J. Geogr. Sci. 2013, 23(1): 3-16
DOI: 10.1007/s11442-013-0989-7

Extreme drought changes in Southwest China from 1960 to 2009

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Abstract: Based on the daily data of temperature and precipitation of 108 meteorological stations in Southwest China from 1960 to 2009, we calculate the monthly and yearly surface humid indexes, as well as the extreme drought frequency. According to the data, the temporal and spatial characteristics of the extreme drought frequency in inter-annual, inter-decadal, summer monsoon period and winter monsoon period are analyzed. The results are indicated as follows. (1) In general, the southwestern Sichuan Basin, southern Hengduan Mountains, southern coast of Guangxi and northern Guizhou are the areas where the extreme drought frequency has significantly increased in the past 50 years. As for the decadal change, from the 1960s to the 1980s the extreme drought frequency has presented a decreasing trend, while the 1990s is the wettest decade and the whole area is turning wet. In the 2000s, the extreme drought frequency rises quickly, but the regional differences reduce. (2) During summer monsoon period, the extreme drought frequency is growing, which generally occurs in the high mountains around the Sichuan Basin, most parts of Guangxi and "the broom-shaped mountains" in Yunnan. It is distinct that the altitude has impacts on the extreme drought frequency; during winter monsoon period, the area is relatively wet and the extreme drought frequency is decreasing. (3) During summer monsoon period, the abrupt change is observed in 2003, whereas the abrupt change during winter monsoon period is in 1989. The annual extreme drought frequency variation is a superposition of abrupt changes during summer monsoon and winter monsoon periods. The departure sequence vibration of annual extreme drought frequency is quasi-5 years and quasi-12 years.

Keywords: Southwest China; extreme drought; summer monsoon; winter monsoon

1 Introduction

In the context of global warming, extreme events seem to be occurring more frequently worldwide (Roy *et al*., 2004; Zolina *et al*., 2010). The socio-economy development, human health and the natural environment are becoming vulnerable to the extreme climate events

Received: 2012-06-19 **Accepted:** 2012-07-12
Foundation: National Natural Science Foundation of China, No.41161012; Program for New Century Excellent Talents in University from the Ministry of Education of China, No.NCET-10-0019; Basic Scientific Research Foundation in University of Gansu Province
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(Changnon *et al*., 2000; Easterling *et al*., 2000). The variations and trends in extreme climate events have received much attention in the recent years, such as in America (Vincent *et al*., 2005; Aguilar *et al*., 2009), Europe (Hundecha and Bardossy, 2005; Schmidli and Frei, 2005) and Asia (Klein Tank *et al*., 2006; Wang *et al*., 2012). Several studies reported that, compared to the total precipitation, the changing range of the extreme precipitation in rainy season increases exponentially in the past 50 years (Heino *et al*., 1999). In China, studying extreme climate has started since 2000 (Yan *et al*., 2000). Zhang (2007) thought that rising temperature range of extreme low temperature is larger than that of extreme high temperature, and that the extreme precipitation in the west of Northwest China increases significantly and changes gradually since the late 1970s, through analyzing the change of extreme temperature and precipitation. Zhai *et al*. (2003) indicated that the number of frost days decreases significantly in the eastern part of northern China, and that the number of precipitation extreme events increases obviously in Northwest China. Ma *et al*. (2003a) thought that the maximum temperature frequency has a significant increasing trend in most parts of northern China since the 1990s, and that there are good relations among the decrease of the extreme low temperature, the increase of minimum temperature and regional warming after studying extreme temperature in northern China. Qian *et al*. (2007) considered that the extreme value events of temperature and precipitation are well consistent with global warming and regional circulation in recent 40 years. In addition, the climate extremes have also been studied in northern China (Ren *et al*., 2007; Yang *et al*., 2003, 2009; Chen *et al*., 2008) and southern China (Zhang *et al*., 2009; Su *et al*., 2007; Xiao *et al*., 2010; Hu *et al*., 2009; Ye *et al*., 2008; Cui *et al*., 2009). However, the previous studies have mainly focused on extreme temperature and precipitation, and there is limitation to study extreme droughts in the recent years except Ma *et al*. (2003b). The study found that the extreme drought frequency in recent 10 years is the highest in Northeast and North China in nearly 100 years, by analyzing distribution characteristics of extreme drought in northern China using surface wetness index. Especially in recent years, several exceptional drought disasters occur in Southwest China such as Yunnan in 2005, Sichuan in 2009, and Southwest China in 2009 and 2010. It is obvious that the extreme drought is increasing constantly and extends from the north of China to Southwest China. Therefore, it is urgent to study the change characteristics of extreme drought in the study area.

2 Data and methods

In this study, Southwest China includes five regions, including Chongqing, Sichuan, Guizhou, Yunnan and Guangxi (Figure 1). The data of daily temperature (mean, maximum and minimum temperature), sunshine duration, daily mean relative humidity, and daily mean wind speed at 108 meteorological stations in Southwest China during 1960–2009 is provided by China Meteorological Administration (CMA).

The extreme drought is defined if standardized variables of monthly surface humid indexes (H) are less than or equal to –0.5 (Ma *et al*., 2003b). Monthly surface humid indexes are

$$H = \frac{P}{ET_0} \tag{1}$$

where P is monthly total precipitation; ET_0 is monthly potential evaporation.

