# Variation Characteristics of Droughts and Floods in Deyang Area in the Past 30 years

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**Abstract** Based on the data of annual average precipitation in Deyang area and its five stations (Mianzhu, Deyang, Zhongjiang, Shifang and Guanghan) from 1984 to 2013, the annual precipitation anomaly percentage was calculated, and then the flood and drought situation in Deyang area was graded to discuss the variation characteristics of droughts and floods in the past 30 years. The results show that the cycle of droughts and floods in Deyang was about 3 – 5 a. The precipitation anomaly percentage indicates that the climate in Deyang area of Sichuan tended to be dry slowly in the past 30 years, and Deyang gradually entered a dry and warm period.

**Key words** Drought and flood; Precipitation anomaly percentage; Deyang, Sichuan

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In recent years, with global warming, the frequency and intensity of extreme weather events, especially drought and flood disasters, have increased rapidly, which seriously affects the production and development of human society, so the current situation of drought has attracted more and more attention. In 2000, Yan Zhongwei *et al.* made a preliminary exploration of the pattern of extreme climate change in China, and pointed out the unique value of the study of extreme climate change, thus starting the prelude to the study of extreme weather and climate events in China[1]. In the 20th century, a series of drought events appeared around the world. Among them, two major drought events in the 20th century have been mentioned in the literature: sandstorm drought in the United States in the 1930s and the continuing drought in the Southern Sahar of North Africa in the second half of the 20th century[2].

Several abnormal drought events have occurred in southwest China in recent years, such as the abnormal drought in Yunnan in spring 2005, the extreme drought in Sichuan and Chongqing in summer 2006, and the severe drought in Southwest China from autumn 2009 to spring 2010[3]. The annual average global economic loss caused by drought is more than 8 billion dollars, far exceeding that of other meteorological disasters[4]. Especially in the context of climate warming, the occurrence of global drought gradually shows a trend of normalization, and the frequency and intensity of extremely serious drought events are increasing, making drought disasters more abnormal and destructive[5]. China's climate is characterized by frequent drought in the north and concurrent drought and flood in the south. A wide range of drought disasters occur year after year, and the area of farmland affected by drought in each year ranges from 6.67 million to 26.67 million $hm^2$, up to 40 million $hm^2$ at most, resulting in a decrease in grain output from millions of tons to more than 30 million tons[6]. It can be seen that the drought and flood situation in southwest China has become more and more serious, which has aroused people's attention. In this paper, Deyang, Sichuan Province, located in southwest China, is selected to analyze and discuss the changes of drought characteristics. Deyang, a prefecture-level city under the jurisdiction of Sichuan Province, also known as Jingcheng, is located in the northeast of Chengdu Plain. Founded in 1983, Deyang now has jurisdiction over 2 districts, 1 county and 3 county-level cities. It is an important regional central city of Chengdu – Chongqing economic circle and an important growth pole of Chengdu Economic Zone, as well as a key planned city with a population of one million in Sichuan Province. The variation characteristics of drought and flood in Deyang in recent 30 years are studied and analyzed from precipitation anomaly percentage.

The changing characteristics of drought and flood have always been an important issue of global concern, because drought-related natural disasters directly affect the economic and agricultural development of a country or region. With the rapid development of China's national economy, the losses caused by drought and flood are gradually increasing. According to statistics, the form of drought and flood in China has gradually intensified in the past 30 years, especially in southwest China, which has a great impact on the production and development of the people. In this paper, based on the data of annual average precipitation in Deyang area and its five stations (Mianzhu, Deyang, Zhongjiang, Shifang and Guanghan) from 1984 to 2013, the annual precipitation anomaly percentage was calculated, and then the flood and drought situation in Deyang area was graded to discuss the variation characteristics of droughts and floods in the past 30 years.

## 1 Data and methods

Most of the early studies focused on the abnormal change of

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precipitation, so precipitation anomaly percentage has become the main indicator to determine drought and flood intensity[7]. Precipitation anomaly percentage $R_i$ is calculated as follows:

$$R_i = \frac{r_i - \bar{r}}{\bar{r}} \times 100\%$$

In the formula, $r_i$ is the precipitation in a certain period; $\bar{r}$ is mean precipitation in the same period of repeated years. Based on the data of annual average precipitation in five stations of Deyang (Mianzhu 56186, Deyang 15198, Zhongjiang 56199, Shifang 56197 and Guanghan 56291) from 1984 to 2013, the annual precipitation anomaly percentage was calculated based on the above formula. According to precipitation anomaly percentage $R_i$, the flood and drought situation in Deyang area can be divided into five grades, including severe floods ($R_i \geqslant 20\%$), moderate floods ($20\% > R_i \geqslant 10\%$), normal ($10\% > R_i > -10\%$), moderate droughts ($-10\% \geqslant R_i > -20\%$) and severe droughts ($R_i \leqslant -20\%$).

