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CLIMATE VARIABILITY OF PRECIPITATION IN CEARÁ REGION, NORTHEAST OF BRAZIL

Variabilidade climática da precipitação no estado do Ceará, Nordeste do Brasil

Variabilidad climática de la precipitación en el estado de Ceará, Nordeste de Brasil

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Abstract: The state of Ceará is a semi-arid region located in the Northeast region of Brazil, characterized by an irregular rainy season, great climate variability mainly driven by the El Niño–Southern Oscillation (ENSO), Sea Surface Temperature (SST) of the tropical South Atlantic and extreme weather events . Droughts and their effects were studied to determine their frequency and help reduce their economic, social and environmental impacts. For that, we evaluated the space-time variability of the Standardized Precipitation Index (SPI) and characterized the drought for the twelve hydrographic regions of the State of Ceará in the scales of 3, 6 and 12 months. The data comprise the period 1980-2020 considering the monthly values of precipitation provided by the Cearense Foundation of Meteorology and Water Resources (FUNCEME)During the years 1982 and 1993, the SPI detected the greatest droughts in the state. It was also verified that 1996 and 1998 were the years with less intense dry events, presented in the 3, 6 and 12 month scales of the SPI. The index proved to be a useful tool for identifying drought in the study area at different time scales. Using wavelet analysis we found increases in spectral power at periodicities of 4-10 years, especially around 1982 and 2011, but these oscillations do not seem to be significant above the red noise spectrum. We found that cooler and warmer ENSO conditions and tropical South Atlantic SST variability were related to wetter rainy seasons, while opposite SST conditions to drier seasons.
Keywords.: Drought. SPI. Precipitation. Ceará. Climate Variability.

Resumo: O estado do Ceará é uma região semiárida localizada na região Nordeste do Brasil, caracterizada por uma estação chuvosa irregular, grande variabilidade climática impulsionada principalmente pelo fenômeno El Niño Oscilação Sul (ENOS), Temperatura da superfície do Mar (TSM) do Atlântico Sul tropical e eventos climáticos extremos. As secas e seus efeitos foram estudados para determinar sua frequência e ajudar a reduzir seus impactos econômicos, sociais e ambientais. Para tanto, avaliamos a variabilidade espaço-temporal do Índice Padronizado de Precipitação (SPI) e caracterizamos a seca para as doze regiões hidrográficas do Estado do Ceará nas escalas de 3, 6 e 12 meses. Os dados compreendem o período 1980-2020 considerando os valores mensais de precipitação fornecidos pela Fundação Cearense de Meteorologia e Recursos Hídricos (FUNCEME). Durante os anos de 1982 e 1993, o SPI detectou as maiores secas do estado. Verificou-se também que 1996 e 1998 foram os anos com eventos secos menos intensos, apresentados nas escalas 3, 6 e 12 meses do SPI. O índice provou ser uma ferramenta útil para a identificação da seca na área de estudo em diferentes escalas de tempo. Usando a análise wavelet encontramos um aumento da potência espectral nas periodicidades de 4-10 anos, especialmente por volta de 1982 e 2011, mas essas oscilações não parecem ser significativas acima do espectro de ruído vermelho. Descobrimos que condições mais frias e mais quentes de ENOS e a variabilidade da TSM do Atlântico Sul tropical, respectivamente, estavam relacionadas com estações chuvosas mais úmidas, enquanto condições opostas de TSM com estações mais secas.
Palavras-chaves : Seca. SPI. Precipitação. Ceará. Variabilidade Climática.

Resumen: El estado de Ceará es una región semiárida ubicada en la región Nordeste de Brasil, caracterizada por una estación lluviosa irregular, gran variabilidad climática impulsada principalmente por el fenómeno El Niño Oscilación del Sur (ENOS), la Temperatura de la Superficie del Mar (TSM) del trópico Atlántico Sur y fenómenos meteorológicos extremos. Se estudiaron las sequías y sus efectos para determinar su frecuencia y ayudar a reducir sus impactos económicos, sociales y ambientales. Para eso, evaluamos la variabilidad espacio-temporal del Índice de Precipitación Estandarizado (SPI) y caracterizamos la sequía para las doce regiones hidrográficas del Estado de Ceará en las escalas de 3, 6 y 12 meses. Los datos abarcan el período 1980-2020 considerando los valores mensuales de precipitación proporcionados por la Fundación Cearense de Meteorología y Recursos Hídricos(FUNCEME). Durante los años 1982 y 1993, el SPI detectó las mayores sequías en el estado. También se verificó que 1996 y 1998 fueron los años con eventos secos menos intensos, presentados en las escalas de 3, 6 y 12 meses del SPI. El índice demostró ser una herramienta útil para identificar la sequía en el área de estudio en diferentes escalas de tiempo. Mediante el análisis de wavelet, encontramos aumentos en la potencia espectral con periodicidades de 4 a 10 años, especialmente alrededor de 1982 y 2011, pero estas oscilaciones no parecen ser significativas por encima del espectro de ruido rojo. Descobrimos que condições mais frias e mais quentes de ENOS y a usare da TSM do Atlântico Sul tropical, respectivamente, estavam relacionados com estações chuvosas mais úmidas, enquanto condições opostas de TSM com estações mais secas.
Palabras-clave.: Sequía. SPI. Precipitación. Ceará. Variabilidad Climática.

