the period 1996–2002 was the driest for Baja California.

The results of the SPEI-24 for Chihuahua-very dry are similar to those of [31], who state that in the period 1953–1957 there were extreme drought events (SPEI-24 < −2.0). For Baja California-very dry, dry and semi-dry and sub-humid temperate, the results are similar to those of [46] and [31], who report that the most intense droughts were recorded in the period 1995–2003, with SPI-24 ranging from −0.45 to −2.59. In Table 5, the results of the SPEI-24 for Sinaloa-very dry are similar to those of [46], who report that the most intense period of drought was 1951–1955, with SPI-24 values from −0.72 to −2.72 (Figure 5). Also, for Sonora-sub-humid temperate, the results are similar to those of [46], who report that the most intense period of drought was 2011–2013 with SPI-24 values from −1.02 to −1.63. In Baja California Sur-dry and semi-dry, the results are similar to those of [46], who report that the period with the most drought was 2008–2013, with SPI-24 from −0.42 to −2.48.

The results of Figure 6a,b are similar to those of [46], who report that the wettest period was 1982–1984 with SPI-3 values that ranged from 4.07 to 2.90. These results are also similar to those of [9,21,47–50], who report that in 1954, 1976–1977, 1981–1983, 1986 and 1992, there were a significant number of extreme precipitation events in northern Mexico and that 1984 and 1992 were the most extreme year, with SPI-3 = 4.07 and SPI-3 = 2.47, respectively.

Z anomalies of extreme wet events coincide with +PDO phase anomalies, which are indicators of extreme rainfall in northern Mexico [9,50]. The results shown in Figure 6c,d are similar to those of [31,46], who report that the periods 1953–1957, 1996–2003 and 2011–2013 presented the most intense droughts in the north of Mexico, with SPI-24 ranging from −2.10 to −2.79. The values of Figure 6e are associated with La Niña events and are indicators of scarce to null precipitation in the north of Mexico [9]. The results shown in Figure 6f and for ONI indicate the very limited influence of ENSO on the occurrence of extreme wet and dry events in northern Mexico [13].

The results in Table 6 are consistent with those of [31], who say that when there are negative anomalies of the summer PDO, wet extreme events also occur for the dry and semi-dry climate classification of Baja California and vice versa, and when there are negative anomalies of the ONI, extreme wet events also occur for the very dry climatic classification of Sinaloa and vice versa (Table 6).

The significant correlations between SPEI-3 and SPEI-4 and PDO and ONI (Tables 6 and 7) are similar to those of [51], who report that for the southern Polish Baltic coast in the period 1951–2010, the Spearman correlations between SPEI and North Atlantic Oscillation (NAO) indices were −0.290 for February and −0.327 for September from the Szczecin weather station. The correlations were −0.338 for February and −0.259 for August from the Ustka weather station, and and −0.299 for January, −0.401 for February and −0.268 for March from the Elblag weather station. The correlations between SPEI-3 and SPEI-24 and ONI are similar to those reported by [52] who state that in Romania for the period 1902–2014, the average correlations between SPEI-6 and SPEI-12 and NAO were −0.34 and −0.31, respectively.

In the results shown in Figure 7a, it can be seen that the presence of −SST phase anomalies in the equatorial and eastern Pacific is an important factor for the occurrence of extreme precipitation in the north of Mexico [27,53,54]. The presence of +SST phase anomalies in Figure 7b is an indicator of extreme dry events in northern Mexico. These results are consistent with those of [27,49,55], who point out that the +SST anomalies in eastern tropical Pacific near the equator are indicators of extreme dry events.

When the magnitudes of SPEI-3 $\geq$ 2.0 during three or more consecutive months in northern Mexico, the study area will be susceptible to floods and significant economic losses due to soil water saturation. When the magnitudes of SPEI-24 ≤ -2.0 during 24 or more consecutive months in northern Mexico, the study area will be susceptible to severe droughts and significant economic losses due to low agricultural yields.

5. Conclusions

Extreme wet events in northern Mexico in the period 1952–2013 were recorded in 1954, 1968, 1976–1977, 1981, 1984, 1986 and 2003, and the greatest magnitude was recorded in 1984 for Sinaloa-very dry. Extreme dry events were recorded in 1952–1953, 1990, 1997, 2003 and 2011–2013, and the greatest magnitude was recorded in 1997 for Baja California-very dry, dry and semi-dry and sub-humid temperate.