We adopt a modified Penman-Monteith model (Revision in 1998 of the Food and

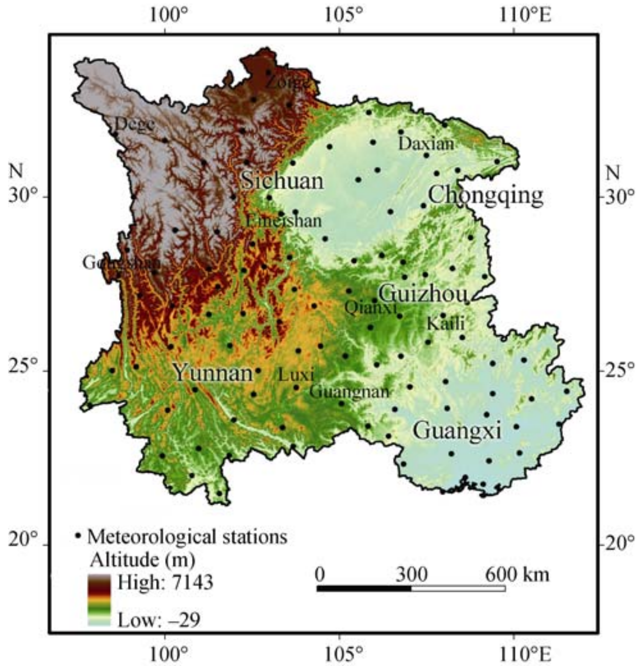

Figure 1 Distribution of meteorological stations in Southwest China

Agriculture Organization of the United Nations) to calculate ET_0. The existing research results show that the model simulation result is accurate (Mao *et al.*, 2003). Its formula is as follows:

$$ET_0 = \frac{0.408\Delta\left(R_n - G\right) + \gamma \dfrac{900}{T+273} U_2\left(e_s - e_a\right)}{\Delta + \gamma\left(1 + 0.34U_2\right)} \tag{2}$$

where R_n is surface net radiation of reference crop, in unit of MJ/(m^2·d); G is soil heat flux, in unit of MJ/(m^2·d); γ is dry wet constant, in unit of kPa/℃; Δ is the curve slope of saturation vapor pressure, in unit of kPa/℃; U_2 is wind speed at a height of 2 m, in unit of m/s; e_s is average value saturation vapor pressure, in unit of kPa; e_a is actual vapor pressure, in unit of kPa; T is mean temperature, in unit of ℃.

The spatial distribution maps of interpolation of extreme drought events are drawn using inverse distance weighted in ArcGIS9 to analyze spatial variation of them. At the same time, the abrupt change of the extreme drought is inspected by using moving *t*-test technique. Morlet wavelet is widely utilized to reveal periodic features of extreme drought and detect periodic variation on different time scales. Variation periods are analyzed by the real part of and the modulus square of the Morlet wavelet. The real part of Morlet wavelet shows signal strength and the phase (Ji *et al.*, 1999), whereas the modulus square of the Morlet wavelet can eliminate false oscillation that is produced by using type of wavelet transform coefficient (Hao *et al.*, 2010).

Summer monsoon period is from May to October, and winter monsoon period includes the rest months (from November to April) in a year. The extreme drought frequency in inter-annual, inter-decadal, summer monsoon period and winter monsoon period is also analyzed.

3 Change characteristics of inter-annual extreme drought

The inter-annual variations of extreme drought are calculated according to the former study (Ma *et al*., 2003b). Over the 1960-2009 period, the regionally averaged extreme drought has slightly decreased by –0.0023 times/year in Southwest China (Figure 2). The annual mean extreme drought has decreased by –0.007, –0.0024 and –0.0022 times/year in Sichuan, Chongqing and Yunnan during 1960–2009, respectively. However, the annual mean extreme drought has increased by 0.0013 and 0.0016 times/year in Guizhou and Guangxi, respectively. The change range of the extreme drought is small in the 1960s and 1970s, and big in the 1980s. The extreme drought decreases uninterruptedly from 1990 to 2002. The change range of the extreme drought magnifies after 2003. The averaged frequency of the extreme drought is 6 times/year in 1969, 5.2 times/year in 1978, 5.2 times/year in 1979, 5.4 times/year in 1988, and 5.8 times/year in 2009, indicating that the drying process is obvious in Southwest China in these years.

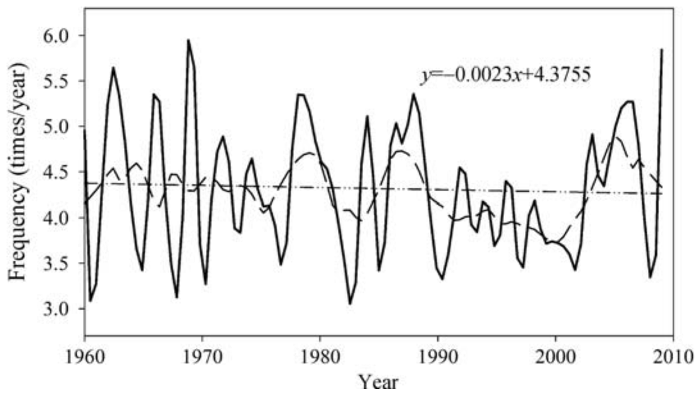

Figure 2 Inter-annual variation of the extreme drought frequency in Southwest China from 1960 to 2009