## 2 Analysis of drought and flood characteristics based on precipitation anomaly percentage

**2.1 Deyang area** Based on the data of annual average precipitation from 1984 to 2013, the precipitation anomaly percentage in Deyang was calculated. Precipitation anomaly percentage was sorted by time to draw a time series plot by NCL. As can be seen from Fig. 1, there were two severe floods in Deyang in the past 30 years, appearing in 1986 and 2013. The precipitation anomaly percentage in the two years exceeded 30%, and it was even more than 40% in 2013. Serious droughts also happened in Deyang in 1986, 1991, 1997 and 2002, and the absolute value of precipitation anomaly percentage was more than 20%. According to the trend equation, the precipitation anomaly percentage in Deyang, Sichuan Province increased by 1%/10 a, and the climate became more and more dry on the whole.

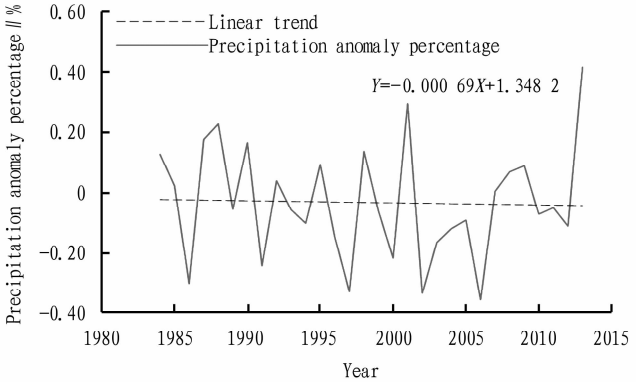


**Fig. 1 Annual variation of precipitation anomaly percentage in Deyang area from 1984 to 2013**

It can be seen from Table 1 that among the past 30 years, flood years accounted for 30%, while the proportion of drought years was 26.7%. Among them, severe droughts happened in 1986, 1991, 1997, 2002 and 2006, and severe floods occurred in 1987, 2001 and 2013. It can be said that there were both droughts and floods in Deyang in the past 30 years, and flood years were slightly more than drought years. Moreover, severe droughts and severe floods appeared mostly after 2000, indicating that the extreme climate in Deyang began to be relatively frequent and intensified after entering the 21st century.

**Table 1 Years and frequency of droughts and floods in Deyang area**

| Grade | Year | Proportion//% |
|---|---|---|
| Severe flood | 1987,2001, and 2013 | 10.0 |
| Moderate flood | 1985, 1988, 1990, 1992, 1995, and 2008 | 20.0 |
| Normal | Other years except for flood and drought years | 43.3 |
| Moderate drought | 1994, 1999, and 2004 | 10.0 |
| Severe drought | 1986, 1991, 1997, 2002, and 2006 | 16.7 |

**2.2 Each station in Deyang area**

**2.2.1** Mianzhu station. Based on the data of annual average precipitation in Mianzhu station during 1984 – 2013, the precipitation anomaly percentage in Mianzhu station was calculated. Precipitation anomaly percentage was ordered by time to draw a time series plot by NCL. As can be seen from Fig. 2, the precipitation anomaly percentage in Mianzhu tended to be stable in the past 30 years. Precipitation anomaly was positive or negative in 1 – 2 years, and only in 2013 there was a larger precipitation than the past. During the 10 years from 1984 to 1994, the drought and flood situation in Mianzhu changed dramatically. Severe droughts appeared in 1986 and 1991, and severe floods happened in 1987 and 1990. According to the trend equation, the precipitation anomaly percentage in Mianzhu increased by 1%/10 a, and there was no significant change on the whole.