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1. INTRODUCTION

Throughout history, droughts have been one of the most complicated meteorological phenomena due to the complexity in the evolution of their severity, duration and geographic extension. During dry periods, millions of people can be affected, causing significant economic losses and social, environmental, agricultural and water resources impacts (DING; HAYES; WIDHALM, 2011; FAO, 2016; NOBRE et al., 2016; WENG et al., 2020; DANTAS; da SILVA; GUIMARÃES, 2020).

According to the considerations about the parameters of duration, severity and intensity, it is possible to classify droughts into different categories, namely those of a meteorological, agricultural, hydrological and socioeconomic nature. From this perspective, although there is an intrinsic interdependence between the different types of drought, there is a greater emphasis on the investigation of its meteorological, hydrological and agricultural aspects (WILHITE; GLANTZ, 1985; SANTOS et al., 2021; ALMEIDA; MARQUES, 2021).

However, there is no generally accepted definition of drought and human perception and perspective of this physical phenomenon and its impacts tends to be regionally specific (HEIM; RICHARD, 2002). There are also many different methodologies for monitoring dry/wet periods; most of the observational studies have been performed using drought indices (HEIM; RICHARD, 2002; HAYES, 2006; ZARGAR et al., 2011; TRENBERTH et al., 2014; QUESADA-HERNANDÉZ et al., 2019), that frequently used meteorological and hydrological data.

Particularly, in the Brazilian Northeast, the behavior and evolution of the drought has been monitored through the Standardized Precipitation Index (SPI) (MCKEE et al., 1993). We found several studies of this particularity, such as Fechine (2015), Santos (2017), Pontes et al. (2020), Da Silva et al. (2020) and Silva et al. (2013) providing an indication of the persistence of precipitation deficit conditions in the region. The state of Ceará in the semi-arid environment of the northeastern part of Brazil is a region with a high water scarcity, and it is periodically affected by this natural hazard (FIAN; NELSON, 2001; DE OLIVIERA, 2019).

The occurrence of severe droughts plays an important role in regional agricultural activities due to the direct effect on the wide availability of irrigation systems (RAMALHO, 2013; ALVALA et al., 2017). Some studies have shown that Ceará is one of the world's most vulnerable regions to extreme climate events (SILVA et al., 2013; ALVALA et al., 2017; SENA et al., 2018; MARENGO et al., 2020) and future climate projections suggest an intensification of water deficits, related to temperature increases and rainfall reductions (GUIMARÃES et al., 2016; MARENGO et al., 2017; TORRES; ALVES, 2017; IPCC, 2022).

In terms of duration and intensity, the worst drought since 1980 that affected the state of Ceará was over the period 2012-2016, where negative precipitation anomalies were recorded in over 50% of the region, mainly in the central and southern parts of the region. In recent years, the federal government has declared a state of "public calamity" over 6,295 times due to the droughts in Ceará State (LIMA, 2020; QUEIROGA, 2019). Thus, the central proposal of this study resides in the evaluation of the space-time variability of the precipitation patterns, as well as the identification of its underlying determinants. In addition, we seek to characterize wet/dry periods for the twelve hydrographic regions of the state of Ceará over the period between 1980 and 2020. Through this investigation, we intend to achieve a deep understanding of the dynamics inherent to droughts, as well as their characteristics, with a view to a more comprehensive understanding of the impacts of these events on the human and environmental spheres. This approach, in turn, may bring positive benefits within the scope of preventive and mitigating measures, seeking to mitigate adverse effects or contain accidents arising from the danger intrinsic to the occurrence of droughts (CARMO; LIMA, 2020; SILVA et al., 2021).

Although several studies on this region have been previously released, the unpredictable nature of the rainfall period, the susceptibility of the local community and the climatic oscillation peculiar to the state of Ceará, confer crucial strength to the persistence of continuous surveillance and the continuation of research related to drought. Given the importance of drought and climate variability impacts, much work remains to be done to increase resilience and improve drought policies and response planning measures in Ceará.