Spatial distribution maps of trends at the individual stations provide more detailed information of how to vary the magnitude of rates in extreme drought events from one weather station to another (Figure 3). The magnitude ranges from –0.061 to 0.041 times/year. The minimum value is in Dege, and the maximum value is in Emeishan (Mount Emei). In western, southern and eastern Sichuan, central Yunnan and the junction between Guangxi and Guizhou, the extreme drought decrease rate varies from –0.03 to 0 times/year, especially in high altitude area of western Sichuan, but the regional trends show increase in southwestern Sichuan Basin, eastern Dalou Mountains, southern Hengduan Mountains, southern Guangxi and Luxi in Yunnan. As can be seen from the above analysis, in recent 50 years, the increasing regions of extreme drought are mainly distributed on windward slope of southwest monsoon and high altitude areas around southwestern Sichuan Basin. Southwest China belongs to temperate and subtropical monsoon climate. Changes in southwest monsoon are well related to precipitation and exert important influences on extreme drought frequency in Southwest China. Many studies have confirmed that, in recent 50 years (Jiang *et al*., 2005; Wang *et al*., 2006; Li *et al*., 2003), especially since the 1970s (Wang *et al*., 2001, 2002), Asian monsoon weakens significantly. In recent years, lots of scholars deduce strong and weak changes of southwest monsoon by analyzing weight changes of δ^{18}O in high resolution stalagmites (Yang *et al*., 2007; He *et al*., 2005; Fleitmann *et al*., 2004), which confirms that the southwest monsoon has a gradually decreasing trend for nearly half a century. So we can infer that weakening southwest monsoon gives rise to reducing in precipitation, which causes the increase of extreme drought frequency.

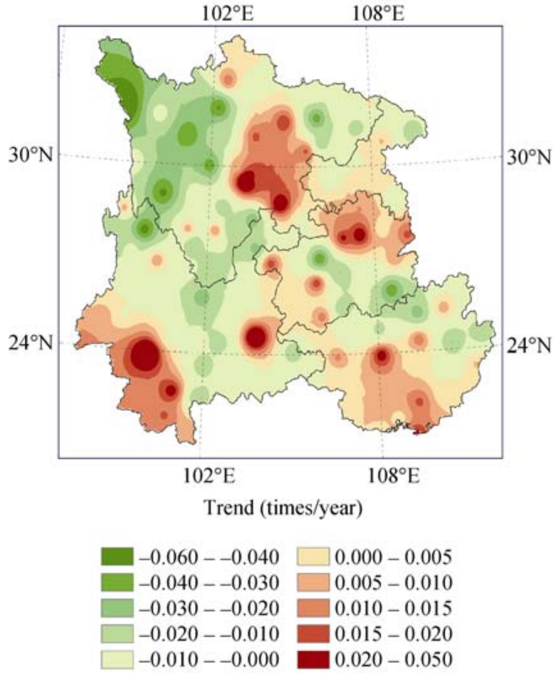

Figure 3 Spatial distribution of linear trend of extreme drought frequency in Southwest China from 1960 to 2009

4 Change characteristics of inter-decadal extreme drought

4.1 Temporal variation of inter-decadal extreme drought

Table 1 demonstrates the inter-decadal variation of the extreme drought in Southwest China from 1960 to 2009. The annual extreme drought anomaly tends to decrease in the 1960s, 1970s and 1980s, but it is still higher than the average value of the 50 years. In the 1990s, the climate in Southwest China becomes abruptly wetter than the past because the global atmospheric circulation influences. So the annual extreme drought anomaly is lower than that in 1960-2009. Some studies (Wang *et al*., 2001, 2002; Zeng *et al*., 2002) show that global atmospheric circulation has adjusted greatly, which leads to an abating East Asian monsoon circulation since the late 1970s. The annual extreme drought anomaly is higher during 2000s than that in studied period. The inter-decadal variation of the extreme drought in each province is similar to the above-mentioned result, but differences still exist during 1960s. In Sichuan, the annual extreme drought anomaly is relatively higher in the 1960s, 1970s and 2000s, but it is 0.12 times and 0.39 times greater in the 1980s and 1990s than the long-time annual average value. The inter-decadal variation of the extreme drought in Chongqing is similar to the changes in Sichuan. In Yunnan, Guizhou and Guangxi, the extreme drought shows a negative anomaly in the 1970s and 1990s, and positive increase in the 1960s, 1980s and 2000s.

Table 1 Inter-decadal departure of the annual extreme drought frequency in Southwest China from 1960 to 2009

Decade	Southwest China	Sichuan	Chongqing	Yunnan	Guizhou	Guangxi
1960s	0.20	0.14	0.45	0.18	0.13	0.29
1970s	0.01	0.33	0.03	–0.10	–0.02	–0.30
1980s	0.06	–0.12	–0.61	0.38	0.03	0.09
1990s	–0.40	–0.39	–0.19	–0.62	–0.25	–0.30
2000s	0.13	0.04	0.31	0.16	0.11	0.21

