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Estimation and Assessment of Temporal Stability of Periodicities of Droughts in Iran

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Abstract The main objective of the present study was to identify the periodic behavior of monthly droughts in Iran. For this purpose, monthly precipitation data obtained from 41 synoptic stations for a period of 22 years (1992–2013) were used. To identify the frequency of different severities of drought, effective drought index (EDI) was calculated at monthly scale and then spectral analysis of time series of EDI was conducted for each station. Temporal stability of these periods was also estimated using the wavelet transform. The results of spectral analysis of monthly droughts in Iran showed that periodicities in time series of Iran's droughts are very diverse and involve periods of 2 to 22 years. Assessment of temporal stability of periodicities using the wavelet transform also indicated that there is a dominant periodic interval (significant at a level of $\alpha = 0.1$) only in 8 stations of Ardebil, Iranshahr, Zahedan, Bandar Lengeh, Shahroud, Khorramabad, Oroomieh, and Shahre Kord. Studying the variability of time series of EDI in 41 stations showed that the severity of wet years is declining and the severity of droughts is increasing. It was also observed that periodic intervals were shorter at the beginning but longer at the end of time series. This suggests that the probability of incidence of drought in Iran is increasing. Additionally, a reduction can be observed in interval between incidences of droughts in Iran. This means that the interval between occurrence of droughts were longer at the beginning and then shorter at the end of times series.

Keywords Drought · Effective drought index · Periodicity · Spectral analysis · Wavelet transform

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1 Introduction

Variability of climatic phenomena is manifested in three intervals in the form of trend, oscillation, and fluctuation. Trend refers to the long-term behavior of time series and fluctuation reflects the unique and unrepeatable behaviors. However, the distinctive aspect of oscillation is its recurring pattern. In this case, after a while, the climatic system presents a configuration "similar" to the previous pattern with a slight difference. Many climate oscillations in a fixed time period (e.g. one year or less) are marked with monthly or seasonal periods. These cycles are called apparent cycles or periods. Many other climatic cycles are not manifested immediately, but rather occur gradually over time. This type of cycles is known as latent cycles.

Drought, as a climatic phenomenon, is considered one of the most important natural disasters due to its special vastness and short-term and long-term economic, social, and environmental consequences. Thus, studies which conducted to reveal the spatiotemporal behavior of this phenomenon and particularly periodicities can be very useful for predicting this phenomenon in the future. In addition, these studies can be used to identify the causes of drought. In numerous studies, drought has been defined as the year in which precipitation is less than the long-term average (Rossi et al. 1992; Tsakiris and Vangelis 2004; Currie 2007). In addition, other indices such as tree rings (Scuderi 2003), water level of rivers (Zhang et al. 2006), surface sediments (Abbott et al. 2005), peat (Hong et al. 2001), and agricultural productivity (Gudeta et al. 2003) have been used for estimating precipitation rate and determining the status of droughts. Determining the amount of damage caused by droughts (Jiang et al. 2006), their relationship with temperature (Zhaoxia et al. 2003), oxygen/nitrogen analysis (Hong et al. 2001; Abbott et al. 2005), and cycles of mountain fires (Garner 2007) are among other indices which have been used for this purpose.

The studies conducted using these indices have reported different periodicities and various causes for droughts which can be classified into several categories. The first category of studies includes those which have shown a direct relationship between drought periodicities and sunspot activity. These studies indicate that 11-year and 22-year cycles of sunspot affect cycles of droughts (Stockton and Meko 1975; O'Brien and Currie 1993; Hodell et al. 2001; Zarin and Mofidi 2005; Paulo and Pereira 2007; Jahanbakhsh and Adalatdoust 2008; Edossa et al. 2010). The second category belongs to studies which have used tree rings for estimation of precipitation rate and extraction of droughts cycle (Juan and Yanben 2005; Currie 2007). The third category of studies discusses the relationship between droughts and ENSO (El Niño-southern oscillation) (Ting and Wang 1997; Chen and Newman 1998; Chiew et al. 1998; Chang and King 1999; Dilley and Heyman 1999; Bordi and Sutera (2001); Nazemosadat and Ghasemi 2003; Jiang et al. 2006; Zhang et al. 2006, 2007; Raziei et al. 2009; Carvalho and Woodroffe 2015). The fourth category is related to studies arguing that blockings in the upper atmosphere (Girardin et al. 2004; Knapp et al. 2004; Habibi 2006, 2008) and eccentric transition of water vapor (Chen and Newman 1998) are the main causes of droughts. Finally, the last category belongs to studies which have focused on the severity of droughts rather than their causes. These studies themselves can be divided into two groups; studies which argue that the frequency of droughts has increased from the late twentieth century onwards (Dai and Trenberth 1998; Gan 2000; Piccarreta et al. 2004; Khazanedari et al. 2011; Moafi Madani et al. 2013; Salehnia et al. 2013) and those which state that the frequency of droughts has declined in some parts of the world (Pandey and Ramasastri 2001).