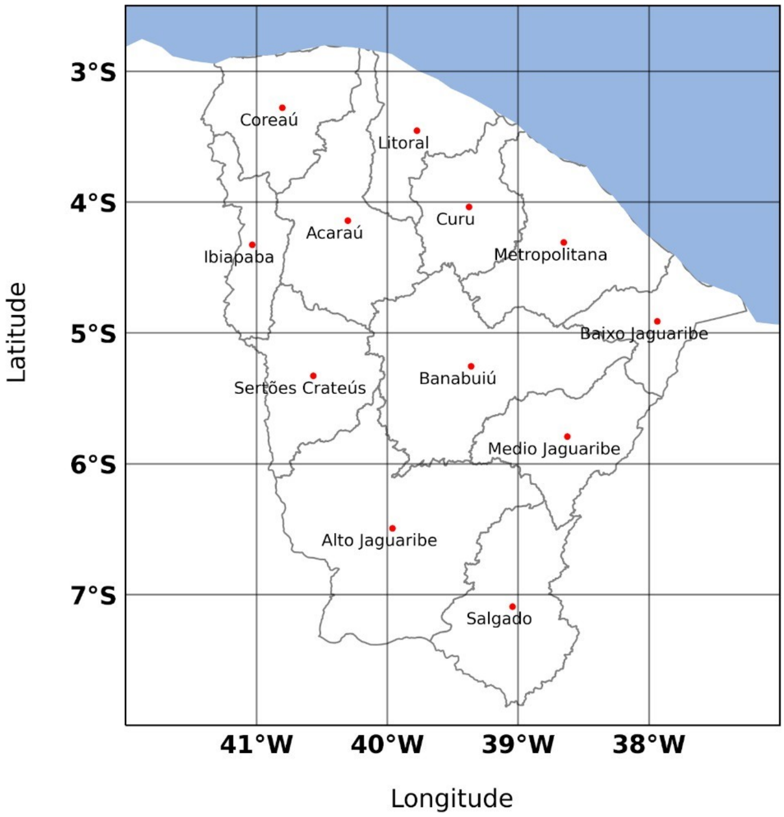
2. MATERIAL AND METHODS

2.1. Study Area

The State of Ceará is located in the Northeast region of Brazil and is composed of twelve river basins (Figure 1), and covers an area of approximately 136,328 km². It is bordered to the east by the states of Rio Grande do Norte and Paraíba, to the south by the state of Pernambuco, to the west by the state of Piauí and is bathed to the north by the Atlantic Ocean. Ceará encompasses 92% of its territory in the semi-arid region and lies upon the northeastern slope of the great Brazilian Highlands and upon the sandy coastal plain. In this region, nearly 80% of agricultural labor is composed of family farming, according to data from the last Agricultural Census conducted by IBGE in 2017 (IBGE, 2019).

The northeastern semi-arid climate of Brazil is characterized by Caatinga vegetation, low precipitation levels, high solar radiation and evaporation rates (GONDIM et al., 2017). As a consequence, the region is remarkable for being vulnerable to drought events, with an intense dry season period of seven months. The dry season lasts from June to December and the main rainy season from January to May (FUNCEME, 2020).

Figure 1 - Location of the hydrographic basins in Ceará state.



Source: Elaborated by the authors (2022).

Weather conditions in the Brazilian Northeast are influenced by local orography, the Intertropical Convergence Zone (ITCZ), easterly wave disturbance, breeze circulations, mesoscale convective systems, instability lines, and high-level cyclonic vortices(UVO;

BERNDTSSON, 1996).The interannual climatic variability is modulated by the Sea Surface Temperature anomalies (SST) (UVO et al., 1998) and drought have been related to the warm phase of Niño–Southern Oscillation (ENSO) episodes (SILVA et al., 2021). Additionally, Enfield and Mestas-Nuñez (1999; 2000) and Mestas-Nuñez and Enfield (1999; 2001), showed that the local climate of the northeast of Brazil could be modulated by multiscale variabilities in global SSTs trough relationships with tropospheric climate patterns.

2.2 Data

Precipitation records were used to evaluate the hydrographic conditions of twelve hydrographic basins in the state of Ceará, namely Acaraú, Alto Jaguaribe, Baixo Jaguaribe, Banabuiú, Coreaú, Curu, Ibiapaba, Litoral, Médio Jaguaribe, Metropolitana, Salgado and Sertões Crateús (as per indicated in Figure 1), during a comprehensive period of 41 years, from 1980 to 2020.

These data were provided by the Cearense Foundation of Meteorology and Water Resources (Funceme) and formed the basis of the analysis to investigate the drought patterns in the region in question. The meteorological stations are automatic and provide monthly data in all periods. The chronological series referring to each region were constructed using the weighted average calculation technique, using Thiessen's method (DAVIS,1986). Data referring to the characteristics of the watersheds, coordinates of the central point and associated altitude values are detailed in Table 1.