4.2 Spatial distribution of inter-decadal extreme drought changes

Figure 4 shows spatial distribution of the extreme drought over Southwest China in the 1960s, 1970s, 1980s, 1990s and 2000s. Similarly, standardized H of annual surface humid indexes is calculated if H is below –0.5, which is regarded as the extreme drought frequency. The annual extreme drought are mainly distributed in the most parts of Guangxi and sporadic regions in the 1960s (Figure 4a), such as Guangnan and Gongshan in Yunnan (9 extreme drought years), and Kaili and Qianxi in Guizhou (6 extreme drought years). In the 1970s (Figure 4b), in most parts of southeast of Southwest China, the annual extreme drought decreases from inner to outer, centered over the eastern Guizhou and Yunnan. Compared to the 1960s, the decrease areas amplify obviously. However, the extreme drought becomes frequent in the high altitude areas in the north of Southwest China, including Hengduan Mountains in western Sichuan and northern Yunnan, and Daba Mountains in eastern Sichuan. In the 1980s (Figure 4c), the distribution of annual extreme drought is opposite to the patterns in the 1970s, that is, low occurrence regions of annual extreme drought exist in most parts of Sichuan and Chongqing, and at the edge of western Yunnan and the southwestern Guangxi. At the same time, high occurrence regions are located in southeast, especially in eastern Guizhou and northern Guangxi where they link together and have the biggest scope. In the 1990s (Figure 4d), the annual extreme drought in Southwest China is the least. With the exception of Daxian in Sichuan (6 extreme drought years) and Xishui in Guizhou (5 extreme drought years), the annual extreme drought frequency is below 4 times/decade, which is the wettest decade of all. The extreme drought is more in Sichuan than that in the other areas, varying from 4 to 6 times/decade. Compared to the 1990s, the occurrence frequency of annual extreme drought from 2000 to 2009 increases significantly over the studied period (Figure 4e). The regional differences in annual extreme drought decrease obviously, and about 67% of stations, mainly in the center of Southwest China, most parts of Guangxi and the west of Yunnan, range from 3 to 5 times/decade but 20% of stations, mostly in central Yunnan, Sichuan, and the east of Guizhou vary between 0 and 2 times/decade. At the same time, the high altitude areas in the southern Hengduan Mountains in Yunnan firstly become frequent area of the extreme drought. To sum up, the occurrence frequency of extreme drought in Southwest China has larger regional differences in different decades. Frequent occurrence regions of the extreme drought appear alternately from the 1960s to 1980s. In the 1990s, the climate turns wet significantly. The occurrence frequency of annual extreme drought in Southwest China has increased, and the regional differences have decreased remarkably since the 2000s.