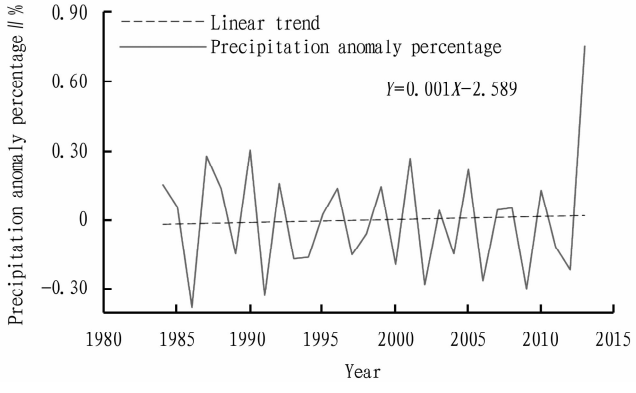


**Fig. 2 Annual variation of precipitation anomaly percentage in Mianzhu area during 1984 – 2013**

As can be seen from Table 2, the frequency of moderate droughts was slightly higher than that of moderate floods, and the frequency of severe droughts was also slightly higher than that of severe floods. Severe droughts and severe floods occurred most frequently after 2000, and the proportion reached 65%. In particular, the precipitation in 2013 was large, which was rare for many years, and the anomaly percentage was as high as 75%.

**Table 2 Years and frequency of different grades of droughts and floods in Mianzhu**

| Grade | Year | Proportion//% |
|---|---|---|
| Severe flood | 1987, 1990, 2001, 2005, and 2013 | 16.7 |
| Moderate flood | 1984, 1988, 1992, 1996, 1999, and 2010 | 20.0 |
| Normal | Other years except for flood and drought years | 20.0 |
| Moderate drought | 1989, 1993, 1994, 1997, 2000, 2004, and 2011 | 23.3 |
| Severe drought | 1986, 1991, 2002, 2006, 2009, and 2012 | 20.0 |

**2.2.2** Shifang station. On the basis of the data of annual average precipitation in Shifang station during 1984 – 2013, the precipitation anomaly percentage in Shifang station was calculated, and precipitation anomaly percentage was ordered by time to draw a time series plot by NCL. As shown in Fig. 3, the change of precipitation anomaly percentage in Shifang was much obvious than that in Mianzhu, and there were frequent severe droughts and floods. Besides the large rainfall in 2013, there was also a severe flood with a percentage anomaly of more than 40% in 1995. In 1985, 2002 and other years, there were different degrees of droughts. The precipitation anomaly percentage in Shifang decreased by 3%/10 a, and the climate tended to be dry in the past 30 years.

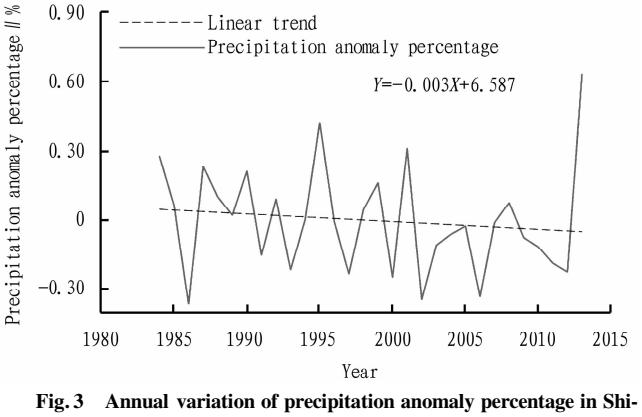


**Fig. 3 Annual variation of precipitation anomaly percentage in Shifang area from 1984 to 2013**

As can be seen from Table 3, there were more normal years in Shifang area, accounting for 36.7% of the total years. Flood and drought years accounted for 30% and 33.3%, respectively. Severe flood and severe drought years accounted for 40%. Compared with Mianzhu area, the proportion of severe flood and severe drought years was higher, and that of normal years was also higher.

**2.2.3** Deyang station. According to the data of annual average precipitation in Deyang station from 1984 to 2013, the precipitation anomaly percentage in Deyang station was calculated, and precipitation anomaly percentage was ordered by time to draw a time series plot by NCL. Seen from Fig. 4, the precipitation anomaly percentage in Deyang station fluctuated greatly, and there were obvious severe droughts and floods. A severe drought appeared in 1986, with an anomaly percentage of more than 30%. A severe flood happened in 2001, with an anomaly percentage of more than 40%. The precipitation anomaly percentage in Deyang station increased by 3%/10 a, that is, the climate in Deyang station developed slowly towards the trend of flood in the past 30 years.