Table 1- List of hydrographic basins in Ceará State, their centroid locations and altitudes. Significant linear trends of the associated precipitation indices with 95% of confidence are highlighted in bold.

Basin number	Basin Name	Latitude North	Longitude West	Altitude (m)	Trend (x 10^{-2} mm/month)
1	Acaraú	-40,3	-4,14	168	-3.68
2	Alto Jaguaribe	-39,96	-6,49	311	-3.78
3	Baixo Jaguaribe	-37,94	-4,91	21	-2.81
4	Banabuiú	-39,36	-5,26	247	-3.24
5	Coreaú	-40,8	-3,28	35	-3.63
6	Curu	-39,38	-4,04	128	-2.58
7	Ibiapaba	-41,03	-4,32	658	-6.18
8	Litoral	-39,77	-3,45	57	-3.35
9	Medio Jaguaribe	-38,62	-5,79	138	**-5.51**
10	Metropolitana	-38,65	-4,31	113	-2.90
11	Salgado	-39,04	-7,09	335	-2.15
12	Sertões Crateús	-40,57	-5,33	297	-2.02

Source: Elaborated by the authors (2022).

SST monthly time series from the Niño 3.4 and Tropical South Atlantic (TSA) indices were used to account for the variations caused by ENSO and Atlantic Ocean climate conditions in the Pacific and Atlantic tropical regions. Data were obtained from the NOAAs Physical Sciences Laboratory (https://psl.noaa.gov/data/correlation/nina34.anom.data and https://psl.noaa.gov/data/correlation/tsa.data, respectively). These indices were selected because they have been suggested as climate variability sources of precipitation in (e.g. MESTAS-NUÑEZ; ENFIELD, 2001; SILVA et al., 2021). The TSA SST variability (ALFARO; SOLEY, 1999) is important through its comparison with the Tropical North Atlantic (TNA) SST variability (ALFARO, 2000), associated with the Atlantic SST Dipole (SILVA et al., 2021) and with the ENSO condition (MESTAS; NUÑEZ; ENFIELD, 2001).

2.3. Methodology

The time series data of 12 monthly precipitations from the river basins of the Ceará region were composed into a normalized precipitation index (PINDEX), by subtracting the historical monthly precipitation averages and dividing these anomalies by their historical monthly standard deviations. Trends were removed from the normalized series subtracting a simple linear regression model (WILKS, 2019).

The correlation matrix was estimated using these last monthly precipitation normalized trend indices to explore the time covariability and their spatial coherence. Due to high correlations between the regions (see Table 3 presented in Section 4), monthly averages of the 12 Pindex were estimated to obtain a single precipitation index for the entire Ceará State. This index was used to calculate the SPI and the wavelet analysis.

2.3.1 SPI index

The Standardized Precipitation Index (SPI) is a drought indicator developed by Mckee et al. (1993) with the purpose of evaluating both deficits (dry periods) and excesses (wet periods) of precipitation in different time scales, based on historical input data. Widely adopted worldwide, the SPI is the pre-eminent tool for identifying and quantifying drought conditions, including their intensity, a natural phenomenon that significantly impacts water supply, agricultural practices and hydrological systems. The notable power of the SPI resides in its simplicity and ease of calculation, because precipitation is the only input parameter; which allows us to study meteorological (1-3 months), agricultural (3-7 months) and hydrological (7 months above) droughts.

Additionally, the SPI assumes a prominent role in the projection of extreme events, serving as a preventive measure in the face of potential drought situations (SILVA et al., 2021). It is important to note that the aforementioned index is highly recommended by the World Meteorological Organization (WMO, 2012), endorsing its substantial validity and usefulness in monitoring and analyzing drought manifestations at a global level.

The SPI values are classified in different drought conditions based on the proposed SPI classification by McKee et al. (1993) shown in Table 2. In this study, the SPI was calculated for the Pceara index from 1980 to 2020 using the software R and the methodology described by Wheatley (2010) for 1, 2, 3, 6, 12, 24 and 36 month time scales. The script was provided by Muñoz and Van Meerbeck (2014) who wrote the code for the Latin American Observatory's (OLA), a center of The New School University in New York.

Table 2- SPI values

SPI value	Category
2+	extremely wet
1.5 to 1.99	very wet
1.0 to 1.49	moderately wet
-0.99 to 0.99	near normal
-1 to -1.49	moderately dry
-1.5 to -1.99	severely dry
-2 and less	extremely dry

Source: Elaborated by the authors (2022).