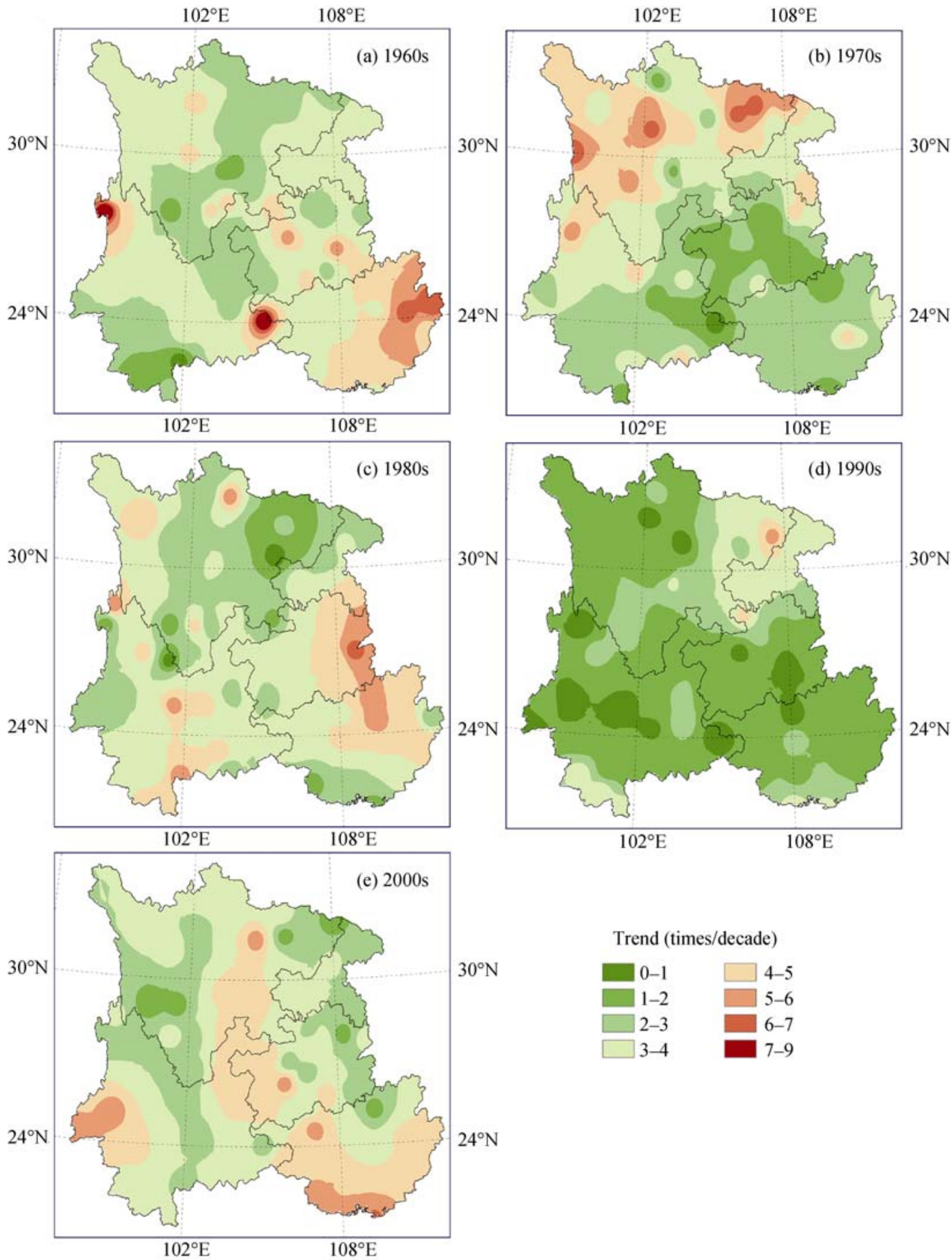

Figure 4 Spatial distribution of extreme drought frequency in Southwest China in different decades

5 Extreme drought during summer monsoon and winter monsoon period

5.1 Temporal variations of summer monsoon and winter monsoon period

Southwest China belongs to a subtropical and temperate monsoon climate, and the seasonal distribution of precipitation is extremely uneven. Precipitation increases from May to October because of influences of South Asian monsoon, accounting for 80%–90% of annual total precipitation. Precipitation is scarce from November to April, only 10%–20% (Zhao, 1997). So the changes in climate over Southwest China are very obvious during summer monsoon and winter monsoon period. Firstly, we calculate the occurrence times of monthly extreme drought in a year as the frequency of it during the two periods in a year, and then analyze change characteristics of extreme drought during summer monsoon and winter monsoon period in recent 50 years.

Over the 1960–2009 period, the regional mean extreme drought has increased by 0.0075 times/year during summer monsoon period (Figure 5a). The variation trend shows different patterns with slow increases from the 1960s to 1990s, with obvious decreases in 1992-2000 and with rapid increases after 2000. It is thus clear that the extreme drought in Southwest China aggravates continuously during summer monsoon period, and presents a violent fluctuation during 2000s. The extreme drought shows increases at rates of 0.007, 0.059, 0.0084, 0.0087 and 0.0093 times/year in Sichuan, Yunnan, Guizhou, Chongqing and Guangxi, respectively. During winter monsoon period, the regional mean extreme drought has decreased by 0.0061 times/year (Figure 5b), whereas different patterns are observed in different decades over the studied period. The extreme drought shows decreasing trends at rates of –0.011, –0.0046, –0.0015, –00077 and –0.0042 times/year in Sichuan, Yunnan, Guizhou, Chongqing and Guangxi, respectively. As can be seen from the above, in recent 50 years, although the annual extreme drought decreases constantly, yet the extreme drought during summer monsoon period intensifies continuously. In addition, after 2000, the extreme drought increases during summer monsoon period and winter monsoon period.

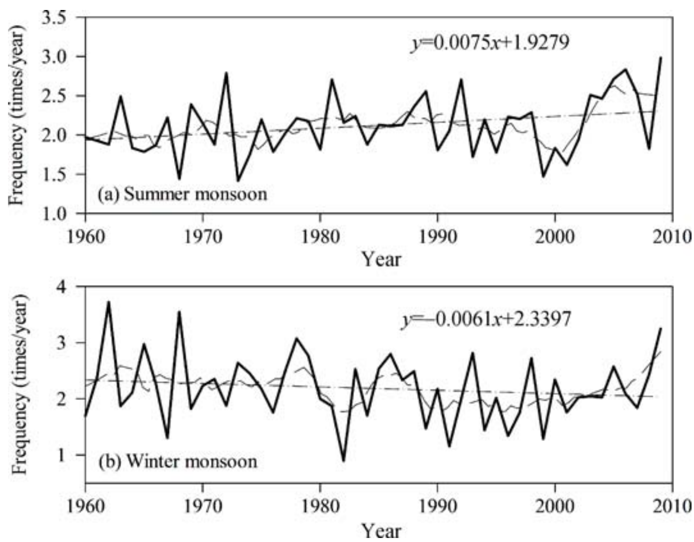

Figure 5 Annual changing trend of the extreme drought frequency in summer (a) and winter (b) monsoon in Southwest China from 1960 to 2009

5.2 Spatial variations of summer monsoon and winter monsoon period

Figure 6 shows spatial distribution of temporal change in extreme drought during summer monsoon and winter monsoon period. During summer monsoon period, spatial distribution for the extreme drought increase magnitude varies from 0 to 0.015 times/year in most areas of Southwest China (Figure 6a), but it exceeds 0.015 times/year in some areas, such as Zoige Plateau, Minshan Mountains, Qionglai Mountains, Daxue Mountains, Wulian Peak in southeastern Sichuan, Wumeng Mountain and Dalou Mountains. Negative values during summer monsoon period are speckled, especially at Guangnan station (–0.035 times/year). On the whole, extreme drought in Southwest China during summer monsoon period is intensified constantly, and occurs mostly in high altitude areas around Sichuan and low altitude areas including most parts of Guangxi and "the broom-shaped mountains" zone in the west of Ailao Mountain in Yunnan. As can be seen from the above analysis, elevation influences the extreme drought greatly. Frequent regions of extreme drought are distributed mainly in transitional zone between high and low altitudes, which is an abnormal phenomenon of the extreme drought during summer monsoon period.