**Table 3 Years and frequency of different grades of droughts and floods in Shifang area**

| Grade | Year | Proportion//% |
|---|---|---|
| Severe flood | 1984, 1987, 1990, 1995, 2001, and 2013 | 20.0 |
| Moderate flood | 1984, 1988, and 1999 | 10.0 |
| Normal | Other years except for flood and drought years | 36.7 |
| Moderate drought | 1991, 2003, 2010, and 2011 | 13.3 |
| Severe drought | 1986, 1993, 1997, 2002, 2006, and 2012 | 20.0 |

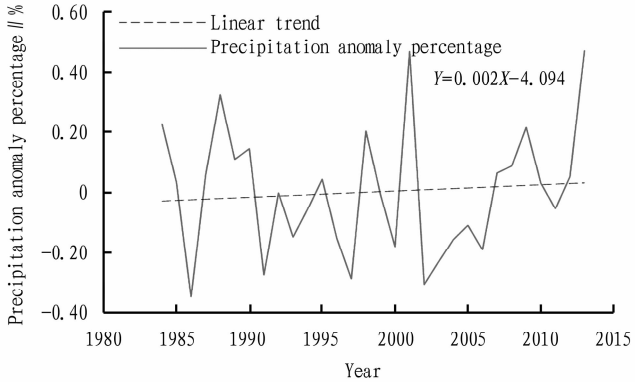


**Fig. 4 Annual variation of precipitation anomaly percentage in Deyang station during 1984 – 2013**

As can be seen from Table 4, severe and moderate floods years accounted for 36.7% of the total years, while severe droughts and moderate droughts accounted for 36.7% of the total years. In the flood years, extreme flood years accounted for 74.9%. Severe floods appeared in 1984, 1988, 1998, 2001, 2009 and 2013. Severe droughts happened in 1986, 1991, 1997, 2002 and 2003. In the drought years, there were more moderate drought years, and severe drought years accounted for 45.5%. It can be said that the climate in Deyang was dry on the whole in the past 30 years, and there were more severe floods.

**Table 4 Years and frequency of different grades of droughts and floods in Deyang area**

| Grade | Year | Proportion//% |
|---|---|---|
| Severe flood | 1984, 1988, 1998, 2001, 2009, and 2013 | 20.0 |
| Moderate flood | 1989, and 1990 | 6.7 |
| Normal | Other years except for flood and drought years | 36.6 |
| Moderate drought | 1993, 1996, 2000, 2004, 2005, and 2006 | 20.0 |
| Severe drought | 1986, 1991, 1997, 2002, and 2003 | 16.7 |

**2.2.4** Zhongjiang station. Based on the data of annual average precipitation in Zhongjiang station during 1984 – 2013, the precip-

itation anomaly percentage in Zhongjiang station was calculated, and precipitation anomaly percentage was ordered by time to draw a time series plot by NCL. The slope of the linear regression equation was −0.001, and the intercept was 2.658, while the unbiased estimated *t* value was −0.246. From Fig. 5, it can be clearly seen that in Zhongjiang, severe floods appeared in many years, and the precipitation anomaly even exceed 40% in some years. For instance, the anomaly reached 43.95% in 1988, 41.63% in 1998, and 44.27% (the maximum positive anomaly) in 2009. Meanwhile, the severe drought in 2006 was particularly striking, with a negative anomaly of 54.42%. The precipitation anomaly percentage in Zhongjiang area decreased by 1%/10 a. That is, the climate in Zhongjiang tended to be dry gradually in the past 30 years, but there was no great change.

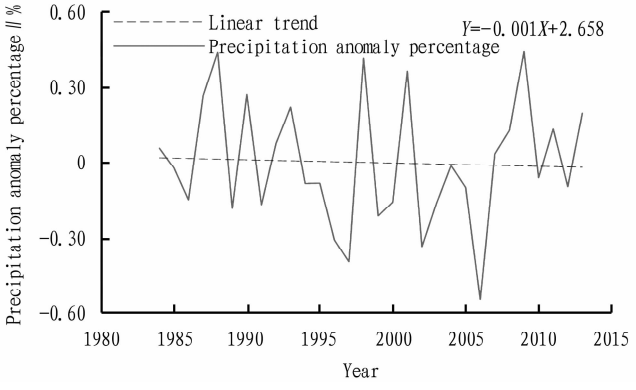


**Fig. 5 Annual variation of precipitation anomaly percentage in Zhongjiang area from 1984 to 2013**

It can be seen from Table 5 that in the past 30 years, flood years accounted for 33.3% of the total years, and drought years accounted for 26.7%, so there were more flood years than drought years in Zhongjiang area. It is worth noting that in the past 30 years, there were server floods in Zhongjiang area. The anomaly percentage exceeded 20% in seven years, and they mostly appeared before 2000.

