Analysis and Forecast of Rainfall in Shapingba District of Chongqing

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Abstract. Flood and seasonal drought occur frequently in Chongqing area. The study of rainfall distribution may provide the theoretical basis for flood control and drought resistance. Daily rainfall data of Shapingba District in Chongqing from 1995 to 2014 are used in this paper to analyse the annual distribution using the method of uneven distribution coefficient, complete adjustment coefficient and concentration degree, meanwhile, the annual variation of rainfall are analysed by the Mann-Kendall trend test and Spearman rank correlation method. The results show that the rainfall in Shapingba area is mainly concentrated in April-September, accounting for 78% of the annual rainfall, especially in June, the rainfall is the most, accounting for 20% of the annual rainfall, which is the key period for flood control. The annual distribution of rainfall is relatively concentrated, and shows an upward trend on the whole, and there is no sudden change in many years. Summer is the most obvious seasonal rainfall change, which may be related to local climate characteristics. The difference of forecasting precipitation was little between P-III distribution and Gumbel distribution. Especially for normal year (P=50%) and dry year (P=90%), the precipitation was very close. Thus, either method can be used to forecast precipitation in the future.

Keywords: Rainfall characteristics; Rainfall distribution and variance; Rainfall forecast.

1. Introduction

Under the background of global warming and rapid urbanization, significant changes have taken place in global or local precipitation structure [3, 4]. As an important driving factor of hydrological cycle, the change of precipitation will lead to the change of regional water cycle process and water resources distribution [5]. The changing characteristics of precipitation play an important role in rational water use and economic development. In recent years, many scholars have analysed the characteristics of precipitation: Xu Lingling etc [4] found that the change of annual precipitation in XuZhou is not significant through the analysis of MK trend test method, based on the monthly climate data of 42 years; Jian Hong etc [5] analysed the change characteristic of precipitation in Shapingba of Chongqing using the daily rainfall data of 50 years through MK trend method; Ling Yan etc [6] using wavelet analysis method to analyse the period of each index based on the daily precipitation data of 33 stations in Huzhou City in 50 years; Wang Chenghai etc [7] analysed precipitation data of China in recent 50 years using wavelet analysis method and obtained the precipitation characteristics and future trends; Chen Shujun etc [8] studied the temporal and spatial characteristics of precipitation in Hubei province.
through Precipitation Concentration Index (PCI), Rainfall Anomaly Index (RAI), Standardization Precipitation Index (SPI), Precipitation Concentration Degree (PCD), and Precipitation Concentration Period (PCP); Liu Wen et al. [9] studied Spatial-temporal pattern and periodic characteristics of precipitation in Yunnan Province. Chongqing is located in southwest of China, where rainfall is abundant, but not evenly distributed, flood and seasonal drought occurs frequently, which lead to serious economic loss, so it is very important to analyse the spatial and temporal distribution of rainfall in Chongqing. This paper studies the annual distribution and inter-annual variation of precipitation, meanwhile forecast future rainfall in order to provide theoretical basis for the control of flood and drought.

2. Data and Methodology
This study used the daily data with the period from 1951-2014 in Shapingba station of Chongqing, from China Meteorological Data Sharing Service System. The method of Annual Uneven Distribution Coefficient of rainfall (AUDC) [10], Annual total Distribution Coefficient of Rainfall Distribution (ADCRD) [11], Precipitation Concentration Degree (PCD) [12], Mann-Kendall rank correlation test [13], and Gumbel Distribution [14] to analyse the annual distribution of rainfall and the Inter-annual variation of rainfall, meanwhile forecast future rainfall of Shapingba district.

3. Result and Analyses
3.1. Annual Distribution of Rainfall
This paper calculated the average of monthly rainfall and its proportion to annual average rainfall. The result of annual rainfall distribution is shown as follows.

| Month | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. |
|-------|------|------|------|------|-----|------|------|------|------|------|------|------|
| Monthly rainfall (mm) | 16   | 19   | 42   | 83   | 121 | 183  | 141  | 110  | 90   | 67   | 43   | 19   |
| Ratio of monthly rainfall to annual rainfall (%) | 2    | 2    | 4    | 9    | 13  | 20   | 15   | 12   | 10   | 7    | 5    | 2    |

From the table 1 and figure 1, we can get that rainfall mainly concentrate on April to September, account for about 78% of annual rainfall. Especially in June, the rainfall is the most, accounting for 20% of the annual rainfall. Thus it can be seen, April to September is the flood season, which can be used for flood control and prevention.

![Figure 1. Annual distribution of rainfall](image-url)
3.1.1. Annual uneven distribution coefficient of rainfall. This paper analysed the annual distribution of rainfall through the method of annual uneven distribution coefficient of rainfall, the result is shown in Table 2.

| Year | Cv  | Year | Cv  |
|------|-----|------|-----|
| 1995 | 0.81| 2005 | 0.75|
| 1996 | 1.05| 2006 | 0.59|
| 1997 | 0.74| 2007 | 1.19|
| 1998 | 0.87| 2008 | 0.79|
| 1999 | 0.69| 2009 | 1.07|
| 2000 | 0.78| 2010 | 0.69|
| 2001 | 0.74| 2011 | 0.62|
| 2002 | 1.00| 2012 | 0.90|
| 2003 | 1.18| 2013 | 0.83|
| 2004 | 0.65| 2014 | 0.70|

Table 2 show us that the maximum value of rainfall uneven coefficient occurred in 2007, which mean the change degree of rainfall distribution is the most; while the minimum value occurred in 2006, which mean the monthly rainfall distribution is stable. Before the year of 2009, the rainfall uneven coefficient is larger than others; then the stability of rainfall distribution increased a little.