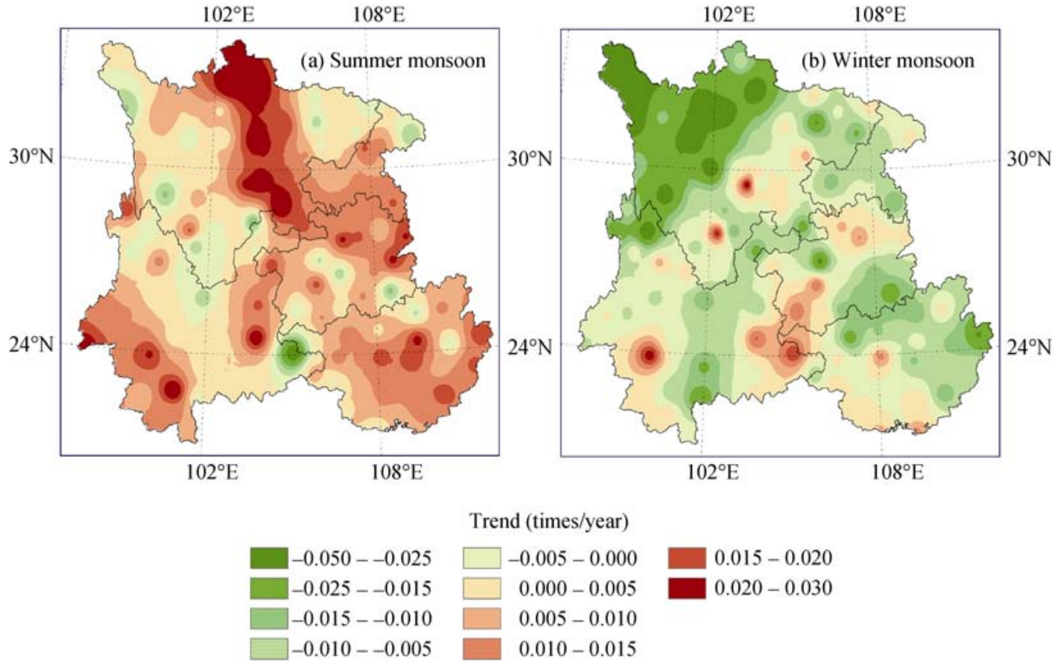

Figure 6 Spatial distribution of the extreme drought frequency in summer (a) and winter (b) monsoon in Southwest China from 1960 to 2009

In contrast to the summer monsoon period, the spatial distribution for the extreme drought during winter monsoon period displays decreases with the high magnitude from –0.05 to 0 times/year (Figure 6b), with greater trend magnitudes in Hengduan Mountains, Sichuan Basin, southeastern Guizhou, central and eastern Guangxi, Wumeng Mountain, and central Yunnan. In addition, the trend magnitude changes from 0 to 0.03 times/year in the border between Guizhou and Guangxi, eastern Dalou Mountains, Daxue Mountains and southern Yunnan.

In a word, the changes of extreme drought in Southwest China during summer monsoon and winter monsoon period differ greatly. South Asian monsoon is an important source of precipitation during summer monsoon period. The most rainfall is observed in monsoon periods in a year. Meanwhile, high temperature and plenty of precipitation create good production environment, which is the best season for growth of grain and economic crops. Frequently increasing extreme drought during summer monsoon period is bound to influence on local industry, agriculture and the sustainable development of the socio-economy. So the relevant departments should pay attention to this phenomenon.

6 Abrupt change analysis

The method of running *t*-test is employed to analyze abrupt change of extreme drought in Southwest China during summer monsoon and winter monsoon period in recent 50 years. During summer monsoon period, there are three abrupt change points of extreme drought which are in 2002, 2003, 2004 respectively (Figure 7a). The abrupt change is significant at the 0.01 level in 2003 when the frequency of extreme drought changes from less to more. During winter monsoon period, only one abrupt change point is observed in 1989 when the occurrence frequency of extreme drought transforms from more to less (Figure 7b), which is the same as the result of Shi *et al*. (2002). Annual extreme drought which is a superposition of changes during summer monsoon and winter monsoon periods has two abrupt change points (Figure 7c). The abrupt changes are observed in 1990 when the frequency of extreme drought converts from more to less, and 2003 when it is opposite to the 1990s.