The Z anomalies of wet extreme events coincide with anomalies of the +PDO phase. In 1952 and 2011–2013, −PDO phases were recorded, which are associated with La Niña events and are indicators for scarce to null precipitation in northern Mexico. +ONI phase anomalies were recorded in 1968, 1976–1977, 1986 and 2003, and −ONI phase anomalies occurred in 2011 and 2013, which indicates the low influence of ENSO in extreme wet and dry events for northern Mexico. When −PDO phase anomalies are present, extreme wet events also occur for the dry and semi-dry climate region of Baja California and vice versa and when −ONI phase anomalies occur, extreme wet events also occur for the very dry climate region of Sinaloa and vice versa. The ONI anomalies have greater influence than the PDO anomalies on the occurrence of extreme wet summers in Durango-sub-humid temperate, Sinaloa-dry and semi-dry and Sonora-dry and semi-dry. When −PDO phases occur, dry extreme events also occur in Chihuahua-very dry and sub-humid temperate and Sonora-dry and semi-dry. The PDO anomalies have greater influence than ONI anomalies on the occurrence of extreme dry summers for Chihuahua-dry and semi-dry, Durango-very dry and dry and semi-dry and Sonora-very dry.

The presence of −SST seasonal phase anomalies in the equatorial and eastern Pacific is an important factor for the occurrence of extreme wet events in northern Mexico, and also the occurrence of +SST seasonal phase anomalies in these same regions of the Pacific is an indicator of extreme dry events in northern Mexico.

This study presents a new method for identifying the seasonal variability of extreme wet and dry events by climatic classification associated with the influence of the PDO and ONI factors in the most important agricultural regions of Mexico.

Acknowledgments: Thanks are extended to the Research and Postgraduate Secretariat of the National Polytechnic Institute (SIP-IPN) for economic support provided through projects with registration SIP20170218 and 20170039.

Author Contributions: Omar Llanes-Cárdenas conceived the idea and verified the analytical methods. Rosa D. Estrella-Gastelum and Mariano Norzagaray-Campos supervised the findings of this work. All authors discussed the results and contributed to the manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Williams, P.A.; Allen, C.D.; Macalady, A.K.; Griffin, D.; Woodhouse, C.A.; Meko, D.M.; Swetnam, T.W.; Rauscher, S.A.; Seager, R.; Grissino-Mayer, H.D.; et al. Temperature as a potent driver of regional forest drought stress and tree mortality. *Nat. Clim. Chang.* **2013**, *3*, 292–297. [CrossRef]
2. Tamara, P.I.; Maria, A.F.; Silva, D.; De Paula, D.S.; Leila, M.V.; Freitas, D.E. Trends and variability in extremes of precipitation in Curitiba—Southern Brazil. *Int. J. Climatol.* **2017**, *37*, 1250–1264. [CrossRef]
3. Díaz, P.G.; Sánchez, C.I.; Quiroz, R.; Garatuza, P.J.; Watts, T.C.; Cruz, M.I.R.; Guajardo, P.R.A. Variación espacio-temporal de la precipitación pluvial en México: Una aproximación a la evaluación de impactos. *Tecnología y Ciencias del Agua* **2011**, *2*, 51–64.