The statistical method which has been used in most of these studies for identification of drought periodicities is based on spectral analysis or frequency domain analysis. The background of using this method in climatology studies, especially in the field of climatology of precipitation, goes back to the 1950s. The first studies in this regard were conducted by Scott and Shulman (1979) and Kirkyla and Hameed (1989). In later years, some studies were carried out on precipitation harmonic by Kadioglu et al. (1999), Tarawneh and Kadioglu (2003), Livada et al. (2008), Nastos and Zerefos (2009).

In the Iranian literature of climatology and meteorology, spectral analysis has been frequently used for identifying the periodic behavior of various climatic variables. Taghavi et al. (2011) studied the maximum monthly 24-h precipitation, mean maximum monthly temperature, and mean minimum monthly temperature in 65 synoptic stations in the period 1986–2005 using spectral analysis. Mohammadi et al. (2011) used harmonic analysis to study the intra-annual variability of frequency of maximum monthly precipitation. Asakereh (2012) studied the changes in extreme precipitation in Zanjan station, western Iran, using the generalized extreme values (GEV) and then extraction of four indices of extreme precipitation (maximum precipitation, five major rainfalls, the fifth percentile, and the ninety-fifth percentile). The results showed that frequency distribution of precipitation obtained from the fifth percentile is different in the first half (1983–1961) and the second half (2006–1984), as it has undergone a shift from skewed distribution to the left in the first half to skewed distribution to the right in the second half. These changes occurred on the fifth percentile of precipitation were observed with less severity in precipitation of the ninety-fifth percentile. Therefore, it can be concluded that the frequency and amount of heavy and light precipitation have gone through a decreasing trend. In addition, the study of four indices using spectral analysis led to the identification of a nearly three-year cycle for total precipitation derived from five major rainfalls in this station. Additionally, Movahedi et al. (2012), Asakereh (2012), Asakereh (2012), and Jalili et al. (2011) used spectral analysis for precipitation, temperature, identification of apparent and latent cycles of time series in water flow of rivers, and times series of water level of Oroomieh Lake, respectively.

According to the results of previous studies, it can be concluded that most studies that have focused on spectral analysis not only did not manage to show cycles of droughts but also were unsuccessful in demonstrating the cycles of floods. Moreover, most previous studies have not used the actual amount of precipitation and used other methods such as tree rings for estimating the precipitation amount and defining dry years. Finally, many of these studies have not used drought indices, but they used the annual precipitation or five-year cumulative precipitation for determining drought cycles (Byun et al. 2008). The present research aims to use effective drought index (EDI) and two statistical techniques of spectral analysis and wavelet transform in order to demystify the ambiguities in previous studies mentioned by and also identify the dominant cycles of drought in Iran. For this purpose, an introduction of Iran and the data and statistical methods used in this study will be presented in the second part. In the next part, the results obtained from spectral analysis and wavelet transform on EDI for extraction of dominant cycles of drought in Iran will be described. Finally, the last part of this paper deals with discussion and conclusion.

2 Methodology

To identify the periodic behavior of droughts in Iran, monthly precipitation data related to 41 synoptic stations for a period of 22 years (1992–2013), obtained from Meteorological

Organization of Iran, were used. These data contained complete and reliable statistics and their slight statistical gap was eliminated using correlation methods and regression models. In order to evaluate the homogeneity of data, run test was used, recommended by scientific meteorological authorities. The results of run test confirmed the data homogeneity at a high level. Distribution of studied stations has been presented in Fig. 1.