2.3.2 Wavelet analysis

The use of the wavelet is indicated for the understanding irregularly distributed events and time series that contain non-stationary powers at different frequencies, since it brings several advantages over the classical spectral analysis, as it allows us to analyze the periodicity of events at different scales of temporal variability and does not need a stationary series.

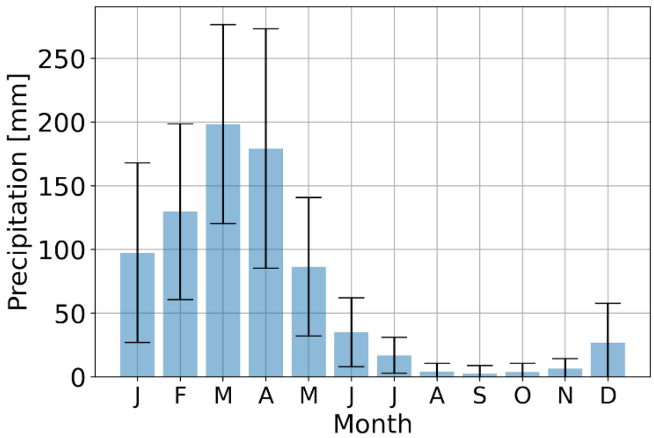
According to Santos et al. (2013) its nomenclature originates from the French word ondelette, which denotes a small wave. The wavelet power spectrum was calculated according to the MatlabR code provided by Torrence and Compo (1998). A red noise spectrum was used as background noise for the spectral signal. Other software parameters in relation to wavelets are: mother wavelet = Morlet, pad =1; with zeros the data on the edges, dj = 0.25 (4 sub-octaves per octave) and j1 = 7/dj (7 powers of two with dj sub-octaves each). The wavelet spectrum was used to determine the dominant frequencies and, therefore, the periodicities of normalized precipitation in the state of Ceará.

The Wavelet Transform (TW) is considered a contemporary advance in signal processing and has aroused interest for several applications since its theoretical development in 1984 by Grossman and Morlet. Its application has expanded rapidly, with the aim of overcoming the limitations of classical signal analysis techniques such as the Fourier Window Transform (TF), presenting itself as an alternative to protecting local, non-periodic and multiple-scale observations . TW has small short-lived waves (called Mother Wavelet) that are transposed through a time series and that dilate and compress to capture high and low frequencies in the signals (BOLZAN, 2006; SANTOS, FREIRE; TORRENCE, 2013; WILKS, 2019).

3. RESULTS AND DISCUSSION

Figure 2 shows the average of the twelve historical annual averages of the indices listed in Table 1. It is possible to observe that rains occurred mainly from January to May (88%), with a maximum in March, similar to da Silva et al. (2021) for Choró sub-Basin. A dry period is present from June to December, with a minimum in September. Months of maximum and minimum variability are April and October, respectively.

Figure 2 -Climatological averages of precipitation (bars) for the Ceará State from 1980 to 2020. Whiskers are for ± one standard deviation considering the variation of the climatology of the 12 regions.



Source: Elaborated by the authors (2022).

The correlation matrix presented in Table 3 shows the high values of positive and statistically significant correlation, suggesting an important covariability between the indices; therefore, the original precipitation indices of the individual regions can be calculated in a single time series representing the climatic variability of the state of Ceará, reducing the dimensionality of the analysis.