4. Intergovernmental Panel on Climate Change (IPCC). *Climate Change 2013: The Physical Science Basis. Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*; Stocker, T.F., Qin, D., Plattner, G.K., Tignor, M., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bex, V., Midgley, P.M., Eds.; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2013; p. 203.
5. Hallack, A.M.; Watkins, W.D., Jr. Annual and Warm Season Drought Intensity–Duration–Frequency Analysis for Sonora, Mexico. *J. Clim.* **2007**, *20*, 1897–1909. [CrossRef]
6. Centro Nacional de Prevención de Desastres (CENAPRED). *Diagnóstico de Peligros e Identificación de Riesgos de Desastres en*; CENAPRED: Mexico City, Mexico, 2001.
7. Pompa, G.M.; Camarero, J.J.; Rodríguez, T.D.A.; Vega, N.D.J. Drought and spatiotemporal variability of forest fires across Mexico. *Chin. Geogr. Sci.* **2018**. [CrossRef]
8. Valiente, O. Sequía: Definiciones, tipologías y métodos de cuantificación. *Investig. Geogr.* **2001**, *26*, 59–80.
9. Llanes, C.O.; Norzagaray, C.M.; Muñoz, S.N.P.; Ruiz, G.R.; González, O.H.A.; Herrera, M.M.N. Estimating Trends and Return Periods of Daily Extreme Precipitation Associated with Tropical Cyclones in the Core North American Monsoon. *Pol. J. Environ. Stud.* **2016**, *25*, 2283–2292. [CrossRef]
10. Norzagaray, C.M.; Muñoz, S.P.; Espinosa, C.L.; Ruíz, G.R.; González, O.H.; Llanes, C.O. Erosivity indicators based on rainfall in Northwestern Mexico. *J. Environ. Eng. Landsc. Manag.* **2016**, *24*, 133–142. [CrossRef]
11. Seager, R.; Ting, M. Mexican drought: An observational modeling and tree ring study of variability and climate change. *Atmósfera* **2009**, *22*, 1–31.
12. Diaz, V.M.; Corzo, P.G.; Solomatine, H.D.H.; van Lanen, A.J. Spatio-temporal analysis of hydrological drought at catchment scale using a spatially-distributed hydrological model. *Procedia Eng.* **2016**, *154*, 738–744. [CrossRef]
13. Llanes, C.O.; Peinado, G.H.J.; Montiel, M.J.; Norzagaray, C.M.; González, O.H.A.; Campista, L.S. Seasonal trend indicators and return periods of meteorological drought in the northern states of Mexico. *Pol. J. Environ. Stud.* **2017**, *26*, 1471–1484. [CrossRef]
14. Serrano, S.M.V.; Beguería, S.; López, M.J.I. A Multi-scalar drought index sensitive to global warming: The Standardized Precipitation Evapotranspiration Index–SPEI. *J. Clim.* **2010**, *23*, 1696–1718. [CrossRef]
15. Yu, M.; Li, Q.; Hayes, M.J.; Svobodab, M.D.; Heim, R.R. Are droughts becoming more frequent or severe in China based on the Standardized Precipitation Evapotranspiration Index: 1951–2010? *Int. J. Climatol.* **2014**, *34*, 545–558. [CrossRef]
16. Stagge, H.H.; Tallaksen, L.M.; Xu, C.-Y.; Van Lanen, H.A.J. Standardized precipitation-evapotranspiration index (SPEI): Sensitivity to potential evapotranspiration model and Parameters. *Hydrol. Chang. World Environ. Hum. Dimens. Proc. Friend-Water* **2014**, 367–373. Available online: http://folk.uio.no/chongyux/papers_SCI/IAHS_363_James.pdf (accessed on 15 January 2018).
17. García, V.O.M.; Gámiz, F.S.R.; Castro, D.Y.; Esteban, P.M.J. Evaluation of WRF capability to detect dry and wet periods in Spain using drought indices. *J. Geophys. Res. Atmos.* **2017**, *122*, 1569–1594. [CrossRef]
18. Serrano, V.; López-Moreno, J.I.; Gimeno, L.; Nieto, R.; Morán, T.E.; Lorenzo, L.J.; Beguería, S.; Azorin, M.C. A multiscalar global evaluation of the impact of ENSO on droughts. *J. Geophys. Res.* **2011**, *116*, D20109. [CrossRef]
19. Meza, J.F. Recent trends and ENSO influence on droughts in Northern Chile: An application of the standardized precipitation evapotranspiration index. *Weather Clim. Extremes* **2013**, *1*, 51–58. [CrossRef]
20. Wang, S.; Huang, J.; He, Y.; Guan, Y. Combined effects of the Pacific Decadal Oscillation and El Niño-Southern Oscillation on Global Land Dry–Wet Changes. *Sci. Rep.* **2014**, *4*, 6651. [CrossRef] [PubMed]
21. Brito, C.L.; Vivoni, E.R.; Gochis, D.J.; Filonov, A.; Tereshchenko, I.; Monzon, C. An anomaly in the occurrence of the month of maximum precipitation distribution in northwest Mexico. *J. Arid Environ.* **2010**, *74*, 531–539. [CrossRef]
22. Zhang, Y.; Wallace, J.; Battisti, D. ENSO-like interdecadal variability: 1900–1993. *J. Clim.* **1997**, *10*, 1004–1020. [CrossRef]
23. Espinosa, C.T.L.; Valdez, H.J.E. Gulf of California interanual chlorophyll variability. *Ecol. Aplicada* **2007**, *6*, 83–92. [CrossRef]
24. Gershunov, A.; Barnett, T.P. Interdecadal modulation of ENSO teleconnections. *Bull. Am. Meteorol. Soc.* **1998**, *79*, 2715–2725. [CrossRef]
25. Mantua, J.N.; Hare, R.S. The Pacific Decadal Oscillation. *J. Oceanogr.* **2000**, *58*, 35–44. [CrossRef]