3.1.2. Annual total distribution coefficient of rainfall distribution. This study analyzed the annual rainfall distribution using the method of annual total distribution coefficient of rainfall distribution (Cr), the results are shown table 3.

| Year | Cr  | Year | Cr  |
|------|-----|------|-----|
| 1995 | 0.33| 2005 | 0.30|
| 1996 | 0.40| 2006 | 0.24|
| 1997 | 0.32| 2007 | 0.39|
| 1998 | 0.38| 2008 | 0.29|
| 1999 | 0.30| 2009 | 0.38|
| 2000 | 0.33| 2010 | 0.30|
| 2001 | 0.32| 2011 | 0.26|
| 2002 | 0.39| 2012 | 0.36|
| 2003 | 0.44| 2013 | 0.33|
| 2004 | 0.28| 2014 | 0.29|

The table show that the maximum of Cr value occurred in 2003, then is the year of 1996, while the minimum in 2006. The larger of Cr value the more concentrated the annual distribution of rainfall. During these 20 years, only in 1996 and 2003, the Cr value is more than 0.4, which mean these two years showed a high level of concentration of rainfall distribution. During the year of 1995-2014, the Cr value of first decade was more than the late decade, which mean the concentration of rainfall distribution had a downward trend.

3.1.3. Precipitation concentration degree (PCD). The result of rainfall concentration degree is shown in figure 2, the maximum of PCD occurred in 1996, while the minimum value is the 1997; the average of PCD value is 0.16 from 1995-2014. During these 20 years, the change of concentration degree is very large, and the fluctuation of PCD in first decade is much obvious than the next decade; From 2005-2014, the PCD value is near to the average of PCD value, it can be seen that the PCD value in the late decade is relatively stable.
3.2. Inter-annual Variation of Rainfall

3.2.1. Mann-Kendall rank correlation test. This paper analysed the variance of annual rainfall and seasonal rainfall from the year 1995-2014 using Mann-Kendall rank correlation test with the confidence P=5%, the result is shown in table 4.

| Items            | Statistics(S) | Z value of statistics | Trend     | Confidence (p=5%) |
|------------------|---------------|-----------------------|-----------|-------------------|
| Annual rainfall  | 6             | 0.16                  | upward    | Non-significant   |
| Spring rainfall  | 12            | 0.36                  | upward    | Non-significant   |
| Summer rainfall  | 20            | 0.68                  | upward    | Non-significant   |
| Autumn rainfall  | 74            | 2.43                  | upward    | Significant       |
| Winter rainfall  | 122           | 3.67                  | upward    | Significant       |

From table 4, we can see that the average of annual rainfall showed a ascend trend, but no significant; The rainfall in spring, summer, autumn and winter also shows an upward trend, but the trend is not significant during spring and summer, while it is significant during autumn and winter. It can be seen that the rainfall had a large seasonal difference.

3.2.2. Spearman rank correlation test. This study analysed the annual rainfall and seasonal rainfall using the method of spearman rank correlation coefficient test and SPSS soft, the result is shown in table 5.

| Items      | Correlation coefficient | Significance level (%) |
|------------|-------------------------|------------------------|
| Annual     | 0.065                   | 79                     |
| Spring     | 0.011                   | 96                     |
| Summer     | -0.223                  | 35                     |
| Autumn     | 0.316                   | 18                     |
| Winter     | -0.036                  | 88                     |

Table 5 show that the correlation coefficient of annual, spring, summer, autumn and winter rainfall was 0.065, 0.011, -0.223, 0.316 and -0.036, and the significant level was 79, 96, 35, 18 and 88 respectively. On the whole, there was positive correlation during whole year, spring and autumn, and the significant level in spring was much higher than others; while was negative correlation during summer and winter. In addition, the correlation coefficient of rainfall in summer and autumn is large by comparing the correlation coefficient of rainfall in four seasons, because Shapingba district belong to subtropical monsoon humid climate, the rainfall mainly concentrate on the June-September, that is the rainfall is abundant in summer, so the correlation coefficient is large.
4. Forecast of Precipitation
The future rainfall was calculated through the method of P-Ⅲ distribution and Gumbel distribution, the comparison results are shown in table 6.

| Items                      | P-Ⅲ distribution | Gumbel distribution | ΔP |
|----------------------------|-------------------|---------------------|----|
| P in high flow year (P=10%) (mm) | 1185              | 1237                | 52 |
| P in normal year (P=50%) (mm)       | 922               | 908                 | 14 |
| P in low flow year (P=90%) (mm)    | 700               | 697                 | 3  |

From the table, we can see that the difference of forecasting precipitation was little between P-Ⅲ distribution and Gumbel distribution. Especially for normal year (P =50%) and dry year (P =90%), the precipitation was very close. Thus, we can use either method to forecast precipitation in the future.

5. Conclusion
This paper calculated and analysed the annual rainfall distribution and Inter-annual variation of rainfall based on the daily rainfall data of 20 years, the main conclusion as follows:

1) The rainfall of Shapingba district mainly concentrate on the April to September, especially in June, the amount of rainfall is the most, about 20% of annual rainfall, which is the key period for flood control; while for the whole dry season, the amount of rainfall is only 22% of annual rainfall. From 1995-2014, the change of rainfall in the first decade is obvious, and have some fluctuations; relatively, the annual rainfall distribution tend to be stable in the next decade.

2) Inter-annual variation of rainfall has an overall upward trend, however no significant; The correlation coefficient of spring, summer, autumn and winter is different, and the maximum correlation coefficient occur in summer, which may be some relation with the climate of same period, because rainfall mainly focus on Summer in Shapingba district of Chongqing.

3) The forecasting rainfall using two methods are almost same in high flow year (P=10%), normal year (P=50%) and low flow year (P=90%) respectively, so we can use either method to forecast precipitation in the future.

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