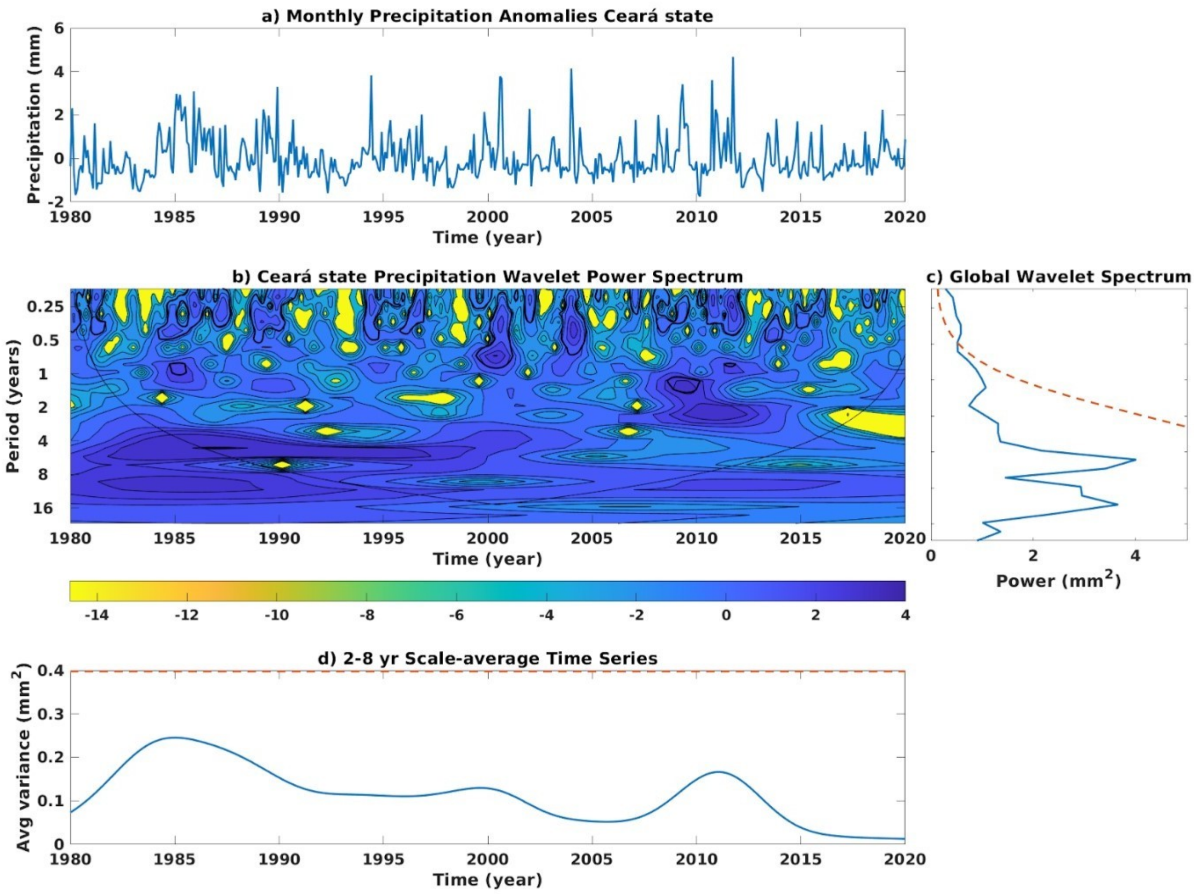
Table 3- Correlation matrix for the twelve normalized and detrended precipitation indices listed in Table 1. All correlations have a p-value < 0.01.

	2	3	4	5	6	7	8	9	10	11	12
1	0,70	0,74	0,71	0,76	0,76	0,80	0,60	0,72	0,71	0,64	0,73
2		0,69	0,73	0,62	0,67	0,71	0,49	0,76	0,69	0,80	0,74
3			0,76	0,66	0,81	0,74	0,50	0,79	0,83	0,64	0,65
4				0,62	0,72	0,70	0,50	0,82	0,75	0,63	0,68
5					0,73	0,80	0,59	0,65	0,69	0,59	0,66
6						0,78	0,66	0,73	0,87	0,64	0,67
7							0,52	0,75	0,70	0,65	0,72
8								0,48	0,63	0,43	0,52
9									0,72	0,69	0,71
10										0,62	0,65
11											0,65

Source: Elaborated by the authors (2022).

From the wavelet time-frequency analysis for Ceará State precipitation index (Pceara, presented in Figure 3a); it is clear that most of the energy is located in periods from 4 to 10 years (Figure 3b), with a maximum around 1985. Two secondary peaks are observed around 2000 and 2011 (Figure 3d). The ENSO band of frequencies (Figure 3c) showed increased power around the same years, although it did not reach significance above the red-noise.

Figure 3 - Time-frequency analysis for Ceará State precipitation index (Pceara), A) index time series, B) wavelet contour plot, C) Fourier spectrum and D) Scale average time series corresponding to the usual frequency band of ENSO.



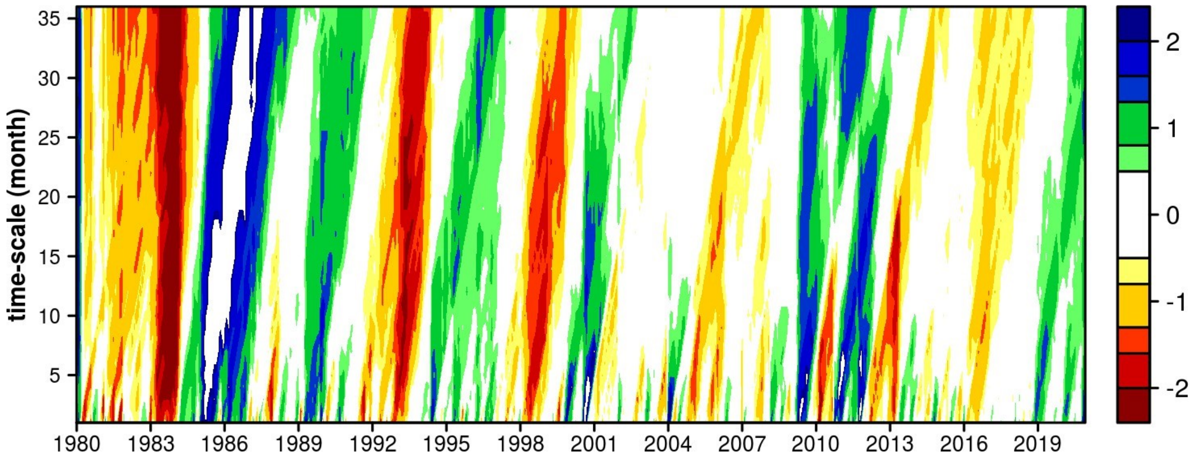
Source: Prepared by the authors (2022).