26. Diedhiou, A.; Janicot, S.; Vitard, A.; Felice, P.; Laurent, H. Easterly wave regimes and associated convection over West Africa and tropical Atlantic: Results from the NCEP/NCAR and ECMWF reanalysis. *Clim. Dyn.* **1999**, *15*, 795–882. [CrossRef]
27. Hallack, A.M.; Ramirez, H.J.; Watkins, D.W. ENSO conditioned rainfall drought frequency analysis in northwest Baja California, Mexico. *Int. J. Climatol.* **2012**, *32*, 831–842. [CrossRef]
28. Troyo, D.E.; Mercado, M.G.; Cruz, F.A.; Nieto, G.A.; Valdez, C.R.D.; García, H.J.L.; Murillo, A.B. Análisis de la sequía y desertificación mediante índices de aridez y estimación de la brecha hídrica en Baja California Sur, noroeste de México. *Investig. Geogr.* **2014**, *85*, 66–81. [CrossRef]
29. Llanes, C.O.; Norzagaray, C.M.; Muñoz, S.P.; Ruiz, G.R.; Troyo, D.E.; Alvarez, R.P. Hydroclimatic trends in áreas with high agricultural productivity in northern Mexico. *Pol. J. Environ. Stud.* **2015**, *24*, 1165–1180. [CrossRef]
30. Instituto Nacional de Estadística y Geografía(INEGI). *Libro anual de Estadísticas por Estado*; INEGI: Aguascalientes, Mexico, 2011; Volume 406.
31. Méndez, M.; Magaña, V. Regional Aspects of Prolonged Meteorological Droughts over Mexico and Central American. *J. Clim.* **2009**, 1175–1188. [CrossRef]
32. Base de Datos del CLICOM. Available online: http://clicom-mex.cicese.mx/mapa.html (accessed on 15 February 2017).
33. Información por Entidad. Available online: http://www.cuentame.inegi.org.mx/monografias/ (accessed on 10 March 2017).
34. The Standardised Precipitation-Evapotranspiration Index (SPEI). Available online: http://sac.csic.es/spei/ (accessed on 30 March 2017).
35. Serrano, S.M.V.; Beguería, S.; Lacruz, L.J.; Camarero, J.J.; López, M.J.I.; Azorín, M.C.; Revuelto, J.M.T.R.; Sánchez, L.A. Análisis comparativo de diferentes índices de sequía para aplicaciones ecológicas, agrícolas e hidrológicas. In Proceedings of the 8th Congreso Internacional de la Asociación Española de Climatología (AEC), Salamanca, Spain, 25–28 September 2012; pp. 679–689. Available online: http://digital.csic.es/bitstream/10261/62168/1/BegueriaS_Analisis_ComnCongSal-AEC_2012.pdf (accessed on 15 January 2018).
36. Mantua, N.J.; Hare, S.R.; Zhang, Y.; Wallace, J.M.; Francis, R.C. A Pacific interdecadal climate oscillation with impacts on salmon production. *Bull. Am. Meteorol. Soc.* **1997**, *78*, 1069–1079. [CrossRef]
37. McKee, T.B.; Doesken, N.J.; Kleist, J. The Relationship of Drought Frequency and Duration to Time Scales. In Proceedings of the Eighth Conference on Applied Climatology, Anaheim, CA, USA, 17–22 January 1993; pp. 179–184. Available online: http://www.droughtmanagement.info/literature/AMS_Relationship_Drought_Frequency_Duration_Time_Scales_1993.pdf (accessed on 15 January 2018).
38. Climate Prediction Center/NCEP. ENSO: Recent Evolution, Current Status and Predictions 2018. Available online: http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/lanina/enso_evolution-status-fcsts-web.pdf (accessed on 5 January 2018).
39. Available online: http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/lanina/enso_evolution-status-fcsts-web.pdf (accessed on 20 April 2017).
40. Pedhazur, E.J. *Multiple Regression in Behavioral Research*, 3rd ed.; Harcourt Brace: Orlando, FL, USA, 1997; Volume 1072.
41. Pacific Decadal Oscillation (PDO). Available online: https://www.ncdc.noaa.gov/teleconnections/pdo/ (accessed on 12 May 2017).
42. Cold & Warm Episodes by Season. Available online: http://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_v5.php (accessed on 10 March 2017).
43. Hammer, Ø. PAleontological STatistics, Version 3.19. Reference Manual. Available online: https://folk.uio.no/ohammer/past/past3manual.pdf (accessed on 15 January 2018).
44. Available online: https://www.esrl.noaa.gov/psd/data/composites/day/ (accessed on 18 July 2017).
45. CONAZA-SAGARPA. Análisis de la Problemática de la Sequía 2011–2012 y Sus Efectos en la Ganadería y la Agricultura de Temporal. 2011. Available online: http://www.conaza.gob.mx/transparencia/Documents/Publicaciones/boletin5.pdf (accessed on 15 January 2018).
46. Base de Datos del Índice Estandarizado de Precipitación (SPI) de la Comisión Nacional del Agua (CONAGUA) y el Servicio Meteorológico Nacional (SMN). Secretaría de Gobernación de México. 2017. Available online: https://smn.cna.gob.mx/es/climatologia/monitor-de-sequia/spi (accessed on 15 January 2018).