After development of the required database, effective drought index (EDI) was used for identification of frequency of different severities of droughts. This index was developed by Byun and Wilhite in 1999 for identifying and determining the beginning and end of droughts. EDI is a very powerful tool for the analysis of precipitation data at two daily and monthly scales (Morid et al. 2006; Kim and Byun 2009; Akhtari et al. 2009; Kalamaras et al. 2010). Classification of EDI has been shown in Table 1.

For acquiring information on calculation of EDI, refer to Morid et al. (2006) and Kim and Byun (2009), Akhtari et al. (2009) and Kalamaras et al. (2010).

2.1 Spectral Analysis

2.1.1 Fourier Transform

Fourier method can be also used for non-periodic time series (Alonso and Finn 1992). In spectral analysis of a time series, uncertainty principle should be taken into account (Mertins

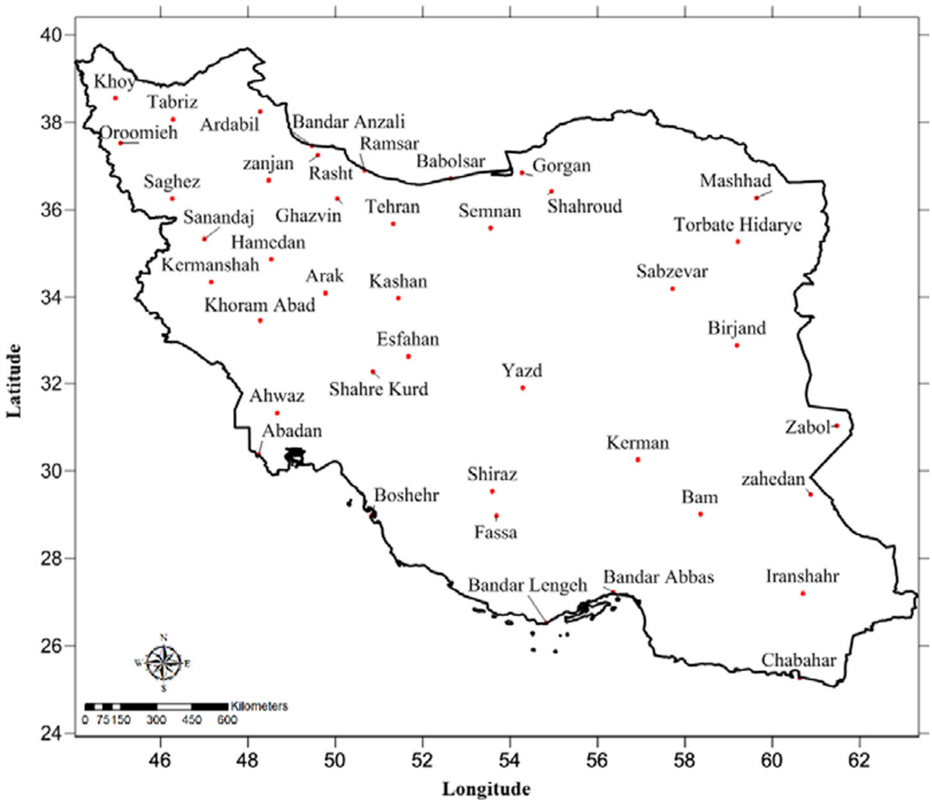

Fig. 1 Location and distribution of the studied stations

Table 1 Classification of effective drought index (EDI)

Class	Values
Extreme wet	Greater than or equal to 2.5
Severe wet	Greater than or equal to 1.5
Moderate wet	Greater than or equal to 0.7
Normal	Smaller than 0.7 and greater than −0.7
Moderate Drought	Smaller or equal to −0.7
Severe drought	Smaller or equal to – 1.5
Extreme drought	Smaller or equal to −2.5

1999). Uncertainty principle specifies the limits on the time-frequency identification. Using the classical Fourier transform, frequencies and periods can be identified precisely. This detailed information in the frequency domain makes temporal information to be missed. To put it simply, temporal identification in frequency domain and frequency identification in time are equal to zero in Fourier transform (Mertins 1999). This reveals inefficiency of Fourier transform in analysis of non-stationary time series. Therefore, it is necessary to consider the stationary or non-stationary of time series before Fourier analysis. There are different approaches of Fourier transform. In this study, fast Fourier transform (FFT) The Decimation –In – Frequency FFT Algorithms method was used. FFT uses the idea of discrete Fourier transform (DFT). In fact, FFT is the fast realization of DFT which takes advantage of the result of matrix multiplication to reduce the computational steps (Mertins 1999). It must be noted that in the rapid Fourier transform the number of data items must be a power of two. If the number of the data items is not a power of two, the other members are considered to be zeros to complete the length of the series (Mertins 1999).