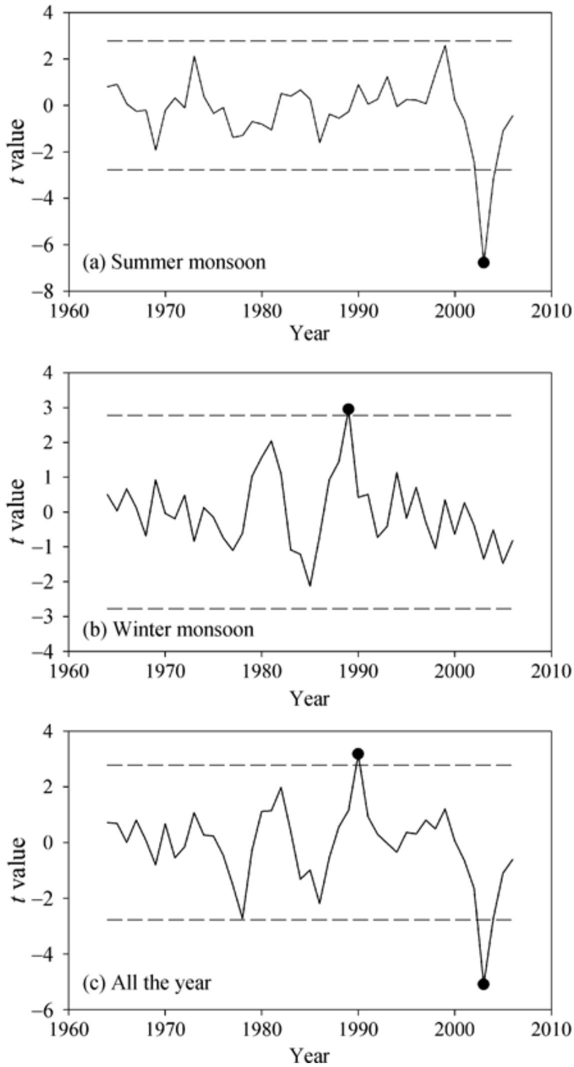

Figure 7 Running *t*-test curve of the extreme drought frequency in summer (a) and winter (b) monsoon and annual level (c) in Southwest China (dashed line represents 95% confidence level)

7 Periods analysis

Figure 8 shows time-frequency distribution of the real part of the Morlet wavelet analysis and the modulus square of the extreme drought events in Southwest China during summer monsoon and winter monsoon period. As can be seen from Figure 8a, during summer monsoon period, the variation periods of the extreme drought have significant 17–27 years' periods and a quasi-period of 12-year period. 17–27 years' periods are divided into two

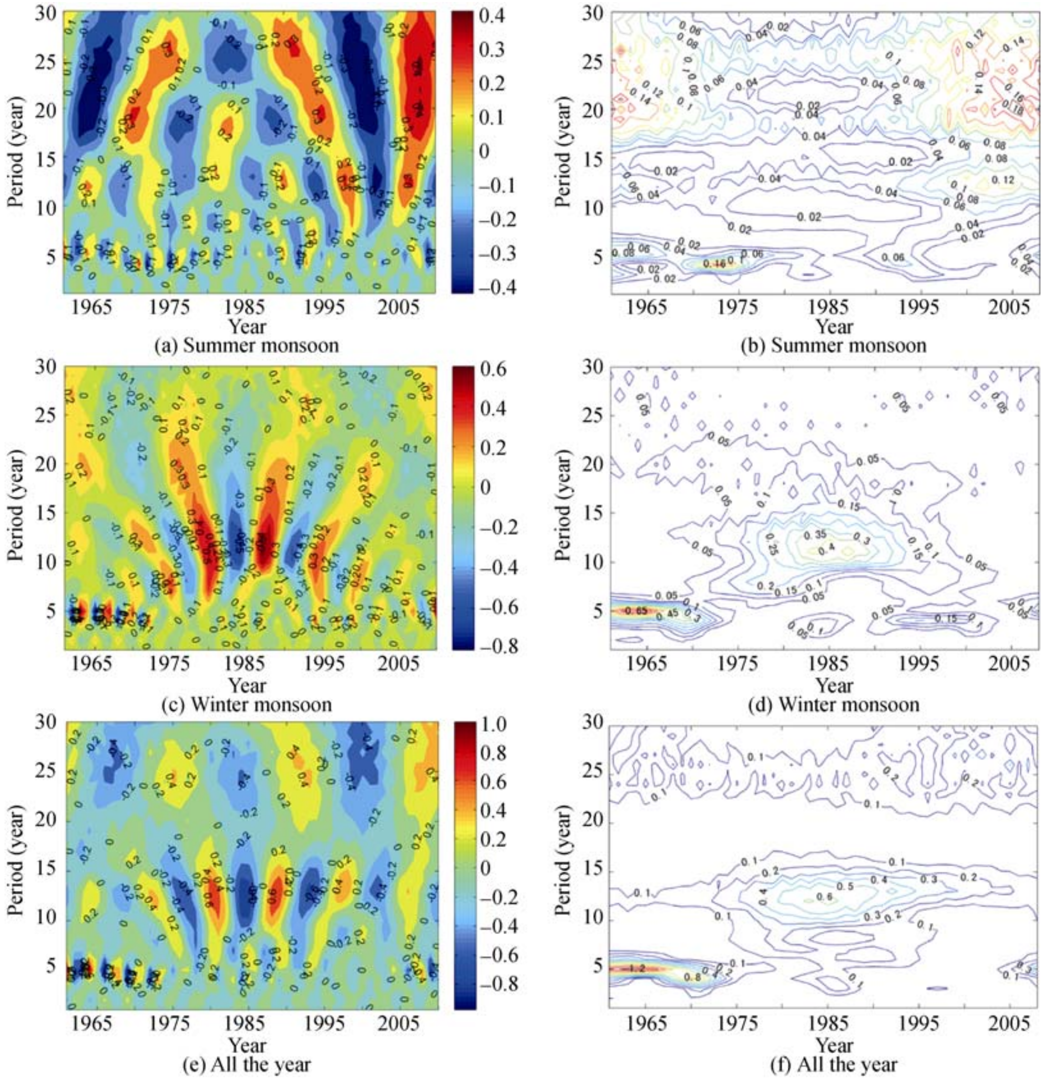

Figure 8 The real part of the Morlet wavelet analysis (a, c, e) and the modulus square (b, d, f) of the extreme drought frequency in summer/winter monsoon and annual level in Southwest China