Figure 4 illustrates the variability of monthly SPI for the Pceara precipitation index (average of the twelve hydrographic regions of Ceará State) at different timescales (1 to 36 months) from 1980 to 2020. The figure shows the cumulative effect of drought on different time scales. Prolonged periods in red indicate long durations (horizontal axis), while red tones extending over multiple time scales (vertical axis) indicate the evolution of meteorological drought (lasting a few months), to agricultural or hydrological droughts (several months).

Note in Figure 4 a recurrence of dry periods (red/orange colors) from 1981 to 1983 and some wet years, such as in 1984–1986 (blue/green colors). Other important dry conditions were observed in Ceará from 1991 to 1993 and from 1998 to 1999. Other minor events were observed starting in 2005-2006, 2010, 2012-2013 and 2016, in agreement with the previous study of da Silva et al. (2021) for Choró sub-Basin. Wetter conditions starting in 1985-1987, 1989-1990, 1994-1995, 1999-2000, 2009, 2011 and 2019. The results of Marengo, Torres and

Alves (2017) showed that from 1979 to 1983 certain areas of the northeastern semi-arid were affected by droughts, which is consistent with the dry events identified. According to the Center for Weather Forecast and Climatic (CPTEC, 2018), 1982 and 1983 were registered as warm phases of ENSO, one of the main causes of rainfall deficiency and drought in the region, in addition to some cold SST conditions observed in the TSA (ALFARO; SOLEY, 1999).

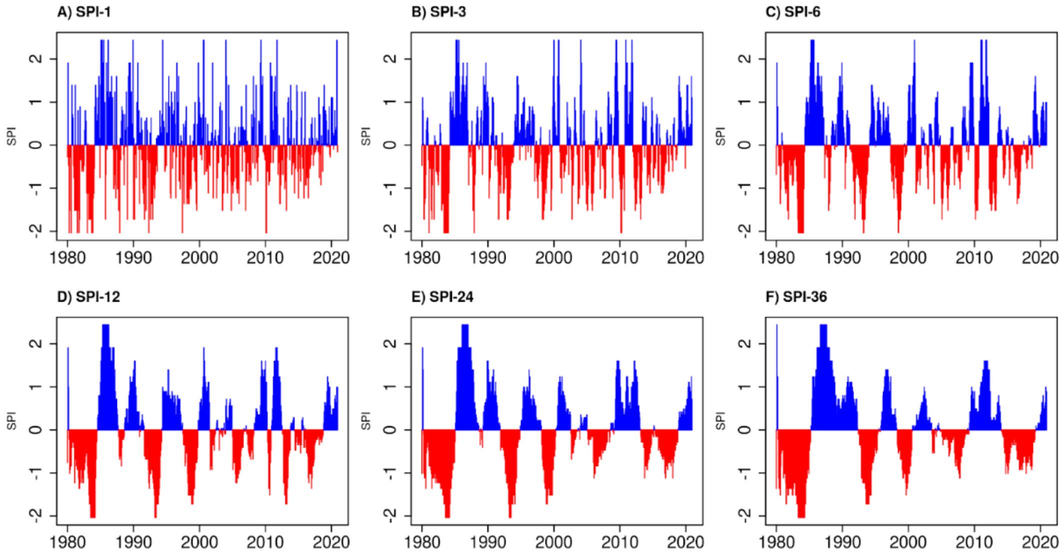
Figure 4 -SPI time-scale for Ceará State for the monthly precipitation index (Pceara).



Source: Elaborated by the authors (2022).

The SPI for Pceara index has been calculated for periods of 1, 3, 6, 12, 24 and 36 months (Figure 5). In this context, the severe and persistent drought conditions that lasted from 1980 to 1983 are noticeable. The most recent occurrence of dry events, which started in 2012, is notable on the SPI-12 scale. Between 2012 and 2018, there were records of deficits influenced by precipitation, impacting various sectors of society (Buriti, 2020). Specifically, the year of 2012 was marked by the presence of warm waters in the Tropical North Atlantic, associated with the phenomenon of the Atlantic Dipole. The sharp peaks of aridity observed between 2012 and 2018 are considered, according to the literature, as one of the most recent and prolonged periods of drought to affect the state (NUNES; MEDEROS,2020; MARENGO; CUNHA; ALVES, 2016; MARENGO; TORRES; ALVES, 2017; MARENGO et al., 2020).