2.1.2 Wavelet Transform

In this study, discrete wavelet transform with Morlet prototype function was used. Morlet wavelet pattern has been shown in Fig. 2.

The Morlet wavelet pattern shown in Fig. 2 is the result of multiplication of a complex exponential wave and a Gaussian package which is as follows:

$$\Psi_{\circ}(n) = \pi^{-\frac{1}{4}} e^{i\omega_{\circ}n} e^{-\frac{n^2}{2}} \quad (1)$$

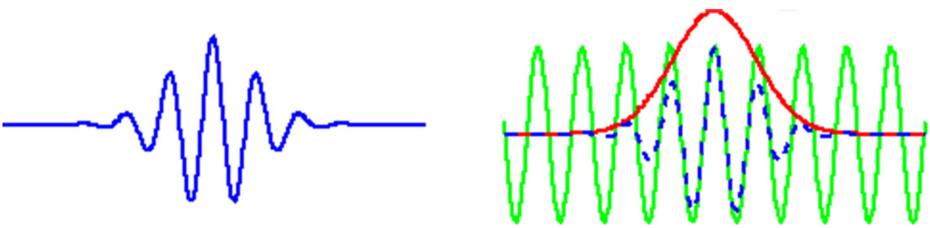

Fig. 2 A sample of Morlet wavelet pattern

This is the basic wavelet function. Scaling wavelet is used to change the size of the wavelet in time. Scaling wavelet is defined as follows:

$$\psi\left[\frac{(n'-n)\delta t}{s}\right] = \left(\frac{\delta t}{s}\right)^{\frac{1}{2}} \psi_{\circ}\left[\frac{(n'-n)\delta t}{s}\right] \tag{2}$$

Where, S and δt represent scaling parameter and transition parameter, respectively. Wavelet transform $W_n(s)$ is an internal multiplication of wavelet function by time series. This transform is shown as follows:

$$W_n(s) = \sum_{n'}^{N-1} x_{n'} \psi^* \left[\frac{(n'-n)\delta t}{s}\right] \tag{3}$$

Where, $x_{n'}$ denotes amounts of time series. It should be noted that n and n' represent time and the asterisk shows the complex conjugate function. In this study, the software developed by Torrence and Compo (1998) was used for wavelet analysis (Torrence and Compo 1998).

3 Discussions

Effective drought index (EDI) was calculated for all studied stations at a monthly scale. Then, the stationary condition of monthly time series of EDI was studied in all 41 stations. In stations where the stationary condition was not true, Box and Cox transformations was used for making them static. Then, the data were analyzed using The Decimation –In – Frequency FFT Algorithms method. Periodogram, which illustrates the relationship between exponentiation (domain square) and frequency, was prepared for studied stations (Fig. 3-A: Periodogram of Ardebil Station). High value of exponentiation in Periodogram indicates the presence of a dominant frequency or periodicity in the desired time series. After identification of periodicities by Fourier transform, their temporal stability was measured using the wavelet analysis (Fig. 3-B: Wavelet analysis for Ardebil Station). If the temporal stability of a periodicity in the statistical period is confirmed by wavelet analysis and it explains the variance at a significance level of 90%, it is known as a series periodicity.