oscillation periods of 25 years and 17 years during the 1970s–1990s when the oscillations are weak. However, in the other decades the oscillations are remarkable, which has two lower centers (1960–1966, 1998–2003) and three more centers (1968–1972, 1992–1998, 2003–2009). Furthermore, periods of quasi-12 years and quasi-5 years are also obvious. In addition, the real parts of the Morlet wavelet have spurious oscillation in the period analysis. In order to further verify the stability of the period, we compile time-frequency distribution maps of the modulus square. Figure 8b shows that oscillation energy of 18–25 years' scale is strong but it is not concentrated, which occurs during 1960–1967 and 1998–2009, centered in 1961 and 2004, respectively. Oscillation energy of quasi-4 years' scale is larger and concentrates taking 1973 as oscillation center. Furthermore, a period of quasi-12 years' scale also appears during 1995–2009, and its energy is weak.

Similarity, periodic changes of extreme drought in Southwest China during winter monsoon period in recent 50 years (Figure 8c) have distinct temporal characteristics. A quasi-5 years' oscillation period which mainly appears from 1960 to 1972 is the most obvious. Period changes of quasi-12 years' scale mainly appear from the late 1970s to the mid-1990s, which displays three high periods and two low ones. Figure 8d shows time-frequency distribution map of the modulus square of extreme drought during winter monsoon.

Oscillation energy of all the scales is strong during 1960–1972, especially in quasi-5 years' scale where its oscillation is the most intense and its energy is more concentrated. Furthermore, a period of quasi-12 years' scale observed during 1976–1993 has larger energy oscillation.

Period changes of annual extreme drought are similar to those in winter monsoon period (Figure 8e). Periodic oscillation signal of quasi-5 years' scale is most obvious, which occurs during 1960–1973 and after 2005. Periodic oscillation signal of quasi-12 years' scale is strong and more obvious during 1975–2000. Its intensity presents a significantly weakening trend. However, inter-decadal periodic signal of annual extreme drought still has a period of quasi-25 years' scale which occupies most of the time, and the strength is weak. The map of the modulus square of Figure 8f also presents similar time-frequency distribution characteristics.

As can be seen from the above, time-frequency characteristics of the real part of the Morlet wavelet analysis and the modulus square are the same, which ensures the stability of occurrence frequency about period of extreme drought. In addition, inter-annual and inter-decadal periodic changes exist in the study area but they are obviously temporal and spatial characteristics and lack larger energy oscillation.

8 Conclusions

(1) Over the 1960-2009 period, the regionally averaged extreme drought has slightly decreased by –0.0023 times/year in Southwest China. The change range of the extreme drought is small in the 1960s and 1970s, and big in the 1980s. The extreme drought decreases uninterruptedly from 1990 to 2002. The change range of the extreme drought magnifies after 2003. The increasing regions of extreme drought are mainly distributed on windward slope of southwest monsoon and high altitude areas around southwestern Sichuan Basin.

(2) The extreme drought exhibits obviously regional differences in Southwest China. The annual extreme drought anomaly tends to decrease in the 1960s, 1970s and 1980s, but it is still higher than the average value of the 50 years. In the 1990s, the climate in Southwest China becomes abruptly wetter than the past because the global atmospheric circulation influences. The annual extreme drought anomaly is higher during 2000s than that in studied period. The high altitude areas in the southern Hengduan Mountains in Yunnan firstly become frequent area of extreme drought.

(3) Over the 1960–2009 period, the regional mean extreme drought has increased by 0.0075 times/year during summer monsoon period. The variation trend shows different patterns with slow increases from the 1960s to 1990s, with obvious decreases in 1992-2000 and with rapid increases after 2000. During winter monsoon period, the regional mean extreme drought has decreased by 0.0061 times/year, whereas different patterns are observed in different decades over the studied period. The extreme drought in Southwest China during summer monsoon period is intensified constantly, and occurs mostly in high altitude areas around Sichuan. Elevation influences the frequency of extreme drought greatly. During winter monsoon period, in most parts of Southwest China, the spatial distribution for the extreme drought displays decreases. Greater trend magnitudes are mainly concentrated in

Hengduan Mountains. The best time to grow grain and economic crops is summer monsoon period. So the extreme drought during summer monsoon should be paid attention.

(4) During summer monsoon period, the abrupt change is significant at the 0.01 level in 2003 when the frequency of extreme drought changes from less to more. During winter monsoon period, only one abrupt change point is observed in 1989 when the occurrence frequency of extreme drought transforms from more to less, which is the same as the result of Shi *et al*. (2002). Annual extreme drought is a superposition of changes during summer monsoon and winter monsoon period. During summer monsoon period, inter-decadal periodic oscillations mainly exist in 17–27 years' and quasi-12 years' scales. Compared to the summer monsoon period, the periodic is strengthened during winter monsoon period. Periodic oscillation signal of quasi-5 years' scale is most obvious, which occurs during 1960–1973 and after 2005. Periodic oscillation signal of quasi-12 years' scale is strong and more obvious during 1975–2000. Annual extreme drought has periods of quasi-5 years and quasi-12 years.

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