**Table 5 Years and frequency of different grades of droughts and floods in Zhongjiang area**

| Grade | Year | Proportion // % |
|---|---|---|
| Severe flood | 1987, 1988, 1990, 1993, 1998, 2001, and 2009 | 23.3 |
| Moderate flood | 2008, 2011, and 2013 | 10.0 |
| Normal | Other years except for flood and drought years | 40.0 |
| Moderate drought | 1986, 1989, 1991, 2000, and 2003 | 13.3 |
| Severe drought | 1996, 1997, 1999, 2002, and 2006 | 13.3 |

**2.2.5** Guanghan. On the basis of the data of annual average precipitation in Guanghan station during 1984 − 2013, the precipitation anomaly percentage in Guanghan was calculated, and precipitation anomaly percentage was ordered by time to draw a time series plot by NCL. The slope of the linear regression equation was −0.001, and the intercept was 1.014, while the unbiased estimated t value was −0.126. As can be seen from Fig. 6, the number of severe floods was not very large, and the precipitation anomaly percentage exceeded 20% in only three years, while there were more drought years with an anomaly percentage of less than −20%. It is seen that in the past 30 years, there were more drought years in Guanghan. In 2013, the precipitation anomaly percentage was very high, up to 47.57%. The precipitation anomaly in Guanghan area decreased by 1%/10 a, showing that the climate in Guanghan tended to be dry gradually in the past 30 years, but there was no great change.

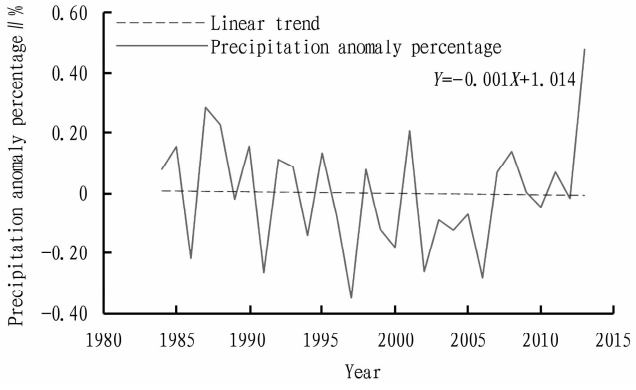


**Fig. 6 Annual variation of precipitation anomaly percentage in Guanghan area during 1984 − 2013**

As shown in Table 6, in Guanghan area in the past 30 years, both flood and drought years accounted for 30%, respectively. Normal years accounted for 40%. It reveals that the drought and flood situation in Guanghan was very average. Severe droughts and floods were also more evenly distributed, and half of them appeared before 2000 and after 2000.

**Table 6 Years and frequency of different grades of droughts and floods in Guanghan area**

| Grade | Year | Proportion // % |
|---|---|---|
| Severe flood | 1987, 1988, 2001, and 2013 | 13.3 |
| Moderate flood | 1985, 1990, 1992, 1995, and 2008 | 16.7 |
| Normal | Other years except for flood and drought years | 40.0 |
| Moderate drought | 1994, 1999, 2000, and 2004 | 13.3 |
| Severe drought | 1986, 1991, 1997, 2002, and 2006 | 16.7 |

## 3 Conclusions

In the past 30 years (from 1984 to 2013), the precipitation anomaly percentage in Deyang area of Sichuan Province had a slow decrease, and the slope of the trend line was negative. The cycle of droughts and floods was about 3 − 5 a. In Deyang area and its five stations (Mianzhu, Shifang, Deyang, Zhongjiang and Guanghan), precipitation decreased and drought intensified especially in the 21st century. It indicates that Deyang entered a dry and warm period.

(To page 39)

commodation experience, increasing their attachment to the place, and making the tenants have the desire to move in again.

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(From page 32)

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