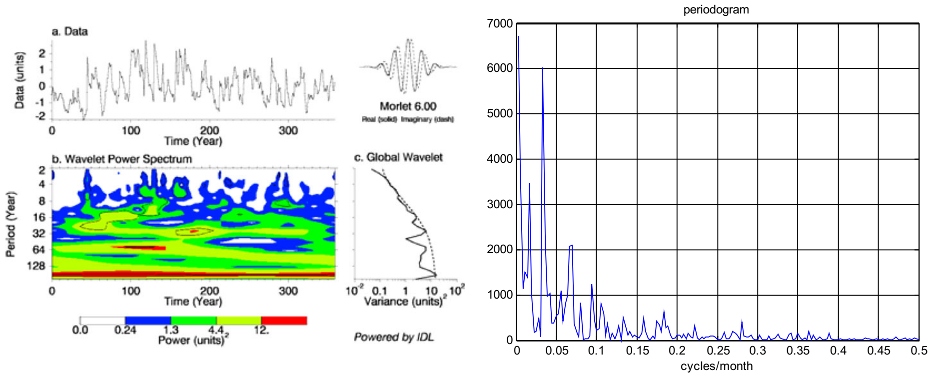

Fig. 3 A- Periodogram of Ardebil Station; B- Wavelet analysis for Ardebil Station

Periodicity has an inverse relationship to frequency. Periodicity represents the return period of drought. Five frequencies or periodicities with the highest powers were identified for each Station. We call these five periodicities or frequencies the first five frequency or periodicity components. At each Station, the periodicity with the highest power is called the first component. For example, at the Ardabil Station the first component, which has the highest power, is a 22-year (265-month) period. This periodicity shows that the probability for the repetition of a drought event every 22 years is far greater than for the other periods identified for this Station. The next four components indicate return periods of drought and repetition of drought events. The powers of these periods decrease from the second to the fifth component, and the fifth component faces the least probability of drought return. In other words, the probability of drought occurrence decreases from the second to the fifth component.

Figure 4 shows the spatial distribution of the five frequency components of droughts in Iran that have the highest powers. In these maps, the kriging interpolation method was used to connect points with the highest identical powers by contour lines. The density of the contour lines in any region indicates the periodicities of the Stations are closer to each other and the Stations have similar behaviors and face almost identical conditions.

The results showed that the highest values of exponentiation in the first component were related to northwest, southwest coasts of the Caspian Sea, south, and southeast of Iran, respectively. In addition, the lowest values of exponentiation were observed in central areas of Iran (Fig. 4-A). In the second component, the highest values of exponentiation were related to the same areas of the first component, with the difference that the centrality of areas was slightly changed and their spatial expansion has decreased, except southwest coasts of the Caspian Sea. Spatial displacement was observed in northwest from Saghez to Oroomieh and in south from Bushehr to Bandar Lengeh. The lowest values of exponentiation in the second component belonged to central areas of Iran with greater spatial expansion compared to the first component (Fig. 4-B). In the third and fourth components, south and southeast areas of Iran presented a reduction in exponentiation (Fig. 4-C, D). In the fifth component, high exponentiation was observed only in southern area of the Caspian Sea centered on Ramsar and most other areas had a low exponentiation (Fig. 4-E). Since precipitation variability is considerable in the western, northwestern, northern, and northeastern parts of Iran, they have various periodicities. However, the central regions of Iran have dry and semi-arid climates, dryness is one of their inherent climate features, and they have little rainfall and very low precipitation variability. Therefore, we observe shorter periodicities in these regions. Short periodicities practically represent presence of almost permanent drought in these regions.

Table 2 lists the five periodicities with the highest powers in the studied Stations. We call these five periods the first five components. Results indicate that the first periodicity component, which has the highest power, is a long-term period in almost 75% of the studied Stations. Intermediate-term periods (15%) and short-term periods (10%) occurred in a small number of Stations. The second component also shows the same results. Therefore, practically most Stations have first and second components of long-term periods. In other words, long-term periods are the dominant drought return periods in Iran. In the third and fourth components, intermediate-term periods are the dominant period in most of the Stations, while short-term periods are the dominant period in the fifth component.