47. Escobar, P.J.J.; González, B.J.L.; Sánchez, C.I.; Muñoz, V.A.; Villa, C.M. Análisis de la lluvia y su relación con fenómenos del cambio climático; estudio de caso en estación meteorológica Sardinas (San Bernardo, Durango). *Rev. Chapingo* **2012**, *11*, 75–84.
48. Castillo, C.; Ibáñez, C.M.; Valdés, L.A.; Arteaga, R.J.B.; Vázquez, P.M.A. Análisis de sequías meteorológicas en la cuenca del río Fuerte, México. *Tecnología y Ciencias del Agua* **2017**, *8*, 35–52. [CrossRef]
49. Turrent, C. Variabilidad climática y fenómenos hidrometeorológicos extremos en el estado de Sinaloa (1960–2010). Taller de Adaptación Temprana al Cambio Climático 2013. In Proceedings of the Conference on Report of a Workshop, Culiacan, Sinaloa, Mexico, 29 November 2013.
50. Muñoz, A.F.; Avissar, R.; Zhu, C.; Lettenmmaier, D.P. Sensitivity of the water resources of Rio Yaqui basin, Mexico, to agricultura extensification under multiscale climate conditions. *Water Resour. Res.* **2009**, *45*, W00A20. [CrossRef]
51. Świątek, M. Effects of NAO on the climatic water budget at the Polish southern Baltic coast. *Bull. Geogr.* **2016**, *11*, 17–25. [CrossRef]
52. Moreira, E.; Russo, A.; Trigo, M.R. Monthly Prediction of Drought Classes Using Log-Linear Models under the Influence of NAO for Early-Warning of Drought and Water Management. *Water* **2018**, *10*. [CrossRef]
53. Ruby, L.L.; Qian, Y.; Hunt, A. Hydroclimate of the Western United States based on observations and regional climate simulation of 1981-2000. Part II: Mesoscale ENSO anomalies. *J. Clim.* **2002**, *16*, 1912–1928. [CrossRef]
54. Matías, R.L.G. Precipitación ciclónica como un riesgo natural. *Tesis de Doctorado de la Universidad Nacional Autónoma de México* **2013**, *130*. [CrossRef]
55. Seager, R.; Ting, M.; Held, I.; Kushnir, Y.; Lu, J.; Vecchi, G.; Ping Huang, H.; Harnik, N.; Leetmaa, A.; Cheung Lau, N.; et al. Model Projections of an Imminent Transition to a More Arid Climate in Southwestern North America. *Science* **2007**, *316*, 1181–1184. [CrossRef] [PubMed]