Figure 5 -SPI time series for Ceará State monthly precipitation index (Pceara) at A) 1-month time-scale (SPI 1), B) 3-month time-scale(SPI 3), C) 6-month time-scale(SPI 6), D) 12-month(SP I2), E) 24-month time-scale(SPI 24) , F) 36-month time-scale(SPI 36).



Source: Elaborated by the authors (2022).

Table 4 shows the contingency between the months JFMAM (January-February-March-April-June) TSA-Niño 3.4 and the Pceara indices. Results show that during years in which SSTs tend to be cooler (warmer) in the TSA when compared with Niño 3.4, rainy seasons tend to be drier (wetter) in Ceará.

Table4- Contingency analysis between annual JFMAM of TSA-Niño 3.4 and precipitation indices, for 1980–2020 (41 years). The values inside the parentheses are for empirical occurrences and the values outside of them are for relative occurrences expressed as row percentages. Spearman correlation = 0.65*** and χ2=17.28***. Low and high counts significance were estimated against a Monte Carlo test of 104 random tables. In this table, *** indicates a statistical significance of α < 0.01. BN indicates below normal, N is normal, and AN denotes above normal.

		P-JFMAM (mm)		
		BN	**N**	**NA**
TSA-Niño 34	**BN**	64(9)***	29(4)	7(1)***
JFMAM	**N**	31(4)	46(6)	23(3)
	AN	7(1)***	21(3)	72(10)***

Source: Elaborated by the authors (2022).

Years for BN (below normal) conditions were: 1981, 1982, 1983, 1987, 1990, 1993, 1998, 2012 and 2015. Meanwhile, years for AN (above normal) conditions were: 1984, 1985, 1986, 1988, 1989, 1996, 2008, 2009, 2011 and 2020. Mestas-Nuñez and Enfield (2001) suggested that the mechanism associated with El Niño–related rainfall deficits in the northeast of Brazil is the northward displacement of the Atlantic Inter-tropical Convergence Zone (ITCZ) in response to El Niño–induced warming in the North Atlantic (ENFIELD; MAYER, 1997), meanwhile La Niña events favors ITCZ south positions and precipitations over the northeast of Brazil. Warm and cool TSA events also influence the Atlantic Intertropical Convergence Zone position, through southern and northern latitudes, favoring wetter and drier rainy seasons in the northeast of Brazil (SILVA et al., 2021).

4. FINAL CONSIDERATIONS

In the context of the state of Ceará, it is important to point out that rainfall was concentrated mainly in the period between January and May, representing approximately 88% of the total recorded. March stood out as the month with the highest rainfall in this range. On the other hand, there was a period characterized by scarce rainfall, which covered the months of June to December, reaching its minimum in September. In addition, when analyzing the basin rainfall rates over the 1980s to 2020, the presence of negative trends becomes evident.

High negative SPI values, characterizing severe and extreme drought events, were identified in all studied stations. These events occurred in many cases due to the simultaneous occurrence of rain-inducing phenomena and multi-scale mechanisms. that are responsible for precipitation anomalies.

The SPI analysis showed a recurrence of dry periods in Ceará from 1981 to 1983 and some wet years, as in 1984-1986. Other important droughts were observed in Ceará from 1998 to 1999. Other smaller events were observed in 2005, 2006, 2010, 2012, 2013 and 2016.Wetter conditions starting in 1985-1987, 1989-1990, 1994-1995, 1999-2000, 2009, 2011 and 2019. The wavelet analysis showed that most of the energy is located in periods from 4 to 10 years, with a maximum around 1985 for Ceará State precipitation index.

The contingency analysis shows that years in which SSTs tend to be cooler (warmer) in the TSA when compared with Niño 3.4, rainy seasons tend to be drier (wetter) in Ceará, favoring north (south) ITCZ positions, since local climate of the Brazilian Northeast could be modulated by multiscale variabilities in global SSTs trough relationships with tropospheric climate patterns.

The SPI proved to be quite capable of quantifying dry events, proving to be an adequate tool to mitigate extreme drought events, since early identification and monitoring result in a set of information that helps several sectors, mitigating the impacts that these events may have on society.

Thus, public policies should also be promoted both at the municipal, state and federal levels, aiming at effective strategies to mitigate socio-environmental problems of the northeastern semi-arid region. Pointing out the importance of knowledge about extreme weather events.

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