After extracting the periodicities of time series for droughts in Iran, wavelet analysis was used to assess temporal stability of these periods. The uncertainty principle explicitly indicates that we are faced with a periodicity during any time interval. Using the wavelet analysis, we can identify the periodicities that occur during a specific time interval. Results of the wavelet

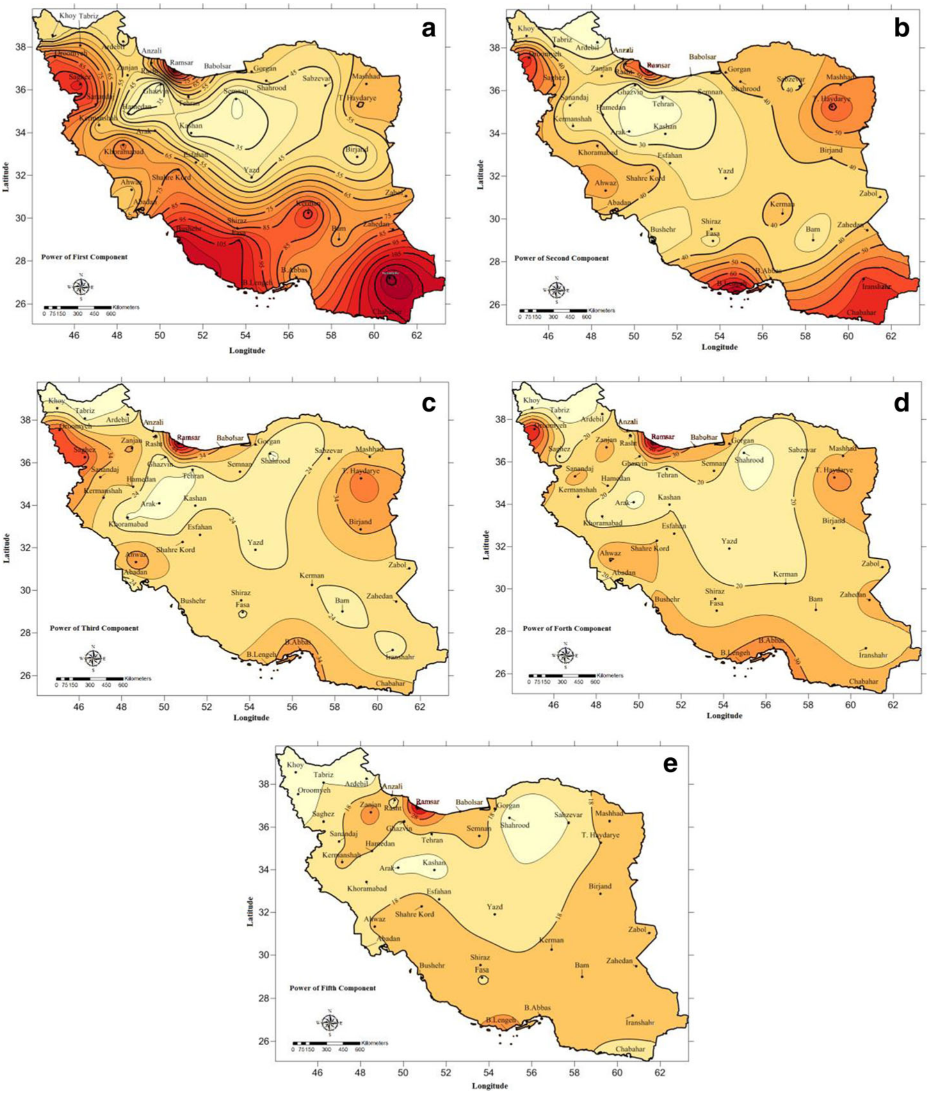

Fig. 4 Spatial distribution of 5 frequency components of droughts in Iran with highest exponentiations

analysis showed that there are three periodicities during specific time intervals at the Ardabil Station. During the first periodicity, droughts have a 50–60 month periodicity that only happened during the time interval 1992–2000. Table 2 shows that the Fourier analysis identified a 60 month periodicity (the fourth component) at this Station Therefore, the 60 month periodicity at the Ardabil Station occurred during the time interval 1992–2000. However, after the year 2000, this Station lacked this periodicity. At this Station, the third periodicity is a 160–220 month periodicity. Wavelet analysis (Table 3) shows that this periodicity exists during the statistical period. Therefore, the third component at this Station (that is, the 180-month periodicity (Table 2) that exists during this periodicity is considered a periodicity for this Station. The first component at the Ardabil Station, which is a 265 month period (Table 2), is

Table 2 The first five components of periodicities in studied stations

Station	first component	second component	third component	Fourth Component	fifth component
Abadan	265	120	60	19	20
Ahvaz	265	72	60	20	19
Bandarabas	265	72	60	20	19
Bandarlengeh	265	180	33	120	30
Birjand	265	180	33	120	30
Bam	265	51	24	45	180
Bushehr	265	120	60	90	180
Fasa	120	265	72	36	90
Kerman	265	120	180	36	45
Mashhad	72	60	28	265	33
Shiraz	256	120	90	36	33
Torbat hayd	265	72	28	60	21
Yazd	51	265	45	22	28
Chabahar	120	30	72	60	22
Iranshahr	180	120	265	90	60
Zabol	265	22	120	90	19
Zahedan	180	28	60	120	72
Arak	120	180	36	26	265
Esfahan	33	36	40	90	265
Ghazvin	45	120	90	24	265
Hamedan	90	18	26	36	33
Kashan	26	60	36	40	33
Khoramabad	120	180	265	51	36
Sabzevar	60	72	28	16	45
Semnan	28	60	45	19	120
Shahrekord	120	180	51	60	45
Shahrood	45	180	28	33	60
Tehran	120	28	60	20	180
Bandaranzali	45	72	22	265	180
Ardabil	265	30	180	60	28
Babolsar	30	90	60	36	26
Gorgan	72	120	30	28	90
Ramsar	265	180	60	120	72
Rasht	120	45	40	22	265
Khoy	120	265	20	33	72
Oroomyh	90	120	100	265	51
Saghez	120	265	90	51	72
Sanandaj	120	265	51	45	40
Kermanshah	265	120	90	51	18
Tabriz	120	72	90	20	21
Zanjan	120	36	28	16	72

not considered a periodicity for this Station because it does not appear in the results of the wavelet analysis. However, the third, fourth, and fifth components, and almost the second component (Table 2) are considered periodicities for this Station because they appear in the results of the wavelet analysis and in the first to the third periodicities (Table 3). At this Station, the 180 month periodicity (the third component in Table 2) that is obtained from the spectral analysis (and the wavelet transform has confirmed its temporal stability during the period at the 90% significance level) is considered a dominant periodicity. Periodicities, time intervals during which these periodicities occur, and the dominant periodicity at each Station can be identified by comparing results listed in Tables 2 and 3. The results of wavelet and spectral analysis showed that in addition to Ardebil, Bandar Lengeh, Iranshahr, Zahedan, Shahroud,

Table 3 Periodic intervals in the studied stations (in Month)

Station	The first Interval	The second Interval	The third Interval	Characteristics
Abadan	96–128	98–130		Periodic
	1992–1997	2005–2013		Time
Ahvaz	54–80			Periodic
	1997–2004			Time
Bandarabas	37–70			Periodic
	1992–1997			Time
Bandarlengeh	28–36	132–210		Periodic
	1992–1997	1992–2013		Time
Birjand	24–48	18–28	32–50	Periodic
	1992–1994	2003–2009	2006–2013	Time
Bam	54–80			Periodic
	1992–1996			Time
Bushehr				Periodic
				Time
Fasa	96–140			Periodic
	1992–2008			Time
Kerman	113–140			Periodic
	1992–2006			Time
Mashhad	54–80			Periodic
	1992–2002			Time
Shiraz	96–140			Periodic
	2002–2012			Time
Torbat hayd	54–80	25–42		Periodic
	1992–2004	2006–2012		Time
Yazd	42–48	24–30	24–48	Periodic
	1992–1996	1993–1997	1999–2009	Time
chabahar	105–150			Periodic
	1997–2012			Time
Iranshahr	170–220			Periodic
	1992–2013			Time
Zabol	20–32			Periodic
	2003–2011			Time
Zahedan	170–220			Periodic
	1992–2013			Time
Arak	205–215	110–140		Periodic
	1992–1999	1998–2003		Time
Esfahan	24–38	26–46		Periodic
	1993–1998	2003–2012		Time
Ghazvin	40–50	16–25	105–120	Periodic
	1992–1999	1994–1997	1996–2003	Time
Hamedan	70–85			Periodic
	1992–2009			Time
Kashan	20–74			Periodic
	1992–2003			Time
Khoramabad	128–140	202–220		Periodic
	1992–2007	1992–2013		Time
Sabzevar	40–75	24–28		Periodic
	1992–2007	2006–2008		Time
Semnan	20–28	20–50		Periodic
	1994–1997	2004–2009		Time
Shahrekord	128–140	202–220		Periodic
	1998–2006	1992–2013		Time
Shahrood	190–210	54–80	208–220	Periodic
	1992–2007	1992–2005	1992–2013	Time
Tehran	20–28	96–140		Periodic
	1994–1998	1992–2012		Time

Table 3 (continued)

Station	The first Interval	The second Interval	The third Interval	Characteristics
Bandaranzali	60–80	60–70		Periodic
	1992–2000	2006–2013		Time
Ardabil	50–60	24–28	160–220	Periodic
	1996–2000	1997–1999	1992–2013	Time
Babolsar	64–110	24–40	20–40	Periodic
	1995–2008	1997–2001	2006–2013	Time
Gorgan	64–80	64–128	24–36	Periodic
	1992–1995	2000–2013	2009–2012	Time
Ramsar	50–80			Periodic
	2000–2008			Time
Rasht	50–80			Periodic
	2000–2008			Time
Khoy	16–28	14–18		Periodic
	1994–1997	2012–2013		Time
Oroomyh	90–100	132–200		Periodic
	1997–2002	1992–2013		Time
Saghez	100–130			Periodic
	1994–2005			Time
Sanandaj	95–140	100–110		Periodic
	1992–2007	2011–2013		Time
Kermanshah	64–128			Periodic
	1993–2006			Time
Tabriz	64–128			Periodic
	1994–2004			Time
Zanjan	96–130			Periodic
	1992–2010			Time

Khorramabad, Oroomieh, and Shahr-e Kord stations have a dominant periodic interval over their statistical period. This periodic interval occurs throughout the statistical period explains the variance at a significance level of 90%. However, no periodic interval, capable of estimating both features, was observed in other studied stations. On the other hand, in all stations, there are periodic intervals which have occurred at a specified point of statistical period. Periodic intervals and their occurrence time were very different, as the shortest periodic interval was related to Isfahan and Yazd stations and the longest one was observed in Iranshahr and Zahedan stations (Table 3).

4 Conclusions

The main objective of the present study was to identify the periodic behavior of monthly droughts in Iran. For this purpose, effective drought index (EDI) was calculated at monthly scale for all studied stations. Then, periodicities were identified using Fourier transform and their temporal stability was measured by wavelet analysis. The most important findings of the present study are as follows:

- The results of spectral analysis of monthly droughts in Iran showed that periodicities in time series of Iran's droughts are very diverse and involve periods of 2 to 22 years. In central areas of Iran, where precipitation follows an irregular temporal-spatial distribution with a certain seasonal precipitation regime, short-term periodicities are dominant. But in areas like the southern coasts of the Caspian Sea, where precipitation follows a more regular distribution throughout the year, periodicities are longer.

- Periodicities of intra-annual droughts were not observed in none of the studied stations except for Babolsar Station in southern coasts of the Caspian Sea. Therefore, all stations of Iran have droughts with extra-annual periodicities.
- Studying the time series of stations showed that EDI presents changes from the beginning to the end of time series of stations. Accordingly, the severity of wet years declines and the severity of droughts increases as we move towards the end of the time series.
- Measurement of temporal stability using the wavelet transform indicated that there is a dominant periodic interval only in 6 stations of Ardebil, Iranshahr, Zahedan, Bandar Lengeh, Oroomieh, and Shahr-e Kord which is significant over the statistical period at a level of 90%. Such a dominant periodic interval was not observed in other studied stations.
- The results of applying wavelet analysis on time series of Iran's droughts showed that periodic intervals were shorter at the beginning but longer at the end of time series. This suggests that the probability of the incidence of drought in Iran is increasing.
- Another finding obtained from applying wavelet analysis on time series of Iran's drought was shorter return periods of drought in Iran at the end of time series. This means that occurrence of droughts in Iran has long-term periods of return at the beginning and shorter ones at the end.
- The study findings showed that Fourier spectral analysis was successful in the estimation of times series spectra for Iran's droughts. Most spectra estimated by Fourier spectral analysis exist in periodicities of wavelet analysis. However, Fourier spectral analysis does not reflect temporal stability of spectra. This is in full consistency with the uncertainty principle.

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